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3,459,267

BLADED ROTORS

Filed April 12, 1967

4 Sheets-Sheet 1

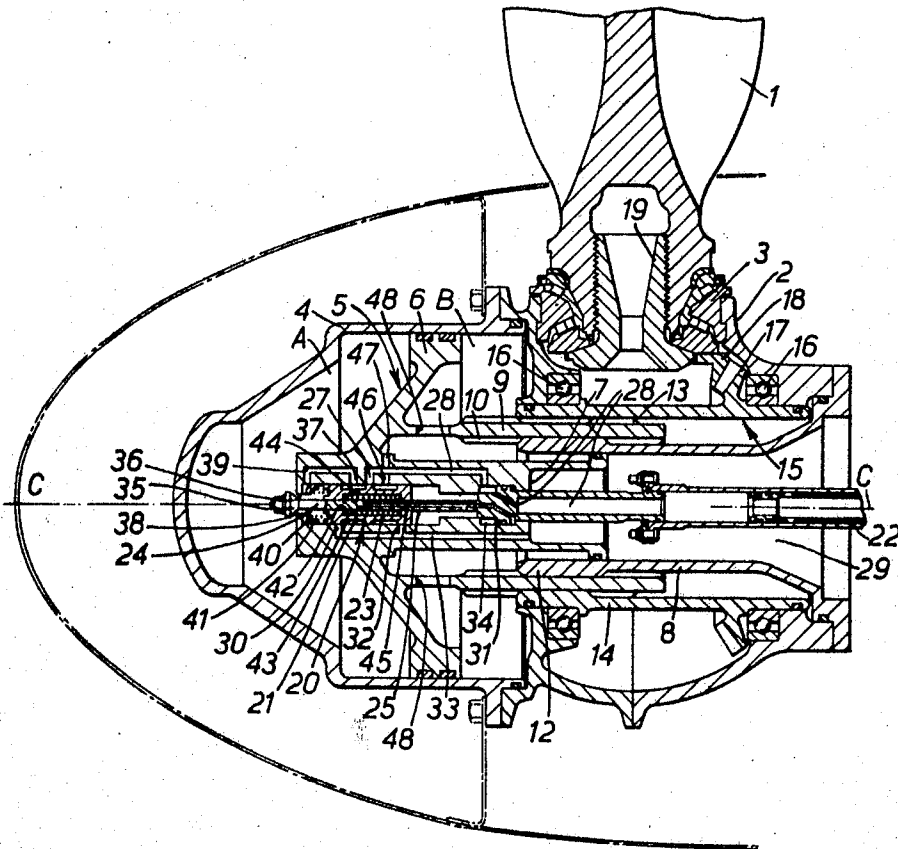


Fig. 1

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4 Sheets-Sheet 2

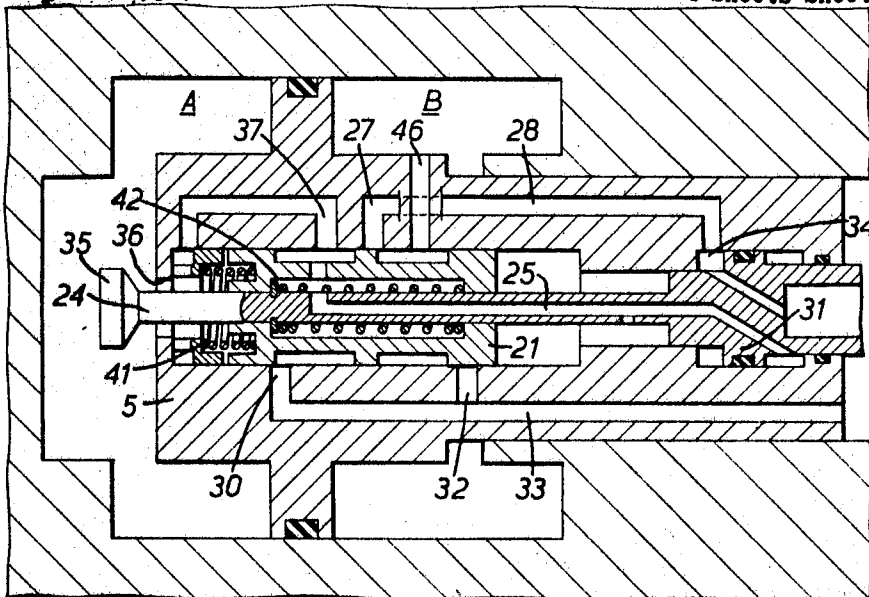


FIG. 2.

