United States Patent [19]

Keenan et al.

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[54] **FANS**

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[51] **Int. Cl.**[2]..... **F01D 7/00**

[58] **Field of Search**..... 415/129, 130, 141; 416/156, 157, 147, 149

[56] **References Cited**

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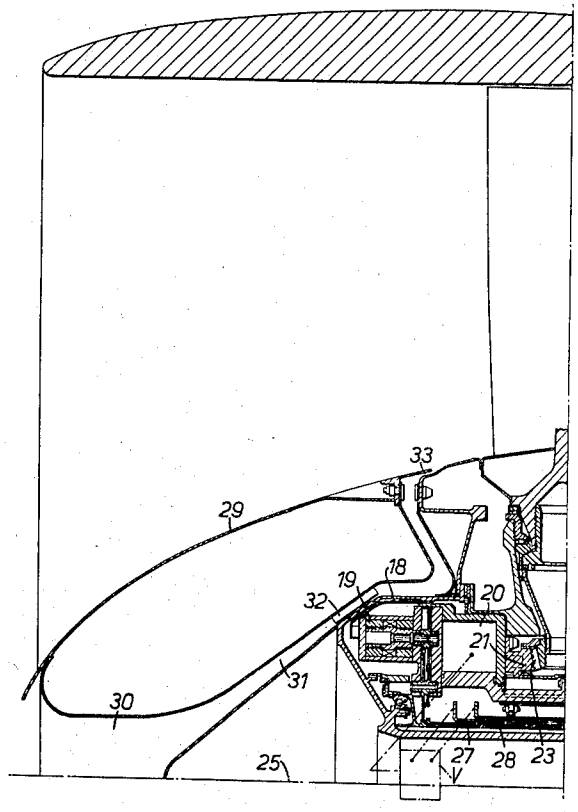
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[57] **ABSTRACT**

A fan assembly for attachment to the front of a main gas turbine engine assembly to provide an engine of the ducted-fan by-pass type, constructed as a unitary assembly which can be fitted and removed as such and comprising a non-rotative sub-assembly, including a by-pass duct, and a rotative sub-assembly supported in bearings by the non-rotative sub-assembly and including a hub and fan blading positioned and rotatably supported within the non-rotative by-pass duct. The hub carries, so as to be rotatable therewith, a liquid reservoir, one or more pumps operable upon rotation of the rotative sub-assembly to draw liquid from the reservoir, a liquid-pressure-operable actuator for adjusting said fan blading to vary flow of fluid over the blading, and control valve means by way of which liquid discharged under pressure by said one or more pumps is directed to operate the actuator.

13 Claims, 3 Drawing Figures



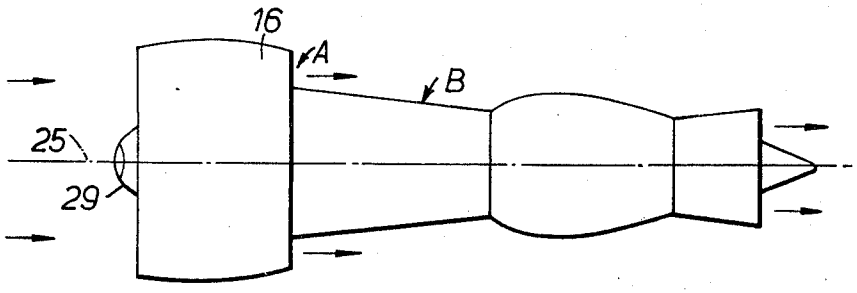


FIG. 1.

