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[33] **Germany**
[31] **P 19 01 707.3**

[54] **AIRCRAFT WITH LIFT-AND-CRUISE FANS**
10 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** ..... **244/12 A,** 244/56
[51] **Int. Cl.** **B64c 29/00**
[50] **Field of Search** ..... 244/12 D, 12 A, 23 D, 23 A, 56

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ABSTRACT: A propulsion-and-lift fan assembly for STOL-type aircraft in which the fan is driven by hot gases produced by a gas generator (turbine) and the fan assembly is mounted in a duct opening at one axial end toward the forward-flight direction. The fan assembly includes a blade arrangement serving as air guide. The assembly is swingable through an angle of 0° to more than 100° about an axis perpendicular to the longitudinal axis or forward-flight direction so that there is negligible loss as a consequence of air diversion, and airflow control flaps and jalousies are avoided.

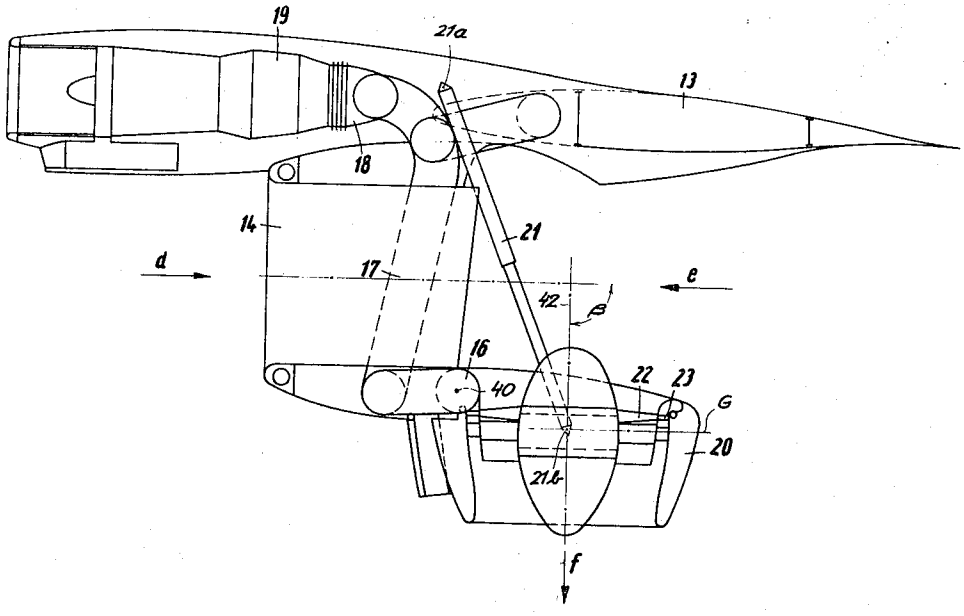
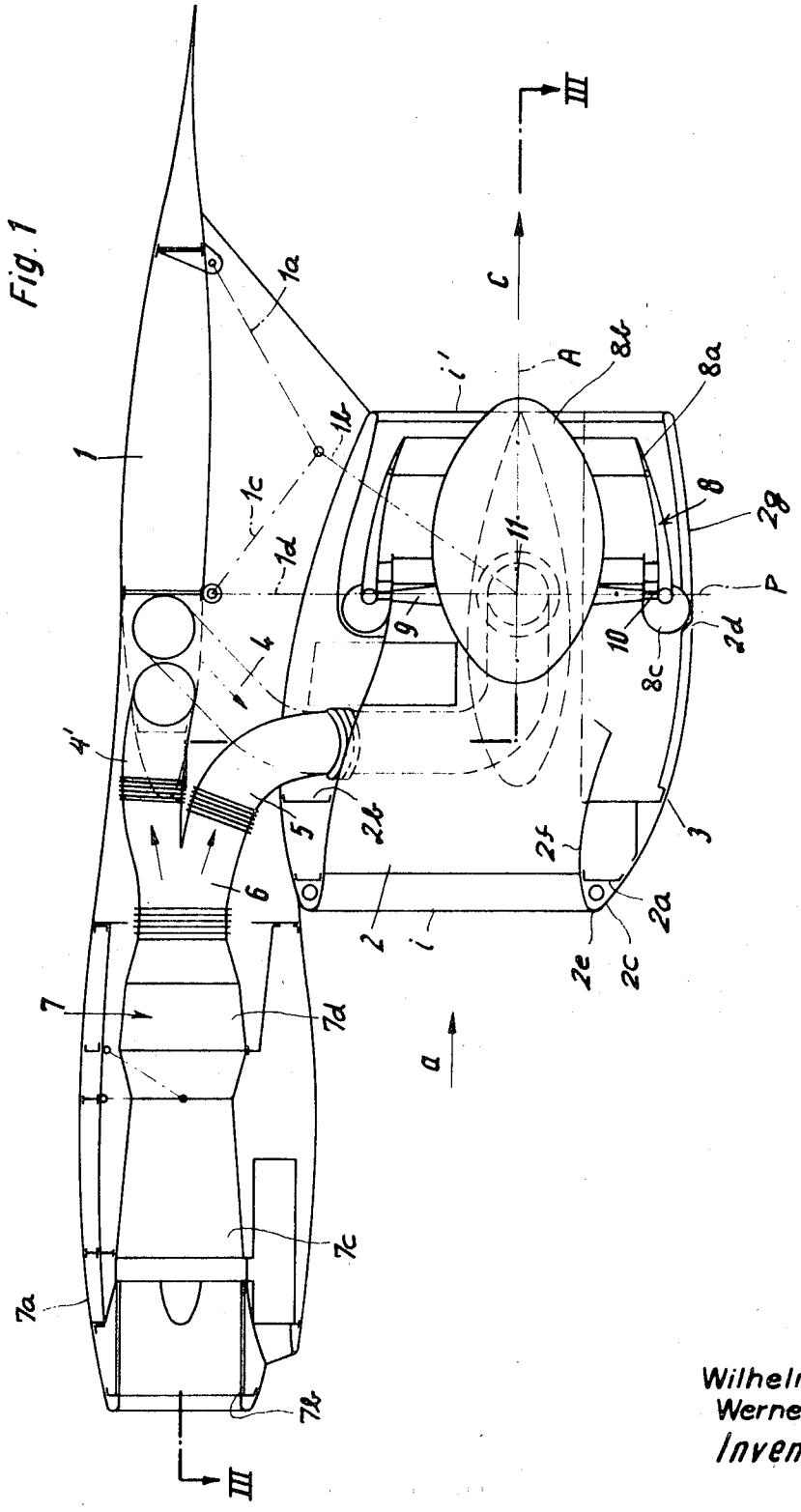


