

June 19, 1951

H. J. NICHOLS
HYDRAULIC SYNCHRONIZING SYSTEM

2,557,679

Filed June 6, 1949

4 Sheets-Sheet 1

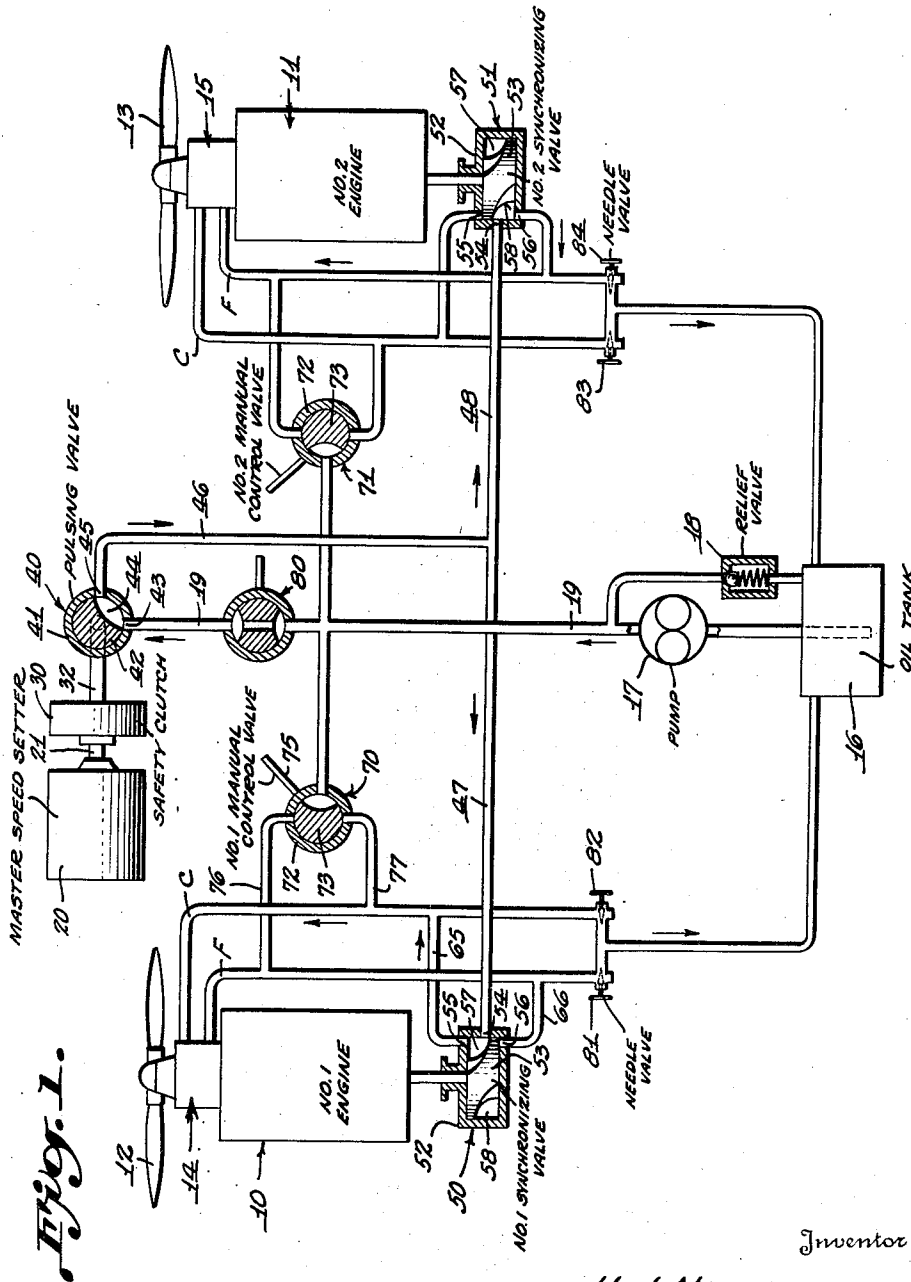


Fig. 1.

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Fig. 2

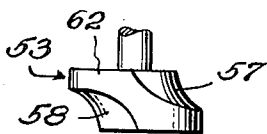


Fig. 3

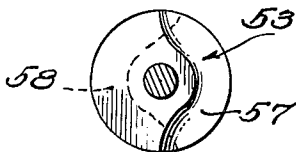


Fig. 5

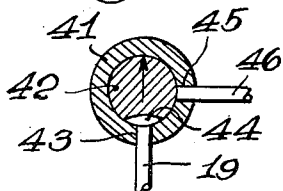


Fig. 4

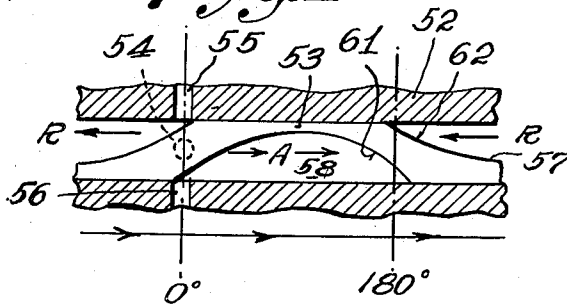
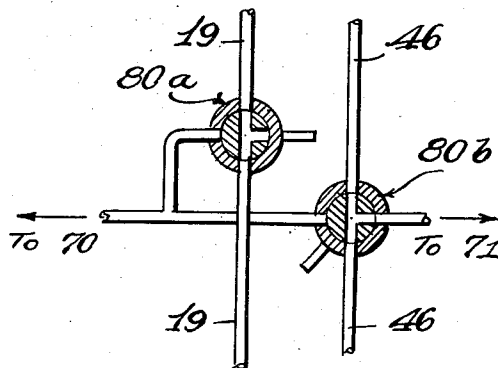


