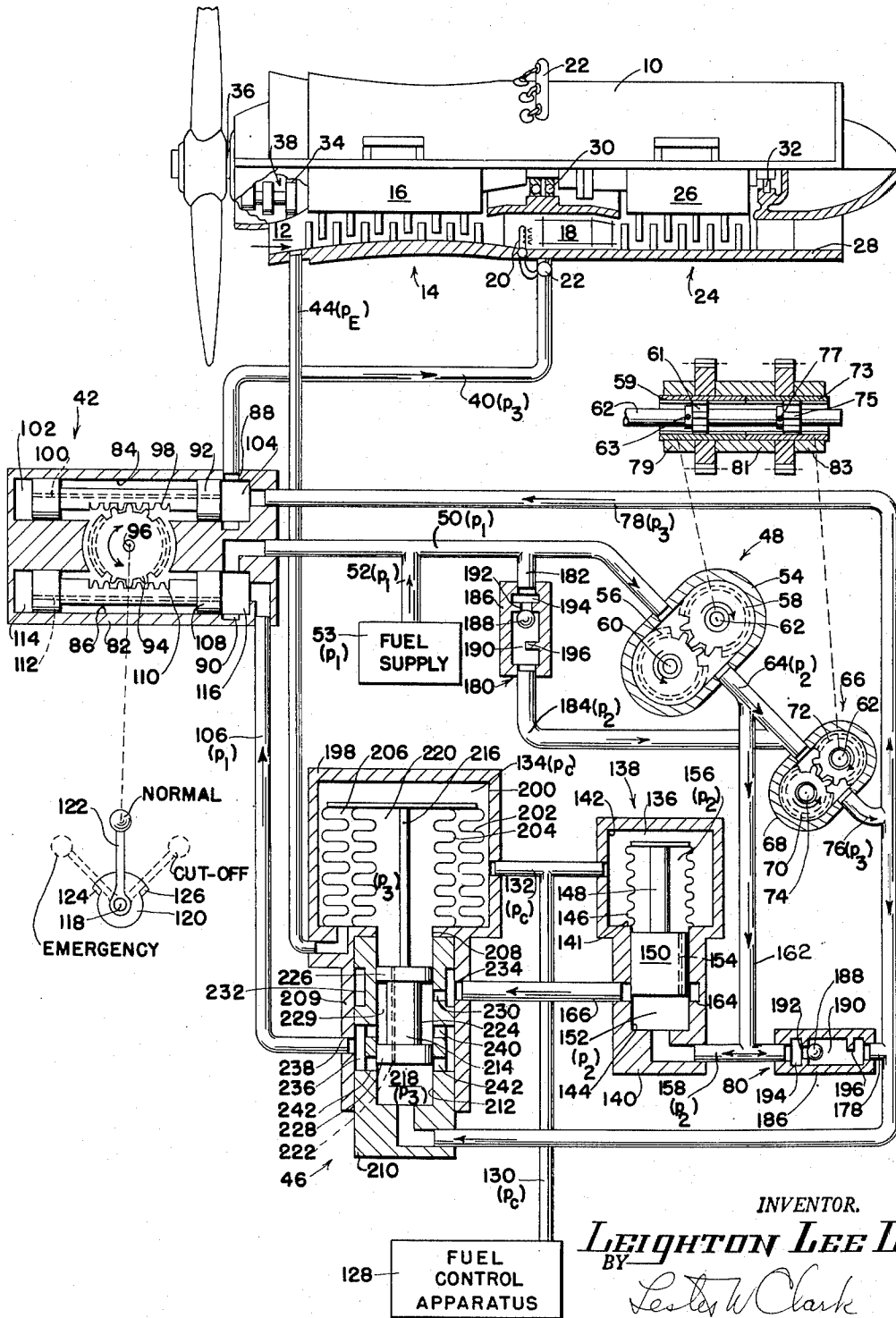


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FLUID PUMP CONTROL APPARATUS FOR INTERNAL-COMBUSTION
TURBINE ENGINES
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FLUID PUMP CONTROL APPARATUS FOR
INTERNAL-COMBUSTION TURBINE EN-
GINES

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The present invention applies to fuel pump control apparatus for an internal combustion engine, and relates particularly to a dual fuel pump system in which failure of either pump does not impair performance of the engine.

Fuel pump control apparatus to which the present invention is related is employed for delivering fuel to internal combustion engines, including those suitable for jet-propulsion, propeller-propulsion or combined propeller-and-jet propulsion of aircraft. Such engines usually include an air compressor, one or more combustion chambers, a turbine, and a tail pipe, in the stated order of arrangement. Associated with the engine there is fuel control apparatus responsive to the engine speed, temperature, and altitude of flight, or to some combination of such engine operating conditions, for determining the fuel pump delivery necessary to satisfy the engine operator's requirements in terms of engine speed, torque, or brake-horsepower. The fuel pump control apparatus is therefore responsive to the fuel control apparatus.

It is an object of my invention to provide improved fuel pump control apparatus for an internal combustion engine, said apparatus including two pumps and being responsive to a control pressure supplied thereto which is a function of the desired fuel pump delivery.

Another object of my invention is to provide a dual fuel pump system and improved means for control thereof to render the normal working load on each pump approximately one half the total pumping load, thereby increasing life expectancy and quality of performance of the pumps.

A further object of this invention is to provide in such apparatus improved means whereby failure of either pump in such a dual pump system does not impair performance of the engine.

Still further objects of the present invention are to provide improved manually operated means for cutting off the supply of fuel from the fuel pumps to the engine, and to provide improved means for manually controlling the fuel flow in an emergency created by failure of either the fuel control apparatus or the fuel pump control apparatus.

Other objects and advantages of the present invention will become apparent from a consideration of the specification, claims, and drawing included herein.

The drawing, shows, somewhat diagrammatically, fuel pump control apparatus embodying the principles of my invention together with the re-

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lationship of such apparatus to an internal combustion engine and to fuel control apparatus associated with said engine.

Referring to the drawing, there are shown the principal elements of an internal combustion engine suitable for propeller-propulsion or propeller-and-jet propulsion of aircraft, as follows: a supporting casing 10, an air inlet 12, a multi-stage compressor indicated as 14, a compressor rotor 16, a combustion chamber 18, a number of fuel discharge nozzles one of which is designated 20, a generally circular fuel manifold 22, a multi-stage turbine indicated as 24, a turbine rotor 26 connected to the compressor rotor 16, a tail pipe 28 for discharge of combustion gases from turbine 24, a center bearing 30 and end bearings 32 and 34 supported by casing 10, a propeller shaft 36, and a gear train 38 connecting shaft 36 to 16.

