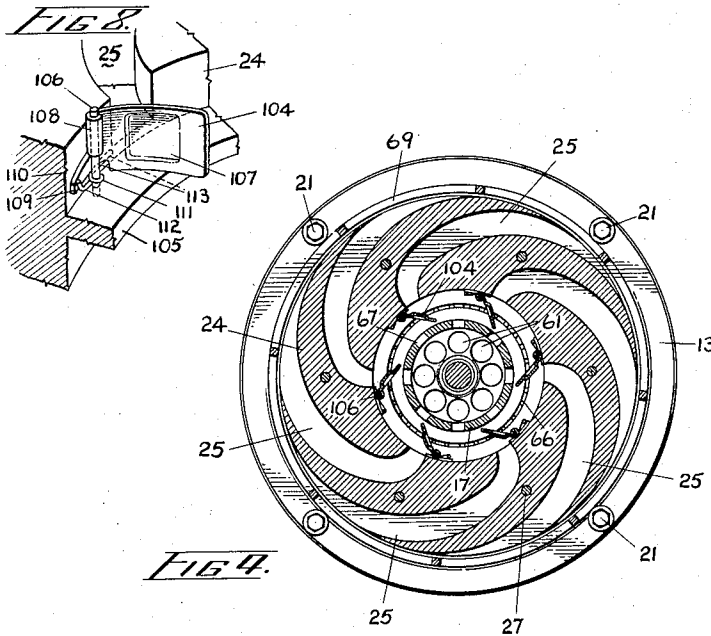


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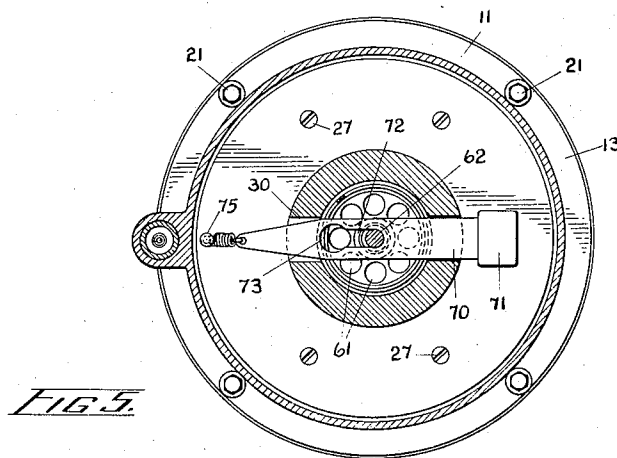
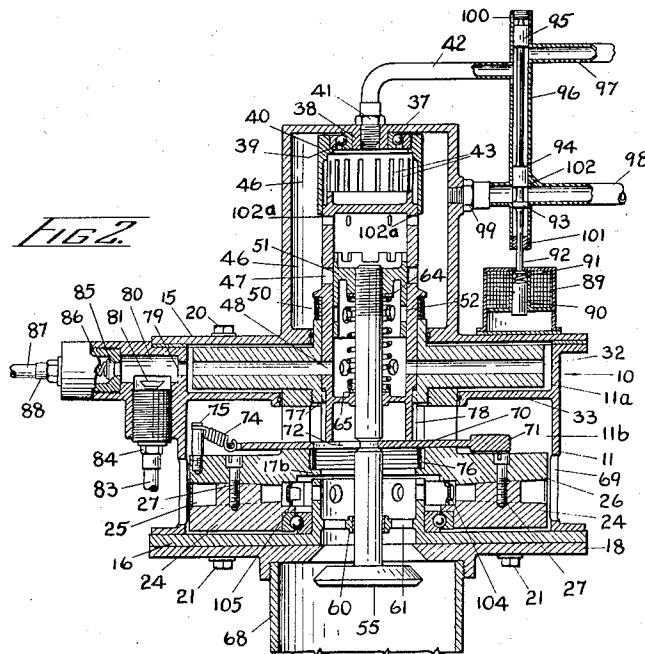
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2,918,010