Fig. 6



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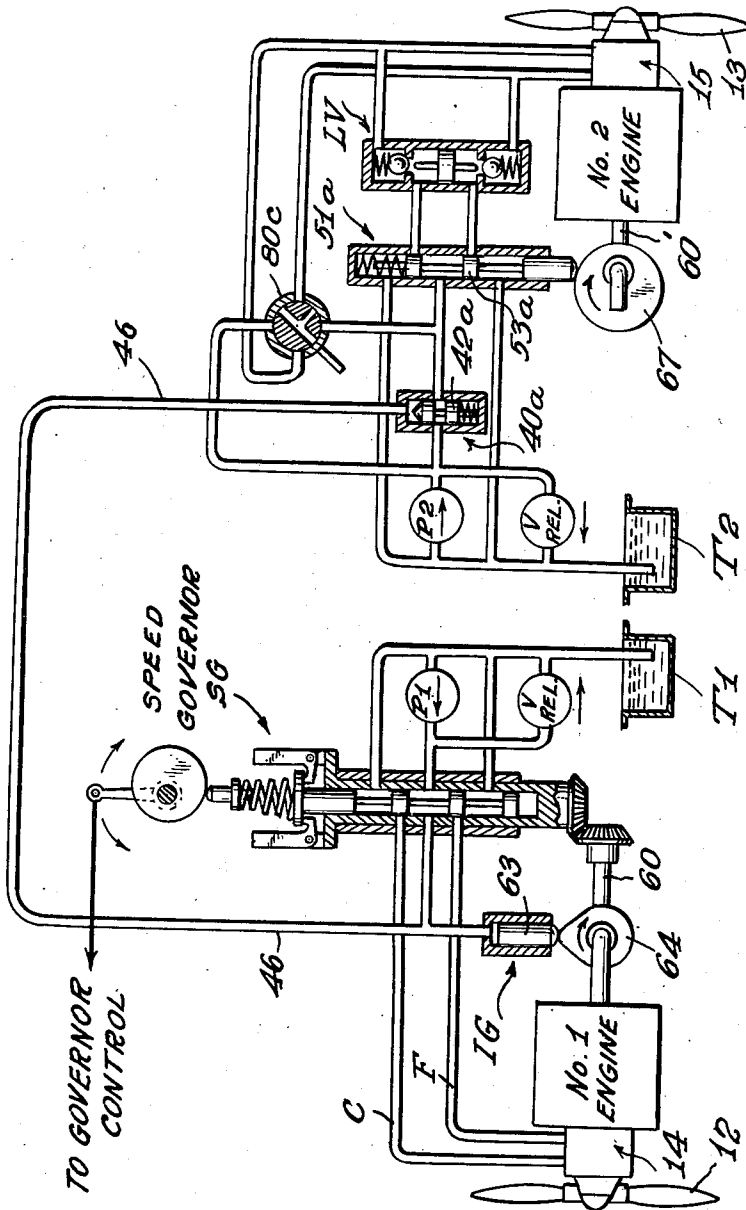
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Fig. 7



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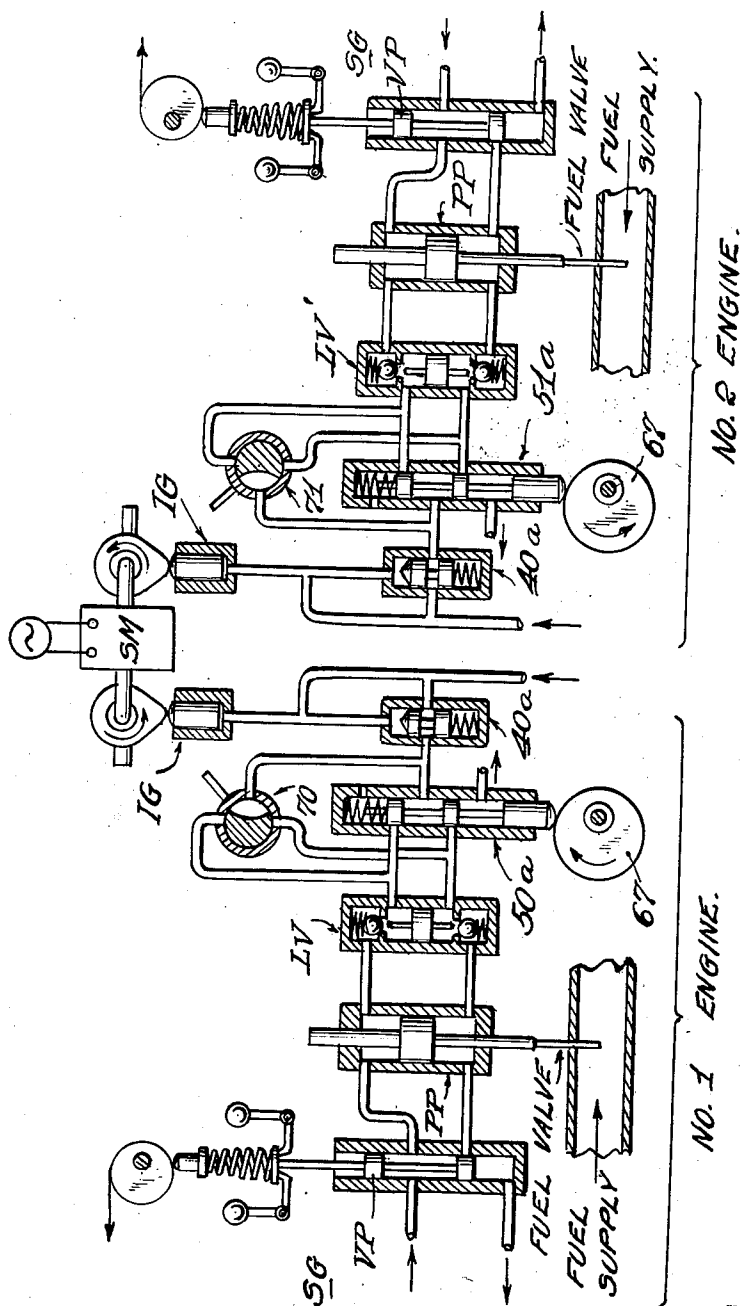
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Fig. 8