The principal elements of the pump control apparatus shown in the drawing are identified in the following brief account of its normal operation which is generally defined to indicate fully automatic functioning of all elements of the fuel pump control apparatus in absence of failure of any element whatever. Fuel enters a fuel supply conduit 52 connected to a source of fuel 53 at a pressure (p_1) and flows therefrom thru a conduit 50, a primary pump 48 and a secondary pump 66 connected in series with pump 48 by a conduit 64, and from secondary pump 66 at a pressure (p_3) thru connected conduits 76 and 78, past a first piston valve 92 in a valving device 42, and thru a conduit 40 to manifold 22 of the engine. The capacity of the primary pump 48 is approximately 10% greater than that of the secondary pump 66, the excess fuel discharged by pump 48 at a pressure (p_2) being by-passed thru a pair of conduits 162 and 158 thru a relief valve mechanism 130 and a conduit 166, thence flowing unrestrictedly thru a control valve mechanism 46 and a conduit 106, past a valve 108 in valving device 42, to conduit 50. The relief valve mechanism regulates the pressure (p_2) in conduits 158, 162 and 64, maintaining this pressure equal to the value of the control pressure (p_c) which is transmitted to mechanism 130 and 48 thru a conduit 132 and another conduit 130 connected to a fuel control apparatus diagrammatically shown as 128. The control pressure (p_c) is a function of the desired fuel flow. The control valve mechanism 46 is connected to conduit 78 and regulates the pressure (p_3) therein and hence the pressure downstream from secondary pump 66 by allowing part of the fuel discharged by pump 66 to flow thru mechanism 46

into conduit 106 and thence past valve 103 in valving device 42 to conduit 50 at the pressure (p_1). The pressure (p_3) in conduit 78 is regulated in response to the control pressure (p_c) at a value approximately twice that of pressure (p_c). Since, in normal operation, ($p_2=p_c$), the pressure rise across pump 48 is approximately (p_c-p_1), and, since the pressure ($p_3\approx 2p_c$), the rise across pump 66 is approximately ($2p_c-p_c$); whence it follows that, considering (p_1) to be approximately atmospheric or other relatively low pressure, the rise across each pump is approximately equal to the value of gage pressure (p_c), the rise across both pumps being approximately ($2p_c$). The ratios ($p_2:p_c$) and ($p_3:p_c$) and hence the ratio ($p_3:p_2$) may be selected to provide any desired distribution of the total load between pumps 48 and 66.

The range of values of the control pressure (p_c) is predetermined by the design of fuel control apparatus 123, the pressure (p_c) being some function of such engine operating conditions as speed, torque, and brake-horsepower. The demand for fuel increases as the brake-horsepower increases, as the speed increases when the torque is constant, and as the torque increases when the speed is constant. In the embodiment shown the control pressure (p_c) increases as the desired fuel flow increases. It is conceivable, however, to employ fuel control apparatus providing a control pressure decreasing as fuel flow increases, in which case a modification of the fuel pump control apparatus shown in the drawing is necessary. In design of the fuel pump control apparatus, the capacity of secondary pump 66 must be slightly greater than necessary to satisfy maximum fuel requirements of the engine at the lowest value of engine speed applying to such maximum fuel flow. Prerequisite to design of the apparatus shown is provision of a range of values of control pressure (p_c) having an approximately 1:2 ratio with the corresponding values of the corresponding range of the pressure (p_3) of fuel delivered to the engine.

The valving device 42 is responsive to movement of a manually operated valve control lever 122 to cut off the flow from conduit 78 to conduit 40, thereby cutting off the flow to the engine and stopping the operation thereof.

In addition to the elements identified in the foregoing brief account of normal operation of the embodiment shown, there are two check valve mechanisms 80 and 180, respectively, and additional conduits which are required in the event of certain types of failure of one or more of the identified elements, as hereinafter described.

Again referring to the drawing in detail, the primary pump 48 is shown to include a body 54 having therein a pair of gears 56 and 58. Gear 56 is rotatable on a shaft 60 by gear 58, and gear 58 is fixed to a drive bushing 59 which has a splined coupling 61 connecting it to a main drive shaft 62 thru a shear pin 63. In the embodiment shown, shaft 62 is rotated by the engine at a speed proportional to the engine speed, but other suitable means of driving the shaft may be employed if desired.

Conduit 64 connects the outlet of primary pump 48 to the inlet of secondary pump 66 which is of approximately ten per cent less capacity than pump 48 but of similar construction, the normal delivery thru pumps 48 and 66 being substantially constant at any given value of pump speed when the mechanical condition of the pumps in respect to wear and pump clearances

is substantially constant. Included in pump 66 there is a body 68 having therein a pair of gears 70 and 72. Gear 70 is rotatable on a shaft 74 by gear 72 which is fixed to a drive bushing 73 having a splined coupling 75 connecting it to main drive shaft 62 thru a shear pin 77. Drive bushings 59 and 73 are rotatable in fixed bearings 79, 81 and 83. Provision of shear pins 63 and 77 is to forestall complete failure of the apparatus in the event of failure of a single pump. Thus, if either pump binds and the torque required for its rotation exceeds a predetermined value, the corresponding shear pin fails, stopping the one pump and allowing operation of the other to continue. Failure of either pump, therefore, resulting from binding or any other cause of stoppage or excessive torque does not impair rotation of the other.

The outlet of secondary pump 66 is connected by conduit 76 to conduit 78 which, in turn, is connected thru valving device 42 to conduit 40. Conduit 78 is also connected to control valve mechanism 46 and, thru a passage 118, to check valve mechanism 80, which is normally closed.

Valving device 42 includes a body 82 having therein a pair of parallel cylindrical bores 84 and 86, the left ends of which are closed by body 82. Near the right-hand ends of bores 84 and 86 there are two annular grooves 88 and 90, respectively. Groove 88 is connected to conduit 40 and a chamber 104 at the right-hand end of bore 84 is connected to conduit 78. Flow from conduit 78 to conduit 40 is controllable by means of piston valve 92 which is slidable in bore 84 in response to movement of a gear 94 mounted on a control shaft 96. Gear 94 engages a centrally located toothed portion 98 of the valve length which has a somewhat smaller diameter than that of bore 84. A channel 100 is provided in the valve to equalize pressures in chamber 104 and a corresponding chamber 102 at the left-hand end of bore 84, and to permit sufficiently rapid movement of a substantially leak-proof piston.

Similarly, groove 90 in bore 86 is connected to conduit 50 and a chamber 116 at the right-hand end of bore 86 is connected to conduit 106. Flow between conduits 106 and 50 is controllable by means of piston valve 108 which is like valve 92 and is similarly slidable in bore 86 in response to movement of gear 94 in relation to a toothed portion 110 of valve 108. A channel 112 is provided in valve 108 to equalize pressures in chamber 116 and a corresponding chamber 114 at the left-hand end of bore 86.

Shaft 96 in valving device 42 is connected to a shaft 118 rotatable in a fixed bearing 120. The manually operated valve control lever 122 is fixed to shaft 118 and is rotatable thru an arc determined by a pair of stops 124 and 126 which are located so that, when lever 122 is moved to the "emergency" position at the extreme limit of counterclockwise travel, gear 94 moves valve 92 leftward from the normal position shown in the drawing and simultaneously moves valve 108 toward the right to block groove 90, thereby closing the passage between conduits 106 and 50. Similarly, when lever 122 is moved to the "cut-off" position at the extreme limit of clockwise travel, gear 94 moves valve 108 leftward from the normal position shown and simultaneously moves valve 92 toward the right to block groove 88, thereby preventing flow from conduit 78 to conduit 40.

In the "normal" position shown, lever 122 is vertical and valves 92 and 108 just clear grooves

88 and 90, respectively. In this position, there is negligible or no pressure loss as flow occurs between conduits 78 and 40, or between conduits 106 and 50. Leftward movement of either valve from the "normal" position does not increase the flow area controlled by that valve; but such movement is accompanied by corresponding movement toward the right of the other valve, which therefore does restrict the area of flow past itself, the amount of such restriction depending on the extent of movement of lever 122 from its "normal" or vertical position. The valve control lever 122 is not to be confused with the engine control lever generally associated with the fuel control apparatus 128.

The fuel control apparatus 128 normally provides a control oil pressure (p_c) which is a measure of the desired fuel flow to the engine. Conduit 130 is connected to apparatus 128 for the flow of control oil at pressure (p_c) to conduit 132, the left-hand and right-hand ends of which are respectively connected to a closed chamber 134 in pressure control valve mechanism 46 and to a closed chamber 136 in relief valve mechanism 138.

