April 22, 1952 E. H. MORRIS ET AL 2,593,910

VARIABLE PITCH REVERSIBLE PROPELLER

Filed Aug. 30, 1948 2 SHEETS—SHEET 1

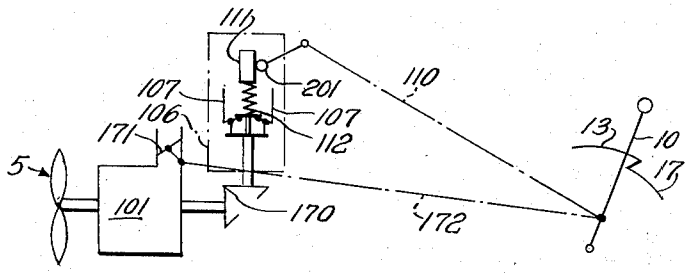

Fig.1.

Fig.4.

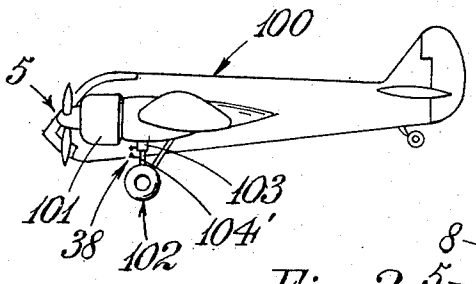

Fig.2.