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HYDRAULIC SYNCHRONIZING SYSTEM

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Application June 6, 1949, Serial No. 97,462

17 Claims. (Cl. 170—135.29)

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This invention relates to an improved method and apparatus for automatically synchronizing rotary machinery and has particular reference to the synchronizing of prime movers such as the engine or engines of an airplane, marine vessel, or power plant, especially where such prime movers have speed regulating means under hydraulic control.

This application is a continuation in part of my application Serial No. 523,301 filed February 21, 1944, now abandoned.

A principal object of the invention resides in the provision of a novel synchronizing method utilizing timed hydraulic impulses for comparing the speed of one or more engines with a master speed and for automatically correcting the speed of any engine which is out of synchronism with the master speed thereby to bring it into synchronism with the master speed and thereafter to maintain synchronism therewith.

Another principal object is to disclose suitable and practical apparatus of known types for implementing the novel synchronizing method of the invention.

Another object is to disclose apparatus for implementing the novel synchronizing method adaptable for manually or automatically synchronizing one or more engines, either by varying the load thereon independently of the throttle adjustment or by controlling the fuel input thereto.

Another object is to provide improved automatic synchronizer apparatus of the utmost simplicity and reliability which is small in size, light in weight, and low in initial installation and maintenance costs.

Another object is to provide a speed control system whereby the centrifugal speed governors commonly used on engines of the class described may be eliminated and the engine placed under the control of a master speed device which remains unaffected by the engine load.

A further object is to provide versatile synchronizing apparatus which is readily applicable to various types of engines and other prime movers without requiring special provisions in the design, construction, or accessories thereof.

Other objects and advantages will be in part obvious or become apparent as the invention is more particularly hereinafter pointed out.

In the accompanying drawings, in which like reference numerals are used to designate similar or corresponding parts throughout, there is illustrated by way of example various manners of applying the improved method and suitable ap-

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paratus therefor. The drawings, however, are for the purpose of illustration only and are not to be taken as limiting the scope of the invention as set forth in the appended claims.

Fig. 1 is a schematic diagram of the improved synchronizing apparatus.

Figs. 2 and 3 show in elevation and plan views, respectively, the details of the rotor of the rotary synchronizing valves shown in Fig. 1.

Fig. 4 is a diagram showing schematically the operation of the rotor of the synchronizing valve.

Fig. 5 is a detail of the pulsing valve shown in Fig. 1 illustrating the position which the rotor assumes on stopping.

Fig. 6 shows an alternative arrangement of the manual control valves in the system shown in Fig. 1.

Fig. 7 is a schematic diagram illustrating another embodiment of the method of the invention.

Fig. 8 is a similar schematic diagram illustrating yet another embodiment of the method of the invention.

Referring to Fig. 1 of the drawings in detail, the numerals 10 and 11 indicate generally two engines which have been illustrated diagrammatically by way of example as the engines carried by a two engine airplane. Each engine drives a controllable pitch propeller, as indicated at 12 and 13. The pitch of each of the propellers is varied by a pitch changing mechanism, as indicated generally at 14 and 15, which mechanism is provided with hydraulic control means. The pitch changing mechanism and hydraulic control means may be of the construction shown in my U. S. Patent No. 2,423,400 issued July 1, 1947.

It is thought sufficient for the purposes of this disclosure to state that when hydraulic fluid under pressure is supplied to the conduits designated "C" and "F," respectively, the pitch changing mechanism rotates the propeller blades axially to coarsen or to fine the pitch. It is of course well known that a coarse pitch tends to increase the engine load and to decrease the engine speed, while a fine pitch tends to decrease the engine load and to increase the engine speed. Means not shown is normally provided to adjust the throttle of the engine to the desired power output.

