Aug. 28, 1962 J. C. M. FROST 3,051,414

AIRCRAFT WITH JET FLUID CONTROL RING

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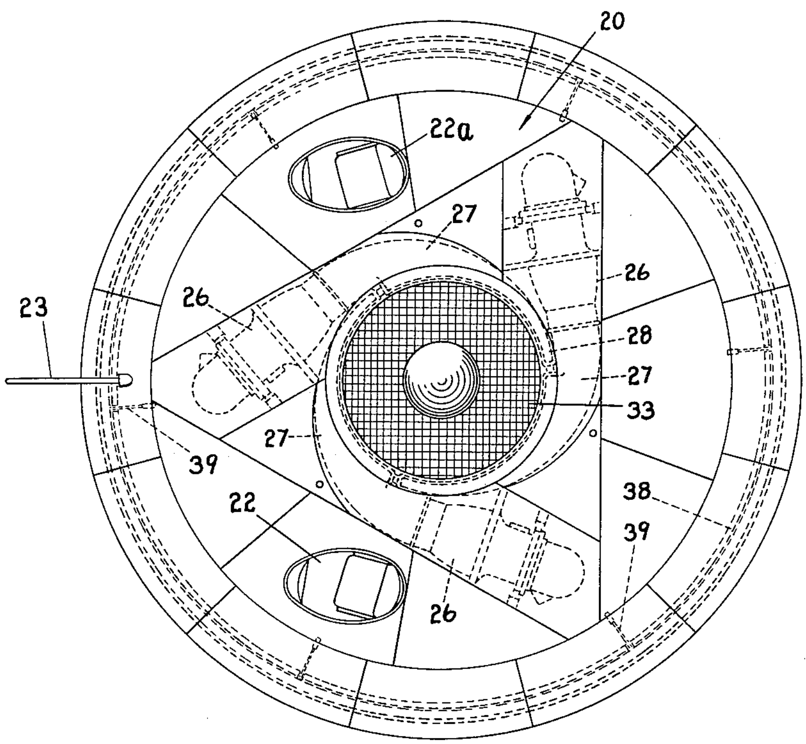

FIG. 1.

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AIRCRAFT WITH JET FLUID CONTROL RING

Filed May 8, 1961 11 Sheets-Sheet 2

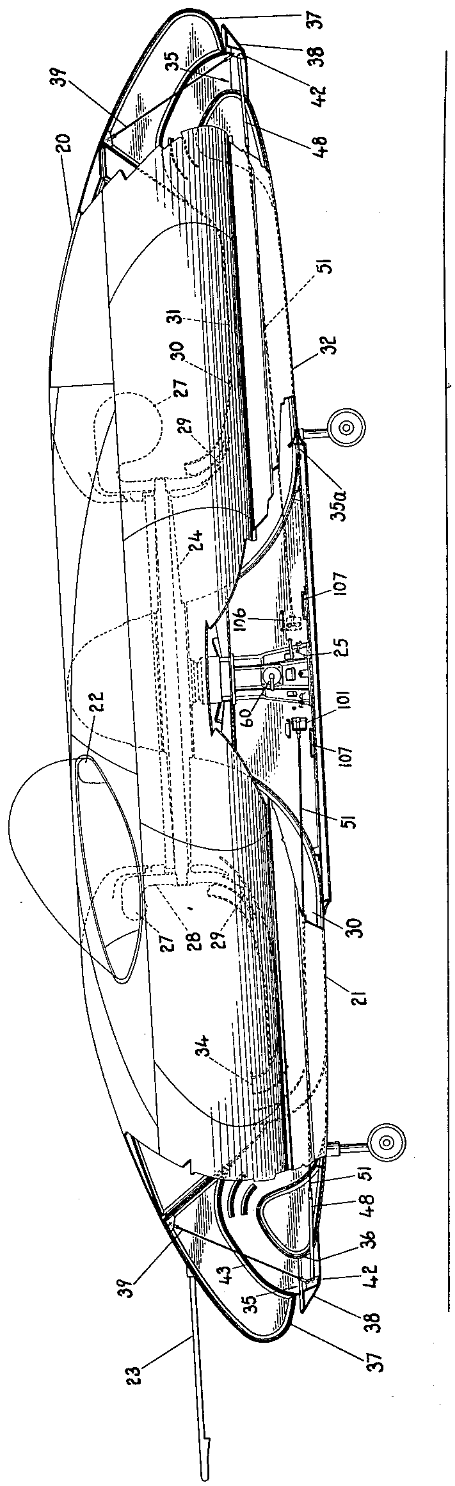

FIG. 2.

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AIRCRAFT WITH JET FLUID CONTROL RING

Filed May 8, 1961 11 Sheets-Sheet 3

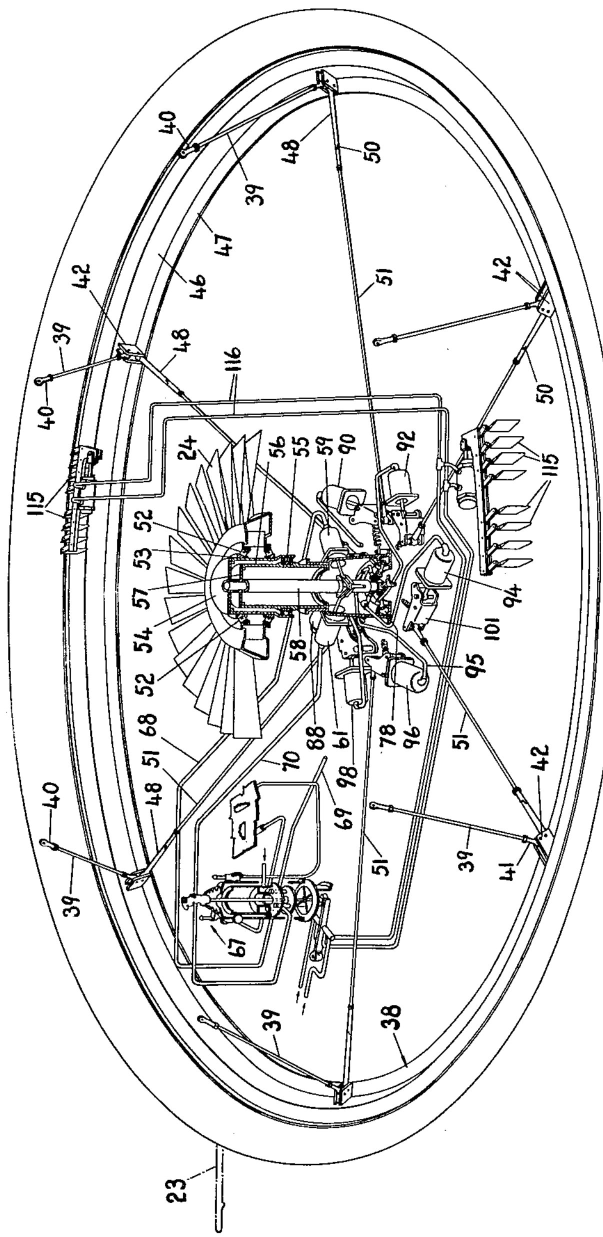

FIG. 3

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AIRCRAFT WITH JET FLUID CONTROL RING

Filed May 8, 1961 11 Sheets-Sheet 4

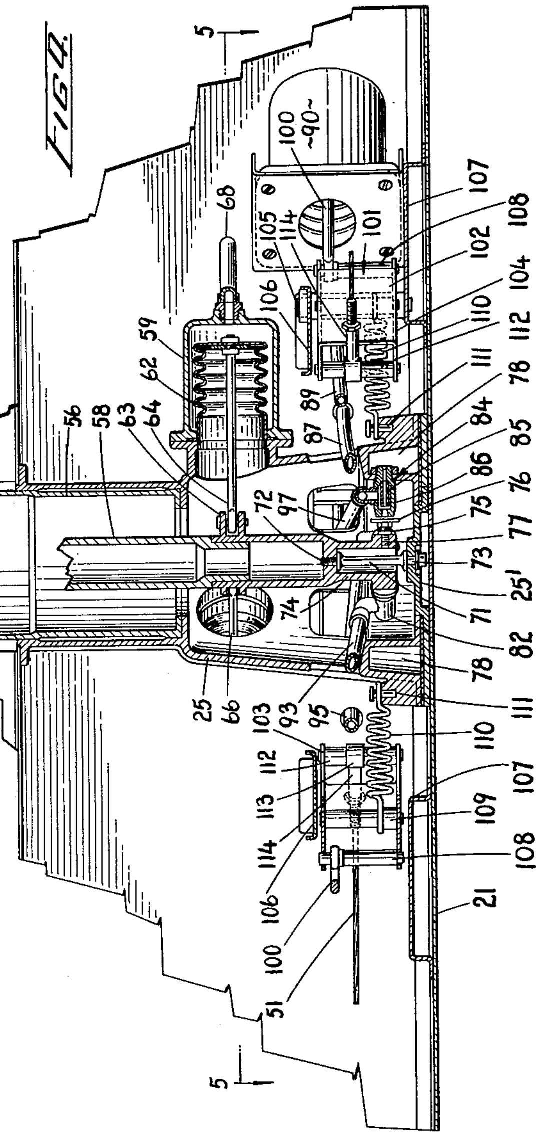

FIG. 4.

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Aug. 28, 1962 J. C. M. FROST 3,051,414

AIRCRAFT WITH JET FLUID CONTROL RING

Filed May 8, 1961 11 Sheets-Sheet 5

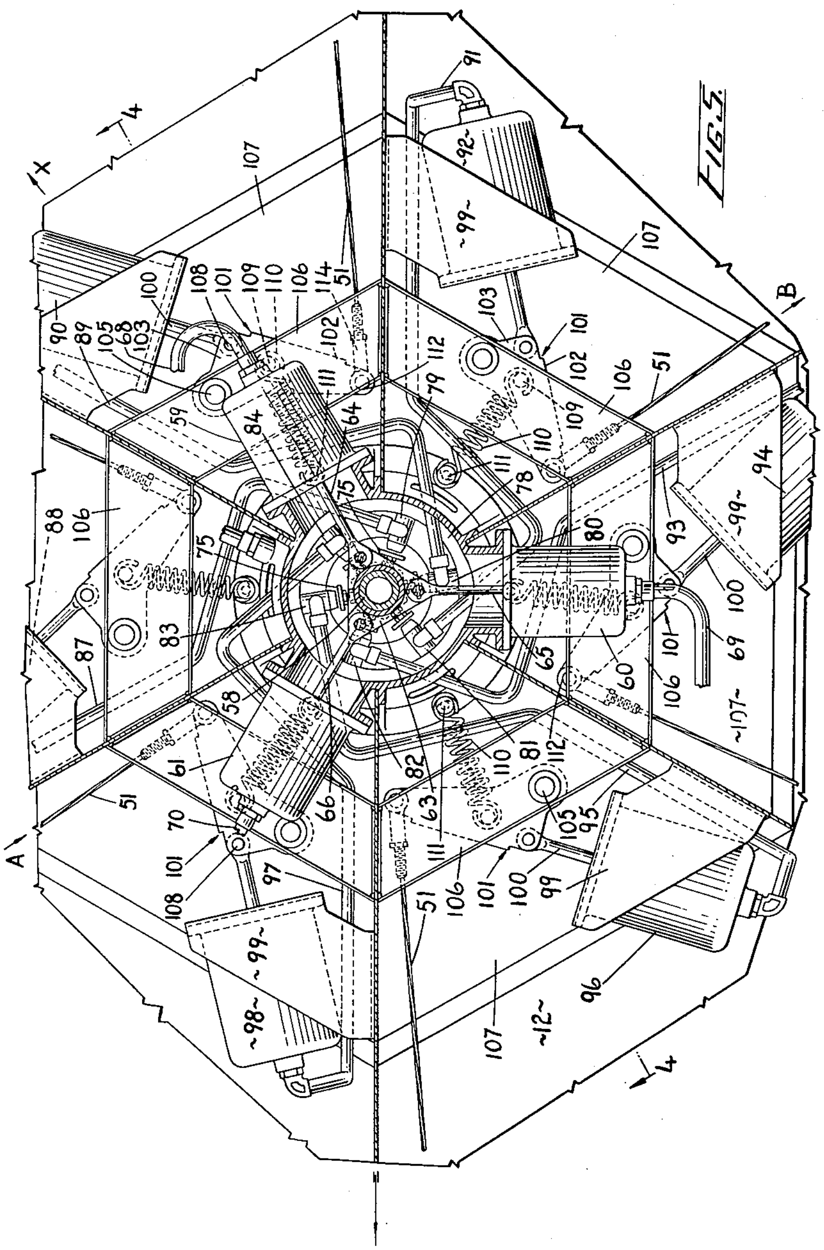

FIG. 5

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Filed May 8, 1961 11 Sheets-Sheet 6

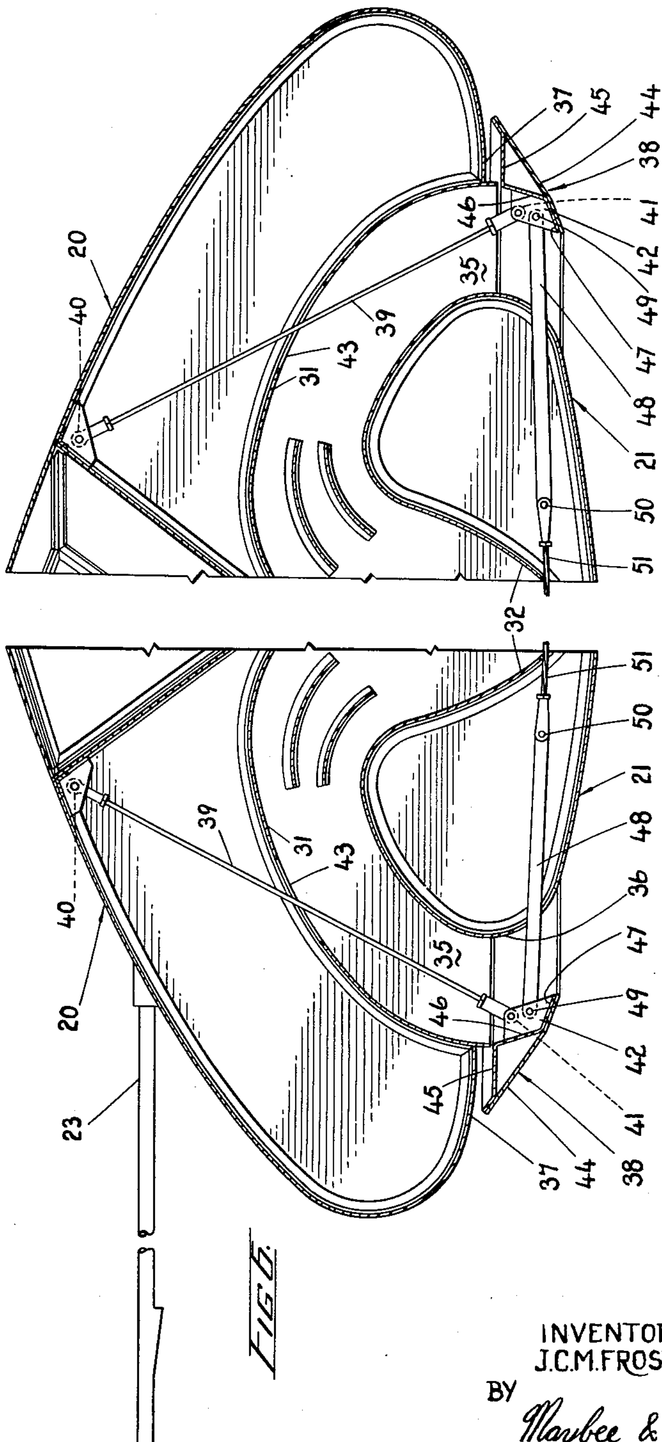

FIG. 6.

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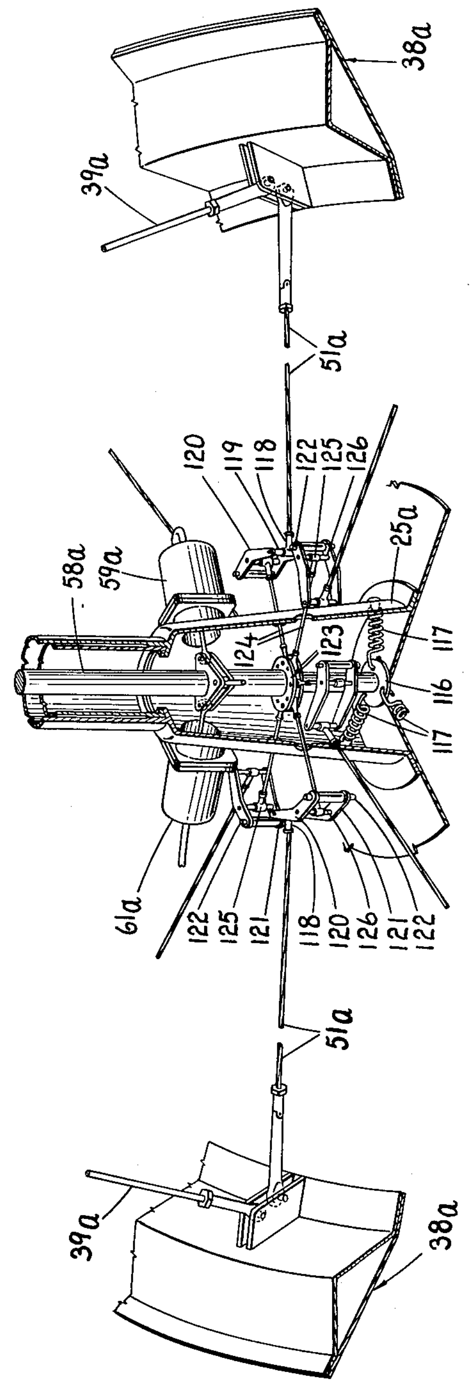

FIG. 7

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AIRCRAFT WITH JET FLUID CONTROL RING

Filed May 8, 1961 11 Sheets-Sheet 8

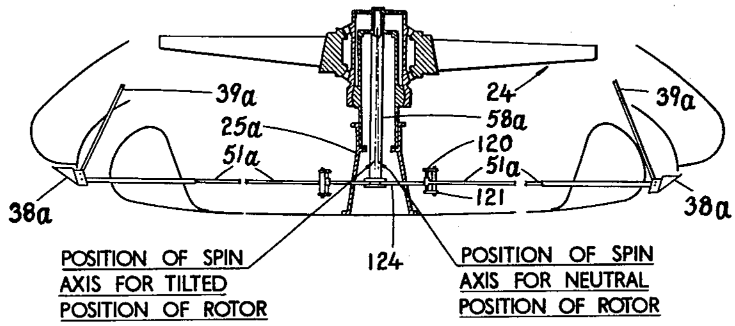

FIG. 8.

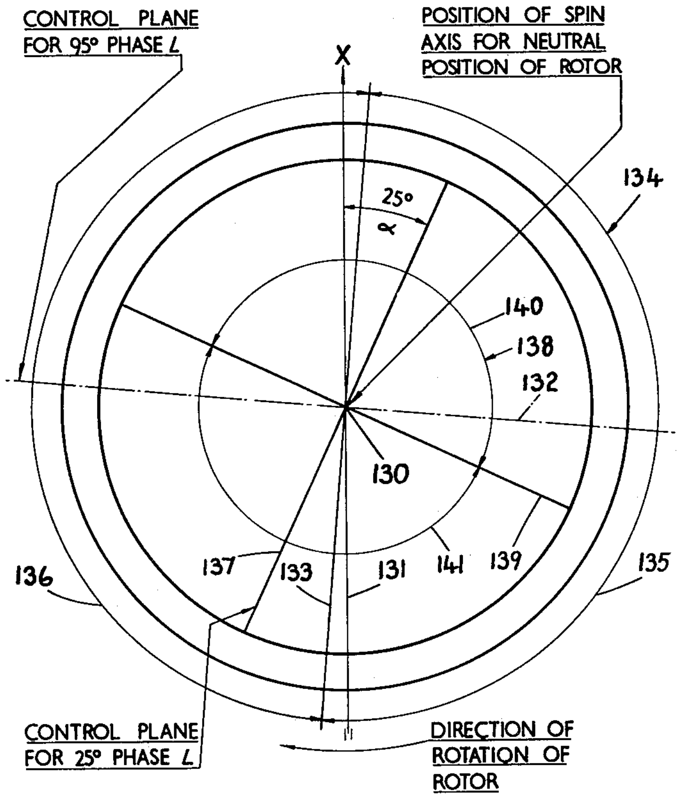

FIG. 9.

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Filed May 8, 1961 11 Sheets-Sheet 9

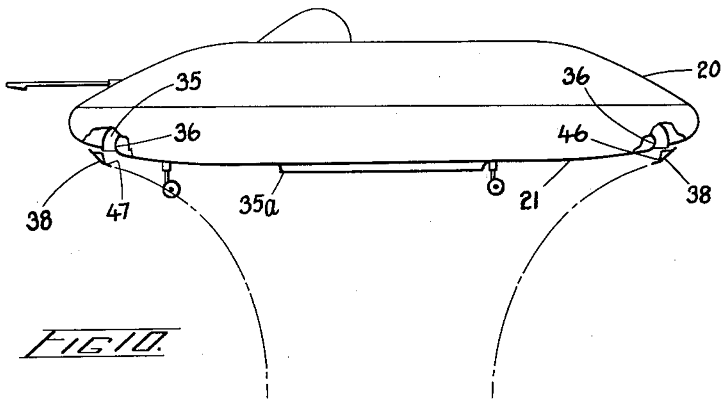

FIG 10.

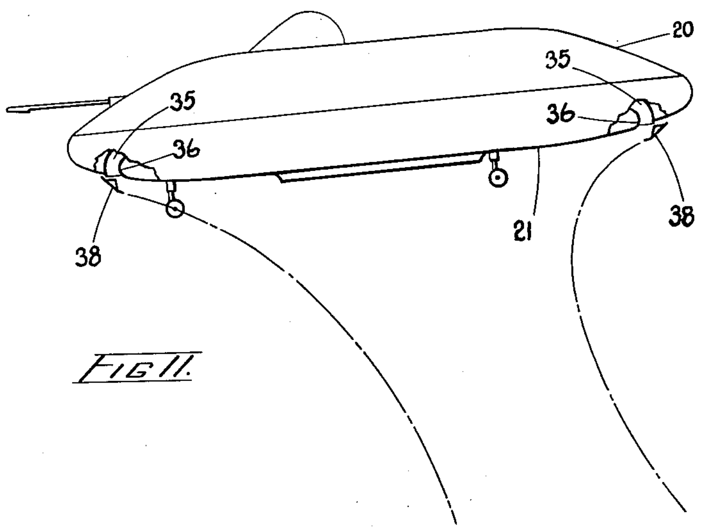

FIG 11.

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AIRCRAFT WITH JET FLUID CONTROL RING

Filed May 8, 1961 11 Sheets-Sheet 10

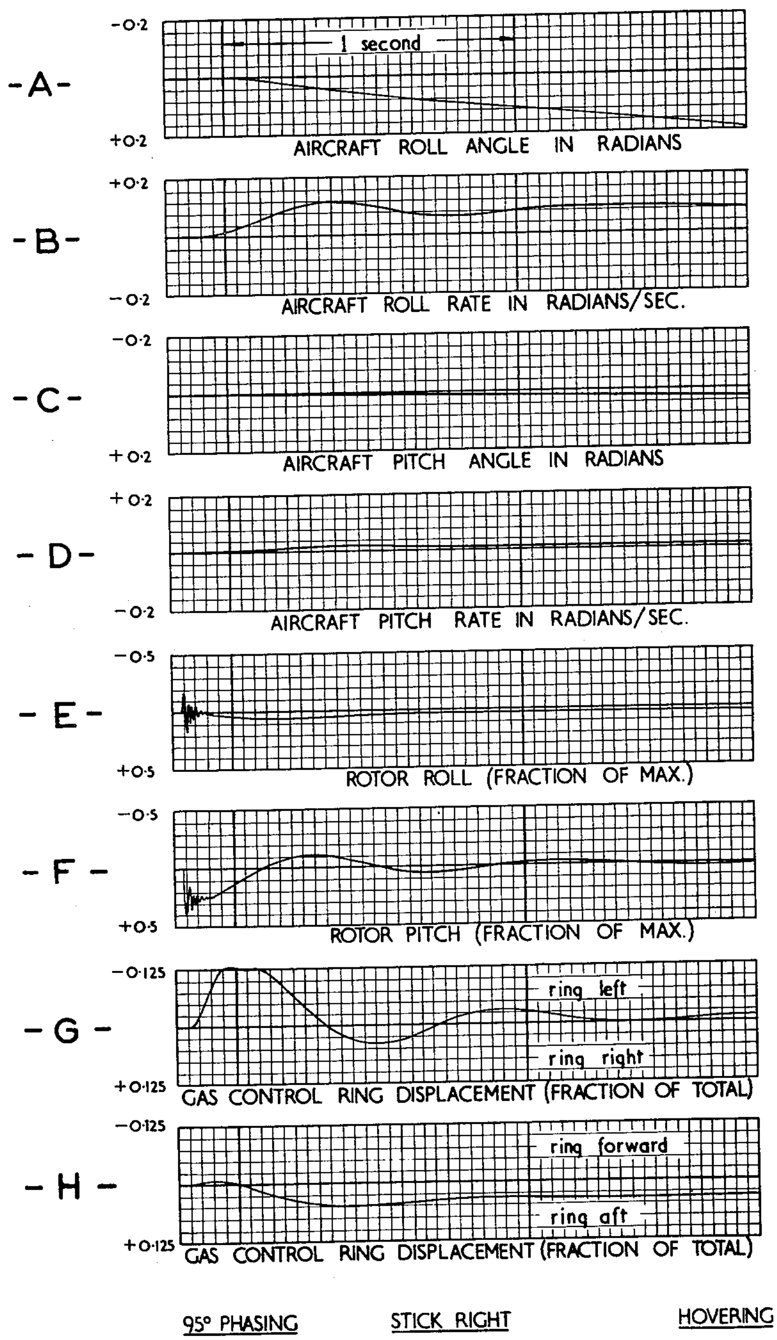

FIG. 12.

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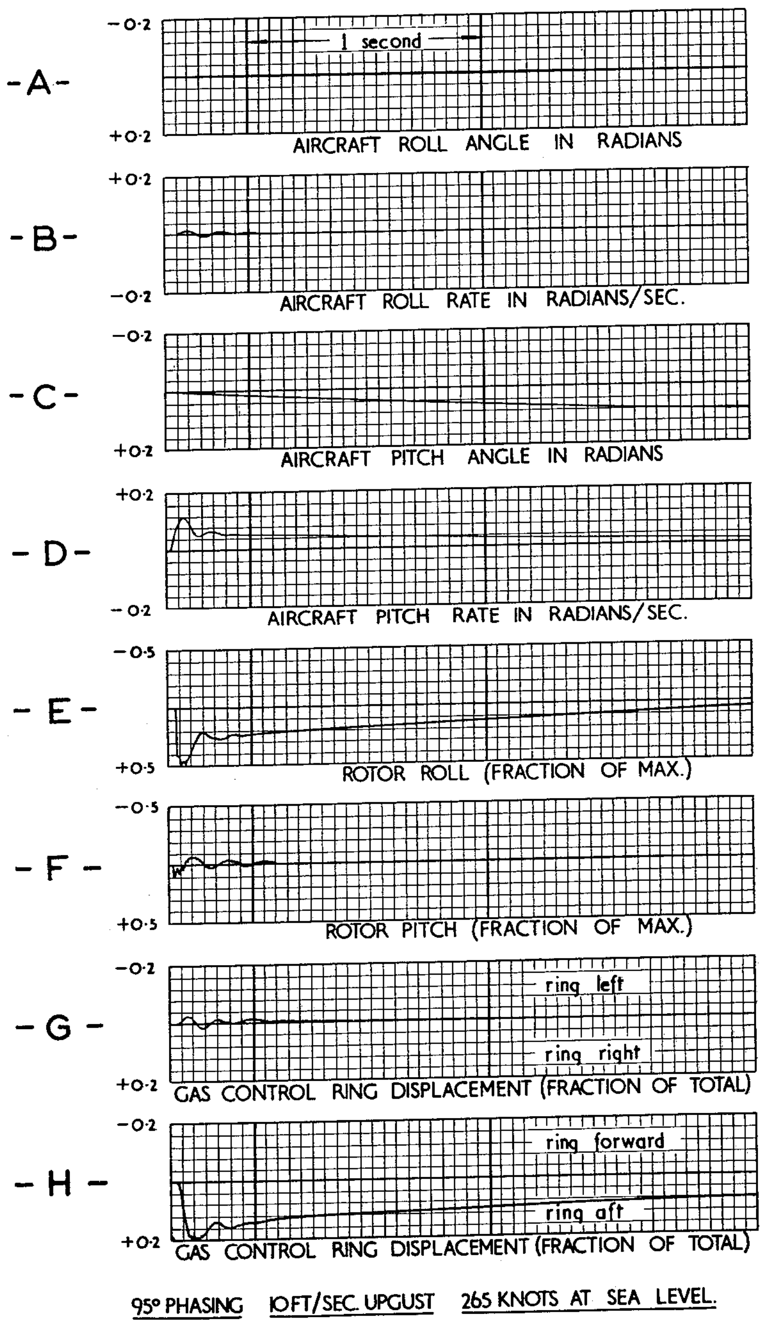

FIG. 13.

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United States Patent Office 3,051,414 Patented Aug. 28, 1962

3,051,414
AIRCRAFT WITH JET FLUID CONTROL RING

John Carver Meadows Frost, Georgetown, Ontario, Canada, assignor, by mesne assignments, to A. V. Roe Canada Limited, Toronto, Ontario, Canada, a corporation

Filed May 8, 1961, Ser. No. 108,365
17 Claims. (Cl. 244—12)

This invention relates to aircraft and more particularly to an aircraft having a body structure and a propulsive nozzle which is preferably downwardly directed and has a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the structure; the aircraft derives propulsive thrust from the ejection of propulsive gas at high velocity through the propulsive nozzle.

The co-pending application Serial No. 832,404 dated August 6, 1959, of John Carver Meadows Frost and Claude John Williams discloses a circular aircraft having a lentiform inboard body structure sheathed by opposed aerofoil surfaces, which provide lift developing surfaces for the aircraft, and an outboard body structure secured to the inboard body structure. That aircraft has a gas displacement passage in the structure which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure, and the outboard body structure is arranged in juxtaposed spaced relation to the outlet nozzle to provide therewith upper and lower peripheral nozzles. Means is provided for impelling gas to flow through the gas displacement passage and through the outlet nozzle and the peripheral nozzles. Primary gas deflecting means is provided associated with the outlet nozzle to apportion the flow of gas between the peripheral nozzles, and secondary gas deflecting means is provided on the outboard body structure to vary the direction in which the propulsive gas leaves the peripheral nozzles.

The aircraft disclosed in said co-pending application has an impelling rotor to impel the gas along the gas displacement passage and the rotor is mounted for universal movement and biased to a neutral position within the inboard body structure. The rotor is operatively connected to the primary gas deflecting means whereby, when the rotor tilts from its neutral position, the gas deflecting means is operated to stabilize the aircraft.

A control system for the aircraft described in application Serial No. 832,404 is claimed in application Serial No. 832,406 filed on August 6, 1959, by John Carver Meadows Frost and Claude John Williams.

The present invention may be considered to be a development of the aircraft described in the above mentioned applications. The specifically described embodiment of the present invention differs from the aircraft described in said applications mainly in the arrangement of its propulsive nozzle and its gas control means. The aircraft of the present invention may use means identical to those disclosed in the previous applications to impel gas along a gas displacement passage which is arranged to terminate in a novel propulsive nozzle arrangement which is substituted for the outlet nozzle and the peripheral nozzles of the aircraft described in said applications. The aircraft of the present invention has gas directing means which is suspended adjacent to a boundary of the mouth of a propulsive nozzle, and the gas directing means has a gas control surface which is shaped to direct gas expelled from the mouth around a convex surface and preferably inboardly. The gas control surface forms a movable extension of the said boundary of the mouth of the nozzle and actuating means is provided to move the gas directing means on its suspension means thus to vary the position of the gas control surface relative to said mouth and to variably control the direction of flow of propulsive gas expelled from the mouth.

In a preferred form of the aircraft according to the present invention, the engine means for impelling gas along the gas displacement passage includes an impelling rotor which is universally mounted in the structure and is biased to a neutral position relative to the structure. The rotor is operatively connected to the gas directing means whereby tilting of the rotor from its neutral position operates the gas directing means to stabilize the aircraft. As in the aircraft described in the above mentioned applications, pilot-control means are provided to apply a tilting force to the rotor whereby the gas directing means may be moved in a desired direction.

The invention will now be described by way of example with reference to the accompanying drawings, in which like reference characters indicate similar parts throughout the several views, and in which:

FIGURE 1 is a plan of an aircraft embodying the invention and showing the location of the engines and the gas directing means in phantom lines;

FIGURE 2 is a side elevation of the aircraft of FIGURE 1 partly broken away to show the gas directing means and the actuating means therefor;

FIGURE 3 is a diagrammatic perspective view of the control system of the aircraft;

FIGURE 4 is a section on the line **4—4** of FIGURE 5 showing the inboard part of the control system shown in FIGURE 3;

FIGURE 5 is a horizontal section on the line **5—5** of FIGURE 4;

FIGURE 6 is a section of the outboard portions of the aircraft showing in detail the gas directing means and its method of suspension;

FIGURE 7 is a detail perspective view, partly broken away, of a modified form of control system for the gas directing means;

FIGURE 8 is a diagram showing the operation of the gas directing means of FIGURE 7 in response to tilt of the rotor from its neutral position;

FIGURE 9 is a diagram indicating the phase angle relationship between displacement of the rotor and operation of the gas directing means;

FIGURE 10 shows, in diagrammatic form, the gas flow from the aircraft when the latter is hovering sufficiently high above the ground to be clear of the "ground-cushion" effect;

FIGURE 11 shows, in diagrammatic form, the gas flow from the aircraft when the latter is travelling in forward flight;

FIGURE 12 is a set of graphs showing the response of the aircraft of FIGURES 1 to 6 to a control input applied by the pilot; and

FIGURE 13 is a similar set of graphs showing the response of the aircraft to an upgust.

Referring now to FIGURES 1 and 2, the aircraft comprises a lentiform body structure which is sheathed by upper and lower aerofoil skins which provide lift surfaces for the aircraft. The skin providing the upper aerofoil surface is indicated at **20** and the skin providing the lower aerofoil surface is indicated at **21**. The upper skin **20** is divided into various panels to facilitate access to the inside of the body structure. The aircraft has two cockpits **22** and **22a**, for a pilot and observer respectively, and a pivot head located at the forward end of a boom **23**. The aircraft includes an impelling rotor **24** mounted substantially centrally within the aircraft for universal movement on a base indicated generally at **25**. The rotor **24** has turbine blades at its periphery and is rotated by means of gas turbine engines **26** which discharge propulsive gas through "tusk" manifolds **27** into a ring manifold **28**. The propulsive gas from the gas turbine engines passes through exhaust boxes **29** into a gas displacement passage **30** defined between upper and lower walls **31**, **32** respectively in the body structure, the lower wall **32** being formed by the upper surface of the lower aerofoil skin **21**. The impelling rotor **24** draws air through a grating **33** and delivers the air into the gas displacement passage **30**. The body structure of the aircraft is made up of radially disposed ribs so that the gas displacement passage comprises a number of segment-shaped elements. Three of these elements stop short of the periphery of the structure and provide air inlets for the engines, one of said air inlets being indicated at **34** in FIGURE 2.

For a more detailed description of the skeletal structure of the aircraft, the impelling rotor, the gas displacement passage and the arrangement of the gas turbine engines, reference should be made to the structure described in the aforementioned applications Nos. 832,404 and 832,406, since in each respect the structure of the present aircraft is similar thereto.

Throughout the description and in the claims, certain terms of positional relationship are used for convenience. The terms "outboard" (or "outboardly") and "inboard" (or "inboardly") denote, respectively, greater and lesser distances from the spin axis of the rotor or the approximate center of the propulsive nozzle when the latter is viewed in plan. The terms "vertical," "upwardly" and "downwardly" denote directions approximately substantially normal to the medial, or chord, plane between the upper and lower aerofoil surfaces.

The gas displacement passage **30** terminates in a downwardly directed propulsive nozzle having an annular mouth **35** in the underside of the structure. The lower wall **32** forms the inboard boundary of the mouth as indicated at **36** and merges with the lower aerofoil skin **21** in a smooth, outboardly convex surface. The upper wall **31** forms the outboard boundary of the mouth **35** as indicated at **37**. A central stabilizing nozzle **35*a*** (see FIGURE 2) is formed in the lower skin **21** inboardly of the main propulsive nozzle mouth **35**.

Gas directing means in the form of a gas control ring **38** is suspended adjacent to, and beneath, the outer boundary **37** of the nozzle; the arrangement is best shown in FIGURES 2, 3 and 6. The ring **38** extends around the entire periphery of the annular propulsive nozzle and is supported by six links **39** spaced circumferentially around the body structure. The links **39** are universally mounted at their upper ends **40** to the body structure and are secured at their lower ends **41** with limited universal movement between spaced pairs of plates **42** secured to the ring. The links pass through apertures **43** in the upper wall **31** and suspend the ring **38** for movement relative to the mouth **35** of the nozzle.

The ring **38** is formed of two parts, an outer part **44** and an inner part **45** shaped so as to enclose, with the part **44**, a triangular space as shown in FIGURE 6. This box-section construction gives rigidity to the ring and the triangular space may be filled with a foamed plastic material to reinforce the ring. The inboard surface of the part **45** provides as gas control surface which may be considered to be in two parts; an upper part **46** which is directed slightly inboardly and a lower part **47** which is directed more steeply inboardly. The parts **46**, **47** together constitute a gas control surface which directs propulsive gas leaving the mouth **35** generally inboardly towards the center of the aircraft.

The gas control surface constituted by the parts **46**, **47** itself constitutes a movable extension of the outboard boundary **37** of the mouth **35** of the propulsive nozzle and, as the ring **38** moves on its suspension links **39**, the position of the gas control surface relative to the mouth will vary and will thereby control the direction of flow of the propulsive gas expelled from the mouth **35** of the nozzle.

The movement of the gas control ring **38** is controlled from the impelling rotor **24** as will now be described and is connected to the impelling rotor by a plurality of spaced outboardly extending links. The outboard part of each link is in the form of a rod **48** universally secured at **49** to the pairs of plates **42** on the ring **38**; the rods **48** are in turn pivotally connected at **50** to wire-rope cables **51**.

Referring now to FIGURE 3, the impelling rotor **24** is rotatably mounted by means of thrust bearings **52** upon an outer sleeve **53**, the upper end of which is closed by a diaphragm **54**. The outer sleeve **53** is mounted by means of part-spherical bearings **55** on an inner sleeve **56** which in turn is secured to the base **25**; the inner sleeve **56** is closed at the top by a diaphragm **57**. An actuating shaft **58** passes through the diaphragm **57** and is secured at its upper end in an aperture in the diaphragm **54**. The diaphragm **57** provides a fulcrum for the actuating shaft **58** whereby, as the rotor **24** tilts about the bearings **55**, the actuating shaft **58** tilts about the diaphragm **57**. A more detailed description of the mounting of the rotor on the inner and outer sleeves will be found in the aforesaid applications.

Referring now to FIGURES 3, 4 and 5, the base **25** has secured thereto three fluid-operated jacks **59**, **60** and **61**. The jacks are disposed radially of the base **25** and, when viewed in plan, are spaced at 120° intervals. Each jack includes a corrugated bellows, such as that shown at **62** in FIGURE 4 for the jack **59**, to which is secured one end of an actuating rod **64**, the other end of the rod **64** being secured to the actuating shaft **58**. The actuating shaft **58** is provided with spaced flanges **63** to which actuating rods **64**, **65** and **66** are pivotally connected, the actuating rods being connected to the bellows of the jacks **59**, **60** and **61** respectively. The jacks **59**, **60** and **61** are operatively connected to a pilot's control column indicated generally at **67** in FIGURE 3 by means of conduits **68**, **69** and **70** respectively. The control column is constructed in accordance with the teaching in the aforementioned applications. Operation of the control column by the pilot will vary the fluid pressures in the conduits **68**, **69** and **70** to cause the bellows of the jacks **59**, **60** and **61** to move the actuating rods **64**, **65**, **66** thus applying a force to the actuating shaft **58**. The force applied to the actuating shaft will tend to rock the shaft about the fulcrum provided by the diaphragm **57** and will result in the application of a tilting force to the rotor **24**. As in the aforementioned applications, the arrangement is such that if the pilot moves the control column in a first direction, the tilting force applied to the rotor will be in a second direction advanced 90° from the first direction in the direction of rotation of the rotor.

Referring now to FIGURE 4, the lower end of the actuating shaft **58** is secured to a torsion bar **71** the upper end of which is threaded at **72** into a bore provided in the lower end of the actuating shaft. The lower end of the torsion bar is secured at **73** to a base member **25'** which is attached to the bottom of the base **25**. The torsion bar **71** constitutes biasing means which tends to keep the rotor in a neutral position with its spin axis parallel to the axis of the inner sleeve **56**.

There will now be described the means for transmitting the effect of tilting movements of the rotor to the gas control ring. Referring in particular to FIGURES 4 and 5, the lower end of the actuating shaft **58** is provided with a sleeve **74** which surrounds the torsion bar **71**. Secured to the outer surface of the sleeve are six abutments or tappets **75**, each tappet having a flat disc-like head **76** and a threaded shank **77** whereby the distance that the head is spaced from the center of the actuating shaft may be adjusted. As will be seen from FIGURE 5, the six tappets are spaced equiangularly around the periphery of the lower end of the actuating shaft. Formed in the bottom of the base **25** is a ring manifold **78** which is provided with high-pressure air bled from the compressors of the engines **26**. Mounted in the inboard wall of the ring manifold **78** are six pressure-sensing nozzles **79**, **80**, **81**, **82**, **83** and **84**, each nozzle projecting into the annular space between the ring manifold and the sleeve **74** which constitutes the base of the actuating shaft **58**. Each nozzle comprises an inner nozzle element and an outer nozzle element, for example, as shown in FIGURE 4, the nozzle **84** has an inner nozzle element **85** and an outer nozzle element **86** which discharges adjacent to the disc-like head **76** of one of the tappets **75**. The inner nozzle element **85** is mounted in a chamber within the outer nozzle element **86** and the chamber of each outer nozzle element is connected by a conduit to a fluid-operated actuator as will hereinafter be described.

The operation of each pressure-sensing nozzle is as follows: high pressure air passes through the inner nozzle element **85** from the ring manifold **78** into the chamber in the outer nozzle element and out of the outer nozzle element **86** to impinge against the head **76** of a tappet **75** so that a pressure is maintained in the chamber. If now the head **76** approaches the outer nozzle element **86**, the pressure in the chamber will increase whereas, if the head **76** moves away from the outer nozzle element **86**, the pressure in the chamber will decrease. It follows that the spacing between the tappet and the nozzle will control the pressure, or back pressure, in the chamber.

Referring now to FIGURE 5, the nozzle **79** is connected by a conduit **87** to a fluid operated actuator **88**; the nozzle **80** is connected by a conduit **89** to a fluid-operated actuator **90**; the nozzle **81** is connected by a conduit **91** to a fluid-operated actuator **92**; the nozzle **82** is connected by a conduit **93** to a fluid-operated actuator **94**; the nozzle **83** is connected by a conduit **95** to a fluid-operated actuator **96**; and the nozzle **84** is connected by a conduit **97** to a fluid-operated actuator **98**. The actuators **88**, **90**, **92**, **94**, **96** and **98** are secured to the body structure upon brackets **99** and each of the actuators is connected to one of the wire rope cables **51** which are connected at their other ends to the rods **48** and thus to the gas control ring **38**.

Each of said actuators is connected to a wire rope cable **51** through a composite lever as will be described with reference to FIGURES 4 and 5 for the actuator **90**, the arrangement for each of the other actuators being similar. The actuator **90** has an actuating rod **100** which is connected to a lever indicated generally at **101**. The lever is substantially of U-shaped cross-section and comprises a web **102** and upper and lower flanges **103** and **104** respectively. The lever is pivotally mounted on a pin **105** which extends between upper and lower brackets **106**, **107** secured to the body structure. The actuating rod **100** is formed with an eye at its free end to pivotally embrace a pivot pin **108** extending between the flanges **103**, **104** of the lever. A further pin **109** having reduced ends is mounted between the flanges **103**, **104** and has secured thereto one end of a tension spring **110**; the other end of the spring **110** is secured by a stud **111** to the base **25**. Another pin **112** extends between the upper and lower flanges **103**, **104** of the lever, the pin **112** having reduced ends which pass through apertures in the flanges **103**, **104**. Embracing the pin **112** is a sleeve **113** having a cylindrical extension **114** to which the inner end of a wire rope cable **51** is secured.

Considering the lever **101** as a whole, it is pivoted about the pin **105** and may be rocked about the pin by means of the actuator **90** through the actuating rod **100**. As the lever is rocked about pin **105** it will either draw the cable **51** to which it is attached inboardly or will allow it to move outboardly; the spring **110** acts on the lever **101** to tend to draw the cable **51** inboardly.

Referring now to FIGURE 3, the aircraft is controlled in yaw by sets of rudder blades **115** mounted in the gas displacement passage **30** and which are controlled through fluid conduits **116** from the base of the control column **67** in a manner identical to that described in aforesaid applications.

In FIGURE 7 there is shown a modification of a control system previously described. In the modified system the links which are secured to the gas control ring are mechanically connected, through pivoted levers, to the actuating shaft of the rotor.

Referring now to FIGURE 7, the gas control ring is indicated at **38a** and is suspended from the structure by links **39a** in the same manner as in the previous embodiment. The actuating shaft of the rotor is indicated at **58a** and is moved by fluid-operated jacks, two of which are shown at **59a** and **61a**, in the same manner as in the previous embodiment. The base of the actuating shaft is provided with a flange **116** to which are attached the inner ends of three tension springs **117**, the outer ends of the tension springs being secured to the base **25a** which supports the rotor. The springs **117** constitute biasing means which tend to retain the actuating shaft **58a** in a neutral position with its axis parallel to the axis of the fixed inner sleeve on which the rotor is universally mounted. The links between the actuating shaft and the gas control ring are similar to those previously described and the wire rope portions thereof are indicated at **51a**. Each wire rope portion **51a** is secured to a sleeve **118** which is pivotally mounted on a pin **119** received between upper and lower arms **120** and **121** of a composite lever, and each lever is pivoted about a pin **122** mounted on the body structure. The actuating shaft **58a** is provided with spaced flanges **123** between which are pivotally received the inboard ends of links **124**. The outboard end of each link **124** is connected to a sleeve **125** which in turn is mounted on a pin **126** received between the upper and lower arms **120** and **121** of one of the composite levers.

The operation of the aircraft described with reference to FIGURES 1 to 6 will now be outlined. When the gas turbine engines **26** are in operation they discharge propulsive gas into the "tusk" manifolds **27**, the gas then flows into the ring manifold **28**, drives the tip turbine of the rotor **24** and passes through the exhaust boxes **29** into the gas displacement passage **30**. As the rotor **24** rotates it draws air in through the grating **33** and impels the air to flow outboardly along the gas displacement passage **30**. The air mixes with the propulsive gas discharged from the exhaust boxes **29** and the mixture of gas and air is impelled outboardly along the gas displacement passage and is expelled from the mouth **35** of the downwardly-directed propulsive nozzle.

The gas ejected from the mouth **35** serves to control the aircraft and at least partly to sustain it. The aircraft, which is capable of hovering and of flight in any direction, is controlled by moving the gas control ring **38** relative to the outboard boundary **37** of the mouth **35**. By suitable adjustment of the position of the ring **38**, the aircraft may be made to hover, move forwardly or backwardly, climb, dive, or turn.

The shape of the aircraft makes it basically unstable aerodynamically and it is thus necessary to provide an automatic control system which will automatically operate the gas control ring **38** to stabilize the aircraft. It is equally necessary that a pilot-operated control system be provided to move the gas control ring to cause the aircraft to execute manoeuvres desired by the pilot. The gas control ring **38** is caused to move in response to movements of the actuating shaft **58** which may either be moved by the pilot or may be moved relative to the aircraft when the latter acquires a rate about an axis normal to the spin axis of the rotor. When the actuating shaft is moved by the pilot, the aircraft is caused to carry out a desired manoeuvre and, when the actuating shaft is moved by virtue of the aircraft acquiring a rate, the control system acts to stabilize the aircraft.

The gas control ring **38** has a central position shown in FIGURES 2 and 6 wherein the part **46** of the gas control surface substantially forms an extension of the outboard boundary **37** of the mouth of the nozzle and the annular space between the inboard edge of the part

47 on the gas control surface and the inboard boundary 36 of the nozzle has equal radial width around the whole periphery of the nozzle mouth. If now a point on the ring 38 is moved radially outboardly, the diametrically opposed point on the ring will move radially inboardly and, since the ring 38 is a unitary structure, each of the other points on the ring will move in accordance with its position on the ring. It will be appreciated that, during such a movement of the ring, around half the periphery of the ring the inboard edge of the part 47 of the gas control surface will move away from the inboard boundary 36 of the nozzle mouth 35 and around the other half of the periphery of the ring the inboard edge of the part 47 will move towards the inboard boundary 36. It follows that the effective area of the mouth of the nozzle, i.e. the area between the inboard edge of the part 47 and the inboard boundary 36, will be increased around half the periphery of the nozzle and will be decreased around the other half of the periphery of the nozzle. The plane of division between that half of the nozzle mouth which increases in effective area and that half which decreases in effective area is perpendicular to the plane containing the point which moves radially outboardly and the center of the nozzle, and itself passes through the center of the nozzle.

Referring now to FIGURES 10 and 11, the resulting gas flow from the mouth 35 when the ring is in its central position and in a displaced position will be explained. In FIGURE 10 the aircraft is shown hovering at a height above the ground sufficient to avoid the "ground cushion" effect. The gas control ring 38 is in its central position and the parts 46, 47 of the gas control surface direct the propulsive gas ejected from the mouth 35 inboardly around the whole periphery of the nozzle mouth. The annular stream of propulsive gas is deflected inboardly around the smoothly curved inner boundary 36 of the nozzle mouth and then breaks away from the underside of the aircraft to flow substantially vertically downwardly. It will be seen from FIGURE 10 that the gas stream has, as it were, an "hour-glass" shape. The annular jet from the mouth 35 forms a tubular curtain of gas and the center of the curtain is filled with gas ejected from the central stabilizing nozzle 35*a*.

The deflection of the gas inboardly around the smoothly curved inboard boundary 36 of the mouth 35 is due to the Coanda effect. It is known that, if one boundary of a nozzle is extended further in the direction of gas flow than the other boundary of the nozzle and is caused to curve smoothly away from said other boundary, then gas flowing through the nozzle will be deflected around said curved boundary; this is known as the Coanda effect. The Coanda effect has a further property which is that, for a nozzle of given area, if the radius of curvature of the curved boundary is increased, the gas is deflected further around said curved boundary without breaking away therefrom than if the boundary had a lesser radius of curvature. This property may be stated conversely for a nozzle having a boundary curving away from the mouth of the nozzle with an invariable radius of curvature. If, for such a nozzle, the thickness of the gas jet is decreased, then the gas will be deflected further around the curved boundary before breaking away therefrom than would a thicker gas jet. This latter property is taken advantage of in the present invention.

In FIGURE 10, the aircraft is shown as being supported on the top of a substantially tubular curtain of gas; the gas is caused to flow some way across the underside of the aircraft before breaking away to flow generally vertically downwards. In FIGURE 10 the center of pressure of the curtain is in line with the center of gravity of the aircraft. If now the gas control ring is moved, as will hereinafter be described, the tubular curtain of gas is given an inclination relative to the aircraft and the center of pressure of the curtain is moved away from the center of gravity of the aircraft. In FIGURE 11 the aircraft is shown with the gas control ring 38 moved rearwardly which has the effect of reducing the effective area of the mouth of the propulsive nozzle around the forward half of the nozzle periphery and increasing the effective area of the mouth around the rear half of the nozzle periphery. As a result, the thickness of the gas stream around the forward half of the periphery is reduced; this has the same effect as increasing the radius of curvature of the inner boundary of the nozzle so far as the gas stream is concerned. It follows that the gas emerging from the forward half of the nozzle mouth will be deflected further around the inboard boundary 36 of the mouth before breaking away from the underside of the aircraft. A comparison of FIGURES 10 and 11 will clearly show this effect.

Conversely, the rearward movement of the half of the ring adjacent to the rear half of the propulsive nozzle mouth will increase the effective area of the rear half of the mouth thereby, in effect, decreasing the radius of curvature of the inner boundary 36 so far as the gas stream is concerned. It follows that the gas emerging from the rear half of the nozzle will be deflected through a lesser angle than in the circumstances of FIGURE 10 and will break away from the underside of the aircraft in a position outboard of that at which it broke away in FIGURE 10. A comparison of FIGURES 10 and 11 will clearly show this effect.

Thus the result of moving the gas control ring rearwardly is that the tubular curtain of gas is inclined relative to the aircraft and the center of pressure of the curtain is moved rearwardly relative to the center of gravity of the aircraft thereby applying to the aircraft a nose-down couple. This couple will be balanced by the aerodynamic lift achieved by the aerofoil skins 20 and 21 so that the aircraft will move forwardly in a nose-down position. As the speed of the aircraft increases and the aerodynamic lift increases, the nose of the aircraft will rise until the latter is flying in a horizontal position. Since the tubular curtain of gas is inclined rearwardly the reaction of the curtain may be resolved into a vertical and horizontal component, the vertical component of the reaction will be directed upwardly and will partly sustain the aircraft (with the help of the aerodynamic lift) whereas the horizontal component will be directed forwardly and will move the aircraft forwardly.

It will be appreciated that while FIGURE 11 shows the gas control ring in a rearward position, the ring could have been moved in any direction and the aircraft would have been subjected to a couple and a propelling force similar to that described with reference to FIGURE 11 but in a different direction. By moving the gas control ring in the desired direction, therefore, the aircraft may be moved in any direction and a couple may be applied to the aircraft to cause it to tilt or to correct a tilt imposed by external conditions, such as a wind gust.

There now follows a description of the manner in which the gas control ring 38 is moved by the pilot in the embodiment shown in FIGURES 1 to 6.

As previously mentioned, operation by the pilot of his control column 67 operates the jacks 59, 60 and 61 to apply a tilting force to the actuating shaft 58 and thus to the impelling rotor 24. The phasing between the pilot's control column and the actuators 59, 60 and 61 is such that, if the pilot moves his column forwardly for example, the force applied to the actuating shaft 58 will be to the right, i.e. the force applied to the actuating shaft will be advanced 90° clockwise from the direction in which the pilot moved his control column.

When the pilot applies a tilting force to the actuating shaft 58 the rotor 24 will be caused to oscillate and will ultimately assume a deflected position (i.e. tilted from its neutral position) with a consequent deflected position of the actuating shaft. Considering FIGURES 4 and 5, let it be assumed that the actuating shaft 58 is in its neutral or central position so that each of the heads 76 of the tappets 75 is spaced equally from its associated pressure-sensing nozzle of the nozzles 79—84. In this position, the pressures in the chambers in all the nozzles will be equal, the pressures in the conduits joining the nozzles to the actuators will be equal and the pressures in the actuators 88, 90, 92, 94, 96 and 98 will be equal thereby pulling equally on the links 48, 51 and holding the gas control ring 38 in its central position.

Let it now be assumed that the pilot applies a tilting force to the actuating shaft 58 by operation of the actuators 59, 60 and 61, let it further be assumed that the resulting deflection of the bottom of the actuating shaft 58 is directly towards the nozzle 84 and directly away from nozzle 81 i.e. in the direction of the arrow X in FIGURE 5. The head 76 of the tappet 75 associated with nozzle 84 will approach the latter and will increase the pressure in the conduit 97 and in the actuator 98. The actuator 98 will rock its associated lever 101 in a clockwise direction and will pull its associated cable 51 inboardly, i.e. in the direction of the arrow A in FIGURE 5. Conversely, the head 76 of the tappet 75 associated with the nozzle 81 will move away from the nozzle and will thereby decrease the pressure in the conduit 91 and in its associated actuator 92. The actuator 92 will thereupon rock its associated lever 101 in an anti-clockwise direction and its associated cable 51 will move outboardly, i.e. in the direction of the arrow B in FIGURE 5.

It follows that the point on the gas control ring which is secured to the cable 51 operated by actuator 98 will move inboardly in the direction of the arrow A and the diametrically opposed point on the ring 38 which is connected to the cable 51 operated by the actuator 92 will move outboardly and that the ring will move bodily into the direction of the arrows A and B. It will be appreciated that the remaining nozzles 79, 80, 82 and 83 will cause operation of their associated actuators in proportion to the positions of the respective nozzles between the nozzles 81 and 84 and that all the actuators will co-operate to move the gas control ring bodily.

The angle, measured clockwise, between the direction X and the direction A, B is 95°. Referring to the diagram of FIGURE 9, the central point 130 represents the position of the spin axis of the rotor when the latter is in its neutral position. If now the rotor tilts, the spin axis of the tilted rotor will lie in a plane containing the neutral position 130 of the spin axis; let it be assumed that this plane is that represented by the line 131 in FIGURE 9 and that the base of the actuating shaft 58 has moved in the direction of the arrow X in FIGURE 9 which corresponds to the direction of the arrow X in FIGURE 5. The plane containing the neutral position 130 of the spin axis of the rotor and being advanced 95° clockwise from the direction X is represented by the line 132 in FIGURE 9. The points on the gas control ring which will be moved furthest in inboard or outboard directions by movement of the base of the actuating shaft in the direction X will be those lying in the plane 132, i.e. those points connected to the actuators 98 and 92. Other points on the ring 58 will be moved inboardly or outboardly in proportion but two diametrically opposed points on the gas control ring which will not be moved at all in inboard or outboard directions are those in the plane containing the point 130 and lying at right angles to the plane 132, i.e. the points lying in the plane represented by the line 133.

If the circle 134 in FIGURE 9 is taken to represent the gas control ring 38, then that part of the gas control ring represented by the semi-circle 135 will move outboardly, thereby increasing the effective area of the nozzle mouth around that part of the ring, and the part of the ring represented by the semicircle 136 will move inboardly, thereby decreasing the effective area of the nozzle mouth around that part of the ring. The semi-circles 135, 136 are separated by the plane 133 and the points on the gas control ring and lying in the plane 133 do not partake of any inboard or outboard movement. The plane at which the maximum inboard or outboard movement takes place is hereinafter called the "control plane" and, since the angle between the direction in which the base of the actuating shaft moves and the control plane is 95°, the terminology used is that the phase angle of the control system is 95°. A phase angle of 95° signifies that, if the base of the actuating shaft moves in a given direction as the rotor tilts, the points on the gas control ring which move inboardly or outboardly the greatest distance will lie in a plane at 95° to the plane containing the neutral and tilted positions of the spin axis of the rotor.

In the said foregoing applications there is described a control system for an aircraft of the same general shape as that described in the present application. The aircraft described in said foregoing applications has a rotor rotatable about a spin axis and having a neutral position relative to the body structure of the aircraft and the rotor is connected to gas deflecting means to control the aircraft. Associated with the rotor is biasing means to bias the rotor to its neutral position and to allow relative movement between the rotor and the body structure, with consequent tilting of the rotor from its neutral position and the application of a gyro-couple to the aircraft, when the aircraft acquired a rotational velocity about a turn axis lying normal to the spin axis of the rotor. The control system causes operation of the gas deflecting means lying adjacent to a control plane which contains the position of the spin axis of the rotor corresponding to the neutral position of the rotor and is advanced in the direction of rotation of the rotor by a phase angle α relative to the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor. The phase angle α is defined to lie between 0° and 90° and the couple applied to the aircraft by the control system can be resolved into two components, a first component proportional to cosine α and which amplifies the gyrocouple applied to the aircraft by the rotor and a second component proportional to sine α which directly opposes the rotational velocity of the aircraft. It is further described in said foregoing applications that the purpose of amplifying the gyro-couple is to cause the aircraft to act as though it contains a larger gyroscope than in fact it does.

It has been found that, when the above described control system is operated, the rotor and the aircraft oscillate due to the amplified gyro-couple and that these oscillations are the more severe the nearer the phase angle approaches 0°, i.e. the more the gyro-couple is amplified. Even when the gyro-couple is not amplified, i.e. with a 90° phase angle, there is some oscillation of the aircraft. Where the aircraft is provided with sufficient control power, i.e. sufficient reaction from the discharged propulsive gas, phase angles between 0° and 90° may be used successfully since the oscillations are rapid and their amplitude small. However, where the control power is low the oscillations of the aircraft are slow and build up to large amplitudes which is very unpleasant for the pilot.

It has now been found that, by increasing the phase angle of the control system to a value greater than 90°, the gyro-couple applied to the aircraft by the rotor can be reduced and in some cases eliminated by the resulting force applied to the aircraft by the propulsive gas, thereby reducing or eliminating the undesirable oscillation of the aircraft even when low control powers are used. While there may be only one particular setting of the controls at which the gyro-couple is completely eliminated by the control force applied by the propulsive gas to the aircraft, the increase of the phase angle to a value greater than 90° provides a control force component which will oppose and reduce the gyro-couple and will thereby reduce the consequent oscillation of the aircraft.

The response of the aircraft of FIGURES 1 to 6 will now be described with reference to FIGURES 12 and 13 each of which shows a series of eight graphs. The graphs of each series show the following displacements and velocities:

(A) The roll angle of the aircraft in radians,

(B) The roll rate or roll velocity of the aircraft in radians per second,

(C) The pitch angle of the aircraft in radians,

(D) The pitch rate or pitch velocity of the aircraft in radians per second,

(E) The amount of roll of the rotor within the aircraft measured as a percentage of its maximum roll which is set by structural limitations and may, for example, be $\pm 1/100°$ from the neutral position,

(F) The pitch of the rotor within the aircraft measured as a fraction of its maximum pitch which is limited as is the maximum roll,

(G) The displacement of the gas control ring to the left and right of its central position measured as a fraction of its total permitted movement, and

(H) The displacement of the gas control ring in fore and aft directions from its central position measured as a fraction of its total permitted movement.

The graphs of FIGURE 12 show the response of the aircraft if, when it is hovering, the pilot moves his control column to the right. The amount which the control column is moved to the right is measured in terms of the resulting movement of the rotor, which is expressed as a percentage of the total permitted movement of the rotor in any direction, the various movements being considered as if the aircraft were on the ground with the rotor stationary. Thus, as mentioned above, the total movement of the rotor in any direction from its neutral position might be $1/100°$, therefore if the pilot moves his control column 10% to the right this means that he has moved his column sufficiently so that, with the aircraft on the ground and the rotor stationary, the rotor would move from its neutral position by 10% of $1/100°$. As explained above, movement of the control column is 90° out of phase with the resulting force applied to the actuating shaft **58** so that, as the pilot moves the column to the right, for example, the actuators **59**, **60**, **61** will apply a pitching moment to the rotor by rocking the actuating shaft **58**. Moreover, the graphs have been prepared on the assumption that the pilot's input is a step input, i.e. a sudden input and not a slow movement in the desired direction.

Returning now to FIGURE 12, as a result of movement of the column to the right, there is applied, through the actuating shaft **58**, a pitching moment to the rotor which, as a result, acquires a pitch velocity or pitch rate; as soon as the rotor acquires this rate it is affected by the gyroscopic laws of motion and precession. Reference to graphs E and F of FIGURE 12 shows that the rotor initially pitches, then rolls and then oscillates both in roll and pitch. The oscillations in roll rapidly die out to leave a small deflection in roll while the oscillations in pitch decrease in frequency.

The resulting displacement of the gas control ring **38** may be seen from the graphs G and H and the total displacement of the ring may be considered to be made up of two components at right angles, the displacement in left and right directions (viewed from the rear of the aircraft) is shown in the graph G and the displacement in fore and aft directions is shown in the graph H. Considering first the displacement in right and left directions, the ring is first moved to the left. This has the effect of increasing the effective area of the portion of the mouth of the propulsive nozzle at the left of the aircraft (viewed from the rear of the aircraft) and decreasing the effective area of the portion of the mouth of the propulsive nozzle at the right of the aircraft. The tubular curtain of gas ejected from the propulsive nozzle will thus be tilted to the left of the aircraft and the tilted curtain of gas will apply a moment to the aircraft as described above with reference to FIGURE 11 and will tend to cause the aircraft to bank to the right. The ring is then displaced to the right to tilt the hollow curtain of propulsive gas to the right of the aircraft and will check the roll rate of the aircraft as may be seen with reference to graph B in FIGURE 12. The left and right displacement of the control ring shown in the graph G therefore causes the aircraft to have a steadily increasing roll angle as shown in graph A and a substantially constant roll rate as shown in graph B.

The gas control ring also has a component of deflection in the aft direction which, as described with reference to FIGURE 11, applies a nose-down couple to the aircraft. As the pilot moves his column to the right he applies a tilting force to the actuating shaft **58** tending to move the base of the shaft to the rear. Due to the laws of gyroscopic precession, the rotor will cause the base of the actuating shaft to move to the left. However, the application of a nose-down couple to the aircraft will tilt the rotor and will tend to cause the base of the actuating shaft to move to the right. The movement of the rotor which tends to move the base of the actuating shaft to the left applies a couple to the aircraft known as the "gyro-couple" and this couple is opposed by the nose-down couple on the aircraft which tends to move the base of the actuating shaft to the right. It will be seen from graph E that the rotor has a slight deflection in pitch after some initial oscillations which are rapidly damped. It will also be seen from graphs C and D that the aircraft has hardly any pitch angle or pitch rate.

The series of graphs in FIGURE 12 should be compared with similar graphs in the aforesaid applications which show the response for a control system having a phase angle of 20°. From the latter it will be seen that the aircraft acquires a pitch rate and, with low control powers, it has been found that this pitch rate builds up so that the aircraft performs slow oscillations of large amplitude which are unpleasant and undesirable.

As more fully described in the aforementioned applications, the behaviour of the aircraft under the influence of the control system will be somewhat different in forward flight than in hovering. When the aircraft is in forward flight there is a de-stabilizing moment acting on the aircraft which is not present when the aircraft is hovering. The effect of the de-stabilizing moment is to cause a divergence of the aircraft from the position shown when hovering and this divergence has to be corrected by the pilot.

The operation of the automatic stabilization system of the embodiment shown in FIGURES 1 to 6 is similar to the pilot-operated system, except that the rotor is tilted not by means of the pilot applying a tilting force to the actuating shaft but by means of a displacement or angular velocity acquired by the aircraft. If the latter acquires a rotational velocity about a turn axis lying normal to the spin axis of the rotor then the rotor will move relative to the body structure and will operate the gas control ring to stabilize the aircraft.

Thus, referring to FIGURE 13, there is shown a series of graphs illustrating the operation of the automatic stabilizing system when the aircraft hits an upgust in forward flight. The upgust imparts a nose-up pitch rate to the aircraft, i.e., a rate about an axis normal to the spin axis of the rotor. As the aircraft commences to pitch it will apply a pitching moment to the rotor which, due to the gyroscopic laws of precession, will roll as shown in graph E. The rotor will then oscillate in roll and pitch and will settle down to a gradually decreasing roll angle and virtually no pitch angle as shown in graphs E and F.

As a result of the rotor's movements, the gas control ring is moved as shown in graphs G and H. There is some initial oscillation in the left and right directions but the major displacement of the ring is rearwardly. This rearward movement increases the effective area at the rearward portion of the nozzle mouth and decreases the effective area of the forward portion of the nozzle mouth thus giving the aircraft a nose-down moment as described with reference to FIGURE 11. This nose-down moment opposes the nose-up moment imparted to the aircraft by the upgust and the pitch rate gradually decreases as shown in graph D. The pitch angle gradually increases as the pitch rate decreases but this may be corrected by the pilot as is necessary in a conventional aircraft when it hits an upgust. It will be seen from graphs A and B that the aircraft acquires substantially no roll angle and only a small initial oscillation in roll rate. The substantially zero roll angle is due to the use of a phase angle of 95° whereby the nose-down couple on the aircraft produces a couple on the rotor which opposes the gyro-couple applied to the aircraft by the rotor.

In the arrangement shown in FIGURE 7, movement of the base of the actuating shaft **58***a* in any given direction will act through the links **124** to rotate the composite levers **120**, **121** thereby moving the wire rope cables **51***a* and the gas control ring **38***a*, and consequently the gas control surface, relative to the mouth of the nozzle. The composite levers **120**, **121** are so arranged that, if the actuating shaft moves in a first direction, the gas control ring will move in a second direction advanced 25° clockwise from the first direction, i.e. the phase angle of the system is 25°. If reference is had to FIGURE 8 it will be clear how the tilting movement of the rotor acts through the actuating shaft **58***a*, the levers **120**, **121** and the links **51***a* to move the gas directing ring **38***a*.

Thus, referring to FIGURE 9, if the base of the actuating shaft **58***a* moves in the direction of the arrow "X" the points on the gas control ring **38***a* which will move the greatest distances inboardly and outboardly will lie in a plane represented by the line **137** which is at 25° to the line **131** which represents the plane containing positions of the spin axis corresponding to the neutral and tilted positions of the rotor. The plane **137** is thus the control plane and if the circle **138** is taken to represent the gas control ring **38***a*, the points where the line **137** cuts the circle **138** will be the points of maximum travel of the ring **38***a*. Conversely, the points of least travel on the ring **38***a* will be the points of intersection of a plane represented by the line **139** and the circle **138**. That part of the ring **38***a* represented by the semi-circle **140** will move outboardly and that part of the ring represented by the semi-circle **141** will move inboardly, the semi-circles being separated by the line **139**.

The response of the control system of the embodiment of FIGURE 7 is very similar to the response of the control systems described in the aforesaid applications when the phase angle of said systems is 20°. Thus, suppose that the pilot, while hovering, moves his control column to the right, the actuators **59**, **60** and **61** will apply a pitching moment to the rotor by rocking the actuating shaft **58***a*. The rotor acquires a pitch velocity and is then affected by the gyroscopic laws of motion and precession. The rotor will initially oscillate in both roll and pitch and will then acquire a steady state with a deflection in pitch and rather less of a deflection in roll. In this steady state the gas control ring is moved to tilt the curtain of gas under the aircraft. As the curtain is tilted its center of pressure moves away from the center of gravity of the aircraft. The reaction of the tilted curtain may be considered to consist of a force through the center of gravity of the aircraft plus a couple tending to turn the aircraft. The couple can be resolved into a component about the longitudinal axis of the aircraft which overcomes the aerodynamic damping of the aircraft and a component about the lateral axis of the aircraft which overcomes the gyroscopic moment and causes the aircraft to roll. After initial oscillation the aircraft acquires a substantially steady roll rate and a steadily increasing roll angle. The aircraft will be substantially undisturbed in pitch but will have an oscillating pitch rate which will be damped out.

If the aircraft is hovering and encounters a gust then the aircraft will begin to roll or pitch and will impart to the rotor a rolling or pitching force. Thus if the aircraft encounters a gust tending to roll it, the aircraft will acquire a roll rate and will impart a roll rate to the rotor which then follows the gyroscopic laws. After initial oscillation the rotor will reach a steady state with a deflection in roll and also a deflection in pitch. The steady state deflection of the actuating shaft acts through the links **51***a* to move the gas control ring to tilt the column of gas under the aircraft to reduce the divergence of the aircraft.

A fuller description of the principle of the control system is given in said aforementioned applications Serial Nos. 832,404 and 832,406. The phase angle of the control system described in the present application may either be between 0° and 90°, as in the previous applications, or the phase angle may be greater than 90° as hereinbefore described. If the phase angle is less than 90° then oscillation of the aircraft will take place upon manoeuvre when low control powers are used since there will be a component of control power tending to amplify the gyro-couple applied to the aircraft. When a phase angle of greater than 90° is used, there will be a component of control power tending to reduce or eliminate the gyro-couple applied to the aircraft.

It will be understood that the form of the invention herewith shown and described is a preferred example and various modifications can be carried out without departing from the spirit of the invention or the scope of the appended claims.

What I claim as my invention is:

1. An aircraft having a body structure; walls within the structure defining a gas displacement passage which includes and terminates in a propulsive nozzle having a mouth, one of said walls forming one boundary of the mouth and curving away therefrom in a smooth convex surface and the other wall forming another boundary of the mouth; means within the structure to impel propulsive gas along the passage and to expel the gas from the mouth; gas directing means; suspsension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to said other boundary of the mouth; said gas directing means having a gas control surface which forms a movable extension of said other boundary of the mouth and which is shaped to direct gas expelled from the mouth around said convex surface; and actuating means to move the gas directing means on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth.

2. An aircraft having a body structure; walls within the structure defining a gas displacement passage which includes and terminates in a propulsive nozzle having a substantially annular mouth, one of said walls forming the radially inner boundary of the mouth and curving away therefrom in a smooth convex surface and the other wall forming the radially outer boundary of the mouth; means within the structure to impel propulsive gas along the passage and to expel the gas from the mouth; a gas control ring; suspension means interposed between the ring and the structure to movably suspend the ring adjacent to said radially outer boundary of the mouth; said ring having a gas control surface which forms a movable extension of said radially outer boundary and which is shaped to direct the gas expelled from the mouth around said convex surface; and actuating means to move the ring on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth.

3. An aircraft having a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed propulsive nozzle having a mouth arranged to

discharge at a multiplicity of positions distributed around a periphery on the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; means within the structure to impel propulsive gas along the passage and to expel the gas from the mouth; gas directing means; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means beneath, and adjacent to, the outboard boundary of the mouth; and actuating means to move the gas directing means on its suspension means thus to vary the position of the gas control surface relative to said mouth and to variably control the direction of flow of the propulsive gas expelled from the mouth.

4. An aircraft having a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed propulsive nozzle having a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; engine means within the structure to impel propulsive gas along the gas displacement passage and to expel the gas from said mouth; a gyroscope mounted in the structure to be capable of a limited degree of universal movement relative to the structure; biasing means interposed between the structure and the gyroscope to bias the latter to a neutral position within the structure; gas directing means; suspension means interposed between the gas directing means and the structure to movably support the gas directing means beneath, and adjacent to, the outboard boundary of the mouth; said gas directing means having a gas control surface which is shaped to direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; and actuating means interposed between the gyroscope and the ring and operable to move the gas directing means on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth, said actuating means operating in response to tilting of the gyroscope from its neutral position.

5. An aircraft having a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed propulsive nozzle having a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; engine means within the structure to impel propulsive gas along the gas displacement passage and to expel the gas from said mouth, said engine means including an impelling rotor mounted in the structure to be capable of a limited degree of universal movement relative to the structure; biasing means interposed between the structure and the rotor to bias the latter to a neutral position within the structure; gas directing means; suspension means interposed between the gas directing means and the structure to movably support the gas directing means beneath, and adjacent to, the outboard boundary of the mouth; said gas directing means having a gas control surface which is shaped to direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; and actuating means interposed between the rotor and the gas directing means and operable to move the gas directing means on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth, said actuating means operating in response to tilting of the rotor from its neutral position.

6. An aircraft having a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed propulsive nozzle having a substantially annular mouth in the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; means within the structure to impel propulsive gas along the passage and to expel the gas from the mouth; a gas control ring; suspension means interposed between the ring and the structure to movably suspend the ring beneath, and adjacent to, the outboard boundary of the mouth; said ring having a gas control surface which is shaped to direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; and actuating means to move the ring on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth.

7. An aircraft having a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed propulsive nozzle having a substantially annular mouth on the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; engine means within the structure to impel propulsive gas along the gas displacement passage and to expel it from said mouth; a gyroscope mounted in the structure to be capable of a limited degree of universal movement relative to the structure; biasing means interposed between the structure and the gyroscope to bias the latter to a neutral position within the structure; a gas control ring; suspension means interposed between the ring and the structure and movably suspending the ring beneath, and adjacent to, the outboard boundary of the mouth, said ring having a gas control surface which is shaped to direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; and actuating means interposed between the gyroscope and the ring and operable to move the ring on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the gas expelled from the mouth, said actuating means operating in response to tilting of the gyroscope from its neutral position.

8. An aircraft having a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed propulsive nozzle having a substantially annular mouth on the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; engine means within the structure to impel propulsive gas along the gas displacement passage and to expel the gas from said mouth, said engine means including an impelling rotor mounted in the structure to be capable of a limited degree of universal movement relative to the structure; biasing means interposed between the structure and the rotor to bias the latter to a neutral position within the structure; a gas control ring; suspension means interposed between the ring and the structure and movably suspending the ring beneath, and adjacent to, the outboard boundary of the mouth, said ring having a gas control surface which is shaped to direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; and actuating means interposed between the rotor and the ring and operable to move the ring on its suspension means to

vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the gas expelled from the mouth, said actuating means operating in response to tilting of the rotor from its neutral position.

9. An aircraft having a lentiform body structure sheathed by opposed upper and lower aerofoil skins which provide lift surfaces for the aircraft; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed propulsive nozzle having a substantially annular mouth in the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; engine means within the structure to impel propulsive gas along the gas displacement passage and to expel the gas from said mouth, said engine means including an impelling rotor mounted in the structure to be capable of a limited degree of universal movement relative to the structure; biasing means interposed between the structure and the rotor to bias the latter to a neutral position within the structure; a gas control ring; suspension means interposed between the ring and the structure and movably suspending the ring beneath, and adjacent to, the outboard boundary of the mouth, said ring having a gas control surface which is shaped to direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; and actuating means interposed between the rotor and the ring and operable to move the ring on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth, said actuating means operating in response to tilting of the rotor from its neutral position.

10. An aircraft having a lentiform body structure sheathed by opposed upper and lower aerofoil skins which provide lift surfaces for the aircraft; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed propulsive nozzle having a substantially annular mouth in the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; engine means within the structure to impel propulsive gas along the gas displacement passage and to expel the gas from said mouth, said engine means including an impelling rotor mounted in the structure to be capable of a limited degree of universal movement relative to the structure; biasing means interposed between the structure and the rotor to bias the latter to a neutral position within the structure; a gas control ring; suspension means interposed between the ring and the structure and movably suspending the ring beneath, and adjacent to, the outboard boundary of the mouth, said ring having a gas control surface which is shaped to direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; actuating means interposed between the rotor and the ring and operable to move the ring on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth, said actuating means operating in response to tilting of the rotor from its neutral position; and pilot-operated control means operatively connected to the rotor and operable to apply a tilting force to the rotor thus operating the actuating means to cause a desired movement of the control ring.

11. An aircraft having a lentiform body structure sheathed by opposed upper and lower aerofoil skins which provide lift surfaces for the aircraft; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed propulsive nozzle having a substantially annular mouth in the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; engine means within the structure to impel propulsive gas along the gas displacement passage and to expel the gas from said mouth, said engine means including an impelling rotor mounted within the structure to be capable of a limited degree of universal movement relative to the structure; biasing means interposed between the structure and the rotor to bias the latter to a neutral position within the structure; an actuating shaft operatively connected to the rotor to tilt therewith; a gas control ring; suspension means interposed between the ring and the structure and movably suspending the ring beneath, and adjacent to, the outboard boundary of the mouth, said ring having a gas control surface which is shaped to direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; a plurality of spaced apart links extending outboardly from the actuating shaft to peripherally spaced points on the ring, whereby tilting of the rotor from its neutral position moves the ring on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth; and pilot-operated control means operatively connected to the rotor and operable to apply a tilting force to the rotor thus operating the actuating means to cause a desired movement of the control ring.

12. An aircraft having a lentiform body structure sheathed by opposed upper and lower aerofoil skins which provide lift surfaces for the aircraft; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed propulsive nozzle having a substantially annular mouth in the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; engine means within the structure to impel propulsive gas along the gas displacement passage and to expel the gas from said mouth; a gyroscope mounted within the structure to be capable of a limited degree of universal movement relative to the structure; biasing means interposed between the structure and the gyroscope to bias the latter to a neutral position within the structure; an actuating member operatively connected to the gyroscope to tilt therewith; a ring member secured to the structure in a position to surround said actuating member but to leave an annular space between the members; a plurality of radially directed sensing nozzles in said space and secured to one of said members; a plurality of abutments in said space and secured to the other of said members so that an abutment is radially opposed to each of said sensing nozzles; means on the structure to supply pressure fluid to each sensing nozzle; means associated with each sensing nozzle to sense the variation in back-pressure in the nozzle as the space between the nozzle and its opposed abutment varies; a gas control ring; suspension means interposed between the ring and the structure and movably suspending the ring beneath, and adjacent to, the outboard boundary of the mouth, said ring having a gas control surface which is shaped to direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; a plurality of pressure-responsive actuators mounted in the structure; a plurality of links extending outboardly from said actuators to peripherally spaced points on the ring; means interconnecting said actuators with said pressure-sensing means of the sensing nozzles

whereby variations in the pressures in the nozzles due to tilting of the gyroscope from its neutral position with consequent variation in the spacing between the nozzles and the abutments operates the actuators to move the ring on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth; and pilot-operated control means in the structure to apply a tilting force to the gyroscope thus to cause a desired movement of the control ring.

13. An aircraft having a lentiform body structure sheathed by opposed upper and lower aerofoil skins which provide lift surfaces for the aircraft; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed propulsive nozzle having a substantially annular mouth in the underside of the structure; the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; engine means within the structure to impel propulsive gas along the gas displacement passage and to expel the gas from said mouth, said engine means including an impelling rotor mounted within the structure to be capable of a limited degree of universal movement relative to the structure; biasing means interposed between the structure and the rotor to bias the latter to a neutral position within the structure; an actuating member operatively connected to the rotor to tilt therewith; a ring member secured to the structure in a position to surround said actuating member but to leave an annular space between the members; a plurality of radially directed sensing nozzles in said space and secured to one of said members; a plurality of abutments in said space and secured to the other of said members so that an abutment is radially opposed to each of said sensing nozzles; means on the structure to supply pressure fluid to each sensing nozzle; means associated with each sensing nozzle to sense the variation in back pressure in the nozzle as the space between the nozzle and its opposed abutment varies; a gas control ring; suspension means interposed between the ring and the structure and movably suspending the ring beneath, and adjacent to, the outboard boundary of the mouth, said ring having a gas control surface which is shaped to direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; a plurality of fluid-operated jacks mounted in the structure around said ring member; a plurality of links extending outboardly from said jacks to peripherally spaced points on the ring; means interconnecting said jacks with said pressure-sensing means of the sensing nozzles whereby variations in the pressures in the nozzles due to tilting of the rotor from its neutral position with consequent variation in the spacing between the nozzles and the abutments operates the jacks to move the ring on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth; and pilot-operated control means in the structure to apply a force to the actuating member to tilt the rotor and thus to cause a desired movement of the control ring.

14. An aircraft having a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed propulsive nozzle having a substantially annular mouth on the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; means within the structure to impel propulsive gas along the passage and to expel the gas from the mouth; a gas control ring; suspension means to movably suspend the ring beneath and adjacent to the outboard boundary of the mouth; said ring having a gas control surface of inverted frusto-conical form shaped to direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; and actuating means to move the ring on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control direction of flow of the propulsive gas expelled from the mouth.

15. A control system for an aircraft having a body structure; engine means within the structure to provide propulsive gas, the engine means including a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor having a limited degree of universal movement; a gas displacement passage along which the propulsive gas is impelled by the rotor; and a propulsive nozzle communicating with the gas displacement passage and arranged to discharge the propulsive gas at a multiplicity of positions distributed around a periphery on the structure; the control system comprising biasing means associated with the rotor to bias it to its neutral position to allow relative movement between the rotor and the body structure, with consequent tilting of the rotor from its neutral position and application of a gyro-couple to the aircraft, when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; gas directing means associated with the nozzle and operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle at any selected position of said multiplicity of positions; a link system interposed between the rotor and the gas directing means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas directing means spaced around said periphery; the response of the link system to tilt of the rotor causing operation of opposite peripheral portions of the gas directing means lying adjacent to a control plane which contains the position of the spin axis corresponding to the neutral position of the rotor and is advanced in the direction of rotation of the rotor by a phase angle α relative to the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor, the phase angle having a value greater than 90°; operation of the gas directing means as a result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from peripherally opposite portions of the propulsive nozzle to apply a force to the aircraft to reduce the divergence of the aircraft incident upon said disturbance; the force having a first component proportional to cosine α and which opposes and reduces the said gyro-couple and a second component proportional to sine α which directly opposes said rotational velocity.

16. An aircraft having a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed nozzle having a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; engine means within the structure to provide propulsive gas, the engine means including a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor having a limited degree of universal movement; gas directing means; suspension means interposed between the gas directing means the structure to movably suspend the gas directing means beneath, and adjacent to, the outboard boundary of the mouth; said gas directing means having a gas control surface which is shaped to

direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; and a control system to move the gas directing means on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth; the control system comprising biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure, with consequent tilting of the rotor from its neutral position and application of a gyro-couple to the aircraft, when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; and a link system between the rotor and the gas directing means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas directing means; the response of the link system to tilt of the rotor causing operation of the opposite peripheral portions of the gas directing means lying adjacent to a control plane which contains the position of the spin axis corresponding to the neutral position of the rotor and is advanced in the direction of rotation of the rotor by a phase angle α relative to the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor, the phase angle having a value between 0° and 90° inclusive; operation of the gas directing means as a result of the disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the gas directing means to apply a force to the aircraft to reduce the divergence thereof incident upon said disturbance, the force having a first component proportional to cosine α and which amplifies said gyro-couple and a second component proportional to sine α which directly opposes said rotational velocity.

17. An aircraft having a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in a downwardly directed nozzle having a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the structure, the lower wall forming the inboard boundary of the mouth and merging with the underside of the structure in a smooth, outboardly convex surface and the upper wall forming the outboard boundary of the mouth; engine means within the structure to provide propulsive gas, the engine means including an impelling rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor having a limited degree of universal movement; gas directing means; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means beneath, and adjacent to, the outboard boundary of the mouth; said gas directing means having a gas control surface which is shaped to direct gas expelled from the mouth generally inboardly and which forms a movable extension of the outboard boundary of the mouth; and a control system to move the gas directing means on its suspension means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth; the control system comprising the biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure, with consequent tilting of the rotor from its neutral position and application of a gyro-couple to the aircraft, when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; and a link system between the rotor and the gas directing means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas directing means; the response of the link system to tilt of the rotor causing operation of opposite peripheral portions of the gas directing means lying adjacent to a control plane which contains the position of the spin axis corresponding to the neutral position of the rotor and is advanced in the direction of rotation of the rotor by a phase angle α relative to the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor, the phase angle having a value greater than 90°; operation of the gas directing means as a result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from the mouth to apply a force to the aircraft to reduce the divergence of the aircraft incident upon said disturbance; the couple having a first component proportional to cosine α and which opposes and reduces said gyro-couple and a second component proportional to sine α which directly opposes said rotational velocity.

References Cited in the file of this patent

UNITED STATES PATENTS

2,838,257 Wibault -------------- June 10, 1958
2,990,137 Willis ---------------- June 27, 1961

Aug. 28, 1962 J. C. M. FROST ETAL 3,051,415

FLUID SUSTAINED AIRCRAFT

Filed Aug. 6, 1959 31 Sheets-Sheet 1

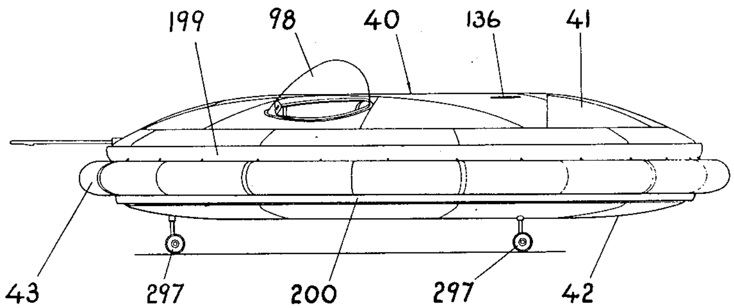

FIG. 1.

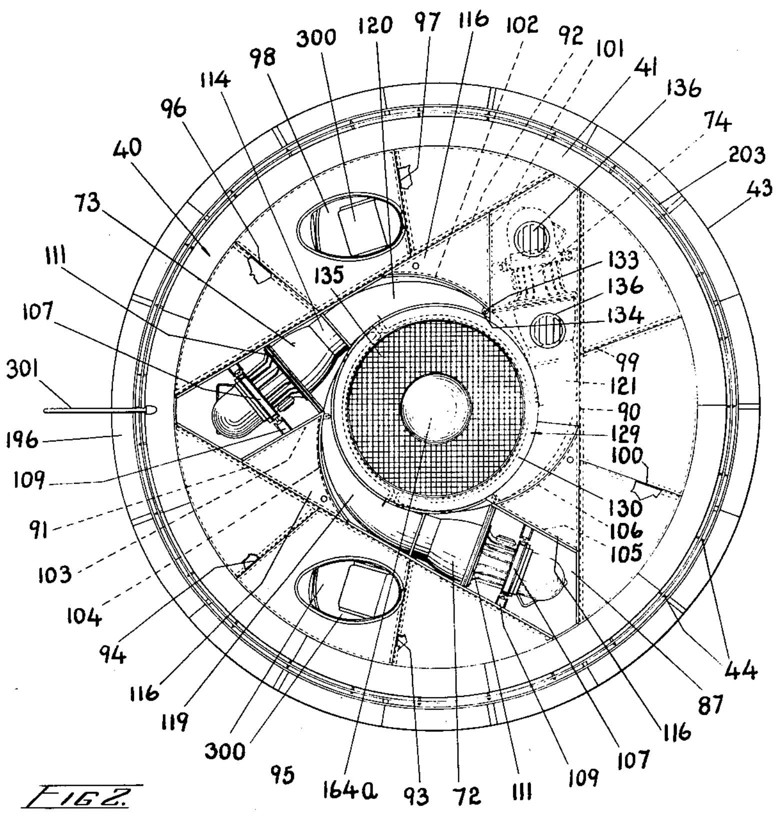

FIG. 2.

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FLUID SUSTAINED AIRCRAFT

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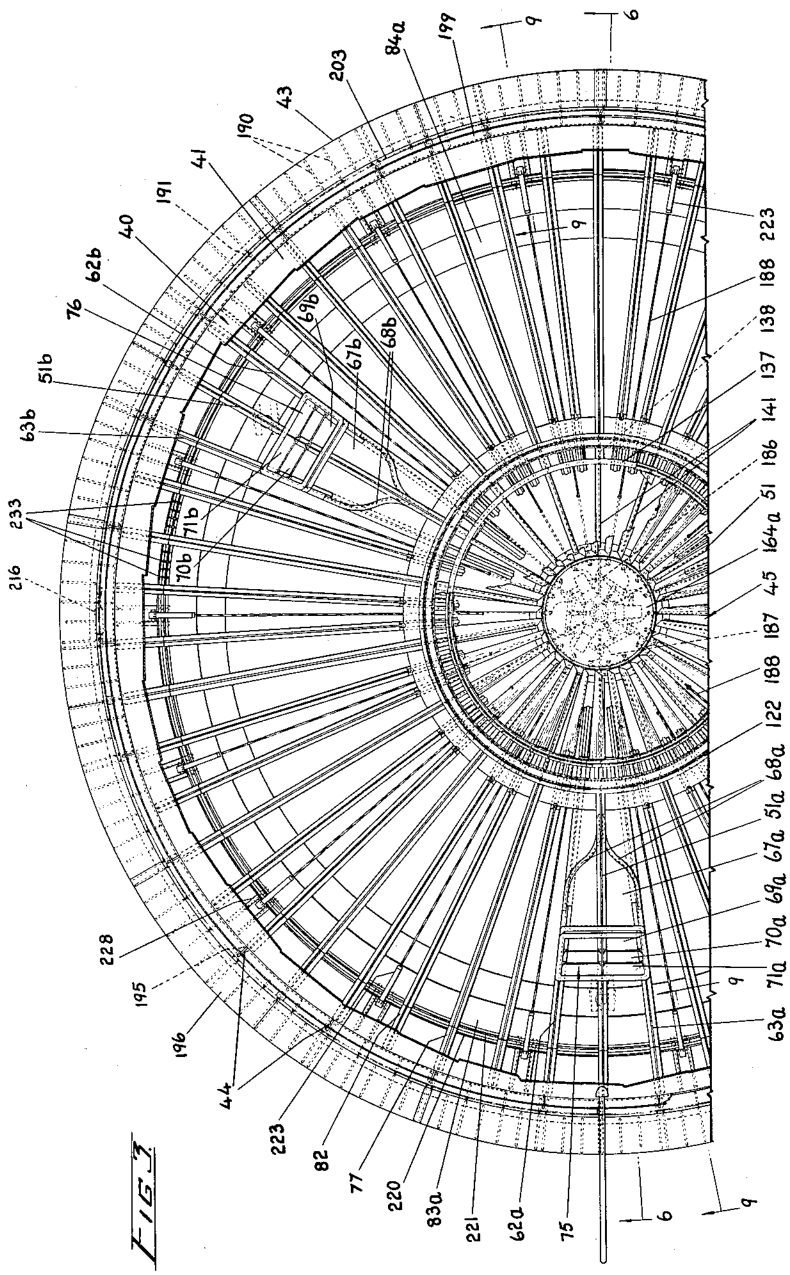

FIG. 3

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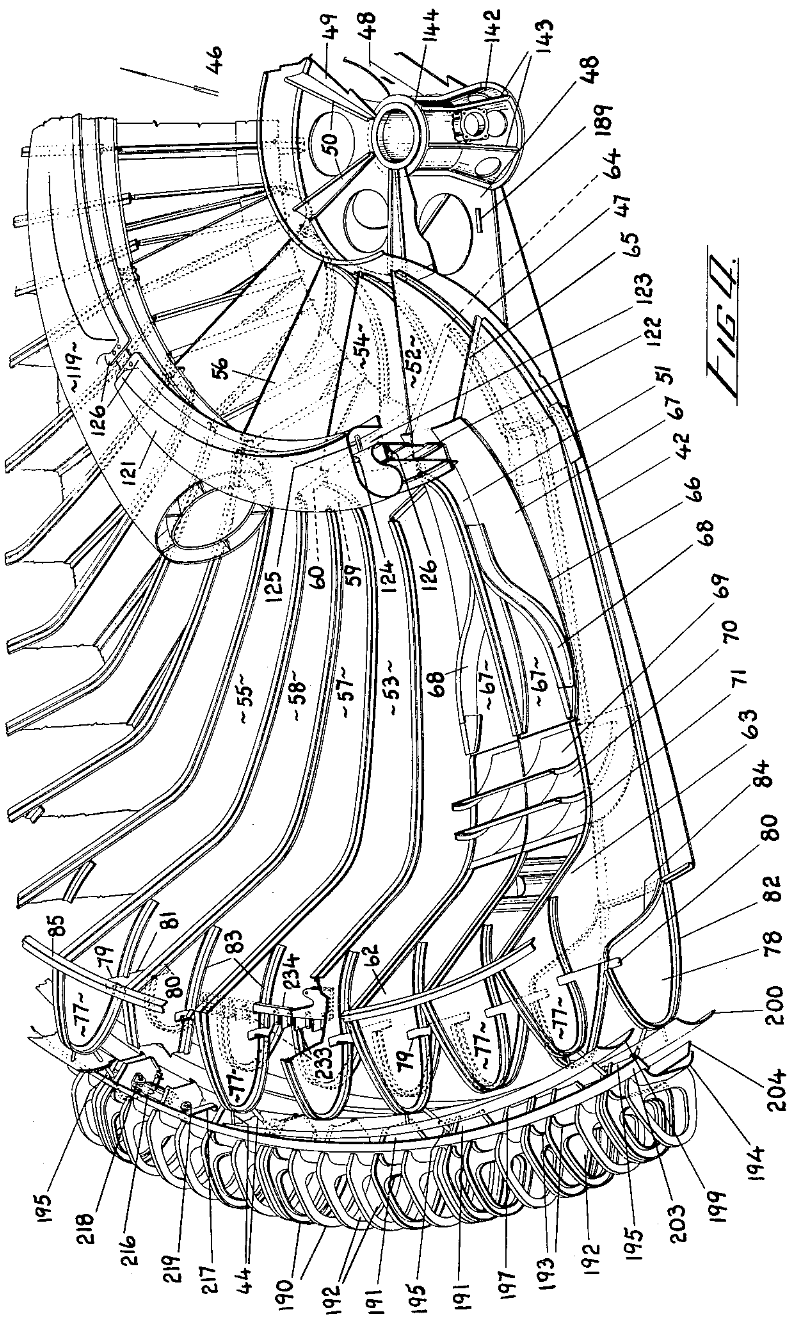

FIG. 4.

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FLUID SUSTAINED AIRCRAFT

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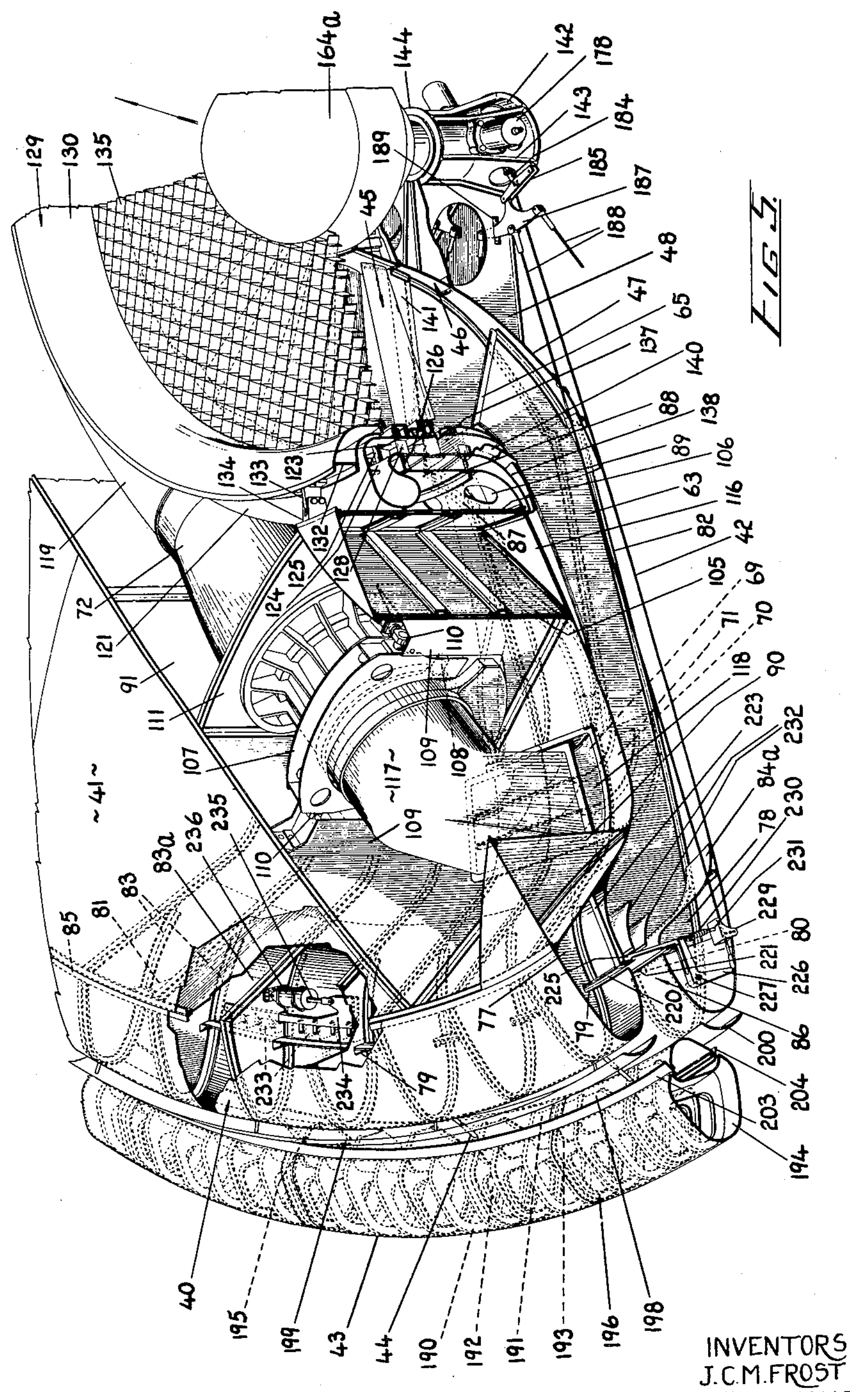

FIG. 5

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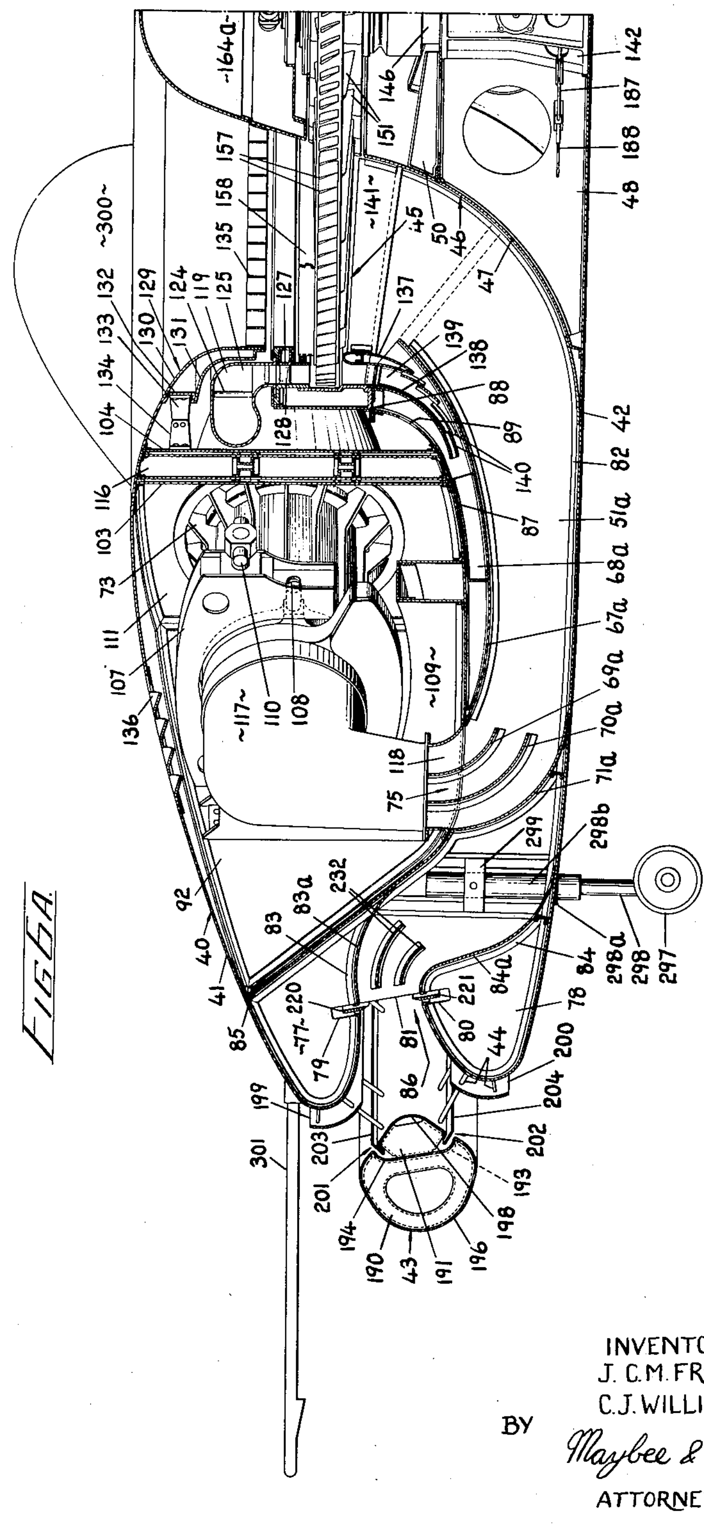

FIG. 6A.

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Aug. 28, 1962 — J. C. M. FROST ET AL — 3,051,415

FLUID SUSTAINED AIRCRAFT

Filed Aug. 6, 1959 — 31 Sheets-Sheet 6

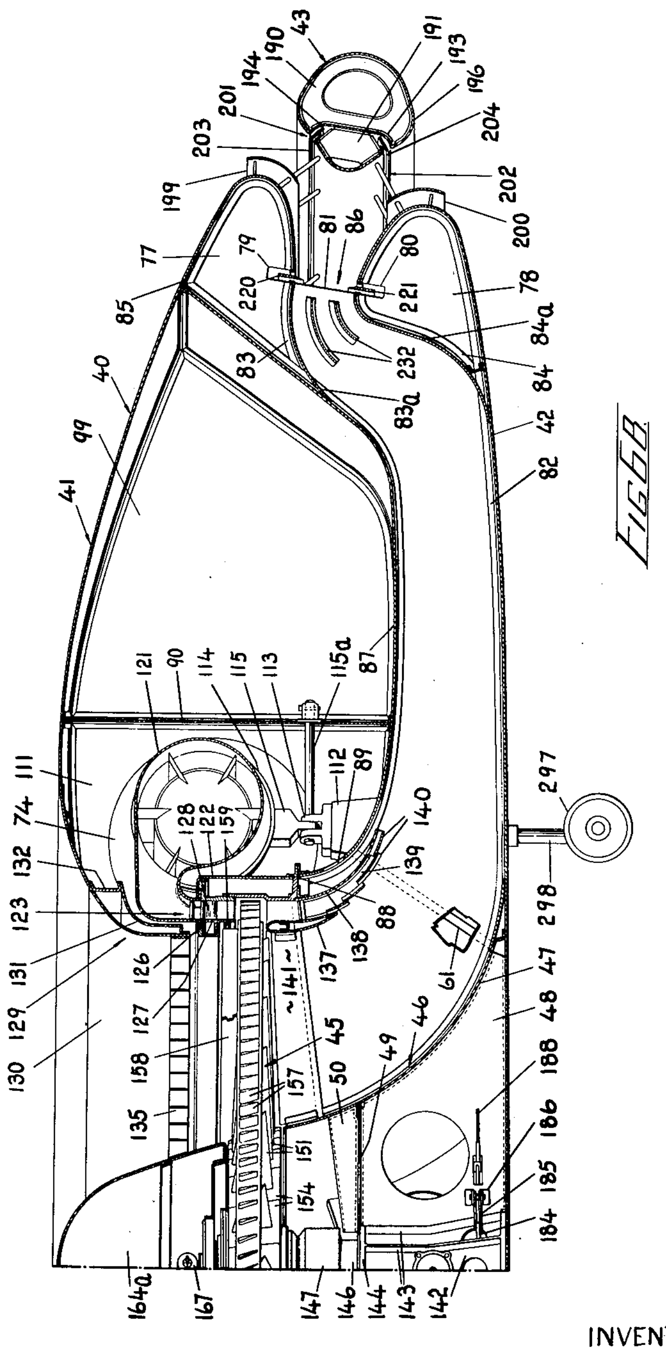

FIG. 6B

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FLUID SUSTAINED AIRCRAFT

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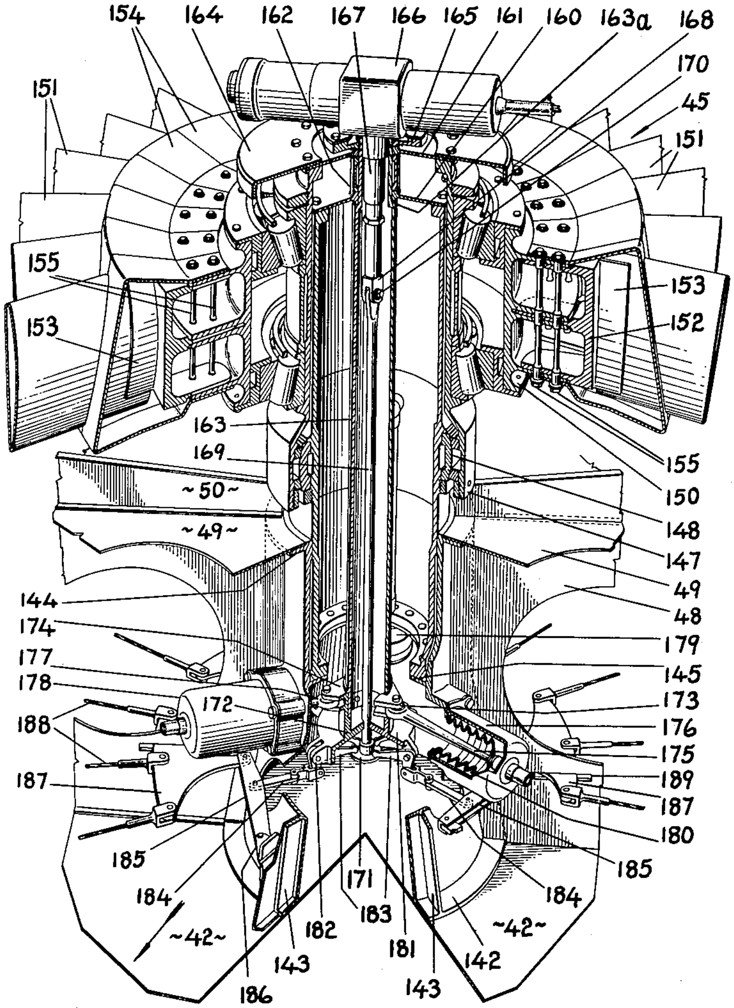

FIG. 7.

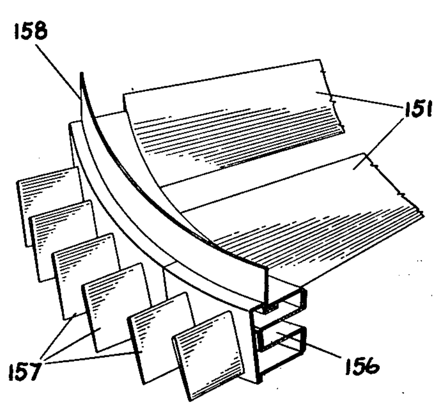

FIG. 8.

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FLUID SUSTAINED AIRCRAFT

Filed Aug. 6, 1959 31 Sheets-Sheet 8

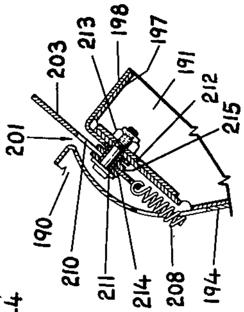

FIG. 10.

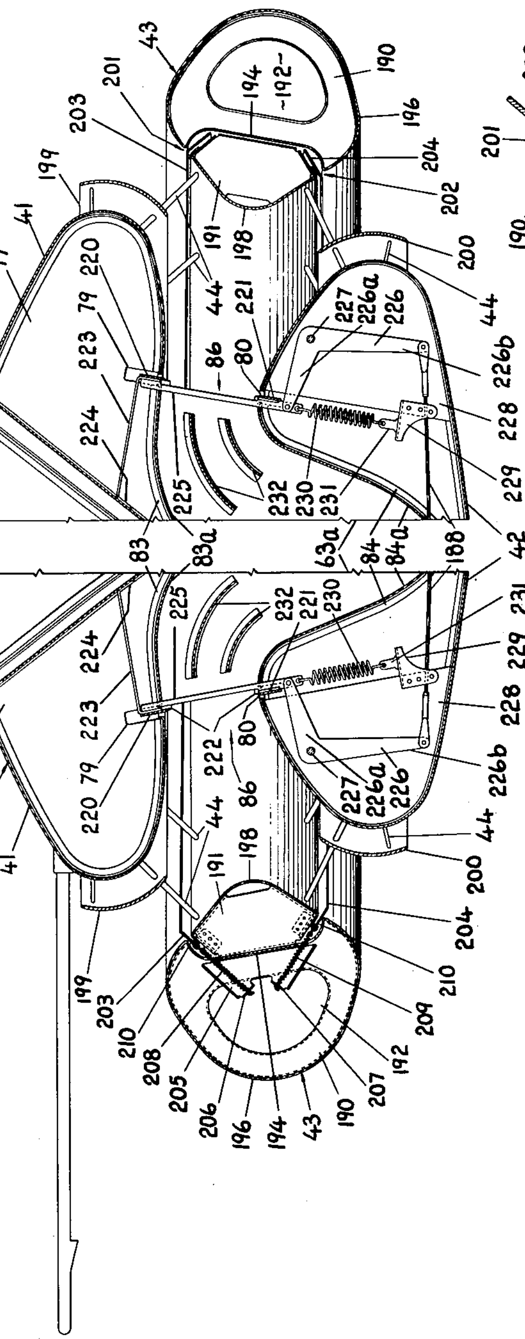

FIG. 9.

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Aug. 28, 1962 J. C. M. FROST ETAL 3,051,415
FLUID SUSTAINED AIRCRAFT
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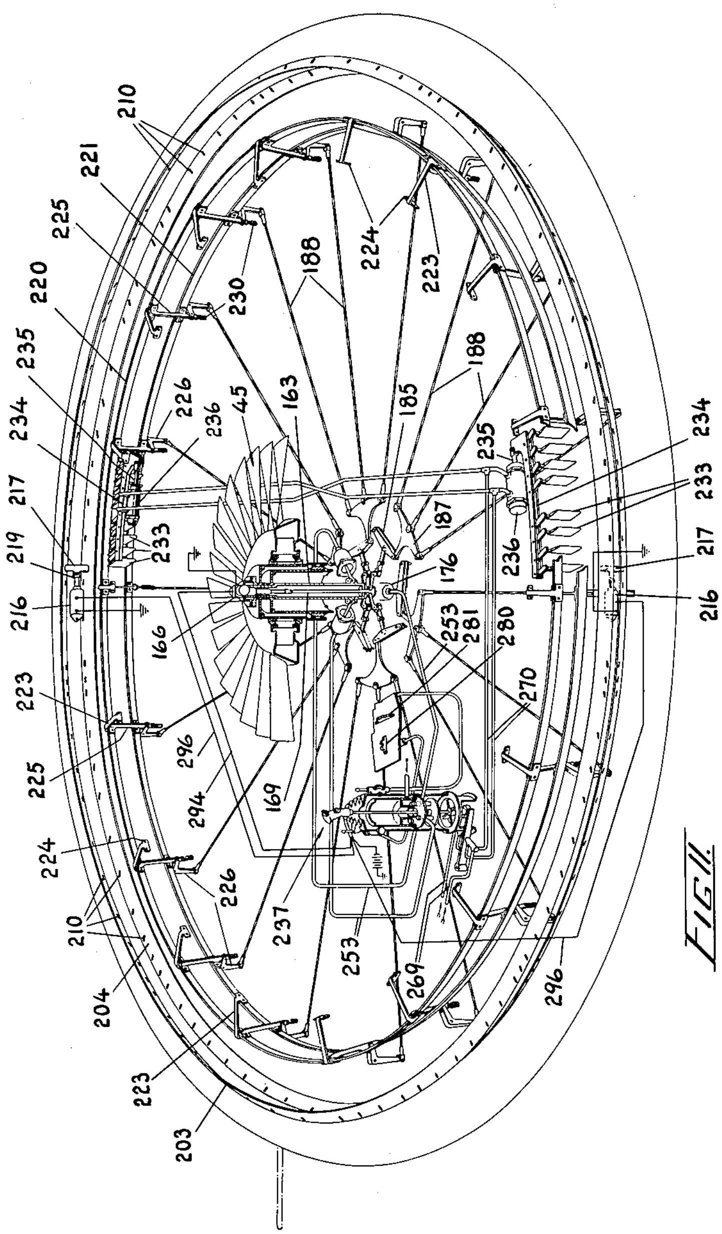

FIG. 11.

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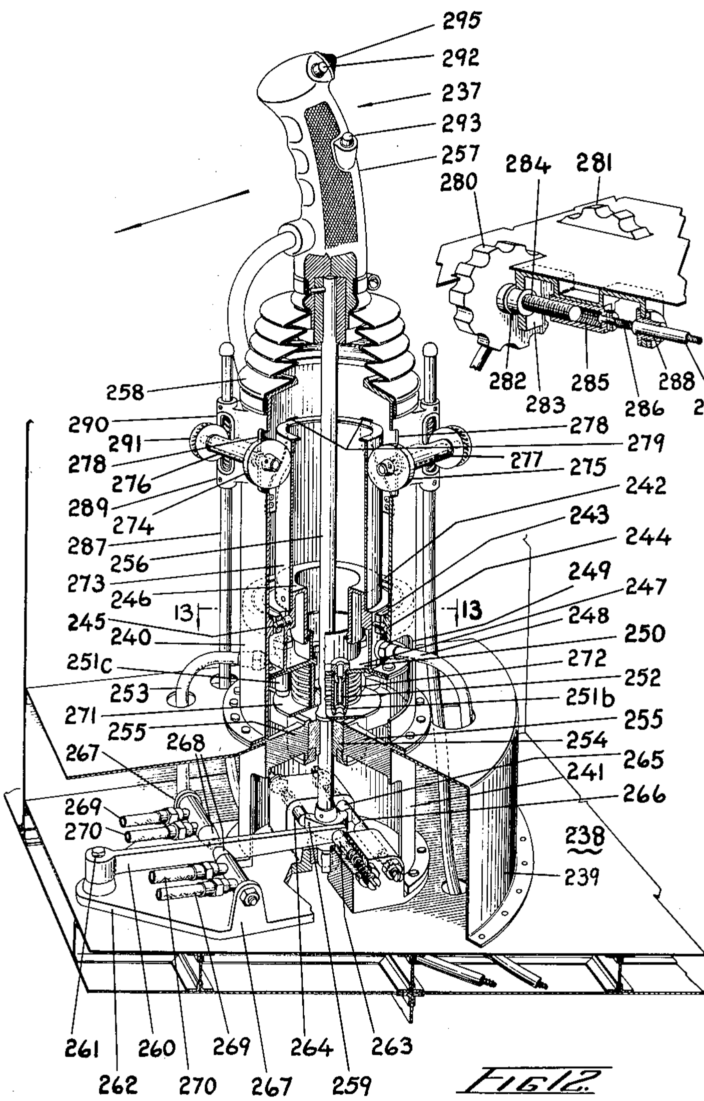

FIG. 12.

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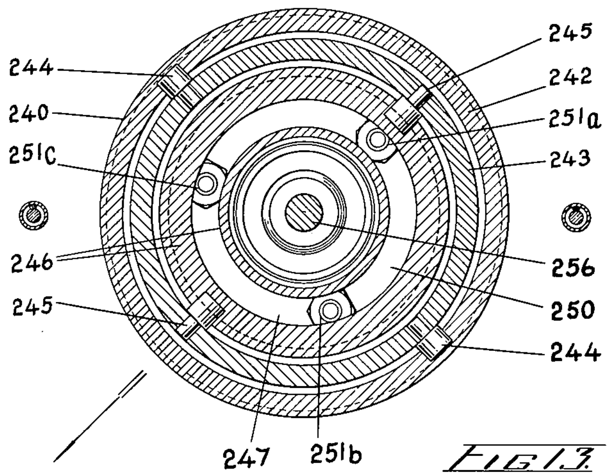

FIG. 13.

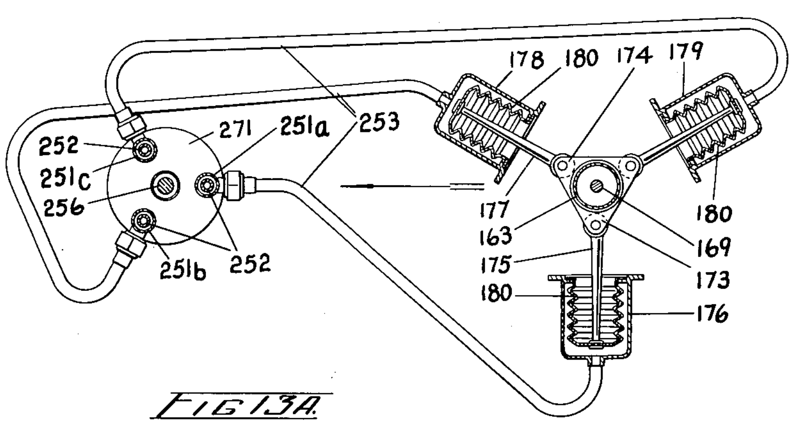

FIG. 13A.

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FLUID SUSTAINED AIRCRAFT

Filed Aug. 6, 1959 31 Sheets-Sheet 12

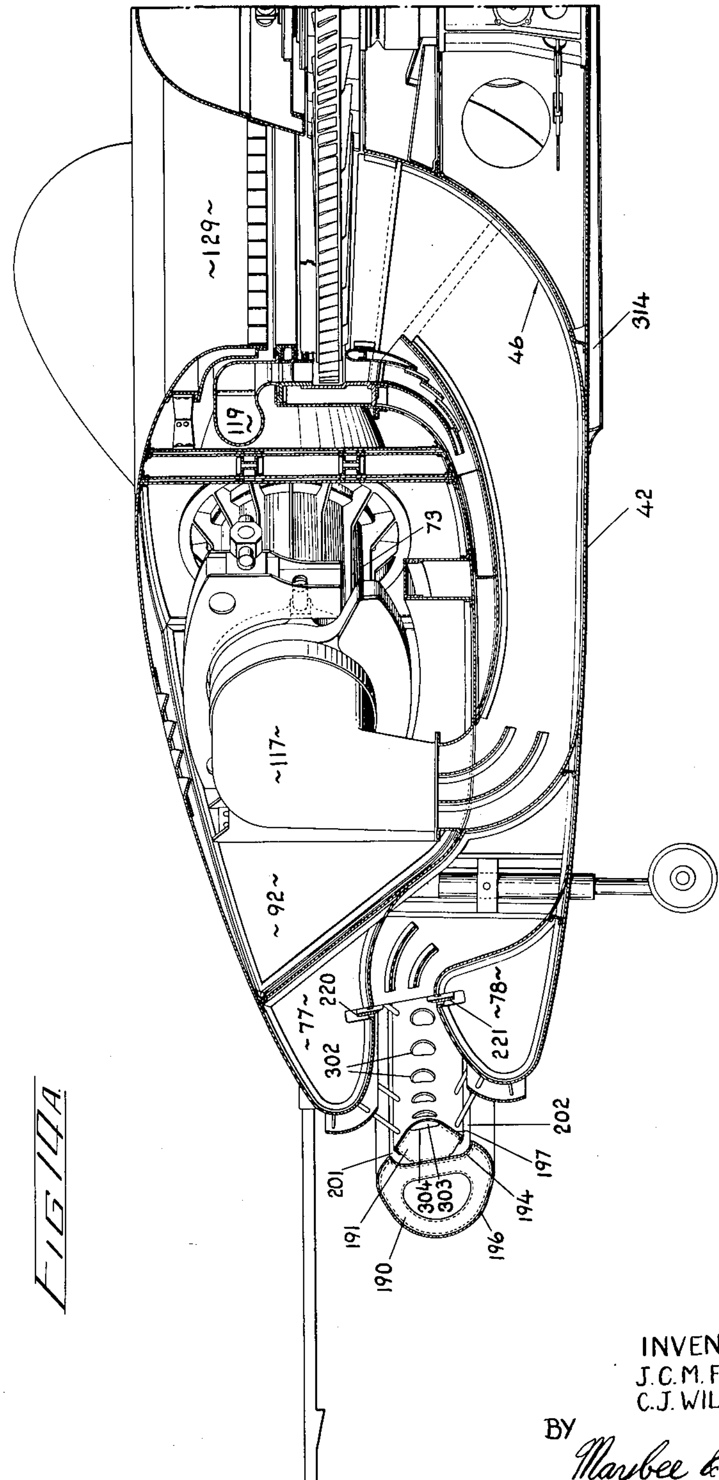

FIG 14A

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FLUID SUSTAINED AIRCRAFT

Filed Aug. 6, 1959 31 Sheets-Sheet 13

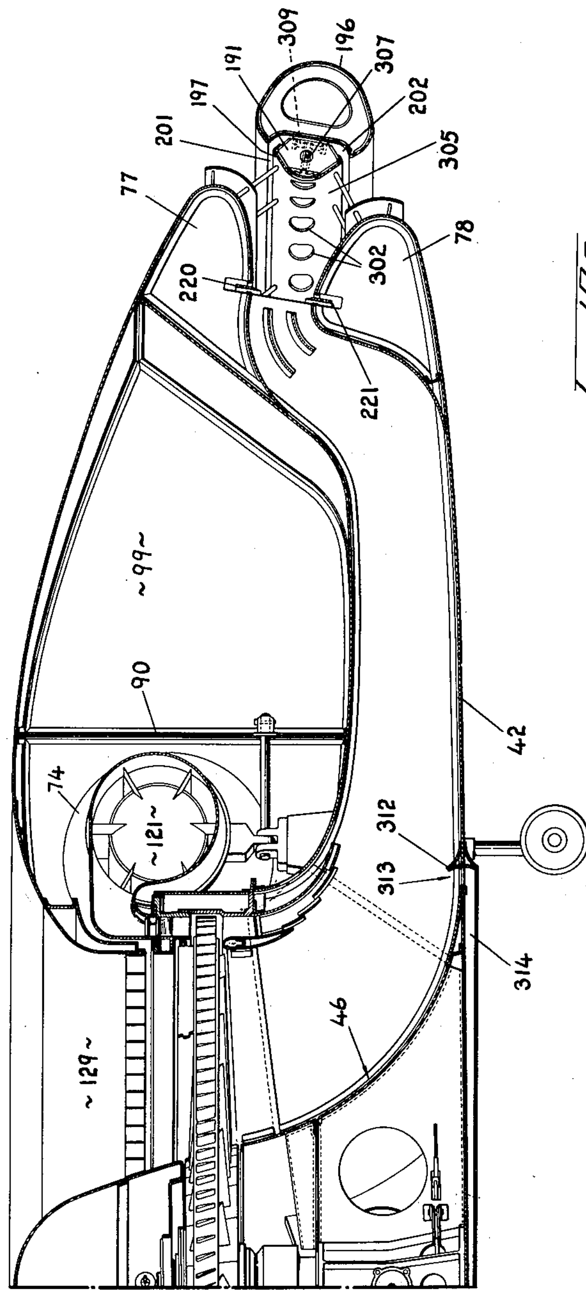

FIG. 14B

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FLUID SUSTAINED AIRCRAFT

Filed Aug. 6, 1959 31 Sheets-Sheet 14

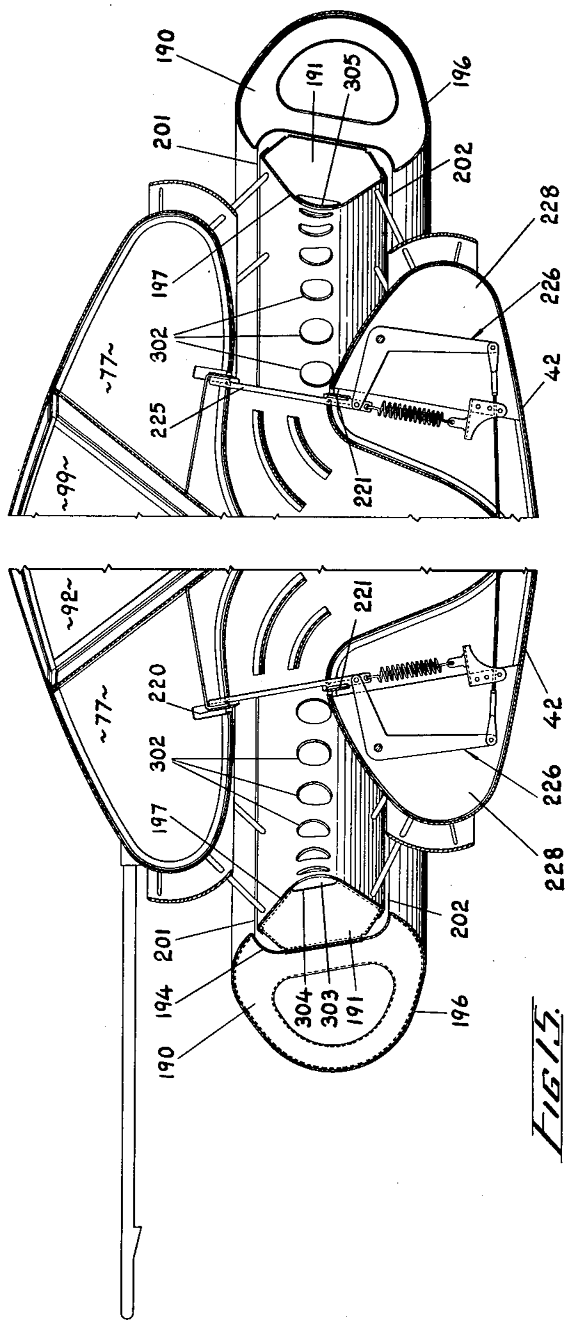

FIG. 15.

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FLUID SUSTAINED AIRCRAFT

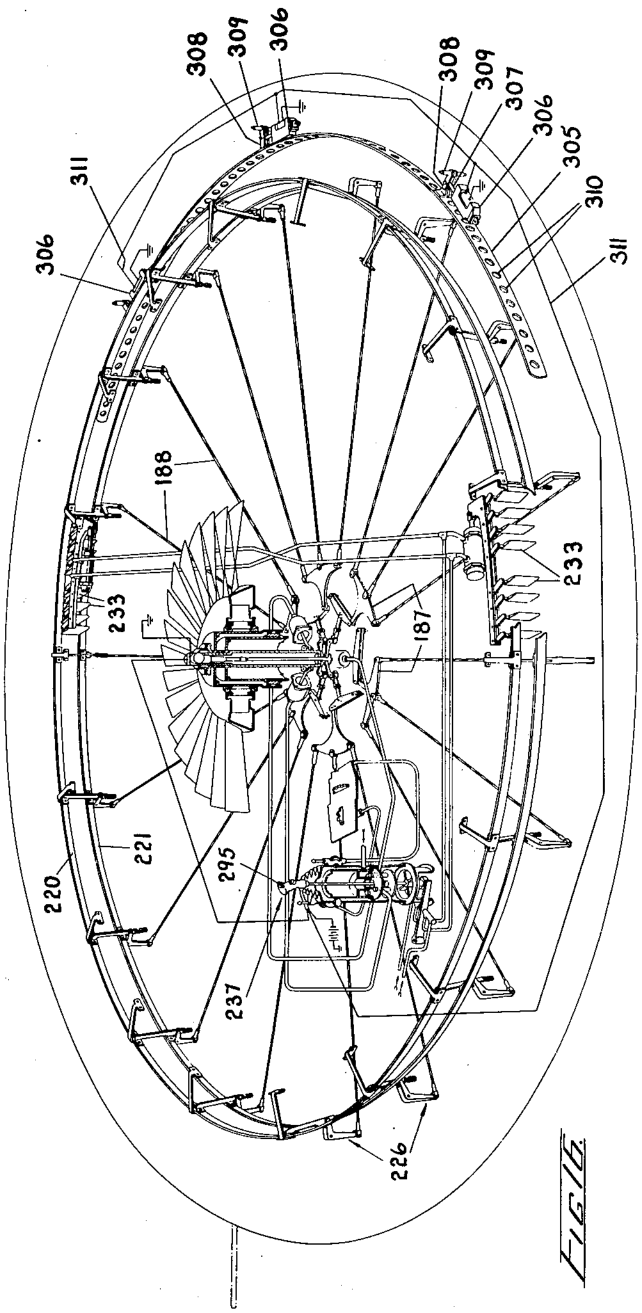

FIG. 16.

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FLUID SUSTAINED AIRCRAFT

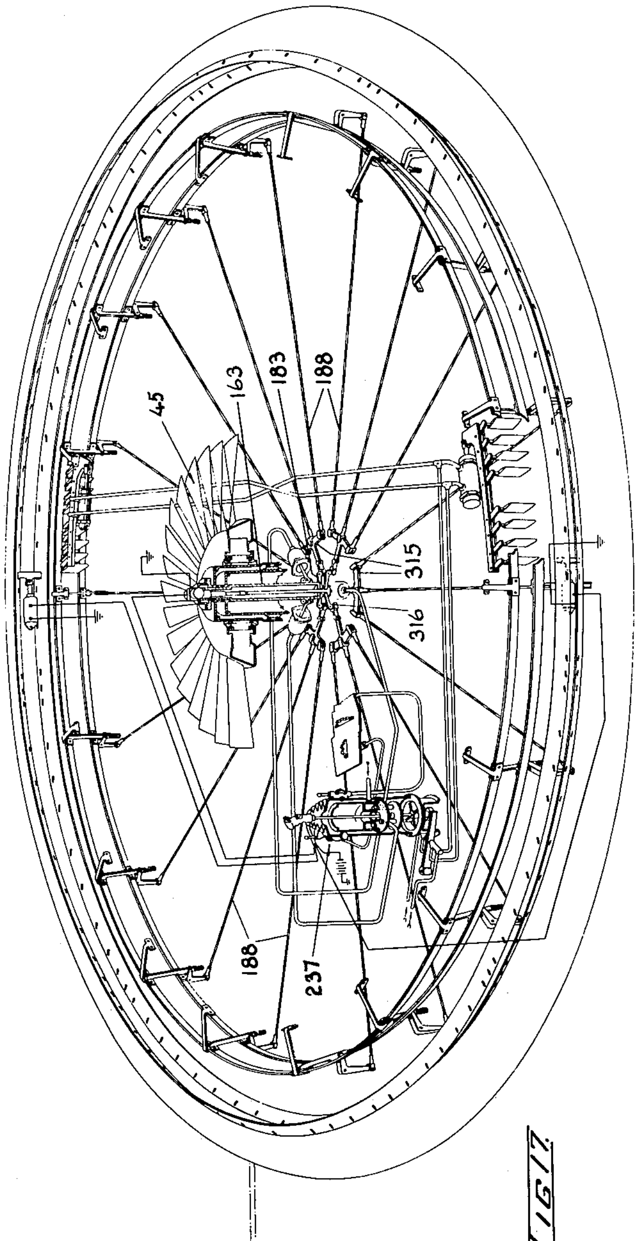

FIG. 17

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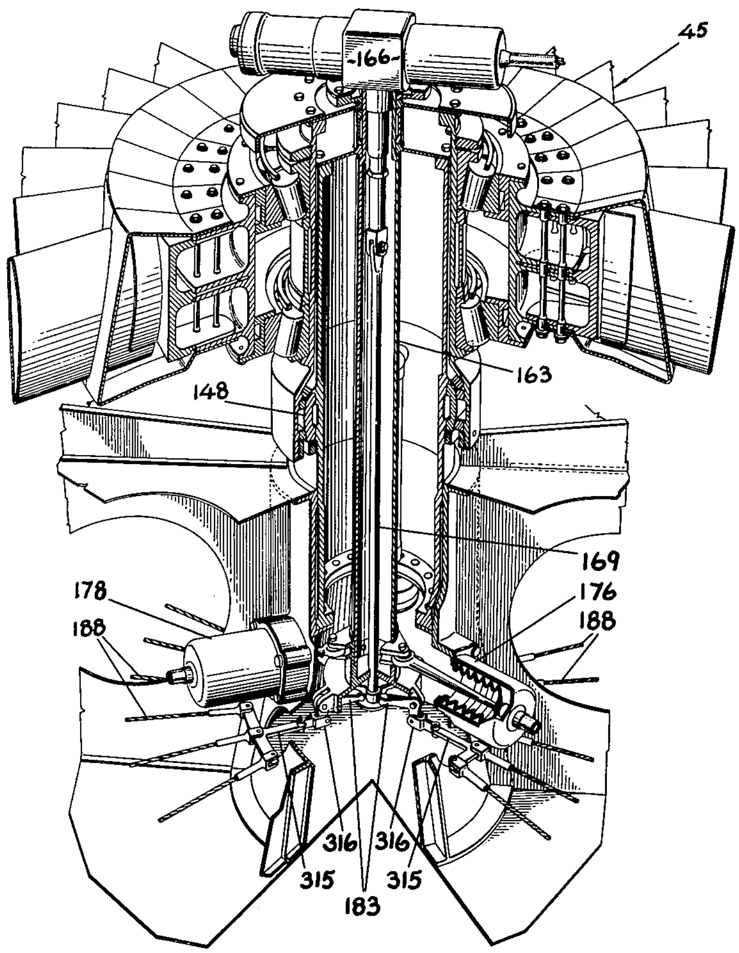

FIG 17A.

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FLUID SUSTAINED AIRCRAFT

Filed Aug. 6, 1959 31 Sheets-Sheet 18

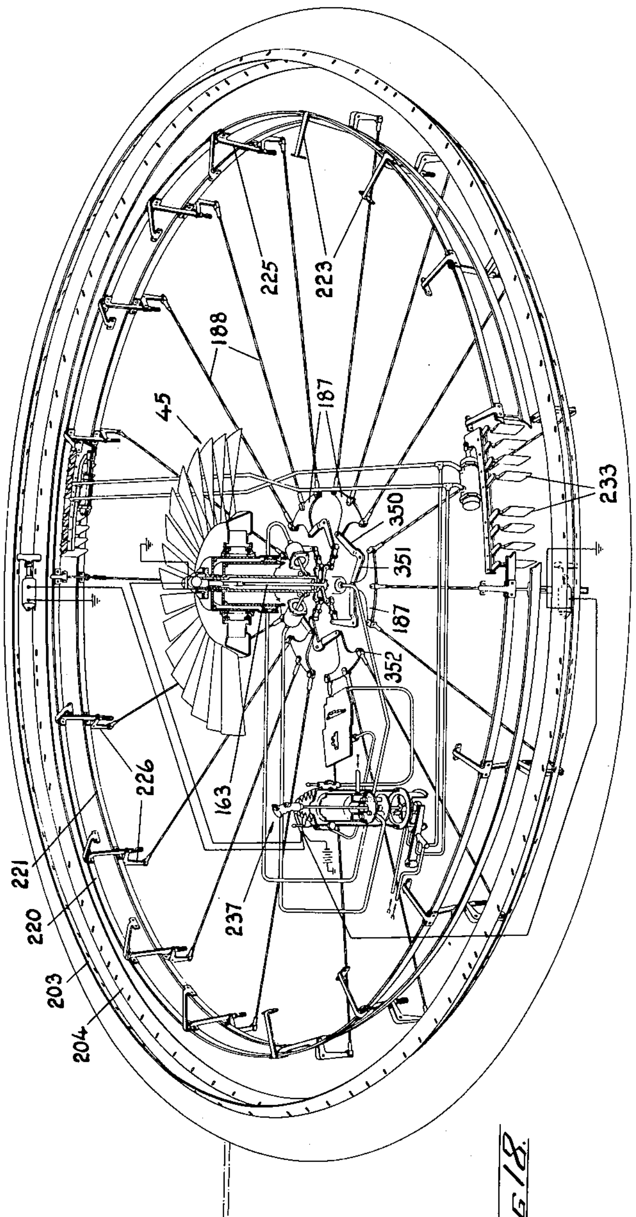

FIG. 18.

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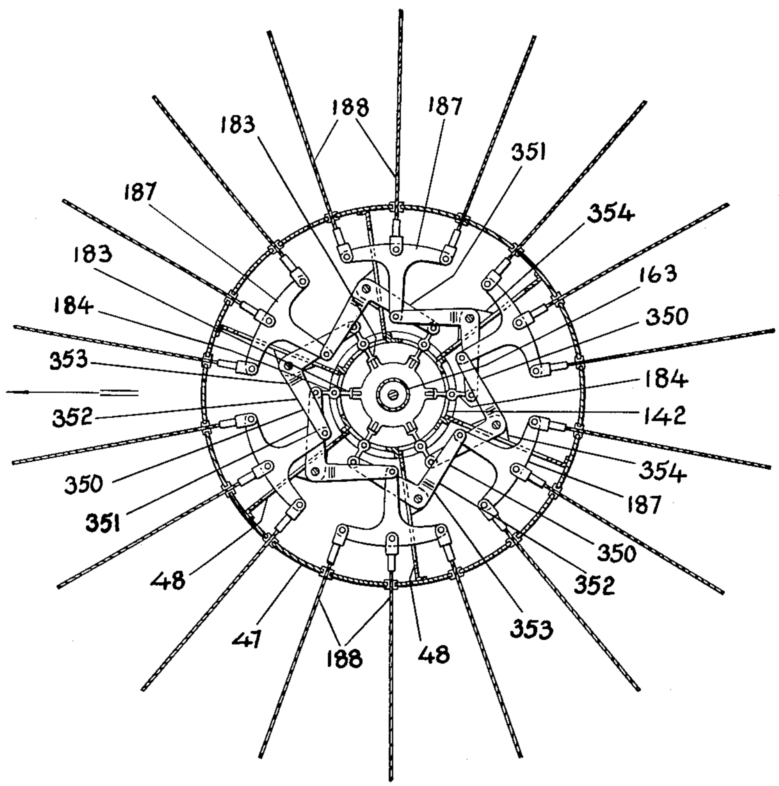

FIG 18A.

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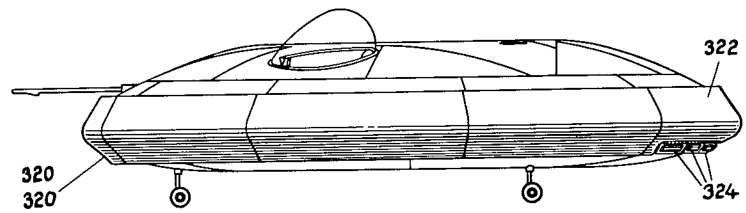

FIG 19.

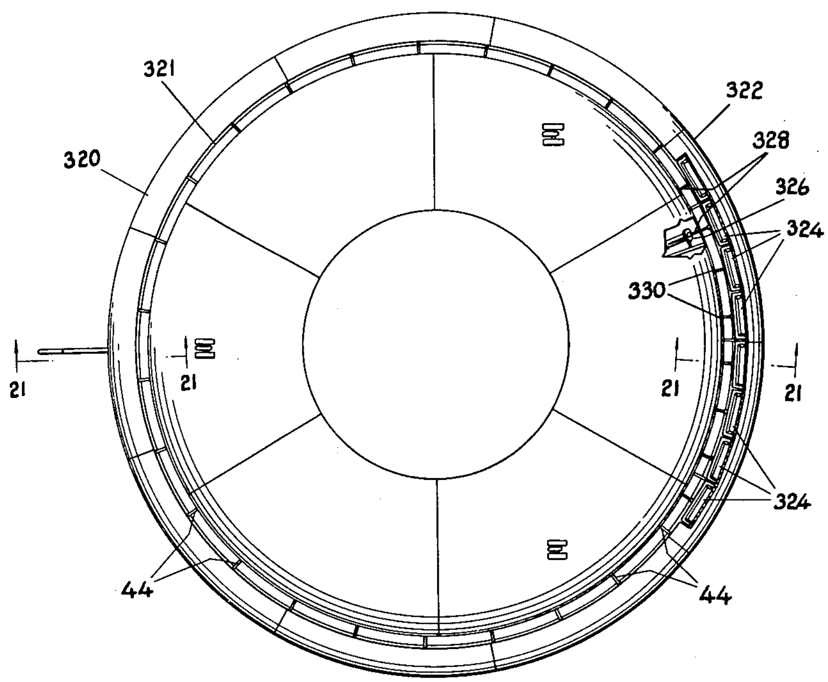

FIG 20.

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Aug. 28, 1962 J. C. M. FROST ET AL 3,051,415

FLUID SUSTAINED AIRCRAFT

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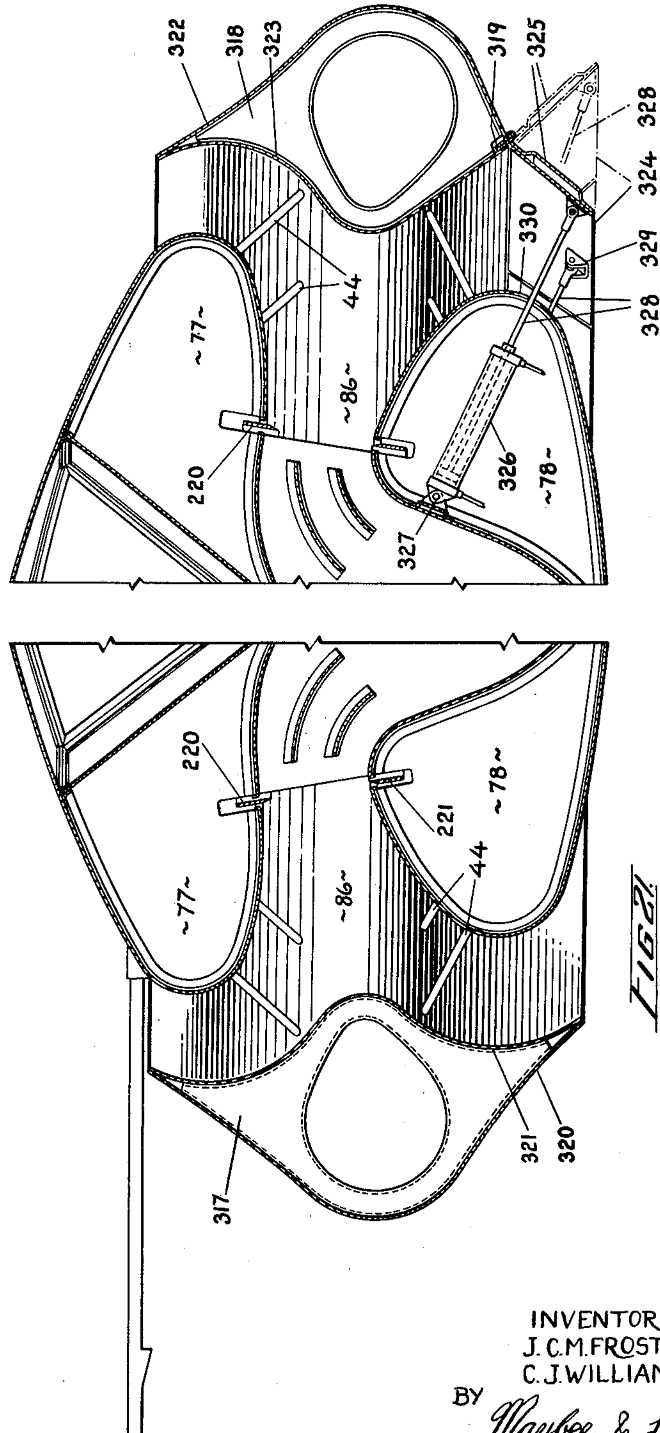

FIG.21.

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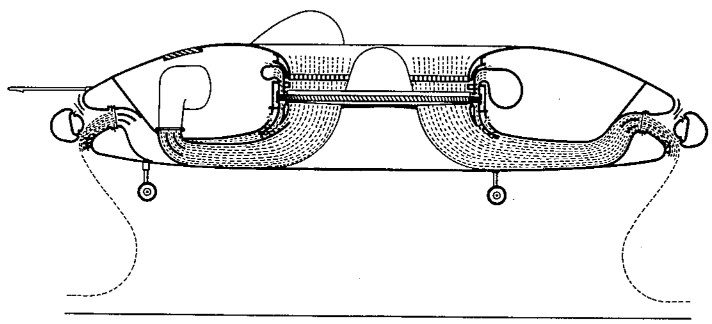


FIG. 22.

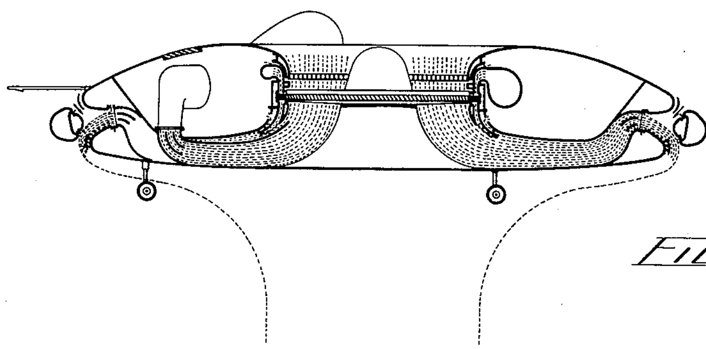
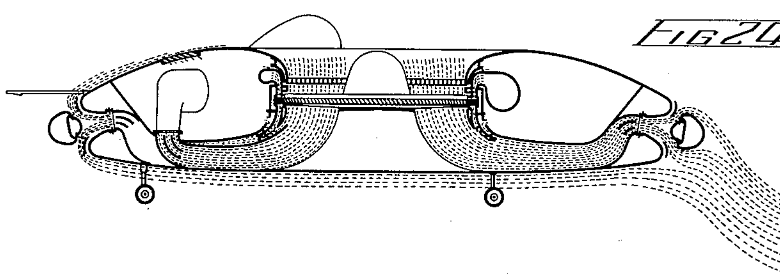


FIG. 23.

FIG. 24.



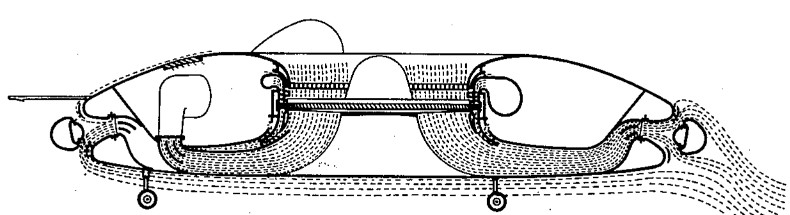


FIG. 25.

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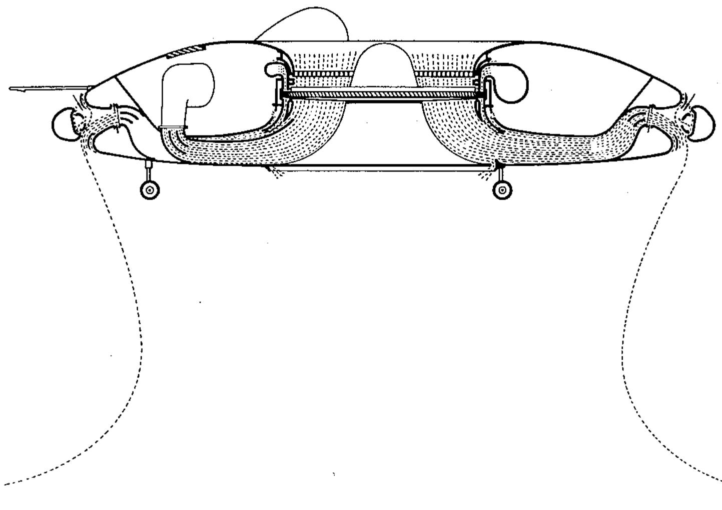

FIG. 26.

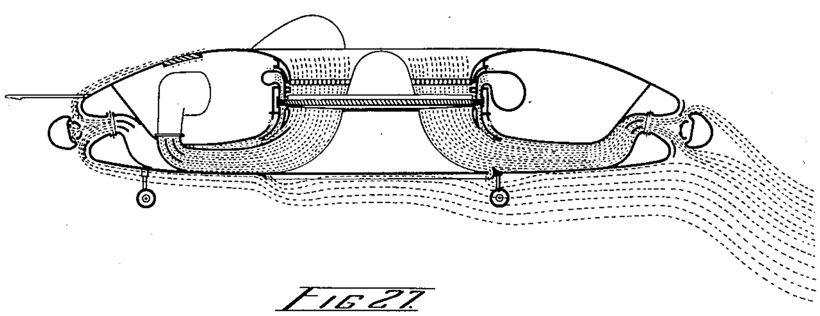

FIG. 27.

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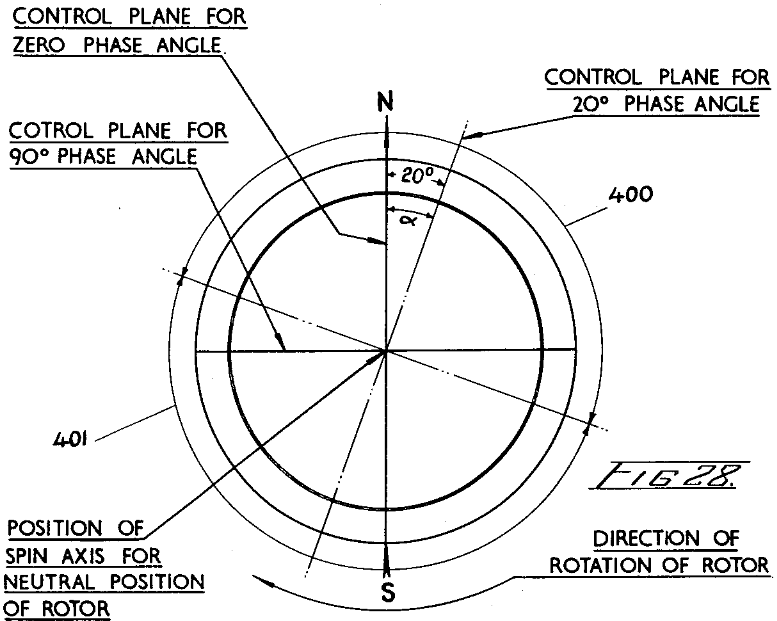

FIG 28.

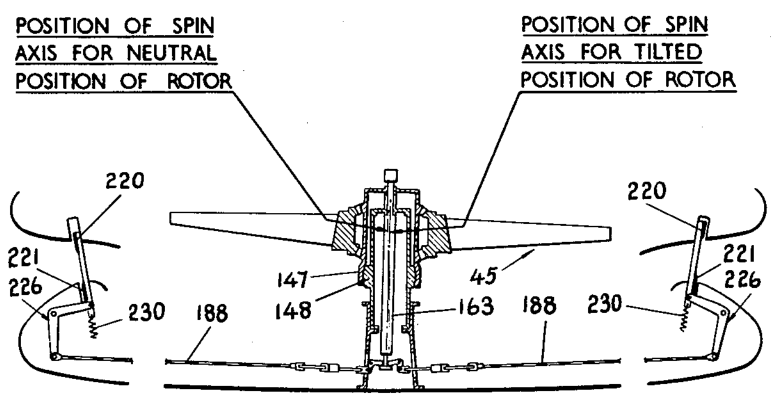

FIG 29.

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FLUID SUSTAINED AIRCRAFT

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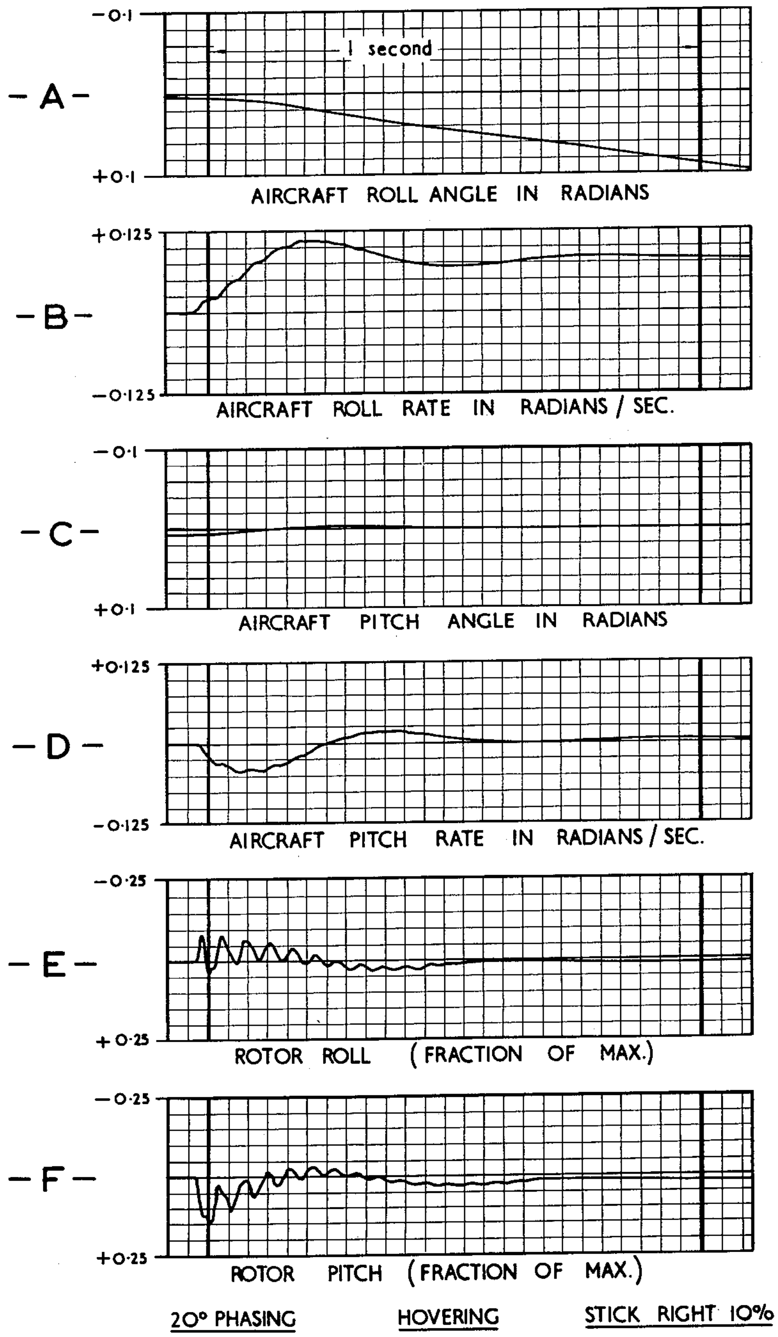

FIG. 30.

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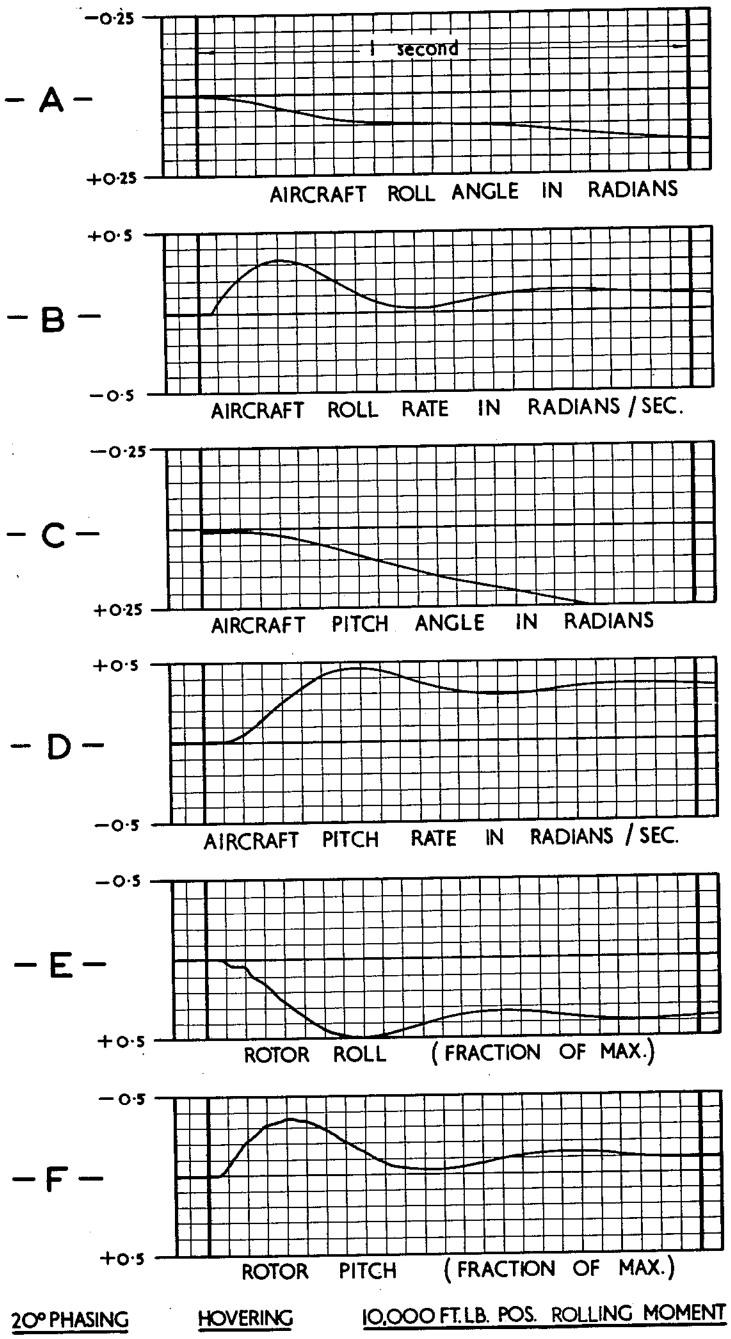

FIG. 31.

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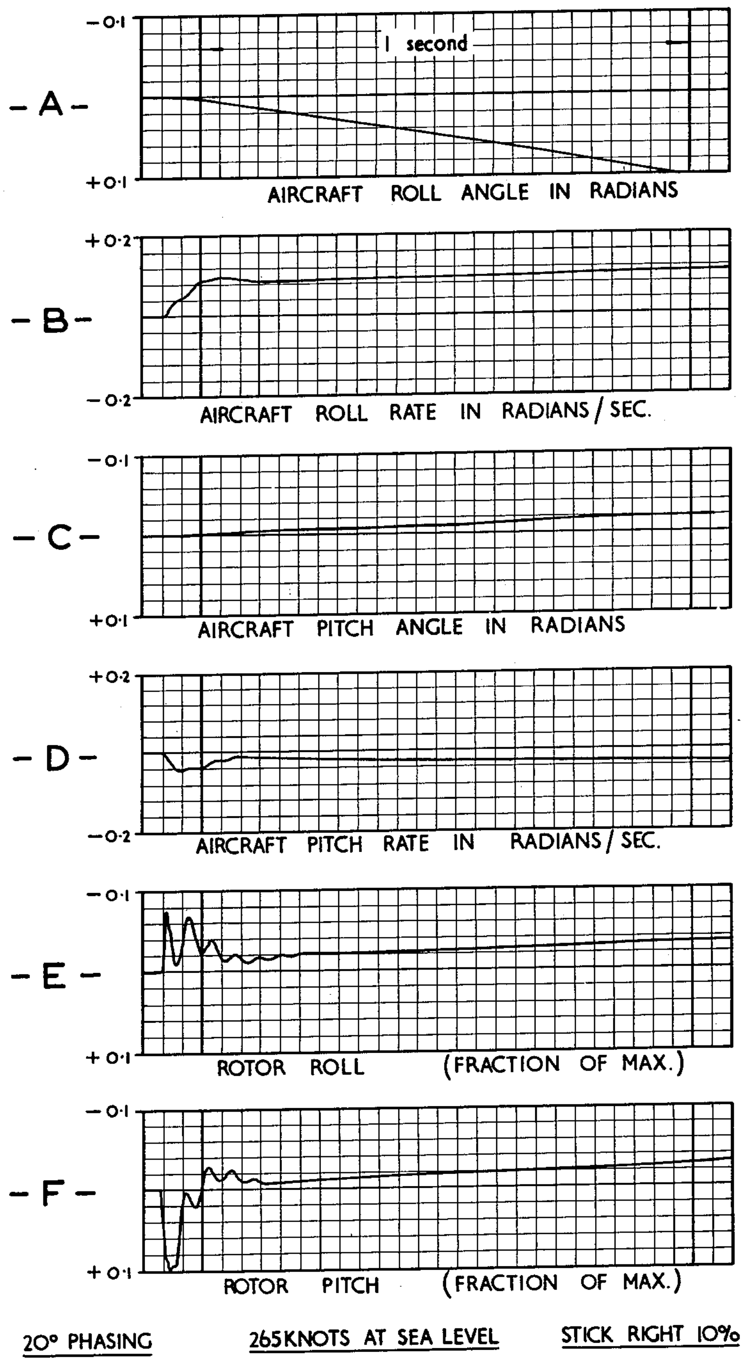

FIG. 32.