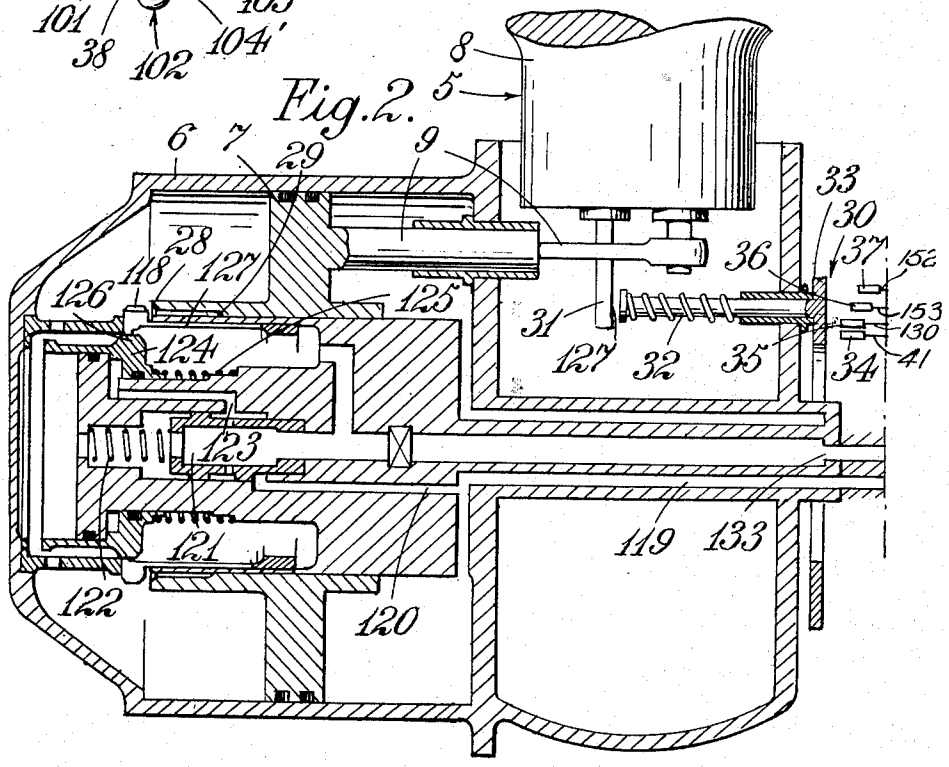

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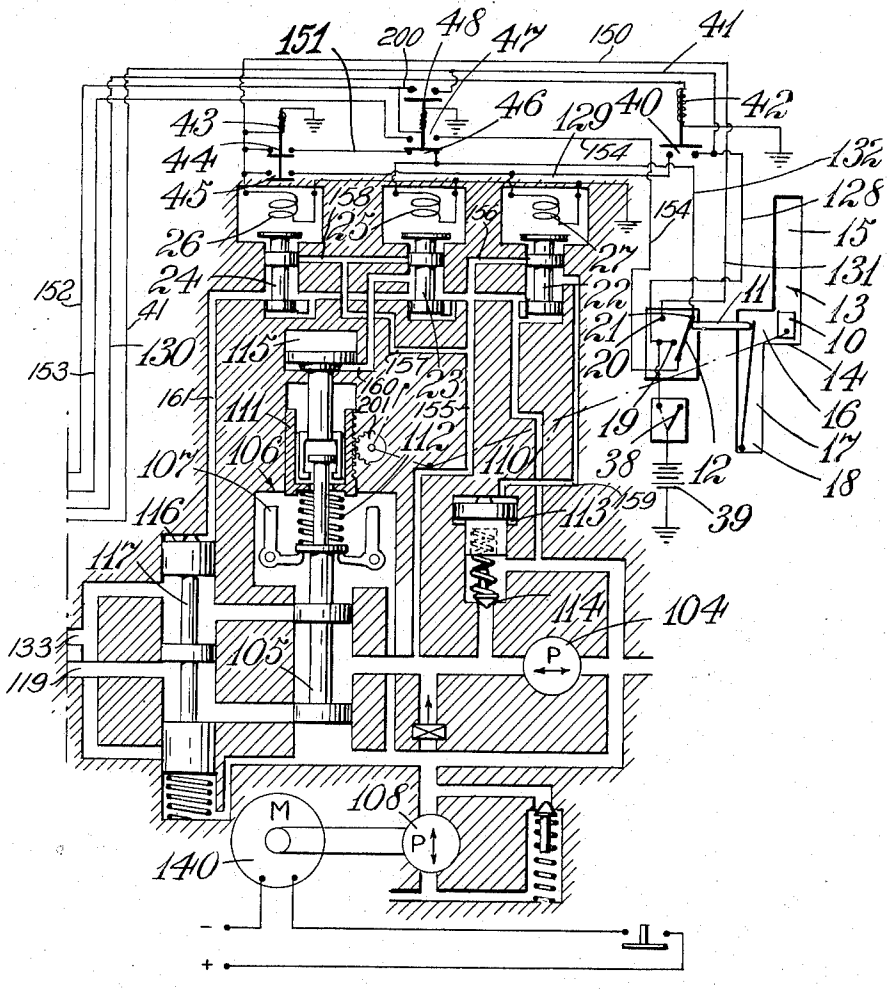
Fig. 3.



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VARIABLE PITCH REVERSIBLE PROPELLER

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5 Claims. (Cl. 244—81)

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This invention concerns variable-pitch propellers of the kind in which the blades are capable of adjustment from a positive angle (to provide forward thrust) to a negative angle (to provide backward thrust). Such propellers will be referred to as "reversible pitch propellers."

Reversible pitch propellers are normally required to provide backward thrust only when the aeroplane is landing and the present invention has for its object to provide a system of control for propellers of the kind referred to in which the backward thrust is obtainable only after the aeroplane has touched down.

According to the present invention a reversible-pitch propeller comprises a constant-speed unit for controlling the pitch of the blades of the propeller, means to over-ride said unit and bring the blades to within the negative pitch-range and means for bringing said over-riding means into operation only whilst the aeroplane is on the ground.

According to one feature of this invention a reversible-pitch propeller comprises a constant-speed unit for controlling the pitch of the blades of the propeller, electrical means to over-ride said unit and bring the blades to within the negative pitch-range and switch means, in the circuit of said electrical means, to control its operation, said switch being actuated to bring the electrical means into operation by the weight of the aeroplane.

