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W. S. HOOVER
BLADE PHASE AND CONSTANT SPEED SYNCHRONIZER
FOR MULTIPLE MOTOR AIRCRAFT
Filed March 12, 1943 2 Sh

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2 Sheets-Sheet 1

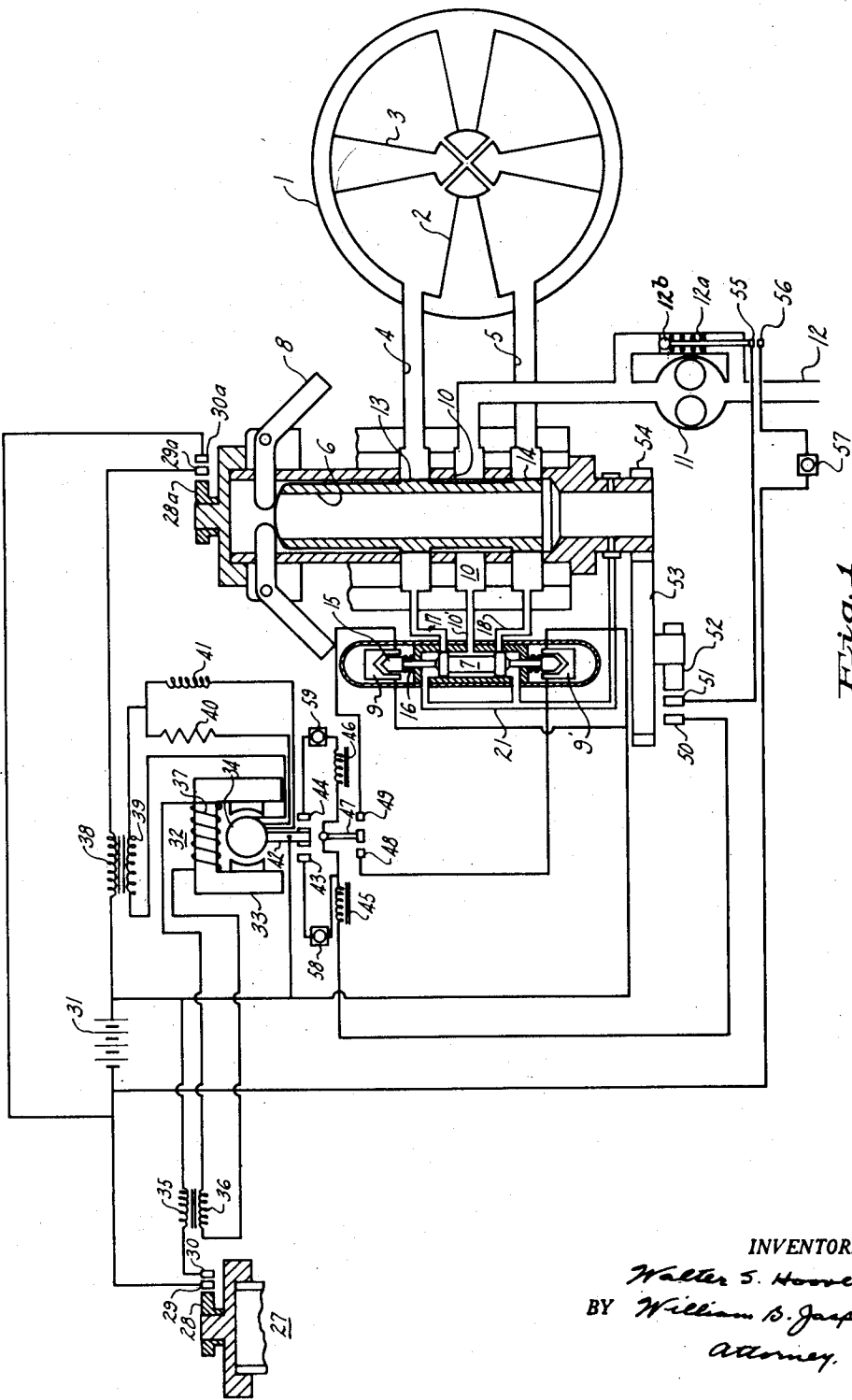


Fig. 1

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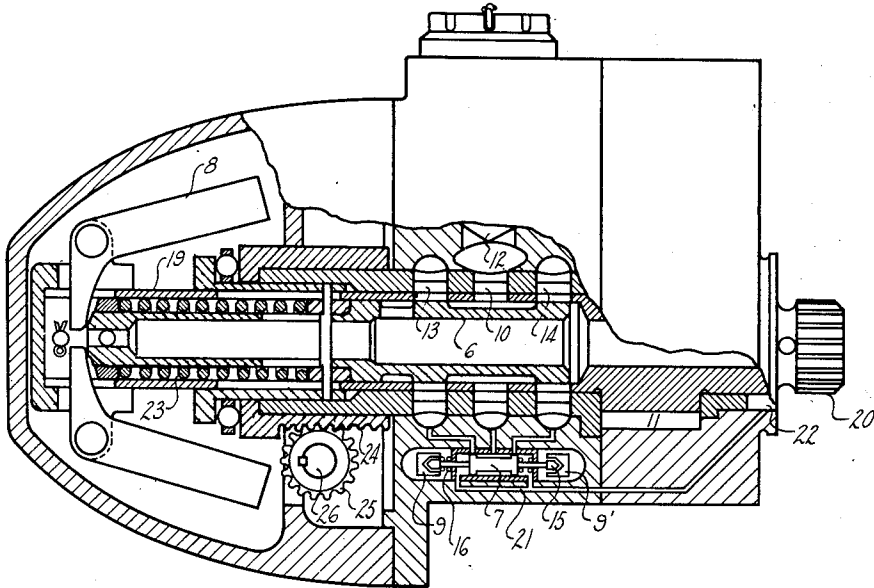


Fig. 2

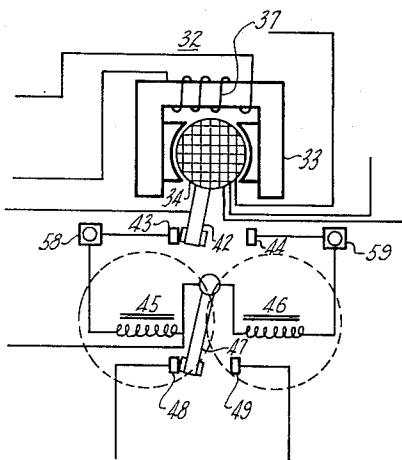


Fig. 3

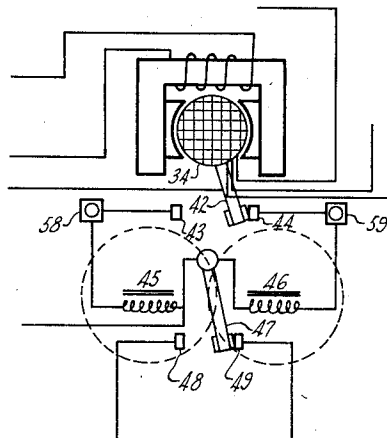


Fig. 4

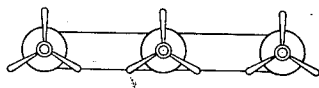


Fig. 5

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UNITED STATES PATENT OFFICE

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BLADE PHASE AND CONSTANT SPEED SYNCHRONIZER FOR MULTIPLE MOTOR AIRCRAFT

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14 Claims. (Cl. 170-135.6)

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This invention relates to apparatus for and a method of maintaining phase relation of a plurality of propeller blades and for synchronizing the speeds of the propeller engines, and it is among the objects thereof to provide a hydraulic governor control for variable pitch propeller mechanisms for maintaining constant load on the propeller engines, having auxiliary pressure-balanced valve means for regulating the pitch adjusting movements of the blades, and means responsive to the phase change in any one of a plurality of such propeller mechanisms for automatically restoring the phase relation of such out-of-phase unit.