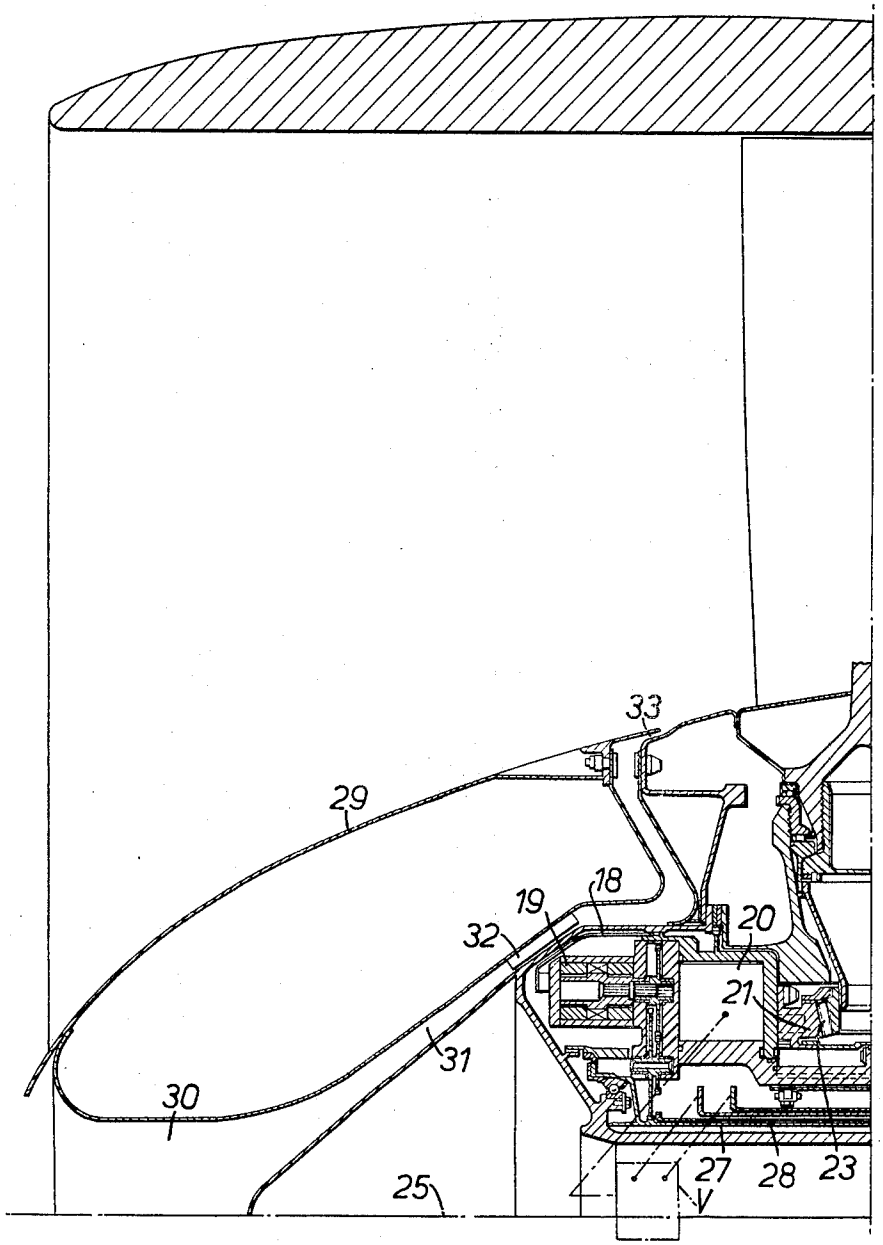


FIG. 2A.