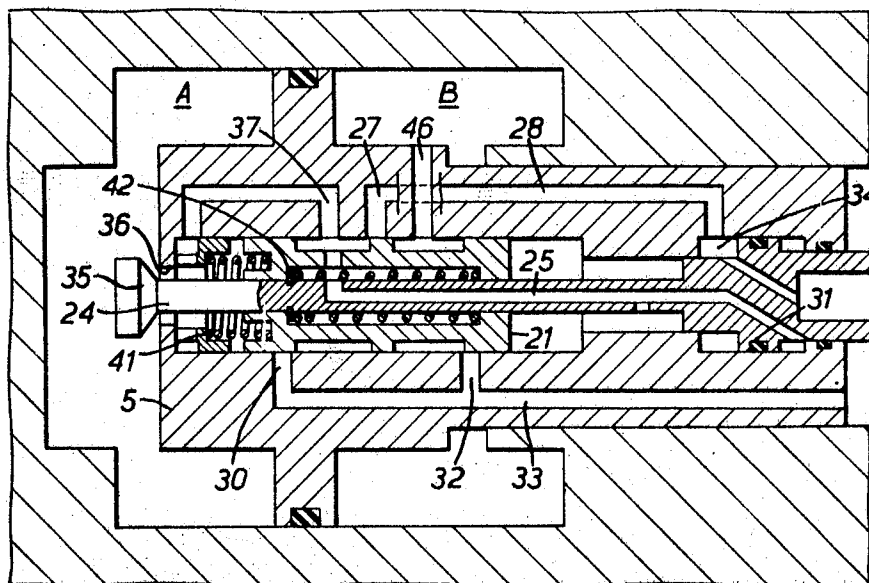


FIG. 3.

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4 Sheets-Sheet 3

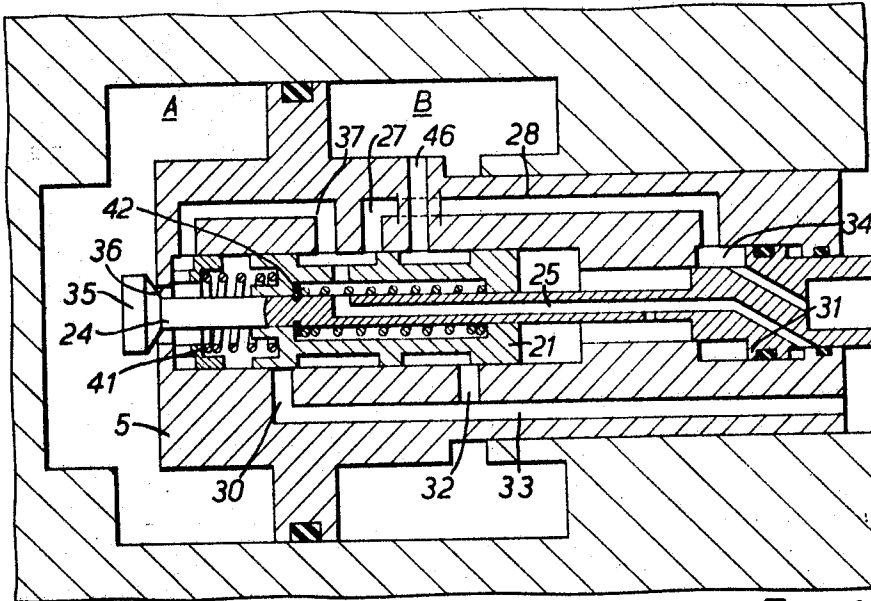


FIG. 4.