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FLUID SUSTAINED AIRCRAFT

Filed Aug. 6, 1959 31 Sheets-Sheet 28

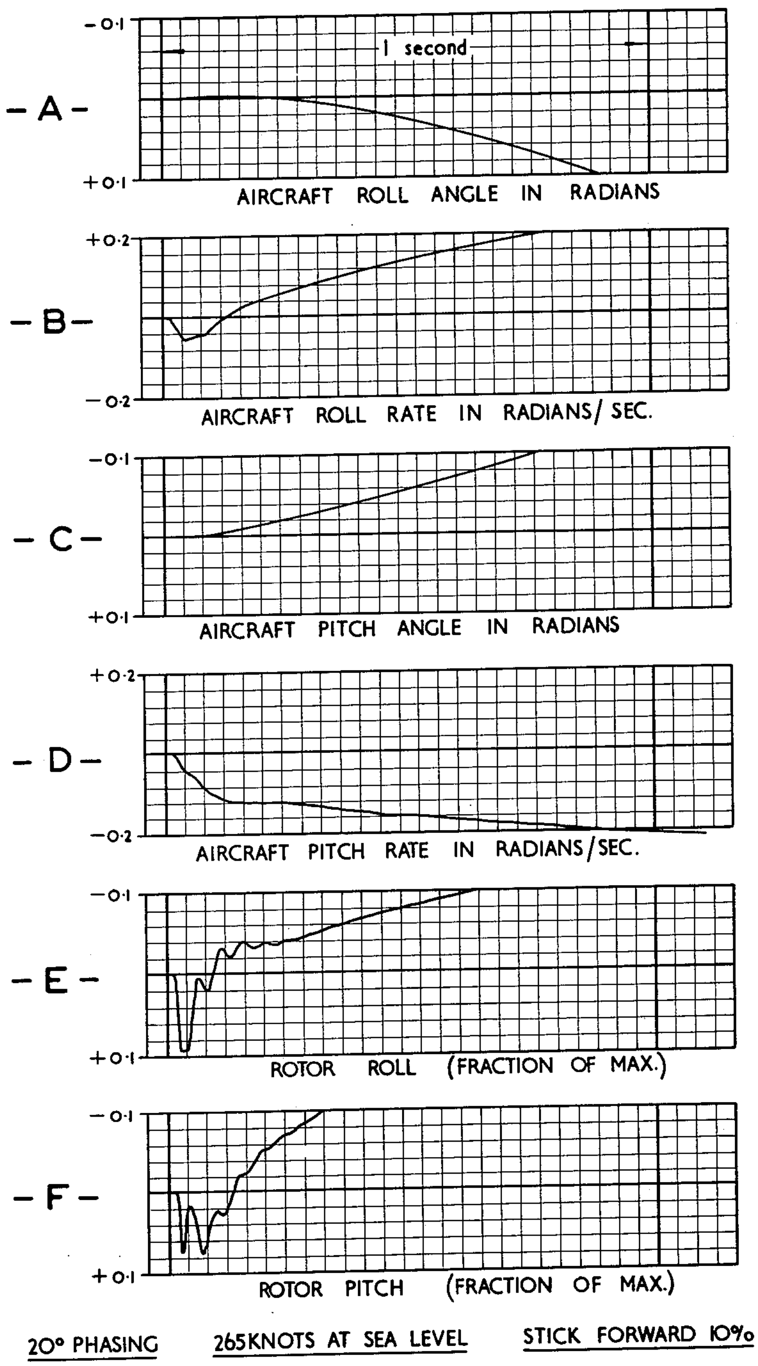

FIG. 33.

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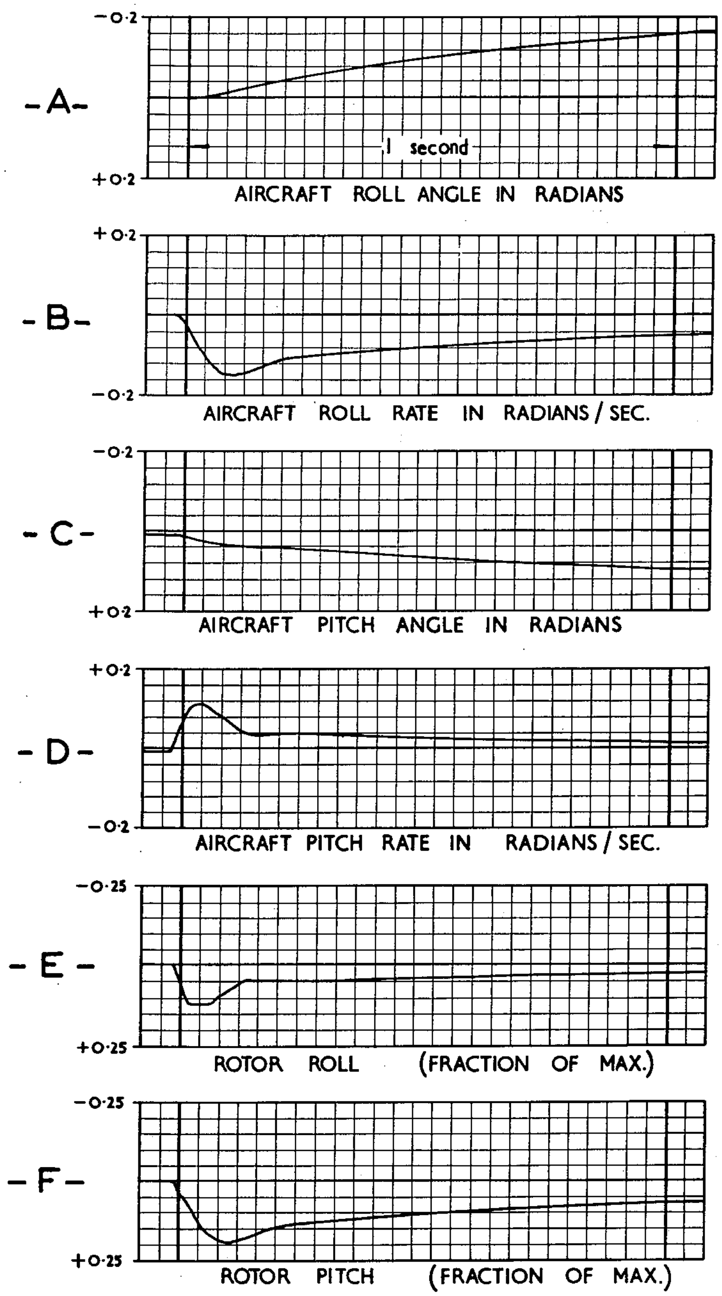
FLUID SUSTAINED AIRCRAFT

Filed Aug. 6, 1959 31 Sheets-Sheet 29



20° PHASING 265KNOTS AT SEA LEVEL

10FT/SEC. SHARP EDGED UPGUST

FIG. 30.

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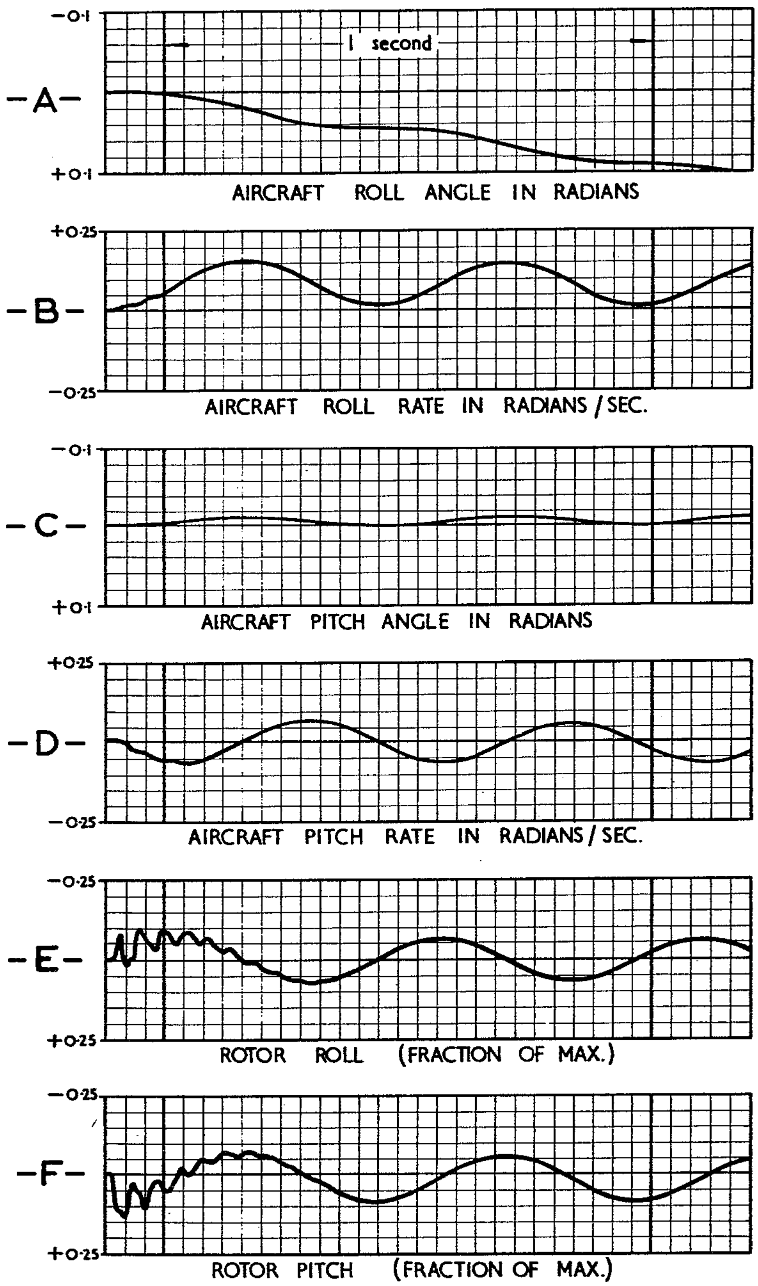
FLUID SUSTAINED AIRCRAFT

Filed Aug. 6, 1959 31 Sheets-Sheet 30



ZERO PHASING HOVERING STICK RIGHT 10%

FIG. 35.

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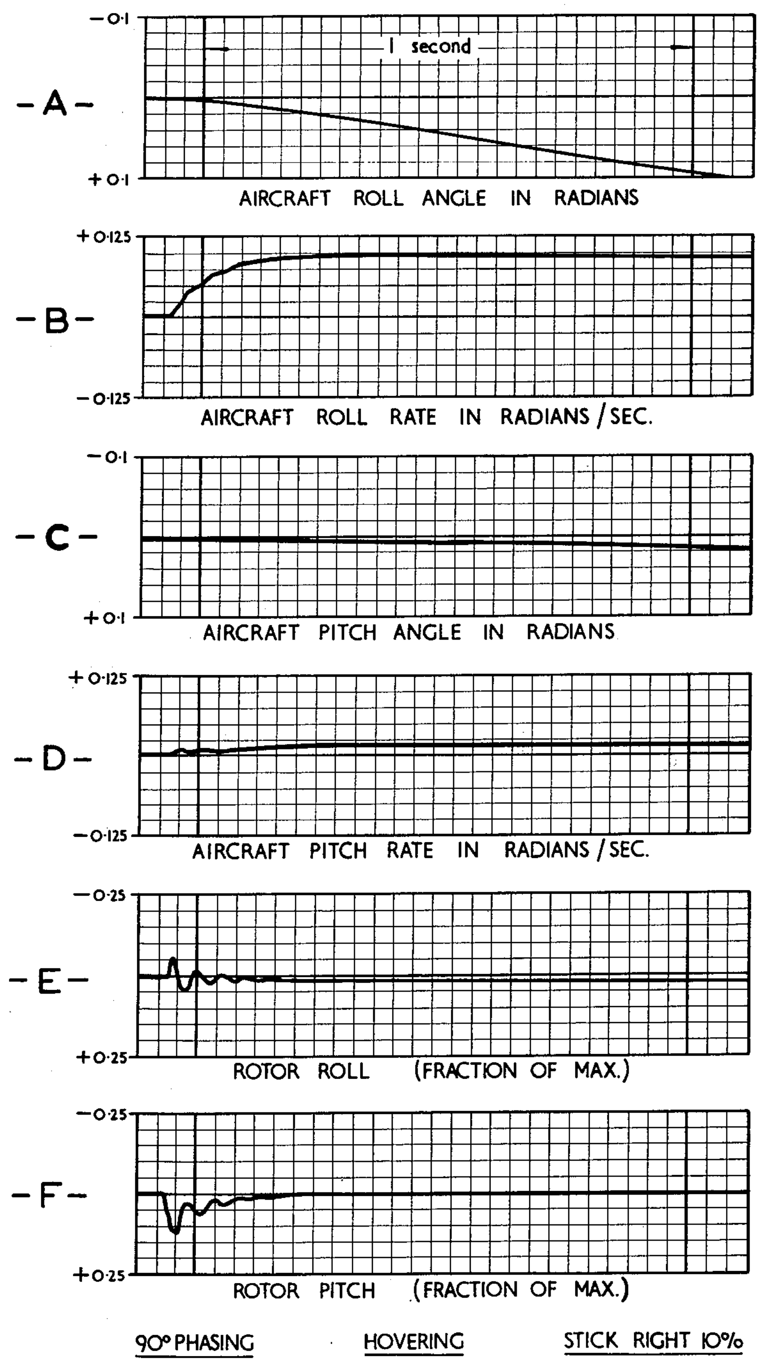

FIG. 36.

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ATTORNEYS

United States Patent Office 3,051,415
Patented Aug. 28, 1962

3,051,415
FLUID SUSTAINED AIRCRAFT

John Carver Meadows Frost, Georgetown, Ontario, and Claude John Williams, Downsview, Ontario, Canada, assignors to Avco Aircraft Limited, Malton, Ontario, Canada, a corporation

Filed Aug. 6, 1959, Ser. No. 832,404
45 Claims. (Cl. 244—23)

This invention relates to aircraft and more particularly to an aircraft having a body structure and an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; the aircraft derives propulsive thrust from the ejection of propulsive gas at high velocity through the outlet nozzle.

Co-pending application Serial No. 684,615 (which is a continuation of patent application Serial No. 502,156 dated April 18, 1955, now abandoned) dated September 17, 1957, and filed by John Dubbury, John Carver Meadows Frost and Thomas Desmond Earl discloses a circular aircraft having a body structure of generally lenticular form which is sheathed by opposed aerofoil surfaces which provide lift developing surfaces. That aircraft includes a gas displacement passage in the structure having an intake and having a substantially annular outlet adjacent to the periphery of the structure. Means are provided for impelling gas to flow through the passage from the intake to the outlet in a plurality of centrifugal directions relative to the yaw axis of the aircraft and to eject the gas at high velocity from the outlet generally radially of the yaw axis and at a multiplicity of positions distributed around the periphery. Gas directing means are provided associated with the outlet and adjustable to selectively alter the directions in which the gas leaves the outlet. In a preferred form of the aircraft disclosed in application Serial No. 684,615, the gas directing means comprises a perimetrical Coanda nozzle which encompasses the outlet to alter the direction of flow of the ejected gas.

The present invention may be considered to be a development of the invention described in application Serial No. 684,615.

It is an object of the present invention to provide in an aircraft having an outlet nozzle arranged to discharge propulsive gas at a multiplicity of positions distributed around the body structure of the aircraft, means effectively to control the direction in which propulsive gas leaves the outlet nozzle.

The invention will now be described by way of example with reference to the accompanying drawings, in which like reference characters indicate similar parts throughout the several views and in which:

FIGURE 1 is a side elevation of an aircraft according to the invention;

FIGURE 2 is a plan of the aircraft of FIGURE 1 with several panels of the upper aerofoil surface removed to show the locations of the engines;

FIGURE 3 is a partial plan, partly broken away and partly in section, of the aircraft of FIGURES 1 and 2;

FIGURE 4 is a perspective view of a portion of the aircraft in partly assembled state and showing the rib structure of the aircraft;

FIGURE 5 is a perspective view of a portion of the completed aircraft similar to that shown in FIGURE 4 and is partly broken away to show the internal structure of the aircraft;

FIGURES 6A and 6B together constitute FIGURE 6 which is a generally longitudinal section of the aircraft on the line 6—6 of FIGURE 3;

FIGURE 7 is a perspective view, partly in section, of the rotor shaft and bearing and also shows part of the aircraft control means;

FIGURE 8 is a detail showing the turbine blades on the outer periphery of the rotor;

FIGURE 9 is a section of the outboard portions of the aircraft taken on the lines 9—9 of FIGURE 3;

FIGURE 10 is a detail showing the means for supporting a baffle on the outboard body structure;

FIGURE 11 shows, in diagrammatic form, the control system of the aircraft;

FIGURE 12 is a perspective view, partly in section, of the pilot's control column which forms part of the control system of FIGURE 11;

FIGURE 13 is a transverse section of the control column of FIGURE 12 taken on the line 13—13 of FIGURE 12;

FIGURE 13A is a diagram showing the correlation between two parts of the control system of FIGURE 11;

FIGURES 14A and 14B together constitute FIGURE 14 which is a generally longitudinal section of an aircraft forming a second embodiment of the invention;

FIGURE 15 is a transverse section, similar to FIGURE 9, of the outboard portions of the aircraft of FIGURE 14;

FIGURE 16 shows in diagrammatic form the control system of the aircraft of FIGURES 14 and 15;

FIGURE 17 shows in diagrammatic form a modified control system for the aircraft of FIGURES 1 to 13;

FIGURE 17A is a perspective view, partly in section, of the rotor shaft and bearing shown in FIGURE 17;

FIGURE 18 is a view similar to FIGURE 17 of a further modified control system for the aircraft of FIGURES 1 to 13;

FIGURE 18A is a detail plan, on a larger scale, of linkage shown in FIGURE 18;

FIGURE 19 is a side elevation of an aircraft constituting a further embodiment of the invention;

FIGURE 20 is an underneath plan of the aircraft of FIGURE 19 partly broken away;

FIGURE 21 is a transverse section, on a larger scale, on the lines 21—21 of FIGURE 20;

FIGURE 22 shows, in diagrammatic form, the gas flow from the aircraft of FIGURES 1 to 13 during take-off;

FIGURE 23 shows, in diagrammatic form, the gas flow from the aircraft of FIGURES 1 to 13 when the aircraft is sufficiently high above the ground to be clear of the "ground cushion" effect;

FIGURE 24 shows, in diagrammatic form, the gas flow from the aircraft of FIGURES 1 to 13 when the aircraft is travelling in forward flight;

FIGURE 25 shows, in diagrammatic form, the gas flow from the aircraft of FIGURES 1 to 13 to produce a "nose-up" couple on the aircraft;

FIGURE 26 shows, in digrammatic form, the gas flow from the aircraft of FIGURES 14 to 16 during take-off;

FIGURE 27 shows, in diagrammatic form, the gas flow from the aircraft of FIGURES 14 to 16 during forward flight;

FIGURE 28 is a diagram indicating the phase angle relationship between the rotor and the primary gas deflecting means;

FIGURE 29 is a diagram showing the operation of the primary gas deflecting means in response to tilt of the rotor;

FIGURES 30 to 34 are graphs showing the response of the aircraft of FIGURES 1 to 13 to certain control conditions;

FIGURE 35 is a group of graphs showing the response of an aircraft having the control system of FIGURES 17 and 17A to a control condition; and

FIGURE 36 is a group of graphs showing the response of an aircraft having the modified control system shown in FIGURES 18 and 18A.

Referring now to FIGURES 1, 2 and 3, the aircraft there shown comprises an inboard body structure **40**, which is generally lentiform and is sheathed by upper and lower skins which provide opposed aerofoil surfaces. The skin providing the upper aerofoil surface is indicated at **41** and the skin providing the lower aerofoil surface is indicated at **42**. The upper and lower aerofoil surfaces provide lift developing surfaces. Encompassing the inboard body structure is an outboard body structure **43** generally in the form of a ring or torus. The outboard body structure **43** is supported in juxtaposed spaced relation to the periphery of the inboard body structure **40** by a plurality of spokes **44**. Mounted within the inboard body structure is a rotor, indicated generally at **45** in FIGURE 3, which is arranged to rotate about a spin axis which is normal to the chord plane of the aircraft when the rotor is in its "neutral" position parallel to the chord plane of the aircraft. The neutral position of the rotor is a position relative to the body structure of the aircraft; for example, the rotor of the aircraft hereinafter described, when the aircraft is horizontal, is in its neutral position when the rotor is horizontal. Rotation of the rotor impels gas to flow within the aircraft and the gas is discharged from nozzles provided between the inboard and outboard body structures as will hereinafter be described.

Throughout the description, and in the claims, certain terms of positional relationship are used for convenience. The terms "outboard" (or "outboardly") and "inboard" (or "inboardly") denote, respectively, greater and lesser distances from the spin axis of the rotor. The terms "vertical," "upwardly" and "downwardly" denote directions approximately substantially normal to the medial, or chord, plane between the upper and lower aerofoil surfaces.

A system of body axes for the aircraft is also used; in the aircraft shown the yaw axis is the axis of symmetry and is coincident with the spin axis of the rotor when the latter is in its neutral position. The longitudinal axis is the intersection of the plane of symmetry and the chord plane; the lateral axis intersects the longitudinal and yaw axes at right angles.

Referring now to FIGURES 1 to 6, but more particularly to FIGURES 4 to 6, the aircraft is built up over a skeleton consisting of a multiplicity of ribs disposed radially of the yaw axis; in the embodiment to be described there are fifty-four ribs which are attached at their inboard ends to a frusto-conical center post generally indicated at **46**. The center post **46** is hollow and has a frusto-conical outer wall **47**; the post is strengthened internally by radial and horizontal webs **48** and **49**. Further radial webs **50** of channel section reinforce the center post above the horizontal webs **49** but do not extend to the upper edge of the wall **47**.

A rib **51** (see FIGURE 4) has an inboard end **52** which extends up the wall **47** to be approximately level with the top of the webs **50**; ribs similar to the rib **51** are hereinafter called main ribs. Counting around the aircraft in a clockwise direction from the rib **51**, every third rib is a main rib; thus, for example, the rib **53** having an inboard end **54**, and the rib **55** having an inboard end **56** are main ribs. Between the ribs **53** and **55** are two short ribs **57** and **58** having inboard ends **59** and **60** respectively which extend to positions similar to that indicated at **61** in FIGURE 6B for the inboard end of a similar short rib in another portion of the aircraft. Except for the ribs adjacent three of the main ribs, there are two short ribs between each pair of main ribs.

One of said three main ribs is rib **51** and on either side of this rib are intermediate ribs **62** and **63** having inboard ends **64** and **65** respectively which extend, as shown in FIGURES 4 and 5, to positions located part way up the frusto-conical wall **47** and intermediate the location of the inboard ends of the short ribs and the location of the inboard ends of the main ribs. The upper edge of each of the ribs **62**, **63** is relieved as shown at **66** in FIGURE 4 for the rib **63**. This relief extends along the inboard portion of the upper edge of each rib **62**, **63** and lowers the inboard portions of the upper edges of these ribs below the upper edge of the rib **51**. Between each of the intermediate ribs **62**, **63** and the next main ribs on either side of the rib **51** is a short rib similar to the ribs **57**, **58** and the relief **66** on the upper edges of the intermediate ribs **62**, **63** lowers the inboard portions of said upper edges below the upper edges of the short ribs adjacent to the intermediate ribs. Extending between the relieved portions of the upper edges of the intermediate ribs and the rib **51** there are generally horizontal dividing walls **67**. Generally vertical gas deflecting walls **68**, see FIGURE 4, are arranged on the upper surfaces of the dividing walls **67** to deflect gas flowing outboardly above the dividing walls **67** into the radial spaces between the intermediate ribs **62**, **63** and their adjacent short ribs for a purpose hereinafter to be described. At the outboard termination of the dividing walls **67**, is arranged a series of three deflecting vanes **69**, **70** and **71** to deflect air from beneath the dividing walls **67** in an upward direction. The deflecting vanes extend on either side of the rib **51** and extend between the ribs **62** and **63**. Moreover, the vanes **69** and **70** extend above the upper edges of the ribs **51**, **62** and **63** while the vane **71** terminates at the upper edges of the ribs **51**, **62** and **63**, see FIGURE 4. The ribs **62**, **63**, the dividing walls **67**, the lower aerofoil skin **42** and the vanes **69**, **70** and **71** define an air intake for a gas turbine engine as will hereinafter be described.

Referring to FIGURE 2, the aircraft has three gas turbine engines **72**, **73** and **74** arranged within the inboard body structure to supply high velocity gas to rotate the rotor **45**. The engines are arranged generally tangentially to the periphery of the rotor and are spaced at 120° intervals about the axis of rotation of the rotor. There is an air intake similar to that previously described for each of the engines **72**, **73** and **74**. The air intake for the engine **73** is indicated generally at **75** in FIGURE 3, the air intake for the engine **74** is indicated generally at **76** in FIGURE 3 and the air intake for the engine **72** is the one shown in FIGURES 4 and 5 and is arranged to the left of the longitudinal axis of the aircraft as a mirror image, as it were, of the air intake **76**. The air intake **75** for the engine **73** extends on either side of a main rib **51*a*** lying on the longitudinal axis of the aircraft. If this rib is considered to be the first of the fifty-four ribs forming the skeletal structure of the aircraft then, counting clockwise in FIGURE 3, the air intake **76** extends on either side of the nineteenth rib **51*b*** and the air intake for the gas turbine engine **72** extends on either side of the thirty-seventh rib, i.e. rib **51**. Thus the first, the nineteenth and the thirty-seventh ribs, i.e. the ribs **51*a***, **51*b*** and **51**, are the three main ribs referred to above as those about which the rib structure differs from the norm of two short ribs between each main rib.

The air intakes **75** and **76** are similar to the air intake described with reference to FIGURES 4 and 5. The air intakes **75**, **76** are arranged about the main ribs **51*a*** and **51*b*** and extend between intermediate ribs **62*a***, **63*a*** and **62*b*** and **63*b*** respectively. The air intake **75** has dividing walls **67*a*** and deflecting walls **68*a*** similar to the corresponding parts **67** and **68** of the air intake of FIGURES 4 and 5. Similarly the air intake **76** has dividing walls **67*b*** and deflecting walls **68*b*** similar to the corresponding parts **67** and **68** of the air intake of FIGURES 4 and 5.

The air intakes **75** and **76** have deflecting vanes **69*a***, **70*a*** and **71*a***, and **69*b***, **70*b*** and **71*b***, respectively, similar to the vanes **69**, **70** and **71** of the air intake of FIGURES 4 and 5.

The outboard end of each of the fifty-four ribs is similar and is bifurcated to provide upper and lower radiused webs **77** and **78** respectively (see FIGURE 6A). It will be seen that at their outboard ends the ribs increase in depth so that the upper radiused web **77** is above the level of the remainder of the rib. The upper radiused web 77 is provided with a slot 79 in its lower surface and the lower radiused web 78 is provided with a slot 80 in its upper surface opposed to the slot 79. The central portion of the rib terminates in an outboard edge 81 extending between the inboard walls of the slots 79 and 80.

The free edges of the ribs, except for their inboard edges, are furnished with flanges extending normal to the ribs on both sides thereof. These flanges are provided by L-section strips riveted to the ribs adjacent to their edges. Referring to the rib 63 in FIGURE 4 by way of example, one of these L-section strips is indicated at 82. In addition to being provided with these L-section strips round their edges, each rib is provided with two further strips of L-section on each side thereof. Referring again to the rib 63 in FIGURE 4 by way of example, each rib has a flange provided by a strip 83 extending from the lower inboard edge of the slot 79 to the upper edge of the rib as it sweeps upwardly to provide the upper radiused web 77. A strip similar to the strip 83 is provided on each side of each rib. The second further strip 84 is downwardly inclined and extends from the upper inboard edge of the slot 80 to the lower edge of the rib. A strip similar to the strip 84 is provided on each side of each rib. A circumferential strip 85 of L-cross section extends around the aircraft and is connected to the uppermost corners of the ribs.

The structure shown in FIGURE 4 is sheathed as shown in FIGURE 5. The lower aerofoil surface skin 42 is secured to the lower edges of the ribs and is continued upwardly and inboardly around the lower radiused webs 78 to terminate at the outboard edges of the slots 80. The upward and inboard extension of the skin 42 forms the lower surface of an outboardly diverging outlet nozzle indicated generally at 86. In a similar manner a peripheral portion of the upper aerofoil surface skin 41 is connected to the upper surfaces of the upper radiused webs 77 and is continued downwardly and inboardly around the webs 77 to terminate at the outboard edges of the slots 79. The downward and inboard extensions of the skin 41 form the upper surface of the outlet nozzle 86. It will be seen that each of the upper and lower surfaces of the outlet nozzle 86 curve away from the other of said surfaces to provide the outlet nozzle with a curved, outboardly divergent cross-section.

The upper edges of the ribs, inboardly of the strip 85, are attached to a sheet metal skin 87. The inboard edge 88 of this skin 87 extends to be level with the inboard edges of the main ribs, to be level, for example, with the inboard edges 52, 54, 56 of the main ribs 51, 53 and 55 mentioned above. The inboard peripheral portion of the skin 87 is provided with a series of circumferentially spaced breather holes 89.

Further sheet metal skins 83*a* and 84*a* are secured between the strips 83 and 84 respectively of each adjacent pair of ribs (see FIGURE 5) and define part of the gas displacement passage which terminates in the nozzle 86.

The skin 87 defines a dished space within which are arranged the three gas turbine engines 72, 73, 74, means to lead air from the air intakes to the gas turbine engines, and means to conduct the exhaust gases from the engines to drive the rotor. The dished space is divided into compartments by a series of bulkheads as shown in FIGURE 2. There are three substantially chordal main bulkheads 90, 91 and 92 which define a central, substantially triangular space within which are arranged the engines, the rotor and the fuel tanks. The space to the left of bulkhead 91 is sub-divided by bulkheads 93 and 94 between which is arranged the pilot's cockpit 95. The space to the right of the main bulkhead 92 is sub-divided by bulkheads 96 and 97 between which is arranged the observer's cockpit 98. The space aft of the main bulkhead 90 is sub-divided by bulkheads 99 and 100. The compartments between the bulkheads not used for the pilot's and observer's cockpits may be used for cargo or parts of the aircraft control system.

Referring to FIGURE 2 the central, generally triangular space is itself sub-divided by three straight dividing walls and three curved dividing walls. There is a straight dividing wall 101 parallel to the bulkhead 90 and a curved dividing wall 102 extending from the inboard end of the wall 101 to the bulkhead 92. Similarly there is a straight dividing wall 103 parallel to the bulkhead 92 and a curved dividing wall 104 extending from the inboard end of the wall 103 to the bulkhead 91. Finally there is a straight dividing wall 105 parallel to the bulkhead 91 and a curved dividing wall 106 extending from the inboard end of the dividing wall 105 to the bulkhead 90.

Each of the engines is mounted in a similar manner which will be described with reference to FIGURES 5 and 6. Referring now to FIGURES 5 and 6A, each engine is supported at its intake end by a yoke 107 which embraces the upper part of the engine and which receives pins 108 secured to the engine frame. The yoke itself is supported from a U-frame 109 forming part of the aircraft structure and extending (in FIGURE 5) between the bulkhead 91 and the dividing wall 105. For the other engines, similar U-frames extend between the bulkhead 92 and the wall 103 and between the bulkhead 90 and the wall 101. The U-frames 109 are of channel section as is clearly shown in FIGURE 6A, and the yokes 107 are supported in the channels of the U-frames by fittings 110. A firewall 111 divides the engine compartment into two parts, and the engine projects through the firewall.

Each engine is supported at its outlet end by means similar to those shown in FIGURE 6B for the engine 74. A pyramidal column 112 is secured to the upper surface of the skin 87 and carries at its upper end a forked lug 113. The engine includes a tailpipe 114 which carries a single lug 115 received in the forked lug 113. The forked lug 113 and the lug 115 have apertures to receive a pin 115*a* which may be inserted from the compartment which lies to the rear of the bulkhead 90 and to the right of the bulkhead 99. Each engine is mounted in a similar fashion in the positions shown in FIGURE 2. The engines are supplied with fuel from removable fuel tanks 116 located in the spaces between the dividing walls 101, 102; 103, 104; and 105, 106.

Air is fed to the engines from the air intakes previously described and two of which are shown at 75 and 76 in FIGURE 3. Between the intake end of each engine and the skin 87 on the upper edges of the ribs is an elbow 117, the lower end of which is connected to a fitting 118 which in turn is connected to the skin 87. The elbow 117 and the fitting 118 are provided with mating flanges which are bolted together; each pair of vanes 69 and 70, as shown in FIGURE 6A, projects to the top of the fitting 118.

The exhaust gases of the engines are fed into a common ring manifold and are arranged to drive the rotor. Associated with each engine, and connected to the outlet end thereof, is a curved converging manifold somewhat in the shape of a tusk (see FIGURES 2 and 4). The manifold for the engine 72 is indicated at 119, the manifold for the engine 73 is indicated at 120 and the manifold for the engine 74 is indicated at 121. The manifolds are connected to the upper edge of a box-section ring member 122 against the lower edge of which abuts the inboard edge 88 of the skin 87. The relative orientation of the narrow end of one tusk manifold and the wide end of an adjacent manifold is shown clearly for the manifolds 119 and 121 in FIGURE 4. The manifolds have a downwardly opening circumferential slot 123 through which the propulsive gases generated by the gas turbine engines are discharged downwardly adjacent to the inboard surface of the ring member 122. Spacer rods 124 and 125 are arranged within the manifolds to preserve their shape. The inboard peripheries of the manifolds are flanged as indicated at **126** in FIGURE 4 and secured to the underside of this flange **126** is a further ring member **127**. Guide vanes **128** are interposed between the ring members **122** and **127** and serve as inlet guide vanes for the tip turbine of the rotor hereinafter to be described.

Supported from the inboard junctions of the dividing walls **101**, **102**; **103**, **104**; and **105**, **106**, is an inlet guide ring **129** for the rotor. This guide ring is clearly shown in FIGURES 5 and 6A and comprises inboard and outboard curved metal skins **130** and **131** joined and spaced at their upper ends by a channel member **132**. The channel member has secured to its outboard periphery three lugs **133** spaced at 120° intervals; the lugs are secured between spaced double lugs **134** which are in turn secured to the dividing walls **102**, **104**, and **106** at the inboard ends thereof. The lower edge of the outboard skin **131** is flanged inboardly and is spaced above the flange **126** of the tusk manifolds while the inboard skin **130** extends downwardly towards the ring member **127** and is secured to a flange provided at the lower edge of the outboard skin **131**. The guide ring **129** is spaced from the "tusk" manifolds so that cooling air may flow over the manifolds and between the ring member **127** and the lower edges of the skins **130**, **131**.

The outer skin **130** of the guide ring is faired into the upper aerofoil surface skin **41** of the aircraft which is divided into panels, the joints between the panels being arranged to lie over the bulkheads, and the panels being removable for access to the engines and to the compartments between the bulkheads. The guide ring **129** carries a cellular grating **135** positioned above the rotor **45** while the panels over the engine compartments are provided with breather louvres **136** which admit air to cool the engine compartments.

After the exhaust gases from the gas turbine engines have passed into the tusk manifolds and downwardly through the guide vanes **128** they drive a tip turbine that constitutes part of the rotor, as will hereinafter be described, and after passing through the tip turbine the gases enter exhaust boxes and are discharged into the gas displacement passage; the exhaust boxes are designed to provide a uniform pressure gradient in the exhaust gases as they drop in pressure upon entering the gas displacement passage. Except over the air intakes to the engines, the arrangement of the exhaust boxes is as follows and will be described with reference to FIGURE 6B. Each exhaust box extends between an adjacent pair of main ribs and has an inboard guide vane **137**, a curved outboard wall **138**, and side walls **139**. The guide vane **137** is continued downwardly by corrugated strips **140** which are arranged partially to overlap one another. The corrugated strips are arranged so that gas may pass from between the guide vane **137** and the wall **138**, then between the corrugations in the strips **140** and out of the exhaust box. The outboard edges of the wall **138** and of the outboard corrugated strip **140** are slotted to accommodate the inboard edges **61** of the short ribs between each adjacent pair of main ribs. Each main rib is provided at its inboard edge with a curved aerofoil section guide vane **141** extending between the upper end of the frusto-conical wall **47** and the upper end of an adjacent guide vane **137** on an exhaust box. The upper end of the curved wall **138** of each exhaust box abuts against the lower edge of the ring member **122**. The flow of air through the sectors of the gas displacement passage induces air to flow from the engine compartments through the holes **89** in the skin **87** and over the curved walls **138**, thereby serving partially to cool the exhaust boxes.

The arrangement of the exhaust boxes over the air intakes of the engines is slightly different and will be described with reference to FIGURES 5 and 6A. All the exhaust boxes are similar to that previously described

with reference to FIGURE 6B but it will be seen by reference to FIGURES 5 and 6A that the exhaust boxes over the air intakes discharge between the dividing walls **67** and the metal skin **87**. The exhaust gas passing between the walls **67** and the skin **87** is deflected by the gas deflecting walls **68** into the sectors of the gas displacement passage lying between the intermediate ribs, such as **62**, **63**, and their adjacent short ribs.

The construction of the rotor and rotor shaft will now be described with reference to FIGURES 4 to 8. Centrally located in the center post structure **46** is a base casting **142** having radial flanges **143**, to which the radial webs **48** are secured, and having an upper horizontal flange **144** to which the horizontal webs **49** are secured. Referring now to FIGURE 7, the base casting **142** is provided with an internal flange **145** and telescoped within the base casting and resting on, and secured to, the flange **145** is a hollow vertical shaft **146** which extends upwardly beyond the base casting **142**. Surrounding the upper portion of the vertical shaft **146** is a sleeve **147**; a part spherical bearing **148** is interposed between the shaft **146** and the lower portion of the sleeve **147**.

The rotor **45** is rotatably mounted at the upper portion of the sleeve **147** by opposed thrust races **149** and rotates about a spin axis which, when the rotor is in its neutral position, is parallel to the yaw axis or axis of symmetry, of the aircraft. The rotor includes an inner ring **150** of E-section, the arms of the E facing outboardly and the center arm being bifurcated. Impeller blades **151** are secured at their roots or inner ends to blocks **152**, also of E-section, which face inboardly, the central arms of the blocks **152** being received between the arms of the bifurcated central arm of the member **150**. The blades **151** are secured to the blocks **152** by being welded to plates **153** forming part of the blocks **152**. The rotor also includes a segmented inner shroud **154**, the inboard ends of which lie against the upper and lower surfaces of the inner ring **150** of the rotor. The members **150**, **152** and the shroud **154** are connected together by bolts **155**, each bolt having enlarged shoulders extending through the arms of the E-section members to provide bearing surfaces. The outboard ends of the impeller blades **151** are secured to an outer segmental ring member **156**, see FIGURE 8, and secured to the outboard surface of the ring **156** is a plurality of turbine blades **157**. Secured to the upper surface of the ring **156** is an element **158** of a labyrinth seal which cooperates with an opposed labyrinth element **159** on the inboard surface of the ring member **127**.

Returning now to FIGURE 7, the upper end of the vertical shaft **146** is closed by a flexible diaphragm **160** and the top of the sleeve **147** is closed by a flexible diaphragm **161**. A sleeve **162** is held between central portions of the diaphragms **160** and **161**; passing through the sleeve and central apertures in both diaphragms is a hollow control shaft **163** which extends downwardly to adjacent to the lower end of the base casting **142**. The sleeve **162** and the central portions of the diaphragms are clamped between a shoulder **163*a*** on the control shaft and a flanged ring nut **165** threaded to the upper end of the control shaft **163**. Secured to the diaphragm **161** is a plate **164**, to which a domed intake cone **164*a*** is secured, see FIGURE 6.

Secured to the flanged nut **165** is an electric linear actuator **166**. The actuator is provided with a depending shaft **167** extending within the control shaft **163** and the lower end of the shaft **167** is provided with a forked end **168**. A rod **169** is connected at its upper end to the forked end **168** by a pin **170** and the lower end of the rod **169** is provided with a detachable mushroom head **171**. The lower end **169** of the rod passes through an aperture in an otherwise solid end piece **172** of the shaft **163**.

Spaced at 120° intervals around the circumference of the lower portion of the control shaft **163** are three bifurcated lugs, two of which are shown at **173** and **174**.

Pivotally attached to each bifurcated lug is the ram of a pneumatic bellows actuator fixed to the base casting 142. Thus the ram 175 of an actuator 176 is attached to the lug 173. Similarly, the ram 177 of a bellows actuator 178 is attached to the lug 174 and a third bellows actuator 179 is connected by its ram to the third lug on the control shaft. Each of the actuators contains a bellows similar to that indicated at 180 for the actuator 176 and is operated by pneumatic pressure as will hereinafter be described. Due to the resilience of the material of which they are made, the bellows act as springs and the combined effect of the springiness of the bellows is to tend to hold the control shaft 163 central within the vertical shaft 146 and thereby hold the rotor in its neutral position.

The lower end of the control shaft 163 is provided with an outboardly directed flange 181 which carries, equally spaced around its outboard periphery, six bifurcated lugs, one of which is indicated at 182. Pivotally mounted between each lug 182 is a bell-crank lever, two of said levers being indicated at 183; each lever has an inboard end which bears on the upper surface of the mushroom head 171 of the control rod 169. It will be seen that vertical movement of the control rod will pivot the bell-cranks in their supporting lugs. Pivotally secured to the other end of each bell crank 183 is a hinged link 184, and the outboard ends of the links 184 are pivotally attached to further links 185 intermediate the ends of the links 185. One end of each of the links 185 is pivotally attached to a lug 186 carried by a radial web 48 as is best shown in FIGURES 3 and 7. Pivotally connected to the other end of each of the links 185 is a T-piece 187 to which the inboard ends of three cables 188 are attached, the points of attachment of the cables being equally spaced along the outboard edge of the T-piece. Where necessary, the radial ribs 48 are slotted as indicated at 189 to permit passage of the T-pieces. The outboard ends of the cables 188 are connected to primary gas deflecting means hereinafter to be described. It will be seen that opposed cables are interconnected by being connected to the control shaft 163.

Referring to FIGURES 4, 5, 6 and 9, the outboard body structure will now be described. It will be recalled that the outboard body structure 43 is supported from the inboard body structure 40 by means of spokes 44 and that it is in the form of a ring or torus made up of a plurality of sections. The outboard body is fabricated in a manner similar to the manner of fabrication of the inboard body, i.e. it consists of formers covered with sheet metal. The formers of the outboard body are of two types, namely a plurality of outboard formers 190 and a plurality of inboard formers 191. Each of the outboard formers 190 is generally triangular with a rounded apex and has a central aperture 192. The base of each former 190 is cut away and is provided with flanges 193 (see FIGURE 4) to which are secured an annular channel member 194 to the inboard periphery of which the formers 191 are secured.

The spokes 44 are secured at their inboard ends to the outboard ends of each alternate rib of the inboard body structure. At their outboard ends the spokes are secured between two formers 191 arranged close together with a block between them to receive the outboard end of the spoke. Such a pair of formers is indicated at 195 in FIGURE 4.

The edges of each former 190 are flanged and to these flanges is secured a sheet metal covering 196 which extends inboardly to terminate at the edges of the channel member 194 as is best shown in FIGURES 6 and 9. The inboard peripheries of the formers 191 are each provided with a pair of inclined flanges 197, and secured to these flanges is a sheet metal covering 198 which provides the inboard periphery of the outboard body structure.

An upper circumferential guide vane 199 is supported on the spokes 44 which extend between the upper periphery of the outboard body and the inboard body; a lower circumferential guide vane 200 is supported on the spokes 44 which extend between the lower periphery of the outboard body and the inboard body. The guide vane 199 is located in an upper peripheral nozzle provided between the outboard body and the inboard body, and the guide vane 200 is located in a lower peripheral nozzle provided between the outboard body and the inboard body. The divergent outlet nozzle 86 communicates with both upper and lower peripheral nozzles.

As is clearly shown in FIGURES 9 and 10, slots are provided between the inboard ends of the covering 196 of the formers 190 and the outboard ends of the covering 198 of the formers 191. There is thus provided an upper peripheral slot 201 and a lower peripheral slot 202 in which are mounted secondary gas deflecting means in the form of baffles which may be operated to control the direction in which the propulsive gas leaves the upper and lower peripheral nozzles. The baffle in the upper slot 201 is indicated at 203 and the baffle in the lower slot at 204. The baffles are formed of strip metal fashioned into the shape of frusta of a circular cone and are mounted in the outboard body by the arrangement shown in FIGURES 9 and 10. Secured to the base portion of suitably spaced formers 190 are flanged fittings 205 having spring anchoring flanges 206 and 207 which are, respectively, generally perpendicular to the baffles 203, 204. A tension spring 208 extends between the flange 206 and the baffle 203 and a tension spring 209 extends between the baffle 204 and the flange 207. The baffles are mounted to slide on the outboard body as better shown in FIGURE 10 for the baffle 203. The baffle is slotted as indicated at 210 and the slot embraces a sleeve 211 secured to a flange 212 by means of a nut and bolt assembly 213; the baffle is guided on the sleeve by spacers 214 and 215.

Referring to FIGURES 3, 4 and 11, the baffles are operated by actuators 216 at opposite ends of the lateral axis of the aircraft. From FIGURE 11 it will be seen that the slots 210 of the baffles 203, 204 are arranged to be parallel to the longitudinal axis of the aircraft and therefore lie at different angles to the vertical at differing points round the periphery of the aircraft. Thus, adjacent to the lateral axis of the aircraft and in the vicinity of the actuators 216, the slots are substantially horizontal while adjacent to the longitudinal axis of the aircraft the slots are, viewed in elevation, substantially vertical.

The resulting support of the baffles is analogous to the support of the base of a hollow cone on a sphere of a diameter somewhat larger than the base of the cone. If the apex of the cone is moved in two directions in a given vertical plane then the base of the cone in that plane will move vertically relative to the sphere while the portions of the base of the cone in a vertical plane containing the apex of the cone and normal to the plane of movement of the apex of the cone will not be vertically displaced relative to the sphere. By moving points on the baffles 203, 204 backwardly and forwardly adjacent to the ends of the lateral axis of the aircraft it is possible to control the extent of projection of the baffles into the upper and the lower peripheral nozzles. Referring now to FIGURE 4, adjacent to the actuators 216, the baffles 203, 204 are secured together by a strap 217. One end of the actuator 216 is pivotally secured at 218 to a pair of formers 191 and the ram of the actuator is secured at 219 to the strap 217. The other actuator is arranged in a similar fashion and operation of the actuators will rock the baffles as described above. The baffles 203, 204 constitute secondary gas deflecting means.

Primary gas deflecting means are arranged in the slots 79 and 80 in the upper and lower radiused webs 77 and 78 at the outboard ends of the ribs of the inboard body and include an upper baffle 220 and a lower baffle 221, each baffle being formed as a frustum of a hollow cylinder. The edges of the baffles which project into the gas displacement passage have sharp edges as indicated at 222. At spaced intervals around the periphery of the aircraft the upper baffle 220 is supported by resilient strips 223 which are secured to the sheet metal skin 87 at their inboard ends by flanges 224 (see FIGURES 9 and 11). At spaced positions in register with the resilient strips 223, the baffles 220, 221 are connected together by straps 225. The lower end of each strap 225 is secured to the upper arm 226*a* of a bell-crank 226 having a second arm 226*b* and which is pivoted at 227 between a pair of supporting ribs 228. The location of the supporting ribs is clear from FIGURE 3; they are interposed between the outboard ends of two adjacent ribs of the inboard body structure. The outboard ends of the cables 188, which were described with reference to FIGURE 7, are connected to the lower ends of the arms 226*b* of the bell-cranks. A bracket 229 is secured between the lower portions of the supporting ribs 228 and a tension spring 230 is interposed between the lower end of each strap 225 and a lug 231 on each bracket 229. It will be seen that the springs 230 tend to pull the baffles 220, 221 into their lowermost positions so that the baffle 220 projects into the gas displacement passage and the baffle 221 is retracted into the slot 80. Guide vanes 232 are provided at the outboard end of the displacement passage to guide the outboardly flowing propulsive gas into the outboardly divergent outlet nozzle 86.

Referring now to FIGURES 3, 4, 5 and 11, the aircraft is provided with two sets of pivotally mounted rudder vanes in the gas displacement passage adjacent to the outlet nozzle. Each set of vanes comprises eight individual vanes indicated at 233, the vanes being arranged in two groups of four, each group being arranged between two adjacent ribs of the inboard body structure. The upper ends of each group of vanes are connected by short links to a main link 234 which is in turn connected to the ram 235 of an actuator 236. The actuators are pivotally mounted on ribs of the inboard body structure and include springs tending to center the rudded vanes in radial positions. Operation of the actuators 236 pivots the vanes 233 to control the directions in which the propulsive gas leaves the two sectors of the gas displacement passage in which the vanes are mounted. The rudder vanes are mounted on corresponding positions on each side of the longitudinal axis of the aircraft, the vanes being arranged just aft of the lateral axis of the aircraft.

The baffles in the outboard body structure (the secondary gas deflecting means), the baffles in the inboard body structure (the primary gas deflecting means) and the rudder vanes are all controlled from a control column indicated generally at 237 in FIGURE 11 and shown in detail in FIGURES 12 and 13 to which reference is now made. The control column is, of course, under the control of the pilot and is situated in the pilot's cockpit 95. The floor of the cockpit is indicated at 238 and the control column is partly encased in a shroud 239 upstanding from the floor 238. The control column itself comprises an upper sleeve 240 which extends above the shroud 239 and is secured at its lower end to a lower sleeve 241, the lower end of the lower sleeve being secured to the floor 238. Mounted within the upper sleeve 240 is an outer gimbal ring 242 and an inner gimbal ring 243, these gimbal rings being shown clearly in FIGURE 13. The inner gimbal ring is supported from the outer gimbal ring on axes 244; supported within the inner gimbal ring by axes 245 is a double-walled sleeve 246. The space between the double walls of the sleeve 246 provides a plenum chamber 247 which is supplied with high pressure air through a conduit 248 which is connected to a union in the outer wall of the double sleeve and passes through a slot 249 in the upper sleeve 240. Secured in a disc 250 closing the lower end of the double sleeve are three Venturi nozzles 251*a*, 251*b* and 251*c*. The three nozzles are spaced around the axis of the sleeve at 120° intervals and each nozzle has an inner stack pipe 252 which opens at its upper end into the plenum chamber 247. The outer casing of the nozzle surrounds the inner stack pipe 252 and is of greater cross sectional area than the inner stack pipe. Conduits 253 are connected at their one ends to the outer casings of the nozzles above the lower ends of the inner stack pipes. The other ends of the conduits are connected to the actuators 176, 178 and 179 as shown in FIGURES 11 and 13A.

Reverting to FIGURE 12, the lower sleeve 241 carries a bearing 254 adjacent its upper end, the bearing being supported by webs 255. Rotatably mounted in the bearing is a resilient rod 256 which projects both upwardly and downwardly from the bearing. The rod is surmounted by a handle 257, and a flexible bellows 258 connects the upper end of the upper sleeve 240 to the lower end of the handle 257. At its lower end the rod carries a cam 259 which co-acts with a tongue 260 which is pivoted at 261 to a base plate 262. Adjustable spring plungers 263, 264 and 265 act on the tongue and cam to bias the former in a central position and an adjustable stop 266 is provided to limit movement of the plunger 265 in one direction and to provide an adjustable datum for the cam. Mounted in upstanding lugs 267 on the base plate 262 are opposed Venturi nozzles 268. The construction of each of these nozzles is similar to the nozzles 251 described above. Thus high pressure air is fed into the nozzles through conduits 269 and the pressures in the outer casings of the nozzles are communicated through the conduits 270 which are connected to the rudder actuators 236 as shown in FIGURE 11.

Above the bearing 254, the rod 256 carries a circular plate 271; a compression spring 272 is interposed between the disc 250, which seals the bottom of the double-walled sleeve 246, and the plate 271. The double walled sleeve 246 is continued upwardly by a hollow sleeve 273 which co-acts with eccentric cam wheels 274 and 275. The cam wheel 274 is housed in a bearing 276 supported on the outer surface of the upper sleeve 240, and the cam wheel 275 is supported in a similar bearing 277. The cam wheels project through slots 278 in the upper sleeve 240, and the sleeve 273 is kept in contact with the cam wheels by leaf springs 279.

The cam wheels are operated by remote control from hand wheels 280 and 281, which are arranged at right angles to one another in the pilot's cockpit and within convenient reach of the pilot. A flexible cable control connects the hand wheels to the cams and is similar for each hand wheel and cam. The hand wheel 280 is provided with a sleeve bearing 282 which is supported by a flange 283. The hand wheel also carries a threaded shaft 284 which is received within an internally threaded bore of a slidable block 285. The slidable block is connected to one end of an inner flexible cable 286, the outer part of the cable, indicated at 287, being anchored at 288. The other end of the outer cable 287 is anchored to the sleeve 240 by a fitting 289 which is slotted at 290 to expose the inner cable 286. The inner cable is wire wound to produce the effect of a worm and it meshes with a worm wheel 291 carried in the bearing 276, the worm wheel being connected to the cam wheel 274. Rotation of the hand wheel 280 moves the inner cable 286 within the outer cable 287 thereby rotating the worm wheel 291 and the cam wheel 274. In a similar manner, rotation of the hand wheel 281 rotates the cam wheel 275. By rotating the hand wheels 280 and 281 fine adjustment of the position of the double-walled sleeve 246 in its gimbal mounting can be obtained since the wheels 274 and 275 are at right angles to each other.

The control column includes two spring loaded push switches 292 and 293 which are connected by leads 294 to the actuator 166 situated at the top of the rotor shaft. As long as pressure is applied to the button 292 the actuator 166 will be caused to lift the rod 169. Conversely, pressure on the button 293 will cause the actuator to lower the rod **169** but, as soon as the pressure is released from the button, the rod will cease to move. The control column also carries a switch **295** connected to the actuators **216** by leads **296**. Operation of the switch **295** operates the actuators **216** to move the baffles **203**, **204** in the outboard body.

Referring to FIGURES 1 and 6, the aircraft is provided with a tricycle undercarriage consisting of castors **297** supported by legs **298**. Each leg has a lower flange **298***a* secured to the lower skin **42** and a cylindrical casing **298***b* secured to a main rib by an upper mounting **299**. Transparent canopies **300** extend over the pilot's and observer's cockpits and a pitot head boom **301** extends from the forward part of the aircraft.

FIGURES 14, 15 and 16 show a modification of the aircraft described with reference to FIGURES 1 to 13. The construction of the inboard body structure of the modified form of aircraft is identical, except in one respect, to that described with reference to FIGURES 1 to 13. One of the modifications incorporated in the second aircraft concerns the secondary gas deflecting means incorporated in the outboard body structure.

Basically the main structure of the outboard body structure shown in FIGURES 14 and 15 is the same as has heretofore been described. Thus there is a series of outboard formers **190** of the same shape as hereinbefore described, and the formers are covered with sheet metal **196** which extends inboardly to the inboard edges of the channel member **194**. Also, there is a plurality of inboard formers **191**, which are covered with sheet metal **197**. The outboard edges of the covering **197** are spaced from the inboard edges of the covering **196** as before to provide upper and lower slots **201** and **202**. However, in this modified construction, there are no baffles mounted in the slots **201**, **202** and no actuators for the baffles. Instead of the baffles, the inboard periphery of the outboard body structure is provided with a plurality of gas entry ports **302** equally spaced around the whole of the inboard periphery. There is a circumferential space **303** between the inboard portion of the covering **197** and the inboard edges of the formers **191** which are cut away at **304**. Movable in the space **303** in a portion of the outboard body structure adjacent to the rear of the aircraft is obturator means comprising a slide **305** operated by actuators **306**.

As shown in FIGURE 16, there are three actuators **306** which are pivotally mounted to the outboard body structure and are spaced along the slide **305** which is curved to conform with the curvature of the outboard body structure. Each actuator **306** has a ram **307** which is pivotally mounted between a pair of links **308** which in turn are pivotally mounted about an axis **309** on the outboard body structure. The inboard ends of the links **308** are secured to the slide **305** which is provided with a plurality of apertures **310** which are spaced apart by distances equal to the distances between the gas entry ports **302** in the covering **197**. The slide **305** may be moved by the actuators **306** so that the apertures **310** in the slide register with the gas entry ports **302** in the covering **197** or the slide may be moved to a position in which it closes the gas entry ports in the rear portion of the outboard body structure. When the apertures **310** are in register with the gas entry ports **302** propulsive gas enters the gas entry ports, is redirected by the channel member **194**, and is ejected through the slots **201** and **202**. The actuators **306** are operated from the pilot's control column **237** through the switch **295**, described with reference to FIGURE 12, and which is connected to the actuators by leads **311**. The control system of the modified aircraft is otherwise identical with the control system described for the first embodiment of the aircraft.

The modification to the inboard body structure comprises a downwardly directed, annularly arranged, stabilizing nozzle in the lower aerofoil skin **42** of the aircraft. Referring to FIGURE 14B, an inner lip **312** is provided to deflect some of the gas flowing through the gas displacement passage to a nozzle slot **313** in the skin **42**. The lip extends between each pair of adjacent ribs of the inboard body structure, however, the lip **312** and the slot **313** are interrupted between the ribs which define the air intake passages for the engines. Thus reference to FIGURE 14A will show that there is no slot **313** or inner lip **312** in the air intakes for the engine **73**. An outer lip **314** is provided to direct gas passing through the slot **313** slightly inboardly. The lip **314** is continuous and is not interrupted under the air intakes. Some of the propulsive gas flowing through the gas displacement passage will be deflected by the lip **312** to pass through the downwardly directed stabilizing nozzle **313** for a purpose which will hereinafter be described.

FIGURES 17 and 17A show a somewhat modified control system for the aircraft shown in FIGURES 1 to 13. Structurally, the modification amounts to the omission of the links **184**, **185** described with reference to FIGURE 7. In FIGURES 17 and 17A, the inboard ends of the cables **188** are connected in groups of three to T-pieces **315** and the inboard ends of the T-pieces are connected directly through clevises **316** to the lower ends of the bell-cranks **183**. The effect of this modified construction on the response of the aircraft will be described hereinafter but it will be seen that if the lower end of the control shaft moves in a given direction the cables **188** lying in that direction will be moved outboardly and opposed cables will be moved inboardly. In all other respects the control system shown in FIGURES 17 and 17A is the same as that described with reference to the aircraft of FIGURES 1 to 13.

FIGURES 18 and 18A show a modified form of control system in which right angled pivoted links, or bell-cranks **350**, are interposed between the links **184** and the T-pieces **187** to which the inboard ends of the cables **188** are connected. Each bell-crank has two arms, one arm **351** being pivotally attached at its free end to a link **184** and the other arm **352** being cranked upwardly at **353** to clear the arm **351** of an adjacent bell-crank **350**. Each of the bell-cranks **350** is pivotally mounted in a lug **354** secured to one of the radial webs **48** which extends between the inner surface of the wall **47** and the base casting **142**.

It will be apparent that the arrangement is such that if the control shaft **163** moves in a given direction, instead of the cables **188** lying in that direction being moved outboardly, cables **188** lying at 90° clockwise from that direction will be moved outboardly and opposed cables will be moved inboardly. The effect of this arrangement on the response of the aircraft will be described hereinafter but in all other respects the control system shown in FIGURES 18 and 18A is the same as that described with reference to the aircraft of FIGURES 1 to 13.

Referring now to FIGURES 19, 20 and 21, the embodiment of the invention there shown differs from the embodiment of the invention shown in FIGURES 1 to 13 in the construction of the outboard body structure and in the arrangement of the secondary gas deflecting means.

Referring to FIGURE 21, the outboard body structure is fabricated from a series of radially arranged formers covered with sheet metal covering in a manner similar to that described in the other embodiments of the invention although the formers providing the skeleton of the outer body structure are somewhat different in shape from those previously described. The formers providing the skeleton of the forward portion of the outer body are of the shape indicated at **317** while the formers providing the skeleton of the rear portion of the outer body are of the shape indicated at **318**. The formers **317** have a comparatively wide central portion which tapers both upwardly and downwardly to upper and lower edges. The formers **318** are similar in their upper parts to the formers **317** but terminate above the lower edges of the formers **317** in a lower edge **319**.

The forward portion of the outer body extends around a major portion of the periphery of the aircraft and subtends an angle of approximately 253° at the center of the aircraft whereas the rear portion extends around an arc which subtends an angle of 107° at the center of the aircraft (see FIGURE 20).

The outboard edges of the formers **317** are covered with a sheet metal covering **320** and their inboard edges are covered with a sheet metal covering **321**. The outboard edges of the formers **318** are covered with a sheet metal covering **322** and their inboard edges are covered with a sheet metal covering **323**. The inboard surfaces of the upper portions of the coverings **321**, **323** provide fixed guide means which directs propulsive gas passing through the upper peripheral nozzle in directions generally upwardly and inboardly. In a similar manner the lower portion of the covering **321** provides fixed guide means which directs gas flowing through the forward portion of the lower peripheral nozzle generally downwardly and inboardly. Pivotally attached to the lower edge **319** of the rear portion of the outboard body structure is a series of flaps **324** arranged in end-to-end relation. It will be seen from FIGURE 20 that there are eight flaps each extending a circumferential length equal to the distance between three ribs on the inboard body structure. Each flap is of double-walled construction and is dished at **325**. The flaps are movable between first positions, shown in full lines in FIGURE 21, and second positions, shown in phantom lines in FIGURE 21, by being rocked about their pivotal mountings on the lower edge **319** of the rear portion of the outboard body structure. The flaps are rocked by a series of actuators, one actuator being provided for each flap. An actuator is indicated at **326** and is pivotally connected at its upper end at **327** to the inboard body structure. Each actuator is provided with a ram **328** which extends across the lower peripheral nozzle and is pivotally attached to a flap **324** between spaced lugs **329** arranged substantially centrally of the lower edge of the flap. The rams **328** pass through apertures **330** in the covering of the inboard body structure. It will be appreciated that, as the actuators **326** are operated, the flaps are rocked between their first and second positions and that during movement of the flaps the actuators will pivot about the pivot points **327**. The apertures **330** are made of larger diameter than the rams **328** since the rams will move transversely of the apertures during movement of the flaps. The actuators are provided with compressed air bled from the compressors of the engines and are operated by an electro-pneumatic valve (not shown) controlled by the switch **295** on the pilot's control column.

The outboard body structure is held in juxtaposed spaced relationship with the outlet nozzle **86** by means of spokes **44** in a manner similar to that hereinbefore described for the other embodiments of the invention, however it will be noted that the guide vanes **199** and **200** are omitted in this embodiment of the invention. The primary gas deflecting means consisting of the baffles **220**, **221** with their associated operating mechanism is identical to that previously disclosed.

The functions of the various components of the aircraft of FIGURES 1 to 13 will now be described. When the gas turbine engines **72**, **73** and **74** are put into operation they will discharge their products of combustion into the "tusk" manifolds **119**, **120**, **121**. The gases flowing at high velocity through these manifolds will be directed downwardly through the slots **123** in the manifolds and will then pass through the guide vanes **128** into the tip turbine constituted by the blades **157** on the outer periphery of the rotor. After leaving the turbine, the gases will pass through the exhaust boxes between the guide vanes **137** and the walls **138** and, except for the exhaust boxes adjacent to the air intake passages for the engines, will be discharged into the gas displacement passage as shown in FIGURE 6B and will flow outboardly along the passage. In positions where the exhaust boxes overlie the air intake passages for the engines, such as in FIGURE 6A, the exhaust gases are deflected by the deflecting walls **68**, **68***a* and **68***b* so that the exhaust gases pass into sectors of the gas displacement passage radially adjacent to the air intake passages for the engines.

The flow of the high velocity gases through the turbine constituted by the blades **157** causes rotation of the rotor **45** thus to impel air to flow within the structure and along the gas displacement passage provided between the radial ribs so that the air is forced out of the outboardly divergent outlet nozzle **86**. Thus, except for positions adjacent to the air intakes of the engines, air flows outboardly along the sectors of the gas displacement passage, is guided by the vanes **232** into the outboardly divergent outlet nozzle **86** and then passes through one or both of the upper and lower peripheral nozzles provided between the outboard body structure and the inboard body structure. Where spaces between adjacent ribs lead to the air intakes of the engine, as shown in FIGURE 6A, air passes outboardly between the ribs and is directed by the vanes **69***a*, **70***a*, **71***a*, into the elbows **117** and thence into the engines. Therefore, once the rotor has started to rotate, air will be forced into the engines by the impelling action of the rotor.

Movement of the baffles **220**, **221** in the slots **79** and **80** of the upper and lower radiused webs at the outboard ends of the ribs of the inboard body structure will control the direction in which the gas passing through the gas displacement passage leaves the outlet nozzle **86**. If the baffles **220**, **221** project into the gas displacement passage by equal amounts then the gas will tend to pass radially outboardly until it is deflected by the outboard body structure. If the baffle **220** projects into the gas displacement passage more than does the baffle **221**, then the propulsive gas will tend to be deflected downwardly to pass through the lower peripheral nozzle between the inboard and outboard body structures and more gas will pass through the lower peripheral nozzle than through the upper peripheral nozzle. Conversely, if the baffle **221** projects into the gas displacement passage more than does the baffle **220** the propulsive gases will tend to pass through the upper peripheral nozzle between the inboard and outboard body structures and more gas will pass through the upper nozzle than through the lower nozzle. It will be appreciated that the baffles **220**, **221** move together by virtue of the straps **225** and are controlled by movement of the cables **188** through the agency of the bell-cranks **226** to the arms of which the straps **225** and the cables **188** are connected. The baffles **220**, **221** may therefore be operated to apportion the flow of propulsive gas between the upper and lower peripheral nozzles.

The deflection of the propulsive gas is attributable to the Coanda effect. (See aforementioned application Serial No. 684,615 for explanation and discussion of Coanda effect.) Thus, supposing that the baffle **220** projects into the gas displacement passage and the baffle **221** is retracted from the passage, gas flowing through the passage will be caused to "break away" from the skin **87** constituting the upper wall of the passage, by the projection of the baffle **220**. However, the major portion of the gas will flow smoothly over the lower wall of the gas displacement passage and will follow the contour of the skin attached to the lower radiused webs **78** by virtue of the Coanda effect, and will flow outboardly and downwardly to pass through the lower peripheral nozzle. The effect of the baffle **220** is assisted by a directing stream of gas which issues from the slot **79**. Some of the propulsive gas impinging on the inboard surface of the baffle **220** is directed by the baffle into the chambers between the upper radiused webs **77** of the adjacent ribs. These chambers are completely closed except for the slots **79** and therefore gas is forced from the chambers through the slots **79** along the outboard surfaces of the baffles **220** since the pressure in the gas displacement passage is less at positions outboardly of the baffle than at positions inboardly thereof.

Conversely, if the baffle 221 is caused to project into the gas displacement passage and the baffle 220 is retracted, then the major portion of the gas is caused to break away from the lower wall of the gas displacement passage and tends to pass upwardly and outboardly around the skin attached to the upper radiused webs 78 of the ribs by virtue of the Coanda effect and therefore passes through the upper peripheral nozzle. Some of the propulsive gas is deflected by the inboard surface of the baffle 221, enters the spaces between the lower radiused webs 78 of the ribs, and is ejected adjacent to the outboard surfaces of the baffle 221 to assist in directing the remainder of the propulsive gas.

It will be seen that by operation of the baffles 220, 221 the quantities of air and exhaust gases from the turbines which flow through the upper and lower peripheral nozzles can be controlled. That is to say, operation of the baffles 220, 221 apportions the flow of propulsive gases between the upper and lower peripheral nozzles.

The baffles 203, 204 in the outboard body may be operated to assist in the deflection of the gases passing through the upper and lower peripheral nozzles. Where the baffles 203, 204 project from the surface of the outboard body they will cause the gas flow to break away from the outboard body surface and will assist the gas to follow the curvature of the upper and lower radiused webs 77 and 78. It will be seen in FIGURE 9 that the baffles 203, 204 at the forward portion of the aircraft project fully into the upper and lower peripheral nozzles, whereas at the rear of the aircraft the baffles are fully retracted. If the actuators 216 are operated to move the baffles 203, 204 forwardly then the baffles in the forward part of the outer body will be retracted and those in the rear portion of the outer body will be projected and, if the actuators are moved sufficiently, the baffles will assume a position in which they project equally around the whole periphery of the aircraft. As mentioned above, the actuators 216 are controlled directly from the pilot's control column through the switch 295.

Returning now to the baffles 220, 221, which constitute the primary gas deflecting means, these can be operated in unison, i.e., to an equal extent at all points around the aircraft periphery, by means of the actuator 166. If the actuator is operated to raise the rod 169 then the bell-cranks 183 are caused to pivot by the co-action of their inboard ends with the mushroom head 171 of the rod 169. The bell-cranks all rock to an equal extent and will draw the links 185 inboardly to an equal extent. The links 185 will, in turn, move the T-pieces 187 inboardly to equal extents which will move the lower arms 226*b* of the bell-cranks 226 inboardly. Movement of the lower arms of the bell-cranks 226 inboardly will raise the upper arms 226*a* and will cause the upper baffle 220 to retract into the slots 79 and the lower baffle 221 to project from the slots 80. Conversely, if the actuator 166 is operated to lower the rod 169, the springs 230 will pull the cables 188 outboardly and the baffle 220 will project from the slots 79 whereas the baffle 221 will retract into the slots 80. Movement of the baffles 220, 221 under the influence of the actuator 166 is equal throughout the periphery of the aircraft and is to be distinguished from the swashing movement of the baffles which will hereinafter be described.

Referring now to FIGURE 7, the control shaft 163 is secured to the diaphragm 160 at the upper end of the vertical shaft 146, and the upper end of the control shaft is connected through diaphragm 161 to the upper end of the sleeve 147 on which the rotor is mounted. If the rotor now tilts about the spherical bearing 148 it will apply to a force to the upper end of the control shaft 163 which will pivot about the fulcrum provided by the diaphragm 160, and the control shaft will be deflected from its central position which is shown in FIGURE 7.

Thus, if the rotor tips to the rear from its neutral position the lower end of the control shaft 163 will move forwardly and in so moving will affect the cables 188 and the primary gas deflecting means, which includes the baffles 220, 221 connected thereto. All the cables will be moved to some extent but the cables affected most will be those attached to the links 184 lying in, or nearest to, the plane of movement of the control shaft.

For reference purposes let it be considered that the longitudinal axes of the aircraft lies North and South and that the aircraft is facing North (see FIGURES 28 and 29). Using these axes of references, as the rotor tips to the rear from its neutral position the lower end of the control shaft will move from its central position to the North and the rotor has tipped towards the South. The plane containing the positions of the rotor spin axis corresponding to both the neutral and tilted positions of the rotor is the North-South plane. The cables 188 which are most affected by the northerly movement of the lower end of the cotnrol shaft are those connected, via the links 185 and T-pieces 187, to the links 184 lying in, or nearest to, the North-South plane. The links 184 to the North of the lower end of the control shaft 163 will be moved outboardly and the links 184 to the South of the lower end of the control shaft will be moved inboardly.

The links 185 are dimensioned and arranged so that the cables 188 most affected by the movement in any given direction of the control shaft will be advanced, in a clockwise sense, i.e. in the direction of rotation of the rotor, by a phase angle of 20° relative to the plane containing both positions of the spin axis corresponding to the neutral and tilted positions of the rotor, in the present case, the vertical plane containing the North-South axis as mentioned above. Thus the portions of the baffles 220, 221 affected most by the northerly movement of the lower end of the control shaft will lie adjacent to a vertical plane 20° East of North and 20° West of South, i.e. a plane advanced 20° from the North-South plane containing both said positions of the spin axis. This advanced plane is referred to for convenience as the control plane (see FIGURE 28).

All the cables 188 will be moved to varying extents by movement of the control shaft. The cables moved to the greatest extent will be adjacent to the control plane and the cables moved to the least extent will be adjacent to a plane normal to the control plane.

The cables 188 in the sector indicated by the line 400 in FIGURE 28, will be moved outboardly and the cables moving most will be those adjacent to the control plane. As the cables move outboardly the baffles in the sector will move downwardly (see FIGURE 29), so that propulsive gas will tend to flow through the lower peripheral nozzle in preference to the upper peripheral nozzle and will therefore provide an upward reaction on the associated sector of the aircraft.

All the cables in the sector indicated by the line 401 in FIGURE 28 will be moved inboardly so that the baffles 220, 221 in this sector will be moved upwardly (see FIGURE 29), and propulsive gas will flow through the upper peripheral nozzle in preference to the lower peripheral nozzle. The greatest movement of the baffles will be in the control plane. The general gas flow pattern for a nose-up moment applied by the gas deflecting means is shown in FIGURE 25.

As the result of moving the lower end of the control shaft forwardly, the aircraft is subjected to a moment which may be considered to be a couple acting in the control plane. This couple may be resolved into two components, namely a component in the North-South plane applying a pitching moment to the aircraft and a component in the East-West plane applying a rolling moment to the aircraft. If the phase angle is designated "α", then the first component will be proportional to cosine α and the second component will be proportional to sine α.

Moreover, the first component will amplify the gyro-couple applied to the aircraft by the rotor as the latter tilts within the aircraft and the second component would oppose a rotational velocity acquired by the aircraft and which would cause the rotor to tilt from its neutral position. This is explained in more detail hereinafter with reference to FIGURES 17, 17A, 18 and 18A.

The movement of the control shaft **163** may be initiated by operation of the actuators **176**, **178** and **179** which are controlled from the pilot's control column.

As described above, each of the actuators **176**, **178** and **179**, is attached by a conduit **253** to one of the nozzles **251**. The relative positions of the associated nozzles and actuators are 90° out of phase as will now be described. Thus referring to FIGURES 13 and 13A it will be seen that the nozzle **251*a*** lies on the longitudinal axis of the aircraft which is indicated by the arrows. The nozzle **251*a*** is connected to the actuator **176** which, as will be seen from FIGURE 3, is on the lateral axis of the aircraft and, in a clockwise direction, is 90° in advance of the nozzle **251*a***. Similarly, the nozzle **251*b*** is connected to the actuator **178** which, as will be seen from FIGURE 13A, is 90° in advance of the nozzle in a clockwise direction. Finally, the nozzle **251*c*** is connected to the actuator **179** which is 90° in advance of the nozzle in a clockwise sense.

The actuators **176**, **178** and **179** are caused to operate by variations in pressure in the conduits **253**. As mentioned above, the plenum chamber **247** in the double-walled sleeve **246**, is provided with high pressure air bled from the compressors of the gas turbine engines. This high pressure air flows through the inner stack pipes **252** of each of the nozzles **251** and, due to the presence of the plate **271**, maintains a pressure in each of the conduits **253**. If the plate **271** (see FIGURE 12) is spaced by an equal distance from each nozzle then the pressure produced in each of the conduits **253** is equal. Suppose now that the plate **271** is equally spaced from the nozzles **251** when the plate is horizontal and that the pilot pulls the handle **257** in a rearward direction. The rod **256** will flex above the bearing **254** and the plate **271** will tilt so that it will move away from the nozzle **251*a*** and will move towards the nozzles **251*b*** and **251*c***. As a result, the pressure in the conduit **253** connected to the nozzle **251*a*** will decrease and the pressure in the other two conduits will increase. As a result of the decrease in the pressure in the nozzle **251*a***, the pressure in the actuator **176** will be reduced and the pressure in the other two actuators **178**, **179** will be increased due to the increase of pressure in their associated nozzles **251*b*** and **251*c***. Due to the changes in pressure the actuators will apply a force to the control shaft tending to move its lower end towards the actuator **176**, i.e. in a direction at 90° to the direction at which the pilot first moved the handle **257**. Similarly, any force applied to the control shaft by the actuators **176**, **178** and **179** acts in a direction advanced 90° in a clockwise sense from the direction in which the pilot moves his handle **257** so that if the pilot moves the handle **257** to his left the force applied to the control shaft by the actuators **176**, **178** and **179** will tend to move it forwardly.

The hand wheels **280**, **281** may be used to trim the aircraft by providing a fine adjustment for the positions of the nozzles **251** relative to the plate **271**. By rotation of the cam wheels **274** and **275**, the sleeve **273** together with the associated double-walled sleeve **246** and the nozzles **251** may be adjusted about two axes at right angles. Thus fine adjustment of the distance between the outlets of the nozzles **251** and the plate **271** may be obtained with correspondingly fine adjustment of the position of the control shaft **163** by means of the actuators **176**, **178** and **179**.

As mentioned above, the rudder actuators **236** are connected to conduits **270** which lead to nozzles **268** associated with the tongue **260** at the base of the control column. If the pilot rotates the handle **257** the tongue **260** is moved by the cam **259** so that it moves closer to one of the nozzles **268** and further away from the other nozzle. By moving the tongue **260**, therefore, the relative pressures in the conduits **270** may be varied and, as will be seen from FIGURE 11, each conduit **270** is connected to each of the actuators **235** but between the actuators the conduits are crossed so that the rudder vanes in both groups will move in the same clockwise or anti-clockwise sense. It will thus be seen that the pilot can control the aircraft in yaw by rotation of the handle **257**.

The aircraft may be considered to have a body structure and engine means within the structure to provide propulsive gas, the engine means including the rotor **45** and the gas turbine engines **72**, **73**, **74**. The aircraft has an outlet nozzle **86** which is arranged to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the body structure. The primary gas deflecting means are associated with the nozzle and are operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle **86** at any selected position of the multiplicity of positions at which the outlet nozzle discharges the propulsive gas. The rotor **45** comprises a gyroscope which is rotatable about a spin axis and the gyroscope has a neutral position relative to the body structure, the neutral position being with the rotor horizontal when the aircraft is horizontal and with the spin axis vertical and parallel, in this particular aircraft coincident, with the yaw axis of the aircraft. In all the drawings, except FIGURE 29, the rotor is shown in its neutral position.

The springs **230** acting through the bell-cranks **226** and the cables **188** provide means which bias the rotor to its neutral position within the body structure although they allow the rotor to move relatively to the body structure. The springs **230** and the cables **188** also cause the rotor to tilt from an original steady state position when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis when the rotor is in said original position. Thus, to take an example, suppose that the rotor is rotating in its neutral position, which may be considered as an original steady state position, with its spin axis vertical then, if the aircraft acquires a rotational velocity about a turn axis normal to said spin axis, in this example about a horizontal axis, the rotor will be caused to tilt from its original position by virtue of the springs **230** and the cables **188**.

The cables **188** with their associated links **184**, **185** at the inboard ends thereof and with the bell-cranks **226** at the outboard ends thereof constitute a link system interposed between the gyroscope, constituted by the rotor, and the primary gas deflecting means, constituted by the baffles **220**, **211**. Moreover, the link system operates the baffles as described with reference to FIGURE 28 in a manner determined by the tilted position of the rotor. The cables **188** radiate from the control shaft **163** and constitute individual links of the link system and it will be seen that the individual links may be considered to be operatively coupled to correlated portions of the gas deflecting means spaced around the periphery. Moreover, links of the system which are operatively coupled to peripherally opposite portions of the gas deflecting means are interconnected by being connected at their inboard ends to the control shaft **163**.

Referring to FIGURES 28 and 29, for any given tilt of the rotor, opposite peripheral portions of the gas deflecting means lying adjacent to a control plane are operated. The control plane contains the position of the spin axis corresponding to the neutral position of the rotor and is advanced in the direction of rotation of the rotor by a phase angle α, in this case 20°, relative to the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor. Thus in FIGURE 28 the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor is the North-South plane and the control plane is advanced 20° clockwise, i.e. in the direction of rotation of the rotor, relative to the North-South plane. The opposite peripheral portions of the gas deflecting means operated by tilt of the rotor are indicated by the sectors **400** and **401** in FIGURE 28.

Referring now to FIGURES 14, 15 and 16, the functioning of the control system of the aircraft there shown is the same as the functioning of the aircraft shown in FIGURES 1 to 13 with the exception that operation of the slide **305** replaces operation of the baffles **203** and **204** of the first embodiment. When the slide **305** is in a position such that its apertures **310** are in register with the gas entry ports **302** in the outboard body structure, propulsive gas enters the gas entry ports **302** and is deflected by the channel member **194** so that the gas issues from the slots **201** and **202** all around the periphery of the aircraft in the form of directing streams. It will be seen from FIGURE 15 that the gas will issue in streams having inboardly directed components of velocity and that these streams will assist the propulsive gas discharged from the outlet nozzle **86** to flow around the upper and lower radiused webs **77, 78** and the guide vanes **199** and **200**. The proportion of the total propulsive gas which flows through each of the upper or lower peripheral nozzles will be controlled by the primary gas deflecting means, i.e. by the baffles **220** and **221**, in a manner similar to that described for the aircraft shown in FIGURES 1 to 13.

If the slide **305** is moved so that the gas entry ports **302** in the rear portion of the outer body are closed by the slide, then propulsive gas around the rear portion of the aircraft will be prevented from entering the gas entry ports **302**. Under these circumstances, gas moving radially outboardly from the outlet nozzle **86** around the rear portion of the aircraft will impinge upon the rear portion of the outboard body structure, will divide and will flow over both the upper and lower surfaces of the outboard body structure.

The functions of the various controls in the embodiment of the invention as shown in FIGURES 17 and 17A are the same as the similar controls with reference to the aircraft shown in FIGURES 1 to 13. However, due to the omission of the links **185**, the phase angle of the control system is 0°, i.e. the control plane adjacent to which the portions of the baffles **220, 221** are most affected for a given tilt of the rotor will be coincident with the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor.

Thus, referring to FIGURE 28 and assuming that the rotor tilts in a southerly direction from its neutral position, the lower end of the control shaft will move northerly. As before, the North-South plane will contain the positions of the spin axis corresponding to the neutral and tilted positions of the rotor. Since, however, the inboard ends of the cables are connected directly to the links **184** the control plane will also be the North-South plane, i.e. the plane containing the positions of the spin axis for the neutral and tilted positions of the rotor.

The aircraft will be subjected to a moment which, as before, may be resolved into two components, a first component in the North-South plane applying a pitching moment to the aircraft and a second component in the East-West plane applying a rolling moment to the aircraft. However, since the phase angle in this case is 0° and since the first component is proportional to the cosine of the phase angle and the second component is proportional to the sine of the phase angle, it follows that the second component will be zero so that the resulting moment will be in the control plane. This moment

amplifies the gyro-couple applied to the aircraft by the tilting of the rotor within the aircraft. Thus as the rotor tilts in a southerly direction it will apply a moment to the aircraft tending to pitch the aircraft nose up. The resulting movement of the baffles **220, 221** will be to retract the baffle **221** and advance the baffle **220** at the forward portion of the aircraft and retract the baffle **220** and advance the baffle **221** at the rear portion of the aircraft. The aircraft will therefore be given a nose-up pitching moment which, as will be seen, amplifies the nose-up pitching moment imparted to the aircraft due to pitching of the rotor within the aircraft. The gyro-couple applied to the aircraft by pitching of the rotor is applied to the aircraft through the springs **230**.

The functions of the various controls in the embodiments shown in FIGURES 18 and 18A are the same as the similar controls described with reference to the aircraft shown in FIGURES 1 to 13. However, in FIGURES 18, 18A, the phase angle of the control system is 90° so that the control plane for the system is advanced 90° in the direction of rotation of the rotor. Thus, due to the interposition of the right-angled links **350**, if the rotor tilts in a southerly direction and the lower end of the control shaft moves in a northerly direction the cables **188** to the East will be moved outboardly and the cables **188** to the West will be moved inboardly. As a result the baffles **220, 221** will be operated to apply a rolling moment to the aircraft about its longitudinal axis tending to roll the aircraft in an anticlockwise direction when viewed from the rear. The rotor may be caused to pitch in a southerly direction if the aircraft attains a rotational velocity tending to turn it to a clockwise direction upon its longitudinal axis when viewed from the rear. It will therefore be seen that the moment applied to the aircraft is such as to directly oppose the rotational velocity which the aircraft has acquired. The general statement that the couple applied to the aircraft may be resolved into two components proportional to the cosine of the phase angle and the sine of the phase angle still holds good. However, since the phase angle is 90° the component proportional to the cosine of the angle, i.e. the component which tends to amplify the gyro-couple applied to the aircraft, is zero and only the component tending to roll the aircraft and to directly oppose the rotational velocity acquired by the aircraft is actually applied to the aircraft.

The functioning of the control system of the aircraft shown in FIGURES 19, 20 and 21 is the same as that of the control system of the aircraft shown in FIGURES 1 to 13, with the exception that operation of the flaps **324** replaces operation of the baffles **203, 204** of the aircraft of FIGURES 1 to 13.

When the flaps **324** are in their first position (shown in full lines in FIGURE 21), gas issuing through the lower peripheral nozzle due to the operation of the primary gas deflecting means will be directed substantially inboardly and downwardly. Conversely, gas issuing through the upper peripheral nozzle due to operation of the primary gas deflecting means will be deflected generally inboardly and upwardly. If now the flaps **324** are moved to their second positions (shown in phantom lines in FIGURE 21), propulsive gas issuing from the forward portion of the lower peripheral nozzle will still be directed generally inboardly and downwardly. However, gas issuing from the rear portion of the lower peripheral nozzle will pass generally downwardly and outboardly and will give to the aircraft a forward and upward thrust.

The operation of the embodiment of the aircraft described in FIGURES 1 to 13 will now be described. The aircraft is capable of taking off and landing vertically and of assuming forward flight after it has risen to a desired height. The aircraft is provided with a control system which is under the control of the pilot and also with an automatic control system to reduce the divergence of the aircraft incident upon a disturbance which imparts to the aircraft a rotational velocity about a turn axis lying normal to the spin axis of the rotor. The control system reduces the divergence of the aircraft incident upon rolling or pitching moments, i.e. moments tending to impart a tilt rate to the aircraft.

When the gas turbine engines **72**, **73**, **74** are started, air and exhaust gas flow outboardly along the gas displacement passage, through the outlet nozzle and, depending on the positions of the primary gas deflecting means, through either or both of the upper and lower peripheral nozzles. For take-off, the controls are set in such a position that the secondary gas deflecting means, i.e. the baffles **203**, **204**, project into the upper and lower peripheral nozzles equally around the whole periphery of the aircraft. The primary gas deflecting means is operated to divert substantially the whole of the propulsive gas through the lower peripheral nozzle and to this end the actuator **166** is operated to retract the baffle **221** into the slots **80** and to project the baffle **220** from the slots **79**. Propulsive gas therefore flows outboardly along the gas displacement passage, but its flow along the upper wall of the passage is interrupted by projection of the baffle **220** and the gas passes downwardly and inboardly through the lower peripheral nozzle. The gas tends to flow along the guide vanes **200** and along the covering of the lower radiused webs **78** of the ribs of the inboard body structure by virtue of the Coanda effect. This downward and inboard flow is assisted by the projection of the baffle **204** which interrupts flow of gas along the lower surface of the outboard body structure. Air is induced to flow through the upper peripheral nozzle by the flow of propulsive gas through the lower peripheral nozzle and this induced air flow is indicated by the arrows in FIGURES 22 and 23 and joins the main flow of gas to increase its thrust slightly.

The general pattern of flow is shown in FIGURE 22 from which it will be seen that the gas flows inboardly and downwardly until it is adjacent to the ground when it curls outboardly. With this setting of the controls it has been found that, when the aircraft is adjacent to the ground, the gas ejected from the aircraft forms a downwardly moving tubular curtain which provides thrust augmentation for landing and take-off. This thrust augmentation when the aircraft is adjacent to the ground is known as the "ground cushion effect" and is obtained with a downwardly moving tubular curtain of gas as described.

As the aircraft rises, the tubular curtain of gas becomes substantially solid as shown in FIGURE 23. When the aircraft is at a substantial height above the ground the propulsive gas leaving the lower peripheral nozzle is able to move inboardly to a greater extent than when the aircraft is adjacent to the ground, and the streams from the various portions of the periphery of the air craft merge to form a solid jet of downwardly moving gas which propels the aircraft upwardly.

When hovering in free air as shown in FIGURE 23, the upward thrust on the aircraft is greater than the static thrust of the engines. It is believed that the thrust augmentation in free air is due to the following facts:

(1) The gas discharged from the lower peripheral nozzle has a large surface area and entrains a substantial quantity of the ambient air. This entrainment increases the mass flow and reduces the speed of the gas flow.

(2) The propulsive gas issuing from the lower peripheral nozzle and the entrained ambient air is caused to traverse the lower aerofoil surface and is deflected downwardly away from the surface with components of velocity generally normal thereto. This downward deflection causes an upward reaction on the surface which provides a lift force for the aircraft.

The propulsive gas is caused to traverse the lower aerofoil surface by means of the primary and secondary gas deflecting means; the baffles **220**, **221** and **203**, **204** respectively as hereinbefore explained. The gas discharged from the nozzle is "bent" inboardly, and the flows of gas coming towards the center of the surface from opposing directions meet adjacent to the center and, since the gas cannot move upwardly due to the presence of the lower aerofoil surface, the gas is deflected downwardly thus providing the upward reaction on said lower surface.

When the aircraft has reached the desired height, the pilot operates the controls to transfer the aircraft from hovering to forward flight. This is accomplished by moving the secondary gas deflecting means, i.e. the baffles **203**, **204**, so that they are fully retracted at the rear portion of the aircraft and project fully at the forward portion of the aircraft, while at the same time operating the actuator **166** to raise the baffles **220**, **221** until they both project to approximately an equal extent into the gas displacement passage. In this position of the controls the gas flow through the upper and lower peripheral nozzles will be substantially equal all around the aircraft as shown in FIGURE 24. Since the secondary gas deflecting means, i.e. the baffles **203**, **204**, at the forepart of the aircraft project from the outer body structure, the propulsive gas leaving the forward portion of the outlet nozzle is caused to flow around the guide vanes **199** and **200** as may be seen from FIGURE 24. Since the baffles **220**, **221** each project from the upper and lower walls of the gas displacement passage the flow of gas is interrupted on both walls but the gas is caused to flow around the guide vanes **199**, **200** by the Coanda effect. The Coanda effect is assisted by the fact that the gas is not permitted to flow smoothly around the forward portion of the skin of the outer body structure due to the projection of the baffles **203**, **204** at the forward portion of the aircraft.

At the rear portion of the aircraft, however, where the baffles **203**, **204** are retracted, the gas is able to pass substantially radially outboardly and is caused to follow the outer surface of the outboard body structure due to the Coanda effect. This results, as will be seen from FIGURE 24, in a generally backwardly and downwardly deflected stream of propulsive gas. The gas flowing through the lower peripheral nozzle in the forward portion of the aircarft is constrained to flow along the underside of the aircraft as shown, and meets the gas ejected from the upper and lower peripheral nozzles at the rear of the aircraft. As a result the aircraft is propelled forwardly and also obtains some lift from the downward direction of the rearwardly discharged propulsive gas. Moreover, since the aircraft cross section is an aerofoil, as the aircraft moves forwardly it experiences aerodynamic lift in a manner similar to the wings of a conventional aircraft.

The response of the aircraft to the automatic stabilization system and to the pilot's control system will now be considered. However, before considering the response in detail it is necessary to mention several points. As has been pointed out above, the aircraft can hover above the ground and it can also move in forward flight; in forward flight, the response of the aircraft is affected by a de-stabilizing moment which does not affect it when hovering. The aircraft which have been described are generally disc-shaped and the centers of gravity of these aircraft are approximately at the centers of the discs. On the other hand, since the sheathing of the aircraft causes the aircraft to act as an aerofoil, the center of pressure is approximately one-third of the chord length behind the leading edge. Thus the center of pressure is in front of the center of gravity during forward flight. It follows that, if the aircraft hits an upgust in forward flight the angle of attack of the aircraft will increase which will increase the lift which, in turn, will increase the pitching moment since the center of pressure is in front of the center of gravity. A converse effect will occur with a nose down pitching moment: as the aircraft pitches nose down the angle of attack decreases, which decreases the lift which decreases the angle of attack, and so on.

With the aircraft described, since there are no tail surfaces, the destabilizing moment causes a divergence in pitch which is extremely rapid so that, in forward flight if there were no correction, the aircraft would be overturned in a matter of one or two seconds after hitting a gust. This rate of divergence is so rapid that the pilot cannot control it manually.

In hovering, there is no destabilizing moment since the center of pressure and the center of gravity are in line. If the aircraft hits a gust while hovering the gust will tend to tip the aircraft but, since a gust may be considered to be an impulse and since there is no destabilizing moment, there will be no steady divergence; the divergence will be transient but will still be so rapid as to normally be beyond the manual control of the pilot.

It follows that both in forward flight, and in hovering, an automatic stabilization system is required to reduce the rate of divergence. The automatic stabilization system provided by the invention is so interconnected with the pilot's control system that the pilot controls the aircraft through the operation of the automatic stabilization system. The automatic stabilization system is brought into operation when the aircraft acquires a rotational velocity about a turn axis normal to the spin axis when the latter is in a steady state position; in other words the system operates if the aircraft acquires a tilt rate (be it a pitch rate or a roll rate). The aircraft may acquire a rate from an outside disturbance, e.g. a gust, or by a pilot input to the control system.

Another point which should be considered is that the aircraft will respond more readily to low frequency forces than to high frequency forces. The forces applied to the aircraft by the control system are, at least in part, a combination of high frequency and low frequency forces; for example the characteristic frequencies of the control system may be 3 c.p.s., 15 c.p.s. and 40 c.p.s. However, the aircraft will respond more or less only to the low frequency forces, the high frequency movements of the control system being confined almost entirely to the control system.

The response of the aircraft will be described with reference to FIGURES 30 to 34 which show a series of graphs; each response is described by six graphs. The graphs show the following displacements and velocities:

(A) The roll angle of the aircraft in radians,

(B) The roll rate or roll velocity of the aircraft in radians per second,

(C) The pitch angle of the aircraft in radians,

(D) The pitch rate or pitch velocity of the aircraft in radians per second,

(E) The amount of roll of the rotor within the aircraft measured as a percentage of its maximum roll which is set by structural limitations and may, for example, be ±¼° from the neutral position, and

(F) The pitch of the rotor within the aircraft measured as a fraction of its maximum pitch which is limited as is the maximum roll.

The response of the aircraft will depend on the phase angle between movement of the control shaft **163** and movement of the primary gas deflecting means which includes the baffles **220**, **221**. The damping of the system increases, up to a point, with an increase in phase angle. A system with zero phase angle has no built-in damping while a system with a 90° phase angle has considerable built-in damping as will be apparent from the following discussion. As described above with reference ot FIGURE 28, the phase angle of the embodiment of FIGURES 1 to 13 is 20° clockwise, i.e. in the direction of rotation of the rotor.

Referring to FIGURE 30, this shows the response of the aircraft of FIGURES 1 to 13 if, when it is hovering, the pilot moves his stick to the right. The amount which the stick is moved to the right is measured in terms of the resulting movement of the rotor, which is expressed as a percentage of the total permitted movement of the rotor in any direction, the various movements being considered as if the aircraft were on the ground with the rotor stationary. Thus, as mentioned above, the total movement of the rotor in any direction from its neutral position might be ¼°, therefore if the pilot moves his stick 10% to the right this will mean that he has moved his stick sufficiently so that, with the aircraft on the ground and the rotor stationary, the rotor would move from its neutral position by 10% of ¼°. As explained above, movement of the control column is 90° out of phase with the resulting force applied to the control shaft so that as the pilot moves his stick to the right the actuators will apply a pitching moment to the rotor by rocking the control shaft **163**. Moreover the graphs have been prepared on the assumption that the pilot's input is a step input, i.e. a sudden input and not a slow movement in the desired direction.

Returning to FIGURE 30, as a result of the pilot's movement of the stick to the right he applies, through the control shaft **163**, a pitching moment to the rotor which, as a result, acquires a pitch velocity, or pitch rate; as soon as it acquires this rate it is affected by the gyroscopic laws of motion and precession. By reference to graphs E and F of FIGURE 30 it will be seen that the rotor initially oscillates both in roll and in pitch and then acquires a steady state with a deflection in pitch and rather less of a deflection in roll. As the rotor oscillates, it operates the control system through the control shaft but the oscillations are of too high frequency to have much effect on the aircraft. In the final steady state, the deflection of the rotor is transmitted through the control shaft to operate the primary gas deflecting means to apply a moment to the aircraft which can be resolved into two components about the lateral and longitudinal axes of the aircraft. The component about the longitudinal axis of the aircraft overcomes the aerodynamic damping of the aircraft due to the internal flow of the propulsive gas through the gas displacement passage. Thus on one side of the longitudinal axis the body of the aircraft tries to move the radially flowing gas downwardly whereas on the other side of the axis the body will tend to move the gas upwardly. The gas will oppose this movement with a force proportional to its mass, its radial velocity and the angular velocity of the aircraft. The component about the lateral axis of the aircraft is employed in overcoming the gyroscopic moment and causes the aircraft to roll.

Graphs A and B of FIGURE 30 show that, after initial oscillation in its roll rate, the aircraft acquires a substantially steady roll rate and a steadily increasing roll angle. Graphs C and D of FIGURE 30 show that the aircraft is substantially undisturbed in pitch but has initially an oscillating pitch rate which is damped out. The graphs show that the aircraft responds substantially only to the low frequency components of the rotor oscillations shown in graphs E and F.

FIGURE 31 shows the response of the aircraft of FIGURES 1 to 13 if, when it is hovering, it encounters a steady rolling moment which is the approximate situation which might arise if the aircraft encountered a sudden side gust. The rolling moment imparts an increasing roll rate to the aircraft (graph B) and it will be seen that the rotor lags slightly behind the movement of the aircraft. The rotor then begins to catch up with the aircraft in roll and acquires a roll rate. Once the rotor acquires a roll rate it will follow the gyroscopic laws and its movement will be as shown in graphs E and F of FIGURE 31. It will be seen that after initial oscillation the rotor reaches a comparatively steady state with a deflection in roll and rather less of a deflection in pitch. The deflection of the rotor is transmitted through the control shaft **163** to operate gas deflecting means to reduce the divergence of the aircraft.

Graphs A and B of FIGURE 31 show that, after an initial sharp increase in roll rate, the roll rate decreases to a substantially steady value and the roll angle steadily increases. Graphs C and D show that the pitch velocity increase rapidly and settles down to a comparatively steady value and the pitch angle increases steadily. The divergence in pitch and roll is sufficiently slow for the pilot to be able to correct it.

FIGURES 32, 33 and 34 show the response of the aircraft of FIGURES 1 to 13 when in forward flight. FIGURE 32 shows the response of the aircraft to the pilot moving his control column 10% to the right, the 10% movement being defined as above. The pilot input applies a pitching moment to the rotor which thus acquires a pitch rate and then follows the gyroscopic laws. The initial portions of the graphs of FIGURE 32 are substantially similar to the graphs of FIGURE 30, that is to say, the disturbance induced by the pilot produces, after the initial transient oscillations, a substantially constant roll rate with virtually zero pitch rate. However, since the aircraft has been caused to pitch to some slight extent, as will be seen from graph C of FIGURE 32, the de-stabilizing moment described above affects the performance of the aircraft. As a result the roll rate and the pitch rate diverge from their substantially steady states. The general overall effect of the de-stabilizing moment is to roll the aircraft, thus increasing the roll rate, which in turn increases the gyro-couple in pitch and causes an increase in pitch rate, which in turn increases the de-stabilizing moment and so on. However, the divergence is sufficiently slow to be controlled by the pilot.

FIGURE 33 shows the response of the aircraft to the pilot moving the stick 10% forward. Whereas in the response shown in FIGURE 32 the effect of the de-stabilizing moment was of secondary importance, since the main output was in roll, in FIGURE 33 the de-stabilizing moment is of primary importance and produces much more rapid divergence in roll rate and pitch rate. The pilot input applies a rolling moment to the rotor which acquires a roll rate and thereafter follows the gyroscopic laws of motion. The effect is essentially similar to that of FIGURE 32 except for the effect of the de-stabilizing moment which prevents the acquisition of steady roll and pitch rates. Thus as the aircraft begins to pitch nose down, the lift decreases, which in turn increases the nose-down pitch, which decreases the lift and so on as explained above. Graphs B and D of FIGURE 32 show the diverging roll rate and pitch rate but the divergence is sufficiently slow to be corrected by the pilot.

FIGURE 34 shows the response of the aircraft when it encounters a sharp edged gust having a speed of 10 ft. per second. In a gust in forward flight the disturbing moment on the aircraft varies due to the movement of the aircraft and should be distinguished from the situation in FIGURE 31 where it is assumed that a steady moment is applied to the aircraft while it is hovering. Referring to FIGURE 34, the gust applies a pitching moment to the aircraft which therefore acquires a pitch rate. The rotor lags slightly and then it also acquires a pitch rate and consequently starts to roll. In rolling, the rotor applies a rolling moment to the control system which starts to roll the aircraft. The resulting motions of the aircraft and the rotor are as shown in the graphs of FIGURE 34. The initial, comparatively high transient values of roll rate and pitch rate are reduced to comparatively small values but diverge due to the de-stabilizing moment as described above. It will be seen that the aircraft is displaced in both roll and pitch but more in roll than in pitch. As before, the divergence is sufficiently slow for the pilot to be able to control the aircraft.

When the aircraft is in forward flight, in addition to there being aerodynamic damping due to the internal air flow as described above, there is also external aerodynamic damping of the aircraft due to the flow of air over the external skin of the aircraft.

It will be seen that the control system operates to reduce the divergence of the aircraft following a disturbance to values which can be corrected by the pilot. Without the automatic stabilization system the aircraft could be overturned in a pitching gust too quickly for the pilot to be able to control the movement.

The operation of the aircraft shown in FIGURES 14, 15 and 16 is the same as the operation of the aircraft described with reference to FIGURES 1 to 13 with the exception of the operations required to change from hovering to forward flight, and vice versa.

As explained above, when the slide **305** is in such a position that the apertures **310** therein are in register with the gas entry ports **302** in the outboard body structure, then propulsive gas enters the gas entry ports and is deflected by the channel member **194** to produce directing streams of gas. For take-off, the slide **305** is arranged so that the apertures **310** are in register with the gas entry ports **302** and the primary gas deflecting means is arranged so that substantially the whole of the propulsive gas is discharged through the lower peripheral nozzle. The general flow of propulsive gas for take-off is indicated in FIGURE 26.

The flow of propulsive gas through the lower peripheral nozzle induces air to flow through the upper peripheral nozzle and also through the gas entry ports **302** and the lower slot **202**. This induced flow of air helps to break away the flow of propulsive gases from the outboard body structure and, due to the Coanda effect, the propulsive gas passes downwardly and inboardly round the lower skin of the aircraft. It is found that with the controls in this position the gas ejected from the aircraft forms a downwardly moving tubular curtain of gas which curls outboardly adjacent to the ground as shown in FIGURE 26. Comparing FIGURE 26 with FIGURE 22 it will be seen that the inboard deflection of the gas is less in FIGURE 26 than in FIGURE 22, this is because the baffles on the outer body structure in the embodiment of FIGURE 22 are more efficient in breaking away the flow from the outboard body structure than is the flow of air induced through the outboard body structure in the embodiment of FIGURE 26. It is found that with an arrangement similar to that shown in FIGURE 26 but without the central stabilizing nozzle, an annular zone of negative pressure occurs under the aircraft adjacent to the center thereof. To relieve this zone of negative pressure the central stabilizing nozzle **313** is provided and some propulsive gas is ejected from this nozzle: this eliminates the zone of negative pressure and increases the upthrust of the aircraft.

To change from hovering to forward flight, the pilot operates the switch **295** on his control column to move the slide **305** so that the apertures **310** in the slide move out of register with the gas entry ports in the rear portion of the outer body structure. At the same time the pilot operates his controls to move the primary gas deflecting means so that gas will flow radially outboardly through the outlet nozzle, i.e. so that the upper and lower baffles **220**, **221** project into the gas displacement passage by equal amounts. With this setting of the controls, propulsive gas ejected from the rear portion of the outlet nozzle will flow over the upper and lower surfaces of the outboard body structure as indicated in FIGURE 27, since the gases are prevented from flowing round the upper and lower skins of the aircraft by virtue of the projection of the baffles of the primary gas deflection means.

Around the forward portion of the aircraft, propulsive gas enters the gas entry ports **302** and is deflected both upwardly and downwardly by the channel member **194** so that it appears as directing streams of gas directed upwardly and inboardly, and downwardly and inboardly, respectively. These directing streams of gas assist the remainder of the propulsive gas to flow upwardly and downwardly around the guide vanes **199** and **200**, and rearwardly along the upper and lower surfaces of the aircraft. Gas ejected from the central stabilizing nozzle **313** joins the gas moving along the lower surface of the aircraft and passes rearwardly until it meets the gas ejected from the rear portion of the aircraft. It will be seen from FIGURE 27 that the resultant rearward flow is directed somewhat downwardly, and therefore the aircraft is propelled both upwardly and forwardly.

In all flight regimes, the control and stabilization of the aircraft of FIGURES 14, 15 and 16 in pitch, roll and yaw is precisely the same as for the aircraft described with reference to FIGURES 1 to 13.

Referring now to FIGURES 17 and 17A, these illustrate a control system having a zero phase angle between movement of the control shaft and resulting movement of the primary gas deflecting means. The system has no built-in damping, and the couple applied to the aircraft as a result of a disturbing force, either external or pilot induced, will amplify the gyro-couple applied to the aircraft by tilt of the rotor axis.

Using the directional convention set out above, if the aircraft is hovering and the pilot pushes his stick 10% to the right, the actuators **176**, **178** and **179** will apply a pitching moment to the rotor through the control shaft. The rotor will acquire a pitch rate and will follow the gyroscopic laws.

FIGURE 35 shows the response of the aircraft of FIGURES 17 and 17A to a pilot moving his stick 10% to the right while the aircraft is hovering. The response is similar to the response shown in FIGURE 30 of the aircraft of FIGURES 1 to 13 for a similar input, except that the motion is undamped save by the aerodynamic damping due to the internal flow of gas through the gas displacement passage. Comparison of the graphs of FIGURE 35 with those of FIGURE 30 will show how the oscillations of the system are damped out by increasing the phase angle to 20°. That is to say, the response of FIGURE 35 differs essentially from the response of FIGURE 30 by the superimposition of an oscillation on the steady roll rate and the steady pitch rate of FIGURE 30 and also on the roll and pitch of the aircraft and of the rotor. While it would be possible to fly an aircraft having such a control system it would be rather less comfortable for the pilot than the aircraft of FIGURES 1 to 13.

FIGURE 36 shows the response of an aircraft having the control system of FIGURES 18 and 18A which has a phase angle of 90°. Comparison of FIGURE 36 with FIGURES 35 and 30 shows that the response is similar to the responses in FIGURES 30 and 35 but is more damped than in either of said systems. Thus as the pilot applies a pitching moment to the rotor, the rotor acquires a pitch rate and follows the gyroscopic laws as shown in the graphs. In the final steady state the rotor has a displacement in roll and rather less a displacement in pitch. The tilted rotor operates the gas deflecting means to apply a couple to the aircraft which is similar to the couple applied to the aircraft in the response of FIGURE 30 but, due to the different phasing, the position of the rotor to apply the couple is different from FIGURE 30. It will be seen that the system is extremely well damped and therefore would be more comfortable to fly than the aircraft shown in FIGURES 1 to 13. However, a disadvantage of such a system is that the time required to produce a given rate would be unnecessarily large and therefore it is desirable to compromise between a zero phase angle and a 90° phase angle, to provide a system which is partially damped but yet has rapid response. Such a compromise can be obtained with a phase angle of 20° as described with reference to FIGURES 1 to 13 and to the responses shown in FIGURES 30 to 34.

Referring now to FIGURES 19, 20 and 21, the control and stabilization of the aircraft there shown in pitch, roll and yaw is, in all flight regimes, similar to the control of the aircraft of FIGURES 1 to 13. The only difference is in the operations required to change from hovering to forward flight.

For hovering, the primary gas deflecting means are arranged so that substantially the whole of the propulsive gas passes downwardly and inboardly through the lower peripheral nozzle. When the aircraft has risen to the desired height the pilot operates his controls to move the flaps **324** to their second position, but he retains the primary gas deflecting means in their original position so that substantially the whole of the propulsive gas is discharged through the lower peripheral nozzle. In forward flight, therefore, propulsive gas issues from the forward portion of the lower peripheral nozzle and passes inboardly and downwardly, whereas the gas which issues through the rear portion of the lower peripheral nozzle passes outboardly and downwardly. The aircraft is propelled forwardly and upwardly in a manner similar to the aircraft previously described. The upper peripheral nozzle is only employed for control purposes and the operation of the control system is the same as that of the control system described with reference to FIGURES 1 to 13.

The term "aircraft" is used in the specification and claims in its broadest connotation of a craft which is propelled through the air but is not necessarily sustained thereby. The term is intended to include, where appropriate, vehicles which do not fly in the generally accepted sense of the word but "skim" over the surface of land or water sustained by generally downwardly directed streams of propulsive gas.

It will be understood that the forms of the invention herewith shown and described are preferred examples and that various modifications can be carried out without departing from the spirit of the invention or the scope of the appended claims.

What we claim as our invention is:

1. An aircraft comprising a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; opposed upper and lower gas deflecting means adjacent to the outlet nozzle, said gas deflecting means being spaced apart across said passage and associated with the upper and lower walls respectively so that the propulsive gas flows outboardly between the upper and lower gas deflecting means, each of said walls curving away from the other of said walls outboardly of the gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said gas deflecting means being operable to vary the directions in which the propulsive gas leaves the nozzle by selectively disturbing the flow of the propulsive gas along the walls; and control means operatively connected to the gas deflecting means.

2. An aircraft comprising a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; opposed upper and lower gas deflecting means adjacent to the outlet nozzle, said gas deflecting means being spaced apart across said passage and associated with the upper and lower walls respectively so that the propulsive gas flows outboardly between the upper and lower gas deflecting means, each of said walls curving away from the other of said walls outboardly of the gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent

cross-section, said gas deflecting means being operable to vary the directions in which the propulsive gas leaves the nozzle by selectively disturbing the flow of the propulsive gas along the walls; and control means connected to operate both gas deflecting means together.

3. An aircraft comprising a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; opposed upper and lower gas deflecting means adjacent to the outlet nozzle, said gas deflecting means being spaced apart across said passage and associated with the upper and lower walls respectively so that the propulsive gas flows outboardly between the upper and lower gas deflecting means, each of said walls curving away from the other of said walls outboardly of the gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, the gas deflecting means including gas ejection means to eject directing streams of gas into the passage to vary the directions in which the propulsive gas leaves the nozzle by selectively disturbing the flow of the propulsive gas along the walls; and control means operatively connected to the gas deflecting means.

4. An aircraft comprising a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; opposed upper and lower gas deflecting means adjacent to the outlet nozzle, said gas deflecting means being spaced apart across said passage and associated with the upper and lower walls respectively so that the propulsive gas flows outboardly between the upper and lower gas deflecting means, each of said walls curving away from the other of said walls outboardly of the gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, the gas deflecting means including baffles arranged for movement into and out of the propulsive gas flowing in the passage to vary the directions in which the propulsive gas leaves the nozzle; and control means operatively connected to the gas deflecting means.

5. An aircraft comprising a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; opposed upper and lower gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, the gas deflecting means including upper and lower baffles spaced apart across the passage so that the propulsive gas flows between the baffles which are arranged to be movable together into and out of the propulsive gas flowing along the passage to vary the directions in which the propulsive gas leaves the nozzle by selectively disturbing the flow of the propulsive gas along the walls; and control means operatively connected to the gas deflecting means.

6. An aircraft comprising a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; opposed upper and lower gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said gas deflecting means being operable to vary the direction in which the propulsive gas leaves the nozzle by selectively disturbing the flow of the propulsive gas along the walls; the gas deflecting means including baffles, with inboard and outboard surfaces, spaced apart across the passage so that the propulsive gas flows between the baffles which are arranged for movement into and out of the propulsive gas flowing along the passage, and ducts to receive at least some of the propulsive gas impinging on the inboard surfaces of the baffles and to eject it into the passage adjacent to the outboard surfaces of the baffles in streams which assist in directing the remainder of the propulsive gas; and control means operatively connected to the gas deflecting means.

7. An aircraft comprising a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; opposed upper and lower gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said gas deflecting means being operable to vary the directions in which the propulsive gas leaves the nozzle by selectively disturbing the flow of the propulsive gas along the walls; the deflecting means including upper and lower baffles, with inboard and outboard surfaces, arranged in slots in said upper and lower walls respectively for movement into and out of the propulsive gas flowing along the passage, and ducts to receive at least some of the propulsive gas impinging on the inboard surfaces of the baffles and to eject it through said slots into the passage adjacent to the outboard surfaces of the baffles in streams which assist in directing the remainder of the propulsive gas; and control means operatively connected to the gas deflecting means.

8. An aircraft according to claim 7 wherein each baffle is in the form of a frustum of a hollow cylinder and is mounted for movement in directions parallel to the yaw axis of the aircraft.

9. An aircraft according to claim 8 wherein the upper and lower baffles are connected to move together.

10. An aircraft comprising an inboard body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary

gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of propulsive gas between the peripheral nozzles; secondary gas deflecting means associated with at least a portion of one of the peripheral nozzles and operable to vary the directions in which the propulsive gas leaves said portion of said one peripheral nozzle; and control means connected to the primary and secondary gas deflecting means for operating the latter independently of one another.

11. An aircraft comprising an inboard body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of propulsive gas between the peripheral nozzles; secondary gas deflecting means associated with the peripheral nozzles and operable to vary the directions in which the propulsive gas leaves the peripheral nozzles; and control means connected to the primary and secondary gas deflecting means for operating the latter independently of one another.

12. An aircraft comprising an inboard body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of the propulsive gas between the peripheral nozzles; upper and lower secondary gas deflecting means associated with the upper and lower peripheral nozzles respectively and operable to vary the directions in which the propulsive gas leaves the peripheral nozzles, each of the secondary gas deflecting means including means redirecting a portion of the propulsive gas stream ejected from the outlet nozzle into streams of gas directed against the remainder of the propulsive gas; and control means connected to the primary and secondary gas deflecting means for operating the latter independently of one another.

13. An aircraft comprising an inboard body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of propulsive gas between the peripheral nozzles; upper and lower secondary gas deflecting means associated with the upper and lower peripheral nozzles respectively and operable to vary the directions in which the propulsive gas leaves the peripheral nozzles; the secondary gas deflecting means including a pair of slots in the inboard periphery of the outboard body structure, one slot of the pair opening into the upper peripheral nozzle and the other slot of the pair opening into the lower peripheral nozzle, a series of gas entry ports in the inboard periphery of the outboard body structure betwen said slots and positioned to receive a portion of the propulsive gas stream ejected from the outlet nozzle, and means within the outboard body structure to direct gas from the entry ports to the slots; and control means connected to the primary and secondary gas deflecting means for operating the latter independently of one another.

14. An aircraft according to claim 13, including a downwardly directed stabilizing nozzle in the lower surface of the inboard body structure; and means directing some of the propulsive gas flowing in the gas displacement passage into said stabilizing nozzle.

15. An aircraft comprising a lentiform inboard body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; a stabilizing nozzle in the lower aerofoil surface and in communication with the gas displacement passage; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the outlet and stabilizing nozzles; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means and merging with one of said aerofoil surfaces in a smooth, outboardly convex curve thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle thereby apportioning the flow of propulsive gas between the peripheral nozzles; upper and lower secondary gas deflecting means associated with the upper and lower peripheral nozzles respectively and operable to vary the directions in which the propulsive gas leaves the peripheral nozzle; the secondary gas deflecting means including a pair of slots in the inboard periphery of the outboard body structure, one slot of the pair opening into the upper peripheral nozzle and

the other slot opening into the lower peripheral nozzle, a plurality of gas entry ports in the inboard periphery of the outboard body structure between said slots and positioned to receive a portion of the propulsive gas stream ejected from the outlet nozzle, means within the outboard body structure to direct gas from the entry ports to the slots, obturator means associated with a number of entry ports situated in a portion of the inboard periphery of the outboard body structure at the rear of the aircraft, and actuating means to operate the obturat or means thus to selectively open and close the entry ports of said number; and control means connected to the primary and secondary gas deflecting means for operating the latter independently of one another.

16. An aircraft comprising an inboard body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning flow of the propulsive gas between the peripheral nozzles; secondary gas deflecting means comprising upper and lower baffles in the outboard body structure and associated with the upper and lower peripheral nozzles respectively, the baffles being arranged for movement into and out of the propulsive gas flowing through the peripheral nozzles to vary the directions in which the gas leaves the nozzles; and control means connected to the primary and secondary gas deflecting means for operating the latter independently of one another.

17. An aircraft according to claim 16 wherein each baffle is in the form of a frustum of a hollow cone and wherein guides are provided on the outboard body structure, the baffles being slidable on the guides.

18. An aircraft comprising a lentiform inboard body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means and merging with one of said aerofoil surfaces in a smooth, outboardly convex curve thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of the propulsive gas between the peripheral nozzles; secondary gas deflecting means comprising upper and lower baffles in the outboard body structure and associated with the upper and lower peripheral nozzles respectively, each baffle being in the form of a frustum of a hollow cone and being arranged for movement into and out of the propulsive gas flowing through one of the peripheral nozzles to vary the directions in which the gas leaves said one nozzle; and control means connected to the primary and secondary gas deflecting means for operating the latter independently of one another.

19. An aircraft comprising an inboard body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing an upper peripheral nozzle and a lower peripheral nozzle having a forward portion and a rear portion, the upper and lower peripheral nozzles being in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of propulsive gas between the peripheral nozzles; fixed guide means on the outer body structure and associated with the upper peripheral nozzle to direct gas issuing therefrom generally upwardly and inboardly; further fixed guide means on the outboard body structure and associated with the forward portion of the lower peripheral nozzle to direct gas issuing from said forward portion generally downwardly and inboardly; secondary gas deflecting means associated with the rear portion of the lower peripheral nozzle and operable to vary the directions in which the propulsive gas leaves said rear portion; and control means connected to the primary and secondary gas deflecting means for operating the latter independently of one another.

20. An aircraft comprising an inboard body structure; upper and lower walls within the structure defining a gas dispalcement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing an upper peripheral nozzle and a lower peripheral nozzle having a forward portion and a rear portion, the upper and lower peripheral nozzles being in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of propulsive gas between the peripheral nozzles; fixed guide means on the outboard body structure and associated with the upper peripheral nozzle to direct gas issuing therefrom

generally upwardly and inboardly; further fixed guide means on the outboard body structure and associated with the forward portion of the lower peripheral nozzle to direct gas issuing from said forward portion generally downwardly and inboardly; secondary gas deflecting means associated with the rear portion of the lower peripheral nozzle and operable to vary the directions in which the propulsive gas leaves said rear portion; the secondary gas deflecting means including a series of flaps arranged in end-to-end relation and pivotally secured to the outboard body structure, and means to move said flaps between first positions, in which the flaps direct gas issuing from said rear portion generally downwardly and inboardly, and second positions in which gas issuing from said rear portion is permitted to flow generally downwardly and outboardly; and control means connected to the primary and secondary gas deflecting means for operating the latter independently of each other.

21. An aircraft according to claim 20, wherein the means for operating the flaps includes actuators mounted on the inboard body structure, the actuators extending across the rear portion of the lower peripheral nozzle to the flaps.

22. An aircraft according to claim 20, wherein the inboard body structure is lentiform and is sheathed by opposed aerofoil surfaces which provide lift developing surfaces and wherein each of said walls merges with one of said surfaces in a smooth, outboardly convex curve.

23. An aircraft comprising a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; opposed upper and lower gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said gas deflecting means being operable to vary the directions in which the propulsive gas leaves the nozzle by selectively disturbing the flow of the propulsive gas along the walls; two sets of pivotally mounted rudder vanes in the gas displacement passage at corresponding positions on opposite sides of the longitudinal axis of the aircraft; means to operate said vanes to deflect the gas passing through the nozzle to control the aircraft in yaw; and control means operatively connected to the gas deflecting means.

24. An aircraft comprising a lentiform inboard body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; a downwardly directed stabilizing nozzle in the lower aerofoil surface and in communication with the gas displacement passage; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the outlet and stabilizing nozzles; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means and merging with one of said aerofoil surfaces in a smooth, outboardly convex curve thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls thereby apportioning the flow of propulsive gas between the peripheral nozzles; secondary gas deflecting means associated with the peripheral nozzles and operable to vary the directions in which the propulsive gas leaves the peripheral nozzles; and control means connected to the primary and secondary gas deflecting means for operating the latter independently of one another.

25. An aircraft comprising a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; a rotor shaft mounted within the structure to have a limited degree of universal movement and having a neutral position substantially parallel to the yaw axis of the aircraft; biasing means interposed between the structure and the shaft to bias the latter to its neutral position; a rotor on the shaft; engine means on the structure to rotate the rotor and thus to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; opposed upper and lower gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said gas deflecting means being operable to vary the directions in which the propulsive gas leaves the nozzle by selectively disturbing the flow of the propulsive gas along the walls; and control means operatively connected to the gas deflecting means, said control means being responsive to the tilt of the rotor shaft from its neutral position.

26. An aircraft comprising an inboard body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; a rotor shaft mounted within the structure to have a limited degree of universal movement and having a neutral position substantially parallel to the yaw axis of the aircraft; biasing means interposed between the structure and the shaft to bias the latter to its neutral position; a rotor on the shaft; engine means on the structure to rotate the rotor and thus to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of propulsive gas between the peripheral nozzles; primary control means connected to the primary gas deflecting means for operating the latter, said primary control means being responsive to the tilt of the rotor shaft from its neutral position; secondary gas deflecting means associated with at least a portion of one of the peripheral nozzles and operable to vary the directions in which the propulsive gas leaves said portion of said one peripheral nozzle; and secondary control means connected to the secondary gas deflecting means for operating the latter.

27. An aircraft comprising a body structure; upper and

lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; a rotor shaft within the structure substantially parallel to the yaw axis of the aircraft but having a limited degree of universal movement; a rotor on the shaft; engine means on the structure to rotate the rotor and thus to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; opposed upper and lower gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, the gas deflecting means including baffles arranged for movement into and out of the propulsive gas flowing in the passage to vary the directions in which the propulsive gas leaves the nozzle by selectively disturbing the flow of the propulsive gas along the walls; mechanical means connecting the baffles to the rotor shaft; means biasing the rotor shaft to a neutral position parallel to the yaw axis; and pilot-operated control means operative to apply a force to the rotor shaft thereby to apply a moment to the rotor.

28. An aircraft comprising a body structure; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; a rotor shaft within the structure substantially parallel to the yaw axis of the aircraft but having a limited degree of universal movement; a rotor on the shaft; engine means on the structure to rotate the rotor and thus to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; opposed upper and lower gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, the deflecting means including baffles arranged in the walls for movement into and out of the propulsive gas flowing in the passage to vary the directions in which the propulsive gas leaves the nozzle by selectively disturbing the flow of the propulsive gas along the walls; a control shaft arranged for rocking movement about a fulcrum fixed relatively to the body structure; means interconnecting the rotor shaft and the control shaft; mechanical means connecting the baffles to the control shaft; means biasing the control shaft to a neutral position parallel to the yaw axis; and pilot-operated control means to apply a force to the control shaft thereby to apply a moment to the rotor.

29. An aircraft comprising a lentiform inboard body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; a rotor shaft mounted within the structure to have a limited degree of universal movement and having a neutral position substantially parallel to the yaw axis of the aircraft; biasing means interposed between the structure and the shaft to bias the latter to its neutral position; a rotor on the shaft; engine means on the structure to rotate the rotor and thus to cause propulsive gas to flow generally outboardly in the displacement pasage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means including baffles arranged for movement into and out of the propulsive gas flowing in the passage to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of the propulsive gas between the peripheral nozzles; upper and lower secondary gas deflecting means associated with the upper and lower peripheral nozzles respectively, the secondary gas deflecting means including means for redirecting a portion of the propulsive gas stream ejected from the outlet nozzle into streams of gas directed against the remainder of the propulsive gas stream; primary control means for the primary gas deflecting means, said primary control means being responsive to the tilt of the rotor shaft from its neutral position; and secondary control means connected to the secondary gas deflecting means for operating the latter.

30. An aircraft according to claim 29, including a downwardly directed stabilizing nozzle in the lower aerofoil surface of the aircraft and in communication with the gas displacement passage.

31. An aircraft comprising a lentiform inboard body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; a rotor shaft mounted within the structure to have a limited degree of universal movement and having a neutral position substantially parallel to the yaw axis of the aircraft; biasing means interposed between the structure and the shaft to bias the latter to its neutral position; a rotor on the shaft; engine means on the structure to rotate the rotor and thus to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means and merging with one of said aerofoil surfaces in a smooth, outboardly convex curve thus providing said outlet nozzle with a curved, outboardly divergent cross-section, the deflecting means including baffles arranged for movement into and out of the propulsive gas flowing in the passage to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of the propulsive gas between the peripheral nozzles; secondary gas deflecting means associated with the peripheral nozzles, the secondary gas deflecting means including upper and lower baffles in the outboard body structure and associated with the upper and lower peripheral nozzles respectively, said baffles of the secondary gas deflecting means being arranged for movement into and out of the propulsive gas flowing through the peripheral nozzles to vary the directions in which the gas leaves the nozzles; primary control means for the baffles of the primary gas deflecting means, said primary control means operating in response to the tilt of the rotor shaft from its neutral position; and secondary control means operatively connected to the baffles of the secondary gas deflecting means for operating said baffles.

32. An aircraft comprising a lentiform inboard body structure sheathed by opposed aerofoil surfaces which

provide lift developing surfaces; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; a stabilizing nozzle in the lower aerofoil surface of the aircraft and in communication with the gas displacement passage; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the outlet and stabilizing nozzles; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means and merging with one of said aerofoil surfaces in a smooth, outboardly convex curve thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of propulsive gas between the peripheral nozzles; upper and lower secondary gas deflecting means associated with the upper and lower peripheral nozzles respectively and operable to vary the directions in which the propulsive gas leaves the peripheral nozzles; the secondary gas deflecting means including a pair of slots in the inboard periphery of the outboard body structure, one slot of the pair opening into the upper peripheral nozzle and the other slot opening into the lower peripheral nozzle, a plurality of gas entry ports in the inboard periphery of the outboard body structure between said slots and positioned to receive a portion of the propulsive gas stream ejected from the outlet nozzle, means within the outboard body structure to direct gas from the entry ports to the slots, obturator means associated with a plurality of entry ports situated in a portion of the inner periphery of the outboard body structure at the rear of the aircraft, and actuating means to operate the obturator means thus to selectively open and close the entry ports of said plurality; an automatic control system to operate the primary gas deflecting means to reduce the divergence of the aircraft when it encounters a disturbance resulting in a tilt rate; and secondary control means operatively connected to the secondary gas deflecting means for operating the latter.

33. An aircraft comprising a lentiform inboard body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at multiplicity of positions distributed around the periphery of the structure; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means and merging with one of said aerofoil surfaces in a smooth, outboardly convex curve thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of the propulsive gas between the peripheral nozzles; secondary gas deflecting means comprising upper and lower baffles in the outboard body structure and associated with the upper and lower peripheral nozzles respectively, each baffle being in the form of a frustum of a hollow cone and being arranged for movement into and out of the propulsive gas flowing through one of the peripheral nozzles to vary the directions in which the gas leaves said one nozzle; an automatic control system to operate the primary gas deflecting means to reduce the divergence of the aircraft when it encounters a disturbance resulting in a tilt rate; and secondary control means operatively connected to the secondary gas deflecting means to operate the latter.

34. An aircraft comprising a lentiform inboard body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; impelling means on the inboard body structure to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing an upper peripheral nozzle and a lower peripheral nozzle having a forward portion and a rear portion, the upper and lower peripheral nozzles being in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means and merging with one of said aerofoil surfaces in a smooth, outboardly convex curve thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle thereby apportioning the flow of propulsive gas between the peripheral nozzles; fixed guide means on the outboard body structure and associated with the upper peripheral nozzle to direct gas issuing therefrom generally upwardly and inboardly; further fixed guide means on the outboard body structure and associated with the forward portion of the lower peripheral nozzle to direct gas issuing from said forward portion generally downwardly and inboardly; secondary gas deflecting means associated with the rear portion of the lower peripheral nozzle and operable to vary the directions in which the propulsive gas leaves said rear portion; the secondary gas deflecting means including a series of flaps arranged in end-to-end relation and pivotally secured to the outboard body structure, and means to move said flaps between first positions, in which the flaps direct gas issuing from said rear portion generally downwardly and inboardly, and second positions in which gas issuing from said rear portion is permitted to flow generally downwardly and outboardly; an automatic control system to operate the primary gas deflecting means to reduce the divergence of the aircraft when it encounters a disturbance resulting in a tilt rate; and secondary control means operatively connected to the secondary gas deflecting means for operating the latter.

35. An aircraft comprising a lentiform inboard body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; a downwardly directed stabilizing nozzle in the lower aerofoil surface of the aircraft and in communication with the gas displacement passage; impelling means on the inboard body structure to cause propulsive gas to flow generally out-

boardly in the displacement passage and through the outlet and stabilizing nozzles; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means and merging with one of said aerofoil surfaces in a smooth, outboardly convex curve thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means being operable to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls thereby apportioning the flow of the propulsive gas through the peripheral nozzles; secondary gas deflecting means associated with the peripheral nozzles and operable to vary the directions in which the propulsive gas leaves the peripheral nozzles; an automatic control system to operate the primary gas deflecting means to reduce the divergence of the aircraft when it encounters a disturbance resulting in a tilt rate; and secondary control means operatively connected to the secondary gas deflecting means for controlling the latter.

36. An aircraft comprising a lentiform inboard body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; a rotor shaft within the structure substantially parallel to the yaw axis of the aircraft but having a limited degree of universal movement; a rotor on the shaft; engine means on the structure to rotate the rotor and thus to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively; each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means and merging with one of said aerofoil surfaces in a smooth, outboardly convex curve thus providing said outlet nozzle with a curved, outboardly divergent cross-section, said primary gas deflecting means including baffles arranged for movement into and out of the propulsive gas flowing in the passage to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning the flow of the propulsive gas between the peripheral nozzles; upper and lower secondary gas deflecting means associated with the upper and lower peripheral nozzles respectively, the secondary gas deflecting means including means for redirecting a portion of the propulsive gas stream ejected from the outlet nozzle into streams of gas directed against the remainder of the propulsive gas stream; primary control means for the primary gas deflecting means, said primary control means being responsive to the tilt of the rotor shaft relative to the aircraft to operate the primary gas deflecting means to reduce the divergence of the aircraft when it encounters a disturbance resulting in a tilt rate; and secondary control means operatively connected to the secondary gas deflecting means for operating the latter.

37. An aircraft according to claim 36, including a downwardly directed stabilizing nozzle in the lower aerofoil surface of the aircraft and in communication with the gas displacement passage.

38. An aircraft comprising a lentiform inboard body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces; upper and lower walls within the structure defining a gas displacement passage which includes and terminates in an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure; a rotor shaft mounted within the structure to have a limited degree of universal movement and having a neutral position substantially parallel to the yaw axis of the aircraft; biasing means interposed between the structure and the shaft to bias the latter to its neutral position; a rotor on the shaft; engine means on the inboard body structure to rotate the rotor and thus to cause propulsive gas to flow generally outboardly in the displacement passage and through the nozzle; an outboard body structure secured to the inboard body structure in juxtaposed spaced relation to the outlet nozzle and providing therewith upper and lower peripheral nozzles in communication with the outlet nozzle; opposed upper and lower primary gas deflecting means adjacent to the outlet nozzle and associated with the upper and lower walls respectively, each of said walls curving away from the other of said walls outboardly of the primary gas deflecting means and merging with one of said aerofoil surfaces in a smooth, outboardly convex curve thus providing said outlet nozzle with a curved, outboardly divergent cross-section, the deflecting means including baffles arranged for movement into and out of the propulsive gas flowing in the passage to vary the directions in which the propulsive gas leaves the outlet nozzle by selectively disturbing the flow of the propulsive gas along the walls and thereby apportioning flow of the propulsive gas between the peripheral nozzles; secondary gas deflecting means associated with the peripheral nozzles, the secondary gas deflecting means including upper and lower baffles in the outboard body structure and associated with the upper and lower peripheral nozzles respectively, said baffles of the secondary gas deflecting means being arranged for movement into and out of the propulsive gas flowing through the peripheral nozzles to vary the directions in which the gas leaves the nozzles; primary control means for the baffles of the primary gas deflecting means, said primary control means operating in response to the tilt of the rotor shaft from its neutral position to operate the primary gas deflecting means to reduce the divergence of the aircraft when it encounters a disturbance resulting in a tilt rate; and secondary control means operately connected to the baffles of the secondary gas deflecting means for operating said baffles.

39. An aircraft comprising a body structure having a lift surface on the underside thereof; an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the outboard periphery of said lift surface; impelling means on the body structure to discharge propulsive gas from the nozzle; guide means associated with the nozzle to direct inboardly the flow of propulsive gas discharged at at least some of said positions to traverse said lift surface and to deflect said flow, as it traverses the lift surface, to flow away from the lift surface with components of velocity generally normal thereto; the reaction against the lift surface caused by the deflection of the gas providing a lift force for the aircraft.

40. An aircraft comprising a body structure having a lift surface on the underside thereof; an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the outboard periphery of said lift surface; impelling means on the structure to discharge propulsive gas from the nozzle; guide means associated with the nozzle to direct inboardly the flow of propulsive gas discharged at at least some of said positions to traverse said lift surface; and further guide means to deflect said flow, as it traverses the lift surface, to flow away from

the lift surface with components of velocity generally normal thereto; the reaction against the lift surface caused by the deflection of the gas providing a lift force for the aircraft.

41. An aircraft comprising a body structure having a lift surface on the underside thereof; an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the outboard periphery of said lift surface; impelling means on the body structure to discharge propulsive gas from the nozzle; guide means associated with the nozzle to direct inboardly the flow of propulsive gas discharged at some of said positions to traverse said lift surface; and further guide means associated with the nozzle to direct the flow of propulsive gas discharged at other of said positions to traverse said lift surface to oppose the first mentioned flow, whereby both said flows are deflected to flow away from said lift surface with components of velocity generally normal thereto; the reaction against the lift surface caused by the deflection of said flows providing a lift force for the aircraft.

42. An aircraft comprising a body structure having a lift surface on the underside thereof; an outlet nozzle arranged to discharge at a multiplicity of positions distributed around an annulus at the outboard periphery of said lift surface; impelling means on the body structure to discharge propulsive gas from the nozzle; and guide means associated with the nozzle to direct gas discharged from the nozzle to traverse the lift surface in directions generally towards the center of said annulus so that the flow of gas discharged at some of said positions opposes the flow of gas discharged from other of said positions, whereby the gas is deflected away from the lift surface with components of velocity normal thereto at positions adjacent to said center; the reaction against the lift surface caused by the deflection of the gas providing a lift force for said aircraft.

43. An aircraft comprising a body structure having a substantially circular lift surface on the underside thereof; an annular outlet nozzle at the outboard periphery of said lift surface; impelling means on the body structure to discharge propulsive gas from the nozzle; and annular guide means associated with the nozzle to direct substantially all the gas discharged from the nozzle towards the center of said lift surface so that the gas traverses the lift surface and adjacent to its center is deflected away from the lift surface with components of velocity normal thereto; the reaction against the lift surface caused by the deflection of the gas providing a lift force for said aircraft.

44. An aircraft comprising a lentiform inboard body structure sheathed by opposed upper and lower aerofoil surfaces; an outboard body structure encompassing and secured to the inboard body structure in juxtaposed spaced relation thereto and defining therewith an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the outboard periphery of the inboard body structure; impelling means on the inboard body structure to discharge propulsive gas from the nozzle; guide means on the outboard body structure associated with the nozzle to direct the flow of propulsive gas discharged at at least some of said positions to traverse the lower aerofoil surface; and further guide means to deflect said flow, as it traverses the lower aerofoil surface, to flow away from said surface with components of velocity generally normal thereto; the reaction against said lower aerofoil surface caused by deflection of the gas providing a lift force for the aircraft.

45. An aircraft according to claim 44, wherein said further guide means is on the outboard body structure and associated with the nozzle to direct the flow of gas discharged at other positions of the nozzle to traverse the lower aerofoil surface in directions to oppose the first mentioned flow, thus to cause said deflection.

References Cited in the file of this patent

UNITED STATES PATENTS

2,461,435	Neumann et al.	Feb. 8, 1949
2,567,392	Naught	Sept. 11, 1951
2,807,428	Wibault	Sept. 24, 1957
2,838,257	Wibault	June 10, 1958
2,967,029	Hill	Jan. 3, 1961

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,051,415 August 28, 1962

John Carver Meadows Frost et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the grant, lines 3 and 13, and in the heading to the printed specification, line 5, name of assignee, for "Avco Aircraft Limited", each occurrence, read -- Avro Aircraft Limited --.

Signed and sealed this 18th day of December 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

Aug. 28, 1962 J. C. M. FROST ET AL 3,051,417

AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 1

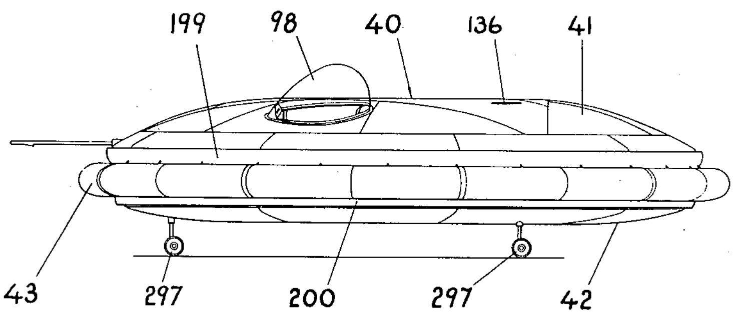

FIG. 1.

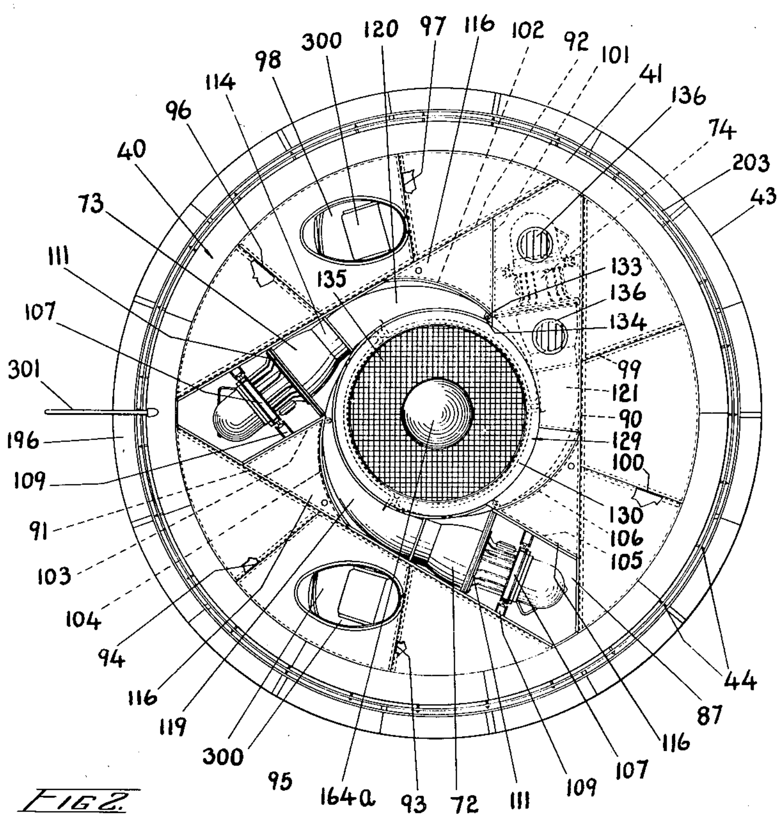

FIG. 2.

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Aug. 28, 1962 J. C. M. FROST ET AL 3,051,417

AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 2

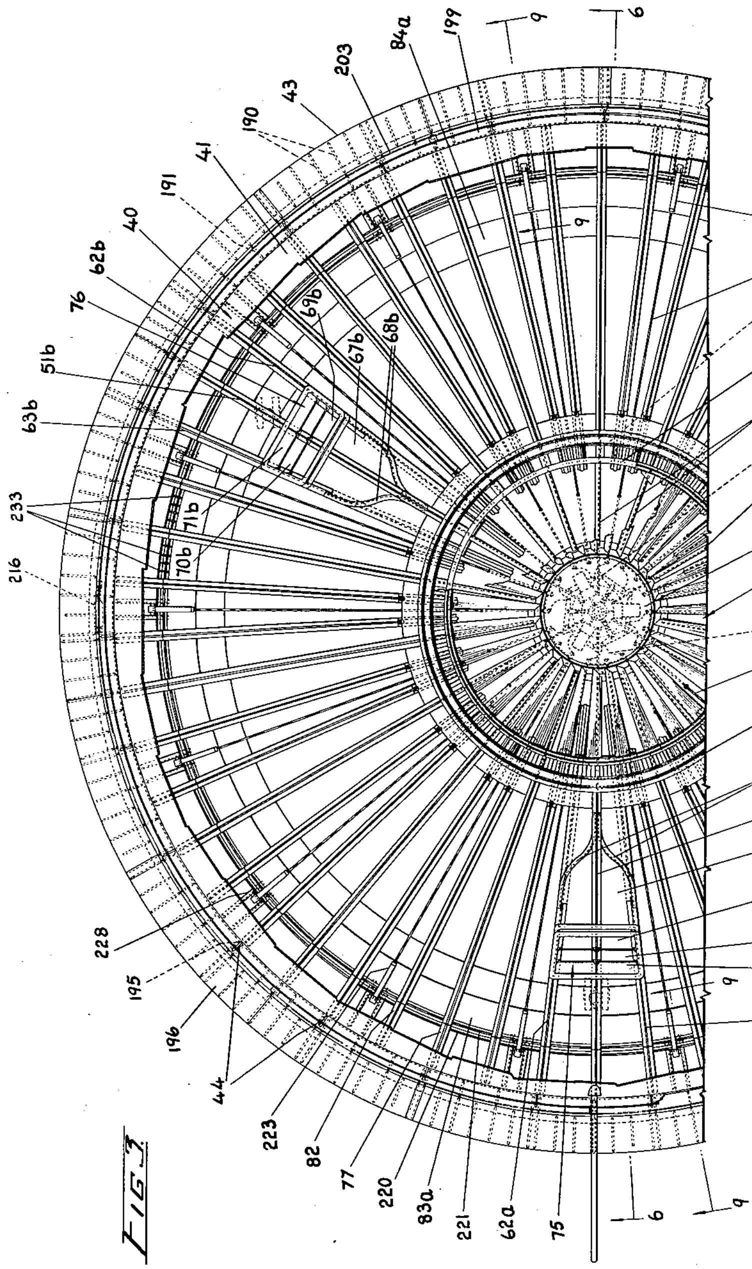

FIG. 3

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AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 3

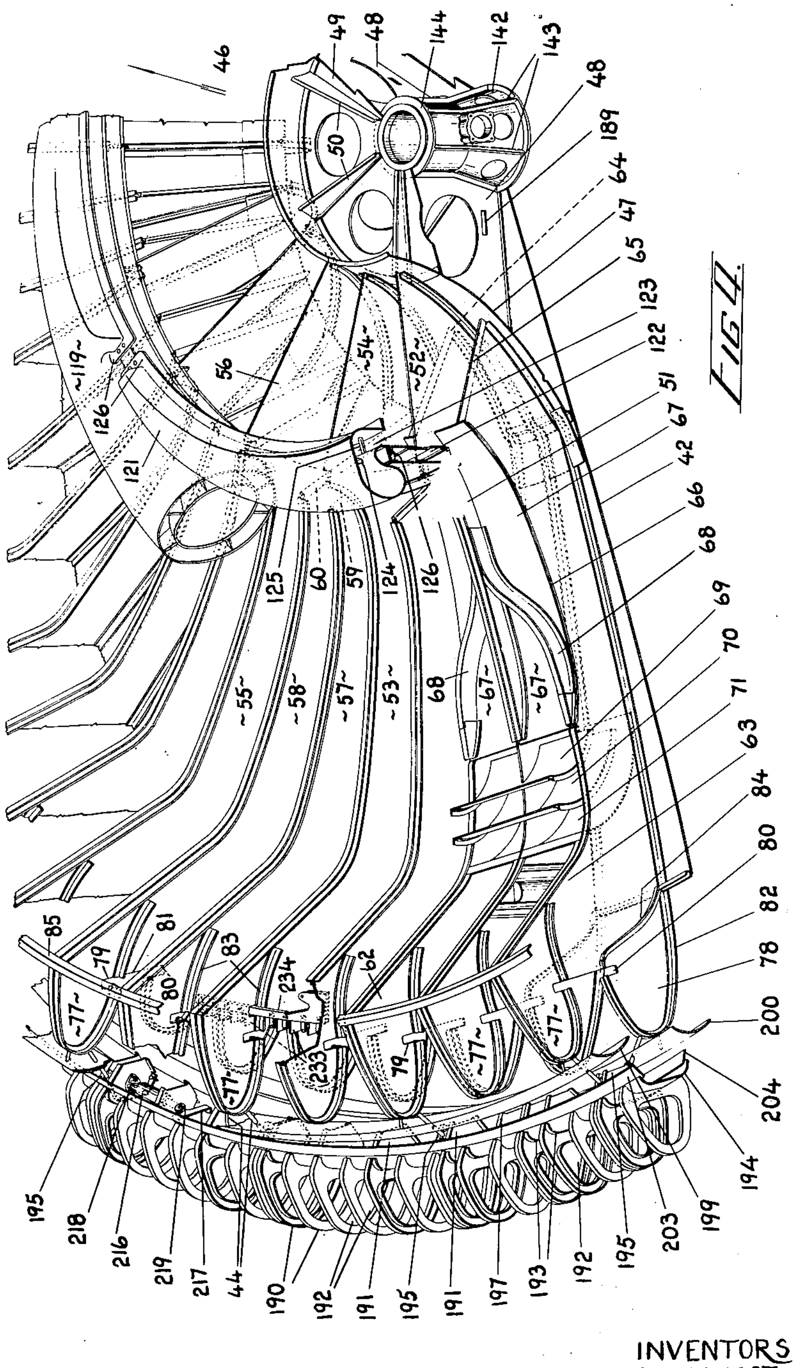

FIG. 4.

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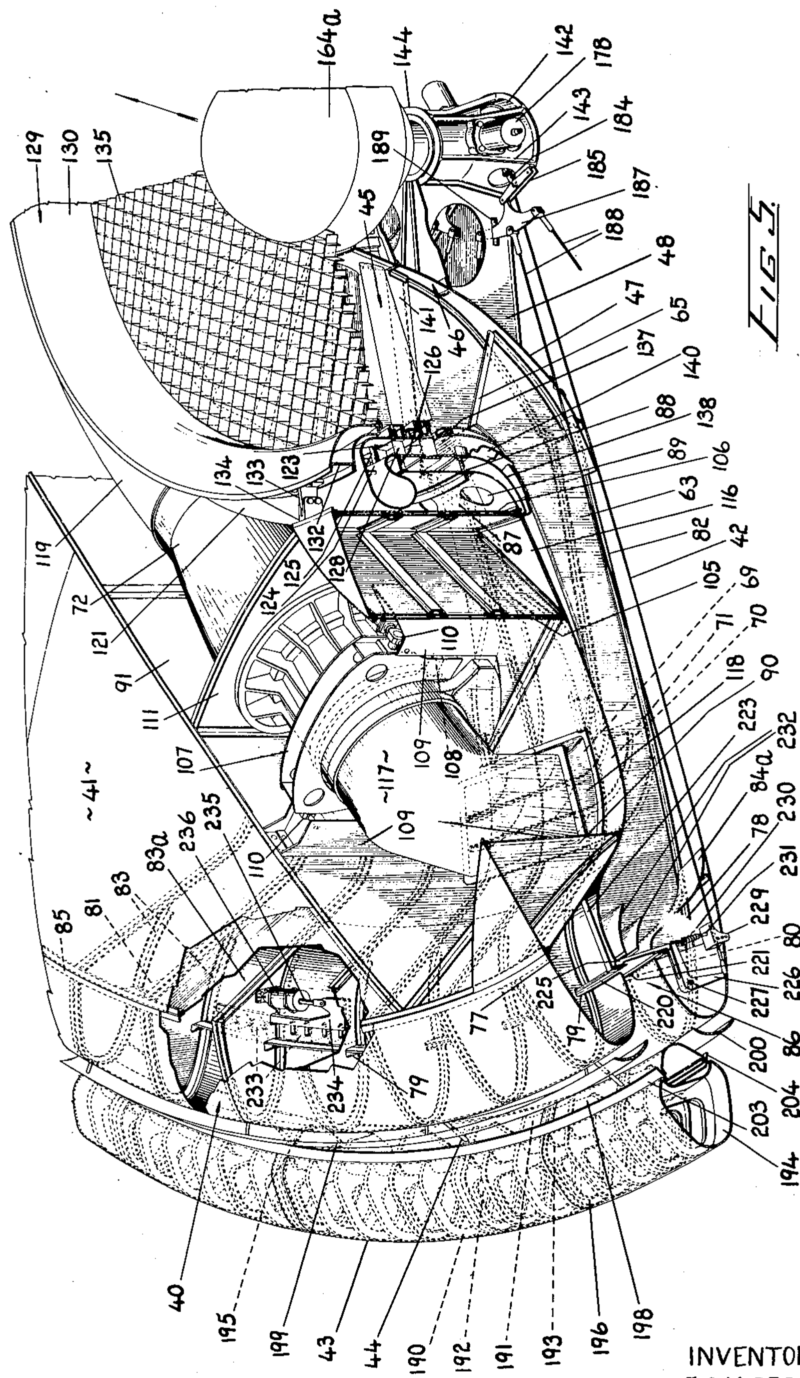

FIG. 5

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Aug. 28, 1962 J. C. M. FROST ET AL 3,051,417

AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 5

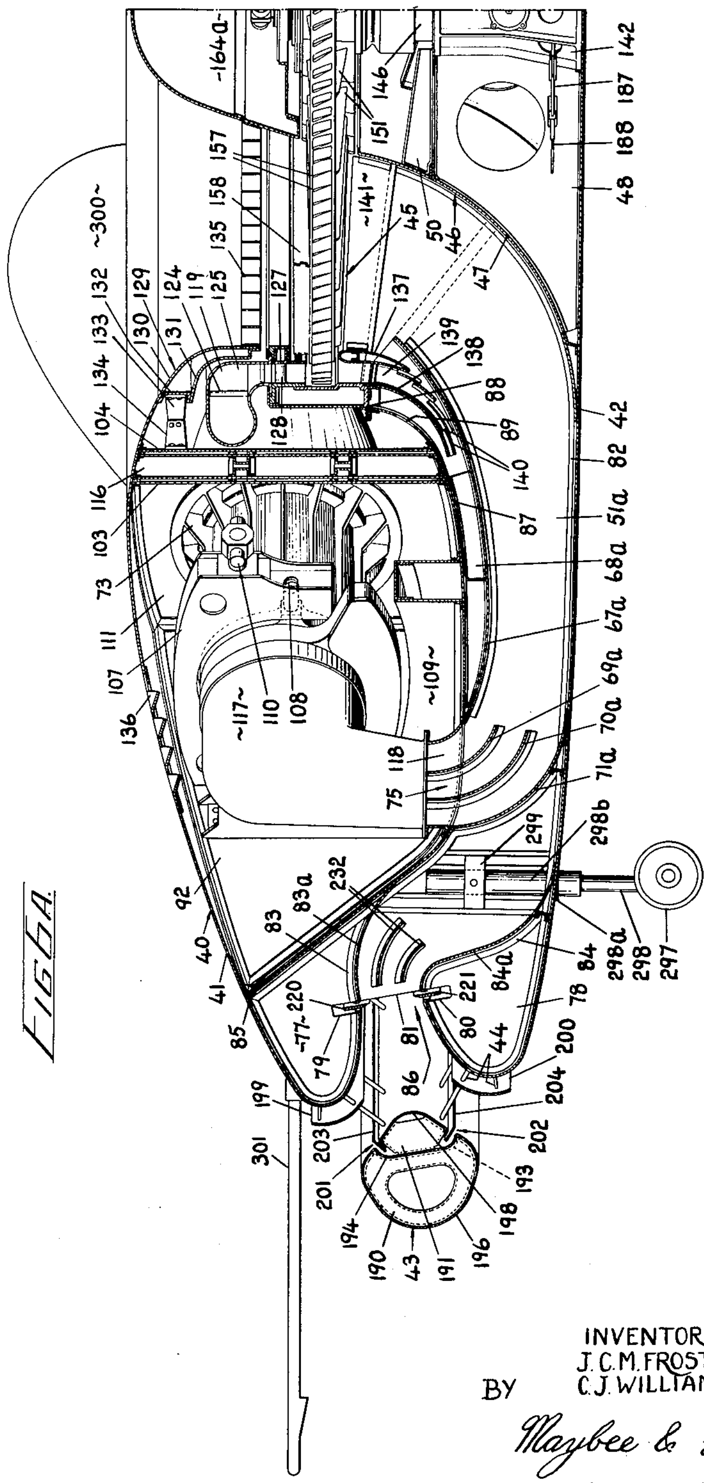

FIG. 6A.

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Aug. 28, 1962 J. C. M. FROST ET AL 3,051,417
AIRCRAFT CONTROL SYSTEMS
Filed Aug. 6, 1959 31 Sheets-Sheet 6

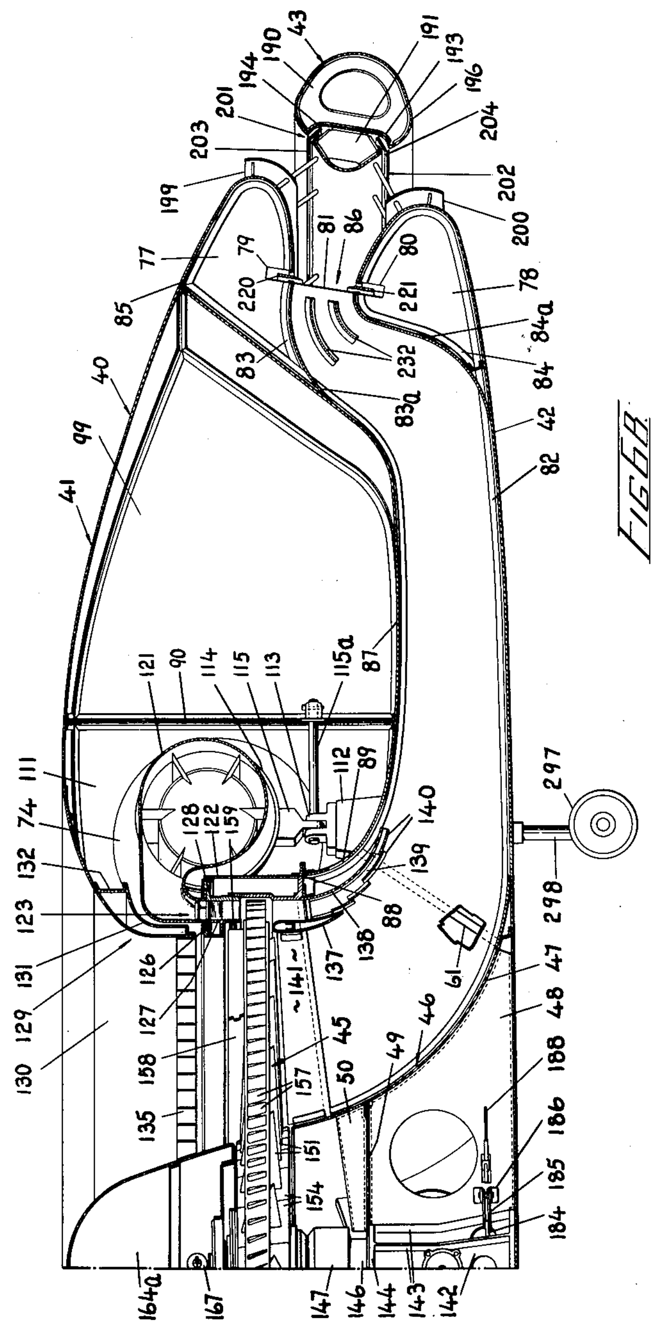

FIG 6B

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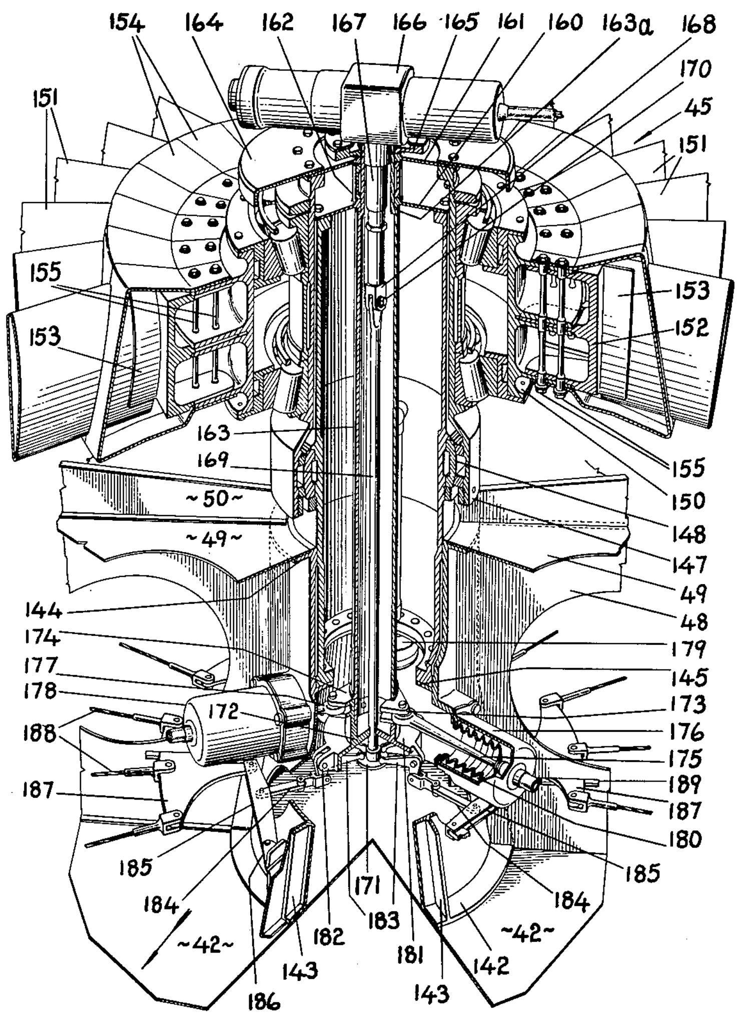

FIG 7.

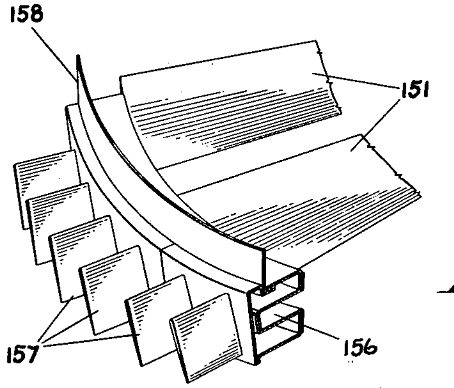

FIG 8.

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AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 8

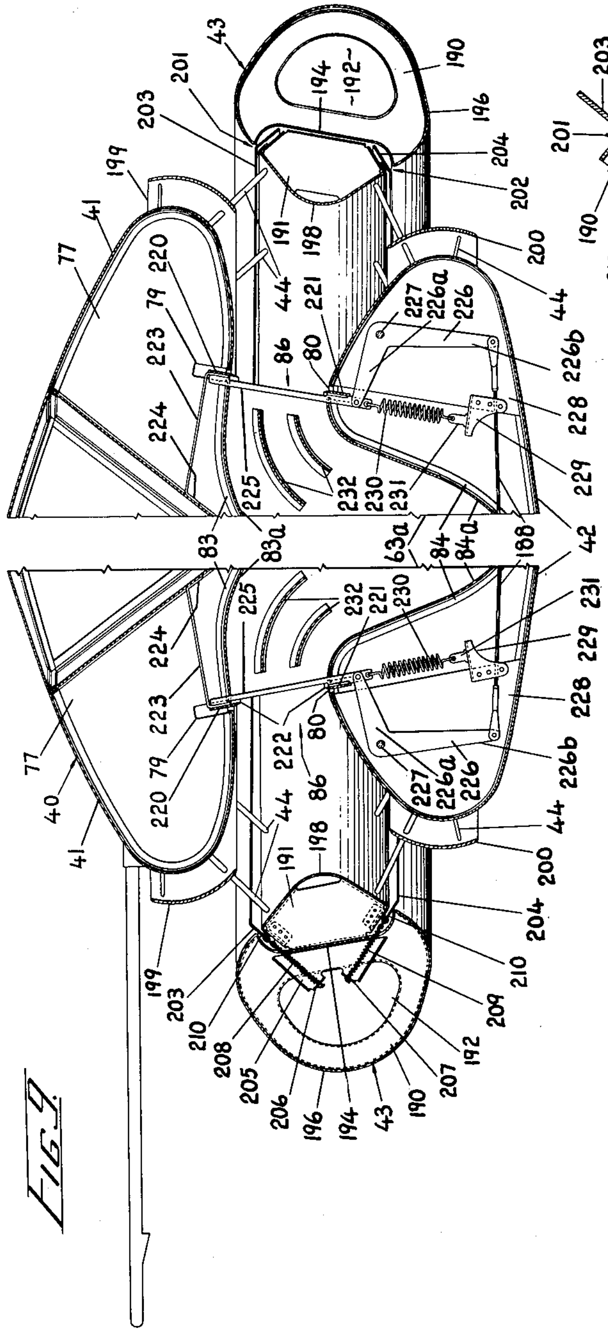

FIG. 9.

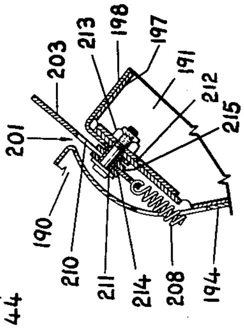

FIG. 10.