The principal elements of the synchronizing system illustrating one embodiment of the invention comprise a source of hydraulic fluid under regulated pressure, as for example a tank 16 and a gear pump 17 with pressure relief valve 18;

a master speed device 20, as for example, an electric motor, with a settable speed governor (not shown); a rotary hydraulic pulsing valve 40, or equivalent, driven by the master speed device 20 and functioning therewith as a periodic impulse generator and rotary speed setter; and a rotary hydraulic synchronizing valve, or equivalent, as for example valves 50, 51, driven by each controlled engine and functioning as a speed comparator and speed regulator; and accessory conduits and valves for connecting the elements of the hydraulic system and for regulating the supply of hydraulic fluid to the hydraulic controls.

An important accessory element of the illustrative system of the invention is the safety clutch device 30 coupling the master speed device 20 to the pulsing valve 40 which acts to disconnect the pulsing device from the master speed device in the event the speed of the master falls below a predetermined value, or exceeds another predetermined value. The pulsing valve 40 acts to cut off the supply of hydraulic fluid to the synchronizing valves 50, 51 in such event, thereby to place the propeller controls in safe condition and solely under manual control.

A suitable form of master speed device 20 is an electric motor equipped with a speed governor with suitable settable means for adjusting the speed to any desired rate within a predetermined range. Such governor controlled motors being well-known and in common use, detailed description herein is deemed unnecessary.

The master speed device 20 drives by means of a shaft 21 and a centrifugal clutch device 30, termed the automatic safety clutch, the rotary pulsing valve, as indicated at 40. The pulsing valve is provided with a rotor 42 housed in a fluid tight casing 41 having two ports 43, 45, the first named connecting with the conduit 19 from pump 17, and the second to conduit 46 leading to conduits 47 and 48 connected with the synchronizing valves 50, 51 respectively.

The rotor 42 is positively driven by safety clutch 30 at the speed of the master speed device 20 or in fixed ratio thereto. The port positions 43, 45 and the cut away portion 44 of rotor 42 are so co-ordinated, as indicated in the diagram Fig. 4 that during a small part of each revolution of rotor 42 hydraulic fluid from pump 17 has passage through the valve. Thus timed hydraulic pulses indicating the speed of the master speed device are provided to the operating circuits of the hydraulic system.

Each of the engines 10 and 11 drives a rotary synchronizing valve, or equivalent, as indicated at 50, 51, respectively, of identical construction and connected by conduits 47 and 48 to conduit 46 carrying the timed fluid pulses from valve 40.

Referring now to Figs. 1 to 4 inclusive, each rotary synchronizing valve may comprise a fluid tight casing 52, and a disc shaped rotor as indicated at 53, the latter being positively driven at the speed of the associated engine, or in fixed ratio thereto. Each casing 52 is provided with a radial port 54 located at the median plane of the casing, and two longitudinal ports located in the same diametral plane as middle port 54 and extending from opposite sides of the casing 52, as indicated at 55 and 56. Each rotor is closely fitted in its casing, except for two arcuate channels 57, 58 cut in opposite edges of the rotor rim as indicated in Figs. 2 and 3.

Referring particularly to Fig. 4, which shows diagrammatically the rim of rotor 53 in linear

development and in schematic relation to the three ports of the casing 52, it will be noted that arcuate channels 57 and 58 extend over a semi-circular arc and at their widest portion are cut into the rim of rotor 53 until only one third of the face remains. At two opposite points on the rim, indicated at 61 and 62, vanes are thus formed which separate the arcuate channels. It is obvious that when either of these vanes is passing the middle port 54, the flow of hydraulic fluid is checked, hence these relative positions may be termed cut-off points. At other rotor positions fluid can pass to one side port or the other via the continuous channel. The vanes are shaped so that the flow of fluid is gradually reduced as the cut-off points are approached.

The synchronizing valve acts both as a speed comparator and as a speed corrector. Assume that the direction of rotation of the master speed device and the engine is clockwise as indicated by the arrows at the bottom of the diagram; also that at the moment the vane 61 covers the middle or entrance port 54 coincident with the arrival of the timed fluid pulses from the pulsing valve 40. Thus for the moment, no speed regulation takes place. However, in the event the engine speed is fast, rotor 53, which rotates with the engine speed, will rotate relatively clockwise thus moving to the right—as viewed in Fig. 4—and bring channel 57 under entrance port 54 co-incident with the arrival of the timed pulses. So long as this situation continues, the timed pulses will pass out port 55 and into conduit "C," causing the propeller pitch controls to initiate speed retarding action.

If, on the contrary, the engine speed is slow, rotor 53 will move counter-clockwise, or to the left as seen in Fig. 4, whereupon channel 58 will conduct the timed fluid pulses to port 56 and eventually into conduit "F" thereby initiating speed regulation in the opposite sense from the first case, that is to accelerate the engine speed. Accordingly, channel 57 can be regarded as the "Retardation" initiator, while channel 58 can be regarded as the "Acceleration" initiator. More extensive analysis will show that regardless of the assumed initial speed conditions, the synchronizing rotor will initiate the proper corrective action to bring the engine into synchronism with the master speed device.