Fig. 1



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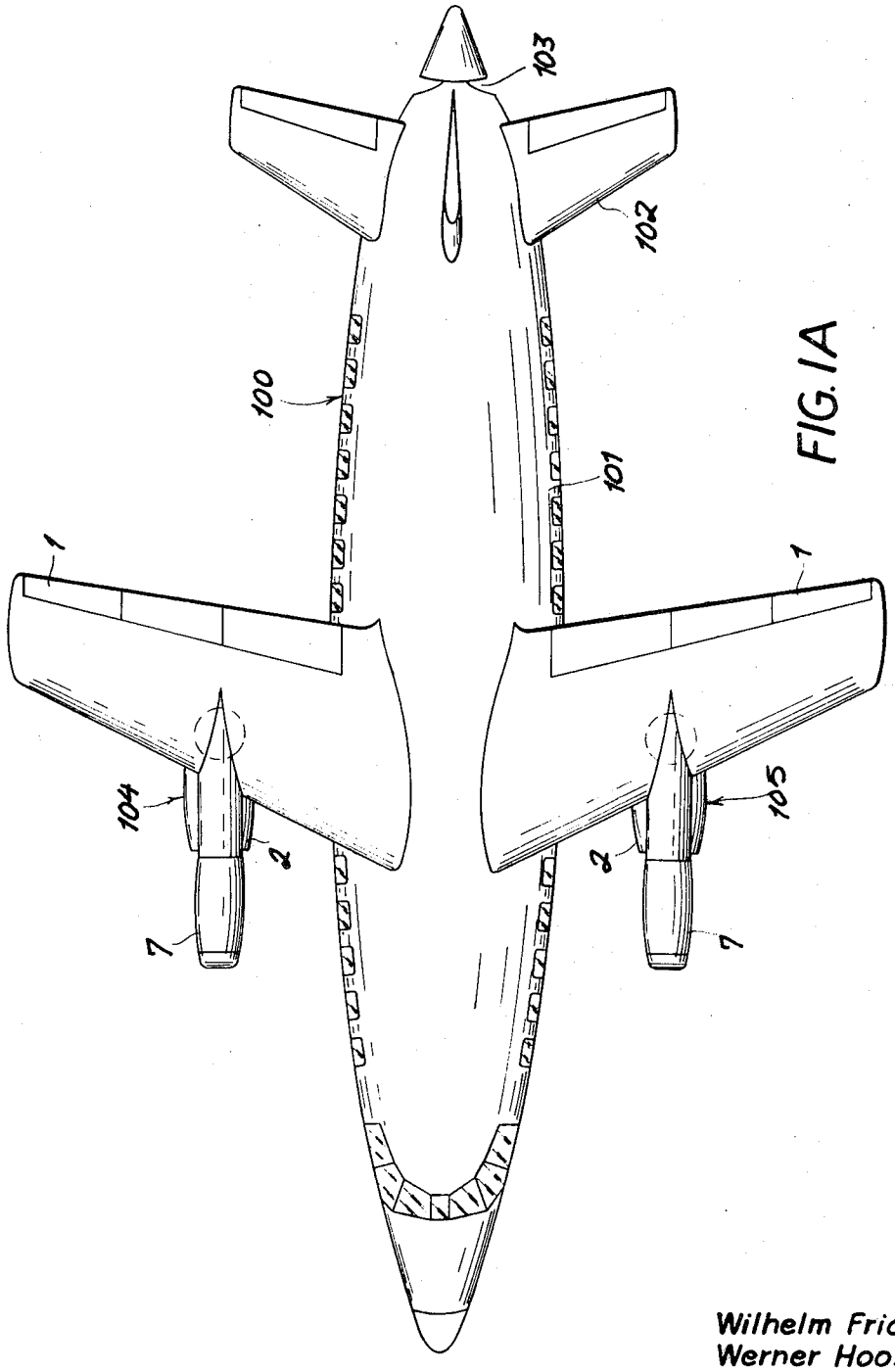