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AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 9

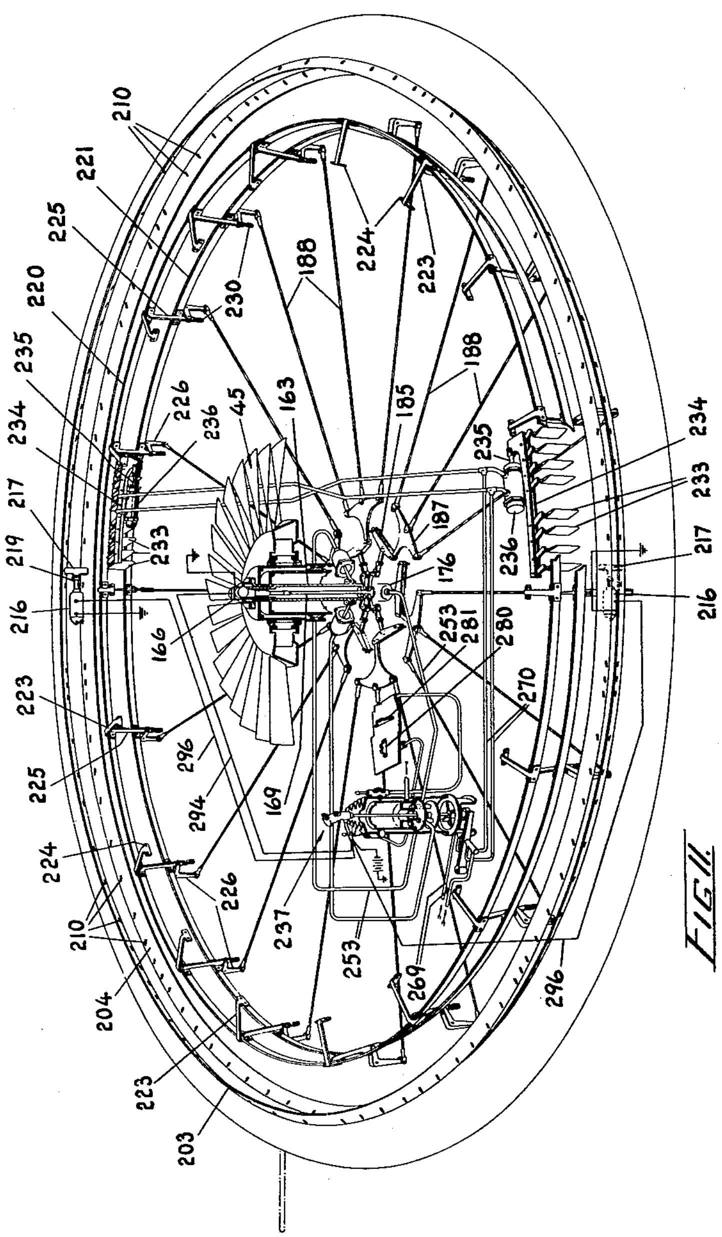

FIG. 11

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Aug. 28, 1962 J. C. M. FROST ET AL 3,051,417

AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 10

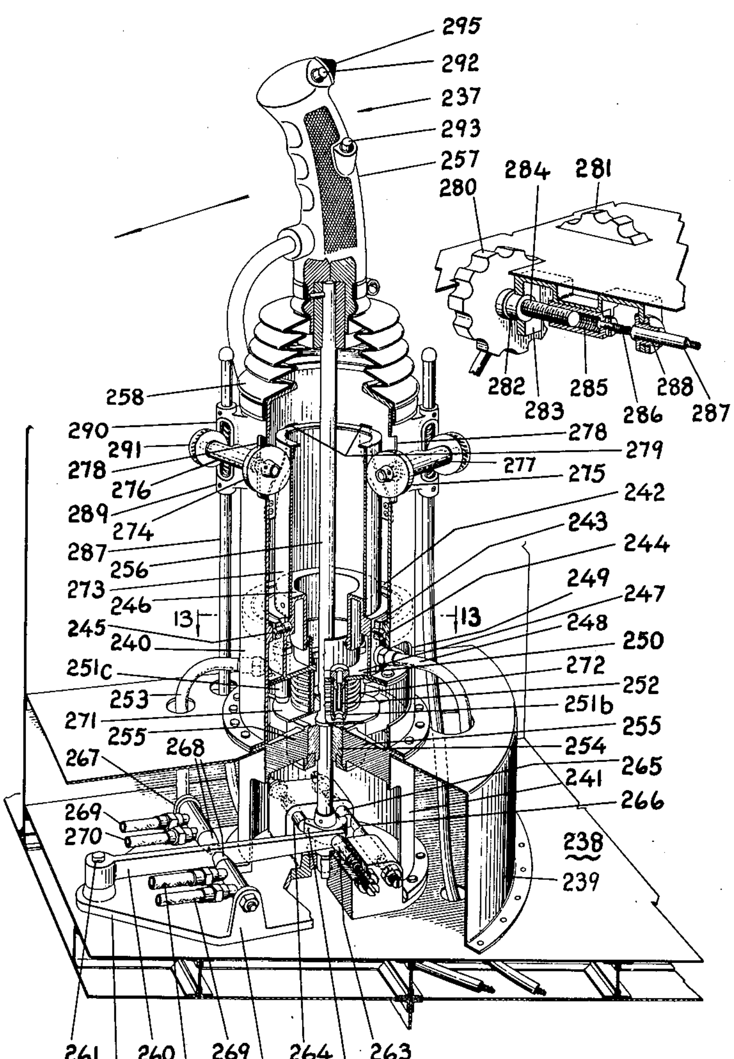

FIG. 12.

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Aug. 28, 1962 J. C. M. FROST ET AL 3,051,417

AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 11

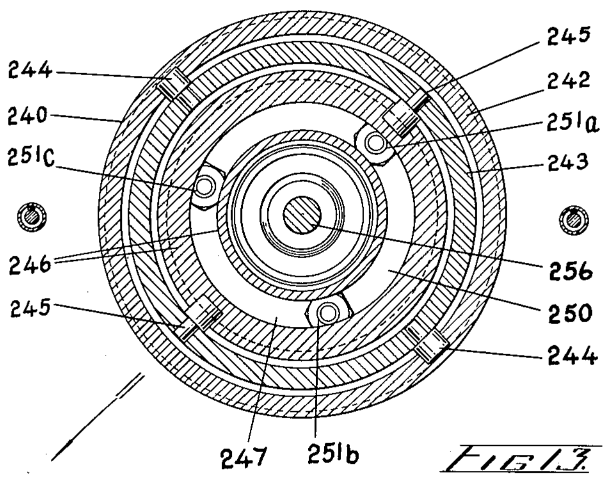

FIG. 13.

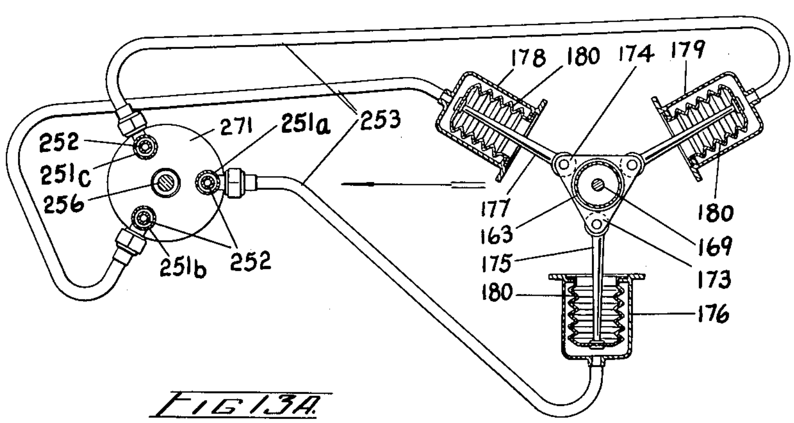

FIG. 13A.

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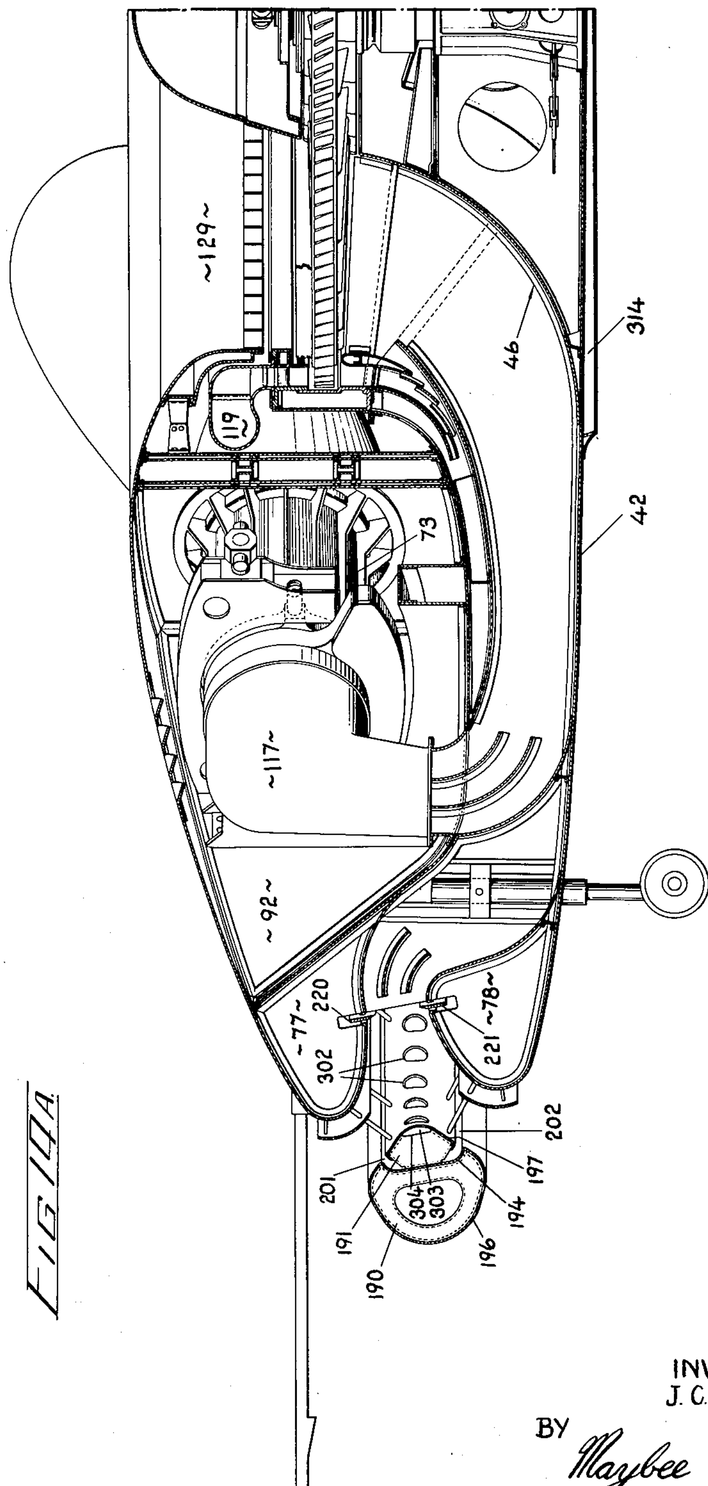

FIG 14A

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Aug. 28, 1962 J. C. M. FROST ET AL 3,051,417

AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 13

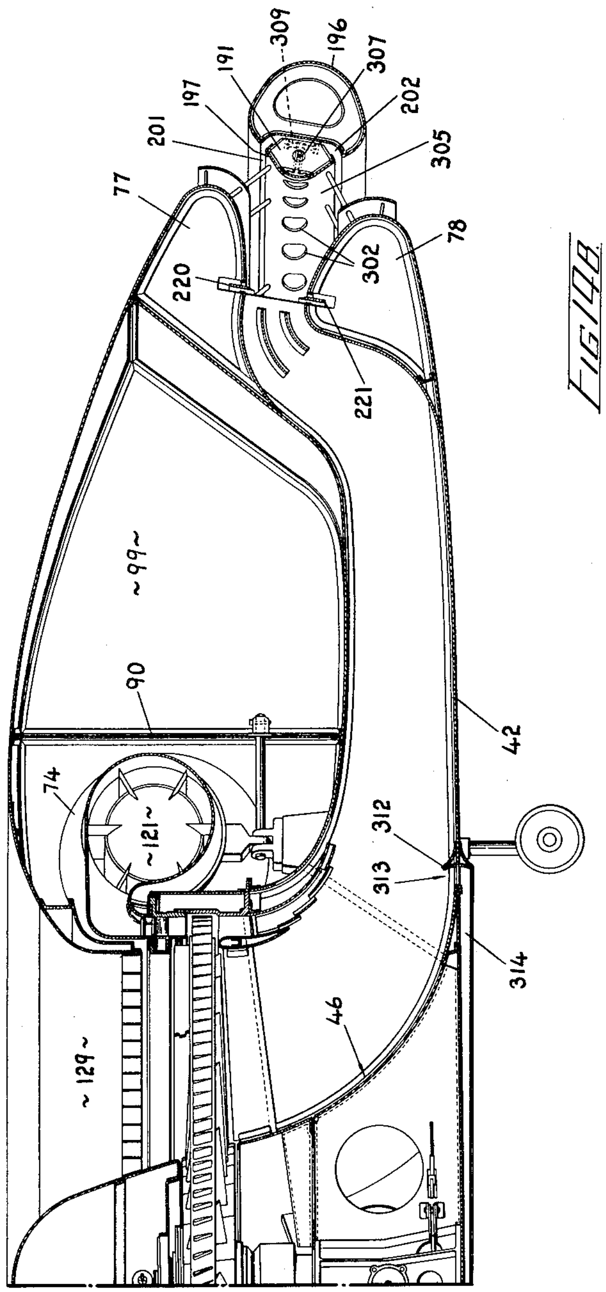

FIG 148

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AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 14

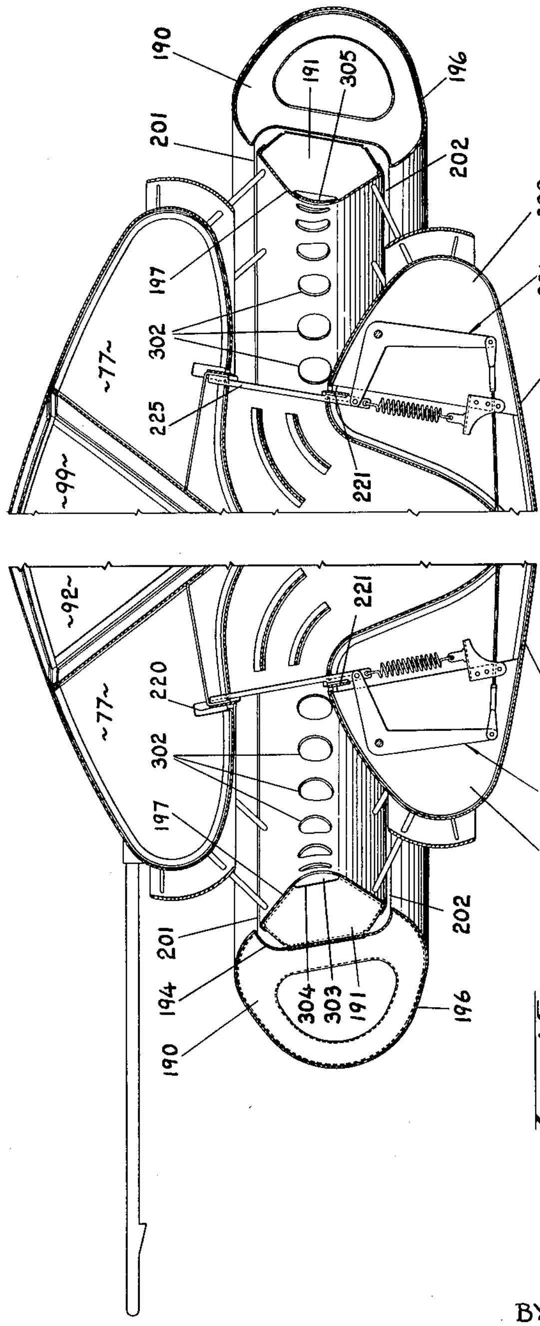

FIG.15.

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AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 15

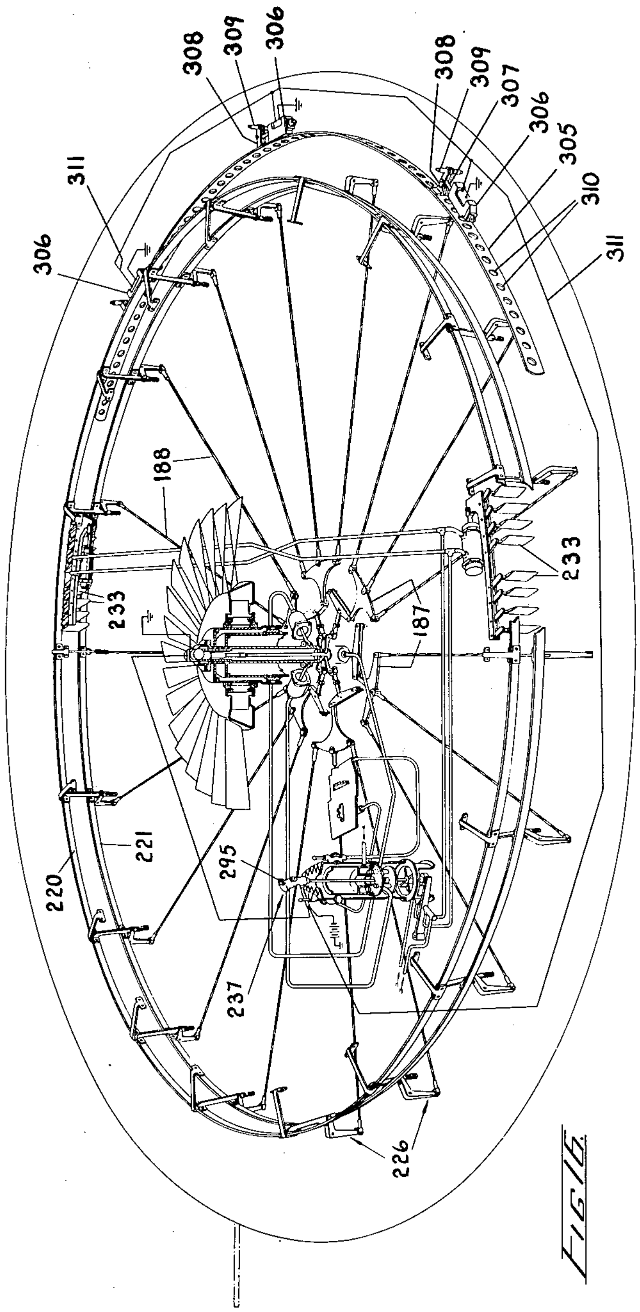

FIG.16.

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AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 16

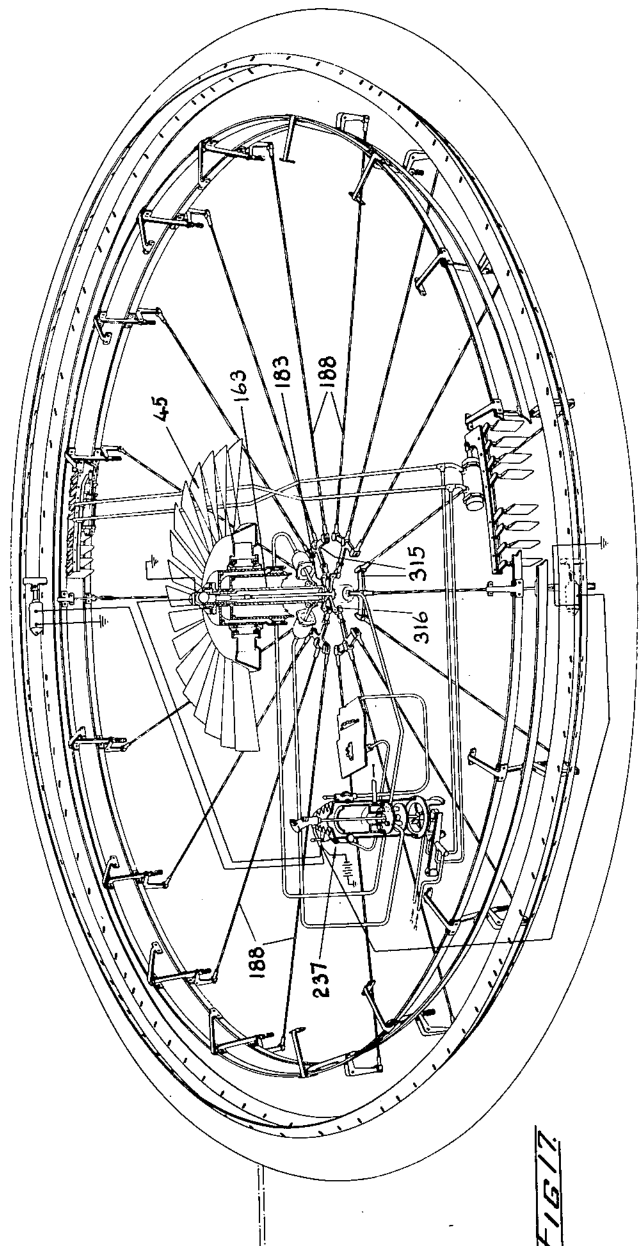

FIG.17

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AIRCRAFT CONTROL SYSTEMS

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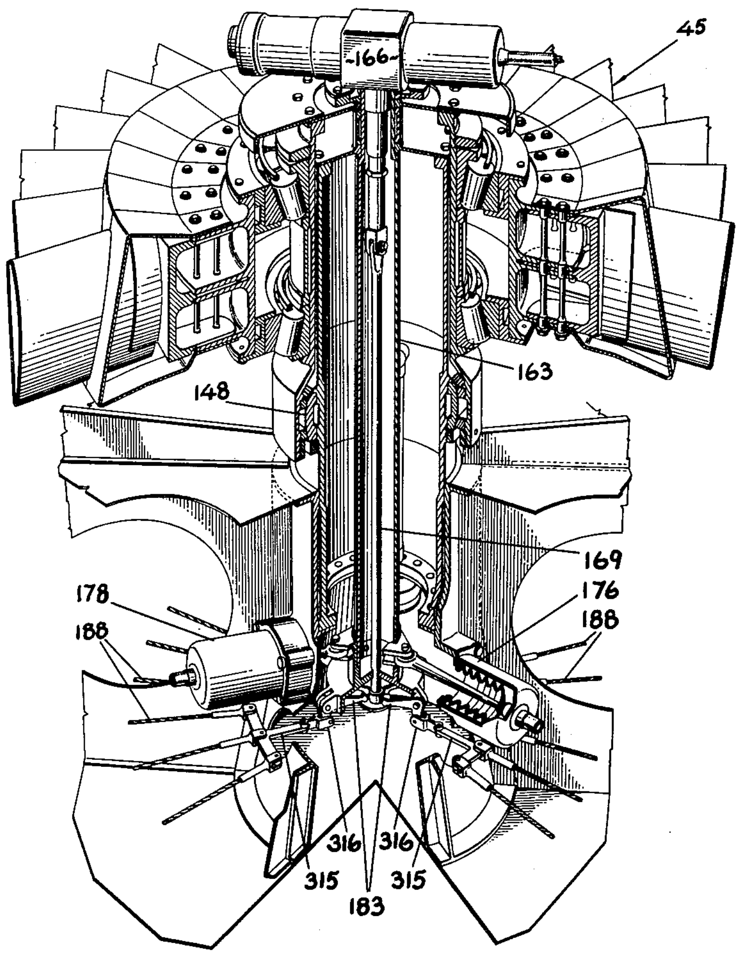

FIG. 17A.

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AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 18

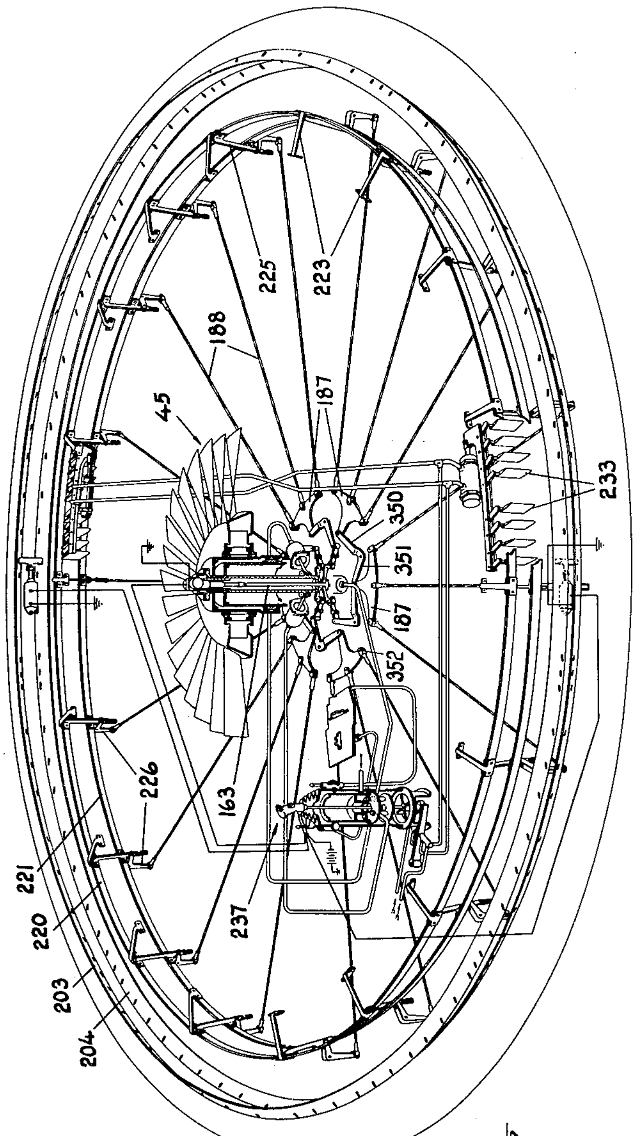

FIG. 18

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AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 19

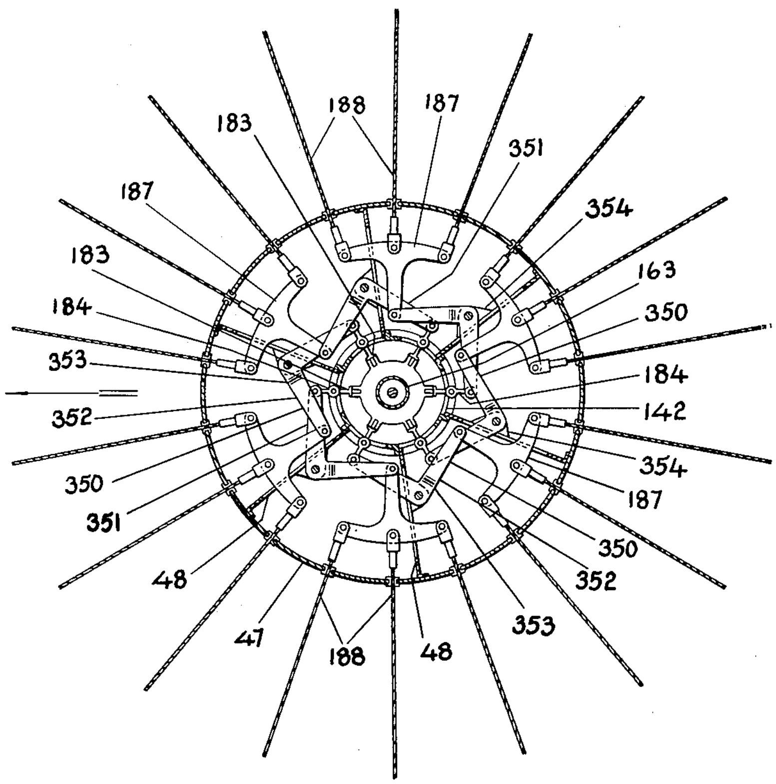

FIG 18A.

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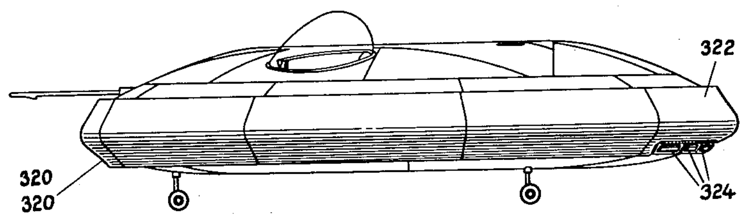

FIG 19.

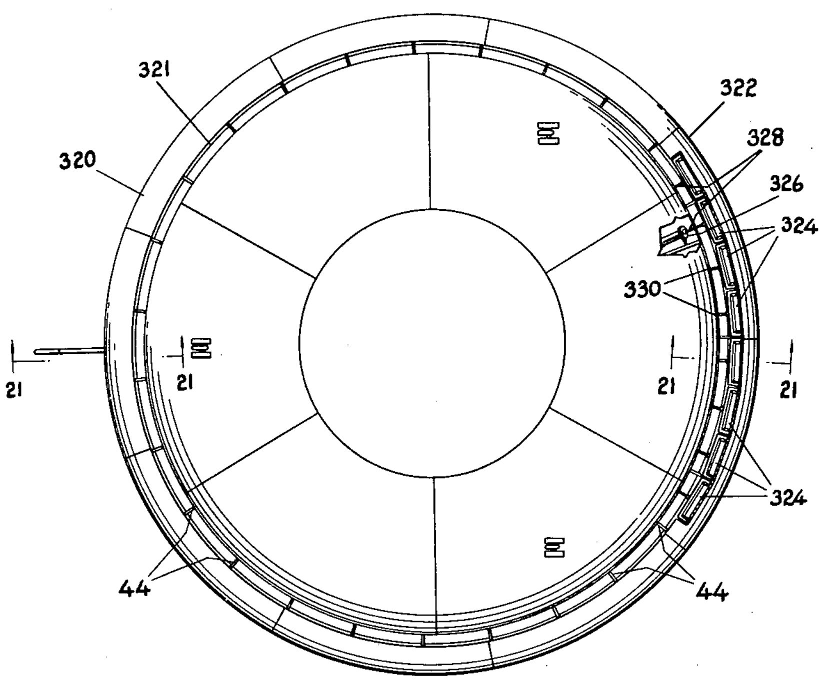

FIG 20.

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Aug. 28, 1962 J. C. M. FROST ET AL 3,051,417

AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 21

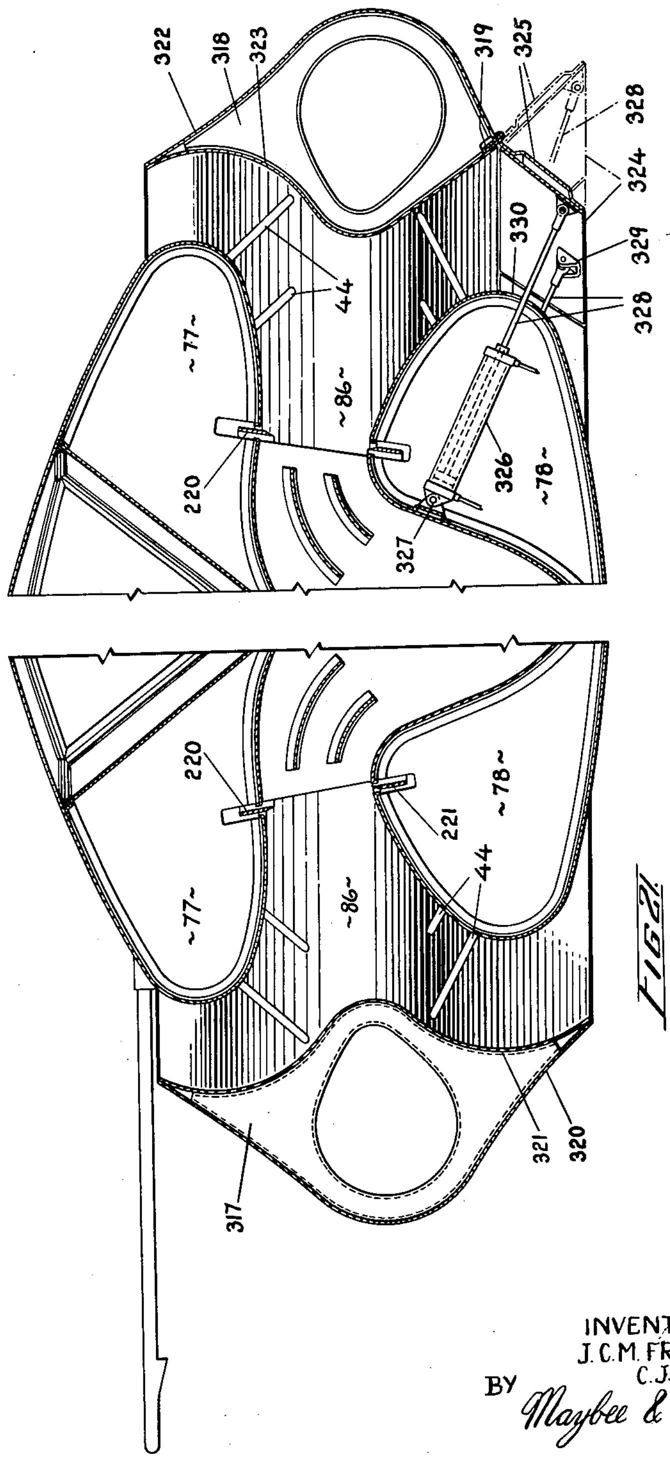

FIG. 21.

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AIRCRAFT CONTROL SYSTEMS

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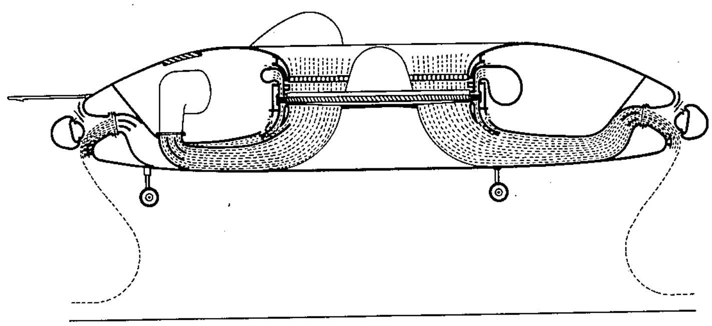


FIG 22.

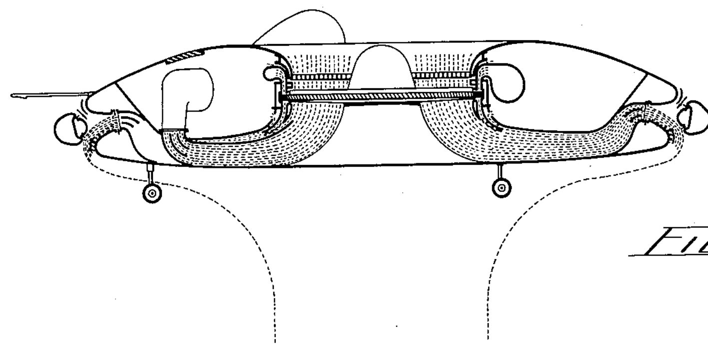
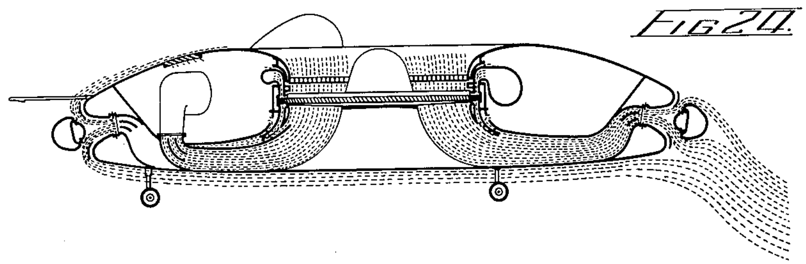


FIG 23.

FIG 24.



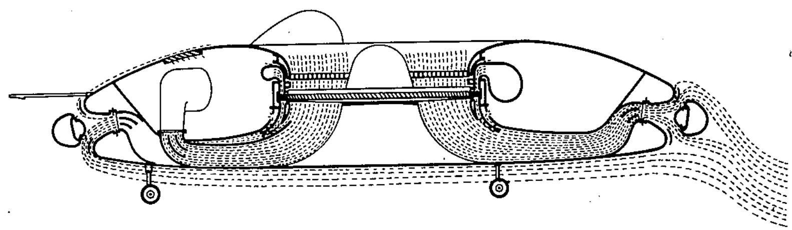


FIG 25.

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AIRCRAFT CONTROL SYSTEMS

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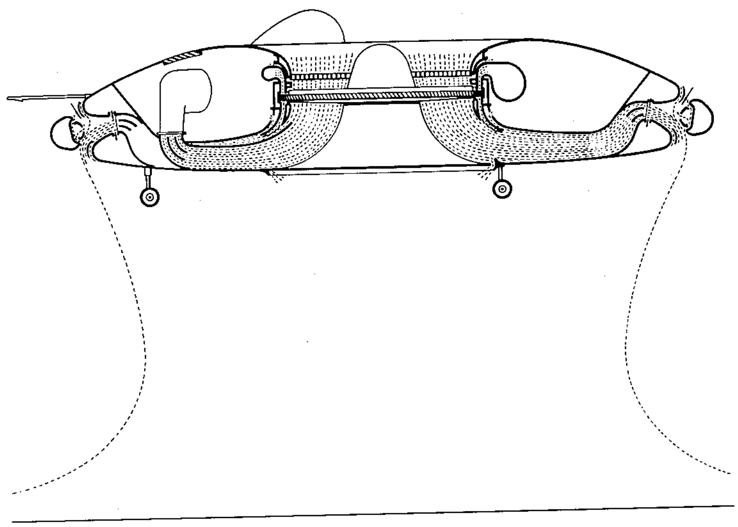

FIG. 26.

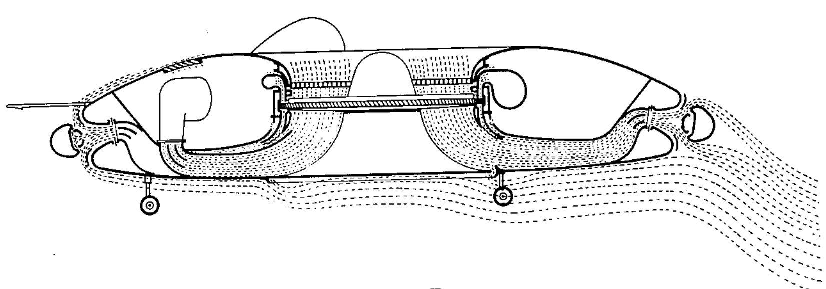

FIG. 27.

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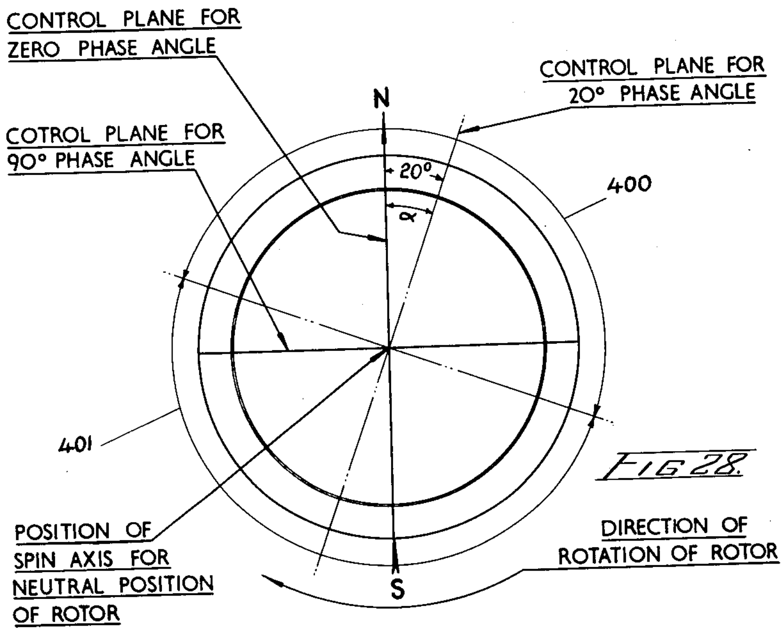

FIG. 28.

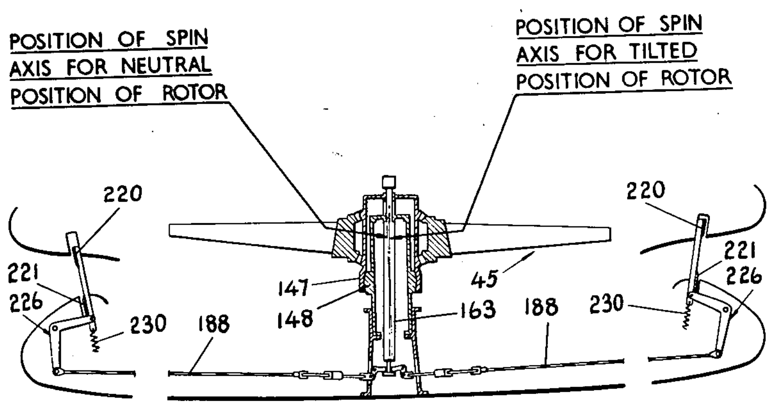

FIG. 29.

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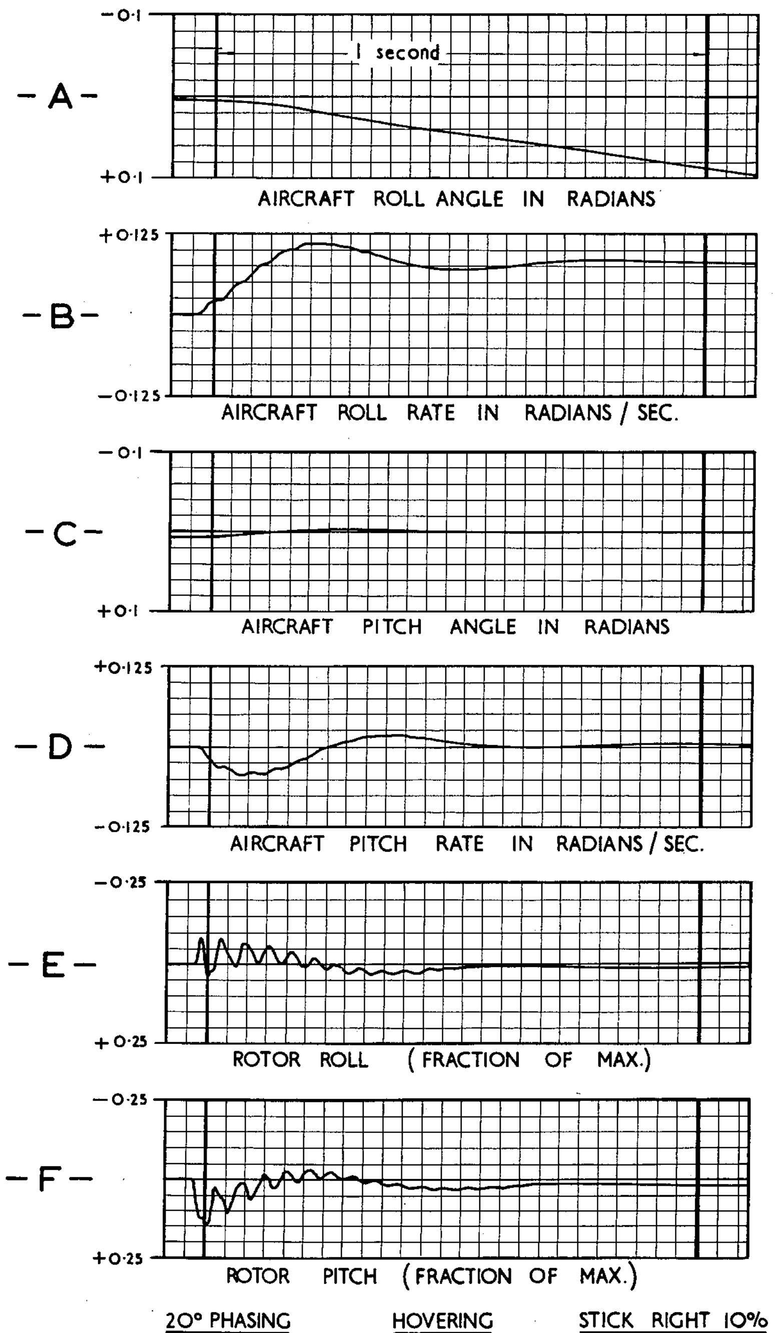

FIG. 30.

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AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 26

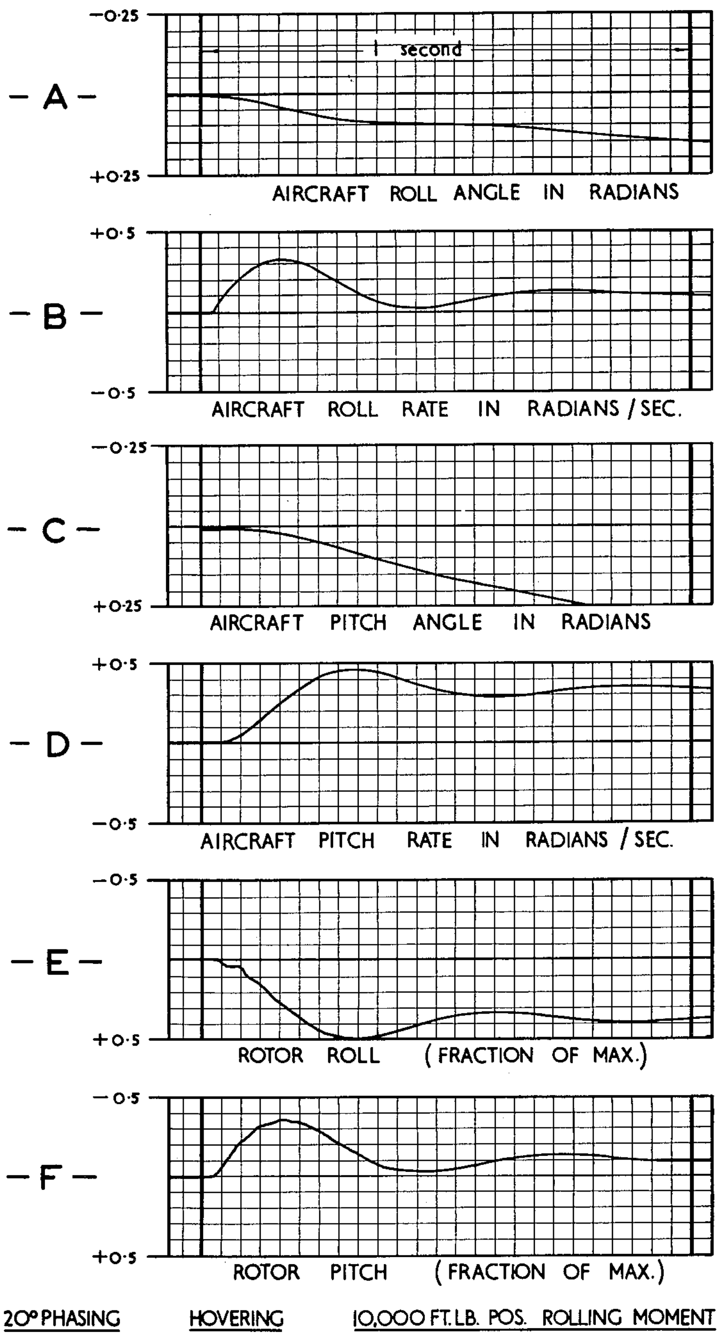

FIG. 31.

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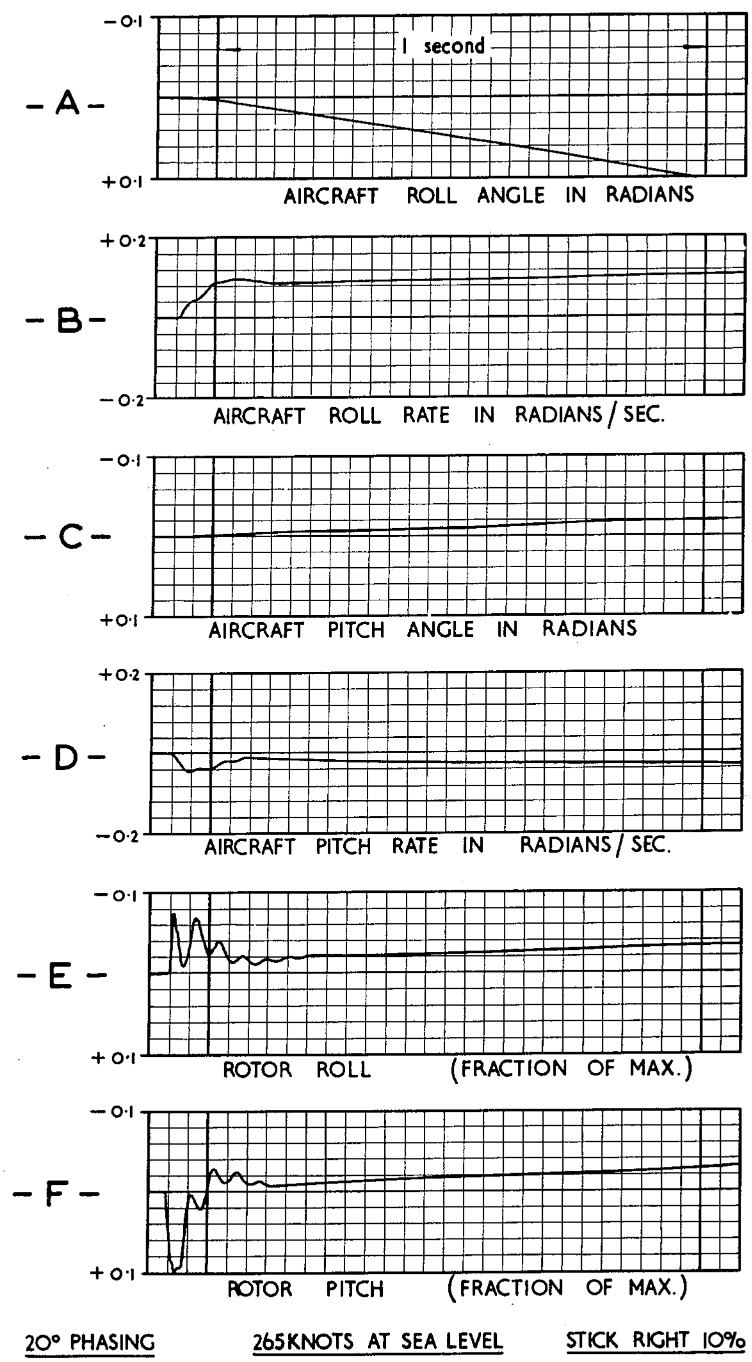

FIG. 32.

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AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 28

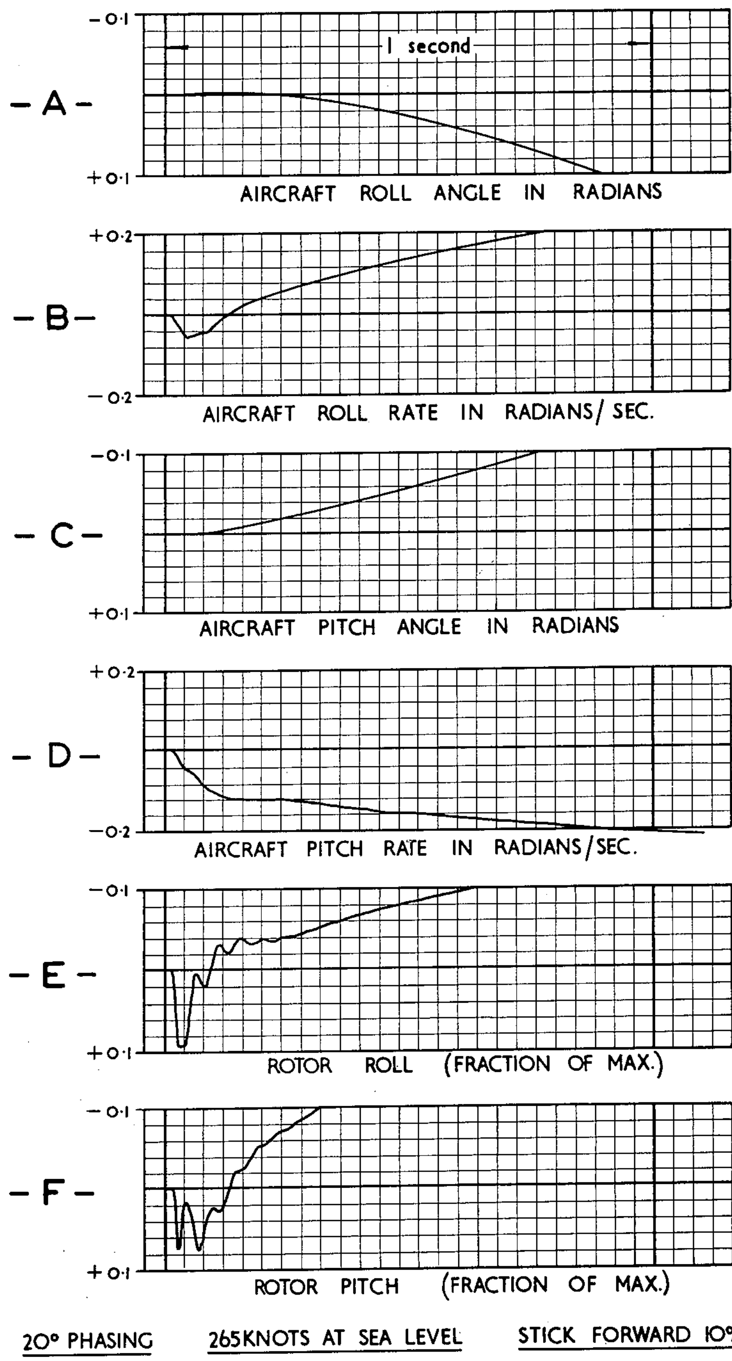

FIG. 33.

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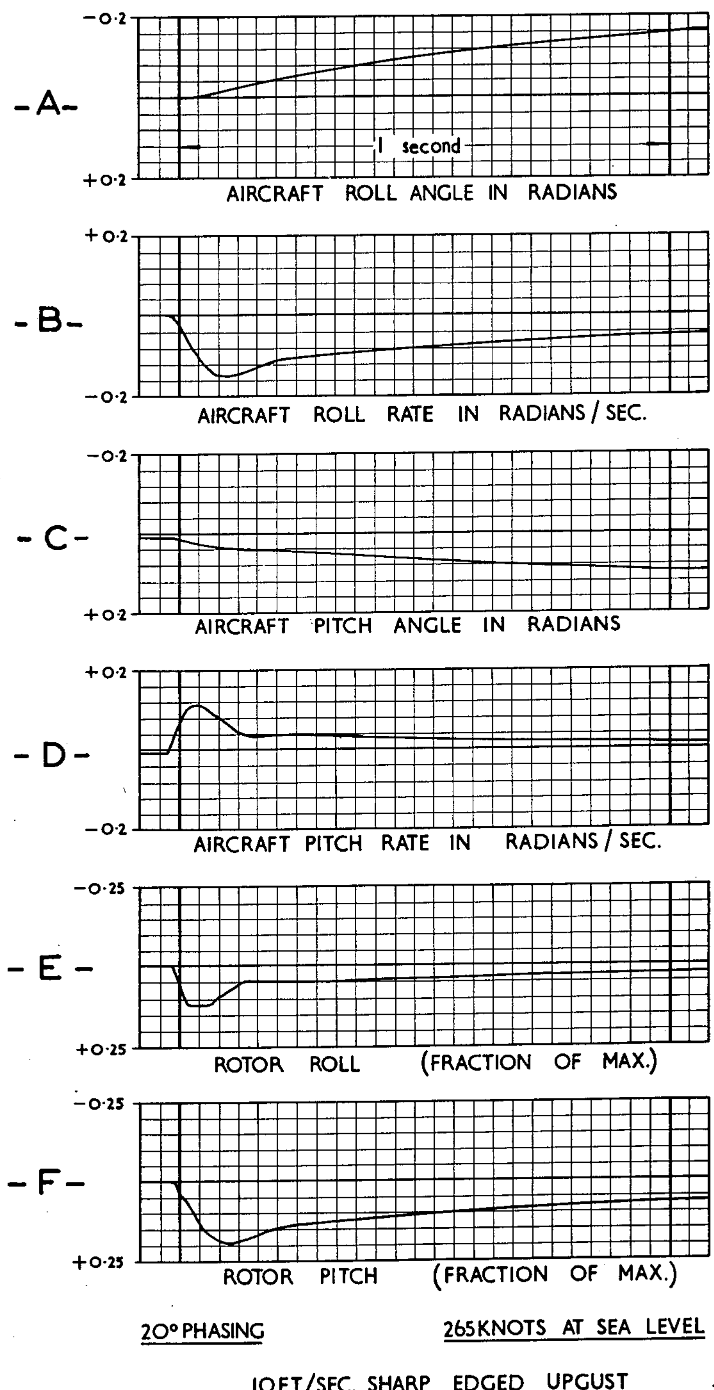

FIG. 34.

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Aug. 28, 1962 J. C. M. FROST ET AL 3,051,417

AIRCRAFT CONTROL SYSTEMS

Filed Aug. 6, 1959 31 Sheets-Sheet 30

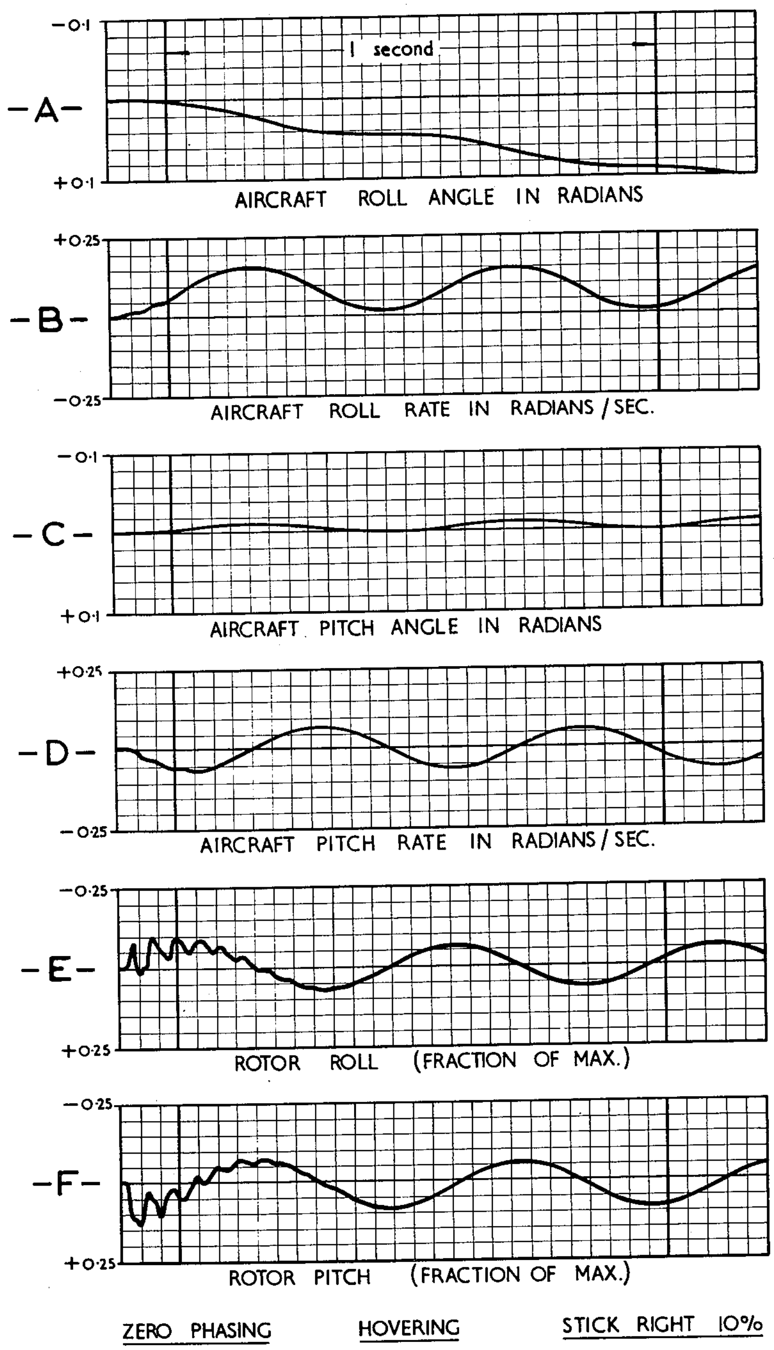

FIG. 35.

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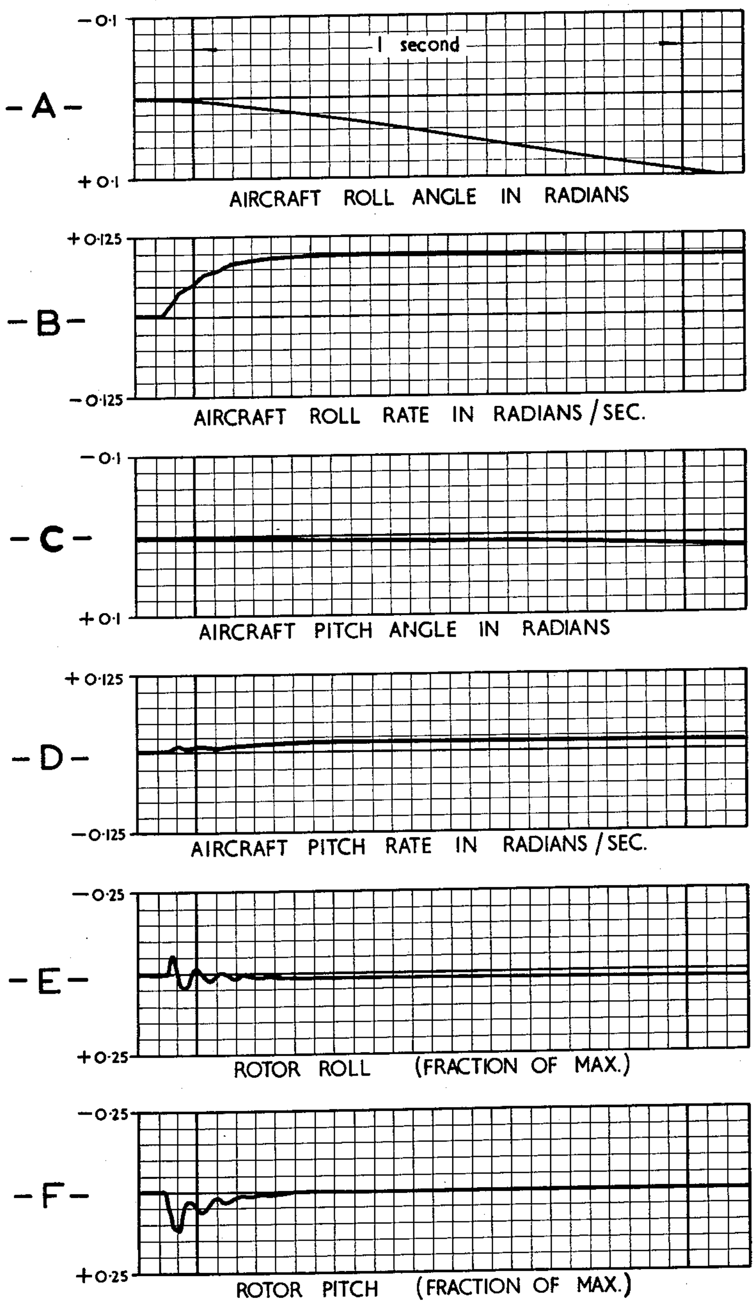

90° PHASING HOVERING STICK RIGHT 10%

FIG. 36.

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United States Patent Office

3,051,417

Patented Aug. 28, 1962

3,051,417

AIRCRAFT CONTROL SYSTEMS

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Filed Aug. 6, 1959, Ser. No. 832,406
17 Claims. (Cl. 244—79)

This invention relates to aircraft control systems and more particularly to a control system for an aircraft having a body structure and an outlet nozzle arranged to discharge at a multiplicity of positions distributed around the periphery of the structure.

An example of such an aircraft is disclosed in co-pending application Serial No. 684,615 (which is a continuation of patent application Serial No. 502,156, dated April 18, 1955, now abandoned) dated September 17, 1957, and filed by John Dubbury, John Carver Meadows Frost and Thomas Desmond Earl. The application describes a circular aircraft having a body structure of generally lenticular form which is sheathed by opposed aerofoil surfaces which provide lift developing surfaces. That aircraft includes a gas displacement passage in the structure having an intake and having a substantially annular outlet adjacent to the periphery of the structure. Means are provided for impelling gas to flow through the passage from the intake to the outlet in a plurality of centrifugal directions relative to the yaw axis of the aircraft and to eject the gas at high velocity from the outlet generally radially of the yaw axis and at a multiplicity of positions distributed around the periphery. Gas directing means are provided associated with the outlet and adjustable to selectively alter the directions in which the gas leaves the outlet. In a preferred form of the aircraft disclosed in application Serial No. 684,615, the gas directing means comprises a perimetrical Coanda nozzle which encompasses the outlet to alter the direction of flow of the ejected gas.

It is an object of the present invention to provide, in an aircraft having an outlet nozzle arranged to discharge propulsive gas at a multiplicity of positions distributed around the body structure of the aircraft, a control system to reduce the divergence of the aircraft when it encounters a disturbance resulting in a tilt rate.

The invention will now be described by way of example with reference to the accompanying drawings, in which like reference characters indicate similar parts throughout the several views and in which:

FIGURE 1 is a side elevation of an aircraft according to the invention;

FIGURE 2 is a plan of the aircraft of FIGURE 1 with several panels of the upper aerofoil surface removed to show the locations of the engines.

FIGURE 3 is a partial plan, partly broken away and partly in section, of the aircraft of FIGURES 1 and 2;

FIGURE 4 is a perspective view of a portion of the aircraft in partly assembled state and showing the rib structure of the aircraft;

FIGURE 5 is a perspective view of a portion of the completed aircraft similar to that shown in FIGURE 4 and is partly broken away to show the internal structure of the aircraft;

FIGURES 6A and 6B together constitute FIGURE 6 which is a generally longitudinal section of the aircraft on the line 6—6 of FIGURE 3;

FIGURE 7 is a perspective view, partly in section, of the rotor shaft and bearing and also shows part of the aircraft control means;

FIGURE 8 is a detail showing the turbine blades on the outer periphery of the rotor;

FIGURE 9 is a section of the outboard portions of the aircraft taken on the lines 9—9 of FIGURE 3;

FIGURE 10 is a detail showing the means for supporting a baffle on the outboard body structure;

FIGURE 11 shows, in diagrammatic form, the control system of the aircraft;

FIGURE 12 is a perspective view, partly in section, of the pilot's control column which forms part of the control system of FIGURE 11;

FIGURE 13 is a transverse section of the control column of FIGURE 12 taken on the line 13—13 of FIGURE 12;

FIGURE 13A is a diagram showing the correlation between two parts of the control system of FIGURE 11;

FIGURES 14A and 14B together constitute FIGURE 14 which is a generally longitudinal section of an aircraft forming a second embodiment of the invention;

FIGURE 15 is a transverse section, similar to FIGURE 9, of the outboard portions of the aircraft of FIGURE 14;

FIGURE 16 shows in diagrammatic form the control system of the aircraft of FIGURES 14 and 15;

FIGURE 17 shows in diagrammatic form a modified control system for the aircraft of FIGURES 1 to 13;

FIGURE 17A is a perspective view, partly in section, of the rotor shaft and bearing shown in FIGURE 17;

FIGURE 18 is a view similar to FIGURE 17 of a further modified control system for the aircraft of FIGURES 1 to 13;

FIGURE 18A is a detail plan, on a larger scale, of linkage shown in FIGURE 18;

FIGURE 19 is a side elevation of an aircraft constituting a further embodiment of the invention;

FIGURE 20 is an underneath plan of the aircraft of FIGURE 19 partly broken away;

FIGURE 21 is a transverse section, on a larger scale, on the lines 21—21 of FIGURE 20;

FIGURE 22 shows, in diagrammatic form, the gas flow from the aircraft of FIGURES 1 to 13 during take-off;

FIGURE 23 shows, in diagrammatic form, the gas flow from the aircraft of FIGURES 1 to 13 when the aircraft is sufficiently high above the ground to be clear of the "ground cushion" effect;

FIGURE 24 shows, in diagrammatic form, the gas flow from the aircraft of FIGURES 1 to 13 when the aircraft is traveling in forward flight;

FIGURE 25 shows, in diagrammatic form, the gas flow from the aircraft of FIGURES 1 to 13 to produce a "nose-up" couple on the aircraft;

FIGURE 26 shows, in diagrammatic form, the gas flow from the aircraft of FIGURES 14 to 16 during take-off;

FIGURE 27 shows, in diagrammatic form, the gas flow from the aircraft of FIGURES 14 to 16 during forward flight;

FIGURE 28 is a diagram indicating the phase angle relationship between the rotor and the primary gas deflecting means;

FIGURE 29 is a diagram showing the operation of the primary gas deflecting means in response to tilt of the rotor;

FIGURES 30 to 34 are graphs showing the response of the aircraft of FIGURES 1 to 13 to certain control conditions;

FIGURE 35 is a group of graphs showing the response of an aircraft having the control system of FIGURES 17 and 17A to a control condition; and

FIGURE 36 is a group of graphs showing the response of an aircraft having the modified control system shown in FIGURES 18 and 18A.

Referring now to FIGURES 1, 2 and 3, the aircraft there shown comprises an inboard body structure 40, which is generally lentiform and is sheathed by upper and lower skins which provide opposed aerofoil surfaces. The skin providing the upper aerofoil surface is indicated at **41** and the skin providing the lower aerofoil surface is indicated at **42**. The upper and lower aerofoil surfaces provide lift developing surfaces. Encompassing the inboard body structure is an outboard body structure **43** generally in the form of a ring or torus. The outboard body structure **43** is supported in juxtaposed spaced relation to the periphery of the inboard body structure **40** by a plurality of spokes **44**. Mounted within the inboard body structure is a rotor, indicated generally at **45** in FIGURE 3, which is arranged to rotate about a spin axis which is normal to the chord plane of the aircraft when the rotor is in its "neutral" position parallel to the chord plane of the aircraft. The neutral position of the rotor is a position relative to the body structure of the aircraft; for example, the rotor of the aircraft hereinafter described, when the aircraft is horizontal, is in its neutral position when the rotor is horizontal. Rotation of the rotor impels gas to flow within the aircraft and the gas is discharged from nozzles provided between the inboard and outboard body structures as will hereinafter be described.

Throughout the description, and in the claims, certain terms of positional relationship are used for convenience. The terms "outboard" (or "outboardly") and "inboard" (or "inboardly") denote, respectively, greater and lesser distances from the spin axis of the rotor. The terms "vertical," "upwardly" and "downwardly" denote directions approximately substantially normal to the medial, or chord, plane between the upper and lower aerofoil surfaces.

A system of body axes for the aircraft is also used; in the aircraft shown the yaw axis is the axis of symmetry and is coincident with the spin axis of the rotor when the latter is in its neutral position. The longitudinal axis is the intersection of the plane of symmetry and the chord plane; the lateral axis intersects the longitudinal and yaw axes at right angles.

Referring now to FIGURES 1 to 6, but more particularly to FIGURES 4 to 6, the aircraft is built up over a skeleton consisting of a multiplicity of ribs disposed radially of the yaw axis; in the embodiment to be described there are fifty-four ribs which are attached at their inboard ends to a frusto-conical center post generally indicated at **46**. The center post **46** is hollow and has a frusto-conical outer wall **47**; the post is strengthened internally by radial and horizontal webs **48** and **49**. Further radial webs **50** of channel section reinforce the center post above the horizontal webs **49** but do not extend to the upper edge of the wall **47**.

A rib **51** (see FIGURE 4) has an inboard end **52** which extends up the wall **47** to be approximately level with the top of the webs **50**; ribs similar to the rib **51** are hereinafter called main ribs. Counting around the aircraft in a clockwise direction from the rib **51**, every third rib is a main rib; thus, for example, the rib **53** having an inboard end **54**, and the rib **55** having an inboard end **56** are main ribs. Between the ribs **53** and **55** are two short ribs **57** and **58** having inboard ends **59** and **60** respectively which extend to positions similar to that indicated at **61** in FIGURE 6B for the inboard end of a similar short rib in another portion of the aircraft. Except for the ribs adjacent three of the main ribs, there are two short ribs between each pair of main ribs.

One of said three main ribs is rib **51** and on either side of this rib are intermediate ribs **62** and **63** having inboard ends **64** and **65** respectively which extend, as shown in FIGURES 4 and 5, to positions located part way up the frusto-conical wall **47** and intermediate the location of the inboard ends of the short ribs and the location of the inboard ends of the main ribs. The upper edge of each of the ribs **62**, **63** is relieved as shown at **66** in FIGURE 4 for the rib **63**. This relief extends along

the inboard portion of the upper edge of each rib **62**, **63** and lowers the inboard portions of the upper edges of these ribs below the upper edge of the rib **51**. Between each of the intermediate ribs **62**, **63** and the next main ribs on either side of the rib **51** is a short rib similar to the ribs **57**, **58** and the relief **66** on the upper edges of the intermediate ribs **62**, **63** lowers the inboard portions of said upper edges below the upper edges of the short ribs adjacent to the intermediate ribs. Extending between the relieved portions of the upper edges of the intermediate ribs and the rib **51** there are generally horizontal dividing walls **67**. Generally vertical gas deflecting walls **68**, see FIGURE 4, are arranged on the upper surfaces of the dividing walls **67** to deflect gas flowing outboardly above the dividing walls **67** into the radial spaces between the intermediate ribs **62**, **63** and their adjacent short ribs for a purpose hereinafter to be described. At the outboard termination of the dividing walls **67**, is arranged a series of three deflecting vanes **69**, **70** and **71** to deflect air from beneath the dividing walls **67** in an upward direction. The deflecting vanes extend on either side of the rib **51** and extend between the ribs **62** and **63**. Moreover, the vanes **69** and **70** extend above the upper edges of the ribs **51**, **62** and **63** while the vane **71** terminates at the upper edges of the ribs **51**, **62**, and **63**, see FIGURE 4. The ribs **62**, **63**, the dividing walls **67**, the lower aerofoil skin **42** and the vanes **69**, **70** and **71** define an air intake for a gas turbine engine as will hereinafter be described.

Referring to FIGURE 2, the aircraft has three gas turbine engines **72**, **73** and **74** arranged within the inboard body structure to supply high velocity gas to rotate the rotor **45**. The engines are arranged generally tangentially to the periphery of the rotor and are spaced at 120° intervals about the axis of rotation of the rotor. There is an air intake similar to that previously described for each of the engines **72**, **73** and **74**. The air intake for the engine **73** is indicated generally at **75** in FIGURE 3, the air intake for the engine **74** is indicated generally at **76** in FIGURE 3 and the air intake for the engine **72** is the one shown in FIGURES 4 and 5 and is arranged to the left of the longitudinal axis of the aircraft as a mirror image, as it were, of the air intake **76**. The air intake **75** for the engine **73** extends on either side of a main rib **51*a*** lying on the longitudinal axis of the aircraft. If this rib is considered to be the first of the fifty-four ribs forming the skeletal structure of the aircraft then, counting clockwise in FIGURE 3, the air intake **76** extends on either side of the nineteenth rib **51*b*** and the air intake for the gas turbine engine **72** extends on either side of the thirty-seventh rib, i.e. rib **51**. Thus the first, the nineteenth and the thirty-seventh ribs, i.e. the ribs **51*a***, **51*b*** and **51**, are the three main ribs referred to above as those about which the rib structure differs from the norm of two short ribs between each main rib.

The air intakes **75** and **76** are similar to the air intake described with reference to FIGURES 4 and 5. The air intakes **75**, **76** are arranged about the main ribs **51*a*** and **51*b*** and extend between intermediate ribs **62*a***, **63*a*** and **62*b*** and **63*b*** respectively. The air intake **75** has dividing walls **67*a*** and deflecting walls **68*a*** similar to the corresponding parts **67** and **68** of the air intake of FIGURES 4 and 5. Similarly the air intake **76** has dividing walls **67*b*** and deflecting walls **68*b*** similar to the corresponding parts **67** and **68** of the air intake of FIGURES 4 and 5.

The air intakes **75** and **76** have deflecting vanes **69*a***, **70*a*** and **71*a***, and **69*b***, **70*b*** and **71*b***, respectively, similar to the vanes **69**, **70** and **71** of the air intake of FIGURES 4 and 5.

The outboard end of each of the fifty-four ribs is similar and is bifurcated to provide upper and lower radiused webs **77** and **78** respectively (see FIGURE 6A). It will be seen that at their outboard ends the ribs increase in depth so that the upper radiused web **77** is above the level of the remainder of the rib. The upper radiused web **77** is provided with a slot **79** in its lower surface and the lower radiused web **78** is provided with a slot **80** in its upper surface opposed to the slot **79**. The central portion of the rib terminates in an outboard edge **81** extending between the inboard walls of the slots **79** and **80**.

The free edges of the ribs, except for their inboard edges, are furnished with flanges extending normal to the ribs on both sides thereof. These flanges are provided by L-section strips riveted to the ribs adjacent to their edges. Referring to the rib **63** in FIGURE 4 by way of example, one of these L-section strips is indicated at **82**. In addition to being provided with these L-section strips round their edges, each rib is provided with two further strips of L-section on each side thereof. Referring again to the rib **63** in FIGURE 4 by way of example, each rib has a flange provided by a strip **83** extending from the lower inboard edge of the slot **79** to the upper edge of the rib as it sweeps upwardly to provide the upper radiused web **77**. A strip similar to the strip **83** is provided on each side of each rib. The second further strip **84** is downwardly inclined and extends from the upper inboard edge of the slot **80** to the lower edge of the rib. A strip similar to the strip **84** is provided on each side of each rib. A circumferential strip **85** of L-cross section extends around the aircraft and is connected to the uppermost corners of the ribs.

The structure shown in FIGURE 4 is sheathed as shown in FIGURE 5. The lower aerofoil surface skin **42** is secured to the lower edges of the ribs and is continued upwardly and inboardly around the lower radiused webs **78** to terminate at the outboard edges of the slots **80**. The upward and inboard extension of the skin **42** forms the lower surface of an outboardly diverging outlet nozzle indicated generally at **86**. In a similar manner a peripheral portion of the upper aerofoil surface skin **41** is connected to the upper surfaces of the upper radiused webs **77** and is continued downwardly and inboardly around the webs **77** to terminate at the outboard edges of the slots **79**. The downward and inboard extensions of the skin **41** form the upper surface of the outlet nozzle **86**.

The upper edges of the ribs, inboardly of the strip **85**, are attached to a sheet metal skin **87**. The inboard edge **88** of this skin **87** extends to be level with the inboard edges of the main ribs, to be level, for example, with the inboard edges **52**, **54**, **56** of the main ribs **51**, **53** and **55** mentioned above. The inboard peripheral portion of the skin **87** is provided with a series of circumferentially spaced breather holes **89**.

Further sheet metal skins **83*a*** and **84*a*** are secured between the strips **83** and **84** respectively of each adjacent pair of ribs (see FIGURE 5) and define part of the gas displacement passage which terminates in the nozzle **86**.

The skin **87** defines a dished space within which are arranged the three gas turbine engines **72**, **73**, **74**, means to lead air from the air intakes to the gas turbine engines, and means to conduct the exhaust gases from the engines to drive the rotor. The dished space is divided into compartments by a series of bulkheads as shown in FIGURE 2. There are three substantially chordal main bulkheads **90**, **91** and **92** which define a central, substantially triangular space within which are arranged the engines, the rotor and the fuel tanks. The space to the left of bulkhead **91** is sub-divided by bulkheads **93** and **94** between which is arranged the pilot's cockpit **95**. The space to the right of the main bulkhead **92** is subdivided by bulkheads **96** and **97** between which is arranged the observer's cockpit **98**. The space aft of the main bulkhead **90** is subdivided by bulkheads **99** and **100**. The compartments between the bulkheads not used for the pilot's and observer's cockpits may be used for cargo or parts of the aircraft control system.

Referring to FIGURE 2 the central, generally triangular space is itself subdivided by three straight dividing walls and three curved dividing walls. There is a straight dividing wall **101** parallel to the bulkhead **90** and a curved dividing wall **102** extending from the inboard end of the wall **101** to the bulkhead **92**. Similarly there is a straight dividing wall **103** parallel to the bulkhead **92**, and a curved dividing wall **104** extending from the inboard end of the wall **103** to the bulkhead **91**. Finally there is a straight dividing wall **105** parallel to the bulkhead **91** and a curved dividing wall **106** extending from the inboard end of the dividing wall **105** to the bulkhead **90**.

Each of the engines is mounted in a similar manner which will be described with reference to FIGURES 5 and 6. Referring now to FIGURES 5 and 6A, each engine is supported at its intake end by a yoke **107** which embraces the upper part of the engine and which receives pins **108** secured to the engine frame. The yoke itself is supported from a U-frame **109** forming part of the aircraft structure and extending (in FIGURE 5) between the bulkhead **91** and the dividing wall **105**. For the other engines, similar U-frames extend between the bulkhead **92** and the wall **103** and between the bulkhead **90** and the wall **101**. The U-frames **109** are of channel section as is clearly shown in FIGURE 6A, and the yokes **107** are supported in the channels of the U-frames by fittings **110**. A firewall **111** divides the engine compartment into two parts, and the engine projects through the firewall.

Each engine is supported at its outlet end by means similar to those shown in FIGURE 6B for the engine **74**. A pyramidal column **112** is secured to the upper surface of the skin **87** and carries at its upper end a forked lug **113**. The engine includes a tailpipe **114** which carries a single lug **115** received in the forked lug **113**. The forked lug **113** and the lug **115** have apertures to receive a pin **115*a*** which may be inserted from the compartment which lies to the rear of the bulkhead **90** and to the right of the bulkhead **99**. Each engine is mounted in a similar fashion in the positions shown in FIGURE 2. The engines are supplied with fuel from removable fuel tanks **116** located in the spaces between the dividing walls **101**, **102**; **103**, **104**; and **105**, **106**.

Air is fed to the engines from the air intakes previously described and two of which are shown at **75** and **76** in FIGURE 3. Between the intake end of each engine and the skin **87** on the upper edges of the ribs is an elbow **117**, the lower end of which is connected to a fitting **118** which in turn is connected to the skin **87**. The elbow **117** and the fitting **118** are provided with mating flanges which are bolted together; each pair of vanes **69** and **70**, as shown in FIGURE 6A, projects to the top of the fitting **118**.

The exhaust gases of the engines are fed into a common ring manifold and are arranged to drive the rotor. Associated with each engine, and connected to the outlet end thereof, is a curved converging manifold somewhat in the shape of a tusk (see FIGURES 2 and 4). The manifold for the engine **72** is indicated at **119**, the manifold for the engine **73** is indicated at **120** and the manifold for the engine **74** is indicated at **121**. The manifolds are connected to the upper edge of a box-section ring member **122** against the lower edge of which abuts the inboard edge **88** of the skin **87**. The relative orientation of the narrow end of one tusk manifold and the wide end of an adjacent manifold is shown clearly for the manifolds **119** and **121** in FIGURE 4. The manifolds have a downwardly opening circumferential slot **123** through which the propulsive gases generated by the gas turbine engines are discharged downwardly adjacent to the inboard surface of the ring member **122**. Spacer rods **124** and **125** are arranged within the manifolds to preserve their shape. The inboard peripheries of the manifolds are flanged as indicated at **126** in FIGURE 4 and secured to the underside of this flange **126** is a further ring member **127**. Guide vanes **128** are interposed between the ring members **122** and **127** and serve as inlet guide vanes for the tip turbine of the rotor hereinafter to be described.

Supported from the inboard junctions of the dividing walls **101, 102; 103, 104;** and **105, 106**, is an inlet guide ring **129** for the rotor. This guide ring is clearly shown in FIGURES 5 and 6A and comprises inboard and outboard curved metal skins **130** and **131** joined and spaced at their upper ends by a channel member **132**. The channel member has secured to its outboard periphery three lugs **133** spaced at 120° intervals; the lugs are secured between spaced double lugs **134** which are in turn secured to the dividing walls **102, 104**, and **106** at the inboard ends thereof. The lower edge of the outboard skin **131** is flanged inboardly and is spaced above the flange **126** of the tusk manifolds while the inboard skin **130** extends downwardly towards the ring member **127** and is secured to a flange provided at the lower edge of the outboard skin **131**. The guide ring **129** is spaced from the "tusk" manifolds so that cooling air may flow over the manifolds and between the ring member **127** and the lower edges of the skins **130, 131**.

The outer skin **130** of the guide ring is faired into the upper aerofoil surface skin **41** of the aircraft which is divided into panels, the joints between the panels being arranged to lie over the bulkheads, and the panels being removable for access to the engines and to the compartments between the bulkheads. The guide ring **129** carries a cellular grating **135** positioned above the rotor **45** while the panels over the engine compartments are provided with breather louvres **136** which admit air to cool the engine compartments.

After the exhaust gases from the gas turbine engines have passed into the tusk manifolds and downwardly through the guide vanes **128** they drive a tip turbine that constitutes part of the rotor, as will hereinafter be described, and after passing through the tip turbine the gases enter exhaust boxes and are discharged into the gas displacement passage; the exhaust boxes are designed to provide a uniform pressure gradient in the exhaust gases as they drop in pressure upon entering the gas displacement passage. Except over the air intakes to the engines, the arrangement of the exhaust boxes is as follows and will be described with reference to FIGURE 6B. Each exhaust box extends between an adjacent pair of main ribs and has an inboard guide vane **137**, a curved outboard wall **138**, and side walls **139**. The guide vane **137** is continued downwardly by corrugated strips **140** which are arranged partially to overlap one another. The corrugated strips are arranged so that gas may pass from between the guide vane **137** and the wall **138**, then between the corrugations in the strips **140** and out of the exhaust box. The outboard edges of the wall **138** and of the outboard corrugated strip **140** are slotted to accommodate the inboard edges **61** of the short ribs between each adjacent pair of main ribs. Each main rib is provided at its inboard edge with a curved aerofoil section guide vane **141** extending between the upper end of the frusto-conical wall **47** and the upper end of an adjacent guide vane **137** on an exhaust box. The upper end of the curved wall **138** of each exhaust box abuts against the lower edge of the ring member **122**. The flow of air through the sectors of the gas displacement passage induces air to flow from the engine compartments through the holes **89** in the skin **87** and over the curved walls **138**, thereby serving partially to cool the exhaust boxes.

The arrangement of the exhaust boxes over the air intakes of the engines is slightly different and will be described with reference to FIGURES 5 and 6A. All the exhaust boxes are similar to that previously described with reference to FIGURE 6B but it will be seen by reference to FIGURES 5 and 6A that the exhaust boxes over the air intakes discharge between the dividing walls **67** and the metal skin **87**. The exhaust gas passing between the walls **67** and the skin **87** is deflected by the gas deflecting walls **68** into the sectors of the gas displacement passage lying between the intermediate ribs, such as **62, 63**, and their adjacent short ribs.

The construction of the rotor and rotor shaft will now be described with reference to FIGURES 4 to 8. Centrally located in the center post structure **46** is a base casting **142** having radial flanges **143**, to which the radial webs **48** are secured, and having an upper horizontal flange **144** to which the horizontal webs **49** are secured. Referring now to FIGURE 7, the base casting **142** is provided with an internal flange **145** and telescoped within the base casting and resting on, and secured to, the flange **145** is a hollow vertical shaft **146** which extends upwardly beyond the base casting **142**. Surrounding the upper portion of the vertical shaft **146** is a sleeve **147**; a part spherical bearing **148** is interposed between the shaft **146** and the lower portion of the sleeve **147**.

The rotor **45** is rotatably mounted at the upper portion of the sleeve **147** by opposed thrust races **149** and rotates about a spin axis which, when the rotor is in its neutral position, is parallel to the yaw axis or axis of symmetry, of the aircraft. The rotor includes an inner ring **150** of E-section, the arms of the E facing outboardly and the center arm being bifurcated. Impeller blades **151** are secured at their roots or inner ends to blocks **152**, also of E-section, which face inboardly, the central arms of the blocks **152** being received between the arms of the bifurcated central arm of the member **150**. The blades **151** are secured to the blocks **152** by being welded to plates **153** forming part of the blocks **152**. The rotor also includes a segmented inner shroud **154**, the inboard ends of which lie against the upper and lower surfaces of the inner ring **150** of the rotor. The members **150, 152** and the shroud **154** are connected together by bolts **155**, each bolt having enlarged shoulders extending through the arms of the E-section members to provide bearing surfaces. The outboard ends of the impeller blades **151** are secured to an outer segmental ring member **156**, see FIGURE 8, and secured to the outboard surface of the ring **156** is a plurality of turbine blades **157**. Secured to the upper surface of the ring **156** is an element **158** of a labyrinth seal which co-operates with an opposed labyrinth element **159** on the inboard surface of the ring member **127**.

Returning now to FIGURE 7, the upper end of the vertical shaft **146** is closed by a flexible diaphragm **160** and the top of the sleeve **147** is closed by a flexible diaphragm **161**. A sleeve **162** is held between central portions of the diaphragms **160** and **161**; passing through the sleeve and central apertures in both diaphragms is a hollow control shaft **163** which extends downwardly to adjacent to the lower end of the base casting **142**. The sleeve **162** and the central portions of the diaphragms are clamped between a shoulder **163*a*** on the control shaft and a flanged ring nut **165** threaded to the upper end of the control shaft **163**. Secured to the diaphragm **161** is a plate **164**, to which a domed intake cone **164*a*** is secured, see FIGURE 6.

Secured to the flanged nut **165** is an electric linear actuator **166**. The actuator is provided with a depending shaft **167** extending within the control shaft **163** and the lower end of the shaft **167** is provided with a forked end **168**. A rod **169** is connected at its upper end to the forked end **168** by a pin **170** and the lower end of the rod **169** is provided with a detachable mushroom head **171**. The lower end **169** of the rod passes through an aperture in an otherwise solid end piece **172** of the shaft **163**.

Spaced at 120° intervals around the circumference of the lower portion of the control shaft **163** are three bifurcated lugs, two of which are shown at **173** and **174**. Pivotally attached to each bifurcated lug is the ram of a pneumatic bellows actuator fixed to the base casting **142**. Thus the ram **175** of an actuator **176** is attached to the lug **173**. Similarly, the ram **177** of a bellows actuator **178** is attached to the lug **174** and a third bellows actuator **179** is connected by its ram to the third lug on the control shaft. Each of the actuators contains a bellows similar to that indicated at **180** for the actuator **176** and is operated by pneumatic pressure as will hereinafter be described.

Due to the resilience of the material of which they are made, the bellows act as springs and the combined effect of the springiness of the bellows is to tend to hold the control shaft **163** central within the vertical shaft **146** and thereby hold the rotor in its neutral position.

The lower end of the control shaft **163** is provided with an outboardly directed flange **181** which carries, equally spaced around its outboard periphery, six bifurcated lugs, one of which is indicated at **182**. Pivotally mounted between each lug **182** is a bell-crank lever, two of said levers being indicated at **183**; each lever has an inboard end which bears on the upper surface of the mushroom head **171** of the control rod **169**. It will be seen that vertical movement of the control rod will pivot the bell-cranks in their supporting lugs. Pivotally secured to the other end of each bell crank **183** is a hinged link **184**, and the outboard ends of the links **184** are pivotally attached to further links **185** intermediate the ends of the links **185**. One end of each of the links **185** is pivotally attached to a lug **186** carried by a radial web **48** as is best shown in FIGURES 3 and 7. Pivotally connected to the other end of each of the links **185** is a T-piece **187** to which the inboard ends of three cables **188** are attached, the points of attachment of the cables being equally spaced along the outboard edge of the T-piece. Where necessary, the radial ribs **48** are slotted as indicated at **189** to permit passage of the T-pieces. The outboard ends of the cables **188** are connected to primary gas deflecting means hereinafter to be described. It will be seen that opposed cables are interconnected by being connected to the control shaft **163**.

Referring to FIGURES 4, 5, 6 and 9, the outboard body structure will now be described. It will be recalled that the outboard body structure **43** is supported from the inboard body structure **40** by means of spokes **44** and that it is in the form of a ring or torus made up of a plurality of sections. The outboard body is fabricated in a manner similar to the manner of fabrication of the inboard body, i.e. it consists of formers covered with sheet metal. The formers of the outboard body are of two types, namely a plurality of outboard formers **190** and a plurality of inboard formers **191**. Each of the outboard formers **190** is generally triangular with a rounded apex and has a central aperture **192**. The base of each former **190** is cut away and is provided with flanges **193** (see FIGURE 4) to which are secured an annular channel member **194** to the inboard periphery of which the formers **191** are secured.

The spokes **44** are secured at their inboard ends to the outboard ends of each alternate rib of the inboard body structure. At their outboard ends the spokes are secured between two formers **191** arranged close together with a block between them to receive the outboard end of the spoke. Such a pair of formers is indicated at **195** in FIGURE 4.

The edges of each former **190** are flanged and to these flanges is secured a sheet metal covering **196** which extends inboardly to terminate at the edges of the channel member **194** as is best shown in FIGURES 6 and 9. The inboard peripheries of the formers **191** are each provided with a pair of inclined flanges **197**, and secured to these flanges is a sheet metal covering **198** which provides the inboard periphery of the outboard body structure.

An upper circumferential guide vane **199** is supported on the spokes **44** which extend between the upper periphery of the outboard body and the inboard body; a lower circumferential guide vane **200** is supported on the spokes **44** which extend between the lower periphery of the outboard body and the inboard body. The guide vane **199** is located in an upper peripheral nozzle provided between the outboard body and the inboard body, and the guide vane **200** is located in a lower peripheral nozzle provided between the outboard body and the inboard body. The divergent outlet nozzle **86** communicates with both upper and lower peripheral nozzles.

As is clearly shown in FIGURES 9 and 10, slots are provided between the inboard ends of the covering **196** of the formers **190** and the outboard ends of the covering **198** of the formers **191**. There is thus provided an upper peripheral slot **201** and a lower peripheral slot **202** in which are mounted secondary gas deflecting means in the form of baffles which may be operated to control the direction in which the propulsive gas leaves the upper and lower peripheral nozzles. The baffle in the upper slot **201** is indicated at **203** and the baffle in the lower slot at **204**. The baffles are formed of strip metal fashioned into the shape of frusta of a circular cone and are mounted in the outboard body by the arrangement shown in FIGURES 9 and 10. Secured to the base portion of suitably spaced formers **190** are flanged fittings **205** having spring anchoring flanges **206** and **207** which are, respectively, generally perpendicular to the baffles **203, 204**. A tension spring **208** extends between the flange **206** and the baffle **203** and a tension spring **209** extends between the baffle **204** and the flange **207**. The baffles are mounted to slide on the outboard body as better shown in FIGURE 10 for the baffle **203**. The baffle is slotted as indicated at **210** and the slot embraces a sleeve **211** secured to a flange **212** by means of a nut and bolt assembly **213**; the baffle is guided on the sleeve by spacers **214** and **215**.

Referring to FIGURES 3, 4 and 11, the baffles are operated by actuators **216** at opposite ends of the lateral axis of the aircraft. From FIGURE 11 it will be seen that the slots **210** of the baffles **203, 204** are arranged to be parallel to the longitudinal axis of the aircraft and therefore lie at different angles to the vertical at differing points round the periphery of the aircraft. Thus, adjacent to the lateral axis of the aircraft and in the vicinity of the actuators **216**, the slots are substantially horizontal while adjacent to the longitudinal axis of the aircraft the slots are viewed in elevation, substantially vertical.

The resulting support of the baffles is analogous to the support of the base of a hollow cone on a sphere of a diameter somewhat larger than the base of the cone. If the apex of the cone is moved in two directions in a given vertical plane then the base of the cone in that plane will move vertically relative to the sphere while the portions of the base of the cone in a vertical plane containing the apex of the cone and normal to the plane of movement of the apex of the cone will not be vertically displaced relative to the sphere. By moving points on the baffles **203, 204** backwardly and forwardly adjacent to the ends of the lateral axis of the aircraft it is possible to control the extent of projection of the baffles into the upper and the lower peripheral nozzles. Referring now to FIGURE 4, adjacent to the actuators **216**, the baffles **203, 204** are secured together by a strap **217**. One end of the actuator **216** is pivotally secured at **218** to a pair of formers **191** and the ram of the actuator is secured at **219** to the strap **217**. The other actuator is arranged in a similar fashion and operation of the actuators will rock the baffles as described above. The baffles **203, 204** constitute secondary gas deflecting means.

Primary gas deflecting means are arranged in the slots **79** and **80** in the upper and lower radiused webs **77** and **78** at the outboard ends of the ribs of the inboard body and include an upper baffle **220** and a lower baffle **221**, each baffle being formed as a frustum of a hollow cylinder. The edges of the baffles which project into the gas displacement passage have sharp edges as indicated at **222**. At spaced intervals around the periphery of the aircraft the upper baffle **220** is supported by resilient strips **223** which are secured to the sheet metal skin **87** at their inboard ends by flanges **224** (see FIGURES 9 and 11). At spaced positions in register with the resilient strips **223**, the baffles **220, 221** are connected together by straps **225**. The lower end of each strap **225** is secured to the upper arm **226*a*** of a bell-crank **226** having a second arm 226b and which is pivoted at 227 between a pair of supporting ribs 228. The location of the supporting ribs is clear from FIGURE 3; they are interposed between the outboard ends of two adjacent ribs of the inboard body structure. The outboard ends of the cables 188, which were described with reference to FIGURE 7, are connected to the lower ends of the arms 226b of the bell-cranks. A bracket 229 is secured between the lower portions of the supporting ribs 228 and a tension spring 230 is interposed between the lower end of each strap 225 and a lug 231 on each bracket 229. It will be seen that the springs 230 tend to pull the baffles 220, 221 into their lowermost positions so that the baffle 220 projects into the gas displacement passage and the baffle 221 is retracted into the slot 80. Guide vanes 232 are provided at the outboard end of the displacement passage to guide the outboardly flowing propulsive gas into the outboardly divergent outlet nozzle 86.

Referring now to FIGURES 3, 4, 5 and 11, the aircraft is provided with two sets of pivotally mounted rudder vanes in the gas displacement passage adjacent to the outlet nozzle. Each set of vanes comprises eight individual vanes indicated at 233, the vanes being arranged in two groups of four, each group being arranged between two adjacent ribs of the inboard body structure. The upper ends of each group of vanes are connected by short links to a main link 234 which is in turn connected to the ram 235 of an actuator 236. The actuators are pivotally mounted on ribs of the inboard body structure and include springs tending to center the rudder vanes in radial positions. Operation of the actuators 236 pivots the vanes 233 to control the directions in which the propulsive gas leaves the two sectors of the gas displacement passage in which the vanes are mounted. The rudder vanes are mounted on corresponding positions on each side of the longitudinal axis of the aircraft, the vanes being arranged just aft of the lateral axis of the aircraft.

The baffles in the outboard body structure (the secondary gas deflecting means), the baffles in the inboard body structure (the primary gas deflecting means) and the rudder vanes are all controlled from a control column indicated generally at 237 in FIGURE 11 and shown in detail in FIGURES 12 and 13 to which reference is now made. The control column is, of course, under the control of the pilot and is situated in the pilot's cockpit 95. The floor of the cockpit is indicated at 238 and the control column is partly encased in a shroud 239 upstanding from the floor 238. The control column itself comprises an upper sleeve 240 which extends above the shroud 239 and is secured at its lower end to a lower sleeve 241, the lower end of the lower sleeve being secured to the floor 238. Mounted within the upper sleeve 240 is an outer gimbal ring 242 and an inner gimbal ring 243, these gimbal rings being shown clearly in FIGURE 13. The inner gimbal ring is supported from the outer gimbal ring on axes 244; supported within the inner gimbal ring by axes 245 is a double-walled sleeve 246. The space between the double walls of the sleeve 246 provides a plenum chamber 247 which is supplied with high pressure air through a conduit 248 which is connected to a union in the outer wall of the double sleeve and passes through a slot 249 in the upper sleeve 240. Secured in a disc 250 closing the lower end of the double sleeve are three Venturi nozzles 251*a*, 251*b* and 251*c*. The three nozzles are spaced around the axis of the sleeve at 120° intervals and each nozzle has an inner stack pipe 252 which opens at its upper end into the plenum chamber 247. The outer casing of the nozzle surrounds the inner stack pipe 252 and is of greater cross sectional area than the inner stack pipe. Conduits 253 are connected at their one ends to the outer casings of the nozzles above the lower ends of the inner stack pipes. The other ends of the conduits are connected to the actuators 176, 178 and 179 as shown in FIGURES 11 and 13A.

Reverting to FIGURE 12, the lower sleeve 241 carries a bearing 254 adjacent its upper end, the bearing being supported by webs 255. Rotatably mounted in the bearing is a resilient rod 256 which projects both upwardly and downwardly from the bearing. The rod is surmounted by a handle 257, and a flexible bellows 258 connects the upper end of the upper sleeve 240 to the lower end of the handle 257. At its lower end the rod carries a cam 259 which co-acts with a tongue 260 which is pivoted at 261 to a base plate 262. Adjustable spring plungers 263, 264 and 265 act on the tongue and cam to bias the former in a central position and an adjustable stop 266 is provided to limit movement of the plunger 265 in one direction and to provide an adjustable datum for the cam. Mounted in upstanding lugs 267 on the base plate 262 are opposed Venturi nozzles 268. The construction of each of these nozzles is similar to the nozzles 251 described above. Thus high pressure air is fed into the nozzles through conduits 269 and the pressures in the outer casings of the nozzles are communicated through the conduits 270 which are connected to the rudder actuators 236 as shown in FIGURE 11.

Above the bearing 254, the rod 256 carries a circular plate 271; a compression spring 272 is interposed between the disc 250, which seals the bottom of the double-walled sleeve 246, and the plate 271. The double-walled sleeve 246 is continued upwardly by a hollow sleeve 273 which co-acts with eccentric cam wheels 274 and 275. The cam wheel 274 is housed in a bearing 276 supported on the outer surface of the upper sleeve 240, and the cam wheel 275 is supported in a similar bearing 277. The cam wheels project through slots 278 in the upper sleeve 240, and the sleeve 273 is kept in contact with the cam wheels by leaf springs 279.

The cam wheels are operated by remote control from hand wheels 280 and 281, which are arranged at right angles to one another in the pilot's cockpit and within convenient reach of the pilot. A flexible cable control connects the hand wheels to the cams and is similar for each hand wheel and cam. The hand wheel 280 is provided with a sleeve bearing 282 which is supported by a flange 283. The hand wheel also carries a threaded shaft 284 which is received within an internally threaded bore of a slidable block 285. The slidable block is connected to one end of an inner flexible cable 286, the outer part of the cable, indicated at 287, being anchored at 288. The other end of the outer cable 287 is anchored to the sleeve 240 by a fitting 289 which is slotted at 290 to expose the inner cable 286. The inner cable is wire wound to produce the effect of a worm and it meshes with a worm wheel 291 carried in the bearing 276, the worm wheel being connected to the cam wheel 274. Rotation of the hand wheel 280 moves the inner cable 286 within the outer cable 287 thereby rotating the worm wheel 291 and the cam wheel 274. In a similar manner, rotation of the hand wheel 281 rotates the cam wheel 275. By rotating the hand wheels 280 and 281 fine adjustment of the position of the double-walled sleeve 246 in its gimbal mounting can be obtained since the wheels 274 and 275 are at right angles to each other.

The control column includes two spring loaded push switches 292 and 293 which are connected by leads 294 to the actuator 166 situated at the top of the rotor shaft. As long as pressure is applied to the button 292 the actuator 166 will be caused to lift the rod 169. Conversely, pressure on the button 293 will cause the actuator to lower the rod 169 but, as soon as the pressure is released from the button, the rod will cease to move. The control column also carries a switch 295 connected to the actuators 216 by leads 296. Operation of the switch 295 operates the actuators 216 to move the baffles 203, 204 in the outboard body.

Referring to FIGURES 1 and 6, the aircraft is provided with a tricycle undercarriage consisting of castors

297 supported by legs 298. Each leg has a lower flange 298a secured to the lower skin 42 and a cylindrical casing 298b secured to a main rib by an upper mounting 299. Transparent canopies 300 extend over the pilot's and observer's cockpits and a pilot head boom 301 extends from the forward part of the aircraft.

FIGURES 14, 15 and 16 show a modification of the aircraft described with reference to FIGURES 1 to 13. The construction of the inboard body structure of the modified form of aircraft is identical, except in one respect, to that described with reference to FIGURES 1 to 13. One of the modifications incorporated in the second aircraft concerns the secondary gas deflecting means incorporated in the outboard body structure.

Basically the main structure of the outboard body structure shown in FIGURES 14 and 15 is the same as has heretofore been described. Thus there is a series of outboard formers 190 of the same shape as hereinbefore described, and the formers are covered with sheet metal 196 which extends inboardly to the inboard edges of the channel member 194. Also, there is a plurality of inboard formers 191, which are covered with sheet metal 197. The outboard edges of the covering 197 are spaced from the inboard edges of the covering 196 as before to provide upper and lower slots 201 and 202. However, in this modified construction, there are no baffles mounted in the slots 201, 202 and no actuators for the baffles. Instead of the baffles, the inboard periphery of the outboard body structure is provided with a plurality of gas entry ports 302 equally spaced around the whole of the inboard periphery. There is a circumferential space 303 between the inboard portion of the covering 197 and the inboard edges of the formers 191 which are cut away at 304. Movable in the space 303 in a portion of the outboard body structure adjacent to the rear of the aircraft is obturator means comprising a slide 305 operated by actuators 306.

As shown in FIGURE 16, there are three actuators 306 which are pivotally mounted to the outboard body structure and are spaced along the slide 305 which is curved to conform with the curvature of the outboard body structure. Each actuator 306 has a ram 307 which is pivotally mounted between a pair of links 308 which in turn are pivotally mounted about an axis 309 on the outboard body structure. The inboard ends of the links 308 are secured to the slide 305 which is provided with a plurality of apertures 310 which are spaced apart by distances equal to the distances between the gas entry ports 302 in the covering 197. The slide 305 may be moved by the actuators 306 so that the apertures 310 in the slide register with the gas entry ports 302 in the covering 197 or the slide may be moved to a position in which it closes the gas entry ports in the rear portion of the outboard body structure. When the apertures 310 are in register with the gas entry ports 302 propulsive gas enters the gas entry ports, is redirected by the channel member 194, and is ejected through the slots 201 and 202. The actuators 306 are operated from the pilot's control column 237 through the switch 295, described with reference to FIGURE 12, and which is connected to the actuators by leads 311. The control system of the modified aircraft is otherwise identical with the control system described for the first embodiment of the aircraft.

The modification to the inboard body structure comprises a downwardly directed, annularly arranged, stabilizing nozzle in the lower aerofoil skin 42 of the aircraft. Referring to FIGURE 14B, an inner lip 312 is provided to deflect some of the gas flowing through the gas displacement passage to a nozzle slot 313 in the skin 42. The lip extends between each pair of adjacent ribs of the inboard body structure, however, the lip 312 and the slot 313 are interrupted between the ribs which define the air intake passages for the engines. Thus reference to FIGURE 14A will show that there is no slot 313 or inner lip 312 in the air intakes for the engine 73. An outer lip 314 is provided to direct gas passing through the slot 313 slightly inboardly. The lip 314 is continuous and is not interrupted under the air intakes. Some of the propulsive gas flowing through the gas displacement passage will be deflected by the lip 312 to pass through the downwardly directed stabilizing nozzle 313 for a purpose which will hereinafter be described.

FIGURES 17 and 17A show a somewhat modified control system for the aircraft shown in FIGURES 1 to 13. Structurally, the modification amounts to the omission of the links 184, 185 described with reference to FIGURE 7. In FIGURES 17 and 17A, the inboard ends of the cables 188 are connected in groups of three to T-pieces 315 and the inboard ends of the T-pieces are connected directly through clevises 316 to the lower ends of the bell-cranks 183. The effect of this modified construction on the response of the aircraft will be described hereinafter but it will be seen that if the lower end of the control shaft moves in a given direction the cables 188 lying in that direction will be moved outboardly and opposed cables will be moved inboardly. In all other respects the control system shown in FIGURES 17 and 17A is the same as that described with reference to the aircraft of FIGURES 1 to 13.

FIGURES 18 and 18A show a modified form of control system in which right angled pivoted links, or bell-cranks 350, are interposed between the links 184 and the T-pieces 187 to which the inboard ends of the cables 188 are connected. Each bell-crank has two arms, one arm 351 being pivotally attached at its free end to a link 184 and the other arm 352 being cranked upwardly at 353 to clear the arm 351 of an adjacent bell-crank 350. Each of the bell-cranks 350 is pivotally mounted in a lug 354 secured to one of the radial webs 48 which extends between the inner surface of the wall 47 and the base casting 142.

It will be apparent that the arrangement is such that if the control shaft 163 moves in a given direction, instead of the cables 188 lying in that direction being moved outboardly, cables 188 lying at 90° clockwise from that direction will be moved outboardly and opposed cables will be moved inboardly. The effect of this arrangement on the response of the aircraft will be described hereinafter but in all other respects the control system shown in FIGURES 18 and 18A is the same as that described with reference to the aircraft of FIGURES 1 to 13.

Referring now to FIGURES 19, 20 and 21, the embodiment of the invention there shown differs from the embodiment of the invention shown in FIGURES 1 to 13 in the construction of the outboard body structure and in the arrangement of the secondary gas deflecting means.

Referring to FIGURE 21, the outboard body structure is fabricated from a series of radially arranged formers covered with sheet metal covering in a manner similar to that described in the other embodiments of the invention although the formers providing the skeleton of the outer body structure are somewhat different in shape from those previously described. The formers providing the skeleton of the forward portion of the outer body are of the shape indicated at 317 while the formers providing the skeleton of the rear portion of the outer body are of the shape indicated at 318. The formers 317 have a comparatively wide central portion which tapers both upwardly and downwardly to upper and lower edges. The formers 318 are similar in their upper parts to the formers 317 but terminate above the lower edges of the formers 317 in a lower edge 319.

The forward portion of the outer body extends around a major portion of the periphery of the aircraft and subtends an angle of approximately 253° at the center of the aircraft whereas the rear portion extends around an arc which subtends an angle of 107° at the center of the aircraft (see FIGURE 20).

The outboard edges of the formers 317 are covered with a sheet metal covering 320 and their inboard edges are covered with a sheet metal covering **321**. The outboard edges of the formers **318** are covered with a sheet metal covering **322** and their inboard edges are covered with a sheet metal covering **323**. The inboard surfaces of the upper portions of the coverings **321**, **323** provide fixed guide means which directs propulsive gas passing through the upper peripheral nozzle in directions generally upwardly and inboardly. In a similar manner the lower portion of the covering **321** provides fixed guide means which directs gas flowing through the forward portion of the lower peripheral nozzle generally downwardly and inboardly. Pivotally attached to the lower edge **319** of the rear portion of the outboard body structure is a series of flaps **324** arranged in end-to-end relation. It will be seen from FIGURE 20 that there are eight flaps each extending a circumferential length equal to the distance between three ribs on the inboard body structure. Each flap is of double-walled construction and is dished at **325**. The flaps are movable between first positions, shown in full lines in FIGURE 21, and second positions, shown in phantom lines in FIGURE 21, by being rocked about their pivotal mountings on the lower edge **319** of the rear portion of the outboard body structure. The flaps are rocked by a series of actuators, one actuator being provided for each flap. An actuator is indicated at **326** and is pivotally connected at its upper end at **327** to the inboard body structure. Each actuator is provided with a ram **328** which extends across the lower peripheral nozzle and is pivotally attached to a flap **324** between spaced lugs **329** arranged substantially centrally of the lower edge of the flap. The rams **328** pass through apertures **330** in the covering of the inboard body structure. It will be appreciated that, as the actuators **326** are operated, the flaps are rocked between their first and second positions and that during movement of the flaps the actuators will pivot about the pivot points **327**. The apertures **330** are made of larger diameter than the rams **328** since the rams will move transversely of the apertures during movement of the flaps. The actuators are provided with compressed air bled from the compressors of the engines and are operated by an electro-pneumatic valve (not shown) controlled by the switch **295** on the pilot's control column.

The outboard body structure is held in juxtaposed spaced relationship with the outlet nozzle **86** by means of spokes **44** in a manner similar to that hereinbefore described for the other embodiments of the invention, however it will be noted that the guide vanes **199** and **200** are omitted in this embodiment of the invention. The primary gas deflecting means consisting of the baffles **220**, **221** with their associated operating mechanism is identical to that previously disclosed.

The functions of the various components of the aircraft of FIGURES 1 to 13 will now be described. When the gas turbine engines **72**, **73** and **74** are put into operation they will discharge their products of combustion into the "tusk" manifolds **119**, **120**, **121**. The gases flowing at high velocity through these manifolds will be directed downwardly through the slots **123** in the manifolds and will then pass through the guide vanes **128** into the tip turbine constituted by the blades **157** on the outer periphery of the rotor. After leaving the turbine, the gases will pass through the exhaust boxes between the guide vanes **137** and the walls **138** and, except for the exhaust boxes adjacent to the air intake passages for the engines, will be discharged into the gas displacement passage as shown in FIGURE 6B and will flow outboardly along the passage. In positions where the exhaust boxes overlie the air intake passages for the engines, such as in FIGURE 6A, the exhaust gases are deflected by the deflecting walls **68**, **68*a*** and **68*b*** so that the exhaust gases pass into sectors of the gas displacement passage radially adjacent to the air intake passages for the engines.

The flow of the high velocity gases through the turbine constituted by the blades **157** causes rotation of the rotor **45** thus to impel air to flow within the structure and along the gas displacement passage provided between the radial ribs so that the air is forced out of the outboardly divergent outlet nozzle **86**. Thus, except for positions adjacent to the air intakes of the engines, air flows outboardly along the sectors of the gas displacement passage, is guided by the vanes **232** into the outboardly divergent outlet nozzle **86** and then passes through one or both of the upper and lower peripheral nozzles provided between the outboard body structure and the inboard body structure. Where spaces between adjacent ribs lead to the air intakes of the engine, as shown in FIGURE 6A, air passes outboardly between the ribs and is directed by the vanes **69*a***, **70*a***, **71*a***, into the elbows **117** and thence into the engines. Therefore, once the rotor has started to rotate, air will be forced into the engines by the impelling action of the rotor.

Movement of the baffles **220**, **221** in the slots **79** and **80** of the upper and lower radiused webs at the outboard ends of the ribs of the inboard body structure will control the direction in which the gas passing through the gas displacement passage leaves the outlet nozzle **86**. If the baffles **220**, **221** project into the gas displacement passage by equal amounts then the gas will tend to pass radially outboardly until it is deflected by the outboard body structure. If the baffle **220** projects into the gas displacement passage more than does the baffle **221**, then the propulsive gas will tend to be deflected downwardly to pass through the lower peripheral nozzle between the inboard and outboard body structures and more gas will pass through the lower peripheral nozzle than through the upper peripheral nozzle. Conversely, if the baffle **221** projects into the gas displacement passage more than does the baffle **220** the propulsive gases will tend to pass through the upper peripheral nozzle between the inboard and outboard body structures and more gas will pass through the upper nozzle than through the lower nozzle. It will be appreciated that the baffles **220**, **221** move together by virtue of the straps **225** and are controlled by movement of the cables **188** through the agency of the bellcranks **226** to the arms of which the straps **225** and the cables **188** are connected. The baffles **220**, **221** may therefore be operated to apportion the flow of propulsive gas between the upper and lower peripheral nozzles.

The deflection of the propulsive gas is attributable to the Coanda effect. (See aforementioned application Serial No. 684,615 for explanation and discussion of Coanda effect.) Thus, supposing that the baffle **220** projects into the gas displacement passage and the baffle **221** is retracted from the passage, gas flowing through the passage will be caused to "break away" from the skin **87** constituting the upper wall of the passage, by the projection of the baffle **220**. However, the major portion of the gas will flow smoothly over the lower wall of the gas displacement passage and will follow the contour of the skin attached to the lower radiused webs **78** by virtue of the Coanda effect, and will flow outboardly and downwardly to pass through the lower peripheral nozzle. The effect of the baffle **220** is assisted by a directing stream of gas which issues from the slot **79**. Some of the propulsive gas impinging on the inboard surface of the baffle **220** is directed by the baffle into the chambers between the upper radiused webs **77** of the adjacent ribs. These chambers are completely closed except for the slots **79** and therefore gas is forced from the chambers through the slots **79** along the outboard surfaces of the baffles **220** since the pressure in the gas displacement passage is less at positions outboardly of the baffle than at positions inboardly thereof.

Conversely, if the baffle **221** is caused to project into the gas displacement passage and the baffle **220** is retracted, then the major portion of the gas is caused to break away from the lower wall of the gas displacement passage and tends to pass upwardly and outboardly around the skin attached to the upper radiused webs **78** of the ribs by virtue of the Coanda effect and therefore passes through the upper peripheral nozzle. Some of the propulsive gas is deflected by the inboard surface of the baffle **221**, enters the spaces between the lower radiused webs **78** of the ribs, and is ejected adjacent to the outboard surfaces of the baffle **221** to assist in directing the remainder of the propulsive gas.

It will be seen that by operation of the baffles **220**, **221** the quantities of air and exhaust gases from the turbines which flow through the upper and lower peripheral nozzles can be controlled. That is to say, operation of the baffles **220**, **221** apportions the flow of propulsive gases between the upper and lower peripheral nozzles.

The baffles **203**, **204** in the outboard body may be operated to assist in the deflection of the gases passing through the upper and lower peripheral nozzles. Where the baffles **203**, **204** project from the surface of the outboard body they will cause the gas flow to break away from the outboard body surface and will assist the gas to follow the curvature of the upper and lower radiused webs **77** and **78**. It will be seen in FIGURE 9 that the baffles **203**, **204** at the forward portion of the aircraft project fully into the upper and lower peripheral nozzles, whereas at the rear of the aircraft the baffles are fully retracted. If the actuators **216** are operated to move the baffles **203**, **204** forwardly then the baffles in the forward part of the outer body will be retracted and those in the rear portion of the outer body will be projected and, if the actuators are moved sufficiently, the baffles will assume a position in which they project equally around the whole periphery of the aircraft. As mentioned above, the actuators **216** are controlled directly from the pilot's control column through the switch **295**.

Returning now to the baffles **220**, **221**, which constitute the primary gas deflecting means, these can be operated in unison, i.e. to an equal extent at all points around the aircraft periphery, by means of the actuator **166**. If the actuator is operated to raise the rod **169** then the bell-cranks **183** are caused to pivot by the coaction of their inboard ends with the mushroom head **171** of the rod **169**. The bell-cranks all rock to an equal extent and will draw the links **185** inboardly to an equal extent. The links **185** will, in turn, move the T-pieces **187** inboardly to equal extents which will move the lower arms **226*b*** of the bell-cranks **226** inboardly. Movement of the lower arms of the bell-cranks **226** inboardly will raise the upper arms **226*a*** and will cause the upper baffle **220** to retract into the slots **79** and the lower baffle **221** to project from the slots **80**. Conversely, if the actuator **166** is operated to lower the rod **169**, the springs **230** will pull the cables **188** outboardly and the baffle **220** will project from the slots **79** whereas the baffle **221** will retract into the slots **80**. Movement of the baffles **220**, **221** under the influence of the actuator **166** is equal throughout the periphery of the aircraft and is to be distinguished from the swashing movement of the baffles which will hereinafter be described.

Referring now to FIGURE 7, the control shaft **163** is secured in the diaphragm **160** at the upper end of the vertical shaft **146**, and the upper end of the control shaft is connected through diaphragm **161** to the upper end of the sleeve **147** on which the rotor is mounted. If the rotor now tilts about the spherical bearing **148** it will apply a force to the upper end of the control shaft **163** which will pivot about the fulcrum provided by the diaphragm **160**, and the control shaft will be deflected from its central position which is shown in FIGURE 7.

Thus, if the rotor tips to the rear from its neutral position the lower end of the control shaft **163** will move forwardly and in so moving will affect the cables **188** and the primary gas deflecting means, which includes the baffles **220**, **221** connected thereto. All the cables will be moved to some extent but the cables affected most will be those attached to the links **184** lying in, or nearest to, the plane of movement of the control shaft.

For reference purposes let it be considered that the longitudinal axis of the aircraft lies north and south and that the aircraft is facing north (see FIGURES 28 and 29). Using these axes of references, as the rotor tips to the rear from its neutral position the lower end of the control shaft will move from its central position to the north and the rotor has tipped towards the south. The plane containing the positions of the rotor spin axis corresponding to both the neutral and tilted positions of the rotor is the north-south plane. The cables **188** which are most affected by the northerly movement of the lower end of the control shaft are those connected, via the links **185** and T-pieces **187**, to the links **184** lying in, or nearest to, the north-south plane. The links **184** to the north of the lower end of the control shaft **163** will be moved outboardly and the links **184** to the south of the lower end of the control shaft will be moved inboardly.

The links **185** are dimensioned and arranged so that the cables **188** most affected by the movement in any given direction of the control shaft will be advanced, in a clockwise sense, i.e. in the direction of rotation of the rotor, by a phase angle of 20° relative to the plane containing both positions of the spin axis corresponding to the neutral and tilted positions of the rotor, in the present case, the vertical plane containing the north-south axis as mentioned above. Thus the portions of the baffles **220**, **221** affected most by the northerly movement of the lower end of the control shaft will lie adjacent to a vertical plane 20° east of north and 20° west of south, i.e. a plane advanced 20° from the north-south plane containing both said positions of the spin axis. This advanced plane is referred to for convenience as the control plane (see FIGURE 28).

All the cables **188** will be moved to varying extents by movement of the control shaft. The cables moved to the greatest extent will be adjacent to the control plane and the cables moved to the least extent will be adjacent to a plane normal to the control plane.

The cables **188** in the sector indicated by the line **400** in FIGURE 28, will be moved outboardly and the cables moving most will be those adjacent to the control plane. As the cables move outboardly the baffles in the sector will move downwardly (see FIGURE 29), so that propulsive gas will tend to flow through the lower peripheral nozzle in preference to the upper peripheral nozzle and will therefore provide an upward reaction on the associated sector of the aircraft.

All the cables in the sector indicated by the line **401** in FIGURE 28 will be moved inboardly so that the baffles **220**, **221** in this sector will be moved upwardly (see FIGURE 29), and propulsive gas will flow through the upper peripheral nozzle in preference to the lower peripheral nozzle. The greatest movement of the baffles will be in the control plane. The general gas flow pattern for a nose-up moment applied by the gas deflecting means is shown in FIGURE 25.

As the result of moving the lower end of the control shaft forwardly, the aircraft is subjected to a moment which may be considered to be a couple acting in the control plane. This couple may be resolved into two components, namely a component in the north-south plane applying a pitching moment to the aircraft and a component in the east-west plane applying a rolling moment to the aircraft. If the phase angle is designated "α," then the first component will be proportional to cosine α and the second component will be proportional to sine α.

Moreover, the first component will amplify the gyro-couple applied to the aircraft by the rotor as the latter tilts within the aircraft and the second component would oppose a rotational velocity acquired by the aircraft and which would cause the rotor to tilt from its neutral position. This is explained in more detail hereinafter with reference to FIGURES 17, 17A, 18 and 18A.

The movement of the control shaft **163** may be initiated by operation of the actuators **176**, **178** and **179** which are controlled from the pilot's control column.

As described above, each of the actuators **176**, **178** and **179**, is attached by a conduit **253** to one of the nozzles **251**. The relative positions of the associated nozzles and actuators are 90° out of phase as will now be described. Thus referring to FIGURES 13 and 13A it will be seen that the nozzle **251*a*** lies on the longitudinal axis of the aircraft which is indicated by the arrows. The nozzle **251*a*** is connected to the actuator **176** which, as will be seen from FIGURE 3, is on the lateral axis of the aircraft and, in a clockwise direction, is 90° in advance of the nozzle **251*a***. Similarly, the nozzle **251*b*** is connected to the actuator **178** which, as will be seen from FIGURE 13A, is 90° in advance of the nozzle in a clockwise direction. Finally, the nozzle **251*c*** is connected to the actuator **179** which is 90° in advance of the nozzle in a clockwise sense.

The actuators **176**, **178** and **179** are caused to operate by variations in pressure in the conduits **253**. As mentioned above, the plenum chamber **247** in the double-walled sleeve **246**, is provided with high pressure air bled from the compressors of the gas turbine engines. This high pressure air flows through the inner stack pipes **252** of each of the nozzles **251** and, due to the presence of the plate **271**, maintains a pressure in each of the conduits **253**. If the plate **271** (see FIGURE 12) is spaced by an equal distance from each nozzle then the pressure produced in each of the conduits **253** is equal. Suppose now that the plate **271** is equally spaced from the nozzles **251** when the plate is horizontal and that the pilot pulls the handle **257** in a rearward direction. The rod **256** will flex above the bearing **254** and the plate **271** will tilt so that it will move away from the nozzle **251*a*** and will move towards the nozzles **251*b*** and **251*c***. As a result, the pressure in the conduit **253** connected to the nozzle **251*a*** will decrease and the pressure in the other two conduits will increase. As a result of the decrease in the pressure in the nozzle **251*a***, the pressure in the actuator **176** will be reduced and the pressure in the other two actuators **178**, **179** will be increased due to the increase of pressure in their associated nozzles **251*b*** and **251*c***. Due to the changes in pressure the actuators will apply a force to the control shaft tending to move its lower end towards the actuator **176**, i.e. in a direction at 90° to the direction at which the pilot first moved the handle **257**. Similarly, any force applied to the control shaft by the actuators **176**, **178** and **179** acts in a direction advanced 90° in a clockwise sense from the direction in which the pilot moves his handle **257** so that if the pilot moves the handle **257** to his left the force applied to the control shaft by the actuators **176**, **178** and **179** will tend to move it forwardly.

The hand wheels **280**, **281** may be used to trim the aircraft by providing a fine adjustment for the positions of the nozzles **251** relative to the plate **271**. By rotation of the cam wheels **274** and **275**, the sleeve **273** together with the associated double-walled sleeve **246** and the nozzles **251** may be adjusted about two axes at right angles. Thus fine adjustment of the distance between the outlets of the nozzles **251** and the plate **271** may be obtained with correspondingly fine adjustment of the position of the control shaft **163** by means of the actuators **176**, **178** and **179**.

As mentioned above, the rudder actuators **236** are connected to conduits **270** which lead to nozzles **268** associated with the tongue **260** at the base of the control column. If the pilot rotates the handle **257** the tongue **260** is moved by the cam **259** so that it moves closer to one of the nozzles **268** and further away from the other nozzle. By moving the tongue **260**, therefore, the relative pressures in the conduits **270** may be varied and, as will be seen from FIGURE 11, each conduit **270** is connected to each of the actuators **235** but between the actuators the conduits are crossed so that the rudder vanes in both groups will move in the same clockwise or anticlockwise sense.

It will thus be seen that the pilot can control the aircraft in yaw by rotation of the handle **257**.

The aircraft may be considered to have a body structure and engine means within the structure to provide propulsive gas, the engine means including the rotor **45** and the gas turbine engines **72**, **73**, **74**. The aircraft has an outlet nozzle **86** which is arranged to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the body structure. The primary gas deflecting means are associated with the nozzle and are operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle **86** at any selected position of the multiplicity of positions at which the outlet nozzle discharges the propulsive gas. The rotor **45** comprises a gyroscope which is rotatable about a spin axis and the gyroscope has a neutral position relative to the body structure, the neutral position being with the rotor horizontal when the aircraft is horizontal and with the spin axis vertical and parallel, in this particular aircraft coincident, with the yaw axis of the aircraft. In all the drawings, except FIGURE 29, the rotor is shown in its neutral position.

The springs **230** acting through the bell-cranks **226** and the cables **188** provide means which bias the rotor to its neutral position within the body structure although they allow the rotor to move relatively to the body structure. The springs **230** and the cables **188** also cause the rotor to tilt from an original steady state position when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis when the rotor is in said original position. Thus, to take an example, suppose that the rotor is rotating in its neutral position, which may be considered as an original steady state position, with its spin axis vertical then, if the aircraft acquires a rotational velocity about a turn axis normal to said spin axis, in this example about a horizontal axis, the rotor will be caused to tilt from its original position by virtue of the springs **230** and the cables **188**.

The cables **188** with their associated links **184**, **185** at the inboard ends thereof and with the bell-cranks **226** at the outboard ends thereof constitute a link system interposed between the gyroscope, constituted by the rotor, and the primary gas deflecting means, constituted by the baffles **220**, **221**. Moreover, the link system operates the baffles as described with reference to FIGURE 28 in a manner determined by the tilted position of the rotor. The cables **188** radiate from the control shaft **163** and constitute individual links of the link system and it will be seen that the individual links may be considered to be operatively coupled to correlated portions of the gas deflecting means spaced around the periphery. Moreover, links of the system which are operatively coupled to peripherally opposite portions of the gas deflecting means are interconnected by being connected at their inboard ends to the control shaft **163**.

Referring to FIGURES 28 and 29, for any given tilt of the rotor, opposite peripheral portions of the gas deflecting means lying adjacent to a control plane are operated. The control plane contains the position of the spin axis corresponding to the neutral position of the rotor and is advanced in the direction of rotation of the rotor by a phase angle α, in this case, 20°, relative to the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor. Thus in FIGURE 28 the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor is the north-south plane and the control plane is advanced 20° clockwise, i.e. in the direction of rotation of the rotor, relative to the north-south plane. The opposite peripheral portions of the gas deflecting means operated by tilt of the rotor are indicated by the sectors **400** and **401** in FIGURE 28.

Referring now to FIGURES 14, 15 and 16, the functioning of the control system of the aircraft there shown is the same as the functioning of the aircraft shown in FIGURES 1 to 13 with the exception that operation of the slide 305 replaces operation of the baffles 203 and 204 of the first embodiment. When the slide 305 is in a position such that its apertures 310 are in register with the gas entry ports 302 in the outboard body structure, propulsive gas enters the gas entry ports 302 and is deflected by the channel member 194 so that the gas issues from the slots 201 and 202 all around the periphery of the aircraft in the form of directing streams. It will be seen from FIGURE 15 that the gas will issue in streams having inboardly directed components of velocity and that these streams will assist the propulsive gas discharged from the outlet nozzle 86 to flow around the upper and lower radiused webs 77, 78 and the guide vanes 199 and 200. The proportion of the total propulsive gas which flows through each of the upper or lower peripheral nozzles will be controlled by the primary gas deflecting means, i.e. by the baffles 220 and 221, in a manner similar to that described for the aircraft shown in FIGURES 1 to 13.

If the slide 305 is moved so that the gas entry ports 302 in the rear portion of the outer body are closed by the slide, then propulsive gas around the rear portion of the aircraft will be prevented from entering the gas entry ports 302. Under these circumstances, gas moving radially outboardly from the outlet nozzle 86 around the rear portion of the aircraft will impinge upon the rear portion of the outboard body structure, will divide and will flow over both the upper and lower surfaces of the outboard body structure.

The functions of the various controls in the embodiment of the invention as shown in FIGURES 17 and 17A are the same as the similar controls with reference to the aircraft shown in FIGURES 1 to 13. However, due to the omission of the links 185, the phase angle of the control system is 0°, i.e. the control plane adjacent to which the portions of the baffles 220, 221 are most affected for a given tilt of the rotor will be coincident with the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor.

Thus, referring to FIGURE 28 and assuming that the rotor tilts in a southerly direction from its neutral position, the lower end of the control shaft will move northerly. As before, the north-south plane will contain the positions of the spin axis corresponding to the neutral and tilted positions of the rotor. Since, however, the inboard ends of the cables are connected directly to the links 184 the control plane will also be the north-south plane, i.e. the plane containing the positions of the spin axis for the neutral and tilted positions of the rotor.

The aircraft will be subjected to a moment which, as before, may be resolved into two components, a first component in the north-south plane applying a pitching moment to the aircraft and a second component in the east-west plane applying a rolling moment to the aircraft. However, since the phase angle in this case is 0° and since the first component is proportionl to the cosine of the phase angle and the second component is proportional to the sine of the phase angle, it follows that the second component will be zero so that the resulting moment will be in the control plane. This moment amplifies the gyro-couple applied to the aircraft by the tilting of the rotor within the aircraft. Thus as the rotor tilts in a southerly direction it will apply a moment to the aircraft tending to pitch the aircraft nose up. The resulting movement of the baffles 220, 221 will be to retract the baffle 221 and advance the baffle 220 at the forward portion of the aircraft and retract the baffle 220 and advance the baffle 221 at the rear portion of the aircraft. The aircraft will therefore be given a nose-up pitching moment which, as will be seen, amplifies the nose-up pitching moment imparted to the aircraft due to pitching of the rotor within the aircraft. The gyro-couple applied to the aircraft by pitching of the rotor is applied to the aircraft through the springs 230.

The functions of the various controls in the embodiments shown in FIGURES 18 and 18A are the same as the similar controls described with reference to the aircraft shown in FIGURES 1 to 13. However, in FIGURES 18, 18A, the phase angle of the control system is 90° so that the control plane for the system is advanced 90° in the direction of rotation of the rotor. Thus, due to the interposition of the right-angled links 350, if the rotor tilts in a southerly direction and the lower end of the control shaft moves in a northerly direction the cables 188 to the East will be moved outboardly and the cables 188 to the West will be moved inboardly. As a result the baffles 220, 221 will be operated to apply a rolling moment to the aircraft about its longitudinal axis tending to roll the aircraft in an anti-clockwise direction when viewed from the rear. The rotor may be caused to pitch in a southerly direction if the aircraft attains a rotational velocity tending to turn it to a clockwise direction upon its longitudinal axis when viewed from the rear. It will therefore be seen that the moment applied to the aircraft is such as to directly oppose the rotational velocity which the aircraft has acquired. The general statement that the couple applied to the aircraft may be resolved into two components proportional to the cosine of the phase angle and the sine of the phase angle still holds good. However, since the phase angle is 90° the component proportional to the cosine of the angle, i.e. the component which tends to amplify the gyro-couple applied to the aircraft, is zero and only the component tending to roll the aircraft and to directly oppose the rotational velocity acquired by the aircraft is actually applied to the aircraft.

The functioning of the control system of the aircraft shown in FIGURES 19, 20 and 21 is the same as that of the control system of the aircraft shown in FIGURES 1 to 13, with the exception that operation of the flaps 324 replaces operation of the baffles 203, 204 of the aircraft of FIGURES 1 to 13.

When the flaps 324 are in their first position (shown in full lines in FIGURE 21), gas issuing through the lower peripheral nozzle due to the operation of the primary gas deflecting means will be directed substantially inboardly and downwardly. Conversely, gas issuing through the upper peripheral nozzle due to operation of the primary gas deflecting means will be deflected generally inboardly and upwardly. If now the flaps 324 are moved to their second positions (shown in phantom lines in FIGURE 21), propulsive gas issuing from the forward portion of the lower peripheral nozzle will still be directed generally inboardly and downwardly. However, gas issuing from the rear portion of the lower peripheral nozzle will pass generally downwardly and outboardly and will give to the aircraft a forward and upward thrust.

The operation of the embodiment of the aircraft described in FIGURES 1 to 13 will now be described. The aircraft is capable of taking off and landing vertically and of assuming forward flight after it has risen to a desired height. The aircraft is provided with a control system which is under the control of the pilot and also with an automatic control system to reduce the divergence of the aircraft incident upon a disturbance which imparts to the aircraft a rotational velocity about a turn axis lying normal to the spin axis of the rotor. The control system reduces the divergence of the aircraft incident upon rolling or pitching moments, i.e, moments tending to impart a tilt rate to the aircraft.

When the gas turbine engines 72, 73, 74 are started, air and exhaust gas flow outboardly along the gas displacement passage, through the outlet nozzle and, depending on the positions of the primary gas deflecting means, through either or both of the upper and lower peripheral nozzles. For take-off, the controls are set in such a position that the secondary gas deflecting means, i.e. the baffles 203, 204, project into the upper and lower peripheral nozzles equally around the whole periphery of the aircraft. The primary gas deflecting means is operated to divert substantially the whole of the propulsive gas through the lower peripheral nozzle and to this end the actuator **166** is operated to retract the baffle **221** into the slots **80** and to project the baffle **220** from the slots **79**. Propulsive gas therefore flows outboardly along the gas displacement passage, but its flow along the upper wall of the passage is interrupted by projection of the baffle **220** and the gas passes downwardly and inboardly through the lower peripheral nozzle. The gas tends to flow along the guide vanes **200** and along the covering of the lower radiused webs **78** of the ribs of the inboard body structure by virtue of the Coanda effect. This downward and inboard flow is assisted by the projection of the baffle **204** which interrupts flow of gas along the lower surface of the outboard body structure. Air is induced to flow through the upper peripheral nozzle by the flow of propulsive gas through the lower peripheral nozzle and this induced air flow is indicated by the arrows in FIGURES 22 and 23 and joins the main flow of gas to increase its thrust slightly.

The general pattern of flow is shown in FIGURE 22 from which it will be seen that the gas flows inboardly and downwardly until it is adjacent to the ground when it curls outboardly. With this setting of the controls it has been found that, when the aircraft is adjacent to the ground, the gas ejected from the aircraft forms a downwardly moving tubular curtain which provides thrust augmentation for landing and take-off. This thrust augmentation when the aircraft is adjacent to the ground is known as the "ground cushion effect" and is obtained with a downwardly moving tubular curtain of gas as described.

As the aircraft rises, the tubular curtain of gas becomes substantially solid as shown in FIGURE 23. When the aircraft is at a substantial height above the ground the propulsive gas leaving the lower peripheral nozzle is able to move inboardly to a greater extent than when the aircraft is adjacent to the ground, and the streams from the various portions of the periphery of the aircraft merge to form a solid jet of downwardly moving gas which propels the aircraft upwardly.

When hovering in free air as shown in FIGURE 23, the upward thrust on the aircraft is greater than the static thrust of the engines. It is believed that the thrust augmentation in free air is due to the following facts:

(1) The gas discharged from the lower peripheral nozzle has a large surface area and entrains a substantial quantity of the ambient air. This entrainment increases the mass flow and reduces the speed of the gas flow.

(2) The propulsive gas issuing from the lower peripheral nozzle and the entrained ambient air is caused to traverse the lower aerofoil surface and is deflected downwardly away from the surface with components of velocity generally normal thereto. This downward deflection causes an upward reaction on the surface which provides a lift force for the aircraft.

The propulsive gas is caused to traverse the lower aerofoil surface by means of the primary and secondary gas deflecting means; the baffles **220, 221** and **203, 204** respectively as hereinbefore explained. The gas discharged from the nozzle is "bent" inboardly, and the flows of gas coming towards the center of the surface from opposing directions meet adjacent to the center and, since the gas cannot move upwardly due to the presence of the lower aerofoil surface, the gas is deflected downwardly thus providing the upward reaction on said lower surface.

When the aircraft has reached the desired height, the pilot operates the controls to transfer the aircraft from hovering to forward flight. This is accomplished by moving the secondary gas deflecting means, i.e. the baffles **203, 204**, so that they are fully retracted at the rear portion of the aircraft and project fully at the forward portion of the aircraft, while at the same time operating the actuator **166** to raise the baffles **220, 221** until they both project to approximately an equal extent into the gas displacement passage. In this position of the controls the gas flow through the upper and lower peripheral nozzles will be substantially equal all around the aircraft as shown in FIGURE 24. Since the secondary gas deflecting means, i.e. the baffles **203, 204**, at the forepart of the aircraft project from the outer body structure, the propulsive gas leaving the forward portion of the outlet nozzle is caused to flow around the guide vanes **199** and **200** as may be seen from FIGURE 24. Since the baffles **220, 221** each project from the upper and lower walls of the gas displacement passage the flow of gas is interrupted on both walls but the gas is caused to flow around the guide vanes **199, 200** by the Coanda effect. The Coanda effect is assisted by the fact that the gas is not permitted to flow smoothly around the forward portion of the skin of the outer body structure due to the projection of the baffles **203, 204** at the forward portion of the aircraft.

At the rear portion of the aircraft, however, where the baffles **203, 204** are retracted, the gas is able to pass substantially radially outboardly and is caused to follow the outer surface of the outboard body structure due to the Coanda effect. This results, as will be seen from FIGURE 24, in a generally backwardly and downwardly deflected stream of propulsive gas. The gas flowing through the lower peripheral nozzle in the forward portion of the aircraft is constrained to flow along the underside of the aircraft as shown, and meets the gas ejected from the upper and lower peripheral nozzles at the rear of the aircraft. As a result the aircraft is propelled forwardly and also obtains some lift from the downward direction of the rearwardly discharged propulsive gas. Moreover, since the aircraft cross section is an aerofoil, as the aircraft moves forwardly it experiences aerodynamic lift in a manner similar to the wings of a conventional aircraft.

The response of the aircraft to the automatic stabilization system and to the pilot's control system will now be considered. However, before considering the response in detail it is necessary to mention several points. As has been pointed out above, the aircraft can hover above the ground and it can also move in forward flight; in forward flight, the response of the aircraft is affected by a de-stabilizing moment which does not affect it when hovering. The aircraft which have been described are generally disc-shaped and the centers of gravity of these aircraft are approximately at the centers of the discs. On the other hand, since the sheathing of the aircraft causes the aircraft to act as an aerofoil, the center of pressure is approximately one-third of the chord length behind the leading edge. Thus the center of pressure is in front of the center of gravity during forward flight. It follows that, if the aircraft hits an up-gust in forward flight the angle of attack of the aircraft will increase which will increase the lift which, in turn, will increase the pitching moment since the center of pressure is in front of the center of gravity. A converse effect will occur with a nose down pitching moment: as the aircraft pitches nose down the angle of attack decreases, which decreases the lift which decreases the angle of attack, and so on.

With the aircraft described, since there are no tail surfaces, the destabilizing moment causes a divergence in pitch which is extremely rapid so that, in forward flight if there were no correction, the aircraft would be overturned in a matter of one or two second after hitting a gust. This rate of divergence is so rapid that the pilot cannot control it manually.

In hovering, there is no destabilizing moment since the center of pressure and the center of gravity are in line. If the aircraft hits a gust while hovering the gust will tend to tip the aircraft but, since a gust may be considered to be an impulse and since there is no destabilizing moment, there will be no steady divergence; the divergence will be transient but will still be so rapid as to normally be beyond the manual control of the pilot.

It follows that both in forward flight, and in hovering, an automatic stabilization system is required to reduce the rate of divergence. The automatic stabilization system provided by the invention is so interconnected with the pilot's control system that the pilot controls the aircraft through the operation of the automatic stabilization system. The automatic stabilization system is brought into operation when the aircraft acquires a rotation velocity about a turn axis normal to the spin axis when the latter is in a steady state position; in other words the system operates if the aircraft acquires a tilt rate (be it a pitch rate or a roll rate). The aircraft may acquire a rate from an outside disturbance, e.g. a gust, or by a pilot input to the control system.

Another point which should be considered is that the aircraft will respond more readily to low frequency forces than to high frequency forces. The forces applied to the aircraft by the control system are, at least in part, a combination of high frequency and low frequency forces; for example the characteristic frequencies of the control system may be 3 cps., 15 cps. and 40 cps. However, the aircraft will respond more or less only to the low frequency forces, the high frequency movements of the control system being confined almost entirely to the control system.

The response of the aircraft will be described with reference to FIGURES 30 to 34 which show a series of graphs; each response is described by six graphs. The graphs show the following displacements and velocities:

(A) The roll angle of the aircraft in radians,
(B) The roll rate or roll velocity of the aircraft in radians per second
(C) The pitch angle of the aircraft in radians,
(D) The pitch rate or pitch velocity of the aircraft in radians per second,
(E) The amount of roll of the rotor within the aircraft measured as a percentage of its maximum roll which is set by structural limitations and may, for example, be ±¼° from the neutral position, and
(F) The pitch of the rotor within the aircraft measured as a fraction of its maximum pitch which is limited as is the maximum roll.

The response of the aircraft will depend on the phase angle between movement of the control shaft **163** and movement of the primary gas deflecting means which includes the baffles **220**, **221**. The damping of the system increases, up to a point, with an increase in phase angle. A system with zero phase angle has no built-in damping while a system with a 90° phase angle has considerable built-in damping as will be apparent from the following discussion. As described above with reference to FIGURE 28, the phase angle of the embodiment of FIGURES 1 to 13 is 20° clockwise, i.e. in the direction of rotation of the rotor.

Referring to FIGURE 30, this shows the response of the aircraft of FIGURES 1 to 13 if, when it is hovering, the pilot moves his stick to the right. The amount which the stick is moved to the right is measured in terms of the resulting movement of the rotor, which is expressed as a percentage of the total permitted movement of the rotor in any direction, the various movements being considered as if the aircraft were on the ground with the rotor stationary. Thus, as mentioned above, the total movement of the rotor in any direction from its neutral position might be ¼°, therefore if the pilot moves his stick 10% to the right this will mean that he has moved his stick sufficiently so that, with the aircraft on the ground and the rotor stationary, the rotor would move from its neutral position by 10% of ¼°. As explained above, movement of the control column is 90° out of phase with the resulting force applied to the control shaft so that as the pilot moves his stick to the right the actuators will apply a pitching moment to the rotor by rocking the control shaft **163**. Moreover the graphs have been prepared on the assumption that the pilot's input is a step input, i.e. a sudden input and not a slow movement in the desired direction.

Returning to FIGURE 30, as a result of the pilot's movement of the stick to the right he applies, through the control shaft **163**, a pitching moment to the rotor which, as a result, acquires a pitch velocity, or pitch rate; as soon as it acquires this rate it is affected by the gyroscopic laws of motion and precession. By reference to graphs E and F of FIGURE 30 it will be seen that the rotor initially oscillates both in roll and in pitch and then acquires a steady state with a deflection in pitch and rather less of a deflection in roll. As the rotor oscillates, it operates the control system through the control shaft but the oscillations are of too high frequency to have much effect on the aircraft. In the final steady state, the deflection of the rotor is transmitted through the control shaft to operate the primary gas deflecting means to apply a moment to the aircraft which can be resolved into two components about the lateral and longitudinal axes of the aircraft. The component about the longitudinal axis of the aircraft overcomes the aerodynamic damping of the aircraft due to the internal flow of the propulsive gas through the gas displacement passage. Thus on one side of the longittudinal axis of the body of the aircraft tries to move the radially flowing gas downwardly whereas on the other side of the axis the body will tend to move the gas upwardly. The gas will oppose this movement with a force proportional to its mass, its radial velocity and the angular velocity of the aircraft. The component about the lateral axis of the aircraft is employed in overcoming the gyroscopic moment and causes the aircraft to roll.

Graphs A and B of FIGURE 30 show that, after initial oscillation in its roll rate, the aircraft acquires a substantially steady roll rate and a steadily increasing roll angle. Graphs C and D of FIGURE 30 show that the aircraft is substantially undisturbed in pitch but has initially an oscillating pitch rate which is damped out. The graphs show that the aircraft responds substantially only to the low frequency components of the rotor oscillations shown in graphs E and F.

FIGURE 31 shows the response of the aircraft of FIGURES 1 to 13 if, when it is hovering, it encounters a steady rolling moment which is the approximate situation which might arise if the aircraft encountered a sudden side gust. The rolling moment imparts an increasing roll rate to the aircraft (graph B) and it will be seen that the rotor lags slightly behind the movement of the aircraft. The rotor then begins to catch up with the aircraft in roll and acquires a roll rate. Once the rotor acquires a roll rate it will follow the gyroscopic laws and its movement will be as shown in graphs E and F of FIGURE 31. It will be seen that after initial oscillation the rotor reaches a comparatively steady state with a deflection in roll and rather less of a deflection in pitch. The deflection of the rotor is transmitted through the control shaft **163** to operate gas deflecting means to reduce the divergence of the aircraft.

Graphs A and B of FIGURE 31 show that, after an initial sharp increase in roll rate, the roll rate decreases to a substantially steady value and the roll angle steadily increases. Graphs C and D show that the pitch velocity increases rapidly and settles down to a comparatively steady value and the pitch angle increases steadily. The divergence in pitch and roll is sufficiently slow for the pilot to be able to correct it.

FIGURES 32, 33 and 34 show the response of the aircraft of FIGURES 1 to 13 when in forward flight. FIGURE 32 shows the response of the aircraft to the pilot moving his control column 10% to the right, the 10% movement being defined as above. The pilot input applies a pitching moment to the rotor which thus acquires a pitch rate and then follows the gyroscopic laws. The initial portions of the graphs of FIGURE 32 are substantially similar to the graphs of FIGURE 30, that is to say, the disturbance induced by the pilot produces, after the initial transient oscillations, a substantially constant roll rate with virtually zero pitch rate. However, since the aircraft has been caused to pitch to some slight extent, as will be seen from graph C of FIGURE 32, the de-stabilizing moment described above affects the performance of the aircraft. As a result the roll rate and the pitch rate diverge from their substantially steady states. The general overall effect of the de-stabilizing moment is to roll the aircraft, thus increasing the roll rate, which in turn increases the gyro-couple in pitch and causes an increase in pitch rate, which in turn increases the de-stabilizing moment and so on. However, the divergence is sufficiently slow to be controlled by the pilot.

FIGURE 33 shows the response of the aircraft to the pilot moving the stick 10% forward. Whereas in the response shown in FIGURE 32 the effect of the de-stabilizing moment was of secondary importance, since the main output was in roll, in FIGURE 33 the de-stabilizing moment is of primary importance and produces much more rapid divergence in roll rate and pitch rate. The pilot input applies a rolling moment to the rotor which acquires a roll rate and thereafter follows the gyroscopic laws of motion. The effect is essentially similar to that of FIGURE 32 except for the effect of the de-stabilizing moment which prevents the acquisition of steady roll and pitch rates. Thus as the aircraft begins to pitch nose down, the lift decreases, which in turn increases the nose-down pitch, which decreases the lift and so on as explained above. Graphs B and D of FIGURE 32 show the diverging roll rate and pitch rate but the divergence is sufficiently slow to be corrected by the pilot.

FIGURE 34 shows the response of the aircraft when it encounters a sharp edged gust having a speed of 10 ft. per second. In a gust in forward flight the disturbing moment on the aircraft varies due to the movement of the aircraft and should be distinguished from the situation in FIGURE 31 where it is assumed that a steady moment is applied to the aircraft while it is hovering. Referring to FIGURE 34, the gust applies a pitching moment to the aircraft which therefore acquires a pitch rate. The rotor lags slightly and then it also acquires a pitch rate and consequently starts to roll. In rolling, the rotor applies a rolling moment to the control system which starts to roll the aircraft. The resulting motions of the aircraft and the rotor are as shown in the graphs of FIGURE 34. The initial, comparatively high transient values of roll rate and pitch rate are reduced to comparatively small values but diverge due to the de-stabilizing moment as described above. It will be seen that the aircraft is displaced in both roll and pitch but more in roll than in pitch. As before, the divergence is sufficiently slow for the pilot to be able to control the aircraft.

When the aircraft is in forward flight, in addition to there being aerodynamic damping due to the internal air flow as described above, there is also external aerodynamic damping of the aircraft due to the flow of air over the external skin of the aircraft.

It will be seen that the control system operates to reduce the divergence of the aircraft following a disturbance to values which can be corrected by the pilot. Without the automatic stabilization system the aircraft could be overturned in a pitching gust too quickly for the pilot to be able to control the movement.

The operation of the aircraft shown in FIGURES 14, 15 and 16 is the same as the operation of the aircraft described with reference to FIGURES 1 to 13 with the exception of the operations required to change from hovering to forward flight, and vice versa.

As explained above, when the slide **305** is in such a position that the apertures **310** therein are in register with the gas entry ports **302** in the outboard body structure, then propulsive gas enters the gas entry ports and is deflected by the channel member **194** to produce directing streams of gas. For take-off, the slide **305** is arranged so that the apertures **310** are in register with the gas entry ports **302** and the primary gas deflecting means is arranged so that substantially the whole of the propulsive gas is discharged through the lower peripheral nozzle. The general flow of propulsive gas for take-off is indicated in FIGURE 26.

The flow of propulsive gas through the lower peripheral nozzle induces air to flow through the upper peripheral nozzle and also through the gas entry ports **302** and the lower slot **202**. This induced flow of air helps to break away the flow of propulsive gases from the outboard body structure and, due to the Coanda effect, the propulsive gas passes downwardly and inboardly round the lower skin of the aircraft. It is found that with the controls in this position the gas ejected from the aircraft forms a downwardly moving tubular curtain of gas which curls outboardly adjacent to the ground as shown in FIGURE 26. Comparing FIGURE 26 with FIGURE 22 it will be seen that the inboard deflection of the gas is less in FIGURE 26 than in FIGURE 22, this is because the baffles on the outer body structure in the embodiment of FIGURE 22 are more efficient in breaking away the flow from the outboard body structure than is the flow of air induced through the outboard body structure in the embodiment of FIGURE 26. It is found that, with an arrangement similar to that shown in FIGURE 26 but without the central stabilizing nozzle, an annular zone of negative pressure occurs under the aircraft adjacent to the center thereof. To relieve this zone of negative pressure the central stabilizing nozzle **313** is provided and some propulsive gas is ejected from this nozzle: this eliminates the zone of negative pressure and increases the upthrust of the aircraft.

To change from hovering to forward flight, the pilot operates the switch **295** on his control column to move the slide **305** so that the apertures **310** in the slide move out of register with the gas entry ports in the rear portion of the outer body structure. At the same time the pilot operates his controls to move the primary gas deflecting means so that gas will flow radially outboardly through the outlet nozzle, i.e. so that the upper and lower baffles **220**, **221** project into the gas displacement passage by equal amounts. With this setting of the controls, propulsive gas ejected from the rear portion of the outlet nozzle will flow over the upper and lower surfaces of the outboard body structure as indicated in FIGURE 27, since the gases are prevented from flowing round the upper and lower skins of the aircraft by virtue of the projection of the baffles of the primary gas deflection means.

Around the forward portion of the aircraft, propulsive gas enters the gas entry ports **302** and is deflected both upwardly and downwardly by the channel member **194** so that it appears as directing streams of gas directly upwardly and inboardly, and downwardly and inboardly, respectively. These directing streams of gas assist the remainder of the propulsive gas to flow upwardly and downwardly around the guide vanes **199** and **200**, and rearwardly along the upper and lower surfaces of the aircraft. Gas ejected from the central stabilizing nozzle **313** joins the gas moving along the lower surface of the aircraft and passes rearwardly until it meets the gas ejected from the rear portion of the aircraft. It will be seen from FIGURE 27 that the resultant rearward flow is directed somewhat downwardly, and therefore the aircraft is propelled both upwardly and forwardly.

In all flight regimes, the control and stabilization of the aircraft of FIGURES 14, 15 and 16 in pitch, roll and yaw is precisely the same as for the aircraft described with reference to FIGURES 1 to 13.

Referring now to FIGURES 17 and 17A, these illustrate a control system having a zero phase angle between movement of the control shaft and resulting movement of the primary gas deflecting means. The system has no built-in damping, and the couple applied to the aircraft as a result of a disturbing force, either external or pilot induced, will amplify the gyro-couple applied to the aircraft by tilt of the rotor axis.

Using the directional convention set out above, if the aircraft is hovering and the pilot pushes his stick 10% to the right, the actuators **176**, **178** and **179** will apply a pitching moment to the rotor through the control shaft. The rotor will acquire a pitch rate and will follow the gyroscopic laws.

FIGURE 35 shows the response of the aircraft of FIGURES 17 and 17A to a pilot moving his stick 10% to the right while the aircraft is hovering. The response is similar to the response shown in FIGURE 30 of the aircraft of FIGURES 1 to 13 for a similar input, except that the motion is undamped save by the aerodynamic damping due to the internal flow of gas through the gas displacement passage. Comparison of the graphs of FIGURE 35 with those of FIGURE 30 will show how the oscillations of the system are damped out by increasing the phase angle to 20°. That is to say, the response of FIGURE 35 differs essentially from the response of FIGURE 30 by the superimposition of an oscillation on the steady roll rate and the steady pitch rate of FIGURE 30 and also on the roll and pitch of the aircraft and of the rotor. While it would be possible to fly an aircraft having such control system it would be rather less comfortable for the pilot than the aircraft of FIGURES 1 to 13.

FIGURE 36 shows the response of an aircraft having the control system of FIGURES 18 and 18A which has a phase angle of 90°. Comparison of FIGURE 36 with FIGURES 35 and 30 shows that the response is similar to the responses in FIGURES 30 and 35 but is more damped than in either of said systems. Thus as the pilot applies a pitching moment to the rotor, the rotor acquires a pitch rate and follows the gyroscopic laws as shown in the graphs. In the final steady state the rotor has a displacement in roll and rather less a displacement in pitch. The tilted rotor operates the gas deflecting means to apply a couple to the aircraft which is similar to the couple applied to the aircraft in the response of FIGURE 30 but, due to the different phasing, the position of the rotor to apply the couple is different from FIGURE 30. It will be seen that the system is extremely well damped and therefore would be more comfortable to fly than the aircraft shown in FIGURES 1 to 13. However, a disadvantage of such a system is that the time required to produce a given rate would be unnecessarily large and therefore it is desirable to compromise between a zero phase angle and a 90° phase angle, to provide a system which is partially damped but yet has rapid response. Such a compromise can be obtained with a phase angle of 20° as described with reference to FIGURES 1 to 13 and to the responses shown in FIGURES 30 to 34.

Referring now to FIGURES 19, 20 and 21, the control and stabilization of the aircraft there shown in pitch, roll and yaw is, in all flight regimes, similar to the control of the aircraft of FIGURES 1 to 13. The only difference is in the operations required to change from hovering to forward flight.

For hovering, the primary gas deflecting means are arranged so that substantially the whole of the propulsive gas passes downwardly and inboardly through the lower peripheral nozzle. When the aircraft has risen to the desired height the pilot operates his controls to move the flaps **324** to their second position, but he retains the primary gas deflecting means in their original position so that substantially the whole of the propulsive gas is discharged through the lower peripheral nozzle. In forward flight, therefore, propulsive gas issues from the forward portion of the lower peripheral nozzle and passes inboardly and downwardly, whereas the gas which issues through the rear portion of the lower peripheral nozzle passes outboardly and downwardly. The aircraft is propelled forwardly and upwardly in a manner similar to the aircraft previously described. The upper peripheral nozzle is only employed for control purposes and the operation of the control system is the same as that of the control system described with reference to FIGURES 1 to 13.

The term "aircraft" is used in the specification and claims in its broadest connotation of a craft which is propelled through the air but is not necessarily sustained thereby. The term is intended to include, where appropriate, vehicles which do not fly in the generally accepted sense of the word but "skim" over the surface of land or water sustained by generally downwardly directed streams of propulsive gas.

It will be understood that the forms of the invention herewith shown and described are preferred examples and that various modifications can be carried out without departing from the spirit of the invention or the scope of the appended claims.

What we claim as our invention is:

1. A control system for an aircraft having a body structure; engine means within the structure to provide propulsive gas; and an outlet nozzle to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising gas deflecting means associated with the nozzle and operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle at any selected position of said multiplicity of positions; a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor being mounted within the structure to have a limited degree of universal movement; biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure with consequent tilting of the rotor from its neutral position when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; and a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilting of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around the periphery; operation of the gas deflecting means as a result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from the outlet nozzle to reduce the divergence of the aircraft incident upon said disturbance.

2. A control system for an aircraft having a body structure; engine means within the structure to provide propulsive gas; and an outlet nozzle to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising gas deflecting means associated with the nozzle and operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle at any selected position of said multiplicity of positions; a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor being mounted within the structure to have limited degree of universal movement; biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure with consequent tilting of the rotor from its neutral position when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; and a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around the periphery and links operatively coupled to peripherally opposite

portions of the gas deflecting means being interconnected; the response of the link system to tilt of the rotor causing operation of opposite peripheral portions of the gas deflecting means; operation of the gas deflecting means as a result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from peripherally opposite portions of the outlet nozzle to apply a couple to the aircraft to reduce the divergence of the aircraft incident upon said disturbance.

3. A control system for an aircraft having a body structure; engine means within the structure to provide propulsive gas; and an outlet nozzle to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising gas deflecting means associated with the nozzle and operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle at any selected position of said multiplicity of positions; a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor mounted within the structure to have a limited degree of universal movement, biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure, with consequent tilting of the rotor from its neutral position and application of a gyro-couple to the aircraft, when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; and a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around the periphery and links operatively coupled to peripherally opposite portions of the gas deflecting means being interconnected; the response of the link system to tilt of the rotor causing operation of opposite peripheral portions of the gas deflecting means lying adjacent to a control plane which contains the position of the spin axis corresponding to the neutral position of the rotor and is advanced in the direction of rotation of the rotor by a phase angle α relative to the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor, the phase angle having a value of between 0° and 90° inclusive; operation of the gas deflecting means as a result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from peripherally opposite portions of the outlet nozzle to apply a couple to the aircraft to reduce the divergence of the aircraft incident upon said disturbance, the couple having a first component proportional to cosine α and which amplifies said gyro-couple and a second component proportional to sine α and which directly opposes said rotational velocity.

4. A control system for an aircraft having a body structure; engine means within the structure to provide propulsive gas, the engine means including a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor having a limited degree of universal movement; a gas displacement passage along which the propulsive gas is impelled by the rotor; and an outlet nozzle communicating with the gas displacement passage and arranged to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure with consequent tilting of the rotor from its neutral position when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; gas deflecting means associated with the nozzle and operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle at any selected position of said multiplicity of positions; and a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around said periphery; operation of the gas deflecting means as a result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from the outlet nozzle to reduce the divergence of the aircraft incident upon said disturbance.

5. A control system for an aircraft having a body structure; engine means within the structure to provide propulsive gas, the engine means including a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor having a limited degree of universal movement; a gas displacement passage along which the propulsive gas is impelled by the rotor; and an outlet nozzle communicating with the gas displacement passage and arranged to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure, with consequent tilting of the rotor from its neutral position and application of a gyro-couple to the aircraft, when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; gas deflecting means associated with the nozzle and operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle at any selected position of said multiplicity of positions; and a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around said periphery and links operatively coupled to peripherally opposite portions of the gas deflecting means being interconnected; the response of the link system to tilt of the rotor causing operation of opposite peripheral portions of the gas deflecting means lying adjacent to a control plane which contains the position of the spin axis corresponding to the neutral position of the rotor and is advanced in the direction of rotation of the rotor by a phase angle α relative to the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor, the phase angle having a value between 0° and 90° inclusive; operation of the gas deflecting means as the result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from peripherally opposite portions of the outlet nozzle to apply a couple to the aircraft to reduce the divergence of the aircraft incident upon said disturbance, the couple having a first component proportional to cosine α and which amplifies said gyro-couple and a second component proportional to sine α and which directly opposes said rotational velocity.

6. A control system for an aircraft having a body structure; engine means within the structure to provide propulsive gas; and an outlet nozzle arranged to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising gas deflecting means associated with the nozzle and operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle at any selected position of said multiplicity of positions; a rotor rotatable about a spin axis and being mounted within the structure to have a neutral posi-

tion relative to the body structure, the rotor having a limited degree of universal movement; biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure with consequent tilting of the rotor from its neutral position when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around said periphery; operation of the gas deflecting means as the result of a disturbance which imparts rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from the outlet nozzle to reduce the divergence of the aircraft incident upon said disturbance; and pilot operated means to operate all of said portions of the gas deflecting means in unison.

7. A control system for an aircraft having a body structure; engine means within the structure to provide propulsive gas; and an outlet nozzle arranged to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising gas deflecting means associated with the nozzle and operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle at any selected position of said multiplicity of positions; a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor being mounted within the structure to have a limited degree of universal movement; biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure with consequent tilting of the rotor from its neutral position when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; pilot operated means to apply a tilting moment to the rotor in a desired direction; and a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around said periphery; operation of the gas deflecting means as a result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from the outlet nozzle to reduce the divergence of the aircraft incident upon said disturbance and operation of said pilot means causing the rotor to tilt and operate the gas deflecting means to disturb the aircraft and to impart thereto a rotational velocity about a turn axis.

8. A control system for an aircraft having a body structure; engine means within the structure to provide propulsive gas, the engine means including a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor having a limited degree of universal movement; a gas displacement passage along which the propulsive gas is impelled by the rotor; and an outlet nozzle communicating with the gas displacement passage and arranged to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure with consequent tilting of the rotor from its neutral position when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; gas deflecting means associated with the nozzle and operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle at any selected position of said multiplicity of positions; pilot operated means to apply a tilting moment to the rotor in a desired direction; and a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around said periphery; operation of the gas deflecting means as a result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from the outlet nozzle to reduce the divergence of the aircraft incident upon the disturbance and operation of said pilot operated means causing the rotor to tilt and operate the gas deflecting means to disturb the aircraft and to impart thereto a rotational velocity about a turn axis.

9. A control system for an aircraft having a body structure; engine means within the structure to provide propulsive gas; and an outlet nozzle to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising gas deflecting means associated with the nozzle and operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle at any selected position of said multiplicity of positions; a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor being mounted within the structure to have a limited degree of universal movement; biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure, with consequent tilting of the rotor from its neutral position and application of a gyro-couple to the aircraft, when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; first pilot operated means to apply a tilting moment to said rotor in a desired direction; a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around the periphery and links operatively coupled to peripherally opposite portions of the gas deflecting means being interconnected; the response of the link system to tilt of the rotor causing operation of opposite peripheral portions of the gas deflecting means lying adjacent to a control plane which contains the position of the spin axis corresponding to the neutral position of the rotor and is advanced in the direction of rotation of the rotor by a phase angle α relative to the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor, the phase angle having a value of between 0° and 90° inclusive; and second pilot operated means to operate all of said portions of the gas deflecting means in unison; operation of the gas deflecting means as a result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from peripherally opposite portions of the outlet nozzle to apply a couple to the aircraft to reduce the divergence of the aircraft incident upon said disturbance, the couple having a first component proportional to cosine α and which amplifies said gyro-couple and the second component proportional to sine α and which directly opposes said rotational velocity; and operation of said first pilot operated means causing the rotor to tilt and operate the gas deflecting means to disturb the aircraft and to impart thereto a rotational velocity about a turn axis.