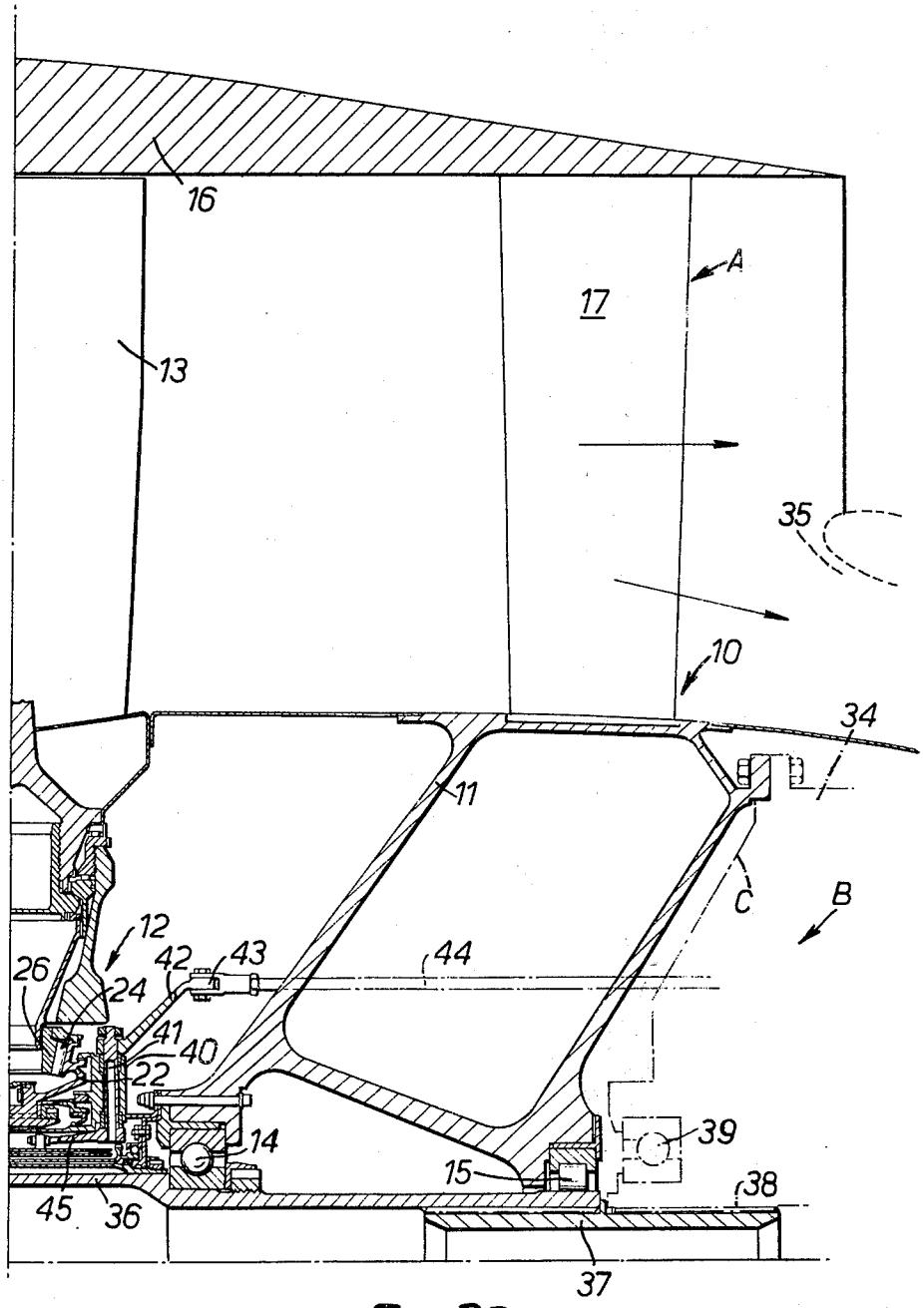


FIG. 2B.

FANS

This invention relates to improvements in or relating to fans.

According to the invention there is provided, for attachment to the front of a main gas turbine engine assembly to provide an engine of the ducted-fan by-pass type, a unitary fan assembly, which can be fitted and removed as such and comprising a non-rotative sub-assembly, including a by-pass duct, and a rotative sub-assembly supported in bearings by the non-rotative sub-assembly and including a hub and fan blading positioned and rotatably supported within the non-rotative by-pass duct, said hub carrying, so as to be rotatable therewith, a liquid reservoir, one or more pumps operable upon rotation of the rotative sub-assembly to draw liquid from the reservoir, a liquid-pressure-operable actuator for adjusting said fan blading to vary flow of fluid over the blading, and control valve means by way of which liquid discharged under pressure by said one or more pumps is directed to operate the actuator.

Preferably, mechanical means connect the pump or pumps with non-rotative structure external of the hub to afford their operation upon rotation of the rotative sub-assembly.

The said mechanical means may include gearing, also carried by the hub, and shafting coaxial with the hub and extending from the gearing to said non-rotative structure.

The pump or pumps may be of gear type.

The reservoir may be of annular form and in part defined by an outer wall of the hub, liquid being retained in said annular reservoir by centrifugal force during rotation of the rotative sub-assembly.

The actuator may be of vane-type having its axis coincident with the axis of rotation of said rotative sub-assembly. The actuator may also be of the balanced kind.

Thus the invention provides a fan assembly, including the by-pass duct, which is detachable and attachable as a whole thereby facilitating manufacture and maintenance of a by-pass engine.

The assembly can also be designed for attachment to an existing engine of the non-by-pass type, thereby converting the engine to one of the by-pass type.

The fan blading is preferably arranged in a single-stage.

The by-pass duct may be supported by a main body of the non-rotative sub-assembly through a ring of stator blading positioned downstream of the fan blading, which main body is adapted for bolting to the front of the main engine assembly and also supports the rotative sub-assembly.

The fan blading is preferably reversible in pitch, and the pitch angle of that blading is desirably variable to provide positive pitch, zero or near-zero pitch, negative pitch and a feathered position in order to provide complete control of the air flow along the duct.