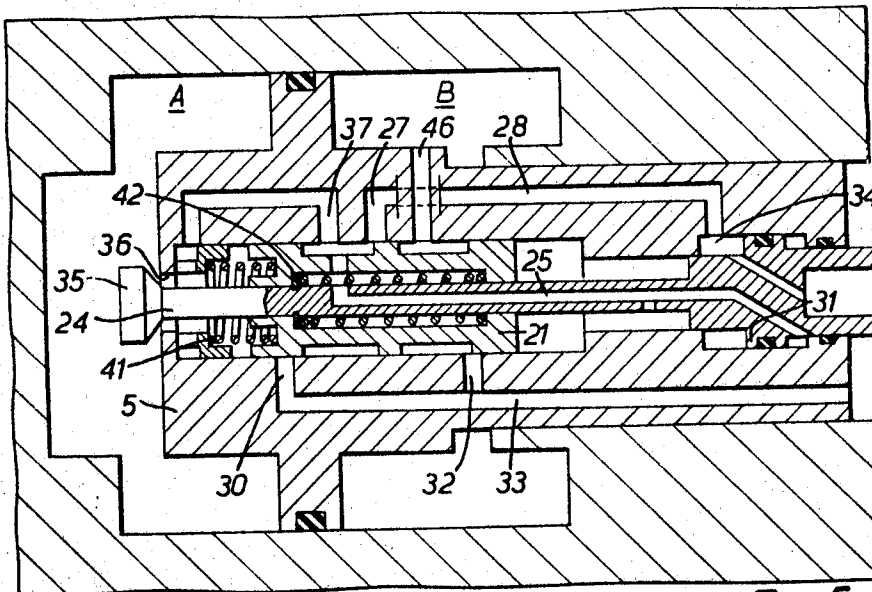


FIG. 5.

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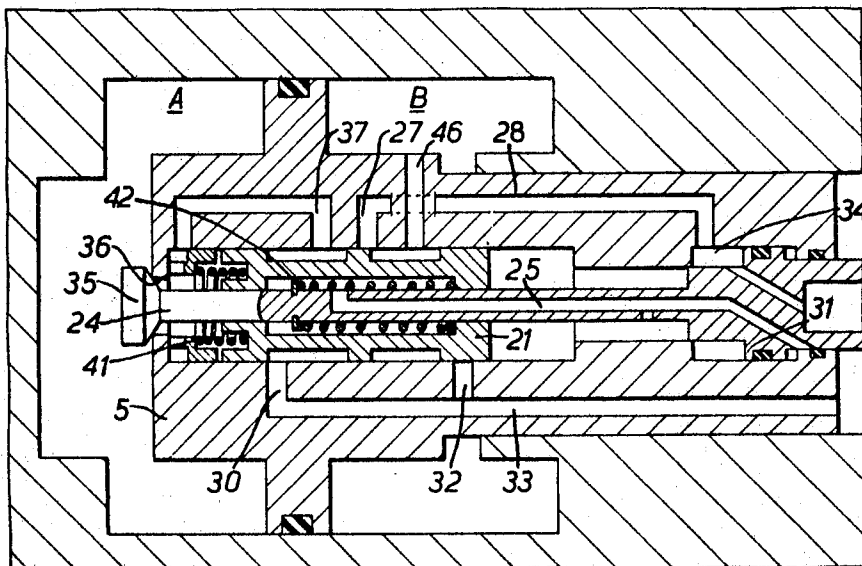


FIG. 6.