10. A control system for an aircraft having a body structure; engine means within the structure to provide propulsive gas, the engine means including a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor having a limited

degree of universal movement; a gas displacement passage along which the propulsive gas is impelled by the rotor; and an outlet nozzle communicating with the gas displacement passage and arranged to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure, with consequent tilting of the rotor from its neutral position and application of a gyro-couple to the aircraft, when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; first pilot operated means to apply a tilting moment to the rotor in a desired direction; a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around the periphery and links operatively coupled to peripherally opposite portions of the gas deflecting means being interconnected; the response of the link system to tilt of the rotor causing operation of opposite peripheral portions of the gas deflecting means lying adjacent to a control plane which contains the position of the spin axis corresponding to the neutral position of the rotor and is advanced in the direction of rotation of the rotor by a phase angle α relative to the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor, the phase angle having a value of between 0° and 90° inclusive; and second pilot operated means to operate all of said portions of the gas deflecting means in unison; operation of the gas deflecting means as a result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from peripherally opposite portions of the outlet nozzle to apply a couple to the aircraft to reduce the divergence of the aircraft incident upon said disturbance, the couple having a first component proportional to cosine α and which amplifies said gyro-couple and a second component proportional to sine α and which directly opposes said rotational velocity; and operation of said first pilot operated means causing the rotor to tilt and operate the gas deflecting means to disturb the aircraft and to impart thereto a rotational velocity about a turn axis.

11. A control system according to claim 10, including a control shaft arranged for rocking movement about a fulcrum fixed relatively to the body structure; means interconnecting one end of the control shaft and the rotor; a plurality of bell-cranks pivotally mounted on the control shaft; and an abutment movable relatively to the control shaft and co-operating with the bell-cranks to move the bell-cranks in unison; and wherein the link system comprises mechanical links radiating outboardly from the control shaft, each link being connected at its inboard end to one of said bell-cranks.

12. A control system according to claim 10, wherein the first pilot operated means includes a pilot's control column; a plurality of fluid conduits associated with the column, means associated with the column to vary the relative fluid pressures in said conduits upon movement of the column and a plurality of actuators connected to said conduits and arranged to apply a tilting moment to the rotor.

13. A control system according to claim 11, wherein the first pilot operated means comprises a pilot's control column; a plurality of fluid conduits associated with the column, means associated with the column to vary the relative fluid pressures in said conduits upon movement of the column and a plurality of actuators connected to said conduits and arranged to apply a tilting moment to said control shaft in a desired direction and thus apply a tilting moment to the rotor.

14. A control system according to claim 13, wherein the rotor is mounted in the body structure on spherical bearings arranged below the center of gravity of the rotor.

15. A control system for an aircraft having a lentiform body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces; engine means within the structure to provide propulsive gas, the engine means including a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor having a limited degree of universal movement; a gas displacement passage along which the propulsive gas is impelled by the rotor; and an outlet nozzle communicating with the gas displacement passage and arranged to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising biasing means associated with the rotor to bias the rotor to its neutral position and to allow relative movement between the rotor and the body structure with consequent tilting of the rotor from its neutral position when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; gas deflecting means associated with the nozzle and operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle at any selected position of said multiplicity of positions; and a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around said periphery; operation of the gas deflecting means as a result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from the outlet nozzle to reduce the divergence of the aircraft incident upon said disturbance.

16. A control system for an aircraft having a lentiform body structure sheathed by opposed aerofoil surfaces which provided lift developing surfaces; engine means within the structure to provide propulsive gas, the engine means including a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor having a limited degree of universal movement; a gas displacement passage along which the propulsive gas is impelled by the rotor; and an outlet nozzle communicating with the gas displacement passage and arranged to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising biasing means associated with the rotor to bias the rotor to its neutral position and to allow relative movement between the rotor and the body structure, with consequent tilting of the rotor from its neutral position and application of a gyro-couple to the aircraft, when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; gas deflecting means associated with the nozzle and operable to variably control the flow characteristics of the propulsive gas discharged from the nozzle at any selected position of said multiplicity of positions; and a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around said periphery and links operatively coupled to peripherally opposite portions of the gas deflecting means being interconnected; the response of the link system to tilt of the rotor causing operation of opposite peripheral portions of the gas deflecting means lying adjacent to a control plane which contains the position of the spin axis corresponding to the neutral position of the rotor and is advanced in the direction of rotation of the

rotor by a phase angle α relative to the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor, the phase angle having a value between 0° and 90° inclusive; operation of the gas deflecting means as the result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from peripherally opposite portions of the outlet nozzle to apply a couple to the aircraft to reduce the divergence of the aircraft incident upon said disturbance, the couple having a first component proportional to cosine α and which amplifies said gyro-couple and a second component proportional to sine α and which directly opposes said rotational velocity.

17. A control system for an aircraft having a lentiform body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces; engine means within the structure to provide propulsive gas, the engine means including a rotor rotatable about a spin axis and having a neutral position relative to the body structure, the rotor having a limited degree of universal movement; a gas displacement passage along which the propulsive gas is impelled by the rotor; and an outlet nozzle communicating with the gas displacement passage and arranged to discharge the propulsive gas at a multiplicity of positions distributed around the periphery of the structure; the control system comprising biasing means associated with the rotor to bias it to its neutral position and to allow relative movement between the rotor and the body structure, with consequent tilting of the rotor from its neutral position and application of a gyro-couple to the aircraft, when the aircraft acquires a rotational velocity about a turn axis lying normal to the spin axis; first pilot operated means to apply a tilting moment to the rotor in a desired direction; a link system interposed between the rotor and the gas deflecting means to operate the latter in response to tilt of the rotor from its neutral position and in a manner determined by the tilted position of the rotor; individual links of the system being operatively coupled to correlated portions of the gas deflecting means spaced around the periphery and links operatively coupled to peripherally opposite portions of the gas deflecting means being interconnected; the response of the link system to tilt of the rotor causing operation of opposite peripheral portions of the gas deflecting means lying adjacent to a control plane which contains the position of the spin axis corresponding to the neutral position of the rotor and is advanced in the direction of rotation of the rotor by a phase angle α relative to the plane containing the positions of the spin axis corresponding to the neutral and tilted positions of the rotor, the phase angle having a value of between 0° and 90° inclusive; and second pilot operated means to operate all of said portions of the gas deflecting means in unison; operation of the gas deflecting means as a result of a disturbance which imparts a rotational velocity to the aircraft about a turn axis controlling the flow characteristics of the propulsive gas discharged from peripherally opposite portions of the outlet nozzle to apply a couple to the aircraft to reduce the divergence of the aircraft incident upon said disturbance, the couple having a first component proportional to cosine α and which amplifies said gyro-couple and a second component proportional to sine α and which directly opposes said rotational velocity; and operation of said first pilot operated means causing the rotor to tilt and operate the gas deflecting means to disturb the aircraft and to impart thereto a rotational velocity about a turn axis.

References Cited in the file of this patent

UNITED STATES PATENTS

2,461,435	Neumann et al.	Feb. 8, 1949
2,822,755	Edwards et al.	Feb. 11, 1958

FOREIGN PATENTS

968,079	France	Apr. 12, 1950
1,070,544	France	Feb. 24, 1954
789,098	Great Britain	Jan. 15, 1958

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,051,417 August 28, 1962

John Carver Meadows Frost et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the grant, lines 3 and 13, and in the heading to the printed specification, line 5, name of assignee, for "Avco Aircraft Limited", each occurrence, read -- Avro Aircraft Limited --.

Signed and sealed this 18th day of December 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

GAS TURBINE ENGINED AIRCRAFT

Filed Aug. 25, 1953 8 Sheets-Sheet 1

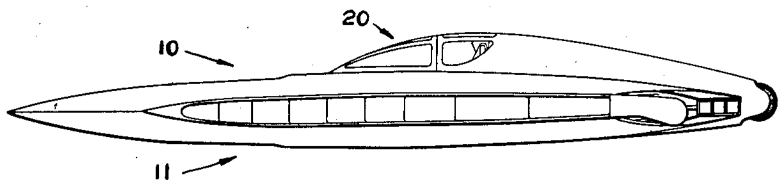

FIG. 1.

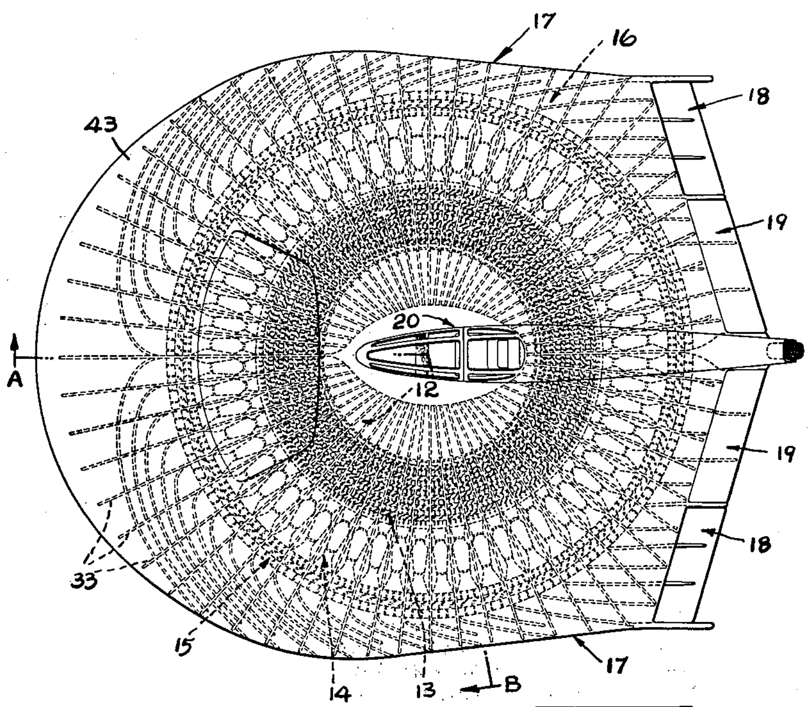

FIG. 2.

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GAS TURBINE ENGINED AIRCRAFT

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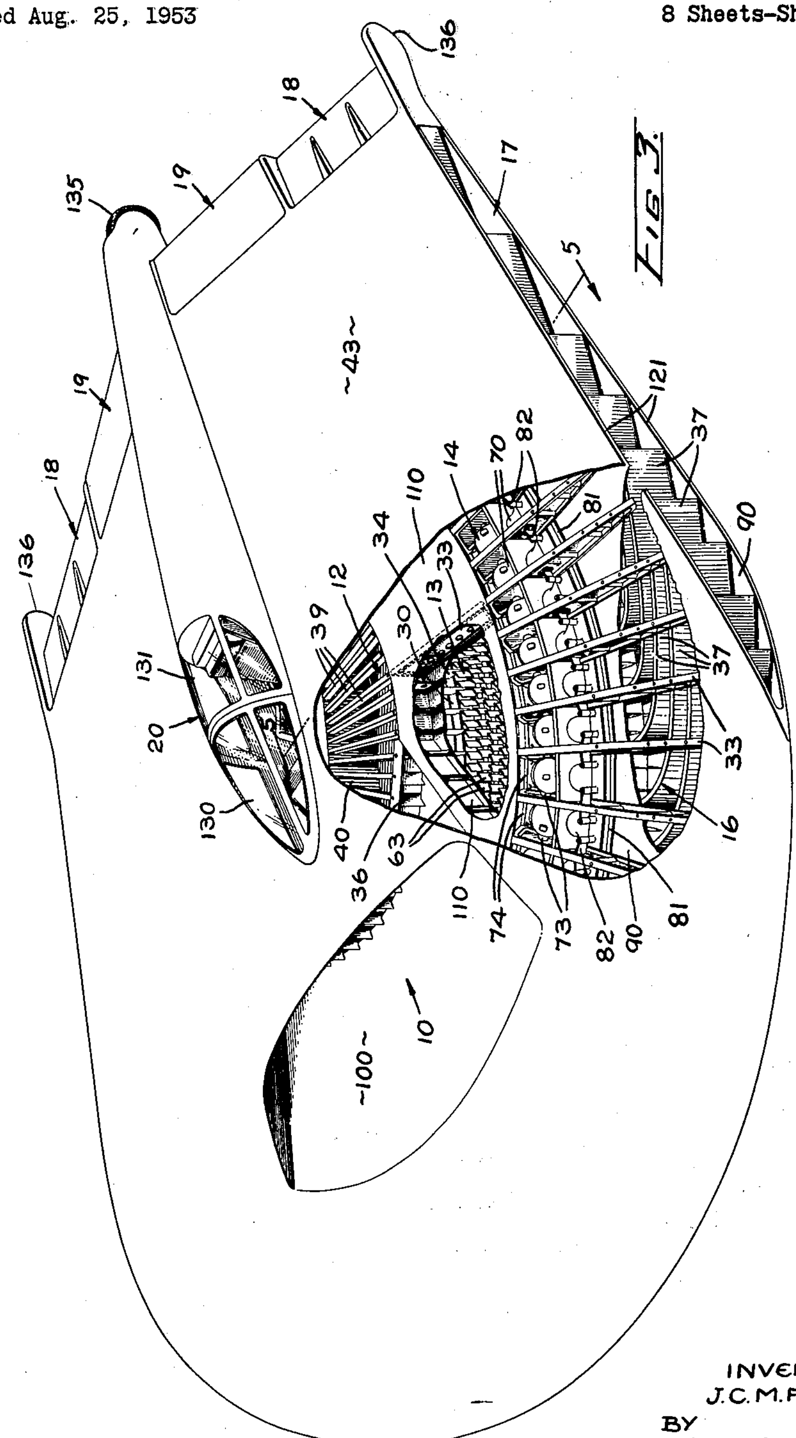

FIG. 3

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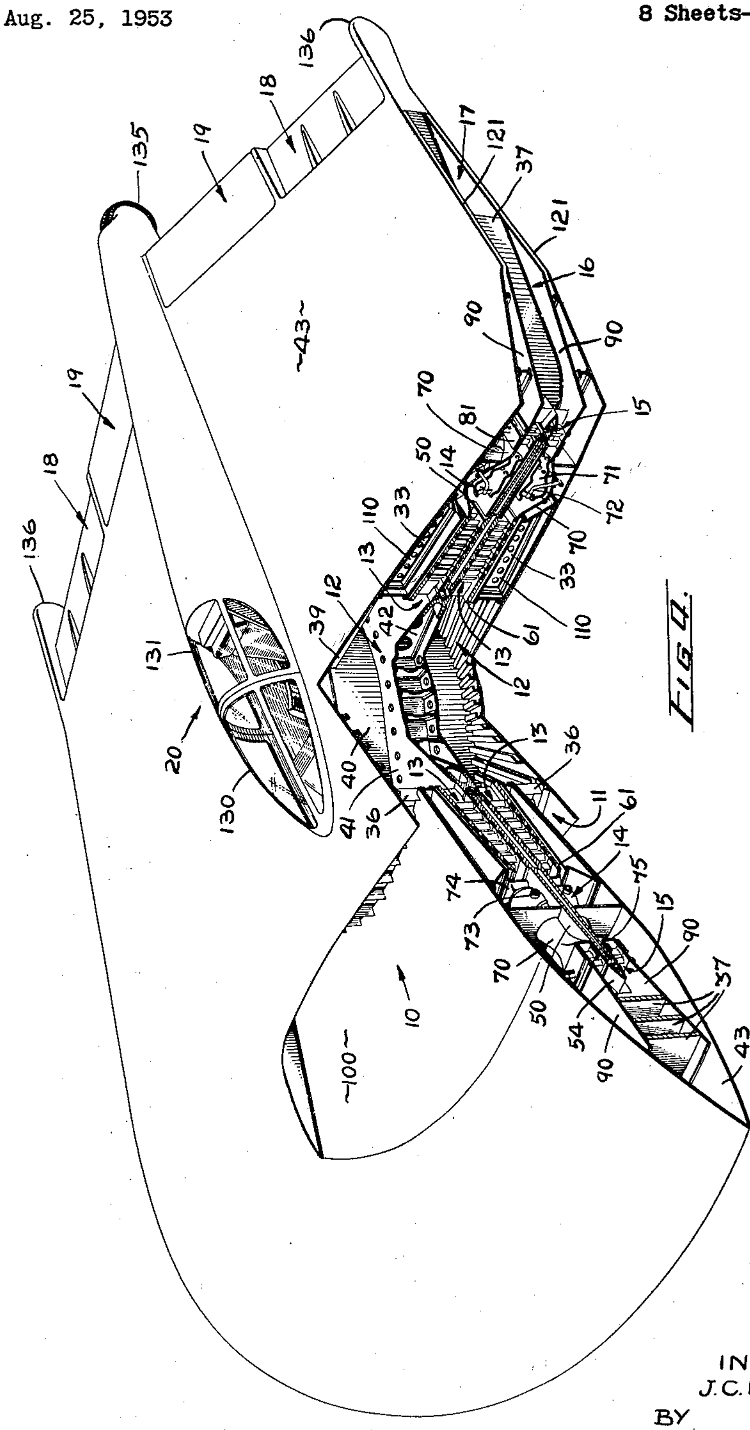

FIG. 4.

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GAS TURBINE ENGINED AIRCRAFT

Filed Aug. 25, 1953 8 Sheets-Sheet 4

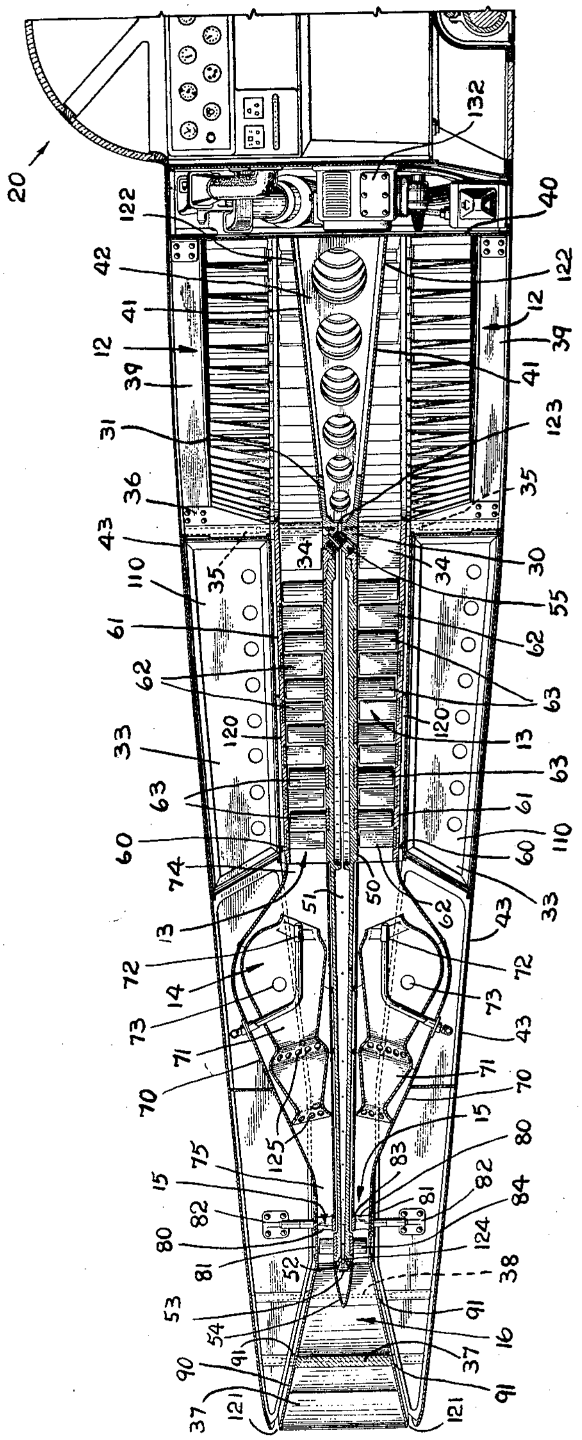

FIG. 5

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Filed Aug. 25, 1953 8 Sheets-Sheet 5

FIG 7.

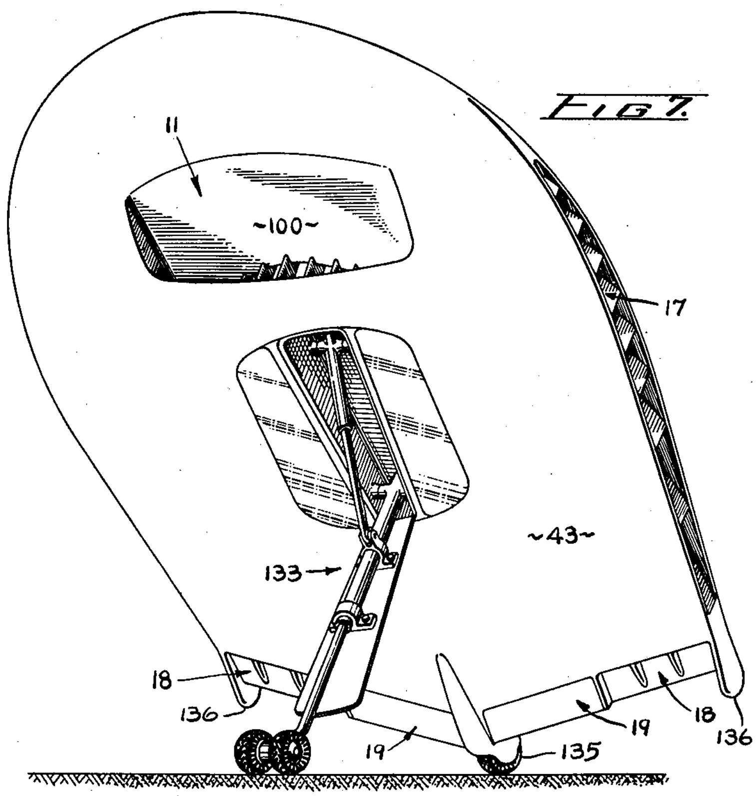
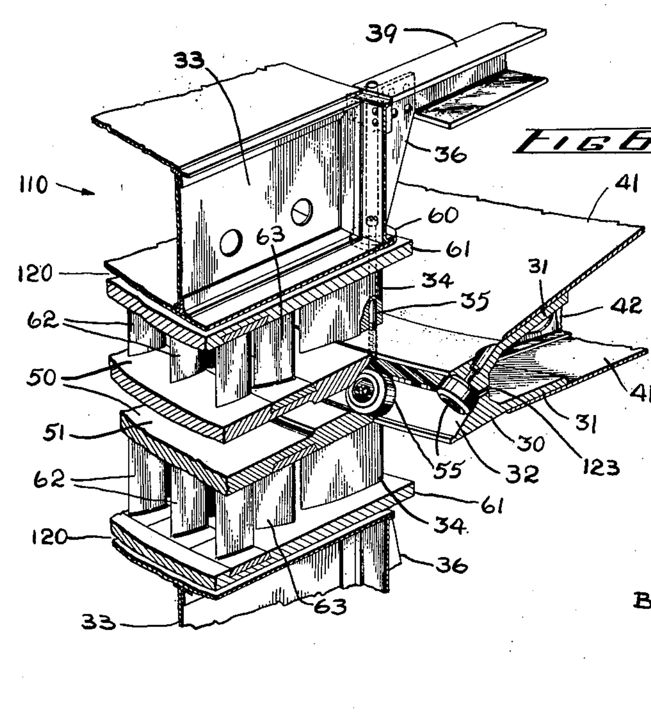


FIG 6.



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Filed Aug. 25, 1953 8 Sheets-Sheet 6

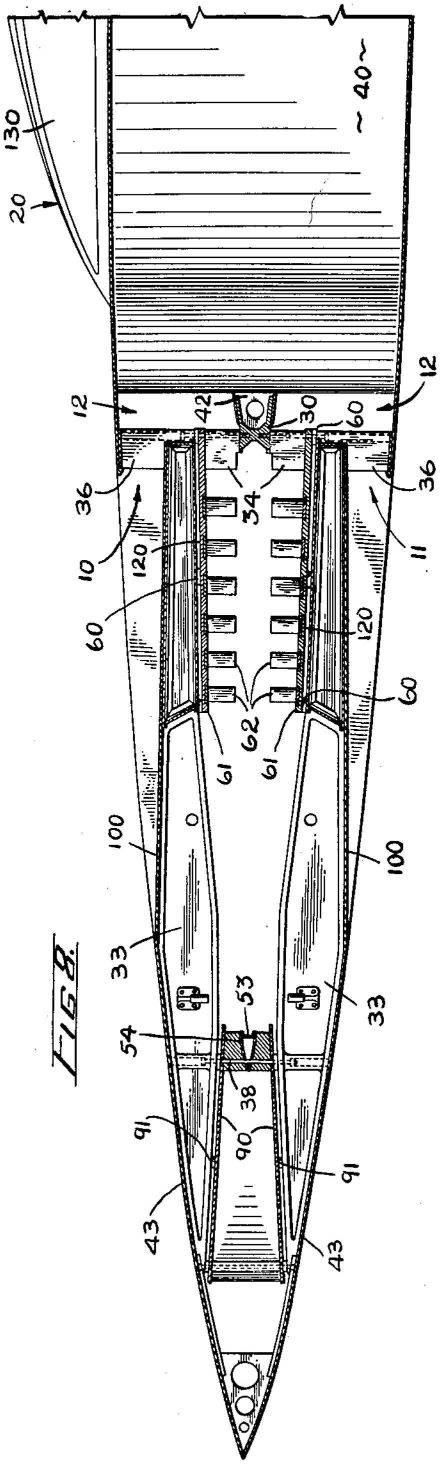

FIG. 8.

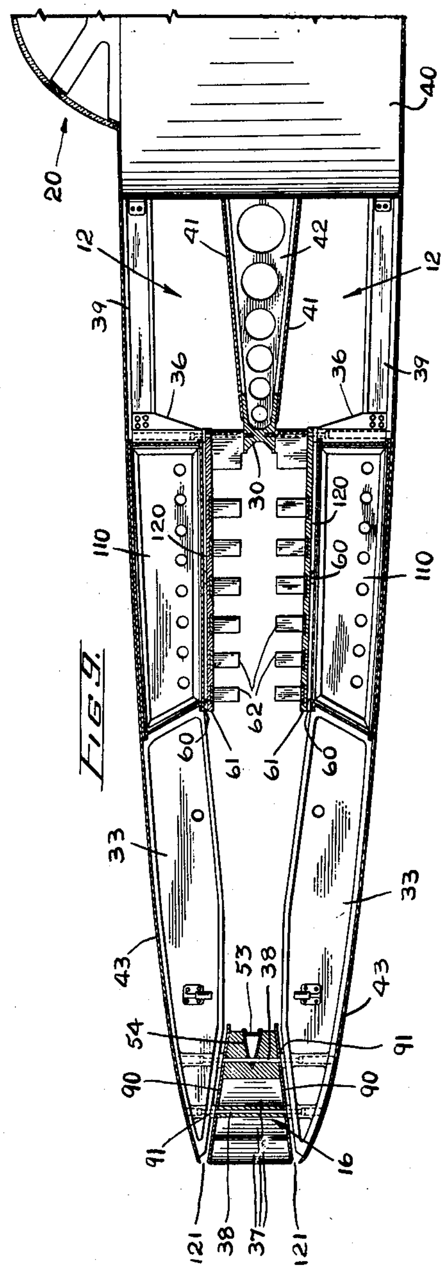

FIG. 9.

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GAS TURBINE ENGINED AIRCRAFT

Filed Aug. 25, 1953 8 Sheets-Sheet 7

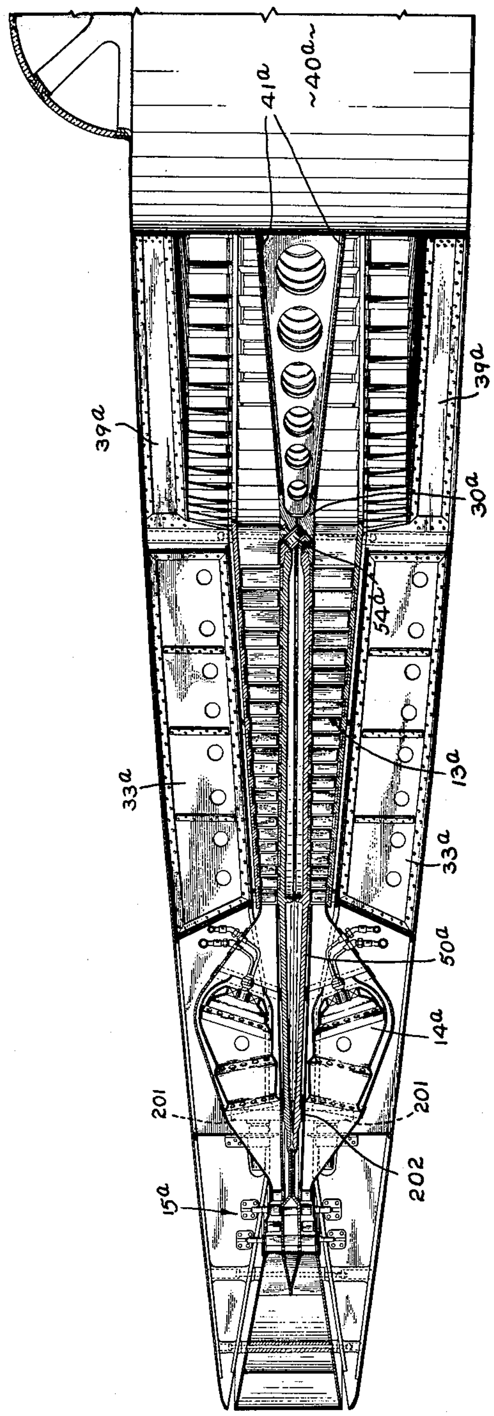

FIG. 10.

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GAS TURBINE ENGINED AIRCRAFT

Filed Aug. 25, 1953 8 Sheets-Sheet 8

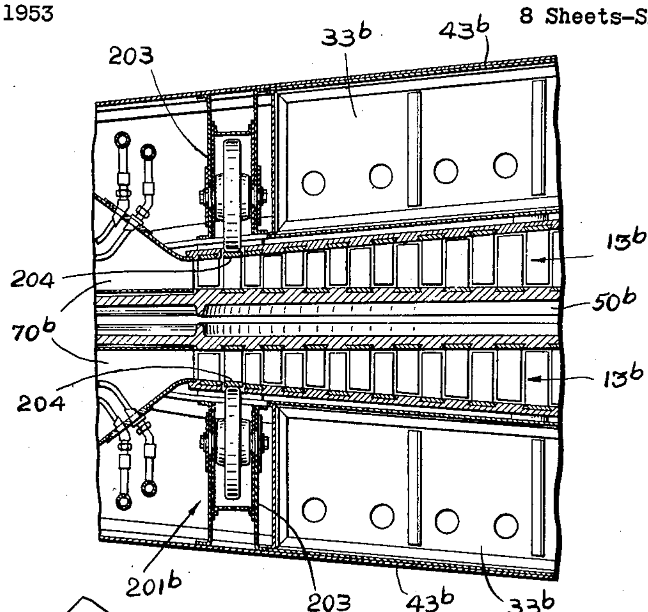

FIG. 12.

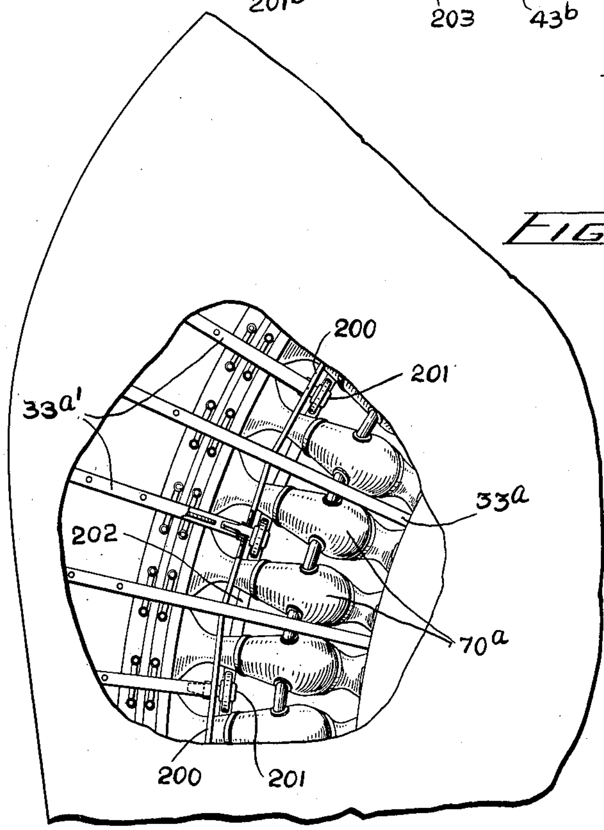

FIG. 11.

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United States Patent Office

3,062,482
Patented Nov. 6, 1962

3,062,482

GAS TURBINE ENGINED AIRCRAFT

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Filed Aug. 25, 1953, Ser. No. 376,320
Claims priority, application Great Britain Aug. 25, 1952
29 Claims. (Cl. 244—15)

The invention relates to aircraft, and more particularly to aircraft deriving a propulsive thrust from gas turbine engines.

According to conventional practice this type of aircraft is provided with one or more gas turbine engines, each engine being mounted with its axis substantially in the direction of flight and discharging its exhaust gases axially and rearwardly to furnish a propulsive thrust. With this conventional arrangement it is, of course, important to construct the engine with as small a cross-sectional area as possible, consistent with power output, in order to minimize the frontal area presented to the air through which it must pass. In consequence, such engines invariably are constructed with axial flow or with centrifugal compressors, and with axial flow turbines, the compressors and turbines being of small diameter and running at very high speeds, the limiting factor of the speed of rotation being the tip speeds of the rotating blades. Furthermore, since such engines have a generally circular cross-section transversely to the direction of flight, their outer envelopes can provide relatively little aerodynamic lift and, though these engines can be buried in the aerofoil surfaces of large airframes, they cannot themselves be adapted to form the said aerofoil surfaces. Hence, an aircraft heretofore has comprised an engine which per se has little aerodynamic lift plus an unavoidably heavy airframe structure in which the engine is buried and which is required to give the engine the necessary aerodynamic lift; the engine per se accounts for only a relatively small proportion of the total volume and mass of the conventional aircraft.

It is the main object of the invention to provide an aircraft in which the engine and the airframe are integral, so that its aerodynamic lift is provided solely by the outer envelope which encloses the integral airframe and engine.

It is another object of the invention to provide an aircraft having a ratio of static thrust relative to gross take-off weight substantially greater than one.

It is a further object of the invention to provide an aircraft which can take-off and land substantially vertically and which has a controllable speed range varying from zero to speeds considerably beyond the velocity of sound.

The foregoing and other objects and advantages of the invention will become apparent from a study of the following specification, taken in conjunction with the accompanying drawings, in which like reference characters indicate corresponding parts throughout the several views, and in which:

FIG. 1 is a side elevation of an aircraft constructed in accordance with the invention and shown as it appears when in flight;

FIG. 2 is a top plan view of the said aircraft and in which major internal details are depicted by dotted lines;

FIG. 3 is a perspective view of the said aircraft, partly broken away to show structural details;

FIG. 4 is a perspective view of the said aircraft, with a sectional fragment removed;

FIG. 5 is a transverse cross-sectional view of one-half of the said aircraft, along the line 5—5 of FIG. 3;

FIG. 6 is a fragmentary perspective view particularly illustrating the rotor supporting bearing assembly of the said aircraft;

FIG. 7 is a perspective view of the said aircraft in take-off position;

FIG. 8 is a cross-sectional view of the aircraft taken through the radial plane indicated at A in FIG. 2, with the rotor and also most background detail removed for greater clarity;

FIG. 9 is a cross-sectional view of the aircraft taken through the radial plane indicated at B in FIG. 2, with the rotor and also most background detail removed for greater clarity;

FIG. 10 is a transverse cross-sectional view generally similar to FIG. 5, and illustrating the structural details of a slightly modified version of the said aircraft;

FIG. 11 is a fragmentary plan view of a typical outboard segment of the aircraft illustrated in FIG. 10 and showing details of structural members and the relative position of outboard bearings; and

FIG. 12 is a fragmentary cross-sectional view of components of an aircraft similar to that illustrated in FIGS. 10 and 11, but showing a modified outboard bearing arrangement.

It is proposed to describe herein firstly the general arrangement of a preferred embodiment of an aircraft constructed in accordance with this invention; then under separate headings the various main features of the said aircraft and its operation will be explained; finally, the modified embodiments illustrated in FIGS. 10–12 will be described.

For greater convenience throughout the description certain terms of positional relationship are used: the terms "outboard" (or "outboardly") and "inboard" (or "inboardly") denote, respectively, greater and lesser distances from the axis of rotation of the rotor, and the terms "outer" and "inner" similarly denote greater and lesser distances from a medial plane of the aircraft coinciding with the plane of the rotor.

Briefly, an aircraft constructed in accordance with the invention can be described as comprising a structure of generally lenticular form and which is sheathed by opposed aerofoil surfaces generally converging towards each other in an outboard direction from their central inboard portions to their perimetrical edges, and a radial flow gas turbine engine disposed between the said aerofoil surfaces and having a disc-like rotor the plane of rotation of which is approximately parallel to the medial plane between the said opposed surfaces. Referring to FIGS. 1 and 2, air enters the inlets **10** and **11** provided in the aerofoil surfaces, then after passing through chambers **12** it flows radially outboardly through a double-sided multi-stage radial flow compressor **13**, then into an annularly disposed combustion system **14** where it supports combustion of the fuel and from which the products of combustion or gases expand through a radial flow turbine **15** into a multiple jet-pipe assembly **16** which directs the flow of gases primarily in a rearward direction to produce a forward propulsive thrust. The direction of flow of the air and of the products of combustion can be particularly understood from a perusal of FIG. 2. Preferably, about three-fifths of the jet exhaust flows from the sides **17** of the aircraft rearwardly, and the remainder is ejected from the trailing edge through control members comprising elevons **18** and trimmers **19**. The flow of compressed air and the products of combustion, prior to entry in the jet pipe assembly, is in generally radial, or centrifugal directions which are normal to the directional, or yaw axis of the aircraft. Accommodation for the pilot is provided in an occupancy chamber or cockpit **20** which is illustrated as being lozenge-shaped and is located at the centre of the aircraft; it might be said that the pilot's cockpit is in the stationary hub of the engine and that the engine rotor rotates around it.

Skeletal Structure

The various structural components of the engine are mutually reinforced, and to determine what is the main component of the structure is problematical. In one respect, the central hollow hub from which the rib assemblies radiate can be considered as the "keystone" of the airframe. However, it may be more accurate and at least for convenience of description it is preferable to consider bearing member or ring **30** (see particularly FIG. 6) as the main structural component. The ring **30** is generally U-shaped in transverse cross-section and it includes a pair of inboardly extending legs **31** and a circumferential outboardly extending V-shaped channel **32** the walls of which preferably are at 90° to each other.

Pairs of angularly spaced rib members **33** radiate outboardly from the ring **30**, the two members of each pair being disposed relative to each other in a generally enantiomorphous arrangement and being secured respectively at their inboard ends to the opposite outer faces of the ring **30** through struts **34** which provide spacers between the ring and the rib members. The rib members and the struts are secured to the ring by long cap screws **35** which pass through bores provided in fishplates **36** of the rib members; the heads of the cap screws seat on shoulders and the shanks pass through bores in the struts, the threaded ends being screwed into tapped holes in the ring. The outboard ends of the rib members of each pair are held together in spaced relationship by suitable spacers including the transverse walls **37** of the jet-pipe assembly **16**; bolts **38** clamp the said outboard ends together. It will be apparent that the ensemble of rib members encompasses an annular space, particularly defined by the inner opposed edges of the members of each pair. The outer edges of the ensemble of rib members generally define the outer configuration of the aircraft.

As will be observed particularly in FIGS. 8 and 9 of the drawings, the ribs preferably are "built-up" members, and they include appropriate flanges and stiffeners; in a general way, they gradually taper from the inboard to the outboard ends. The structure consists of two symmetrical halves on either side of the longitudinal centre line of the aircraft, which provides an axis of symmetry. Although the many rib members generally are similar to one another (there are 60 pairs in the aircraft described), they are not identical, since the aircraft is not a perfect disc; the rib members are of varying overall lengths, and more noticeably those which radiate toward the leading edge are longer than those which radiate toward the sides. Furthermore the outboard ends of the various rib members must have differing tapers since, as will be noticed particularly in FIGS. 3, 4 and 7, the leading edge of the aircraft tapers to a sharp edge while its sides and its trailing edges have appreciable thickness in order to accommodate the jet pipe assembly **16**. In addition the outer faces or edges of the ribs which are adjacent the air inlets **10** and **11** must be somewhat cut back in order to accommodate the said air inlets, as will be described subsequently. However, the ribs on either side of the axis of symmetry which are equiangularly spaced from the said axis (all the angular measurements being from the same origin), preferably are identical.

Secured to the ring **30** through each of the fishplates **36** and the cap screws **35** are inboardly extending radial ribs or channel members **39**. The inboard ends of the channel members are secured to a perimetrical wall **40** which defines the cockpit **20**. The outer edges of the channel members **39** are in the same slightly convex surface as the outer edges of the rib members **33**.

Annular walls **41** which provide the inner walls of the plenum chambers **12** respectively are secured at their outboard peripheries to the legs **31** of the ring **30** and at their lozenge-shaped inboard peripheries to the wall **40**. The walls are mutually reinforced by radial spacers **42**.

Riveted to the outer edges of the rib members **33** and of the channel members **39**, and thus enclosing the structure are skins **43** which together provide an envelope which in diametrical cross-section is substantially lenticular; the skins provide an aerofoil which gives the aircraft aerodynamic lift, and also reinforces the structure. As best seen in FIG. 4, the two skins taper and meet at the leading edge of the aircraft, whilst at its sides and at its trailing edge they are spaced by the jet pipe assemblies **16**.

It will already be apparent that the frame of the engine as such also is the frame of the aircraft; in other words, the invention in effect provides a "flying engine."

Rotor Structure and Suspension

The compressor **13** and the turbine **15** have a common rotor **50**, which comprises two similar annular discs, secured together in face to face relationship so that a space **51** is provided therebetween. At its outer periphery the rotor is encompassed by a channel-shaped rim **52** which provides a rubbing strip. The rubbing strip registers in, but normally is spaced from, an inboardly facing ring **53** held within a V-shaped annulus **54** which is secured to the afore-described skeletal structure within the jet pipe assembly **16**.

The rotor is rotatably mounted at its inboard periphery on the bearing ring **30** through two groups of roller bearings **55** which are set at 45° to the plane of rotation of the rotor and alternately at 90° to each other to carry both axial and radial loads. The inboard portion of the rotor **50** provides a rotor for the compressor **13**, while the outboard portion provides a rotor for the turbine **15**. The combustion system **14** is located adjacent the portion of the rotor which is intermediate the inboard and the outboard portions. It will be noted that the rotor divides into two halves the aforementioned annular space outlined by the inner edges of the ensemble of pairs of rib members **33**.

Compressor

Secured to the inner edges of the rib members **33** but spaced therefrom by spacers **60** are annular discs which provide two annular stator casings **61**. Concentric rings of blades of aerofoil section with their longitudinal axes substantially parallel to the axis of rotation are provided in the spaces between the stators and either side of the rotor. Alternate rings comprise stator blades **62** having their root ends secured to a stator casing **61** and their other ends extending towards the rotor **50**, while the other rings comprise rotor blades **63** having their root ends secured to the rotor **50** and their other ends extending toward a stator casing **61**. The blades may be secured to the stators or to the rotor by any conventional means, such as dovetails.

Thus, there is provided a double-sided multi-stage radial flow compressor **13** having circuferential inlets at its inboard periphery and circumferential outlets at its outboard periphery. The compressor of the aircraft particularly illustrated in FIGS. 3, 4 and 5, is a six-stage compressor. The two annular passages defined by the rotor **50** and the stator casings **61** at either side thereof progressively converge towards each other radially from the inboard periphery toward the outboard periphery, and the blades which span the passage correspondingly are of progressively decreasing length from the inboard rings to the outboard rings.

Combustion System

Located in the spaces between adjacent rib members **33** on both sides of the rotor **50** are radially extending combustion chambers **70** of the annularly disposed combustion system **14**. Although the combustion chambers are unsymmetrical in transverse cross-section, they are nevertheless of conventional design. Each includes a flame tube **71**, suitable ignitors, and burners **72**. The flame tubes of adjoining combustion chambers are connected by interconnectors **73**. The inlet of each combustion chamber is formed into a rectangular opening **74** so that the two series of adjacent openings constitute circumferential inlets registering with the circumferential outlets of the compressor **13**. Likewise, the combustion chamber outlets **75** terminate in rectangular openings or nozzle boxes so that the two series of adjacent outlets constitute circumferential outlets registering with the circumferential inlets of the turbine **15**.

Turbine and Exhaust

Disposed in concentric rings adjacent the circumferential outlets **75** of the combustion chambers **70** are stator blades **80** of the turbine **15**. The stator blades are firmly secured at their root ends to bridging members **81** which extend between the combustion chamber outlets **75** and the jet pipe assemblies **16**, these bridging members being adjustably connected by means **82** secured to the ribs **33**. It will be noted particularly from FIG. 3 that preferably the bridging members which together constitute the stator ring of the turbine are not a continuous ring but they are a number of annulus sectors, there being one sector for each space between adjacent rib members **33**. At the other ends of the stator blades are annular shrouds **83**. The stator rings and the shrouds, between which extend the stator blades, provide circumferential inlets for the turbine.

Extending from each side of the rotor **50** adjacent the turbine stator blades **80** is a ring of turbine rotor blades **84**; they are secured to the rotor by conventional means, as by dove-tails. Both the stator blades **80** and the rotor blades **84** are of aerofoil section, with their longitudinal axes substantially parallel to the axis of rotation of the rotor **50**.

Around the circumferential outlet of the turbine are the jet-pipe assemblies **16**. These are formed by two outboardly diverging walls **90**, each being secured to the inner edges of the rib members **33** and spaced therefrom by spacers **91**, the inboard peripheries of the walls registering with the stator rings of the turbine provided by the bridging members **81**, and by the two series of transverse walls **37**, one series being on each side of the longitudinal axis of symmetry of the aircraft. The walls **90** and **37** together constitute ducts, the inboard ends of which are radially directed and register with the circumferential outlet of the turbine. The outboard ends of the ducts situate in the aft portion of the aircraft terminate in a common fishtail at the trailing edge of the aircraft, whilst the remaining ducts on either side of the axis of symmetry are curved adjacent their inlet ends to extents which are progressively greater with increases in the angular distance between the respective ducts and the central duct of the fishtail. The curved ducts are swept back and terminate at the sides **17** of the aircraft. Due to the rearward sweep of these ducts the discharges therefrom are substantially tangential to the edges of the aircraft and they have thrust components which are predominantly rearward.

Air Intake

Referring particularly to FIGS. 4 and 8, the air inlets **10** and **11** are provided by large openings in the skins **43** in the leading quarter-sector of the aircraft. It can be said that the inlets or intakes are in a portion of the structure which is generally central planformwise. Of necessity, the outer faces or edges of the ribs **33** in that sector are cut-back, and skins **100** are riveted to the cut-back portions of the said ribs. Air entering the intakes, after passing through the chambers **12**, is drawn into the circumferential compressor inlets.

Fuel Supply System

Fuel tanks **110**, which are C-shaped, are provided in the spaces between the compressor stator casings **61** and the skins **43**. The "breaks" in the tanks (corresponding to the open side of the C) are to accommodate the air inlets **10** and **11**. As will be apparent from the drawings, the ribs **33** pass through the tanks.

Fuel is conducted by appropriate supply lines and pumps from the tanks **110** to the burners **72** of each combustion chamber **70**.

Cooling System

Complete provision is made for cooling those portions of the aircraft which otherwise would overheat.

Narrow passages **120** are provided between the inner surfaces of the fuel tanks **110** and the outer surfaces of compressor stator casings **61**. Air is bled from the plenum chambers **12**, and flows radially outboardly through the said passages, thus cooling the compressor. The said air then scrubs the outer surfaces of the combustion chambers **70**, thus cooling the combustion chambers, and finally it is ejected through peripheral slots **121** provided between the skins **43** and the walls **90** of the jet pipe assemblies.

To cool the rotor, apertures **122** are provided in the annular walls **41**, and thus air is bled from the chambers **12** into the space within the said walls, thence flows through a series of apertures **123** provided in the ring **30** and into the passage **51** within the rotor **50**. The said air flows radially outboardly through the said passage and is discharged through apertures **124** in the rim **52** of the rotor.

In addition, cooling air from the compressor **13** flows through the spaces between the outer walls of the combustion chambers **70** and the flame tubes **71** and is ejected through holes **125** provided in the downstream ends of the flame tubes and then mixes with the products of combustion.

Pilot Accommodation, Landing Gear, and Controls

Accommodation for the pilot is provided in the cockpit **20** which is defined by the wall **40** at the centre of the aircraft. A windshield **130** and a canopy **131** of conventional design, covering the pilot's cockpit, protrude above the contour of the upper skin **43**. Within the structure and adjacent the cockpit (see FIG. 5) are provided a cockpit pressurization system and conventional auxiliaries generally indicated at **132**.

Pivotally mounted in a wheel well below the cockpit (see FIG. 7) is a main landing gear strut **133** having dual wheels **134** at its lower end, and which is adapted to retract into the wheel well when the aircraft is in flight. In addition, a tail wheel **135** is mounted at the centre of the fishtail on the longitudinal axis of the aircraft. Lateral stability on the ground is furnished by bumpers **136** on the tips of the fishtail.

At either side of the wheel well are transparent panels **137** which provide observation ports; these are particularly helpful when the pilot is landing the aircraft.

Flight control is effected by the elevons or movable flaps **18** mounted on the fishtail and situate immediately behind the orifices of the jet-pipe assembly **16** so that they will be operable upon the discharge from the said orifice. In addition, the trimmer flaps **19** may be provided. The elevons and the trimmer flaps are linked by conventional means to a control column in the cockpit **20**.

Operation

In operation, air enters the inlets **10** and **11** whence it is rammed into the chambers **12** and thence into the radial compressor **13**. The air is compressed by the compressor as in the orthodox gas turbine engine cycle, then flows radially outboardly into the combustion system **14** where it supports the combustion of fuel. The expanded products of combustion are discharged through the radial turbine **15** (whereby the compressor is driven), the exhaust from the turbine being ducted rearwardly by the jet-pipe assembly **16** to provide a forward propulsive thrust.

Alternative Constructions

The first alternative structure, which is illustrated in

FIGS. 10 and 11 generally is similar to the machine previously described. The skeletal frame includes a ring **30***a* to which are secured pairs of outboardly extending rib members **33***a*, pairs of inboardly extending channel members **39***a* and annular walls **41***a*; a cockpit **20***a* is defined by a perimetrical wall **40***a*.

However, it will be noted from FIG. 11 that in this embodiment of the invention there are only half as many ribs **33***a* as there are ribs **33** in the first described embodiment, and that two combustion chambers **70***a* (instead of one as in the first described embodiment) are located between adjacent ribs. Furthermore, short reinforcing ribs **33***a'* extend outboardly from gusset plates **200** which span between adjacent ribs **33***a*, to the outboard perimeter of the aircraft.

In this embodiment of the invention there is provided an eleven-stage high-compression compressor **13***a* and a two-stage turbine **15***a*. Structurally, the compressor **13***a* is similar to the compressor **13** of the first described embodiment and likewise the turbine **15***a* is similar structurally to the turbine **15**. There are minor variations in the combustion system **14***a*, but these need not be discussed.

The essential distinction between the two machines is in the rotor suspensions. The rotor **50** of the first embodiment has a cantilever suspension, its outboard perimeter being free. In the present embodiment of the invention, there is in addition to inboard bearings **54***a* a series of outboard bearings **201** circumferentially arranged in the alternate spaces between combustion chambers **70***a* and secured to the gusset plates **200**. These bearings comprise rollers which lightly engage the rotor **50***a* on races **202** provided thereon. The rollers serve to steady the rotor and to reduce deflections thereof, thereby minimizing the necessary running clearances at the tips of the blades.

The third embodiment of the invention is illustrated in FIG. 12 which is a fragmentary cross-sectional view of components of an aircraft similar to that illustrated in FIGS. 10 and 11, but showing a modified outboard bearing arrangement **201***b*. In that view there are shown rib members **33***b*, skins **43***b*, a fragment of an eleven-stage compressor **13***b*, a rotor **50***b* and the inlet ends of combustion chambers **70***b*. The distinctive feature of this machine is that the outboard bearings **201***b* are located adjacent the combustion chamber inlets instead of adjacent the outlets as in the second embodiment illustrated in FIGS. 10 and 11. These bearings comprise large rollers adjustably mounted on plates **203** and which support the outboard portion of the rotor **50***b* through a shroud ring **204** provided on the outboard ring of compressor rotor blades.

Final Remarks

It will be noted that by the arrangements described of an integral engine and aircraft it is possible to accommodate a proportionally much larger engine than has hitherto been practicable, since the frontal areas of all aircraft powered by axial flow gas turbine engines bear a much larger relationship to the thrust which engines of such relatively small diameters are capable of delivering. Furthermore, since according to the invention the structure of the engine itself is the primary structure of the entire aircraft a very substantial overall saving in weight can be achieved in comparison with the conventional constructions now in use.

It can readily be demonstrated that the power/frontal area ratio and the power/weight ratio of an aircraft according to this invention are such that its performance will be very high. A high degree of stability is provided by the gyroscopic affect of the large rotor, giving a stable platform for the firing of guns or rocket projectiles in the difficult conditions encountered at supersonic speeds. In addition, such gyroscopic stability is an asset in the slow speed control of an aircraft of substantially unit aspect ratio.

The scheme of providing positive control of the aircraft through the deflection of large thrust forces combines with the gyroscopic stability to provide an excellent low speed control down to and beyond the stalling speed, to zero speed. These characteristics combine with the unprecedented thrust/weight ratio, in enabling substantially vertical take-off and landing to be achieved. The paramount importance of this aspect of control needs no emphasis.

It will be understod that the forms of the invention herein shown and described are to be considered merely as examples. The aircraft is most unorthodox, and obviously many changes in the shape, size and arrangement of parts not only are possible but may be desirable in order that the machine may have optimum performance. Such changes may, of course, be made without departing from the spirit of the invention or the scope of the subjoined claims.

What I claim as my invention is:

1. An aircraft comprising a radial flow gas turbine engine, including a radial flow turbine having a circumferential outlet, an annularly disposed combustion chamber means nested inboard of the turbine, and a radial flow compressor driven by the turbine and nested inboard of the annularly disposed combustion chamber means, the turbine, the combustion chamber means and the compressor being concentric and lying in the same general plane; means encompassing the circumferential turbine outlet and directing exhaust gases therefrom to provide a propulsive thrust; and opposed aerofoil surfaces sheathing the axial ends of the engine and the encompassing means, the said aerofoil surfaces providing lift developing surfaces of the aircraft, the medial plane between the said surfaces being approximately parallel to the aforesaid general plane of the turbine, the combustion chamber means and the compressor.

2. An aircraft comprising a radial flow gas turbine engine, including a radial flow turbine having a circumferential outlet, an annularly disposed combustion chamber means nested inboard of the turbine, and a radial flow compressor driven by the turbine and having a circumferential air inlet at its inboard periphery and nested inboard of the annularly disposed combustion chamber means, the turbine, the combustion chamber means and the compressor being concentric and lying in the same general plane; means encompassing the circumferential turbine outlet and directing exhaust gases therefrom to provide a propulsive thrust; and opposed aerofoil surfaces sheathing the axial ends of the engine and the encompassing means, the said aerofoil surfaces providing lift developing surfaces of the aircraft, an opening being provided in at least one of the aerofoil surfaces, the medial plane between the said surfaces being approximately parallel to the aforesaid general plane of the turbine, the combustion chamber means and the compressor; an occupancy chamber encompassed by the circumferential air inlet of the compressor; and a passage located between the compressor inlet and the occupancy chamber for conducting air from the opening to the compressor inlet.

3. An aircraft comprising a radial flow air compressor including a stator and a rotor and having a circumferential inlet at its inboard periphery and a circumferential outlet at its outboard periphery, a radial flow turbine disposed concentrically around the compressor and radially spaced therefrom, the turbine having a rotor fast to the compressor rotor and a stator and having a circumferential inlet at its inboard periphery and a circumferential outlet at its outboard periphery, combustion chamber means having a circumferential inlet registering with the compressor outlet and a circumferential outlet registering with the turbine inlet, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine rotor which in turn drives the

compressor rotor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer surfaces of the stators and spanning from the turbine stator to the compressor stator to enclose the combustion chamber means, the said aerofoil surfaces providing lift developing surfaces of the aircraft, the medial plane between the said surfaces being approximately parallel to the plane of rotation of the rotors.

4. An aircraft comprising a radial flow air compressor including a stator and a rotor and having a circumferential inlet at its inboard periphery and a circumferential outlet at its outboard periphery, a radial flow turbine disposed concentrically around the compressor and radially spaced therefrom, the turbine having a rotor fast to the compressor rotor and a stator and having a circumferential inlet at its inboard periphery and a circumferential outlet at its outboard periphery, combustion chamber means having a circumferential inlet registering with the compressor outlet and a circumferential outlet registering with the turbine inlet, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine rotor which in turn drives the compressor rotor connected to it, a plurality of exhaust ducts having their inlet ends serially arranged side by side to provide an annular inlet which encompasses the circumferential turbine outlet, the said ducts comprising two similar but enantiomorphous groups, the outlet ends of ducts of one group extending in a direction which diverges relative to the direction in which the outlet ends of ducts of the other group extend, the exhaust gases emitted through the ducts thus providing a forward propulsive component of thrust and also providing a component of thrust which is perpendicular to the forward propulsive component of thrust, the said perpendicular component of thrust from the ducts of one group being opposed to the perpendicular component of thrust from the ducts of the other group, and opposed aerofoil surfaces substantially covering the outer surfaces of the ducts and of the stators and spanning from the turbine stator to the compressor stator to enclose the combustion chamber means, the said aerofoil surfaces providing lift developing surfaces of the aircraft, the medial plane between the said surfaces being approximately parallel to the plane of rotation of the rotors.

5. An aircraft comprising a radial flow air compressor including a stator and a rotor and having a circumferential inlet at its inboard periphery and a circumferential outlet at its outboard periphery, a radial flow turbine disposed concentrically around the compressor and annularly spaced therefrom, the turbine having a rotor fast to the compressor rotor and a stator and having a circumferential inlet at its inboard periphery and a circumferential outlet at its outboard periphery, a plurality of radially extending combustion chambers each having an inlet at one end and an outlet at the other end, the combustion chamber inlets being serially arranged side by side to provide a circumferential inlet registering with the compressor outlet, the combustion chamber outlets being serially arranged side by side to provide a circumferential outlet registering with the turbine inlet, fuel supply means for the combustion chambers, the compressor supplying air which supports combustion of the fuel in the combustion chambers, the products of combustion expanding to drive the turbine rotor which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer surfaces of the stators and spanning from the turbine stator to the compressor stator to enclose the combustion chambers, the said aerofoil surfaces providing lift developing surfaces of the aircraft, the medial plane between the said surfaces being approximately parallel to the plane of rotation of the rotors.

6. An aircraft comprising a radial flow air compressor including a stator and a rotor and having a circumferential inlet at its inboard periphery and a circumferential outlet at its outboad periphery, a radial flow turbine disposed concentrically around the compressor and radially spaced therefrom, the turbine having a rotor fast to the compressor rotor and a stator and having a circumferential inlet at its inboard periphery and a circumferential outlet at its outboard periphery, combustion chamber means having a circumferential inlet registering with the compressor outlet and a circumferential outlet registering with the turbine inlet, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine rotor which in turn drives the compressor rotor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, an occupancy chamber encompassed by the compressor inlet, and opposed aerofoil surfaces substantially covering the outer surfaces of the stators and spanning from the turbine stator to the compressor stator to enclose the combustion chamber means, the said aerofoil surfaces providing lift developing surfaces of the aircraft, the medial plane between the said surfaces being approximately parallel to the plane of rotation of the rotors.

7. An aircraft comprising a radial flow air compressor including a stator and a rotor and having a circumferential inlet at its inboard periphery and a circumferential outlet at its outboard periphery, a radial flow turbine disposed concentrically around the compressor and radially spaced therefrom, the turbine having a rotor fast to the compressor rotor and a stator and having a circumferential inlet at its inboard periphery and a circumferential outlet at its outboard periphery, exhaust ducts having one end registering with the turbine outlet, the said ducts extending outboardly from the turbine outlet and having their other ends directed in a generally rearward sense, combustion chamber means having a circumferential inlet registering with the compressor outlet and a circumferential outlet registering with the turbine inlet, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine rotor which in turn drives the compressor connected to it and thence being ejected through the ducts to provide a propulsive thrust, moveable flaps for flight control situate adjacent the said other ends of at least some of the ducts and operable upon the discharge therefrom, and opposed aerofoil surfaces substantially covering the outer surfaces of the stators and spanning from the turbine stator to the compressor stator to enclose the combustion chamber means, the said aerofoil surfaces providing lift developing surfaces of the aircraft, the medial plane between the said surfaces being approximately parallel to the plane of rotation of the rotors.

8. An aircraft comprising a hollow hub, an annular rotor mounted for rotation relative to and around the hub, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, annular stator means secured to the inner side of one of the annular structures, a first series of concentric rings of blades between the rotor and the stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other

rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a radial flow compressor having a circumferential inlet defined by the inboard ring of blades and a circumferential outlet defined by the outboard ring of blades, annularly arranged combustion chamber means having a circumferential inlet registering with the circumferential compressor outlet and having a circumferential outlet at its outboard periphery, a second series of concentric rings of blades between the rotor and the stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending towards the opposed stator means and another ring of the second series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a radial flow turbine having a circumferential inlet defined by the inboard ring of turbine blades and a circumferential outlet defined by the outboard ring of turbine blades, the turbine inlet registreing with the outlet of the combustion chamber means, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

9. An aircraft comprising a hollow hub, a bearing member annularly disposed around the hub and secured thereto, an annular rotor coaxially mounted relative to the bearing member and rotatable thereon, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, a group of annularly arranged bearings secured to each annular structure, and engaging the rotor, the said groups of bearings being concentric with the aforesaid bearing member and being located radially intermediate the bearing member and the outboard periphery of the rotor and cooperating with the bearing member to support the rotor, annular stator means secured to the inner side of one of the annular structures, a first series of concentric rings of blades between the rotor and the stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a radial flow compressor having a circumferential inlet defined by the inboard ring of blades and a circumferential outlet defined by the outboard ring of blades, annularly arranged combustion chamber means having a circumferential inlet registering with the circumferential compressor outlet and having a circumferential outlet at its outboard periphery, a second series of concentric rings of blades between the rotor and the stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending towards the opposed stator means and another ring of the second series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a radial turbine having a circumferential inlet defined by the inboard ring of turbine blades and a circumferential outlet defined by the outboard ring of turbine blades, the turbine inlet registering with the outlet of the combustion chamber means, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine inlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

10. An aircraft comprising a hollow hub, an annular rotor mounted for rotation relative to and around the hub, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, annular stator means secured to the inner side of one of the annular structures, a first series of concentric rings of blades between the rotor and the stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a radial flow compressor having a circumferential inlet defined by the inboard ring of blades and a circumferential outlet defined by the outboard ring of blades, a plurality of radially extending combustion chambers arranged in a ring, each combustion chamber being secured to the annular structure which supports the stator means and having an inlet at its inboard end and an outlet at its outboard end, the combustion chamber inlets being serially arranged side by side to provide a circumferential inlet registering with the circumferential compressor outlet, the combustion chamber outlets being serially arranged side by side to provide a circumferential outlet, a second series of concentric rings of blades between the rotor and the stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending towards the opposed stator means and another ring of the second series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a radial flow turbine having a circumferential inlet defined by the inboard ring of turbine blades and a circumferential outlet defined by the outboard ring of turbine blades, the turbine inlet registering with the circumferential outlet of the combustion chambers, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chambers, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine inlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

11. An aircraft comprising a hollow hub, a bearing member annularly disposed around the hub and secured thereto, an annular rotor coaxially mounted relative to the bearing member and rotatable thereon, an annular structure on each side of the rotor and firmly secured

to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, annular stator means secured to the inner side of one of the annular structures, a first series of concentric rings of blades between the rotor and the stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a radial flow compressor having a circumferential inlet defined by the inboard ring of blades and a circumferential outlet defined by the outboard ring of blades, a plurality of radially extending combustion chambers arranged in a ring around and outboard of the radial compressor, each combustion chamber being secured to the annular structure which supports the stator means and having an inlet at its inboard end and an outlet at its outboard end, the combustion chamber inlets being serially arranged side by side to provide a circumferential inlet registering with the circumferential compressor outlet, the combustion chamber outlets being serially arranged side by side to provide a circumferential outlet, a group of annularly arranged bearings secured to each annular structure and engaging the rotor, the said groups of bearings being concentric with the aforesaid bearing member and cooperating with it to support the rotor, the bearings of one group being annularly arranged and being located between adjacent combustion chambers to engage one side of the rotor and the other group of bearings being located substantially opposite the said one group of bearings to engage the other side of the rotor, a second series of concentric rings of blades between the rotor and the stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending towards the opposed stator means and another ring of the second series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a radial flow turbine having a circumferential inlet defined by the inboard ring of turbine blades and circumferential outlet defined by the outboard ring of turbine blades, the turbine inlet registering with the circumferential outlet of the combustion chambers, fuel supply means for the combustion chambers, the compressor supplying air which supports combustion of the fuel in the combustion chambers, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

12. An aircraft comprising a hollow hub, a bearing member annularly disposed around the hub and secured thereto, an annular rotor coaxially mounted relative to the bearing member and rotatable thereon, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, annular stator means secured to the inner side of one of the annular structures, a first series of concentric rings of blades between the rotor and the stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a radial flow compressor having a circumferential inlet defined by the inboard ring of blades and a circumferential outlet defined by the outboard ring of blades, a group of annularly arranged bearings secured to each annular structure, the said groups of bearings being concentric with the bearing member and cooperating with it to support the rotor, a shroud on the outboard ring of blades of the compressor rotor, one group of annularly arranged bearings engaging one side of the rotor through the shroud and the other group of bearings being located substantially opposite the said one group of bearings to engage the other side of the rotor, annularly arranged combustion chamber means having a circumferential inlet registering with the circumferential compressor outlet and having a circumferential outlet at its outboard periphery, a second series of concentric rings of blades between the rotor and the stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending towards the opposed stator means and another ring of the second series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a radial flow turbine having a circumferential inlet defined by the inboard ring of turbine blades and a circumferential outlet defined by the outboard ring of turbine blades, the turbine inlet registering with the outlet of the combustion chamber means, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer side of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

13. An aircraft comprising a hollow hub, an annular rotor mounted for rotation relative to and around the hub, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, annular stator means secured to the inner side of one of the annular structures, a first series of concentric rings of blades between the rotor and the stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a radial flow compressor having a circumferential inlet defined by the inboard ring of blades and a circumferential outlet defined by the outboard ring of blades, annularly arranged combustion chamber means having a circumferential inlet registering with the circumferential compressor outlet and having a circumferential outlet at its outboard periphery, a second series of concentric rings of blades between the rotor and the stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending towards the opposed stator means and another ring of the second series com-

prising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a radial flow turbine having a circumferential inlet defined by the inboard ring of turbine blades and a circumferential outlet defined by the outboard ring of turbine blades, the turbine inlet registering with the outlet of the combustion chamber means, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft, an opening being provided in at least one of the aerofoil surfaces, and a passage located between the compressor inlet and the hub for conducting air from the aerofoil opening to the compressor inlet.

14. An aircraft comprising a hollow hub, an annular rotor mounted for rotation relative to and around the hub, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, annular stator means secured to the inner side of each of the annular structures and spaced from the rotor, a first series of concentric rings of blades in the spaces between the rotor and the two stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a double-sided radial flow compressor having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, annularly arranged combustion chamber means at each side of the rotor and having a circumferential inlet registering with the circumferential compressor inlet and having a circumferential outlet at the outboard periphery, a second series of concentric rings of blades in the spaces between the rotor and the two stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and another ring of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a double-sided radial flow turbine having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, the turbine inlet registering with the outlet of the combustion chamber means, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

15. An aircraft comprising a hollow hub, an annular rotor mounted for rotation relative to and around the hub, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, annular stator means secured to the inner side of each of the annular structures and spaced from the rotor, a first series of concentric rings of blades in the spaces between the rotor and the two stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a double-sided radial flow compressor having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, annularly arranged combustion chamber means at each side of the rotor and having a circumferential inlet registering with the circumferential compressor inlet and having a circumferential outlet at the outboard periphery, a second series of concentric rings of blades in the spaces between the rotor and the two stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and another ring of series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a double-sided radial flow turbine having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, the turbine inlet registering with the outlet of the combustion chamber means, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft, the fuel supply means including tanks located between the outer sides of the annular stator means and the inner sides of the aerofoil surfaces, the said tanks being substantially opposite the compressor.

16. An aircraft comprising a hollow hub, a bearing member annularly disposed around the hub and secured thereto, an annular rotor coaxially mounted relative to the bearing member and rotatable thereon, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, a group of annularly arranged bearings secured to each annular structure and engaging the rotor, the said groups of bearings being concentric with the aforesaid bearing member and being located radially intermediate the bearing member and the outboard periphery of the rotor and cooperating with the bearing member to support the rotor, annular stator means secured to the inner side of each of the annular structures and spaced from the rotor, a first series of concentric rings of blades in the spaces between the rotor and the two stator means, alternate rings of the series

comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a double-sided radial flow compressor having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, annularly arranged combustion chamber means at each side of the rotor and having a circumferential inlet registering with the circumferential compressor inlet and also having a circumferential outlet at the outboard periphery, a second series of concentric rings of blades in the spaces between the rotor and the two stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and another ring of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a double-sided radial flow turbine having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, the turbine inlet registering with the outlet of the combustion chamber means, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

17. An aircraft comprising a hollow hub, an annular rotor mounted for rotation relative to and around the hub, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, annular stator means secured to the inner side of each of the annular structures and spaced from the rotor, a first series of concentric rings of blades in the spaces between the rotor and the two stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a double-sided radial flow compressor having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, two groups of radially extending combustion chambers arranged in a ring, each combustion chamber having an inlet at its inboard end and an outlet at its outboard end, the combustion chambers of one group being secured to one annular structure and the combustion chambers of the other group being secured to the other annular structure, the inlets of the combustion chambers of each group being serially arranged side by side to provide a circumferential inlet registering with the circumferential compressor outlet, the outlets of the combustion chambers of each group being serially arranged side by side to provide a circumferential outlet, a second series of concentric rings of blades in the spaces between the rotor and the two stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and another ring of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a double-sided radial flow turbine having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, the turbine inlet registering with the circumferential outlet of the combustion chambers, fuel supply means for the combustion chambers, the compressor supplying air which supports combustion of the fuel in the combustion chambers, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

18. An aircraft comprising a hollow hub, a bearing member annularly disposed around the hub and secured thereto, an annular rotor coaxially mounted relative to the bearing member and rotatable thereon, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, annular stator means secured to the inner side of each of the annular structures and spaced from the rotor, a first series of concentric rings of blades in the spaces between the rotor and the two stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a double-sided radial flow compressor having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, two groups of radially extending combustion chambers arranged in a ring around and outboard of the radial compressor, each combustion chamber having an inlet at its inboard end and an outlet at its outboard end, the combustion chambers of one group being secured to one annular structure and the combustion chambers of the other group being secured to the other annular structure, the inlets of the combustion chambers of each group being serially arranged side by side to provide a circumferential inlet registering with the circumferential compressor outlet, the outlets of the combustion chambers of each group being serially arranged side by side to provide a circumferential outlet, a group of annularly arranged bearings secured to each annular structure and engaging the rotor, the said groups of bearings being concentric with the aforesaid bearing member and cooperating with it to support the rotor, the bearings of one group being annularly arranged and being located between adjacent combustion chambers to engage one side of the rotor and the bearings of the other group being annularly arranged and being located between adjacent combustion chambers to engage the other side of the rotor, a second series of concentric rings of blades in the spaces between the rotor and the two stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and another ring of the series comprising blades having their root ends secured to the stator means and their other ends extending

toward the rotor, the said rings of the second series on the stator means and on the rotor providing a double-sided radial flow turbine having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, the turbine inlet registering with the circumferential outlet of the combustion chambers, fuel supply means for the combustion chambers, the compressor supplying air which supports combustion of the fuel in the combustion chambers, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

19. An aircraft comprising a hollow hub, a bearing member annularly disposed around the hub and secured thereto, an annular rotor coaxially mounted relative to the bearing member and rotatable thereon, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, annular stator means secured to the inner side of each of the annular structures and spaced from the rotor, a first series of concentric rings of blades in the spaces between the rotor and the two stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a double-sided radial flow compressor having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, a group of annularly arranged bearings secured to each annular structure, the said groups of bearings being concentric with the bearing member and cooperating with it to support the rotor, a shroud on the blades at one side of the rotor which are comprised in the outboard ring, a shroud on the blades at the other side of the rotor which are comprised in the outboard ring, one group of annularly arranged bearings engaging one side of the rotor through one shroud and the other group of annularly arranged bearings engaging the other side of the rotor through the other shroud, combustion chamber means at each side of the rotor annularly disposed around and outboard of the radial compressor and having a circumferential inlet registering with the circumferential compressor inlet and having a circumferential outlet at the outboard periphery, a second series of concentric rings of blades in the spaces between the rotor and the two stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and another ring of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a double-sided radial flow turbine having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, the turbine inlet registering with the outlet of the combustion chamber means, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

20. An aircraft comprising a hollow hub, an annular rotor mounted for rotation relative to and around the hub, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, annular stator means secured to the inner side of each of the annular structures and spaced from the rotor, a first series of concentric rings of blades in the spaces between the rotor and the two stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a double-sided radial flow compressor having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, combustion chamber means at each side of the rotor annularly disposed around and outboard of the radial compressor and having a circumferential inlet registering with the circumferential compressor inlet and having a circumferential outlet at the outboard periphery, a second series of concentric rings of blades in the spaces between the rotor and the two stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and another ring of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a double-sided radial flow turbine having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, the turbine inlet registering with the outlet of the combustion chamber means, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft, openings being provided in the aerofoil surfaces, and passages located between the circumferential compressor inlet and the hub for conducting air from the aerofoil openings to the compressor inlet.

21. An aircraft comprising a hollow hub, a bearing member annularly disposed around the hub and secured thereto, an annular rotor coaxially mounted relative to the bearing member and rotatable thereon, an annular structure on each side of the rotor and firmly secured to the hub, the annular structure being of larger diameter than the rotor to provide portions extending outboard of the rotor, the said extending portion of one annular structure being secured to the extending portion of the other annular structure to provide a frame within which the rotor is encompassed, inboard annular stator means secured to the inner side of each of the annular structures and spaced from the rotor, a series of concentric rings of blades in the spaces between the rotor and the two

inboard stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed inboard stator means and the other rings of the series comprising blades having their root ends secured to the inboard stator means and their other ends extending toward the rotor, the said rings on the inboard stator means and on the rotor providing a double-sided radial flow compressor having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, two groups of radially extending combustion chambers arranged in a ring around and outboard of the radial flow compressor, each combustion chamber having an inlet at its inboard end and an outlet at its outboard end, the combustion chambers of one group being secured to one annular structure and the combustion chambers of the other group being secured to the other annular structure, the inlets of the combustion chambers of each group being serially arranged side by side to provide a circumferential inlet registering with the circumferential compressor outlet, the outlets of the combustion chambers of each group being serially arranged side by side to provide a circumferential outlet, outboard annular stator means at the inner side of each of the annular structures and spaced from the rotor, each of the said outboard stator means comprising a plurality of annulus sectors serially arranged side by side to provide an annulus, means adjustably securing each annulus sector to the adjacent annular structure, a series of concentric rings of blades in the spaces between the rotor and the two outboard stator means, one of the rings of the last-mentioned series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed outboard stator means and another ring of the last-mentioned series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the last-mentioned series on the outboard stator means and on the rotor providing a double-sided radial flow turbine having a circumferential inlet at each side of the rotor defined by the inboard ring of blades of the last-mentioned series and a circumferential outlet at each side of the rotor defined by the outboard ring of blades of the last-mentioned series, the turbine inlet registering with the circumferential outlet of the combustion chambers, fuel supply means for the combustion chambers, the compressor supplying air which supports combustion of the fuel in the combustion chambers, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

22. An aircraft comprising a ring, an annular rotor coaxially mounted relative to the ring and rotatable relative thereto, an annular structure on each side of the rotor and firmly secured to the ring, the annular structures together comprising a plurality of pairs of angularly spaced rib members radiating outboardly from the bearing member, one member of each pair forming part of one annular structure and the other member of each pair forming part of the other annular structure, the two members of the pairs being disposed relative to each other in a generally enantiomorphous arrangement with their inboard ends secured to and spaced by the ring and with their outboard ends extending beyond the periphery of the rotor and being spaced but rigidly secured together, the two annular structures thus providing a frame which encompasses an annular space particularly defined by the inner opposed edges of the rib members of each pair and which hollow space is bisected by the rotor, annular stator means secured to the inner side of each of the annular

structures and spaced from the rotor, a first series of concentric rings of blades in the spaces between the rotor and the two stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a double-sided radial flow compressor having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, annularly arranged combustion chamber means at each side of the rotor and having a circumferential inlet registering with the circumferential compressor inlet and having a circumferential outlet at the outboard periphery, a second series of concentric rings of blades in the spaces between the rotor and the two stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and another ring of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a double-sided radial flow turbine having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, the turbine inlet registering with the outlet of the combustion chamber means, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

23. An aircraft comprising a ring, an annular rotor coaxially mounted relative to the ring and rotatable relative thereto, a perimetrical wall disposed within but spaced from the ring and providing an occupancy chamber, an annular structure on each side of the rotor and firmly secured to the ring, the annular structures together comprising a plurality of pairs of angularly spaced rib members radiating outboardly from the bearing member, one member of each pair forming part of one annular structure and the other member of each pair forming part of the other annular structure, the two members of the pairs being disposed relative to each other in a generally enantiomorphous arrangement with their inboard ends secured to and spaced by the ring and with their outboard ends extending beyond the periphery of the rotor and being spaced but rigidly secured together, and a plurality of angularly spaced ribs radiating inboardly from the ring to the perimetrical wall, the inboard ends of the said ribs being secured to the perimetrical wall and the outboard ends being spaced from and secured to the ring so that their outer edges are substantially in the same surface as the outer edges of the outboardly radiating rib members, the two annular structures thus providing a frame which encompasses an annular space particularly defined by the inner opposed edges of the outboardly radiating members of each pair and which hollow space is bisected by the rotor, annular stator means secured to the inner side of each of the annular structures and spaced from the rotor, a first series of concentric rings of blades in the spaces between the rotor and the two stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other

rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a double-sided radial flow compressor having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, annularly arranged combustion chamber means at each side of the rotor and having a circumferential inlet registering with the circumferential compressor inlet and having a circumferential outlet at the outboard periphery, a second series of concentric rings of blades in the spaces between the rotor and the two stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and another ring of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a double-sided radial flow turbine having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, the turbine inlet registering with the outlet of the combustion chamber means, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, and opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft.

24. An aircraft comprising a ring, an annular rotor coaxially mounted relative to the ring and rotatable relative thereto, a perimetrical wall disposed within but spaced from the ring and providing an occupancy chamber, an annular structure on each side of the rotor and firmly secured to the ring, the annular structures together comprising a plurality of pairs of angularly spaced rib members radiating outboardly from the ring, one member of each pair forming part of one annular structure and the other member of each pair forming part of the other annular structure, the two members of the pairs being disposed relative to each other in a generally enantiomorphous arrangement with their inboard ends secured to and spaced by the ring and with their outboard ends extending beyond the periphery of the rotor and being spaced but rigidly secured together, and a plurality of angularly spaced ribs radiating inboardly from the ring to the perimetrical wall, the inboard ends of the said ribs being secured to the perimetrical wall and the outboard ends being spaced from and secured to the ring so that their outer edges are substantially in the same surface as the outer edges of the outboardly radiating rib members, the two annular structures thus providing a frame which encompasses an annular space particularly defined by the inner opposed edges of the outboardly radiating members of each pair and which hollow space is bisected by the rotor, annular stator means secured to the inner side of each of the annular structures and spaced from the rotor, a first series of concentric rings of blades in the spaces between the rotor and the two stator means, alternate rings of the series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and the other rings of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings on the stator means and on the rotor providing a double-sided radial flow compressor having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, annularly arranged combustion chamber means at each side of the rotor and having a circumferential inlet registering with the circumferential compressor inlet and having a circumferential outlet at the outboard periphery, a second series of concentric rings of blades in the spaces between the rotor and the two stator means, one of the rings of the second series comprising blades having their root ends secured to the rotor and their other ends extending toward the opposed stator means and another ring of the series comprising blades having their root ends secured to the stator means and their other ends extending toward the rotor, the said rings of the second series on the stator means and on the rotor providing a double-sided radial flow turbine having a circumferential inlet at each side of the rotor defined by the inboard ring of blades and a circumferential outlet at each side of the rotor defined by the outboard ring of blades, the turbine inlet registering with the outlet of the combustion chamber means, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor connected to it, means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust, opposed aerofoil surfaces substantially covering the outer sides of the frame, the said aerofoil surfaces providing lift developing surfaces of the aircraft and also providing the outer walls of an annular chamber which is encompassed by the circumferential compressor inlet and the inboard limits of which are defined by the perimetrical wall, and ports in the aerofoil surfaces to provide air inlets for the chamber.

25. An aircraft comprising a structure including an annular bearing member and a plurality of pairs of angularly spaced rib members radiating from the bearing member in an outboard direction, the two members of the pairs being disposed relative to each other in a generally enantiomorphous arrangement with their inboard ends secured to and spaced by the bearing member and with their outboard ends spaced but rigidly secured together, the plurality of radiating rib members thus encompassing an annular space particularly defined by the inner opposed edges of the members of each pair, opposed aerofoil surfaces sheathing the outer edges of the rib members to substantially cover the structure and providing lift developing surfaces of the aircraft, a radial flow compressor in the inboard portion of the hollow space, a radial flow turbine in the outboard portion and having a circumferential outlet at its outboard periphery, combustion chamber means in the intermediate portion and joining the compressor to the turbine, an annular rotor mounted for rotation at its inner periphery on the annular bearing member and dividing the aforesaid annular space into two halves, the inboard portion of the rotor providing a rotor for the compressor and its outboard portion providing a rotor for the turbine, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor, and means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust.

26. An aircraft comprising a structure including an annular bearing member and a plurality of pairs of angularly spaced rib members radiating from the bearing member in an outboard direction, the two members of the pairs being disposed relative to each other in a generally enantiomorphous arrangement with their inboard ends secured to and spaced by the bearing member and with their outboard ends spaced but rigidly secured

together, the plurality of radiating rib members thus encompassing an annular space particularly defined by the inner opposed edges of the members of each pair, a perimetrical wall disposed within but spaced from the annular bearing member and providing an occupancy chamber, a plurality of angularly spaced ribs radiating inboardly from the bearing member to the perimetrical wall, the inboard ends of the said ribs being secured to the perimetrical wall and the outboard ends being spaced from and secured to the bearing member so that their outer edges are substantially in the same surfaces as the outer edges of the outboardly radiating rib members, opposed aerofoil surfaces sheathing the outer edges of the rib members and of the ribs from the outboard ends of the rib members to the perimetrical wall to substantially cover the structure and providing lift developing surfaces of the aircraft, a radial flow compressor in the inboard portion of the hollow space, a radial flow turbine in the outboard portion and having a circumferential outlet at its outboard periphery, combustion chamber means in the intermediate portion and joining the compressor to the turbine, an annular rotor mounted for rotation at its inner periphery on the annular bearing member and dividing the aforesaid annular space into two halves, the inboard portion of the rotor providing a rotor for the compressor and its outboard portion providing a rotor for the turbine, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor, and means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust.

27. An aircraft comprising a structure including an annular bearing member and a plurality of pairs of angularly spaced rib members radiating from the bearing member in an outboard direction, the two members of the pairs being disposed relative to each other in a generally enantiomorphous arrangement with their inboard ends secured to and spaced by the bearing member and with their outboard ends spaced but rigidly secured together, the plurality of radiating rib members thus encompassing an annular space particularly defined by the inner opposed edges of the members of each pair, a perimetrical wall disposed within but spaced from the annular bearing member and providing an occupancy chamber, a plurality of angularly spaced ribs radiating inboardly from the bearing member to the perimetrical wall, the inboard ends of the said ribs being secured to the perimetrical wall and the outboard ends being spaced from and secured to the bearing member so that their outer edges are substantially in the same surfaces as the outer edges of the outboardly radiating rib members, opposed aerofoil surfaces sheathing the outer edges of the rib members and of the ribs from the outboard ends of the rib members to the perimetrical wall to substantially cover the structure and providing lift developing surfaces of the aircraft, a radial flow compressor in the inboard portion of the hollow space, a radial flow turbine in the outboard portion and having a circumferential outlet at its outboard periphery, combustion chamber means in the intermediate portion and joining the compressor to the turbine, an annular rotor mounted for rotation at its inner periphery on the annular bearing member and dividing the aforesaid annular space into two halves, the inboard portion of the rotor providing a rotor for the compressor and its outboard portion providing a rotor for the turbine, the opposed aerofoil surfaces also providing the outer walls of an air supply chamber which is encompassed by the compressor and the inboard limits of which are defined by the perimetrical wall, ports in the aerofoil surfaces to provide air inlets for the chamber, fuel supply means for the combustion chamber means, the compressor supplying air which supports combustion of the fuel in the combustion chamber means, the products of combustion expanding to drive the turbine which in turn drives the compressor, and means around the circumferential turbine outlet directing the exhaust gases to provide a propulsive thrust.

28. An aircraft comprising a generally lenticular structure sheathed by opposed lift developing surfaces, a gas displacement passage in the structure having an inlet and a substantially annular outlet adjacent to the periphery of the structure, the passage extending generally radially from the yaw axis of the aircraft in a multiplicity of diverging directions, the annulus defining the outlet being disposed generally perpendicular to the yaw axis, means for impelling air to flow through the passage from the intake in a plurality of centrifugal directions relative to the yaw axis, means for compressing the centrifugally flowing air, means for burning fuel in the compressed air, the combustion gases resulting from the burning of the fuel being emitted from the outlet, and further means, associated with the outlet, for directing the gases emitted from the outlet to provide the aircraft with a resultant thrust in a desired direction.

29. An aircraft comprising a generally lenticular structure sheathed by opposed lift developing surfaces, a central plenum chamber in said structure, a gas displacement passage in the structure having an intake at said plenum chamber and having a substantially annular outlet adjacent to the periphery of the structure, the passage extending generally radially from the yaw axis of the aircraft in a multiplicity of diverging directions, the annulus defining the outlet being disposed generally perpendicular to the yaw axis, means for impelling air to flow through the passage from the plenum chamber in a plurality of centrifugal directions relative to the yaw axis, means for compressing the centrifugally flowing air, means for burning fuel in the compressed air, the combustion gases resulting from the burning of the fuel being emitted from the outlet, and further means, associated with the outlet, for directing the gases emitted from the outlet to provide the aircraft with a resultant thrust in a desired direction.

References Cited in the file of this patent

UNITED STATES PATENTS

2,377,835	Weygers	June 5, 1945
2,384,893	Crook	Sept. 18, 1945
2,461,435	Neumann	Feb. 8, 1949
2,511,502	Gluhareff	June 13, 1950
2,575,264	Feilden	Nov. 13, 1951
2,609,664	Staley	Sept. 9, 1952
2,619,302	Loedding	Nov. 25, 1952
2,736,514	Ross	Feb. 28, 1956
2,850,250	Smith	Sept. 2, 1958

FOREIGN PATENTS

331,292	France	July 24, 1903
713,330	France	Aug. 11, 1931

Nov. 27, 1962 J. DUBBURY ET AL 3,065,935

VERTICAL TAKE-OFF AIRCRAFT

Original Filed April 18, 1955 4 Sheets-Sheet 1

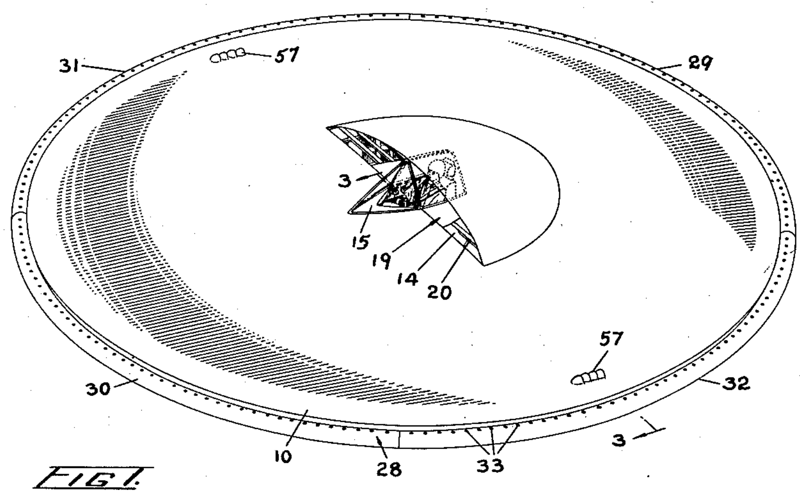
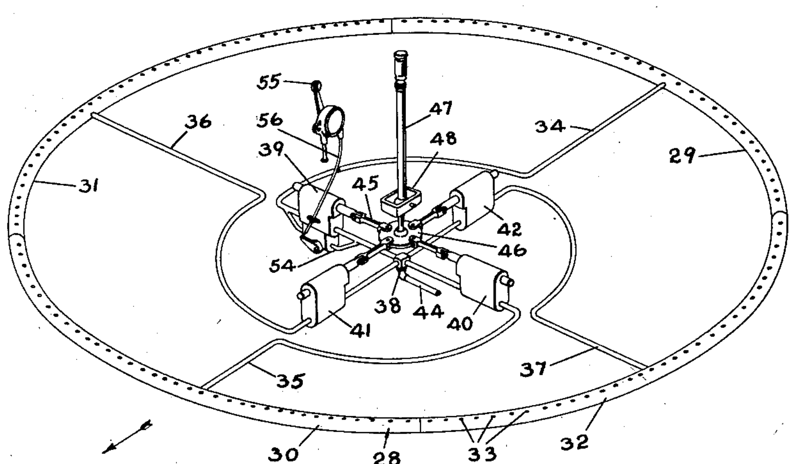


FIG.1.

FIG.5.



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VERTICAL TAKE-OFF AIRCRAFT

Original Filed April 18, 1955 4 Sheets-Sheet 2

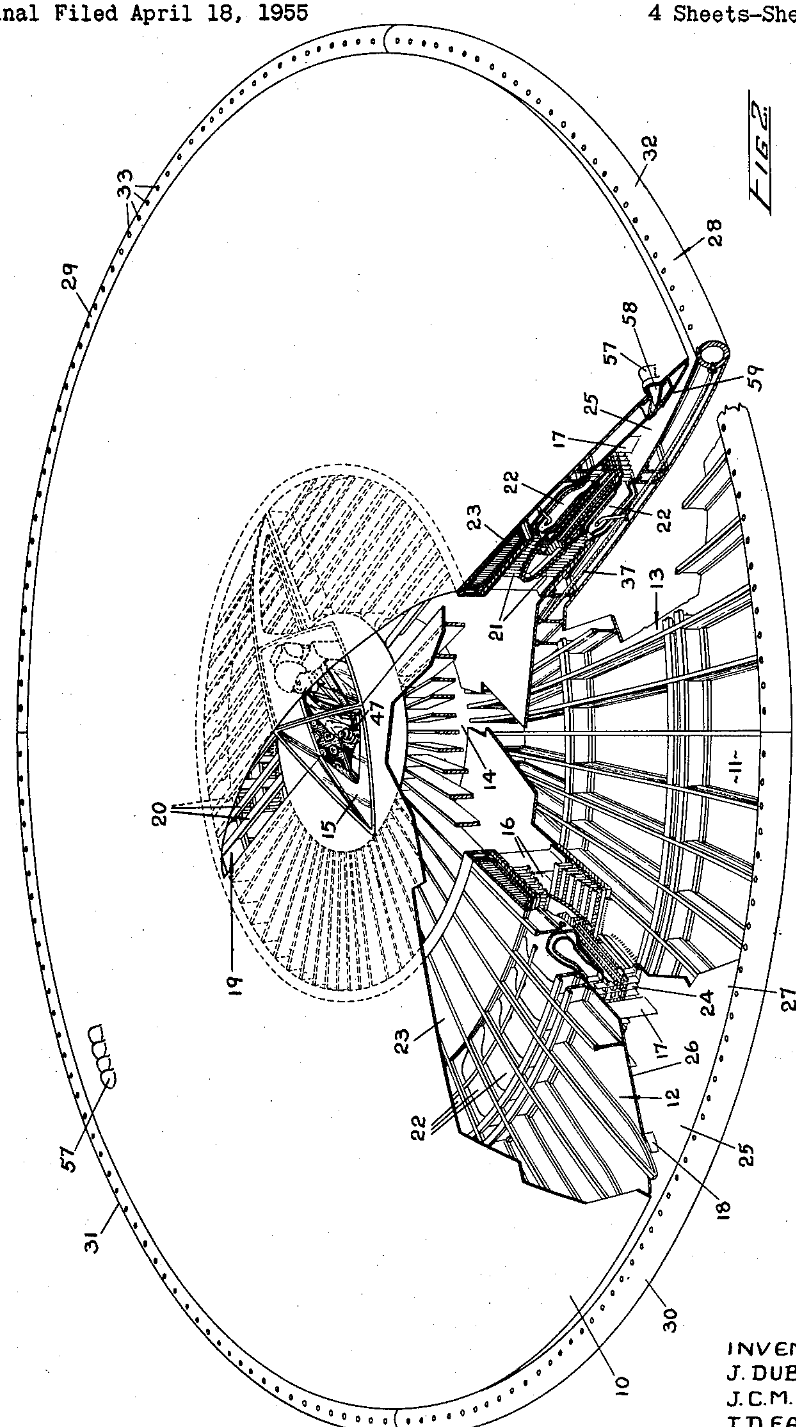

FIG. 2

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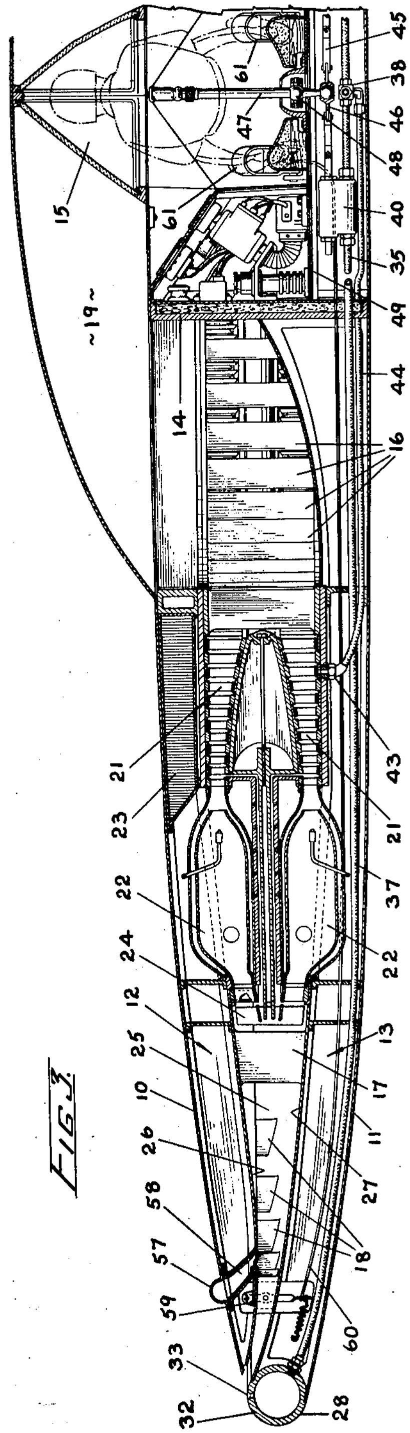
VERTICAL TAKE-OFF AIRCRAFT

Original Filed April 18, 1955 4 Sheets-Sheet 3



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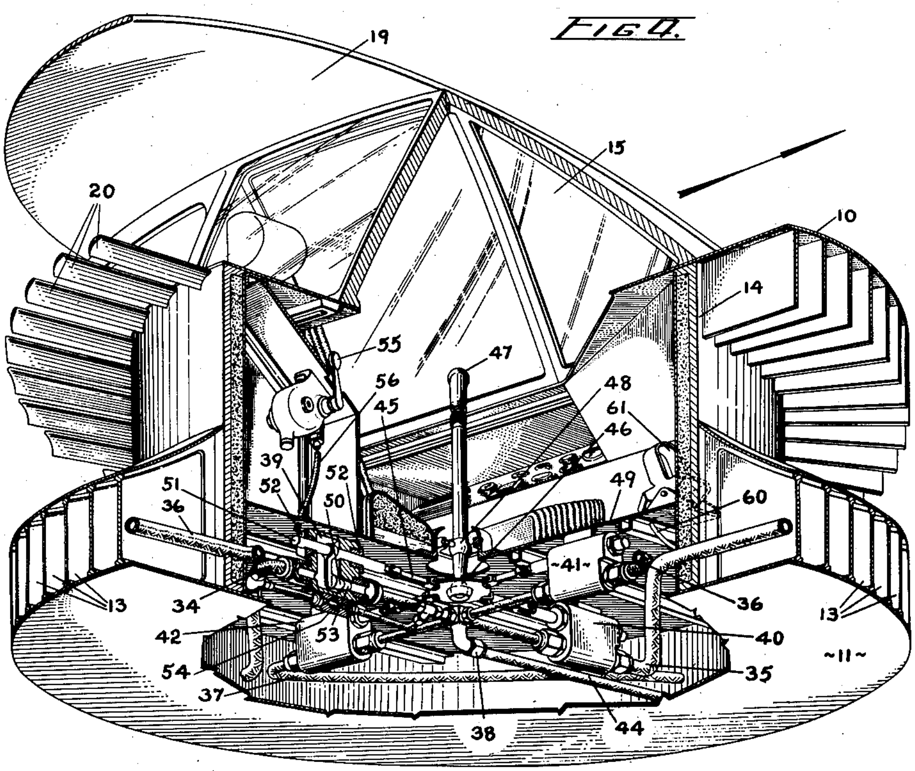
VERTICAL TAKE-OFF AIRCRAFT

Original Filed April 18, 1955 4 Sheets-Sheet 4

FIG. 4.



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3,065,935
VERTICAL TAKE-OFF AIRCRAFT

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Continuation of application Ser. No. 502,156, Apr. 18, 1955. This application Sept. 17, 1957, Ser. No. 684,615
Claims priority, application Great Britain Apr. 20, 1954
23 Claims. (Cl. 244—23)

This application is a continuation of our application Serial No. 502,156, filed April 18, 1955, now abandoned.

The invention relates to the propulsion and control of aircraft, particularly of aircraft of the general type disclosed in the co-pending United States patent application of John Carver Meadows Frost, Serial No. 376,320, filed on August 25, 1953.

The aforementioned co-pending application describes an aircraft which comprises a structure of generally lenticular form and which is sheathed by opposed aerofoil surfaces generally converging towards each other in an outboard direction from their central inboard portions to their perimetrical edges, and a radial flow gas turbine engine disposed between the said aerofoil surfaces and having a disc-like rotor the plane of rotation of which is approximately parallel to the medial plane between the said opposed surfaces. Air enters inlets provided in the aerofoil surfaces, then after passing through plenum chamber it flows radially outboardly through a double-sided multistage radial flow compressor of the gas turbine engine, then into an annularly disposed combustion system of the engine where it supports the combustion of the fuel and from which the products of combustion or gases expand through a radial flow turbine of the engine into a multiple jet-pipe assembly which directs the flow of gases to produce a forward propulsive thrust. The flight controls of that aircraft comprise hinged surfaces situated within the path of the propulsive jet.

The thrust/weight ratio of an aircraft of the type described in that application is such that the aircraft is capable of taking off, climbing and landing vertically without deriving any aerodynamic lift by virtue of its external form. To achieve such vertical flight however, the aircraft must assume an attitude whereby the plane of flight is disposed substantially vertically, that is to say, the plane of rotation of the engine rotor is vertical or nearly vertical, and this requirement presents certain design complications in the arrangement of landing gear and pilot's accommodation.

There are moreover several other features which are undesirable. The deflecting ducts or tail pipes are, of course, provided in order to direct the thrust gases, which are discharged radially around the periphery of the engine, so that they shall be discharged from the aircraft within a wide-angled sector having an angle of less than 180°, thus combining to apply the overall output of the engine to provide propulsive thrust; otherwise, diametrically opposed elements of the output would simply balance each other. However, the ducts add weight to the aircraft, and of necessity they are subjected to very high temperatures, thereby presenting structural and metallurgical problems.

Similarly, the hinged control surfaces operating within the jet stream are subject to very arduous conditions of temperature and of aerodynamic loading, and they add weight and complications to the aircraft.

A main object of the present invention is to provide means for controlling the direction of the jet discharged from the periphery of the engine, which will enable the aircraft to rise in a horizontal attitude, that is to say, in a direction perpendicular to the plane of rotation of the engine.

Another object of the invention is to provide means for selectively controlling the direction of the jet discharged from the periphery of the engine, thereby eliminating such potentially troublesome structural parts as the ducts or tail pipes, and the hinged surfaces.

A further object of the invention is to provide discharge jet control means which will enable the aircraft to rise vertically from the ground even if the thrust/weight ratio of the aircraft is less than one.

Still another object of the invention is to provide an improved method of propelling and controlling an aircraft, and of initiating its take-off.

The invention is based on a novel application of a phenomenon known as the "Coanda effect," whereby a jet of gas emerging from an orifice can be deflected to adhere to a surface situated obliquely to the axis of the jet. This effect can be demonstrated by holding a smoothly rounded edge of a plate of a given thickness adjacent a jet emerging from a slit or orifice having a width or "thickness" less than the thickness of the plate, the said edge being disposed substantially parallel to the length of the orifice; even though the plate is inclined obliquely to the plane of symmetry of the jet, the jet will be deflected around the edge of the plate and will adhere to the surface of the plate remote from the orifice. Under certain conditions the jet can be deflected through nearly 180° by this means. Air is entrained in an unobstructed jet, causing an apparent increase in the angular divergence of the jet as it leaves the orifice. If the entrainment on one side of the jet is obstructed in relation to the entrainment on the other side of the jet, the jet will be diverted and will adhere to the obstructed side. Conversely, if a contribution is made to the entrainment on one side of the jet, the jet will be diverted away from the side receiving the addition to the entrainment. In the first case the diversion of the jet is a result of the reduction of pressure between the jet and the obstruction. However, if other means are provided for introducing air between the jet and the obstruction the pressure difference will be destroyed and the jet will break away from the surface downstream of the point at which air was introduced.

The foregoing and other objects and advantages of the invention will become apparent from a study of the following specification, taken in conjunction with the accompanying drawings, in which like reference characters indicate corresponding parts throughout the several views, and in which:

FIG. 1 is a perspective view of an aircraft constructed in accordance with the invention, and viewed from above;

FIG. 2 is a perspective view of the said aircraft, partly broken away to show the internal construction;

FIG. 3 is a radial sectional view taken substantially transversely of the direction of flight, and more particularly as indicated by lines 3—3 of FIG. 1;

FIG. 4 is a fragmentary perspective view of the pilot's compartment, viewed from below, and showing particularly the pilot's control mechanism; and

FIG. 5 is a schematic view showing the interrelation between the pilot's control mechanism and the peripheral controls of the aircraft.

In accordance with the invention the construction of an aircraft in a general manner may be similar to the construction described in the aforementioned application Serial No. 376,320, except that the aircraft of the present invention preferably is circular in plan form and the tail pipes and the hinged control surfaces are dispensed with. A discharge orifice extends peripherally around the aircraft, allowing the exhaust gases from the engine to be discharged in a radial direction uniformly around the periphery thereof. The peripheral discharge orifice is so constructed that in effect it is a perimetrical Coanda nozzle, and it is provided with means whereby the entrainment on one side of the orifice may be varied selectively at various sectors, and with means whereby various sectors of the orifice selectively may be obstructed in toto or in part. Thus by the selective adjustment of appropriate controls, the direction and magnitude of the jet emitted may be varied selectively in various sectors of the peripheral nozzle, to provide control of the aircraft.

For greater convenience throughout the description certain terms of positional relationship are used. The terms "outboard" (or "outboardly") "inboard" (or "inboardly") denote, respectively, greater and lesser distances from the axis of rotation of the rotor which constitutes the centre of the aircraft, and the terms "outer" and "inner" similarly denote greater and lesser distances from a medial plane of the aircraft coinciding with the plane of the rotor. Since the structural details of the aircraft and of its integral engine do not form part of the invention, they will not be described specifically.

The opposed aerofoil surfaces of the aircraft are constituted by upper skin **10** and lower skin **11**, supported respectively on the outer edges of an upper series of ribs and spacers generally indicated at **12** and a lower series of ribs and spacers generally indicated at **13**; the two series of ribs and spacers and the skins which they support are secured together in spaced relationship by a central cylindrical shell **14** within which is a pilot's compartment **15**, and by a circumferentially arranged group of inboard struts **16** and two circumferentially arranged groups of outboard struts **17** and **18**. Air enters an inlet **19** which is provided by the central protuberance in the upper skin **10**, is deflected downwardly by cascades **20**, then after passing through a central plenum chamber it flows radially outboardly through a double-sided multi-stage compressor **21**, then into an annularly disposed combustion system **22** where it supports combustion of the fuel supplied from an annular fuel tank **23**. The products of combustion expand through a single-stage radial flow turbine **24** into a peripheral outlet **25** defined by stator plates **26** and **27** secured respectively to the inner edges of the upper series of ribs **12** and of the lower series of ribs **13**. The flow of the products of combustion through the outlet **25** is in generally radial directions. The compressor and the turbine have a common rotor which in the construction illustrated is supported by radial load and axial load air bearings.

The outboard ends of the lower series of ribs **13** are encompassed by a hollow toroidal element or bead generally indicated at **28**. It will be observed particularly from FIGS. 2 and 3 of the drawings that the bead extends beyond the outboard periphery of the upper skin **10** and that its curved surface blends smoothly with the lower lip of the orifice **25** and also with the peripheral edge of the lower skin **13**.

The bead **28** is divided into several independent sectors; in the embodiment of the invention illustrated there are four sectors, namely a rear sector **29**, a front sector **30**, a right sector **31** and a left sector **32**; the sectors are disposed in end-to-end relationship to provide together an annular control member.

Circumferentially spaced holes **33** are provided in the upper surface of the bead, and the chambers within each sector **29**, **30**, **31** and **32** are connected respectively by ducts **34**, **35**, **36** and **37** to a distributor **38** through valves **39**, **40**, **41** and **42** respectively. Air is bled at **43** from the compressor of the engine through a duct **44** to the distributor **38**, and thus if a valve is open there is a flow of air from the compressor to the openings **33** of the particular sector to which the open valve is connected.

Since the four valves are similarly constructed, only valve **39** will be described. Each of the valves is connected by a rod and link mechanism which, in the case of valve **39** is identified by reference numeral **45**, to a ball and socket fitting **46**, the ball of which is the lower ex-

tremity of a pilot's control column **47**. The control column is freely pivoted by means of a universal joint **48** fast to the cockpit floor **49**.

Referring specifically to valve **39**, a tapered plug **50** is supported by a rod **51** which is slidable in seals **52**, and it co-acts with tapered inner walls of the valve casing to stop the flow of air from the distributor **38** to the duct **34**, or to restrict the flow variably as desired. The plug has a cylindrical tip portion **53** and thus it is adapted to hold the valve in closed condition throughout that portion of its travel which is caused by the opening of the valve **40** oppositely disposed to it.

In parallel with the valve **39** is a by-pass valve **54** which is mechanically operated by a control lever **55** to which it is coupled by a flexible actuating cable **56**. By means of this control air may be caused to flow from manifold **38** to sector **29** irrespective of the position of the pilot's control column **47**, for a purpose which subsequently will be described. It will be noted that the valves **40**, **41** and **42** are not provided with parallel by-pass valves.

Rearwardly directed louvres **57** are provided at diametrically opposite sides of the aircraft, and they are connected by ducts **58** to the engine outlet **25**; thus a small fraction of the exhaust gases may be ejected to atmosphere through the louvres **57**. The ducts may be opened or closed by sliding shutters **59** each of which is linked by a flexible actuating cable **60** to the respective rudder pedals **61**. The sliding shutters operate differentially, and the resulting additional thrust component caused by the gases ejected through the louvres is sufficient to cause an unbalance of the forces about the yaw axis of the aircraft to provide directional control.

In operation, with the aircraft on the ground in a horizontal attitude, the pilot sets his controls in the neutral position of FIG. 4, so that no air is admitted to any of the holes **33** of the bead **28**; because of the Coanda effect the jet of exhaust gases is deflected downwardly and the gases thus form a hollow column upon which the aircraft is supported. The thrust/weight ratio of the aircraft and the resultant "ground cushion" (as will be described) are such that the output of the engine is ample to lift the aircraft without any aerodynamic assistance. In fact, it has been found that within a limited distance from the ground, say one-half the diameter of the aircraft, the "ground cushion" allows the aircraft to be supported even though its total weight is much in excess of the static thrust developed by the engine. This phenomenon is believed to result from the fact that the hollow column or cylindrical sheet of downwardly directed high-speed gases provides a high pressure within the column; the pressure is great enough to support an aircraft whose weight is in excess of the static thrust of the engine. Actually, the cylindrical sheet or jet of gases on striking the ground is thought to be separated into two components, namely one which turns radially outboardly and another which turns radially inboardly. The inboardly directed stream forms a toroidal vortex, the effect of which is to produce an area of high pressure over the central region of the lower surface of the aircraft to form a "cushion" of high stability on which the aircraft is supported. The outer boundary of the toroidal vortex is confined within the cylindrical sheet of gases from which there is a constant transfer of energy into the vortex to maintain support of the aircraft. The effect of this "ground cushion" increases as the distance from the ground decreases, and it is such that at a distance from the ground of one-tenth the diameter of the aircraft, the aircraft will be supported even though its weight is substantially twice the statice thrust of the engine. Known methods of vertical take-off provide a solid column of downwardly directed gases, and the ground effect will reduce the "lift" below the static thrust of the engine when the nozzle is near to the ground.

Because of the construction and of the phenomenon described, the pilot by controlling the engine output is able to raise the aircraft from the ground in vertical ascent, while the aircraft retains a horizontal attitude. By further manipulation of the pilot's control column **47** air may be emitted through the holes **33** in any selected sector of the bead **28**, and as hereinbefore explained the jet of exhaust gases emerging over the selected sector will break away from the surface of the bead and will develop an outboardly directed horizontal component of thrust while the remainder of the jet (that is, that which passes over sectors of the bead to the holes of which air is not being emitted) will continue to be subject to the Coanda effect and will produce a downwardly extending sheet of high-speed gases.

In order to transfer to forward flight, the pilot moves the control lever **55** so that the by-pass valve **54** is gradually opened thereby admitting air to the holes in the rear sector **29** of the bead, thus destroying the tendency to "coand" and producing a rearwardly directed horizontal component of thrust; the resultant thrust is in the sense of the selected sector, and the aircraft moves in the opposite sense. Once forward speed has reached a point where the aerodynamic forces on the aerofoil will support the aircraft, the control lever **55** may be returned to its original position. As the aircraft moves through the air, the exhaust gases will be influenced by the dynamic pressure of the air; the gases issuing from the various sectors will be bent rearwardly, i.e. become "wrapped under," and exert a substantial portion of the thrust in that direction.

It will be understood that the component of thrust in the horizontal and vertical directions may be varied by suitable manipulation of the control column **47** to vary selectively the amount of air emitted through the holes **33** of the individual sectors **29**, **30**, **31** and **32**. It will be noted from FIG. 5 that the valves **39**, **40**, **41** and **42** are led in a clockwise direction to connect respectively with the sectors of the bead **28** over which pass the exhaust gases whose resultant direction of horizontal thrust is disposed 90° from the axis of the valves to which the respective sectors are connected. This construction is made necessary by reason of the gyroscopic effect of the radial engine on any forces which are applied parallel to the axis of rotation and spaced from it. Banked turns can be effected by the manipulation of the pedals **61** to open or close the shutters **59** for the louvres **57** and by manipulation of the control column **47** to cause emission of gases to the holes **33** in the rear or front sectors **29** or **30** as may be necessary to locally break down the Coanda effect and thus apply an appropriate pitching couple to the aircraft. The incidence of the aircraft to the axis of flight may be controlled by the admission of air as required to the lateral sectors **31** and **32** thereby locally breaking down the Coanda effect to apply a rolling couple to the aircraft.

In order to better describe the control of the aircraft, four typical control operations are submitted below. It is assumed in each of the four cases that the aircraft is flying at normal cruising speed, the control column **47** thus being at the neutral position illustrated in FIG. 4 so that no air is being emitted through the holes **33** of any of the four sectors. The jet at the rear is streaming substantially horizontally but with a slight downward component of thrust; the forward jet is "wrapped under" and is directed aft with a slight downward component of thrust; the jets from the two lateral sectors also are "wrapped under" and they are directed aft with a slight downward component of thrust.

(1) *To Correct Right Side Drop*

It will be necessary to apply an up force to the front portion of the aircraft or a down force to the rear portion in order to stabilize the aircraft. Consequently the control **47** will be moved to the left for corrective action thus opening the right valve **39** and supplying air to the rear sector **29**. The portion of the jet ejected over the rear sector will then have no tendency to "coand" and its downward component of thrust will be removed. This will, in effect, apply a down force at the rear and stabilize the aircraft.

(2) *To Correct Left Side Drop*

It will be necessary to apply an up force to the rear portion of the aircraft or a down force to the front portion in order to stabilize the aircraft. The control handle **47** will be moved to the right for corrective action thus opening the left valve **40** and supplying air to the front sector **30**. The porton of the jet ejected over the front sector will tend to "unwrap" thus increasing the suction on the undersurface of the aircraft near the front edge and resulting in a down force at the front portion of the aircraft which stabilizes the aircraft.

(3) *To Correct Rear Drop*

It will be necessary to apply an up force to the right portion of the aircraft or a down force to the left portion in order to stabilize the aircraft. The control handle **47** must be moved forwardly for corrective action thus opening the valve **42** and supplying air to the left sector **32**. The jet ejected over the left sector will "unwrap" and there will be no downward component of thrust. The aircraft thus will be stabilized due to the down force which is applied to the left portion.

(4) *To Correct Front Drop*

It will be necessary to apply an up force to the left side of the aircraft or a down force to the right side. To effect this the control handle **47** will be moved aft for corrective action thus opening the front valve **41** and supplying air to the right sector **31**. The jet passing over the right sector will "unwrap" and all downward component of thrust will be removed. This will, in effect, apply a down force to the right portion of the aircraft and stabilize it.

It will be understood that the toroidal element **28**, which may be exposed to high temperatures and aerodynamic loading due to its location relative to the jet, can be of light yet robust construction. The control of the aircraft by the selective variation of the Coanda effect, as described herein, makes it possible to design a truly circular aircraft to the elimination of almost all structure not essential to the structure of the engine per se and to the accommodation of the pilot and his equipment and armament. Furthermore the necessity of an undercarriage is eliminated, as are other design problems associated with take-off and flight with an aircraft in a vertical attitude. Finally, design and production are greatly simplified by the symmetry and uniformity of the circular arrangement, making it possible to define the whole aircraft (other than its central core) by the definition of one sector.

The forms of the invention herein shown and described are to be considered merely as examples. The details of construction of the engine and its supporting structure do not form part of the invention. The control system proposed is by way of example only and is not an essential part of the invention. Obviously many changes in the invention not only are possible but may be desirable in order that the aircraft may have optimum performance. Such changes may, of course, be made without departing from the spirit of the invention or the scope of the subjoined claims.

What we claim as our invention is:

1. An aircraft comprising a structure of generally lenticular form and which is sheathed by opposed aerofoil surfaces which provide lift developing surfaces, engine means witihn the structure and embodying an air displacement passage having an intake end and a peripheral outlet which is adjacent the perimeter of the structure and from which the air is ejected in generally radial directions, and adjustable means encompassing the outlet and operable to

selectively alter the direction of flow of the ejected air so that at least some of the air, as it is being ejected from the outlet, flows in directions generally parallel to the yaw axis of the aircraft and in a downward sense to form a moving tubular curtain of gas which provides thrust on said aircraft in the direction of said axis.

2. An aircraft comprising a structure of generally lenticular form and which is sheathed by opposed aerofoil surfaces which provide lift developing surfaces, engine means within the structure and embodying an air displacement passage having an intake end and a peripheral outlet which is adjacent the perimeter of the structure and from which the air is ejected in generally radial directions, a plurality of control sectors arranged around the engine outlet and disposed in end-to-end relationship to provide together an annular control member, each control sector including adjustable operable means to selectively alter the direction of flow of the ejected air so that at least some of the air, as it is being ejected from the outlet, flows in directions generally parallel to the yaw axis of the aircraft and in a downward sense to form a moving tubular curtain of gas which provides thrust on said aircraft in the direction of said axis, and means to separately control the adjustable means of each control sector.

3. An aircraft comprising a structure of generally lenticular form and which is sheathed by opposed aerofoil surfaces which provide lift developing surfaces, engine means within the structure and embodying an air displacement passage having an intake end and a peripheral outlet which is adjacent the perimeter of the structure and from which the air is ejected in generally radial directions, and a perimetrical Coanda nozzle encompassing the outlet to alter the direction of flow of the ejected air.

4. An aircraft comprising a structure of generally lenticular form and which is sheathed by opposed aerofoil surfaces which provide lift developing surfaces, engine means within the structure and embodying an air displacement passage having an intake end and a peripheral outlet which is adjacent the perimeter of the structure and from which the air is ejected in generally radial directions, a perimetrical Coanda nozzle encompassing the outlet to direct the flow of the ejected air, and means cooperating with the Coanda nozzle to modify the operating characteristics of the nozzle and thus vary the direction of flow of the ejected air.

5. An aircraft comprising a structure of generally lenticular form and which is sheathed by opposed aerofoil surfaces which provide lift developing surfaces, engine means within the structure and embodying an air displacement passage having an intake end and a peripheral outlet which is adjacent the perimeter of the structure and from which the air is ejected in generally radial directions, a plurality of control sectors arranged around the engine outlet and disposed in end-to-end relationship to provide together an annular control member, each control sector including a Coanda nozzle through which the air ejected from the engine outlet is discharged and also including adjustable means to selectively alter the direction of flow of the ejected air, and means to control separately the adjustable means of each control sector.

6. An aircraft comprising a structure of generally lenticular form and which is sheathed by opposed aerofoil surfaces which provide lift developing surfaces, engine means within the structure and embodying an air displacement passage having an intake end and a peripheral outlet which is adjacent the perimeter of the structure and from which the air is ejected in generally radial directions, and means encompassing the outlet and adjustable to direct the flow of the ejected air in a direction substantially normal to the medial plane between the aerofoil surfaces to provide a cylindrical sheet of moving air the reaction of which against the aircraft together with the force of the air within it support the aircraft.

7. An aircraft comprising a structure of generally lenticular form and which is sheathed by opposed upper and lower aerofoil surfaces which provide lift developing surfaces, a hollow toroidal element perimetrically encompassing the aerofoil surfaces, the lower aerofoil surface blending with the lower surface of the toroidal element, engine means within the structure and embodying an air displacement passage having an intake end and a peripheral outlet from which the air is ejected in generally radial directions, a perimetrical Coanda nozzle registering with the peripheral engine outlet and including a gap defined by the upper surface of the toroidal element and the perimeter of the upper aerofoil surface, and means of the Coanda nozzle to alter the direction of flow of the air ejected through the nozzle.

8. An aircraft comprising a body structure, a gas displacement passage in the structure having an intake and having a substantially annular outlet adjacent to the periphery of the structure, means for impelling gas to flow through the passage from the intake to the outlet in a plurality of centrifugal directions relative to the yaw axis of the aircraft and to eject the gas at high velocity from the outlet generally radially of the yaw axis and at a multiplicity of positions distributed around said periphery, and gas directing means associated with the outlet and adjustable to selectively alter the directions in which the gas leaves the outlet, the directing means being operable to change the direction of flow of at least some of the gas, as it is being ejected from the outlet, so that it flows in directions generally parallel to the yaw axis and in a downward sense to form a moving tubular curtain of gas which provides thrust on said aircraft in the direction of said axis.

9. An aircraft as defined in claim 8, wherein the body structure is of generally lenticular form and is sheathed by opposed aerofoil surfaces which provide lift developing surfaces, and wherein said periphery is the circumferential edge portion of the structure.

10. An aircraft comprising a body structure, a gas displacement passage in the structure having an intake and having a substantially annular outlet adjacent to the periphery of the structure, means for impelling gas to flow through the passage from the intake to the outlet in a plurality of centrifugal directions relative to the yaw axis of the aircraft and to eject the gas at high velocity from the outlet generally radially of the yaw axis, gas directing means associated with the outlet and adjustable to selectively alter the directions in which the gas leaves the outlet, the directing means being operable to change the direction of flow of at least some of the gas, as it is being ejected from the outlet, to flow toward the ground and generally normal thereto to define a tubular curtain of gas, the directing means being so positioned that a portion of the aircraft substantially closes the upper end of the tube defined by the curtain, whereby, when the aircraft is adjacent to the ground, gas pressure is built up within the tubular curtain by some of the gas confined therein between the aircraft and the ground and at least partially sustains the aircraft above the ground.

11. An aircraft as defined in claim 10, wherein the body structure is of generally lenticular form and is sheathed by opposed aerofoil surfaces which provide lift developing surfaces, and wherein said periphery is the circumferential edge portion of the structure.

12. An aircraft comprising, means for ejecting gases at high velocity through a substantially annular nozzle adjacent to the outboard periphery of the aircraft, the nozzle being directed so that the gases are normally ejected in directions generally radial of the yaw axis of the aircraft and at a multiplicity of positions distributed about said periphery, and gas directing means associated with the nozzle and adjustable to selectively alter the directions in which the gas leaves the nozzle, the directing means being operable to change the direction of flow of at least some of the gases, as they are being ejected from the nozzle, so that they flow in directions generally paral-

lel to the yaw axis and in a downward sense to form a moving tubular curtain of gas which provides thrust on said aircraft in the direction of said axis.

13. An aircraft as defined in claim 12, wherein said aircraft is of generally lenticular form and is sheathed by opposed aerofoil surfaces which provide lift developing surfaces and wherein the outboard periphery is a circumferential edge portion of the aircraft.

14. An aircraft comprising, means for ejecting gases at high velocity through a substantially annular nozzle adjacent to the outboard periphery of the aircraft, the nozzle being directed so that the gases are normally ejected in directions generally radial of the yaw axis of the aircraft and at a multiplicity of positions distributed about said periphery, and gas directing means associated with the nozzle and adjustable to selectively alter the directions in which the gases leave the nozzle, the directing means being operable to change the direction of flow of at least some of the gases, as they are being ejected from the nozzle, so that they flow in a stream towards the ground and generally perpendicular thereto and are confined to define a moving tubular curtain of gas, the directing means being so positioned that a portion of the aircraft substantially closes the upper end of the tube defined by the curtain, whereby, when the aircraft is adjacent to the ground, gas pressure is built up within the tubular curtain by some of the gas confined therein between said aircraft and the ground and at least partially sustains the aircraft above the ground.

15. An aircraft as defined in claim 14, wherein said aircraft is of generally lenticular form and is sheathed by opposed aerofoil surfaces which provide lift developing surfaces and wherein the outboard periphery is a circumferential edge portion of the aircraft.

16. An aircraft comprising means for ejecting propulsive gases at high velocity from the aircraft in generally radial directions and through an annular nozzle having a central body and gas directing means adjustable to selectively alter the directions in which the gases leave the aircraft, the directing means being operable to direct the gases, upon ejection from the aircraft, in a downward stream to form a tubular curtain of gas parallel to the yaw axis of the aircraft, the central body closing the upper end of the tube defined by the curtain whereby, when the aircraft is adjacent to the ground, gas pressure is built up between the central body and the ground by some of the gas curling under the central body and at least partially sustains the aircraft above the ground.

17. An aircraft comprising a body structure, a gas displacement passage in the structure having an intake and having a substantially annular outlet adjacent to the periphery of the structure, means for impelling gas to flow through the passage from the intake to the outlet in a plurality of centrifugal directions relative to the yaw axis of the aircraft, and gas directing means associated with the outlet to alter the direction of flow of at least some of the gas leaving the outlet so that such gas flows away from the aircraft in a downward sense in directions generally parallel to the law axis, the said gas directing means also providing means which define the gas flowing out of the outlet into a moving tubular curtain which provides thrust on the aircraft in the direction of said axis.

18. An aircraft comprising a body structure sheathed by opposed aerofoil surfaces which provide lift-developing surfaces, a gas displacement passage in the structure having an intake and having a substantially annular outlet adjacent to the periphery of the structure, means for impelling gas to flow through the passage from the intake to the outlet in a plurality of centrifugal directions relative to the yaw axis of the aircraft, and gas directing means associated with the outlet to alter the direction of flow of at least some of the gas leaving the outlet so that such gas flows away from the aircraft in a downward sense in directions generally parallel to the law axis, the said gas directing means also providing means which define the gas flowing out of the outlet into a moving tubular curtain which provides thrust on the aircraft in the direction of said axis.

19. An aircraft comprising a body structure, a gas displacement passage in the structure having an intake and having a substantially annular outlet adjacent to the periphery of the structure, an annular nozzle having a central body and communicating with the outlet, means for impelling gas to flow through the passage from the intake to the outlet in a plurality of centrifugal directions relative to the yaw axis of the aircraft, and gas directing means associated with the nozzle to alter the direction of flow of at least some of the gas leaving the outlet so that such gas, after leaving the nozzle, flows away from the aircraft in a downward sense in directions generally parallel to the yaw axis, the said gas directing means also providing means which define the gas flowing out of the outlet into a moving tubular curtain of gas, the central body closing the upper end of the tube defined by the curtain whereby, when the aircraft is adjacent to the ground, gas pressure is built up between the central body and the ground by some of the gas curling under the central body and at least partially sustains the aircraft above the ground.

20. An aircraft comprising a body structure sheathed by opposed aerofoil surfaces which provide lift-developing surfaces, a gas displacement passage in the structure having an intake and having a substantially annular outlet adjacent to the periphery of the structure, an annular nozzle having a central body and communicating with the outlet, means for impelling gas to flow through the passage from the intake to the outlet in a plurality of centrifugal directions relative to the yaw axis of the aircraft, and gas directing means associated with the nozzle to alter the direction of flow of at least some of the gas leaving the outlet so that such gas, after leaving the nozzle, flows away from the aircraft in a downward sense in directions generally parallel to the yaw axis, the said gas directing means also providing means which define the gas flowing out of the outlet into a moving tubular curtain of gas, the central body closing the upper end of the tube defined by the curtain whereby, when the aircraft is adjacent to the ground, gas pressure is built up between the central body and the ground by some of the gas curling under the central body and at least partially sustains the aircraft above the ground.

21. An aircraft comprising a body structure, an annular nozzle on the structure adjacent to the periphery thereof and having a central body, a gas displacement passage in the structure and extending between an intake and the nozzle, means for impelling gas to flow through the passage from the intake to the nozzle in a plurality of centrifugal directions relative to the yaw axis of the aircraft, and gas directing means associated with the nozzle to direct at least some of the gas leaving the nozzle to flow away from the aircraft in a downward sense in directions generally parallel to the yaw axis, the said gas directing means also providing means which define the gas flowing out of the outlet into a moving tubular curtain of gas, the central body closing the upper end of the tube defined by the curtain whereby, when the aircraft is adjacent to the ground, gas pressure is built up between the central body and the ground by some of the gas curling under the central body and at least partially sustains the aircraft above the ground.

22. An aircraft comprising a body structure sheathed by opposed aerofoil surfaces which provide lift-developing surfaces, an annular nozzle on the structure adjacent to the periphery thereof and having a central body, a gas displacement passage in the structure and extending between an intake and the nozzle, means for impelling gas to flow through the passage from the intake to the nozzle in a plurality of centrifugal directions relative to the yaw axis of the aircraft, and gas directing means as-

sociated with the nozzle to direct at least some of the gas leaving the nozzle to flow away from the aircraft in a downward sense in directions generally parallel to the yaw axis, the said gas directing means also providing means which define the gas flowing out of the outlet into a moving tubular curtain of gas, the central body closing the upper end of the tube defined by the curtain whereby, when the aircraft is adjacent to the ground, gas pressure is built up between the central body and the ground by some of the gas curling under the central body and at least partially sustains the aircraft above the ground.

23. An aircraft comprising means for impelling propulsive gases at high velocity within the aircraft in generally centrifugal directions and ejecting the gases through an annular nozzle having a centerbody and means to direct the gases, upon ejection from the aircraft, in a downward stream to form a tubular curtain of gas parallel to the yaw axis of the aircraft, the centerbody closing the upper end of the tube defined by the curtain whereby, when the aircraft is adjacent to the ground, gas pressure is built up between the centerbody and the ground by some of the gas curling under the centerbody and at least partially sustains the aircraft above the ground.

References Cited in the file of this patent

UNITED STATES PATENTS

1,724,226	Sorensen	Aug. 13, 1929
2,444,318	Warner	June 29, 1948
2,718,364	Crabtree	Sept. 20, 1955
2,777,649	Williams	Jan. 15, 1957
2,807,428	Wilbault	Sept. 24, 1957

FOREIGN PATENTS

770,874	Great Britain	Mar. 27, 1957

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,065,935 November 27, 1962

John Dubbury et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

In the grant, line 3, after "Canada," insert -- assignors, by mesne assignments, to Avro Aircraft Limited, of Malton Village Ontario, Canada, a corporation, --; lines 12 and 13, for "John Dubbury, John Carver Meadows Frost, and Thomas Desmond Earl, their heirs" read -- Avro Aircraft Limited, its successors --; and in the heading to the printed specification, line 5, after "Canada" insert -- , assignors, by mesne assignments, to Avro Aircraft Limited, Malton Village, Ontario, Canada, a corporation --.

Signed and sealed this 15th day of October 1963.

(SEAL)
Attest:

ERNEST W. SWIDER

Attesting Officer

EDWIN L. REYNOLDS

Acting Commissioner of Patents

Dec. 4, 1962 N. C. PRICE 3,066,890

SUPERSONIC AIRCRAFT

Original Filed Jan. 23, 1953 3 Sheets-Sheet 1

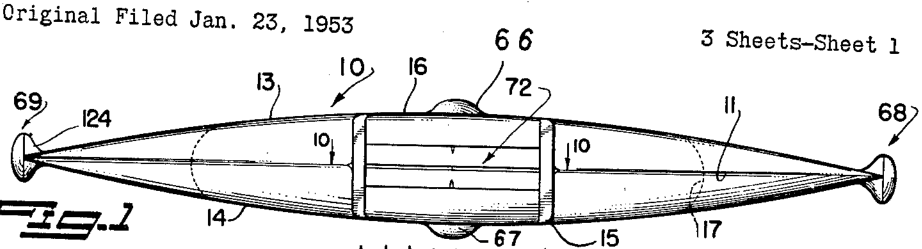

Fig. 1

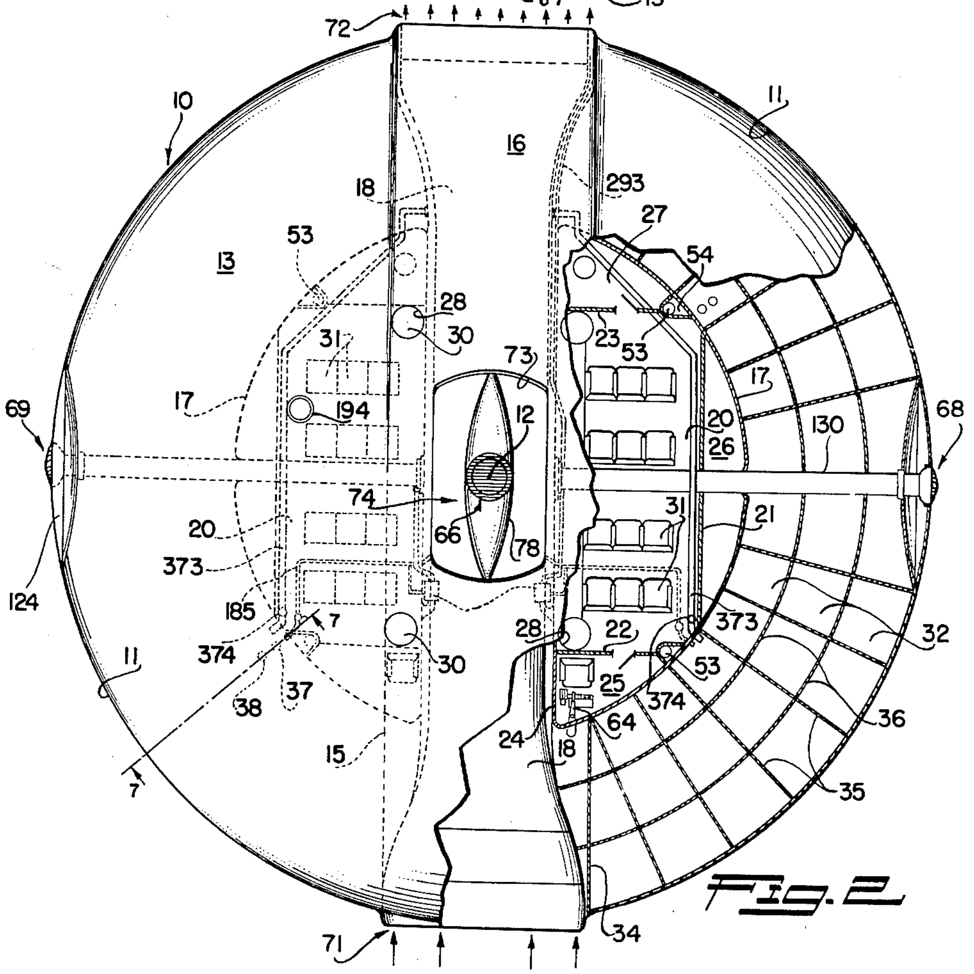

Fig. 2

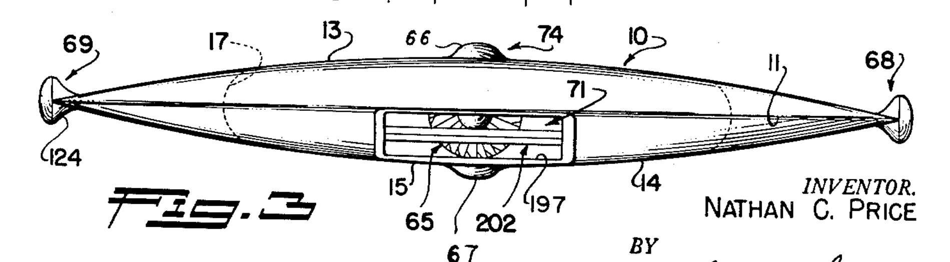

Fig. 3

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SUPERSONIC AIRCRAFT

Original Filed Jan. 23, 1953

3 Sheets-Sheet 2

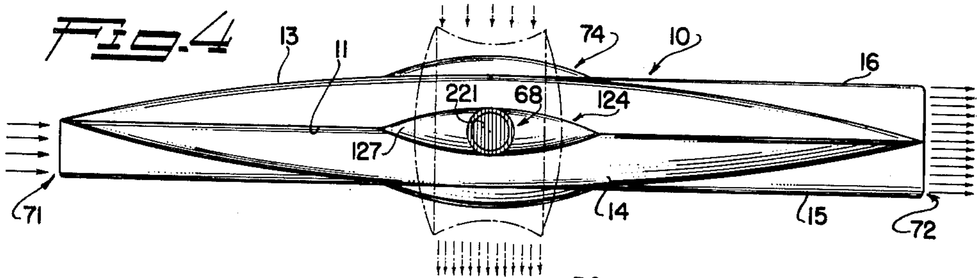

Fig. 4

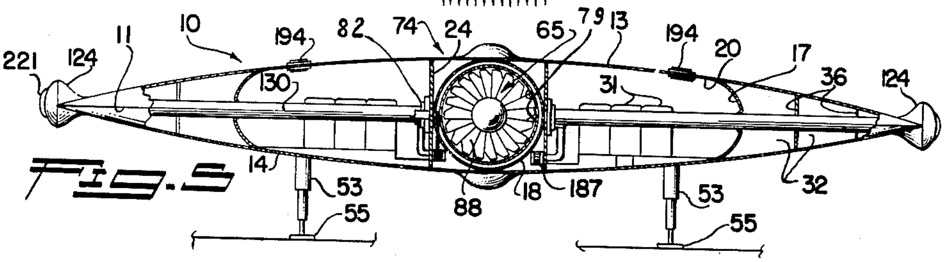

Fig. 5

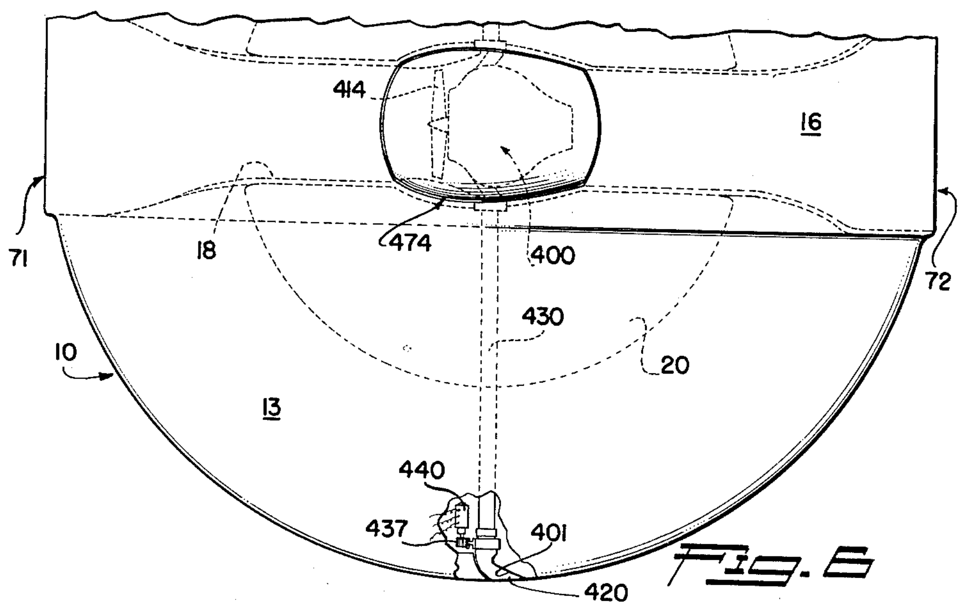

Fig. 6

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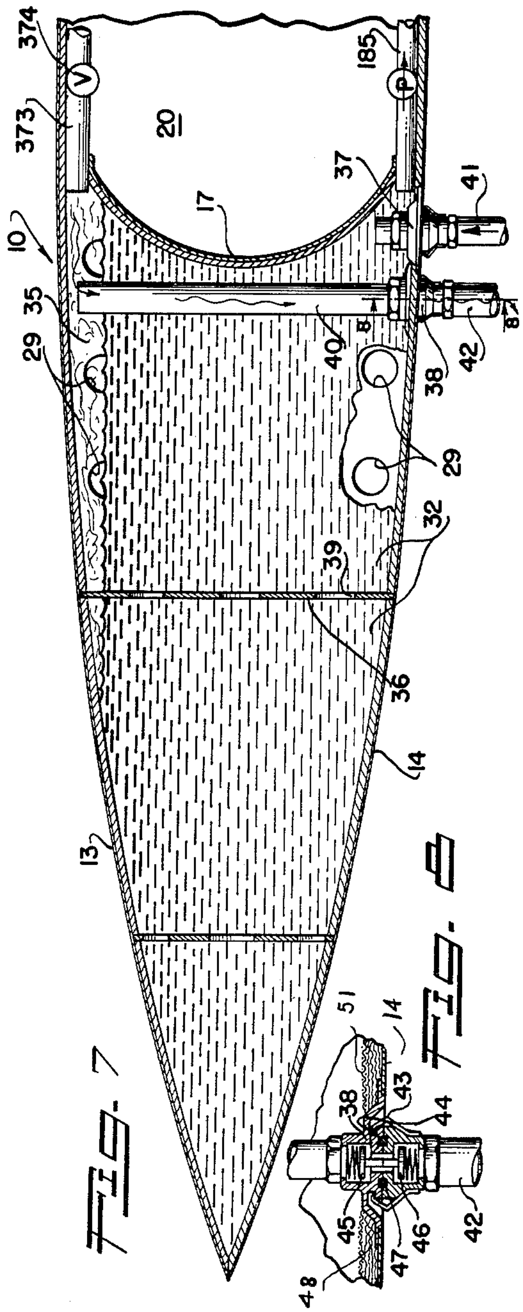
SUPERSONIC AIRCRAFT

Original Filed Jan. 23, 1953 3 Sheets-Sheet 3



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3,066,890
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1

3,066,890
SUPERSONIC AIRCRAFT

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Original application Jan. 23, 1953, Ser. No. 332,957. Divided and this application July 1, 1957, Ser. No. 669,369
22 Claims. (Cl. 244—15)

This invention relates to aircraft, and relates more particularly to aircraft capable of vertical ascent and descent during takeoff and landing and of high altitude flight at supersonic velocities. It is a general object of this invention to provide vertical rising and descending aircraft characterized by their unique aerodynamically efficient design and by a propelling system for producing safe, efficient, supersonic, long range flight. The aircraft of the invention is designed not only for vertical ascent and descent to facilitate landing and taking off at small fields or landing areas but also for long range flight at a Mach number of, say, 4, and at altitudes in the region of 100,000 ft.

The application is a division of my copending application Serial Number 332,957, filed January 23, 1953, entitled "High Velocity High Altitude Aircraft."

Another object of the invention is to provide aircraft of circular plan-form and of bi-convex vertical cross section which may be devoid of the conventional fuselage, wings, and empennage. The circular plan-form airplane of the invention has spherical has spherical convex upper and lower skin surfaces constituting the major surface areas of the airplane. This simple structure or design has many inherent advantages and features. It:

(1) Is an inherently rigid, strong structure having greater resistance to bending and torsional moments than other airborne configurations;

(2) Provides for a more uniform weight distribution over the lifting surface than other aircraft configurations;

(3) Allows a more uniform distribution of landing forces into the airplane structure and due to its circular plan-form permits the employment of any selected or required number of landing struts;

(4) Is not subject to flutter or to damage by gusts;

(5) Is structurally efficient in containing internal cabin pressures, fuel and other internal loads by reason of the spherical convex upper and lower skin surfaces joined one to the other at the circular periphery of the craft;

(6) Operates to effectively or uniformly distribute the thermal stresses and deformations resulting from high Mach number flight;

(7) Permits the positioning or concentrating of the useful loads in concentric relation to the center of gravity and geometric center of the structure and the disposition of the fuel loads in balanced or concentric relation to the center of gravity and geometric center;

(8) Is stable during vertical ascent and descent due to its circular plan-form;

(9) Provides a maximum volumetric capacity for the pay loads and fuel;

(10) Is simple and inexpensive to construct owing to its simple regular configuration and because many of its parts may be of like or identical size and shape;

(11) Occupies a minimum of field or floor space when not in flight due to its inherent compactness;

(12) Is inherently aerodynamically efficient, having a good *L/D* ratio and presents a substantially continuous unbroken peripheral edge (leading and trailing edges) and a smooth profile offering a minimum of skin friction drag; and

2

(13) May land and takeoff from any medium, being stable even on rough water.

These and other considerations and advantages all result from the simple compact circular plan-form airframe of bi-convex cross section.

Another object of the invention is to provide an aircraft of this character having a diametrically extending thin plate airfoil region or portion containing in part the primary propulsive mechanism or means, this thin plate airfoil constituting only a relatively small portion of the total airfoil and yet assisting in producing aerodynamic lift with a minimum of drag.

Another object of the invention is to provide an aircraft of the character above referred to which employs a low boiling point fuel, such as butane or propane as the fuel and refrigerant. Such fuels have approximately 15% more energy value than conventional aircraft fuels but are much less dense, thereby requiring considerably greater tank space or volume. The circular plan-form bi-convex airplane of the invention supplies this necessary fuel storage volume and contains the low boiling point fuel in such a manner that it effectively cools the skin and assists in protecting the passenger and cargo compartments against excessively high temperatures. The low boiling point fuel through vaporization of even only one-third of the total fuel carried absorbs in the neighborhood of 1 million B.t.u. per hour, thereby bringing the skin temperatures into equilibrium at a substantially lower value. Thus the configuration of the airframe or body and the type of propulsive fuel and its mode of storage mutually contribute to the cooling of the skin and provide storage regions of ample volume for the low density fuel.

Another object is to provide aircraft of this kind having a safe dependable propulsive system wherein operational failure of certain of its components will not endanger the craft or its occupants. The load turbines which incorporate the high velocity rotors of the system are so positioned that the planes of rotation of these rotors do not in any instance intersect the passenger compartment or vital portions of the craft while in translational flight. Accordingly, failure or bursting of a rotor will not endanger the occupants of the craft.

Another object of the invention is to provide an aircraft of this kind wherein the variable inlet and the controllable outlet or nozzle of the main duct are generally rectangular and are elongated spanwise of the circular craft to best conform with its thin periphery. The elongated inlet and outlet contribute to the desirable thin central airfoil region and reduce wake losses. The main propulsive duct is diametric of the circular airfoil or body so that there is ample length for the propulsive mechanism in the circumference of the body and therefore no need to extend or project either the ram inlet or the nozzle from the periphery of the circular craft.

A further object is to provide a circular plan-form aircraft as described characterized by the bi-convex skin surfaces capable of carrying substantial internal pressures and by simple yet strong and effective passenger, cargo and fuel compartmentation. The cabin is surrounded by a circular wall or bulkhead extending between the upper and lower convex skin structures, this bulkhead together with the skin structures providing or constituting the fuel tanks or compartments and there are circumferentially spaced radial baffles in the fuel compartments secured to the skins and the circular bulkhead. This internal structure, including, of course, minor local stiffening ribs, etc., is so strong and rigid as to readily withstand all aerodynamically induced vibration forces as well as all other operational loads and forces.

Other objectives and features will become apparent from the following detailed description of typical preferred embodiments of the invention throughout which reference will be made to the accompanying drawings, wherein:

FIGURE 1 is a rear elevational view of an aircraft of the invention;

FIGURE 2 is a plan view of the aircraft with a portion broken away to illustrate the internal structure;

FIGURE 3 is a front elevation of the craft;

FIGURE 4 is an edge or side elevation of the craft with broken lines illustrating the propulsive island in a vertical position to produce vertical thrust for ascent or descent;

FIGURE 5 is a transverse sectional view taken substantially as indicated by line 5—5 on FIGURE 2 and illustrating the landing struts and the tip portions in elevation;

FIGURE 6 is a fragmentary plan view of another aircraft of the invention with a portion broken away to illustrate one of the tip nozzles;

FIGURE 7 is an enlarged fragmentary vertical sectional view taken as indicated by lines 7—7 on FIGURE 2 showing one of the fuel compartments and a portion of the fueling means; and

FIGURE 8 is an enlarged fragmentary sectional view taken as indicated by line 8—8 on FIGURE 7.

The aircraft of the invention as illustrated in FIGURES 1 through 5, 7 and 8, includes an airframe, airfoil or body **10**, which I will usually hereinafter refer to as the body, of circular plan-form. As best illustrated in FIGURE 2, the body **10** has a periphery **11** which is preferably concentric with an axis **12** which may constitute the center of gravity and the geometric center of the airplane. This periphery **11** is continuous and unbroken except for minor interruptions at the inlet and outlets of the propulsive system, to be subsequently described, and as seen in FIGURES 1, 3, 4 and 5, it is quite sharp to have good aerodynamic characteristics and to minimize the frontal area of the craft. In accordance with the invention the upper and lower surfaces or skins **13** and **14** of the airplane are convex and are preferably spherically convex, being in the nature of two like opposing spheroidal segments having their bases or chords coincident and joining at the plane of the peripheral edge **11**. These spherical convex surfaces or skins **13** and **14** are smooth and regular to offer a minimum of drag and join at the circumferential edge **11** (leading and trailing edge) which itself is sharp and aerodynamically efficient. As briefly mentioned above, the body **10** has a diametric airfoil-rear region which is defined by a rather broad yet shallow rib portion **15** extending completely diametrically across the underside of the body **10** and a similar shallow rib portion **16** at the upper side of the body extending from adjacent the center thereof to its trailing edge. The lower side of the lower rib portion **15** is flat and substantially parallel with the plane occupied by the peripheral edge **11** and in a like manner the surface of the upper rib portion **16** is flat and parallel with the same plane. The primary purpose of the rib portion is to provide ample space within the aircraft for elements of the propulsive system, to be later described, although the rib portion constitutes a thin plate airfoil which assists in providing aerodynamic lift for the airplane. In practice, the rib portions **15** and **16** need not be very thick and may die into the contours of the skins **14** and **13** adjacent the center of the craft. The sides or edges of the rib portions **15** and **16**, which extend chord-wise of the body **10**, are faired into the skins **14** and **13** respectively. However, where the portions **15** and **16** extend fore and aft along the fore and aft axis of the craft, they constitute a rib which serves as a vertical stabilizer for the airplane. The surfaces or skins **13** and **14**, the skins of the rib portions **15** and **16**, the peripheral edge **11**, and other exposed parts of the airplane such as fairings, etc. are preferably constructed of stainless steel or other material capable of retaining adequate strength when subjected to the high temperatures developed during the multi-Mach number flight program.

The airframe **10**, as just described, is inherently capable by reason of its geometrical configuration of withstanding heavy stresses and loads and the invention provides a simple yet strong internal structure for reinforcing the airframe and for assuming major structural and functional loads. A pressure bulkhead **17**, curved in both plan-form and radial planes is provided in the body **10** and extends between and is secured to the upper and lower skins **13** and **14**. The bulkhead **17** is concentric with the axis **12** and may be substantially vertical. A large diametered propulsive air duct **18** extends diametrically through the body **10** and intersects the circular bulkhead **17** to divide the space encircled thereby into two main passenger and/or cargo compartments **20**. The duct **18**, which will later be described in connection with the propulsive system, extends fore and aft and is coaxial with the rib portions **15** and **16** above described. As the duct **18** interrupts the bulkhead **17** and divides the bulkhead into two sections, there are walls **24** adjacent to and parallel with the duct for connecting the ends of their respective partially circular bulkhead portions. The main compartments **20** which may or may not be interconnecting depending upon the relative diameter of the air duct **18**, are shown in the drawings as passenger compartments, being provided with rows of aft facing seats **31**. The compartments **20** may, in practice, be defined by portions of the above mentioned walls **24** and by partitions **21**, **22** and **23**. The bulkheads or partitions **21**, **22** and **23**, together with the walls **24**, define generally rectangular passenger compartments **20** and as the bulkhead **17** is circular, marginal compartments **25**, **26** and **27** remain forward, aft and outboard of the main compartments.

The forward compartments **25** may constitute the pilot and crew areas, the outboard compartments **26** may be used to carry luggage, mail, cargo, etc. and the aft compartments **27** may be restrooms or toilets. The various compartments, just described, may be interconnecting. Entrances or hatchways **28** in the upper and lower skins **13** and **14** lead to the main compartments **20** and are equipped with sealed hatches or closures **30** capable of withstanding substantial pressure differentials. The various partitions and walls and particularly the bulkhead **17** and its wall portions **24** may be structural load assuming elements secured to one another and to the skins **13** and **14** to constitute a strong internal assembly or structure.

As briefly noted above, the regions or areas of the circular plan-form bi-convex body **10** around the passenger and load carrying compartments serve as fuel tanks or fuel cells which I have designated **32**. The fuel tanks or cells **32** are bounded or defined by the skins **13** and **14**, the bulkhead **17** and chord-wise walls or bulkheads **34** extending from the bulkhead **17** to the periphery **11** adjacent and generally parallel to the main air duct **18**. I prefer to provide the fuel cells **32** with multiplicities of circumferentially spaced radially disposed internal baffles or bulkheads **35** and spaced circumferential or circular bulkheads **36**. These bulkheads **35** and **36** which extend between the skins **13** and **14** and which are attached to the skins materially increase the strength and rigidity of the structure. The bulkheads **35** and **36** are perforated, having openings **29** and **39** respectively (see FIGURE 7), so that the various regions or areas of the individual fuel cells **32** are in communication. It is to be noted that the fuel in the cells **32** is in heat absorbing or heat transfer relation to the major portions of the skins **13** and **14** and the bulkhead **17** and thus serves as a refrigerant to reduce the temperature of the skins and to protect the passenger and cargo compartments **20**, **25**, **26** and **27** against excessively high temperatures. The cooling or refrigerating action of the fuel and the refrigerating system will be more fully described hereinafter.

Special provision is made to supply or fill the fuel cells 32 with the low pressure fuel. Because butane, propane, and like fuels vaporize readily at normal ground temperatures, it is necessary to continuously withdraw vaporized fuel from the cells or tanks 32 as the cells are filled with liquid fuel and until the craft takes off. For this purpose the lower wall or skin 14 of each fuel cells 32 has two fuel conduits or fittings 37 and 38 (see FIGURE 7 and 8), the fitting 37 serving to discharge liquid fuel into the cell and the fitting 38 being adapted to bleed off fuel vapor from its respective cell. The fittings 38 have stand pipes 40 extending upwardly to adjacent the tops of the cells 32 to receive the fuel vapor. When refueling the airplane and until ascent has been initiated, pipes or hoses 41 are connected with the fittings 37 to supply liquid fuel to the cells and similar hoses 42 are connected with the fittings 38 to draw or carry away the fuel vapor. The fittings 37 and their related hoses 41 and the fittings 38 and their related hoses 42 may have identical detachable connections and valve means and while I will specifically describe the detachable connections and the valve means of the fittings 38 and their pipes or hoses 42, it is to be understood that this description is equally applicable to the corresponding connections and valve means of the fittings 37 and their pipes 41. As shown in FIGURE 8, the hoses or pipes 42 have spring clips 43, or the equivalent, detachably engaged with shoulders 44 on the fittings 38 to hold them in communicating connection with the fittings. Seal rings 47 are engaged between the fittings 38 and the hoses or pipes 42 to prevent the leakage of the vapor or fuel. The fittings 38 and the hoses or pipes 42 have opposing poppet valves 45 and 46, respectively, spring urged to closed positions. The relationship of the valves 45 and 46 is such that so long as the pipes 42 remain coupled with the fittings 38 the valves cooperate with one another to be held in the open positions where the fuel vapor is free to flow out through the hoses or pipes 42. The pipes 42 are connected with an absorption pump (not shown) for drawing away the fuel vapor and the hoses or pipes 42 are connected with a source or sources of the liquid fuel under pressure so as to deliver the liquid fuel to the cells 32 of the airplane. Preparatory to takeoff and so long as the aircraft remains on the ground or field, liquid fuel is pumped in through the hoses or pipes 41 and the vaporized fuel is withdrawn through the hoses or pipes 42. When the aircraft rises vertically from the field or ground, the spring clips 43 snap out of engagement with their shoulders 44 allowing the fittings 37 and 38 to move upwardly out of engagement with their respective pipes 41 and 42. When this occurs the valves 45 and 46 automatically close to retain the liquid fuel and the vaporized fuel within the fuel cells 32 of the airplane and to avoid the spilling or leakage of the fuel from the hoses or pipes 41 and 42.

It is to be observed that the circular plan-form biconvex aircraft body 10 provided with the partly circular fuel cells 32 has a large aggregate volumetric fuel storage capacity. This well adapts the craft for the utilization of butane or propane which have approximately 15% greater energy value than conventional aircraft fuels on a weight basis but are far less dense and, therefore, require large capacity storage space for comparable ranges of flight. By making the bulkhead 17 of less diameter the fuel capacity of the cells 32 may be greatly increased to extend the operational range of the craft. This is indicated and practical in the case of military craft where the personnel and the payload areas or compartments may be quite small. Furthermore, for military craft it may be desirable to use liquid hydrogen as the propulsive fuel to materially extend the operational range. Liquid hydrogen has a very low density (.086) with a boiling point density of 0.070 and on a volume per heat content basis requires approximately three times as much space as gasoline. However, for pilotless military aircraft and military aircraft carrying one or two men, the body 10 is such that it may be readily compartmented to contain ample liquid hydrogen as its fuel for a non-stop flight of, say, 7,500 miles. Such liquid hydrogen could well be supplied to or pumped into the fuel cells 32 in the same manner as the other fuels.

The lower boiling points fuels are especially well adapted for cooling the passenger and payload compartments and other critical regions of the aircraft and greatly reduce the temperature of the skin. Butane has a boiling point under 33° F. and propane has a boiling point of —45° F. Such fuels and the vapor therefrom in contact with the inner surfaces of the skins 13 and 14 prevent the skins from being excessively heated by the aerodynamically induced heat. Assuming the body 10 has a diameter of 50 ft. and that the craft is operated at a speed of Mach number 4 at an altitude of 100,000 ft. it is calculated that the temperature of the skins unless provision is made for cooling it, would reach 1139° F. However, the skins 13 and 14 preferably has their outer surfaces chemically oxidized black, or otherwise treated, or coated to have a heat emissivity of approximately 0.95. This high emissivity will result in radiation of a substantial amount of heat energy into space. Although the emissivity of a surface is numerically equal to its absorptivity there is a distinct and novel advantage in providing the skins 13 and 14 of the airplane of this invention with external surfaces having high emissivity. The heat input to the skins 13 and 14 as a result of the frictional drag and the airplane speed is considerable. On the other hand, solar radiation will tend to increase the skin temperature to only a very minor extent. It is estimated that the aerodynamically induced heat input to the skin will be approximately thirty times as much as the heat induced by solar radiation. Accordingly, the skin surfaces of high emissivity and correspondingly high absorptivity have the net effect of emitting many times as much heat energy as they are capable of absorbing and the surfaces of high emissivity function as effective heat dissipating elements of the cooling or refrigerating means of the invention. Additionally, the heat energy required to vaporize approximately 30% of the low boiling point fuel during the flight program is substantial, being in the neighborhood of 1 million B.t.u. per hour under the above assumed conditions. Thus it is calculated that the skin temperatures under the above conditions will come into equilibrium at about 940° F. The stainless steel skins 14 and 13 maintain their structural integrity at such a temperature and the internal structure adjacent thereto is not adversely affected at such a temperature. The material reduction in the temperature of the skins of the aircraft has the effect of increasing the efficiency and range of the craft. The reduction in skin temperature proportionately reduces the viscosity of the boundary layer air and therefore increases the aerodynamic efficiency of the circular plan-form biconvex airfoil or craft.

The invention provides effective thermal insulation at the inner surfaces of the skins 13 and 14 at the bulkheads 17, walls 24, bulkheads 34, and other walls, bulkheads, etc. where necessary or desirable to thermally insulate the internal structure and the passenger and payload areas of the aircraft, it being observed that the fuel cells 32 containing the low boiling point fuel and its vapor substantially surround the passenger and payload compartments 20, 25, 26 and 27. The fuel cells 32 and their contents thus form effective thermal barriers protecting the passenger and payload regions. FIGURE 8 shows a form of insulation that may be used on the skins 13 and 14 and the several bulkheads, walls, etc. The insulation, as illustrated, is provided on the inner surface of the skin 14, is being understood that it is equally applicable to the other insulated areas and regions. The insulation includes "Alfoil" blankets 48 which are comprised of pluralities of corrugated or crinkled aluminum or other metal foil sheets arranged and related so that there are multiplicities of air spaces betwen the adjacent foil sheets. Such insulation has a very low apparent density and a low k factor and is therefore well adapted for this application. However, other appropriate thermal insulation or insulating materials may be use if desired. The blankets 48 of metal foil are engaged on or fixed to the inner side of the skin 14. In order to retain the rather loosely arranged blankets 48, I provide metal mesh, screens or the like, 51 to extend across the blankets 48. Immersion of this type of insulation, either temporarily or permanently, in the fuel and/or fuel vapor of the cells 32 does not impair the insulating qualities although it may alter the k factor while the insulation is immersed, depending upon the proportion of fuel vapor between the layers. The foil of the insulating blankets 48 is preferably polished or bright to be most efficient in reflecting radiant energy under practically all conditions.

In accordance with the broader aspects of my invention any suitable or selected type of alighting or landing gear may be employed. In the drawings, and more particularly in FIGURES 2 and 5, I have shown a plurality of spaced generally vertical shock absorbing struts 53 projectable from the underside of the body 10. The retractable struts 53 may be of the oleo type and are preferably arranged for vertical retraction into relatively small spaces or compartments 54 at the bulkhead 17 and adjacent the adjoining corners of the above described compartments 20, 26 and 27. In this connection it is to be observed that the landing gear struts 53 may readily be anchored or attached to the body 10 at regions where the landing loads may be transmitted directly to the strong rigid internal structure of the craft and that by reason of the circular configuration of the body 10 and the circular arrangement of its bulkhead 17 and other structural parts any selected or required number of the struts 53 may be installed in practically any required pattern or relationship. The lower ends of the landing struts 53 may be equipped with wheels, pads, or the like. In the drawings I have shown pads 55 on the struts 53 of such a nature that they may lie substantially flush with the surfaces of the lower skin 14, when the struts are retracted, so as to offer little or no aerodynamic drag.

It is contemplated that translational flight will usually be at such great altitude that visual observation by the passengers will be of minor consequence and there is no real necessity for the provision of windows, or the like, in the passenger compartment 20. It is also contemplated that the flight of the craft will be controlled by a remotely controlled automatic pilot means thus reducing the flight personnel to a minimum. However, to facilitate pilot controlled landings, maneuvers during emergencies, etc. either one or both of the pilot compartments 25 is provided with a periscope 64, shown in a general way in FIGURE 2.

The propulsive system of the aircraft illustrated in FIGURES 1 to 5 inclusive may be said to comprise, generally, a ducted compressor 65 capable of angular adjustment or movement to produce vertical lift and translational propulsion, upper and lower load turbo powerplants 66 and 67 for driving the compressor 65 and for producing propulsive and directional thrust, a variable ram or air inlet 71 for the ducted compressor 65 and ram jet means 70, a variable area and directional outlet or propulsive nozzle 72 for the ducted compressor and ram jet means, and various other parts and mechanisms associated with these primary propulsive elements.

The ducted compressor 65 is preferably located at or adjacent the geometric center of the circular planform airframe or body 10 and is pivotally mounted to be movable about a spanwise and preferably diametric axis so as to be turned to a vertical or generally vertical position during the vertical ascent and descent of the craft and to be brought to a position coaxial with the abovementioned fore and aft duct 18 and during translational flight of the craft. The main air duct 18 extends diametrically through the circular body 10, as above described, and is provided at its forward end with the variable area inlet 71 and at its aft end with the variable area and directional nozzle 72. The major portion of the duct 18 is preferably cylindrical although its end portions are horizontally elongated, as will be more fully described in connection with the inlet 71 and the outlet or nozzle 72. The airframe or body 10 has a central vertical opening 73 which intersects the duct 18 and the propulsive compressor 65 is housed or carried in a structure 74 which I will term an "island." This island 74 is journaled at the vertical opening 73 to be movable or turnable therein about a horizontal spanwise axis. The island 74 may be a generally rectangular structure to fit between the walls 24 of the compartments 20 with suitable clearance, and has upper and lower walls which are generally flush with the upper and lower sides of the rib portions 15 and 16 of the body 10 when the island is in the horizontal position. The island 74 is tubular or provided with a through duct 79 to register with, and in effect form a part of, the propulsive duct 18 when the island is in the generally horizontal position.