The fan assembly may be adapted for bolting up to the main engine assembly so as to pick up a drive for the rotative sub-assembly either directly from the output shaft of that engine assembly or from a reduction gear-box embodied in the engine assembly. However, and particularly when the fan assembly is designed for conversion of an existing engine, the non-rotative main body may itself house reduction gearing to drive the rotative sub-assembly and arranged to pick up a drive from the output shaft of the engine assembly.

Also according to the invention there is provided a gas turbine engine of the ducted-fan by-pass type having a front-mounted fan assembly which is detachable as a complete assembly and which comprises a rotative sub-assembly which includes blading and a hub of the fan, and a non-rotative sub-assembly by which the assembly as a whole is mounted and which includes a stationary duct portion which surrounds the fan blading, said hub including, carried thereby so as to be rotatable therewith, a liquid reservoir, one or more pumps operable upon rotation of the rotative sub-assembly to draw liquid from the reservoir, a liquid-pressure-operable actuator for adjusting the blading to vary flow of fluid over that blading, and control valve means by way of which liquid discharged under pressure by said one or more pumps is directed to operate the actuator.

One embodiment of the invention will now be particularly described by way of example with reference to the accompanying drawings, of which,

FIG. **1** is a diagrammatic side elevation of a gas turbine engine of the by-pass type, and,

FIG. **2,** comprising parts A and B, is an enlarged half-view in axial section of a fan assembly forming part of the engine shown in FIG. **1.**

With reference to the drawings, the fan assembly A is attachable to and detachable from the main gas turbine engine assembly B as a unit. For the purpose of differentiation the fan assembly is shown in full lines in FIG. **2,** while the adjacent portion of the main gas turbine engine assembly is shown in broken lines. The fan assembly A comprises a non-rotative sub-assembly **10** having a main body **11** which defines an interface, identified by the line C in FIG. **2,** at which the assembly A is bolted up to the front end of the main gas turbine engine assembly B.

A rotative sub-assembly including a hub structure **12** and blading **13** of the fan is rotatably supported in spaced anti-friction bearings **14** and **15** in the non-rotative main body **11.** The blading **13** of the rotative sub-assembly is of variable-pitch which is reversible to produce a reverse air flow along a non-rotative by-pass duct **16** within which the fan is rotatable.

The by-pass duct **16,** which forms part of the non-rotative sub-assembly **10,** is supported by the main body **11** through a ring of stator blades **17** disposed downstream of the fan blading **13.**

The fan is of self-contained form in that the hub **12** thereof carries within it, so as to be rotatable therewith, an annular reservoir **18,** a plurality of gear pumps **19** which are operable upon rotation of the rotor, a vane-type fluid-pressure-operable blading-adjusting actuator **20,** and control valve means V for controlling the operation of the actuator.

Such a fan of self-contained form is disclosed in the Specification of our co-pending Application Ser. No: 443,146.

The vane-type actuator **20** is generally of the kind disclosed in the specification of U.S. Pat. No: 3,664,763.

A control system (not shown), such as may be associated with the self-contained fan, is disclosed in the Specification of Application Ser. No: 443,145 in the name of Michael Poucher and Ivan Harold Brooking.

The pitch of the fan blading **13** is adjustable under the control of the control system (not shown) which in-

cludes the vane-type actuator **20.** The two output members **21** and **22** of the vane-type actuator each carry a respective large bevel gear **23, 24,** the axes of these gears being co-incident with the rotational axis **25** of the fan. Each of the fan blades has a relatively small bevel pinion **26** fixed to the root end, and the bevel gears **23** and **24** respectively mesh with each pinion **26** diametrically opposite the front and rear sides of the latter. Thus all the fan blades are adjustable in unison with a balanced torque applied to the blade roots from the vane-type actuator **20.**

The control valve means indicated diagrammatically at V includes a positional control valve assembly and a condition control valve assembly for control of the self-contained fan in various modes of operation, i.e., normal running operation, feathering and unfeathering operation, and operation in the negative pitch range. In order to adjust the blading into the latter range, for effecting braking of an aircraft in which the engine and fan assembly are fitted, it is necessary to withdraw pitch stop means (not shown). Such withdrawal is effected upon appropriate operation of the condition control valve assembly.

Mechanical means which includes shafting **27** and **28** connect the hub-mounted gear pumps **19** with the main body **11** to afford their operation upon rotation of the rotor.