Relief valve mechanism 138 has a body 140 with a generally cylindrical hollow interior, the upper end of which is of somewhat greater diameter than the lower end, there being a symmetrical step 141 between an upper cylinder 142 and a lower cylinder 144. A bellows 146 is fixed in cylinder 142 to step 141, chamber 136 being defined by cylinder 142, step 141, and the exterior surface of bellows 146.

A stem 148 attached to the lower side of the upper end of bellows 146 serves to transmit motion of bellows 146 to a piston valve 150 which is slidable in cylinder 144. A chamber 152 below piston 150 is connected by a channel 154 in the piston to a chamber 156 inside bellows 146, the pressures in chambers 152 and 156 thus being equalized. An annular groove 164, in guide 144, is connected to conduit 166 for permitting flow of fuel along a path including conduit 166, chamber 152, groove 164, and conduit 166, in the stated order. When such flow occurs, motion of piston 150 is effective to vary the effective area of flow into groove 164, thereby varying the pressure (p_2) in chamber 152.

In relief valve mechanism 138, the effective area (A) of bellows 146 equals that of piston 150. Since the opposite forces acting on piston 150 due to identical pressures (p_2) in chambers 156 and 152 are equal and therefore ineffective to produce motion of the piston, the position of piston 150 is controlled by a balance between two other forces, as follows: a downward force ($p_c A$) due to the pressure (p_c) in chamber 136 acting on bellows 146 and an opposing force ($A \times$ the pressure in chamber 152) acting on the piston. Piston 150 seeks a position at which the stated forces are in equilibrium or at which the pressure (p_2) in chamber 152 equals the control pressure (p_c). It is apparent therefore that the pressure (p_2) in conduits 158, 162, and 64 is maintained at the value of the control pressure (p_c) of oil supplied to the fuel pump control apparatus by the fuel control apparatus 128.

Pressure control valve mechanism 46 includes a housing 198 in the upper end of which there is a generally cylindrical cavity 200 having as its centerline the vertical centerline of housing 198. The lower end of a bellows 202 is fixed to the lower end of cavity 200, chamber 134 being defined by the exterior of bellows 202 and the periphery of cavity 200.

A second bellows 204 inside bellows 202 has its respective ends fixed to the upper end of bellows 202 and to the lower end of cavity 200. A chamber 206 thus formed between bellows 202 and 204 is connected to a conduit 44 for transmission of the compressor inlet pressure (p_E) from the engine to mechanism 46.

A circular opening 208 is provided in housing 198 at the lower end of cavity 200 at the approximate center of the lower end of bellows 204. Housing 198 is extended downward from the opening 208 to form a substantially cylindrical shell 209 which serves to retain a valve guide 210 which is pressed into shell 209. Use of separate pieces 198 and 210 is for the purpose of facilitating machining of the guide 210.

Guide 210 has a cylindrical bore 212 in line with opening 208, the lower end of bore 212 being closed by the end of guide 210. A piston 214 connected to the top of bellows 204 and hence to the top of bellows 202, by means of a stem 216, is slidable in bore 212 in response to movement of bellows 202 and 204. There is a chamber 218 below valve 214 to which conduit 78 is connected. The respective pressures in chamber 218 and in a chamber 220 above valve 214 and inside bellows 204 are equalized by provision of a channel 222 in piston 214. Piston 214 is of a generally cylindrical shape and has an undercut 224 which provides an upper valve 226, a lower valve 228, and an annular chamber 229 inside bore 212.

Bore 212 of guide 210 has an upper port 230 connecting chamber 229 to an upper annular groove 232 on the outside of guide 210. Conduit 166 is connected to groove 232 and hence to chamber 229 thru an aperture 234 in shell 209 opposite groove 232. As shown, port 230 is unrestricted but it is valved by the lower face of upper valve 226 when bellows 202 and 204 are sufficiently contracted, as is subsequently explained. If desired, a multiple port arrangement may be employed instead of the single port 230 shown.

A lower annular groove 236 similar to groove 232 is provided approximately opposite lower valve 228. Shell 209 has an opening 238, opposite groove 236, to which conduit 166 is connected. At the upper end of groove 236 two like apertures 240 are provided in guide 210 which afford a passage of constant area from chamber 229, thru apertures 240, and past groove 236 to conduit 166 so that flow along this path is always unrestricted, the pressure in chamber 229 therefore always equaling the pressure (p_1) in conduit 166 when bellows 102 and 104 are not sufficiently contracted to cause closure of port 230.

At the lower end of groove 236 a pair of ports 242 is provided in guide 210 which provide passage from chamber 218 to groove 236 and into conduit 166. Any suitable number of ports 242 may be employed. Ports 242 are valved by the lower edge of lower valve 228, thereby restricting the area of flow from chamber 218 to conduit 166, when bellows 202 and 204 are sufficiently contracted, the degree of restriction depending upon the position of valve 228. Valves 226 and 228 and ports 240 and 242 are so disposed in relation to each other that, as bellows 202 and 204 contract, valve 228 first closes ports 242 and then valve 226 closes port 230.

The position of piston 214, and hence the position of valves 226 and 228, is determined solely by the balance of forces acting on bellows 202 and 204, since the same pressure (p_3) in chambers

220 and 218 acts directly on the piston to produce opposite forces of identical magnitude. The effective forces are equated as follows, for the condition of equilibrium which exists in steady state operation of control valve mechanism 46:

$$(\text{Downward force}) = (\text{sum of upward forces})$$

or

$$p_c A = p_E (A - a) + p_3 a$$

in which (A) and (a) are the effective areas of bellows 202 and 204, respectively. The quantity (A-a) is of small value and the value of pressure (p_E) is also small compared with the respective values of the pressures (p_c) and (p_3). Therefore, the force [$p_E (A - a)$] in the above equation is small and is neglected in the present discussion for purposes of simplification, whence it is possible to say that:

$$p_c A = p_3 a$$

or

$$(p_3) : (p_c) = A : a$$

In the embodiment shown, the area (A) of bellows 202 is approximately twice the area (a) of bellows 204; or $(A) \approx 2(a)$. It is apparent, that $(p_3) : (p_c) \approx 2:1$, or that the value of the pressure (p_3) in chamber 218 is approximately equal to 2(p_c) in normal operation. The normal function of control valve mechanism 46 is to regulate the pressure (p_3) in this substantially constant relationship with the control pressure (p_c).

NORMAL OPERATION—SUMMARY

Equally efficient primary and secondary pumps

In normal operation, valve control lever 122 is in its "normal" or vertical position; unrestricted flow may then occur thru valve mechanism 42, from conduit 78 to conduit 40, and from conduit 106 to conduit 50. Also, relief valve mechanism 138 regulates the pressure (p_2) at the outlet from primary pump 48 and hence at the inlet to secondary pump 66, at a value approximately equal to the value of the control pressure (p_c) supplied by the fuel control apparatus 128. Similarly, the control valve mechanism 46 regulates the pressure (p_3) at the outlet from secondary pump 66, at a value approximately equal to twice the value of the control pressure (p_c). Thus, in normal operation, both primary and secondary pumps 48 and 66 are functioning properly with the same or nearly the same efficiency and approximately one half of the total pumping load is imposed on each. The life expectancy of each pump is thereby approximately doubled and the character of pump performance is maintained at a higher level than would be possible with a single pump subject to wear resulting from carrying the entire pumping load. In normal operation, with both pumps about equally efficient, all fuel entering secondary pump 66 is delivered to it thru conduit 64 from primary pump 48.