According to another feature of the invention a reversible-pitch propeller comprises a hydraulic pitch-change motor, a constant-speed unit to control the blade movements in the positive and negative pitch ranges, means for over-riding the constant speed unit to move the blades from one pitch range to the other, an electrical control for said over-riding means and a switch for controlling the operation of said electrical control, said switch being actuated by the weight of the aeroplane.

Preferably said switch is actuated to bring the electrical over-riding control into operation by telescoping of the undercarriage of the aeroplane on landing.

In order that the nature of the invention may be more clearly understood a practical application of it will now be described, by way of example, with reference to the accompanying drawings whereof:

Figure 1 is a side elevation of an aeroplane shown as it is coming in to land, the aeroplane incorporating propellers in accordance with this invention,

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Figure 2 is a schematic representation of the propellers of the aeroplane of Figure 1,

Figure 3 is a circuit diagram of the control system for the propeller of Figure 2, and

Figure 4 is a schematic view of the engine-propeller assembly and of the main controls therefor.

In Figure 1 the aeroplane 100 has a pair of propellers 5 (one only of which is seen in the drawings) which are driven, one each, by an engine carried within the nacelle 101. The aeroplane carries a rectractable undercarriage 102 comprising, in known manner two telescoping leg members 103, 104'.

Each propeller 5 is hydraulically operated and is provided, in known manner, with a pitch-change motor 6 (see Figure 2) the ram 7 of which is connected with the individual propeller blades 8 by means of a linkage 9.

Hydraulic fluid for the operation of the motor 6 is provided by a pump 104 which supplies fluid to the valve 105 of a constant speed unit, generally indicated at 106, and thence to the motor 6. The constant speed unit 106 is of known construction and comprises a fly-weight governor 107 provided to adjust the valve 105, the flyweights being driven in usual manner from engine 101 through gearing 170.

There is also associated with the propeller 5 a feathering pump 108, which is driven by electric motor 140 and is adapted to provide fluid for the operation of the motor 6 when blades 8 are to be moved to the feathered position or returned from that position.

The engine in nacelle 101 is under the control of the pilot, the power delivered by the engine being regulated in well known manner by throttle 171, which is adjustable by any suitable linkage, diagrammatically indicated at 172 (Figure 4), from lever 10 in the pilot's cockpit. The lever 10 is also connected through a suitable linkage (indicated at 110 in Figure 3) with a pinion 201 which engages a rack on a sleeve 111, the latter being axially adjusted with rotation of the pinion to vary, in usual manner, the loading of spring 112 to change the loading on the fly-weight governor 107. It will be appreciated, therefore, that when the lever 10 is adjusted the engine power is regulated. Simultaneously, the datum setting of the constant speed unit 106 is varied so that it accords with the operating conditions of the engine selected by the pilot: the blades 8 are moved in known manner as the datum setting of the constant speed unit is adjusted so that their pitch corresponds to the newly selected value of speed. The lever 10 is also connected by means of a link-

age, diagrammatically indicated at 11 (Figure 3) with a switch, the arm of which is shown at 12.

The lever 10 is movable along a slot 13 from one end 14, corresponding to slow running of the engine, to the end 15 which corresponds to full power. The lever 10 may also pass through a gate 16 and into a slot 17 and be thereafter moved towards the end 18—which also corresponds to the full power of the engine. In passing through gate 16 from slot 13 to slot 17 the lever 10 adjusts the switch 12 through linkage 11 so that the arm is set on the studs 19, 20. Similarly, when the lever is moved through the gate in the opposite direction the arm 12 is moved on to stud 21 for other movements of lever 10 the switch arm is not adjusted in any way.

Whilst lever 10 is in the slot 13 the blades 8 are in the positive pitch-range so that the thrust is applied to propel the aeroplane forwardly. When the lever 10 is in the slot 17 the blades 8 are set within the negative pitch-range and the propeller thrust is applied as a braking force to the aeroplane.