TURBINE PUMP

Filed March 17, 1958

3 Sheets-Sheet 2



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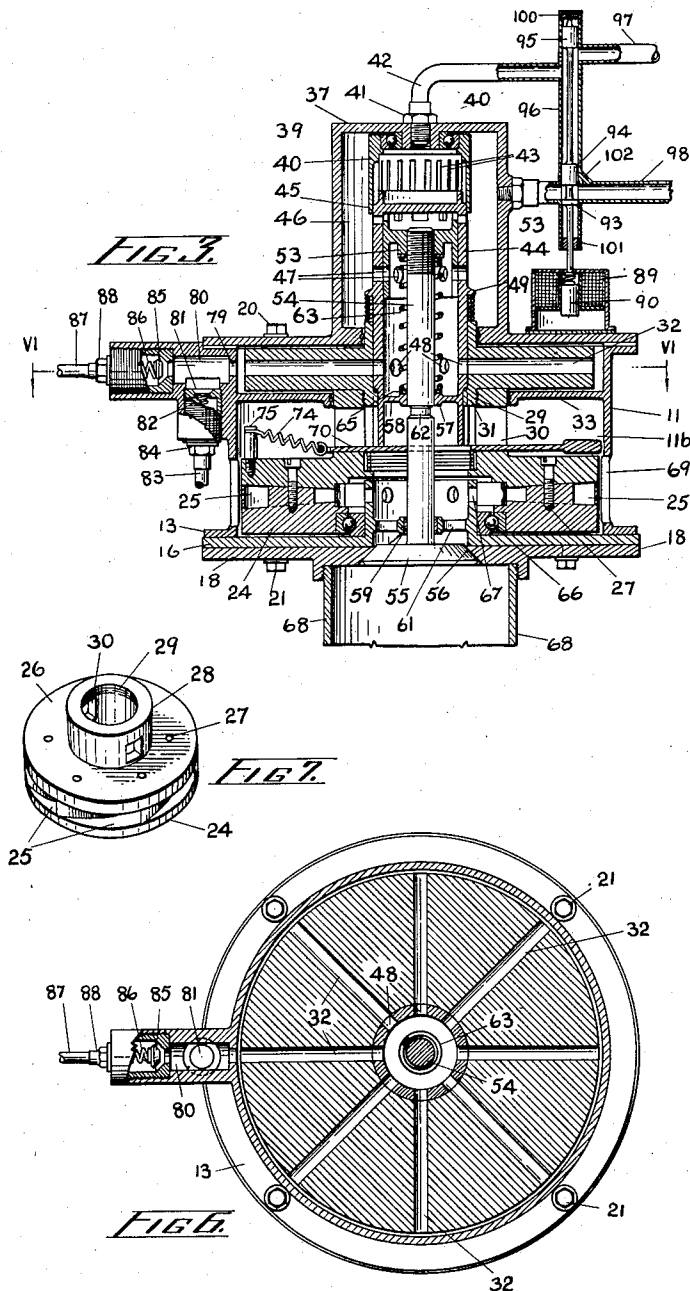
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TURBINE PUMP

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3 Sheets-Sheet 3



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2,918,010

TURBINE PUMP

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Application March 17, 1958, Serial No. 721,838

13 Claims. (Cl. 103—13)

This invention relates to a pump for operation in successive separate operating cycles. Such pumps are known as "one-shot" pumps and are arranged to operate in short cycles and to deliver a discrete quantity of fluid at relatively high pressure during each cycle of operation.

The pump of the invention is especially useful as a fuel pump for use in a "hot-streak" ignition system for lighting an afterburner of a gas turbine engine. The essence of a "hot streak" ignition system is that an extra quantity of fuel is delivered to special jets in one of the combustion chambers of a gas turbine engine. The drops of fuel in the quantity delivered are sufficiently large that, after they have been ignited in the combustion chamber, they pass, still burning, through the turbine blades and light the afterburner. The injection of the fuel takes place quickly and the turbine is not damaged.

Such a system requires some form of pumping arrangement which will deliver a succession of discrete quantities of fuel to a combustion chamber until the afterburner is lighted. Various arrangements have been proposed. In some of the arrangements there is used excess fuel pump capacity, which is undesirable since, as the fuel required for the "hot-streak" ignition is delivered, the fuel pump pressure falls considerably and the engine operation is upset. In some other arrangements a fuel accumulator is used to store and discharge the fuel; such an accumulator is cumbersome and presents a fire hazard. The use of a "one-shot" pump of the type described in this application overcomes the disadvantages of the previous systems.

Another use of the pump of the invention on an aircraft is to operate the jacks which actuate variable propulsive nozzles associated with gas turbine engines and where a high pressure source of fluid power is required for a very short time. Although the pump of the invention is especially useful for these two purposes it may also be used in other situations where "one-shot" pumps are normally employed.