Cutoff

When valve control lever 122 is moved clockwise to "cut-off" position, valve 92 in device 42 moves toward the right and blocks flow from conduit 78 thru chamber 104 and port 88 into conduit 40, regardless of the value of the control oil pressure (p_c). Cut-off is thus rendered immediately responsive to movement of lever 122 without any time lag such as might result by stopping the engine by first reducing the control oil pressure (p_c). The value of the pressure (p_3), in normal cut-off, continues to be regulated by

mechanism 46 as a function of the control oil pressure (p_c), there being no abnormal strain imposed on the system by movement of lever 122 to cut-off position.

Primary pump failure

When the primary pump 48 fails owing to stoppage or excessive torque, shear pin 63 fails, thereby allowing drive shaft 62 to rotate in splined coupling 61, and the secondary pump 66 continues to operate at the correct speed. Failure of primary pump 48 may also occur as a result of wear or other cause of a reduction of capacity which prevents it from maintaining a desired value (p_2) of fuel pressure in conduit 64. In general, therefore, failure may be considered a prohibitive capacity decrease whether such decrease is caused by wear or leakage due to inefficiency of a pump being driven at the correct speed or by reduction of the pump speed to zero by shear pin failure.

When primary pump 48 fails so that mechanism 138 cannot regulate the pressure in conduit 64 and hence at the entrance of secondary pump 66 at a value as great as that of the control pressure (p_c) relief valve mechanism 138 responds by lowering piston 150 to an extreme position at which the annular groove 164 is blocked off and flow from conduit 162 to conduit 166 is stopped. Thus, no pressure loss occurs in conduit 64 as a result of flow thru conduit 162 when the pressure (p_2) in conduit 64 is less than that of the control pressure (p_c), and all fuel delivered by primary pump 48 to conduit 64 enters secondary pump 66, under this condition.

The capacity of secondary pump 66 is sufficiently great to supply all fuel required by the engine at the value of the pressure (p_3) determined by the control oil pressure (p_c) acting in the control valve mechanism 46. As the pressure in conduit 64 decreases the pressure differential acting across secondary pump 66 is required to increase accordingly, pump 66 being subjected to the load imposed by the total normal differential across both pumps, when primary pump 48 fails completely, or to an increased load corresponding to the degree of partial failure of primary pump 48.

As the flow from primary pump 48 into conduit 64 decreases because of the failure referred to, secondary pump 66 continues to supply conduits 76 and 78 with sufficient fuel to maintain the value of pressure (p_3) determined by mechanism 46. Since secondary pump 66 cannot obtain sufficient fuel from primary pump 48, however, the value of the pressure (p_2) in conduit 64 continues to fall below that of the control pressure (p_c). When the value of pressure (p_2) in conduit 64 becomes less than the value of pressure (p_1) in conduit 50, provision is made for the flow of fuel from conduit 50, and thru a conduit 182 and a check valve mechanism 180, into a conduit 184 and thence to conduit 64, thereby by-passing primary pump 48 and permitting secondary pump 66 to operate at full capacity but at the greater rise measured by the increased value of the differential ($p_3 - p_2$).

Check valve mechanism 180 includes a housing 186 and a ball valve 188 movable in a chamber 190, chamber 190 being connected to conduit 184 and being separated by a seat 192 from another chamber 194 which is open to conduit 182. When the pressure (p_2) in chamber 190 exceeds the pressure (p_1) in chamber 194, ball valve 188 moves upward to seat 192, thereby preventing

flow thru mechanism 180. As previously indicated, however, when the pressure (p_2) in chamber 190 is less than the pressure (p_1) in chamber 194, ball valve 188 moves downward to a stop 196 in chamber 190 to allow fuel to flow thru check valve mechanism 180 along the path previously defined. If desired, a spring may be used to bias ball valve 188 toward open position in order to permit opening of the valve in response to a smaller decrease of pressure in conduit 64 when primary pump 48 fails.

It is thus apparent that, when primary pump 48 fails owing to inefficiency or stoppage to pump sufficient fuel into conduit 64 to maintain the value of pressure (p_2) equal to that of the control pressure (p_c), secondary pump 66 assumes the entire load or whatever increased load is necessary without changing the fuel flow to the engine and hence without impairing engine operation. In order to accomplish this, piston 150 moves to shut off fuel flow across mechanism 138, and check valve mechanism 180 operates to by-pass fuel around pump 48 to conduit 64 and hence to pump 66.

Secondary pump failure

When secondary pump 66 fails owing to stoppage or excessive torque, shear pin 77 fails, thereby allowing drive shaft 62 to rotate in splined coupling 73, and the primary pump 48 continues to operate at the correct speed. Failure of secondary pump 66 may also occur as a result of wear or other cause of a reduction of capacity which prevents it from maintaining desired values of the volume of flow and of the pressure (p_3) in conduit 78. As is true of primary pump 48, failure of secondary pump 66 may be generally ascribed to prohibitive capacity decrease, whether such decrease is caused by wear or leakage while the speed is correct, or by reduction of the pump speed to zero by shear pin failure.

When secondary pump 66 fails to produce a desired value of the pressure (p_3), primary pump 48 response by assuming whatever increased load is necessary to maintain pressure (p_3) at the desired value. Since, at any given pump speed corresponding to a given engine operating condition, the fuel delivery from primary pump 48 is constant; it is apparent that, when a normal proportion of the fuel discharged by pump 48 does not pass thru secondary pump 66, the pressure in conduits 64, 124, 162 and 188 increases to a value greater than the value of the control pressure (p_c). The initial effect produced by this pressure increase is to cause piston 150 in relief valve mechanism 138 to open to reduce the pressure (p_2) to the value of pressure (p_c). Thus mechanism 138 will not allow pressure (p_2) to exceed pressure (p_c) as long as there is unrestricted flow from conduit 186 across mechanism 46 to conduit 196 as has been the case thus far. Depending upon the nature and extent of failure of secondary pump 66, however, while mechanism 138 tries to maintain pressure (p_2) at the value of pressure (p_c), the pressure in conduit 78 has a value between zero and a value somewhat less than that of the pressure (p_c), since all fuel entering conduit 78 must pass thru pump 66 from conduit 64. As the pressure (p_3) in conduit 78 falls below the pressure (p_c) the control valve mechanism 46 responds by contraction of bellows 202 and 204 until valve 226 closes port 242, the bellows continuing to contract until valve 226 restricts port 230. The regulation of the pressure (p_3) in conduit 78 thus becomes a function

of valve 226 in relation to port 230 rather than of valve 228 in relation to ports 242 as is normally the case. Since the fuel flowing into conduits 76 and 78 from pump 66 is insufficient to maintain the pressure (p_3) in conduit 78 at a desired value, bellows 202 and 204 in mechanism 46 would continue to contract until valve 226 closed port 230, there then being no fuel whatever flowing from conduit 64 thru conduits 162 and 188 to mechanisms 138 and 46. As the pressure (p_2) in conduit 162 becomes equal to or exceeds the pressure (p_3) in conduit 78, however, which it does when pressure (p_2) is only slightly greater than (p_c), flow of fuel is permitted along a path from conduit 158, thru a check valve mechanism 80, and thence thru conduit 178 to conduit 78. The pressure (p_3) in conduit 78 is thereby restored to a desired value and its regulation by mechanism 46 is accomplished by movement of valve 226 in respect to port 230. Check valve mechanism 80 comprises elements identical with those of mechanism 180, conduits 158 and 178 being related to mechanism 80 as conduits 182 and 184 are related to mechanism 180.

Thus, when the secondary pump 66 fails, owing to inefficiency or stoppage, to pump sufficient fuel into conduits 76 and 78 to maintain a required value of the pressure (p_3), primary pump 48 assumes all or whatever additional load is required. In this condition of the apparatus, check valve mechanism 80 is open, relief valve mechanism 138 is ineffective, and regulation of pressure (p_3) is accomplished by the movement of valve 226 in mechanism 46 in relation to port 230. Fuel flow to the engine is unaffected and hence the engine performance is unimpaired by such failure.