It is a primary object of the invention to provide a combined constant speed control mechanism for variable pitch propeller mechanism responsive to a governor valve in combination with auxiliary valve means controlling the application of pressure fluid for actuating the blades in their pitch adjusting movements, with means for rendering the auxiliary valve means inoperative during any pitch adjusting movement of the governor valve.

It is a further object of the invention to provide a combined governor control and auxiliary valve control mechanism for constant speed propellers as a unitary structure which may be mounted on the propeller engine or incorporated in the propeller hub.

It is still a further object of the invention to provide phase change and constant speed control mechanism of the above designated character in which the auxiliary valves are rendered operative through an electric control system by means related to a master governor or selective speed operator.

Still a further object of the invention is the provision of phase-change and constant speed propeller mechanism of the above designated character in which the auxiliary valves are electrically operated and controlled by a synchroscope responsive to the difference in speeds of the propeller mechanism in relation to a master governor or selective speed drive mechanism.

These and other objects of the invention will become more apparent from a consideration of the accompanying drawings constituting a part hereof in which like reference characters designate like parts and in which:

Fig. 1 is a diagrammatic view partially in section of a blade phase and constant speed synchronizer for multiple motor aircraft embodying the principles of this invention;

Fig. 2 a vertical section partially in elevation taken longitudinally of a governor valve and pump mechanism;

Figs. 3 and 4 diagrammatic views of a synchroscope and relays;

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Fig. 5 a schematic view of a plurality of propeller mechanisms with their blades in phase.

In Fig. 1 of the drawing, the numeral 1 designates a fluid motor having stationary vanes 2 and movable vanes 3, the latter being associated with a propeller blade to adjust the pitch angle by the application of pressure fluid through channels 4 and 5 to get a positive pitch adjustment for both high and low pitch angle setting.

The application of the pressure fluid to the rotor 3 is controlled by a governor valve 6 and an auxiliary valve 7, the former being actuated in its flow controlling movements by governor flyweights 8, and the auxiliary valve by electrical solenoids 9 and 9'.

Fluid is delivered to the high pressure port 10 of the governor valve by a pump 11 from a source 12 which may be the engine lubricating fluid or a fluid stored in the propeller hub or other independent self-contained source. A relief valve 12b normally biased by coil spring 12a returns the fluid to the low pressure side of pump 11 if the pressure exceeds a predetermined pounds-per-square-inch pressure. Movement of the governor valve 6 will communicate the pressure fluid from port 10 with either ports 13 or 14, depending upon the directional movement of the rotor 3 for the desired pitch adjustment.

The auxiliary valve 7 is a pressure balanced spool type valve communicating with the high pressure port 10 of governor valve 6. Movement of valve 7 is effected by energization of the solenoids 9, 9', to draw the armatures 15 that are an integral part of the valve body. Valve 7 is biased by coil springs 16 to normally cover ports of passages 17 and 18 which communicate with the flow passages 4 and 5 of the fluid motor 1.

The embodiment of the governor valve and auxiliary control valves 6 and 7 respectively as an integral unit is shown in Fig. 2 of the drawings in the form in which it may be mounted on the nose of the propeller hub or on the propeller engine.

The governor shaft designated by the numeral 19 is driven through the spline 20 and the pump 11, which is a gear pump, is shown incorporated in the valve housing. A drain gland 21 from the auxiliary valve communicates at 22 with the drain, which as shown in Fig. 1 may be through the hollow governor shaft. The governor valve 6 is provided with a speeder spring 23 that may be preloaded through a manual control comprising the gear rack 24 and pinion 25, the latter being mounted on a shaft 26 that is operated by the pilot.

The relief valve 12b is shown in Fig. 2 communicating with the high pressure port 10, the valve 12b being displaced in an upward direction to permit recirculation of the high pressure fluid to the low pressure side of pump 11.