The island 74 is supported for angular movement about the spanwise axis on tubular trunnions 82 projecting from the opposite sides of the island and journaled on the walls 24. The trunnions 82 are tubular for the reasons to be later described. The ducted compressor 65 is of the supersonic class insofar as the relative velocity of entrained air against the blading is concerned and carries a row of supersonic blades 83. The supersonic compressor 65 is adjacent and slightly forward of the axis of angular movement of the island 74 and the geometric center of the airframe or body 10.

In order to facilitate a better understanding of the invention the following data is given of a typical installation or embodiment wherein the airframe or body 10 is assumed to be 50 ft. in diameter and the craft is assumed to have a gross loaded weight of about 55,000 pounds. In such a case the diameter of the ducted compressor 65 will be 6 ft. and the speed of rotation of the compression rotor will not exceed 3700 r.p.m., which is equivalent to the comparatively conservative top speed of 1200 feet per second, precluding the possibility of the rotor bursting. The compression ratio of the ducted compressor 65 will be 1.89 to 1 and the total weight flow of air through the ducts will be 770 pounds per second. It is to be understood that these figures are merely illustrative and, of course, will vary in different applications and aircraft.

The load turbo powerplants 66 and 67 serve to assist in driving or rotating the ducted compressor 65 and themselves produce propulsive gas streams or jets. The powerplants 66 and 67 are provided or arranged at a vertical axis which intersects the axis of rotation of the ducted compressor at or adjacent the geometric center 12 of the craft. The powerplants 66 and 67 are carried by the island 74 and are arranged on the upper and lower sides respectively of the island, assuming the island to be in the full line position illustrated throughout the drawings. The powerplants 66 and 67 are supercharged by the ducted compressor 65 and serve to drive the compressor through a transmission means as described in my application Serial Number 332,957, identified above, which describes and claims the propulsive system or means of the airplane including the island 74, the propulsive means carried by the island, the means for moving the island between the full line and broken line positions of FIGURES 4 and 5, the fuel supply and burner means and the other elements of the overall propulsion system.

The tip or outboard powerplants 68 and 69, which are fully described in my application Serial Number 332,957, are provided to assist in driving the ducted compressor 65, to produce propulsive jets, and they are controllable to provide for or to assist in the steering or directional control of the craft. The turbo jet load powerplants 68 and 69 are positioned on the periphery of the circular plan-form airframe or body 10 on a common diametric axis which intersects the axis of rotation of the ducted compressor 65 and the longitudinal axis of the ducts 18 and 79 at or adjacent the geometric center 12 of the body 10. In the aircraft illustrated where the periphery of the body 10 is sharp or thin, I provide streamlined enlargements or pods 124 at the outboard edges or "tips" of the body to contain the powerplants 68 and 69 and their auxiliaries and controls. These pods 124 may be designed or shaped to reduce the vortices losses at the margins or tips of the craft.

Like the inboard load powerplants 66 and 67, the outboard or tip turbo powerplants 68 and 69 are supercharged by the ducted compressor 65, receiving compressed air from the compressor and further compressing it before it reaches their respective combustion zones. Tunnels or tubes 130 of substantial capacity which extend radially outward through the compartments 20 and 21 and the fuel cells 32 conduct the compressed air from the compressor to the outboard powerplants 68 and 69. The powerplants 68 and 69 are carried for angular movement about a spanwise or diametric axis which intersects the fore and aft axis of the body 10 at the geometric center 12 of the body. The tip or outboard turbo load powerplants 68 and 69 are drivingly connected with the ducted compressor by shafts (not shown) extending outwardly through the tubes 130 and drivingly connected with the compressor by a transmission means.

The load turbo powerplants 66, 67, 68 and 69 are arranged and located in such a fashion that explosion or bursting of any of them during flight will not endanger the occupants or any critical portions of the craft, the rotors of the powerplants 66 and 67 being arranged to rotate in planes parallel with and spaced above and below the airframe proper and remote from the passenger compartments and fuel cells 32 and the rotors of the outboard load powerplants 68 and 69 being arranged to rotate in planes far remote from and parallel with the side walls 24 of the occupied compartments and outboard from the fuel cells 32 and the periphery of the airframe.

As mentioned above, the island 74 carrying the ducted compressor 65 is pivotally movable about the spanwise axis of the airframe or body 10 between the position when its air duct 79 is aligned with and in register with the main air duct 18 of the body 10 for translational flight and the position where the island duct 79 is vertical or substantially normal to the duct 18 for generally vertical takeoff and landing.

The present specification is not primarily concerned with the details of the propulsive system such as the means for moving the island 74, the controls and fuel systems for the powerplants 66, 67, 68 and 69, the fuel injector or combustor means for introducing fuel downstream from the compressor 65, the means for controlling or directing the jet streams from the powerplants 68 and 69, and like features, since these and the other elements of the propulsive system are fully described in my copending application Serial Number 332,957. However, it may be noted that fuel or fuel vapor is led from the upper portions of the fuel cells by pipes 373 for consumption by the propulsive system. These pipes 373, which are controlled by valves 374, extend along the walls of the passenger compartments 20 so that the fuel vapor assists in refrigerating the compartments. Other pipes 185, lead from the lower portions of the fuel cells to the propulsive system or propulsive components.

The inlet 71 of the main propulsive air duct 18 is in the nature of a supersonic variable ram inlet. The forward or inlet end portion of the duct 18 is elongated in the spanwise direction, the forward portion of the duct flaring forwardly and spanwise while at the same time being reduced in its vertical dimension to terminate at a rectangular forward opening 197, see FIGURES 2 and 3. The opening 197 is in the lower rib portion 15 being below the periphery 11 of the body 10, and has generally straight horizontal and vertical margins at its forward terminus. It should be noted that the elongate entrance of the opening 97 conforms generally with the thin forward edge or periphery of the body 10 to keep the frontal area of the craft at a minimum. The ram inlet 71 is of variable area, having an island 202 of variable volume or variable cross section. The main propulsive jet nozzle 72 at the aft end of the main duct 18 automatically changes from a subsonic nozzle to a supersonic nozzle and vice versa in accordance with the flow conditions of the discharging air and gas jet, incorporates variable direction features to obtain pitching trim, and is operable as an air brake to reduce the velocity of flight under certain conditions. The variable area inlet 71 and the variable propulsive nozzle 72 are more fully described in my copending application Serial Number 332,957, identified above.

FIGURE 6 illustrates another aircraft of the invention characterized by turbo-propeller powerplant 400 serving as the primary propulsive means. In this aircraft the body 10, the duct 18, the ram inlet 71, the propulsive nozzle 72, and the various other parts may be the same as in the above described embodiment of the invention. The central island 474 is substantially the same as the island 74, however, it is shaped and proportioned to contain the powerplant 400. The island 474 is arranged to be turned or pivoted on the spanwise axis of the body 10 and the trunnions or means for pivotally supporting the island also serve to supply compressed air from the powerplant to lateral ducts 430 which carry the air outboard to directional nozzles 420. These nozzles 420, which are movable in curved slots 401 in the periphery of the body 10, are rotated or pivoted by reversible electric motors 440 acting through suitable rack and pinion means 437 associated with the nozzles. The powerplant 400 may be of the type disclosed in my earlier Patents 2,563,270 issued August 7, 1951, and 2,575,682 issued November 20, 1951. The powerplant 400 has a propeller or compressor means 414 in the tubular island 474 and is a turbo-powerplant serving to drive the compressor means and to discharge a propulsive jet rearwardly through the duct 18. The propeller or compressor means 414 serves to compress air in the duct system to supercharge the turbo engine and to increase the pressure of the air discharging through the duct 18 and nozzle 72. The rammed air in the duct 18 supercharged or further compressed by the compressor 414 is also directed to the directional propulsive nozzles 420 at the periphery of the body 10. For vertical ascent and descent of the aircraft the island 474 is swung to a vertical position where it discharges the propulsive jet downwardly and the outboard nozzles 420 are likewise turned to face downwardly to produce upward or lifting thrusts. For translational flight the island 474 is brought to the horizontal or normal position where its propulsive jet stream flows aft through the main propulsive duct and the outboard nozzles 420 are also turned to face aft to provide additional forward thrust although these nozzles may be simultaneously and/or differentially adjusted or controlled to assist in directional control of the aircraft.

It is believed that the operation and features of the aircraft of this invention will be apparent from the foregoing description. It will be seen that the circular plan-form-bi-convex aircraft body 10 is a rigid, strong structure particularly resistant to bending and torsional loads. The body 10 being circular permits substantially uniform weight distribution over its lifting surfaces and a good distribution of landing forces. The spherical convex upper and lower surfaces 13 and 14 joined at the circular leading-trailing edge 11 are especially structurally efficient in carrying the internal loads, the cabin air pressures, and the body 10 being circular allows for the disposition of the useful loads and fuel loads in concentric or balanced relation to the C.G. and geometrical center of the structure. Since the aircraft is devoid of wings, and empennage, etc. and since it has a simple regular configuration so that many of its parts may be similar or identical in size and shape, the body 10 and the overall aircraft is inexpensive to manufacture and maintain. The aircraft is aerodynamically efficient, having an excellent *L/D* ratio and because it presents a substantially continuous unbroken peripheral edge 11 and a smooth profile, it offers a minimum of skin friction drag. The portions 15 and 16 extending diametrically fore and aft provide a rib which serves as a vertical stabilizer and define a region which contains the main propulsive elements of the aircraft. This diametric fore and aft thin plate airfoil region has the added function of assisting in producing aerodynamic lift with a minimum of drag. It will be observed that the elements of the propulsion system are arranged or located so that their high velocity rotating members will not endanger either the aircraft or its occupants in the event of operational failure. The internal compartmentation of the circular plan-form aircraft, as above described, provides for effective protected passenger compartments as well as extensive cargo and fuel cells or spaces. The circular bulkhead 17, together with the spaced radial dividers or baffles of the outer compartments or fuel compartments are secured together and to the upper and lower skins 13 and 14 to constitute a strong rigid airframe.

Having described only typical forms of the invention I do not wish to be limited to the specific details herein set forth, but wish to reserve to myself any variations or modifications that may appear to those skilled in the art and fall within the scope of the following claims.

I claim:

1. In an aircraft; an aircraft body of circular plan-form having convex spheroidal upper and lower sides and including a fore and aft relatively flat airfoil section substantially diametric and parallel to the direction of horizontal flight.

2. In an aircraft the combination of; an aircraft body of circular plan-form and including a convex spheroidal upper skin, a lower skin, the body having a fore and aft duct substantially diametric and parallel to the direction of horizontal flight extending therethrough, and propulsive means in the duct for propelling the aircraft.

3. In an aircraft the combination of; an aircraft body of circular plan-form and including a convex spheroidal upper skin, a lower skin, the body having a fore and aft propulsive jet duct substantially diametric and parallel to the direction of horizontal flight extending therethrough, propulsive means in the duct, and means carried by the body external of the duct for driving the propulsive means.

4. In an aircraft the combination of; an aircraft body of substantially circular plan-form including a convex upper skin, a lower skin, and a substantially circular marginal edge connecting the skins, fuel consuming propulsion means in the body, circular bulkhead means in the body substantially concentric with said edge and spaced therefrom, the bulkhead means extending between the upper and lower skins and together with the skins defining cells for containing fuel for the propulsion means, said cells being at the outer side of the bulkhead means, and pay load compartments within the circular bulkhead means.

5. In an aircraft the combination of; an aircraft body of substantially circular plan-form including a convex upper skin, a lower skin, and a substantially circular marginal edge connecting the skins, fuel consuming propulsion means in the body, circular bulkhead means in the body substantially concentric with said edge and spaced therefrom, the bulkhead means extending between the upper and lower skins and together with the skins defining cells for containing fuel for the propulsion means, said cells being at the outer side of the bulkhead means, and pay load compartment means defined by the two skins and the inner side of the circular bulkhead means.

6. In an aircraft having fuel consuming propulsion means the combination of; an aircraft body of substantially circular plan-form carrying the propulsion means and including a convex generally spheroidal upper skin, a lower skin, and a substantially circular marginal edge connecting the skins, circular bulkhead means in the body substantially concentric with said edge and spaced therefrom, the bulkhead means extending between the upper and lower skins and together with the skins defining cells for containing fuel for the propulsion means, and spaced reinforcing bulkheads in the cells substantially concentric with said edge and connecting the upper and lower skins.

7. In an aircraft having fuel consuming propulsion means the combination of; an aircraft body of substantially circular plan-form carrying the propulsion means and including upper and lower skins, and a substantially circular marginal edge connecting the skins, circular bulkhead means in the body substantially concentric with said edge and spaced therefrom, the bulkhead means extending between the upper and lower skins and together with the skins defining cells for containing fuel for the propulsion means, said cells being at the outer side of the bulkhead means, and circumferentially spaced bulkheads in the cells extending substantially radially with respect to the axis of curvature of said edge and secured to the upper and lower skins to strengthen the body.

8. In an aircraft having fuel consuming propulsion means the combination of; an aircraft body of substantially circular plan-form carrying the propulsion means and including upper and lower skins, and a substantially circular marginal edge connecting the skins, circular bulkhead means in the body substantially concentric with said edge and spaced therefrom, the bulkhead means extending between the upper and lower skins and together with the skins defining cells for containing fuel for the propulsion means, said cells being at the outer side of the bulkhead means, spaced bulkheads in the cells curved substantially concentric with the axis of curvature of said edge, and spaced bulkheads in the cells extending radially with respect to said axis, the first and second mentioned bulkheads being secured to the skins to strengthen the body.

9. In an aircraft having propulsive means; an aircraft body of circular plan-form and having convex generally spheroidal upper and lower sides, the body including a diametric portion extending fore and aft and presenting generally flat upper and lower external surfaces to constitute a flat airfoil, said diametric portion containing said propulsive means.

10. In an aircraft; an aircraft body of circular plan-form and having convex spheroidal upper and lower sides, the body including a portion extending fore and aft and presenting generally flat upper and lower external surfaces to constitute a flat airfoil, and a propulsive air duct system extending through said portion from the forward end to the aft end of the body.

11. In an aircraft having propulsive means producing a propulsive air stream; an aircraft body of circular plan-form and having convex spheroidal upper and lower sides, the body including a diametric portion extending fore and aft and presenting generally flat upper and lower external surfaces to constitute a flat airfoil, an air duct extending through said portion from the forward end to the aft end of the body to carry said propulsive airstream, and a propulsive nozzle at the aft end of the duct for discharging the stream as a propulsive jet.

12. In an aircraft; an aircraft body of circular plan-form and having convex spheroidal upper and lower sides, the body including a diametric portion extending fore and aft and presenting generally flat upper and lower external sur-

faces to constitute a flat airfoil, an air duct extending through said portion from the forward end to the aft end of the body, a horizontally elongated ram inlet at the forward end of the duct, means for propelling an air stream aft through the duct, and a horizontally elongated propulsive discharge nozzle at the aft end of the duct.

13. In an aircraft the combination of; an aircraft body of circular plan-form having a convex upper side and a lower side, a duct extending fore and aft through the body from its leading edge to its trailing edge, a variable area ram inlet at the forward end of the duct, a variable area propulsive nozzle at the aft end of the duct, and propulsive means in the duct operable to further compress the ram-compressed air flowing aft through the duct.

14. In an aircraft the combination of; an aircraft body of circular plan-form having a convex upper side, a lower side, a duct extending fore and aft through the body from its leading edge to its trailing edge, a variable area ram inlet at the forward end of the duct, a variable area propulsive nozzle at the aft end of the duct, and powerplant means in the duct for adding propulsive energy to the ram-compressed air flowing aft through the duct.

15. In an aircraft the combination of; an aircraft body of circular plan-form having a convex upper side, a lower side, and a straight through duct extending fore and aft through the body from its leading edge to its trailing edge having a variable area propulsive nozzle at its aft end.

16. In an aircraft the combination of; an aircraft body of circular plan-form having a convex upper side, a lower side, a duct extending fore and aft through the body from its leading edge to its trailing edge, a variable area ram inlet at the forward end of the duct, a variable area propulsive nozzle at the aft end of the duct, compressor means operable in the duct to further compress the ram-compressed air flowing therethrough, and turbo-jet engines on the body spaced outboard from the duct for driving the compressor means.

17. In an aircraft the combination of; an aircraft body of circular plan-form having a convex upper side, a lower side, a duct extending fore and aft through the body from its leading edge to its trailing edge, a variable ram inlet at the forward end of the duct, compressor means operable in the duct to further compress the ram-compressed air flowing therethrough, and turbo-jet powerplants on the body above and below the duct for driving the compressor means.

18. In an aircraft the combination of; an aircraft body of circular plan-form having upper and lower sides, a duct extending fore and aft through the body from its leading edge to its trailing edge, a variable area ram inlet at the forward end of the duct, a variable area propulsive nozzle at the aft end of the duct, means operable in the duct to further compress the ram-compressed air flowing therethrough, and engines on the outboard margins of the circular body for driving said means.

19. In an aircraft; an aircraft body of circular plan-form having convex upper and lower skins, a propulsive air duct extending fore and aft through the medial region of the body having a ram inlet at its forward end and a propulsive nozzle at its aft end, a circular bulkhead in the body extending between and connected with the skins to reinforce the body, the bulkhead defining the outer walls of central region passenger compartments, there being storage compartments in the body between its periphery and the bulkhead.

20. An aircraft including an aircraft body of substantially circular plan-form and having upper and lower sides, bulkhead means in the body curved about the central vertical axis of the body and extending between its upper and lower sides, passenger and payload compartments within the bulkhead means, a propulsive ram air duct extending fore and aft through the body having a ram inlet at its forward end and a propulsive nozzle at its aft end, a relatively low velocity propulsive means operable in the duct, and powerplants in the body spaced above and below the duct for driving the propulsive means, said powerplants being in planes spaced above and below the plane of said compartments.

21. In an aircraft; an aircraft body of circular plan-form having upper and lower skins, a propulsive air duct extending fore and aft through the medial region of the body having a ram inlet at its forward end and a propulsive nozzle at its aft end, and a circular bulkhead in the body extending between and connected with the skins to reinforce the body, the bulkhead defining the outer walls of central region passenger compartments, there being storage compartments in the body between its periphery and the bulkhead, the bulkhead being arcuate in vertical cross section and arranged with its convex side facing toward the periphery of the circular body.

22. In an aircraft the combination of; an aircraft body of substantially circular plan-form having convex upper and lower surfaces, bulkhead means in the body defining large volume storage compartments in the major peripheral regions of the body for containing low boiling point fuel and also defining passenger compartments in the central region of the body encircled by the storage compartments to be protected against aerodynamically induced high temperatures by the stored fuel, and a propulsive system for propelling the craft consuming said fuel.

References Cited in the file of this patent

UNITED STATES PATENTS

1,585,281	Craddock	May 18, 1926
1,957,896	Marguglio	May 8, 1934
2,377,835	Weygers	June 5, 1945
2,384,893	Crook	Sept. 18, 1945
2,397,184	Klose	Mar. 26, 1948
2,563,270	Price	Aug. 7, 1951
2,567,392	Naught	Sept. 11, 1951
2,575,682	Price	Nov. 20, 1951
2,619,302	Loedding	Nov. 25, 1952
2,718,364	Crabtree	Sept. 20, 1955
2,726,671	Zand et al.	Dec. 13, 1955
2,730,311	Doak	Jan. 10, 1956
2,772,057	Fischer	Nov. 27, 1956
2,807,428	Wibault	Sept. 24, 1957

FOREIGN PATENTS

1,047,657	France	Apr. 19, 1950
547,021	Italy	Aug. 6, 1956
50,033	France (Addition to 799,655)	Aug. 1, 1939

OTHER REFERENCES

Western Aviation Magazine, September 1956, pages 9 and 10.

Dec. 11, 1962 I. R. BARR 3,067,967

FLYING MACHINE

Filed Nov. 19, 1958 3 Sheets-Sheet 1

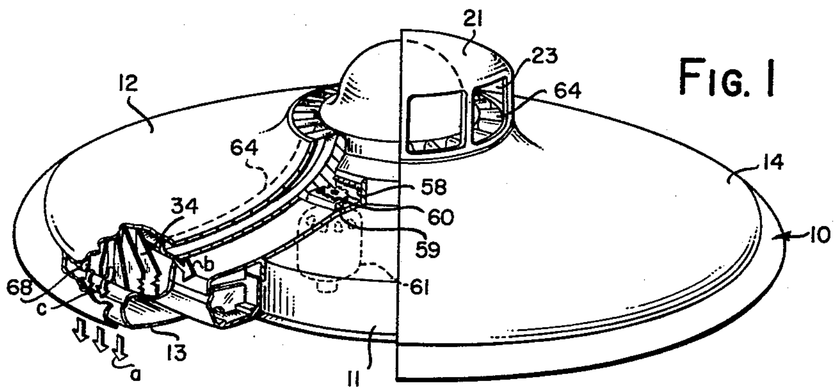

FIG. 1

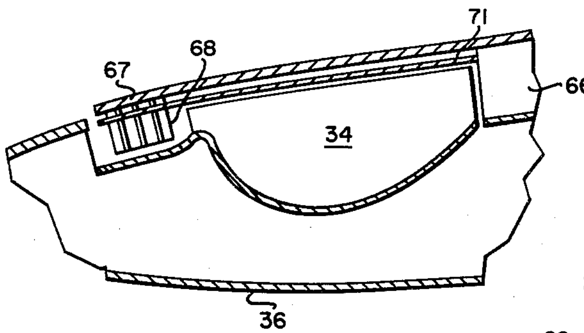

FIG. 3

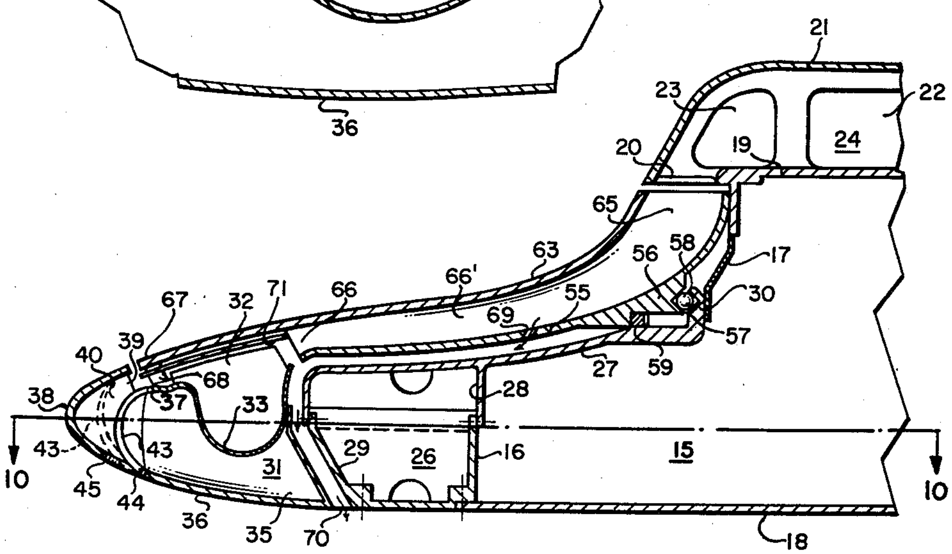

FIG. 2

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FLYING MACHINE

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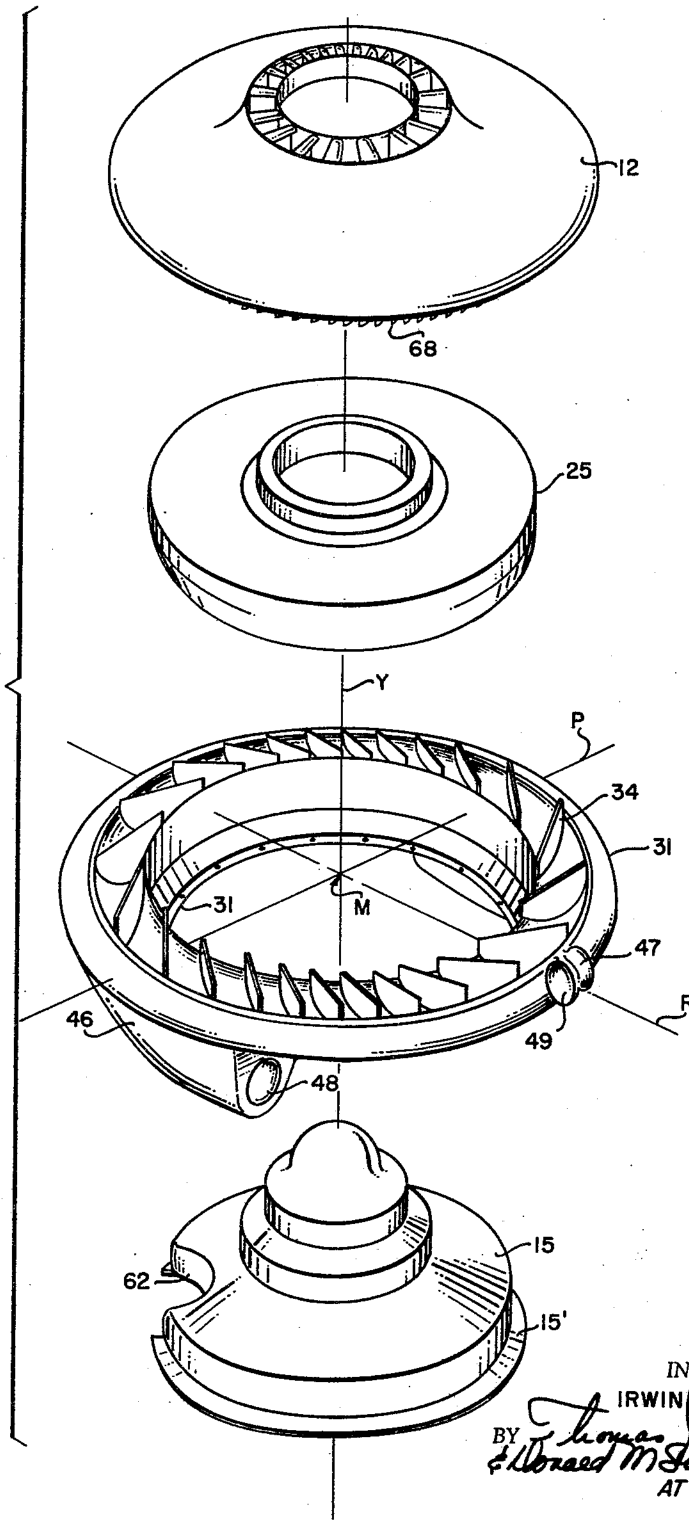
3 Sheets-Sheet 2

FIG. 4



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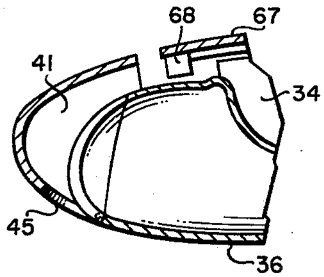
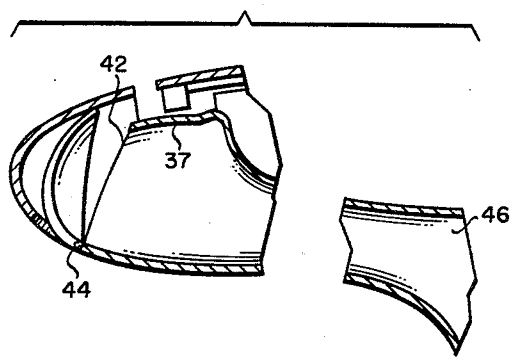


FIG. 5

FIG. 6



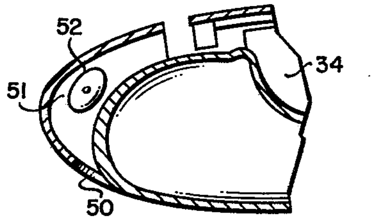


FIG. 7

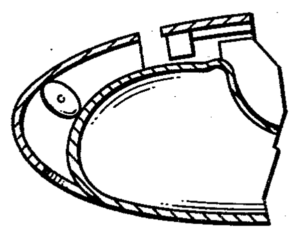


FIG. 8

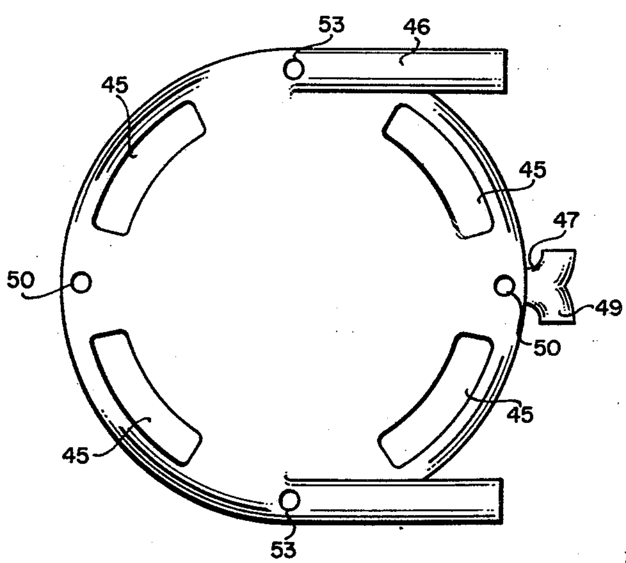


FIG. 9

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1

3,067,967
FLYING MACHINE

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7 Claims. (Cl. 244—12)

This invention relates generally to flying machines, and more particularly to flying machines of the type which can take off and land, hover, travel at high speeds, and quickly turn and maneuver in azimuth heading.

A primary object of this invention is to provide a flying machine of the class described in which reducing the empty weight while maintaining the gross weight for increasing payload capacity does not result in reduced aerodynamic performance of the flying machine.

Another object of this invention is to provide a flying machine of the class described in which gyroscopic couples may be utilized for increasing stability during hovering without requiring the empty weight of the flying machine to be increased.

Another object of this invention is to provide a flying machine of the class described which has increased stability and maneuverability during all phases of its travel.

As a feature of this invention, whereby the objects thereof are achieved, a part of the structure of the power plant forms a part of the aerodynamic lifting surface of the airframe. Stated otherwise, a portion of the power plant is common to both the power plant and to the airframe. By a novel integration of power plant with airfoil, the entire upper portion of the airfoil which is normally a part of the airframe is eliminated and replaced by a portion of the power plant. Since the weight of the replaced airfoil is eliminated, a significant reduction in airframe weight is achieved while the same gross weight can be maintained. Thus, the payload of the flying machine can be increased by the amount of the weight of the airfoil eliminated. However, the flying machine presents substantially the same appearance to ambient air such that aerodynamic performance is not reduced. In fact, such performance is appreciably increased.

As another feature of this invention, the integration of power plant with airframe causes the rotating parts of the power plant to have an angular momentum sufficient to give rise to gyroscopic couples which exert an inherent stabilizing influence on the flying machine, particularly when hovering. In such construction, moments or forces acting on a flying machine made in accordance with the invention and arising from atmospheric disturbances and the like, cause small deviations of the machine from its equilibrium position to be decreased rather than increased as is the case for conventional flying machines. Inherent stability in hovering is, therefore, achieved with only the angular momentum of the power plant being utilized.

The more important features of this invention have thus been outlined rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contribution to the art may be better appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will also form the subject of the claims appended hereto. Those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for designing other apparatus for carrying out the several purposes of this invention.

FIGURE 1 is a cut-away section of a flying machine made in accordance with this invention.

FIGURE 2 is a sectional view of the flying machine showing various interior details.

FIGURE 3 is a view of the combustion chamber looking normal to the flame holders.

FIGURE 4 is an exploded view of the various major components making up the flying machine.

2

FIGURES 5 and 6 are sectional views taken at the periphery of the flying machine showing the operation of the vanes for distributing the thrust.

FIGURES 7 and 8 are sectional views taken at the periphery of the flying machine showing the operation of the valves for controlling pitch and roll.

FIGURE 9 is a view of the bottom of the flying machine.

Referring now more particularly to the drawing, a flying machine 10 embodying the present invention is shown in FIGURE 1 as a stator 11 and a rotor 12 mounted on top of said stator for rotation about central axis Y. Stator 11 and rotor 12 constitute body 10 which has a center of mass M preferably located below the center of mass of rotor 12 on axis Y. Center of mass M forms the origin for yaw axis Y, roll axis R, and pitch axis P of body 10, as shown best in FIGURE 4.

As seen in FIGURE 1, body 10 is essentially disc-shaped and constitutes a flying airfoil having a lower aerodynamic surface 13 and an upper aerodynamic surface 14. Yaw axis Y is normally substantially vertical when in flight so that the vector representing the weight of body 10 and passing through center of mass M is aligned with the yaw axis. Basically, body 10 is a radial flow jet engine that has means to direct the jet downward for lift when hovering, aft when flying at high speed, and combinations of aft and down for slow speed flight.

Stator 11 includes payload housing 15 which is generally cylindrical in shape and has a lower portion 16 of substantially greater diameter than upper portion 17. The bottom 18 of housing 15 forms a portion of lower aerodynamic surface 13. Attached to the top of housing 15 is ring 19 having openings 20 spaced around the periphery thereof and extending beyond housing 15. Air scoop 21 is attached to ring 19 to form intake plenum 22. Air scoop 21 has a plurality of openings 23. In the aft portion of scoop 21, intake doors 24 are provided which may be selectively opened or closed to control the quantity of air available to the power plant.

Fitted on housing 15 is fuel tank 25. Tank 25 has a toroidal fuel cell 26 fitted adjacent portion 16 of housing 15, and web 27 extending over housing 15 and into contact with portion 17. Fuel cell 26 may be made in two parts: an upper part 28 integral with web 27 and a lower part 29 attached to part 28 and to bottom 18 of housing 15. Surge baffles having openings therein are also provided in fuel cell 26 in a manner and for the purpose well known to those skilled in the art. On the part of web 27 engaged with portion 17, is inner race 30 which forms the main bearing for rotor 12 to be described presently.

On the peripheral portion of container 26 is propulsion ring 31. Ring 31 is toroidal in shape and consists of combustion chamber 32 defined by a substantially semicircular wall 33 extending around container 26. As seen in FIGURE 4, combustion chamber 32 is open at the top and is divided into compartments by flame holders 34. Holders 34 are not placed radially in chamber 32, but are inclined with respect to a radial for a purpose to be described hereinafter. Furthermore, holders 34 extend upwardly above the top edges of wall 33. Beneath wall 33 is a thrust plenum chamber divided into four compartments 35 by structural dividers 35′. Compartments 35 are defined by lower plenum chamber wall 36 and curved side walls 37. Flange 31′ is used to help attach ring 31 to fuel tank 25. The peripheral rim of ring 31 is formed by curved wall 38 connecting with wall 36. Wall 38 is spaced from wall 37 such that an annular opening 39 is formed therebetween. This opening is substantially the same dimension as the distance flame holders 34 extend beyond the edges of wall 33. Suitable baffles 40 divide the space between walls 37, 38 into four lift nozzle chambers 41 quadrantly spaced around the circumference of body 10. Openings 42 are formed in wall 37 to connect chambers 35 with chambers 41. Control vanes 43 pivotally mounted at 44 on wall 37 close openings 42, but are operable by suitable linkages in a conventional manner for selective movement to the position shown in broken lines in FIGURE 2 wherein annular opening 39 is directly connected to chambers 35. Nozzles 45 in the lower part of nozzle chambers 41 connect the same with the atmosphere so that exhaust gases flow as indicated by arrows *a* in FIGURE 1. Suitable manipulation of control vanes 43 permits flow entering annular opening 39 to be divided between nozzles 45 and chamber 35 in any ratio.

The structure of chamber 31 so far described is symmetrical about yaw axis Y of body 10. To give meaning to roll axis R and pitch axis P, two horizontal thrust ducts 46, are placed on the pitch axis of chamber 31 removed from each other by 180 degrees; and a yaw duct 47 is placed on the roll axis of ring 31. Each of ducts 46 is connected to two of chambers 35 by duct 46' and has a nozzle 48 to produce a thrust directed perpendicular to the plane of the pitch and yaw axis. Nozzle 48 may be of the type having a variable throat for thrust control. Bi-directional nozzles 49 are connected to duct 47 to produce individually controllable thrusts tangent to ring 31 and perpendicular to the plane of the roll and yaw axes for controlling azimuth heading. Nozzles 49 likewise may have variable throats for thrust control. In addition, two pitch jets 50 are mounted on the pitch axis 180° apart. These jets are connected to pitch jet chambers 51 segregated from lift nozzle chambers 41 by baffles 40. Chambers 51 are very much smaller than chambers 41 so that only a small flow from annular opening 39 enters for control purposes. Such flow is controlled by butterfly valves 52. Also, two roll jets 53 are mounted on the roll axis 180° apart. These jets are connected to roll jet chambers 54 segregated from lift nozzle chambers 41 by baffles 40. The flow through chamber 54 is likewise controlled by butterfly valves. Thus ring 31 is divided into four plenum chambers 35, four lift nozzle chambers 41 and four control chambers 51, 54. Two of the plenum chambers on the left hand of body 10 feed the left horizontal exhaust nozzle 48, and two of the plenum chambers on the right hand of body 10 feed the right horizontal exhaust nozzle 48. The two aft plenum chambers are connected by opening 47' to duct 47 to supply bi-directional nozzle 49. Two lift nozzle chambers are on the left hand and two on the right hand of body 10, each connected to lift nozzles 45. Control chambers are located on the left hand and on the right hand of the pitch axis, and on the forward and aft part part of the body on the roll axis.

Referring now to rotor 12, FIGURE 2 shows the rotor to have a generally flattened inner surface 55 sweeping down from openings 20 in ring 19 to a position adjacent wall 33 of combustion chamber 32. Surface 55 has thickened portion 56 forming a bearing raceway 57 into which balls 58 are engaged. Adjacent portion 56 is internal ring gear 59. Gear 59 engages pinion 60 on generator 61 which may be attached in recess 62 in housing 15 and form a connection for generator 61. Rotor 12 also has generally flattened outer surface 63 connected to inner surface 55 by compressor vanes 64. Surface 63 sweeps down from the periphery of ring 19 to annular opening 39 of combination chamber 31 and forms the upper aerodynamic lifting surface of body 10. Vanes 64 extend from annular inlet 65 almost to annular outlet 66 to form a compressor 66'. Beyond outlet 66, flame holders 34 extend almost to the inside of outer surface 63, which terminates in peripheral portion 67. Turbine blades 68 are attached to portion 67 and extend into the space between annular opening 39 and baffle 34. Thus, surface 63 structurally interconnects the turbine with the compressor. Bleed holes 69 in inner surface 55 allow cooling air from the compressor 66 to bleed off and enter between surface 55 and web 27 on the fuel tank. This cooling air is vented at 70 and serves to insulate fuel cell 26 from combustion chamber 32. To reduce the skin temperature of the rotor surface 63 directly above combustion chamber 32, a part of the compressed air leaving outlet 66 of compressor 66' is bled through hollow portion 71.

From the above description it is seen that body 10 has four major components so arranged as to form a compact disc shaped flying machine. The components are air scoop 21, rotor or compressor-turbine assembly 12, propulsion ring 31, and fuel tank 25 and payload compartment 15. Body 10 is thus an airframe into which a power plant is integrated. Surface 63 of rotor or compressor-turbine assembly 12 forms a portion of the upper surface of body 10 and acts as a part of the wing or lifting element. In operation, air is taken aboard through openings 23 in air scoop 21. Provision of doors 24 in the aft portion of body 10 allows a maximum amount of air to be made available at take-off, climbing and hovering flight. In high speed flight, aft doors 24 are closed to utilize the ram effect of the air in the intake chamber 22. Intake baffles may be provided in chamber 22 to assist in proper distribution of intake air to the compressor.

Portion 66 of rotor 12 forms a radial flow compressor. Ambient air entering openings 20 in ring 19 passes through inlet 65 of the compressor and is acted upon by vanes 64 such that the air leaving outlet diffuser section 66 is at a higher pressure. From diffuser section 66, the main flow is through combustion chamber 32 where fuel from cell 26 is added and burned. Flame holders 34 not only serve to anchor the flame, but are positioned so that at the design operating speed of compressor 66', air entering combustion chamber 32 flows tangentially to the flame holders as shown by arrows *b*. Thus, no straightening vanes are required in this area. The hot gases produced in combustion chamber 32 pass through turbine blades 68 as shown by arrows *c*. The work extracted from the gases by the turbine is applied to drive the compressor through interconnecting surface 63. The remaining energy left in the exhaust gases leaving blades 68 is utilized to produce a jet thrust. After leaving blades 68, the exhaust gases enter annular opening 39 in ring 31 in a plane substantially parallel with that defined by the pitch and roll axes. By proper design of the turbine blades, the angle at which the gases leave the blades is substantially 90° at the operating point. Thus, the vector representing these gases is aligned with a radial normal to the yaw axis. Most of the gases entering annular opening 39 are guided by walls 37, 38 into nozzle chambers 41. Straightening and turning vanes may be used to assist in controlling the direction of exhaust gas flow. Control vanes 43 proportion the gases between nozzles 45 and plenum chamber 35. The portion expanding through nozzles 45 produces a thrust directed parallel with the yaw axis. The portion of the gases shunted by control vanes 43 into plenum chamber 35 is expanded in horizontal nozzles 48 to produce a thrust directed normal to the yaw axis. Thus, by closing all control vanes, all of the exhaust gases expand through nozzles 45 and produce a thrust which causes body 10 to hover or move vertically, either upwardly or downwardly, depending upon adjustments to the nozzle areas. By opening all control vanes, the gases are directed to nozzles 48 through plenum chambers 35 which are designed to expand in cross-sectional area as nozzles 48 are approached. After flow peripherally around body 10, the gases pass into ducts 46 and are expanded in nozzles 48 to produce a thrust which causes body 10 to be displaced laterally. By selectively controlling the opening of vanes 43, a resultant thrust is produced which allows any desired displacement of body 10. For low speed flight, some use is made of nozzles 45 because the displacement of body 10 at an angle of attack (yaw axis inclined with respect to the vertical) is generally not sufficient to maintain the proper lift to drag ratio. For high speed flight, only nozzles 48 may be used.

A portion of the exhaust gases leaving turbine blades 68 may enter control chambers 51, 54 and be expanded through pitch jets 50 and roll jets 53 so as to maintain the proper attitude of the yaw axis by controlling pitch and roll. In addition, another portion of the exhaust gases may enter duct 47 for expansion through bi-directional nozzle 49. This latter nozzle by suitable controls is used to orient stator 11 about yaw axis Y with respect to the ground in order to achieve a proper azimuth heading. In this manner, displacement of body 10 may occur with its attitude maintained such that yaw axis Y is substantially vertical at all times. The displacement may be vertical, lateral, or a resultant of a vertical and a lateral displacement. Furthermore, a change in azimuth heading of body 10 may be easily accomplished without changing the attitude of yaw axis Y. Thus, sharp alterations in the course of body 10 are easily made without banking. Ascent or descent is likewise achieved without banking. As a result, an extremely maneuverable flying machine is achieved which can maintain its attitude throughout ascent, descent, lateral displacement or any combination of these movements.

Rotation of interconnecting surface 63 with respect to stationary surface 13 will, when there is relative velocity between body 10 and ambient air, produce a measure of lift. Such relative velocity arises even when hovering as a result of the geometric configuration of surface 63 with respect to lift nozzles 45. As the jet thrust emerges from the rim of body 10, it induces a downward flow of air over rotating surface 63. This induced flow increases the lift provided by the jet thrust.

Recalling that the center of mass M of body 10 is located on axis Y below that of rotor 12, and that rotor 12 is rotating about axis Y with respect to stator 11, it will be appreciated that body 10 possesses high inherent stability while hovering. This stability arises because body 10 is virtually a gyroscopic disc carrying a gravity pendulum. As is well known, gyroscopic motion will occur when a body rotates about one of its principal axes of inertia with an angular speed which is very much greater than the speed of precession of the principal axes about some other axis in the body that is not parallel to the principal axes. Yaw axis Y is a principal axis of inertia of rotor 12, and stator 11 corresponds to a pendulous mass since center of mass M of body 10 lies below the center of mass of rotor 12. Thus, when hovering, small deviations of the yaw axis from alignment with the weight vector passing through the center of mass of body 10, which are caused by wind gusts and the like, are self-decreasing as if body 10 were a gyroscope having a pendulum which, after perturbation, would tend to become aligned with the direction of gravitational pull. As a result, while hovering, the equilibrium of body 10 is stable because the forces or moments acting thereon cause a small deviation from the position of equilibrium (yaw axis vertical) to be decreased.

Excellent control while hovering is achieved also by virtue of the fact that there are a plurality of nozzles 45 remote from axis Y located at the rim of body 10. Due to the gyroscopic properties of body 10, rolling or precession of axis Y about roll axis R is corrected not by jets 50 on the pitch axis but by jets 53 on the roll axis. Likewise, pitching or precession of axis Y about pitch axis P is corrected not by jets 53 on the roll axis but by jets 50 on the pitch axis. This paradoxical situation arises because application of a moment about the pitch axis upon selective actuation of jets 53 will produce substantially no movement of the yaw axis about the pitch axis but will result in precession of the yaw axis about the roll axis due to the rotating mass of rotor 12. The tremendous inherent stability of body 10 in pitch and roll provided by the high angular momentum of rotor 12 greatly simplifies the static stability problems in these axes. For example, a rotor having a polar moment of inertia of 20 slug-feet^2 rotating at 3,000 r.p.m. has an angular momentum of 6,300 lb.-ft.-sec. An unbalanced moment of 100 lb.-ft. acting about a diameter of the disc for 30 seconds will produce an angular precession about a perpendicular diameter of only 27 degrees. Were the disc not rotating, the same angular deflection is produced in 0.3 second. This means that body 10 would roll only one-one hundredth the rate of an aircraft of similar mass moment of inertia when disturbed by a gust or other air load.

Those skilled in the art will now appreciate that this invention provides a flying machine which can take off and land, hover, travel at high speeds, and quickly turn and maneuver in azimuth heading. By incorporating the power plant into the basic structure, considerable weight for a given overall performance is saved. When all or part of the thrust produced by the engine is directed aft, the flying machine is displaced in a manner similar to that of a conventional flying machine. Aerodynamic lift is produced on the disc shaped body during forward flight by air flow over the airfoil-like section of the body. Thus, there there is no sacrific in performance even though a considerable part of the airframe has been eliminated and replaced by a specially integrated power plant. At very low speeds, lift produced by the airfoil may be added to by directing the jet thrust in a downward direction.

It will also be recognized by those skilled in the art that displacement and control of the flying machine can be achieved by selectively producing angular moments about the pitch, roll and yaw axes to control the lift to thrust ratio, and by selectively regulating the fuel flow into the combustion chamber. Pitch and roll moments are provided by the small jets located in the lower peripheral portion of the stator which vent downwardly, a small portion of the turbine exhaust gases. Control is achieved by varying the mass flow through the nozzles. Two jets are mounted 180 degrees from each other on both the roll and pitch axes. Because of the gyroscopic effect of the rotor, the jets to control pitch are on the roll axis, and the jets to control roll are on the pitch axis. Yaw moments are provided by a variable flow, bi-directional tangential jet located at the rear of the stator between the two exhaust ducts. This latter jet vents some of the turbine gases tangentially, and serves to balance turning effects due to aerodynamic loading and bearing forces from the rotating compressor. In addition, azimuth heading of the flying machine is controlled by this jet by proper orientation of the two exhaust ducts.

What is claimed is:

1. In combination, a stator having an axis, a rotor mounted on top of said stator for rotation about said axis, said stator and rotor constituting a body having upper and lower aerodynamic surfaces for producing lift, means on said rotor for drawing air therethrough to increase its pressure, burner means associated with said body for increasing the energy level of air leaving said rotor, turbine means responsive to air leaving said burner means for converting some of the energy thereof into a mechanical output, nozzle means responsive to air leaving said turbine for converting some of the energy thereof to a thrust adapted to displace said body, and means interconnecting said rotor with said turbine means for applying said output to said rotor, said last named means including a part of said upper aerodynamic surfaces.

2. The combination of claim 1 wherein said nozzle means is adjustable to direct said thrust at variable angles with respect to said axis for controlling the direction of displacement of said body.

3. In combination, a stator, a rotor rotatably mounted on top of said stator, said stator and rotor constituting a body having yaw, pitch, and roll axes with said rotor being rotatable about said yaw axis, upper and lower aerodynamic surfaces on said body for producing lift, means on said rotor for drawing air therethrough to increase its pressure, burner means associated with said body for increasing the energy level of air leaving said rotor, turbine

means responsive to air leaving said burner means for converting some of the energy thereof into a mechanical output, means interconnecting said rotor with said turbine means to apply said output to said rotor for causing it to rotate with respect to said stator, nozzle means responsive to air leaving said turbine for converting some of the energy thereof to a thrust, first control means to selectively direct a part of said thrust for producing a moment on said body substantially only about its pitch axis, second control means to selectively direct a part of said thrust for producing a moment on said body substantially only about its roll axis, and means on the rotating parts of said body when rotating responsive to actuation of said first control means for producing rotation of said body about its roll axis without substantial accompanying rotation of said body about its pitch axis and to actuation of said second control means for producing a rotation of said body about its pitch axis without substantial accompanying rotation of said body about its roll axis, whereby the attitude of said yaw axis may be controlled.

4. The combination of claim 3 wherein said means interconnecting said rotor with said turbine includes a part of said upper aerodynamic surface.

5. In combination, a stator having an axis, a rotor mounted on top of said stator for rotation about said axis, said stator and rotor constituting a body having upper and lower aerodynamic surfaces for producing lift, means on said rotor for drawing a continuous flow of air through said rotor to increase its pressure, burner means associated with said body for increasing the energy level of the air leaving said rotor, turbine means responsive to air leaving said burner means for converting some of its energy into a mechanical output, means interconnecting said rotor with said turbine means for applying said output to said rotor, a plenum chamber operatively associated with said turbine means having inlet means by which enters air leaving said turbine means, adjustable nozzle means on said plenum chamber for producing upon flow of air therethrough a thrust having components parallel to said axis and normal to said axis, and means selectively movable to control the flow of air through said nozzle means, said means interconnecting said rotor with said turbine means including a part of said upper aerodynamic surfaces.

6. A flying machine comprising a stator having an axis, a rotor mounted on top of said stator for rotation about said axis, said stator having a surface of revolution

generated about said axis, said rotor having a surface of revolution generated about said axis, the aforementioned surfaces of revolution defining the exterior of said flying machine and forming aerodynamic surfaces capable of producing lift upon movement of air relative thereto, said rotor being mounted on said stator so that the surface of revolution of said rotor constitutes the upper aerodynamic surface of said flying machine and the surface of revolution of said stator constitutes the lower aerodynamic surface, and means on said rotor for causing it to rotate about said axis.

7. A flying machine comprising a stator having an axis, a rotor mounted on top of said stator for rotation about said axis, said stator having a surface of revolution generated about said axis, said rotor having a surface of revolution generated about said axis, the aforementioned surfaces of revolution defining the exterior of said flying machine and forming aerodynamic surfaces capable of producing lift upon movement of air relative thereto, said rotor being mounted on said stator so that the surface of revolution of said rotor constitutes the upper aerodynamic surface of said flying machine and the surface of revolution of said stator constitutes the lower aerodynamic surface, compressor means on said rotor, combustion chamber means on said stator, rotation of said rotor causing said air compressor means to supply compressed air to said combustion chamber means, combustion of fuel in said combustion chamber means producing high energy gases, turbine means on said rotor through which said gases pass, a portion of the energy of said gases being converted by said turbine means into mechanical energy which rotates said rotor, plenum chamber means through which said gases pass after leaving said turbine means, and nozzle means connected to said plenum chamber means, the gases in said plenum chamber means adapted to expand through said nozzle means for converting a portion of the energy of the gases into thrust which reacts upon said machine for propelling the same.

References Cited in the file of this patent

UNITED STATES PATENTS

2,807,428	Wibault	Sept. 24, 1957
2,850,250	Smith	Sept. 2, 1958

FOREIGN PATENTS

770,873	Great Britain	Mar. 27, 1957

Jan. 8, 1963 L. Z. FREELAND 3,072,366

FLUID SUSTAINED AIRCRAFT

Original Filed Dec. 7, 1960 5 Sheets-Sheet 1

Fig. 1

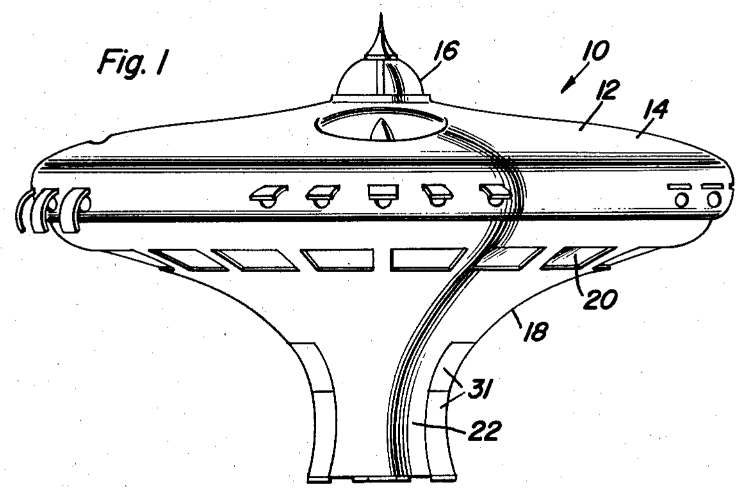


Fig. 2

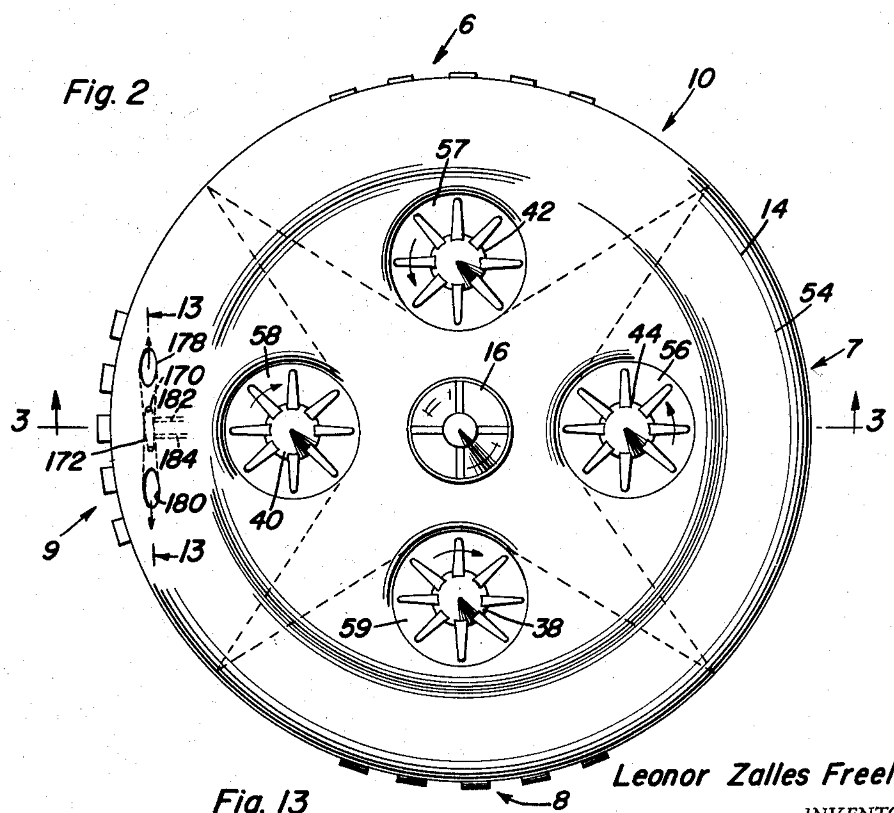
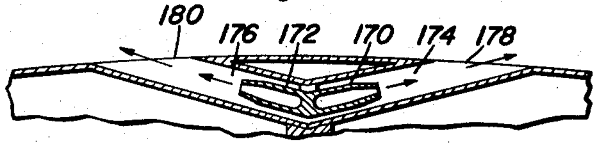


Fig. 13



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FLUID SUSTAINED AIRCRAFT

Original Filed Dec. 7, 1960 5 Sheets-Sheet 2

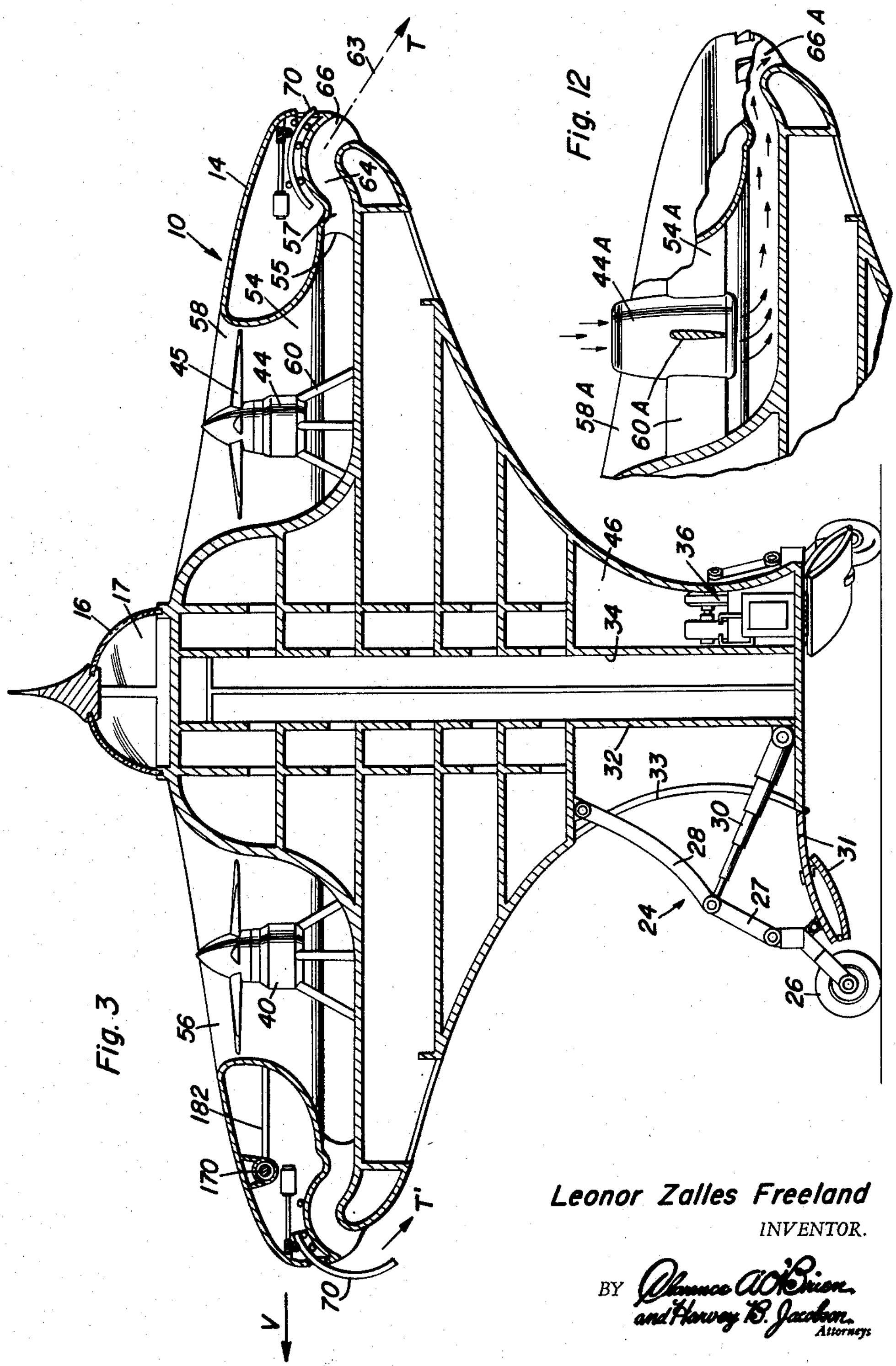

Fig. 3

Fig. 12

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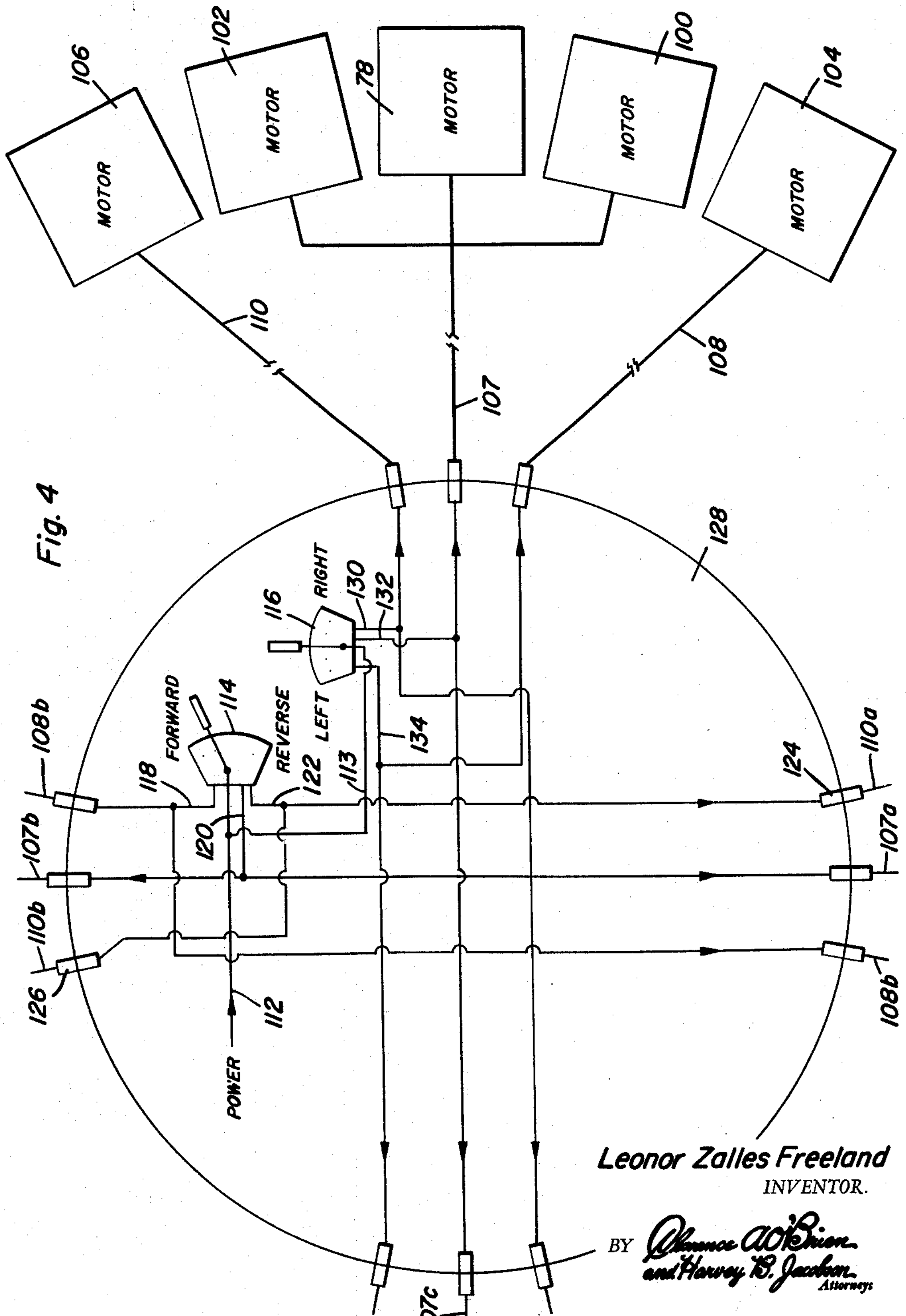

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FLUID SUSTAINED AIRCRAFT

Original Filed Dec. 7, 1960 5 Sheets-Sheet 4

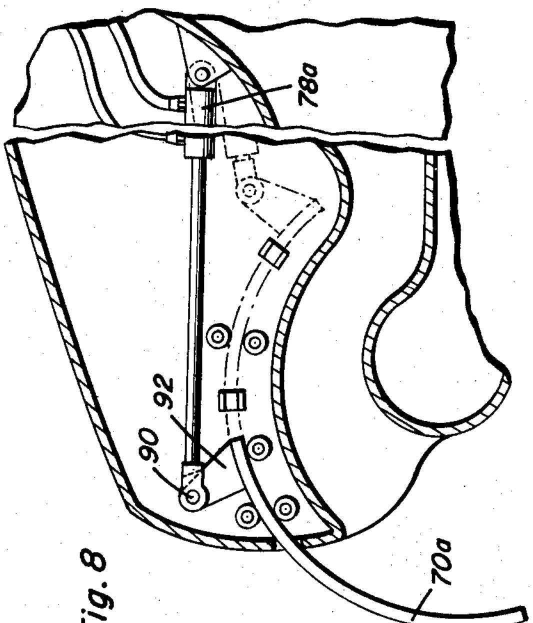

Fig. 8

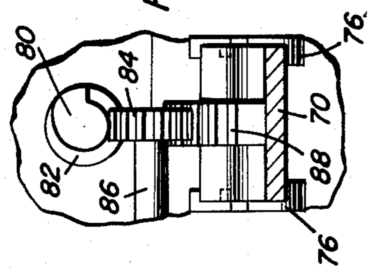

Fig. 7

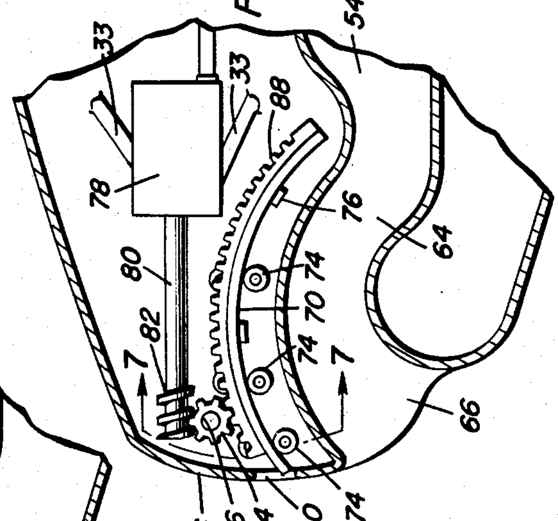

Fig. 6

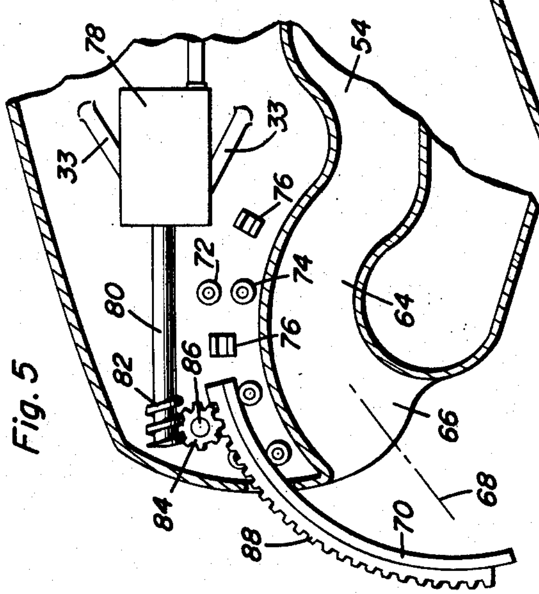

Fig. 5

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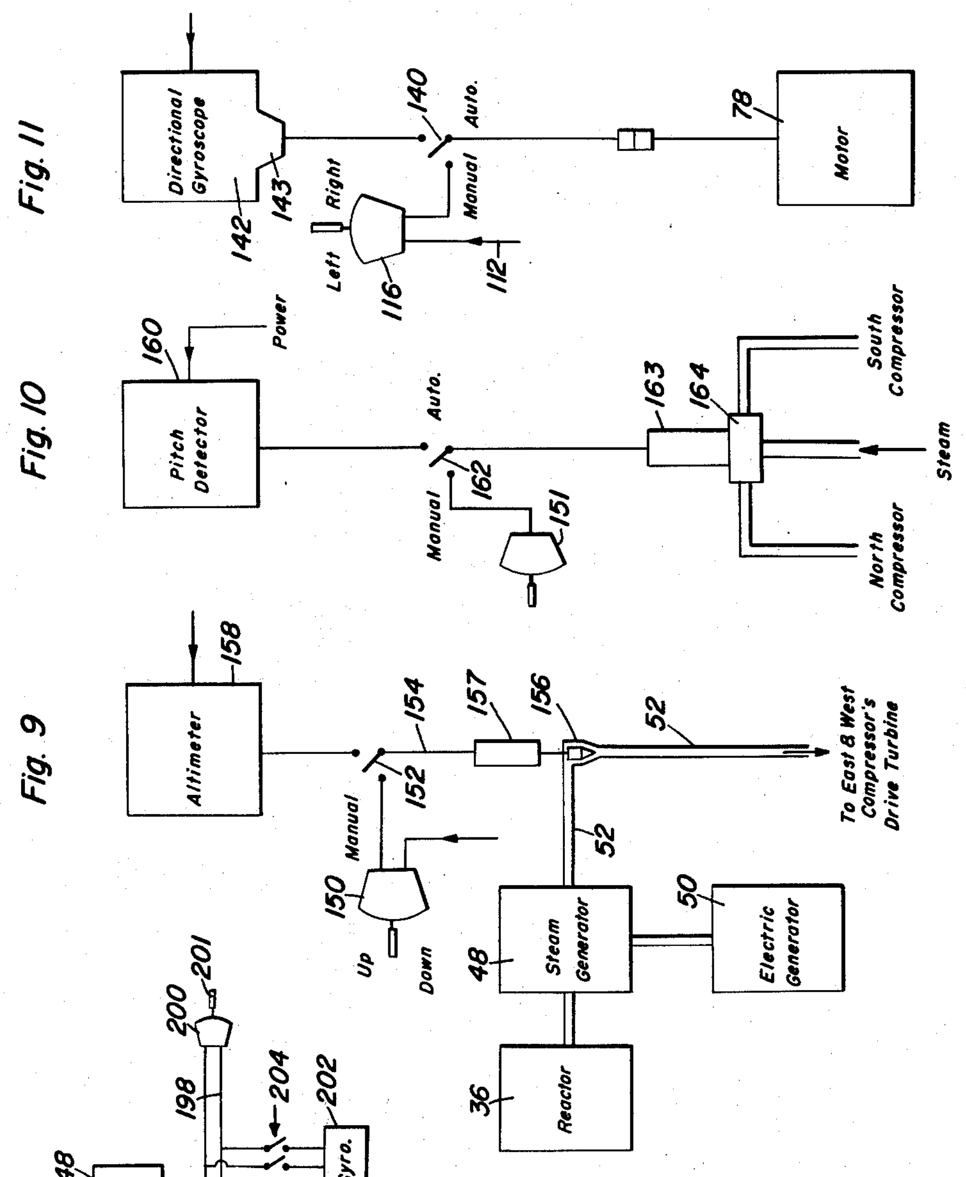
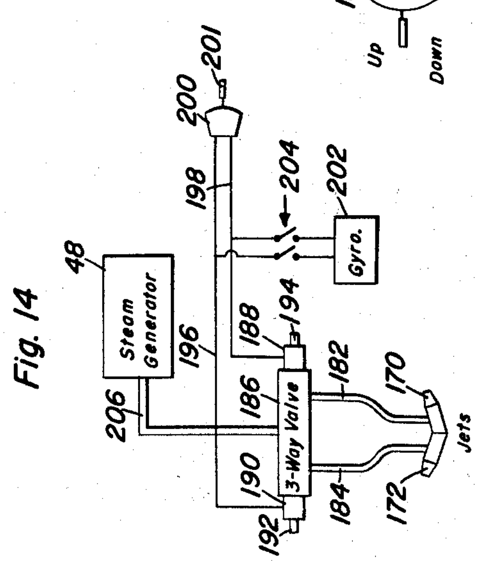
FLUID SUSTAINED AIRCRAFT

Original Filed Dec. 7, 1960 5 Sheets-Sheet 5





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United States Patent Office 3,072,366
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3,072,366
FLUID SUSTAINED AIRCRAFT

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Continuation of application Ser. No. 75,047, Dec. 7, 1960. This application Oct. 30, 1961, Ser. No. 149,487
8 Claims. (Cl. 244—23)

This application is a continuation of application U.S. Ser. No. 75,047, filed December 7, 1960, now abandoned which is a continuation-in-part application of U.S. Ser. No. 858,446, filed December 9, 1959, now abandoned, and which in turn is a continuation-in-part application of U.S. Ser. No. 566,650, filed February 20, 1956, now abandoned.

This invention relates to a class of aircraft capable of vertical flight, hovering and lateral flight.

An object of the invention is to provide a safe aircraft which is capable of vertical flight and of various maneuvers which a conventional aircraft cannot achieve. For example, an aircraft in accordance with the invention may fly horizontally or vertically or in any direction therebetween. Further, the aircraft is capable of hovering or descending very slowly in accordance with the desires of the pilot.

Although there have been prior airplanes capable of vertical flight, it is quite well known that they have lacked stability. This includes the type of aircraft having one or more engines providing thrust and sustaining wings connected to the fuselage, and not to the helicopter class of aircraft.

True helicopters have the drawback of being incapable of comparatively high speeds, even though they do possess the advantages of hovering flight and very low landing speeds.

An aircraft constructed in accordance with the invention uses air compressors of one type or another, and these are mounted in upwardly opening ducts at the top part of the body of the aircraft. The ducts also open laterally and vertically to the body of the aircraft and provide jet streams of air under pressure when the compressors are in operation. Directional control is achieved by an arrangement of deflectors located at the discharge ports of the ducts and adapted to be adjusted so that the resultant of the airstream and its deflection may be controlled to impose various directional forces on the aircraft body.

Accordingly, it is another object of the invention to provide an aircraft capable of hovering and which is supported and propelled by means of streams of air directed and controlled by novel arrangement of ducts and remotely controlled deflectors.

It is another object of the invention to provide an aircraft having a low center of gravity thereby increasing the stability of aircraft.

Still another object of the invention is to provide an aircraft whose movement in any direction is under the control of the pilot.

It is yet another object of this invention to provide novel deflectors for directing and controlling lifting and propelling airstreams issuing from an aircraft and which are operated and controlled by a reliable and efficient mechanism.

These together with other objects and advantages which will become subsequently apparent reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout, and in which:

FIGURE 1 is a side elevational view of an aircraft constructed in accordance with the invention;

FIGURE 2 is a top view of the aircraft in FIGURE 1;

FIGURE 3 is an enlarged sectional view taken on the line 3—3 of FIGURE 2;

FIGURE 4 is a diagrammatic view showing five air deflector motors which occupy one quadrant of the aircraft, there being three additional groups of motors which are not shown, and this view also diagrammatically illustrating controls for energizing the motors and causing them to adjust the air deflectors;

FIGURE 5 is an enlarged fragmentary sectional view showing one of the motors in FIGURE 4 and the air deflector which it operates;

FIGURE 6 is a sectional view similar to FIGURE 5 but showing the air deflector in a retracted position;

FIGURE 7 is a sectional view taken on the line 7—7 of FIGURE 6.

FIGURE 8 is a sectional view of a modification showing a hydraulic motor connected to a hydraulic system substituted for the electric motor and system;

FIGURE 9 is a diagrammatic view showing the power plant for the aircraft and also showing that the compressors may be automatically or manually controlled;

FIGURE 10 is a further diagrammatic view to be considered in conjunction with FIGURE 9 and showing further that additional automatic control for the compressors may be resorted to;

FIGURE 11 is another diagrammatic view showing the choice between manual and automatic directional control for the deflector motors;

FIGURE 12 is a fragmentary partially sectional and partially elevational view showing that the type of compressor shown in FIGURE 3 for instance, may be substituted by another type of compressor;

FIGURE 13 is an enlarged cross sectional view taken substantially on the vertical plane of line 13—13 of FIGURE 2; and

FIGURE 14 is a diagrammatic view showing the means for controlling the rotation of the aircraft about its vertical axis.

In the accompanying drawings there is an illustration of an aircraft **10** which has an aircraft body of unusual configuration. The upper part **12** of the body has an upper wall **14** shaped generally in the form of a very shallow dome, and there is a pilot and crew cabin **16** also formed as a smaller dome having windows **17** therein. The dome **16** is located at the center and at the top part of wall **14**. The side wall of the body is circular in plan form, and the side wall is smoothly curved in cross section. The lower wall **18** of the uper part of the aircraft body is dished inwardly and has a number of windows **20** therein. Wall **18** curves downwardly to form a stem-like lower part **22** and the general appearance of the aircraft when viewed from the side resembles a mushroom.

The tricycle landing gear shown in FIGURE 3 is indicated by the reference numeral **24**. It includes landing wheels **26**, a scissors brace linkage **27—28** and an oleo strut **30** at the juncture of the links of scissors linkage **27—28** and pivoted to the frame structure **32** of the aircraft. The landing gear **24** is preferably retractable as illustrated in FIGURE 1, and when retracted, the apertures **33** are closed by fairing members **31**. The landing gear may be operated to its retracted position by conventional means, not shown, such as hydraulic or electrical motors.

The aircraft structure **32** has a central shaft **34** (FIGURE 3) which accommodates various lines which extend from power plane **36** to the four compressors **38**, **40**, **42** and **44**. Power plant **36** is preferably an atomic reactor and it is disposed in power plant compartment **46** that is properly shielded and which is located at the lower part **22** of the aircraft so as to lower its center of gravity.

It is specifically pointed out that the atomic reactor **36** is the preferred power plant, but the aircraft **10** could be made to function by using other conventional power plants. When an atomic reactor (FIGURE 9) is used as the power plant, the conventional power transfer system will be required. Steam generator 48 is operatively connected with the reactor 36, and there is a turbo-electric generator 50 operatively connected with the steam generator. Generators 48 and 50 are conventional. Steam from the steam generator passes through one or more conduits 52 in order to operate the steam turbines which constitute part of the four air compressors or propellers 38, 40, 42 and 44. Further details of the application of steam to the steam turbines will be given below.

The upper part 12 of the aircraft body has aerodynamic ducts formed therein, the two ducts 56 and 58 being shown in FIGURE 3 and it being clearly understood as can be seen in FIGURE 2 that there are four individual ducts, each being identical, and one provided for each of the four air compressors. Duct 58 has an outwardly flared or curved air inlet which opens upwardly through the top wall 14. Compressor unit 44 in the embodiment of FIGURE 3, has a steam turbine which drives a propeller 45 located in a portion of the air inlet 58. Compressor 44 is supported by mounting bracket 60 that is suitably secured to the frame structure 32. The side wall 64 of duct 54 is smoothly curved in cross section. The lower ends of each of the vertically extending ducts 56, 57 and 58, 59 branch out into a plurality of individual horizontal ducts such as shown in 64 in FIGURE 3. Preferably there are five individual horizontal ducts connected to each vertical duct and illustrated in FIGURE 1. The discharge end 64 of the total cross sectional area of each group of ducts 54 is smaller than the total cross sectional area of its corresponding vertical duct to allow for an efficient pressure build-up behind the propellers in the vertical duct in advance of the outlet of discharge upon the horizontal ducts. Also, the total area of the discharge ports 66 at the terminal part of the vertical duct is considerably smaller in cross sectional area than the inlets to the vertical ducts, and as shown in FIGURE 3, the part 64 of the horizontal duct is arched so that the discharge axis 68 of the duct is downwardly and outwardly with respect to the direction or line of flight of the aircraft when flying horizontally. The discharge axis is shown in FIGURE 3 at 68.

As shown in FIGURES 1 and 2, each group 6, 7, 8 and 9 of discharge ports 66 are arranged around the periphery of the aircraft so as to the spaced substantially 90 degrees from one another. Since there are four groups of identical ducts for each of the four compressors spaced 90 degrees around the periphery of the aircraft, lateral control is quite easily obtained. With the discharge axis 66 of each port angled downwardly and outwardly as described above, the thrust obtained from an issuing gas stream, will have a horizontal and vertical component to provide horizontal flight and also to provide an overcoming force in a vertical upward direction tending to provide a lift for vertical flight.

Attention is now directed to FIGURE 12 showing a modification of the compressing means. The compressor 44*a* is supported by mounting bracket 60*a* at the inlet 58*a* of duct 54*a*, but the compressor or power plant is a different type than previously disclosed. The compressor 44*a* and each of the other three compressors have individual steam inducting lines extending from the steam generator 48 to the compressors. Each of the individual steam lines has an adjustable valve therein individually controlled by the pilot of the aircraft. The valves are of the conventional type and therefore are not shown in the drawings. The housing of the compressor 44*a* preferably has a vertically extending venturi passage therethrough. The passage through the housing 44*a* also has a plurality of steam ejecting nozzles therein connected to the steam supply pipe and each of the nozzles points primarily in a downward direction but is inclined slightly radially inwardly of the duct. When the steam control valves for the compressor 44*a* are open, the nozzles in the compressors ejects steam downwardly as indicated by the arrows in FIGURE 12 so as to compress the gases below the compressor and create a suction at the entrance of the compressor as indicated by the arrows. The steam and air are ejected from nozzle 66*a* in a manner similar to the ejection of gases from nozzle 66. The specific details of the nozzles and their specific arrangement are conventional and since they form no part of this invention, they are not shown in the drawings.

Each port 66 in each group of discharge ports of the four ducts defines a discharge nozzle for air compressed by means of a compressor such as shown in FIGURE 3 or compressed by compressor 44*a* regardless of whether the steam is directly used in compressor 44*a* or used to operate a steam turbine 44.

Flight control in all directions is obtained by adjustment of deflectors 70 in conjunction with control of the compressors. There is one deflector for each discharge port or nozzle 66 as shown in FIGURES 5 and 6. A typical deflector 70 is arcuate in cross section and is extensible and retractable in a curved path to direct the jet stream issuing from the discharge nozzle 66. As shown in FIGURES 5 through 8, a typical deflector 70 is constrained in its movement by being mounted between upper and lower guides 72 and 74, which may be roller guides supported by a vertically extending portion of the aircraft structure. Laterally extending flanges 70 on each side of the gear portion 88 extend into guide 76 fixed to the aircraft structure thereby preventing lateral displacement of the deflector 70.

One of the previously mentioned electric motors 78 is shown in FIGURE 5, this electric motor has a motor shaft 80 extending therefrom and has a worm 82 fixed to the shaft 80. The worm is in engagement with the pinion worm 84 mounted for rotation on a fixed spindle 86 which is rotatably attached to a part of the frame structure 32. The motors are supported on the frame by means of brackets 33. Gear segments 88 are fixed to one surface of each deflector 70 and are enmeshed with worm wheels 84. Upon energization of any motor 78, the gearing causes the deflector 70 to be retracted or extended depending upon the direction of rotation of the motor. It is preferred that motor 78 be a conventional reversible motor to facilitate extension and retraction of the deflector 70. When a deflector 70 moves from its withdrawn position, FIGURE 6, it passes through a small slot 90 in side wall 16 of aircraft body and assumes a position radially outwardly spaced from nozzle 66 to function as a deflector for the jet stream issuing therefrom. By changing the direction of the jet stream, the force components of the stream are altered, that is the vertical component is increased or decreased depending on whether the horizontal component increases or decreases, and this change is in direct function of the position of deflector 70.

It is to be understood that an electric system need not be used. When an electric system is used, its components including the wiring, the limit switches and the like will be selected from conventional equipment which is commercially available or will be adapted from available equipment but engineered to suit the aircraft, the same holds true of a hydraulic system used with the modified motor shown in FIGURE 8, wherein a hydraulic motor 78*a* is illustrated. The hydraulic motor is coupled by means of a pivot 90, brackets 92 and the shaft of the hydraulic motor to the deflector 70*a*. The guide system for the deflector is the same as used with an electric operation arrangement. The functional utility of deflector 70*a* is precisely the same as that of deflector 70.

FIGURE 4 shows a diagrammatic representation of one group of motors. Motor 78 has been previously described as to function. Motors 100 and 102 are located on opposite sides of motor 78 and as shown from the schematic wiring, motors 78, 100 and 102 are simultaneously energized. Motors **104** and **106** flank motors **100** and **102** respectively, and separate cables **108** and **110** are shown operatively connected therewith since these motors are individually controlled. The groups of five motors such as the group shown in FIGURE 4, for the three additional quadrants are not shown, although the cable connections for each are illustrated. Considering now the procedure for lateral control of the aircraft, electrical power input from generator **50** is obtained by cable **112** which feeds two multi-position switches **114** and **116**. These switches may be made quite simple, consisting of a movable contactor and a number of fixed contacts. Switch **114** is arbitrarily termed a forward and reverse switch implying flight direction. Switch **116** is arbitrarily designated a left-right switch further implying flight direction. When switch **114** is operated, there is power from cable **112** directed by way of the switch to cables **118** or **120** or **122**. Assuming that cable **122** is energized, current flows to cable **110***a* and **110***b* by way of slip ring and brush assemblies **124** and **126** inasmuch as the center part of the switch assembly is preferably stationary with respect to the aircraft. The switch assembly can be built in platform **128** forming the floor of cabin **16** so that the pilot and his crew always maintain a fixed rotational position while the balance of the aircraft can rotate about the vertical axis of the aircraft. This is an optional feature as it is preferred that the floor of the cabin **16** be fixed to the aircraft structure so as to rotate with the aircraft when and if the aircraft is rotated.

When cables of **110***a* and **110***b* are energized, the right rear motor in the rear quadrant and the left forward motor in the forward quadrant are energized simultaneously with the motors operating in opposite directions so that for instance, the right rear deflector of the rear quadrant is withdrawn while the left front deflector in the forward quadrant is extended, and this will cause the aircraft to pitch slightly since the front of the aircraft will move upwardly relative to the rear portion thereof. If cable **118** were energized, cables **108***a* and **108***b* would also be energized through the switch **114** to cause a similar control force to be exerted on the aircraft. If cable **120** were energized by operation of switch **114**, cables **107***a* and **107***b* which feed the center three motors responding to motors **78**, **100** and **102** would be simultaneously operated with the forward deflectors projecting from the aircraft while the rear deflectors retract and vice versa. Inasmuch as the motors are reversible motors, limit switches may be provided or switch **114** may be made a dual switch with two separate groups of contacts, one for movement of the motors in one direction and the other for energization of the motors in the other direction. For instance, there may be a left and a right group of contacts and two vertical planes spaced from each other, and the contactor of the switch may be on a pivot such as a ball joint, so that it may be swung left or right to energize the selected contacts of a given group.

Operation of switch **116** will cause a very similar functioning of the motors in the left and right quadrants. Switch **116** obtains energy from cable **112** by way of cable **113** that is secured thereto. There are three cables **130**, **132** and **134** extending from switch **116**. Assuming that cable **132** is energized, cables **107** and **107***c* will also be energized by way of the slip ring and brush assemblies, and this will cause the three motors **78**, **100** and **102** to be simultaneously energized with the three motors (not shown in figure) in the opposing quadrant. These are thrust motors, just as the motors which are energized by cables **107***a* and **107***b*, and the principal function is to provide lateral or side thrust, either left or right, while the motors energized by **107***a* and **107***b* are used principally to provide forward and rearward thrust. The terms forward and rearward are used merely in explaining the operation of the wiring diagram shown in FIGURE 4 since the exterior shape of the aircraft is symmetrical about any vertical plane passing through its vertical axis, and the aircraft has no true front or rear as in conventional aircraft. The aircraft being symmetrical, it is clear that it may be flown in any direction on the compass by merely manipulating switches **114** and **116** to the proper position. Cables **130** and **134** energize the flanking motors **106** and **104**, respectively and the correspondingly, diagonally opposed motors of the group in the opposing quadrant. When any of the described motors are in operation, the deflectors connected therewith are, of course, actuated. As was previously indicated, the electrical system may be substituted by a hydraulic system with valves taking the place of the switches and hydraulic motors taking the place of the electrical motors. It is contemplated that the switches **114** and **116** each have two full speed positions which is obtained by moving the control levers of these switches either to the extreme forward or extreme reverse positions. The full speed positon operates all five motors in each of two opposing groups at the same time.

One of the pair of switches shown in FIGURE 4, is duplicated in FIGURE 11. The power input line **112** is shown connected with switch **116**, but there is a selector switch **140** between the power output lines of switch **116** and one typical motor **78**, it being understood that the other motors are not shown in this view for simplicity of illustration. Selector switch **140** is connected between a switch **143** controlled by a directional gyroscope **142** and the manual control switch **116**. This view shows that an automatic pilot or a directional gyroscope of conventional description may be used to operate the various motors in the control system of the aircraft.

FIGURE 9 shows diagrammatically a control system for each of the four compressors. Valve **156** is in a steam conduit **52** which feeds steam pressure to the east and west compressors from generator **48**. Valve **156** is located in line **152** and is operated by solenoid **157** while supplying or cutting off or regulating the amount of steam going into the east or west compressors. A solenoid or valve **156** is controlled by a manual control switch **150** or an automatic altimeter control switch **158**. Selector valve **152** is employed for selectively connecting the manual control or the automatic control **158** to the solenoid **157**. When the east and west compressors are on automatic control the altimeter switch **158** may be manually set so as to automatically maintain the aircraft at any desired altitude.

Alternatively, each of the four compressors would be individually controlled by the apparatus shown in FIGURE 9. In such an arrangement, there would be four separate systems, one for each of the compressors, and the four valves **150** would be arranged side-by-side in a manner commonly used for arranging its valves in multi-engine conventional aircraft. In such an arrangement, the handles **150** for the control switches for the east and west compressors would be arranged side-by-side, and in addition to those two switches the north and south switches would be arranged side-by-side whereby all four switches would be controlled by one hand of the pilot.

The control system shown in FIGURE 10 is designed to control the north and south compressors and is intended to be used in conjunction with the system shown in FIGURE 9 for controlling the east and west compressors. When these two systems are used together, it is contemplated that the aircraft will have a point on its periphery which will in effect comprise the front thereof so that the aircraft will always be orientated in the same direction in relation to its path of movement. The pitch detector switch **160** is controlled by an automatic means such as a gyroscope which may be used in place of the manual control **151** for the north and south compressors. Selector switch **162** permits the pilot to select between manual control and automatic control by means of the pitch detector switch 160. An electric valve 164 is of a rotary type and operated by a reversible motor 163 which is either connected by means of switch 162 to the pitch detector switch 160 or the manual switch 151. An electric valve 164 applies more or less steam to the north and south compressor depending on the direction of the voltage output from the pitch detector or manual control. If separate lines are desired, the pitch detector may use a balancing bridge so long as the power output is such that the motor of the electric valve 164 is energized in the proper direction to make correction of the flight attitude of the aircraft by applying more or less steam to the north or south compressors. A Selsyn motor system is ideally united for this application.

In understanding the operation and effect of the vane 70, reference is made to FIGURE 3. As shown in this figure, the right vanes 70 are fully retracted and the left vanes 70 are fully extended. As shown by the arrows T and T', the gases exhausting from the nozzle 66 move downwardly to the right. This in turn causes a reaction which moves the aircraft to the left. Since all nozzles at both the front and the rear of the aircraft are producing thrust, maximum horizontal velocity and efficiency are thereby produced. When it is desired to hover, or rise in a vertical direction, all the vanes 70 partially retract so that the gases exhaust from the nozzles 66 in a vertical direction. This provides maximum lift and therefore maximum climbing speed. For descending the aircraft in a straight downward direction, all the vanes are either retracted or extended an equal amount and power to the compressors 40 through 44 is reduced accordingly. If the aircraft is for example moving north and it is desired to suddenly move the aircraft in a westerly direction, then the vanes on the right side of the aircraft are retracted and the vanes on the left side of the aircraft are extended while at the same time the vanes at the rear of the aircraft are extended an amount equal to the extension of the vanes at the front of the aircraft. Thus it can be seen that the aircraft can change its direction of flight without rotating about its vertical or yaw axis.

Pitch of the aircraft is controlled by regulating the fore and aft deflectors 70 or by controlling the relative power between the fore and aft compressors. Likewise, roll of the aircraft may be controlled by the deflector 70 on each side of the aircraft as well as the relative speed of the compressors on opposite sides of the aircraft.

FIGURES 9 to 11 principally show that by following the design principles and using automatically controlled devices employed in conventional aircraft, the aircraft 10 may be controlled either automatically or manually in flight.

Referring to FIGURE 3, it can be seen that the horizontal ducts 64 are separated by vertical partitions 57 having streamlined inner edges 55.

To prevent rotation of the aircraft in flight, it is contemplated that two of the propellers of the compressor units will rotate in a clockwise direction and the other two propellers will rotate in a counter-clockwise direction so as to neutralize the torque produced by these propellers. Also, rotation of the aircraft may be produced or prevented by controlling the relative speed of the propellers thereby producing an unbalanced torque force on the aircraft tending to rotate it in one direction. The direction of the rotation of each propeller is indicated by the four arrows in FIGURE 2. The pitch of the propellers rotating in a clockwise direction is just the reverse of those rotating in a counterclockwise direction. All the propellers force air downwardly and out of exhaust ducts 66.

To simplify control of the aircraft about its vertical or yaw axis, an additional means may be employed thereon for controlling its rotation about this axis. Referring to FIGURES 2, 3, 13 and 14, it may be seen that nozzles 170 and 172 may be installed within the aircraft adjacent one edge thereof. These nozzles face in opposite directions and are inclined slightly upwardly and parallel to

enclosed ducts 174 and 176 which have openings 178 and 180 on the upper surface of the aircraft. As shown in FIGURE 14, the jet nozzles 172 and 170 are connected by means of passageways 184 and 182 to a three-way valve 186 which in turn is connected by a passage 200 to steam generator 48. Located in the pilot's compartment is a manually controlled switch 200 and selector switch 204. The switch 200 is connected to solenoids 188 and 190 by means of leads 198 and 196 respectively. The three-way valves is of the reciprocating type having a control plunger therein which has armatures 192 and 194 fixed to its ends extending through the solenoids 188 and 190. To rotate the aircraft in a counter-clockwise direction or to prevent it from rotating in a clockwise direction, the pilot moves the switch handle 201 in a downward direction from its neutral position thereby energizing solenoid 188 which operates three-way valve from its closed position to a position to connect line 206 with line 182 thereby permitting steam to flow from steam generator 48 to the nozzle 170 and out of opening 178 so as to impose a rotational force on the aircraft 10 tending to rotate it in a counter-clockwise direction. If it is desired to rotate the aircraft in a clockwise direction or prevent it from rotating it in a counter-clockwise direction, the pilot raises the handle 201 of the rheostat 200 the desired amount so as to energize solenoid 190 a correspondingly desired amount thereby moving armature 192 to the left to open the three-way valve so as to cut-off passageway 182 and connect passageway 184 to the stream generator thereby energizing jet 172. This causes a jet of steam to flow out of opening 180 as indicated by the arrow in FIGURE 2 thereby creating a clockwise rotational force or torque upon the aircraft 10. If it is desired to prevent rotation of the aircraft by automatic means, then switches 204 are closed and valve handle 201 is left in its neutral position, as shown in FIGURE 14. Gyroscopic control switch or rheostat 202 then automatically operates three-way valve 186 to control jet nozzles 172 and 170 as necessary to prevent rotation of the aircraft. Valve 186 is normally held in a neutral, closed position by internal spring means.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly all suitable modifications and equivalents may be resorted to, falling within the scope of the invention as claimed.

What is claimed as new is as follows:

1. In an aircraft having a body provided with an upper wall, a circular side wall and a bottom wall, a plurality of ducts within said walls, each duct having an inlet which opens through said upper wall and a plurality of discharge nozzles which open outwardly and downwardly through said side wall and which have discharge axes extending outwardly and downwardly with respect to the vertical axis of the aircraft body, said ducts being arranged to define quadrants, airstream direction changing deflectors, means movably mounting said deflectors on the aircraft body, means connected with said deflectors for propelling said deflectors to a position at which portions of the deflectors are in the airstreams passing from said nozzles to thereby change the direction of flow of air extending through said nozzles and thereby imposing reaction forces on the aircraft body to alter the attitude and flight direction of the aircraft body, at least some of said deflectors in opposing quadrants being operative simultaneously and in synchronism, and means for so synchronously and simultaneously actuating some of said deflectors, air compressors in said ducts to induce an airstream therethrough, and control means connected with said air compressors for operating at least some of said air compressors synchronously.

2. The subject matter of claim 1, wherein said deflec-

tors comprise curved deflector plates, said side wall having openings therein, and said curved deflector plates being movable in said openings between the retracted and extended positions respectively.

3. In an aircraft having a body provided with an upper wall, a circular side wall and a bottom wall, a plurality of ducts within said walls, each duct having an inlet which opens through said upper wall and a plurality of discharge nozzles which open outwardly and downwardly through said side wall and which have discharge axes extending outwardly and downwardly with respect to the yaw axis of the aircraft body, said ducts being arranged to define quadrants, airstream direction changing deflectors, means movably mounting said deflectors on the aircraft body, means connected with said deflectors for propelling said deflectors to a position at which portions of the deflectors are in the airstreams passing from said nozzles to thereby change the direction of flow of air extending through said nozzles and thereby imposing reaction forces on the aircraft body to alter the attitude and flight direction of the aircraft body, said deflectors each comprising an arcuate plate oscillatable about a horizontal axis, an inner surface of each plate being parallel with an adjacent surface of one of said discharge nozzles, said means for propelling said deflectors comprising an arcuate rack fixed to the outer surface of each of said deflectors, a pinion rotatably mounted within the edge of said aircraft and operatively engaging said rack, and remotely controlled power means connected with said pinion for rotating same.

4. In an aircraft which has a circular aircraft body, the body provided with a plurality of separated ducts having air inlets and a plurality of discharge nozzles at the arcuate periphery of the aircraft body, a compressor in each duct to draw ambient air into the inlets of the ducts and to discharge the air as a jet stream through the discharge nozzles of the ducts, arcuate control deflector means comprising curved deflectors mounted within the body of the aircraft immediately above each nozzle and said deflectors being capable of moving outwardly from the body of the aircraft so that the curved ends of the deflectors intercept the jet streams of the nozzles to the lesser extent or greater extent that they curve downwardly into the discharge streams of the nozzles, said deflectors in their fully retracted positions making no contact with the discharge streams of the nozzles, means mounting said deflectors as movable elements on the body of the aircraft above said nozzles and jet streams and regulating the movement of the deflectors so that the movement thereof is between a position at which at least a portion of the deflectors extends into the paths of movement of the discharge streams from the nozzles and at an open position at which deflectors are essentially removed from any contact with the discharge stream of the nozzles.

5. The subject matter of claim 4 wherein each nozzle has the axis of its discharge stream arranged at approximately a 45° angle to the vertical axis of the circular aircraft body.

6. The subject matter of claim 5 wherein there are means for synchronously operating said deflectors to obtain coordinated control of the direction of the jet streams from said nozzles.

7. The subject matter of claim 6 wherein there are means for controlling the operation of said compressors individually so that the force of the jet streams issuing from the nozzles at selected positions of the aircraft may be individually varied thereby resulting in a change in the attitude of the aircraft.

8. In an aircraft which has an aircraft body of generally circular plan form, said body having an upper wall, a side wall and a lower wall, a plurality of ducts between said upper and lower walls, each duct having an air inlet which opens through said upper wall, a compressor in each inlet separately controlled, and a plurality of discharge nozzles which open through said side walls, each of said compressors inducing an airstream through said duct inlets and out of said discharge nozzles, and flight control means carried by said aircraft body and adjustable to selected positions for deflecting the jet airstreams which issue from said discharge nozzles in either a downward or lateral direction relative to the aircraft, said flight control means consisting essentially of a plurality of deflectors, means mounting said deflectors in said aircraft body for movement to regulated positions intercepting and hence deflecting the discharge airstreams issuing from said nozzles.

References Cited in the file of this patent

UNITED STATES PATENTS

2,838,257 Wibault ---------------- June 10, 1958

May 21, 1963 A. B. KEHLET ET AL 3,090,580

SPACE AND ATMOSPHERIC RE-ENTRY VEHICLE

Filed April 13, 1962 3 Sheets-Sheet 1

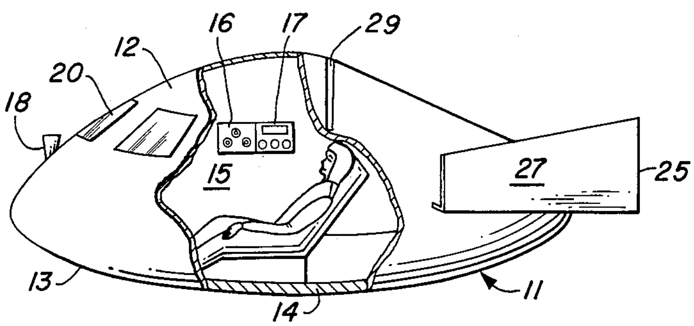

FIG. 1

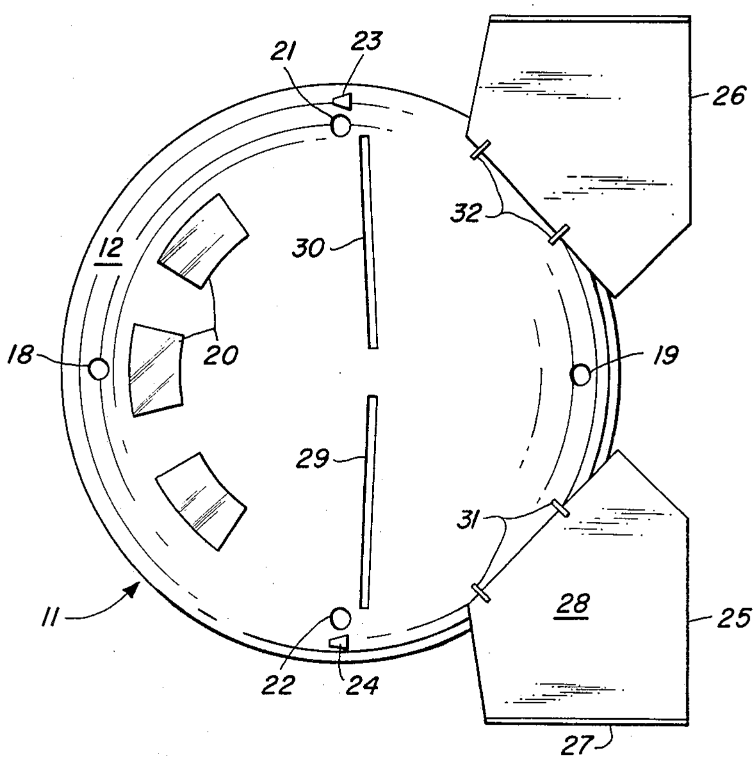

FIG. 2

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SPACE AND ATMOSPHERIC RE-ENTRY VEHICLE

Filed April 13, 1962 3 Sheets-Sheet 2

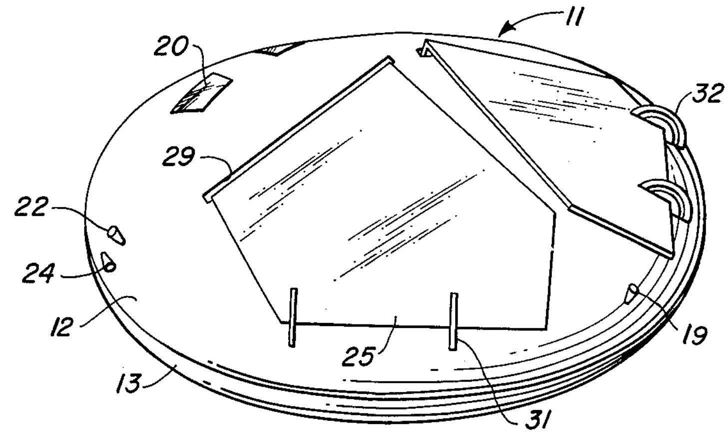

FIG. 3

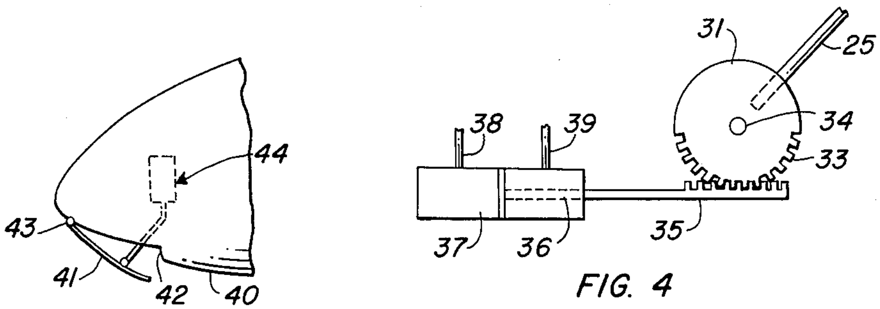

FIG. 4

FIG. 5

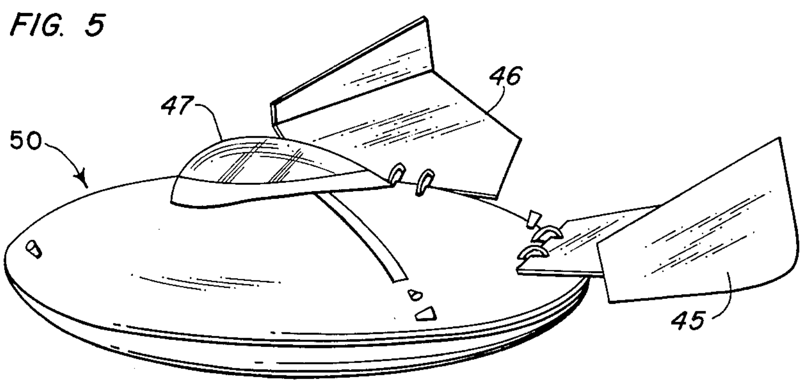

FIG. 6

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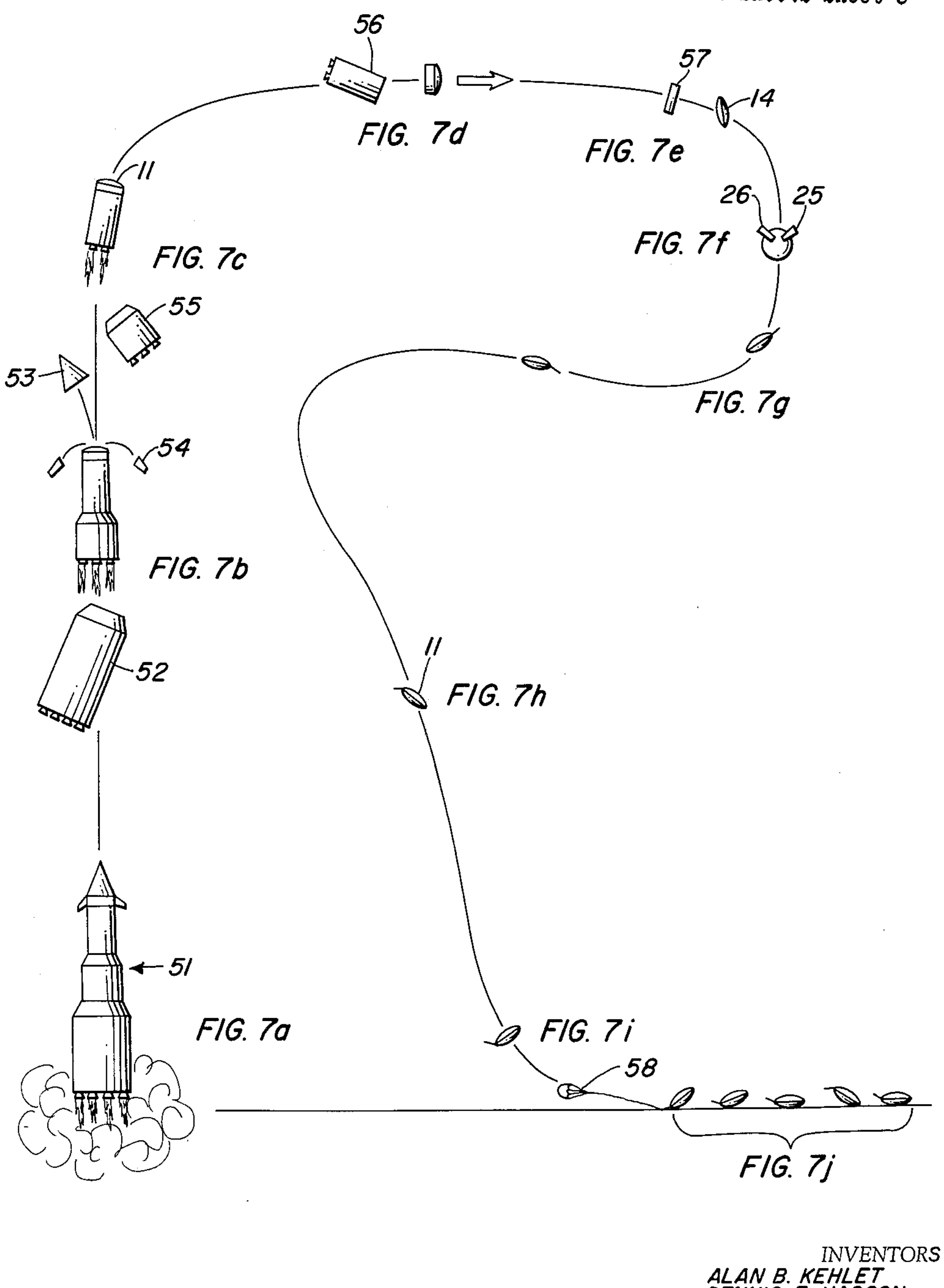
SPACE AND ATMOSPHERIC RE-ENTRY VEHICLE

Filed April 13, 1962 3 Sheets-Sheet 3



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SPACE AND ATMOSPHERIC RE-ENTRY VEHICLE

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(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates generally to space vehicles, and more particularly to manned reentry vehicles for operation both above and within the Earth's atmosphere.

A vehicle capable of performing manned orbital and space missions, and possessing the additional capability of atmospheric maneuverability, such as is generally attributed to fixed wing aircraft, is not presently available in the field of space technology. A vehicle of the type described need necessarily incorporate a plurality of diverse features to provide performance as desired under the different environmental conditions to which it will be exposed. The space vehicle may be normally launched into space as the final stage of a booster-vehicle system and therefore should initially be of such shape as to minimize the launch or boost vehicle's control and structural loading problems. The space vehicle must have an attitude stabilization system for employment while in flight outside the Earth's atmosphere. The vehicle must be capable of surviving the heat generated during its subsequent reentry into the Earth's atmosphere and of shielding its occupants therefrom. Further, the vehicle must then have an atmospheric maneuvering capability of a degree such as to enable the occupants to control the rate of deceleration, to select a desired landing area for the vehicle and to perform a glide type landing thereon. From the viewpoint of operation sequence reliability and selection of landing area, a flared or glide type landing capability is considered preferable to landing space vehicles by parachute in accordance with prior art methods.

Winged vehicles and vehicles with body asymmetry have been proposed as reentry vehicles capable of atmospheric maneuvering and glide type landings. However, for a fixed maximum total vehicle weight requirement with which to accomplish a given mission, both the winged and the asymmetric vehicles present two major problems, the solution of which would result in the reduction of usable payload; the problem of providing thermal shielding over a much larger vehicle surface area, and a booster-vehicle attachment problem which can be solved only through the use of a heavy booster-vehicle adapter.

Accordingly, it is an object of the present invention to provide a novel space vehicle for orbital flight.

Another object is to provide a space vehicle capable of being attitude stabilized outside of the Earth's atmosphere and of being maneuvered subsequent to reentry into the Earth's atmosphere.

A further object of the present invention is to provide a symmetrical space vehicle capable of performing glide type landings.

A still further object of the instant invention is to provide a space vehicle having glide type water landing capabilities.

According to the present invention, the foregoing and other significant objects are attained by the provision of a lenticular vehicle having foldable aerodynamic control flaps pivotally mounted on the upper convex vehicle surface. The control flaps are adapted to form a substantially continuous extension of the upper convex vehicle surface when in folded or retracted position during the launch and orbital stages of a vehicle mission, and to be deployed into an operative, extended position upon reentry of the vehicle into the Earth's atmosphere. The space vehicle further includes individually actuated reaction jets, positioned on the vehicle's upper convex surface, for attitude control while outside of the Earth's atmosphere. In a further aspect of the instant invention, the vehicle is provided with an extendible nose ski for landing on water.

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily apparent as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a side elevational view, partly broken away, of the space vehicle of the present invention with the flaps in operative, extended position;

FIG. 2 is a planform view of the space vehicle of FIG. 1;

FIG. 3 is a perspective view of the space vehicle of FIG. 1 with the flaps in retracted position;

FIG. 4 is a somewhat schematic view of one form of flap actuating means;

FIG. 5 is a partial side view of an alternative embodiment of the vehicle of FIG. 1 incorporating an extendible nose ski;

FIG. 6 is a perspective view of a further alternative embodiment of a space vehicle according to the present invention; and

FIGS. *7a–7j* illustrate the sequence of events that take place in the launching, space flight, reentry, and landing of the space vehicle of the present invention.

Referring now to the drawings wherein like reference numerals designate identical or corresponding parts throughout the several views, and more particularly to FIGS. 1 and 2, the space vehicle according to the present invention, generally indicated by the reference numeral **11**, is shown. Space vehicle **11** includes a body of revolution having a circular planform and a double convex lens-like cross section. The lenticular body of space vehicle **11** includes an upper convex surface **12** and a lower convex surface **13**; the lower convex surface being formed by a relatively thick, curved heat shield **14**. One type of heat shield having the inherent strength suitable for use is disclosed in the copending in the copending application of Roger A. Anderson et al., Serial No. 141,220, filed September 27, 1961. The employment of such a shield as the surface **13** of vehicle **11** serves two important functions. The shield **14** protects the vehicle **11** and its occupants from the heat generated during the vehicle's reentry into the Earth's atmosphere, and also acts as a "skid-rocker" for the vehicle, as will be discussed more fully hereinafter. The use of heat shield **14** enables the vehicle to land on hard surfaces without developing high impact loads, thereby obviating the need for providing additional, heavy, complicated landing gear. Observation windows **20** are provided in the forward sector of the vehicle **11**.

The advantages derived from utilizing a lenticular shaped body for a space craft are many fold. Some of these advantages may be briefly summarized as follows: The lenticular vehicle has a higher usable volume to surface area ratio than a winged vehicle and requires less thermal protection and shielded area than such a vehicle. Also the lenticular vehicle, because of its short afterbody in a high angle of attack attitude, i.e., volume to the rear of heat shield maximum diameter, will have less severe afterbody heating problems than the afterbody of a blunt nose-cone semi-lifting capsule or craft. Therefore, the structural weight to total weight of the lenticular vehicle is less than either the winged or the semi-lifting capsule configuration. The lenticular vehicle, being symmetrical, permits the use of a minimum strength and therefore lightweight vehicle-booster attachment adapter, and imposes lower aerodynamic loads on the booster than the winged or asymmetric vehicles, reducing booster control problems. The lenticular shaped vehicle is amenable to simple pressure compartment design. Further, the lenticular vehicle, because of its circular planform and heat shield design, is, unlike the winged or asymmetric vehicles, inherently stable in both pitch and yaw at high angles of attack. Therefore, should the aerodynamic flaps fail to function due to some unforeseen casualty, a successful reentry and landing could be accomplished with only the use of a parachute and reaction jet controls.

A sealed compartment **15** for one or more occupants is formed within the vehicle **11**. As shown schematically in FIG. 1, an attitude control unit **16** and a flap control unit **17** are provided within the compartment **15**, each operable either automatically or manually by a vehicle occupant. A system of individually actuated reaction jets is provided on the vehicle for attitude stabilization of the vehicle above the Earth's atmosphere and directional control within the atmosphere. The system comprises diametrically spaced pairs of nozzle orifices positioned on the upper convex surface **12** of vehicle **11** as shown in FIG. 2. The pitch control jets **18**, **19** are located on the fore and aft axis of the vehicle while the roll and yaw control jets **21**, **22** and **23**, **24**, respectively, are positioned on the vehicle transverse axis. The jets are selectively actuated by the opening and closing of individual feed valves, not shown, connected between each jet and a reaction medium supply, not shown, preferably of the type utilizing a hydrogen peroxide fuel, as exemplified in Technical Note D–480 published in October 1960, by the National Aeronautics and Space Administration in Washington, D.C. The attitude control unit **16** may include a conventional gyro stabilization system, not shown, for automatic operation which transmits output signals to the above mentioned feed valves for actuation of the appropriate control jet. Gyro systems of the type described are generally known and available in the art and the system per se does not constitute a part of the present invention. A manual control system, not shown, operated by one of the occupants may be provided as a secondary means for selectively actuating the reaction jets **18**, **19**, **21**, **22**, **23**, **24**. It will be further noted that the reaction jets **18**, **19**, **21**, **22** are positioned so as to direct the reaction medium upwardly, whereas jets **23**, **24** expel the reaction medium in a rearward direction. It will likewise be apparent that only one of each pair of reaction jets is actuated at any one time so as to produce a correctional, rotational moment for stabilizing the vehicle.

To provide the desired atmospheric maneuvering capability, aerodynamic control members or flaps **25**, **26** are foldably or pivotally attached by hinge means **31**, **32** to the after, upper convex surface of vehicle **11**. The hinge means **31**, **32**, as best shown in FIG. 2, are oriented at an angle of approximately 45° to the fore and aft axis of the vehicle. The flaps **25**, **26** are each formed with an end plate or fin **27** projecting normally to the flat, planar surface **28**. In the upper convex surface **12** of the vehicle are provided two slots **29**, **30** which extend essentially transverse to the fore and aft vehicle axis. A housing, not shown, projecting inwardly from upper convex surface **12** at a slight forward angle so as to receive and house the flap end plates **27** in vehicle compartment **15**, when the flaps **25**, **26** are in inoperative, folded or retracted position, may be provided. The flaps **25**, **26** when folded are thereby enabled to form a substantially continuous extension of the convex vehicle surface **12**, as best shown in FIG. 3.

One form of conventional actuating means for extending flaps **25**, **26** into operative position and for retracting them into folded position is shown in FIG. 4. The actuating means for each flap are similar and therefor only one will be described. The fin **25** at one edge is secured to a pair of circular elements **31**, each element being formed with a toothed, gear segment **33**. The elements **31** in turn are fixed to an axle **34** which is rotatably mounted in brackets or otherwise, not shown, to vehicle surface **12**. The geared elements **31** are individually driven by a rack **35** which is affixed to a piston rod **36**, the rod being reciprocable in hydraulic cylinder **37**. The piston rod **36** may be caused to move in either direction by hydraulic pressure introduced into cylinder **37** through pipes **38**, **39** which are connected to a conventional hydraulic supply system, not shown, whereby the vehicle occupant may actuate cylinder **37** from the flap control unit **17**, FIG. 1, and thus extend or retract the flap **25**. Although a hydraulic actuating means has been shown, the actuating means may be hydraulic or electrical since servo mechanisms of any well-known type may be used in adjustably and controllably positioning flaps **25**, **26**.

In FIG. 5 is shown a partial side view of an alternative embodiment of the space vehicle above described, modified to provide glide type water landing capabilities. The modification consists of the provision of a extendible nose ski **41** to the vehicle lower convex heat shield surface **40**. The surface **40** is formed with a recess **42** to receive the ski **41** when retracted. The ski **41** is pivotally attached to the vehicle nose at **43** and means for operating the ski are diagrammatically illustrated at **44**. The specific means for operating the ski is not critical to the present invention and any conventional mechanism capable of performing this function may be utilized. One such mechanism capable of being used is disclosed in U.S. Patent 2,402,379. In operation, the ski **41** is maintained retracted in recess **42** until the occupant is ready to land the space vehicle on water. Then, the ski **41** is extended by means **44** to aid in stabilizing the vehicle during the landing operation.

A further alternative embodiment of the space vehicle of the present invention is shown in FIG. 6. In this configuration, the end plates or lateral fins **45** projecting normally from the flat or horizontal flap surfaces **46** are modified from the end plates shown in the embodiment of FIG. 1. The end plates or fins **45** are designed to eliminate the need for using reaction jets in the atmosphere for lateral and directional stability. Trim tabs, not shown, or other movable control surfaces may be added to flap surfaces **45**, **46** to provide additional control if desired. The space vehicle **50** of FIG. 6 is also provided with an astrodome **47** to increase the usable vehicle volume both for occupants and for additional equipment.

For the purpose of providing a better understanding of the space vehicle of the present invention the operational sequence as depicted in FIG. 7 will now be described. The vehicle **11** with flaps **25**, **26** in folded inoperative position may be launched into orbit as the payload of a three stage booster rocket **51** as illustrated in FIG. 7*a*. Subsequent to ignition and lift off of rocket **51**, the first stage motor **52**, the low drag nose section **53**, and the escape system fins **54** are jettisoned, as shown in FIG. 7*b*. The second and third stage motors **55**, **56** are next separated and dropped, FIG. 7*c*, 7*d*, as vehicle **11** is injected into space. In FIG. 7*e*, the vehicle **11** trailed by vehicle-booster adapter **57** is shown reentering the Earth's atmosphere, the vehicle **11** at this time being trimmed to a high angle of attack to produce high drag and moderate lift by means of the reaction jets **18**, **19**, **21**, **22**, **23**, **24**, which have been operative throughout the space flight to attitude stabilize the vehicle **11**. It will be noted that the lower convex heat shield surface **14** is positioned foremost for protection of the vehicle and its occupants from the heat generated upon reentry. At approximately 100,000 feet, subsequent to peak heating, and at a velocity of approximately Mach 2, the vehicle occupant through flap control unit **17** actuates the hydraulic cylinders **37** to pivot the flaps **25**, **26** into extended, operative position, depicted in FIG. 7*f*. The occupant then maneuvers the space vehicle **11** to the desired touchdown location, either by using flaps **25**, **26** for roll and pitch control in combination with directional jets **23**, **24**, or, in the embodiment of FIG. 6, by utilizing flaps **45**, **46** alone, as illustrated at **7*g***. The vehicle **11** then goes into its glide path, FIG. 7*h*, and is flared to essentially zero sinking velocity as at FIG. 7*i*. A horizontal landing is then made, FIG. 7*j*, with the curved lower heat shield surface **14** serving as a skid-rocker to convert the vehicle sinking-speed energy into angular energy, through rocking oscillation of the vehicle on its lower convex surface, the energy thus being dissipated by friction and aerodynamic damping. If desired, a drogue chute **58** may be ejected from the vehicle upon touchdown to stabilize the vehicle in the edgewise direction.

As a result of this invention, it is evident that a space vehicle may be provided which combines the lightweight structure-high usable volume of the lenticular configuration with the high maneuvering capabilities at supersonic and subsonic speeds of the winged vehicle and eliminates the need for heavy, complicated landing gear systems.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A space vehicle capable of atmospheric maneuvering comprising in combination a lenticular body having an upper convex surface, aerodynamic control flaps pivotally connected to said convex surface, means positioned in said body for pivotally moving said flaps from an inoperative, folded position to an operative, extended position, said body having a lower convex surface, said lower convex surface comprising a heat shield for said body, and individually actuated reaction jets positioned on said upper convex surface for stabilizing said lenticular body in roll, pitch and yaw.

2. A space vehicle as defined in claim 1, and including slot means formed in said upper convex surface, each of said flaps comprising a flat surface and an end plate projecting normally therefrom, said flap end plate being received in said slot means when said flaps are pivoted to said inoperative, folded position.

3. A space vehicle as defined in claim 1, and including a ski pivotally connected to the bow of said body, said lower convex surface having a recess adapted to receive said ski, and means positioned in said body for extending said ski to an operative position and for retracting said ski into said recess.

4. A space vehicle capable of atmospheric maneuvering comprising in combination a lenticular body having an upper convex surface, slot means formed in said convex surface, aerodynamic control flaps pivotally connected to said convex surface, each of said flaps comprising a flat surface and an end plate projecting normally therefrom, and means located in said body for pivotally moving said flaps from an inoperative folded position wherein said flap end plate is received in said slot means, said flaps thereby forming a substantially continuous extension of the upper convex surface, to an operative, extended position.

5. A space vehicle as defined in claim 4, wherein said slot means extend essentially transverse to the fore and aft axis of said body.

6. A space vehicle as defined in claim 5, wherein said slot means includes a pair of slots, one positioned on either side of the fore and aft axis of said body, and said flaps include a pair of flaps, one flap pivotally connected to said upper convex surface on either side of the fore and aft axis of said body.

7. A space vehicle as defined in claim 4, and wherein said lenticular body has a lower convex surface, said lower convex surface comprising a heat shield for said body.

8. A space vehicle as defined in claim 7, and including a ski pivotally connected to the bow of said body, said lower convex surface having a recess adapted to receive said ski, and means positioned in said body for extending said ski to an operative position and for retracting said ski into said recess.

9. A space vehicle capable of atmospheric maneuvering comprising in combination a lenticular body having an upper convex surface and a lower convex surface, aerodynamic control members pivotally connected to said upper convex surface, means located in said body for pivotally moving said members from an inoperative, retracted position to an operative, extended position, and said lower convex surface comprising a heat shield for said body.

10. The space vehicle as defined in claim 9, and including a ski pivotally connected to the bow of said body, said lower convex surface having a recess adapted to receive said ski, and means positioned in said body for extending said ski to an operative position and for retracting said ski into said recess.

11. A space vehicle capable of atmospheric maneuvering comprising in combination a lenticular body having an upper convex surface, aerodynamic control members pivotally attached to said upper convex surface, means located in said body for pivotally moving said members from an inoperative, retracted position to an operative, extended position, and individually actuated reaction jets positioned on said upper convex surface for stabilizing said lenticular body in roll, pitch and yaw.

12. A space vehicle as defined in claim 11, and including slot means formed in said upper convex surface, each of said members comprising a flat surface and an end plate projecting normally therefrom, said end plate being received in said slot means when said members are pivoted to said inoperative, retracted position, said members thereby forming a substantially continuous extension of said upper convex surface.

13. A space vehicle capable of atmospheric maneuvering comprising a lenticular body having an upper convex surface, aerodynamic control flaps pivotally connected to said convex surface, each of said flaps comprising a flat surface and an end plate projecting normally therefrom, means for pivotally moving said flaps from an inoperative, folded position to an operative, extended position, the lower portion of said flap end plate in said extended position being formed with a curvilinear edge, said body having a lower convex surface, said lower convex surface comprising a heat shield for said body, and individually actuated reaction jets positioned on said upper convex surface for stabilizing said lenticular body in roll, pitch and yaw.

14. The space vehicle as defined in claim 13, and including an astrodome positioned on said upper convex surface.

References Cited in the file of this patent

Aviation Week Magazine of July 11, 1960, page 67.

HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

Filed Jan. 23, 1953 12 Sheets-Sheet 1

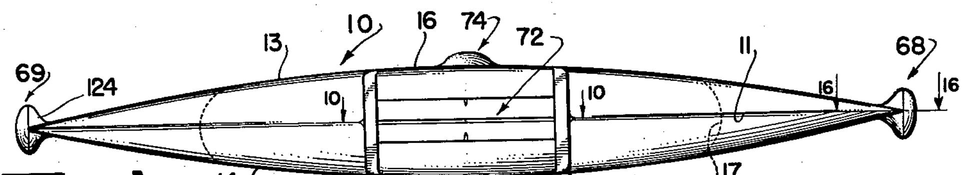

Fig. 1

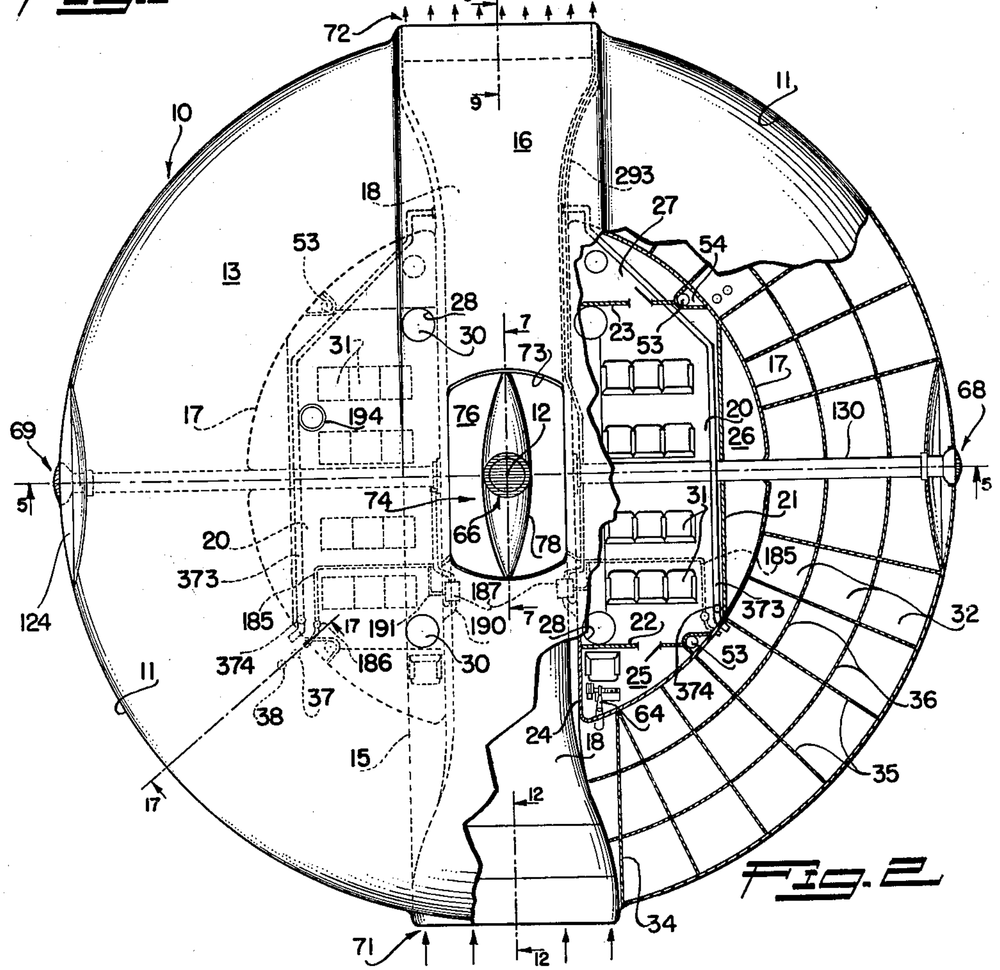

Fig. 2

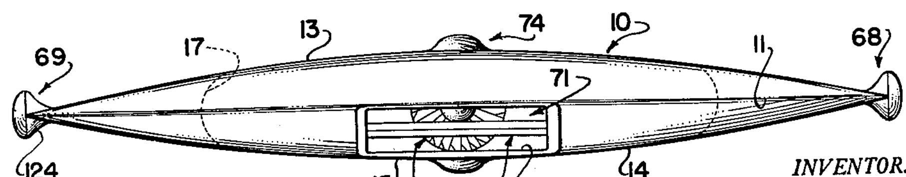

Fig. 3

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HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

Filed Jan. 23, 1953 12 Sheets-Sheet 2

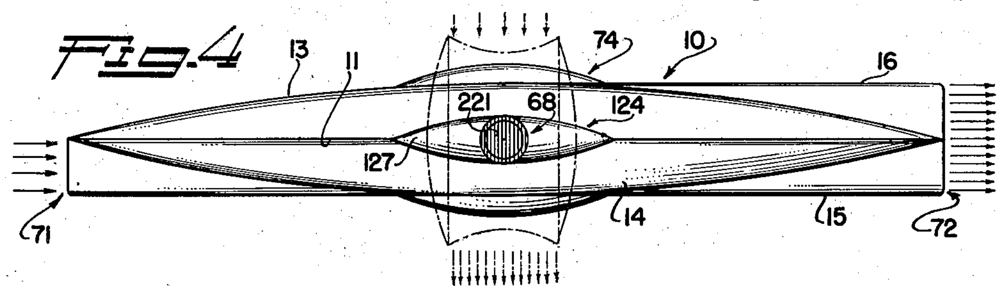

Fig. 4

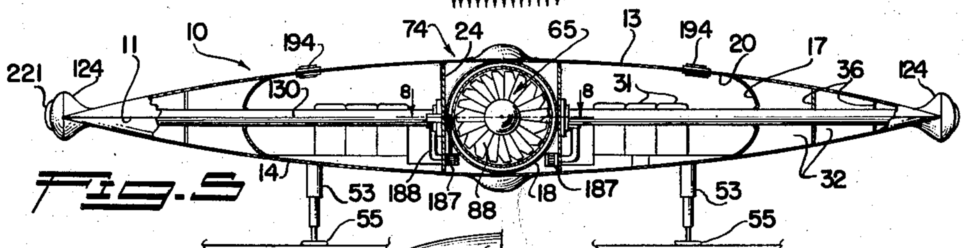

Fig. 5

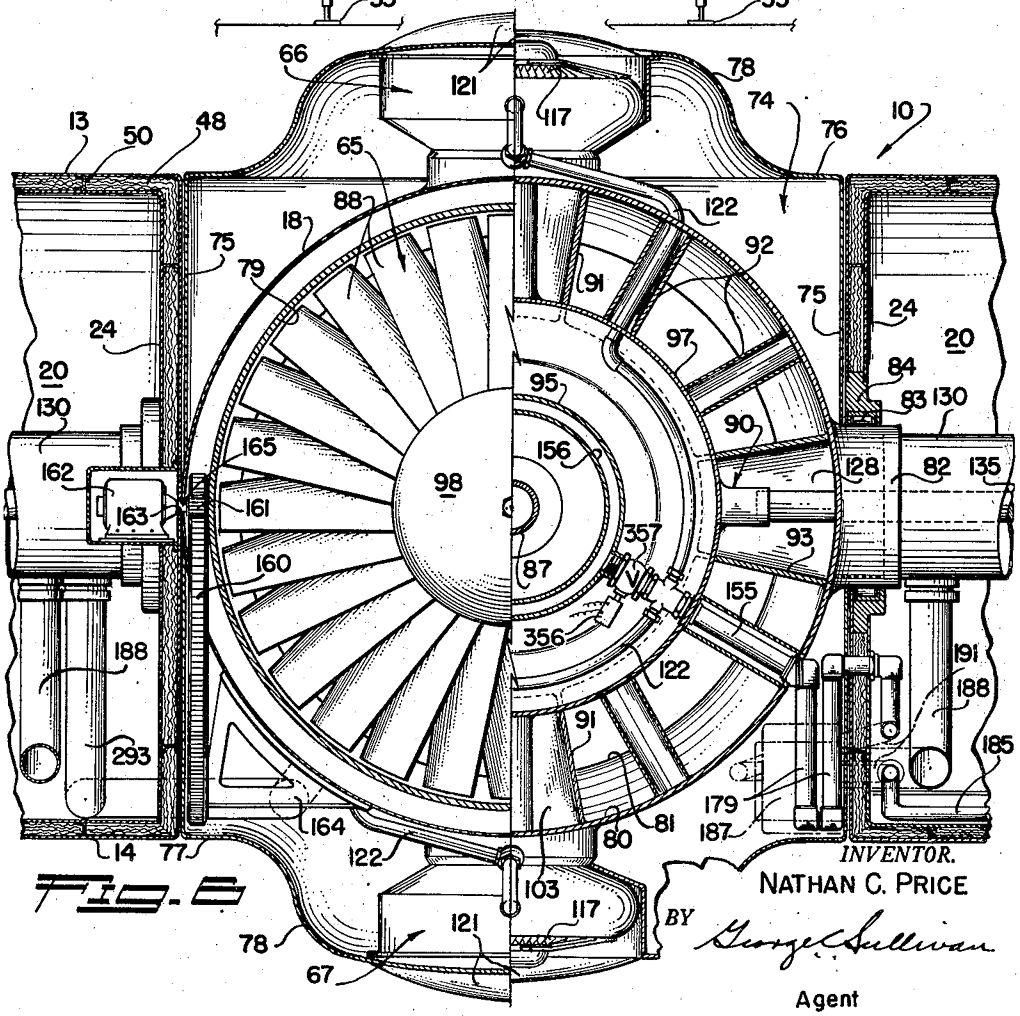

Fig. 6

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Sept. 10, 1963 N. C. PRICE 3,103,324

HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

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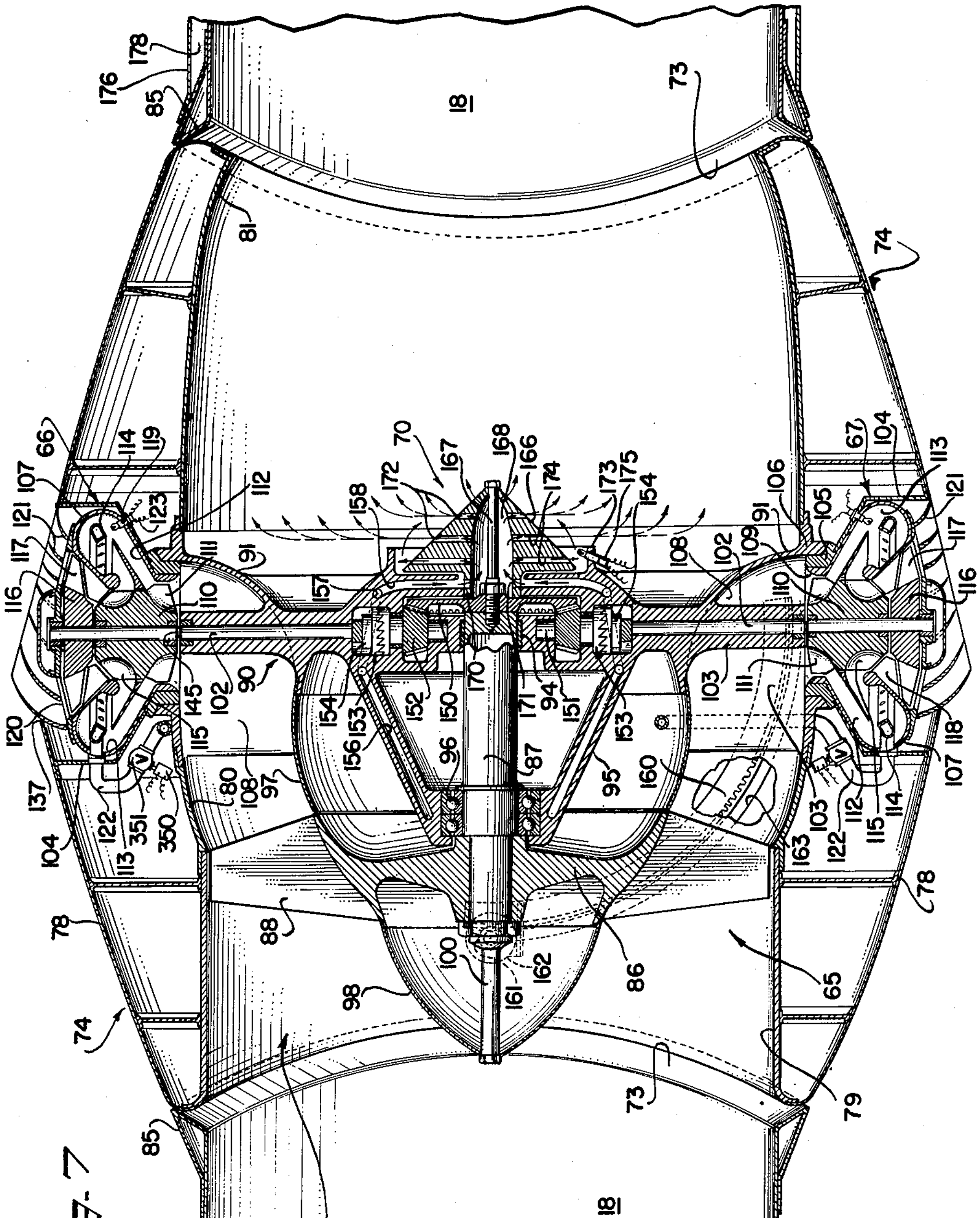

FIG. 7

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HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

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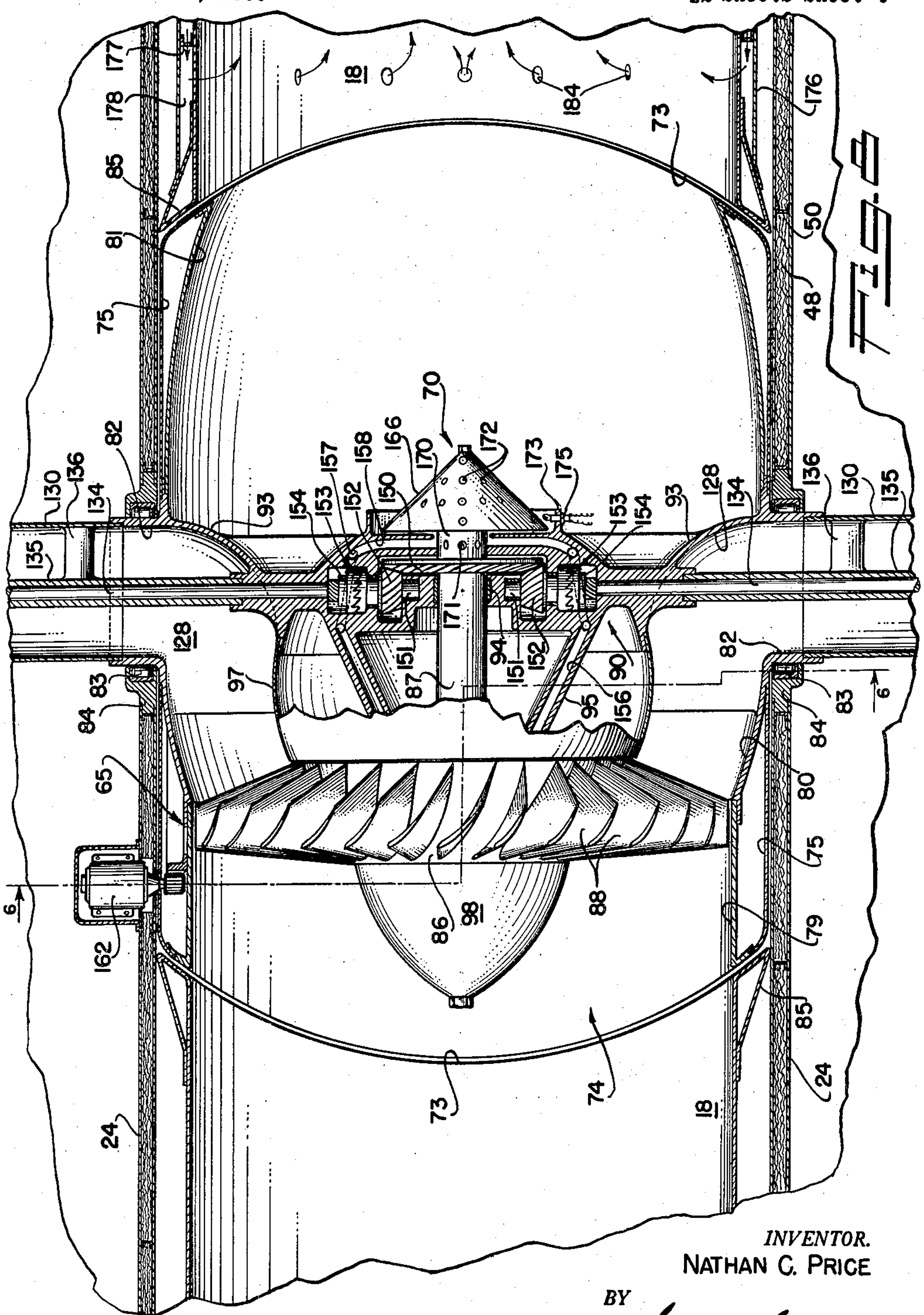

Fig. 2

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HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

Filed Jan. 23, 1953 12 Sheets-Sheet 5

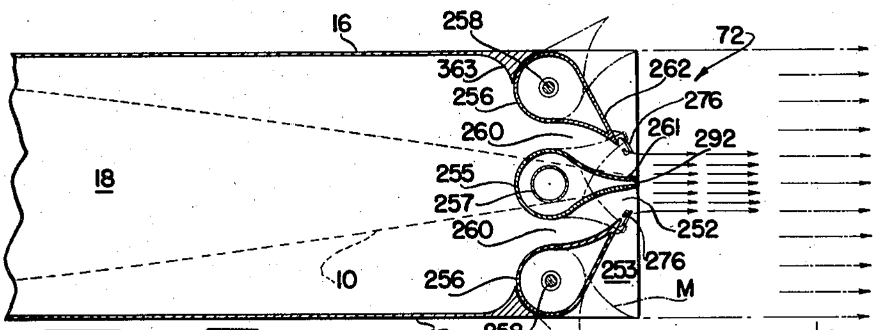

Fig. 9

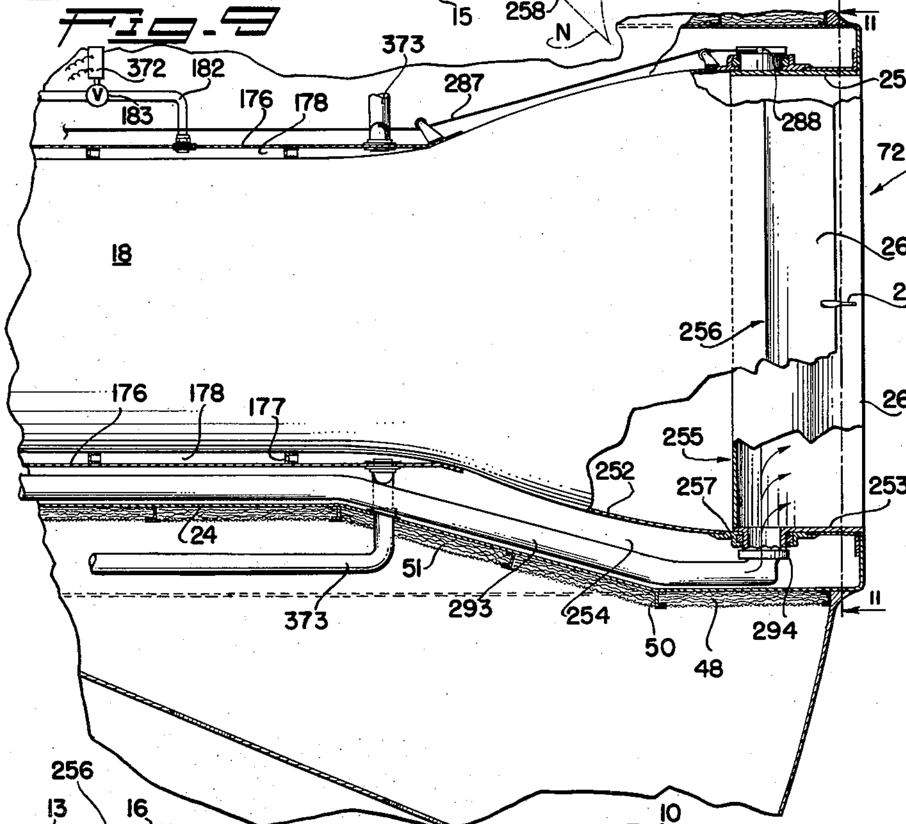

Fig. 10

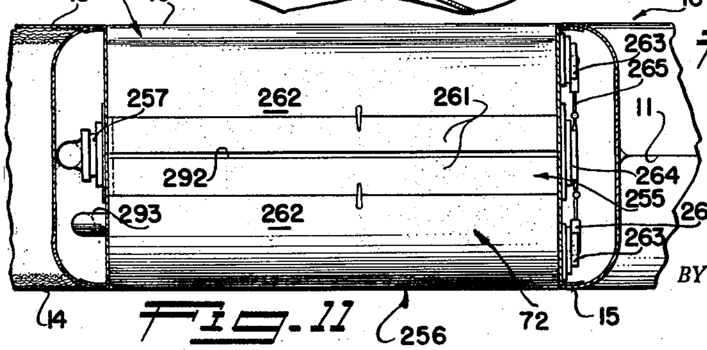

Fig. 11

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HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

Filed Jan. 23, 1953 12 Sheets-Sheet 6

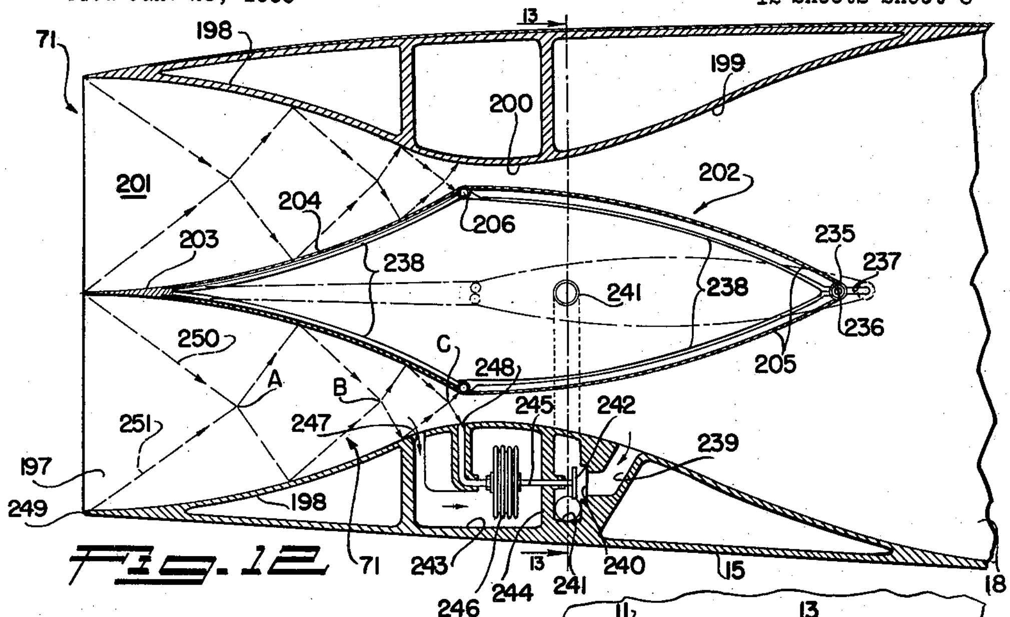

Fig. 12

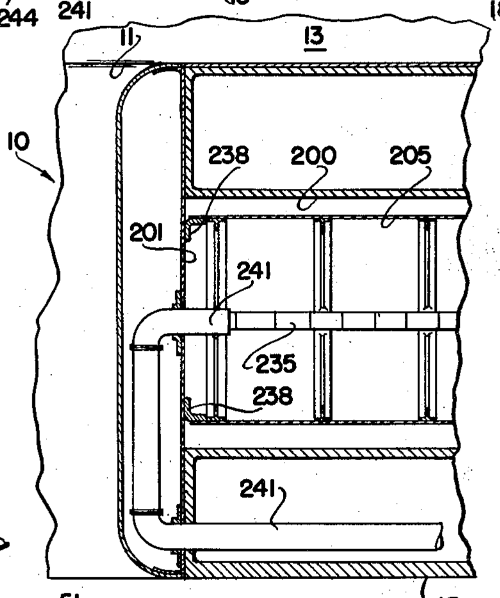

Fig. 13

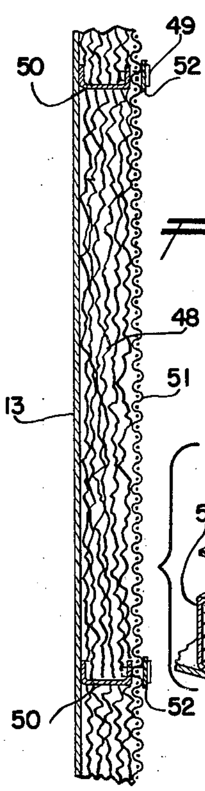

Fig. 14

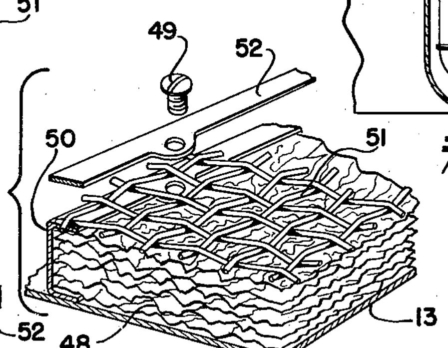

Fig. 15

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HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

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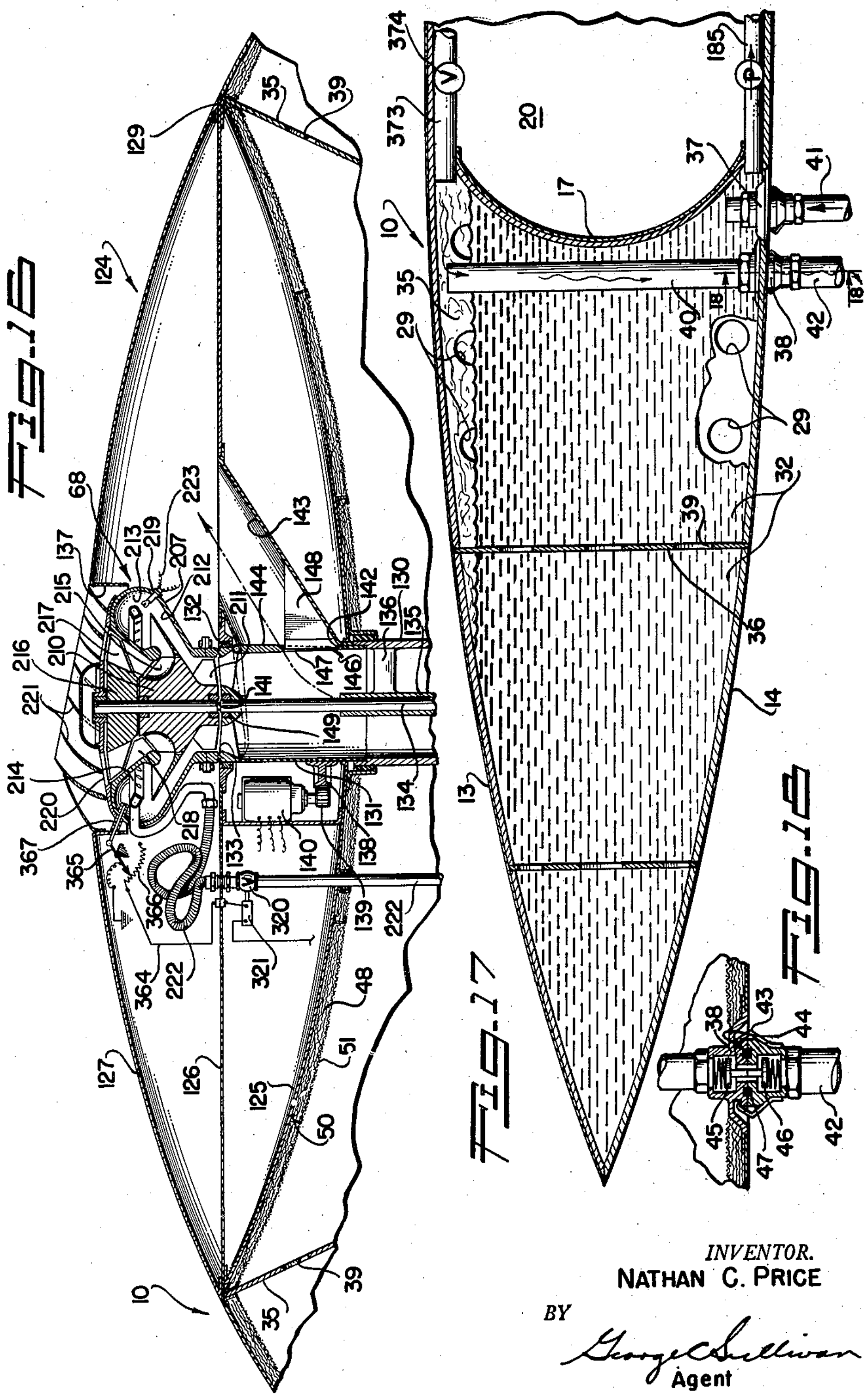

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HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

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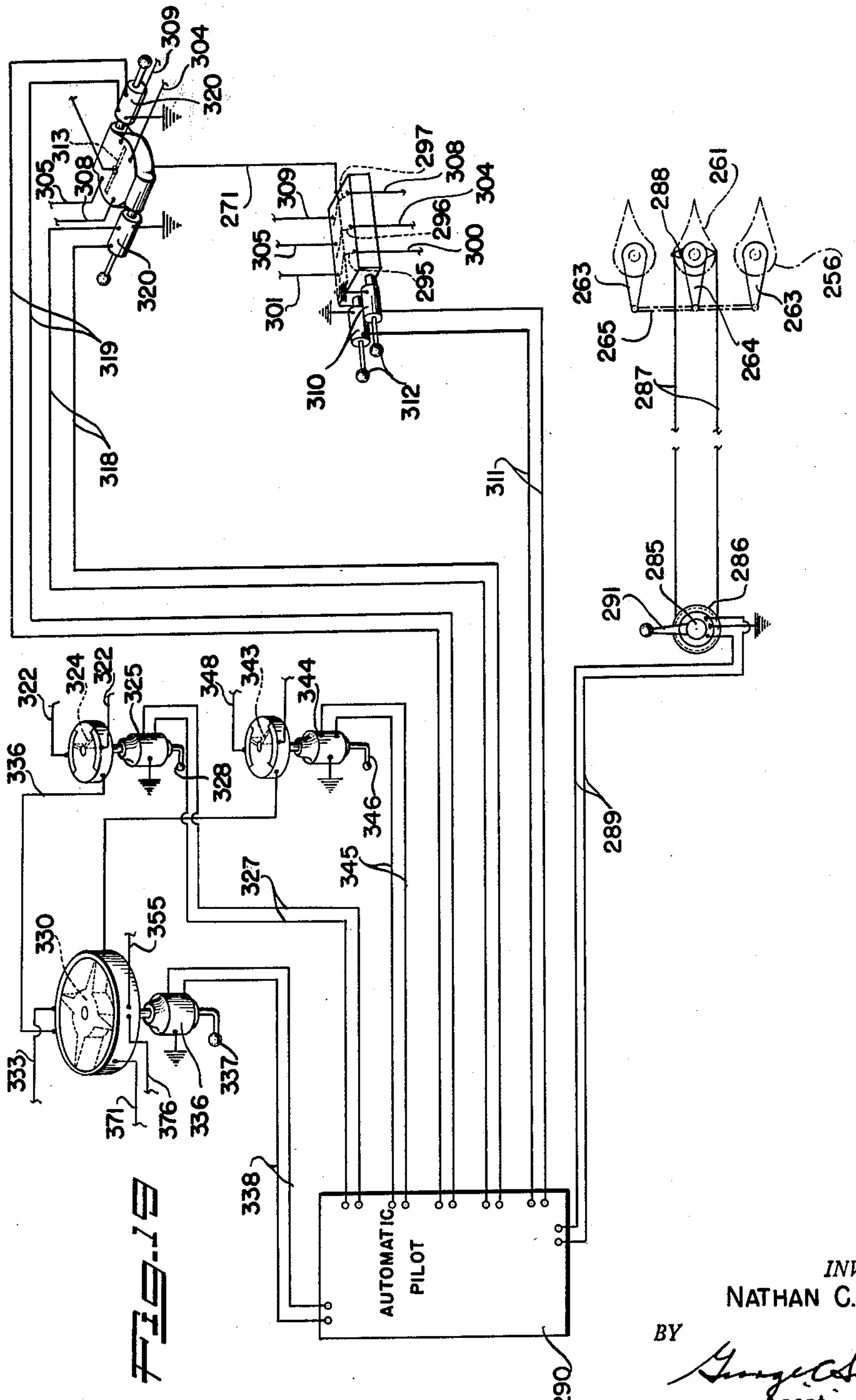

FIG-19

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HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

Filed Jan. 23, 1953 12 Sheets-Sheet 9

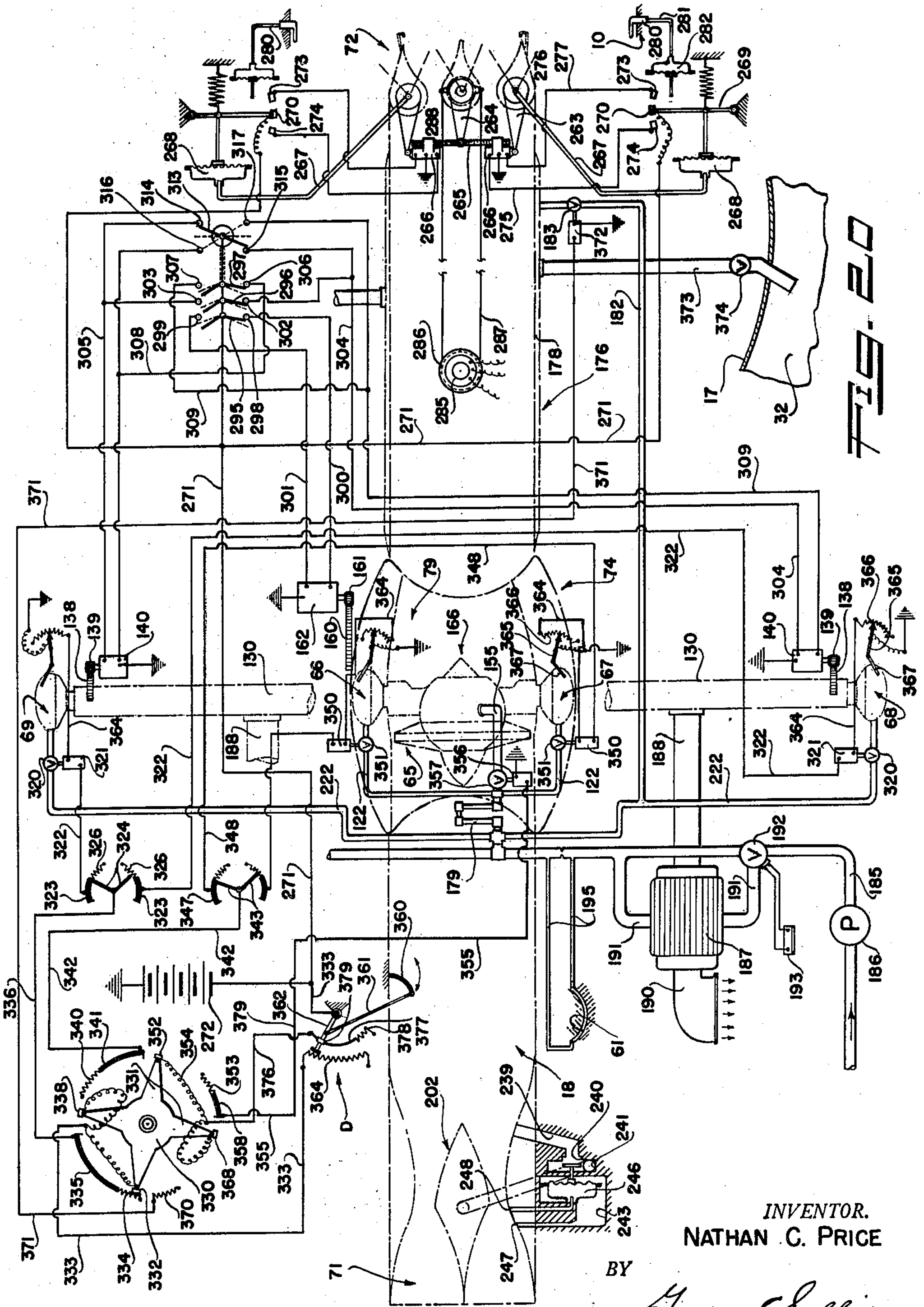

FIG. 20

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HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

Filed Jan. 23, 1953

12 Sheets-Sheet 10

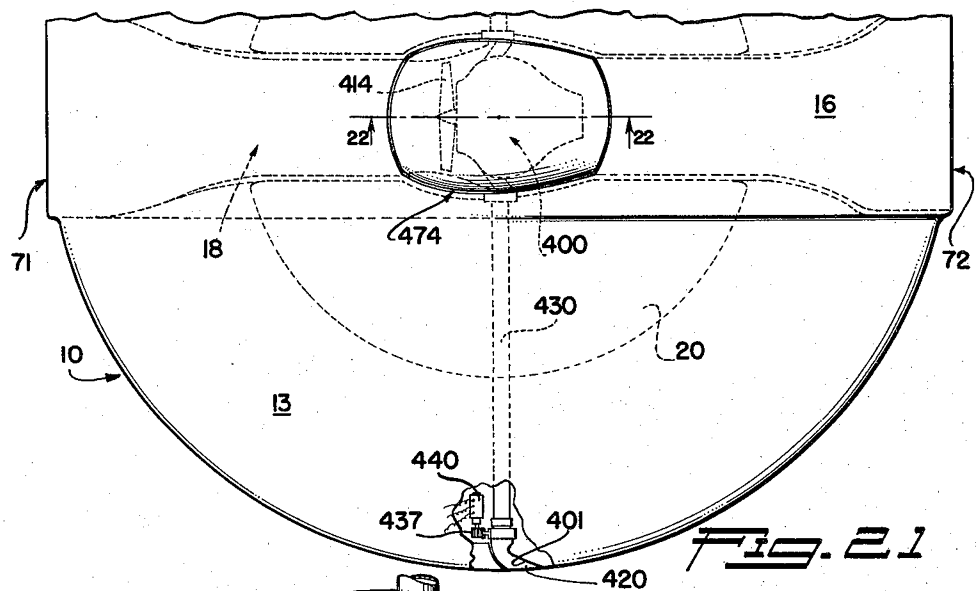

Fig. 21

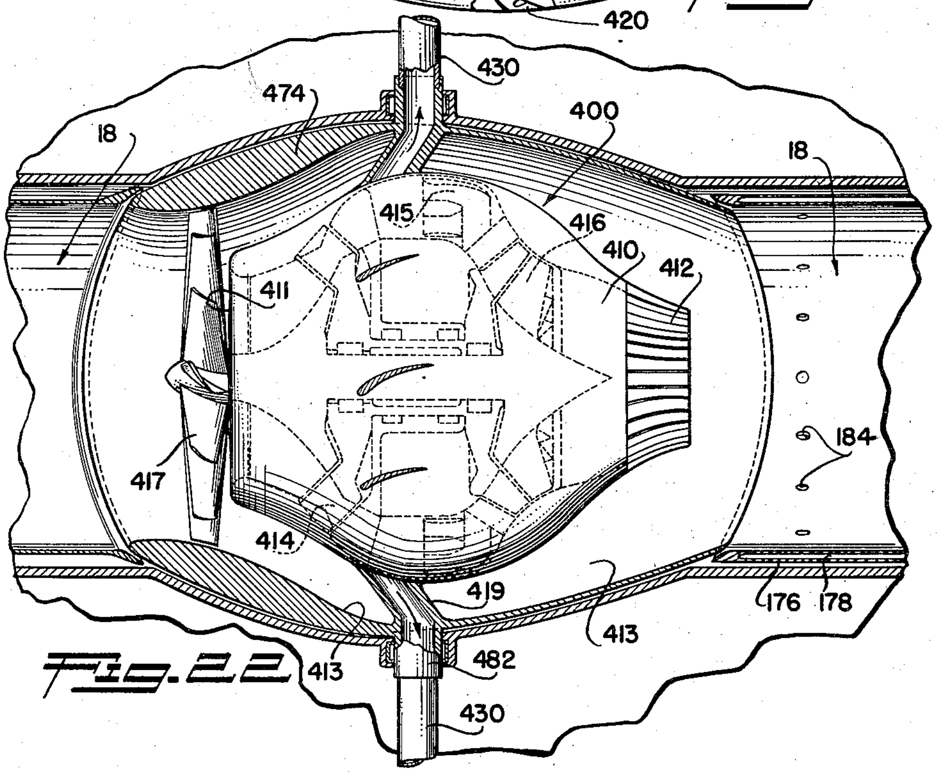

Fig. 22

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HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

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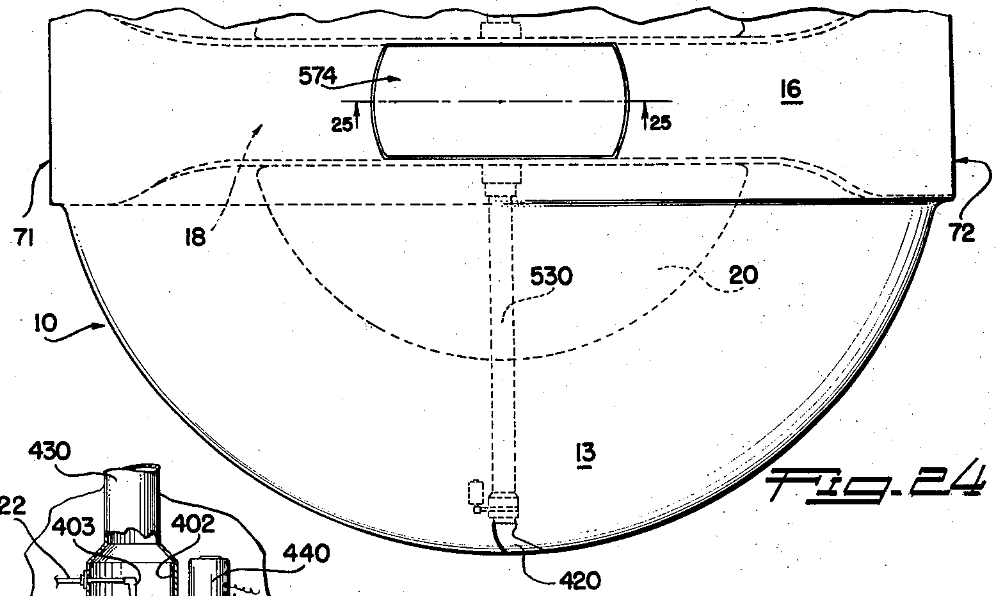

Fig. 24

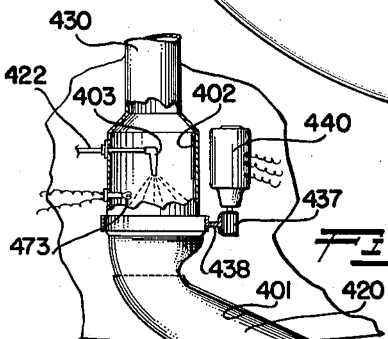

Fig. 23

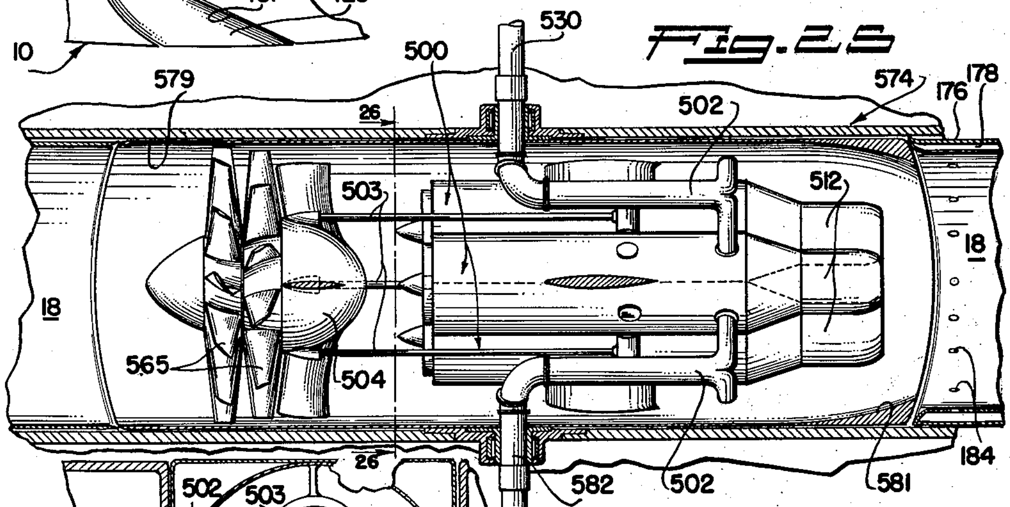

Fig. 25

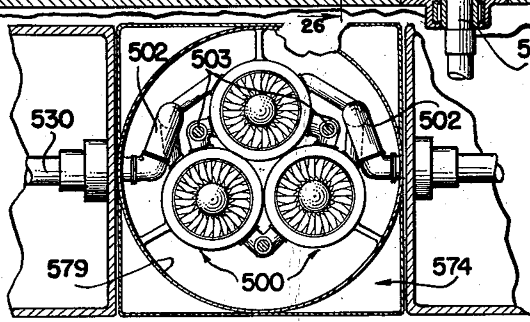

Fig. 26

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HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

Filed Jan. 23, 1953 12 Sheets-Sheet 12

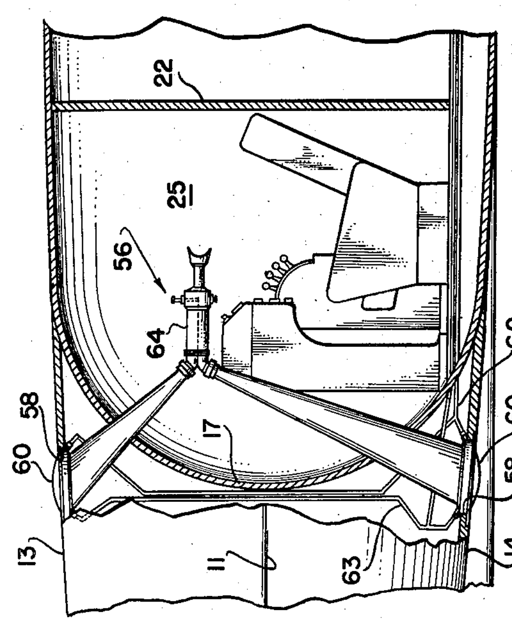

FIG. 26

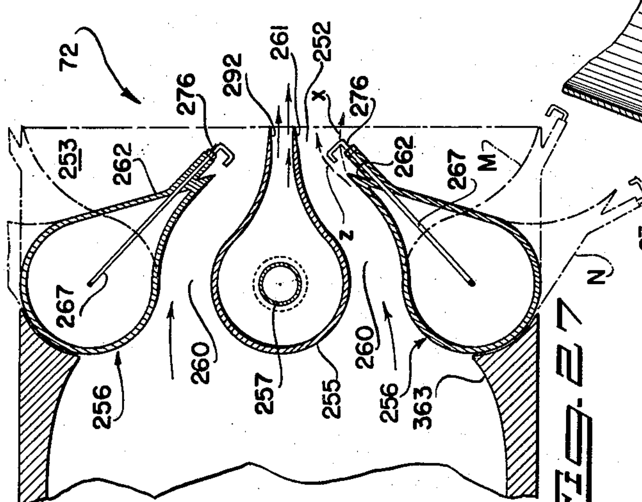

FIG. 27

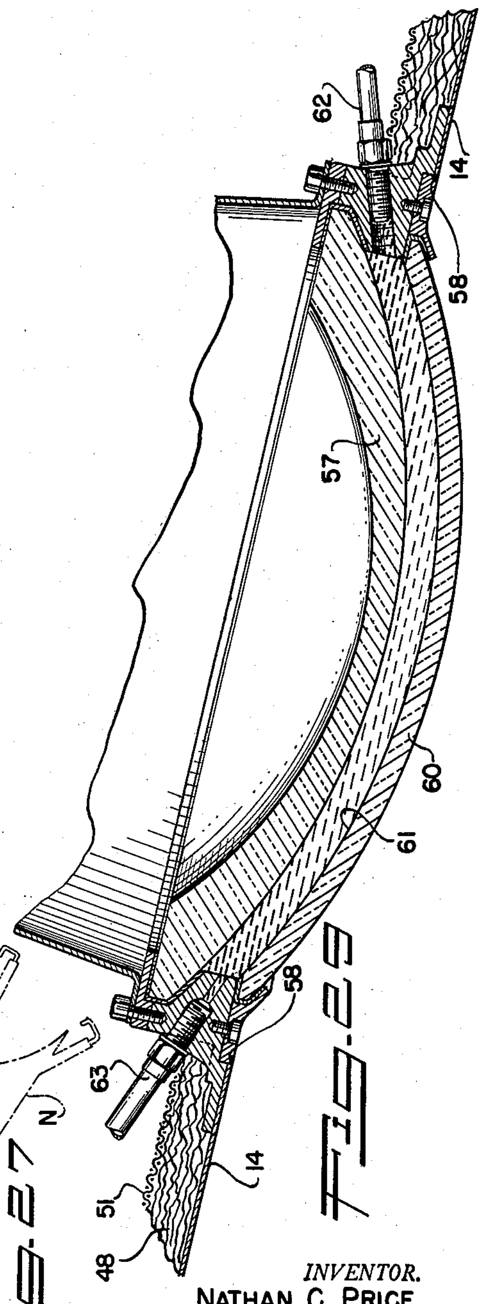

FIG. 29

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United States Patent Office

3,103,324
Patented Sept. 10, 1963

3,103,324

HIGH VELOCITY HIGH ALTITUDE V.T.O.L. AIRCRAFT

Nathan C. Price, Hollywood, Calif., assignor to Lockheed Aircraft Corporation, Burbank, Calif.