Control valve failure—both pumps operating

In the event of failure of control valve mechanism 46 in a manner which prevents it from regulating pressure (p_3), whether or not as a result of a bellows leak or other cause, piston 214 moves upward or downward from its correct position depending upon the nature of such failure. The failure is made apparent by faulty engine performance.

When mechanism 46 fails and the fuel flow is low as is the case when pressure (p_3) is less than desired, valve control lever 122 is moved counterclockwise toward the "emergency" position, thereby causing valve 108 to restrict the flow of fuel from conduit 106 across valving device 42 to conduit 50. As such restriction is increased, the pressure (p_3) in conduit 78 increases and the position of the lever 122 is determined to produce the desired engine speed.

When mechanism 46 fails and the fuel flow is high as is the case when pressure (p_3) is higher than desired, valve control lever 122 is moved clockwise toward "cut-off" position, thereby causing valve 92 to restrict the flow of fuel from conduit 78 across valving device 42 to conduit 40. As such restriction is increased, the fuel flow to the engine decreases but the pressure (p_3) continues to remain higher than normally desired. In this case, control of fuel flow is accomplished by regulating the effective area of flow past valve 92 rather than by regulation of the pressure (p_3). The position of lever 122 is determined to produce the desired engine speed.

Manual control of fuel flow to either increase or decrease the flow disturbs the normal relationship between the respective functions of mechanisms 46 and 138 and between the pres-

tures (p_c), (p_2), and (p_3). Similarly, failure of mechanism 46 disturbs the normal relationship between the respective loads on the pumps, the effect being most serious when mechanism 46 fails in a manner which completely stops flow into conduit 106. When this occurs, the pressure (p_2) increases to a value which is a function of the speed and capacity of primary pump 48, the pressure (p_3) in conduit 78 correspondingly increases and hence the fuel flow increases. It is provided, however, that shear pin 63 associated with pump 48 fails under a lower overload than the corresponding pin 77 associated with pump 66 so that on occurrence of such failure of mechanism 46 pump 48 fails and pump 66 assumes the entire load. Proper movement of lever 122 toward cut-off will then reduce flow to the engine, cause deceleration, reduce the speed of pump 66, and enable the operator to maintain manual control for the duration of the emergency. The possibility of such failure is relatively remote since it is principally causable by binding of piston 214 in guide 212 and dependable means of avoiding such sticking are subject to provision in design.

Relief valve failure

Failure of relief valve mechanism 138 causes primary pump 48 to assume an additional load or substantially the total load, when the failure causes stoppage of flow into conduit 106, and flow occurs across check valve mechanism 80 from conduit 158 to conduit 78. If normal operation of control valve mechanism 46 continues, the pressure (p_3) determining the fuel flow to the engine is in correct relationship with the control oil pressure (p_c). If the failure causes piston 150 to rise so that pressure (p_2) has a low value approximating that of the pressure (p_1) in conduit 106, pump 48 carries little or no load and pump 66 carries the entire load, drawing fuel thru check valve mechanism 180 and requiring the apparatus to function about as in the case of primary pump failure previously explained.

In all cases, manual regulation of the pressure (p_3) and hence manual regulation of the rate of fuel flow to the engine is an emergency measure, the character of regulation being dependent upon the condition of flight and the skill of the operator.

Failure of either control valve mechanism 46 or relief valve mechanism 138, or of both, may result in a condition substantially equivalent to failure of the fuel control apparatus 128 which results in faulty regulation of the control oil pressure (p_c). If no other means of emergency control are available, lever 122 may be operated to provide manual control of the pumps when such failure of the fuel control apparatus occurs.

While the embodiment of my invention shown and described herein specified use of collapsible bellows as pressure responsive means, the invention does not preclude employment of pressure responsive pistons, diaphragms, or other suitable means.

Other terms and expressions which I have employed are used as terms of description and not of limitation, and I have no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described or portions thereof, but recognize that various modifications are possible within the scope of the invention claimed.

I claim as my invention:

1. Fluid pump control apparatus for a rotating associated therewith a source of fluid, a conduit

mechanism having for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of said fluid flow, and a device for producing a control pressure in said apparatus which is a selected function of the desired rate of said fluid flow and hence said speed; comprising: a connection for the flow of fluid from said source to said conduit, a pair of pumps in series in said connection for producing said flow, and means responsive to said control pressure for regulating the respective pressures in said connection between said pumps and in said conduit, so that said fluid flow and the speed of said mechanism are each a selected function of said control pressure.

2. Fluid pump control apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of said fluid flow, and a device for producing a control pressure in said apparatus which is a function of the desired rate of said fluid flow and hence said speed; comprising: a connection for the flow of fluid from said source to said conduit, a pair of pumps in series in said connection for producing said flow, first means responsive to said control pressure for regulating the respective pressures in said connection between said pumps and in said conduit; and second means effective, when one of said pumps fails so that said first means cannot maintain said conduit pressure at a value corresponding to a predetermined function of said control pressure, to cause the other of said pumps to deliver fluid to said conduit from said source so that said first means restores said conduit pressure to said predetermined value; whereby said conduit flow and hence the speed of said mechanism are predetermined functions of said control pressure.

3. Fluid pump control apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of said fluid flow, and a device for producing a control pressure in said apparatus which is a function of the desired rate of said fluid flow and hence said speed; comprising: connecting means including a pair of pumps in series therein for delivering fluid from said source to said conduit, first means for operating said pumps including a pair of shear pins, one of which is subject to failure when the torque required to operate the corresponding pump exceeds a predetermined value; second means effective, when said shear pin corresponding to either of said pumps fails, to cause the other of said pumps to produce flow to said conduit from said source, third means responsive to said control pressure for regulating said conduit flow by regulating the pressure in said conduit in a preselected relationship with said control pressure; and manually operated means for overriding said third means to control said conduit flow; whereby said conduit flow and hence the speed of said mechanism are functions of said control pressure, said conduit flow is not affected by failure of either of said pumps, and whereby said speed is also subject to manual override control.

4. Fluid pump control apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said

source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of said fluid flow, and a device for producing a control pressure in said apparatus which is a function of the desired rate of said fluid flow and hence said speed; comprising: a connection for the flow of fluid from said source to said conduit, a pair of pumps in series in said connection for producing said flow, means responsive to said control pressure for regulating the respective pressures in said connection between said pumps and in said conduit so as to maintain the respective values of the pressure differentials across said pumps in a substantially constant predetermined relationship with each other, and manually operated means for varying the effective area of flow thru said conduit from a maximum value at which said flow is unrestricted to a zero value at which fuel flow to said mechanism is cut off, whereby said flow is a function of said control pressure and of said manually operated means.

5. Fluid pump control apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of said fluid flow, and a device for producing a control pressure in said apparatus which is a function of the desired rate of said fluid flow and hence said speed; comprising: a connection for the flow of fluid from said source to said conduit, a pair of pumps in series in said connection for producing said flow, first means responsive to said control pressure for regulating the respective pressures in said connection between said pumps and in said conduit; and second means effective, when one of said pumps fails so that the pressure produced by said one pump at its outlet falls beyond a predetermined limit below a value corresponding to a preselected function of said control pressure, to permit flow thru the other of said pumps directly from said source to said conduit, said second means being also effective when said failure occurs to increase the pressure rise across said other pump by an amount corresponding to the degree of said failure, thereby compensating for said failure and maintaining said conduit pressure at the value determined by said first means; whereby the speed of said mechanism is a function of said control pressure and is not affected by failure of one of said pumps.