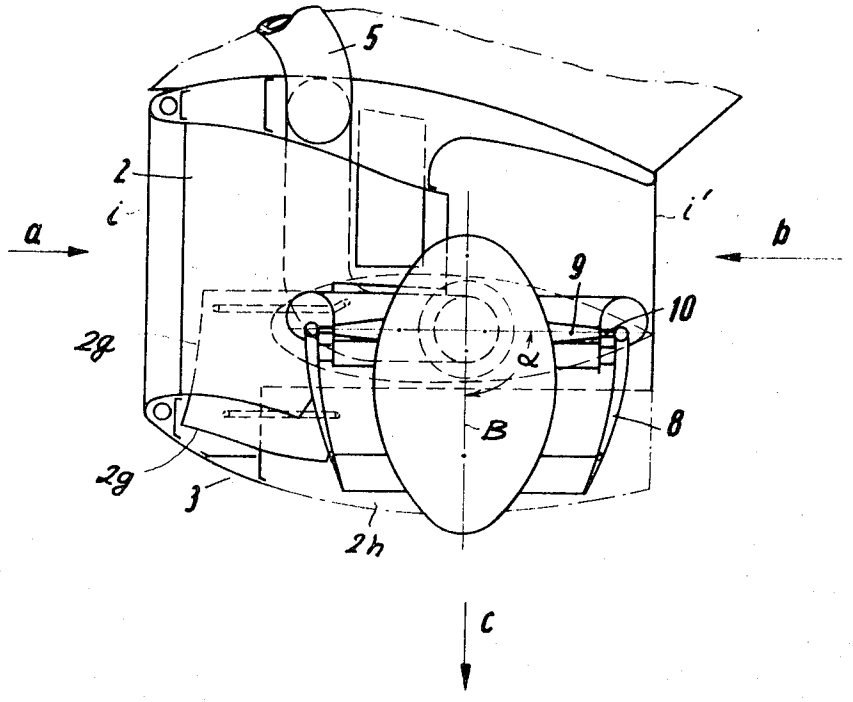
FIG. 1A

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Fig. 2



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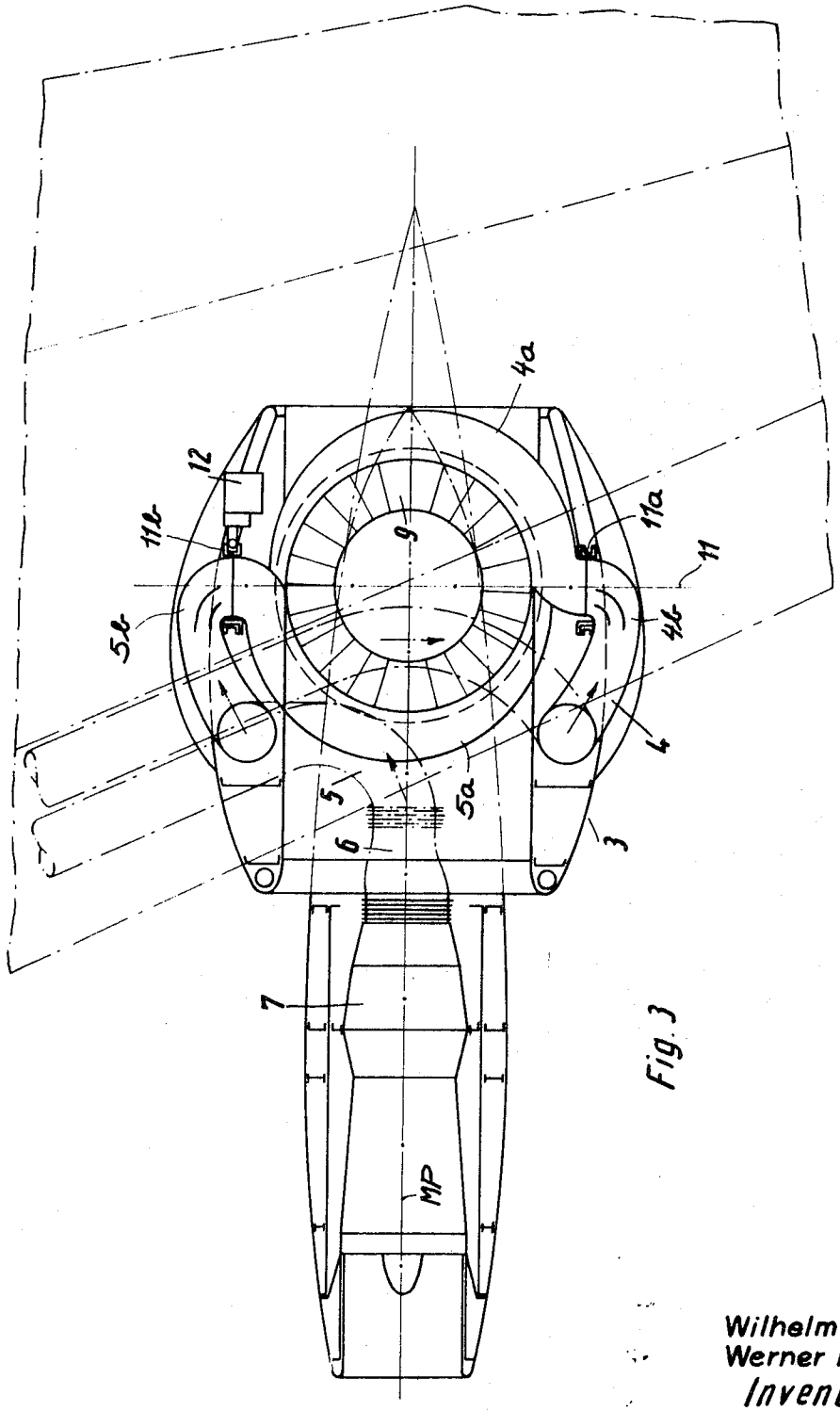