With reference to Fig. 1, the numeral 27 generally designates another hydraulic governor valve for a propeller pitch adjusting mechanism, and both the governor valve 6 and the valve 27 are provided with interrupter cams 28 and 28a which engage movable contacts 29 and 29a of an electrical circuit which effect intermittent contact with terminals 30 and 30a of the circuit.

A source of power as indicated by batteries 31 supplies current to the circuit, which functions to operate a synchroscope generally designated by the numeral 32 which consists of the pole pieces 33 and the armature 34. A transformer comprising a primary winding 35 and a secondary winding 36 is connected to the field winding 37 of the synchroscope, which is energized by the intermittent contact of terminals 29 and 30.

A second transformer comprising a primary winding 38 and a secondary winding 39 is connected to a resistance and induction coil 40 and 41, respectively, to peak up the current which flows to the synchroscope so that it will break off sharply, thereby aiding sensitivity.

The armature 34 of the synchroscope is provided with an arm 42 which engages terminals 43 and 44 energizing relays 45 and 46 that operate switch 47 to contact terminals 48 and 49 of the auxiliary valve solenoids 9 and 9'. The power circuit of the solenoids is connected to terminals 50 and 51, the latter being actuated by an interrupter cam 52 operated by gear wheel 53 interacting with the teeth of a pinion 54 on the governor shaft. The terminal 51 is connected to a movable terminal 55 operated by pressure on relief valve 12 to contact terminal 56, and lights 57, 58 and 59 are provided to indicate that the auxiliary valve solenoid circuit is energized.

The synchroscope, relays and operating switch are shown in Figs. 3 and 4, Fig. 3 indicating one position of switch 47, which energizes the auxiliary valve solenoid for one direction of valve movement, and Fig. 4 shows the switch set to move the valve in the opposite direction of its flow control movement.

Operation of the above described phase-change and constant speed propeller control system is briefly as follows.

Assuming the governor 27 to be driven by the master engine of a multiple motor plane or by a selective speed electric motor to operate the circuit interrupter 29, the interrupter cam 28 will make contact of terminals 29 and 30 each revolution of the engine or motor as the case may be, producing alternating current in the line from the source 31 through the transformer windings 38 and 39 and the armature will not be subject to movement, if the speed of cams 28 and 28a are the same.

If the frequency of interrupter cam 28a is changed so that the current of the synchroscope winding and armature are out of phase, armature 34 will be moved to contact terminals 43 or 44, depending upon whether the frequency is greater or lesser than the master interrupter cam 28.

Assuming that the switch 42 contacts terminal 43, as shown in Fig. 3, the relay switch 47 will contact terminal 48 and establish a power circuit with solenoid 9', which moves the pressure balanced valve 7 in a downward direction as viewed in Fig. 1, exposing port 17 to the drainline 21 and port 18 to the high pressure line 10' of pump 11, the pressure fluid flowing through valve 7 to the gland 5, and thence to the fluid motor 1 to actuate the rotor 3 in its pitch adjusting movement. The

pitch setting of the propeller blade will adjust the load on the engine until the speed of the engine governor is again in synchronism with the master governor 27. The auxiliary valve will continue to deliver pressure fluid to the pitch adjusting motor until it is again in synchronism with the master engine.

If the synchroscope switch 42 contacts terminal 44, as shown in Fig. 4, relay switch 47 will engage terminal 49 to energize solenoid 9 of the auxiliary valve to apply pressure fluid to the pitch adjusting fluid motor in the opposite direction.

To provide for increment adjustment of the pitch of the blades, the interrupter cam 52 continues to make and break the solenoid circuit so that the auxiliary valve is subjected to slight fluctuations to avoid abrupt adjustment of the pitch during the period the propeller engine is brought up to speed, which is almost instantaneous.