Referring again to Fig. 1, the improved hydraulic apparatus described operates to regulate the speed of each engine to establish and maintain synchronism of each engine with the master speed device in the following manner: For each rotation of the master speed device 20, the pulsing valve 40 admits a pulse of hydraulic fluid under pressure to conduit 46 and thence to conduits 47 and 48. Assuming that engine 10 is running fast relative to the master speed device 20, the rotor 53 of synchronizing valve 50 will rotate in leading phase relation and port 55 will be uncovered by retarding channel 57 in communication with that port, as indicated for engine 10, permitting the fluid pulses to enter conduit 65 and thence proceed to conduit "C" which controls the pitch changing mechanism to coarsen the pitch, thereby increasing the load on the engine and reducing the engine speed. When the engine speed is reduced below that of the master speed device, rotor 53 will rotate in lagging phase relation, and the accelerating channel 58 will come opposite port 54 coincident with the arrival of the fluid pulses, as indicated

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by valve 51 of engine 11. Thereupon, the above described events will take place in reverse to increase the engine speed. When the engine speed is regulated to that of the master speed device, the neutral vane 61 will cover the port 54 coincident with the arrival of the synchronizing pulses, terminating the corrective action for the time being, thereby establishing synchronism.

The improved synchronizing apparatus thus acts to compare the speeds of the master speed device and the engine and, when the speeds are different, to apply proper corrective control to bring the engine speed into synchronism with that of the master speed device. As the controlled engine approaches synchronism, the neutral vane reduces the corrective action until it becomes nil when synchronism is established. The synchronizer apparatus thus automatically provides a correction rate proportional to the departure from synchronous speed, resulting in so-called "dead-beat" speed regulation. It will be noted that the synchronizing system of the invention will produce exact synchronism of each engine with the master speed device, since any difference in speed is cumulative and will eventually be corrected. Obviously, additional engines could be synchronized by a simple duplication of the synchronizing apparatus which applies to the individual engine.

Referring again to Fig. 1 in connection with Fig. 5, it is to be noted that the rotor 42 of pulsing valve 40 is hydraulically unbalanced, that is, when the opening 44 comes opposite the entrance port 43 and before exit port 45 is uncovered, the pressure of the hydraulic fluid tends to force the rotor 42 to the opposite side as indicated by the arrow in Fig. 5. As a consequence, when the rotor 42 is uncoupled from the master speed device by the double safety clutch as mentioned above, the rotor 42 will naturally come to rest in the off-position as shown in Fig. 4. This feature automatically renders the synchronizing system non-operative whenever the pulsing valve is allowed to come to rest, whereupon the pitch adjustment is solely under manual control.

Suitable manual control valves may be provided for each engine, as for example the three-way rotary valves 70, 71 shown in the diagram of Fig. 1, to subject the engines to direct manual control of the propeller pitch independently of the usual throttle controls. Each manual control valve is preferably connected in the hydraulic circuits between the fluid source 17 and the conduits "C" and "F" leading directly to the propeller controls. These valves may be of well-known type in which a rotary member 73 is actuated by a handle 75 to cut-off the fluid supply or to divert it to one or the other of two conduits 76 and 77 leading to the propeller control conduits "C" and "F" respectively. Each manual control valve is thus effective to cause actuation of the associated propeller to fine or coarsen the pitch of the blades, whether or not the synchronizing controls are in operation. With this arrangement, the pilot can manipulate the manual controls to set the blades at any desired pitch at any time, such as for example, in starting up the engines or in emergencies.

Suitable manual hydraulic valves, of known type, as for example valve 80, may be provided to enable the synchronizing hydraulic circuits to be turned on or shut off as desired.

Referring to Fig. 6, which shows an alternative arrangement of the manual control valves, lines 19 and 46 may be connected by a 3-way valve 80a (in lieu of valve 80) and another 3-way valve 80b

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connected in line 46 as shown. With this arrangement, by properly setting valve 80b the synchronizing pulses may be applied by means of manual control valves 70, 71 to either or both propellers, thereby to obtain a micrometric adjustment of the pitch for purposes of synchronization. By properly setting valves 80a and 80b pressure fluid may be supplied to valves 70, 71 as before.

Finely adjustable valve means, as for example needle valves 81, 82, 83 and 84 indicated in Fig. 1, may be provided to regulate the drainage of fluid from the propeller hydraulic controls. These valves provide a ready means of adjusting the rate of hydraulic action of the synchronizing apparatus to be applied smoothly under various operating conditions. This adjustment feature enables the synchronizing apparatus of the invention to be applied to a wide variety of sizes and types of engines working under various load conditions with good results.

Referring now to Fig. 7 which shows generally and schematically another embodiment of the synchronizing method of the invention, it is assumed for purposes of illustration that the system to be synchronized comprises two engines, one under the independent control of an adjustable speed governor of known centrifugal type. Since the requisite apparatus may consist of components of known types which may vary in details of construction, the system is shown schematically, the components being arranged for convenience in illustration and non-essential details of the apparatus being generally omitted.

Engine No. 1 is assumed to function as the master speed setting device, while engine No. 2 is assumed to function as the slave or follower engine, whose speed is so regulated to establish and maintain synchronism of the system as a whole. Each engine is illustrated as having an independent source of hydraulic fluid, indicated generally by tanks T1, T2 and pumps P1, P2. The speed of engine No. 1 is assumed to be under the control of an adjustable, constant-speed centrifugal governor which hydraulically actuates the pitch changing mechanism, as for example that shown and described in U. S. Patent No. 2,392,364 to F. W. Caldwell et al., issued Jan. 8, 1946. It is to be expressly understood however that the method described can be applied to other types of engines and prime movers employing hydraulic governors which actuate throttles, fuel injectors, and other means whereby the speed thereof can be regulated. As will become evident, other engines could be added to the system and, by application of the method of the invention and mere duplication of the apparatus illustrated, can be synchronized with the master engine in the same manner as engine No. 2.