A spinner **29** which forms part of the rotative sub-assembly **12**/13 encloses the forward end of the hub structure **12.** An opening **30** in the nose portion of the spinner merges into an annular duct **31** whereby ram air is impelled by blading **32** within that duct to come into heat-exchange relation with the forward portion of the hub **12** for cooling the liquid of the control system circulating within the hub. Such cooling air passes outwardly of the spinner through the opening **33.**

The blading **13** charges both the engine compressor and the by-pass duct **16.** The non-rotative main body **11** of the assembly A bolts up to the front of the engine casing **34** immediately ahead of the engine compressor inlet **35.** This part of the casing **34** houses reduction gearing (not shown).

A central hollow portion **36** of the hub structure **12** which extends rearwardly therefrom into the main body **11** is supported for rotation in the spaced bearings **14** and **15** and is driven by a splined quill coupling member **37** which is in splined engagement, on the one hand with the portion **36** and, on the other hand, with a forward female end **38** of the main output shaft extending from the reduction gear of the engine assembly B. The forward end **38** of the engine shaft is supported by an anti-friction bearing **39.**

The main body **11** carries upon its forward end portion two supports, one of which is shown at **40,** respectively for an input member for the positional control valve assembly and for an input member for the condition control valve assembly. The input member **41** shown is that associated with the positional control valve assembly and at its upper end in the drawing carries a crank member **42** which is pivotally connected at **43** to a rod member **44** which passes rearwardly through the main body **11** to the engine structure where, in a manner not shown, it is connected with a pilot's positional control lever. The connection **43** is readily accessible through means (not shown) for quick uncoupling.

A crank member and rod member (not shown) are provided in association with the input member for the condition control valve assembly.

Each input member **41** is, upon linear movement of its rod member **44,** rotated about its longitudinal axis and consequent rotary movement of a crank member **45** at the lower end thereof effects adjustment of its associated control valve assembly through suitable linkage which includes translation bearing means provided between fixed and rotative components of the fan assembly.

Although not shown in the drawings, the main body **11** carries a feathering motor while in a manner disclosed in the Specification of our co-pending application Ser. No: 443,146 one of the pumps **19** within the hub **12** is operable upon energising of the feathering motor to effect feathering and unfeathering of the blading **13.**

By so providing a fan assembly adapted for bolting up to the main engine assembly at the interface of the line C so as to pick up a drive for the rotative fan from the engine output shaft, a module construction is afforded which facilitates rapid removal of the fan assembly and replacement by another fan assembly without the necessity of undertaking dismantling, component by component, of the front portion of the installation. The straight-forward bolt-on construction of the fan assembly at the interface C and the quick release connections as at **43** in the input linkages to the control system of the fan renders this rapid removal of the fan assembly possible even in the field where limited engineering equipment may only be available for servicing of the installation.

The invention is not limited to the form of bolt-on assembly hereinbefore described, as variations of this construction may be used. For example, instead of providing a reduction gear to the rear of the position of bolting of the fan assembly to the engine, the reduction gear may instead be provided within the interior of the non-rotative portion of the fan assembly, in which case the position of bolting of the fan assembly to the engine is aft of the reduction gear itself.

By so providing a fan assembly so adapted for bolting up to the main engine assembly as a module, and by so providing that the fan is self-contained, the fan does not rely upon any source of hydraulic fluid disposed externally of the hub for its operation and thus the use of high pressure fluid transfer means between non-rotative and rotative structure is avoided.

Although in the embodiment described with reference to the drawings the fan assembly is of single-stage form, in alternative embodiments the assembly may instead be of multi-stage form. Again, instead of being of non-tiered form the fan assembly may be of tiered form.

Finally, although in the embodiment described with reference to the drawing the fan assembly is suitable for attachment to a gas turbine engine for installation in an aircraft, in other embodiments an engine having such a self-contained bolt-on fan assembly may be suitable for installation in vehicles other than aircraft.

We claim:

1. A fan assembly, for attachment to the front of a main gas turbine engine assembly to provide an engine of the ducted-fan by-pass type, constructed as a unitary assembly which can be fitted and removed as such and comprising a non-rotative sub-assembly, which in-

cludes a non-rotative main body and a non-rotative by-pass duct supported by the main body, and a rotative sub-assembly which is supported in bearings by the non-rotative sub-assembly and which includes a hub, carrying variable-pitch fan blading, positioned and rotatably supported within the by-pass duct, said hub including, disposed wholly therein so as to be rotatable all as one therewith, (a) a liquid reservoir, (b) at least one pump operable upon rotation of the rotative sub-assembly to draw liquid from said reservoir, (c) a liquid-pressure-operable actuator connected to said fan blading for effecting adjustment thereof, and (d) control valve means by way of which liquid discharged under pressure by said pump is directed to operate the actuator, and said main body being adapted to provide for said attachment of the fan assembly to the engine assembly.