When a condition exists in the normal maneuverability of a plane which calls for constant speed adjustment of the propeller blades, the governor fly-weights 8 will actuate governor valve 6 to connect the high pressure fluid from port 10 with port 13 or 14 depending on the direction of movement of the valve. When this occurs, pressure on relief valve 12 will drop and spring 12a will move the valve to open circuit terminals 55 and 56 so that no power can be applied to the auxiliary valve solenoids 9 or 9'. When the governor valve 6 has effected its pitch adjusting control, pressure will again build up on the relief valve 12 displacing it against the spring 12a and closing terminals 55 and 56 which establishes the circuit of the auxiliary valve solenoids to render it operative in response to the control of the synchroscope as previously described.

It is thus seen that the auxiliary valve mechanism is inoperative during normal pitch adjusting of the blades and functions only to maintain synchronism of the multiple propeller engines in relation with the master engine or selective speed motor. By means of the synchronization control through the auxiliary valve, the blades of the respective motors will be kept in phase relation, as shown in Fig. 5.

In other words, if initially the blades are set as shown in Fig. 5, the auxiliary valve 7 will maintain the phase relation of the blade units at all times through the synchroscope control. Fig. 1 shows the phase change and constant speed control as applied to a pair of propeller units. However, any number of such units may be controlled by the master engine by the use of synchroscope control systems for energizing the auxiliary valve by merely connecting them in the circuit with the terminals 29 and 30 of the master interrupter cam.

With reference to Fig. 2 of the drawings, the several motors of the plane are originally regulated in their speed through the manual control gear 25 which, through the speeder spring, preloads the governor fly-weights to maintain a selective speed of the particular engine.

After this adjustment has been made, the auxiliary valve and synchroscope control maintains the phase relation of the several propeller units. The light 57 indicates to the pilot that the auxiliary valve is powered to operate, and when it is out, it indicates that the governor valve is functioning to deliver fluid pressure to the pitch setting mechanism. Lights 58 and 59, when energized, indicate the direction of adjustment, whether it is for high or low pitch setting, which

is taking place through the synchroscope control.

It is evident from the foregoing description of this invention that a rapid and minute adjustment of the phase relation of a plurality of propeller engines may be effected automatically through the governor controlled fluid system without interfering with the normal operation of the governor control valve.

It is further evident that by the use of a pressure balanced auxiliary valve, very little energy is required to actuate the valve, which can be controlled through a commercially available synchroscope.

While the auxiliary valve will remain inoperative during violent maneuvering of the plane as in power diving, the auxiliary valve will rapidly restore the phase relation of the blades and engines when the plane has been restored to normal flight.

It is further evident that the synchroscope unit and auxiliary valve can be incorporated in or mounted on the propeller hub or governor housing and constitute a single compact unit for mounting on the engines with no connections other than the electrical conductors from the synchroscope to the interrupter cam circuits.

Although one embodiment of the invention has been herein illustrated and described, it will be evident to those skilled in the art that various modifications may be made in the details of construction without departing from the principles herein set forth.

For example, the system may be employed on variable pitch propeller mechanisms wherein the pitch adjustment may be effected by prime movers other than a fluid motor. In such cases the fluid motor 1 would function as a servo motor for operating the control of the prime mover.

I claim:

1. In a system of control for synchronizing the speed of propeller engines with the speed of a selected speed prime mover, constant speed propeller mechanism including adjustable pitch propeller blades mounted on said engines, fluid motors for controlling the pitch setting of the propeller blades, governor valves controlling the application of pressure fluid to said motors, and valves for directing the application of pressure fluid to said motors independently of said governor valves, said last named valves being operative to maintain phase relation of said propeller engines with the selected speed prime mover.

2. In a system of control for synchronizing the speed of propeller engines with the speed of a selected speed prime mover, constant speed propeller mechanism including adjustable pitch propeller blades mounted on said engines, fluid motors for controlling the pitch setting of the propeller blades, governor valves controlling the application of pressure fluid to said motors, valves for directing the application of pressure fluid to said motors independently of said governor valves, said last named valves being operative to maintain phase relation of said propeller engines with the selected speed prime mover, and means operative in response to movement of said governor valves for rendering said second named valves inoperative.