The pump 104 of the unit 106 draws oil from the lubricating system of the engine and, besides supplying the motor 6 through the valve 105 it passes oil to the valves diagrammatically indicated at 22, 23 and 24. Thus, valve 22 is supplied through channels 155, 156 and valves 23 and 24 through channels 155, 157 and 158. The valve 22 regulates the passage of the pressure fluid along channel 159 to a motor 113 associated with a relief valve 114 which is provided on the delivery side of pump 104 along channel 160. The valve 23 regulates the passage of fluid from pump 104 along channel 160 to a motor 115 associated with the constant speed unit so as to override it in a manner later described. The valve 24 regulates the passage of pressure fluid along channel 161 to a motor 116 which is provided to adjust a two-position valve 117.

When motor 115 is brought into operation the unit is overriden in its operation. Accordingly, for convenience, this motor will be referred to as the "overriding motor," valve 23 as the "overriding valve" and a solenoid 25 which controls the operation of the valve 23 will be called the "overriding solenoid." Valve 117 is only brought into operation when it is desired to move the blades from one pitch range to the other during reversing or unreversing of the blades 8. Accordingly, motor 116 will be referred to, for convenience, as the "reversing motor," its valve 24 as the "reversing valve" and a solenoid 26 which is provided to adjust the valve as the "reversing solenoid." The valve 22 regulates the passage of pressure fluid to relief valve 114 so as to increase the pressure at which it operates and accordingly the valve 22 and its actuating solenoid 27 will be referred to as the "pressure-increasing" valve and solenoid respectively.

The reversing valve 24 is normally spring urged to a position at which valve 117 is set so that pitch adjustments are performed (under the control of the constant speed unit) in the positive-pitch range.

Carried by ram 7 of pitch-change motor 6 are a pair of shoulders 28 and 29 which are so arranged that, as ram 7 moves to the left (Figure 2) to bring the blades 8 from the positive pitch-range to the negative pitch-range, shoulder 28 engages abutment 118 when the blades have assumed a position hereinafter referred to as the "fine-pitch position." The ram 7 is again stopped, when stop 29 engages stop 118, with the

blades at zero pitch. Stop 118 is removable to allow the ram to move to the left after the stop is engaged by shoulders 28, 29. Thus, the ram is brought into and adjusted in the negative pitch range.

The stop 118 is moved clear of shoulders 28, 29 in the following way:

When pressure fluid is delivered by pump 104 to motor 6 by pipe 119 to move the ram 7 to the left it also passes by duct 120 to valve 121. The latter is urged by spring 122 to the right (Figure 2). The normal fluid pressure on valve 121 is incapable of moving it against spring 122. When shoulder 28 or 29 engages stop 118 and ram 7 is brought to rest, the continued delivery by pump 104 raises the pressure in motor 6—and, thus on valve 121. When the pressure reaches a predetermined value valve 121 is moved to the left due to the pressure in motor 6 acting thereon and duct 120 communicates with duct 123 and acts on piston 124. This piston is then moved to the right against spring 125 and shoulder 126 is moved from under stop 118. The latter comprises a plurality of circumferentially spaced spring fingers 127 which tend to contract inwardly but are prevented from so doing by shoulder 126. When the shoulder is moved clear of abutment 118 the fingers contract and carry the stop away from shoulders 28 or 29. When the ram is thus permitted to continue its travel to the left the resultant pressure fall resets valve 121 and piston 124 to the position shown in Figure 2. In this way after stop 118 is cleared from shoulder 28 it will be automatically re-set to engage shoulder 29.

The increased pressure required to remove abutment 118 will be reached as the blow-off pressure of relief valve 114 is made greater as later described. The arrangement of shoulders 28, 29 and stop 118 are well known and will not, therefore, be described in greater detail.