In applying the method of the invention, engine No. 1, as the master speed setter, may be provided with a device, generally termed an impulse generator IG, for generating timed fluid impulses each indicative of the master speed. This device comprises essentially a cam-driven small plunger 63 which works tightly in a miniature cylinder so as to generate a pressure wave or impulse in an impulse transmission line, indicated generally at 46, upon each quick stroke of the plunger. The cam 64 may have a single lobe, as shown, and may be rotated by a drive shaft 60 at engine speed, in which case each timed impulse represents one revolution of the engine, or it may be driven at some fixed ratio to the engine speed, say at half-speed. An impulse generator

suitable for present purposes is described in U. S. Patent No. 1,372,944 to G. Constantinesco issued March 29, 1921. The line 46 should be kept under hydraulic pressure, and is connected to the pressure line of the governor for that purpose, as shown.

Engine No. 2, representing any follower engine, may be provided with an impulse responsive device 40a, generally termed an impulse motor, which in this case actuates a valve plunger 42a arranged so as to produce a timed fluid pulse in a local hydraulic line leading to the synchronizing valve as described hereinafter. This device comprises essentially a spring-opposed valve plunger 42a working tightly in a miniature cylinder as shown. The plunger spring should be strong enough to hold the valve plunger 42a in closed position against the normal pressure in the impulse transmission line 46. An impulse motor adaptable for present purposes is described in the Constantinesco patent cited above.

Engine No. 2 may also be provided with a reciprocating valve 51a of known type, functioning as a synchronizing valve, which may be driven by a cam 61 mounted on a drive shaft 60' driven at the same speed ratio as the impulse generator. As shown, the synchronizing valve plunger 53a is driven by an eccentric cam, and hence makes one reciprocation for each revolution of its drive shaft 60'.

A locking valve LV, of known type, is connected in the hydraulic circuit between the synchronizing valve and the lines C and F leading to the propeller, thereby normally to isolate these portions of the hydraulic circuits, as is well understood.

The operation of the arrangement described is as follows: It is assumed that the two engines are running and that their speeds have been regulated to parity by adjusting their throttles, that is, the engines have been adjusted to approximately the same speed but not to an exact synchronous speed. Further, it is assumed that a timed impulse has just been transmitted and received, and the synchronizing valve 51a is in mid position. Under these assumptions the instantaneous position of valve 51a could indicate a condition of synchronism, or that the follower engine was lagging or leading by an even number of revolutions.

If it be assumed that engine No. 2 is leading, on following revolutions cam 61 will gradually advance clockwise as indicated by the arrow, relative to the successive openings of pulsing valve 46a; and consequently local hydraulic pulses, corresponding to the received timed impulses, will be admitted by synchronizing valve 51a to the top-half of the lock valve LV. Responsively thereto, the floating plunger of the lock valve will open line F to exhaust and simultaneously the local pulses will enter line C, thereby coarsening the pitch by small increments. This coarser pitch will gradually slow down engine No. 2, causing an eventual establishment of true synchronism, with the system again functioning in the condition illustrated.

If, conversely, it has been assumed that engine No. 2 was lagging, synchronizing valve 51a would gradually open in the other direction relative to the timed pulses, thus admitting local pulses to the lower half of lock valve LV. This would cause line C to be opened to exhaust and local pulses to be admitted to line F, thereby fine-tuning the pitch and causing the engine to speed up,

again causing an eventual establishment of true synchronism.

It should be noted that the synchronizing action is responsive to the phase of the follower relative to that of the master. The synchronizing action thus amounts to regulating the phase of the follower to conform with that of the master, and will occur at any speed to which the governor of the master engine may be adjusted; the synchronizing means acting to make up any difference between the actual speeds of the two engines.

Assuming synchronism has been established as described, a change of relative phase will precede any change of speed to which the governor of the master engine would be responsive, hence the synchronizing action is inherently more sensitive than the governor action. It follows that a governor of low sensitivity and high stability may be employed to regulate the speed of the master engine with practical advantages well known in the art, yet accurate synchronization of the slave engine will be maintained during variations in the speed of the master engine. Furthermore, once synchronism is established any momentary differences in speed will be made up, hence the average speeds of the two engines will be exactly equal. Moreover, a uniform phase relation will be maintained, and in practice this relation can be adjusted to minimize vibration effects, in well-known manner.

A 3-way valve 80c may be connected in the hydraulic circuits as shown, and by manipulating this valve, synchronizing pulses may be applied to the propeller driven by engine No. 2 as desired, as for example in starting up or for purposes of manual synchronization as before described.

Referring now to Fig. 8 which shows generally and schematically another embodiment of the method of the invention, in this case it is assumed by way of example that two engines are to be employed for driving two independent generators connected in parallel in an alternating current system. In such applications, both engines are required to run at the same synchronous speed, thereby to maintain a predetermined constant frequency of the generated current. As is well understood, ordinary centrifugal governors are unable to maintain a constant speed in such systems, because the speed set by the governors varies with the load, due to the speed droop characteristic. It will now be explained how the method of the invention can be applied to supplement the action of centrifugal speed governors, so as to maintain a constant frequency in an A. C. system.