3. In a system of control for synchronizing the speed of propeller engines with the speed of a selected speed prime mover, constant speed propeller mechanism including adjustable pitch propeller blades mounted on said engines, fluid motors for controlling the pitch setting of the propeller blades, governor valves controlling the ap-

plication of pressure fluid to said motors, valves for directing the application of pressure fluid to said motors independently of said governor valves, and means operative in response to the speed differential of said engines and prime mover for actuating said second named valve.

4. In a system of control for synchronizing the speed of propeller engines with the speed of a selected speed prime mover, constant speed propeller mechanism including adjustable pitch propeller blades mounted on said engines, fluid motors for controlling the pitch setting of the propeller blades, governor valves controlling the application of pressure fluid to said motors, valves for directing the application of pressure fluid to said motors independently of said governor valves, means operative in response to the speed differential of said engines, and prime mover for actuating said second named valves, and means operative in response to movement of said governor valves for rendering said second named valves inoperative.

5. In a system of control for synchronizing the speed of propeller engines with the speed of a selected speed prime mover, constant speed propeller mechanism including adjustable pitch propeller blades mounted on said engines, fluid motors for controlling the pitch setting of the propeller blades, governor valves directing the application of pressure fluid to said motors, valves directing the application of pressure fluid to said motors independently of said governor valves, said second named valves having solenoids for actuating the same in their flow control movements, electrical power circuit for selectively energizing said solenoids including a synchroscope, circuit interrupters operated by said engines and selected speed prime mover for energizing said synchroscope in response to a speed differential of said interrupters to advance or retard the pitch setting of the propeller blades.

6. In a system of control for multiple propeller engines having variable pitch propeller mechanisms and blades mounted thereon, one of said engines being a master engine, actuators for adjusting the blades to high or low pitch setting including a fluid motor, a governor valve for each of said motors controlling the fluid flow to said motor, a second valve for some of said motors controlling the fluid flow thereto independently of their governor valve, each of said second-named valves having a pair of solenoids connected in an electrical power circuit, a synchroscope for selectively energizing said solenoids, said synchroscope being operative in response to a differential in the speed of said propeller engines controlled by the fluid motors having said second-named valves and said master engine to energize the solenoid to actuate the second-named valve to effect high or low pitch setting movements of the propeller blades.

7. In a system of control for multiple propeller engines having variable pitch propeller mechanisms and blades mounted thereon, one of said engines being a master engine, actuators for adjusting the blades to high or low pitch setting including a fluid motor, a governor valve for each of said motors controlling the fluid flow to said motor, a second valve for some of said motors controlling the fluid flow thereto independently of their governor valve, each of said second-named valves having a pair of solenoids connected in an electrical power circuit, a synchroscope for selectively energizing said solenoids, said synchroscope being operative in response to a differential

in the speed of said propeller engines controlled by the fluid motors having said second-named valves and said master engine to energize the solenoid to actuate the second-named valve to high or low pitch setting movement of the propeller blades, and means for disconnecting the solenoids from the power circuit when said governor valves are operative in their pitch adjusting movement.

8. In a system of control for multiple propeller engines having variable pitch propeller mechanisms and blades mounted thereon, of means for maintaining synchronous speed of said engines and phase relation of the propeller blades of said engines consisting of a fluid motor for actuating the blades in their high and low pitch setting movements, one of said engines being a master engine, a source of fluid pressure for said fluid motors, a governor valve controlling the application of the pressure fluid to control the direction and degree of pitch setting movement of said motors, a second valve for some of said fluid motors connected to a pressure fluid source for controlling their directional and degree of movement independently of said governor valves, each of said second named valves having a pair of solenoids connected in an electric power circuit, a synchroscope in said power circuit for selectively operating said second-named valves, an interrupter cam operated by said master engine for intermittently energizing said circuit, and interrupter cams operated by the other propeller engines for controlling said power circuit whereby the second-named valves are selectively energized in response to the speed differential between said interrupter cam operated by said master engine and the other interrupter cams to effect pitch adjustment of the propeller blades to maintain the engine speeds in synchronism with the master engine and to maintain phase relation of the blades of the respective engines.