Filed Jan. 23, 1953, Ser. No. 332,957
29 Claims. (Cl. 244—12)

This invention relates to aircraft, and relates more particularly to aircraft capable of vertical ascent and descent during take-off and landing and of high altitude flight at supersonic velocities. It is a general object of the invention to provide vertical rising and descending aircraft characterized by their unique aerodynamically efficient design and by propelling, refrigerating and control systems for producing safe, efficient, supersonic, long range flight. The aircraft of the invention is designed not only for vertical ascent and descent to facilitate landing and taking off at small fields or landing areas but also for long range flight at a Mach number of, say, 4, and at altitudes in the region of 100,000 ft.

Another object of the invention is to provide aircraft of circular plan-form and of bi-convex vertical cross section which may be devoid of the conventional fuselage, wings, and empennage. The circular plan-form airplane of the invention has spheric convex upper and lower skin surfaces constituting the major surface areas of the airplane. This simple structure or design has many inherent advantages and features. It:

(1) Is an inherently rigid, strong structure having greater resistance to bending and torsional moments than other airborne configurations;
(2) Provides for a more uniform weight distribution over the lifting surface than other aircraft configurations;
(3) Allows a more uniform distribution of landing forces into the airplane structure and due to its circular plan-form permits the employment of any selected or required number of landing struts;
(4) Is not subject to flutter or to damage by gusts;
(5) Is structurally efficient in containing internal cabin pressures, fuel and other internal loads by reason of the spherical convex upper and lower skin surfaces joined one to the other at the circular periphery of the craft;
(6) Operates to effectively or uniformly distribute the thermal stresses and deformations resulting from high Mach number flight;
(7) Permits the positioning or concentrating of the useful loads in concentric relation to the center of gravity and geometric center of the structure and the disposition of the fuel loads in balanced or concentric relation to the center of gravity and geometric center;
(8) Is stable during vertical ascent and descent due to its circular plan-form;
(9) Provides a maximum volumetric capacity for the pay loads and fuel;
(10) Is simple and inexpensive to construct owing to its simple regular configuration and because many of its parts may be of like or identical size and shape;
(11) Occupies a minimum of field or floor space when not in flight due to its inherent compactness;
(12) Is inherently aerodynamically efficient, having a good *L/D* ratio and present a substantially continuous unbroken peripheral edge (leading and trailing edges) and a smooth profile offering a minimum of skin friction drag; and
(13) May land and take off from any medium, being stable even on rough water.

These and other considerations and advantages all result from the simple compact circular plan-form airframe of bi-convex cross section.

Another object of the invention is to provide an air-

craft of this character having a diametrically extending thin plate airfoil region or portion containing in part the primary propulsive mechanism or means, this thin plate airfoil constituting only a relatively small portion of the total airfoil and yet assisting in producing aerodynamic lift with a minimum of drag.

Another and important object of the invention is to provide a novel, effective and dependable refrigerating system for an aircraft of the kind mentioned, which utilizes the propulsive fuel as a refrigerant. As is well known, operation of an aircraft at supersonic velocities is accompanied by aerodynamically induced skin temperatures that are so high or excessive as to endanger the structural integrity of the aircraft and to make it untenable for the personnel and passengers. For example, the heat input to the skin of the airplane of this invention having a diameter of 50 ft. flying at a Mach number of 4 and an altitude of 100,000 ft. will be in the neighborhood of 28 million B.t.u.'s per hour, resulting in a skin temperature approaching 1140° F., disregarding solar radiation which is of no material consequence in the case of this aircraft. Present day aircraft cooling systems are wholly inadequate to cope with temperatures of this magnitude and such temperatures would endanger the internal structure and make human occupation of the aircraft impossible. With the fuel storage cooling system of the invention the skin temperatures at such speeds and altitudes are reduced to a level where a skin formed of stainless steel, or comparable material, maintains adequate strength characteristics and the invention utilizes the fuel as a refrigerant to maintain the temperature of the cabin or passenger and cargo compartments at levels where passenger comfort is assured. To further reduce the temperature of the skin the surface of the latter is treated chemically or coated to impart a high emissivity of radiant heat. The reduction in skin temperature substantially reduces the skin frictional drag because the viscosity of the boundary layer air is proportionately reduced. Furthermore, the fuel-refrigerant is employed to cool the regions or portions of the propulsive mechanisms, etc. embodying bearings, shafts, rotors, gearing, and the like, which might be adversely affected by high temperatures.

Another object of the invention is to provide an aircraft of the character above referred to which employs a low boiling point fuel, such as butane or propane as the fuel and refrigerant. Such fuels have approximately 15% more energy value than conventional aircraft fuels but are much less dense, thereby requiring considerably greater tank space or volume. The circular plan-form bi-convex airplane of the invention supplies this necessary fuel storage volume and contains the low boiling point fuel in such a manner that it effectively cools the skin and assists in protecting the passenger and cargo compartments against excessively high temperatures. The low boiling point fuel through vaporization of even only one third of the total fuel carried absorbes in the neighborhood of 1 million B.t.u. per hour, thereby bringing the skin temperatures into equilibrium at a substantially lower value. Thus the configuration of the airframe or body and the type of propulsive fuel and its mode of storage mutually contribute to the cooling of the skin and provide storage regions of ample volume for the low density fuel. It is of primary importance that the invention effectively utilizes the low boiling fuel as a refrigerant for cooling the air supplied to the passenger and cargo compartments and for cooling the rotors, bearings, and other critical mechanisms.

Another object of the invention is to provide a fuel system and cooling system for this type of aircraft wherein the fuel or a portion thereof is vaporized in an annular vaporizer around the high temperature tail pipe or ram jet combustion zone to protect the structure thereof and to vaporize the fuel and also where the heat energy absorbed by the fuel at the skin, at the cabin air cooler, at the vaporizer and at the mechanism-cooling regions is recovered by the fuel and utilized to assist in propelling the aircraft, there being a regenerative action or effect in the fuel-cooling system.

Another object of the invention is to provide a propulsive system for aircraft of the class herein described that is emminently well adapted for the flight program or flight sequence of the craft. The propulsive system incorporates elements or instrumentalities for efficiently producing the vertical or substantially vertical ascent and descent of the craft, flight to and from the high altitude high velocity level flight region of the program and the propulsion of the craft in this region at multi-Mach number velocities.

Another object of the invention is to provide a vertical rising and descending aircraft operable at high velocities at relatively high altitudes incorporating a propulsive method and system characterized by their versatility and ability to function in different manners in the distinct regions or portions of the flight program to assure the most efficient propulsion sequence. During vertical ascent and descent for take-off and landing the craft is propelled or operated by a ducted compressor with an afterburner producing a vertical propulsive jet, the compressor being driven by what I will term "load turbines." These load turbines are turbo jet powerplants supercharged by the ducted compressor and their propulsive jets together with the jet from the ducted compressor and afterburner may be directionally controlled for the purpose of trimming the craft. Upon becoming airborne and in flying from adjacent the ground level to an altitude of, say, 50,000 ft., the flight path angle is from 10 to 20° and the ducted compressor operates without its afterburner but is assisted by the jets from its load turbines to propel the aircraft at subsonic velocities. In approaching and accelerating through the transonic speed range and in thereafter accelerating and climbing to the selected level flight altitude of, say, 100,000 ft., the afterburner is employed to provide additional thrust. Upon reaching this selected altitude and obtaining a suitable supersonic velocity the propulsive system operates as a pure ram jet, the ducted compressor blading merely windmilling and the ram jet action serving as the sole propulsive force assisted only by the air jets from the nozzles of the load turbines which are primarily employed at this time as trimming and directional control devices. The self-same ducts which serve to carry the ducted compressor air and its propulsive jet also serve as a duct for the ram jet, the variable area ram inlet and the variable area propulsive nozzle of the duct operating during the subsonic, transonic and supersonic phases of the flight, that is during ducted compressor operation stages and ram jet operation stages. Thus this propulsive apparatus operates as a ducted compressor propulsive device during low and moderate elevation operations at subsonic and transonic speeds where this type of propulsion is effective and efficient and as a ram jet at the higher altitudes and multi-Mach number velocities where ram jet propulsion is more practical and more efficient.

Another object of the invention is to provide a vertical rising high velocity aircraft of the type referred to above wherein the ducted compressor and a portion of its duct are movable through an angle of 90° or more so that the compressor may direct its propulsive jet or stream in the vertical or substantially vertical direction from the underside of the circular plan-form airplane for vertical and substantially vertical rising and descent and in a generally horizontal direction through the main duct and propulsive nozzle of the craft for generally horizontal flight. The compressor and the fuel injector means of its afterburner are within a duct section which may be termed an "island" and this island is rotatable about a spanwise axis which may preferably intersect the center of gravity and the geometric center of the craft, the island being movable in a vertical opening in the circular plan-form body so as to swing to its various operative positions. When in the normal generally horizontal position the island duct is in register with the main duct which occupies the above-mentioned thin plate airfoil of the body and the island surfaces are flush with and form parts of the aircraft skin so as to offer a minimum of aerodynamic drag.

Another object is to provide aircraft of this kind having a safe dependable propulsive system wherein operational failure of certain of its components will not endanger the craft or its occupants. The load turbines which incorporate the high velocity rotors of the system are so positioned that the planes of rotation of these rotors do not in any instance intersect the passenger compartment or vital portions of the craft while in translational flight. Accordingly, failure or bursting of a rotor will not endanger the occupants of the craft and provision is made for freeing or jettisoning failed load turbines in such a manner that the overall cooperation of the propulsive system and directional control features are affected to a minimum extent.

Another object is to provide an aircraft of this kind wherein the ram inlet and propulsive nozzle of the main propulsive duct are automatically controlled in response to the flight velocity, and local Mach numbers adjacent thereto, etc. to assure the most efficient and effective propulsion action.

Another object is to provide an aircraft of the type described having a novel supersonic variable ram inlet automatically operating in response to flight speed and/or flow conditions to be most effective at both subsonic and supersonic speeds. During subsonic air flow into the ram the inlet or throat is open to the maximum extent, or uncontracted, whereas at supersonic speeds the throat is automatically contracted to a greater or lesser extent, to obtain the most efficient supersonic diffuser action.

Another object is to provide an aircraft of the kind described incorporating a specialized jet outlet or nozzle for the main propulsive duct that is automatically operated to provide the most efficient propulsive jet at supersonic jet velocities and at subsonic jet speeds; that is adapted to change the direction of the jet to obtain a trimming action for the craft; and that may be operated to serve as an air brake to lessen flight velocity. The multi-purpose nozzle has movable flow controlling members operable to various relative positions to effect these purposes and at least one of them discharges a stream or jet of compressed air to facilitate and augment the pitch control or pitch trimming of the craft.

Another object of the invention is to provide an aircraft of this kind wherein the variable inlet and the controllable outlet or nozzle of the main duct are generally rectangular and are elongated spanwise of the circular craft to best conform with its thin periphery. The elongated inlet and outlet cause or contribute to the desirable thin central airfoil region and reduce wake losses. The main propulsive duct is diametric of the circular airfoil or body so that there is ample length for the propulsive mechanism in the circumference of the body and therefore no need to extend or project either the ram inlet or the nozzle from the periphery of the circular craft.

Another object is to provide a high speed aircraft of the class described wherein the propulsive devices are employed to obtain directional control. As already noted the island containing the ducted propulsive compressor is turnable about an axis at the geometric center of the circular craft to produce vertical lift during ascent and descent and to propel or operate the craft at steep climb and descent angles. In addition there are outboard load turbines at the lateral edges or "span" extremities of the circular body assisting in driving the ducted compressor. These outboard turbines have propulsive jet discharging nozzles or outlets arranged for independent angular movement and adjustable or operable to direct their propulsive streams in various directions to obtain or produce directional control for the craft. In the event of failure and jettisoning or detachment of one or both of these outboard turbines, compressed air from the main propulsive duct continues to discharge from directional nozzles that are movable to obtain or preserve the directional control. In accordance with the invention the propulsive means and elements associated therewith are utilized to produce the directional control and trimming forces making unnecessary control surfaces of the conventional types. Furthermore, as the circular plan-form body is inherently stable, stabilizers of the conventional types are not needed although the margins of the central diametric portion, containing in part the main duct, serve as vertical stabilizing surfaces and the pods containing the outboard load turbines act as tip shields to reduce vortices losses. Thus except for the said diametric rib region and tip pods the craft is substantially symmetrical, constituting an aerodynamically efficient circular plan-form with spherically convex upper and lower surfaces.

Another object of the invention is to provide a novel, effective fueling system for supplying the fuel compartments or tanks of the craft with the low boiling point fuel. The system is such that during the fueling operation and until actual takeoff of the craft, liquid fuel is pumped into the compartments and the vaporized fuel is continuously returned or drawn off from the compartments, the conduits or lines handling the liquid fuel and vapor being automatically disconnected when the craft leaves the ground.

A further object is to provide a circular plan-from aircraft as described characterized by the by-convex skin surfaces capable of carrying substantial internal pressures and be simple yet strong and effective passenger, cargo and fuel compartmentation. The cabin is surrounded by a circular wall or bulkhead extending between the upper and lower convex skin structures, this bulkhead together with the skin structures providing or constituting the fuel tanks or compartments and there are circumferentially spaced radial baffles in the fuel compartments secured to the skins and the circular bulkhead. This internal structure, including, of course, minor local stiffening ribs, etc., is so strong and rigid as to readily withstand all aerodynamically induced vibration forces as well as all other operational loads and forces.

Other objectives and features will become apparent from the following detailed description of typical preferred embodiments of the invention throughout which reference will be made to the accompanying drawings, wherein:

FIGURE 1 is a rear elevational view of an aircraft of the invention;

FIGURE 2 is a plan view of the aircraft with a portion broken away to illustrate the internal structure;

FIGURE 3 is a front elevation of the craft;

FIGURE 4 is an edge or side elevation of the craft with broken lines illustrating the island in a vertical position to produce vertical thrust for ascent or descent;

FIGURE 5 is a transverse sectional view taken substantially as indicated by line **5—5** on FIGURE 2 and illustrating the landing struts and the tip portions is elevation;

FIGURE 6 is an enlarged fragmentary vertical sectional view of the island and adjacent portions being a view taken substantially as indicated by line **6—6** on FIGURE 8;

FIGURE 7 is an enlarged fragmentary vertical sectional view of the island and adjacent portions taken as indicated by line **7—7** on FIGURE 2;

FIGURE 8 is an enlarged horizontal fragmentary sectional view taken substantially as indicated by line **8—8** on FIGURE 5, with certain portions appearing in elevation;

FIGURE 9 is an enlarged fragmentary vertical sectional view through the main propulsive nozzle taken substantially as indicated by line **9—9** on FIGURE 2 with broken lines indicating various positions of the nozzle members;

FIGURE 10 is an enlarged horizontal detailed sectional view of the nozzle taken substantially as indicated by line **10—10** on FIGURE 1 with certain of the nozzle parts appearing in elevation;

FIGURE 11 is a view taken substantially as indicated by line **11—11** on FIGURE 10 showing the nozzle members in elevation and adjacent parts in vertical cross section;

FIGURE 12 is an enlarged vertical sectional view of the ram inlet portion of the main propulsive jet being a view taken as indicated by line **12—12** on FIGURE 2 with the broken lines and arrows illustrating the shock waves and reflected shock waves;

FIGURE 13 is a fragmentary vertical sectional view taken as indicated by line **13—13** on FIGURE 12;

FIGURE 14 is an enlarged detailed sectional view of the insulating means as employed on the skin and bulkhead portions;

FIGURE 15 is an enlarged fragmentary perspective view of a portion of the insulating assembly with the parts separated;

FIGURE 16 is an enlarged fragmentary horizontal sectional view taken as indicated by line **16—16** on FIGURE 1 illustrating one of the outboard load turbines and adjacent equipment;

FIGURE 17 is an enlarged fragmentary vertical sectional view taken as indicated by lines **17—17** on FIGURE 2 showing one of the fuel compartments and a portion of the fueling means;

FIGURE 18 is an enlarged fragmentary sectional view taken as indicated by line **18—18** on FIGURE 17;

FIGURE 19 is a wiring diagram of the circuits and equipment controlled by the automatic pilot;

FIGURE 20 is a schematic diagram of the electrical circuits, the pneumatic system and the fuel-refrigerating system and other elements of the airplane;

FIGURE 21 is a fragmentary plan view of another aircraft of the invention with a portion broken away to illustrate one of the tip nozzles;

FIGURE 22 is an enlarged fragmentary vertical sectional view taken as indicated by line **22—22** on FIGURE 21;

FIGURE 23 is an enlarged fragmentary horizontal sectional view illustrating one of the variable direction control nozzles and combustion chamber units of the airplane shown in FIGURES 21 and 24;

FIGURE 24 is a plan elevation of another aircraft of the invention employing a multiplicity of turbo powerplants driving counter-rotating ducted compressors;

FIGURE 25 is an enlarged fragmentary vertical sectional view taken as indicated by line **25—25** on FIGURE 24 illustrating the angularly movable island and the powerplant units contained therein;

FIGURE 26 is a transverse or vertical sectional view taken as indicated by line **26—26** on FIGURE 25;

FIGURE 27 is an enlarged vertical sectional view of the main propulsive nozzle with broken lines illustrating various positions of the vanes;

FIGURE 28 is a fragmentary vertical section of an airplane of the invention illustrating a periscope means; and

FIGURE 29 is an enlarged sectional view of one of the outer lens assemblies of the periscope means.

The aircraft of the invention as illustrated in FIGURES 1 to 20 inclusive, includes an airframe, airfoil or body **10**, which I will usually hereinafter refer to as the body, of circular plan-form. As best illustrated in FIGURE 2, the body **10** has a periphery **11** which is preferably concentric with an axis **12** which may constitute the center of gravity and the geometric center of the airplane. This periphery **11** is continuous and unbroken except for minor interruptions at the inlet and outlets of the propulsive system, to be subsequently described, and as seen in FIGURES 1, 3, 4 and 5, it is quite sharp to have good aerodynamic characteristics and to minimize the frontal area of the craft. In accordance with the invention the upper and lower surfaces or skins **13** and **14** of the airplane are convex and are preferably spherically convex, being in the nature of two like opposing spheroidal segments having their bases or chords coincident and joining at the plane of the peripheral edge 11. These spherical convex surfaces or skins 13 and 14 are smooth and regular to offer a minimum of drag and join at the circumferential edge 11 (leading and trailing edge) which itself is sharp and aerodynamically efficient. As briefly mentioned above, the body 10 has a diametric airfoil-rear region which is defined by a rather broad yet shallow rib portion 15 extending completely diametrically across the underside of the body 10 and a similar shallow rib portion 16 at the upper side of the body extending from adjacent the center thereof to its trailing edge. The lower side of the lower rib portion 15 is flat and substantially parallel with the plane occupied by the peripheral edge 11 and in a like manner the surface of the upper rib portion 16 is flat and parallel with the same plane. The primary purpose of the rib portions is to provide ample space within the aircraft for elements of the propulsive system, to be later described, although the rib portion constitutes a thin plate airfoil which assists in providing aerodynamic lift for the airplane. In practice the rib portions 15 and 16 need not be very thick and may die into the contours of the skins 14 and 13 adjacent the center of the craft. The sides or edges of the rib portions 15 and 16 which extend chord-wise of the body 10 are faired into the skins 14 and 13 respectively. However, where the portions 15 and 16 extend fore and aft along the fore and aft axis of the craft, they constitute a rib which serves as a vertical stabilizer for the airplane. The surfaces or skins 13 and 14, the skins of the rib portions 15 and 16, the peripheral edge 11, and other exposed parts of the airplane such as fairings, etc. are preferably constructed of stainless steel or other material capable of retaining adequate strength when subjected to the high temperatures developed during the multi-Mach number flight program.

The airframe 10, as just described, is inherently capable by reason of its geometrical configuration of withstanding heavy stresses and loads and the invention provides a simple yet strong internal structure for reinforcing the airframe and for assuming major structural and functional loads. A pressure bulkhead 17, curved in both plan-form and radial planes is provided in the body 10 and extends between and is secured to the upper and lower skins 13 and 14. The bulkhead 17 is concentric with the axis 12 and may be substantially vertical. A large diametered propulsive air duct 18 extends diametrically through the body 10 and intersects the circular bulkhead 17 to divide the space encircled thereby into two main passenger and/or cargo compartments 20. The duct 18, which will later be described in connection with the propulsive system, extends fore and aft and is coaxial with the rib portions 15 and 16 above described. As the duct 18 interrupts the bulkhead 17 and divides the bulkhead into two sections, there are walls 24 adjacent to and parallel with the duct for connecting the ends of their respective partially circular bulkhead portions. The main compartments 20 which may or may not be interconnecting depending upon the relative diameter of the air duct 18, are shown in the drawings as passenger compartments, being provided with rows of aft facing seats 31. The compartments 20 may, in practice, be defined by portions of the above mentioned walls 24 and by partitions 21, 22 and 23. The bulkheads or partitions 21, 22 and 23, together with the walls 24, define generally rectangular passenger compartments 20 and as the bulkhead 17 is circular, marginal compartments 25, 26 and 27 remain forward, aft and outboard of the main compartments.

The forward compartments 25 may constitute the pilot and crew areas, the outboard compartments 26 may be used to carry luggage, mail, cargo, etc, and the aft compartments 27 may be rest-rooms or toilets. The various compartments, just described, may be interconnecting. Entrances or hatchways 28 in the upper and lower skins 13 and 14 lead to the main compartments 20 and are equipped with sealed hatches or closures 30 capable of withstanding substantial pressure differentials. The various partitions and walls and particularly the bulkhead 17 and its wall portions 24 may be structural load assuming elements secured to one another and to the skins 13 and 14 to constitute a strong internal assembly or structure.

As briefly noted above, the regions or areas of the circular plan-form bi-convex body 10 around the passenger and load carrying compartments serve as fuel tanks or fuel cells which I have designated 32. The fuel tanks or cells 32 are bounded or defined by the skins 13 and 14, the bulkhead 17 and chord-wise walls or bulkheads 34 extending from the bulkhead 17 to the periphery 11 adjacent and generally parallel to the main air duct 18. I prefer to provide the fuel cells 32 with multiplicities of circumferentially spaced radially disposed internal baffles or bulkheads 35 and spaced circumferential or circular bulkheads 36. These bulkheads 35 and 36 which extend between the skins 13 and 14 and which are attached to the skins materially increase the strength and rigidity of the structure. The bulkheads 35 and 36 are perforated, having openings 29 and 39 respectively, so that the various regions or areas of the individual fuel cells 32 are in communication. It is to be noted that the fuel in the cells 32 is in heat absorbing or heat transfer relation to the major portions of the skins 13 and 14 and the bulkhead 17 and thus serves as a refrigerant to reduce the temperature of the skins and to protect the passenger and cargo compartments 20, 25, 26 and 27 against excessively high temperatures. The cooling or refrigerating action of the fuel and the refrigerating system will be more fully described hereinafter.

Special provision is made to supply or fill the fuel cells 32 with the low pressure fuel. Because butane, propane, and like fuels vaporize readily at normal ground temperatures, it is necessary to continuously withdraw vaporized fuel from the cells or tanks 32 as the cells are filled with liquid fuel and until the craft takes off. For this purpose the lower wall or skin 14 of each fuel cell 32 has two fuel conduits or fittings 37 and 38 (see FIGURES 17 and 18), the fitting 37 serving to discharge liquid fuel into the cell and the fitting 38 being adapted to bleed off fuel vapor from its respective cell. The fittings 38 have stand pipes 40 extending upwardly to adjacent the tops of the cells 32 to receive the fuel vapor. When refueling the airplane and until ascent has been initiated, pipes or hoses 41 are connected with the fittings 37 to supply liquid fuel to the cells and similar hoses 42 are connected with the fittings 38 to draw or carry away the fuel vapor. The fittings 37 and their related hoses 41 and the fittings 38 and their related hoses 42 may have identical detachable connections and valve means and while I will specifically describe the detachable connections and the valve means of the fittings 38 and their pipes or hoses 42, it is to be understood that this description is equally applicable to the corresponding connections and valve means of the fittings 37 and their pipes 41. As shown in FIGURE 18, the hoses or pipes 42 have spring clips 43, or the equivalent, detachably engaged with shoulders 44 on the fittings 38 to hold them in communicating connection with the fittings. Seal rings 47 are engaged between the fittings 38 and the hoses or pipes 42 to prevent the leakage of the vapor or fuel. The fittings 38 and the hoses or pipes 42 have opposing poppet valves 45 and 46, respectively, spring urged to closed positions. The relationship of the valves 45 and 46 is such that so long as the pipes 42 remain coupled with the fittings 38 the valves cooperate with one another to be held in the open positions where the fuel vapor is free to flow out through the hoses or pipes 42. The pipes 42 are connected with an absorption pump (not shown) for drawing away the fuel vapor and the hoses or pipes **42** are connected with a source or sources of the liquid fuel under pressure so as to deliver the liquid fuel to the cells **32** of the airplane. Preparatory to take-off and so long as the aircraft remains on the ground or field, liquid fuel is pumped in through the hoses or pipes **41** and the vaporized fuel is withdrawn through the hoses or pipes **42**. When the aircraft rises vertically from the field or ground, the spring clips **43** snap out of engagement with their shoulders **44** allowing the fittings **37** and **38** to move upwardly out of engagement with their respective pipes **41** and **42**. When this occurs the valves **45** and **46** automatically close to retain the liquid fuel and the vaporized fuel within the fuel cells **32** of the airplane and to avoid the spilling or leakage of the fuel from the hoses or pipes **41** and **42**.

It is to be observed that the circular plan-form bi-convex aircraft body **10** provided with the partly circular fuel cells **32** has a large aggregate volumetric fuel storage capacity. This well adapts the craft for the utilization of butane or propane which have approximately 15% greater energy value than conventional aircraft fuels on a weight basis but are far less dense and, therefore, require large capacity storage space for comparable ranges of flight. By making the bulkhead **17** of less diameter the fuel capacity of the cells **32** may be greatly increased to extend the operational range of the craft. This is indicated and practical in the case of military craft where the personnel and the payload areas or compartments may be quite small. Furthermore, for military craft it may be desirable to use liquid hydrogen as the propulsive fuel to materially extend the operational range. Liquid hydrogen has a very low density (.086) with a boiling point density of 0.070 and on a volume per heat content basis requires approximately three times as much space as gasoline. However, for pilotless military aircraft and military aircraft carrying one or two men, the body **10** is such that it may be readily compartmented to contain ample liquid hydrogen as its fuel for a non-stop flight of, say, 7,500 miles. Such liquid hydrogen could well be supplied to or pumped into the fuel cells **32** in the same manner as the other fuels.

The lower boiling point fuels are especially well adapted for cooling the passenger and payload compartments and other critical regions of the aircraft and greatly reduce the temperature of the skin. Butane has a boiling point under 33° F. and propane has a boiling point of −45° F. Such fuels and the vapor therefrom in contact with the inner surfaces of the skins **13** and **14** prevent the skins from being excessively heated by the aerodynamically induced heat. Assuming the body **10** has a diameter of 50 ft. and that the craft is operated at a speed of Mach number 4 at an altitude of 100,000 ft. it is calculated that the temperature of the skin, unless provision is made for cooling it, would reach 1139° F. However, the skins **13** and **14** preferably have their outer surfaces chemically oxidized black or otherwise treated or coated to have a heat emissivity of approximately 0.95. This high emissivity will result in radiation of a substantial amount of heat energy into space. Although the emissivity of a surface is numerically equal to its absorptivity there is a distinct and novel advantage in providing the skins **13** and **14** of the airplane of this invention with external surfaces having high emissivity. The heat input to the skins **13** and **14** as a result of the frictional drag and the airplane speed is considerable. On the other hand solar radiation will tend to increase the skin temperature to only a very minor extent. It is estimated that the aerodynamically induced heat input to the skin will be approximately thirty times as much as the heat induced by solar radiation. Accordingly the skin surfaces of high emissivity and correspondingly high absorbtivity have the net effect of emitting many times as much heat energy as they are capable of absorbing and the surfaces of high emissivity function as effective heat dissipating elements of the cooling or refrigerating means of the invention. Additionally, the heat

energy required to vaporize approximately 30% of the low boiling point fuel during the flight program is substantial, being in the neighborhood of 1 million B.t.u. per hour under the above assumed conditions. Thus it is calculated that the skin temperatures under the above conditions will come into equilibrium at about 940° F. The stainless steel skins **14** and **13** maintain their structural integrity at such a temperature and the internal structure adjacent thereto is not adversely affected at such a temperature. The material reduction in the temperature of the skins of the aircraft has the effect of increasing the efficiency and range of the craft. The reduction in skin temperature proportionately reduces the viscosity of the boundary layer air and therefore increases the aerodynamic efficiency of the circular plan-form bi-convex airfoil or craft.

The invention provides effective thermal insulation at the inner surfaces of the skins **13** and **14** at the bulkheads **17**, walls **24**, bulkheads **34**, and other walls, bulkheads, etc. where necessary or desirable to thermally insulate the internal structure and the passenger and pay load areas of the aircraft, it being observed that the fuel cells **32** containing the low boiling point fuel and its vapor substantially surround the passenger and pay load compartments **20**, **25**, **26** and **27**. The fuel cells **32** and their contents thus form effective thermal barriers protecting the passenger and pay load regions. FIGURES 14 and 15 illustrate one preferred form of insulation that may be used on the skins **13** and **14** and the several bulkheads, walls, etc. In describing this insulation, as illustrated, it will be assumed that it is provided on the inner surface of the skin **13**, it being understood that such description is equally applicable to the other insulated areas and regions. The insulation includes "Alfol" blankets **48** which are comprised of pluralities of corrugated or crinkled aluminum or other metal foil sheets arranged and related so that there are multiplicities of air spaces between the adjacent foil sheets. Such insulation has a very low apparent density and a low *k* factor and is therefore well adapted for this application. However, other appropriate thermal insulation or insulating materials may be used if desired. The blankets **48** of metal foil are engaged between spaced channels **50** fixed to the inner side of the skin **13** and arranged in parallel corresponding positions so that each blanket **48** has one edge received in a channel and has its opposite edge at the closed or back-side of the adjacent channel. In order to retain the rather loosely arranged blankets **48** I provide metal mesh, screens, or the like, **51**, which extend between the inner flanges of the spaced channels **50** to extend across the blankets **48**. Strips **52** overlie the screens **51** and are secured to the channels **50** by screws **49** to retain the insulating assembly in place. Immersion of this type of insulation, either temporarily or permanently, in the fuel and/or fuel vapor of the cells **32** does not impair the insulating qualities although it may alter the *k* factor while the insulation is immersed, depending upon the proportion of fuel vapor between the layers. The foil of the insulating blankets **48** is preferably polished or bright to be most efficient in reflecting radiant energy under practically all conditions.

My copending application, Serial Number 669,369, filed July 1, 1957, is directed to the airfoil or body **10**, its compartmentation, the fore and aft propulsive duct, the bulkhead means, etc.

In accordance with the broader aspects of my invention any suitable or selected type of alighting or landing gear may be employed. In the drawings, and more particularly in FIGURES 2 and 5, I have shown a plurality of spaced generally vertical shock absorbing struts **53** projectable from the underside of the body **10**. The retractable struts **53** may be of the oleo type and are preferably arranged for vertical retraction into relatively small spaces or compartments **54** at the bulkhead **17** and adjacent the adjoining corners of the above described compartments **20**, **26** and **27**. In this connection it is to be observed that the landing gear struts **53** may readily be anchored or attached to the body **10** at regions where the landing loads may be transmitted directly to the strong rigid internal structure of the craft and that by reason of the circular configuration of the body **10** and the circular arrangement of its bulkhead **17** and other structural parts any selected or required number of the struts **53** may be installed in practically any required pattern or relationship. The lower ends of the landing struts **53** may be equipped with wheels, pads, or the like. In the drawings I have shown pads **55** on the struts **53** of such a nature that they may lie substantially flush with the surface of the lower skin **14**, when the struts are retracted, so as to offer little or no aerodynamic drag.

It is contemplated that translational flight will usually be at such great altitude that visual observation by the passengers will be of minor consequences and there is no real necessity for the provision of windows, or the like, in the passenger compartment **20**. It is also contemplated that the flight of the craft will be controlled by a remotely controlled automatic pilot means thus reducing the flight personnel to a minimum. However, to facilitate pilot controlled landings, maneuvers during emergencies, etc. either one or both of the pilot compartments **25** is provided with a periscope **56**. Such a periscope is shown in FIGURES 28 and 29 where it will be seen to include a plano-convex lens **57** secured to each skin **13** and **14** adjacent to but inwardly of an appropriate opening **58** in its respective skin. Partially spherical outer lenses **60** are secured and sealed in these openings **58** and may have concentric inner and outer surfaces. The inner lenses **57** are spaced from the inner sides of the outer lenses **60** leaving fluid chambers or passages **61** and the inner lenses are sealed and secured at their margins in such a manner that cooling fluid or the propulsive fuel may be circulated to the passages by pipes **62** to be led away from the passages by pipes **63**. These pipes **62** and **63** are connected with the fuel system, as will be later described, so that fuel under pressure is circulated through the passages **61** to cool the lenses **57** and **60**. This cooling of the lenses by the low boiling point fuel maintains the transparency and optical properties as well as structural strength of the lenses during the high Mach number flight and as the fuel is colorless and transparent it does not materially interfere with the optical characteristics of the periscope. The periscope further includes a dual or common revolving eyepiece **64** at the pilot location receiving the light rays or images from the outer lens systems. The present invention is not primarily concerned with the specific details of the eyepiece **64** and any appropriate optical systems may be employed therein. The convex surfaces of the outer lenses **60** may protrude from the skins of the aircraft to increase the field of vision of the periscope but being smooth and spherical offer a minimum of aerodynamic drag. If desired, similar periscopes may be installed at the passenger compartments **20**, etc.

The propulsive system of the aircraft illustrated in FIGURES 1 to 26 inclusive may be said to comprise, generally, a ducted compressor **65** capable of angular adjustment or movement to produce vertical lift and translational propulsion, upper and lower load turbo powerplants **66** and **67** for driving the compressor **65** and for producing propulsive thrust, outboard load turbo powerplants **68** and **69** for driving the compressor **65** and for producing propulsive and directional thrust, afterburner and ram jet combustor means **70** downstream from the ducted compressor **65**, a variable ram or air inlet **71** for the ducted compressor **65** and ram jet means **70**, a variable area and directional outlet or propulsive nozzle **72** for the ducted compressor and ram jet means, and various other parts and mechanisms associated with these primary propulsive elements.

The ducted compressor **65** is preferably located at or adjacent the geometric center of the circular planform airframe or body **10** and is pivotally mounted to be movable about a spanwise and preferably diametric axis so as to be turned to a vertical or generally vertical position during the vertical ascent and descent of the craft and to be brought to a position coaxial with the abovementioned fore and aft duct **18** for and during translational flight of the craft. The main air duct **18** extends diametrically through the circular body **10**, as above described, and is provided at its forward end with the variable area inlet **71** and at its aft end with the variable area and directional nozzle **72**. The major portion of the duct **18** is preferably cylindrical although its end portions are horizontally elongated, as will be more fully described in connection with the inlet **71** and the outlet or nozzle **72**. The airframe or body **10** has a central vertical opening **73** which intersects the duct **18** and the propulsive compressor **65** is housed or carried in a structure **74** which I will term an "island." This island **74** is journaled at the vertical opening **73** to be movable or turnable therein about a horizontal spanwise axis. The island **74** may be a generally rectangular structure including an outer shell **75** which has flat vertical side walls that fit between the walls **24** of the compartments **20** with suitable clearance, and having upper and lower walls **76** and **77** which are generally flush with the upper and lower sides of the rib portions **15** and **16** of the body **10** when the island is in the horizontal position. This shell **75** is best shown in FIGURES 6, 7 and 8. The island **74** further includes a tube or duct **79** within the shell **75** having ends which join or merge with the ends of the shell **75**. The forward portion of this duct **79** is cylindrical and of approximately the same diameter as the main air duct **18** to register therewith when the island is in the fore and aft position of FIGURES 6, 7 and 8. The major aft portion of the duct **79** is enlarged in diameter having a rearwardly flaring wall part **80** extending aft from the cylindrical forward duct portion and also having a rearwardly convergent wall part **81** at its aft end. This wall part **81** of the duct **79** acts as an effective propulsive nozzle when the island **74** is in a vertical position during vertical ascent and descent of the craft and discharges into the aft half of the main duct **18** when the island is in its fore and aft horizontal position.

The island **74** is supported for angular movement about the spanwise axis of tubular trunnions **82** projecting from the opposite sides of the island and journaled in roller bearings **83**, or the equivalent, mounted in blocks **84** on the walls **24**. The trunnions **82** are tubular for the reasons to be later described. In order that the island **74** may turn or pivot in the opening **73** with a minimum of air flow loss or leakage from the duct system, the opening and the island are of special configuration. As shown in FIGURES 2 and 8, the opposite ends of the island **74** as seen in top and bottom plan view are curved outwardly or are convex and the forward and aft end walls of the opening **73** are shaped to receive these parts of the island with appropriate working clearance. However, as best shown in FIGURE 7, the opposite side walls of the island **74** at its ends are curved inwardly or concave and the side walls of the duct at the intersecting opening **73** are shaped to conform with and receive these walls with clearance. With this formation and relationship of parts the island **74** is free to turn on its bearings **83** from the positions of FIGURES 6, 7 and 8 to the broken line vertical position of FIGURE 4 and yet conform with the opening **73** in the body **10**. To reduce excessive air leakage from the opening **73** when the island **74** is in the position of FIGURES 6, 7 and 8, I provide lips or fairings **85** which overlap or overhang the margins of the island **74** at the ends of its opening or duct **79**.

The ducted compressor **65** is of the supersonic class insofar as the relative velocity of entrained air against the blading is concerned and includes a rotor **86** fixed on a shaft **87** and carrying a row of supersonic blades **88**.

The shaft 87 is coaxial with the island duct 79 and its axis intersects the axis of the trunnions 82. A web structure or spider 90 supports the shaft 87 and other elements in the island 74. The spider 90 has two vertical tubular struts 91 and a plurality of spaced radial struts 92, seen in FIGURE 6, extending outwardly to the wall of the duct 79 and has two lateral or spanwise struts 93 extending outwardly to and preferably integral with the trunnions 82. The several struts are spaced, proportioned and shaped to offer a minimum of resistance and drag to airflow through the duct 79 and the struts 91 and 93 are of special construction, as will be subsequently described. As best seen in FIGURES 7 and 8, the spider 90 has a central axial opening provided with a bearing 94 for the compressor shaft 87 and has a forwardly projecting hollow conical portion 95 whose forward end carries antifriction bearings 96 for the shaft. The compressor rotor 86 is secured on the shaft 87 ahead of this portion 95 and its blades 88 extend radially outward to have their tips adjacent the wall of the duct 79. With this construction it will be seen that the supersonic compressor 65 is adjacent and slightly forward of the axis of angular movement of the island 74 and the geometric center of the airframe or body 10. The periphery of the rotor 86 is rearwardly flaring and provided with a spheric or convex curvature and a tubular or annular fairing 97 is provided on the spider 90 to continue rearwardly therefrom and to present a surface which constitutes a continuation of the rotor configuration. The surfaces of the rotor 86 and fairing 97 may be generally concentric with the above described wall portion 80 of the duct 79. A spinner or streamlined hub 98 of generally conical shape is provided in front of the rotor 86, being carried by an extension 100 of the shaft 87.

In order to facilitate a better understanding of the invention the following data is given of a typical installation or embodiment wherein the airframe or body 10 is assumed to be 50 ft. in diameter and the craft is assumed to have a gross loaded weight of about 55,000 pounds. In such a case the diameter of the ducted compressor 65 will be 6 ft. and the speed of rotation of the compression rotor 86 will not exceed 3700 r.p.m., which is equivalent to the comparatively conservative top speed of 1200 feet per second, precluding the possibility of the rotor bursting. The compression ratio of the ducted compressor 65 will be 1.89 to 1 and the total weight flow of air through the ducts will be 770 pounds per second. It is to be understood that these figures are merely illustrative and, of course, will vary in different applications and aircraft.

The load turbo powerplants 66 and 67 serve to assist in driving or rotating the ducted compressor 65 and themselves produce propulsive gas stream or jets. The powerplants 66 and 67 are provided or arranged at a vertical axis which intersects the axis of rotation of the ducted compressor at or adjacent the geometric center 12 of the craft. In accordance with the invention the powerplants 66 and 67 are carried by the island 74 and are arranged on the upper and lower sides respectively of the island shell 75 assuming the island to be in the full line position illustrated throughout the drawings. As mentioned above the upper and lower sides of the island shell 75 have protruding fairings 78 for containing the powerplants 66 and 67. These fairings 78 are shallow and streamlined to offer a minimum of aerodynamic drag. The powerplants 66 and 67 drive shafts 102 which pass through tubular portions 103 of the spider struts 91 to points adjacent the compressor shaft 87 and are operatively connected with the compressor shaft by a transmission, to be later described. In accordance with the invention the powerplants 66 and 67 are supercharged by the ducted compressor 65, that is compressed air from the compressor is bled or delivered to the inlets of the powerplants. For this purpose the struts 91 of the spider 90 have air passages 108 of substantial capacity leading from their forward edges rearwardly and then vertically to the powerplants 66 and 67.

The two load turbo powerplants 66 and 67 may be substantially identical and each is arranged within a housing 104 in its respective fairing 78. These housings 104 have bosses 105 at their inner sides secured in sockets 106 in the outer ends of the struts 91. Each turbo powerplant 66 and 67 has a casing 107 engaged in its housing 104 and provided at its inner side with a boss 109 removably engaged in the boss 105 of the housing. This arrangement facilitates ready removal of the powerplants from the housings 104 for servicing, replacement, etc. Each powerplant 66 and 67 includes a unirotor 110 freely rotatable on its respective shaft 102 and provided with compressor blading 111 at the entrance of the casing 107. Annular conic passages 112 lead from the compressor blading 111 to annular combustion chambers 113. The casings 107 have partitions and walls defining the compressor passages 112 and the annular combustion chambers 113, and fuel injection rings 114 are provided in the combustion chambers. The chambers 113 are shaped to substantially reverse the flow of the compressed air and products of combustion and discharge through nozzles against curved or Francis type turbine blades 115 on the unirotors 110. Electrical ignitors 119 are provided for the chambers 113. The blades 115 acted upon by these gases drive the unirotors 110 at high velocity, say at 46,000 r.p.m. Load turbine wheels or rotors 116 are splined or keyed on the shafts 102 at the outer ends of the unirotors 110 and carry rows of turbine blades 117. Rows of stator blades 118 on the casings 107 extend into the expansion zones of the turbine system between the blades 115 and 117. The high pressure, high velocity gases and air impinging or acting on the turbine buckets 117 drive the load turbines 116 and shafts 102 at a speed of, say, 16,000 r.p.m., the data of this paragraph being based on a structure where the unirotors 110 have a diameter of 11 inches and the load rotors 116 have a diameter of 19.2 inches. The streams or jets of the high pressure, high velocity gases discharging from the powerplants 66 and 67 are utilized to assist in propelling the aircraft and to add stability to its flight. Fittings 120 are provided at the outer sides of the housings 104 and have series of streamlined vanes 121 for directing the gas flow. These turning vanes 121 are directed outwardly or vertically and rearwardly so that the issuing jets or streams are directed rearwardly to produce forward propulsive thrusts. Fuel pipes 122 carry fuel to the injection rings 114 and electrical conductors 123 lead to the ignitors 119 of the powerplants 66 and 67. It will be seen that upon disconnection of the pipes 122 and wires 123 the fittings 120 may be removed to allow easy withdrawal of the entire powerplants from their housings 104. This facilitates maintenance and replacement of the powerplants. The pipes 122 receive fuel from a flexible pipe unit 179 comprised of pipe sections connected by rotary joints, see FIGURES 6 and 20. The pipe unit 179 in turn receives the fuel from a main fuel line 185, to be later described in more detail. The flexible unit 179 is such that it does not interfere with free pivoting of the island 74.

The tip or outboard powerplants 68 and 69 are provided to assist in driving the ducted compressor 65, to produce propulsive jets, and they are controllable to provide for or to assist in the steering or directional control of the craft. The turbo jet load powerplants 68 and 69 are positioned on the periphery of the circular plan-form airframe or body 10 on a common diametric axis which intersects the axis of rotation of the ducted compressor 65 and the longitudinal axis of the ducts 18 and 79 at or adjacent the geometric center 12 of the body 10. In the aircraft illustrated where the periphery of the body 10 is sharp or thin, I provide streamlined enlargements or pods 124 at the outboard edges or "tips" of the body to contain the powerplants 68 and 69 and their auxiliaries and controls. These pods 124 may be designed or shaped to reduce the vortices losses at the margins or tips of the craft. As best shown in FIGURE 16, each pod 124 may be considered to have an inner permanent section and an outer detachable or jettisonable section. The inner sections are defined by inner walls 125 which may extend between two adjacent radial bulkheads 35 and intermediate walls 126 which may occupy chordal planes relative to the periphery 11 of the body 10. The inner walls 125 may constitute bulkheads or walls of the fuel cells 32. The outer sections of the pods 124 are defined by the intermediate walls 126 and by outer walls 127. The outer walls 127 are secured to the aircraft structure by breakable or frangible connections or joints 129 so that they may be detached or broken from the craft in the event their respective powerplants burst. The powerplants 68 and 69 are housed in the outer sections of the pods 124, that is between the walls 126 and 127, while their auxiliaries are housed between the walls 125 and 126.

Like the inboard load powerplants 66 and 67, the outboard or tip turbo powerplants 68 and 69 are supercharged by the ducted compressor 65, receiving compressed air from the compressor duct 79 and further compressing it before it reaches their respective combustion zones. The above described struts 93 of the island spider 90 and the trunnions 82 are tubular to have air passages 128 opening forwardly at the forward ends of the struts to receive the compressed air from the duct 79 and curving rearwardly and laterally to pass through the trunnions. The outer ends of these passages 128 communicate with tunnels or tubes 130 of substantial capacity which extend radially outward through the compartments 20 and 21 and the fuel cells 32 to conduct the compressed air to the outboard powerplants 68 and 69. The tubes 130 have their outer ends at the inner walls 125 of the pods 124 where they communicate with turnable or rotatable tubular trunnions 131. The trunnions 131 are rotatably supported by bearing means 132 at the walls 126 and their outer ends join and communicate with the inlets of the casings 207 of the powerplants 68 and 69. The trunnions 131 and casings 207 are connected so that the trunnions support the powerplants 68 and 69 for angular movement about a spanwise or diametric axis which intersects the fore and aft axis of the body 10 at the geometric center 12 of the body. However, the connections between the trunnions 131 and casings 207 are frangible to fail in the event of explosion of their respective powerplants or the bursting of a related powerplant rotor so that the individual powerplants and their respective pod walls 127 are free to detach or jettison from the craft in the event of such failure. In the particular arrangement illustrated the trunnions 131 and powerplant casings 207 are joined at internal and external annular weakening grooves 133, these joints or connections being such as to withstand all normal operating loads but to fail in the event of explosion or bursting of the related powerplants.

The tip or outboard turbo load powerplants 68 and 69 are operable to drive radial shafts 134 which, in turn, are drivingly connected with the ducted compressor shaft 87. The shafts 134 extend outwardly through the struts 93 and axially through the tubes 130, being supported in bearing sleeves 135 mounted coaxially in the tubes by spaced webs 136. The inner ends of the shafts 134 are drivingly connected with the compressor shaft 87 by the transmission means, to be subsequently described, while the outer portions of the shafts extend through or into the casings 207 of the outboard powerplants. The load turbo powerplants 68 and 69 may be of the same construction and have the same mode of operation as the inboard powerplants 66 and 67, each comprising a unirotor 210 rotatable on its shaft 134 and carrying compressor and turbine blading 211 and 215, an annular air passage 212 and combustion chamber 213, a fuel injection ring 214 in the combustion chamber, a load driving wheel or rotor 216 having turbine buckets 217 and the stator vanes 218 between the rows of turbine buckets 215 and 217. Reference may be had to the description of the powerplants 66 and 67 for the construction and operation of the corresponding elements of the powerplants 68 and 69. The fuel injection rings 214 are supplied with fuel by pipes 222 and electrical leads 223 extend to the ignitors 219 of the combustion chambers 213. The pipes 222 and wires 223 or suitable portions thereof, are flexible to permit rotation of the respective powerplants 68 and 69 and have disconnect fittings at the bulkhead 126. The pipes 222 receive fuel from the supply pipe 185 where the latter connects with the flexible pipe unit 179, see FIGURES 6 and 20. The outboard load powerplants 68 and 69 have discharge or nozzle fittings 220 corresponding generally with the fittings 120 and provided with direction changing vanes 221 for directing the propulsive jets substantially normal to the axes of rotation of the rotors 210 and 216. The fittings 220 are secured to the casings 207 to move therewith and the outer walls 127 of the pods 124 have openings 137 in which the fittings and vanes 221 are free to turn. The means for turning the outboard powerplants 68 and 69 to alter or control the direction of the propulsive jets discharging from the nozzle fittings 220 include curved or segmental racks 138 fixed on the trunnions 131 and pinions 139 meshing with these racks. Reversible electric motors 140 drive the pinions 139. The controls for the motors 140 will be later described. The motors 140 are housed in the inner portions or sections of the pods 124. As will be later described the power output or thrust from the outboard powerplants 68 and 69 may be correspondingly and differentially regulated and the powerplants may be turned to various angular positions to alter the direction of their propulsive jets to effect directional control of the aircraft.

It is to be observed that the load turbo powerplants 66 and 67 and 68 and 69 are arranged and located in such a fashion that explosion or bursting of any of them during flight will not endanger the occupants or any critical portions of the craft. The rotors and wheels 110 and 116 of the powerplants 66 and 67 rotate in planes parallel with and spaced above and below the airframe proper and remote from the passenger compartments and fuel cells 32 and bursting of these elements will not endanger either the occupants or any critical regions of the craft. The rotors and wheels 210 and 216 of the outboard load powerplants 68 and 69 rotate in planes far remote from and parallel with the side walls 24 of the occupied compartments and outboard from the fuel cells 32 and the periphery of the airframe. Bursting of these elements 210 and 216 cannot endanger either the occupants or the structure. The shafts 134 of the outboard load powerplants 68 and 69 have weakening grooves 141 adjacent the planes of the walls 126, the planes of the weakening grooves 133 of the trunnions 131 and adjacent the inner ends of the rotors 210. Bearings 149 support the shafts 134 adjacent these grooves 141. By reason of the breakable attachments of the pod walls 127, the break grooves 133 in the trunnions 131, and the break grooves 141 of the shafts 134 an entire powerplant 68 or 69 and the associated wall 127 will break free and detach from the craft in the event one of its wheels or rotors explodes. Likewise the inboard load turbines 66 and 67 are furnished with frangible regions 145 in the shafts 102 whereby the explosion of a rotor would permit the particular load turbine concerned to separate from the main structure and to be jettisoned by breaking open the relatively light fairing 78.

The invention provides means for maintaining a directionally controllable propulsion jet or stabilizing and direction maintaining jet from the remaining trunnion 131 of the failed powerplant 68 or 69. This means includes a lateral opening 142 in the wall of each trunnion 131 and passages or ducts 143 leading from the openings to discharge compressed air outwardly and rearwardly from the faces of the walls 126. The openings 142 are normally closed by doors 144, hinged in the trunnions 131, so that prior to failure of a powerplant compressed air from the tubes 130 is obliged to flow to and through the powerplants. The pressure within the trunnions 131 holds the doors 144 closed during normal operations. However, in the event of failure and detachment of a powerplant 68 or 69, the pressure within the related trunnion 131 drops and the airflow acting on a lip 146 at the inner edge of the respective door 144, swings the door to the broken line position of FIGURE 16 where it closes off the outer end of the trunnion and opens the opening 142. The doors 144 have slots 147 for receiving the adjacent shafts 134 when the doors swing to the positions where they close off the outer ends of the trunnions, these slots normally being closed by posts 148 in the ducts 143. When a door 144 is swung to the position where it closes off the outer end of its trunnion 131, the airflow is diverted through the related duct 143 and discharges therefrom in the form of a propulsive and directional jet. The duct 143 may be broad or arcuate and of sufficient width to permit the jet discharged through the opening 142 to be employed as a directional control jet as well as a propulsive jet.

The invention provides a simple, compact and refrigerated or cooled transmission for transmitting power from the shafts 102 and 134 of the inboard load turbine powerplants 66 and 67 and the outboard load powerplants 68 and 69 to the shaft 87 of the ducted compressor 65. This transmission includes a spiral bevel gear 150 fixed on the aft end of the compressor shaft 87 to operate within the spider 90. Four stub shafts 151, spaced about 90° apart and arranged to be coaxial with the central vertical axis of the island 74 and the spanwise axis of the body 10, are rotatably supported in the spider 90 and have spiral bevel pinions 152 fixed thereon to mesh with the gear 150. The pinions 152 meshing or cooperating with the gear 150 at four regions spaced 90° apart assure balanced or symmetrical loading of the gear and its shaft. There is a stub shaft 151 axially aligned with the inner end of each shaft 102 and 134. I prefer to provide overrunning clutches 153 between the shafts 102 and 134 and their respective or related stub shafts 151 whereby the turbine powerplants 66 to 69 inclusive are each operable to drive or transmit power to the ducted compressor 65 and yet the compressor may overrun or rotate faster than any one or all of the load powerplants without transmitting power thereto. These overrunning clutches 153 may be of any preferred or appropriate type. In the case illustrated they each include a toothed sleeve 154 meshing with the toothed end of a stub shaft 151 and cooperating with spiral splines on the respective shaft 102 or 134 to back away from the adjacent stub shaft when the compressor 65 overruns the related powerplant 66, 67, 68 or 69. The hollow conic portion 95 of the spider 90 serves as a lubricant sump or reservoir for the shafts, bearings and other working parts in or associated with the spider.

The means or system for cooling or refrigerating the transmission and working parts in and adjacent the spider 90 utilizes the low boiling point fuel as the coolant or refrigerant. As best shown in FIGURES 6 and 20, a fuel pipe 155 connects with the flexible fuel pipe unit 179 and extends inwardly through one of the spider struts 92 and the spider fairing 97 to have its inner end communicate with an annular manifold or jacket chamber 156 in the wall of the conic spider portion 95. This chamber 156 encircles the fuel reservoir of the fairing 97 and the bearings 96 of the compressor shaft 87 and has its rear end adjacent the overrunning clutches 153. Annular or circular cooling passages 157 are formed in the spider 90 to communicate with the aft end of the chamber 156 and to surround the several overrunning clutches 153. A coolant chamber 158 is provided in the aft portion of the spider 90 and the four passages 157 communicate with the peripheral region thereof. The chamber 158 generally parallels the plane of the gear 150 and the refrigerant therein cools the gear and pinions 152 and protects the various elements of the transmission against the heat of the fuel consumed in the duct 79 and the duct 18. The chamber 158 serves to conduct the fuel-refrigerant radially inward to the fuel injector 166, to be later described, so that there is a fuel flow through the chamber, the passages 157 and the jacket or chamber 156. It will be seen that the fuel-refrigerant flowing through the jacketed and ported spider 90 effectively cools the various rotating or moving parts of the transmission system, the bearings 94 and 96 of the compressor shaft 87 and the lubricant in the spider. The heat energy absorbed by the fuel in flowing through the jackets and passages of the spider 90 is recovered or utilized upon burning the fuel and augments the propulsive effect of the propulsion system.

As mentioned above, the island 74 carrying the ducted compressor 65 is pivotally movable about the spanwise axis of the airframe or body 10 between the position where its air duct 79 is aligned with and in register with the main air duct 18 of the body 10 and the position where the island duct 79 is vertical or substantially normal to the duct 18. The means for rotating or moving the island 74 includes a rack 160 secured to the island and a pinion 161 meshing with the rack and driven by a reversible electric motor 162. The motor 162 is mounted on or at one of the body walls 24 as shown in FIGURE 6 and its shaft 165 extends through a slot 163 in the shell 75 of the island 74 so that the pinion 161 may mesh with the rack 160. As seen in FIGURE 7 the rack 160 and the slot 163 are curved or arcuate, being concentric with the pivotal axis of the island 74. Appropriate brackets 164 mount the elongate curved rack 160 in the island 74. It will be seen that upon operation of the motor 162 in one direction the island 74 is turned or swung from the position of FIGURES 6, 7 and 8 where it is aligned with the duct 18 to the broken line position of FIGURE 4 where it is vertical or normal to the duct 18 to provide for vertical operation of the craft and upon operation of the motor 162 in the other direction the island is returned to the position where its duct 79 is aligned with the main air duct 18. The island 74 of course may be moved to intermediate positions where it is disposed at angles of less than 90° to the duct 18. The control system for the motor 162 will be later described.

The combustor means or fuel injection means 70 provides for the injection of fuel into the island duct 79 adjacent but downstream from the ducted compressor 65 and for the introduction of regenerative fuel vapor into the duct 18 at a region further downstream from the compressor. The first mentioned area or phase of fuel injection may be considered afterburning and the means 70 includes what may be termed an afterburner fuel spinner 166 associated with the ducted compressor 165. The aft end of the compressor shaft 87 has an extension 167 and the spinner 166 is keyed or fixed thereon to rotate with the shaft. The spinner 166 is a conical member having its apex facing aft and the spinner has a central fuel cavity 168. A boss 170 on the forward end of the spinner 166 rotatably engages in the aft end of the spider 90 and has a plurality of radial ports 171 communicating with the above described refrigerant-fuel chamber 158 of the spider. The ports 171 lead to the cavity 168 so that the fuel after passing through the several cooling chambers and passages of the spider 90 flows into the interior of the spinner 166. The spinner 166 which rotates with the compressor shaft 87 has several rows of radial ports 172 extending outwardly from the cavity 168 to the periphery of the spinner. These ports 172 discharge the fuel radially outward into the air duct 79, centrifugal force acting to throw the liquid fuel outwardly across the passage 79, as indicated by the arrows in FIGURE 7, to be effectively distributed and mixed with the compressed air flowing through the passage to assure substantially complete well distributed combustion of the fuel. The means for igniting the fuel discharging from the spinner 166 includes an annular wall or baffle 173 on the aft end of the spider 90 surrounding the forward end of the spinner 166 with considerable clearance. A few spaced ports 174 extend radially through the wall of the spinner 166 from its cavity 168 to its periphery to discharge the fuel outwardly against the baffle 173, the baffle providing a relatively stagnant region of near-stoichiometric fuel-air ratio, favorable to ignition of the fuel under all conditions. The baffle directs or diverts this fuel rearwardly to intersect the planes of fuel flow from the main fuel ports 172. An electrical ignitor 175 extends into or through the baffle 173 to ignite the fuel diverted rearwardly by the baffle. It will be seen that the fuel diverted aft by the baffle 173 and ignited in this manner progressively ignites the fuel discharging from the axially spaced rows of main fuel ports 172. Thus the baffle 173, the ports 172 and the ignitor 175 constitute an effective fuel ignition system for the afterburner.

The fuel injecting means 70 further includes what may be termed a regenerator for introducing fuel vapor into the ram jet duct 18 at a point or region downstream from the island 74. This regenerator serves to protect the walls of the duct 18 against the high temperatures that are produced therein during flight. A regenerator shell 176 surrounds the duct 18, extending rearwardly from adjacent the island 74 to the aft region of the duct. The shell 176 is spaced around the duct 18 to leave or provide an annular vaporizing and insulating fuel space 178, the shell and duct being connected for mutual reinforcement and support by longitudinally spaced circular perforated channels or bulkheads 177. Fuel vapor is led from the upper portions of the fuel cells 32 to the aft end of the regenerator space 178 by pipes 373. The pipes 373 may extend along the walls of the passenger compartments 20 so that the fuel vapor assists in refrigerating the compartments, see FIGURE 2. Liquid fuel is also led into the aft portion of the regenerator space 178 by a pipe 182. The pipe 182 also has a control valve 183, see FIGURES 2 and 10, controlled in the manner to be subsequently described. The fuel vapor and/or liquid fuel flows forwardly through the regenerator space 178 and discharges radially inward at substantial velocity from one or more rows of jets or ports 184 in the wall of the duct 18 adjacent the forward end of the regenerator. The arrows in FIGURE 8 illustrate the manner in which the fuel vapor is injected radially into the air and gas stream flowing through the duct 18 to be distributed therein for combustion to add materially to the thrust output of the propulsive system. The fuel vapor and the liquid fuel vaporized in the regenerator space 178 absorbs heat from the walls of the duct 18, thereby reducing the temperature of the duct and protecting the duct against damage by the high temperature in the afterburner or combustion zones of the duct. The heat thus absorbed by the fuel is returned to the propulsive cycle or system when the vapor is introduced into the duct 18 for combustion therein.

The fuel supply system for the load turbo powerplants 66, 67, 68 and 69 and for the afterburner and regenerator combustor means 70 includes a main liquid fuel line 185 leading from the lower portions of the fuel cells 32 and equipped with a suitable pump 186 for pumping the fuel to the propulsive units, see FIGURE 20. The main liquid fuel pipe 185 leads to the above described flexible unit 179 and pipe 155 which in turn discharges into the spider jacket space 156, the ports 157 and chamber 158 leading from this space to the fuel injecting spinner 166 as above described. The fuel supply pipes 122 for the inboard load turbo powerplants 66 and 67 extend through struts 92 of the spider 90 and through the fairing 97 to connect with and receive fuel from the flexible pipe unit 179, see FIGURE 6. The fuel supply pipes 222 of the outboard load powerplants 68 and 69 extend inwardly through the fuel cells 32 to connect with the pipe 185 so that fuel is supplied directly to the powerplants 68 and 69. A conductor or pipe 182 for supplying liquid fuel to the regenerator space 178 leads to and connects with one of the pipes 222 to receive fuel under pressure therefrom.

In accordance with the invention the liquid fuel, being pumped or delivered to the several propulsive units of the propulsion system is utilized as a coolant or refrigerant to cool the air being supplied to the passenger compartments and other occupied compartments of the craft. The passenger compartment or cabin air supply system includes a heat exchanger 187 for each compartment 20 and its associated compartments 25, 26 and 27. The heat exchangers 187 are suitably positioned adjacent the duct 18 and pipes 188 tap into or communicate with the above described air ducts or tubes 130 and extend to the heat exchangers to circulate compressed air therethrough. Ducts 190 carry this air under pressure, after being cooled in the heat exchangers 187, to the compartments 20 for discharge therein. Bypasses 191 in the main fuel pipe 185 circulate the liquid fuel through the heat exchangers 187, the heat exchangers being designed to effect a transfer of heat from the compressed air flowing therethrough to the liquid fuel thus circulated therethrough. It is to be observed that the aerodynamically induced heat and the heat of compression of the air thus supplied to the cabins is extracted by the fuel which is subsequently burned in the several propulsive units and this heat is accordingly recovered or utilized to assist in propelling the aircraft. The bypasses 191 have valves 192 for regulating the coolant-flow therethrough to thus regulate the air cooling action of the heat exchangers 191. These valves 192 are, in turn, operated or regulated by thermostats 193 arranged to be responsive to the temperatures of the air in the cabins or compartments 20. The compartments 20 have outflow valves 194 designed to maintain a suitable air pressure level in the cabin areas, such valves being conventional and well known in the aircraft industry.

As illustrated in FIGURE 20, liquid fuel bypass lines 195 connect with the main liquid fuel pipe 185 and extend to the outer lens systems 57—60 of the periscopes 56. The liquid fuel flowing through these bypasses 195 circulates through the above described chambers or passages 61 of the periscopes to cool the lenses 57 and 60 and maintain their structural and optical characteristics.

The inlet 71 of the main propulsive air duct 18 is in the nature of a supersonic variable area ram inlet and is illustrated in detail in FIGURES 12 and 13. As already briefly described the forward or inlet end portion of the duct 18 is elongated in the spanwise direction. Thus, as seen in FIGURES 2, 3 and 13, the forward portion of the duct 18 flares forwardly and spanwise while at the same time is reduced in its vertical dimension to terminate at a rectangular forward opening 197. This opening 197 is in the lower rib 15, being below the periphery 11 of the body 10, and has generally straight horizontal and vertical margins at its forward terminus. It should be noted that the elongate entrance of the opening 197 conforms generally with the thin forward edge or periphery of the body 10 to keep the frontal area of the craft at a minimum. As best illustrated in FIGURE 12 the ram inlet 71 has a Venturi like throat provided by upper and lower forward wall portions 198 which curve rearwardly and inwardly toward the longitudinal axis of the inlet opening and rearward upper and lower wall portions 199 which curve forwardly and inwardly to join with the wall portions 198 at a throat 200. The forward wall portions 198 are slightly concave while the rearwardly flaring rear wall portions 199 are curved and shaped to merge with the cylindrical walls of the duct 18. The throat 200 presents opposing upper and lower convex surfaces. As seen in FIGURE 13 the end walls 201 of the inlet are flat and vertical, these flat walls extending rearwardly from the forward terminus of the inlet opening 197 to a region some distance rearwardly of the throat 200.

The variable ram inlet 71 includes an island 202 of variable volume or variable vertical cross section arranged in the ram inlet opening 197. This island 202 includes a fixed rigid nose 203 extending horizontally or spanwise through the forward end of the opening 197. The ends of the nose 203 are anchored at the sidewalls 201 and the nose is thin in vertical cross section to present a forward knife edge and has upper and lower sides diverging slightly from this edge. The island 202 further includes flexible metal walls 204 extending rearwardly from the nose 203 and rigid-material rear walls 205. Hinge connections 206 join the rear edges of the flexible walls 204 with the forward edges of the rigid-material walls 205. A hinge connection 235 hingedly connects the rear edges of the two rear walls 205 and the pin or pins 236 of this connection are slidable in longitudinal slots 237 in the sidewalls 201 of the opening 197. Seal strips 238 of asbestos cloth, or the like, are secured to the ends of the walls 204 and 205 to engage and seal with the side walls 201 of the opening 197, to reduce or prevent the leakage of fluid pressure from the interior of the island 202. These seal strips 238 are shown in FIGURE 13 where it will be seen they are arranged and designed to effectively prevent the outward leakage of fluid from the island.

The island 202 constructed and arranged as just described, is adapted to be inflated to a condition such as shown in full lines in FIGURE 12 to constrict or reduce the effective capacity of the throat 200 for supersonic flow and supersonic diffusion and also for deflation to a condition such as shown in broken lines in FIGURE 12 to permit large mass flow through the throat 200 during subsonic flow. The inflatable island 202 is responsive to aerodynamic conditions in the ram inlet 71, being automatically inflated or enlarged supersonic flow to more or less restrict the throat 200 and being deflated during subsonic flow to increase the effective or operational size or cross section of the throat. In accordance with the invention means for admitting the expanding or inflating air under pressure to the interior of the island 202 is controlled by an air pressure relay means which, in turn, is responsive to the aerodynamic conditions in the ram inlet. The means for admitting air under pressure to the interior of the island 202 includes a port or passage 239 having an open end communicating with the inlet passage 197 aft of the most restricted region of the throat 200. As shown in FIGURE 12, passage 239 has its open end at one of the walls 199 to receive high pressure air from the diffuser region of the ram inlet passage where a large portion of the kinetic energy of the air is converted into pressure. A valve seat 240 is provided on the wall of the passage 239 and a pipe 241 leads from adjacent the valve seat to one side wall 201 of the ram inlet opening 197 where it communicates with the interior of the island 202, see FIGURE 13. A movable valve closure 242 is adapted to cooperate with the seat 240 to control the pressure flow through the passage 239. The wall structure of the inlet ram 271 has a chamber 243 separated from the passage 239 by a wall or partition 244 and a stem 245 on the valve closure 242 slidably passes through an opening in this partition to extend into the chamber 243. A diaphragm, Sylphon bellows 246, or the equivalent, has one end anchored in the chamber 243 and has its other end operatively connected with the valve stem 245. The free or unanchored end of the bellows 246 is exposed to and acted upon by air pressure in the chamber 243 which tends to compress or contract the bellows and thus open the valve closure 242. The pressure for effecting this actuation of the diaphragm or bellows 246 is admitted to the chamber 243 by a port or

pressure tap 247 communicating with the ram inlet opening 197 some distance forwardly of the region of greatest restriction of its throat 200. Internal pressure in the bellows 246 tends to expand the bellows and move its free end in a direction to close the valve closure 242 against its seat 240. A port or pressure tap 248 supplies this internal pressure to the bellows 246. This pressure tap 248 communicates with the inlet opening or passage 197 in a region downstream from the tap 247 and adjacent the area of greatest restriction of the throat 200 where the final shock waves strike or impinge against the walls of the throat. The broken lines 250 and 251 in FIGURE 12 represent shock waves originating at the knife edge of the island nose 203 and the marginal lips 249 respectively of the ram opening 197, under supersonic operating conditions. These expansion waves or shock waves 250 and 251 originating at the nose 203 and lips 249 are successively reflected by the walls 198 and 204 so as to repeatedly intersect before reaching the throat 200. In this connection it is to be observed that the walls 198 and 204 are preferably concave so that upon each reflection of a given shock wave from a wall the wave leaves said wall at a lesser angle than its angle of incidence. This tends to bring the final shock waves to the region adjacent the tap 248. Further and more important, there is a distinct change in angle of the shock waves 250 and 251 after they intersect. Thus, as seen at the point or line A of intersection of the waves 250 and 251, the angle of the waves has been appreciably changed and been made more oblique to the longitudinal axis of the inlet. Again at the line B of intersection the waves 250 and 251 travel at more oblique angles to the longitudinal axis of the passage and this is also true at the third line of intersection C. The net result of these several changes of the angles of reflecting and intersecting waves 250 and 251 traveling aft in the inlet passage is the final impingement of the wave 250 against the wall 198 at or adjacent the pressure tap 248. As the wave 250 is a region of increased pressure the impingement of the wave against the wall 198 at the leading edge of the pressure receiving tap 248 produces increased pressure in the bellows 246. Such increased pressure in the bellows 246 tends to move the valve closure 242 toward its seat 40 to reduce the pressure in the island 202 allowing the island to contract by reason of the external forces and pressures acting thereon and thereby increase the area or effective flow path through the throat 200. This is the action of the automatic ram inlet 71 when the island 202 is obstructing the throat 200 to a greater extent than the flow conditions warrant. Conversely when the inflatable island 202 is not, under the prevailing conditions, sufficiently obstructing the flow through the throat 200, the final shock wave 250 will tend to move downstream away from the pressure tap 248 so that the pressure in the bellows 246 is reduced relative to the pressure in the chamber 243 and the valve closure 242 is moved away from its seat 240 to admit additional air pressure into the island 202 to expand the island and thereby further restrict the throat 200. Thus under supersonic flow conditions the island 202 is automatically partially inflated and deflated in response to the aerodynamic conditions in the ram inlet itself to regulate the air flow into the main propulsive air duct 18 and the final oblique shock wave will tend to assume a position of equilibrium with its terminus near the central portion of the tap 248. During subsonic operating conditions the forces and pressures acting on the walls 204 and 205 of the island 202 deflate or collapse the island to a condition such as illustrated in broken lines in FIGURE 12 where it offers a minimum of obstruction to airflow into the duct 18. It is to be observed that upon inflation and deflation of the island 202 its walls 204 are flexed from the substantially straight or flat condition of the broken lines in FIGURE 12 to the curved or concave conditions of the full lines, the flexible walls and their nose 203 presenting aerodynamically efficient surfaces under all conditions. The pins 236 are free to slide in the slots 237 during inflation and deflation of the island and it will be noted that the slightly convex walls 205 present smooth aerodynamically efficient surfaces under all conditions. The variable area inlet ram means 71 is self sufficient and requires no external control means or motive power.

My copending application, Serial Number 669,879, filed July 3, 1957, now Patent No. 2,973,621, describes and claims the above described variable area ram inlet.

The main propulsive jet outlet or nozzle 72 at the aft end of the duct 18 automatically changes from a subsonic nozzle to a supersonic nozzle and vice versa in accordance with the flow conditions of the discharging air and gas jet, incorporates variable direction features to produce pitching trim during certain phases of the flight program and is operable as an air brake to reduce the velocity of flight under certain conditions. As already mentioned the nozzle 72 is elongated horizontally or spanwise of the body 10 and, as illustrated in FIGURE 1, the medical spanwise plane of the nozzle is substantially coincident with the plane of the periphery 11. Furthermore, the nozzle 72 is substantially rectangular having a passage or opening 252 that has a rear terminus defined by vertical side walls 253 and horizontal upper and lower margins. The nozzle passage or opening 252 merges into the aft end of the cylindrical main propulsive duct 18 having its walls converging or curving forwardly and inwardly to smoothly join the walls of the duct. The above-mentioned walls 24 extend aft to the periphery 11 of the body 10 in spaced generally parallel relation to the duct 18 and nozzle sidewalls 253 to leave spaces 254 useful in containing certain actuating elements of the nozzle 72. As best illustrated in FIGURES 9, 10 and 11, the nozzle 72 includes three movable or pivotal vanes, a center 255 and upper and lower vanes 256. The vanes 255 and 256 extend horizontally or spanwise, being in planes parallel with the periphery 11 of the body 10 and are in parallel relation to one another in the horizontally elongated nozzle opening 252. The three vanes are turnable or rotatable on their longitudinal axes, the center vane 255 having tubular end trunnions 257 journaled in openings in the end walls 253 of the nozzle opening. The upper and lower vanes 256 have end shafts 258 also journaled in the end walls 253. In accordance with the invention the three vanes 255 and 256 are spaced apart vertically, having partially cylindrical bodies concentric with their respective axes of rotation and spaced one from the other to leave the two parallel exit or discharge passages 260. The noozle vanes 255 and 256 are streamlined and of "tear-drop" shape, the central vane 255 having a tapering tail or lip 261 and the upper and lower vanes having similar rearwardly extending lips 262. The rear surfaces of the lip 261 are slightly concave and extend rearwardly from the cylindrical periphery of the vane 255 in converging relation to provide the lip 261 with a rather sharp rear edge. The rear surfaces of the lips 262 on the vanes 256 which face or oppose the vane 255, are concentric with the cylindrical surface of the vane 255 when the nozzle 72 is adjusted to minimum opening while the outer sides of the lips 262 may be flat, the surfaces of the lips 262 converging rearwardly to sharp rear edges. The vanes 255 and 256 are preferably hollow and are constructed of heat-resistant material such as chromium-cobalt-nickel alloy or sintered ceramic-metal combination. The upper and lower walls of the nozzle opening 252 preferably have appropriately shaped flow directing surfaces or fairings 363 to divert or direct the upper and lower regions of the gas and air stream in a manner to flow smoothly over the cylindrical surfaces of the upper and lower nozzle vanes 256. It will be seen that with the nozzle structure thus far described the high velocity propulsive stream or jet is caused to flow through and discharge from the two passages 260 with a minimum of friction and loss and because of the thinness of the central lip 261 these two streams again merge into a single common high velocity or supersonic jet where they discharge from the opening 252, as indicated by the arrows in FIGURE 9.

The propulsive nozzle means 72 is operable to pivot or actuate the vanes 255 and 256 to vary or regulate the effective operational area of the nozzle in accordance with the propulsive jet flow conditions and to alter the direction of the discharging propulsive jet to effect a directional control of the craft. Further, the upper and lower vanes 256 are operable to positions where they form air brakes for reducing the speed of flight and the central vane 255 is utilized as a nozzle for discharging a stabilizing and trimming thrust jet during certain phases of the flight program. The means for operating the nozzle vanes includes horns or operating levers 263, fixed to the shafts 258 of the upper and lower vanes 256 and a similar lever 264 fixed on a trunnion 257 of the central vane 255, see FIGURES 19 and 20. A jack screw 265 is pivoted on the lever 264 and bi-directional electrical screwjacks 266 are pivoted on the levers 263 of the upper and lower vanes to receive and cooperate with the screw 265. The screw-jacks 266 may be of a conventional type including reversible electric motors driving traveling or rotating nuts meshing with the screw 265, such mechanisms being well known in the art. The screw-jacks 266 are operated or controlled by the positions of the shock waves and margins of the propulsive jet discharging from the nozzle 72. Pitot tubes 276 are secured to the lips 262 of the vanes 256 and have their pressure receiving ends spaced aft from the sharp trailing tips or edges of the lips and facing forwardly. Tubes or lines 267 carry the pressure thus received to pressure diaphragms 268. The diaphragms 268 in turn are operatively connected with spring biased pivoted levers 269 carrying contacts 270. These contacts 270 are connected in a power circuit 271 leading to a generator, battery or other electrical power source 272. The contacts 270 are each spaced between stationary contacts 273 and 274 connected by lines 275 and 277 respectively, with the forward and reverse windings or sides of their respective reversible electric screw-jacks 266.

The mechanism just described for actuating or controlling the vanes 256 of the nozzle means 72 is operable to automatically adjust or position the vanes 256 for the most efficient utilization of the compressed air and gas stream or jet under sonic, transonic and supersonic jet velocity conditions. The Pitot tubes 276 arranged as above described, are affected by or responsive to the positions of the margins of the jet stream discharging through the nozzle. When the velocity conditions are such that the jet of gases exhausting from the nozzle is underexpanded, the margins of the jet move outwardly at the surfaces of the vane lips 262, that is away from the central axis of the nozzle and increased pressure at these margins is sensed by the Pitot tubes 276. The broken line X in FIGURE 27 indicates diagrammatically the margin of an underexpanded jet stream as produced by the shock waves at the nozzle exit. On the other hand when the jet velocity conditions are such that the jet as it discharges from the nozzle 72 is overexpanded the margins of the jet move inwardly or toward the central axis of the nozzle. The broken Z in FIGURE 27 indicates diagrammatically a margin of the overexpanded jet as produced by the oblique reflection shock waves at the nozzle exit. It is to be understood that the particular full line positions of the vanes 256 in FIGURE 27 bear no operative or intended relation to the margins X and Z, the lines X and Z being entirely schematic. The automatic means for operating the nozzle vanes 256 employs or is sensitive to the movement of the margins of the exhausting gas stream jet to position the vanes 256 in accordance with the jet velocity conditions in order to most efficiently utilize the jet in the propulsion of the aircraft. Thus when the jet is underexpanded the margins of the jet move outwardly to apply increased pressure at the Pitot tubes **276** and this pressure acts on the diaphragms **268** to move the contacts **270** against the contacts **273**. This in turn energizes the screw-jacks **266** to pivot the vanes **256** to swing their lips **262** outwardly and thus permit further expansion of the exhausting jet stream. However, when the discharging jet is overexpanded the margins of the jet move inwardly away from the surfaces of the vane lips **262** and the Pitot tubes **276** to lessen the pressure on the diaphragms **268** so that the contacts **270** engage the contacts **274**. This energizes the screw-jacks **266** to swing the vane lips **262** inwardly into conformance with the margins of the jet. In practice during relatively stable or normal operating conditions the margins of the jet will move but little relative to the Pitot tubes **276** and the vanes **256** will be relatively stabilized. Referring to FIGURE 27 of the drawings the full line positions of the vanes **256** are the supersonic jet positions and the broken line positions M are the positions assumed by the vanes during supersonic jet operations of greatest jet velocity. It will be observed that with the upper and lower vanes **256** in the full line positions of FIGURE 7 the vanes define a convergent nozzle passage for the effective discharge and utilization of the subsonic propulsive stream or jet. However, with the upper and lower nozzle vanes **256** is the broken line positions M the fairings **363**, the cylindrical upper and lower vanes **256** and their lips **262** define or provide a convergent-divergent nozzle passage or exit for the efficient utilization of the discharging supersonic propulsive jet.

The above described upper and lower nozzle vanes **256** are adapted to be used as dive brakes or air brakes to brake or reduce the translational speed and descent of the craft during certain maneuvers and in the event the speed of flight exceeds the maximum intended speed. The means for utilizing the vanes **256** as air brakes includes what I will term air speed indicators having Pitot tubes **280** arranged to extend from the body **10** to receive or respond to the relative air speed. Tubes **281** extend from the Pitot tubes **280** to air relays in the form of diaphragms **282** for biasing the switch levers **269** to cause the vanes **256** to move to the positions N. The diaphragms **282** are calibrated or constructed so that the switches or contacts **270** remain under sole control of the diaphragms **268** so long as the intended maximum indicated speed of flight is not exceeded. However, when this speed is exceeded the increased pressure received by the Pitot tubes **280** acts on the diaphragms **282** to actuate the same to close the switches **270** against the contacts **274**. Closing of the switches **270** against the contacts **274** energizes the screw-jacks **266** to swing the vanes **256** to the fully extended positions indicated by the broken lines N in FIGURES 9 and 27. When the vanes **256** are in these positions N their lips **262** extend from the body **10** to project into the air stream or slip stream and act as effective air brakes to retard forward flight. The switches **270** may be constructed and arranged for manual operation by the pilot or engineer as well as by the diaphragms **282** and **268**.

The three nozzle vanes **255** and **256** are operable to positions to deflect or divert the propulsive air and gas stream from the main propulsive duct **18** for the vertical directional control or pitch control of the craft. It will be observed that with the above described arrangement of the jack-screw **265** connected with the lever **264** of the central vane **255** and the screw-jacks **266** connected with the levers **263** of the upper and lower vanes **256**, the screw-jacks may move the vanes **256** without altering the position of the intermediate vane **255**. However upon angular movement of the central vane **255** the screw **265** and the jacks **266** transmit this movement to the upper and lower vanes **256** so that the three vanes move in unison and in the same direction. The means for utilizing the nozzle vanes **255** and **256** for direction or pitch control of the craft serves to pivot or move one of the vanes, for example the center vane **255**, and includes a servo motor **285** for operating a drum **286**. Cables **287** extend from the drum **286** and are attached to horns or levers **288** on one of the trunnions **256** of the central vane **255**. The servo motor **285** is adapted to be controlled and energized by an automatic pilot **290** as are certain other devices and instrumentalities of the aircraft. In FIGURE 19 I have shown the automatic pilot **290** in a diagrammatic manner and have shown the control or energizing leads **289** for the servo motor **285** extending to the automatic pilot. Automatic pilots of the type controlled by ground station or airborne station radio signals are now well known in the art and any appropriate or selected type of automatic pilot may be used. A manual lever **291** is provided on the drum **286** so that the vanes **255** and **256** may be manually controlled or directed if such is desired or necessary. It will be seen that upon turning the drum **286** in one direction either by the action of the servo motor **285** or by the manual lever **291**, the three vanes **255** and **256** are swung to positions where their lips extend downwardly to direct the propulsive jet downwardly and aft to exert a forward and downward pitching moment to the craft to move it downwardly. Upon turning the drum **286** in the other direction by the servo motor **285** or the hand lever **291** the vanes **255** and **256** are moved to positions where they extend upwardly and aft to direct the propulsive jet upwardly so that the craft is directed upwardly.

The nozzle means **72** is further utilized to discharge a pitch trim jet of compressed air to assist in stabilizing or trimming the craft during its vertical ascent and descent. The tail or lip **261** of the central nozzle vane **255** has a discharge opening **292** in its aft end or edge. This opening **292** is horizontally elongated and may extend throughout the length of the vane **255**. The vane **255** is hollow and its interior and the interior of its lip **261** form an effective convergent nozzle terminating at the air discharging opening **292**. A pipe **293** communicates with one of the lateral air ducts **130** and extends aft through the space **254** to the central vane **255**. A swing joint or rotary coupling **294** connects the rear end of the pipe **293** with a trunnion **257** of the central vane **255** so that air under pressure from the duct **18** and the duct **130** is supplied to the interior of the vane **255**. This air under pressure discharges from the opening **292** in the form of a propulsive and stabilizing or trimming jet. During vertical ascent and descent when the island **74** is vertically disposed or substantially vertical, the thrust produced by this jet of air under pressure discharging from the opening **292** trims the pitch angle of the craft and, if desired or necessary, the lever **291** or the servo motor **285** may be actuated to direct this trimming jet as conditions require to trim the craft during its vertical ascent and descent. Air under pressure from the ducted compressor **65** supplied to the interior of the central vane **255** as just described, may discharge from the opening **292** during all of the various phases of the flight program and at the times when the main propulsive jet is discharging from the nozzle means **72** the jet of compressed air from the opening **292** augments the main propulsive jet. It will be observed that the air under pressure circulated through and discharged from the central vane **255** serves to cool the vane.

My copending application, Serial Number 669,880, filed July 3, 1957, now Patent No. 3,038,305, covers the above described propulsive nozzle means.

As above described the reversible motors **140** are operable through the medium of the racks **138** and pinions **139** to rotate or turn their respective outboard powerplants **68** and **69** and thus control the direction of the propulsive jets discharging from their nozzle fittings **220**. It is contemplated that the outboard load turbins or powerplants **68** and **69** are to be employed to obtain directional control of the craft during the phases of ascent and descent by turning the powerplants on their individual axes either correspondingly or differentially. Also, as above described, the motor 162 acting through the rack 160 and pinion 161 is operable to turn the island 74 between the position where the island duct 79 is aligned with the main propulsive duct 18 and the vertical position where the island is perpendicular to the duct 18 and the motor 162 is further operable to move the island 74 to positions where it is inclined upwardly and rearwardly relative to the longitudinal axis of the duct 18. The invention includes a switch means or mechanism for energizing the reversible electric motors 140 and the reversible motor 162 to effect these operations. This switch mechanism includes a gang switch, shown in FIGURE 20, embodying three double blades or double ended blades 295, 296 and 297, all connected in the power line 271. One arm or end of the blade 295 is engageable with a contact 298 and the other end of this blade is engageable with a contact 299. A conductor or lead 300 extends from the contact 298 to one side or winding of the reversible motor 162 and a lead 301 extends from the contact 299 to the other side of the motor 162. The blade 295 has a neutral position, where it is out of engagement with both contacts 298 and 299, a position where it engages contact 295 to energize the motor 162 to move the island 74 toward its normal position aligned with the duct 18 and a position where it engages contact 299 to energize the motor 162 to move the island toward its vertical position. One end of the switch blade 296 is engageable with a contact 302 and the other end of the blade is engageable with a contact 303. A lead 304 extends from contact 302 to one side of the motor 140 associated with the outboard powerplant 68 and a similar lead 305 extends from the contact 303 to the corresponding side of the motor 140 for turning the outboard powerplant 69. The blade 296 has a neutral position clear of both contacts 302 and 303 and a position where it engages the two contacts to effect turning of the powerplants 68 and 69 in one direction. The switch blade 297 is movable from a neutral position clear of any contacts to a position where it engages contacts 306 and 307 and electric leads 308 and 309 extend from the contacts 306 and 307 respectively to the other sides or windings of the motors 140 so that the motors are operable to turn or direct the powerplants 68 and 69 in the other direction. The gang of switch blades 295, 296 and 297 is operated by motors or solenoids 310, shown schematically in FIGURE 19, the energizing leads 311 extend from the automatic pilot 390 to the solenoids 310 so that the automatic pilot may control the positions of the island 74 and the outboard powerplants 68 and 69. Manual operating handles or levers 312 may also be provided to move or operate the gang of switch blades 295, 296 and 297.

The directional control system for the outboard powerplants 68 and 69 includes a differential switch operable to cause differential turning of the powerplants that is simultaneous rotation or angular movement of the powerplants in opposite directions. This switch, shown in FIGURE 20, has a double blade or double ended blade 313 electrically connected with the power line 271. The switch further includes two contacts 314 and 315 adapted to be simultaneously engaged by the blade 313 with the blade in one position. The contact 314 is connected in the lead 305 extending to one side of the motor 140 for turning the powerplant 69 and the contact 315 is connected in the lead 30 4extending to the other or non-corresponding side of the motor 140 for turning the powerplant 68. Thus when the blade 313 is in the full line position of FIGURE 20 the powerplant 68 is turned in one direction and the powerplant 69 is turned in the opposite direction. The differential switch further includes two contacts 316 and 317 adapted to be simultaneously engaged by the blade 313. The contact 316 is connected in the lead 308 extending to one winding or side of the motor 140 for turning the outboard powerplant 69 and the contact 317 is connected in the lead 304 extending to the opposite or non-corersponding side of the motor 140 for turning the powerplant 68. When the blade 313 is in engagement with the contacts 316 and 317 the motors 140 are simultaneously operated in opposite directions to adjust or turn the powerplants 68 and 69 in opposite directions. When the differential switch is operated the blades 295, 296 and 297 are in neutral positions. In a like manner when the gang switch is to be operated the blade 313 is in a neutral position. The differential or opposite turning or adjustment of the outboard powerplants 68 and 69 by the action of the switch blade 313 as just described, serves to bank the aircraft for and during turns, etc. and the blade 313 is preferably under the control of the automatic pilot 290, for example the gyroscopic means of the automatic pilot. As diagrammatically shown in FIGURE 19, the blade 313 is operated by motors or solenoids 320 connected with the automatic pilot 290 by leads or conductors 318 and 319.

The invention includes a fuel control system for the several propulsive units of the propulsion system, this fuel control means serving to supply fuel to the driving turbines or powerplants 66, 67, 68 and 69, to the fuel pumping and injecting spinner 166 of the combustor means 70 and to the regenerator shell 176 of the combustor means 70 in a sequential or related manner to most effectively follow a flight program for the craft. The aircraft may, of course, be operated in accordance with various flight programs and the fuel control system may be appropriately varied or altered to provide for such operation. As herein disclosed the fuel control system is designed to effect vertical ascent from the field or ground, a climb at a flight path angle of, say, 10 degrees to about 10,000 ft. altitude, a further climb at a flight path angle of, say, 20 degrees and at increased speed to about 50,000 ft. altitude, acceleration through the transonic range of from Mach No. .83 to Mach No. 1.32 at this altitude, flight to about 100,000 ft. altitude at diminishing acceleration, level flight at a Mach No. of about 4 at the 100,000 ft. altitude and then descent and deceleration to the point of landing at the ground or field. This program is initiated by first supplying fuel to the outboard load turbines 68 and 69, the island 74 containing the ducted compressor being in its vertical or 90° position at this time, and the powerplants 68 and 69 being turned or directed to assist in the vertical lift of the aircraft and in providing whatever directional control is necessary. The air under pressure discharging from the opening 292 of the nozzle 72 assists in stabilizing the vertical ascent. The means for supplying fuel to the outboard powerplants 68 and 69 includes the abovementioned pipes 222 conveying the fuel to the combustors 213 of the powerplants 68 and 69 and valves 320 in these fuel pipes. The valves 320 are operated by solenoids 321 having energizing leads 322 extending to stationary contact strips or buses 323, see FIGURE 20. The contact strips 323 constitute elements of a variable resistance device for individually regulating the valves 320 to provide for operation of the outboard powerplants 68 and 69 at different speeds or thrust output to obtain directional control of the craft in flight. Each contact strip 323 has associated therewith a resistance 326 and two blades 324 connected to turn in unison are operable to move along the contact strips and their respective resistances. As shown in FIGURE 19, a servo motor 325 is operable to turn the blades 324. Electrical leads 327 for energizing the servo motor 325 extend to the automatic pilot 290 so that the automatic pilot is operable to regulate the powerplants 68 and 69 for directional turn and roll control of the aircraft. A manual handle 328 may be associated with the shaft of the servo motor 325 to permit manual actuation or adjustment of the blades 324. The blades 324, the contact strips 323, and the resistances 326, are related so that the blades may simultaneously contact both strips 323 so that there is little or no resistance added to the circuits of the solenoids 321. Upon turning the blades 324 in one direction one blade remains in cooperation with its respective contact strip 323 to supply full current to the solenoid 321 of the powerplant 68 but the other blade 324 is moved a greater or lesser distance along its related resistance 326 to reduce the flow of current to its related solenoid 321 and thus reduce the delivery of fuel to the powerplant 69. However, upon turning the blade 324 in the other direction one blade merely moves along its contact strip 323 to continue to deliver full current to the solenoid 321 of the fuel valve 320 for the powerplant 69 but the other blade 324 moves along its related resistance 326 to reduce the current flow to the solenoid 321 of the fuel control valve 320 for the powerplant 68 so that fuel is delivered to the powerplant 68 at a reduced rate. It will be seen that by differentially regulating the fuel consumed at the powerplants 68 and 69 with or without altering the angular positions of the powerplants effective directional control of the aircraft is obtained.

The fuel control system for the outboard load turbines or powerplants 68 and 69 further includes a pivoted or turnable contact wheel 330 having a plurality of spaced radially projecting spokes or points 331, one of which carries a contact 332 Contact 332 is cooperable with a stationary bus 335 having a resistor 334 extending from one end. A lead 336 extends from the other end of the bus 335 to the blades 324. A power line 333, a portion of which is flexible, connects with the contact 332. So long as contact 332 engages the extremity of resistor 334 little or no current is supplied to the solenoids 321. However as the wheel 330 is turned to move the contact 332 along the resistor and onto the bus 335 increased and then full current is supplied to the solenoids 321 to open the fuel valves 320 of the outboard load turbines 68 and 69. A temperature responsive control device D is interposed in lead 333 as will be later described. As the programming wheel 330 is instrumental in effecting operation of several elements of the aircraft during the flight program, I will describe the operation of the several propulsive units and other elements of the craft as the description of the programming wheel 330 and associated parts progresses.

Preparatory to taking off the fuel pipes 41 and 42 are connected with their fittings 37 and 38 so that fuel is pumped into or delivered to the fuel cells 32 with a continuous withdrawal of vapor from the cells until actual take-off. The automatic pilot 290 is operable to cause actuation of the island 74 to the vertical position where its nozzle 81 faces downwardly and to turn the powerplants 68 and 69 to have their fittings 220 discharge downwardly. With the hatches 30 closed and the flight personnel and passengers in their seats or stations, the ignitors 223 are energized and the craft is otherwise prepared for flight. The programming wheel 330 is turned to move the contact 332 along the resistor 334 and on to the bus 335 to open the fuel valves 320. The wheel 330 carries a second contact 338 connected with the power lead 333 and adapted to move along a resistor 340 and then on to a bus 341. An electrical lead 342 extends from the end of the bus 341 which is most remote from the resistor 340 to the blades 343 of a differential resistor device similar to or identical with the device 323—324—326, described above. The blades 343 are operated by a servo motor 344 connected with the automatic pilot 290 by energizing leads 345 and a manual lever 346 may also be provided to operate the contact blades 343. Leads 348 extend from the busses 347 of the differential resistance device to the solenoids 350 for operating the fuel valves 351 controlling the fuel pipes 122 supplying fuel to the combustion chambers 113 of the inboard load turbines or powerplants 66 and 67. The parts are related so that when the contact 332 of the wheel 330 moves from the resistor 334 onto the bus 335 to bring about full or substantially full power output of the outbroad powerplants 68 and 69, the contact 338 moves onto the resistor 340 to energize the solenoids 350 to crack or partially open the valves 351. The ignitors 123 are energized at this time so that

the fuel is ignited in the combustion chambers 113 to initiate idling operation of the inboard powerplants 66 and 67. As the programming wheel 330 is further advanced in the clockwise direction contact 338 moves along the resistor 340 toward the bus 341 and then moves onto the bus so as to gradually increase current flow to the solenoids 350 and therefore gradually increase the supply of fuel to the power plants 66 and 67 to full or substantially full power output. As the island 74 is in the vertical position at this time, that is at approximately 90° to the longitudinal axis of the duct 18, the discharge fittings 120 and vanes 121 of the powerplants 66 and 67 face or discharge downwardly. Thus the propulsive jets of the inboard powerplants 66 and 67 as well as those of the outboard powerplants 68 and 69 are directly downwardly to provide vertical lifting forces for lifting the craft from the ground or field.

The programming contact wheel 330 has a third contact 352 on a point 331 engageable with a resistor 353 and a bus 358 associated with the resistor. A lead 354, a portion of which is flexible, connects the contact 352 with the power line 333 through the medium of the temperature responsive control device D to be later described. A lead or wire 355 extends from the bus 358 to a motor or solenoid 356 which operates a valve 357 controlling the fuel pipe 155 supplying fuel to the fuel injecting spinner 166 associated with the ducted compressor 65. After the contact 338 of the programming wheel 330 has moved some distance along the bus 341 further turning of the wheel 330 in the clockwise direction brings the contact 352 into engagement with the resistor 353. This causes opening of the valve 357 and fuel is discharged into the island duct 79 to be ignited therein by the ignitor 175. Continued movement of the wheel 330 in the clockwise direction brings the contact 352 into cooperation with the bus 358 and the valve 357 is opened to admit substantially full volume fuel to the afterburner spinner 166 of the ducted compressor 65. As the load turbines or powerplants 66, 67, 68 and 69 are at this time in full operation they drive the ducted compressor 65 through the transmission means above described. The ducted compressor 65 serves to move a large mass of air through the island duct 79 at a substantial velocity and at high pressure and the fuel from the spinner 166 is burned downstream from the compressor to greatly increase the propulsive thrust produced by the blast or jet discharging from the island nozzle 81. This propulsive jet is directed downwardly and serves to augment the propulsive thrusts from the discharge fittings of the powerplants 66, 67, 68 and 69. The combined thrust output of the ducted compressor 65 with its afterburner, and the powerplants 66, 67, 68 and 69 is sufficient or more than sufficient to cause susbtantially vertical ascent or takeoff of the craft. Immediately upon takeoff the fuel hoses or pipes 41 and 42 are automatically disconnected from the aircraft as above described. The craft may be operated vertically a suitable distance, say 150 ft. and the landing gear 53 is retracted as the craft rises from the ground. During the vertical ascent the compressed air under pressure discharging from the opening 292 of the nozzle vane 255 serves as a pitch trimming stream or thrust jet and although not ordinarily required the blades 343 and/or the blades 324 may be operated either manually or by the automatic pilot 290 to produce differential operation of the powerplants 66 and 67 and 68 and 69 to obtain pitch differential control and turn or bank differential control respectively.

Upon reaching 150 ft. or thereabouts, the island 74 is turned by energizing the motor 162 to an angle of about 60° for a few seconds to effect a transition from vertical ascent to translational climb. The automatic pilot 290 acting through the solenoids 310 operates the switch blade 295 to bring about this turning of the island 74 and the powerplants 68 and 69 may be turned correspondingly by the action of their related switch blades 302 and 297 also actuated by the solenoids 310. The contact wheel

330 is then turned back or in the counter-clockwise direction to move the contact 352 out of engagement with the bus 258 and resistor 353 but this movement of the wheel is limited so as to retain the contacts 338 and 332 in engagement with their respective busses 341 and 335. At about the same time the island 74 is turned by energization of the motor 162 to the position where its duct 79 is aligned with the duct 18 of the body 10 and the powerplants 68 and 69 are turned by energizing their respective motors 140 to have their vanes 221 and fitting 210 face generally rearward. This is done by the pilot or the automatic pilot 290 operating the servo motors or solenoids 310 to actuate the switch blades 295, 297 and 302. With the island 74 in this position the powerplants 66 and 67 produce rearwardly directed propulsive jets and the outboard powerplants 68 and 69 also produce rearward propulsive jets. Furthermore, the ducted compressor 65 is driven by the powerplants 66 to 69 inclusive to produce a propulsive jet of compressed air which discharges rearwardly through the nozzle 72. Thus the craft is propelled forwardly at a substantial velocity, say at a speed of from 112 to 880 ft. per second, being accelerated during this initial climb. The nozzle vanes 255 and 256 actuated by the servo motor 285 as controlled in turn by the automatic pilot 290 may maintain a flight path angle of, say, 10° until an altitude of about 10,000 ft. is reached whereupon a flight path angle of about 20° is maintained until an altitude of about 50,000 ft. is reached.

In accordance with the specific flight program being described the craft is accelerated through the transonic speed range at about the 50,000 foot altitude. During flight or climb from 30,000 to 50,000 ft. the afterburner or spinner 166 of the ducted compressor 65 may be supplied with fuel by the action of the automatic pilot 290 advancing the programming wheel 330 in the clockwise direction to move the contact 352 along the resistor 353 to open the valve 357 to some extent. When the craft is to be accelerated through the transonic range, say from a Mach number of .83 to a Mach number of 1.32, the programming wheel 330 is advanced by the action of the automatic pilot 290 to move the contact 352 on to the bus 358 so that a full volume of fuel is supplied to the fuel injecting spinner 166. The resultant additional thrust obtained by the burning of this fuel in the compressed air duct downstream from the ducted compressor 65 accelerates the craft through the transonic range. The flight path angle of the craft may be 0° at this time and upon reaching supersonic velocities the flight path angle may be maintained at about 10° to an altitude of 70,000 ft. and from 70,000 to 90,000 ft. the flight path angle may be about 2° with a lesser angle being maintained up to the 100,000 foot altitude.

In accordance with the invention the speed of the load turbines or powerplants 66 to 69 inclusive, is modulated or controlled in such a manner that these engines operate at idling speeds, for example at not more than 19% of normal speed, when the craft reaches a velocity of Mach Number 4 at the 100,000 ft. altitude. With the craft operating at this velocity and altitude, it is propelled substantially entirely by a ram jet action, the fuel being burned in the main duct system 18—79 behind or downstream from the ducted compressor 65 and in the highly ram compressed air flowing through the duct system and discharging from the nozzle 72 as the main propulsive jet. The abovementioned device D constitutes the means for controlling or modulating the speed of operation of the load powerplants 66–69 inclusive. The device D is responsive to the temperature of the ram compressed air in the duct 18 downstream from the ram inlet 71. A temperature responsive device, for example a curved bi-metal thermostat element 360 is arranged in the duct downstream from the inlet 71. The element 360 is subjected to the ram air temperature and is operatively connected with a pivoted electrical conducting arm 362 by appropriate linkage 361. As noted above, the device D is interposed in the power line 333 and the pivoted end of the arm 362 is electrically connected to the portion of the line 333 extending to the power source 272. An arcuate or curved resistor 364 has one end connected with the portion of the power line 333 extending to the contacts 332 and 338 which, as above described, control current flow to the solenoids 350 and 321 for regulating fuel flow to the powerplants 66 to 69 inclusive. With a relatively low temperature prevailing in the ram inlet portion of the duct 18, say a temperature of about 120° F., the thermostat element 360 holds the arm 362 at the end of the resistor 364 adjacent the power line 333 so that there is substantially full current flow through the lead 333 to the contacts 332 and 338 and therefore to the fuel valve operating solenoids 350 and 321. As the temperature of the ram compressed air increases the arm 362 is moved outwardly along the resistor 364 by the action of the element 360 to increase the resistance in the circuits and to proportionately reduce the flow of fuel to the powerplants 66 to 69 inclusive. With the craft flying at a Mach number 4 and at approximately 100,000 ft. altitude, the temperature of the rammed air in the forward portion of the duct 18 is relatively high, being about 1100° F. At such a temperature the bi-metal element 360 will have moved the arm 362 along the resistor 364, a distance to reduce the current flow to the solenoids 321 and 350 to the extent that the powerplants 66 to 69 inclusive operate at about only 19% normal speed, in effect merely idling, with a relatively small amount of fuel being consumed in the streams of compresed air flowing through them. Under such conditions the ducted compressor 65 is windmilling or driven at a relatively low speed by the highly ram compressed air flowing through the duct 18. Further, under such conditions, the inlet ram island 202 is expanded or inflated to a condition, such as illustrated in full lines in FIGURE 12, for the most effective supersonic air admission and ram compression effect, the island 202 being operated or inflated in the manner above described.

In addition to the control or modulation by the device D, as just described, the fuel valves 321 and 351 of the powerplants 66 to 69 inclusive, are controlled by individual temperature responsive means which prevents excessive high speed operation of the powerplants during the flight or climb of the craft to the 100,000 ft. altitude and at all other times. The solenoids 321 and 350 are grounded by lines 364, see FIGURE 16. The temperature responsive device of the powerplant 68 is clearly illustrated in FIGURE 16 and will now be described, it being understood that this description is applicable to the temperature responsive devices of the other plants 66, 67 and 69. The temperature responsive control device of the powerplant 68 includes a pivoted conducting arm 365, having a portion of the ground line 364 connected therewith and extending to ground. The arm 365 is movable along a curved resistor 366 which has one end connected to the portion of the ground line 364 extending to the related solenoid 321. The arm 365 is operatively connected with a temperature responsive or thermostatic element 367 projecting into the combustion chamber 213 of the powerplant 68. The parts are related so that during operation of the powerplant at relatively low temperatures, or normal temperatures, the arm 365 remains in engagement with the inner portion of the resistor 366 to add a minimum of resistance to the circuit of the solenoid 321. As the operating temperature of the powerplant 68 increases, the element 367 moves the arm 365 outwardly along the resistor 366 to increase the resistance in the circuit of the related solenoid 321. When the operating temperature of the powerplant 68 reaches a predetermined upper limit, the arm 365 will have been moved to an outer position on the resistor 366 where the current flow through the solenoid 321 is reduced appreciably to proportionately reduce the fuel flow to the powerplant, the valve 320 in the fuel line being closed down substantially by the solenoid to reduce the fuel flow into the powerplant.

Returning now to the programming contact wheel 330, illustrated in FIGURE 20, it will be seen to have a fourth contact 368. The contact 368 is connected with the line 354 above described, and is engageable with a stationary resistor 370. A line 371 extends from an end of the resistor 370 to a solenoid 372 controlling or operating the valve 183 in the fuel line 182 which extends to the regenerator space 178 around the aft portion of the main air duct 18. The parts are related so that contact 368 engages the resistor 370 when the wheel 330 is moved in the clockwise direction with the contact 352 moving along the bus 358 of the energizing circuit for the solenoid 356 of the fuel valve 357 supplying the afterburner spinner 166. Upon the contact 368 engaging the resistor 370 the valve 183 is opened to admit the liquid fuel to the regenerator space 178 for discharge radially from the ports 184 into the main propulsive duct 18. The liquid fuel flowing forwardly through the space 178 from the pipe 182 to the ports 184 cools the walls of the duct 18 to protect them against damage by the high temperatures and the fuel is vaporized as it flows forwardly through the space to be discharged as vapor from the ports 184. It will be noted that the heat energy absorbed by the fuel as it cools the duct walls and as it is vaporized is reintroduced into the propulsive duct system thus providing a regenerative effect. In practice the contact 368 of the programming wheel 330 cooperates with the resistor 370 to open the valve 183 and thus provide for the injection of fuel vapor from the ports 184 during the latter phases of the climb of the craft to the operational altitude of 100,000 ft. and if desired this may be made to occur before or shortly after the transition to the supersonic velocity.

During the ascent and climb of the craft the fuel in the tanks or cells 32 is vaporized to some extent and provision is made to bleed the fuel vapor from the cells 32 at this time and more particularly after high speed and relatively high altitudes have been attained. This means includes a vapor pipe system or manifold 373 having communication with the upper portion of each fuel cell 32, see FIGURE 17 and FIGURE 20. The pipes 373 may extend directly to the aft portion of the regenerator space 178 and have a poppet valve 374 for each fuel tank 32. The valves 374 are set to open at a given fuel tank vapor pressure, say at 1 p.s.i. The pressure required to open the valves 374 will not ordinarily develop until the craft has climbed to a substantial altitude at which time fuel vapor discharges into the regenerator space 178 and the duct 18 to be burned with the fuel injected by the spinner 166 when the latter is in operation.

When the craft is flying at the operational altitude there may be a tendency for the flight velocity to exceed the design air speed of four times the speed of sound, particularly if the airplane has been in flight for some period of time, and has therefore decreased in total weight. An operation speed substantially exceeding the exemplary design speed of four times the speed of sound would decrease the total range and would cause the skin temperature to rise above design limits. Although the nozzle vanes 255 and 256 will be actuated to the air brake positions N under circumstances exceeding the placard speed of 450 knots indicated (for gust protection) by the action of the Pitot tubes 280 and relays 282 to retard the flight speed during descent, it is desirable to first reduce the fuel consumption at the combustor means 70 so that the nozzle vanes, acting as air brakes will never be obliged to absorb the excessive thrust energy produced by the propulsive system. To this end the above described device D incorporates means for reducing the fuel delivery to the spinner 166 and regenerator ports 184 under such circumstances. The above described contacts 352 and 368 of the programming wheel 330 are supplied with power by a lead 376, a portion of which is flexible to permit rotation of the wheel. The line 376 extends to a bus 377 which is concentric with the resistor 364 of the device D. The outer end of the bus 377 has a resistor 378 extending therefrom and the pivoted arm of the device D has a slider or contact 379 engaging and movable along the bus and resistor. When the temperature of the ram compressed air in the forward portion of the duct 18 exceeds the temperature that should prevail at the maximum air speed at the operational altitude (100,000 ft.), the thermostatic element 360 moves the arm 362 to the position where the contact 379 engages the resistor 378. This introduces substantially increased resistance in the circuits of the solenoids 356 and 372 which respectively control the fuel valves 357 and 183 of the fuel injecting spinner 166 and regenerator 178. This increased resistance causes the valves 357 and 183 to be closed down sufficiently to reduce the propulsive thrust to the extent that the flight velocity is retarded to the desired limit or speed. When the ram air temperature returns to the normal value the contact 379 moves back onto the bus 377 and the valves 357 and 183 are opened wider.

During the flight or climb to the operational altitude of about 100,000 ft. and during the translational flight at this altitude, the nozzle vanes 255 and 256 are operated to provide the required pitch control and the powerplants 68 and 69 are turned and/or operated at differential speeds to produce turning and banking or directional control, the automatic pilot 290 actuating the related servo motors, etc. to effect actuation of these and the other controls to direct the flight of the craft, all as above described. In event of over-speeding of the craft the Pitot tubes 280 and the related air relays 282 serve to actuate the jacks 266 to move the nozzle vanes 255 and 256 to the air brake positions N, the device D serving to modulate the propulsive fuel supply in the event of any sustained over-speeding, as described above. The nozzle vanes 255 and 256 of the propulsive nozzle 72 are automatically moved or actuated by the screw-jacks 266 as controlled by the diaphragms 268 and switches 270—273—274 which, in turn, are responsive to the marginal shock wave pressures of the jet as received by the Pitot tubes 276, the vanes 255 and 256 being at all times actuated to the positions where they most efficiently discharge the subsonic and supersonic jet, as the case may be. During the flight the compressed air bled from the lateral ducts 130 by the pipes 188 passes through the intercoolers 187 and discharges into the passenger compartments 20, 25 and 27 to maintain comfortable air temperature and air pressure conditions in the compartments. The low boiling point fuel is circulated through the intercoolers 187 under the control of the thermostats 193 and the valves 192 to cool the cabin pressurizing air.

When the craft approaches its destination the automatic pilot 290 actuates the programming contact wheel 330 in the counterclockwise direction to a position where the delivery of fuel to the fuel injecting spinner 166 and the regenerator space 178 is terminated, and where the contacts 334 and 338 cooperate with their respective resistors 334 and 340 to provide for the limited delivery of fuel to the powerplants 66 to 69 inclusive. The propulsive nozzle vanes 255 and 256 and the outboard powerplants 68 and 69 are moved or directed by the action of the automatic pilot 290, as above described, to nose the aircraft down and to land the same. During the descent the powerplants 68 and 69 are operated at just sufficient speeds to obtain the required directional and trimming control and the ducted compressor 65 is idle, merely windmilling in the rammed air flowing through the duct 18. The nozzle vanes 255 and 256 may move to their dive-brake or air brake positions N to retard the descent. The craft may, if desired, be landed in much the same way as a conventional aircraft so as to make a generally horizontal approach to the field and the actual touchdown or landing while moving forwardly. However, it is preferred, in order to economize on fuel and save time, to effect a vertical landing. This is done by moving the island 74 to the vertical position where the nozzle 81 faces downwardly and swinging the powerplants 68 and 69 to positions where their discharge fittings or nozzles 220 face downwardly. Fuel is supplied to the spinner 166 and to the powerplants 68 and 69 in sufficient volumes to provide a considerable aggregate upward thrust so that the craft may be landed vertically slowly while in the horizontal attitude, the programming wheel 330 being operated by the automatic pilot 290 or by flight personnel to obtain this action. The landing gear 53 is extended to engage the field at the touchdown and to thereafter support the aircraft on the field and the propulsive system is shut down to terminate the flight.

FIGURES 21, 22 and 23 illustrate another aircraft of the invention characterized by a turbo-propeller powerplant 400 serving as the primary propulsive means. In this aircraft the body 10, the duct 18, the ram inlet 71, the propulsive nozzle 72, the regenerator means 176—178—184, the control systems and various other parts may be the same as above described. The central island 474 is substantially the same as the island 74 of the previously described aircraft except that it is shaped and proportioned to conform with and contain the powerplant 400. The island 474 is arranged to be turned or pivoted on the spanwise axis of the body 10 in the same manner as the island 74. The trunnions 482 for pivotally supporting the island 474 are tubular to supply compressed air from the powerplant 400 to lateral ducts 430 which carry it to outboard directional nozzles 420. These nozzles 420, which turn or move in curved slots 401 in the periphery of the body 10, are rotated or pivoted by reversible electric motors 440 driving pinions 437 which mesh with racks or gears 438 fixed on the nozzles. The motors 440 may be controlled in the same manner as the motors 140 described above to produce turning and banking of the aircraft. It will be seen that operation of the motors 440 serve to swing the nozzles 420 to various positions, the nozzles being adapted to be directed upwardly, downwardly and rearwardly.

Provision is made to burn fuel in the compressed air streams immediately ahead of the directional nozzles 420. The outboard ends of the ducts 430 are enlarged to form combustion chambers 402 and fuel injectors 403 discharge fuel into these chambers, see FIGURE 23. Ignitors 473 are provided to ignite the fuel in the chambers. Fuel pipes 422 corresponding to the above described pipes 222 carry the fuel to the injectors 403. The nozzles 420 are operable to discharge propulsive and directional jets of high temperature compressed air and the gases of combustion.

The powerplant 400 may be the same as the powerplant disclosed in my earlier Patents 2,563,270, granted August 7, 1951, and 2,575,682, granted November 20, 1951. The powerplant 400 has a streamlined rather bulbous casing 410 provided at its forward end with an air inlet 411 and at its rear end with a variable area nozzle 412. The island 474 is shaped to conform with the casing 410, receiving the same with substantial clearance to leave an annular duct 413 around the casing. As described in the above identified patent, the powerplant 400 has a compressor means 414, a combustion chamber 415, and turbine stages 416 all contained within the casing 410. The turbine stages 416 drive the compressor means 414 and a propeller 417 positioned ahead of the casing. The gases of combustion and the residual compressed air discharge from the nozzle 412 as a propulsive jet, this jet flowing rearwardly through the duct 18 to issue from the propulsive and directional nozzle 72. The powerplant nozzle 412 is temperature and pressure responsive to automatically discharge the most efficient jet under the various operating conditions of the powerplant. The compressor or propeller 417 is ducted, operating in the duct 413 which is shaped to have a rearwardly convergent-divergent throat in the region of the propeller. The propeller 417 serves to compress the air in the duct 413 to supercharge the compressor means 414 of the powerplant 400 and to increase the pressure of the air discharging through the duct 413, duct 18, and nozzle 72. During translational flight the rammed air received by the ram inlet 71 and flowing through the duct 18 is further compressed by the propeller 417 to flow around and through the powerplant 400 and the powerplant provides a high temperature high velocity jet which, together with the compressed air, discharges through the duct 18 and nozzle 72 to form the primary propulsive jet of the craft. The vaporized fuel discharging from the ports 184 provides augmented or additional thrust and the compressed air bled from the compressor means 414 of the powerplant 400 through struts 419 and the ducts 430 is reheated and discharged from the outboard nozzles 420 to provide additional propulsive thrust. For vertical ascent and descent the island 474 is turned to the vertical position where the nozzle 412 and the rearwardly convergent end of the duct 413 faces downwardly and the outboard nozzles 420 are likewise turned to face downwardly to provide the upward or lifting thrusts.

The aircraft of the invention illustrated in FIGURES 25 and 26 is characterized by two or more turbo-jet powerplants 500 in the central pivoted island 574 driving ducted propellers or compressors 565 and constituting the primary propulsive means of the aircraft. The body 10, the duct 18, the ram inlet 71, the propulsive and directional nozzle means 72, the regenerator 178, the control system and the various other elements may be the same as described above. The plurality of powerplants 500, serves to drive a pair of counter-rotating fans or compressors 656 operating in the duct 579 of the pivoted island 574. The powerplants 500, the operative relationship between the powerplants, the compressors or propellers 565 and the drives between the powerplants and the propellers for driving the latter may be the same as disclosed in Patent 2,613,749 granted to me October 14, 1952. As in the other forms of the present invention the island 574 is pivotally supported by tubular trunnions 582 to turn about a spanwise axis. The trunnions 582 receive compressed air from pipes 502 extending from the compressors of the powerplants 500 and supply this compressed air to spanwise ducts 530 extending to the outboard peripheral regions of the body 10 where they communicate with the propulsive and directional discharge nozzles 420, already described. In this case, if desired, the combustion chambers 402 may be omitted from the outboard nozzle assemblies. The powerplants 500 are each self-contained turbo-jet engines including compressors receiving the rammed compressed air from the island duct 579, combustion chambers, turbines, and exhaust nozzles 512. The turbine stages of the powerplants 500 drive the compressor stages of the powerplants and also drive forwardly extending shafts 503 which extend to a gear box 504 at the propellers or compressors 565. The gear box 504 provides for the counter-rotation of the compressors 565. All of these elements are described in Patent 2,613,749. The counter-rotating compressors 565 operating in the island duct 579 to further compress the rammed compressed air flowing therethrough, supercharge the powerplants 500 and provide an effective propulsive stream which discharges from the nozzle 72. The jets of high velocity, high temperature gases and air discharging from the nozzles 512 of the powerplants 500 augment this propulsive stream and the fuel vapor injected at the ports 184 and burned downstream from the nozzles 512, further augments the propulsive effect for translational flight of the aircraft. The aft portion of the island duct 579 has a rearwardly convergent nozzle 581. For vertical ascent and descent the island 574 is turned to the vertical position where the nozzle 581 faces downwardly and the outboard nozzles 420 are likewise directed downwardly so that the propulsive jets issuing from the island duct 579 and the nozzles 420 provide the necessary upward thrust for vertical rising and controlled vertical descent of the craft.

It will be observed in the aircraft illustrated in FIGURES 21 to 26 inclusive, the ducted compressors **417** and **565** are driven by turbo powerplants contained within the central pivoted island and that the above described inboard and outboard load turbo powerplants **66** to **69** inclusive, may be dispensed with. Furthermore, in the aircraft shown in FIGURES 21 to 26 the propulsive jets issuing from the discharge nozzles **412** and **512** of the powerplants augment the main propulsive stream of compressed air flowing through the central duct **18** and issuing from the propulsive and directional nozzle **72**. The compressors **417** and **565** serve to supercharge and supplement the compressors of their respective powerplants **400** and **500**. In certain installations or aircraft these compressors **417** and/or **565** may either be omitted or operated within the casings of the powerplants **400** and **500** providing pure turbo-jet engines within the diametric propulsive ram jet duct system.

Having described only typical forms of the invention I do not wish to be limited to the specific details herein set forth, but wish to reserve to myself any variations or modifications that may appear to those skilled in the art and fall within the scope of the followings claims.

I claim:

1. In a vertical rising aircraft, an aircraft body having a propulsive air duct extending fore and aft therethrough and having a vertical opening intersecting the duct, an island in the opening comprising a shell and a duct extending therethrough, means supporting the island on the body for movement in said opening between a first position where the island duct is in registration with the air duct to constitute an operative portion thereof and a second position where the island duct is vertical and substantially normal to the air duct with its upper end in communication with the atmosphere at the upper side of the body and with its lower end discharging into the atmosphere at the under side of the body, the shell including upper and lower walls which are substantially flush with the upper and lower sides of the body when the island is in said first position, propulsive means in the island duct for producing a high velocity propulsive airflow therethrough, and means for moving the island to the vertical position where the propulsive means creates a downwardly directed propulsive stream for exerting a lifting thrust to raise the craft.

2. In a vertical rising aircraft, an aircraft body having a propulsive air duct extending fore and aft therethrough and having a vertical opening intersecting the duct, a generally rectangular island in the opening having side walls conforming to the walls of said vertical opening, upper and lower walls, spaced ends and a duct adapted to register with the air duct and extending between said ends, means supporting the island on the body for movement in the opening about a spanwise axis between a first position where the island duct is in registration with the air duct to form an operative part thereof and a second position where the island duct is vertical with its upper end in communication with the atmosphere at the upper side of the body and with its lower end discharging into the atmosphere at the under side of the body, said upper and lower walls being generally flush with the upper and lower sides of the body when the island is in said first position, and propulsion means in the island duct for producing a high velocity and high temperature air and gas stream through the island duct to create a lifting thrust when the island is in the second position and a forward thrust when the island is in the first position.

3. In a vertical rising aircraft, an aircraft body having a propulsive main duct extending fore and aft therethrough and having a vertical opening intersecting the duct, an island in the opening having a duct adapted to register with the main duct, means supporting the island for movement in the opening about a spanwise axis between a first position where the island duct is aligned with the main duct and a second position where the island duct is vertical, a propulsive nozzle at the aft end of the main duct, propulsive means in the island for producing a propulsive stream of air and gases through the island duct to exert a lifting force when the island is in the second position and to provide a propelling jet discharging from the nozzle when the island is in the first position, powerplant means carried by the aircraft body, and drive means operatively connecting the powerplant means with the propulsive means to drive the same.

4. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening, the island including a shell structure having spaced sides conforming to the fore and aft walls of the vertical opening, upper and lower walls and spaced ends and a duct extending through said structure to have its opposite ends at said ends of the structure, the island duct being adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream, means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight, and parts on the main duct and the opposite ends of island duct cooperating to prevent the loss of said stream when the island is in the second named position.

5. An aircraft comprising an aircraft body having a main propulsive duct extending therethrough in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct extending therethrough adapted to register with the main duct so that the two ducts together constitute a through fore and aft passage in the body, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream, at least one turbo engine in the island at the exterior of the island duct for driving said compressing means, and means for pivoting the island to a vertical position where the island duct is out of register with the main duct and discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct is in register with the main duct to direct said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight.

6. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high propulsive gas stream comprising a compressor in the island duct and afterburner means downstream from the compressor, powerplant means carried by the island externally of the island duct for driving the compressor, and means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct

discharges said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight.

7. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct extending therethrough adapted to register with the main duct so that the two ducts together constitute a through fore and aft passage in the body, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream, means for pivoting the island in the opening to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct registers with and in effect forms a part of the main duct to discharge said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight, and means for injecting the burning fuel in the main duct downstream from the opening when the island is in the last named position.

8. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream comprising a compressor operating in the island duct, and afterburner means in the island duct downstream from the compressor, at least one gas turbine powerplant on the island external of the island duct for driving the compressor, and means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight.

9. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream comprising a compressor operating in the island duct, and afterburner means in the island duct downstream from the compressor, turbo-jet engines on the upper and lower sides of the island having propulsive nozzles facing aft when the island duct is in register with the main duct, driving connections between the engines and the compressor, and means for pivoting the island to a vertical position where nozzles of said engines and the island duct discharge downwardly from the underside of the body to exert lifting thrusts to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle and where the nozzles of said engines discharge rearwardly to provide forward thrusts for translational flight.

10. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high propulsive gas stream comprising a compressor in the island duct, afterburner means downstream from the compressor, a discharge nozzle for said duct of the island, and powerplant means external of the island duct for driving the compressor, and means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight.

11. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream, said means including a compressor operable in the island duct, and afterburner means downstream from the compressor, turbo-jet engines on the body outboard from the island for driving the compressor and having propulsive nozzles adapted to discharge rearwardly, and means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight, and means for injecting and burning fuel in the main duct downstream from the opening when the island is in the last named position.

12. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream comprising a compressor operating in the island duct, and afterburner means in the island duct downstream from the compressor, at least one gas turbine powerplant on the island for driving the compressor, means for bleeding compressed air from the island duct to said powerplant to supercharge the same, and means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight.

13. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct and extending between the upper and lower sides of the body, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a through duct adapted to register with

the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream, said means including a compressor operable in the island duct, and afterburner means downstream from the compressor, power plant means, the body remote from the propulsive duct for driving the compressor and having propulsive discharge nozzles, and means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight.

14. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream, said means including a compressor operable in the island duct, and afterburner means downstream from the compressor, turbo-jet engines on the outboard extremities of the body for driving the compressor and having propulsive discharge nozzles, means for bleeding compressed air from the compressor to said engines to supercharge the same, and means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight.

15. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, a compressor in the island duct for compressing the air flowing therethrough to create a high velocity propulsive stream, turbojet engines on the outboard extremities of the body for driving the compressor and having propulsive discharge nozzles, means for operating the engines to provide differential thrusts to effect directional control of the craft and means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight, and means for injecting and burning fuel in the main duct downstream from the opening when the island is in the last named position.

16. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream, said means including a compressor operable in the island duct and afterburner means downstream from the compressor, means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle to propel the craft forwardly, said nozzle including vane means movable to direct the discharging jet upwardly and downwardly to obtain pitch control, turbo-jet engines on the outboard regions of the body for driving the compressor and having propulsive discharge nozzles, and means for operating the engines at differential thrusts to produce directional control of the craft.

17. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream, said means including a compressor operable in the island duct and afterburner means downstream from the compressor, means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle to propel the craft forwardly, said nozzle including vane means movable to direct the discharging jet upwardly and downwardly to obtain pitch control, turbo-jet engines on the outboard regions of the body for driving the compressor and having propulsive discharge nozzles directed aft, the engines being turnable about an axis extending spanwise of the body to change the direction of their nozzles, means for turning the engines to alter the positions of the engine nozzles, and means for operating the engines at differential thrusts to obtain direction control of the craft.

18. In a vertical rising aircraft, an aircraft body having a propulsive main duct extending fore and aft therethrough and having a vertical opening intersecting the duct, an island in the opening having a duct adapted to register with the main duct, means supporting the island on the body for movement in said opening about a spanwise axis between a first position where the island duct is aligned with the main duct and a second position where the island duct is vertical, a ram inlet for the forward end of the main duct, a propulsive nozzle for the aft end of the main duct, means in the island duct for producing a propulsive stream of air and gases in the ducts for discharge from the lower end of the island when the island is in said second position and to discharge from said nozzle to constitute a propulsive jet when the island is in said first position, and power producing means external of said main and island ducts for driving the last named means.

19. In a vertical rising aircraft, an aircraft body having a propulsive main duct extending fore and aft therethrough and having a vertical opening intersecting the duct, an island in the opening having a duct adapted to register with the main duct, means supporting the island on the body for movement in the opening about a spanwise axis between a first position where the island duct is aligned with the main duct and a second position where the island duct is vertical, a variable area ram inlet for the forward end of the main duct, means responsive to aerodynamic conditions in the ram inlet for varying the area of the same, a propulsive nozzle for the aft end of the main duct, means in the island duct for producing a propulsive stream of air and gases in the island duct for discharge from the lower end of the island when the island is in said second position and to discharge from said nozzle to constitute a propulsive jet when the

island is in said first position, and power producing means external of said main and island ducts for driving the last named means.

20. In a vertical rising aircraft, an aircraft body having a propulsive main duct extending fore and aft therethrough and having a vertical opening intersecting the duct, an island in the opening having a duct adapted to register with the main duct, means supporting the island on the body for movement about a spanwise axis between a first position where the island duct is aligned with the main duct and a second position where the island duct is vertical, a ram inlet for the forward end of the main duct, a variable area propulsive nozzle for the aft end of the main duct, means responsive to the position of the marginal shock waves of the stream discharging from the nozzle for varying the area of the nozzle, means in the island duct for producing a propulsive stream of air and gases in the ducts for discharge from the lower end of the island when the island is in said second position and to discharge from said nozzle to constitute a propulsive jet when the island is in said first position, and power producing means external of said main and island ducts for driving the last named means.

21. An aircraft comprising an aircraft body having a main propulsive duct extending therethrough in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream comprising at least one turbo engine in the island, propulsive nozzles at the outboard regions of the body, ducts bleeding compressed air from said means to said nozzles for discharge therefrom, fuel burning means at said nozzles for adding heat energy to the air discharged therefrom, and means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight.

22. An aircraft comprising an aircraft body having a main propulsive duct extending therethrough in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream comprising at least one turbo engine in the island, propulsive directional control nozzles movably mounted at outboard regions of the body, ducts bleeding compressed air from said means to said nozzles for discharge therefrom, fuel burning means at the nozzles for adding heat energy to the air discharging therefrom, and means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flights.

23. In a vertical rising aircraft, an aircraft body having a propulsive main duct extending fore and aft therethrough and having a vertical opening intersecting the duct, an island in the opening having a duct adapted to register with the main duct, means supporting the island on the body for movement about a spanwise axis between a first position where the island duct is aligned with the main duct and a second position where the island duct is vertical, including tubular trunnions, a propulsive nozzle at the aft end of the main duct, propulsion means in the island for adding propulsive energy to the air stream flowing therethrough to exert a lifting force when the island is in the second position and a propelling jet at the nozzle when the island is in the first position, outboard propulsive nozzles on the body, and means including said tubular trunnions for bleeding compressed air from the island to said nozzles for discharge therefrom.

24. An aircraft comprising an aircraft body having a main propulsive duct extending through it in the fore and aft direction and having a vertical opening intersecting the duct, a ram inlet at the forward end of the main duct, a propulsive nozzle at the aft end of the main duct, an island pivotally supported in the opening and having a duct adapted to register with the main duct, means in the island duct for compressing the air flowing therethrough and for supplying heat energy to the compressed air to create a high velocity high temperature propulsive gas stream comprising a plurality of turbo engines in the island duct and compressor means in the island duct driven by said engines, and means for pivoting the island to a vertical position where the island duct discharges said stream downwardly from the underside of the body to exert a lifting thrust to lift the body vertically and then to a position where the island duct discharges said stream rearwardly through the main duct to discharge from the nozzle and provide a forward thrust for translational flight.

25. In a vertical rising aircraft, an aircraft body having a propulsive main duct extending fore and aft therethrough and having a vertical opening intersecting the duct, an island in the opening having a duct adapted to register with the main duct, means supporting the island on the body for movement about a spanwise axis between a first position where the island duct is aligned with the main duct and a second position where the island duct is vertical, a propulsive nozzle at the aft end of the main duct including a plurality of pivoted vanes, and means responsive to the positions of the jet stream for moving the vanes between positions where they define a rearwardly convergent passage for subsonic flow operations and positions where they define a rearwardly convergent-divergent passage for supersonic flow operations, and propulsive means in the island for producing a propulsive stream of air and gases through the island duct to exert a lifting force when the island is in the second position and to provide a propelling jet discharging from the nozzle when the island is in the first position.

26. In a vertical rising aircraft, an aircraft body having a propulsive main duct extending fore and aft therethrough and having a vertical opening intersecting the duct, an island in the opening having a duct adapted to register with the main duct, means supporting the island on the body for movement about a spanwise axis between a first position where the island duct is aligned with the main duct and a second position where the island duct is vertical, a propulsive nozzle at the aft end of the main duct including a plurality of pivotal vanes, at least one vane being hollow and having a discharge opening facing aft, and means for pivoting the vanes to vary the effective area of the nozzle, means for bleeding compressed air from the island to said hollow vane for discharge from said opening thereof to provide a pitch-trimming jet, and propulsive means in the island for producing a propulsive stream of air and gases through the island duct to exert a propelling jet discharging from the nozzle when the island is in the first position.

27. In a vertical rising aircraft, an aircraft body having a propulsive main duct extending fore and aft therethrough and having a vertical opening intersecting the duct, an island in the opening having a duct adapted to

register with the main duct, means supporting the island on the body for movement about a spanwise axis between a first position where the island duct is aligned with the main duct and a second position where the island duct is vertical, a propulsive nozzle at the aft end of the main duct including a plurality of pivoted vanes, means for pivoting the vanes to define a rearwardly convergent passage for subsonic propulsive flow and a rearwardly convergent passage for supersonic propulsive jet flow, and means for moving the vanes to positions where they project into the slip stream around the body to act as air brakes.

28. In a vertical rising aircraft, an aircraft body having a propulsive main duct extending fore and aft therethrough and having a vertical opening intersecting the duct, an island in the opening having a duct adapted to register with the main duct, means supporting the island on the body for movement about a spanwise axis between a first position where the island duct is aligned with the main duct and a second position where the island duct is vertical, a propulsive nozzle at the aft end of the main duct including a plurality of pivoted vanes, means for pivoting the vanes to define a rearwardly convergent passage for subsonic propulsive flow and a rearwardly convergent-divergent passage for supersonic propulsive jet flow, means responsive to the positions of the margins of the jet streams leaving the vanes for controlling the vane pivoting means, and means responsive to the velocity of the relative air flow past the body operable to control the vane pivoting means to project the vanes into the slip stream to serve as air brakes.

29. An aircraft including a body having a fore and aft propulsive duct and a vertical opening intersecting the duct, an island in the opening having a passage, means for supporting the island for movement between a first position where the passage registers with the duct and a second position where the passage is vertical and discharges from the underside of the body, a compressor in the passage, fuel injecting means in the passage downstream from the compressor, turbo powerplants for driving the compressor and having fuel combustors, a fuel system for supplying fuel to the injecting means and combustors, and programming means controlling said system to supply fuel to the injecting means and combustors when the island is in the first position to effect vertical ascent and when the island is in the second position to accelerate to near sonic speeds and to reduce fuel flow to the combustors to bring the powerplants to idling speeds when the craft is operating at supersonic speeds.

References Cited in the file of this patent

UNITED STATES PATENTS

1,585,281	Craddock	May 18, 1926
1,957,896	Marguglio	May 8, 1934
2,316,751	Adler	Apr. 20, 1943
2,374,075	Bunevich	Apr. 17, 1945
2,384,296	Gluhareff	Sept. 4, 1945
2,402,358	Bauman	June 18, 1946
2,463,352	Broluska	Mar. 1, 1949
2,479,991	Wood	Aug. 23, 1949
2,481,600	Knox	Sept. 13, 1949
2,540,594	Price	Feb. 6, 1951
2,552,359	Winslow	May 8, 1951
2,623,721	Harrington	Dec. 30, 1952
2,632,295	Price	Mar. 24, 1953
2,634,578	Kallal	Apr. 14, 1953
2,637,513	Wallen	May 5, 1953
2,644,315	Jamieson	July 7, 1953
2,677,931	Prieto	May 11, 1954

FOREIGN PATENTS

607,686	Great Britain	Sept. 3, 1948

March 3, 1964 E. E. SLAUGHTER 3,123,320

VERTICAL RISE AIRCRAFT

Filed Oct. 22, 1962 3 Sheets-Sheet 1

Fig. 1.

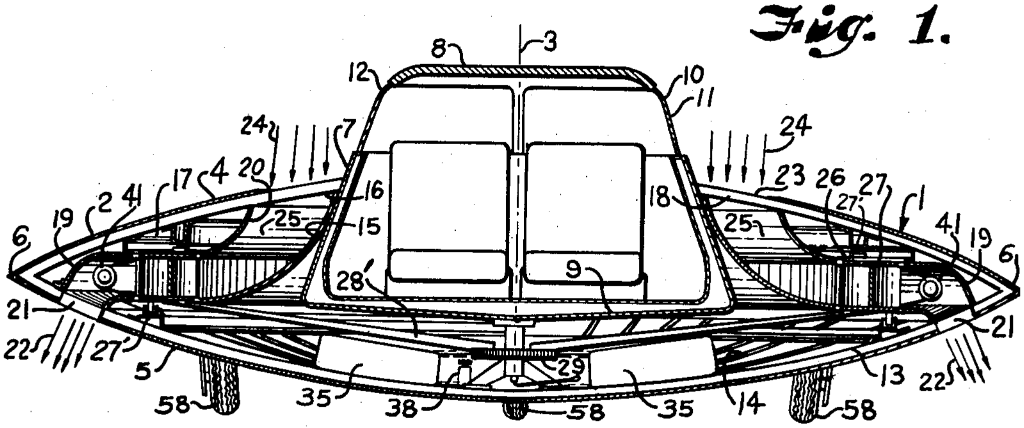
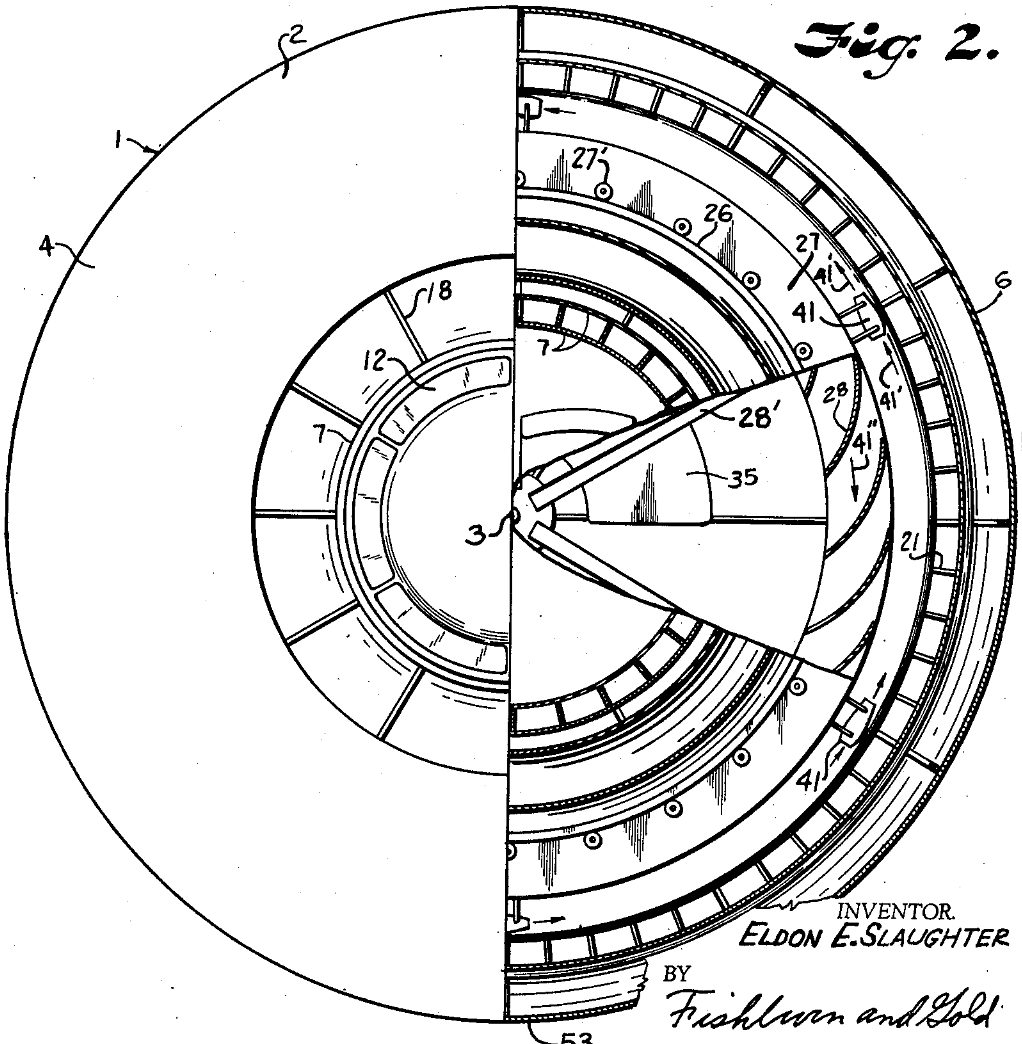


Fig. 2.



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VERTICAL RISE AIRCRAFT
Filed Oct. 22, 1962
3 Sheets-Sheet 2

Fig. 8.

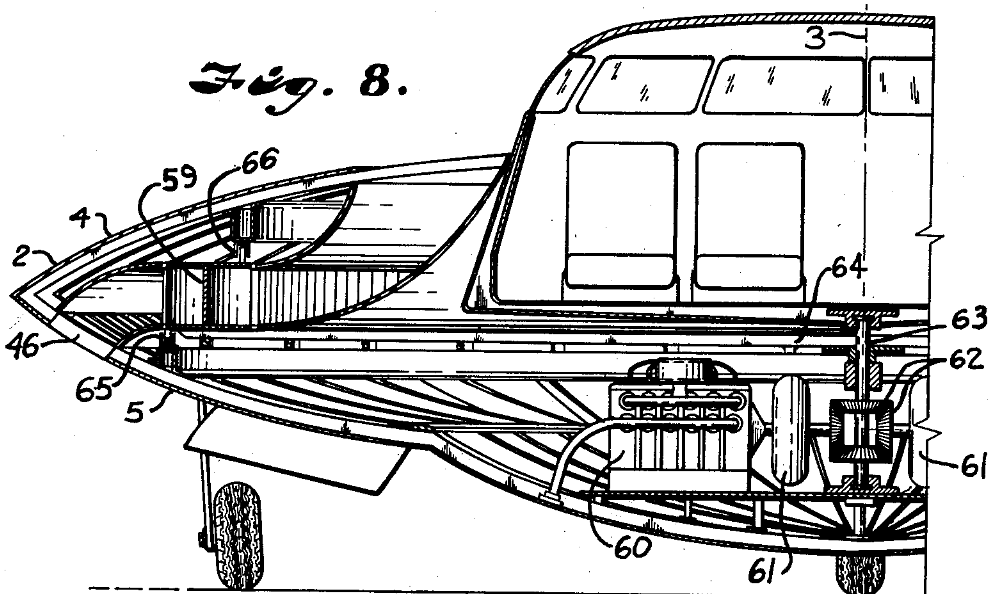

Fig. 4.

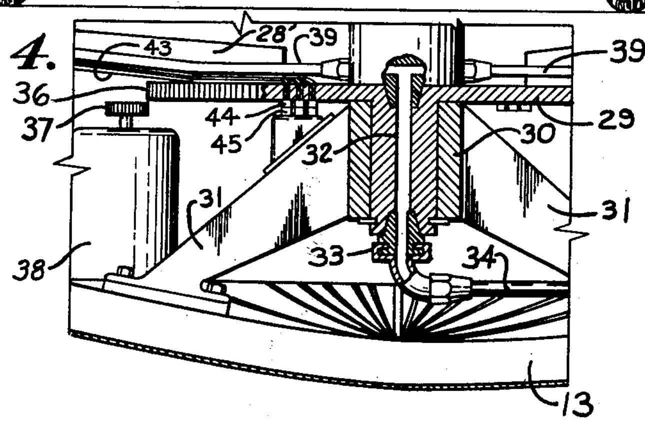

Fig. 3.

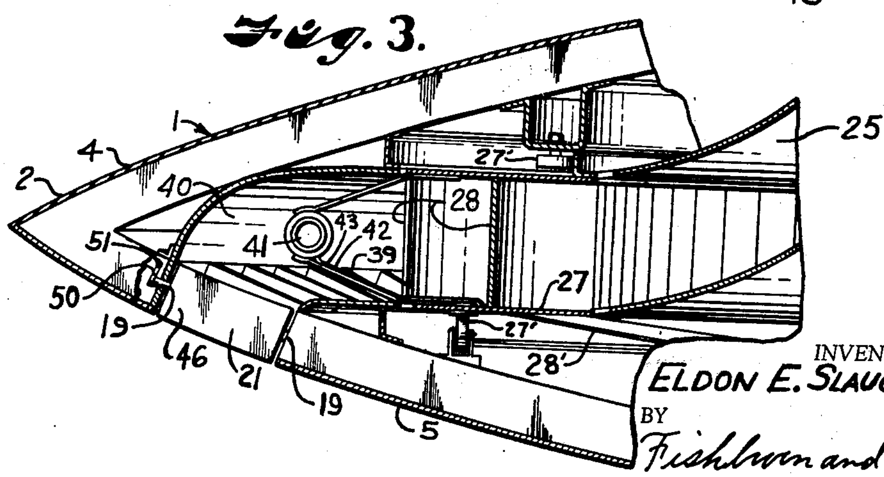

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Fig. 9.

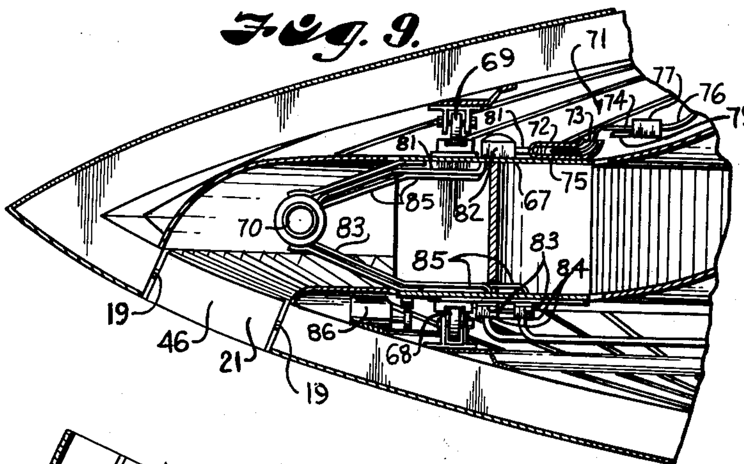


Fig. 10.

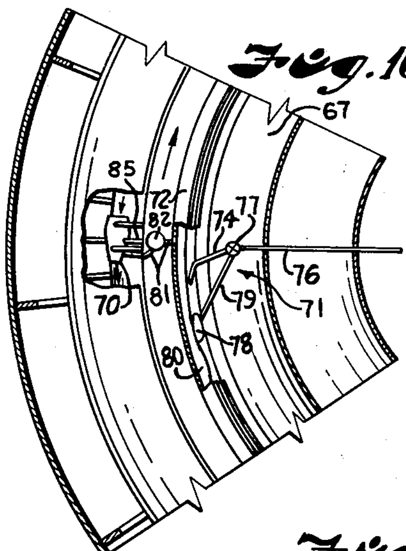


Fig. 5.

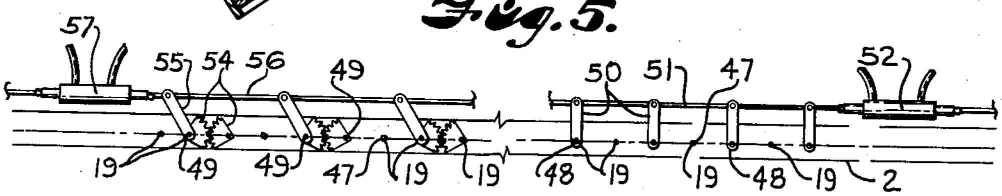


Fig. 6.

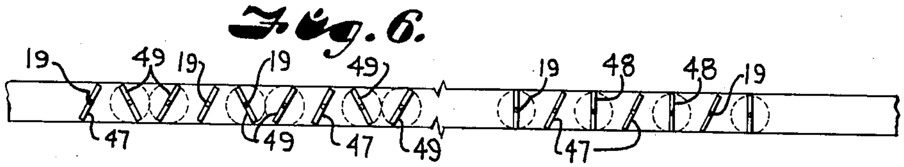
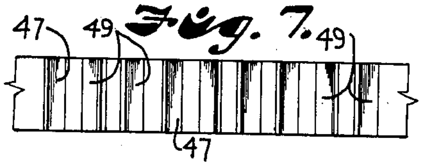


Fig. 7.



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VERTICAL RISE AIRCRAFT

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6 Claims. (Cl. 244—12)

This invention relates to heavier-than-air aircraft and more particularly to aircraft of the type having an enclosed centrifugal blower which discharges air downwardly from a radial slot substantially surrounding the aircraft for developing an upward thrust.

The principal objects of the present invention are: to provide a disk-like aircraft which is substantially symmetrical about a vertical axis and requires no external movable flow control surfaces; to provide such an aircraft wherein the upper and lower surfaces thereof are substantially convex in shape presenting a bi-convex airfoil for producing a lifting component in lateral flight; to provide such an aircraft having a windowed passenger and control compartment conveniently located centrally thereof and protruding upwardly therefrom; to provide such an aircraft having an annular intake slot adjacent the passenger and control compartment and an annular discharge slot on the lower surface thereof and including a radial passageway between said intake and discharge slots; to provide such an aircraft wherein a centrifugal blower is rotatably mounted therein which blower has circumferentially spaced air slinging blades rotatable in a radial passageway for centrifugally slinging air from an intake slot toward a discharge slot; to provide such an aircraft wherein a pressure ring duct is formed in the passageway between the blower blades and the discharge slot and a plurality of ram-jet engines are mounted for rotation with said duct; to provide such an aircraft having a plurality of vanes mounted in the discharge slot and forming various control sets to produce individual control functions; to provide such an aircraft wherein the centrifugal blower may be driven through a central shaft or in absence of a central shaft, and to provide such an aircraft which is simple in construction, presents a high cargo-to-dead-weight ratio and is adapted to hover with ease though capable of developing high lateral speeds.

Other objects and advantages of this invention will become apparent from the following description taken in connection with the accompanying drawings wherein are set forth by way of illustration and example certain embodiments of this invention.

FIG. 1 is a vertical cross sectional view through an aircraft embodying this invention showing the relationship of parts therewithin.

FIG. 2 is a top view of the aircraft of FIG. 1 with a portion broken away particularly showing a centrifugal blower rotor and a discharge slot.

FIG. 3 is a fragmentary vertical cross sectional view on an enlarged scale particularly showing one of several ram-jet engines fixed to the blower rotor within the aircraft.

FIG. 4 is a fragmentary vertical cross sectional view on an enlarged scale particularly showing structure for feeding fuel to the ram-jet engines.

FIGS. 5, 6 and 7 are schematic representations of control vanes mounted in the annular discharge slot and the angle controlling mechanism therefore.

FIG. 8 is a fragmentary vertical cross sectional view through another embodiment of this invention which has a centrifugal blower rotor driven through a central shaft.

FIG. 9 is a fragmentary vertical cross sectional view through a still further embodiment of this invention wherein the centrifugal blower rotor has no central support.

FIG. 10 is a fragmentary cross sectional top view on

a reduced scale of the embodiment of FIG. 9 showing details of the fuel feeding system therefor.

Referring to the drawings in more detail:

The reference numeral 1 generally indicates one form of a heavier-than-air aircraft embodying this invention. The aircraft 1 is comprised of a disk-like structure 2 which is substantially symmetrical about a vertical axis 3. The disk-like structure 2 presents an upper surface 4 and a lower surface 5 which unite at an outer sharp peripheral edge 6. The upper and lower surfaces 4 and 5 are substantially convex in shape whereby a bi-convex airfoil is presented to the atmosphere during lateral motion of the structure 2, which airfoil is adapted to provide a lifting component in the manner of conventional winged aircraft.

Generally conically shaped side walls 7, a top wall 8 and a bottom wall 9 together form a passenger and control compartment 10 located centrally of the structure 2 and protruding upwardly from the center thereof at 11. Suitable windows 12 are located in circumferentially spaced relation on the side walls 7 above the upper surface 4 presenting a substantially unobstructed view in a horizontal direction 360° about the aircraft.