Fig. 3

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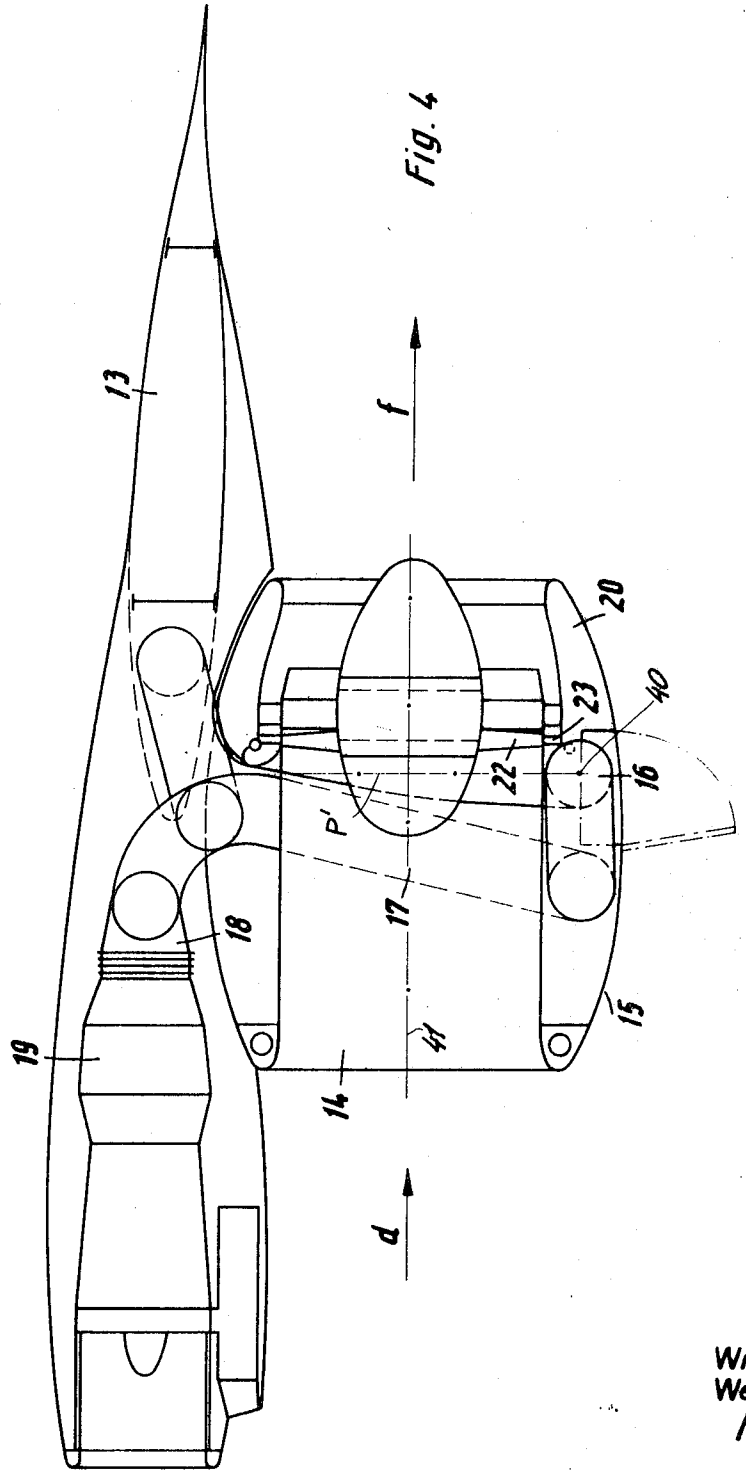


Fig. 4

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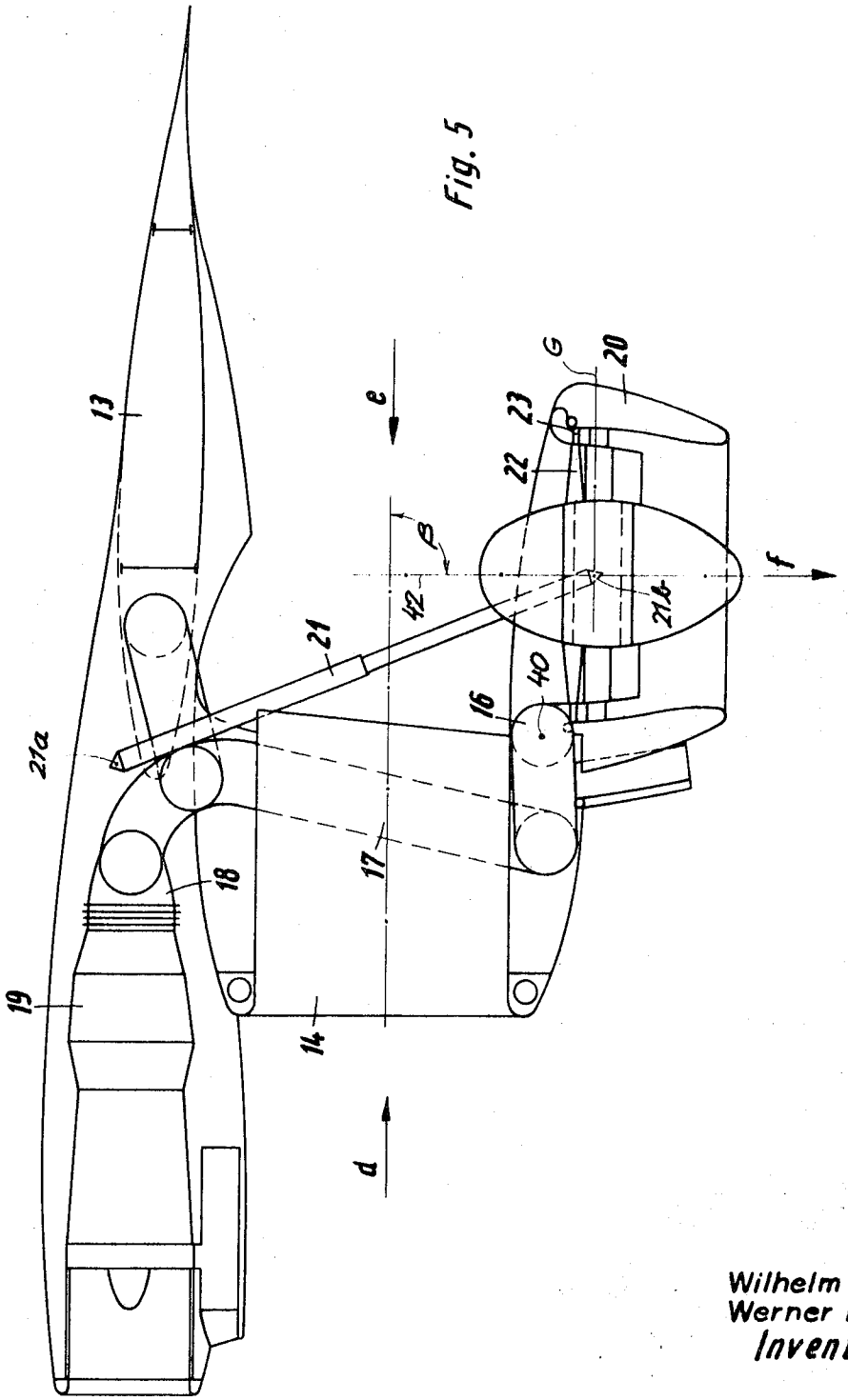