There is associated with the blades 8 a pitch-following mechanism, generally indicated at 30, and comprising a pin 31 carried by the root of a blade, a rod 32 and a plate 33 carried by the rod. The pin 31 and rod 32 are normally spaced apart (at 127) so that the mechanism has a lost-motion effect and it is arranged that slightly before the blades reach their fine-pitch setting the pin 31 will have been moved to engage rod 32 to move the plate 33 against a pair of contacts 34, 35. This could occur, for instance, at +10° pitch setting. The plate 33 is of conducting material and completes a circuit through the contacts 34, 35. Similarly, with the continued movement of the blades 8 towards the negative-pitch range at about +5° the plate 33 engages contact 36 thereby completing a circuit through contacts 34 and 36: finally at about −5° the plate engages contact 37 thereby completing a circuit through the contacts 34, 37.

Generally, the function of the mechanism described is that when the lever 10 is moved from the slot 13 into the slot 17 the switch arm 12 is brought to engage contacts 19, 20. As a consequence the solenoids 25, 26 and 27 are energised in a selected manner thereby (i) to bring the ram 7 successively against the shoulders 28, 29, (ii) to enable the pressure fluid passing to the motor 6 to be increased so as to remove said stops automatically, (iii) to override the constant speed unit 106 so that the blades are moved from the positive pitch-range to the negative pitch-range and (iv) to reverse the flow of pressure fluid from valve 105 to motor 6 so that when

the blades are in the negative pitch-range the constant speed unit 106 will be effective suitably to adjust the blades in the required sense.

It is considered desirable that this sequence of operations just outlined be prevented from taking place until such time as the aeroplane has touched down since it is only during the landing run and for manoeuvring on the ground generally that the braking force is required. To this end, there is provided a switch 38 (see also Figure 1) which is closed when the undercarriage legs 103, 104 are telescoped, as occurs when the aeroplane touches down on landing. The switch 38 is in series with the aeroplane battery 39 and with the solenoids 25, 26, 27 so that until the switch 38 has been closed as indicated no circuit may be completed from the battery 39 to any of the solenoids.

The sequence of operations performed under different flight conditions will now be described.

It will be assumed that the aeroplane is airborne and the sequence of operations which take place as the landing approach is made, as the machine touches down, as the braking effect is obtained by moving the blades to the negative pitch-range, as the unbraking operation is performed, as starting of the engine from rest takes place and, finally, as the aeroplane takes-off will then be described, in that order.

Whilst the machine is flying there is of course no load on the undercarriage and the switch 38 is open. As a consequence the entire circuit controlling the solenoids 25, 26 and 27 is dead. The propeller blades are within the positive pitch-range and are being adjusted automatically by the constant speed unit 106, the datum setting of which is varied by moving lever 10. The two shoulders 28 and 29 are in position to prevent movement of the ram 7, firstly, beyond fine pitch and, secondly, beyond zero pitch into the negative-pitch range.

As the landing approach is made the pilot moves the power lever 10 from some position along the slot 13 to the slow-running end 14 thereof. As a consequence the datum setting of unit 106 is adjusted and it is arranged that the power developed by the engine under these conditions is insufficient to provide the power required to drive the propeller. As a consequence, the propeller windmills at the fine-pitch setting, i. e., ram 7 is against shoulder 28, to provide the remaining portion of the power. This will have the effect of producing drag thereby preventing the gliding speed of the aircraft from becoming excessive. If the pilot wishes to reduce this drag (or to obtain a thrust in the forward direction) he suitably adjusts the lever 10 away from position 14 and along slot 13.