6. Fluid pump control apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of said fluid flow, and a device for producing a control pressure in said apparatus which is a function of the desired rate of said fluid flow and hence said speed; comprising: a connection for the flow of fluid from said source to said conduit, a primary pump and a secondary pump in said connection, said primary pump being normally operable to deliver fluid from said source to said secondary pump and said secondary pump being normally operable to deliver fluid to said conduit, first means for regulating a first pressure in said connection between said pumps at a first predetermined proportional value of said control pressure, second means for regulating a second pressure in said conduit at a second predetermined proportional value of said control pressure which determines said con-

duit flow, said first and said second predetermined proportional values being in a substantially constant preselected relationship with each other whereby the respective pressure differentials across said primary and said secondary pumps are in a corresponding substantially constant relationship with each other; a channel for the flow of fluid from said source to the inlet of said secondary pump, valve means in said channel effective to prevent flow therethru when said first pressure has said first predetermined proportional value; said valve means being also effective, when said primary pump fails so that the value of said first pressure decreases more than a pre-established amount below said first predetermined proportional value, to permit flow thru said channel; the value of said pressure differential across said secondary pump increasing, when said primary pump failure occurs, an amount substantially equal to the decrease in value of said first pressure so that the value of said second pressure is maintained at said second predetermined proportional value; whereby the speed of said mechanism is a function of said control pressure and is not affected by said primary pump failure.

7. Fluid pump control apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of said fluid flow, and a device for producing a control pressure in said apparatus which is a function of the desired rate of said fluid flow and hence said speed; comprising: a first connection for the flow of fluid from said source to said conduit, a primary pump and a secondary pump in said first connection, said primary pump being normally operable to deliver fluid from said source to said secondary pump and said secondary pump being normally operable to deliver fluid to said conduit; first and second channels, respectively, for the flow of fluid from the outlets of said primary and secondary pumps to said source; first and second valve means, respectively, in said first and second channels for regulating the fuel flow therethru, said first and second valve means being responsive to said control pressure and effective to regulate first and second pressures respectively at the outlets of said primary and said secondary pumps at first and second proportional values of said control pressure; said conduit flow being a function of said second pressure; third and fourth channels respectively for the flow of fuel between said source and the inlet to said secondary pump and between the outlet from said primary pump and said conduit, third and fourth valve means respectively in said third and fourth channels responsive to the respective differentials thereacross for regulating the flow therethru, said third and fourth valve means being normally effective to prevent flow therethru when the values of said first and second pressures respectively equal said first and second proportional values of said control pressure; said fourth valve means being also effective when said second pressure falls below said second proportional value to permit flow thru said fourth valve means thereby restoring said second pressure to said second proportional value and increasing the pressure rise across said primary pump an amount corresponding to the extent of said failure of said secondary pump; and a second connection be-

tween said first and second channels so that, when said secondary pump failure occurs, said second valve means stops flow thru said second channel and overrides said first valve means to regulate the flow thru said first channel; whereby said conduit flow and hence the speed of said mechanism is a function of said control pressure and is not affected by said secondary pump failure.

8. Fluid pump control apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of said fluid flow, and a device for producing a control pressure in said apparatus which is a function of the desired rate of said fluid flow and hence said speed; comprising: a primary pump having the inlet thereto connected to said source, a secondary pump having the outlet therefrom connected to said conduit, a first connection for the flow of fluid from said primary pump to said secondary pump, said primary pump normally supplying fluid to said connection at a predetermined rate greater than the corresponding rate of flow from said secondary pump to said conduit, a second connection for the flow of fluid from said conduit to said source, a third connection for the flow of fluid from the outlet from said primary pump to said second connection, first valve means in said third connection for regulating the flow therethru, second valve means in said second and said third connections for regulating the flow therethru, said second valve means being normally ineffective to affect the flow from said first valve means to said source, said first and second valve means being responsive to said device and normally effective to regulate first and second pressures respectively at the outlets from said primary and said secondary pumps at first and second proportional values of said control pressure so that the respective values of the pressure differentials across said primary and said secondary pumps are in substantially constant preselected relationship; said second valve means being effective, when said secondary pump fails to produce flow there-thru, to override said first valve means and to regulate said first pressure at said second proportional value of said control pressure; means for flowing fluid from said primary pump to said conduit when said failure occurs, and first manually operated means for overriding said second valve means to regulate said flow in said conduit by varying the effective area of flow thru said conduit, whereby said conduit flow is a function of said control pressure and said manually operated means, and whereby failure of said secondary pump does not affect said conduit flow.

9. Fluid pump control apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of said fluid flow which is a function of the pressure in said conduit, a device for producing a control pressure in said apparatus which is a function of the desired rate of said fluid flow, and a pump control lever; comprising: a first connection between said source and said conduit, a primary pump and a secondary pump downstream therefrom and in series therewithin said connection for producing said conduit flow, first means for by-passing a part of the fluid discharged from said primary pump

to said source, second means including a valve and a bellows responsive to said control pressure for operation of said valve, said valve being effective to control said first means in order to regulate a first pressure in said first connection between said pumps at a first predetermined proportional value of said control pressure, third means for by-passing a part of the fluid discharged from said secondary pump to said source, fourth means including a valve and a pair of bellows responsive to an operating pressure in said mechanism and to said control pressure for operation of said valve, said valve being effective to control said third means in order to regulate said conduit pressure at a second predetermined proportional value of said control pressure, said first and second predetermined proportional values being effective to maintain the respective values of the pressure differentials across said pumps in a substantially constant preselected relationship with each other, fifth and sixth means responsive to said pump control lever for overriding said second means and said fourth means to control said conduit flow, said fifth and sixth means being ineffective to vary said conduit flow when said lever is in a predetermined normal position, said lever being effective upon movement from said normal position to cause said fifth means to progressively decrease the area of flow thru said conduit downstream from said fourth means or to progressively increase the pressure downstream from said second and third means so that said conduit pressure is increased from a minimum value corresponding to the value of said control pressure to a maximum value corresponding to the maximum capacity of said pumps, whereby said speed is normally a function of said control pressure and is subject to override control by said pump control lever to increase or decrease the speed of said mechanism.

10. Fluid pump control apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of said flow, a device for producing a control pressure in said apparatus which is a function of the desired rate of said fluid flow, and a pump control lever; comprising: a pair of pumps in series in said conduit, a driving means for simultaneous operation of both pumps at identical pump speeds; the respective deliveries thru said pumps having rates determined by first and second pre-established empirical functions of said pump speed, the respective torque loads imposed on said driving means by said pumps having values determined by third and fourth pre-established empirical functions of said pump speed and of the respective values of the pressure rise across said pumps, and said flow to said engine having a value determined by a fifth pre-established empirical function of the sum of said respective torque loads; a pair of pins for connecting said pumps to said driving means for transmitting said torque loads from said pumps to said driving means and adapted to fail so as to remove said torque loads from said driving means when said torque loads exceed predetermined values, said failure of one of said pins removing the load of the corresponding pump from said driving means so that the speed of said driving means is not affected and whereby operation of the other of said pumps continues uninterrupted, control means responsive to said

device for varying the respective values of said torque loads in accordance with predetermined functions of said force measure, said control means also being normally effective to maintain the respective torque loads of said pumps substantially in constant preselected relationship with each other, by-pass means effective to maintain the value of said sum of said torque loads when said failure occurs, said by-pass means being effective in the event of said failure to increase the torque load of one pump an amount corresponding to the value of said torque load normally carried by said pump rendered inoperative by said failure, and means connected to said control lever for overriding said control means and said by-pass means to vary said value of the sum of said respective torque loads, whereby the speed of said mechanism varies as a function of said control pressure and said control lever.