Fig. 5

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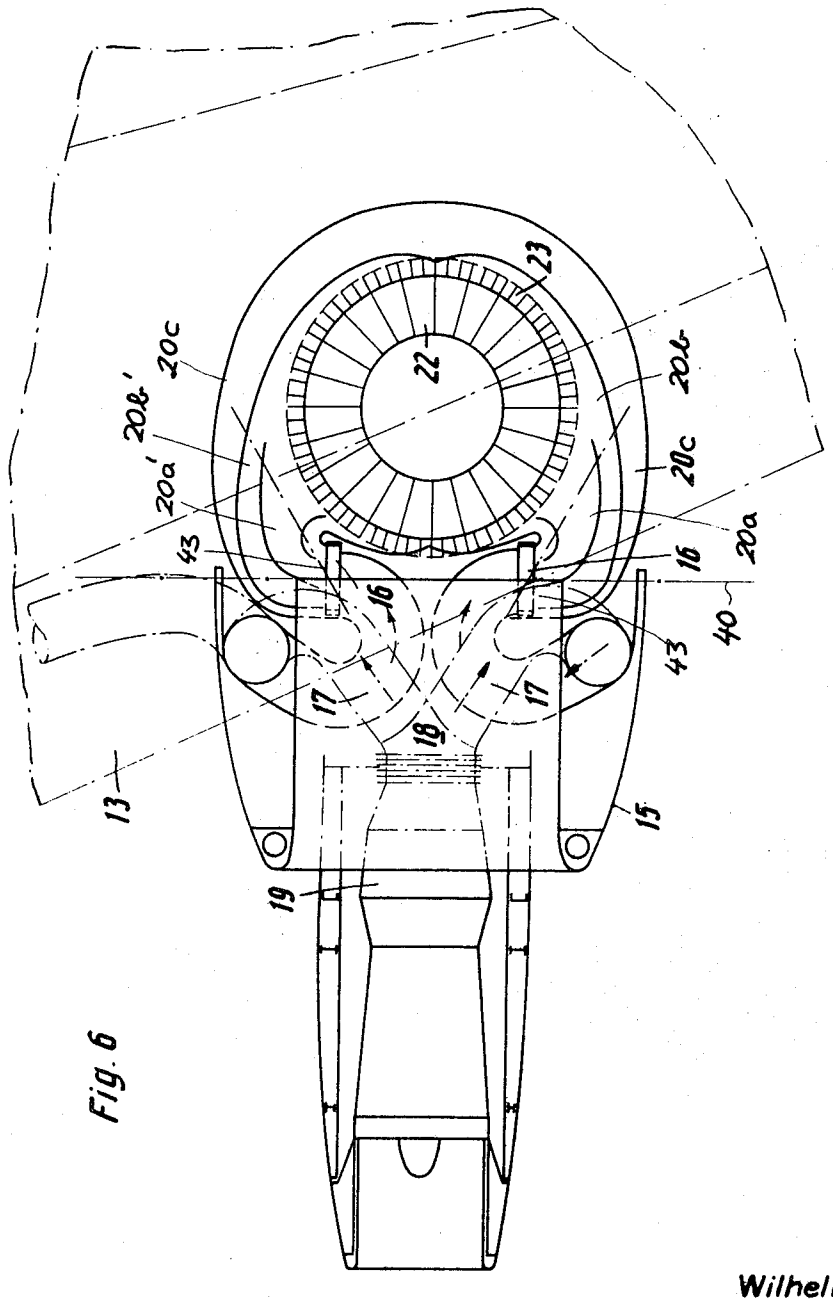


Fig. 6

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AIRCRAFT WITH LIFT-AND-CRUISE FANS

1. FIELD OF THE INVENTION

Our present invention relates to STOL-type aircraft and, more particularly, to aircraft having fans which serve to produce lift or forward propulsion (i.e., cruise and lift fans).

2. BACKGROUND OF THE INVENTION

In general, the attention of workers in the aircraft industry has increasingly been drawn to fixed-airfoil or fixed-wing aircraft of the short-takeoff-and-landing type, i.e., so-called STOL fixed-wing aircraft, in which at least part of the lift is produced by cruise-and-lift fans or a single cruise-and-lift fan carried by the wing structure or on the fuselage of the aircraft. In aircraft of this general character, an elongated fuselage may be provided intermediate its ends with one or more cruise-and-lift fans adapted to eject downward airstreams in the lift mode so that the reaction force, in conjunction with any lift provided by the flow of air over the fixed airfoils, is capable of raising the aircraft or at least of controlling its rate of climb or descent. For forward propulsion, the aircraft may be provided on the fixed airfoils or wings with cruise fans and/or fans capable of thrusting the aircraft forwardly and contributing to the lift mentioned above.

In the commonly assigned copending application, Ser. No. 834,647, filed 19 June 1969 (now abandoned) by Hans-Lucius Studer, there is described and claimed a fixed-wing aircraft having dual-function fans on the fixed airfoils and upon the fuselage. In this system and in certain other STOL-type aircraft, the fan fulfills a dual purpose by virtue of the deflectors, baffles or control flaps which are provided to direct the airstream selectively downwardly or rearwardly and thereby produce propulsion or lift or proportionately distribute the thrust between the two.

As pointed out in that application, moreover, the fans are preferably driven by external combustion means, e.g. by hot gases, generated in gas-generating installations separate from the fans. In such arrangements, a plurality of hot-gas generators may be provided in or on the body of the aircraft and are connected with the cruise-and-lift fans of the fuselage and any cruise-and-lift fans of the airfoils by hot-gas ducts. To control the flow of hot gas through these ducts, manually or automatically regulated valves may be provided or check valve systems may be employed. In the event of failure of one of the gas generators, means is usually provided to reduce the lift or propulsion thrust at each of the fans by a corresponding redistribution of the remaining generator gas supply. A system of this type ensures uniform reduction of thrust at all fans and therefore does not give rise to any unbalanced force which must be resisted by compensating controls or actions on the part of the operator of the aircraft.

In the copending application, moreover, it is pointed out that failure of one of the gas generators feeding the cruise-and-lift fans of a STOL-type aircraft may nevertheless cause the aircraft to yaw, i.e., to swing about the yaw axis.