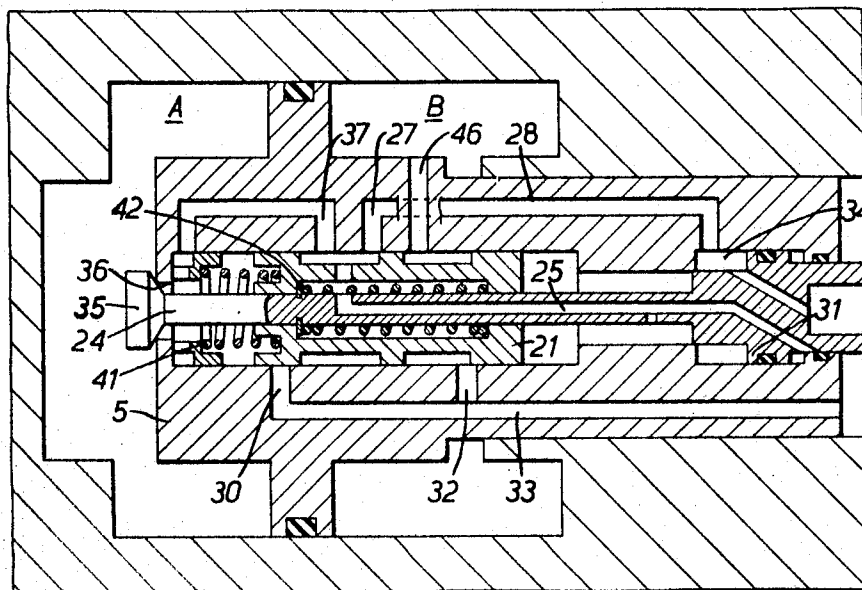


FIG. 7.

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BLADED ROTORS

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U.S. Cl. 170—160.32 23 Claims

ABSTRACT OF THE DISCLOSURE

A bladed rotor having adjustable blading, adjustment of which is effected by the operation of a fluid pressure motor, includes a control valve adjustable for appropriate control of the motor. A further valve is operative, upon the occurrence of a predetermined but inadvertent amount of drift of the motor and thus of the blading, to lock the motor hydraulically. The blading is conveniently of variable pitch, and the further valve may be disposed hydraulically in series with the control valve and arranged to close in the event of said inadvertent drift of the motor and blading.

This invention relates to bladed rotors having adjustable blading, such as blading of variable pitch, variable camber or variable twist type, it being intended that the term "rotor" should include propellers, wind motors, fans and the like.

According to the invention a bladed rotor having adjustable blading, adjustment of which is effected by the operation of a fluid pressure motor, includes first valve means adjustable for appropriate control of the motor and further valve means operative, upon the occurrence of a predetermined but inadvertent amount of drift of the motor and thus of the blading, to lock the motor hydraulically to prevent further drift.

The first valve means may be manually controlled or may form part of a speed-responsive governor the datum setting of which is adjustable. In most cases the further valve means will be arranged to become operative in the event of inadvertent drift of the blading in the pitch-fining direction, or the corresponding direction when flow-varying blading of a type other than variable pitch is employed.

Preferably the further valve means are so arranged in series circuit with the first valve means as to be capable of preventing flow of pressure fluid to, and/or exhaust of pressure fluid from, the motor. When the motor is of the piston and cylinder type the first valve means may operate to prevent flow of pressure fluid to, and exhaust of pressure fluid from, a working chamber on one side of the piston.

The said first and further valve means may be arranged within a hub of the bladed rotor coaxially of the rotation axis of the rotor.

The first valve means may form part of a closed-loop follow-up servo mechanism, and be arranged within a motor piston in such manner that relative axial displacement of the first valve means and the piston initiates movement of the piston in one direction or the other according to the direction of the relative axial displacement, with such movement following-up the movement of the first valve means and effectively returning the latter to a condition of equilibrium when the selected or governed condition is reached by the motor. If, during operation of the bladed rotor and following displacement of the first valve means, the piston fails to follow-up the movement of those valve means, due to some mechanical failure or pressure loss, a predetermined amount of drift of the piston is tolerated but any movement beyond

2

this predetermined amount causes said further valve means to close and thereby lock the motor piston against further drift.

Preferably a movable element of the further valve means is mechanically connected to control means which operate the first valve means, for example a manually operated linkage. Spring box means may be provided between the movable element of the further valve means and the first valve means to afford a limited amount of relative movement therebetween, and the control force for the first valve means may be applied thereto at least in one direction through the spring box means.

The movable element of the further valve means may be of poppet type with a stem which extends axially through the movable element of the first valve means for connection externally of the latter to the control means, the spring box being arranged within the movable element of the first valve means which is slidable within the motor piston. The poppet element in this arrangement preferably closes against a seat formed in or on the piston itself and through which the pressure liquid has to flow to one side of the motor piston. The stem of the poppet element may be connected to an element of the control linkage with which it is aligned and which passes axially through the hub.