11. Pump control apparatus for an internal combustion engine having associated therewith a compressor and a conduit for delivering combustion air and fuel respectively thereto, a source of said fuel connected to said conduit, means for regulating the speed of said engine by the rate of fuel flow from said source to said engine, and a device for producing a control pressure in said apparatus which is a selected function of the desired rate of fuel flow in said conduit, comprising: a pair of pumps in series in said conduit for producing said fuel flow, means responsive to said control pressure and to an air pressure in said engine for regulating said fuel pressure so that the value of said fuel flow is said selected function of said control pressure, whereby said engine speed is a function of said control pressure and has a desired value.

12. Pump control apparatus for an internal combustion engine having associated therewith a compressor and a conduit for delivering combustion air and fuel respectively thereto, a source of said fuel connected to said conduit, means for regulating the speed of said engine by the rate of fuel flow from said source to said engine, and a device for producing a control pressure in said apparatus which is a selected function of the desired rate of fuel flow in said conduit, comprising: a pair of pumps in series in said conduit for producing said fuel flow, first means responsive to said control pressure and to an air pressure in said engine for regulating both the pressure in said conduit between said pumps and said conduit pressure downstream from said pumps, as predetermined functions of said control pressure, and second means in said first means for maintaining a substantially constant preselected relationship between the respective values of said regulated pressures in said conduit, whereby said engine speed is a function of said control pressure and has a desired value.

13. Pump control apparatus for an internal combustion engine having associated therewith a compressor and a conduit for delivering combustion air and fuel respectively thereto, a source of said fuel connected to said conduit, means for regulating the speed of said engine by the rate of fuel flow from said source to said engine, and a device for producing a control pressure in said apparatus which is a selected function of the desired rate of fuel flow in said conduit, comprising: a primary pump and a secondary pump in said conduit for producing said flow, said secondary pump being downstream from said primary pump, first means responsive to said con-

trol pressure for regulating the pressure downstream from said primary pump as a preselected function of said control pressure, second means responsive to said control pressure and to an air pressure in said engine for regulating said conduit pressure downstream from said secondary pump as said predetermined function of said control pressure; said respective pressures downstream from said primary and said secondary pumps being in a pre-established substantially constant relationship with each other; and third means effective, when said primary pump fails so that the normal supply of fuel from said primary pump to said secondary pump is diminished more than a predetermined amount, to connect the inlet of said secondary pump to said source for flow of fuel therebetween at a rate which compensates said diminished supply, the sum of the respective pressure differentials across said pumps remaining substantially constant regardless of said primary pump failure; whereby said engine speed is a function of said control pressure and has a desired value which is not affected by said failure of said primary pump.

14. Pump control apparatus for an internal combustion engine having associated therewith a conduit for delivering fuel thereto, a source of said fuel connected to said conduit, means for regulating the speed of said engine by the rate of fuel flow from said source to said engine, and a device for producing a control pressure in said apparatus which is a selected function of the desired rate of fuel flow in said conduit, comprising: a primary pump and a secondary pump in said conduit for producing said flow, said secondary pump being downstream from said primary pump, first means for regulating the pressure downstream from said primary pump as a preselected function of said control pressure, second means for regulating said conduit pressure as said predetermined function of said control pressure, said first and second means being normally effective to maintain the ratio between the respective values of said downstream pressures a substantially constant preselected value; and third means effective, when said secondary pump fails so that the normal delivery thereof to said conduit is diminished to an extent which renders said second means ineffective to maintain said conduit pressure as said predetermined function of said control pressure, to connect the outlet of said primary pump directly to said conduit for the flow of fuel directly therebetween; said primary pump thereby being effective, in the event of said secondary pump failure, to compensate for said failure and to maintain the value of the sum of the respective differentials across said pumps in a pre-established relationship with the value of said control pressure, said value of said sum being unaffected by said failure, whereby said engine speed is a function of said control pressure and has a desired value which is not affected by said failure of said secondary pump.

15. Pump control apparatus for an internal combustion engine having associated therewith a conduit for delivering fuel thereto, a source of said fuel connected to said conduit, means for regulating the speed of said engine by the rate of fuel flow from said source to said engine, and a device for producing a control pressure in said apparatus which is a selected function of the desired rate of fuel flow in said conduit, comprising: a primary pump and a secondary pump in said conduit for producing said flow, said sec-

ondary pump being downstream from said primary pump, first means for regulating the pressure downstream from said primary pump as a preselected function of said control pressure, second means for regulating said conduit pressure as said predetermined function of said control pressure, said first and second means being normally effective to maintain the ratio between the respective values of said downstream pressures a substantially constant preselected value; third means effective, when either of said pumps fails to deliver sufficient fuel therethrough to maintain said value of said regulated pressure downstream therefrom, to connect the other of said pumps directly between said source and said conduit thereby rendering said other pump subject to a pressure differential having a value greater than normal by an amount equal to the corresponding decrease of the pressure differential across said failed pump; said conduit pressure being unaffected by said pump failure; and manually operated means for overriding said first and second means to vary said respective downstream pressures or the effective area of flow through said conduit so that the fuel flow is varied by said manually operated means, whereby the engine speed is normally a function of said control pressure and has a predetermined value not affected by failure of either of said pumps and whereby said speed is also a function of said overriding means.

16. Pump control apparatus for an internal combustion engine having associated therewith a conduit for delivering fuel thereto, a source of said fuel connected to said conduit, means for regulating the speed of said engine by the rate of fuel flow from said source to said engine, a device for producing a control pressure in said apparatus which is a selected function of the desired rate of fuel flow in said conduit, and a manually operated pump control lever; comprising: a primary pump and a secondary pump in said conduit for producing said flow, said secondary pump being downstream from said primary pump, first means for flowing fuel from the downstream side of said primary pump to said source, second means in said first means for controlling the flow therethrough to regulate the pressure downstream from said primary pump as a preselected function of said control pressure, third means for flowing fuel from said conduit to said source, fourth means in said third means for regulating the flow therethrough as a predetermined function of said control pressure, fifth means for the flow of fuel from the downstream side of said primary pump to said conduit, sixth means for the flow of fuel from said source to the inlet of said secondary pump, seventh and eighth means respectively in said fifth and sixth means for regulating the flow therethrough in response to the respective pressure differentials thereacross, said seventh and eighth means being normally effective to prevent flow therethrough when the respective values of the pressures downstream from said primary and secondary pumps are determined by said preselected and said predetermined functions of said control pressure; said seventh means being effective, when the delivery through said secondary pump decreases as a result of failure thereof so that said fourth means cannot regulate said conduit pressure as said predetermined function of said control pressure, to permit flow through said fifth means so that said primary pump delivers an amount of fuel directly to said

conduit equal to the amount of said secondary pump delivery decrease thereby maintaining said conduit pressure at the value corresponding to said predetermined function of said control pressure, a connection between said second and fourth means for rendering said second means subject to override control by said fourth means when said secondary pump failure occurs; said eighth means being effective, when corresponding failure of said primary pump occurs, to permit flow through said sixth means so that said secondary pump obtains an amount of fuel directly from said source equal to the amount of the primary pump delivery decrease thereby maintaining said conduit pressure at the value corresponding to said preselected function of said control pressure, the sum of the respective pressure differentials across said primary and secondary pumps remaining substantially constant at any given value of said control pressure regardless of the occurrence or of the extent of failure of either of said pumps; and valve means connected to said control lever for overriding said second and fourth means for varying the flow in either said first and said third means or in said conduit, respectively, to vary said conduit flow from a zero value corresponding to a predetermined "cut-off" position of said lever to a value corresponding to a predetermined "emergency" lever position at which said conduit flow is the maximum producible by said pumps; whereby the engine speed normally has a desired value that is a function of said control pressure; failure of either of said pumps is compensated by the other without affecting the engine speed, and the engine speed is subject to override control by manual operation of said lever.