To avoid this disadvantage, the system of the copending application provides an aircraft having an elongated fuselage and one or more downwardly directed cruise-and-lift fans mounted thereon at an intermediate location along the length of the fuselage. The fans are so arranged as to have a plane of resultant lift thrust or of lift thrust symmetry extending perpendicularly to the longitudinal axis of the fuselage and preferably located slightly beyond the center of gravity of the aircraft. The aircraft is provided with a number of hot-gas generators (e.g. gas turbines), each of which is connected tangentially to one of the segmental compartments of the housing of each of the cruise-and-lift fans of the fuselage while branch ducts connect the conduits between each hot-gas generator and the respective compartments of each fan.

On the fixed airfoils or wings of the aircraft, there are provided cruise-and-lift fans having respective hot-gas generators but formed with controllable deflectors for selectively directing the airstreams of these fans rearwardly or downwardly or in any proportion between a rearward and a downwardly direction, thereby providing forward thrust or propulsion together with a selected degree of lift thrust.

The airfoil fans are arranged and constructed so that their resultant lift is effective in the aforementioned plane of the lift resultant of the cruise-and-lift fans of the fuselage so that no moment about the yaw axis is produced upon failure of one of the gas generators. The aircraft may be trimmed and steered at least in part by one further fan located along an axis parallel to the longitudinal axis of the fuselage and preferably at one end of the latter.

It has been noted earlier that systems in which the fans have the thrust diverted by deflectors (e.g. blades or jalousies) extending into the airstream emerging from the fans to deflect these airstreams, have significant disadvantages in that power loss occurs with deflection or change of direction of the airstream

3. OBJECTS OF THE INVENTION

It is, therefore, the principal object of the present invention to provide a lift-and-cruise fan assembly in which loss by redirection of airstreams is eliminated or minimized.

Another object of this invention is to provide a short-takeoff-and-landing aircraft using lift-and-cruise fans wherein the disadvantages of earlier systems can be obviated.

It is also an object of the invention to provide an improved propulsion-and-lift assembly adapted to be mounted upon the fixed airfoil of a short-takeoff-and-landing aircraft.

4. FEATURES OF THE INVENTION

These objects and others which will become apparent hereinafter, are attained, in accordance with the present invention, in a lift-and-propulsion fan arrangement for aircraft, especially systems of this type which are mounted upon a fixed airfoil of a short-takeoff-and-landing (STOL) aircraft in which the fan may be used selectively for ascent, descent and hovering flight as well as for forward propulsion or cruising. The fan assembly is arranged, according to the invention, within an air passage or duct open in the forward direction to form an intake and, beyond the fan assembly, both in the rearward direction for discharge of an airstream for forward propulsion, and in the rearward direction for discharge of an airstream to provide lift.

The fan assembly according to this invention is swingable about an axis transverse to the longitudinal axis of the air passage (parallel to the longitudinal axis of the aircraft and generally in the direction of forward propulsion) through an angle ranging from 0° to in excess of 100°, as measured with reference to the longitudinal axis from the forward propulsion or cruise position of the fan assembly in which its axis coincides with the longitudinal axis.

The fan assembly, which is driven by hot gases from the gas generator (e.g. a gas turbine of any conventional type known in similar applications and of the type described in the aforementioned copending patent application), is provided with a generally tubular air-guide apron which is generally of funnel shape, i.e., is convergent from the intake end of the fan. This apron is fixed with respect to the axis of the fan assembly and pivots with the latter to ensure direction of the outflowing air corresponding to the angle of orientation of the axis of the fan assembly. Preferably, the apron terminates at a plane of the fan assembly transverse to its axis but containing the pivotal axis. In this manner it is possible to swing the effective true direction from the normal cruise position through angles of 90° to a lift position, or even further to contribute a forward component of thrust (e.g. for braking) without the use of control flaps or jalousies and without any deflection or diversion of the outflow of the fan. Consequently, deflection losses are eliminated.

In swinging the assembly from its cruise position to its lift position, moreover, there is no change in the cross section of

the intake window of the assembly or in the cross section of the intake or outflow paths as has frequently been the case with earlier systems in which circular flow cross sections were transformed into rectangular cross sections by the control flaps or jalousies. Moreover, the actual length of the fan assembly can be sharply reduced by comparison with earlier systems which require posterior ducts in which the control flaps and jalousies can be positioned. Furthermore, a most important advantage resides in the fact that the position of the cruise-and-lift fan assembly maintains its position with respect to the center of gravity of the aircraft regardless of the orientation of the fan assembly, thereby requiring no adjustment in the trim or other alteration of the controls of the aircraft.

According to a more specific feature of this invention, the fan assembly is swingable about an axis transverse to the longitudinal axis and lying in the plane of the drive turbine blades, turbine buckets or vanes of the fan. This portion of the fan assembly thus remains within the outer contours of the assembly in all angular positions thereof, thereby minimizing the airflow resistance to the fan assembly. This system has been found to be particularly suitable for aircraft in which the cruise-and-lift fan assemblies are disposed at low points of the aircraft such that the assemblies are close to the ground when the aircraft is at rest. Moreover, the hot-gas inlets to the fan assembly preferably communicate with the latter along the pivot axis so that gas supply is not obstructed or altered upon swinging movement of the assembly. The assembly may be swung or canted by hydraulic, electric or pneumatic drive to allow fine positioning and stepless control of the orientation of the fan assemblies with a minimum of mechanical parts subject to failure. The energy required for this purpose may derive from the hydraulic system commonly provided in aircraft control.

While the fan assemblies of the present invention may make use of remotely positioned gas generators of the type provided, for example, in the fuselage of the aircraft described in application Ser. No. 834,647, we prefer to form the gas generator and an associated cruise-and-lift fan assembly as a unit or integral structure with the air passage of the fan being mounted upon the pod or nacelle of the gas turbine serving as the gas generator. Air resistance during high-speed travel of the aircraft is thereby reduced and the length of the hot-gas ducts can also be lessened. It will be appreciated that the efficiency of the engine constituted by the gas generator and the fan is a function of the temperature of the gases reaching the driving blades or buckets of the fan and, consequently, that thermal loss should be held to a minimum. In addition, the integral construction of gas generator and fan assembly permits a reduction in the weight of the parts, an advantage of special significance in dealing with short-takeoff-and-landing aircraft.