A lower stator construction 13 includes suitable struts 14, material forming the lower surface 5 and an inner curved wall 15. The lower stator construction 13 supports the walls forming the compartment 10. The inner curved wall 15 terminates adjacent to the inner periphery 16 thereof in contact with the compartment side walls 7. An upper stator construction 17 is fixed to and supported on the lower stator construction 13 by means of suitable radial struts 18 and the supporting shafts or members 19 of certain discharge directing vanes described more fully hereinafter. The upper stator construction 17 is maintained spaced generally upwardly and radially outwardly of the lower stator construction 13 and has an inner curved wall 20 spaced outwardly of the lower stator inner curved wall 15.

The separation between the lower stator construction 13 and upper stator construction 17 produces an annular discharge slot 21 therebetween near the outer peripheral edge 6 but spaced downwardly therefrom. The discharge slot 21 interrupts the lower surface 5 for ejecting gases downwardly and conically outwardly from the structure 2 at high velocity as indicated by the arrows at 22. The upper stator construction is spaced radially outwardly from the compartment 10 forming an annular intake slot 23 therebetween at the upper surface 4 and surrounding the compartment 10. It is noted that the radial struts 18 extend across the annular intake slots 23 and the vane supporting members 19 extend across the annular discharge 21. As described more fully below, air is directed into the annular intake slot 23 as shown by the arrows at 24.

A radial passageway 25 is formed between the upper and lower stator constructions bounded by the respective curved inner walls 20 and 15 and the passageway 25 communicates between the intake slot 23 and the discharge slot 21. A centrifugal blower rotor 26 has a frame 27 supporting circumferentially spaced air slinging blades 28 operatively contained within the radial passageway 25. In the embodiment of FIG. 1 the rotor frame 27 rides on bearing rollers 27′ and, is fixed to radial spokes 28′ which extend inwardly of the aircraft structure 2 beneath the compartment 10 and terminate secured to a platform structure 29, FIG. 4.

The platform structure 29 is rotatably mounted on and in suitable bearing members 30 which are supported by legs 31 secured to the lower stator construction 13. The platform structure 29 has a passageway 32 extending upwardly coaxially therewithin and terminating at the lower end thereof in a rotating seal 33. The seal 33 communicates with a fuel line 34 adapted to receive fuel from fuel tanks 35 located below the compartment 10. The fuel in fuel tanks 35 is used for rotating the frame 27 and blades 28 by ram-jet apparatus described below. The platform structure 29 has gear teeth 36 on the outer periphery thereof engageable with a pinion or gear 37 forming part of a suitable starter motor 38 of the type adapted to produce an axial shaft motion prior to turning for engaging with the gear teeth 36 and withdrawing same after starting. The starter motor 38 is used for rotating the rotor to produce starting conditions for the ram-jet apparatus described below. The passageway 32 communicates with suitable individual fuel lines 39 having respective remote controlled valves (not shown) which are secured to and rotate with the radial spokes 28′ for carrying fuel to the ram-jet apparatus.

A pressure ring duct 40 is formed in the passageway 25 between the blades 28 and the discharge slot 21. A plurality of suitable ram-jet engines 41 are mounted in circumferentially balanced relation by means of support struts 42 to the frame 27 of the rotor 26 and are spaced radially outwardly thereof within the pressure ring duct 40, FIG. 3. The engines 41 receive and discharge air in the direction indicated by the arrows 41′ to drive the blades in the direction indicated by the arrow 41″. The fuel lines 39 travel from the spokes 28′ along selected support struts 42 for feeding fuel into the respective ram-jet engines 41. Also traveling along spokes 28′ and selected support struts 42 are electrical ignition and control wires 43 for the ram-jet engines 41. The ignition and control wires 43 connect to slip rings 44 which are contacted by suitable brushes 45 for transmitting control signals from the compartment 10 to the moving ram-jet engines 41.

A plurality of circumferentially spaced radially extending vanes broadly designated 46 are mounted between the upper and lower stator constructions 17 and 13 in the discharge slot 21 on the supporting shafts or members 19. The vanes 46, although identical in external appearance are distributed in three vane sets designated 47, 48 and 49, the sets being diagrammatically or schematically illustrated in FIGS. 5, 6 and 7. The vanes in the group or set designated 47 are parallel to each other and substantially fixed at a small angle with respect to the discharge slot 21 for deflecting discharged air and exhaust gas in a somewhat circumferential direction for producing a torque on the structure 2 equal and opposite to the net resultant torque transferred by bearing friction, gas flow forces and other forces between the rotor 26 and the structure 2.

The second set 48 of vanes 46 are maintained parallel to each other but variable in angle with respect to discharge slots 21 to produce in-flight turning of the aircraft on the vertical central axis 3 thereof. The vanes of the set 48 may be interspersed between other vanes. Structure for producing control of the set 48 is illustrated in FIG. 5 wherein lever arms 50 are pivotally mounted on the aircraft structure 2 but fixed to the respective vanes in the set 48, the lever arms 50 being parallel and connected with a common control rod or cable 51 which anchors to a suitable linear motion hydraulic control 52 adapted to axially pull the lever arm 50 to a suitable angle by controls (not shown) located within the compartment 10.

The third set 49 of the vanes 46 are located in adjacent pairs which may be interspersed with other vanes like the vanes in sets 47 and 48. The vanes in the set 49 are controllable for slanting in opposite direction with respect to each other in the respective pairs to selectively restrict gas flow therepast without introducing a separate torque reaction on the aircraft about the vertical axis 3. The various pairs of vanes in the set 49 are operable to cause banking and tilting of the aircraft and also to severely restrict or strangle flow from the forward portion

53 of the aircraft to produce a lateral force component for increasing the atmospheric speed of the aircraft which in turn induces airflow and lift on the airfoil surface 4. The vanes 46 in the set 49 are maintained in opposite angular relation with respect to each other by means of mating segment gears 54 respectively fixed to each member of a pair of vanes in the set. A suitable lever arm 55 is fixed to one of the vanes of the pair and terminates in one of several control rods 56. The control rods 56 may be axially moved by suitable hydraulic controls 57 signalled from the compartment 10 to produce closure or opening of the respective vane pairs in selected areas in the discharge slot 21.

In operation, the starting motor 38 rotates the rotor 26 to a desirable speed within the pressure ring duct 40 to permit proper starting of the ram-jet engines 41. Upon starting the ram-jet engines 41 cause the centrifugal compressor blower blades 28 to rotate within the radial passageway 25 drawing air into the annular intake slot 23 and forcing same into the pressure ring duct 40. A relatively high pressure is maintained in the pressure ring duct 40 for increasing the efficiency of the ram-jet engines 41 and the exhaust of the ram-jet engines 41 adds to the pressure contained in said ring duct. Air and ram-jet gases discharge in a high velocity stream through the discharge slot 21 past the vanes 46, the reaction of said discharge stream causing the aircraft to rise and subsequently hover or proceed in a lateral direction as desired and dictated by the vanes 46. When traveling forward the discharge stream is in the form of an interrupted conical shape. A suitable preferably retractable landing gear 58 is provided upon which the aircraft may land and remain supported on the ground. It is noted that the rotating mass of the rotor 26 provides a gyroscopic effect for stabilizing the aircraft in flight. It is further noted that separate thrust means (not shown) may be provided for increasing forward thrust of the aircraft if desired.

Referring to FIG. 8, an additional embodiment of this invention is provided wherein the centrifugal blower rotor 59 is driven by suitable engines 60, here illustrated as an in-line reciprocating piston type, but which may be of the radial piston type or the turbine type without departing from the scope of this invention, and which drive through suitable fluid couplings 61, bevel gear sets 62, drive shaft 63 and rotor spokes 64. Suitable freely rotating bearing rollers 65 and 66 support the rotor 59 against unwanted vertical displacement without substantially interfering with the rotation thereof.

Referring to FIGS. 9 and 10 there is illustrated a still further embodiment of this invention wherein the rotor 67 is not connected to a central shaft but merely forms a ring which rotates upon suitable bearing rollers 68 and 69. The embodiment of FIGS. 9 and 10 uses ram-jet engines 70 in the manner of the embodiment of FIG. 1, however, since there is no central shaft or spokes for supporting rotating fuel lines a special fuel feeding assembly 71 is provided. The fuel feeding assembly 71 comprises an annular container 72 having upwardly extending inner lips 73 which are spaced apart but adapted to hold fuel during periods of rotation and non-rotation. The annular container 72 is fixed to and rotates with the rotor 67. A fuel discharge line 74 is stationary with respect to the aircraft and has an open end 75 which passes the lips 73 and terminates within the annular container 72. Fuel is fed from a fuel line 76 through a valve 77 which is controlled by a means of a float 78 mounted on a pivotal arm 79. As the container 72 fills with fuel 80 the float 78 is moved radially inwardly of the aircraft and shuts off flow through the valve 77. The centrifugal force produced on the fuel 80 by the rotation of the rotor 67 dictates that the fuel surface level be measured radially of the aircraft rather than vertically as would normally be expected. The fuel 80 discharges into individual ram-jet engine fuel lines 81 and passes through respective electrically controlled valves 82 into the respective engines **70**. Suitable slip rings **83** and brushes **84** engaged therewith carry ignition and control signals to the ram-jet engines **70** and valves **82** through control wires **85**. The embodiment of FIG. 9 is started by means of a suitable starting motor **86** which turns the rotor **67** a speed sufficient to operate the ram-jet engines **70**.

It is to be understood that although certain forms of this invention have been illustrated and described they are not to be limited to the specific form or arrangement of parts herein described and shown except insofar as such limitations are included in the claims.

What I claim and desire to secure by Letters Patent is:

1. A heavier-than-air aircraft comprising:

(*a*) a disk-like structure substantially symmetrical about a vertical axis and having an upper surface and lower surface and an outer peripheral edge,

(*b*) said upper and lower surface being of airfoil shape and adapted to provide a lifting component in lateral flight,

(*c*) a lower stator construction and an upper stator construction fixed to said lower stator construction and spaced generally upwardly therefrom forming an annular discharge slot therebetween near said outer peripheral edge, said discharge slot interrupting said lower surface for ejecting gases downwardly and conically outwardly from said structure at high velocity, said upper stator construction forming an annular intake slot at said upper surface,

(*d*) a radial passageway formed between said upper and lower stator constructions and communicating between said intake and exhaust slots, a centrifugal blower rotor rotatably mounted in said structure and having circumferentially spaced blades operatively contained and rotatable in said radial passageway for directing air from said intake slot toward said discharge slot, a pressure ring duct formed in said radial passageway between said blades and said discharge slot, a plurality of jet engines mounted on said blower rotor and within said pressure ring duct for rotating said blower rotor, means for fueling said jet engines, and

(*e*) control means in said discharge slot for selectively controlling flow therethrough.

2. The aircraft of claim 1 wherein said control means comprise:

(*a*) a plurality of circumferentially spaced radially extending vanes extending between said upper and lower stator constructions in said discharge slot,

(*b*) selected vanes being selectably tiltable for controlling torque reaction, aircraft rotation, aircraft tilt and bank, and aircraft forward motion.

3. The aircraft of claim 1 wherein said control means comprise:

(*a*) a plurality of circumferentially spaced radially extending vanes mounted between said upper and lower stator constructions in said discharge slot, said vanes forming three vane sets,

(*b*) said first set of vanes being parallel to each other and fixed at an angle with respect to said discharge slot for deflecting discharged gas in a direction to produce torque equal and opposite to the net torque transferred between said rotor and said structure,

(*c*) said second set of vanes being parallel and variable in angle with respect to said discharge slot for in-flight turning of said aircraft on the vertical axis thereof,

(*d*) said third set of said vanes being located in adjacent pairs controllable for slanting in equal and opposite direction to each other to selectively restrict gas flow therepast without introducing a torque reaction on said aircraft about a vertical axis, said third set of vanes being operable to bank and tilt said aircraft and restrict flow from said discharge slot to produce a desired lateral component for inducing airflow and lift on said airfoil.

4. A heavier-than-air aircraft comprising:

(*a*) a disk-like structure substantially symmetrical about a vertical axis and having an upper surface and lower surface and an outer peripheral edge,

(*b*) said upper and lower surface being substantially convex in shape presenting a bi-convex airfoil adapted to provide a lifting component in lateral flight,

(*c*) conical walls forming a passenger and control compartment located centrally of said structure and protruding upwardly from the center thereof,

(*d*) a lower stator construction supporting said compartment walls, an upper stator construction fixed to said lower stator construction and spaced generally upwardly and radially outwardly therefrom forming an annular discharge slot therebetween near said outer peripheral edge, said discharge slot interrupting said lower surface for ejecting gases downwardly and conically outwardly from said structure at high velocity,

(*e*) said upper stator construction being spaced radially outwardly from said compartment walls forming an annular intake slot therebetween at said upper surface and surrounding said compartment,

(*f*) a radial passageway formed between said upper and lower stator constructions and communicating between said intake and exhaust slot, a centrifugal blower rotor rotatably mounted between said stator constructions and having circumferentially spaced blades operatively contained and rotatable in said radial passageway for directing air from said intake slot toward said discharge slot,

(*g*) a pressure ring duct formed in said passageway between said blades and said discharge slot, a plurality of balanced ram-jet engines mounted on said rotor and spaced outwardly thereof within said pressure ring duct, and means for fueling said ram-jet engines for rotating said rotor.

5. The aircraft of claim 2 wherein said vanes are mounted on supporting shafts respectively engaging said upper and lower stator constructions.

6. The aircraft of claim 1 wherein said centrifugal blower rotor is center shaftless.

References Cited in the file of this patent

UNITED STATES PATENTS

2,718,364	Crabtree	Sept. 20, 1955
2,807,428	Wibault	Sept. 24, 1957

March 10, 1964 J. C. M. FROST 3,124,323

AIRCRAFT PROPULSION AND CONTROL

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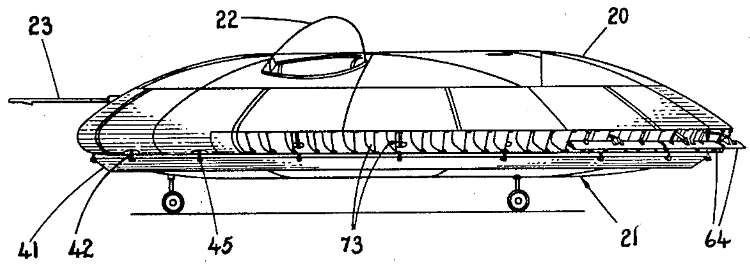

FIG. 1.

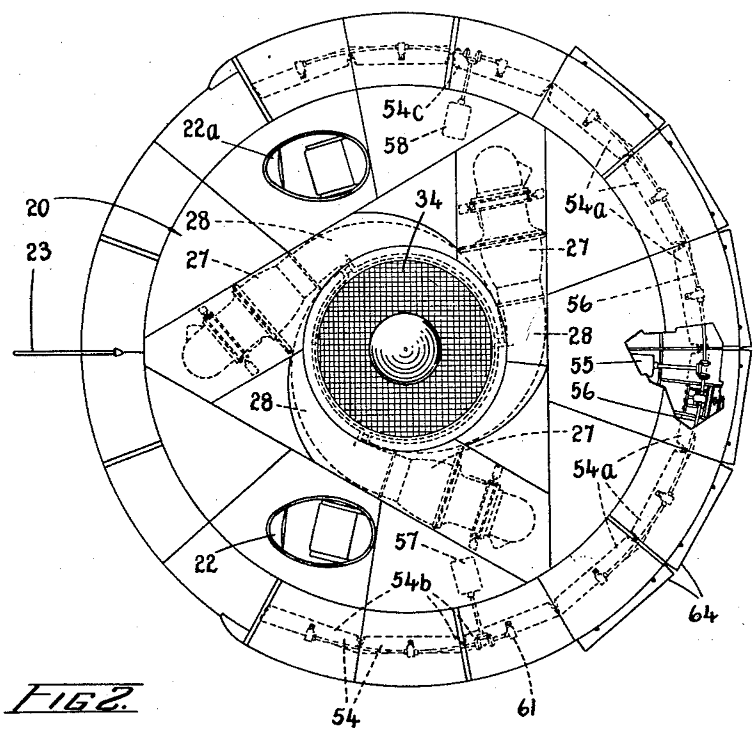

FIG. 2.

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AIRCRAFT PROPULSION AND CONTROL

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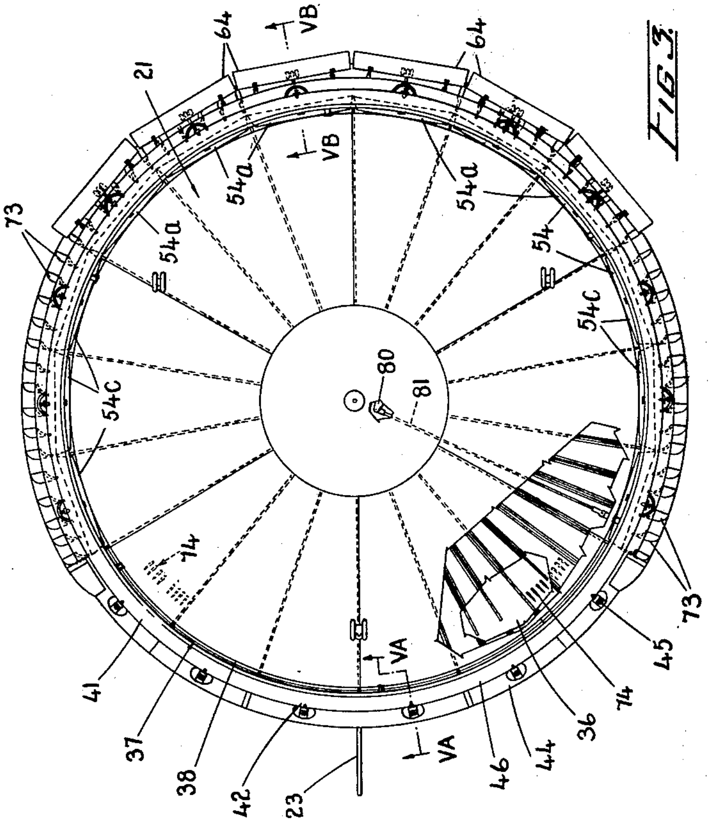

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AIRCRAFT PROPULSION AND CONTROL

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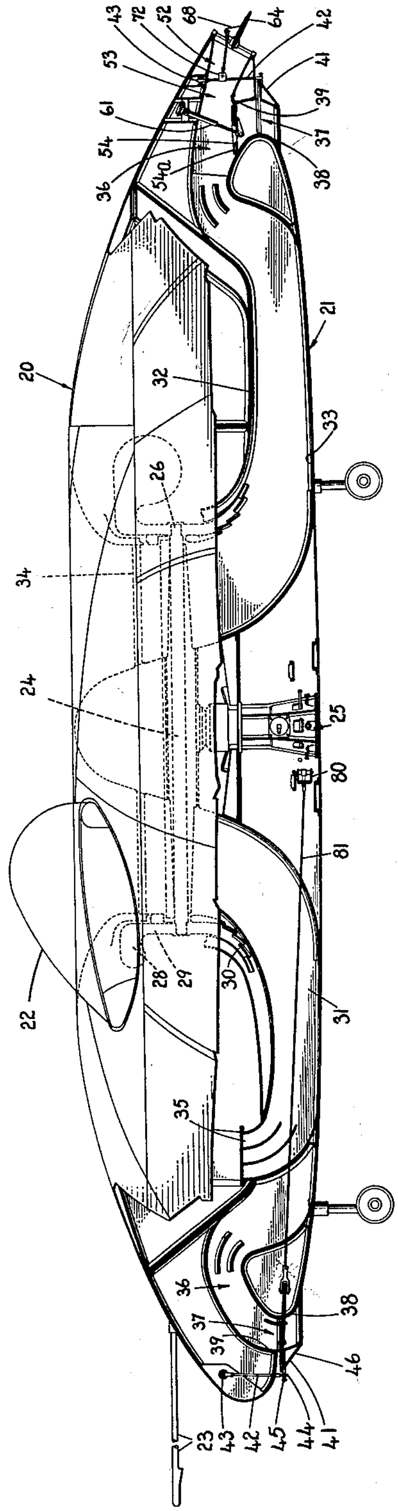

FIG 4.

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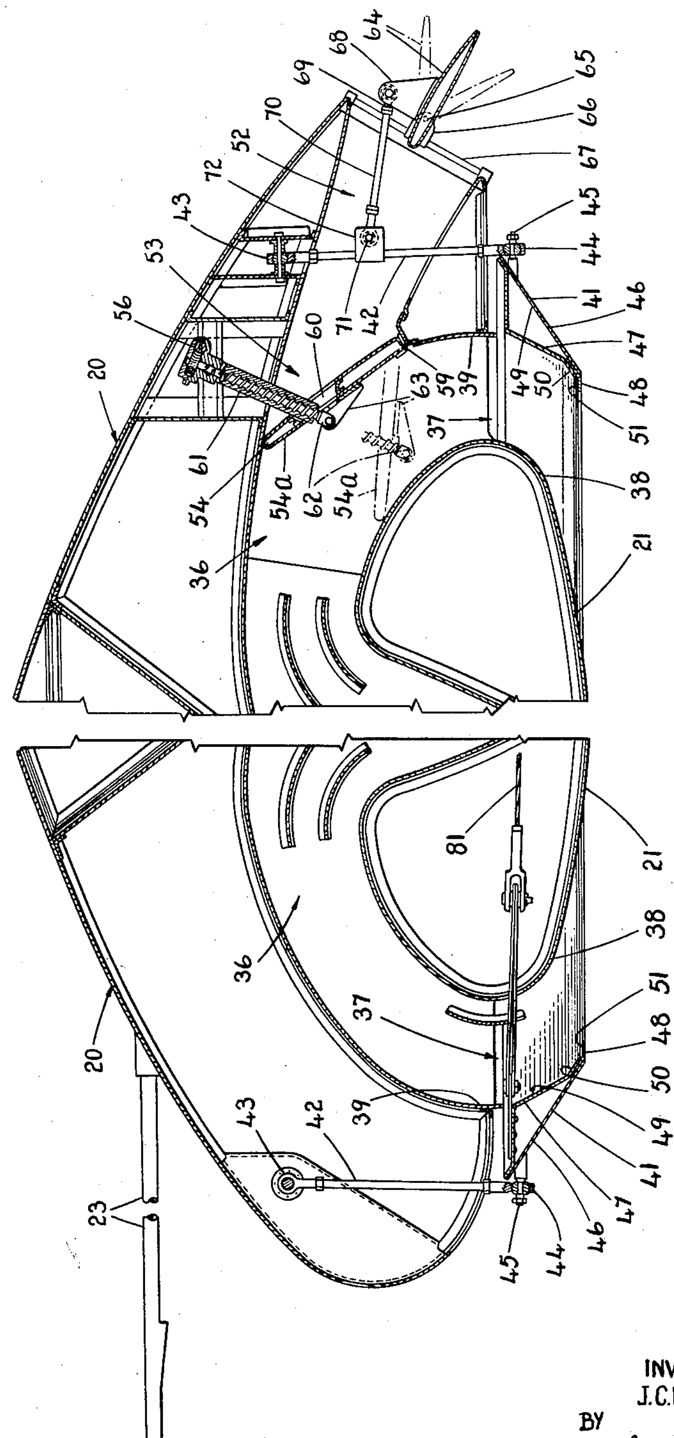

FIG. 5B.

FIG. 5A.

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AIRCRAFT PROPULSION AND CONTROL

Filed March 7, 1963 6 Sheets-Sheet 5

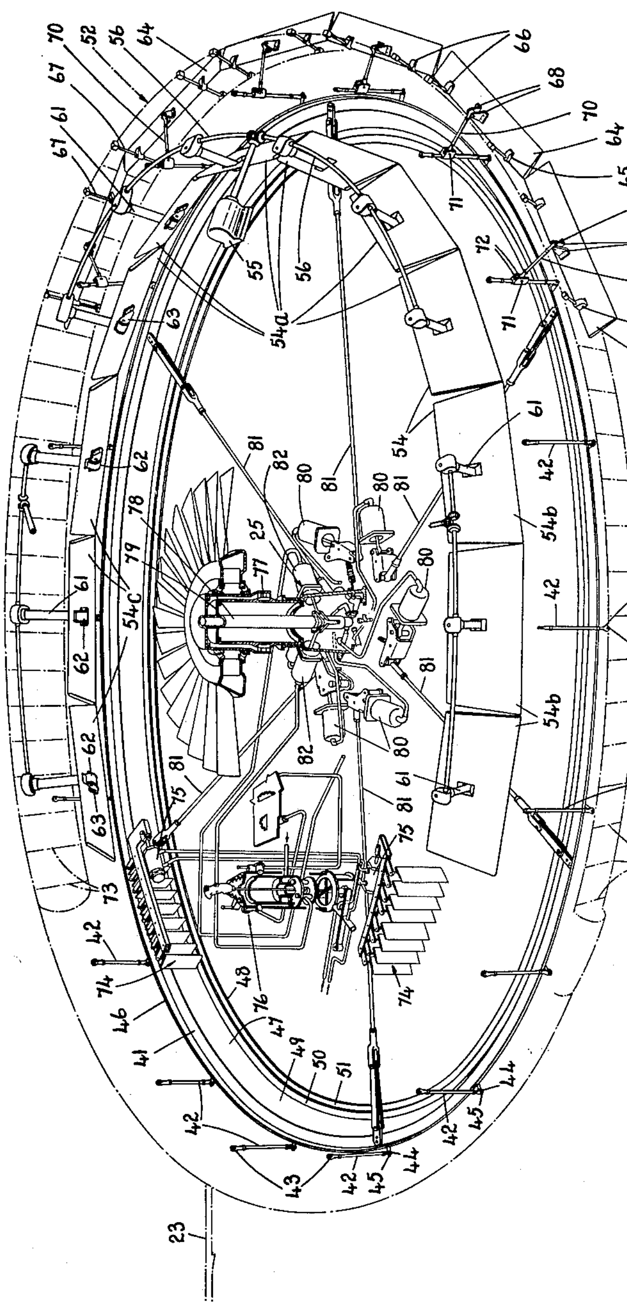

FIG. 6.

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AIRCRAFT PROPULSION AND CONTROL

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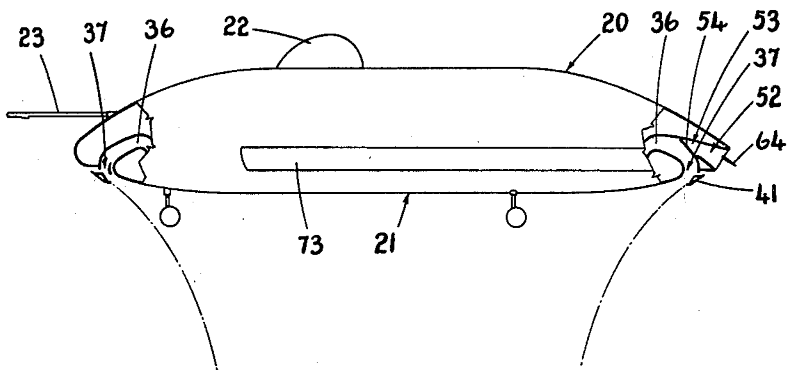

FIG 7.

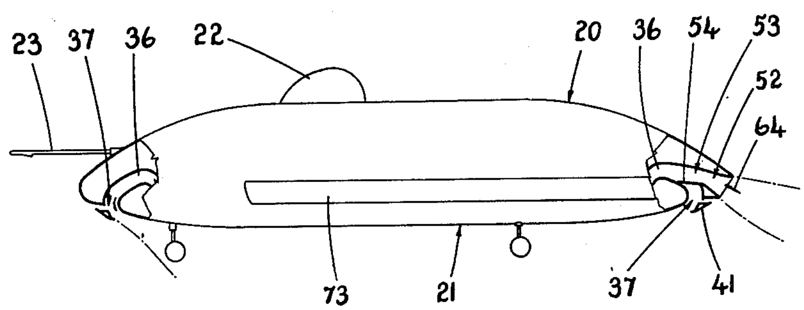

FIG 8.

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United States Patent Office 3,124,323
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3,124,323
AIRCRAFT PROPULSION AND CONTROL

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Filed Mar. 7, 1963, Ser. No. 263,532
26 Claims. (Cl. 244—12)

This invention relates to aircraft and more particularly to an aircraft having a body structure and a downwardly directed propulsive nozzle having a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the structure and a further propulsive nozzle extending around a rear portion of the periphery of the structure. The aircraft derives propulsive thrust from the ejection of propulsive gas at high velocity through one or both of the propulsive nozzles.

The co-pending application Serial No. 108,365 dated May 8, 1961, of John Carver Meadows Frost discloses a circular aircraft having a lentiform body structure sheathed by opposed aerofoil surfaces which provide lift developing surfaces for the aircraft. That aircraft has a gas displacement passage which is arranged to terminate in a propulsive nozzle having a mouth in the underside of the aircraft. Gas directing means is suspended adjacent to a boundary of the mouth of the nozzle and has a gas control surface shaped to direct gas expelled from the mouth inboardly around a convex surface. The gas control surface forms a movable extension of the outboard boundary of the mouth of the nozzle and actuating means is provided to move the gas directing means on its suspension means to vary the position of the gas control surface relative to said mouth and to variably control the direction of flow of propulsive gas expelled from the mouth. Appropriate movement of the gas directing means enables the aircraft to hover or move in forward flight and to accomplish the transition between hovering and forward flight.

The aircraft described in said co-pending application has engine means for impelling gas along the gas displacement passage which includes an impelling rotor which is universally mounted in the structure and is biased to a neutral position relative to the structure. The rotor is operatively connected to the gas directing means whereby tilting of the rotor from its neutral position operates the gas directing means to stabilize the aircraft. This is accomplished automatically and, in addition, pilot operated means are provided to apply a tilting force to the rotor whereby the gas directing means may be moved in a desired direction to impose a control force on the aircraft.

The aircraft of the present invention is a development of the aircraft described and claimed in the previously mentioned application Serial No. 108,365. The present aircraft differs from that described in said application primarily in the propulsion and control arrangements provided for forward flight and for the transition between forward flight and hovering. Thus there is provided, in addition to a downwardly directed propulsive nozzle controlled by gas directing means as in the previous application, a generally rearwardly directed peripheral nozzle for forward flight. Variable flow-proportioning means are provided for splitting the flow in a desired manner between the two nozzles to effect transition from hovering to forward flight. Moreover, in the preferred form of the invention, elevator vanes hinged about substantially horizontal axes are provided in the gas flow ejected from the central portion of the peripheral nozzle and operate as jet flaps. These vanes are inter-connected with the gas directing means and move therewith so that

there is no hiatus of control while the transition from hovering to forward flight and vice-versa is taking place.

The invention will now be described by way of example with reference to the accompanying drawings, in which like reference characters indicate similar parts throughout the several views, and in which:

FIGURE 1 is a side elevation of an aircraft embodying the invention;

FIGURE 2 is a plan view of the aircraft of FIGURE 1 showing the location of the engines and the flow-proportioning means in phantom lines and being partly broken away to show the actuating means for the flow-proportioning means;

FIGURE 3 is an under-plan view of the aircraft of FIGURES 1 and 2 partly broken away to show the actuating cables of the gas directing means and the location of the rudder blades;

FIGURE 4 is a side elevation of the aircraft on a larger scale partly broken away to show the gas directing means, the actuating means, the flow-proportioning means and the elevator vanes for forward flight;

FIGURES 5A and 5B are sections of the outboard portions of the aircraft taken on the lines VA—VA and VB—VB, respectively, of FIGURE 3 and showing the gas directing means, the flow proportioning means and the elevator vanes in detail;

FIGURE 6 is a diagrammatic perspective view of the control system of the aircraft; and

FIGURES 7 and 8 are diagrams showing the gas flow from the aircraft while the latter is hovering and in forward flight, respectively.

Referring now to FIGURES 1 to 4, the aircraft comprises a lentiform body structure which is sheathed by upper and lower aerofoil skins which provide lift surfaces for the aircraft. The skin providing the upper aerofoil surface is indicated at **20** and the skin providing the lower aerofoil surface is indicated at **21**. The upper skin is divided into various removable panels as shown in FIGURE 2 to facilitate access to the inside of the body structure. The aircraft has two cockpits, **22** and **22***a* for the pilot and for the observer, respectively. A pitot head is located at the forward end of a boom **23** projecting from the front of the aircraft. As shown most clearly in FIGURE 4, the aircraft includes an impelling rotor **24** mounted substantially centrally within the aircraft for universal movement on a base indicated generally at **25**. The rotor **24** has turbine blades **26** at its periphery and is rotated by means of gas turbine engines **27** which discharge propulsive gas through "tusk" manifolds **28** into a ring manifold **29**. The propulsive gas from the gas turbine engines passes from the turbine blades **26** through exhaust boxes **30** into a first gas displacement passage **31** defined between upper and lower walls **32** and **33** respectively in the body structure. The lower wall **33** is formed by the upper surface of the lower aerofoil skin **21**. The impelling rotor **24** draws air through a grating **34** and delivers the air into the first gas displacement passage **31**. The body structure of the aircraft is made up of radially disposed ribs so that the gas displacement passage comprises a number of segment-shaped elements. Three of these elements stop short of the periphery of the structure and provide air inlets for the engines **27**; one of these air inlets is indicated at **35** in FIGURE 4.

For a more detailed description of the skeletal structure of the aircraft, the impelling rotor, the first gas displacement passage and the arrangement of the gas turbine engines, reference should be made to the structure described in application Serial No. 832,404 dated August 6, 1959, of John Carver Meadows Frost and

Claude John Williams since in each respect the structure of the present aircraft is similar thereto.

Throughout the description and in the claims, certain terms of positional relationship are used for convenience. The terms "outboard" (or "outboardly") and "inboard" (or "inboardly") denote, respectively, greater and lesser distances from the spin axes of the rotor or the approximate centre of the downwardly directed propulsive nozzle when the latter is viewed in plan. The terms "vertical," "upwardly" and "downwardly" denote directions approximately substantially normal to the medial, or chord, plane between the upper and lower aerofoil surfaces of the body sheath.

The first gas displacement passage **31** extends outboardly from the impelling rotor **24** to a substantially annular chamber **36** and then generally downwardly to terminate in a propulsive nozzle having an annular mouth **37** in the underside of the structure.

The lower wall **33** forms the inboard boundary of the mouth as indicated at **38** and merges with the lower aerofoil skin **21** in a smooth, outboardly convex surface. The upper wall **32** forms the outboard boundary of the mouth **37** as indicated at **39**.

Gas directing means in the form of a gas control ring **41** is suspended adjacent to, and beneath, the outboard boundary **39** of the nozzle; the arrangement is best shown in FIGURES 3, 4 and 5. The ring **41** extends around the entire periphery of the annular propulsive nozzle **37** and is supported by eighteen links **42** spaced circumferentially around the body structure. Each link **42** is substantially vertical when the ring **41** is in its central position and is universally mounted at its upper end **43** to the body structure and is secured at its lower end **44** with limited universal movement to a pin **45** projecting from the outboard surface of the ring. The links pass through apertures in the body structure and suspend the ring **41** for movement relative to the mouth **37** of the nozzle.

The ring **41** is formed of three parts, an outer part **46**, an inner part **47** shaped so as to enclose, with the part **46**, a triangular space as shown in FIGURE 5, and a lower part **48** interposed between the lower ends of the outer and inner parts. This box-section construction gives rigidity to the ring and the triangular space may be filled with a foamed plastic material to reinforce the ring. The inboard surfaces of the parts **47** and **48** provide a gas control surface which may be considered to be in three parts; an upper part **49** which is directed slightly inboardly, an intermediate part **50** which is directed more steeply inboardly and a lower part **51** which is horizontal and inboardly directed. The parts **49**, **50** and **51** together constitute a gas control surface which directs propulsive gas leaving the mouth **37** generally inboardly towards the center of the aircraft.

The gas control surface constituted by the parts **49**, **50** and **51** itself constitutes a movable extension of the outboard boundary **39** of the mouth **37** of the propulsive nozzle and, as the ring **41** moves on its suspension links **42**, the portion of the gas control surface relative to the mouth will vary and will thereby control the direction of flow of the propulsive gas expelled from the mouth **37** of the nozzle.

Around the rear 120° of the aircraft there is provided a further propulsive nozzle which discharges around the rear part of the periphery of the aircraft. This peripheral nozzle is indicated generally at **52** and is fed with propulsive gas from a second gas displacement passage **53** which leads off the first gas displacement passage **31** at the annular chamber **36**. As will be appreciated, the junction between the first and second gas displacement passages in the annular chamber **36** is arcuate, and mounted at the junction is flow-proportioning means to apportion between the passages the flow of propulsive gas. The flow-proportioning means takes the form of three series of flaps **54**. The arcuate arrangement of the flaps

54 is clearly shown in FIGURES 2 and 6. The central series consists of six flaps indicated at **54*a***. One lateral series of three flaps is indicated at **54*b*** and the three flaps of the other lateral series are indicated at **54*c***. The flaps of each series are connected to move together but each series of flaps is movable independently of each of the other series of flaps. Thus the flaps **54*a*** are moved by an electric screw-jack actuator **55** and are interconnected by conventional flexible drives indicated at **56**. Similarly, the flaps **54*b*** are moved by an actuator **57** shown in FIGURE 2 and the flaps **54*c*** by an actuator **58** also shown in FIGURE 2. The flaps **54*b*** are connected together by flexible drives as are the flaps **54*c***.

Each flap **54** is hinged at its outboard edge as indicated at **59** in FIGURE 5 and is generally aerofoil in cross-section. Each flap is slotted at **60** to give passage to a screw jack **61**, the lower end **62** of which is pivotally secured to a bracket **63** on the lower side of the flap. The upper ends of the screw jacks **61** are interconnected by the flexible drives **56** referred to heretofore and are driven in unison by the various actuators **55**, **57** and **58** so that the flaps in each series move in unison as controlled by their respective actuators. Each flap **54** is movable between the full line and phantom line positions shown in FIGURE 5B. In the full line position all the propulsive gas flowing along the first gas displacement passage will be caused to pass through the downwardly directed annular nozzle **37** whereas, when the flaps are in their phantom line positions, all the gas passing along those segments of the first gas displacement passage **31** which are joined by the second gas displacement passage **53** will flow through the peripheral nozzle **52**. It is apparent that various combinations of gas flow may be obtained by suitable variations of the settings of the various series of flaps **54*a***, **54*b***, and **54*c***.

Mounted outboardly of the central portion of the peripheral nozzle **52** are six elevator vanes **64**; the vanes are arranged arcuately and extend over an arc of 120°. Each vane **64** corresponds in position and arcuate extension to one of the flaps **54*a***, and is pivoted about a substantially horizontal axis lying in the path of gas flow from the peripheral nozzle **52** and more or less centrally of the vertical extension of said nozzle. Each vane **64** is mounted on two spaced-apart pivot pins **65** which are supported by lugs **66** which in turn are supported by rods **67** spanning the mouth of the peripheral nozzle **52**. The arrangement wherein two rods support each vane **64** is clearly shown in FIGURE 6.

Means are provided to interconnect the vanes **64** with the gas control ring **41**. Thus, centrally of each vane is a pair of upstanding lugs **68** between which is pivotally mounted the outboard end **69** of a coupling rod **70**. The inboard end of each coupling rod **70** is pivotally connected at **71** between a pair of lugs **72** secured to one of the suspension links **42** for the gas control ring. The interconnection between the vanes **64** and the gas control ring **41** is such that, when a point on the gas control ring which is adjacent to one of the flaps **64** moves inboardly, the outboard edge of the vane **64** will be elevated whereas, when the point on the gas control ring moves outboardly, the outboard edge of the vane **64** will be depressed. As will be explained hereinafter, this arrangement ensures that there is no loss of control during the transition from hovering, when the flaps **54** are in their full line positions, and forward flight, when the flaps **54** are in their phantom line positions.

Arranged outboardly of the major lateral portions of the peripheral nozzle **54** are fixed cascade vanes **73** which are shown in FIGURES 1 and 3. The vanes **73** occupy all but the central 40° of the arc subtended by the peripheral nozzle **52** at the rotor axis and serve to direct propulsive gas expelled from said nozzle generally rearwardly.

Mounted forwardly of the forward ends of the peripheral nozzle **54** are two sets of movable rudder blades indicated at 74. Each set of blades is operated by a pneumatic cylinder 75 which in turn is controlled from the pilot's control column assembly 76. Details of these rudder blades and their operation by the control column are described fully in the aforementioned application Serial No. 832,404.

Movement of the gas control ring 41 is effected from the rotor 24 in a manner identical to that described in the aforementioned application Serial No. 108,365, and reference should be made to that application for a detailed description of such operation. Briefly, referring to FIGURE 6, the rotor 24 is mounted on spherical bearings 77 and is connected to a control shaft 78. Tilting of the rotor 24 on the bearings pivots the control shaft 78 about a fulcrum provided by a diaphragm 79 so that the lower end of the shaft 78 is moved laterally. This movement of the shaft 78 is sensed by a pneumatic system which operates pneumatic actuators 80, which are connected to the gas directing ring by links 81. If the aircraft is tilted, the rotor tilts with reference to the body structure thus leaving the neutral position to which it is biased so moving the lower end of the shaft 78 to operate the actuators 80 thus causing movement of the gas control ring 41 to stabilize the aircraft as fully described in said application Serial No. 108,365. In order for the pilot to be able to control the aircraft, the shaft 78 may be tilted by means of actuators 82 controlled from the pilot's control column as fully described in said application Serial No. 108,365.

The operation of the aircraft will now be described so far as it differs from the operation of the aircraft described in the previous application Serial No. 108,-365. The operation of both aircraft during hovering is identical. In this state, the gas control ring 41 is held in the central position as shown in FIGURE 5. The flow-proportioning flaps 54 are held in their upper positions as shown in full lines in FIGURE 5B and all the propulsive gas passing along the first gas displacement passage passes through the downwardly directed annular nozzle. The resultant gas flow is as shown diagrammatically in FIGURE 7 and the aircraft is supported upon a hollow column of gas. If, while the aircraft is hovering, it is hit by a gust of wind, the aircraft is stabilized by movement of the gas directing ring by the rotor as fully described in said previous application Serial No. 108,365.

In the aircraft described in application Serial No. 108,-365, forward flight was obtained by moving the gas control ring rearwardly so that the aircraft tilted slightly nose downward and the column of gas discharged from the annular nozzle was angled backwardly so that the column both partially supported the aircraft and gave it a forward thrust. In the present invention, the transition to forward flight is effected by opening the flaps 54 so that the propulsive gas which is being passed down the first gas displacement passage is diverted over a substantial proportion of the periphery of the aircraft into the peripheral nozzle 52. The propulsive gas issuing from lateral portions of the peripheral nozzle 52 is rearwardly directed by the fixed cascade vanes 73.

Control of the aircraft in forward flight is obtained by means of the elevator vanes 64 which act as jet flaps. These vanes are able to control the aircraft in pitch and roll due to their distribution around 120° of arc at the rear of the aircraft. The control of the vanes 64 is effected by movement of the control shaft 78 of the rotor either automatically to stabilize the aircraft or by operation by the pilot of his controls. The movement of the vanes 64 depends upon the position of the gas control ring 41, and the interconnection between the vanes and the gas control ring by means of the rods 70 is such that, with gas flowing through both nozzles, the forces exerted on the aircraft due to movements of the vanes and the gas control ring would both be in the same sense. Let us assume, for example, that the rear portion of the gas control ring is moved inboardly. This would have the effect, if all the

gas is passing through the annular nozzle, of decreasing the flow at the rear of the aircraft and increasing the flow at the forward end of the aircraft thus giving the aircraft a nose-up pitching moment. If now we consider a similar movement of the gas control ring with the gas being expelled from the peripheral nozzle 52, the two central vanes 64 will be elevated due to movement of the gas control ring 41 and will similarly produce a nose-up pitching moment on the aircraft. Similar remarks apply to the other vanes and movement of lateral series of vanes will have an effect in roll whereby the aircraft may be controlled in roll. By interconnecting the vanes 64 with the gas control ring 41, there is no discontinuity or hiatus in control of the aircraft during movement of the flaps 54 in transitions between hovering and forward flight.

During forward flight the rudder blades 74 are moved together to divert air rearwardly but are moved in opposition to one another to control the aircraft in yaw as has been previously described.

It will be seen that except for control in forward flight and the transition from hovering to forward flight, the aircraft is similar to that described in the afore-mentioned application Serial No. 108,365, and the response of the aircraft to control by the pilot or by automatic control in response to disturbance of the aircraft is identical to that described in the previous application to which reference should be made.

It will be understood that the form of the invention herewith shown and described is a preferred example and that various modifications may be carried out without departing from the spirit of the invention or the scope of the appended claims.

What I claim as my invention is:

1. An aircraft having a body structure; walls within the structure forming first and second gas displacement passages; the first gas displacement passage terminating in a downwardly directed propulsive nozzle having a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the aircraft and the second gas displacement passage leading off the first passage at a junction and terminating in a peripheral nozzle extending around a rear portion of the periphery of the structure; one of said walls forming the inboard boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; variable flow-proportioning means at the junction between the passages; means within the structure to impel propulsive gas along said first passage to the junction and thence to the nozzles in the proportions determined by the position of the flow-proportioning means; gas directing means associated with the mouth of the downwardly directed nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to the outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; first actuating means to operate the flow-proportioning means to variably apportion between the passages the flow of propulsive gas; and second actuating means to move the gas directing means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth.

2. An aircraft having a body structure; walls within the structure forming first and second gas displacement passages; the first gas displacement passage terminating in a downwardly directed propulsive nozzle having a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the aircraft and the second gas displacement passage leading off the first passage at a junction and terminating in a peripheral nozzle extending around a rear portion of

the periphery of the structure; one of said walls forming the inboard boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; variable flow-proportioning means at the junction between the passages; means within the structure to impel propulsive gas along said first passage to the junction and thence to the nozzles in the proportions determined by the position of the flow-proportioning means; gas directing means associated with the mouth of the downwardly directed nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to the outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; movable elevator vanes carried by the structure outboardly of said peripheral nozzle in positions to lie in the flow of gas expelled from the peripheral nozzle; first actuating means to operate the flow-proportioning means to variably apportion between the passages the flow of propulsive gas; second actuating means to move the gas directing means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from said mouth; and third actuating means for varying the orientations of the vanes relative to the structure.

3. An aircraft having a body structure; walls within the structure forming first and second gas displacement passages; the first gas displacement passage terminating in a downwardly directed propulsive nozzle having a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the aircraft and the second gas displacement passage leading off the first passage at a junction and terminating in a peripheral nozzle extending around a rear portion of the periphery of the structure; one of said walls forming the inborad boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; variable flow-proportioning means at the junction between the passages; means within the structure to impel propulsive gas along said first passage to the junction and thence to the nozzles in the proportions determined by the position of the flow-proportioning means; gas directing means associated with the mouth of the downwardly directed nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to the outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; movable elevator vanes carried by the structure outboardly of said peripheral nozzle in positions to lie in the flow of gas expelled from the peripheral nozzle; first actuating means to operate the flow-proportioning means to variably apportion between the passages the flow of propulsive gas; second actuating means to move the gas directing means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from said mouth; and interconnecting means between individual vanes and correlated portions of the gas directing means so that movement of the gas directing means causes changes in the orientations of the vanes.

4. An aircraft according to claim 3, wherein the vanes are pivotally mounted on the structure outboardly of said peripheral nozzle and about axes transverse to the gas flow through the peripheral nozzle.

5. An aircraft having a body structure; walls within the structure forming first and second gas displacement

passages; the first gas displacement passage terminating in a downwardly directed propulsive nozzle having a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the aircraft and the second gas displacement passage leading off the first passage at a junction and terminating in a peripheral nozzle extending around a rear portion of the periphery of the structure; one of said walls forming the inboard boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; variable flow-proportioning means at the junction between the passages; means within the structure to impel propulsive gas along said first passage to the junction and thence to the nozzles in the proportions determined by the position of the flow-proportioning means; gas directing means associated with the mouth of the downwardly directed nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to the outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; movable elevator vanes pivotally mounted on the structure outboardly of said peripheral nozzle about axes transverse to the gas flow through the peripheral nozzle and in positions to lie in the flow of gas expelled from said nozzle; first actuating means to operate the flow-proportioning means to variably apportion between the passages the flow of propulsive gas; second actuating means to move the gas directing means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from said mouth; and interconnecting means between individual vanes and correlated portions of the gas directing means so that a change in position of the gas directing means causes corresponding changes in the orientations of the vanes such that with gas flowing through both said nozzles the corresponding movements of the gas directing means and the vanes each causes a force to be exerted on the aircraft in the same sense.

6. An aircraft having a body structure; walls within the structure forming first and second gas displacement passages; means within the structure to impel gas outboardly along the passages; the first passage extending generally outboardly from the gas impelling means to an annular chamber and then downwardly to terminate in a downwardly directed annular nozzle having a mouth in the underside of the aircraft; one of said walls forming the inboard boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; the second gas displacement passage leading off the first passage, at an arcuate junction lying in the annular chamber, and terminating in a peripheral nozzle extending around a rear portion of the periphery of the structure; variable flow-proportioning means at the junction between the passages; gas directing means associated with the mouth of the annular nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to the outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; first actuating means to operate the flow-proportioning means to variably apportion between the passages the flow of propulsive gas; and second actuating means to move the gas directing means to vary the position of the gas control surface relative to said mouth thus to variably control the direction of flow of the propulsive gas expelled from the mouth.

7. An aircraft having a body structure; walls within

the structure forming first and second gas displacement passages; means within the structure to impel gas outboardly along the passages; the first passage extending generally outboardly from the gas impelling means to an annular chamber and then downwardly to terminate in a downwardly directed annular nozzle having a mouth in the underside of the aircraft; one of said walls forming the inboard boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; the second gas displacement passage leading off the first passage, at an arcuate junction lying in the annular chamber, and terminating in a peripheral nozzle extending around a rear portion of the periphery of the structure; a multiplicity of flaps arranged side by side at said junction and hinged to the structure, the flaps being movable between positions in which that part of the gas flow controlled by the flap may be directed entirely through a selected one of said nozzles; gas directing means associated with the mouth of annular nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to the outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; first actuating means to operate said flaps to variably apportion between the passages the flow of propulsive gas; and second actuating means to move the gas directing means to vary the position of the gas control surface relative to said mouth and thus variably to control the direction of flow of the propulsive gas expelled from the mouth.

8. An aircraft having a body structure; walls within the structure forming first and second gas displacement passages; means within the structure to impel gas outboardly along the passages; the first passage extending generally outboardly from the gas impelling means to an annular chamber and then downwardly to terminate in a downwardly directed annular nozzle having a mouth in the underside of the aircraft; one of said walls forming the inboard boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; the second gas displacement passage leading off the first passage, at an arcuate junction lying in the annular chamber, and terminating in a peripheral nozzle extending around a rear portion of the periphery of the structure; a multiplicity of hinged flaps arranged in a plurality of arcuate series around the junction; means interconnecting each flap of a series with the other flaps of the same series, each series of flaps being movable between positions in which that part of the flow of propulsive gas controlled by the series may be directed entirely through a selected one of said nozzles; gas directing means associated with the mouth of the annular nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to the outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; first actuating means to operate the series of flaps independently of each other to variably apportion between the passages the flow of propulsive gas; and second actuating means to move the gas directing means to vary the position of the gas control surface relative to said mouth and thus variably to control the direction of flow of propulsive gas expelled from said mouth.

9. An aircraft having a body structure; walls within the structure forming first and second gas displacement passages; the first gas displacement passage terminating in a downwardly directed propulsive nozzle having a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the aircraft and the second gas displacement passage leading off the first passage at a junction and terminating in a peripheral nozzle extending around a rear portion of the periphery of the structure; one of said walls forming the inboard boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; variable flow-proportioning means at the junction between the passages; means within the structure to impel propulsive gas along said first passage to the junction and thence to the nozzles in the proportion determined by the position of the flow-proportioning means; gas directing means associated with the mouth of the downwardly directed nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to the outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; movable elevator vanes carried by the structure outboardly of the central portion of said peripheral nozzle in positions to lie in the flow of gas expelled from said nozzle; cascade vanes positioned outboardly of the lateral portions of the peripheral nozzle to direct the propulsive gas expelled from said lateral portions rearwardly of the aircraft; first actuating means to operate the flow-proportioning means to variably apportion between the passages the flow of propulsive gas; second actuating means to move the gas directing means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from said mouth; and third actuating means for varying the orientations of the elevator vanes relative to the structure.

10. An aircraft having a body structure; walls within the structure forming first and second gas displacement passages; means within the structure to impel gas outboardly along the passages; the first passage extending generally outboardly from the gas impelling means to an annular chamber and then downwardly to terminate in a downwardly directed annular nozzle having a mouth in the underside of the aircraft; one of said walls forming the inboard boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; the second gas displacement passage leading off the first passage, at an arcuate junction lying in the annular chamber, and terminating in a peripheral nozzle extending around a rear portion of the periphery of the structure; a multiplicity of flaps arranged side by side at said junction and hinged to the structure and movable between positions in which that part of the flow of propulsive gas controlled by the flap may be directed entirely through a selected one of said nozzles; gas directing means associated with the mouth of the annular nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to the outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; first actuating means to operate said flaps to variably apportion between the passages the flow of propulsive gas; second actuating means to move the gas directing means to vary the position of the gas control surface relative to said mouth and thus variably to control the direction of flow of the propulsive gas expelled from said mouth; movable elevator vanes carried by the structure outboardly of said peripheral nozzle and positioned to lie in the flow of gas expelled from said nozzle, the flaps being hinged about substantially horizontal axes; and third actuating means for varying the orientations of the elevator vanes relative to the structure.

11. An aircraft according to claim 10, wherein said third actuating means comprises means interconnecting the elevator vanes with said gas directing means whereby the orientations of individual vanes having peripheral positions adjacent to correlated points on the gas directing means are changed with changes of position of the gas directing means.

12. An aircraft having a body structure; walls within the structure forming first and second gas displacement passages; means within the structure to impel gas outboardly along the passages; the first passage extending generally outboardly from the gas impelling means to an annular chamber and then downwardly to terminate in a downwardly directed annular nozzle having a mouth in the underside of the aircraft; one of said walls forming the inboard boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; the second gas displacement passage leading off the first passage, at an arcuate junction lying in the annular chamber, and terminating in a peripheral nozzle extending around a rear portion of the periphery of the structure; a multiplicity of hinged flaps arranged in a plurality of arcuate series around the junction; means interconnecting each flap of a series with the other flaps of the same series, the flaps of each series being movable between positions in which that part of the flow of gas controlled by the series may be directed entirely through a selected one of said nozzles; gas directing means associated with the mouth of the annular nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to the outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; movable elevator vanes carried by the structure outboardly of said peripheral nozzle and positioned to lie in the flow of gas expelled from said nozzle, said vanes being hinged about substantially horizontal axes; interconnecting means between points on the gas directing means and individual elevator vanes having peripheral positions adjacent to said points so that changes in position of the gas directing means cause corresponding changes in the orientation of the vanes in such a manner that the force applied to the aircraft by a change in position of the gas directing means when gas is flowing through the annular nozzle is in the same sense as the force applied to the aircraft by the corresponding change in orientation of the vanes; first actuating means to operate each series of flaps independently of the other series to variably apportion between the passages the flow of propulsive gas; and second actuating means to move the gas directing means and, through the interconnecting means, the vanes to vary the positions of the gas control surface relative to said mouth and also to vary the positions of the vanes and thus variably to control the direction of flow of the propulsive gas expelled from each nozzle.

13. An aircraft according to claim 12, wherein the hinged elevator vanes are provided adjacent to the central portion of the peripheral nozzle and fixed cascade vanes are provided at the lateral portions of the peripheral nozzle to direct gas expelled from said lateral portions substantially rearwardly of the aircraft.

14. An aircraft according to claim 12, including two series of rudder blades arranged in the first gas displacement passage at positions forwardly of the forward ends of the junction between the two gas displacement passages and on opposite sides of the longitudinal axes of the aircraft; and means for operating the rudder blades to divert the gas passing through them thus to control the aircraft in yaw.

15. An aircraft having a body structure; walls within the structure forming first and second gas displacement passages; the first gas displacement passage terminating in a downwardly directed propulsive nozzle having a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the aircraft and the second gas displacement passage leading off the first passage at a junction and terminating in a peripheral nozzle extending around a rear portion of the periphery of the structure; one of said walls forming the inboard boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; variable flow-proportioning means at the junction between the passages; means within the structure to impel propulsive gas along said first passage to the junction and thence to the nozzles in the proportions determined by the position of the flow-proportioning means; gas directing means associated with the mouth of the downwardly directed nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to the outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; first actuating means to operate the flow-proportioning means to variably apportion between the passages the flow of propulsive gas; a gyroscope rotor mounted in the structure to be capable of a limited degree of universal movement relative to the structure; biasing means interposed between the structure and the rotor to bias the latter to a neutral position within the structure; and second actuating means to move the gas directing means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth, said second actuating means operating in response to tilting of the rotor from its neutral position.

16. An aircraft according to claim 15 including pilot-operated means to tilt the rotor from its neutral position to actuate the gas directing means.

17. An aircraft according to claim 15 wherein the means to impel propulsive gas along the passages includes an impelling rotor which constitutes said gyroscope rotor.

18. An aircraft having a body structure; walls within the structure forming first and second gas displacement passages; the first gas displacement passage terminating in a downwardly directed propulsion nozzle having a mouth arranged to discharge at a multiplicity of positions distributed around a periphery on the underside of the aircraft and the second gas displacement passage leading off the first passage at a junction and terminating in a peripheral nozzle extending around a rear portion of the periphery of the structure; one of said walls forming the inboard boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; variable flow-proportioning means at the junction between the passages; means within the structure to impel propulsive gas along said first passage to the junction and thence to the nozzles in the proportions determined by the position of the flow-proportioning means; gas directing means associated with the mouth of the downwardly directed nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to the outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; movable elevator vanes carried by the structure outboardly of said peripheral nozzle in positions to lie in the flow of gas expelled from the peripheral nozzle; first actuating means to operate the flow-proportioning

means to variably apportion between the passages the flow of propulsive gas; a gyroscope rotor mounted in the structure to be capable of a limited degree of universal movement relative to the structure; biasing means interposed between the structure and the rotor to bias the latter to a neutral position within the structure; and second actuating means to move the gas directing means to vary the position of the gas control surface relative to said mouth and thus to variably control the direction of flow of the propulsive gas expelled from the mouth, said second actuating means operating in response to tilting of the rotor from its neutral position; and interconnecting means between individual vanes and correlated portions of the gas directing means so that movement of the gas directing means causes changes in the orientations of the vanes.

19. An aircraft according to claim 18 including pilot-operated means to tilt the rotor from its neutral position to actuate the gas directing means.

20. An aircraft according to claim 18 wherein the means to impel propulsive gas along the passages includes an impelling rotor which constitutes said gyroscope rotor.

21. An aircraft having a body structure; walls within the structure forming first and second gas displacement passages; means within the structure to impel gas outboardly along the passages; the first passage extending generally outboardly from the gas impelling means to an annular chamber and then downwardly to terminate in a downwardly directed annular nozzle having a mouth in the underside of the aircraft; one of said walls forming the inboard boundary of said mouth and curving inboardly away therefrom in a smooth convex surface and another wall forming the outboard boundary of the mouth; the second gas displacement passage leading off the first passage, at an arcuate junction lying in the annular chamber, and terminating in a peripheral nozzle extending around a rear portion of the periphery of the structure; a multiplicity of hinged flaps arranged in a plurality of arcuate series around the junction; means interconnecting each flap of a series with the other flaps of the same series, the flaps of each series being movable between positions in which that part of the flow of gas controlled by the series may be directed entirely through a selected one of said nozzles; gas directing means associated with the mouth of the annular nozzle; suspension means interposed between the gas directing means and the structure to movably suspend the gas directing means adjacent to outboard boundary of said mouth; said gas directing means having a gas control surface which forms a movable extension of said outboard boundary and which is shaped to direct gas expelled from the mouth inboardly around said convex surface; movable elevator vanes carried by the structure outboardly of said peripheral nozzle and positioned to lie in the flow of gas expelled from said nozzle, said vanes being provided adjacent to the central portion of the peripheral nozzle and hinged about substantially horizontal axes; fixed cascade vanes adjacent to the lateral portions of the peripheral nozzle to direct gas expelled from said lateral portions substantially rearwardly of the aircraft; interconnecting means between points on the gas directing means and individual elevator vanes having peripheral positions adjacent to said points so that changes in position of the gas directing means cause corresponding changes in the orientation of the vanes in such a manner that the force applied to the aircraft by a change in position of the gas directing means when gas is flowing through the annular nozzle is in the same sense as the force applied to the aircraft by the corresponding change in orientation of the vanes; first actuating means to operate each series of flaps independently of the other series to variably apportion between the passages the flow of propulsive gas; a gyroscope rotor mounted in the structure to be capable of a limited degree of universal movement relative to the structure; biasing means interposed between the structure and the rotor to bias the latter to a neutral position within the structure; and second actuating means to move the gas directing means and, through the interconnecting means, the elevator vanes to vary the positions of the gas control surface relative to said mouth and also to vary the positions of the elevator vanes and thus to variably control the direction of flow of the propulsive gas expelled from each nozzle, said second actuating means operating in response to tilting of the rotor from its neutral position.

22. An aircraft according to claim 21 including pilot-operated means to tilt the rotor from its neutral position to actuate the gas directing means.

23. An aircraft according to claim 21 wherein the means to impel propulsive gas along the passages includes an impelling rotor which constitutes said gyroscope rotor.

24. An aircraft according to claim 15 wherein the body structure is lentiform and is sheathed by opposed aerofoil surfaces which provide lift developing surfaces for the aircraft.

25. An aircraft according to claim 18 wherein the body structure is lentiform and is sheathed by opposed aerofoil surfaces which provide lift developing surfaces for the aircraft.

26. An aircraft according to claim 21 wherein the body structure is lentiform and is sheathed by opposed aerofoil surfaces which provide lift developing surfaces for the aircraft.

References Cited in the file of this patent

UNITED STATES PATENTS

2,838,257	Wibault	June 10, 1958
2,997,254	Mulgrave	Aug. 22, 1961
3,045,951	Freeland	July 24, 1962
3,067,967	Barr	Dec. 11, 1962

ELECTRIC AEROSPACE PROPULSION SYSTEM

Filed Sept. 26, 1961 3 Sheets-Sheet 1

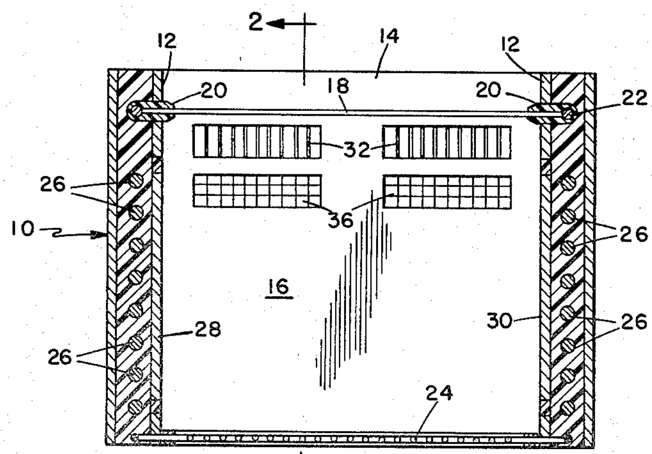

Fig. 1

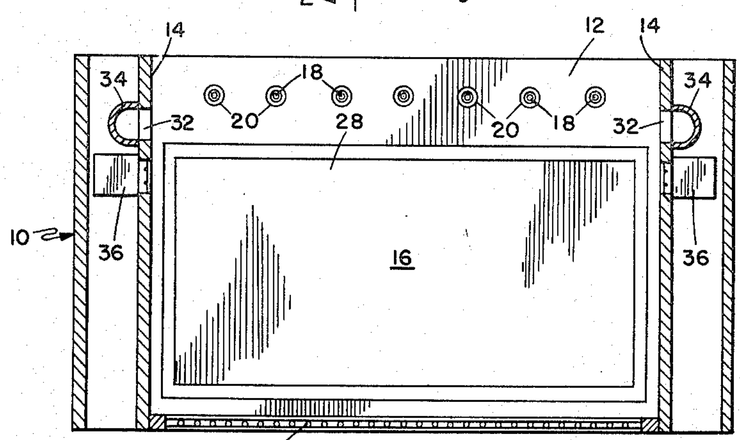

Fig. 2

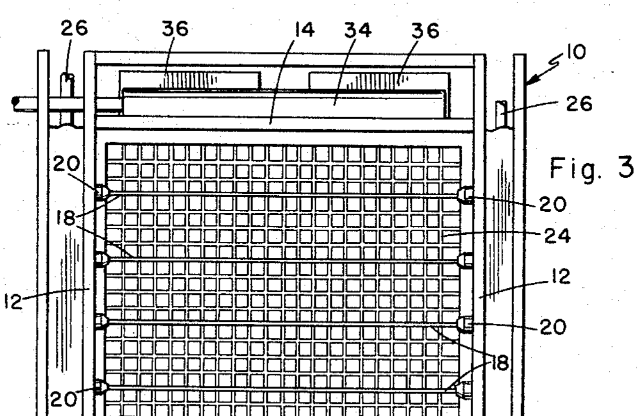

Fig. 3

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ELECTRIC AEROSPACE PROPULSION SYSTEM

Filed Sept. 26, 1961 3 Sheets-Sheet 2

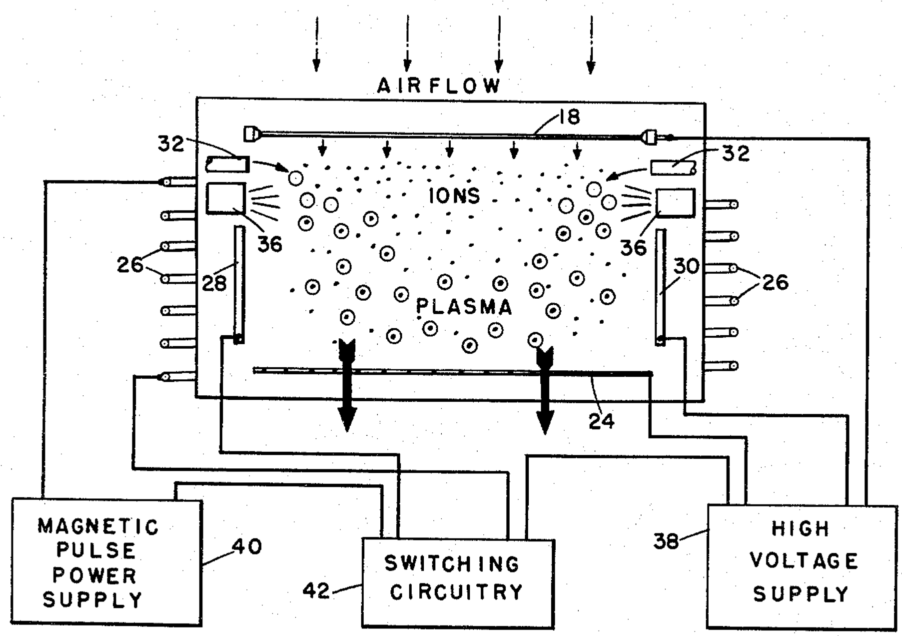

Fig. 4

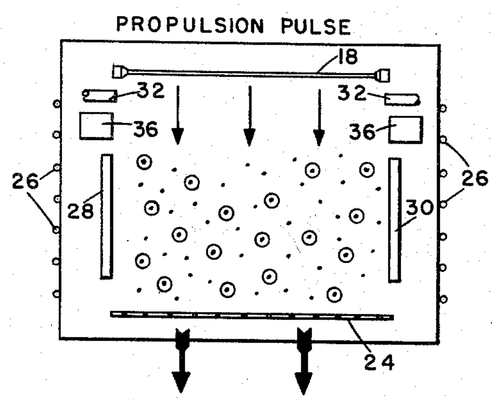

Fig. 5

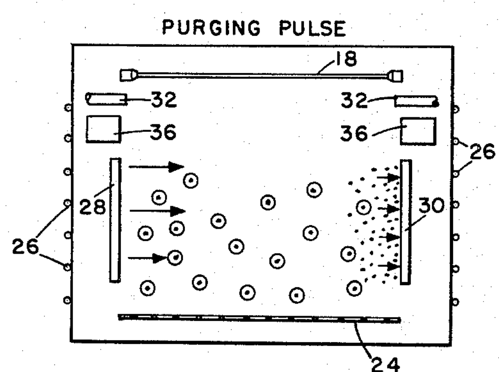

Fig. 6

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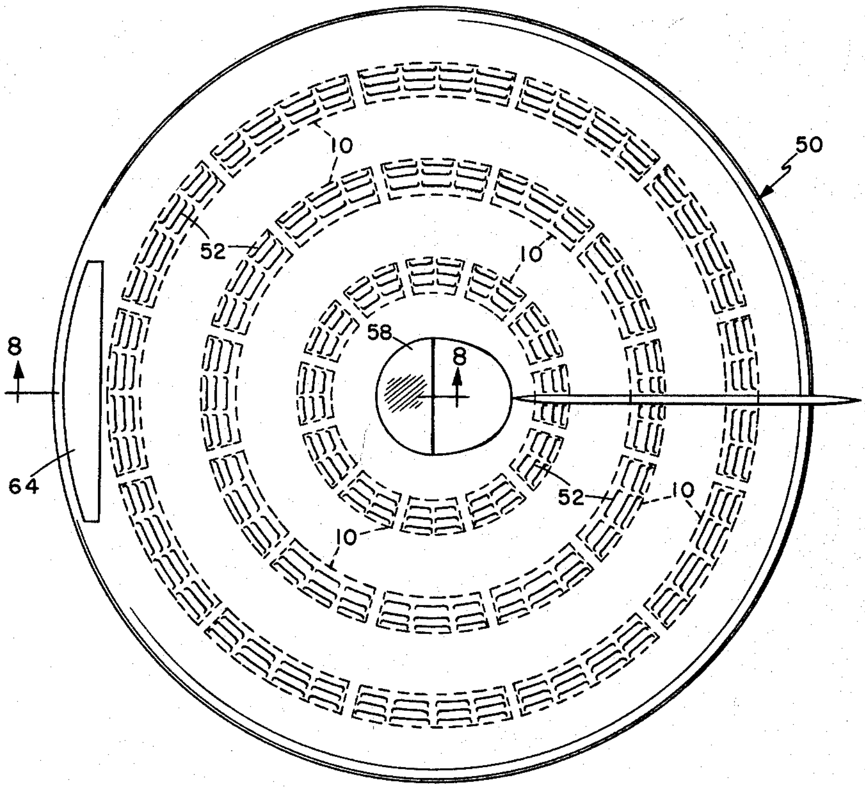

Fig. 7

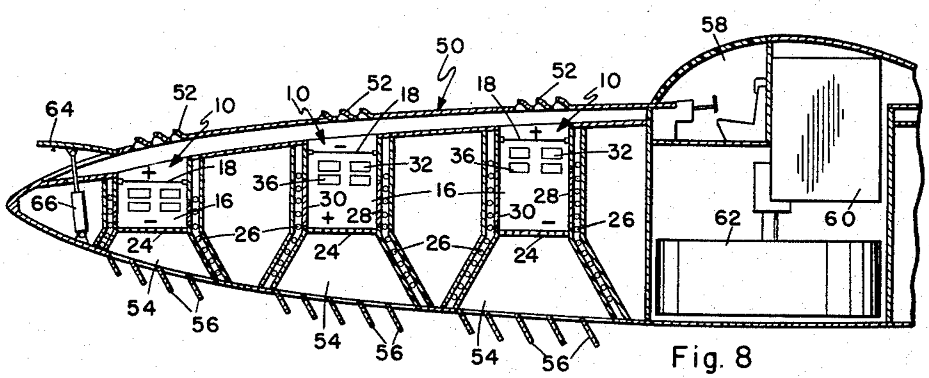

Fig. 8

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ELECTRIC AEROSPACE PROPULSION SYSTEM

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Filed Sept. 26, 1961, Ser. No. 140,919
12 Claims. (Cl. 60—35.5)

The present invention relates generally to propulsion and specifically to an electric aerospace propulsion system.

Present systems and proposals for space vehicles mainly rely on the thrust of a large booster rocket for the initial stage of the journey, the booster being dropped when exhausted and another source of thrust used for continued travel. For orbital flight and limited maneuvering chemical fueled systems are adequate, but for extended space flight it is necessary to have thrust available for long periods. Once in space, a small amount of thrust is sufficient to accelerate and guide a vehicle and proposed systems include the use of solar energy, photon propulsion and electric propulsion. The electric propulsion systems fall broadly into three categories: the electrothermol jet in which a gaseous propellant is electrically heated and thermodynamically accelerated; the ion rocket in which ions are electrostatically accelerated; and the magneto-hydrodynamic system in which a plasma is accelerated by an electromagnetic field. All of these systems have specific impulses considerably higher than chemical rockets, but the thrust is very limited and suitable for use in space only.

The ideal propulsion system would have a high specific impulse or long duration of useful thrust, with sufficient thrust to lift a vehicle directly from the ground and continue the flight into space. This would eliminate the large boosters and high acceleration and vibration stresses normally associated with space vehicle launching. Such a propulsion system would also have to be capable of operating in atmosphere or in space and would thus provide for controlled re-entry into atmosphere without aerodynamic heating caused by high speed re-entry and frictional braking.

The primary object of this invention, therefore, is to provide a propulsion system for enabling controlled flight in the atmosphere, continuing into space without changing the basic operation of the system and achieving extended space flight.

Upon future reinfinement of the known electrical generating systems, it is contemplated that the electric propulsion systems described hereafter might be adapted for use in lift-off and ground landing techniques.

Another object of this invention is to provide an electric propulsion system in which extremely high voltages are used to ionize a fluid in a coronal discharge field, the ionized fluid being accelerated by extremely high powered magnetic pulses which produce a pinch effect in the propulsion chamber.

A further object of this invention is to provide an electric propulsion system in which the propulsion unit chamber is open at both ends so that in atmosphere, air is admitted to the chamber and ionized to form plasma, the un-ionized air being entrained by the accelerated plasma and adding to the mass flow to increase thrust.

It is another object of this invention to provide an electric propulsion system wherein a supply of colloids is used as a source of plasma for operation in space, the ionization being enhanced by an auxiliary source of radiation in the vicinity of the coronal discharge.

Another object of this invention is to provide an electric propulsion system which may be operated as a single unit or in multiple units distributed throughout an aerospace vehicle, the polarity of alternate units being reversed to avoid build-up of a space charge in the vicinity of the vehicle.

A final object of this invention is to provide a propulsion system in which the unit is purged of excess electrons between propulsion pulses, to avoid arcing between electrodes.

With these and other objects in view, this invention resides in the novel construction, combination and arrangement of elements, as will be hereinafter described in the specification, particularly pointed out in the claims, and illustrated in the drawings which form a material part of this disclosure, and in which:

FIGURE 1 is a transverse sectional view of a single propulsion unit;

FIGURE 2 is a sectional view taken on the line **2—2** of FIGURE 1;

FIGURE 3 is a partial top plan view of the unit;

FIGURE 4 is a diagrammatic view of the propulsion system;

FIGURE 5 is a diagrammatic view of the propulsion pulse stage;

FIGURE 6 is a diagrammatic view of the operation between propulsion pulses;

FIGURE 7 is a top plan view of an aerospace vehicle incorporating multiple propulsion units; and

FIGURE 8 is an enlarged sectional view taken on the line 8—8 of FIGURE 7.

Similar numerical designations indicate similar elements and portions throughout the various views of the drawings.

Structure of propulsion unit

Referring now to FIGURES 1–3, the propulsion unit **10** is illustrated as a rectangular, box-like structure having side walls **12** and end walls **14** enclosing a chamber **16** which is substantially open at the top and bottom. The walls are hollow or constructed of suitable thickness to enclose wiring and minor accessories associated with the unit. Extending between the upper ends of side walls **12** are spaced, parallel discharge electrodes **18**, which may be metallic rods supported between insulators **20** and connected at one end at least to a common high voltage conductor **22**. Across the lower end of chamber **16** is a screen or mesh-like grid **24**. Within the side walls **12** are vertically spaced electromagnetic coils **26** which may be wrapped completely around the chamber **16** for a single unit, or extend from each end as part of a multiple unit assembly having a common electromagnet portion.

Mounted on or in the inner faces of side walls **12** are electrodes **28** and **30** in opposition to each other. Within end walls **14** and directly below the electrodes **18** are inlets **32** to which is connected a supply duct **34**, for injecting colloids into the chamber. Below the inlets **32** are radiation sources **36**, from which the fluid and colloids in the chamber are subjected to radiation. The structure may vary considerably in detail and configuration, according to size and specific installation, the arrangement illustrated merely being an example.

Operation of propulsion unit

As illustrated in FIGURE 4, the electrodes **18** are connected to one side of a high voltage supply **38** and the grid **24** to the other side thereof, to provide a high potential from top to bottom of chamber **16**. To achieve the desired results a potential on the order of a million volts or more is contemplated. The high voltage causes coronal discharge from electrodes **18** which ionizes gas or fluid in the vicinity. In atmosphere, air is used as the working fluid and the upper portion of the chamber **16** is filled with a mixture of air and ions, the ions being attracted to grid **24**, which is of opposite polarity. When a pulse of high current is applied to the electromagnetic coils **26** from a power supply **40**, a magnetic field is produced in which the lines of force are effective axially through the chamber. This drives the ions downwardly with considerable acceleration, the phenomenon being commonly known as "pinch effect." The plasma formed by the working fluid and the ions is thus driven downwardly through the grid 24, producing thrust by reaction. A considerable quantity of air is entrained by the plasma motion and greatly adds to the mass flow, so that appreciable thrust can be obtained in atmosphere. In addition to the high voltage, extremely high electromagnetic power pulses are contemplated, on the order of several hundred thousand amperes. Since the actual power supply may vary, no specific type is illustrated. For example, an electrostatic generator could provide the high voltage necessary, while a capacitor bank could supply the high current pulses.

Since each magnetic pulse may not be sufficient to drive a chamber full of plasma completely out through grid 24, the accumulation of excess electrons in the chamber could cause a breakdown path and initiate arcing between electrodes 18 and the grid. This would stop the plasma flow and cause loss of thrust. To avoid such an occurrence, an electrical potential is established between plate electrodes 28 and 30 which is orthogonal to the electromagnetic field and causes excess electrons to be attracted to one or other of the plate electrodes, depending on polarity.

The necessary voltage can be obtained, with suitable reduction, from the high voltage supply 38. To ensure proper purging of excess electrons at the proper time, the circuits to the electromagnetic coils 26 and plate electrodes 28 and 30 are coupled to a high speed switching circuit 42 to operate alternately. Thus in the propulsion pulse illustrated in FIGURE 5, the plasma is driven downwardly by the electromagnetic field, while in the purging pulse illustrated in FIGURE 6, the excess electrons are swept to the plate electrode 30. The switching means may be electronic, electromechanical, or any other suitable type depending on the operating frequency.

It will be noted that no specific polarities are indicated. Either positive or negative ions can be produced at electrodes 18, according to the polarity of the electrodes, and attracted toward the oppositely polarized grid 24. Also, the field between plate electrodes 28 and 30 can be in either direction.

At extreme altitudes where the air is rarified, or in space, working fluid must be provided from a suitable supply. The working fluid may be in the form of colloids, metallic powders, hygroscopic salts, or gases, which can be injected into the chamber 16 through inlets 32. Electrons become attached to the colloid molecules and form charged particles of low ionic mobility and considerably larger than ionized air particles, thus providing a high mass plasma which is readily acted upon by the electromagnetic field. In FIGURES 4–6 the colloid particles are indicated by open circles and the electrons by dots, the circles containing dotes representing charged particles.

To assist in ionization of the colloids, radiation is used to make the colloidal particles unstable and facilitate capture of electrons. The radiation may be from ultraviolet, X-ray, or gamma ray sources, radio frequency excitation, or the like. The sources 36 are thus indicated in box form and are disposed immediately below the inlets 32 to irradiate the emerging particles.

The radiation sources 36 may be used to enhance ionization of air without colloid injection, or colloids may be injected during atmosphere travel for added thrust when necessary.

Application to aerospace vehicle

The propulsion unit is adaptable to many different types of vehicles for travel in atmosphere or in space, such as aircraft, orbital satellites, or interplanetary craft. The vehicle illustrated in FIGURES 7 and 8, by way of an example, is a disc shaped aerospace craft indicated generally at 50. A number of propulsion units 10, each constructed as previously described, are distributed in con-

centric rings within the discoid body, the upper surface of which is provided with louvers 52 to admit air. The louvers are indicated as fixed but could be adjustable and have closure means. The propulsion units 10 have individual divergent nozzles 54 opening downwardly through the lower surface of the craft, the openings being fitted with pivotal vanes 56 which can be adjusted selectively to various angles or closed completely.

The electromagnetic coils 26 can be continuous around a complete ring of propulsion units as one large coil, or wound around individual units, according to the degree of control required. The coils 26 extend downwardly around the nozzles 54 to continue the plasma acceleration as long as possible for maximum efficiency.

In the central portion of the craft is a cabin 58 containing all necessary controls and instruments, the arrangement being variable. Also in the central portion is a power unit 60, which can be a high speed gas turbine, or some similar source of power, to drive the electrical generator 62 which supplies the working power for the vehicle. A nuclear power source could be used for long range operation, although the turbine has a distinct advantage in that the exhaust gases may be used as a working fluid to produce plasma in the propulsion units. The various spaces and bays between units may be used to contain electrical apparatus, capacitor banks, controls, colloids, fuel and life support necessities such as oxygen and water.

If all of the propulsion units are of similar polarity and producing particles of similar electrical charge, the accumulation of plasma downstream of the vehicle will cause a high potential space charge which would prevent ejection of further charged particles and destroy thrust. Schemes have been proposed to inject oppositely charged particles into exhaust streams to neutralize the electrical charge, but the problems involved are many. With a multiple unit propulsion system as illustrated, space charge build-up is avoided by making alternate units operate at opposite polarity as indicated in FIGURE 8, the downstream mixing providing charge neutralization.

To ensure an adequate supply of air in forward flight in atmosphere, the leading edge of the upper surface of the craft is fitted with a hinged flap 64 actuated by a jack 66, or similar mechanism. When flap 64 is open, air is admitted under ram effect and distributed to the various propulsion units. The lower vanes 56 may be deflected to direct the plasma flow rearwardly for forward propulsion, or forwardly for deceleration. With vanes 56 vertical, the craft can be made to hover, ascend, or decend, according to the power applied to the propulsion units. The vanes can be mechanically, electrically, or fluid operated, with suitable control means for the pilot, such systems being well known.

At low altitudes, or in dense atmosphere, the pulsed magnetic field may be operated at relatively low frequency, while in rarified atmosphere, or in space, high frequency pulsing is desirable. The pulsing prevents build-up of a charged short circuit path and subsequent arcing, particularly in a near vacuum where electrical resistance is low. The extremely high voltages and high magnetic pulse currents contemplated provide thrust several orders of magnitude higher than previously proposed systems, and a multiplicity of units can produce an appreciable total thrust over a wide surface area.

It should be understood that the propulsion system may be installed in vehicles of widely varying configurations with proper distribution of the individual units. If the units are independently operable, or at least some of the units adjacent the periphery of the vehicle, directional control may be achieved by differential thrust operation of appropriate units.

Advantages

Since the propulsion units are operable with a wide variety of working fluids, a vehicle so equipped can maneuver in atmosphere and climb to any altitude. Transition from atmosphere to space is accomplished without any change in the basic propulsion system and without the need for auxiliary propulsion means. If a turbine is used as a primary power source, the exhaust gases provide a working fluid in space and colloids can be added if required. Thrust is critical only in atmosphere and to overcome gravitational attraction. In orbit or in space, very little thrust is required to maintain speed, accelerate, or decelerate at a comfortable rate.

The system is particularly suitable for very large, low density vehicles, in which a large number of propulsion units can be distributed over a considerable area. Spacious satellites could be placed directly in orbit fully assembled and equipped, or space vehicles could be propelled on fully controlled interplanetary trips. Landings on other planets might be accomplished by using the existing planetary atmosphere to provide a working fluid.

In returning to earth, re-entry into atmosphere might be made in a gradual, controlled manner, avoiding frictional heating and violent deceleration. On entering atmosphere, air is again used as a working fluid.

It is understood that minor variation from the form of the invention disclosed herein may be made without departure from the spirit and scope of the invention, and that the specification and drawing are to be considered as merely illustrative rather than limiting.

I claim:

1. An ionized jet propulsion system, comprising:
an open ended chamber;
a source of ions comprising a corona field emission electrode at one end of said chamber;
a grid electrode at the other end of said chamber;
a source of high voltage connected between said grid electrode and said corona field emission electrode;
electromagnetic field producing means around said chamber to provide a field, the lines of force of which are substantially axially divergent of said chamber;
a pulsed source of power connected to said field producing means to drive ions toward said grid electrode;
a source of working fluid directed into said chamber to form a plasma with the ions therein;
and a means to produce an electrical field transversely of said chamber between pulses of the electromagnetic field to purge excess electrons from the chamber.

2. An ionized jet propulsion system, comprising:
an open ended chamber;
a source of ions comprising a corona field emission electrode at one end of said chamber;
a grid electrode at the other end of said chamber;
a source of high voltage connected between said grid electrode and said corona field emission electrode;
electromagnetic field producing means around said chamber to provide a field, the lines of force of which are substantially axially divergent of said chamber;
a pulsed source of power connected to said field producing means to drive ions toward said grid electrode;
a source of working fluid directed into said chamber to form a plasma with the ions therein;
means to produce an electrical field transversely of said chamber to purge excess electrons therefrom;
and switch means operable to apply said last mentioned electrical field between pulses of the electromagnetic field.

3. An ionized jet propulsion system, comprising:
an open ended chamber;
a source of ions comprising a corona field emission electrode at one end of said chamber;
a grid electrode at the other end of said chamber;
a source of high voltage connected between said grid electrode and said corona field emission electrode;
electromagnetic field producing means around said chamber to provide a field, the lines of force of which are substantially axially divergent of said chamber,

a pulsed source of power connected to said field producing means to drive ions toward said grid electrode;
a source of working fluid directed into said chamber to form a plasma with the ions therein;
said source of high voltage providing a potential on the order of one million volts.

4. An ionized jet propulsion system according to claim 3, wherein said pulsed source of power has an output on the order of a hundred thousand amperes.

5. An ionized jet propulsion system, comprising:
an open ended chamber;
a source of ions comprising a corona field emission electrode at one end of said chamber;
a grid electrode at the other end of said chamber;
a source of high voltage connected between said grid electrode and said corona field emission electrode;
electromagnetic field producing means around said chamber to provide a field, the lines of force of which are substantially axially divergent of said chamber;
a pulsed source of power connected to said field producing means to drive ions toward said grid electrode;
said chamber being exposed to atmosphere, whereby ambient air is entrained by the plasma flow in the chamber.

6. An ionized jet propulsion system, comprising:
an open ended chamber;
a source of ions comprising a corona field emission electrode at one end of said chamber;
a grid electrode at the other end of said chamber;
a source of high voltage connected between said grid electrode and said corona field emission electrode;
electromagnetic field producing means around said chamber to provide a field, the lines of force of which are substantially axially divergent of said chamber;
a pulsed source of power connected to said field producing means to drive ions toward said grid electrode;
said chamber being exposed to atmosphere, whereby ambient air is entrained by the plasma flow in the chamber;
said chamber having inlets adjacent said source of ions;
and means to inject colloids into said chamber through said inlets.

7. An ionized jet propulsion system according to claim 6 and including means to inject colloids into said chamber through said inlets;
and radiation sources adjacent said inlets to irradiate the colloids and enhance combination thereof with ions from said ion source.

8. In a vehicle, the combination comprising:
a plurality of ionized jet propulsion units operatively mounted in said vehicle;
each of said propulsion units comprising an open ended chamber having an outlet end at the surface of the vehicle;
a source of ions comprising a corona field emission electrode at one end of said chamber;
a grid electrode at the other outlet end of said chamber;
a source of high voltage connected between said grid electrode and said corona field emmission electrode;
electromagnetic field producing means around said chamber to provide a field, the lines of force of which are substantially axially divergent of the chamber;
a pulsed source of power connected to said field producing means to drive ions toward said grid electrode;
a source of working fluid directed into said chamber to form a plasma with the ions therein;
said propulsion units being alternately connected to produce ions of opposite polarity, whereby the combined discharge therefrom is substantially neutral.

9. The combination according to claim 8, wherein said vehicle has air inlets providing ambient air to said propulsion units for entrainment by the plasma flow therein.

10. The combination according to claim 9 and including angularly adjustable flow guiding vanes at the outlet ends of said propulsion units.

11. In a vehicle, the combination comprising:

a plurality of ionized jet propulsion units operatively mounted in said vehicle;

each of said propulsion units comprising an open ended chamber having an outlet end at the surface of the vehicle;

a source of ions comprising a corona field emission electrode at one end of said chamber;

a grid electrode at the other outlet end of said chamber;

a source of high voltage connected between said grid electrode and said corona field emission electrode;

electromagnetic field producing means around said chamber to provide a field, the lines of force of which are substantially axially divergent of the chamber;

a pulsed source of power connected to said field producing means to drive ions toward said grid electrode;

a source of working fluid directed into said chamber to form a plasma with the ions therein;

means to produce an electrical field transversely of said chamber;

switch means connected to operate said last mentioned field between electromagnetic pulses to purge excess electrons from the chamber;

and said propulsion units being alternately connected to produce ions of opposite polarity, whereby the combined discharge therefrom is substantially neutral.

12. In a vehicle, the combination comprising:

a plurality of ionized jet propulsion units operatively mounted in said vehicle;

each of said propulsion units comprising an open ended chamber having an outlet end at the surface of the vehicle;

a source of ions comprising a corona field emission electrode at one end of said chamber;

a grid electrode at the other outlet end of said chamber;

a source of high voltage connected between said grid electrode and said corona field emission electrode;

electromagnetic field producing means around said chamber to provide a field, the lines of force of which are substantially axially divergent of the chamber;

a pulsed source of power connected to said field producing means to drive ions toward said grid electrode;

a source of working fluid directed into said chamber to form a plasma with the ions therein;

said chamber having an extended outlet nozzle;

said electromagnetic field producing means extending around said nozzle;

and said propulsion units being alternately connected to produce ions of opposite polarity, whereby the combined discharge therefrom is substantially neutral.

References Cited by the Examiner

UNITED STATES PATENTS

1,363,037	12/20	Goddard.	
1,687,550	10/28	Ehret	60—35.5
2,826,708	3/58	Foster	60—35.5
2,880,337	3/59	Langmuir et al.	
2,936,969	5/60	Griffith et al.	60—35.5
2,940,689	6/60	Howell	60—35.5
2,952,970	9/60	Blackman	60—35.5
3,014,154	12/61	Ehlers et al.	60—35.5
3,032,978	5/62	Kunen	60—35.5
3,041,824	7/62	Berhman	60—35.6
3,050,652	8/62	Baldwin	60—35.5
3,052,088	9/62	Davis et al.	60—35.5

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Aug. 10, 1965 J. N. MODESTI 3,199,809

CIRCULAR WING FLYING CRAFT

Filed Aug. 12, 1963 3 Sheets-Sheet 1

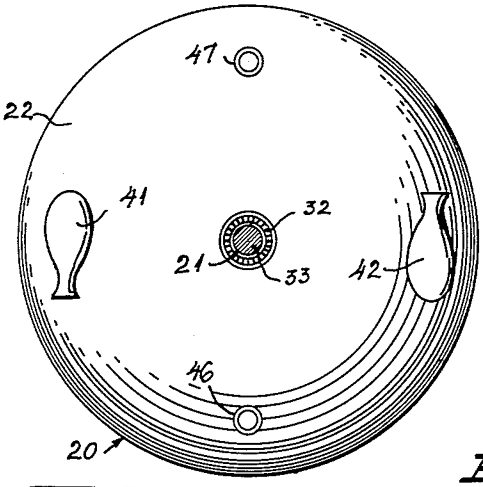

FIG-1-

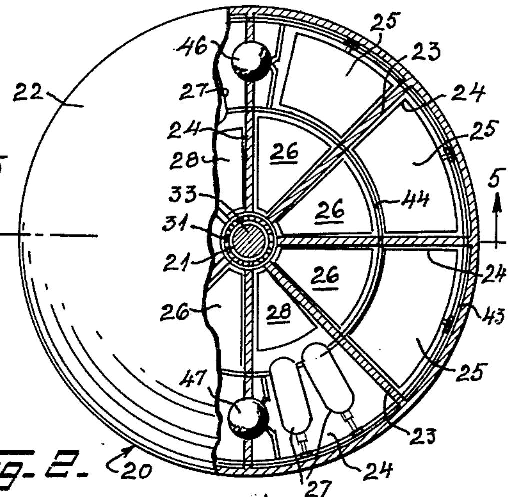

FIG-2-

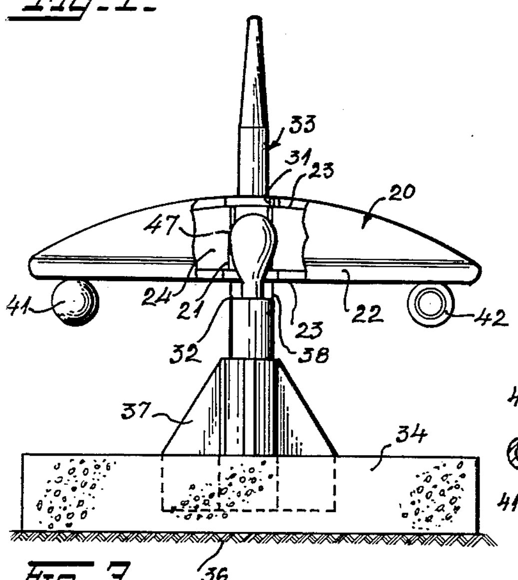

FIG-3-

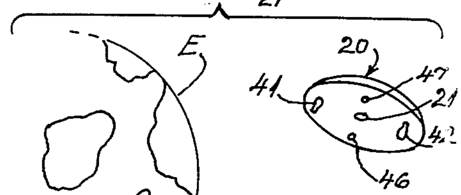

FIG-4-

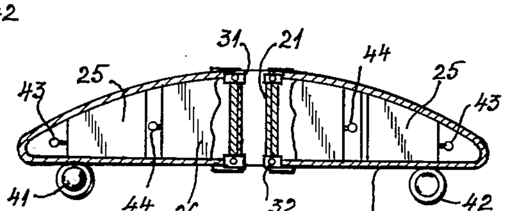

FIG-5-

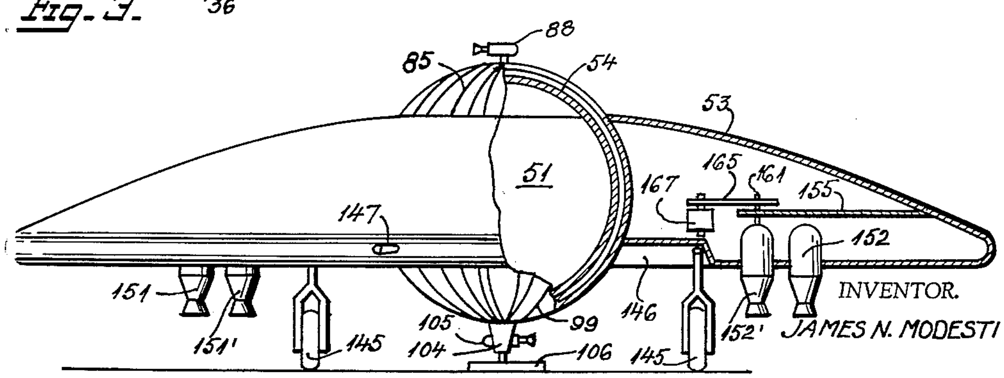

FIG-7-

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CIRCULAR WING FLYING CRAFT

Filed Aug. 12, 1963

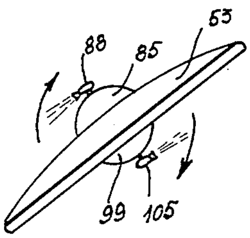

Fig. 11.

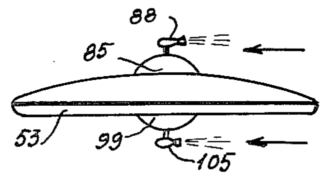

Fig. 13.

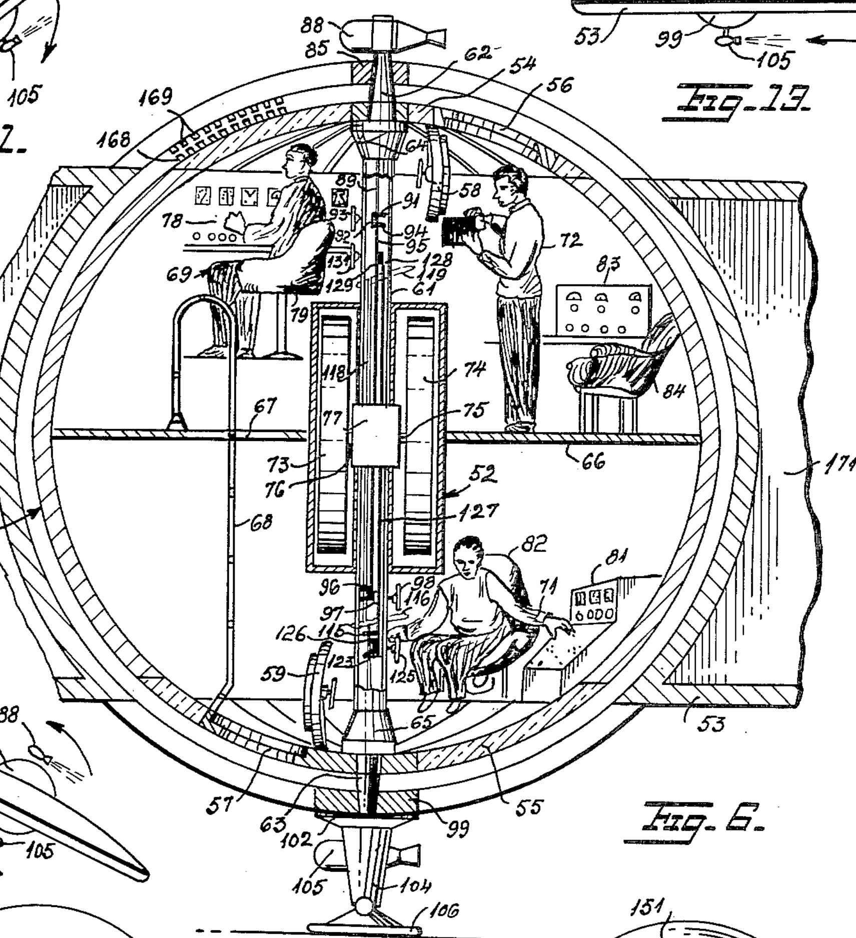

Fig. 6.

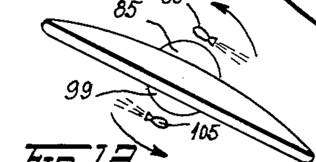

Fig. 12.

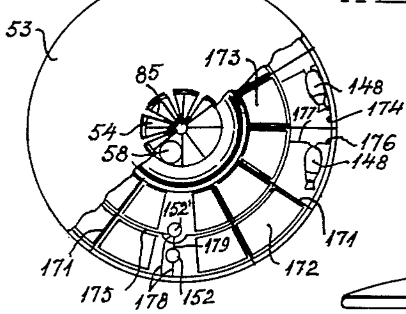

Fig. 9.

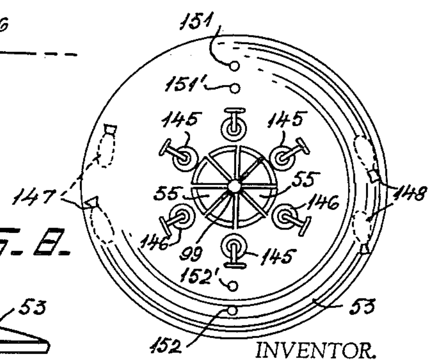

Fig. 8.

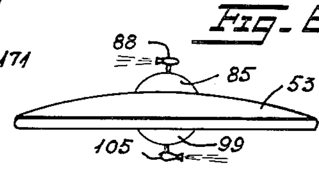

Fig. 10.

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CIRCULAR WING FLYING CRAFT

Filed Aug. 12, 1963

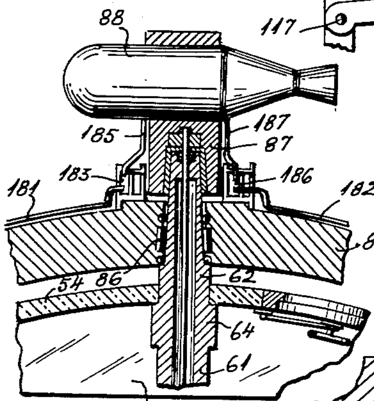

FIG. 15.

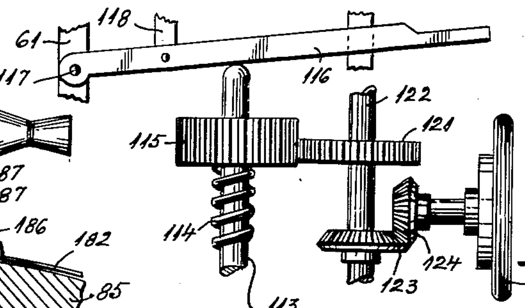

FIG. 16.

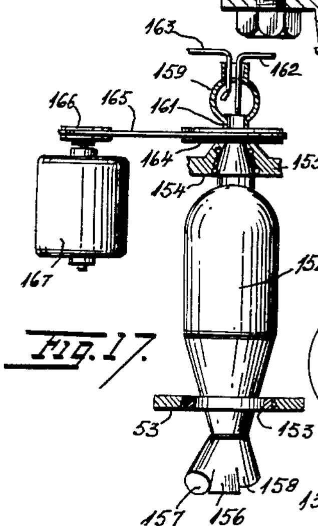

FIG. 17.

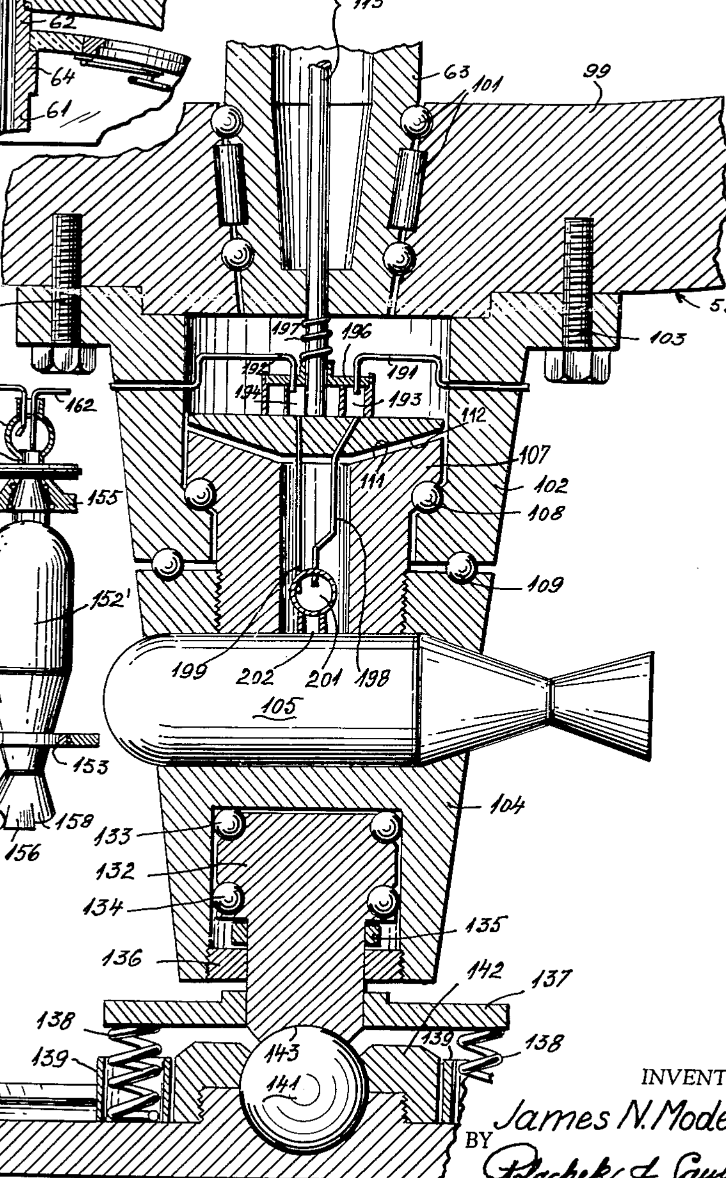

FIG. 14.

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United States Patent Office

3,199,809
Patented Aug. 10, 1965

3,199,809

CIRCULAR WING FLYING CRAFT

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Filed Aug. 12, 1963, Ser. No. 301,317
7 Claims. (Cl. 244—12)

This invention relates to experimental and manned circular wing flying craft.

It is the principal object of the present invention to provide a flying craft that can under its own propulsion be launched from the ground and maneuvered in any direction.

It is still another object of the invention to provide a flying craft of an experimental type that can be launched from a launching pole about which it will be spun by rocket motors and lifted by the rotative force of an airfoil shaped circular wing in conjunction with vertically extending rocket motors.

It is still another object of the invention to provide such a flying craft having a circular wing or airfoil that is spun about a compartment in which the personnel is housed and through the top and bottom of which observation may be made and wherein the circular foil, when the flying craft is on the ground preparatory to take off and upon landing, can be supported on a single pivot foot.

It is still another object of the invention to provide a flying craft having the immediately above object in mind, with rocket motors turnable upon the top and bottom of the flying craft independently of one another for steering the flying craft when in flight.

It is a further object of the invention to provide a flying craft that has a spinning circular wing or airfoil in which the fuel supply tanks will be disposed and spun so that the fuel will be forced into the rocket motors under pressure created by centrifugal action.

It is still a further object of the invention to provide a flying craft comprising a compartment having a vertically-extending pivot post and a circular wing or airfoil cross section pivoted upon the compartment and to the post, and spun by horizontally-extending rocket motors and adapted to be lifted by a rotating airfoil wing augmented by vertically-extending rocket motors, and in which certain of the vertically-extending motors are formed and adapted to be rotated by their jet action about their vertical axis and serve to drive electric generating means that may supply electric current into the flying craft, and electrically-operated gyratory rotated flywheel stabilizing means supported upon the pivot post in the center of the compartment, and supplied by the electric current from the rocket operated electric generator.

It is a still further object of the invention to provide a spinning type craft in which the velocity of spinning started upon the ground may be maintained when the craft is in flight.

It is still a further object of the invention to provide a manned flying craft of the spinning circular foil type operated by horizontally-extending spin rocket motors, vertically-extending thrust rocket motors, steerable top and bottom motors, with which the turning of the motors on and off controls the flight and direction of the craft and wherein this is effected from a simple control system and the actuation of simple off and on switches provided for the respective rocket motors to be turned off and on at the will of the pilot.

It is still another object of the invention to provide a flying craft operated by horizontally and vertically-extending rocket motors in which the body of the rocket motors will be enclosed within the circular foil with but the exhaust or firing cone protruding from the undersurface of the flying craft.

It is a still further object of the invention to provide a spinning wing flying craft with but a single pivot foot for take off and landing and further with a plurality of circumferentially spaced retractable landing gear wheels that can be used to support the craft upon the ground when it is not rotating and to slow down the spinning action upon landing.

Still further objects of the invention are to provide a spinning wing flying craft having the above objects in mind which is of simple construction, easy to assemble, easy to control, light in weight, compact, adapted for either experimental or manned use, which may utilize standard equipment such as rocket engines, well known fuel tanks, and instruments, and which is efficient and effective in use.

For a better understanding of the invention, reference is made to the following detailed description taken in connection with the accompanying drawing, in which

FIGURE 1 is a bottom plan view of the experimental flying craft constructed according to one form of the invention,

FIG. 2 is a fragmentary top plan view of the experimental flying craft broken away to show the interior construction of the same, the lifting jet rocket motors and the fuel compartments,

FIG. 3 is an elevational view of the launching pole with the flying craft supported thereon preparatory to take off,

FIG. 4 is an illustrative view of the flying craft in flight removed from the earth surface,

FIG. 5 is a fragmentary elevational view of the flying craft broken away to show the central construction thereof,

FIG. 6 is an enlarged fragmentary manned flying craft constructed according to a modified form of the invention, the view being in section to show the interior of the flying craft resting on the ground surface,

FIG. 7 is an elevational view of the manned flying craft resting on the ground with the landing wheels extended to support the craft on the ground, portions of the craft being broken away to show the interior construction thereof,

FIG. 8 is a bottom plan view of the manned flying craft showing the landing wheels retracted and the locations of the vertical lifting and the horizontally-extending spinning jet rocket motors,

FIG. 9 is a fragmentary top plan view of the manned flying craft with one side of the craft broken away to show internal rockets within the outer disc,

FIGS. 10, 11, 12 and 13 are illustrative views respectively showing the manned flying craft on the ground preparatory to take off, and being under control in flight by the guidance jet motors to level the ship from the left and from the right, and to move the ship horizontally,

FIG. 14 is an enlarged vertical sectional view of the bottom of the manned flying craft and in particular of the take off and landing pivot foot with the lower steering jet motor being shown in elevation,

FIG. 15 is an enlarged vertical sectional view of the top of the manned flying craft and in particular the upper steering jet motor mechanism,

FIG. 16 is a fragmentary elevational view of a portion of the steering gear control mechanism, and

FIG. 17 is an elevational view of one of the combined lifting and rotational electrical generator operating jet rockets.

Referring now particularly to FIGS. 1 to 5, the experimental flying craft will first be described. This craft is indicated generally at 20, and comprises generally a central sleeve 21 lying in the center of a disc-shaped wing or foil of airfoil cross section 22 that extends outwardly from the central sleeve over internal radially-extending ribs 23 providing thereby the outer surface of the foil 22. Between the ribs 23, there are provided triangular-shaped compartments 24 for housing bulk liquid fuel and oxygen gas tanks 25 and 26. In certain other compartments, there are located pressurized liquid fuel bottles 27 that are pressurized to supply their contents. All of these tanks can be of any desired shape but are preferably the same size in the different compartments to contain the same volume of the liquid fuel and oxygen in order to maintain a balanced weight throughout all of the compartments of the flying craft. Guidance control and pump valve equipment 28 are provided in opposing bottle compartments 24. They will be particularly retained and braced against great stress that will be set up by centrifugal action.

On the upper end of the central sleeve 21 is a ball bearing assembly 31 and at the bottom end of the central sleeve is a ball bearing assembly 32. The central sleeve 21 and the ball bearing assemblies 31 and 32 receive a launching pole 33 partially tapered and on which the flying craft is spun to assist its take off. This launching pole 33 is embedded at its lower end in a large concrete structure 34 provided on ground surface 36 and is adequately braced to and within this concrete structure 34 by embedded radially-extending side ribs 37. The circular foil flying craft when lying about the launching pole is supported upon a shoulder 38 by the bottom ball bearing assembly 32.

Suspended from the underside of the circular foil 22 at diametrically opposite sides thereof, to effect the spinning of the flying craft on the launching pole 33 and in flight, FIG. 4, are horizontally-extending liquid fuel and oxygen supplied jet rocket motors 41 and 42, that lie parallel to each other, equally radially spaced from the center of the craft and which extend tangentially to effect a spinning force about the center of the flying craft to create a gyroscopic effect so as to keep the craft in balance.

These jet rocket motors 41 and 42 are supplied with liquid fuel and oxygen from any of the fuel and oxygen tanks and bottles in the triangular-shaped compartments 24 by means of suction pumps, as well as by centrifugal action. The fuel and oxygen tanks 25 and 26 and bottles 27 are respectively connected at their outer ends by respective supply pipes 43 and 44 to the jet motors or in any other suitable manner whereby the fuel and oxygen will be supplied to these spinning motors from the tanks under the action of centrifugal force because of their location, in the flying craft. Before the spinning of the flying craft and centrifugal action has been obtained, the pressurized fuel bottles 27 may supply the fuel under pressure along with oxygen gas from the tanks to these horizontally-extending rocket motors 41 and 42. A fuel and oxygen supply system including suitably located pumps and valves will regulate and control the selection of supply sources to be used for the different jet motors, the horizontal ones and the vertical ones soon to be mentioned. However, it is to be understood that use will be made of the centrifugal action to supply the rocket motors with the liquid fuel and oxygen when the high spinning speeds are reached and demand is great.

After the flying craft has built up rotational speed on the launching pole 33, diametrically-opposite vertical thrust jet rocket motors 46 and 47 are opened up and will immediately carry the flying craft into the air. The fuel and oxygen supply to these vertical motors can be derived from any of the fuel and oxygen tanks, through any of the piping and by the operation of selected valves forming a part of the system. Such valves and the controls therefore may be of any desired conventional type, such for example, as described in U.S. Patent No. 2,939,648.

The guidance control equipment 28 may then be operated to turn off the horizontal motors 41 and 42 and the upward thrust of the flying craft can be maintained in its upward flight by the vertical thrust rocket motors 46 and 47. If the flying craft is to be left without vertical thrust, the control equipment will operate to turn off the vertically thrust motors. If there is drifting, the vertical and horizontal motors can be turned on by instruments forming part of the control equipment. Such instruments may take the form of any well known remote control switch operating equipment, such for example as that shown in U.S. Patent numbers 2,939,020 or 2,930,955. The vertical and horizontal rocket motors 46 and 47 and 41 and 42 thus can be started and stopped as desired by the control equipment and as well. The flying craft can be steered and navigated from the starting and stopping of one or both of the vertical motors to tilt the disc as desired from the ground or from other craft by any suitable conventional control radio means, such, for example, as that shown in U.S. Patent No. 2,939,020.

The craft will have a large supply of fuel and will be permitted to maneuver freely under instrument control according to the pattern of the guidance control equipment and from instruments upon the ground, or other craft. With all of the rocket motors turned off, the craft can drift toward the ground and be returned to land again, by the spinning motors 41 and 42.

Referring now particularly to FIGS. 6, 7, 8 and 9, the manned flying craft will be described. There is provided a central compartment 51, spherical in shape, which is held against turning by gyroscopic mechanism 52 and about which a disc or circular foil 53 rotates at high speed.

The inner spherical compartment 51 is large enough to comfortably house the pilots and is completely enclosed. The top and bottom of the compartment 51 are glassed as indicated respectively at 54 and 55 and these glass enclosures respectively have in them trap door openings 56 and 57 for entry into and escape from the compartment 51. They are closed respectively by lock hatch doors 58 and 59.

A central hollow pivot post 61 extends vertically from the bottom of the compartment to the top and has top and bottom stub axles 62 and 63 that respectively extend through the top and bottom of the compartment 51 from respective shoulder enlargements 64 and 65 engaging the inner wall surface of the compartment and fixed thereto against rotation.

The compartment 51 is divided by a floor 66 to provide upper and lower spaces for the pilot, navigator and copilot. They can pass through an opening 67 in the floor and over a ladder 68 to go between the spaces. The pilot, copilot and navigator are respectively indicated at 69, 71 and 72.

There is a dual control so that each pilot can control the ship from either the upper or lower space of the compartment 51. The pilot in the upper space will assume control on take off and ascent while the pilot in the lower space may assume control on landing. They make their observations respectively through the respective top and bottom glass enclosures 54 and 55, these glass enclosures providing the window domes for the craft. The entire compartment 51, with the hatch doors closed, is air tight and may be pressurized by the usual equipment provided on aircraft for this purpose.

In order to keep the compartment 51 from turning while the disc-shaped airfoil 53 is rotated at high speed thereabouts in a manner to be described hereinafter, the vertical pivot post 61 supports the gyroscopic mechanism 52 at the center point of the compartment. This mechanism 52 has two electric motor flywheels 73 and 74, the motor being incorporated within the flywheel, powered by electric current supplied by rocket driven generators to be later mentioned and supported respectively upon axles 75 and 76 extending outwardly from a mounting sleeve bracket 77 fixed to the vertical post 61 at the central location within the compartment and of the flying craft. These flywheels are respectively driven in same directions at very high speed and will give a gyroscopic action abount an axis perpendicular to that of the rotating foil to keep the canned compartment 51 from revolving with the outer circular foil 53 as the foil 53 is spun. Stabilization may be augmented and tumbling prevented in any conventional manner as by means of a rate gyro mechanism as disclosed in U.S. Patent No. 2,939,648.

The pilot 69 in the upper space has a control panel 78 accessible to him from his seat 79 and on which the various instruments used in flying of the craft are located. The landing pilot is provided with a somewhat similar control panel 81 that he can operate from his chair 82. Both of these pilots also have accessible to them hand steering wheel control mechanism which will be later described in detail. The navigator 72 has a data panel 83 adjacent to his chair 84 and such hand instruments as he may need.

The disc-shaped airfoil 53 has an open top hub and open spider-like structure 85 through which the stub axle 62 of the hollow post 61 extends, FIGS. 6 and 15. The stub axle 62 is generally tapered to keep the structure 85 spaced from the outer surface of the spherical compartment 51 and has a thrust ball and roller bearing assembly 86 to provide substantially free rotation with little friction tending to rotate the compartment with the disc airfoil 53.

On the still outer end of the stub axle 62, there is connected for turning movement a mounting cap 87 that supports a horizontally-extending top steering guidance rocket engine 88. This cap rocket engine can be adjusted angularly in a horizontal plane by a shaft 89 extending downwardly through the pivot post 61. This shaft 89 has a bevel gear 91 which is turned by a gear 92 and a hand wheel 93 on the post 61 that is readily accessible to the pilot 69. A gear 94 opposing the gear 91, meshes with the gear 92 and a shaft 95 depends downwardly therefrom through the pivot post and has a bevel gear 96 that can be turned by a gear 97 and a hand wheel 98 adjacent to the copilot 71. Thus, through this gearing the copilot as well as the pilot can turn the top steering rocket 88.

At the bottom of the craft and beneath the bottom glass enclosure 55 of the compartment 51 is a spider hub construction 99 to which the tapered bottom stub axle 63 depends and is connected therewith through a combined roller and ball bearing assembly 101, similar to the upper roller and ball bearing assembly 86 on the top stub axle 62, allowing thereby free rotation of the circular foil 53 about the pivot post 61 and the manned compartment 51, FIGS. 6 and 14. Shouldered to the underside of the bottom spider hub structure 99 is a depending sleeve bearing bracket 102 and fixed by means of fastening bolts 103. Steerably connected to the bearing block 102, in a manner to be set forth more in detail, is a combined steering rocket and landing foot supporting member 104 that carries a horizontally-extending bottom steering guidance rocket engine 105 and a landing foot assembly 106. This supporting member 104 has an upwardly-extending projection 107 fitted in the bracket 102 (FIG. 14) and is supported against downward displacement therefrom by ball bearings 108 while the support member itself is held against the lower end of the bracket 102 by the ball bearings 109 to offset the upward thrust of the support member 104 while the craft is supported on its landing foot 106 and upon the craft being landed. The upwardly-extending projection 107 has a conical clutch face 111 on its upper end which can be engaged by a conical movable clutch member 112 that is fixed to the lower end of a vertically-adjustable operating rod 113 extending upwardly through the stub axle 63. A compression spring 114 surrounds the operating rod 113 and reacts between an operating gear 115, FIG. 16, fixed to the upper end of the rod 113 and the pivot post 61 to normally maintain the clutch member 112 out of engagement with the clutch face 111 allowing the support member 104 with the steering rocket 105 and landing foot 106 to be free and remain still while the circular foil 53 is rotated at high speeds about the pivot post 61 and compartment 51.

When it is desired to use the bottom steering rocket 105 the clutch member 112 is depressed through engagement with the upper end of the operating rod by a hand lever 116 accessible to the copilot 71 and pivoted at one end to one side of the pivot post 61 at 117 and extends outwardly through the opposite side of the pivot post. Extending upwardly from the hand lever 116 and through the pivot post 61 is a connecting rod 118 that connects with another hand lever 119 which is accessible to the pilot 69 or navigator 72 whereby they may also depress the clutch 112 to operate the bottom steering rocket 105.

With the clutch member 112 in engagement with the clutch surface 111 mechanism is provided to effect the turning of the rocket support member 104 and the rocket 105 and which includes a gear 121 fixed to an operating shaft 122 and extending upwardly through the pivot post 61 and slidable upon and in mesh with the gear 115 fixed to the clutch operating rod 113. A bevel gear 123 is fixed to the operating shaft 122 and the gear and shaft are turned by a bevel gear 124 meshing with the bevel gear 123 and a hand wheel 125 accessible to the copilot 71. Conventional reduction gearing may be interposed in any part of the gear train to reduce torque imparted to wheel 125, if necessary.

In order that the pilot can likewise effect the steering of the bottom rocket 105, a bevel gear 126 engages the gear 124 and is driven by a vertically-extending rod 127 that extends upwardly through the pivot post 61 and has at its upper end a bevel gear 128 and is operated by a bevel gear 129 and a hand wheel 131 that is easily accessible to the pilot.

It should now be apparent from this mechanism that the top and bottom steering rockets 88 and 105 can be turned independently of one another and directed in different directions with the bottom steering rocket 105 permitted when desired to turn freely as when use is made of the landing foot 106.

The lower end of the bottom rocket support 104 is hollowed and receives a bearing block 132 which has upper and lower ball bearing assemblies 133 and 134 and is retained within the supporting member 104 by a collar 135 and a retaining plate 136 threaded into the bottom end of the support member 104. Tightly secured to the projecting lower end of the bearing block 132 is a circular plate 137 from which compression springs 138 depend, the same being fixed thereto at angularly spaced positions thereabout. The landing foot 106 is connected to the lower ends of the springs and has sleeves 139 that surround the springs 138 to hold the coils thereof in axial alignment with one another for maximum spring action as upon landing the craft upon the foot 106. The foot assembly can rotate about its vertical axis upon the ball bearings 133 and 134 with the thrust being taken up by the ball bearings 133, but to permit the foot 106 to tilt and level itself with the ground surface, a universal ball 141 is retained upon the foot by a threaded retaining cap 142 and engages with a concaved surface 143 provided on the lower projecting end of the bearing block 132.

To further support the craft upon the ground, and which may come into play on take off and landing, are six circumferentially-spaced retractable landing wheels 145 that can be retracted into wells 146 in the bottom surface of the circular foil 53, FIGS. 7 and 8. When the craft is on the ground it will accordingly be supported not only by the landing pivot foot assembly 106 but by the retractable landing gear wheels 145. These landing wheels 145 are used on take off up to a predetermined spinning speed of the circular foil 53 and until such time as the gyroscopic action has come into effect to balance the craft upon the pivot foot assembly 106. Upon landing the craft the landing wheels 145 are lowered after the craft has landed upon the landing pivot foot assembly 106 and after the speed of rotation of the circular foil 53 has been reduced sufficiently so that the wheels 145 can be operated upon the ground without rupture or great wear. Under conditions where the landing surface is smooth, the wheels can be lowered for the initial landing. Any appropriate and well known landing gear operating mechanism contained within the disc and remotely controlled from the cabin in any conventional manner, as by radio may be used to extend and retract the landing gear wheels.

Within the outer periphery of the disc-shaped foil 53 and at directly opposite sides thereof are respectively installed pairs of tandemly arranged horizontally-extending rocket motors 147 and 148 that have their discharge nozzle ends extending through the bottom surface of the foil 53 to exhaust into the atmosphere and spin the circular foil 53. By the rocket motors 147 and 148 lying primarily within the circular foil 53 the resistance to the rotation of the foil 53 is greatly reduced.

These horizontal rocket motors 147 and 148 burn liquid fuel and oxygen and when started will cause the circular foil 53 to be roated and spun at high speed and when sufficient speed has been reached the craft can be balanced upon its pivot foot assembly 106 and the landing gear wheels 145 retracted. The disc may be rotated by any desired manual means, either from the exterior or within the cabin, until the trip switches 169 are actuated to start the motors. The craft is then made ready for its vertical ascent. The discharge nozzle ends of the rocket motor that protrude from the underside of the circular foil 53 are preferably inclined slightly downwardly and pointed slightly radially inwardly from the tangent. These nozzles thus arranged will give a slight lifting effect sufficiently to hold the sides of the disc foil upwardly upon the pivot foot assembly and allow the landing gear to be retracted.

With the circular foil 53 spinning upon the pivot foot assembly 106 and the landing wheels 145 retracted, the primary vertical lift is effected by pairs of vertically-extending rocket motors 151, 151' and 152, 152'. These vertical rocket motors are also mounted primarily within the circular foil 53 and have their discharge nozzles protruding downwardly through and from the undersurface of the circular foil 53 and will have only slight resistance to the turning of the foil 53. While the horizontal rocket motors are slightly angled off their centers, these vertical motors are kept directly upon their centers so that there will be a true vertical thrust made from them. These vertical rocket motors 151, 151' and 152, 152' of each pair are radially-spaced from one another within the pairs and the pairs of rocket motors are respectively disposed on the opposite sides of the disc foil one hundred and eighty degrees from one another and angled ninety degrees from the respective pairs of horizontal motors 147, 148 and circumferentially-spaced between them as best viewed in FIG. 8.

The inner vertical rockets 151' and 152' of each pair are mounted within the circular foil 53 to rotate about its axis at high speed, FIG. 17. These rocket motors are respectively mounted in a horizontal guide bearing assembly 153 at their discharge end and at their upper end in a combined vertical thrust and horizontal bearing assembly 154 at the upper part of the rocket and lying within a horizontally-extending partition wall 155. Thus, the rocket motors can rotate within these bearings.

The discharge end of the vertically-extending rocket motor 152' has a central fire opening 156 and two fire openings 157 and 158 radially and angularly offset from the central opening so as to effect upon the rocket motors being fired the rotation of the rocket motor 152' about its axis. In order to make possible the supply of fuel to the rocket motor while it is under rotation an inverted cup-shaped mixing chamber 159 receives a nose supply projection 161 for rotation therein. The mixing chamber is supplied with fuel and oxygen by respective branch pipes 162 and 163.

The projection 161 also carries a large pulley 164 from which a pulley belt 165 extends to drive pulley 166 of an electric generator 167 that will supply electric current to the motor driven flywheels 73 and 74 of the gyroscopic mechanism 52, and to the various auxiliary and control equipment requiring the same for its operation. Thus are provided two such rockets 151' and 152' and two such generators 167 for the entire craft.

On the compartment wall 51 above the pilot 69 is a plurality of projections 168, ten in number, corresponding respectively to the respective rocket motors used in the operation of this craft. On the spider web structure 85 are a series of corresponding depending double acting one way conventional trip switches 169 that can be respectively operated by the extending of the projections 168. These switches will be respectively connected into the electric control system to turn on and off the rocket motors at the will of the pilot 69 from his panel 78, or the copilot from his control panel 81. Both of the control panels 78 and 81, as well as the navigator's panel 83, may have instruments from which workings of the craft are readily determined.

The circular foil 53 is divided into compartments by radially-extending ribs 171 and they are of equal size and in which fuel and oxygen containing tanks 172 and 173 are disposed and which are in turn of equal size and kept supplied with an equal weight of fuel and oxygen to maintain and keep the craft in balance at all times. The horizontal and vertical motors are supplied respectively, as best shown diagrammatically in FIG. 9, by circular pipe lines 174 and 175 connected with the respective fuel and oxygen tanks 172 and 173 at their outer peripheries so that with the circular foil 53 turning at a high rate of speed, the fuel and oxygen will be delivered to the rocket motors under pressure from centrifugal force and the thrust of the liquid and oxygen to the outer periphery of the respective tanks. Branch pipes 176 and 177 lead from the respective circular pipe lines to supply the respective horizontal rocket motors 147 and 148 while branch pipes 178 and 179 serve to supply the vertical rocket motors 151, 151', 152 and 152' leading from the respective circular pipe lines 174 and 175.

The top steering rocket motor is supplied with fuel and oxygen through branch pipes 181 and 182, FIG. 15 that will lead from the respective circular pipe lines 174 and 175. The branch pipe 181 leads to an outer annular chamber 183 that is closed by an annular turnable plate 184. A pipe 185 is carried by the rocket motor 88 and depends through the turnable plate 184 into the annular fuel supply chamber 183.

Concentric with the annular chamber 183 is an inner annular chamber 186 that is also closed by the turnable plate 184 for the supply of oxygen to a pipe 187 leading from the chamber 186 through the plate 184 to the rocket motor 88. In this manner the rocket motor 88 is supplied with fuel and oxygen and yet permitted to be turned to steer the craft and at the same time permitting high speed rotation of the circular foil 53 and the hub structure 85 relative to the rocket motor 88.

The bottom steering rocket motor 105 is similarly supplied with fuel and oxygen from branch pipes 191 and 192 leading respectively from respective circular pipe lines 174 and 175 to respective concentric annular outer and inner chambers 193 and 194 and closed by a turnable cover plate 196 downwardly through which operating rod 113 for the clutch part 112 extends. The cover plate 196 is retained over the chambers 194 by a compression spring 197 reacting against the underface of the stub axle 63 of the pivot post 61. Pipes 198, 199 lead respectively from the respective annular chambers 193 and 194 through the clutch member 112 and to an inverted cup-shaped mixing chamber 201 with which an inlet supply member 202 on the rocket motor 105 is journalled. In this manner the bottom steering rocket motor 105 may be supplied without interference upon the turning of the circular foil 53 and the depending bracket 102 at high speed relative to the support member 104 and the rocket motor 105 that is carried by it. Conventional fuel pumps (not shown) may be employed to supply fuel to rocket motors 88 and 105, although fuel may flow to bottom rocket motor 105 by gravity.

The craft when in flight can be handled by the steerable top and bottom rocket motors 88 and 105 that extend horizontally and in a manner best illustrated in the diagrammatic FIGS. 10, 11, 12 and 13. These steering rocket motors 88 and 105 are carried by the stationary compartment 51 and are unaffected by the circular foil 53. With the rocket motors 88 and 105 extending in opposite side directions, and they can be turned through three hundred and sixty degrees to be operable in any radial plane, by assuming they are both in the same radial plane, the jet action will be effected as shown in FIG. 11 to level the craft to the right to be in a horizontal position as it is on the ground and illustrated in FIG. 10, or with the top and bottom rocket motors 88 and 105 reversed, the craft can be leveled to the left, from the position shown in FIG. 12 to the horizontal position shown in FIG. 10. With the craft in the horizontal position in flight and it is desired to move the craft to the left as viewed in FIG. 13, the rocket motors 88 and 105 are extended in the same direction and operated to move the craft to the left. If the rocket motors are turned one hundred and eighty degrees from the position illustrated in FIG. 13 the craft can be moved to the right. With the steering rocket motors 88 and 105 respectively angled out of a common radial plane, a combination of or resultant vectorial movements can be simultaneously effected upon the craft.

It should now be apparent that there has been provided both an experimental and manned flying craft that while having a central body retained against rotation and that may be adapted to house the personnel of the craft, has a rotating circular foil that is rotated and at high speed by rocket motors to place the craft in a state of stabilization resulting from gyroscope action and be lifted by vertical rocket motors disposed in the circular foil and sweeping the underside of the craft to give vertical thrust to the craft.

It should be further apparent that use has been made of pressures given to the liquid fuel and oxygen by centrifugal action to supply the rocket motors. It should be still further apparent that adequate means has been provided to steer the craft.

While various changes may be made in the detailed construction, it should be understood that such changes shall be within the spirit and scope of the present invention as defined by the appended claims.

What is claimed is:

1. A flying craft comprising a central body and a rotatable circular disc-like airfoil shaped wing journalled upon the central body, horizontally-extending rocket motors respectively carried on the respective opposite sides of the circular foil and extending substantially tangentially thereto and serving to spin the circular wing upon the central body to provide gyroscopic action upon the flying craft, and vertically-extending rocket motors respectively disposed on respective opposite sides of the circular wing to discharge gases downwardly to provide the lift of the flying craft upon the gyroscopic action having

been effected, and means for supplying combustion fuel and gas to said rocket motors.

2. A flying craft as defined in claim 1, wherein said circular wing has peripherally arranged compartments, said fuel and gas supply means include fuel and oxygen supply tanks symmetrically formed alike and symmetrically disposed in said compartments in such a manner as to permit balance of the craft when the circular wing with the tanks is spun about the central body, and supply lines lead from said fuel and gas tanks from their outer peripheries to utilize the centrifugal action developed by the wing for the forcing of the fuel and oxygen gas to the rocket motors.

3. A flying craft as defined in claim 1, wherein said central body is provided with a central opening extending from the underside of the craft through the upper side thereof for the purpose of receiving a launching pole from which the craft upon being powered by its rocket motors can be launched for vertical ascent.

4. A flying craft as defined in claim 1, wherein said central body comprises a compartment adapted to be manned with personnel, said compartment having axles extending from the top and bottom and axially aligned with one another, and said circular wing has top and bottom spider hub structures receiving said axles for the circular wing to rotate thereabout, and means for restraining said central body against rotation while said circular wing is being spun thereabout.

5. A flying craft as defined in claim 4, wherein said central body further includes a pivot post extending from the top to the bottom of the compartment to support the compartment and having said axles integrally formed thereon, and said central body rotation restraining means including electrically driven flywheels carried by said pivot post centrally of the compartment and adapted for rotation and to provide gyroscopic stabilizing action.

6. A flying craft as defined in claim 1, including a solitary pivot landing foot structure depending from the center of the circular wing, said landing foot structure including a bracket fixed to said circular wing, a foot supporting member pivotally connected to the depending bracket and a landing foot, and means for universally and rotatably connecting said landing foot to the support member.

7. A flying craft as defined in claim 1, including a pivot landing foot structure depending centrally from the bottom center of said circular wing, and a series of retractable landing gear wheels circumferentially spaced with respect to one another and disposed in the bottom of the circular wing radially removed from and about the landing gear pivot and serving to support the craft while the craft is lying idle upon the ground and to reduce the spinning of the circular wing about the landing pivot foot upon the craft being landed.

References Cited by the Examiner

UNITED STATES PATENTS

2,939,648	7/60	Fleissner	244—12

FOREIGN PATENTS

533,751	9/55	Italy.
535,469	11/55	Italy.
547,021	8/56	Italy.

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March 1, 1966 W. M. WILLIS 3,237,888

AIRCRAFT

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Fig. 1

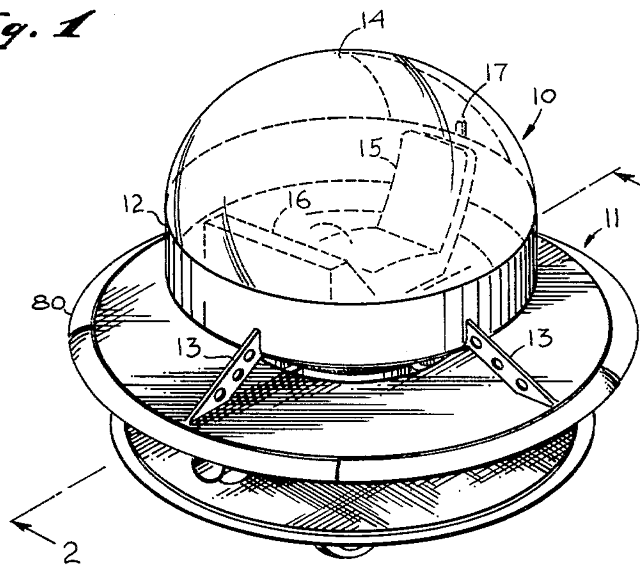
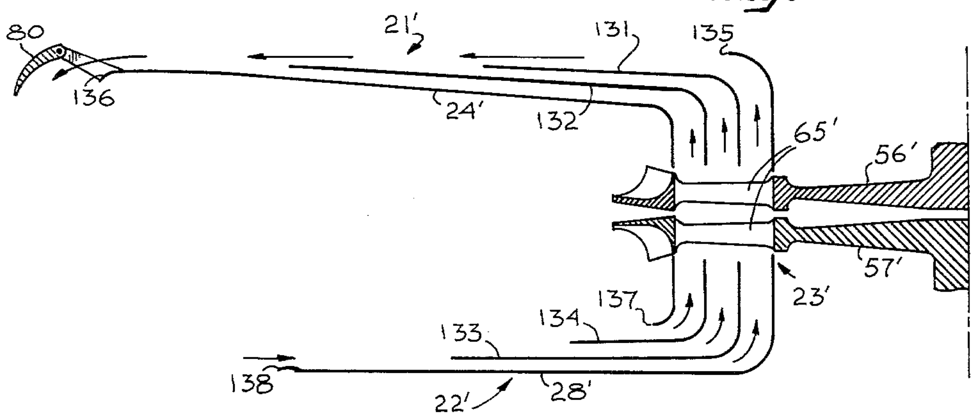


Fig. 8



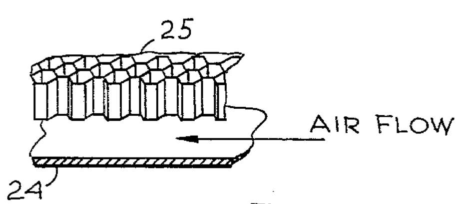


Fig. 3

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March 1, 1966 | W. M. WILLIS | 3,237,888

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Filed Sept. 18, 1962 | 4 Sheets-Sheet 2

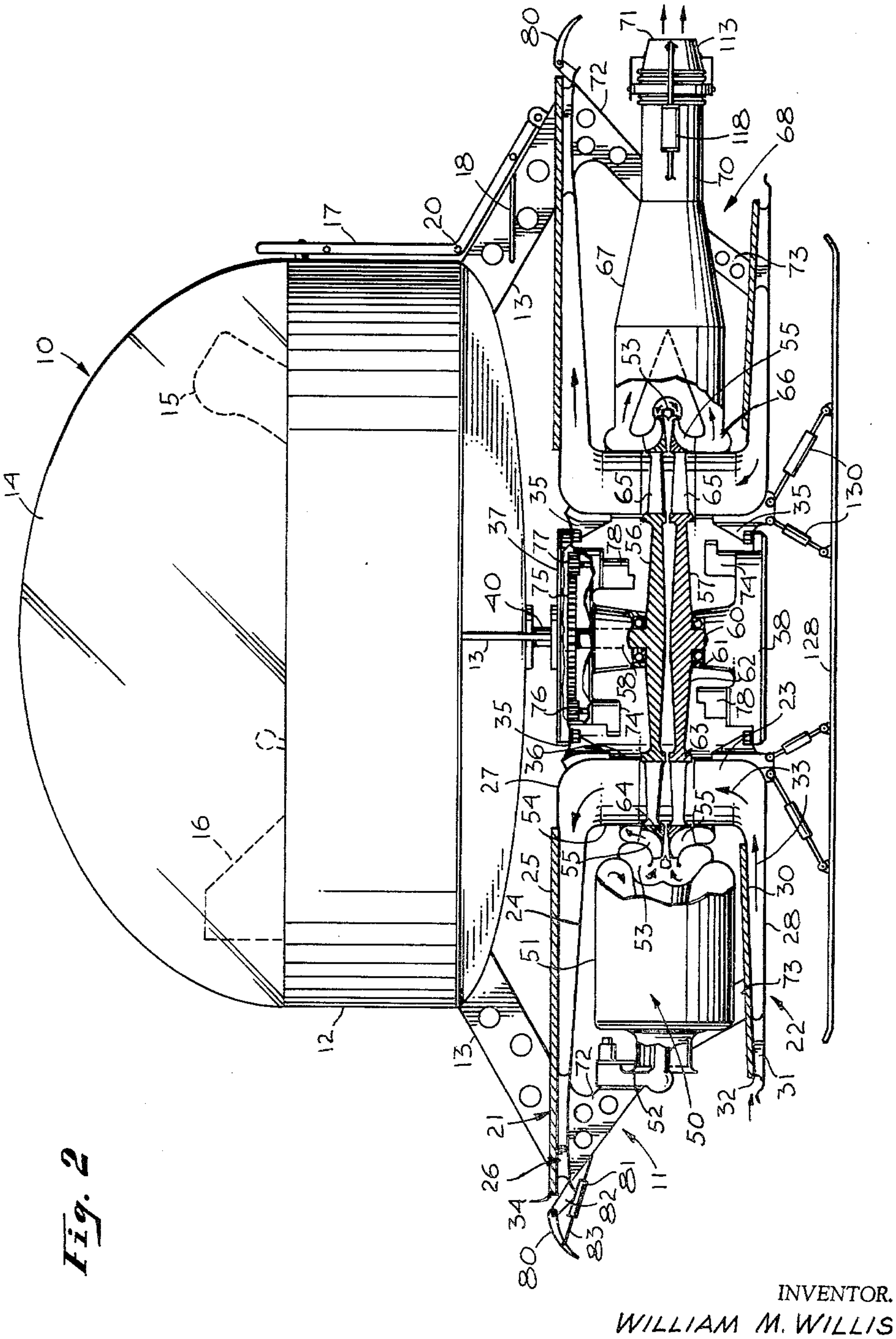

Fig. 2

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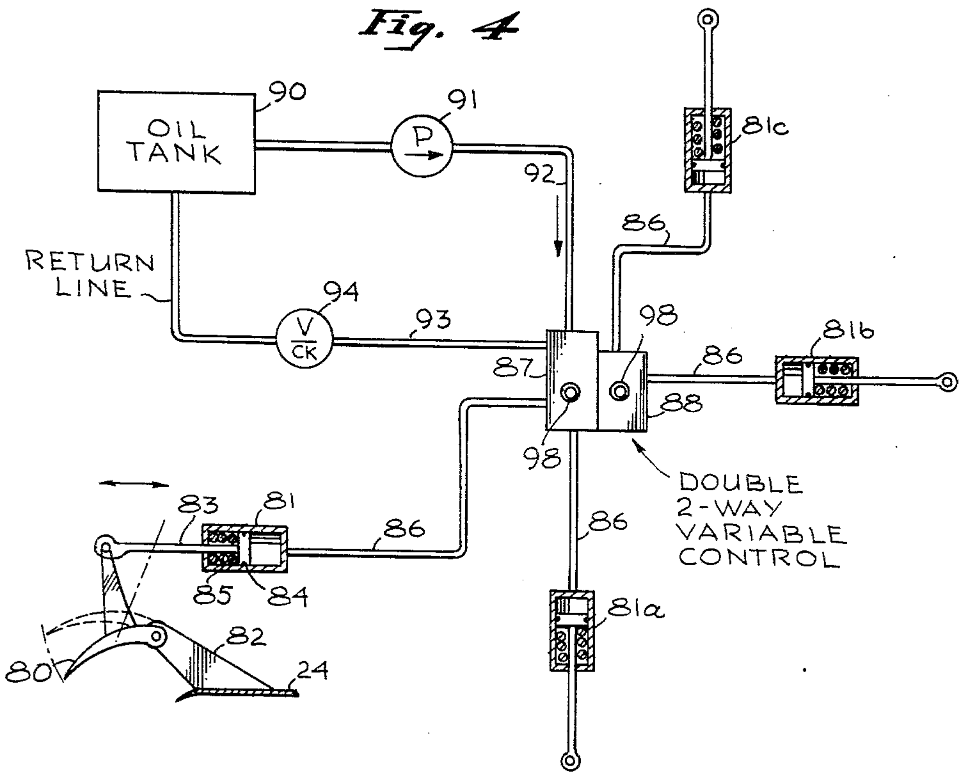
Filed Sept. 18, 1962 4 Sheets-Sheet 3

Fig. 4



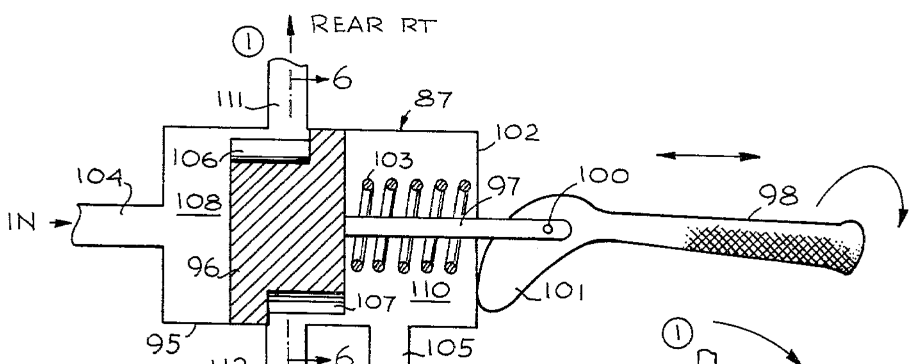


Fig. 5

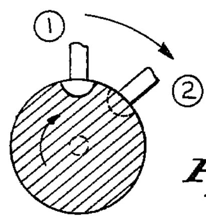


Fig. 6

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March 1, 1966 W. M. WILLIS 3,237,888
AIRCRAFT
Filed Sept. 18, 1962 4 Sheets-Sheet 4

Fig. 7

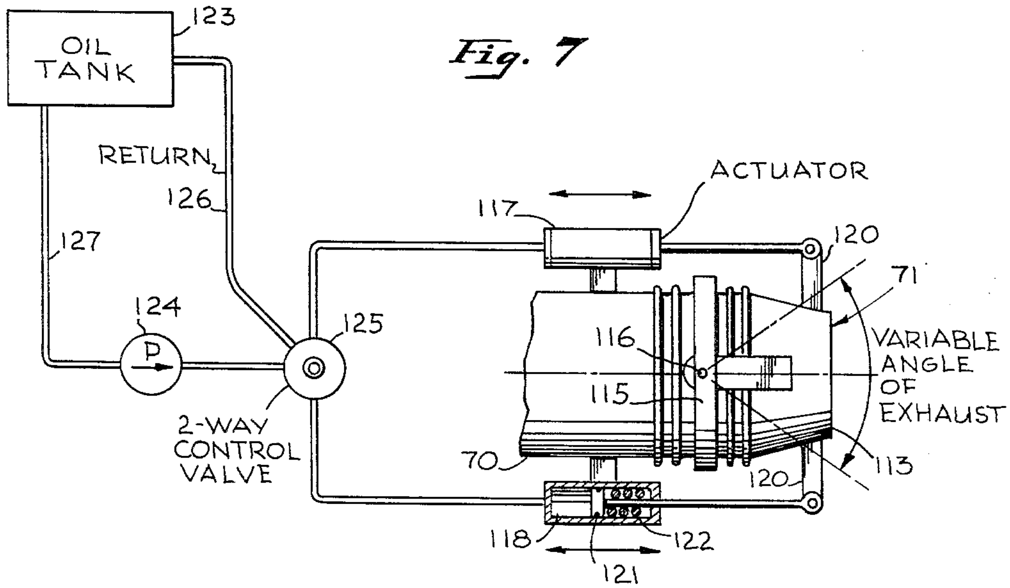
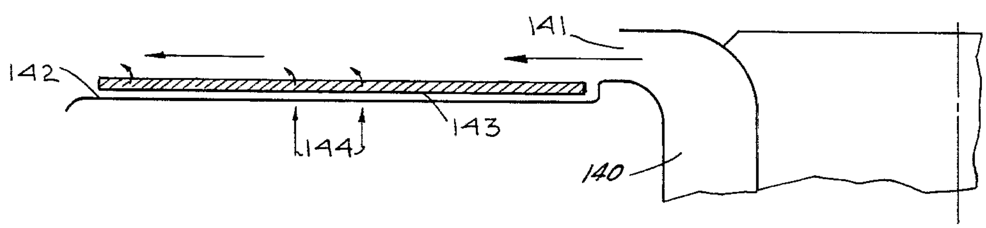


Fig. 9



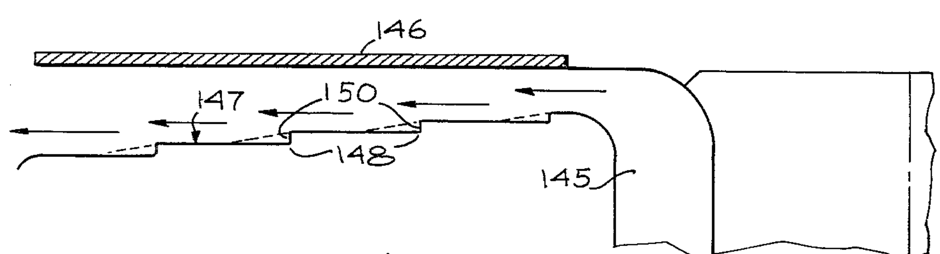


Fig. 10

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United States Patent Office

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Patented Mar. 1, 1966

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AIRCRAFT

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Filed Sept. 18, 1962, Ser. No. 224,293
3 Claims. (Cl. 244—23)

The present invention finds particular utility in the field of aircraft and relates particularly to vertical takeoff and landing type aircraft and, further, relates to hovering type aircraft adapted also for forward, reverse and lateral movements.

The aircraft of this invention is an improvement on and incorporates lift and propulsion principles similar to those set forth in Patent Number 2,990,137, issued June 27, 1961, and entitled Aircraft and Lift-Propulsion Means Therefor by the common inventor.

There has long been continued activity relating to the invention and development of many different types of aircraft employing a large variety of lift and propulsion systems. Additionally, many contemporary investigators and designers of such machinery have produced designs, built and tested aircraft for a large variety of purposes. Additionally, many attempts have been made with varying degrees of success to design, construct and operate small so-called personal type aircraft based upon known principles of operation and including new propulsion methods as these became known in the arts. It has been found generally that lift and propulsion methods and apparatus suitable for one size and type of aircraft may not be suitable for other sizes and types thereof with considerable contemporary effort being made in an extremely crowded field toward arrival at an optimum type design and construction to provide advantages of all known lift and propulsion methods when incorporated in vertical takeoff and landing type machines of varying sizes and load capacities.

Vertical takeoff and landing (VTOL) types of aircraft have taken the form of heavily powered conventional devices utilizing propellers, reaction type engines and combinations of these still further associated with ducted fans and apparatus employing displaceable axis lift and propulsion units. Additionally, various lighter-than-air structures have been used and proposed to accomplish similar ends.

In all of these prior devices, the relative efficiencies thereof as related to power requirements and necessary weight and complexity of control structures, have provided serious limitations on production of such aircraft inasmuch as the mere size and complexity necessarily dictated high cost thereof. Additionally, inasmuch as such prior structures have been relatively inefficient, fuel requirements have been high, landing and takeoff areas restricted and storage or special landing facilities had to be provided. Still further, these prior structures have required a highly trained pilot for operation thereof, inasmuch as the stability and control problems were ever present.

In other instances, matters of safety relating to operators of such aircraft and ground personnel or individuals who may casually be in an area of takeoff or landing have been considered and certain compromises had to be recognized in view of problems relating to rotating elements such as propellers or blades and exhaust from reaction type engines. These prior types have taken the form of helicopters employing single or multiple rotors, convertible types of vehicles, as well as the ducted fan arrangements. It is, therefore, desirable in such types of aircraft to avoid the use of exposed rotating propellers or blades and to minimize the effects of heated exhaust gases in reaction type devices.

2

It is accordingly one important object of the present invention to provide a VTOL type aircraft employing improved lift and propulsion propellers.

It is another object of the invention to provide a VTOL type aircraft having lift and propulsion mechanisms of high efficiency and enabling use of relatively inexpensive and small types of power plants.

It is still another object of the invention to provide an aircraft employing a turbine driven ducted fan arrangement together with an improved lifting principle enabling incorporation of such principles in relatively small as well as conventionally large types of aircraft.

It is a further important object of the invention to provide a VTOL aircraft including a novel lift and propulsion mechanism wherein high velocity air flow is established and maintained over a relatively stationary surface, means being provided to direct such air flow in close proximity to such surface.

A still further important object of the invention is to provide a VTOL type aircraft including novel means for containing a flow of high velocity air over a surface and in such close proximity to the surface as to create a reduction in static or atmospheric pressure therealong and a resultant component of force resulting from a differential pressure over atmospheric pressure which may thereafter be used for lift and control of the aircraft.

Another object of the invention is to provide a VTOL aircraft having a novel control means associated and operable in conjunction with improved lift and propulsion principles.

A still further object of the invention is to provide a VTOL type aircraft that is relatively simple in design, extremely efficient in operation, reliable in use and relatively inexpensive in manufacture.

Another object of the invention is to provide an improved aircraft mechanism of the VTOL type and including lift and propulsion means therefor wherein such aircraft presents a relatively low silhouette, is comparatively simple to operate, has improved stability and control characteristics enabling accurate maneuverability and hoverability and which is of such a size and weight as to enable a high load to weight ratio, transportation to a point of use, storage, and like necessary activities.

In accordance with one aspect of the present invention, the VTOL type aircraft hereof includes a power plant which may be of the turbine variety that is utilized to drive one or more ducted fans. The fans serve to provide a controlled flow of air over one or more surfaces whereby to produce a high velocity air flow over such surfaces to reduce the static pressure therealong below ambient atmospheric pressure. Disposition of such surfaces facing in an upwardly direction serves to provide a vertical component of force on the aircraft. Further, in accordance with the invention, means are provided for directing and/or containing the high velocity flow of air along and in close proximity to the described surfaces, such containing means being of a nature whereby to be non-pressure supporting in a vertical direction, or at 90° to the lift rector.

In accordance with a further aspect of the invention, power absorption means is provided as one manner of control of the operating speed and associated air flow volume whereby to control air flow over the described surfaces and the level of a directional motive component produced thereby. This type of control is also associated with further types of directional controls whereby to provide maneuverability of the aircraft in all directions and with no regard for immediately prior directions of movement.

In accordance with still another aspect of the invention, a plurality of surfaces are serially arranged in a manner more efficient to utilize the air flow derived from the rotating fan or fans and to enable provision of substantial lifting forces within a relatively small and compact VTOL type aircraft.

Other and further important objects and advantages and aspects of the invention will become apparent from the disclosures in the following detail specification, appended claims and accompanying drawings wherein:

FIGURE 1 is a general perspective view of the VTOL aircraft of the present invention;

FIG. 2 is a side elevational view partially in section of the aircraft and taken substantially as indicated by line 2—2, FIG. 1;

FIG. 3 is an enlarged fragmentary sectional perspective view showing details of a lifting surface and air flow confinement means associated therewith;

FIG. 4 is a diagrammatic hydromechanical diagram showing a typical form of control for the present aircraft;

FIG. 5 is a diagrammatic representation of a typical two-way variable control valve which may be used in conjunction with diagrammatic control arrangement of FIG. 4;

FIG. 6 is a transverse sectional view through the valve of FIG. 5 as taken substantially as indicated by line 6—6, FIG. 5;

FIG. 7 is a partially diagrammatic illustration representing a gimbal nozzle control for the reaction engine of the present aircraft;

FIG. 8 is a fragmentary sectional view showing a modified means for maintaining high velocity air flow over lifting surfaces;

FIG. 9 is an illustration of an alternative arrangement for creating a pressure differential across a surface; and

FIG. 10 is a view similar to FIG. 9 illustrating a further modified arrangement for creating lift acrosss a particularly contoured surface.

With reference to the drawings and with reference primarily to FIG. 1, the VTOL aircraft of the present invention includes a passenger compartment indicated generally at **10** and mounted in conjunction with a lifting control and propulsion portion **11** of the aircraft. While the passenger compartment **10** may take various forms the aircraft of the present invention is shown as including a relatively small compartment that is adapted primarily for a single individual. For this purpose inclosure **10** includes a cylindrical frame portion **12** that is supported by means of a plurality of struts **13** to the upper surface of the lift and propulsion portion **11**. The inclosure may also be provided with a suitable dome **14** in which a conventional seat **15** and controls **16** are located. The dome may further be provided with a hatch **17** with a suitable ladder or collapsible step mechanism **18** being mounted on one of the struts **13** to enable entry to the hatch **17**. If desired, the step mechanism **18** may be associated with the hatch **17** and pivotally supported as at **20** to permit stowage thereof.

The propulsion portion **11** comprises generally upper and lower annular passage structures **21** and **22**, respectively, each of which have inner peripheral ends connected to an annular passage **23**. The passage structures **21** and **22** are disposed normal to and in communication respectively with upper and lower ends of the passage **23**, an axis of the passage **23** being disposed vertically with respect to a normal attitude of the aircraft. The passage structure **21** includes a disk-like member **24** defining a lower wall thereof, an upper wall of the passage structure **21** being defined by a non-pressure supporting element or non-force element in assisting or retarding lift, indicated generally at **25**. The element **25** is also disk-like and is maintained in space relationship to the member **24** or **22** as by ribs **26** adjacent an outer peripheral area thereof, an inner peripheral area being connected to a curved transition portion **27** intermediate the passage structure **23** and the passage structure **21**. The wall **25** may be composed of any suitable material which will serve to protect a flow of high velocity air along the wall **24** while not of and by itself supporting pressure for the purpose of protecting the air stream from being disturbed or diffused by outside gust of air or the raw air in flight. Such a material may be as indicated at FIG. 3 wherein the wall **25** is shown as comprising a honeycomb structure having the plurality of openings therein positioned substantially normal to an upwardly directed surface of the wall **24**. The wall **25** may also comprise a porous medium of the type disclosed in the before-mentioned Patent Number 2,990,137. The passage structure **22** is similar to the passage structure **21** and includes an annular lower wall **28** and a non-pressure supporting upper wall **30** that is maintained in space relation to the wall **28** as by a plurality of radially extending struts **31**. In other words, the element **30**, defined as being non-pressure supporting, is of a nature whereby to support no forces that are disposed to act parallel to the direction of lift as produced on the upwardly directed surfaces of the walls **24** and **28** by the flow of air thereover. In this connection, it is to be understood that this non-pressure supporting wall **30** also serves in the nature of a means to provide the before-mentioned protection of the high velocity air flow along the upper surfaces of the walls **24** and **28**, and in the absence of external gusts of air and the like which may tend to disturb the flow of air along these surfaces such protecting structure is not needed. However, the present specific example of the aircraft is described in a manner to include such protecting structures inasmuch as most anticipated and present uses of this type of aircraft encounter flight problems wherein these protecting structures are desirable.

The passage structures **21** and **22** together with the passage structure **23** serve to define an air flow path which has an annular entrance as at **32** intermediate with the peripheral ends of the lower wall **28** and non-pressure supporting wall **30**. The air flow path is indicated by the arrows **33** and has a discharge intermediate the outer annular peripheral ends of the lower wall **24** and the non-pressure supporting wall **25** as indicated at **34**. The effect of high velocity air flowing along the path defined by the arrows **33** will be hereinafter described in detail.

The propulsion portion **11** is supported with respect to other components of the aircraft by means of brackets **35** which are connected to an inner annular surface portion **36** at the passage structure **33** and adjacent upper lower ends thereof. The brackets **36** serve also to support a pair of accessory housing members **37** and **38**, the purpose of which will be hereinafter more fully described. Also, depended from an upper surface of the housing member **37** a pillar element **40** serves to provide a support intermediate the propulsion portion **11** and the frame portion **12**, this pillar element **40** cooperating with the struts **13** to provide an adequate support for the frame portion **12** comprising a portion of the pilot's compartment.

The propulsion portion **11** further includes an engine indicated generally at **50** which for purposes of the present invention may be a gas turbine motor having a compressor and turbine section indicated generally at **51** and an accessory section indicated generally at **52**. High velocity heated gases developed by the motor **50** and delivered therefrom into an annular scroll **53** which is positioned about and in radially spaced relationship to an outer annular surface element **54** of the passage structure **23**. The hot gases are adapted to flow from the scroll **53** through a plurality of turbine blades **55** carried by the outer peripheral portion of a pair of rotors **56** and **57**. The rotors **56** and **57** are carried respectively on shafts **58** and **60** which are in turn journaled in suitable bearings **61** in the upper and lower housing structure **37** and **38**. Each of the rotors **56** and **57** have a hub portion **62** having an outer peripheral portion **63** that is spaced radially inwardly from an outer annular ring **64**. The radially juxtaposed surfaces of the rotor portions **63** and the rings **64** are generally contiguous with the inner and outer annular surfaces of the surface elements **36** and **54** defining the passage structure **23**. The portion **63** and the rings **64** are maintained in their spaced relationship by means of a plurality of generally radially extending fan blades **65**. The rings **64** serve further to support the turbine blades **55** that are suitably shrouded by means of the scroll **53**, the ring **64** being suitably contoured to define a radially outwardly directed surface along which the hot high velocity gases may flow and pass over the blades **55** and into a scroll **66**. The blades **55** on each of the rotors **56** and **57** are contoured in a reverse fashion relative to each other whereby to effect counter rotation of the rotors **56** and **57**. The blades **65** on each of the rotors **56** and **57** are also pitched in opposite directions whereby to induce a flow of air along the path defined by the arrows **33** in the direction of the arrows **33**. The hot gases leaving the scroll **66** are adapted to flow into an expansion chamber **67** of a tail pipe assembly, indicated generally at **68** and outwardly through a tail pipe **70** through an adjustable nozzle structure **71**. As shown, the engine **50** as well as the tail pipe assembly **68** are supported relative to other components of the propulsion portion **11** as by suitable struts **72** and **73**.

It may thus be seen that a high velocity flow of air is induced through the passage structures **21**, **22** and **23** along the path defined by the arrows **33** by means of the counter rotating fan blades **65**. This high velocity air flows along and is defined with respect to the upper surfaces of walls **24** and **28** by means of the non-pressure supporting walls **25** and **30**, respectively. A pressure differential is, therefore, developed across each of the walls **24** and **28**, respectively, atmospheric pressure acting upon downwardly directed surfaces thereof and lower than atmospheric pressure acting upon the downwardly directed surfaces thereof, whereby to produce a vertical component of force which may serve to lift the aircraft in a vertical direction. Such an effect is commonly known as a Coanda effect, this effect defining a well known principle wherein a stream of high velocity air will follow a surface contour and at various velocity gradients creating a lower than atmospheric pressure, giving what amounts to a lift component at the surface. It has been found that structures of the type set forth in this invention will produce a pressure differential ratio lower than atmospheric of from 1.01 to 2.7 dependent on velocity, e.g. at Mach .6 velocity a ratio of 1.23 is created. Accordingly, the primary function of the honeycomb walls **25** and **30** is to protect the flow of high velocity air over the upper surfaces of walls **24** and **28**, respectively, whereby to create the desired lifting force. In this connection, it is also well known that the static pressure existing at a surface is dependent upon the velocity of the air flowing over the surface. A relatively constant velocity gradient is maintained over the upper surfaces of walls **24** and **28** by a proper proportioning of the vertical distances between the walls **24** and **28** and the non-pressure supporting walls **25** and **30** in a radial direction. In other words, all areas of the passage structures **21** and **22** are substantially the same in a radial direction whereby to maintain a relatively constant velocity of air flow over the upper surfaces of the walls **24** and **28**. This maintenance of constant velocity over the surfaces is of substantial importance and is accomplished by the particular structural arrangement of the aircraft lift and propulsion portion of the present invention.

As one specific example relating to a particular version of the present invention that has been constructed and successfully tested, a structure was employed for test purposes that utilized a fan having a diameter of 2.98" and a hub of 1.40". Air flow created by this fan amounted to 46 c.f.m. with a velocity in the area of Mach .12. The pressure ratio created at Mach .12 was equal to 1.013. In this particular instance, and neglecting any back pressure normally encountered in passages, and further considering a lift surface having a 10" diameter, a total lift component on one such surface was found to be equal to 3.6 pounds of lift force. In this particular instance, the power required for this particular test arrangement was .0014 H.P. It may thus be seen that these relationships in sizes and forces may be proportionally changed in a manner to provide substantially equivalent forces and lifting characteristics of a full size aircraft.

The amount, volume and velocity of air passing through the passage structures **21**, **22** and **23** may be controlled in an accurate manner by means of a power absorption device, such as a hydraulic pump or dynamometer **74** that is carried by and depended from each of the housing structures **37** and **38**. Outer ends of the shafts **58** and **60** may be connected to a suitable gear **75** which in turn drive gears **76** and **77**, the gear **76** being carried by a shaft that is operably connected to the power absorption unit **74**. The gear **77** is carried by a shaft that is operatively associated with an accessory element, as for example a generator indicated at **78**. Additional accessories, such as oil pumps, generators, fuel pumps, and the like, as needed in connection with the engine **50** may be provided in the accessory package **52** carried and driven by the engine **50**.