17. Fluid pumping apparatus comprising a pair of pumps connected in series, a relief valve for regulating the discharge pressure of the first pump at a first predetermined value, a control valve for controlling the discharge pressure of the second pump at a second predetermined value greater than said first value, by-pass means associated with each pump so that if one pump fails the other can pump fluid thru the by-pass means of the failed pump, and means effective upon failure of said second pump to place said control valve in control of the discharge pressure of the first pump, so that no drop in the discharge pressure from the second pump occurs upon failure of that pump.

18. Fluid pumping apparatus, comprising first and second pumps for delivering fluid to a discharge conduit, first relief valve means for regulating the discharge pressure of said first pump at a first predetermined value, control valve means for regulating the discharge pressure of said second pump at a second predetermined value higher than said first value, second relief valve means for regulating the discharge pressure of said first pump at substantially said second value, and means responsive to the discharge pressure of said second pump for transferring control of said first pump from said first relief valve means to said second relief valve means upon failure of said second pump.

19. Fluid pump apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of fluid flow, and a control device for producing a control pressure in said apparatus which controls the rate of said

fluid flow and hence the speed of said mechanism; comprising: a pair of pumps connected in series for delivering fluid from said source to said conduit, means responsive to said control pressure for regulating the delivery of said pumps so that said fluid flow to and the speed of said mechanism is always a selected function of said control pressure.

20. Fluid pump apparatus according to claim 19, including a manually operated cutoff valve in said conduit for cutting off the flow of fluid from said pumps to said mechanism, and means for regulating the fluid pressure in said conduit during cutoff as a predetermined function of said control pressure, whereby no abnormal strain is produced in said apparatus by the closing of said cutoff valve.

21. Fluid pump apparatus according to claim 19, including a relief valve, responsive to said control pressure, for normally regulating the fluid pressure between said pumps at a value approximately equal to the value of said control pressure.

22. Fluid pump apparatus according to claim 19, including a control valve responsive to said control device pressure for normally regulating the fluid pressure in said conduit at a value approximately equal to twice the value of said control device pressure.

23. Fluid pump apparatus according to claim 19, including a relief valve for normally regulating the fluid pressure between said pumps at a value approximately equal to the value of said control device pressure, and a control valve for normally regulating the fluid pressure in said conduit at a value approximately equal to twice the value of said control device pressure, both of said valves being responsive to said control device pressure, whereby both of said pumps operate with one-half the total pumping load and approximately the same efficiency and the life expectancy of each pump is thereby doubled.

24. Fluid pump apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of fluid flow, and a control device for producing a control pressure in said apparatus which controls the rate of said fluid flow and hence the speed of said mechanism; comprising: a pair of pumps connected in series for delivering fluid from said source to said conduit, and means responsive to said control pressure for regulating the delivery of said pumps so that said delivery remains the same in the event of failure of either of said pumps, whereby the said fluid flow to and the speed of said mechanism is always a selected function of said control pressure.

25. Fluid pump apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of fluid flow, and a control device for producing a control pressure in said apparatus which controls the rate of said fluid flow and hence the speed of said mechanism; comprising: a pair of pumps connected in series for delivering fluid from said source to said conduit, said pumps being so arranged that each normally performs substantially one-half of the total pumping load, and means responsive to said control pressure for regulating the delivery of

said pumps so that said delivery remains the same in the event of failure of either of said pumps, whereby the said fluid flow to and the speed of said mechanism is always a selected function of said control pressure.

26. Fluid pump apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of fluid flow, and a control device for producing a control pressure in said apparatus which controls the rate of said fluid flow and hence the speed of said mechanism; comprising: a pair of pumps connected in series for delivering fluid from said source to said conduit, a relief valve for regulating the fluid pressure between said pumps, and means responsive to said control pressure for operating said relief valve and regulating the delivery of said pumps so that said delivery remains the same in the event of failure of either of said pumps, or said relief valve, whereby the said fluid flow to and the speed of said mechanism is always a selected function of said control pressure.

27. Fluid pump apparatus for a rotating mechanism having associated therewith a source of fluid, a conduit for supplying fluid from said source to said mechanism for rotation thereof, means for rotating said mechanism at a speed determined by the rate of fluid flow, and a control device for producing a control pressure in said apparatus which controls the rate of said fluid flow and hence the speed of said mechanism; comprising: a pair of pumps connected in series for delivering fluid from said source to said conduit, a control valve for regulating the fluid pressure in said conduit, and means responsive to the control pressure of said control device for operating said control valve and regulating the delivery of said pumps so that said delivery remains the same in the event of failure of either of said pumps or of said control valve, whereby the said fluid flow to and the speed of said mechanism is always a selected function of said control pressure.

28. Fluid pump apparatus according to claim 19 including a control valve, responsive to said control device pressure and a fluid pressure in said mechanism, for normally regulating the fluid pressure in said conduit.

29. Fluid pumping apparatus comprising a pair of pumps adapted to receive fluid from a common source and to deliver said fluid to a common discharge conduit under a selected pressure at a selected pump speed; means to regulate the operation of said apparatus so that the normal discharge pressure of one pump is constantly maintained at a predetermined fixed ratio to the normal discharge pressure of the other pump at all operating speeds; and means whereby either pump will automatically continue to discharge fluid through said conduit at said selected pressure in case the other pump fails to function normally.

30. Fluid pumping apparatus according to claim 29, wherein the normal discharge pressure of one pump is constantly maintained at a value of one-half the discharge pressure of the other pump.

31. Fluid pumping apparatus according to claim 29, having means whereby both pumps always operate at equal speeds until one pump fails completely, after which the other pump auto-

32. Fluid pumping apparatus according to claim 31, having means whereby both pumps are driven by a common drive shaft which, upon complete failure of one pump, automatically continues to drive the other pump without interruption.

33. Fluid pumping apparatus comprising a pair of pumps connected in series and adapted to receive fluid from a common source and to deliver said fluid to a common discharge conduit under a selected pressure at a selected pump speed; means to regulate the operation of said apparatus so that the total pumping load is normally divided equally between both pumps at all operating speeds; and means for making either pump automatically assume the total pumping load upon complete failure of the other pump.

34. Fluid pumping apparatus according to claim 33, having means whereby, upon the partial failure of one pump, the other pump will automatically assume such part of the total pumping load as required to always maintain the normal discharge of said apparatus.

35. Fluid pumping apparatus according to claim 33, having means whereby both pumps always operate at equal speeds until one pump fails completely, after which the other pump automatically continues to operate without interruption.

36. Fluid pumping apparatus according to claim 33, having means whereby both pumps are driven by a common drive shaft which, upon complete failure of one pump, automatically continues to drive the other pump without interruption.

37. Fluid pumping apparatus according to claim 33, wherein both pumps are of constant delivery type and of substantially equal capacity under normal operation.

38. Fluid pumping apparatus according to claim 33, having means whereby, upon partial or total failure of one pump, the discharge of the other pump is partially or totally by-passed around the first pump.

39. Fluid pumping apparatus according to claim 33, wherein both pumps normally operate in series with each other.

40. Fluid pumping apparatus according to claim 39, having means whereby, upon the partial failure of one pump, both pumps operate partially in series and partially in parallel.

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