The invention is of particularly advantageous application to a variable pitch rotor mounted at the forward end of an aircraft power plant, for example a propeller, a wind motor (such as a ram air turbine) or a by-pass fan of a gas turbine engine. A further suitable application is to fans used in gas-cushion vehicles or the like. The invention is in no way limited as to the form of the blade adjusting means, and although the blades are preferably of variable pitch they may alternatively be of variable camber or variable twist type. Blades of variable camber type each have a fixed leading portion with an adjustable trailing portion pivoted thereon. Blades of variable twist type each have a hollow blade working portion of flexible material fixed to the hub at the blade root and a backbone member running through the interior of the blade and connected to a flange member or the like at the blade tip; the backbone member is angularly adjustable by a twist-change mechanism to effect angular movement of the blade tip about the longitudinal axis of the blade which in turn effects variation of the blade along its length by virtue of the flexible nature of the blade.

As an alternative to manual control, the first valve means may form part of a speed-responsive governor arranged to control the rotor speed automatically in dependence upon the datum setting of a speeder spring of the governor. The governor may be arranged with its axis coincident with the axis of rotation of the propeller, in which case the governor fly-weights rotate about this axis, or the governor may be arranged externally of the hub as may the valve means themselves.

When a speed-responsive governor is positioned within the hub, or when manually-operated valve means are within the hub, a pump supplying liquid under pressure for operation of the motor may also be mounted in the hub, and also so mounted as to be driven by rotation of the rotor. In these cases a liquid reservoir may also be disposed in the hub and be formed by the hub structure, centrifugal force urging the liquid radially outwardly against the inner wall of the hub to constitute an annular reservoir.

A bladed rotor in accordance with the invention may be so constructed as to include other means both for locking blade pitch and for restricting the range of the movement of the motor and thus the range of adjustment of the blading.

The invention will now be further described with ref-

erence to the accompanying drawings which illustrate, by way of example, a variable pitch aircraft propeller constructed in accordance with the invention. In the drawings:

FIGURE 1 is an axial sectional view of the propeller, and

FIGURES 2 to 7 are diagrammatic views illustrating the operation of the valve means which control the blade pitch of the propeller.

The propeller has three variable pitch blades such as 1 separately mounted in a hub 2 by means of respective blade retention bearing assemblies such as 3. In the drawings the root end of only one blade 1 is illustrated.

A fluid pressure motor operative to vary the blade pitch comprises a cylinder 4 bolted to and projecting forwardly of the hub 2, and within which a piston assembly 5 is axially slidable. This assembly comprises an outer portion 6 forming the piston proper and slidable directly within the cylinder 4, front and rear working chambers A and B of the motor respectively being formed within the cylinder on opposite sides of the portion 6, and an inner tubular portion 7 slidable within a hollow cylindrical spigot 8 which is supported at the rear side of the hub 2 and projects forwardly through the latter.

An intermediate tubular portion 9 of the assembly 5 projects rearwardly into the hub 2, and this portion 9 is formed internally with straight teeth 10 which cooperate with complementary teeth 12 on the outer surface of the spigot 8 to prevent rotation of the piston assembly 5 relatively to the hub 2. On its outer surface the intermediate portion 9 is provided with helical teeth 13 which engage helical tooth spaces in the hollow boss 14 of a bevel gear 15 mounted centrally within the hub 2.

The bevel gear 15 is rotatably mounted within the hub 2 in anti-friction bearings 16, and has a toothed external flange 17 towards the rear end of the boss 14. The teeth of the flange 17 mesh with toothed sector-like projections such as 18 formed on blade-retaining bolts 19, so that rotation of the gear 15 as a result of axial movement of the piston assembly 5 acts, through the bolts 19, to turn the blades 1 for pitch variation thereof.

The described pitch-change mechanism is controlled by first valve means in the form of a manually operated control valve 20 having a slidable valve element 21 disposed coaxially within the inner piston portion 7, i.e. with its axis coincident with the rotation axis C—C of the propeller. A manual control linkage, the adjacent end of which is shown at 22, connects with the valve element 20 through spring box means 23 and a lock valve element 24 of poppet type and with a stem 25 which passes centrally through the spool-like valve element 20 and is mechanically connected to the control linkage 22.