Inasmuch as the method of obtaining vertical lift has been described herein, forward and lateral movement of the present aircraft may be accomplished by means of suitable controls including plurality of vanes **80** that are pivotally carried by an outer peripheral edge of the non-pressure supporting wall **25**. The vanes **80** are positioned in groups at various locations disposed approximately 45° from each other and are selectively actuated by means of any suitable actuating device, such as indicated at **81** and which may be a hydraulic, pneumatic or electric type actuator carried by a bracket **82** that is attached to an outwardly peripheral portion of the passage structure **21**. The actuators **81** have output shafts **83** connected to the vanes **80**. The vanes **80** are also positioned with respect to air flowing outwardly from the periphery of the passage structure **21** whereby to deflect such air flow and produce a force movement in a direction to tilt the aircraft about its central vertical axis. Upon such tilting, a resultant force created by the lifting action of the air flow along the path of the arrows **33** will have a component that is lateral to the vertical axis of the aircraft whereby to produce lateral movement thereof in any desired direction or to provide stability for the aircraft when in ambient wind conditions.

In other words, the vane **80** may be considered a complete circumferential turning vane by which the air exhausted from over the upper surface of the wall **24** will be deflected downwardly thus creating a lifting force by ram air effect and the change in the directional flow thereof. These vanes also serve as both a pitch and yaw control means or may be used in conjunction with rotatable sections in the form of a stabilizing ring or vane which may be adapted for radial outward turning to adjust the amount of ram effect in a manner similar to that employed in connection with thrust spoilers. Through such structure complete stabilization of the aircraft is made possible. In order that adequate control of the craft may be achieved, it has been found that five or more movable vanes **80** about the periphery of the propulsion portion **11** comprise a suitable number; however, it is to be understood that more or less such vanes may be employed without departing from the spirit and scope of the invention.

With reference primarily to FIG. 4, the vanes **80** may be controlled by any suitable mechanism common and well known in the art of aircraft control surface movement. In FIG. 4, a suitable control arrangement is illustrated diagramatically and is shown as including a plurality of actuators **81**, **81**–*a*, **81**–*b* and **81**–*c*. Each of these actuators are in the form of hydraulic piston arrangements, each having a piston **84** connected to the output shaft **83** and forming a movable wall one side of which engages a compression spring **85**, the other side of which is subjected to hydraulic fluid under pressure delivered thereto by way of suitable conduits **86** from a pair of two-way valves indicated at **87** and **88**. The two-way valves **87** and **88** are supplied with oil under pressure from a suitable tank **90** as by a pump **91** and through a conduit **92**. The oil under pressure is returned by way of a conduit **93** to the tank **90**, there being a check valve **94** disposed in the conduit **93**. The two-way valves **87** and **88** are in the form of control valves, one arrangement for which is illustrated in FIGS. 5 and 6. For purposes of illustration, the valve **87** is diagramatically shown and includes a body **95** in which a valve element **96** is disposed. The valve element is connected to an operating shaft **97** that is both rotatable and linearly movable by means of an operating handle or stick **98** that is pivotally connected thereto as at **100**. The handle **98** has an integral leg portion **101** which bears against a transverse end **102** of the valve body **95**. A compression spring **103** is disposed between the valve element **96** and an inner surface of the transverse end **102**. An inlet for oil under pressure is provided to the interior of the body **95** as at **104** and is delivered to a side of the valve member **96** remote from the spring **103**. A return for the oil under pressure is provided as at **105**. The valve body **96** has a pair of semicircular recesses **106** and **107** in the periphery thereof and laterally opposite one another, the recess **106** having an open longitudinal end toward a chamber **108** communicating with the inlet **104** and the recess **107** having a longitudinal end open into a chamber **110** communicating with the return port **105**. A pair of outflow connections **111** and **112** are provided in the body **95** and respectively communicate with the recesses **106** and **107**. While in FIG. 5 the recesses **106** and **107** are shown diagrammatically opposite each other for illustrative purposes, these recesses are positioned in a manner to control flow to and from a pair of the hydraulic cylinders **81**, as for example cylinders **81**–*c* and **81**–*b*. Upon rotation of the handle **98**, communication is selectively provided to one of these hydraulic cylinders with return flow from the other. Upon movement of the handle **98** in a direction pivotally about the pivot **100**, a proportional flow of fluid may be accomplished in these conduits by partial occlusion of the ports **111** and **112** by a peripheral edge surface of the valve member **96**. The described valve **87** is typical with the valve **88** operating in a similar manner.

Normal forward motion of the aircraft may be achieved through action of the exhaust gases being ejected from the tail pipe assembly **68**. As indicated hereinbefore, the tail pipe assembly is provided with the tail pipe **70** and the adjustable nozzle **71**. The adjustable nozzle is schematically illustrated in FIG. 7 and includes an exhaust gas exit structure which may be suitably controlled to direct the exhaust gases as desired. The nozzle exit structure includes a cone arrangement **113** that is pivotally connected to a gimbal structure **115** as at **116**. The gimbal structure is carried by the tail pipe **70**. The position of the cone **113** is determined by action of a pair of actuators **117** and **118** positioned on lateral sides thereof and carried by the outer surface of the tail pipe **70** as by struts **119**. The actuators **117** and **118** have output shafts peripherally connected to brackets **120** on each lateral side of the cone **113**. The actuators **117** and **118** are typically illustrated as at **118** and each includes a piston **121** that is biased in one direction by means of a spring **122** and movable in another direction by hydraulic fluid under pressure delivered from a suitable tank **123** by means of a pump **124** through a two-way control valve **125**. Excess fluid may be returned to the tank **123** by means of a conduit **126** with the fluid delivered from the tank passing through a conduit **127** to the pump **124** and two-way valve **125**. The two-way valve may be of a type illustrated in FIG. 5.

Thus, the direction of the reactive forces created by the exhaust thrust through the nozzle **71** and cone **113** may be suitably controlled.

It will be understood that the various controls, including the two-way valves **87**, **88** and **125**, may be suitably arranged in the passenger or pilot's compartment and that interconnecting lines may be provided as desired. It is also to be understood that the pumps, as for example those indicated at **91** and **124**, may be suitably driven by direct connection to the gears driven from the shafts **58** and **60** or by electrical power source, such as a battery (not shown) supplied by the generators **78**. It is also to be noted that the cone arrangement **113** serves as an anti-rotation control for the aircraft as may be desired in particular instances or as a means for orienting the craft for movement in a particular direction.

Referring primarily to FIG. 2, the aircraft of this invention is also provided with suitable landing gear which may comprise wheel structures or, as shown, may comprise skid arrangements as at **128** and supported in connection with the brackets **35** as by suitable struts **130**. It is to be understood that while skids are shown and described in connection with the present aircraft, other types of landing structures may be employed without departing from the spirit and scope of the invention.

With reference primarily to FIG. 8, a modified form of the invention is illustrated wherein means are provided for inducing a pressure differential across walls indicated generally at **24′** and **28′**. In this form of the invention, the passage structure **21′** and passage structure **22′** are connected as described hereinabove to a passage structure indicated generally at **23′**. Additionally, rotors **56′** and **57′** support suitable blades **65′** within the passage structure **23** whereby to induce a flow of air through the passage structures. It may be seen that a pair of annular vane members **131** and **132** are positioned within the passage structure **21′** and a pair of annular vane members **133** and **134** are positioned within the passage structure **22′**. Inner peripheral ends of the vane members **132**, **133** and **134** are suitably curved and disposed within the passage structure **23** having terminal ends positioned adjacent the fan blades **65′**. It may be seen that the outer peripheral edges of the vane elements **131** and **132** are radially spaced from an outer peripheral end **135** of the upper portion of the passage structure **23** and from an outer peripheral edge **136** of the surface element **24′**. Additionally, it may be seen that the outer peripheral edges of the vane members **133** and **134** are spaced radially from a radial edge **137** of the passage structure **23′** and an outer radial edge **138** of the wall **28′**. This particular arrangement obviates the necessity for use of a non-pressure supporting element to confine the flow of high velocity air over the lifting surfaces. Inasmuch as short radial areas are presented intermediate the outer radial edges of the passage structure **23**, vane members **131**, **132**, **133** and **134**, the flow of air will be adequately directed over the surfaces immediately radially outwardly from each of the outer peripheral edges of these elements. Accordingly, exposed portions of each of the elements as well as the upper surfaces of the walls **24′** and **28′** serve as the passage walls across which a pressure differential is developed to provide the desired lifting force. The particular advantage of providing the turning vanes **131**, **132**, **133** and **134** resides in the fact that such vanes provide constricting passages of peripherally increasing diameters to produce the desired efficiency. In this connection it will be recognized that the air flowing over the vanes and outwardly from peripheral ends thereof will tend to diffuse in a radially outwardly expanding cone pattern which may result in a positive pressure on a lifting surface unless suitably controlled thereover. The movable passages thus provided by the turning vanes therefore prevent such conical diffusion to provide a lift producing stucture which requires less power to accomplish a given radial length of high velocity air flow. In other words, a single passage requires a substantially greater amount of power to maintain a high velocity flow pattern with separation from the surface over which it is deployed or conical diffusion thereof.

With reference to FIGS. 9 and 10, alternative arrangements are diagramatically illustrated which may be used in conjunction with the present aircraft to provide the desired vertical lifting forces by high velocity flow of air over or through particular structures. These alternate arrangements are illustrated in the diagrammatic manner and may obviously be structurally combined with the mechanisms illustrated primarily in FIGS. 2 and 8. In the form of the invention illustrated in FIG. 9, a high velocity flow of air is delivered by way of a passage **140** to an exit therefrom as at **141**. A lifting surface **142** is provided and stepped downwardly from a lowermost surface of the passage **140**. Within the stepped portion a suitable cellular structure **143** is positioned, having openings disposed substantially normal to the surface **142**. The structure **143** may be similar to the honeycomb arrangement illustrated in FIG. 3 and has an uppermost surface that is contiguous with the lower surface of the passage **140**. Accordingly, high velocity air flowing from the exit **141** of the passage **140** is directed over the upper surface of the structure **143**, thus by aspiration creating a reduction in pressure on the surface **142** below that of atmospheric pressure which acts in an upwardly direction as indicated by the arrows **144**. As shown, this reduction in pressure is possible inasmuch as the area through the multiple passages of the structure **143** is extremely large compared to the area intermediate outermost edges of the structure and the surface **142**.

With reference to FIG. 10, this form of the invention includes a high velocity air flow passage **145**, there being a suitable honeycomb structure **146** disposed contiguous with an upper extremity of the passage **145**. In this form of the invention a skirt or radially extending element indicated generally at **147** is disposed radially outwardly from the lowermost surface of the passage **145** and is provided with a plurality of annular steps as at **148**. Accordingly, as the high velocity air flows over each of the steps **148**, a plurality of low pressure bands are developed as at **150** in conjunction with each of the steps, thus to provide an overall pressure differential across the member **147** and a vertical lifting component of force.

It may thus be seen that other types of construction may be employed to confine a high velocity flow of air along a surface of a passage wall whereby to create a force component in one direction to provide lift and/or propulsion to an aircraft vehicle.

In accordance with the foregoing, it may be seen that an aircraft device has been provided wherein objects and advantages set forth hereinbefore are accomplished and problems related to prior types of VTOL type aircraft are avoided.

Having thus described the invention and the present embodiments thereof, it is desired to emphasize the fact that many further modifications may be resorted to in a manner limited only by a just interpretation of the following claims.

I claim:

1. In an aircraft, the combination of:

a frame structure;

a pair of generally horizontally disposed annular wall members carried by said frame structure and having upwardly directed surfaces defining a pair of lifting surfaces and downwardly directed surfaces;

an annular continuous passage pneumatically interconnecting radially inner portions of said lifting surfaces;

means for inducing a high velocity flow of air over only and in close proximity to a first of said lifting surfaces, through said passage and thereafter over only and in close proximity to a second of said lifting surfaces to produce a pressure differential across said wall members, said pressure differential resulting from ambient atmospheric pressure acting upon said downwardly directed surfaces of said wall members and a pressure lower than atmospheric pressure acting upon said upwardly directed surfaces of said wall members; and

means carried by said frame structure for driving said air flow inducing means.

2. An aircraft according to claim **1** wherein said horizontally disposed wall members are annular disks having a common axis and disposed substantially parallel to each other.

3. An aircraft according to claim **1** wherein each of said upwardly directed surfaces of said wall members is provided with a flow confining and protecting means positioned adjacent and substantially parallel to said upwardly directed surfaces, said confining and protecting means being honeycomb panels each having an area substantially equivalent to an area of one of said upwardly directed surfaces and having unrestricted openings therein positioned substantially normal to said upwardly directed surfaces.

References Cited by the Examiner

UNITED STATES PATENTS

1,907,160	5/1933	Schauman	244—23
2,151,687	3/1939	Campbell	170—135.75
2,419,443	4/1947	Eaton.	
2,468,787	5/1949	Sharpe	244—12 X
2,609,068	9/1952	Pajak.	
2,843,339	7/1958	Streib	244—12
2,959,377	11/1960	Kaplan	244—40
2,973,166	2/1961	Stahmer	244—23
2,978,206	4/1961	Johnson	244—23
2,990,137	6/1961	Willis	244—12
3,041,830	7/1962	Thomas et al.	244—23 X
3,073,551	1/1963	Bowersox	244—23

FOREIGN PATENTS

393,086	10/1908	France.
129,142	7/1919	Great Britain.

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March 29, 1966 P. B. CLOVER 3,243,146

VERTICAL-TAKEOFF-LANDING AIRCRAFT

Filed April 27, 1964

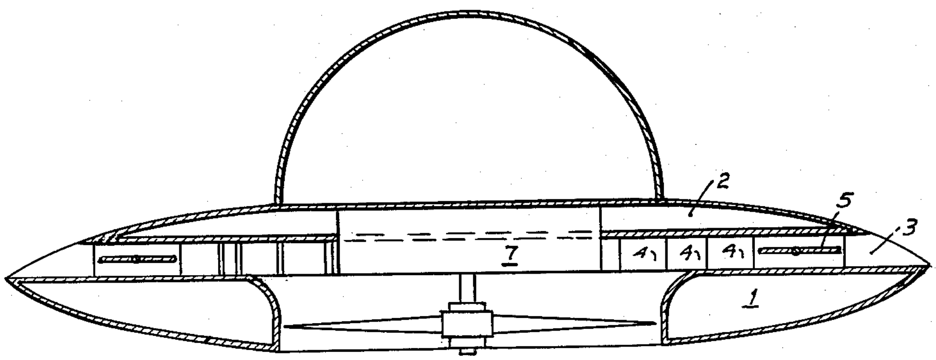

Fig. 1

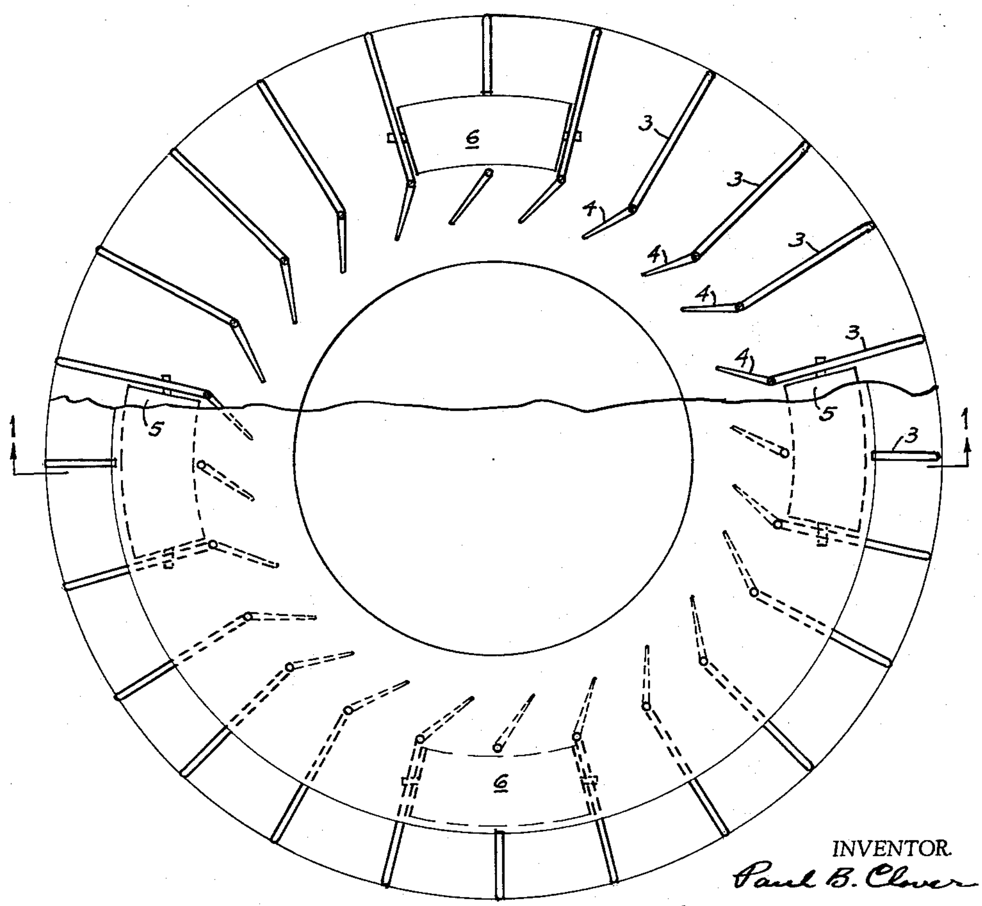

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Fig. 2

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3,243,146

VERTICAL-TAKEOFF-LANDING AIRCRAFT

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Filed Apr. 27, 1964, Ser. No. 363,347
4 Claims. (Cl. 244—23)

The object of this invention is to produce aircraft capable of vertical rise, descent, and maneuverability in flight based on principles enunciated by Daniel Bernoulli, and known to students of fluid mechanics. Birds, airplanes, and helecopters utilize and airfoil that is pushed through the air. In this machine air is made to flow over the airfoil inducing lift then discharging downward producing thrust.

Reference to the drawings indicates a sectional view of the aircraft in FIG. 1, taken along the horizontal diameter, and a plan view with part of the cap cut away to expose the structure in FIG. 2.

The aircraft consists of an airfoil **1**, cap **2**, supports **3**, torque vanes **4**, fore and aft ailerons **5**, lateral ailerons **6**, and a power plant **7** together with a propeller, fan, or other means for moving air. When assembled as shown on the drawings with the power plant in operation, air is drawn through openings at the outer edge over the airfoil in a plane perpendicular to the power plant axis then discharged downward parallel to the axis of the power plant. Lift is produced by the lower-than-atmospheric pressure over the upper surface of the airfoil coupled with thrust from the discharging air. Loads may be carried within the structure of the airfoil and cap or an enclosure on the cap. Construction methods and materials are those commonly used for aircraft.

The airfoil **1** and cap **2** are spaced and secured in their proper relative positions by means of the supports **3**. The supports may be simple structural members such as posts or they may be vanes as shown serving to direct air smoothly over the airfoil while acting as airfoil stiffeners. The cap may serve as an anchor for the power plant or the power plant may be anchored independently to the airfoil. The three parts airfoil, cap, and supports enclose the power space causing incoming air to move in proper relation to the airfoil to produce lift and thrust.

The torque vanes **4** can be either fixed, movable, or a combination of fixed and movable vanes. They are placed in the induced air stream and connected to convention controls. They serve to prevent undesired rotation about the power plant axis, also enable the aircraft to rotate as desired to face in any direction.

Fore and aft ailerons **5** and lateral ailerons **6** are placed in the induced air stream and connected to the conventional aircraft control system for stability and maneuvering. Tilting the aircraft in the desired direction of flight by means of the fore and aft ailerons produces a horizontal force component and movement in that direction. Flight is facilitated by low edge resistance due to intake of air and exterior streamlining.

The power plant **7** together with propeller, fan, or other methods of moving air may be of conventional type adaptable to used.

It is important to note that considerable flexibility in the design of the aircraft and its parts may be employed without destroying its ability to function. The drawings indicate an aircraft that is circular in plan with a given number of supports and torque vanes. The circular plan might be modified by eliminating circular segments from opposite sides of the airfoil leaving the fore and aft sections to produce lift thus making the aircraft narrower

in the lateral direction. Again the craft might be made thicker or thinner in section, the airfoil might incorporate landing gear, and the number of torque vanes and supports increased or decreased to suit a particular design. In short all parts of the aircraft can be modified to some extent from those shown so long as their basic functions are not impaired.

I claim as my invention:

1. An aircraft comprised of a circular airfoil with an integral center opening and an impelling means for moving air mounted axially and operatively therein; said airfoil supporting a cover spaced above and mounted axially with the airfoil opening defining a duct within which, and operatively mounted on the supporting structure, a number of pivoted aileron-like surfaces and a plurality of vane-like surfaces pivoted to contact the inlet airstream on both faces providing means for control and stability; said impelling means operating to draw air inwardly over the upper surface of the airfoil producing a negative pressure and resultant lift, thence around the faces of control surfaces within the duct, thence ejected downwardly producing thrust.

2. An aircraft comprised of a circular airfoil modified by the omission of a number of chordal segments from the periphery with an integral central opening and an impelling means for moving air mounted axially and operatively therein; said airfoil supporting a cap spaced above and mounted axially with the airfoil opening defining a duct within which, and operatively mounted on the supporting structure, a number of movable aileron-like surfaces and a number of vane-like surfaces some fixed and some movable to contact the inlet airstream on both faces providing means for control and stability; said impelling means operating to draw air inwardly over the upper surface of the airfoil, thence around the faces of control surfaces within the duct, thence ejected from the aircraft.

3. A control unit for an aircraft as described in claim **2** wherein said aileron-like surfaces are operatively mounted on the supporting structure within said duct by means of pivots or hinges, said surfaces in contact with the airstream and connected to actuating means whereby movement of the surfaces deflect the airstream with resultant forces deflecting the aircraft providing a means for lateral and fore and aft control and stability.

4. A control unit for an aircraft as described in claim **2** wherein said vane-like surfaces either movable or some fixed are operatively mounted on the supporting structure within said duct by means of pivots or hinges for movable vanes and rigid connections for fixed vanes, said movable vane-like surfaces in contact with the airstream connected to actuating means whereby the vanes function to deflect the airstream with resultant forces deflecting the aircraft providing a means for torque and turning control.

References Cited by the Examiner

UNITED STATES PATENTS

2,718,364	9/1955	Crabtree	244—12
2,876,964	3/1959	Streib	244—12
2,972,455	2/1961	Borchers	244—23 X
2,990,137	6/1961	Willis	244—12

MILTON BUCHLER, *Primary Examiner.*

L. C. HALL, *Assistant Examiner.*

AIRCRAFT

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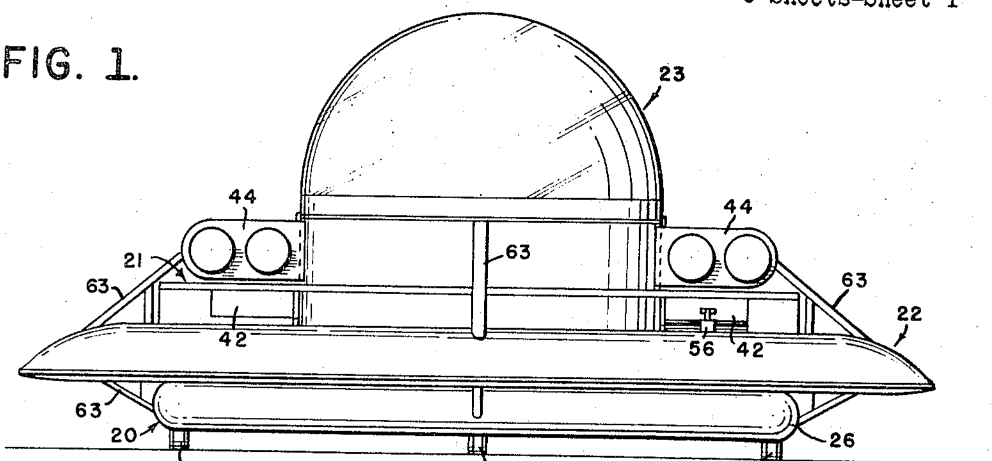
FIG. 1.



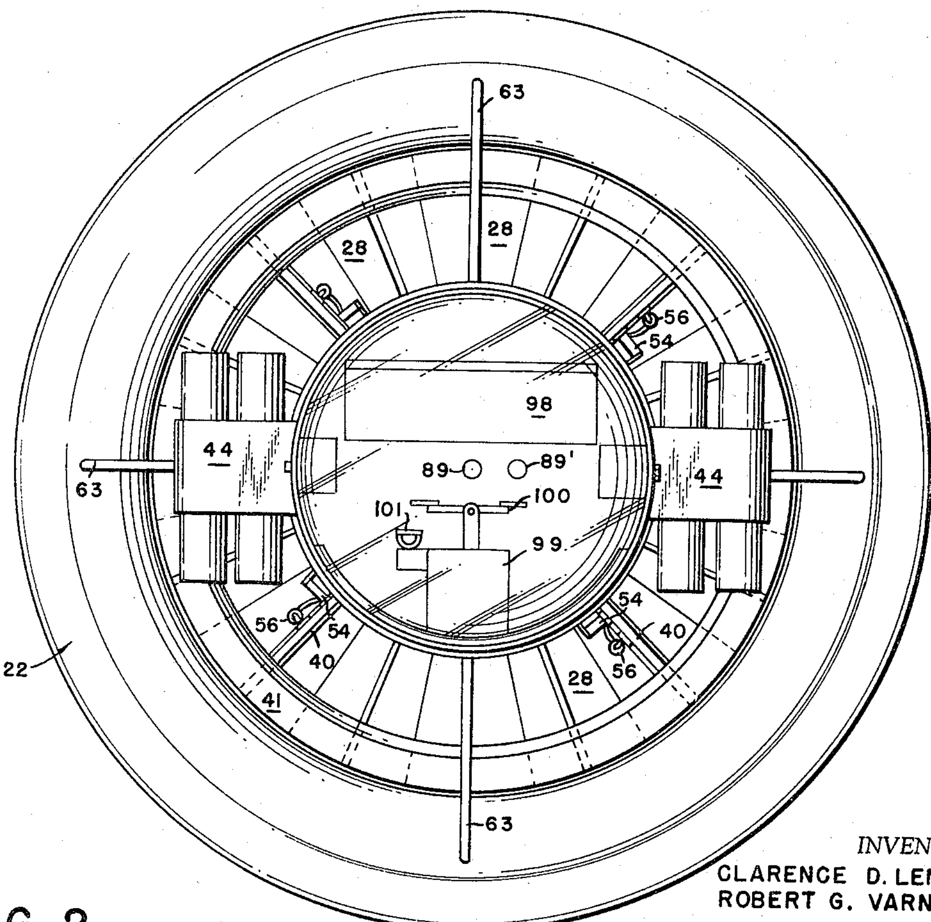


FIG. 2.

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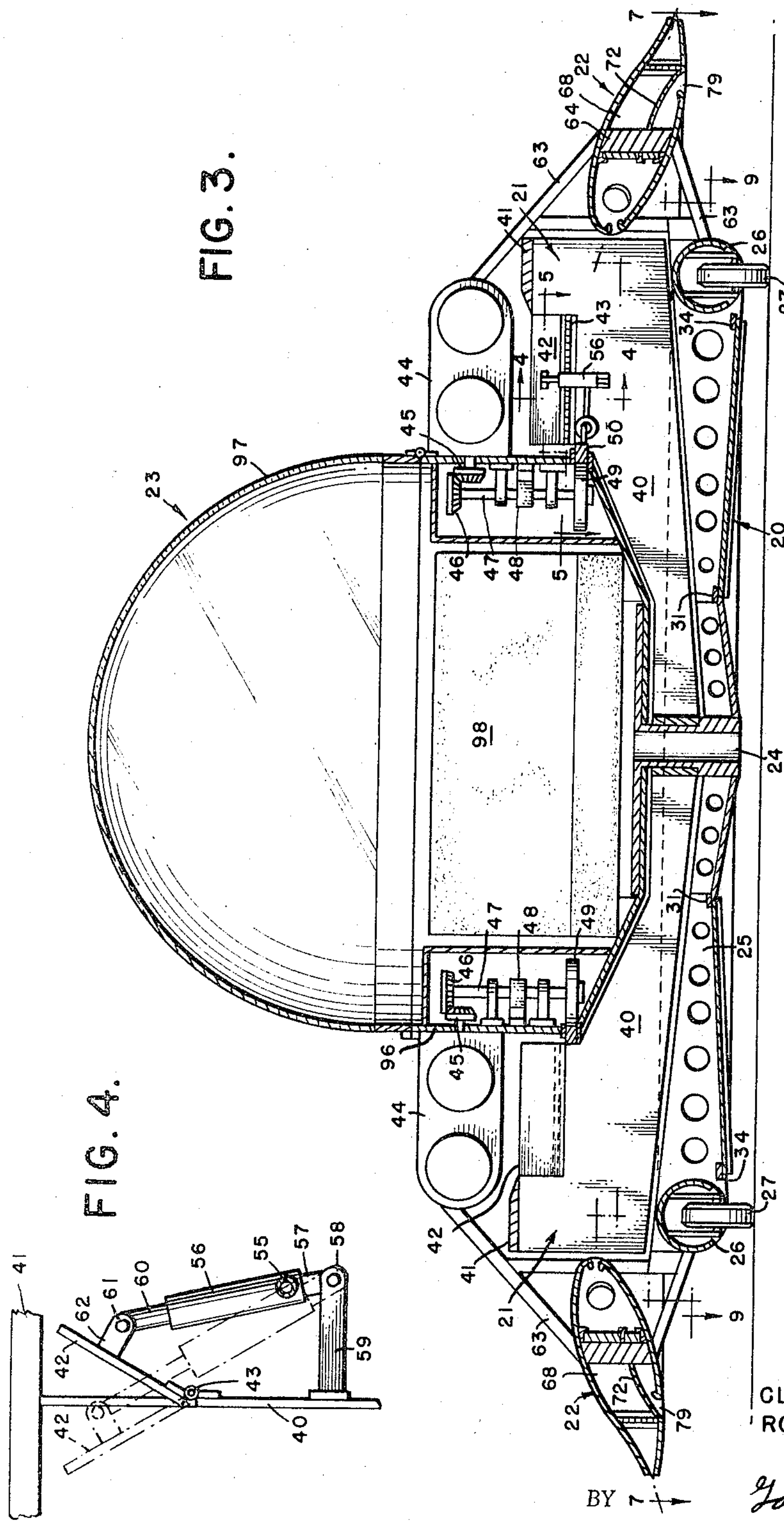

FIG. 3.

FIG. 4.

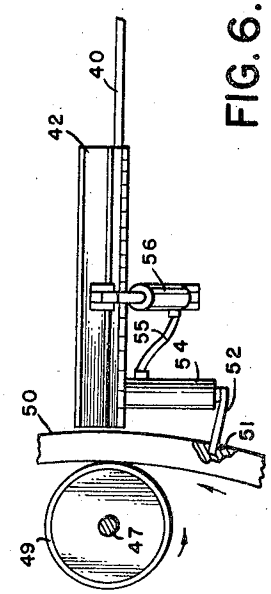

FIG. 6.

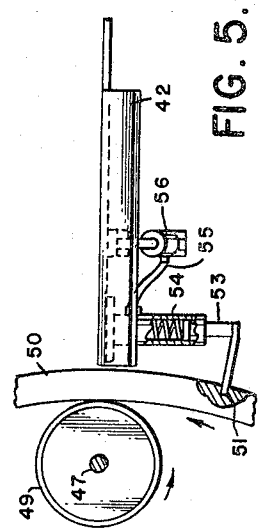

FIG. 5.

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Filed Oct. 12, 1965

5 Sheets-Sheet 3

FIG. 7.

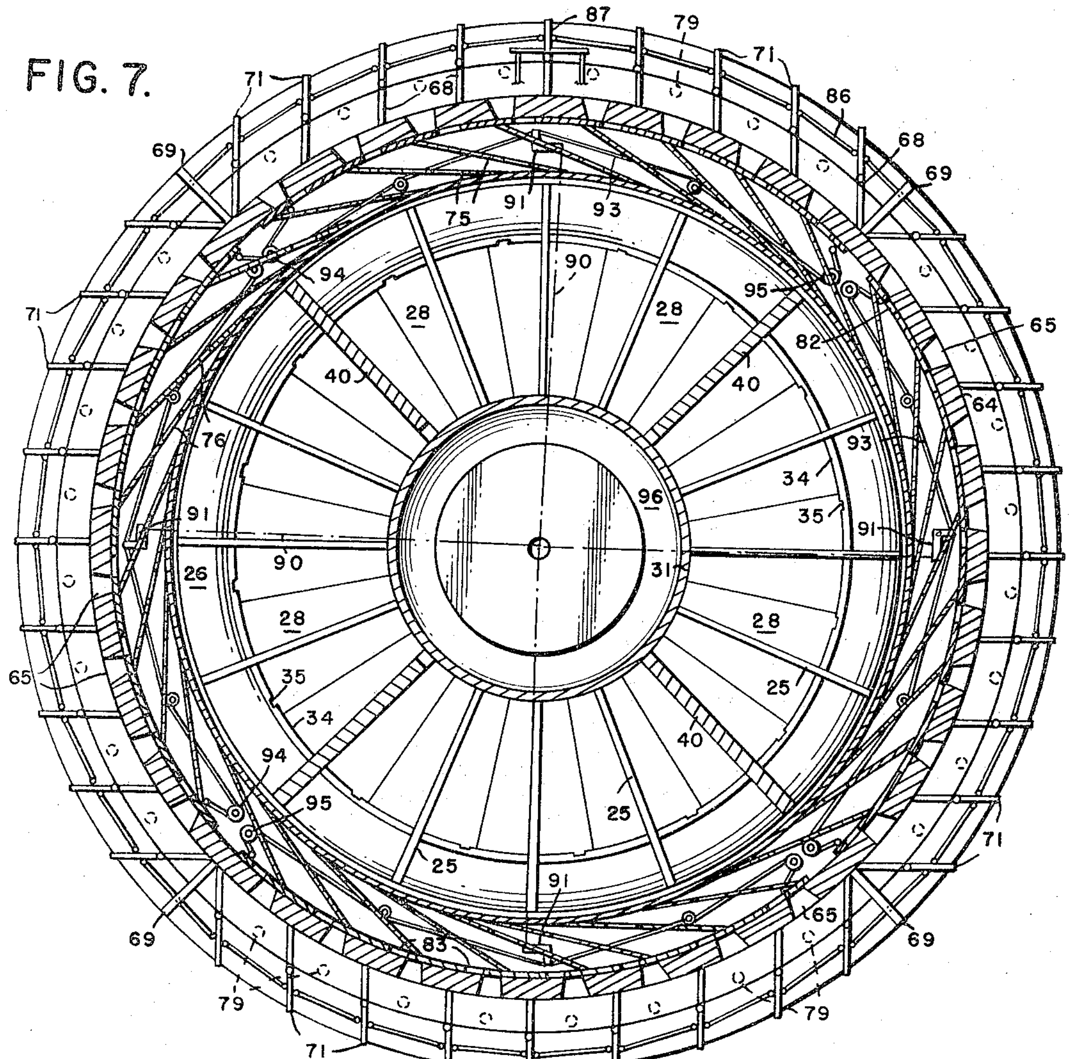
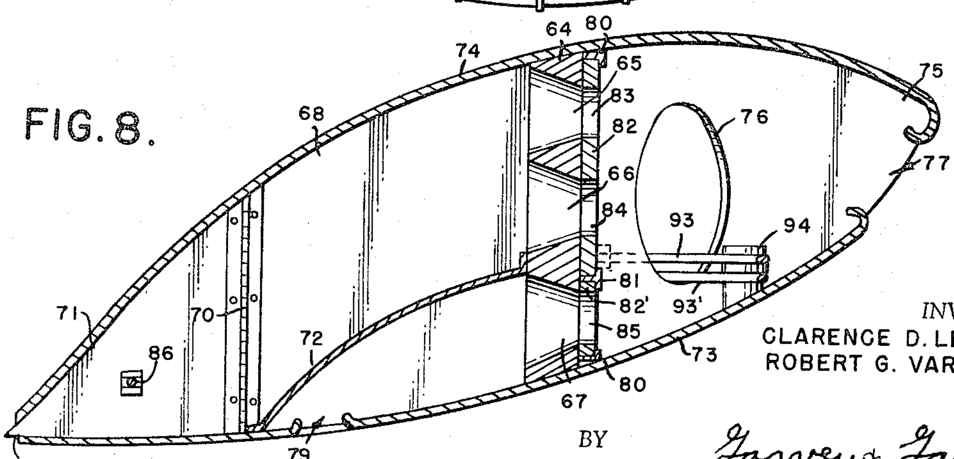


FIG. 8.



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AIRCRAFT

Filed Oct. 12, 1965 5 Sheets-Sheet 4

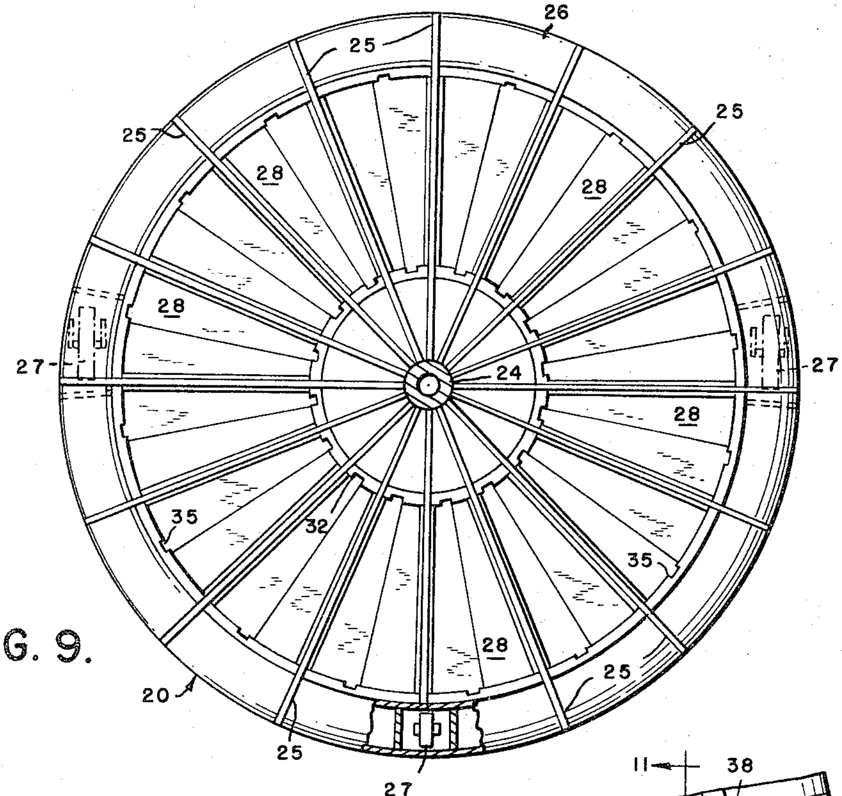

FIG. 9.

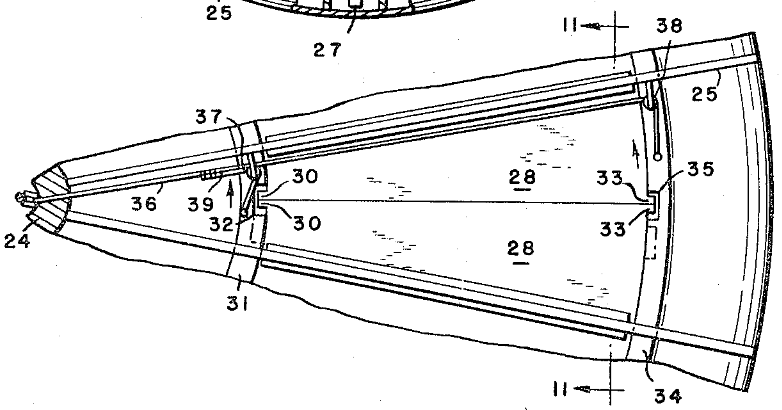

FIG. 10.

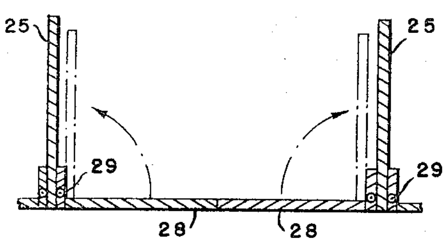

FIG. 11.

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FIG. 12.

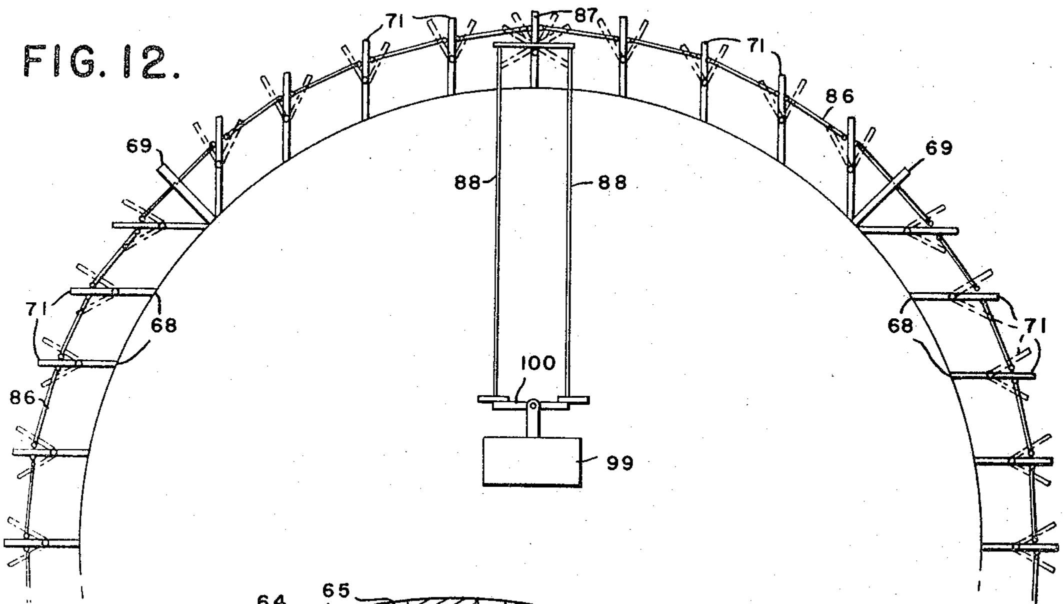
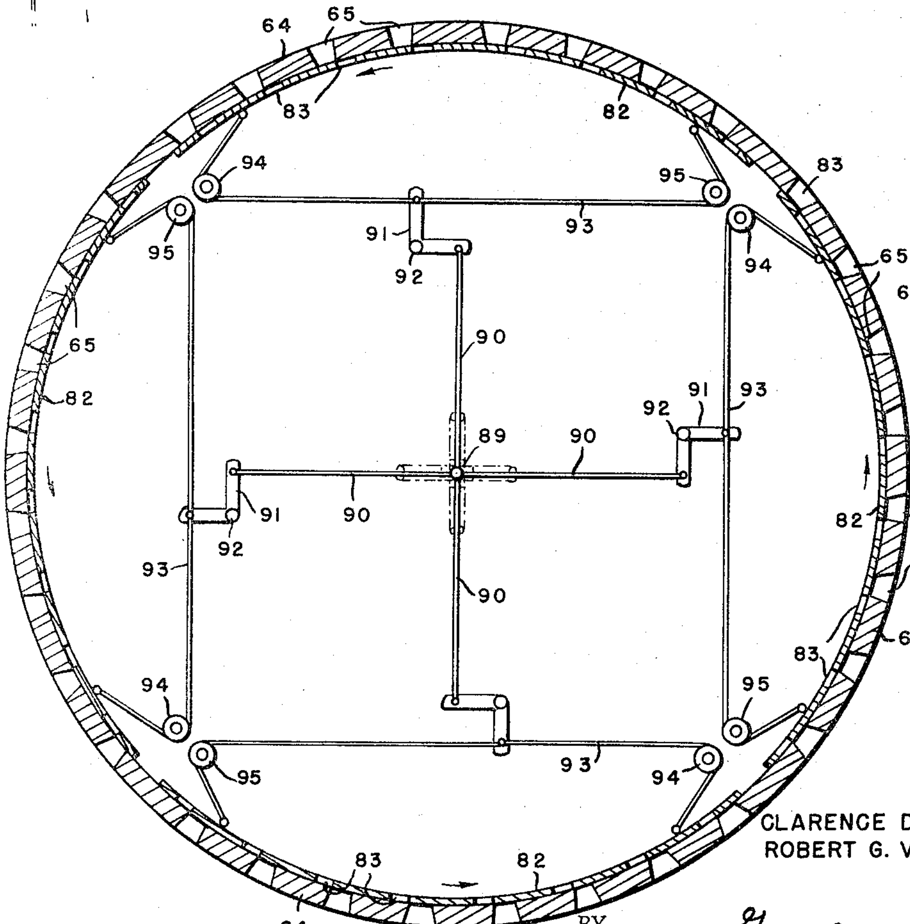


FIG. 13.



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United States Patent Office

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AIRCRAFT

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10 Claims. (Cl. 244—12)

This invention relates to aircraft, and more particularly, to aircraft adapted for vertical take-off and landing, an object of which is to effect superior lift characteristics and high lateral speed capability.

Another object is to provide a disc-shaped aircraft including a cabin, a circular, horizontally-disposed, centrifugal impeller assembly around the cabin, and an airfoil embodying a lift and control device mounted circumferentially about, and immediately adjacent to, the impeller assembly, for directing air over and through the airfoil.

Other objects are to provide an airfoil of predetermined shape set at an angle to the horizontal, for effecting optimum lift; to provide an airfoil including a lift and control device having spaced, stationary and movable vanes forming a plurality of air chambers for effecting control, the movable vanes being adjusted to produce directional heading of the aircraft; and to provide an airfoil of the character described having a plurality of orifices selectively opened and closed to produce vertical and lateral thrust components with resultant vertical and lateral movement of the aircraft.

A further object is to provide an aircraft including an impeller assembly and airfoil of the character described, wherein the upper face of the impeller assembly is open and the lower face thereof is normally closed, closure being effected by a system of shutters which are adapted to be opened in the event of failure of the aircraft engines, producing auto-rotation of the impeller, to permit a safe emergency landing.

Other objects of the invention will be manifest from the following description of the present preferred form of the invention, taken in connection with the accompanying drawings, wherein:

FIG. 1 is a front elevational view of an aircraft constructed in accordance with the present invention;

FIG. 2 is a top plan view of the same;

FIG. 3 is a transverse sectional view of the aircraft of the present invention, showing to advantage details of construction;

FIG. 4 is an enlarged sectional view taken along the lines 4—4 of FIG. 3, looking in the direction of the arrows, and showing the movable blade of the impeller assembly forming a part of the present invention;

FIG. 5 is an enlarged sectional view taken on the lines 5—5 of FIG. 3, looking in the direction of the arrows, showing the movable blade of the impeller assembly in inoperative position;

FIG. 6 is a view similar to FIG. 5, showing the movable blade in operative position;

FIG. 7 is a sectional view taken along the lines 7—7 of FIG. 3, looking in the direction of the arrows and showing to advantage the airfoil lift and control assembly forming a part of the present invention;

FIG. 8 is an enlarged horizontal sectional view taken through the airfoil forming a part of the present invention;

FIG. 9 is a sectional view taken on the line 9—9 of FIG. 3, looking in the direction of the arrows, showing to advantage the base of the present aircraft;

FIG. 10 is an enlarged fragmentary plan view of a portion of the base showing to advantage the emergency shutter system forming a part of the present invention;

FIG. 11 is a sectional view taken along the lines 11—11 of FIG. 10, looking in the direction of the arrows, showing in dotted lines, the alternate position of the shutters;

FIG. 12 is a schematic showing of the control system for the movable vanes of the airfoil lift and control device; and

FIG. 13 is a schematic showing of the control mechanism for a sliding valve of the airfoil lift and control assembly forming a part of the present invention.

Referring now in greater detail to the drawings, the aircraft of the present invention comprises a base **20** of disc shape on which is centrally mounted a circular, centrifugal impeller assembly **21**. An airfoil lift and control assembly **22** is mounted circumferentially about, and immediately adjacent impeller assembly **21** for coaction therewith. A cabin **23** is centrally mounted above base **20** and impeller assembly **21**.

As shown to advantage in FIGS. 3 and 9, base **20** includes a central hub **24** from which a plurality of equispaced girders **25** of equal length extend radially. An annular flotation ring **26** is fixed in any suitable manner to the outer limits of girders **25** for buoying the aircraft in water. Base **20** further includes wheel assemblies **27** fixed to, and pending from, flotation ring **26** at 90° intervals for supporting the aircraft on land surfaces.

Base **20** is further provided with a plurality of shutters **28** hingedly connected at **29** to girders **25** intermediate flotation ring **26** and hub **24**. As shown in FIG. 11, shutters **28** are preferably hinged to both faces of each girder **25**, each shutter extending to a point midway adjacent girders **25**, so that a pair of shutters lies between the girders. Each shutter **28** is provided with an extension tab or abutment **30**, the tabs of adjacent shutters **28** being so located that they are contiguous when in the lowered position, as shown in FIG. 10. An inboard slidable ring **31** is supported by girders **25** superjacent extensions **30** of shutters **28**, said ring being provided with a series of recesses or notches **32** normally non-aligned with shutter extension tabs **30** but adapted to be moved into superjacent relationship with the tabs when it is desired to open shutters **28** to the position shown in dotted lines in FIG. 11. Each shutter **28** is additionally provided with an outer extension tab or abutment **33**, which tabs, as shown in FIG. 10, are also adapted to be in contiguous relationship when the shutters are in lowered or closed position. An outboard ring **34** is also slidably supported by girders **25**, which ring is also provided with recesses or notches **35** adapted to register with extensions **33** synchronously with the alignment of inboard ring recesses **32** with extensions **30** to permit opening of the shutters.

In accordance with the objects of the present invention, shutters **28** are opened only in case of emergency to effect safe landing of the aircraft, and the opening is effected manually by means of a shutter cable **36** trained over pulleys **37** and **38** to outboard ring **34**. A supplemental shutter cable **39** affixed to cable **36** is trained over pulley **37** into engagement with movable inboard ring **31**. Cable **36** extends upwardly into cabin **23** for ready access to the pilot. Shutters **28** are normally left in the closed position shown in FIGS. 3 and 9 and are only raised to the open position under emergency conditions to be hereinafter more fully discussed.

Impeller assembly **21** is of the centrifugal type and includes a plurality of vertically-disposed blades **40** extending radially from hub **24** in spaced relationship, a portion of each blade being reduced for interpositioning between base **20** and cabin **23**. The height of each blade **40** is increased laterally of cabin **23** and to the outermost portion thereof is affixed a ring **41** in engagement with the upper edge of each blade and extending completely around the aircraft, for shaping and directing the centrifugal flow of air produced by the rotating blades. Adjacent ring **41**, a portion of blade **40** is hingedly connected at **43** to the main portion thereof to provide a moving surface and thereby change the chamber of said blade relative to its vertical component. Blades **40** are rotated by a suitable source of power such as engines **44**. These engines may be mounted laterally adjacent cabin **23**. The source of power may be of the reciprocal type, as illustrated, rotary, jet, turbine or electric. For supplying rotary motion to the impeller blades, each engine is provided with a geared power take-off **45** connected to a mating gear **46** of a driven shaft **47**. A conventional centrifugal clutch **48** is positioned intermediate the length of shaft **47**. A friction-type roller **49**, disposed in a horizontal plane, is fixed to the lower terminal of the shaft. Each roller **49** is in diametrically opposed engagement with the inner periphery of a rotatably mounted impeller drive ring **50** disposed between cabin **23** and impeller blades **40**.

As shown to advantage in FIGS. 5 and 6, ring **50** is provided with diametrically opposed recesses **51** in the outer periphery thereof, each of which is adapted for the reception of a pin **52** of a hydraulic actuator mounted on a blade **40** and including a piston **53** movable in a cylinder **54**, the piston being normally urged to its extended position by a compression spring. The actuator is connected by a hose **55** to a movable vane actuating cylinder **56** which is shown to advantage in FIG. 4. Cylinder **56** is provided with a lower arm **57** which is pivotally connected at **58** to a rigid horizontally disposed support member **59**, the free end of which is in fixed engagement with blade **40** at a point subjacent an intermediate section of movable portion **42** of blade **40**. Cylinder **56** is further provided with a piston **60** the outer terminal of which is pivotally connected at **61** to an arm **62**, the free end of the arm being fixed to a face of movable portion **42** of blade **40**. Pivotal connection **58** and **61** permit movement of cylinder **56** from the inoperative position shown in full lines in FIG. 4 to the operative position shown in dotted lines in the same view, at which time, piston **60** is in fully extended position.

In accordance with the objects of the present invention, when engines **44** are actuated, clutch **48** is engaged to rotate friction-type rollers **49**, ring **50** being rotated in the direction indicated by the arrows in FIGS. 5 and 6. By virtue of the connection of pin **52** in recess **51** of ring **50**, the latter opposes the hydraulic pressure of the hydraulic actuator. This effects movement of piston **53** into cylinder **54** and creates limited relative movement of ring **50** with respect to blades **40**. The entry of piston **53** into cylinder **54** in turn, results in application of hydraulic pressure **55** to cylinder **56**, causing movement of piston **60** to its extended position and movement of movable part **42** of blade **40** from the inoperative position to the operative position as shown in FIG. 4. When piston **53** has been urged wholly within cylinder **54**, ring **50** and blades **40** are rotated together to produce rotation of the impeller blades.

Airfoil lift and control assembly **22** is mounted circumferentially about, and immediately adjacent to, impeller assembly **21**, assembly **22** being supported by a plurality of struts **63**. Assembly **22** is so constructed that a cross section thereof taken from a point adjacent to, and tangentially from, the periphery of the circular path described by blades **40** of impeller assembly **21** is of the most desirable airfoil shape. Additionally, as will be noted from FIG. 3, assembly **22** is disposed at an angle to the horizontal which provides the most desirable lift coefficient for the airfoil shape. This assembly therefore is of optimum shape and angle of attack.

Assembly **22** basically includes a circular spar **64** which, as shown to advantage in FIG. 8, is provided with vertically aligned orifices **65**, **66** and **67**. Extending outwardly from spar **64** are spaced stationary vanes **68**, the upper and lower contours of which are curved to produce the desired airfoil shape. It will be noted from FIG. 7 that stationary vanes **68** are so arranged that the vanes of each quadrant of the circular aircraft are parallelly arranged

with respect to each other, which quadrants are separated by walls **69**, the latter being radially disposed with respect to the aircraft and extending from spar **64** to the outer periphery of the aircraft. The outboard edge of each stationary vane **68** is hingedly connected at **70** to a movable vane **71** which is of generally triangular shape to effect the desired airfoil shape, the movable vane extending to the outer periphery of the aircraft. A curved baffle **72** extends from spar **64** at a point above orifice **67** rearwardly and downwardly into engagement with the lower skin surface **73** of the airfoil assembly, and upper skin surface is indicated at **74**.

Assembly **22** further includes a plurality of spaced ribs **75** inboard of spar **64** which are tangentially arranged with respect to the circular path of movement of blades **40** and between which ribs, a portion of the air is directed by the impeller assembly. The upper and lower surfaces of ribs **75** are contoured for optimum airfoil shape and are adapted to support skin surfaces **73** and **74**. Each tangential rib **75** is provided with a compression port **76** through which air may pass to effect more uniform air pressure in the air chambers formed by the ribs and skin surfaces.

It will be noted from FIG. 8 that assembly **22** is provided with an intake slot **77** which is located along the inner periphery of the assembly adjacent impeller assembly **21** for admitting air interiorly of the airfoil assembly as well as over the surfaces thereof. The outboard edge of the airfoil lift and control assembly also includes horizontal thrust orifice **78**, at its outer periphery, where surfaces **73** and **74** are proximate each other, which orifice establishes a path for the explosion of air passing through orifices **65** and **66**. Assembly **22** further includes a vertical thrust orifice **79** in skin surface **73** beneath baffle **72** and adjacent its connection to skin surface **73** thereby establishing a path for the expulsion of air flowing through orifice **67**.

Inboard of circular spar **64** there are provided spaced upper and lower tracks **80** adjacent the upper and lower limits of the spar and intermediate track **81** located between orifices **66** and **67**. A plurality of spaced valve members **82** are slidably mounted between upper track **80** and intermediate track **81** and similar valve members **82'** are slidably mounted between intermediate track **81** and lower track **80**, as shown to advantage in FIGS. 8 and 13. Each valve member **82** preferably extends through approximately a quadrant of the circular spar and is provided with pairs of spaced, vertically aligned openings **83** and **84** adapted to be moved into and out of alignment with openings **83** and **84**. Under these conditions, air flowing through intake slot **77** is compressed and forced through orifices **65** and **66** and then outwardly through orifice **78** to produce horizontal thrust. Valve member **82'** is movable independently of member **82** to align openings **85** and orifices **67** when desired, thereby causing air to be directed downwardly by baffle **72**, for explosion through orifice **79**, with resultant vertical thrust.

There is schematically illustrated in FIG. 12, means for controlling directional heading and torque of the aircraft by means of orientation of movable vanes **71** in unison. For this purpose, the movable vanes are connected by a cable **86**, one end of the cable being secured to a face of a pivotally mounted cross-shaped member **87**, the opposite end of the cable being engaged with the opposite face of the cross-shaped member. The transverse portion of the cross-shaped member is, in turn, provided with operating cables **88** which extend into cabin **23** for manipulation thereof in a manner to be hereinafter more fully set out.

The thrust control of the aircraft includes mechanism for slidably moving valve mmebers **82** and **82'**. This mechanism comprises two identical systems operable independently of one another for controlling movement of the valve members, the one system being operated by a control stick **89** and the other by a control stick **89'**, both located in cabin **23**. This effects selective opening of horizontal thrust orifice **78** and vertical thrust orifice **79**. In FIG. 13, there is illustrated the system for operating valve member **82**, parts of the system shown in other figures of the drawings for operating valve member **82'** being identified by like, primed numbers. The system for operating valve member **82** includes stick **89** preferably located in cabin **23**, and connected to four push rods **90** located at 90° angles to each other. The lower terminal of stick **89** is journaled in any suitable bearing, permitting movement of the stick through 360°. The free terminals of push rods **90** are connected to conventional bell crank levers **91** which are pivoted at **92** in response to movement of push rods **90**. Each bell crank **91** is affixed to an intermediate portion of an actuating cable **93**, the terminals of which cable pass over spaced double pulleys **94** and **95** and are affixed to opposite ends of valve member segments **82**. Stick **89** is also movable vertically to effect simultaneous opening of all valve members **82**.

Cabin **23** includes a lower compartment **96** to which is hingedly connected a transparent bubble top **97**. As shown in FIG. 2, compartment **96** includes a seat **98** in front of which is a control panel designated **99**. A steering member or rudder bar **100** is mounted on the floor proximate seat **98**, which steering member is connected to cables **88** for operating vanes **87** of the airfoil lift and control assembly **22** to effect heading and torque control of the aircraft. Control stick **89** of the thrust control is located between steering member **100** and seat **98** for controlling the opening and closing of horizontal thrust orifice **78** to effect movement of the aircraft in the desired lateral direction, i.e. forward, backward or to either side. Control stick **89'** is located adjacent stick **89** for controlling the opening and closing of vertical thrust orifice **79** to effect balancing of the aircraft with respect to its vertical axis. There is also mounted on control panel **99**, a manually operated handle **101** which is connected to shutter cable **36** for opening shutters **28** to effect autorotation of impeller blades **40** in the event of power failure.

In operation, engines **44** are activated to engage centrifugal clutch **48** for transmitting rotary motion from friction gear **49** to impeller drive ring **50** to initiate rotary motion of the latter about its central axis. This action forces piston **53** of each hydraulic actuator **54** inwardly, thereby effecting movement of piston **60** of cylinder **56** to its extended position, thereby inclining the movable portion **42** of blade **40** in the direction of rotation. After piston **53** has been urged into cylinder **54** to its maximum extent, blades **40** and ring **50**, by virtue of connection **52**, are rotated together. In normal operation, shutters **28** are in the closed position shown in FIG. 3 thereby preventing the flow of air upwardly through the base. It will be noted from FIGS. 2 and 3 however, that the upper surface of the impeller assembly is open to permit the flow of air between impeller blades **40**. Upon rotation of blades **40**, the air is thrown radially outwardly under centrifugal force on a line tangential to the path of rotation of the blades. The discharged air is confined between the upper surface of base **20** and the lower face of impeller ring **41**.

A portion of the discharged air flows diagonally across the external surface of airfoil lift and control assembly **22**, from the inboard to the outboard edge thereof. This air flow will therefore produce lift to permit vertical take-off of the aircraft. Further, as the air that is discharged from the impeller assembly strikes the inboard edge of the airfoil, a portion thereof passes through intake slot **77** into an air chamber formed by the upper and lower surfaces of the airfoil, tangentially disposed ribs **75** and circular spar **64**. This air becomes partially compressed in the chamber and is then discharged selectively through orifices **65** and **66** or orifices **67**. By virtue of operation of two sliding valves **82**, the partially compressed air is directed into the desired discharge chamber for expulsion of the same through either horizontal thrust orifice **78** or vertical thrust orifice **79**. The selective discharge of the air effects a thrust forward, backward, to either side, or in a vertical direction, to produce movement in a lateral plane and balance about its vertical axis. Operation of movable vanes **71** by steering member **100** in the stream of discharged air effects heading and torque control.

In the event that one of engines **44** fails, said engine is immediately and automatically disconnected from the impeller assembly by disengagement of centrifugal clutch **48**, allowing the remaining engine to continue powering the impeller assembly. In the event of failure of the second engine, the clutch **48** is disengaged, causing relative movement of impeller drive ring **50** with respect to blades **40** under urging of hydraulic actuator **54**. Piston **53** is thereby returned under hydraulic pressure to the position shown in FIG. 5 and movable portion **42** of the impeller blade inclined at an angle to the main body portion of the blade in the direction opposite to the direction of rotation. Emergency shutter handle **101** is then pulled to rotate shutter rings **31** and **34** until recesses **32** and **35** are aligned with extension tabs **30** and **33**. Shutters **28** are forced open under air pressure to the position shown in dotted lines in FIG. 11 to allow air to flow upwardly through base **20** where it strikes blades **40**, causing rotation thereof in the same direction in which the blades are normally rotated by engines **44**. This sustains the aircraft to permit a gradual descent thereof for an emergency landing.

With the aircraft of the present invention the ascent and descent thereof are controlled by the engine throttle since an increase or decrease in the velocity of the air passing over the airfoil creates additional or less lift as desired. Therefore no moving external parts and no lateral movement of the aircraft are necessary to provide lifting, so that take-off and landing may be safely carried out from restricted areas. The present aircraft is, in effect, operating within a self-induced moving body of air, which air is directed outwardly in all directions, enabling the aircraft to obtain higher lateral velocities due to reduced overall drag. By eliminating airfoil tips, all resulting efficiency losses are eliminated and further, a relative chord greater than the actual chord is utilized, thereby creating greater relative lift for a given area than possible with conventional airfoils. In all phases of operation, the airfoil is positioned in its optimum position eliminating the need of compromise conditions such as inefficient angles of attack. Additional lift is created by virtue of the impeller assembly creating a lower air pressure on the upper surface of the base than that on the lower surface. With the control and propulsion systems of the present invention, there is no need to upset the normal gyroscopic balance produced by the revolving impeller blades to provide control in all directions. At the same time, however, the present system provides for correcting an unbalanced condition caused by loading or atmospheric disturbances. The present invention also provides the highest possible safety factors.

Although a preferred form of the present invention has been shown and described, it is nevertheless to be understood that various changes may be made therein, without departing from the spirit and scope of the claims hereto appended.

We claim:

1. An aircraft comprising a circular base, a control station mounted on said base, an impeller assembly rotatably mounted on said base, for rotation about said control station, a lift-producing air-foil circumferentially positioned around said impeller assembly, said airfoil being provided with an air intake slot inboard thereof, adjacent the outer extremity of said impeller assembly, a horizontal thrust orifice in the outer periphery of said airfoil, a vertical thrust orifice in the lower portion of said airfoil, means for selectively directing air to the

horizontal thrust orifice and vertical thrust orifice, and power means for actuating said impeller assembly, to direct air substantially radially over and through said airfoil.

2. The aircraft of claim 1 with the addition of spaced stationary members within said airfoil forming air chambers, movable vanes extending from the outward edge of said stationary members, and means for relocating said movable vanes with respect to said stationary members to change the lateral direction of flight of the aircraft.

3. An aircraft comprising a circular base, a control station mounted on said base, an impeller assembly rotatably mounted on said base for rotation about said control station, said impeller assembly including a plurality of spaced blades movable in a horizontal plane, the main body portion of said blades being vertically disposed, each of said blades including a movable part hingedly connected to the main body portion of the blade, means for positioning said movable part of each blade at an angle to the main body portion thereof to change the camber of the blade relative to its vertical component, a lift-producing airfoil circumferentially positioned around said impeller assembly, and power means for actuating said impeller assembly to direct air substantially radially over and through said airfoil.

4. The aircraft of claim 3 with the addition of means in engagement with the power means comprising a drive ring rotatably mounted on said base, drive means for transmitting rotary motion from said power means to said drive ring, an actuator connected to said drive ring, said actuator being operated by movement of said driven ring, a power cylinder mounted on the main body portion of the blade, said power cylinder being in operative engagement with said actuator, a piston within said power cylinder, the free terminal of said piston being engaged with the movable part of said blade, said piston being urged by said actuator to its extended position to adjust the moving part at an angle to the main body portion of the blade.

5. An aircraft comprising a circular base embodying a central hub, spaced supports radially extending from said hub to the outer periphery of the base, shutters hingedly connected to said supports and extending between said supports when in closed position to cut off the flow of air upwardly through said base, means for opening said shutters for allowing the passage of air upwardly through said base, an impeller assembly rotatably mounted above, and operable in a plane parallel to said base, power means for normally actuating said impeller assembly, and means for changing the camber of the blades of the impeller assembly to an auto-rotative position upon failure of the power means, said impeller assembly being auto-rotated by air pressure upon opening said shutters, in the event of failure of said power means.

6. The aircraft of claim 5, wherein extension tabs are provided at the inboard and outboard edges of the shutters and a pair of rings are provided in superjacent relationship with said extension tabs.

7. An aircraft comprising a circular base, a control cabin mounted on said base, an impeller assembly rotatably mounted on said base, power means for actuating said impeller assembly, and an airfoil lift and control assembly circumferentially positioned around said impeller assembly, said airfoil lift and control assembly including an airfoil, a circular spar within said airfoil concentric with said base and impeller assembly, said spar being provided with air orifices, spaced ribs inboard of said circular spar, said ribs being disposed tangentially with respect to the circular path of movement of said impeller assembly, spaced stationary vanes within said airfoil outboard of said circular spar, forming air chambers, movable vanes extending from the outer limit of said stationary vanes, means for relocating said movable vanes with respect to said stationary vanes, an air intake slot at the inner periphery of said airfoil, a horizontal thrust orifice in the outer periphery of said airfoil, a vertical thrust orifice in the lower portion of said airfoil, and means for selectively directing air within the airfoil to the horizontal thrust orifice and vertical thrust orifice.

8. The aircraft of claim 7 wherein said means for selectively directing air to the horizontal thrust orifice and vertical thrust orifice comprises sliding valves mounted on said circular spar, said sliding valves being provided with openings selectively aligned with the air orifices of said circular spar for directing the flow of air through the vertical thrust orifice or the horizontal thrust orifice of the airfoil.

9. The aircraft of claim 8 wherein said circular base embodies a central hub, spaced supports radially extending from said hub to the outer periphery of the base, shutters hingedly connected to said supports and extending between said supports when in closed position to cut off the flow of air upwardly through the base, said shutters being provided with longitudinal extension tabs extending beyond the main body portion thereof and shutter-retaining rings mounted on said base and rotatably movable about the axis thereof, said rings being superjacent said shutters and engageable with the longitudinal extension tabs to normally retain the shutters in closed position, said rings being provided with a plurality of recesses complementing the extension tabs and normally not aligned therewith, and means for simultaneously aligning the ring recesses with said shutter extension tabs to effect opening of the shutters under air pressure in the event of power failure.

10. An aircraft comprising a circular base embodying a central hub, spaced supports radially extending from said hub to the outer periphery of the base, shutters hingedly connected to said supports and extending between said supports when in closed position to cut off the flow of air upwardly through said base, said shutters being provided with longitudinal extension tabs extending beyond the main body portion thereof, a ring mounted on said base and rotatably movable about the axis thereof, said ring being superjacent said shutters and engageable with the longitudinal extension tabs to normally retain the shutters in closed position, the ring being provided with a plurality of recesses complementing the extension tabs and normally not aligned therewith, means for simultaneously aligning the ring recesses with said shutter extension tabs to effect opening of the shutters, an impeller assembly rotatably mounted above, and operable in a plane parallel to, said base, and power means for normally actuating said impeller assembly, said impeller assembly being auto-rotated by air pressure upon opening said shutters, in the event of failure of said power means.

References Cited by the Examiner

UNITED STATES PATENTS

2,567,392	9/1951	Naught	244—23
2,863,621	12/1958	Davis	244—23
3,045,951	7/1962	Freeland	244—23
3,159,360	12/1964	Ryan et al.	244—17.11 X

FOREIGN PATENTS

678,700	1/1964	Canada.

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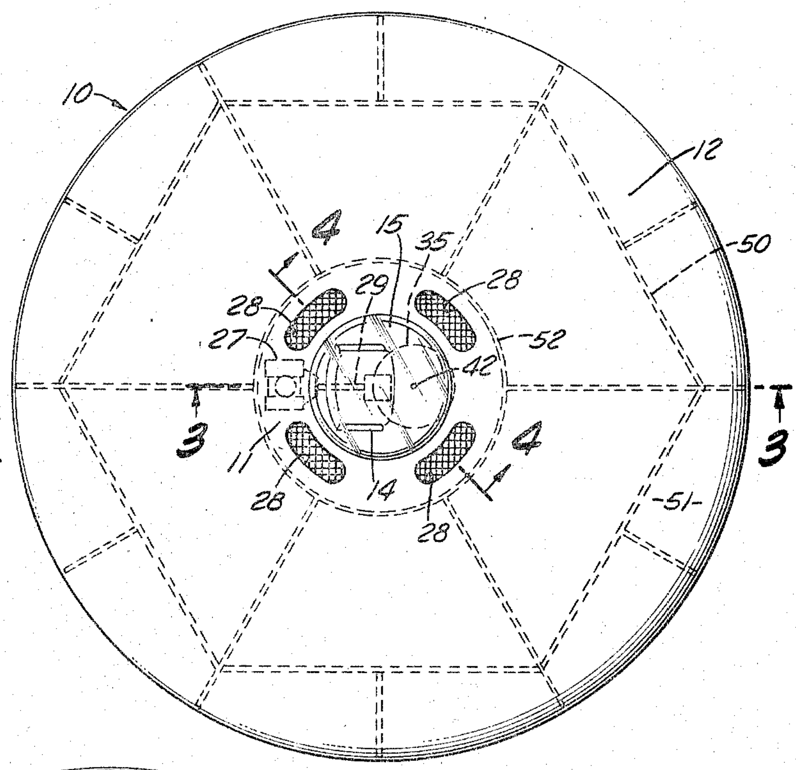
UNIVERSALLY MANEUVERABLE AIRCRAFT

Filed March 18, 1965 3 Sheets-Sheet 1

FIG. 1.



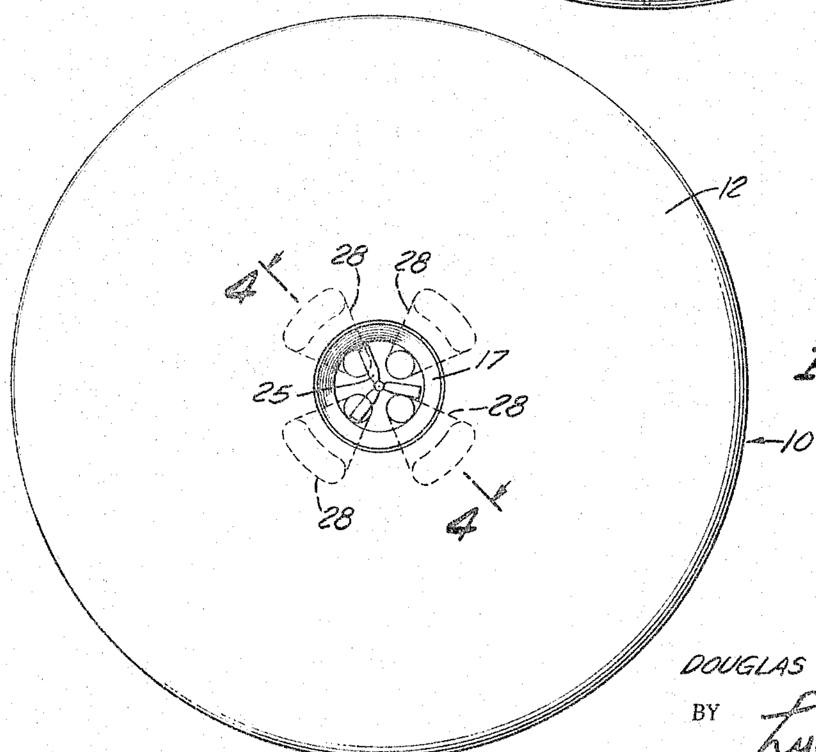


FIG. 2.

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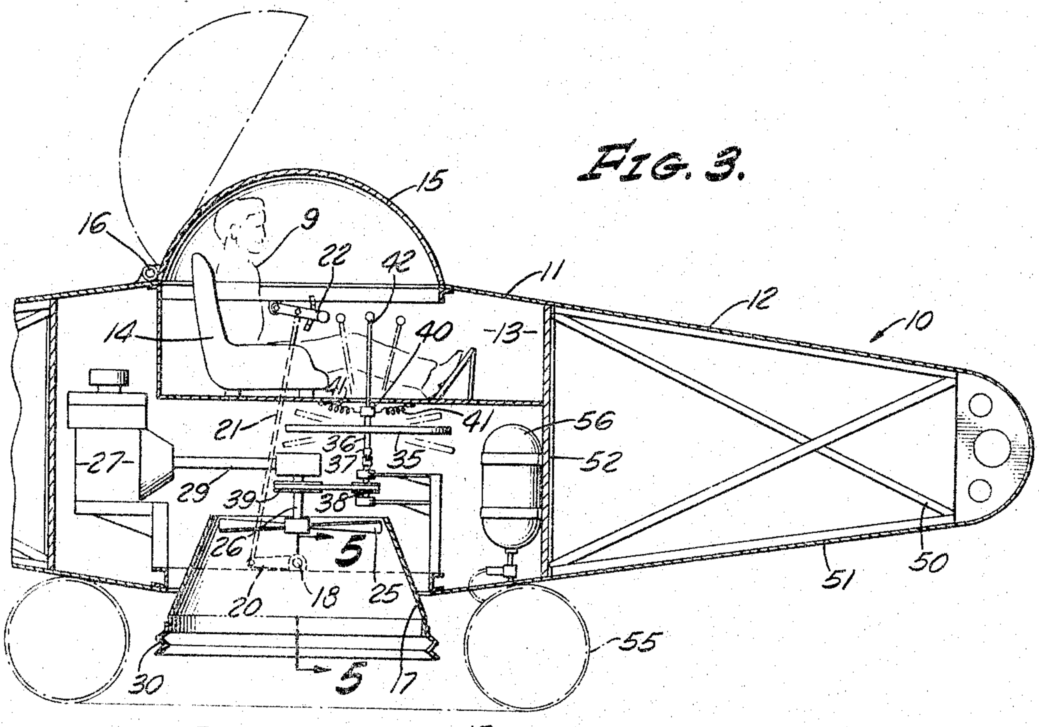
UNIVERSALLY MANEUVERABLE AIRCRAFT

Filed March 18, 1965 3 Sheets-Sheet 2

FIG. 3.



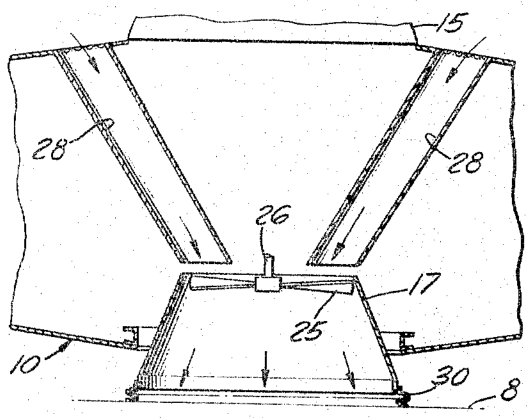
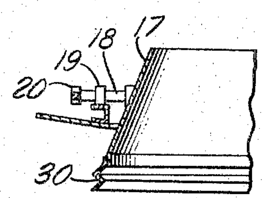


FIG. 4.

FIG. 5.



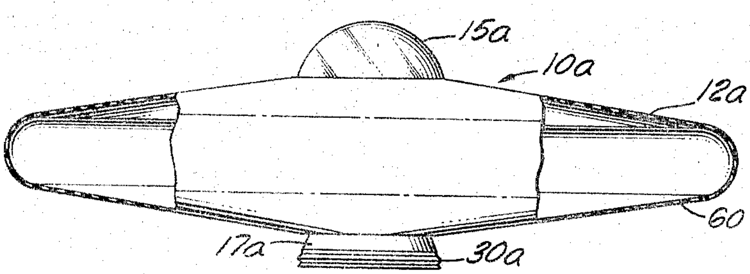


FIG. 6.

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UNIVERSALLY MANEUVERABLE AIRCRAFT

Filed March 18, 1965 3 Sheets-Sheet 3

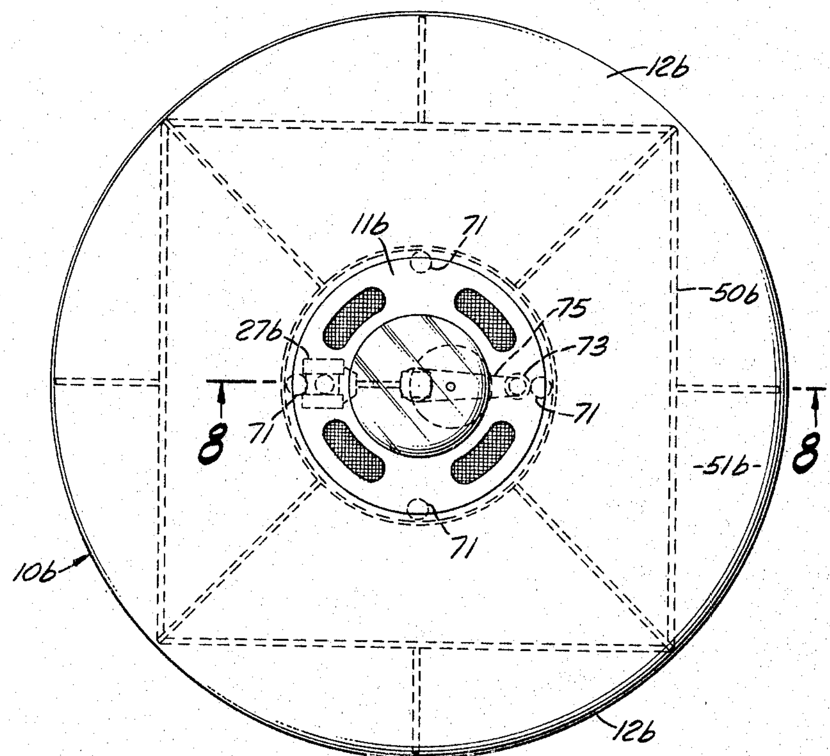

FIG. 7.

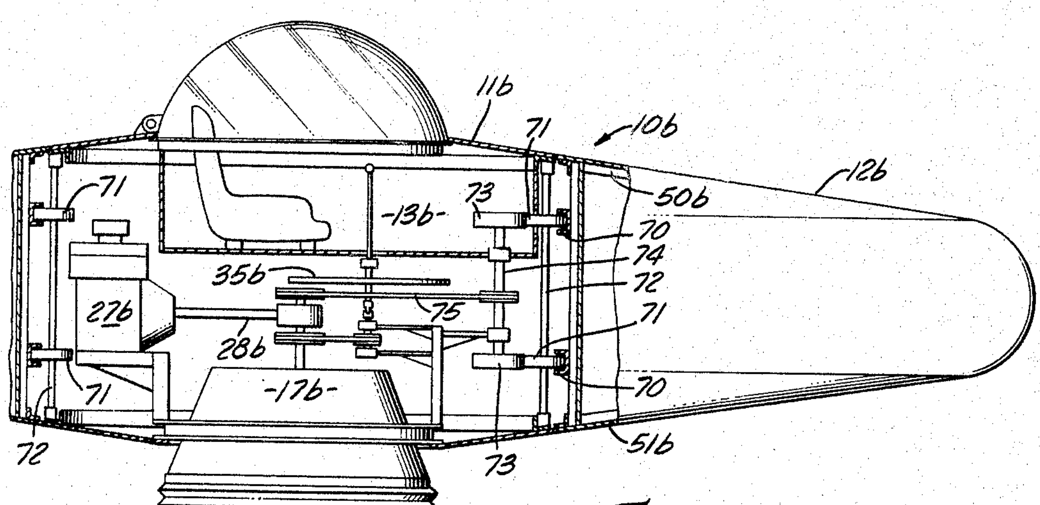

FIG. 8.

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UNIVERSALLY MANEUVERABLE AIRCRAFT

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12 Claims. (Cl. 244—5)

This invention relates to an aircraft which is maneuverable in any desired direction and, in particular, is directed to an extremely lightweight aircraft requiring only a small horsepower engine to produce the necessary motive power.

Conventional aircraft employ aerodynamic surfaces which are moved through the air to produce the necessary lift force for retaning the craft aloft. These aerodynamic surfaces are comprised of the rotor blades in a helicopter or the wings of a conventional airplane. The lift force in a buoyant airship is provided by filling a cell of sufficient size with a lighter-than-air gas whereby no outside force need be applied for retaining the airship aloft.

It is a principal object of this invention to provide an aircraft wherein a significant proportion but less than all of the weight is counteracted by a lighter-than-air buoyant cell and the entire aircraft is shaped for producing an aerodynamic lift force as the craft is moved through the air.

Another object of this invention is to provide a semi-buoyant aircraft wherein a relatively small engine operating an air fan is capable of producing sufficient upward thrust to lift the resultant non-buoyant weight of the aircraft.

A further object of this invention is to provide a novel form of semi-buoyant aircraft of a circular symmetrical airfoil shape whereby tilting and moving the aircraft in any horizontal direction produces a resultant aerodynamic upward force to assist in retaining the aircraft aloft.

Still another object of this invention is to provide a novel form of semi-buoyant aircraft having an air fan for producing sufficient upward force to retain the aircraft aloft and a resultant horizontal force in any given direction toward which the craft is tilted.

Another object of this invention is to provide a novel form of aircraft which employes a movable rotating wheel to produce a gyroscopic effect and provide the sole means for tilting the aircraft in any desired direction for appropriately maneuvering the aircraft.

Still another object of this invention is to provide a novel form of aircraft which employs a downwardly facing air fan enclosed within a truncated cone for producing the necessary upward thrust to retain the craft airborne. A still further object is to provide such an arrangement wherein the lower periphery of such truncated cone includes an extensible and collapsible sealing means for engaging a ground surface whereby the cone is virtually sealed to the ground surface during the first upward movements of the aircraft.

A further object of this invention is to provide a relatively flat circular aircraft comprising a buoyant envelope surrounding a central compartment adapted to contain the motive power and the operator. A still further object is to provide such an aircraft wherein the buoyant envelope is completely flexible for absorbing the shocks incurred in a collision with another object. Still another alternate object of this invention is to provide such an aircraft wherein the encircling envelope rotates relative to the compartment for both stabilizing the flight of the airship and dissipating heat developed on the surfaces of the envelope.

Other and more detailed objects and advantages of this invention will appear from the following description and the accompanying drawings, wherein:

FIGURE 1 is a top plan view of the preferred form of the aircraft of this invention with certain internal structural members shown in dashed lines.

FIGURE 2 is a bottom plan view of the aircraft shown in FIGURE 1.

FIGURE 3 is a fragmentary sectional elevation view taken substantially on the line 3—3 in FIGURE 1.

FIGURE 4 is a fragmentary sectional elevation view taken substantially on the lines 4—4 shown in FIGURES 1 and 2.

FIGURE 5 is a fragmentary elevation view of the cone tilting mechanism taken substantially on the line 5—5 shown in FIGURE 3.

FIGURE 6 is a partial sectional elevation of a modified form of the airship of this invention which employs a completely flexible encircling envelope.

FIGURE 7 is a top plan view similar to FIGURE 1 and illustrating a further modified embodiment of the airship of this invention.

FIGURE 8 is a fragmentary section elevation view taken substantially on the line 8—8 in FIGURE 7.

Referring now to FIGURES 1 through 5 the preferred form of aircraft, generally designated **10**, is shown although it will be appreciated that many of the details of this preferred form may also be included in the other forms of the aircraft. The aircraft **10** includes a central frame or compartment **11** encircled by an annular envelope **12** although these two portions may be integral and continuous in the final assembly. The compartment **11** is of a lightweight construction and a generally cylindrical shape with its axis oriented in the vertical direction. The upper portion of compartment **11** includes the section **13** having a seat **14** adapted to accommodate the operator **9**. A transparent canopy **15** encloses the section **13** and permits visibility of the operator **9** around the entire aircraft. The canopy **15** is hinged at **16** for opening thereof to permit ingress and egress of the operator **9**.

In the lower portion of compartment **11** a truncated cone **17** is mounted with its larger end extending downwardly beyond the lower extremity of compartment **11**. Cone **17** is pivotally mounted by diametrically positioned stub shafts **18** which extend outwardly from the cone and are rotatably supported in bearings **19**. A crank arm **20** is connected to a stub shaft **18** on one side of the cone **17**. A link rod **21** extends upwardly from crank arm **20** and is connected to a lever **22** accessible by the operator **9** for causing tilting of the cone **17** in response to changing the position of lever **22**. The cone **17** is mounted on a pivotal axis which extends laterally relative to the normal direction in which the operator **9** faces whereby the cone **17** is tilted either forwardly or rearwardly relative to the operator. The tilting of cone **17** is relatively limited and is employed merely to assist in producing a resultant forward or rearward component of force on the aircraft to cause travel in the desired direction.

An air fan **25** is positioned within the upper extremity of cone **17** and depends from a rotatable shaft **26**. An engine **27** is mounted in the compartment **11** and serves to rotate shaft **26** and fan **25** through an appropriate drive mechanism **29**. Engine **27** may be of any desired type but it is specifically contemplated that an extremely lightweight engine of a high horsepower-to-weight ratio be employed to achieve the best operational characteristics. A plurality of passageways **28** extend downwardly from the upper extremity of compartment **11** to a location immediately adjacent the upper extremity of cone **17**. In the illustrated embodiment four passageways **28** are employed and these are symmetrically spaced around the compartment **11**. The fan **25** and driving engine **27** serve to draw air through the passageways **28** and discharge such air out the cone **17** to produce a resultant upward thrust on the aircraft **10**. As the cone **17** is tilted in the afore-described manner, the major portion of the thrust force will still be in the upward direction to retain the aircraft aloft but a portion of the thrust force will be directed either forwardly or rearwardly to cause appropriate movement of the aircraft.

The lower periphery of cone **17** is provided with a downwardly extending annular member **30** which is extensible and collapsible relative to the cone. In the starting condition of the aircraft **10**, the member **30** engages the ground surface **8** and forms a seal therewith as shown in FIGURE 4. As the fan **25** is rotated to urge the air downwardly the air pressure within cone **17** builds up and causes the reaction of lifting the aircraft **10**. Since member **30** functions somewhat as an extensible gasket this pressure build-up within cone **17** is maintained over a short distance of upward movement of the aircraft thereby assisting in initially overcoming the inertia of the aircraft.

Means are provided for stabilizing and controlling the attitude of the aircraft **10** and as shown in the drawings, these means may include a wheel **35** mounted for rotation in a generally horizontal plane. A shaft **36** connects wheel **35** through a universal joint **37** to a drive shaft **38**. Drive shaft **38** is rotated by any convenient means such as through a V-belt drive connected to shaft **26**. Wheel **35** is of a sufficient weight and diameter and is rotated at a sufficient speed to produce a gyroscopic affect on the aircraft **10** whereby the attitude of the aircraft **10** is stabilized at any particular unchanging position of wheel **35**. The upper end of shaft **36** is rotatably mounted in a bushing **40** which is in turn resiliently secured in a central position by plurality of tension springs **41** extending outwardly from the bushing. A handle **42** extends upwardly from the bushing and is accessible by the operator **9**. By manually urging the handle **42** away from its vertical position, the plane of rotation of wheel **35** relative to the aircraft **10** is changed, thereby producing a resultant force and change of attitude of the aircraft.

The envelope portion **12** of the aircraft **10** comprises an outwardly extending frame or superstructure **50** covered by an imperforate skin **51**. Superstructure **50** is of the lightest possible weight commensurate with providing the necessary strength to retain the shape of skin **51**. The imperforate skin **51** together with the imperforate cylindrical wall **52** surrounding compartment **11** forms an inflatable compartment of the envelope **12**. Envelope **12** may be filled with a lighter-than-air gas such as helium to produce a buoyant affect on the aircraft **10** in an amount less than the total weight of the aircraft. The periphery of envelope **12** is circular in the plan view and is bluntly rounded as shown in FIGURE 3. The envelope **12** is tapered toward the periphery to form a wedge-shaped profile of the aircraft **10**. As is well known to those skilled in the aerodynamics art, this wedge-shape profile produces a resultant upward lift force on the aircraft **10** when the aircraft is moved through the air at a slight inclined attitude in the direction of movement. Thus the lifting force to sustain the aircraft **10** aloft is a product of both the upward thrust produced by the air fan **25** and the upward lift force produced by the movement of the aircraft through the air. By changing the attitude of the aircraft **10** through movement of handle **42**, the aircraft may be turned in any direction. By appropriately tilting the cone **17**, a resultant forward or rearward thrust may be imposed on the aircraft to initiate forward motion or bring the craft to rest, respectively. Since the fan **25** is not exposed to the passing atmosphere as the aircraft moves through the air, the problems of different relative rates of air speed of the rotors confront the opeartion of a helicopter are not involved with the operation of aircraft **10**.

As an example of the relative sizes and weights contemplated in constructing the aircraft **10**, such an aircraft has been constructed having a diameter of approximately 22 feet, a thickness of approximately 4 feet with a weight of approximately 160 pounds. By filling the envelope **12** with helium an offsetting buoyancy of about 70 pounds is achieved, thereby producing a resultant weight of approximately 90 pounds. This includes a 72 horsepower high r.p.m. gasoline engine **27**, thereby producing a highly respectable horsepower to weight ratio. The exact ratio will depend on the weight of the operator **9** which is not included in the aforementioned resultant aircraft weight of 90 pounds. This example of a particular aircraft **10** is intended as illustrative and is in no way to be interpreted as a limitation of the scope of this invention.

An accessory item for using aircraft **10** over bodies of water is shown in FIGURE 3 and includes in inflatable ring **55** mounted on the bottom of compartment **11**. A compressed air tank **56** is mounted in compartment **11** and may be actuated to inflate ring **55**. Ring **55** is of a sufficient volumetric capacity to buoyantly support the craft **10** on water.

Referring now to FIGURE 6 a modified embodiment of this invention is shown comprising the aircraft **10*a***. The aircraft **10*a*** includes a central compartment area similar or identical to the aforementioned compartment **11** but the outwardly extending envelope **12*a*** is comprised solely of an unsupported inflatable member **60**. Envelope **12*a*** omits the aforedescribed superstructure **50** thereby making the envelope relatively flexible. The envelope is filled with a lighter-than-air gas to add the desired buoyant affect. This embodiment produces a particularly safe aircraft in that the operators compartment is effectively surrounded by a large inflated bumper for protection against collision with stationary or other moving objects.

Referring now to FIGURES 7 and 8, a further embodiment of the aircraft, generally designated **10*b*** is shown. The central compartment **11*b*** is substantially similar to the afore-described compartment **11** including an operator's section **13*b***, a truncated downwardly facing cone **17*b*** for containing the fan (not shown) and an engine **27*b*** for rotating the fan and the gyroscope wheel **35*b***. The envelope **12*b*** is annular in shape and structurally independent of the compartment **11*b***. The envelope **12*b*** includes a superstructure **50*b*** covered with an imperforate skin **51*b*** similar to the afore-described construction of envelope **12**. A pair of annular tracks **70** are vertically spaced and mounted on the interior periphery of envelope **12*b***. A plurality of wheels **71** mounted on vertical shafts **72** engage the tracks **70** at circumferentially spaced locations. The shafts **72** are rotatably mounted on the compartment **11*b***, whereby the envelope **12*b*** is rotatable on a vertical axis about the compartment **11*b***. A driving mechanism is employed for causing rotation of envelope **12*b*** around compartment **11*b*** and may be comprised of rollers **73** mounted on a shaft **74** and engaging a pair of the wheels **71**. Shaft **74** is rotated by a V-belt drive **75** through the drive mechanism **28*b*** from the engine **27*b***. Rotation of envelope **12*b*** about compartment **11*b*** produces a further stabilizing gyroscope affect. Further, as the aircraft **10*b*** moves through the air this rotation causes a continual change in the portion of the skin **51*b*** of the envelope **12*b*** which is directly confronted by the air thereby minimizing the heat built-up that might otherwise be produced when the aircraft is moved at high rates of speed through the air.

Having fully described my invention it is to be understood that I do not wish to be limited to the specific details herein set forth or shown in the drawings, but rather my invention is of the full scope of the appended claims.

I claim:

1. In an aircraft, the combination of; a compartment, a downwardly facing fan mounted in the compartment, means for rotating said fan for drawing air from above the compartment, and forcing such air out the bottom of the compartment to produce an upward thrust on the aircraft, gyroscope means operably mounted in said compartment for stabilizing said compartment and having means for selectively changing the attitude of said gyroscopic means for selectively causing tilting of said compartment, and an inflated envelope encircling said compartment in the horizontal plane and mounted thereon.

2. In an aircraft, the combination of; a compartment, a power-driven fan rotatably mounted in the compartment for drawing air from above the compartment, and forcing air out the bottom of the compartment to produce an upward thrust on the aircraft, means for selectively causing tilting of said compartment, an inflated envelope mounted on said compartment and encircling said compartment in the horizontal plane, said envelope having a relatively flat circular shape with said compartment at the center and tapering upper and lower surfaces converging outwardly into a bluntly rounded circular periphery, and a gas of less density than air filling said envelope for buoyantly supporting a portion of the aircraft weight.

3. In an aircraft, the combination of; a compartment, a downwardly facing fan rotatably mounted in the compartment, means for rotating said fan for drawing air from above the compartment and forcing such air out the bottom of the compartment to produce an upward thrust on the aircraft, means for partially directing such air in a horizontal direction without tilting the compartment to urge the aircraft in the opposite horizontal direction, means for selectively causing tilting of said compartment, and an inflated envelope horizontally encircling and mounted on said compartment, said envelope having a relatively flat circular shape with said compartment at the center and forming a wedge shaped airfoil.

4. In an aircraft, the combination of; a compartment, a downwardly facing fan mounted in the compartment, means for rotating said fan for drawing air from above the compartment and forcing such air out the bottom of the compartment to produce an upward thrust on the aircraft, means for selectively causing tilting of said compartment, an envelope horizontally encircling and movably mounted on said compartment, said envelope having a relatively flat circular shape with said compartment at the center and tapering lower and upper surfaces converging outwardly and means for rotating the envelope relative to said compartment.

5. In a universally maneuverable aircraft operable by an occupant thereof, the combination of; a lightweight central compartment frame for accommodating the occupant, a downwardly facing and open truncated cone movably mounted in said compartment frame, a power-driven air fan rotatably mounted in said cone on a substantially vertical axis for drawing air through said compartment frame and discharging that air downwardly out said cone for producing a resultant upward thrust on said frame, means operable by the occupant for changing the position of said cone to direct the discharged air angularly of the vertical direction and produce a resultant component of force in a desired horizontal direction, means operable by the occupant for selectively causing tilting of said compartment frame, an inflated envelope mounted on and encircling said compartment frame and extending outwardly in a generally horizontal direction, and a gas having a density less than air filling said envelope for providing a buoyant lift force on the aircraft of an amount less than the total weight of the aircraft.

6. In a universally maneuverable aircraft operable by an occupant thereof, the combination of; a lightweight central compartment frame having upper and lower portions, said upper portion having means for accommodating the occupant, a downwardly facing and open truncated cone movably mounted in said lower portion, passageway means in said compartment frame communicating the said cone with the atmosphere above said compartment frame, a power-driven air fan rotatably mounted in said cone on a substantially vertical axis for drawing air through said passageway means and discharging that air downwardly out said cone for producing a resultant upward thrust on said frame, means operable by the occupant for changing the position of said cone to direct the discharged air angularly of the vertical direction and produce a resultant component of force in a desired horizontal direction, means operable by the occupant for causing tilting of said compartment frame, and an inflated envelope mounted on and encircling said compartment frame and extending outwardly in a generally horizontal direction.

7. In a universally maneuverable aircraft operable by an occupant thereof, the combination of; a central compartment frame for accommodating the occupant, a power-driven air fan rotatably mounted in said compartment frame for discharging air downwardly and producing a resultant upward thrust on said frame, a large diameter wheel of substantial weight relative to the weight of the aircraft mounted in said compartment frame for rotation on a given axis, means for rotating said wheel at a substantial speed for producing a gyroscopic effect, means operable by the occupant for tilting said wheel from said axis to produce a resultant force directly causing tilting of said compartment frame, and an inflated envelope mounted on and encircling said compartment frame and extending outwardly in a generally horizontal direction.

8. In a universally maneuverable aircraft operable by an occupant thereof, the combination of; a lightweight central compartment frame for accommodating the occupant, a power-driven air fan rotatably mounted in said compartment frame for discharging air downwardly and producing a resultant upward thrust on said frame, a large diameter wheel of substantial weight relative to the weight of the aircraft mounted in said compartment frame for rotation on a generally vertical axis, means for rotating said wheel at a substantial speed for producing a gyroscopic effect, means operable by the occupant for selectively tilting said wheel from said vertical axis to produce a resultant force directly causing tilting of said compartment frame, an inflated envelope mounted on and encircling said compartment frame and extending outwardly in a generally horizontal direction, said envelope having a circular outer periphery and being uniformly tapered from said compartment frame to said outer periphery, and a gas having a density less than air filling said envelope for providing a buoyant lift force on the aircraft of an amount less than the total weight of the aircraft.

9. In a universally maneuverable aircraft operable by an occupant thereof, the combination of; a lightweight central compartment frame having means for accommodating the occupant, a downwardly facing and open truncated cone mounted in said compartment frame, passageway means in said compartment frame communicating the said cone with the atmosphere above said compartment frame, a power-driven air fan rotatably mounted in said cone on a substantially vertical axis for drawing air through said passageway means and discharging that air downwardly out said cone for producing a resultant upward thrust on said frame, extensible and collapsible annular means mounted on the periphery of the lower extremity of said cone for sealably engaging a ground surface during the initial upward movement of said frame, means operable by the occupant for causing tilting of said compartment frame, an inflated envelope mounted on and encircling said compartment frame and extending outwardly in a generally horizontal direction, and a gas having a density less than air filling said envelope for providing a buoyant lift force on the aircraft of an amount less than the total weight of the aircraft.

10. In a universally maneuverable aircraft operable by an occupant thereof, the combination of; a lightweight central compartment frame having upper and lower portions, said upper portion having means for accommodat-

ing the occupant, a downwardly facing and open truncated cone movably mounted in said lower portion, passageway means in said compartment frame communicating the said cone with the atmosphere above said compartment frame, a power-driven air fan rotatably mounted in said cone on a substantially vertical axis for drawing air through said passageway means and discharging that air downwardly out said cone for producing a resultant upward thrust on said frame, means operable by the occupant for changing the position of said cone to direct the discharged air angularly of the vertical direction and produce a resultant component of force in a desired horizontal direction, a large diameter wheel of substantial weight relative to the weight of the aircraft mounted in said compartment frame for rotation on a generally vertical axis, means for rotating said wheel at a substantial speed for producing a gyroscopic effect, means operable by the occupant for tilting said wheel from said vertical axis to produce a resultant force causing tilting of said compartment frame, an inflated envelope mounted on and encircling said compartment frame and extending outwardly in a generally horizontal direction, said envelope having a circular outer periphery and being uniformly tapered from said compartment frame to said outer periphery, and a gas having a density less than air filling said envelope for providing a buoyant lift force on the aircraft of an amount less than the total weight of the aircraft.

11. In a universally maneuverable aircraft operable by an occupant thereof, the combination of; a lightweight central compartment frame having upper and lower portions, said upper portion having means for accommodating the occupant, a downwardly facing and open truncated cone movably mounted in said lower portion, passageway means in said compartment frame communicating the said cone with the atmosphere above said compartment frame, a power-driven air fan rotatably mounted in said cone on a substantially vertical axis for drawing air through said passageway means and discharging that air downwardly out said cone for producing a resultant upward thrust on said frame, means operable by the occupant for changing the position of said cone to direct the discharged air angularly of the vertical direction and produce a resultant component of force in a desired horizontal direction, extensible and collapsible annular means mounted on the periphery of the lower extremity of said cone for sealably engaging a ground surface through the initial upward movement of said frame, a large diameter wheel of substantial weight relative to the weight of the aircraft mounted in said compartment frame for rotation on a generally vertical axis, means for rotating said wheel at a substantial speed for producing a gyroscopic effect, means operable by the occupant for tilting said wheel from said vertical axis to produce a resultant force causing tilting of said compartment frame, an inflated envelope mounted on and encircling said compartment frame and extending outwardly in a generally horizontal direction, said envelope having a circular outer periphery and being uniformly tapered from said compartment frame to said outer periphery, and a gas having a density less than air filling said envelope for providing a buoyant lift force on the aircraft of an amount less than the total weight of the aircraft.

12. In a universally maneuverable aircraft operable by an occupant thereof, the combination of; a central compartment frame having means for accommodating the occupant, a downwardly facing and power-driven air fan rotatably mounted in said compartment frame on a substantially vertical axis for drawing air through said compartment frame and discharging that air downwardly for producing a resultant upward thrust on said frame, a large diameter wheel of substantial weight relative to the weight of the aircraft mounted in said compartment frame for rotation on generally vertical axis, means for rotating said wheel at a substantial speed for producing a gyroscopic effect, means operable by the occupant for tilting said wheel from said vertical axis to produce a resultant force causing tilting of said compartment frame, an envelope rotatably mounted on and encircling said compartment frame and extending outwardly in a generally horizontal direction, said envelope having a circular outer periphery and being uniformly tapered from said compartment frame to said outer periphery, and means for rotating said envelope relative to said compartment frame.

References Cited by the Examiner

UNITED STATES PATENTS

995,819	6/1911	Walker	244—79
3,054,578	9/1962	Brocard	244—23
3,083,934	4/1963	Vanderlip	244—5

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VERTICAL TAKEOFF AIRCRAFT

Filed March 8, 1966 2 Sheets-Sheet 1

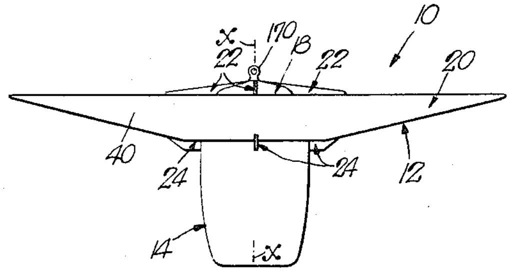

Fig.1

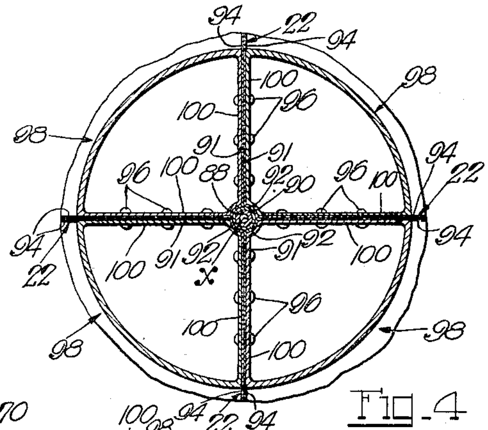

Fig.4

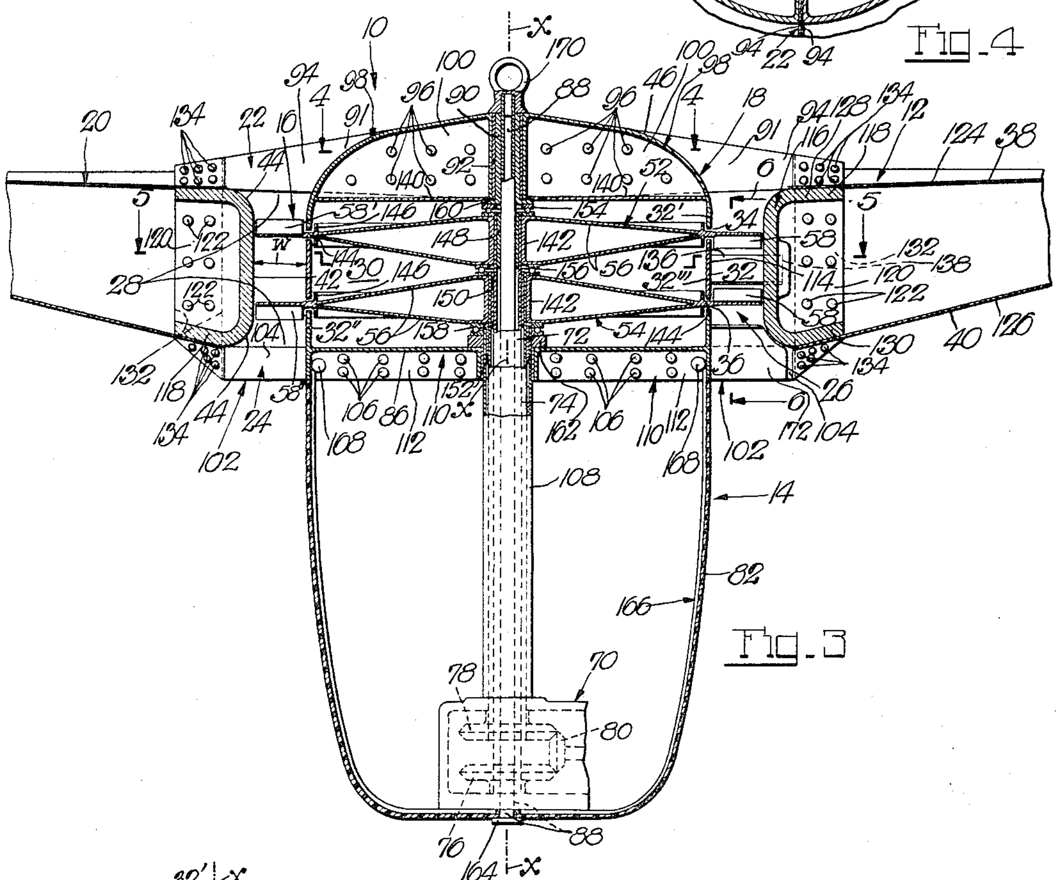

Fig.3

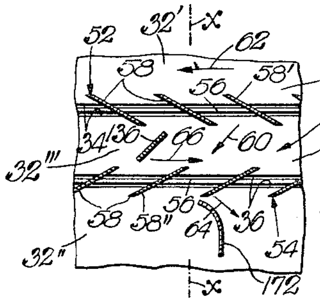

Fig.6

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VERTICAL TAKEOFF AIRCRAFT

Filed March 8, 1966 2 Sheets-Sheet 2

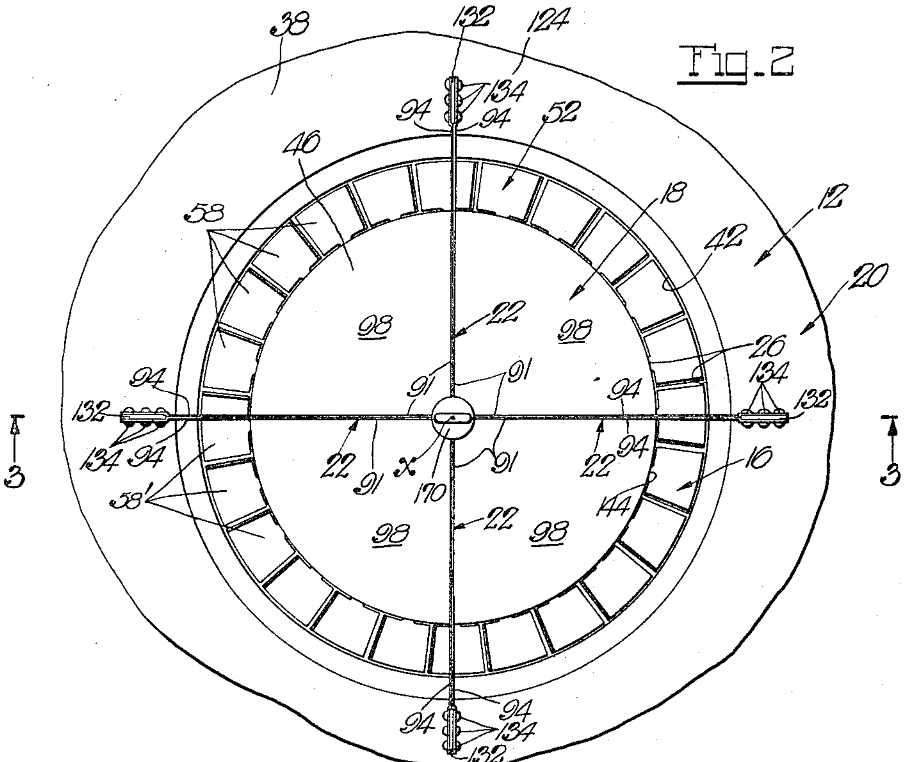

Fig. 2

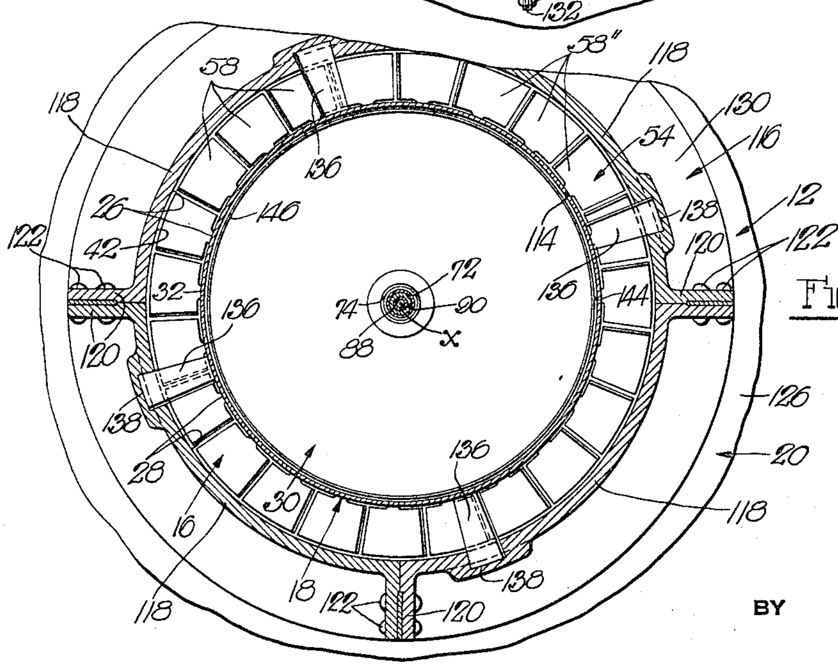

Fig. 5

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VERTICAL TAKEOFF AIRCRAFT

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8 Claims. (Cl. 244—23)

ABSTRACT OF THE DISCLOSURE

A vertical takeoff aircraft provides a wing structure with a vertical axis having inner and outer sections of which the inner section has spaced outwardly extending braces on which the outer section is mounted so as to form between the sections a through-duct about the axis. Spinner members in a chamber in the inner wing section are power-driven about the axis and have outer air impeller blades projecting into the through-duct, and a fuselage is suspended from the inner wing section.

This invention relates to aircraft of propeller-powered vertical takeoff type in general, and to lift-producing structure of this type of aircraft in particular.

The type of aircraft with which the present invention is concerned has a fixed wing structure in contrast to the movable wing structure of a helicopter, and a high-speed impeller to displace air for its dynamic lift reaction with the wing structure. Aircraft of this type are known and have been introduced more frequently in recent years, but none of them is or has been used to any notable extent undoubtedly because of their more or less inferior and even risky lift performance and/or complicated and expensive construction or excessive size and bulk for a given load.

It is a primary object of the present invention to provide an aircraft of this type which in its lift performance is quite superior to and more reliable than that of prior aircraft of this type, yet is of exceedingly simple inexpensive and condensed construction for a given load, so much so that the aircraft becomes costwise competitive with, and to many more attractive in performance and safety than, private automobiles, for example.

It is another object of the present invention to provide an aircraft of this type of which the power impeller and wing system produces a particularly high lift component of the sum total of both, vacuum and air pressure. This is achieved by arranging the wing structure disc-like and of good aerodynamic section throughout, and providing in the otherwise uninterrupted disc expanse of the wing structure a substantially concentric ring-like through-duct of rather extensive diametral expanse so as to be well spaced from both, the center and outer periphery of the wing structure, and of a width sufficiently smaller in comparison to its diametral expanse to produce by high-speed counter-driven impeller blades therein at reasonably moderate power application to the latter downward displacement of air in very large volume and at a high rate per time unit, which makes not only for quite forceful and rather even vacuum lift effect on the upper wing surface throughout its extensive area but also for particularly forceful up-thrust reaction of the air on the spinning impeller blades, whereby the lift component on the impeller and wing system becomes quite high.

It is a further object of the present invention to provide an aircraft of this type in which the fuselage carries the impeller power drive besides the passenger load, and is arranged below and substantially centrally of the wing structure, and the aforementioned through-duct in the wing structure is of a diametral expanse to encompass the fuselage. With this arrangement, the aircraft has a particularly low center of gravity for stable and substantially sway-free flight in all directions, including safe descent by the parachute effect of the wing structure on a power stall or shutoff, and the impelled air will on the impeller and wing system have up-thrust and vacuum lift reaction which is at a maximum and not in any way impeded by the fuselage.

Another object of the present invention is to provide an aircraft of this type in which the wing structure is a self-contained unit assembled on a center post from which the fuselage is also suspended, with the aforementioned counter-driven impeller blades in the wing duct being provided on the periphery of spinner discs which in the interior of the wing structure are journalled on the center post through intermediation of telescoped hollow drive shafts for the respective discs that extend into the fuselage to the power drive unit, and the spinner discs exerting their operative thrust through antifriction bearings, directly to the center post. With this arrangement, the parts or sections of the impeller and wing system and the fuselage advantageously have in the center post a common mount and reference location which makes for simple and low-cost as well as accurate mass production of the aircraft, and operational up-thrust of the impeller is transmitted to the rest of the craft advantageously centrally thereof and well above its center of gravity for the ultimate in stable power flight and ease of steering the craft.

A further object of the present invention is to provide an aircraft of this type in which the aforementioned spinner discs of the impeller blades and their journal bearings are provided in a partitioned internal chamber in the wing structure which is sealed off except for anular passages to the wing duct through which extend with minimum clearance the blade-carrying spinner disc peripheries and which are preferably formed quite tortuous to impede air flow between the wing duct and chamber. With this arrangement, the air pressure in the chamber will at all times be the same as that in the wing duct, but air turbulence in the chamber is virtually non-existent, whereby the wing duct is to all practical intents and purposes closed except at its inlet and outlet ends for optimum efficiency.

Further objects and advantages will appear to those skilled in the art from the following, considered in conjunction with the accompanying drawings.

In the accompanying drawings, in which certain modes of carrying out the present invention are shown for illustrative purposes:

FIG. 1 is a side view of an aircraft embodying the present invention;

FIG. 2 is an enlarged fragmentary top view of the aircraft;

FIG. 3 is a fragmentary vertical section through the aircraft taken substantially on the line 3—3 of FIG. 2;

FIGS. 4 and 5 are fragmentary horizontal sections through the aircraft taken substantially on the lines 4—4 and 5—5, respectively, of FIG. 3; and

FIG. 6 is a fragmentary section through the aircraft taken substantially on the line 6—6 of FIG. 3.

Referring to the drawings, the reference numeral **10** designates an aircraft of vertical takeoff type, having a wing system **12**, a fuselage **14** and power flight means **16**. The wing system **12** is formed, in this instance, by a center unit **18** with a vertical axis x, and a surrounding ring-like wing structure **20** which by angularly-spaced braces, in this instance braces **22** and **24** of upper and lower sets (FIG. 3), is mounted on the center unit **18** in equally spaced relation therewith to form therebetween an axial through-duct **26** concentric with the axis x of which the duct part **28** between the upper and lower braces **22** and **24** is annularly uninterrupted. The center unit 18 provides an annular chamber 30 concentric with the axis x, and has in its outer peripheral wall 32 axially-spaced annular passages 34 and 36 from the chamber 30 to the duct part 28, with the chamber 30 being sealed from the outside except at the passages 34 and 36. The ring-like wing structure 20 has upper and lower surfaces 38 and 40 and an inner peripheral, and preferably cylindrical, surface 42 which joins the upper and lower wing surfaces 38 and 40 in the preferred smooth curvature fashion indicated at 44 (FIG. 3). The upper surface 46 of the center unit 18 forms a central wing surface complemental with the upper surface 38 of the surrounding wing structure 20, with this central wing surface 46 and the ring-like wing structure 20 together forming the wing system 12.

Suspended from the center unit 18 in a manner described hereinafter is the fuselage 14 as shown more or less diagrammatically in FIGS. 1 and 3. Included in the power flight means 16 are air impellers 52 and 54, each having a spinner member or disc 56 and air impeller blades 58 on its outer periphery. The spinner members 56 are in the chamber 30 journalled for rotation about the axis x and extend peripherally with clearance through the annular passages 34 and 36 for the projection of their air impeller blades 58 into the duct part 28 (FIG. 3). The air impellers 52 and 54 are in operation driven in opposite directions, with the blades 58′ of the upper impeller 52 being inclined to the axis x in the exemplary fashion shown in FIG. 6 so as to thrust air downwardly in the general direction of arrow 60 in the power drive of impeller 52 in the exemplary direction of arrow 62, and the blades 58″ of the lower impeller 54 being oppositely inclined to the axis x (FIG. 6) so as to continue the downward thrust of the air from the upper impeller 52 in the general direction of the arrow 64 on the power drive of impeller 54 in the direction of the arrow 66, i.e., opposite to the exemplary drive direction of the upper impeller 52. Operational upward thrust of the power-driven impellers 52 and 54 is transmitted to the center unit 18 in a manner described hereinafter. The power flight means also include an aircraft engine (not shown) and a transmission 70 which in this instance is mounted in the fuselage 50 at the bottom thereof, and hollow drive shafts 72 and 74 which carry at their lower ends bevel gears 76 and 78 of the transmission 70 and extend upwardly in the fuselage 14 and into the chamber 30 in the center unit 18 wherein they carry the impellers 52 and 54, respectively, with the bevel gears 76 and 78 in the transmission 70 being driven by a common bevel pinion 80 for the power drive of the air impellers 52 and 54 in opposite directions as specified. Suitable landing gear, steer provisions, as well as numerous details of the fuselage and interior thereof, have been omitted since they do not form part of the present invention, the fuselage 14 being in this instance confined in a normally closed, but accessible, casing 82 of any suitable tough and preferably transparent plastic. Further, the fuselage 14 is arranged so as to be preferably substantially within the peripheral confines of the center unit 18 thereabove so as not to interfere with the free downward exhaust of the air forced through the duct 26 in the wing system 12 by the power-driven impellers 52 and 54.

The present aircraft is highly efficient in its operation and reliable in its performance. Thus, with the ring-like wing structure 20 being of good aerodynamic section throughout and even augmented in its lift capacity in power flight by the upper wing surface 46 of the center unit 18, the wing system 12 affords optimum lift capacity for its size. Further, with the axial through-duct 26 in the wing system 12 being well spaced from the center as well as the outer periphery of the latter, the therein operating air impellers draw air fairly evenly over the entire upper surface of the wing system with ensuing equally even vacuum lift effect of the air on this entire upper wing surface. Further, with the through-duct 26 in the wing system 12 being of limited width w (FIG. 3) and the air impellers 52 and 54 being counterdriven at fairly high speeds, the downward displacement of air through the duct 26 occurs in very large volume and at a high rate per time unit, which makes not only for quite forceful and even air lift effect on the entire upper surface of the wing system and also air up-thrust against the lower surface of the wing system, but also for particularly foreceful up-thrust reaction of the air on the spinning impeller blades, whereby the lift component on the impeller and wing system becomes quite high. Also, with the fuselage, which carries the impeller power drive and also the passenger load, being arranged below and substantially centrally of the wing system, the aircraft has a particularly low center of gravity for stable and substantially sway-free flight in all directions, including the safe descent by the parachute effect of the wing system on a power stall or shutoff.

The present aircraft is also of exceedingly simple and low-cost construction and readily lends itself to efficient mass production. Thus, the center unit 18 and fuselage 14 may be constructed in any articulated fashion in the form of a single body with a transverse partition 86 to divide the body into the chamber 30 and the fuselage 14 therebeneath, with the body having the axially-spaced outward braces 22 and 24 for mounting the ring-like wing structure 20. In its preferred form, however, the center unit 18 is formed in several separate sections which are directly or indirectly mounted on and located from a center post 88 coaxial with the axis x. Thus, the upper end of the center post 88, which is preferably a light-weight but strong tube, has fast thereon a mounting sleeve 90 to which are secured the upper braces 22. These upper braces 22 are formed from initially flat metal sheets or sections 91 of which each is bent to form a hub-like part 92 and therefrom radiating arm parts 94 which in this instance are spaced 90° apart (FIG. 4). These bent sections 91 are assembled with each other on the mounting sleeve 90 in the fashion shown in FIG. 4, i.e., their hub-like parts 92 are placed against the mounting sleeve 90 in surrounding fashion and their arm parts 94 are placed against each other to form four separate and equi-angularly spaced braces 22, with the engaging arm parts 94 being at 96 riveted to each other for securement of the individual sections 91 to each other and their firm clamp-on on the mounting sleeve 90. The upper surface 46 and a continuing part 32′ of the peripheral wall 32 of the center unit 18 is formed by complemental quarter sections 98 having end flanges 100 which bear against the upper braces 22 and are riveted thereto at 96 (FIGS. 3 and 4). The lower braces 24 are in this instance formed, similarly as the upper braces 22, from bent sheet metal sections 102, with the radiating arms 104 of adjacent sections being placed against each other and riveted together at 106 (FIG. 3) for their assembly into four equi-angularly spaced lower braces 24 and their firm attachment by clamping to a tubular column 108. A lower part 32″ of the peripheral wall 32 of the center unit 18 and in this instance also the partition 86 are formed by complemental quarter sections 110 having end flanges 112 which bear against the lower braces 24 and are riveted thereto at 106. The remaining part 32‴ of the peripheral wall 32 of the center unit 18 is formed by a cylindrical ring 114 which is supported from the surrounding wing structure 20 in a manner described hereinafter, and which is interposed between and axially spaced from the wall parts 32′ and 32″ to provide the annular passages 34 and 36 thereat.

The ring-like wing structure 20 has a center ring 116 which is formed of a plurality, in this instance four, preferably molded complemental parts 118 (FIG. 5) of the preferred section shown in FIG. 3, with each part having end flanges 120 placed against each other and riveted together at 122 (FIG. 5), with the upper and lower surfaces 38 and 40 of the wing structure 20 being formed in this instance by suitably reenforced sheet metal parts

124 and 126 that are suitably joined at their outer peripheries and suitably secured, as by welding or riveting, to the top and bottom flanges 128 and 130 of the center ring 116. The ring-like wing structure 20 may in all or most respects be like the wing structure disclosed in my copending application Ser. No. 516,604, filed Dec. 27, 1965.

For the attachment of the ring-like wing structure 20 to the upper and lower braces 22 and 24, there are riveted at 122 to the complemental central ring parts 118 between their adjoining end flanges 120 axial mounting plates 132 which extend with their ends beyond the center ring 116 and there are riveted at 134 to the upper and lower braces 22 and 24 between their arm parts 94 and 104 (FIGS. 2 and 3).

The cylindrical ring 114 of the center unit 18 is supported from the ring-like wing structure 20 by a plurality of vanes 136, in this instance four, which extend outwardly from the ring 114 through the duct part 28 in the wing system 12 and are anchored at 138 in the center ring 116 of the wing structure 20 (FIGS. 3 and 5). The vanes 136 are preferably inclined to the axis x so as to extend planewise in the general flow direction (arrow 60 in FIG. 6) of the forced air from the upper impeller blades 58' for least impediment of this air.

As already mentioned, the chamber 30 in the center unit 18 is sealed from the outside except at the annular passages 34 and 36 to the duct part 28. This chamber 30 is preferably kept annularly uninterrupted throughout, and to this end the chamber is terminated at the top by complemental partitions 140 in the quarter sections 98 of the center unit 18 below their end flanges 100 (FIG. 3). Each of the spinner members 56 of the air impellers 52 and 54 has in this instance opposite disc-like webs that extend from a hub 142 and join at a common outer peripheral margin 144 from which the impeller blades project outwardly. The spinner members 56 extend with their outer peripheral margins 144 through the annular passages 34 and 36 preferably with minimum clearance to impede as much as possible air flow from the duct part 28 into the chamber 30. In order to impede such air flow even further, the spinner members 56 are at their peripheral margins 144 provided with annular skirts 146 which extend into close proximity to and overlap the respective annular passages 34 and 36 (FIG. 3), thereby forming quite tortuous flow paths for air through these passages 34 and 36 into the chamber 30. Of course, while these tortuous flow paths permit sufficient air passage into the chamber 30 to establish the same air pressure therein as prevails at any time in the duct part 28, these tortuous flow paths and the non-interrupted condition of the chamber 30 annularly throughout combine to prevent the rise of any disturbing air turbulence in this chamber, as will be readily understood.

The hollow drive shaft 72, which carries the air impeller 52 in the chamber 30, is journalled directly on the center post 88, preferably through intermediation of a bearing sleeve or lining 148 on the latter (FIG. 3). The other hollow drive shaft 74, which carries the other air impeller 54, is journalled, internally on an outer bearing sleeve or lining 150 on the drive shaft 72, and externally in a bearing sleeve or lining 152 in the tubular column 108 (FIG. 3), whereby the tubular column 108 is also centered with respect to the center post 88 and its axis x.

For transmitting axial thrust of the air impellers 52 and 54 to the center unit 18, and advantageously to the center post 88, there are provided anti-friction thrust bearings 154, 156 and 158 (FIG. 3), of which bearing 154 is interposed between the upper air impeller 52 and a bottom flange 160 on the mounting sleeve 90 on the center post, bearing 156 is interposed between the air impellers 52 and 54, and bearing 158 is interposed between the lower air impeller 54 and a spacer ring 162 on the partition 86. The tubular column 108 extends with its upper end into the thrust bearing 158 to center the same, and rests with its lower end on top of the transmission 70. Of course, the primary function of the tubular column 108 is to support the assembly of the lower braces 24 and quarter sections 110 therebetween from the fuselage 14, and more particularly from the transmission 70 therein, and centered with respect to the center post 88 and its axis x.

The center post 88 extends in this instance downwardly through the fuselage 14 and also through the transmission 70 therein, and has in this instance a collar 164 at its lower end on which the fuselage is supported. The fuselage 14 may also have a framework 166 suitably suspended at 168 from the center unit 18, with this suspended framework affording additional support for the fuselage or providing the sole support for the latter in lieu of the center post 88, whichever is desired. Also, the center post 88 is at its top end preferably provided with an eye 170 with which to lift the aircraft when needed. The center unit 18 is preferably also provided with a plurality, for example four, equi-angularly spaced vanes 172 which project outwardly from the lower peripheral wall part 32'' of the center unit 18 into the wing duct 26 and are shaped as shown in FIG. 6 to direct the forced air from the lower air impeller 54 axially downwardly.

The invention may be carried out in other specific ways than those herein set forth without departing from the spirit and essential characteristics of the invention, and the present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

What is claimed is:

1. In a vertical takeoff aircraft, the combination of a circular wing structure having a central axis and complemental inner and outer wing sections of which the outer section has an annular aperture about said axis and the inner section is substantially cylindrical about said axis and of smaller diameter than said aperture and provides a chamber, and angularly-spaced braces between said sections for mounting the outer section on the inner section with the latter located in said aperture to define therein a ring-shaped through-duct about said axis and having inlet and outlet ends, with said through-duct extending parallel to said axis from its inlet end to its outlet end and having a part axially spaced from said braces and annularly uninterrupted, said inner section having axially-spaced annular passages from said chamber to said duct part and said chamber being sealed from the outside except at said passages; a fuselage suspended from said inner section and being in axial projection within the peripheral confines of said inner section; spinner members with air impeller blades on their outer peripheries of which the members are in said chamber journalled for rotation about said axis and extend peripherally with clearance through said passages, respectively, for projection of their impeller blades into said duct part; means imparting axial thrust of said members to said inner wing section; and power means for driving said members.

2. In a vertical takeoff aircraft, the combination of a hollow body with a vertical axis having a transverse partition dividing said body into upper and lower sections, of which said lower section is in the form of a fuselage, and said upper section provides a chamber and has a top surface and a substantially cylindrical periphery about said axis and spaced outwardly extending braces on said periphery; a ring-like wing structure having upper and lower surfaces and an inner peripheral surface defining an annular aperture about said axis, said wing structure being carried by said braces with its peripheral surface in equally spaced and surrounding relation with said periphery of said upper section to define therebetween a through-duct with inlet and outlet ends, with said through-duct extending parallel to said axis from its inlet end to its outlet end and having a part axially spaced from said braces and annularly uninterrupted, with said top surface

of said upper section being formed as a wing surface complemental with the upper surface of said wing structure, said upper section having in its periphery axially-spaced annular passages from said chamber to said duct part and said chamber being sealed from the outside except at said passages; spinner members with air impeller blades at their outer peripheries of which the members are in said chamber journalled for rotation about said axis and extend peripherally with clearance through said passages, respectively, for projection of their impeller blades into said duct part; means imparting axial thrust of said members to said body; and power means for driving said members.

3. The combination in a vertical takeoff aircraft as in claim **2**, in which said fuselage section has a bottom and said power means include a power transmission in, and mounted on the bottom, of said fuselage section, and inner and outer hollow drive shafts coaxial with said axis and extending from said transmission through said fuselage section into said chamber and carrying said members, respectively.

4. The combination in a vertical takeoff aircraft as in claim **2**, in which said spinner members are provided with an annular peripheral skirt in close proximity to and overlapping relation with said passages to provide a tortuous air path through the latter into said chamber.

5. The combination in a vertical takeoff aircraft as in claim **2**, in which said lower body section is substantially within the peripheral confines of said upper body section and has a substantially cylindrical periphery about said axis and continuous with said cylindrical periphery of said upper section, and said top surface of said upper section is generally convex in cross-section and merges substantially tangentially into said cylindrical periphery of said upper section.

6. In a vertical takeoff aircraft, the combination of a center unit having a center post with a vertical axis, axially-spaced upper and lower sets of angularly-spaced radial braces fast on said post, a wall structure of inverted cup-shape with a top and a first annular rim concentric with said axis, with said structure being formed of complemental sections between and secured to the braces of the upper set, and another cup-shaped wall structure with a bottom and a second annular rim concentric with and of the same diameter as said first annular rim and axially spaced from the latter, with said other wall structure being formed by complemental sections between and secured to the braces of the lower set; a ring-like wing structure with upper and lower surfaces and an inner peripheral surface joining said upper and lower surfaces, with said wing structure being mounted on said brace sets with its inner peripheral surface in equally-spaced and surrounding relation with said rims to form therebetween an axial through-duct of which the part between said brace sets is annularly uninterrupted; an annular wall of the same diameter as said annular rims, angularly spaced arms extending in said duct part from said wing structure to said annular wall for supporting the latter from the former, with said wall being concentric with and extending between and in axially spaced relation with said rims, said wall structures and annular wall defining a chamber sealed from the outside except at annular passages to said duct part formed between said spaced rims and annular wall; upper and lower spinner members with air impeller blades on their outer peripheries of which the members are in said chamber journalled for rotation about said axis and extend peripherally with clearance through said passages, respectively, for projection of their impeller blades into said duct part above and below said arms; a fuselage beneath said other wall structure and mounted on said center post; means imparting axial thrust of said members to said center post; and power means for driving said members.

7. The combination in a vertical takeoff aircraft as in claim **6**, in which said arms are vanes extending in the general flow direction of air impelled by the blades of the upper member when power-driven.

8. The combination in a vertical takeoff aircraft as in claim **6**, in which said power means include a transmission in said fuselage having a housing and two bevel gears, and inner and outer hollow drive shafts coaxial with said axis and surrounding said center post, said drive shafts carrying said bevel gears, respectively, and projecting into said chamber to therein carry said members, respectively, and said center post extending through said housing.

References Cited

UNITED STATES PATENTS

3,170,285	2/1965	Ferri	244—23 X
3,182,929	5/1965	Lemberger	244—23 X

FOREIGN PATENTS

828,090	2/1960	Great Britain.

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Aug. 6, 1968 J. B. GREEN **3,395,876**

AIRCRAFT WITH HOUSED COUNTER ROTATING PROPELLORS

Filed May 5, 1966 4 Sheets-Sheet 1

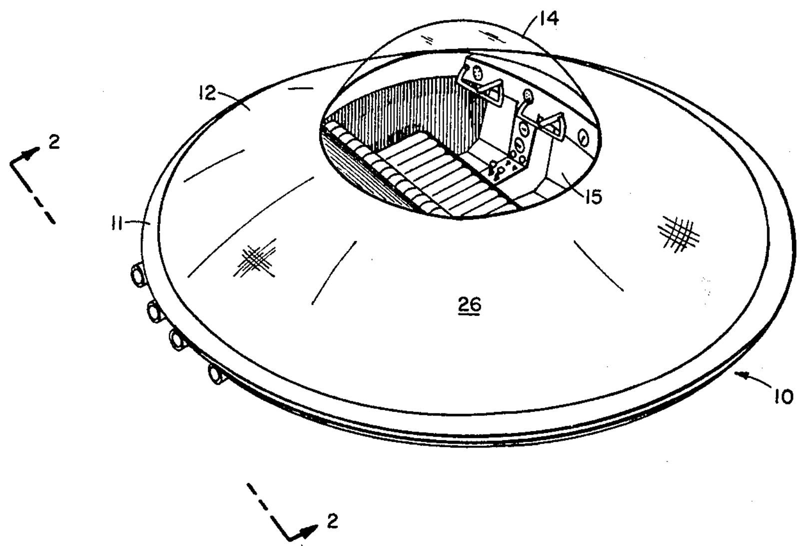

FIG. 1

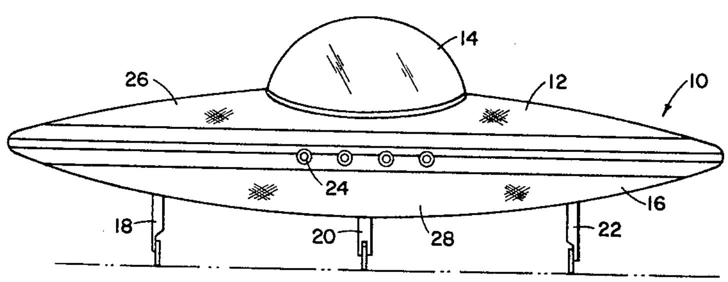

FIG. 2

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AIRCRAFT WITH HOUSED COUNTER ROTATING PROPELLORS

Filed May 5, 1966 4 Sheets-Sheet 2

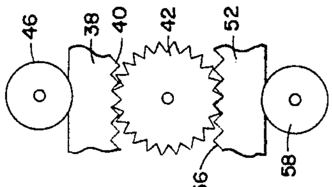

FIG. 4

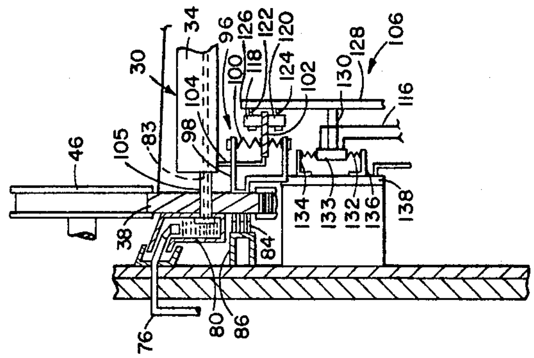

FIG. 5

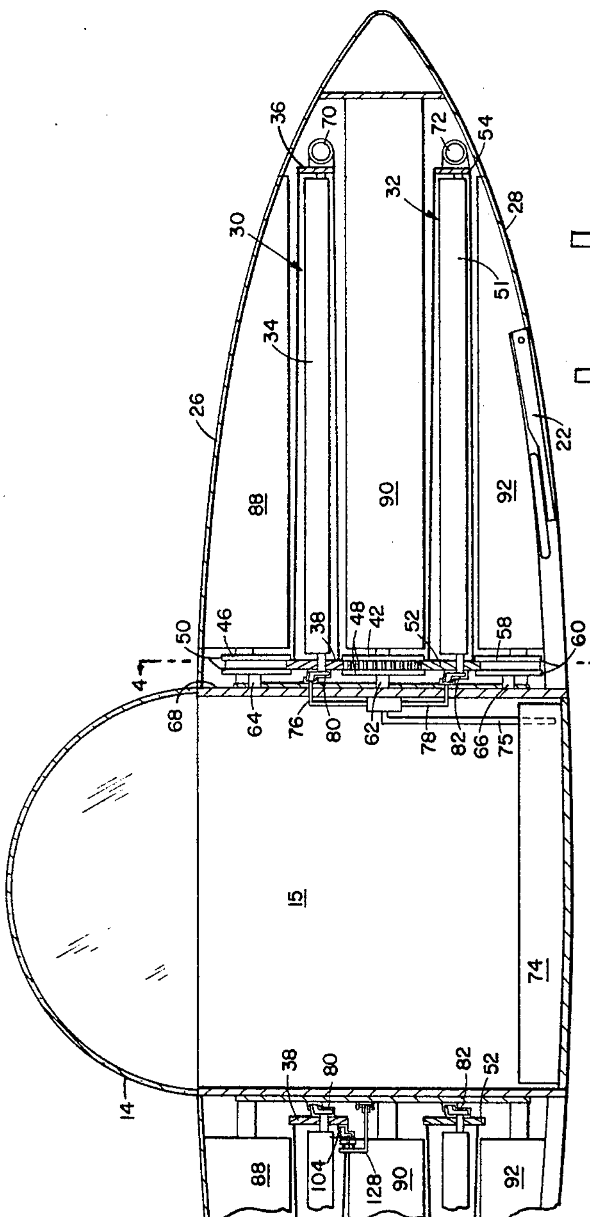

FIG. 3

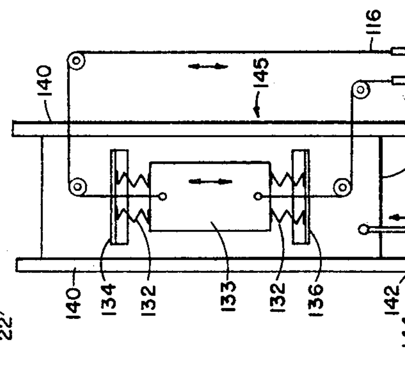

FIG. 6

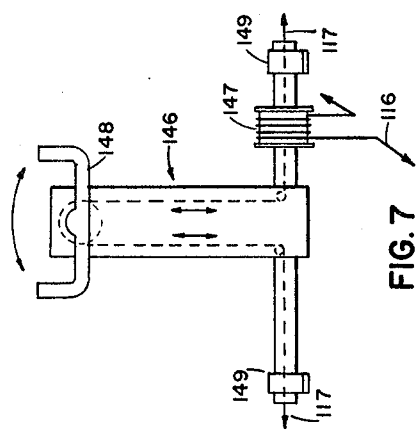

FIG. 7

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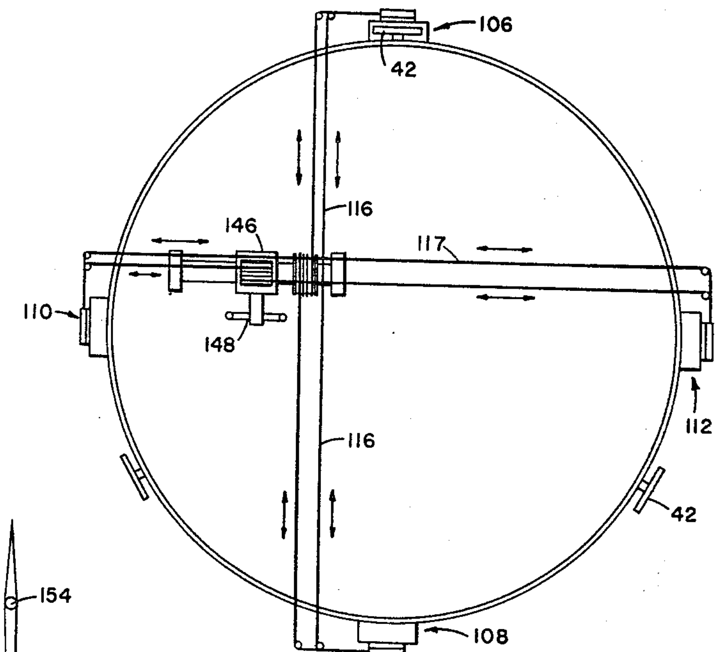

FIG. 9

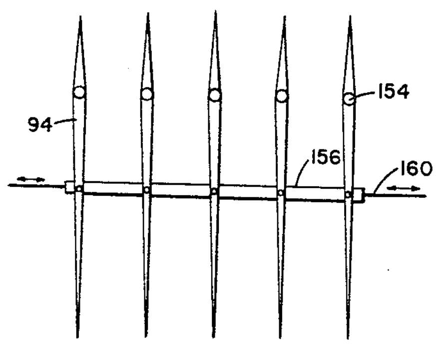

FIG. 8

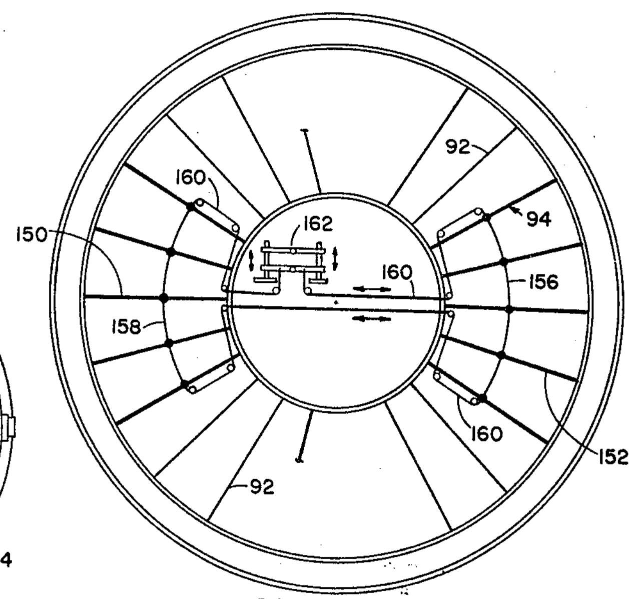

FIG. 10

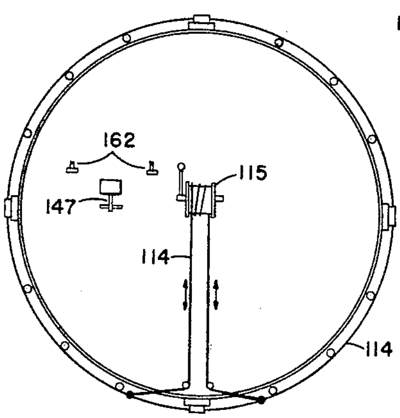

FIG. 11

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AIRCRAFT WITH HOUSED COUNTER ROTATING PROPELLORS

Filed May 5, 1966 4 Sheets-Sheet 4

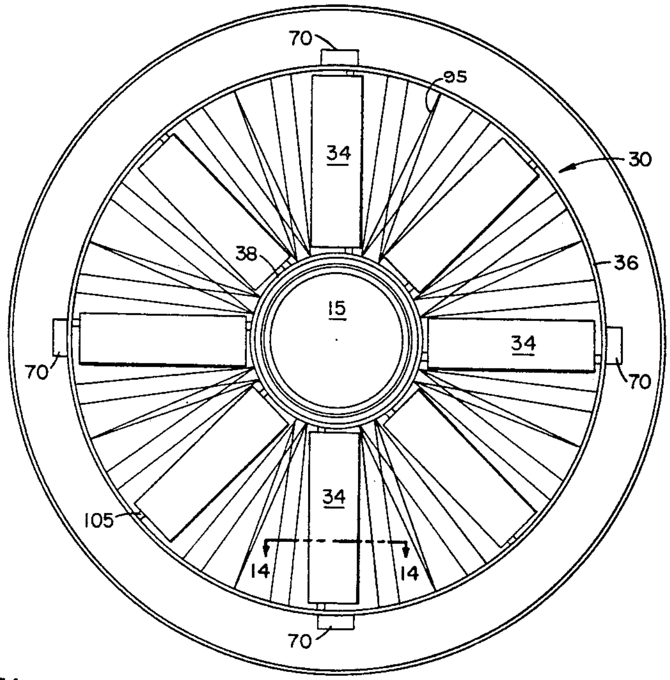

FIG. 12

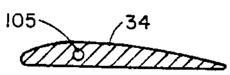

FIG. 14

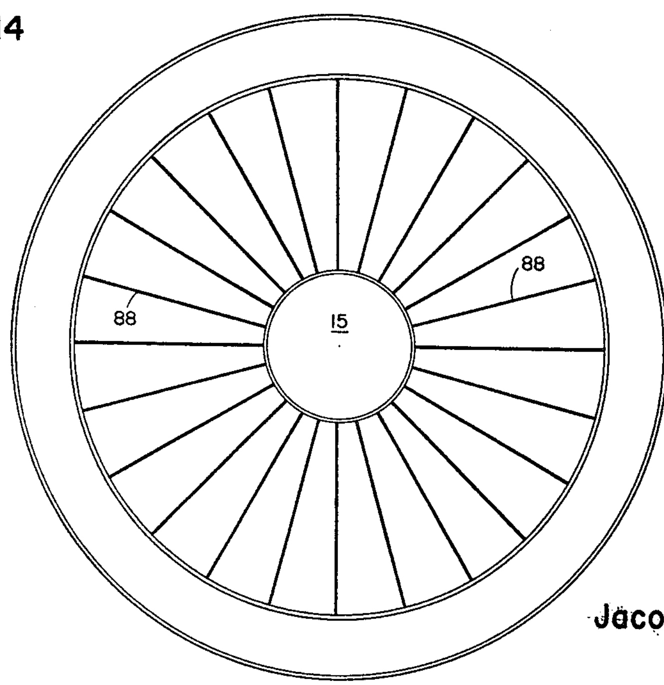

FIG. 13

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United States Patent Office

3,395,876

Patented Aug. 6, 1968

3,395,876

AIRCRAFT WITH HOUSED COUNTER ROTATING PROPELLORS

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Filed May 5, 1966, Ser. No. 547,905
1 Claim. (Cl. 244—23)

ABSTRACT OF THE DISCLOSURE

An aircraft capable of vertical lift having a pair of counter-rotating lift blade assemblies wherein blade pitch can be controlled to control the attitude of the aircraft.

This invention relates to aircraft and particularly to aircraft wherein lift is obtained directly from counter rotating fans or propellors.

The development of helicopters and other aircraft capable of vertical or near vertical ascent by means of lift propellors or fans has proceeded fairly rapidly in the past decade and thousands of such aircraft are in daily use. Unfortunately, their cost has been high and generally out of the reach of most purchasers desiring to own one. Further, while modern day helicopters are equipped and capable of taking off from the average home yard, their complexity of control as well as price make them unsuited for the average householder. Still further, while the helicopter enjoys its principal use by the military where the substantial expenditure for equipment and training of pilots can be afforded, it is obvious that if simplified and cheaper aircraft capable of performing the same missions were available, they would be widely enjoyed. While the applicant does not profess to have solved all the problems relating to aircraft in the category described, it is believed that the aircraft of his invention provides a substantial stride forward toward their solution.

Accordingly, it is an object of the present invention to provide an improved aircraft capable of vertical take off and ascent which is much more economical to manufacture and maintain than its prior counterparts.

Another object of this invention is to provide an aircraft of the category described which can be flown by persons capable of flying conventional aircraft with minimum of transition time and which may be flown after no longer than normal flight instruction time for winged aircraft by nonaviators.

Still another object of this invention is to provide a dish-shaped aircraft without external extending moving parts or wings which can be made to fly in any desired direction as, for example, straight up or down, backward, forward, or to either side at any variable speeds and also to hover or hold over a given area.

A still further object of this invention is to provide an aircraft of the category described which may be adapted for military use as a gun platform or for the performance of other duties now performed partly by the helicopter and partly by winged aircraft.

In accordance with the invention a basically circular aircraft is constructed in which lift is achieved by a propulsion chamber intregal with the aircraft body and wherein two counter rotating fans or propellors are equally driven to provide lift without net torque and with substantial aerodynamic stability. As a particular feature of the invention, air directors are built into the body structure of the aircraft and positioned on top of, between and below the counter rotating fans. In this manner, flow is directed substantially perpendicular to the fans at all times and thus the air directors prevent blade stall when the lateral speed of the aircraft exceeds fan tip speed, a difficulty presently experienced with helicopter operations.

The fans are provided with variable pitch blades to accomplish roll, pitch and vertical movement. Yaw, or azimuth, is controlled by making certain of the air directors below the bottom fan variable angle directors.

Other objects, features and advantages of the invention will become apparent from the following description when considered together with the drawings in which:

FIG. 1 is a perspective view of an aircraft constructed in accordance with the invention.

FIG. 2 is a rear view of the aircraft illustrated in FIG. 1 with the landing gear extended.

FIG. 3 is a half cross-sectional view illustrating details of construction and the location of fan rings, idler gears, air directors and cabin area.

FIG. 4 is a diagrammatic view of a portion of FIG. 3 showing idlers, gears and racks.

FIG. 5 is an enlarged view of a portion of FIG. 3 illustrating in greater detail the fuel system and commutater ring for engine electrical power and control.

FIG. 6 is one of four control stations illustrating the pitch and roll networks superimposed on the vertical control network.

FIG. 7 is a conventional control column for roll and pitch control.

FIG. 8 is an elevation view of a portion of the yaw or azimuth control directors.

FIG. 9 is a diagrammatic plan view showing four control stations, controls and rigging for roll and pitch control and the location of the three gear groups that are used to attach the fan rings to the main section of the cabin.

FIG. 10 is a diagrammatic plan view illustrating the method of yaw or azimuth control, rudder-type pedals and rigging to variable air directors.

FIG. 11 is a diagrammatic plan view illustrating the vertical control system and the rigging that is attached to each control station.

FIG. 12 is a plan view showing fan blades, power jets and air foil spokes used for strength.

FIG. 13 is a plan view illustrating the arrangement of vertical air directors.

FIG. 14 is a cross-section view showing a fan blade air foil section and the location of the shaft near the center of lift.

Referring now to the drawings, there is shown a non-winged aircraft **10** of generally circular configuration. Extending from periphery **11** upward is an upward convex shaped region **12** interrupted by a centrally positioned spherical canopy **14** housing passenger cabin **15**. Extending downward, the lower portion of the aircraft consists of lower convex shaped region **16** to which is attached retractable tricycle landing gears **18**, **20** and **22**, spaced at 120 degree positions equally distant from the center of the aircraft. Lateral movement of the aircraft is assisted or provided by jets **24** positioned at appropriate points on the periphery of the body of the aircraft, as for example at the rear or aft side, as illustrated. Skin covering **26** and **28** on upper convex region **12** and lower convex region **16**, respectively, is of open wire mesh construction. This permits air to pass through vertically as driven by counter rotating fan or blade assemblies **30** and **32** (FIG. 3), fan **30** being an upper fan assembly and fan assembly **32** being a lower fan assembly. Fan assembly **30** is formed of variable pitch blades **34**, outer supporting ring **36** and inner supporting ring **38**. A rack gear **40** (FIG. 4) is provided on the underside of supporting ring **38**, which gear engages three idler gears **42** positioned at 120° intervals around passenger cabin **15**. Three idler pulleys **46**, similarly positioned at 120° intervals around passenger cabin **15** provide an upper support for inner supporting ring **38**. Idler gears **42** are provided with locking rims **48** (FIG. 3) and idler pulleys **46** are provided with lateral supporting or locking rims 50, which locking rims extend radially to engage a portion of a side of inner supporting ring 38 and thus together provide lateral as well as vertical support for upper fan assembly 30.

Similarly, lower fan assembly 32 is formed of variable pitch blades 51, inner supporting ring 52, and outer supporting ring 54. Rack 56 on the upper edge of inner ring 52, engages and is vertically supported by idler gears 42. Also, and in a like manner, three idler pulleys 58 spaced at 120° intervals and having lateral supporting or locking rim 60 engage the lower edge of inner ring 52 of lower fan assembly 32. Rim 60 of idler pulleys 58 together with rim 48 of idler gears 42, provide lateral support for lower fan assembly 32. Idler gears 42 and idler pulleys 46 and 58 are supported by means of shafts 62, 64 and 66, respectively, by mounting supports (not shown in detail) on the side wall 68 of passenger cabin 15.

Jet engines 70 are attached to outer ring 36 of upper fan assembly 30 to produce rotation in a first direction and, like jet engines 72 are attached to outer ring 54 of fan assembly 32 and oriented to produce rotation of fan assembly 32 in a direction opposite to fan assembly 30. Fan assemblies 30 and 32 are effectively locked together insofar as speed of rotation is concerned by idler gears 42. Fuel is fed to jet engines 70 and 72 from fuel tank 74 through pipelines 75, 76 and 78 to troughs 80 and 82 on fan assemblies 30 and 32, respectively. This is accomplished by the overlapping of portions of fuel line 76 with trough 80 and of fuel line 78 with trough 82. In this manner, fuel flows without direct physical contact between the troughs and fuel lines, the troughs, of course, moving with the fan assemblies relative to the fuel lines. Fuel is forced out through fuel lines 83 in fan assemblies 30 and 32 by centrifugal force to the peripheral mounted jet engines.

Necessary electrical power is provided to the jet engines by means of commutating or slip-ring contacts 84 and 86, diagrammatically shown in FIG. 5.

Air directors 88, 90 and 92 are held in a fixed position above, between and below fan assemblies 30 and 32 and serve to direct air flow perpendicular to the direction of fan motion; hence, they prevent blade air stall when forward speed of the aircraft exceeds fan tip speed. In addition, there is included movable air directors 94 (FIG. 10) on the same level as lower fixed directors 92, and positioned on each side of the aircraft and employed to provide yaw control for the vehicle in a manner to be described.

FIG. 13 further illustrates diagrammatically from a plan view perspective, the arrangement of air directors 88.

FIG. 12 shows in a plan view fan jets 70 positioned at 90° intervals about outer supporting ring 36 of upper fan assembly 30 which are employed to drive upper blades 34. Spokes 95 provide reinforcement for the upper and lower (not shown) fan blade assemblies.

FIG. 14 is an enlarged cross-section of a fan air foil blade 34 and mounting member 105.

Variable pitch blades 34 and 51 making up upper fan assembly 30 and lower fan assembly 32, respectively, are driven at a constant speed with lift controlled by controlling the variable pitch of the blades.

The pitch or angle of blades 34 and 51 (FIGS. 3 and 5) is mechanically changeable by blade angle control member assemblies 96 (FIG. 5), associated with each of fan assemblies 30 and 32 and consisting of U-brackets 98 mounted on inner rings 38 and 52 extending as a ring about the fan assemblies and supporting a plurality of spaced spring members 100, which bias movable control ring 102, which in turn is pivotably connected to the trailing edge of each blade by arms 104 to effect angular changes in attitude of blades 34 and 51 by causing the blades to pivot about rotary blade mounting members 105 of inner ring 38 and 52. Control ring 102 is positioned to effect the volume of regional vertical air flow by four control stations 106, 108, 110 and 112 (FIGS. 5, 6 and 9), being located, fore and aft and port (left) and starboard (right), respectively. Each of control stations 106, 108, 110 and 112 includes means for being activated to produce vertical movement on control ring 102 by two mechanical inputs, one superimposed on the other. One input is by means of a general vertical flight control cable 114 (FIGS. 6 and 11) operated by vertical flight control assembly 115 and the other is by means of pitch control cable 116 as to pitch control effected by fore and aft stations 106 and 108 (FIGS. 5, 6, 7 and 9), and by means of roll control cable 117 as to roll control effected by port and starboard control stations 110 and 112.

Engagement between each control station and control ring 102 is accomplished by upper idling roller 118 and lower idler roller 120 (FIG. 5), positioned above and below control ring 102, respectively. Rollers 118 and 120 are mounted by shafts 122 and 124 on one end 126 of right angle arm 128 of each control station. The other end 130 is biased to hold arm 128 in a basically neutral flight position by spring member 132 (in conjunction with spring members 100) coupled between arm end member 133 and supporting brackets 134 and 136 mounted on slidable vertical flight control linkage 138. Slidable vertical flight control linkage 138 is mounted to move vertically in guide members 140 in response to vertical flight control cable 114 coupled through straight control linkages 141 and right angle control linkage 142, the latter being pivoted by pin 144 on cabin sidewall 68.

Local or individual station blade angle of attack control, as for example pitch control, is superimposed on the vertical flight control networks 145, as illustrated in FIG. 6, by means of pitch control cable 116, operated by conventional pitch control column assembly 146 and rotating drum 147 acting on end member 133 of arm 128, the latter being also supported by flight control linkage 138, as described above. In a similar manner, roll control is effected by conventional flight control column wheel assembly 148 coupled to like but port and starboard control stations 110 and 112 by roll control stations 110 and 112 by roll control cable 117 (FIGS. 7 and 9). Control column assembly 146 upon which control wheel assembly 148 is mounted, is in turn rotatably mounted by bushings 149 by conventional means not shown to the frame of passenger cabin 15.

Yaw control is effected by making a portion of the lower directors movable directors. These are designated as movable directors 94 and, by way of example, five port side movable directors 150 and five starboard side directors 152 are shown in FIG. 10. Movable directors 94 are pivotably mounted to the aircraft by pins 154 (FIG. 8) and moved in a fixed spaced relation by connecting arms 156 and 158 (FIG. 10) responsive to yaw control cable 160 as controlled by yaw or rudder pedals 162.

Operation and control of the aircraft is accomplished by a relatively standard type control system as described above. With jet engines 70 and 72 running, take-off is achieved by movement of vertical control assembly 115 to vary the attitude from a zero pitch or neutral position to a position of fan blades 34 and 51 causing air to be forced downward from the top of the aircraft through upper air directors 88, center air directors 90 and lower air directors 92 and 94. With sufficient thrust achieved in this manner, the aircraft will become airborne and continue to rise.

The pilot controls pitch by virtue of movement of conventional pitch control column 146, being movable in a fore and aft line of direction. Typically, and in accord with conventional practice, movement of the control column assembly forward causes the aircraft to pitch downward and moving it aft to cause the aircraft to pitch upward. This control is accomplished by changing the relative pitch of fan blades forward with respect to those aft. Thus, for pitch downward the blades at control station 106 would be decreased in angle of attack and those at control station **108** would be increased in angle of attack.

Roll control is achieved by appropriate rotation of flight control column wheel **148** and wherein a roll downward to the right (and upward to the left) would be produced by reducing fan blade angle attack at station **112** and increasing it at station **110**.

Lateral directional heading, as variations in yaw or azimuth, is accomplished by reciprocal deflection of port and starboard director blades **94** by movement of rudder pedals **162**. For example, to effect a right turn, starboard movable deflectors **152** would deflect discharged air forward and port movable deflectors **150** would be reciprocally moved to direct discharged air aft.

Forward motion of the aircraft is achieved by application of power in a lateral direction by jets **24** or by holding the vehicle in a slightly pitched or roll direction and thus achieving directional force in the direction of downward pitch or roll by creating a resultant lateral force.

From the foregoing description, it is to be observed that the applicant has provided a novel aircraft comprising a centrally positioned cabin with two sets of fan blades rotating in opposite directions about the cabin. The blades are driven in opposite directions but at equal speeds by virtue of idler gears connecting them. Or, alternately, at least one of the idler gears, as illustrated, would be an engine driven gear and, in which case the outboard jets on the ends of the fan blade assemblies would not be used. Novel means are presented for controlling the aircraft in pitch, yaw, roll, and vertical movement by varying blade pitch and air director angles.

While I have shown a particular aircraft and particular devices and combination of devices in the description and illustration of the aircraft, I contemplate that other detailed devices and combination devices may be employed without departing from the principles and true spirit and scope of the invention as claimed.

What I claim is:

1. An aircraft comprising:

(a) a centrally positioned cabin, the bottom and top portions of said aircraft being of convex configuration, said convex configuration of said top portion being interrupted by a generally spherical top portion of said centrally positioned cabin;

(b) a first fan blade assembly supported by said cabin adapted to rotate in a generally horizontal plane in a first direction around said cabin;

(c) a second fan blade assembly supported below said first fan blade assembly by said cabin and adapted to rotate in a generally horizontal plane in a direction opposite to the rotation of said first fan blade assembly;

(d) regional control means for selectively varying the angle of attack of the blades of said fan blade assemblies regionally as blades pass through fore, aft, port and starboard regions of said aircraft;

(e) power drive means for driving said first and second fan blade assemblies in opposite directions but at equal speeds;

(f) air flow directors adjacent to said first and second fan blade assemblies for controlling the direction of air flow at least at one flow surface of each of said fan blade assemblies and a portion of said air directors being adjustable;

(g) first control means coupled to air flow with respect to said aircraft for varying the attitude of the aircraft in a pitch mode and comprising means associated with said regional control means for varying the angle of attack of said blades in said fore and aft regions for simultaneously aplying opposite angle of attack control to said blades passing through said fore region with respect to blades passing through said aft region;

(h) second control means coupled to air flow with respect to said aircraft for varying the attitude of said aircraft in a roll mode and comprising means associated with said regional control means for varying the angle of attack of said blades passing through said port region with respect to blades passing through said starboard region;

(i) third control means coupled to air flow with respect to said aircraft for varying the attitude of said aircraft in a yaw mode and comprising said portion of said air directors;

(j) fourth control means coupled to said first and second fan blade assemblies for controlling movement of said aircraft perpendicular to said generally horizontal plane of said fan assemblies and comprising means associated with said regional control means for varying the angle of attack equally of said blades in said fore, aft, port and starboard regions;

(k) propelling means comprising at least one jet engine positioned at the aft side of said aircraft and oriented to propel said aircraft in a forward direction;

(l) said fan blade assemblies comprising blades extending between an inner ring support and outer ring support and the inner ring supports of the fan blade assemblies are coupled together by idler gears positioned at 120° intervals about said cabin and are supported vertically to effect constant engagement between said gears and said ring supports by idler rollers engaging rings opposite each said idler gear.

References Cited

UNITED STATES PATENTS

2,473,331	6/1949	Dunley	170—135.26
2,777,649	1/1957	Williams	244—69 X
2,863,621	12/1958	Davis	244—23
2,978,205	4/1961	David	244—23
3,135,481	6/1964	Sudrow	244—23
3,312,425	4/1967	Lennon et al.	244—23 X

FOREIGN PATENTS

1,347,733	11/1963	France.

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