2. A fan assembly, for attachment to the front of a main gas turbine engine assembly to provide an engine of the ducted-fan by-pass type, constructed as a unitary assembly which can be fitted and removed as such and comprising a non-rotative sub-assembly, which includes a non-rotative main body and a non-rotative by-pass duct supported by the main body, and a rotative sub-assembly which is supported in bearings by the non-rotative sub-assembly and which includes a hub, carrying variable-pitch fan blading, positioned and rotatably supported within the by-pass duct, said hub including, disposed wholly therein so as to be rotatable all as one therewith, (a) a liquid reservoir, (b) at least one pump operable upon rotation of the rotative sub-assembly to draw liquid from said reservoir, (c) a liquid-pressure-operable actuator connected to said fan blading for effecting adjustment thereof, and (d) control valve means by way of which liquid discharged under pressure by said pump is directed to operate the actuator, and said main body being adapted to provide for said attachment of the fan assembly to the engine assembly and to provide for said rotative sub-assembly to pick up a drive therefor from the output shaft of the engine assembly.

3. An assembly as claimed in claim **2,** wherein mechanical means connect said pump with non-rotative structure external of the hub to afford its operation upon rotation of the rotative sub-assembly.

4. An assembly as claimed in claim **3,** wherein said mechanical means include gearing, also carried by the hub, and shafting co-axial with the hub and extending from the gearing to said non-rotative structure.

5. An assembly as claimed in claim **2,** wherein said pump is of gear type.

6. An assembly as claimed in claim **2,** wherein the reservoir is of annular form and in part defined by an outer wall of the hub.

7. An assembly as claimed in claim **2,** wherein said actuator is of vane-type.

8. An assembly as claimed in claim **2,** wherein said fan blading is arranged in a single stage.

9. An assembly as claimed in claim **2,** wherein said by-pass duct is supported by said main body of the non-rotative sub-assembly through a ring of stator blading positioned downstream of the fan blading, said main body being adapted for bolting to the front of the main engine assembly and supporting said rotative sub-assembly.

10. An assembly as claimed in claim **2,** wherein said fan blading is reversible in pitch.

11. A fan assembly, for attachment to the front of a main gas turbine engine assembly to provide an engine of the ducted-fan by-pass type, constructed as a unitary assembly which can be fitted and removed as such and comprising a non-rotative sub-assembly, which includes a non-rotative main body, a non-rotative by-pass duct and a single ring of stator blading by way of which the by-pass duct is supported from said main body, and a rotative sub-assembly which is supported in bearings by the non-rotative sub-assembly and which includes a hub, carrying variable-pitch fan blading, positioned and rotatably supported within the by-pass duct ahead of said stator blading, said hub including, disposed wholly therein so as to be rotatable all as one therewith, (a) a liquid reservoir, (b) at least one pump operable upon rotation of the rotative sub-assembly to draw liquid from said reservoir, (c) a liquid-pressure-operable actuator connected to said fan blading for effecting adjustment thereof, and (d) control valve means by way of which liquid discharged under pressure by said pump is directed to operate the actuator, and said main body being adapted to provide for said attachment of the fan assembly to the engine assembly and to provide for said rotative sub-assembly to pick up a drive therefor directly from the output shaft of the engine assembly.

12. A gas turbine engine of the ducted-fan by-pass type having a front-mounted fan assembly which can be fitted and removed as a complete unitary assembly and which comprises a non-rotative sub-assembly, which includes a non-rotative main body and a non-rotative by-pass duct supported by said main body, and a rotative sub-assembly which is supported in bearings by the non-rotative sub-assembly and which includes a hub, carrying variable-pitch fan blading, positioned and rotatably supported within the by-pass duct, said hub including, disposed wholly therein so as to be rotatable all as one therewith, (a) a liquid reservoir, (b) at least one pump operable upon rotation of the rotative sub-assembly to draw liquid from said reservoir, (c) a liquid-pressure-operable actuator connected to said fan blading for effecting adjustment thereof, and (d) control valve means by way of which liquid discharged under pressure by said pump is directed to operate the actuator, and said main body being adapted for fitting of the fan assembly to the main part of the engine, and for removal therefrom, as a unit.

13. A gas turbine engine as claimed in claim **12,** wherein said main body is adapted for bolting up to the main part of the engine and to provide for said rotative sub-assembly to pick up a drive therefor directly from the output shaft of said main part of the engine.

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