The control valve 20 has a pressure inlet port 27 which is supplied with pressure liquid derived from a pump (not shown) mounted within the driving engine and driven by the latter. The pressure liquid is connected to the port 27 through a conduit the axis of which is, in part, coincident with the axis of rotation and includes interconnecting passageways 28 formed in the control linkage 22, the stem of the valve element 24 and the inner piston portion 7. The pump draws the liquid from a reservoir (also not shown) within the engine, a drain conduit 29 from the pitch-change motor back through the hub to the reservoir utilising the internal space of the spigot 8. Exhaust ports 30 and 32 of the control valve 20 communicate with the latter space through a common drain passage 33 also formed in the inner piston portion 7. Thus the valve porting is formed in the piston assembly of the pitch-change motor and cooperates with an arrangement of lands on the valve element 22 in a manner which is described hereinafter with particular reference to FIGURES 2 to 7.

The stem 25 of the lock valve element 24 extends forwardly of the control valve element 20 to a poppet head 35 of frusto-conical shape. Rearwardly of the control

valve element the stem 25 is stepped to provide an intermediate balancing piston portion 31 slidable in a balancing cylinder chamber 34 formed in the piston portion 7. The lock valve element 24 is arranged at the forward end in a passageway 36 in the piston portion 7, which passageway connects a control port 37 of the control valve 20 to the front working chamber A. The arrangement is such that application of fluid pressure to this chamber results in movement of the piston assembly 5 which turns the bevel gear 15 in the direction corresponding to increasing pitch of the blades 1. Thus the lock valve is hydraulically arranged in series circuit with the control valve 20.

When in the open position, as illustrated in FIGURE 1, the lock valve element 24 permits flow of liquid to and from the coarse pitch side of the motor, i.e. the working chamber A, but when closed on to its seating 38 formed at the forward end of the passageway 36 the element 24 locks the liquid in the coarse pitch chamber A ahead of the piston assembly 5 and thus prevents movement of the piston assembly within the cylinder 4.

The control port 37 communicates with the passageway 36 through a passage 39 and past a ported spring abutment plate 40 which surrounds the stem 25 and is engaged by a spring 41 which urges the control valve element 21 in the righthand direction as shown in FIGURE 1, i.e. to a coarse-pitch control position corresponding to increasing blade pitch. The lock valve element 24 is capable of axial movement relatively to the control valve element 21 against the action of the spring box means 23, and these means urge the valve element 24 to a limit position in which a circlip 42 on the stem 25 engages an abutment shoulder 43 formed within the valve element 21.

The control port 37 is constantly in communication, internally of the control valve 20 and through a radial bore 44 in the valve element 21, with a passageway 45 in the stem 25. This passageway leads to one end of the balancing chamber 34, the other end of which is permanently in communication with the pressure passageways 28 and in fact forms part of the pressure supply conduit to the valve 20. The differential area of the piston 41 is so chosen that at all times the valve elements and operation linkage are pressure balanced.

A second control port 46 of the control valve 20 operative to decrease the blade pitch, i.e. effect pitch fining, communicates with the rear working chamber B of the pitch-change motor through radial passageways 47 and 48 formed respectively in the inner piston portion 7 and the intermediate piston portion 9.

As will now be described with particular reference to FIGURES 2 and 3, the control valve 19 provides a closed-loop follow-up servo mechanism which in normal operation provides precise and accurate positional control of the piston assembly 5 and hence of the blade pitch. FIGURE 2 illustrates a position of the control valve element 20 corresponding to a pitch-fining operation, the control port 46 being connected to the pressure port 27, and the control port 37 connected to exhaust, i.e. back to drain, via the exhaust port 30. This results in pitch adjusting movement of the piston assembly 5 which follows-up the previous control movement of the valve element 20.

Thus when the selected pitch position is reached the relative positions of the piston portion 7 and the control valve element 20 correspond to an equilibrium condition shown in FIGURE 1 in which the ports 27, 30 and 32 are closed off. Hence the control ports 37 and 46 are effectively sealed by the valve element 20, in that they communicate neither with the pressure supply nor the exhaust ports, and the piston assembly 5 is hydraulically locked in the adjusted position.