When the machine touches down, the undercarriage becomes loaded and the switch 38 is closed so that the circuit to the solenoids 25, 26, 27 becomes effective. The switch arm of switch 38 is then in the chain-dotted position shown in Figure 3. As a consequence a circuit is completed from the battery 39, switch 38, lead 128, switch 40 (which is normally closed) lead 129 to the solenoid 27 to energize the latter. The pressure-increasing valve 22 is opened to apply the pressure of pump 104 to motor 113 thereby loading relief valve 114 so that the pressure of fluid within the motor 6 may be increased sufficiently to withdraw stop 118 from the fine-pitch shoulder 28 against which the ram 7 has been brought during the landing approach (see above). As the propeller moves towards zero-pitch the plate 33 is brought into engagement with the studs 34, 35 thereby completing a circuit from the battery 39 through switch 38, lead 128, lead 41, contacts 34, 35, lead 130 and a solenoid 42 so that the switch 40 is opened and the solenoid 27 is de-energised. This restores the normal pressure conditions in the motor 6 so that the stop 118 cannot be withdrawn from shoulder 29. As a result the propeller is now free to constant speed over the range of pitch settings above the zero-pitch shoulder 29.

When the pilot wishes to obtain a braking thrust he moves power lever 10 through the gate 16 and as a consequence switch arm 12 is moved to engage studs 19 and 20. In so doing a pair of circuits are completed from the battery 39 one through lead 131 to solenoid 26 and the other through lead 131 to solenoid 43—the circuits being in parallel. When solenoid 43 is energised, switches 44 and 45 are closed and there is completed a circuit from the battery 39 through the studs 19, 20, lead 150, switch 44, lead 151 and switch 46 to the solenoid 25. At the same time a circuit is completed from the battery 39 through switch 45 to solenoid 27. As a consequence solenoids 25, 26 and 27 are now all energised.

When the machine touches down, the switch 38 may tend to open and close with bouncing of the undercarriage and to overcome this there is associated with the solenoid 43 a known form of holding circuit (not shown) which is brought into use when the solenoid is energised to ensure that it is maintained in this state.

When solenoids 25, 26 and 27 are energised valves 23, 24 and 22, respectively, are opened thereby applying the pressure of pump 104 to motors 115, 116 and 113.

Operation of motor 113 loads relief valve 114 to ensure that a pressure build-up will take place in motor 6 sufficient to remove stop 118 from shoulder 29 so that the blades 8 may enter the negative-pitch range. Operation of motor 115 over-rides the unit 106 to ensure that the pressure fluid is delivered by pump 104 continuously in one way and operation of motor 116 ensures that the pressure fluid passes by duct 119 to carry the blades into the negative pitch range.

When the zero-pitch shoulder 29 is removed and the blades placed within the negative pitch-range, plate 33 engages contact 37 at −5°: contact 36 has previously been engaged but as this is in series with a switch 47, which has so far remained open, it is not effective. When plate 33 engages contact 37 a circuit is completed from the battery 39 through leads 128, 41, contacts 34, 37, lead 152 to solenoid 48 and switch 46 is opened whilst switch 47 is closed. There is associated with the solenoid 48 a known form of holding circuit 200 which ensures that the solenoid remains energised.

When switch 46 is opened the overriding solenoid 25 is de-energised so that the constant speed unit 106 is free to take over control of the propeller. The conditions then prevailing are that the solenoids 26, 27, 43 and 48 remain energised to provide that the propeller is operating within the negative pitch-range and is being automatically adjusted by unit 106 under the control of the lever 10. The latter is movable along slot 17 so as to vary the power of the engine. The lever 10 now controls to determine the braking force which is obtained.

When the aeroplane is brought to a standstill it is desirable that the control system be re-set prior to the engine being stopped. To this end,

the lever 10 is moved through the gate 16 so that it is in the slow-running position 14. As a result the switch arm 12 is moved to engage the stud 21 and the circuits to the solenoids 26, 27 and 43 are broken so that the reversing and pressure-increasing valves 26, 27 respectively are set in their normal inoperative position.

During this time, solenoid 48 has remained energised and when switch arm 12 engages stud 21 a circuit is completed from the battery 39 through leads 128, 41, contacts 34, 36, lead 153, switch 47, lead 154, switch 21, lead 132 and solenoid 25. The overriding solenoid 25 is therefore energised and the valve 23 is set to bring motor 115 into operation to override unit 116 so as to move the propeller blades into the positive pitch-range. The pressure fluid will now pass to motor 6 by duct 133 since valve 117 is not being adjusted to reverse the flow. As the blades are moved the zero-pitch shoulder 29 is moved towards its engaging position. At +5° the plate 33 moves away from the contact 36 the circuit to solenoid 48 is broken, switch 47 is opened and solenoid 25 is de-energized. The propeller is then within the positive pitch-range and is again returned to the control of the constant speed unit. The entire system is now ready for starting. The engine may then be stopped.