9. In multiple engine aircraft in which each engine is provided with constant speed propeller mechanism including adjustable pitch propeller blades, a fluid motor controlling the pitch setting of the propeller blades, a governor valve controlling the direction and degree of pitch adjusting movement of the fluid motor in response to speed of its propeller engine and an auxiliary valve connected to control the direction and degree of movement of the fluid motor independently of the governor valve, said auxiliary valve being rendered inoperative in response to pitch adjusting movement of the governor valve.

10. In multiple engine aircraft in which engine is provided with constant speed propeller mechanism including adjustable pitch propeller blades and a fluid motor for adjusting the propeller blades to the high or low pitch setting including a source of pressure fluid, a governor valve for each of said fluid motors operative in response to the speed of its propeller engine having a plurality of spaced ports connected to the fluid motor and a port connected to the source of pressure fluid, said valve operating to connect the high pressure fluid with one of said first-named ports to effect pitch adjusting movement of the fluid motor as determined by the direction of movement of the governor valve, an auxiliary valve having ported passages connected to the ports of the governor valve to route the pressure fluid through the governor valve passages to the fluid motor when the governor valve is in neutral position, and means for actuating said auxiliary valve to effect pitch adjusting move-

ment of the fluid motor independent of the governor valve.

11. In multiple engine aircraft in which each engine is provided with variable pitch propeller mechanism including adjustable pitch propeller blades, a fluid motor for actuating the propeller blades in their pitch adjusting movements, a constant speed control mechanism therefor comprising a booster pump, a source of fluid pressure for said pump, a governor valve having fly-weights and a port, means connecting said port to the high pressure side of the booster pump, a return flow passage in communication with said connecting means and the fluid source, a plurality of ported passages controlled by the governor valve connected to the hydraulic actuator for adjusting the blades to high or low pitch setting in response to movement of the governor valve determined by the speed of the propeller engine, a speeder spring for preloading the governor valve fly-weights, manual means for adjusting said spring to effect pitch adjusting movement of the hydraulic actuator independent of the speed of the engine, and an auxiliary valve having ported passages connected to the ports of the governor valve to effect pitch adjusting movement of the hydraulic actuator independently of the governor valve.

12. In a combination with a plurality of propeller engines having variable pitch propellers, of means for maintaining synchronous speed of said engines and phase relation of the propeller blades consisting of fluid motors for actuating the blades in their pitch adjusting movements, one of said engines being a master engine, a source of pressure fluid for said motors, governor valves controlling the application of the pressure fluid to control the degree and direction of movement of said fluid motors, an auxiliary valve for some of said fluid motors for supplying pressure fluid thereto and for controlling the direction and degree of the movement of the fluid motors independently of the governor valves, said auxiliary valves having solenoids for actuating the same, a power circuit for said solenoids including interrupter cams actuated by said engines having circuit making and breaking contacts for regulating the phase of the current of said power circuit, a synchroscope energized in response to phase relation of its field and armature windings which are respectively connected to be energized by said power circuit to energize said auxiliary valve solenoids in response to variations in the speed of the engines controlled by the fluid motors having said auxiliary valves and said master engine to obtain increments of adjusting movement of the auxiliary valves to thereby effect increments of pitch adjustment of the propeller blades, and a switch for opening said power circuit when the governor valves are moved to pitch controlling position.

13. A system of control as set forth in claim 12 in which the solenoids of the auxiliary valve are selectively operated by a relay switch energized by the synchroscope to determine the directional movement of the auxiliary valve.

14. In a control system as set forth in claim 12, signal lights connected in the auxiliary valve control circuit for indicating a setting of the valve for selected pitch adjusting movement and a signal light in said auxiliary light circuit for indicating the functional position of the governor valve.

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