FIGURE 3 illustrates a coarse-pitch position of the control valve element 21 corresponding to a pitch changing operation with the blades 1 moving in the direction of increasing pitch. In this case the pressure and exhaust connections are interchanged as compared with FIGURE

2, the port 46 being connected to the pressure port 27 and the port 46 connected to exhaust through the port 32. As before the piston assembly 5 follows-up movement of the valve element 21 until equilibrium conditions are again restored corresponding to the selected pitch position.

The remaining FIGURES 4 to 7 illustrate the manner in which the mechanism is safeguarded against pitch drift in the event of several different forms of control failure. The effect of loss of oil supply pressure is illustrated in FIGURE 4, which shows that any drift of the piston assembly 5 in the decreasing pitch or pitch-fining direction is limited by closure of the lock valve element 24 which seals the passageway 36. As a result the liquid in the working chamber A at the forward end of the cylinder 4 is trapped, as previously described, to retain the pitch adjustment. Any further slight movement, the rate of which is dependent on any leakage past the lock valve element 24 which may occur, tends to shut the lock valve even more to reduce still further any leakage drift which may occur.

In the event of failure of the control linkage 22, for example mechanical breakage thereof, the condition illustrated in FIGURE 5 obtains. The spring 41 urges the control valve element 21 in the direction corresponding to increasing pitch, in which direction it is free to move if the linkage breaks. There is thus no danger of inadvertent movement in the pitch-fining direction with possible consequent propeller overspeeding and catastrophic failure. If the control valve element 21 is free to move under the action of the spring 41 to the position in which the lock valve element 24 closes, the condition illustrated in FIGURE 4 again appertains.

The effect of seizure of the control valve element 21 within the piston assembly 5 is illustrated in FIGURE 6. If seizure occurs with the control valve element 21 in the pitch-fining position, then the element 21 and the piston assembly 5 move together towards the fine-pitch position, relatively to the control linkage 22 and the lock valve element 24. After a small angle of pitch adjustment the drift is automatically halted when the piston assembly 5 engages the head 35 of the lock valve member 24, as shown in FIGURE 6. As in the condition of FIGURE 4, the assembly 5 is now hydraulically locked against further drift other than the negligible amount which may result from valve leakage. If seizure is alternatively such that the control valve element 21 jams with respect to the linkage 22, i.e. on the stem 25, the maximum drift is again limited to a few degrees of pitch-fining adjustment until the lock valve element 24 closes as shown in FIGURE 7.

It will thus be seen that if, in operation of the propeller, movement of the blades 1 in the pitch-fining direction is selected by appropriate adjustment of the control valve 20, but due to some failure in the control system the piston assembly 5 drifts further in the pitch-fining direction beyond the position selected by displacement of the control valve element 21, then after a predetermined permissible drift has occurred the piston assembly automatically, in its follow-up function, engages the frusto-conical head 35 of the lock valve element 24. Hence the coarse pitch chamber A on the forward side of the piston assembly 5 is hydraulically locked against passage of liquid therefrom back to the reservoir, and thus drift of the pitch-change motor and blading further in the fine pitch direction and possible consequent propeller overspeeding are obviated.

I claim:

1. A bladed rotor having adjustable blading, adjustment of which is effected by the operation of a fluid pressure motor, and including first valve means adjustable for appropriate control of the motor and including a valve element movement of which controls both directions of adjustment of the blading, and further valve means which are normally open so as to have no effect on blade adjustment but which close, upon the occurrence of a predeter-

mined but inadvertent amount of drift of the motor and thus of the blading, to lock the motor hydraulically to prevent further drift.

2. A bladed rotor according to claim 1, wherein the further valve means is arranged to become operative in the event of inadvertent drift of the blading in the pitch-finding direction, or the corresponding direction when flow varying blading of a type other than variable pitch is employed.

3. A bladed rotor according to claim 1, wherein the further valve means is so arranged in series circuit with the first valve means as to be capable of preventing flow of pressure fluid to, and/or exhaust of pressure fluid from, the motor.

4. A bladed rotor according to claim 3, wherein the motor is of the piston and cylinder type and the first valve means is operative to prevent flow of pressure fluid to, and exhaust of pressure fluid from, a working chamber on one side of the motor piston.

5. A bladed rotor according to claim 1, wherein said first and further valve means are arranged within a hub of the rotor coaxially of the rotation axis of the rotor.