5. DESCRIPTION OF DRAWING

The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. **1** is a vertical cross section, in diagrammatic form, through a gas generator and fan assembly mounted upon a fixed airfoil of an aircraft;

FIG. **1A** is a plan view of the aircraft illustrating the positioning of the assembly of FIG. **1** relative to the remaining parts;

FIG. **2** is a vertical section through the fan assembly of FIG. **1**, but illustrating the swingable parts thereof in a position 90° offset from position of the same parts shown in FIG. **1**;

FIG. **3** is a cross section taken generally along the line III—III of FIG. **1** but showing the fan assembly in the position of FIG. **2**;

FIG. **4** is a vertical cross section through another embodiment of a cruise-and-lift fan arrangement according to the invention with the fan assembly in position for horizontal flight;

FIG. **5** is a vertical section through the embodiment of FIG. **4** but illustrating the position of the fan assembly for providing vertical thrust; and

FIG. **6** is a horizontal section through the fan assembly of FIG. **5** and through part of the gas generator associated therewith.

6. SPECIFIC DESCRIPTION

In FIG. **1A**, we show a passenger-carrying aircraft **100** which comprises a fuselage **101**, the underside of which may be provided with a multiplicity of hot-gas-generating turbines and lift fans as described in the copending application, Ser. No. 834,647 (see also U.S. Pat. No. 2,939,649). The tail structure **102** includes a trimmer fan **103** to reduce yaw. The fixed airfoils or wings **1** of the aircraft are provided with integral or unitary gas generator and lift-fan assemblies as represented generally at **104** and **105**. The assemblies may be of the types shown in FIGS. **1–3** or FIGS. **4–6**.

As illustrated in FIGS. **1–3**, the fixed airfoil or wing **1** of the aircraft carries an air intake passage **2** of a cruise-and-lift fan assembly generally designated at **3**. At its forward end, the housing of the assembly is formed at **2***a* with a reinforcing channel, a further such channel being provided inwardly thereof at **2***b*. The outer skin **2***c* of the air intake channel terminates at **2***d* and has a streamlined curvature designed to increase the lift of the aircraft during forward travel. The teardrop-profile forward end **2***e* is continued by an internal skin **2***f* of streamlined curvature establishing a longitudinal axis A parallel to the longitudinal axis of the aircraft. The air passage during normal cruising flight (horizontal flight) is continued by a duct portion **2***g* which may be retracted upwardly along the size of the housing (broken lines in FIG. **2**) when an opening **2***h* is to be provided in the downward direction. Otherwise, the skin **2***g* forms a continuation of the outer skin of the fan housing.

The gas generator has been illustrated in FIG. **1** at **7** and may be of the type shown and described at pages 9–173 ff. of MARKS' MECHANICAL ENGINEER'S HANDBOOK, 6th Edition, McGraw-Hill Book Co., New York 1964. Such turbines include a nacelle **7***a* forming an intake duct **7***b* for the air, a turbocompressor **7***c* in which the air is compressed in one or more stages and one or more turbine stages **7***d* in which combustible fuels are reacted with the compressed air and are permitted to expand, the high-pressure gases being used in part to drive the turbocompressor and in part to operate the lift-and-cruise fans of the aircraft. To ensure proper balance under all conditions, each of the gas-generating turbines of the airfoils of the aircraft have a branched output **6** (FIG. **1**) from which one hot-gas conduit **5** leads to the drive turbine of the associated fan while the other duct **4'** or **4** leads to the drive turbine of the other fan.

From FIGS. **1** and **3**, it can be seen that the hot gases from ducts **4** and **5** are led to respective scrolls **4***a* and **5***a* of the driving turbine of the lift-and-cruise fans. Within the ducts feeding the scrolls, there are provided gas-guide vanes **4***b*, **5***b* at the junction with the scrolls to minimize turbines and reduce resistance losses in the velocity of the gas streams. The swingable assembly of the lift-and-cruise fan is represented generally at **8**.

From FIGS. **1–3**, it can be seen that the last-mentioned assemblies include an apron **8***a*, the wall of which converges rearwardly in a teardrop profile and which forms a rearwardly converging duct which cooperates with an intermediate body **8***b* to direct the outflowing gases along the axis of the fan. The axis is represented at B in FIG. **2** and shown to lie at an angle $\alpha=90°$ to the longitudinal axis A mentioned earlier. At the entrance end, a manifold **8***c* is subdivided into the scrolls **4***a* and **5***a* to feed hot gases to the turbine buckets or vanes **10** constituting the drive for the fan, whose main air-displacement blades are represented at **9**. The assembly **8**, including the scrolls and the blades **9**, **10** is swingable about an axis **11** best seen in FIG. **3** and lying in a plane P (FIG. **1**) perpendicular to the axis A and to the axis B, but fixed with respect to the center of gravity of the aircraft. The angle through which the assembly is permitted to swing may range $0°<\alpha<100°+$ as previously noted.

To swingably mount the fan assembly within the air duct 2, we provide a bearing structure 11*a*, 11*b* on opposite sides of the fan assembly at which the scrolls 4*a* and 5*a* respectively are aligned axially with the ducts 4 and 5. A hydraulic motor 12 is coupled to the assembly 8 and may be energized to swing the latter. Member 12 may also represent a pneumatic servomotor or an electric motor connected by a worm drive with the swingable assembly. Struts 1*a*, 1*b*, 1*c* and 1*d* may be provided to suspend the fan assembly from the wing.

For forward cruising flight, the fan assembly is maintained in its horizontal orientation (α=0°) while hot gases are fed from the gas-generating turbines through the scrolls 4*a* and 5*a* to the driving blades 10 of the fan. The blades 10 are, of course, connected with the blade assembly 9 and rotate the latter to draw air inwardly in the axial direction (arrow *a*) and injected rearwardly (arrow *c*), thereby sustaining the forward thrust necessary for aircraft propulsion. The lift during high-velocity forward travel may be provided solely by the fixed airfoils.