It is assumed that each of the two engines is equipped with an adjustable-speed hydraulic governor SG of known type, which governors control the fuel supplied to the engines in well-known manner as indicated schematically. The main function of each governor is to measure the speed of the engine, and to regulate the fuel so as to maintain a substantially constant speed during sudden load variations. Since the governors are capable of continuous action, while the synchronizing means is capable only of intermittent action, it can be assumed that the governors can override the synchronizing action in event of sudden and large changes of load. As indicated schematically the governors each control a pilot valve plunger VP which in turn controls the admission of pressure oil to a power

piston PP which regulates a fuel valve supplying the engine.

A master speed setter, which may take the form of a synchronous motor SM supplied with A. C. at the desired frequency from an external source, drives two impulse generators IG, as in the first example. Each engine may be provided with an impulse motor driving a pulsing valve 40a, a synchronizing valve 50a, 51a and a lock valve LV, these being connected hydraulically to actuate the power piston PP, as indicated. Each power piston is therefore under the joint control of the governor and the synchronizing means.

As before it is assumed that the governors have been adjusted to approximately synchronous speed and the control elements are in mid-position, indicating either a condition of synchronism, or an initial lead or lag due to lack of precise accuracy in the governor settings.

If it be assumed that engine No. 1 is leading, cam 67 will advance clockwise relative to the arrival of the synchronizing impulses, which indicate the synchronous speed, and consequently the synchronizing valve 50a will admit synchronizing pulses to the top half of the lock valve LV, the floating plunger of which will open the lower check valve, permitting fluid to escape from the underside of power piston PP, thus reducing the fuel supply to the engine. Engine No. 1 will therefore gradually slow down until it runs at the synchronous speed, whereupon the hydraulic elements will be restored to neutral position, as illustrated.

If it be assumed that engine No. 2 is lagging, cam 67' will move counterclockwise relative to the arrival of the synchronizing impulses, and consequently synchronizing valve 51a will admit synchronizing pulses to the lower half of lock valve LV, and thence to the bottom of power piston PP. Power piston PP will thereby be gradually raised, admitting more fuel to the engine and increasing its speed to synchronous speed.

It is well understood in the art of governors that the relative loads assumed by two engines driving parallel connected alternators will normally depend upon the droop characteristics of the governors. However, it is to be noted that in the present embodiment of the method of the invention, the position of the power piston PP and hence of the fuel valve can be varied by the synchronizer means independently of the governors. It follows that the load division is no longer dependent upon the droop characteristics of the governors, but can be adjusted independently of the governors. Manual 2-way valves 70, 71 may therefore be connected in the hydraulic circuits as shown to enable an operator to adjust the load division as desired. To facilitate this, load indicators, not shown but of known type, may be employed to advantage.

In summary, it is to be noted that in each embodiment of the method of the invention, definite information indicative of the master speed is introduced into the speed control system by means of timed hydraulic impulses. The general method thus comprises the steps of producing a series of timed hydraulic impulses indicative of a master speed, and utilizing these impulses to compare the speed of an engine with the master speed and to apply corrective speed control measures to an engine which may be out of synchronism with the master speed.

While certain arrangements have been illustrated in the accompanying drawings and here-

inabove described for the purpose of disclosing the invention, it is to be understood that the invention is not limited to the particular arrangements described, but that various changes in the component parts and arrangement of these parts may be resorted to within the scope of the subjoined claims.

Having now described the invention so that others skilled in the art may clearly understand the same, what it is desired to secure by Letters Patent is as follows:

I claim:

1. Hydraulic apparatus for synchronizing the propeller driving engines of a multi-engine aircraft, each engine having means responsive to hydraulic fluid under pressure to control its speed, comprising, a rotary master speed device for providing a reference speed, a pump connected therewith supplying hydraulic fluid under pressure, rotary hydraulic valve means driven by said master speed device and connected in the output channels of said pump for generating timed hydraulic impulses representative of the speed of said master speed device, and rotary hydraulic valve means driven by each engine for comparing the engine speed with the reference speed and for applying corrective hydraulic pressure to the responsive speed control means.

2. Hydraulic apparatus for synchronizing the speed of an engine with the speed of a master speed device comprising hydraulic control means for varying the load on the engine, an hydraulic impulse generator driven by said master speed device, an hydraulic valve device having a portion rotatable at engine speed, and means for utilizing impulses from said impulse generator to compare the engine speed with the master speed device and to vary the adjustment of the speed of the engine inversely to and proportionally to the difference in speed between the engine and the master speed device.

3. Hydraulic apparatus for synchronizing the speed of engines comprising a master speed device for establishing a reference speed, an engine speed control for each engine, hydraulic adjusting means for each engine speed control, an hydraulic impulse generator driven by each engine, hydraulic valve means including a rotatable portion driven at engine speed for utilizing timed impulses from said impulse generator to compare the engine speed with the reference speed and to apply corrective adjustments to the engine speed controls inversely and proportionally to the difference in speed between the engine speed and the reference speed.

4. In hydraulic apparatus for synchronizing a plurality of prime movers one of which is equipped with hydraulic control means and the other with a timed hydraulic impulse generator, rotary hydraulic valve means for comparing the speed of the prime movers and for applying corrective hydraulic control to the one of said prime movers equipped with hydraulic control means which is out of synchronism to adjust the speed of said prime mover to conform with the speed of the other prime mover.