6. A bladed rotor according to claim 5, wherein the motor is of the piston and cylinder type with the piston axially slidable and the cylinder fixed with respect to the hub and rotatable therewith, and both valve means are mounted in the motor piston.

7. A bladed rotor according to claim 6, wherein porting for the first valve means is provided in said motor piston as are flow passages leading to and from the respective ports.

8. A bladed rotor according to claim 6, wherein the first valve means forms part of a closed-loop follow-up servo mechanism, and is arranged within said motor piston in such manner that relative axial displacement of the first valve means and the piston initiates movement of the piston in one direction or the other according to the direction of the relative axial displacement.

9. A bladed rotor having blading of adjustable pitch, a fluid pressure motor for adjustment of the pitch of the blading, first valve means for control of the motor and including a valve element movement of which is operative to adjust the blading pitch in both directions, control means for remote pitch control and mechanically connected to said valve element, and further valve means including a lock valve element which normally occupies an open position so as not to impede operation of said motor but which in the event of inadvertent drift of the motor moves to a closed position in which the further valve means act to lock the motor hydraulically and thus halt the drift.

10. A bladed rotor according to claim 9, wherein said element of the further valve means is mechanically connected to a manually operated control linkage.

11. A bladed rotor according to claim 9, wherein spring box means between the movable element of the further valve means and the first valve means affords a limited amount of relative movement therebetween.

12. A bladed rotor according to claim 11, wherein the control force for the first valve means is applied, at least in one direction, through the spring box means.

13. A bladed rotor according to claim 10, wherein the control force for the first valve means is applied through said movable element of the further valve means.

14. A bladed rotor according to claim 9, wherein the movable element of the further valve means is of poppet type with a stem which extends axially through a movable element of the first valve means for connection externally of the latter to pitch control means.

15. A bladed rotor according to claim 14, wherein the motor is of the piston and cylinder type and the poppet element closes against a seat formed in or on the motor piston itself and through which the pressure liquid has to flow to one side of the piston.

16. A bladed rotor according to claim 10, wherein the stem of the poppet element is connected to an element

of a manually-operated control linkage with which it is aligned and which linkage element passes axially through the rotor hub.

17. A bladed rotor according to claim 1, wherein said first valve means is spring loaded in a direction corresponding to blade adjustment in the direction opposite to that in which drift renders the further valve means operative.

18. A bladed rotor adapted for mounting at the forward end of an aircraft power plant and including variable pitch blading, a fluid pressure motor operation of which effects pitch variation of the blading, first valve means for control of the motor and having a valve element appropriate movement of which is effective for both directions of pitch adjustment, and further valve means which are normally open so as to have no effect on blade adjustment but which close, upon the occurrence of a predetermined but inadvertent amount of drift of the motor and thus of the blading, to lock the motor hydraulically to prevent further drift.

19. A bladed rotor according to claim 18, wherein pressure supply and drain passages which connect with porting of the first valve means are respectively arranged for connection to an engine driven pump and a liquid reservoir disposed externally of the rotor.

20. A bladed rotor having adjustable blading and a hub structure within which is disposed a hydraulic motor for adjustment of the blading, a follow-up servo valve which is moved by a control linkage for control of the motor in both operative directions thereof and a lock valve which operates to lock the motor hydraulically, both valves being mechanically linked in such manner

that in the event of failure of hydraulic pressure or seizure of either valve the lock valve becomes operative if the motor, and hence the blading, inadvertently drifts a small predetermined amount from the control position.

21. A bladed rotor according to claim 20, wherein the lock and control valves are linked through spring means and disposed one within the other, and the lock valve is connected to the control linkage so that it transmits the control force to the control valve, at least in one direction through the spring means.

22. A bladed rotor according to claim 20, wherein the servo valve is spring loaded in a direction corresponding to adjustment of the blading opposite to the direction in which the blading tends to drift, so that in the event of linkage fracture the servo valve automatically acts to oppose the tendency to drift and adjusts the blading to a safe condition.

23. A bladed rotor according to claim 22, wherein the blading is of variable pitch and the servo valve is spring loaded in the coarse pitch direction.

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