During ascent or descent and for a hovering type of flight, the assembly 8 is rotated downwardly to the position shown, for example, in FIGS. 2 and 3 (α=90°) while the walls 2*q* are retracted to permit the airduct to open downwardly. Air can then be drawn into the fan in the direction of arrow *a* as previously described or in the opposite direction (arrow *b*) and is injected downwardly (arrow *c*). As shown in FIG. 2, the intake windows *i* and *i'* for the airstreams entering at *a* and *b* may be identical so that there is no net horizontal component either direction. Of course, the orientation of the fan assembly to a slight off-vertical position, e.g. α=80°, will contribute a forward thrust component while a slight off-vertical orientation in the opposite direction (α=100°) will contribute a horizontal thrust component in the forward direction. The longitudinal median plane of the assembly is shown at MP.

In FIGS. 4–6, we have shown another embodiment of our invention wherein the fan assembly is swingable out of the air duct when positioned to provide an upward or lift thrust. Here again the gas generator 19 is integral with the air duct 14 of the cruise-and-lift fan assembly 15 and is mounted together therewith upon the fixed airfoil or wing 13. Hot gas is delivered from the turbine 19 and, if desired, from another gas generator as previously described via the duct 16, 17 and 18 through the scrolls 20*a*, 20*b*, 20*c* and 20*a'*, 20*b'* and 20*c'* to respective sets of driving blades 23 of the fan 24. The pivotal fan assembly is swingable about an axis 40 lying in a plane perpendicular to the longitudinal axis 41 of the assembly in normal cruise position, the plane being represented at P' in FIG. 4. In this embodiment, however, the axis 40 is located below the axis 41 and is not coincident therewith in any position of the fan assembly although the axis 42 of the latter may include angles β ranging from 0° (FIG. 4) to 100° or more, including the angle 90° as shown in FIG. 5. The ducts 16 thus extend to the lower part of the housing of the air passage 14 and there register with the inlets 43 to the scrolls along the pivot axis 41. A hydraulic piston-and-cylinder arrangement 21 has its cylinder pivotally connected at 21*a* to the turbine housing and its piston pivotally connected at 21*b* to the pivotal fan assembly in the plane of its center of gravity G perpendicular to the axis 42. Contraction of the assembly 21 swings the fan in the counterclockwise sense (FIG. 5) about the pivot 40, while elongation of the assembly 21 swings the fan in the clockwise sense from its position shown in FIG. 4 downwardly in the position illustrated in FIG. 5.

In FIG. 4, the position of the fan assembly for horizontal flight has been illustrated while, in its position shown in FIG. 5, the aircraft is capable of hovering flight or is provided with vertical thrust for ascent or descent. To drive the fans, hot gas from the gas generators are supplied by ducts 16–18 to drive blades 23 of the fans 22. The latter draw air inwardly through the intake duct 14 (arrow *d*) when the fan is in a position shown in FIG. 4 and inject air in the direction of arrow *f* to provide the thrust necessary for forward propulsion. When the fan assembly is in its position illustrated in FIG. 5, however, air is drawn equally into the fan as indicated by arrows *d* and *e* and is injected in the direction illustrated by arrow *f*, to provide upward lift without a net horizontal component. Of course any intermediate position of the fan with corresponding horizontal and vertical components may also be established by adjustment of conventional hydraulic controls not otherwise illustrated.

Various modifications of the invention described and illustrated, within the scope of the appended claims, will become immediately apparent to those skilled in the art and are intended to be included within the compass of the claimed invention. These modifications include, but are not limited to arrangements in which the lift-and-cruise fan assemblies are removed from the gas generators and do not constitute a single integral unit therewith as is the case of the systems illustrated in FIGS. 1–6, arrangements in which the gas generators are provided, with or without the lift-and-cruise fans, above the airfoils or the other locations on the aircraft structure, e.g. below or above the fuselage, in, below or above the tail assemblies etc. or in the nose section of the fuselage.

We claim:

1. In an aircraft, in combination means forming a forwardly open air passage having a longitudinal axis, a hot-gas generator mounted on said aircraft, a gas-driven lift-and-cruise fan assembly mounted on said aircraft in said passage and provided with means defining a duct having an air outflow axis, mechanism for swinging said assembly in said air passage relative to said means forming said passage about a pivot axis in the plane of the fan of said assembly through an angle ranging from 0° to at least 100° included between said longitudinal axis and said air outflow axis, and at least one gas duct connecting said generator with said assembly for driving same.

2. The combination defined in claim 1 wherein a fan is rotatable about said air outflow axis and said assembly includes an array of fan-driving blades contacted by the hot gas from said generator, said pivot axis being perpendicular to said longitudinal and air outflow axes and lying substantially in said plane.

3. The combination defined in claim 1 wherein said means has a lower part and said assembly is swingably mounted on said lower part.

4. The combination defined in claim 1 wherein said mechanism includes a hydraulic drive.

5. The combination defined in claim 1 wherein said assembly forms part of a single unit with said generator.

6. The combination defined in claim 5 wherein said pivot axis lies in a horizontal median plane through said assembly.

7. The combination defined in claim 6 wherein said pivot axis lies at a bottom part of said means defining said passage.

8. The combination defined in claim 7 wherein said hot-gas generator includes a nacelle suspended from a fixed airfoil of said aircraft and said means is mounted integrally on said nacelle, said assembly including an ellipsoidal central body centered on said air outflow axis, an apron spacedly surrounding said body and converging axially away from said air passage in a position of said assembly wherein said longitudinal and air outflow axes are substantially parallel to one another, said fan surrounding said body for inducing the flow of air through the space between said body and said apron, at least one scroll connected to said apron and surrounding said array of blades for directing hot gases from said generator against said blades to drive said fan, and a pivot between said means and said assembly substantially in the plane of said array of blades defining said pivot axis perpendicular to said longitudinal axis and said air outflow axis.

9. The combination defined in claim 8, wherein said scroll and said duct are aligned and interconnected along said pivot axis.

10. The combination defined in claim 9, wherein at least a pair of scrolls are provided on opposite sides of a longitudinal median plane through said gas generator and said assembly containing said longitudinal axis and said air outflow axis, at least two gas ducts being provided for respectively supplying

hot gases to said scrolls and communicating therewith along said pivot axis on opposite sides of said median plane.

* * * * *