When the engine is to be started, the lever 10 is placed at the slow-running position 14 and the engine started up. As the engine power increases the constant speed unit adjusts the blades 8 so that the pitch becomes coarser. At −10° the plate 33 moves away from the contacts 34, 35 so that solenoid 42 becomes de-energised and consequently solenoid 27 is energised. The fluid pressure to motor 6 is therefore at its higher-than-normal value and holds the fine-pitch shoulder 28 in its inoperative position so that the propeller is free to constant speed above the zero-pitch shoulder 29, towards which it moves as the power is reduced.

From the starting position the lever 10 is moved along the slot 13 towards the full power position when it is desired to take-off. As a result the propeller speeds up and ram 7 moves to, and beyond, engagement of the fine-pitch shoulder 28 with stop 118: this stop, as has been indicated above, is held inoperative until the areoplane becomes airborne whereupon the load on the undercarriage is relieved and the switch 38 is opened. The entire electrical circuit thereupon becomes dead and the solenoid 27 is de-energised.

If desired the plate 33 and contacts 34—37 may be replaced by a pair of two-position switches which are operated by the rod 32 which engages a plate rotatable with the propeller. The switch arms are actuated by a bell-crank lever either directly or indirectly through the agency of a slider but which, in any case, is adjusted by a slipper with movements of the rotatable plate. The actuation of the switches will be similar to that of the hub contacts described above.

We claim:

1. The combination with a variable-pitch, reversing, hydraulically-operated propeller for an aeroplane having an undercarriage and an engine to drive the propeller, of a constant-speed unit to control the pitch adjustment of the blades of the propeller, a single control to adjust, over a range, both the power output of the engine and the speed setting of the constant speed unit in the positive and negative pitch ranges, means to over-ride the constant speed unit comprising a valve controlled motor operatively connected to the constant speed unit whereby the blades are moved from one pitch range to the other, electrical means operatively associated with said valve to control said over-riding means, said electrical means being actuated by the single control at its slow-running position of the engine and switch means operated by the aeroplane undercarriage to render said electrical control means inoperative, except when the undercarriage supports the aeroplane.

2. An engine-propeller assembly as claimed in claim 1 wherein the hydraulically-operated propeller includes a pitch-change motor and hydraulic connections between the constant-speed unit and the pitch-change motor and wherein the circuit of the electrical control means incorporates switches which are actuated by the blades of the propeller, said switches controlling hydraulic valve means which transpose the hydraulic connections between the constant-speed unit and a pitch-change motor of the propeller while the propeller blades are in the negative-pitch range whereby said unit automatically adjusts the blades in the negative-pitch range.

3. An engine-propeller assembly as claimed in claim 2 in which a stop is provided normally to prevent movement of the blades to within the negative-pitch range, said stop being displaced to allow such movement by an increase in the hydraulic pressure in the pitch-change motor to a higher-than-normal value, means being provided to ensure that said higher pressure is built up when the speed-power control is suitably adjusted after the aeroplane has landed.

4. An engine propeller assembly as claimed in claim 3 in which the means for over-riding the constant-speed unit, for transposing the hydraulic connections between said unit and the pitch-change motor and for producing the higher-than-normal hydraulic pressure is each hydraulically controlled by the pressure fluid delivered by the pump supplying the pitch-change motor.

5. An engine propeller assembly as claimed in claim 4 wherein there is provided a hydraulic motor to adjust each of said means, a valve to control the supply of pressure fluid from the pump to each said motor and a solenoid, forming part of said electrical control, for adjusting each valve.

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