5. Means for controlling and synchronizing the speed of an engine with a settable master speed device, said engine driving a controllable pitch propeller having hydraulic means for controlling the pitch of said propeller, a hydraulic fluid pump, means controlled by said master speed device for producing impulses in the output fluid of said pump timed proportionally to the speed of said master speed device, a hydraulic device

driven proportionally to the speed of said engine for utilizing said impulses to compare the speed of said engine with that of the master speed device and for actuating the hydraulic control means of its associated propeller to correct any speed difference between said engine and said master speed device, and fluid conduits for operatively connecting the aforesaid hydraulic elements.

6. Hydraulic apparatus for synchronizing the speed of an engine with that of a reference speed comprising hydraulic means for controlling the speed of said engine, means for producing timed hydraulic impulses indicating said reference speed, a rotary hydraulic valve driven proportionally to the engine speed for comparing the engine speed with the reference speed and for automatically actuating said hydraulic speed control means so as to correct any speed difference, and fluid conduits for operatively connecting the aforesaid hydraulic elements.

7. In combination with an engine having hydraulic speed regulating means associated therewith, hydraulic synchronizing apparatus comprising an hydraulic impulse generator, a master device for controlling said impulse generator to produce timed hydraulic impulses indicative of the speed of said device, hydraulic valve means operatively associated with said speed regulating means and said impulse generator for comparing the speeds of said engine and said master device and for initiating the automatic correction of any difference in the speed of said engine from the speed of said device.

8. In combination with the combination of claim 7, means for regulating manually the said hydraulic speed regulating means independently of said synchronizing apparatus.

9. In apparatus for synchronizing the speeds of a plurality of engines, the combination including a master speed setter, means for producing timed hydraulic impulses indicative of the speed of said master speed setter, means for utilizing said impulses to compare the engine speeds with the master speed, and means for controlling the speeds of said engine in accordance with the comparison so as to correct the speed of an engine which may be out of synchronism with the master speed setter.

10. In apparatus for synchronizing the speed of a plurality of engines, the combination including a master speed setter, means for producing a series of timed hydraulic impulses indicative of the speed of said master speed setter, means for utilizing said impulses to compare the engine speeds with the master speed, and means for applying corrective hydraulic speed control measures to any of said engines which may be out of synchronism with the master speed setter as determined by the comparison.

11. In apparatus for synchronizing the speed of an engine with respect to the speed of a master speed setter, the combination which includes means for transmitting a series of timed hydraulic impulses indicative of the speed of said master speed setter, means for utilizing said impulses to compare the engine speed with the master speed, and means for varying the engine speed in accordance with the comparison so as to correct any speed difference.

12. In apparatus for synchronizing the speed of an independently driven rotating element with respect to a reference rotary speed, the combination which comprises means for generating a series of timed hydraulic impulses indicative of

said reference speed, means for transmitting said impulses to said rotary element, means for utilizing said impulses to compare the timing of said impulses with the speed of said rotating element, and means for utilizing such comparison to regulate the speed of said rotary element in such manner as to establish and thereupon maintain synchronism of the speed of said rotating element with said rotary speed.

13. In apparatus for synchronizing the speed of an independently driven rotating element with respect to a reference rotary speed, the combination which comprises means for generating a series of timed hydraulic impulses indicative of said rotary speed, means for transmitting said series of impulses for utilization at said rotating element, means for utilizing said impulses to compare the speed of the rotating element with the reference speed, and means for regulating the speed of the rotating element in accordance with the comparison thereby to establish and maintain a predetermined ratio between said speeds.

14. In a synchronous mechanical system comprising a master speed setter and a plurality of engines equipped with speed regulating means, apparatus for synchronizing the speeds of any of the engines with that of the master speed setter which includes means for generating periodic hydraulic impulses indicative of the speed of the master speed setter, means for transmitting said impulses to said engines, means for utilizing said impulses to compare the speed of each of the engines with that of the master speed setter, and means for regulating the speed of any engine out of synchronism with the master speed setter in such manner as to establish and thereupon maintain it in synchronism with said master speed setter.

15. In a system for synchronizing the speeds of a plurality of engines, each equipped with speed regulating means, with that of a master speed setter, the combination of means for generating periodic hydraulic impulses indicative of the speed of said master speed setter, means for transmitting said impulses to points of utilization, means for utilizing said impulses to compare the speed of each of the engines with that of the master speed setter, and means for regulating the speeds of the engines in accordance with the results of the comparison to establish and maintain synchronism with the master speed setter.

16. Apparatus for synchronizing the speed of a prime mover with respect to a reference speed having, in combination, means for regulating the speed of said prime mover, means for generating timed hydraulic impulses indicative of the reference speed, means for transmitting said hydraulic impulses, means for receiving said hydraulic impulses, means operatively associated with said means for receiving said hydraulic impulses and said means for regulating the speed of said prime mover for comparing the prime mover speed with the reference speed, and means for correcting the prime mover speed in accordance with such comparison so as to establish and maintain a predetermined synchronous relation between the prime mover speed and the reference speed.

17. In combination with the combination of claim 16, means for controlling the speed of said

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prime mover independently of said synchronizing apparatus.

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