It is an object of the invention to provide a small, turbine driven pump which will operate in separate successive operating cycles to deliver discrete quantities of fluid.

It is another object of the invention to provide a turbine driven pump having a turbine rotor and a pump rotor of substantially the same size and in which the rotors are caused to acquire considerable kinetic energy before fluid is admitted to the pump rotor to be pumped.

It is a further object of the invention to provide a pump for operation in successive separate operating cycles and capable of being driven from sources of fluid pressure normally available on aircraft having gas turbine engines.

The invention will now be described by way of example with reference to the accompanying drawings, in which like reference numerals denote like parts throughout the several views, and in which:

Figure 1 is a transverse cross section of a pump according to the invention, the parts occupying positions of rest which they assume between operating cycles of the pump.

Figure 2 is a section similar to Figure 1 but showing

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the parts in different positions after the cycle of operation of the pump has commenced,

Figure 3 is a section similar to Figure 2 showing the parts in positions occupied at a stage of the cycle of operation later than that shown in Figure 2.

Figure 4 is a horizontal section on the line IV—IV of Figure 1.

Figure 5 is a horizontal section on the line V—V of Figure 1.

Figure 6 is a horizontal section on the line VI—VI of Figure 3,

Figure 7 is a perspective view, on a smaller scale, of the turbine rotor of the pump of Figure 1, and

Figure 8 is a detail perspective view, on a larger scale, showing one of the overspeed flaps mounted on the inner periphery of the turbine rotor.

Referring now to the drawings, the pump includes a housing indicated generally at 10 and comprising four main parts; the first part is a generally cylindrical drum 11 having an upper peripheral flange 12 and a lower peripheral flange 13, the second part is a generally cylindrical housing 14 having a flange 15 which mates with the flange 12, the third part is a base plate 16 having an upstanding cylindrical portion 17, and the fourth part is a flanged plate 18 having an internally screw threaded boss 19. The drum 11 is secured to the cylindrical housing 14 by bolts passing through the flanges 12 and 15, one of the bolts being indicated at 20. Similarly, the drum 11 is secured to the base plate 16 and the flanged plate 18 by four bolts 21 equally spaced around the periphery of the flange 13.

Rotatably mounted in the drum 11 is an annular turbine rotor, indicated generally at 22, and an annular pump rotor indicated generally at 23. The turbine rotor comprises a lower member 24, machined at its upper surface to provide convolute passages 25, see Figure 4, extending between the inner and outer peripheries of the lower member 24, and an upper plate member 26, the members being secured together by threaded pins 27. Upstanding from the upper surface of the plate member 26 is a generally cylindrical boss 28, see Figure 7, internally screw threaded at 29 at its upper end and being provided with a pair of oppositely spaced vertical slots 30. The pump rotor 23 is provided with a depending spigot 31 which is externally screw threaded to mate with the screw thread 29 in the upstanding boss 28 of the turbine rotor 22. The pump and turbine rotors are interconnected by screwing the spigot 31 into the boss 28 and then inserting a locking pin (not shown) to prevent the rotors from becoming disconnected. The pump rotor is provided with a plurality of radial passages 32, shown clearly in Figure 6.

An annular diaphragm 33 extends within the drum 11 and divides the interior of the drum into an upper pump chamber 11a, in which the pump rotor 23 is received, and a lower turbine chamber 11b, in which the turbine rotor 22 is received. A sealing ring 34 is interposed between the inner periphery of the diaphragm 33 and the outer periphery of the boss 28 to provide a fluid-tight seal between the upper and lower chambers.

The lower portion of the cylindrical housing 14 has an turned annular flange 35 which closely surrounds an upstanding boss 36 on the pump rotor 23. A sealing ring 36' is interposed between the inner periphery of the flange 35 and the outer periphery of the boss 36 to provide a fluid-tight seal. The upper wall 37 of the cylindrical housing 14 is provided with a hollow depending spigot 38. Received on the outer periphery of the spigot 38 is a ball race 39 up on which is mounted a rotary cylinder 40. Mounted within the bore of the spigot 38 is a union 41 to which is attached a fluid conduit 42.

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Referring now to Figure 3, the interior surface of the rotary cylinder 40 is splined as indicated at 43 and mounted for reciprocation within the cylinder is a fluid transfer member or sleeve 44 which extends through the central aperture of the pump rotor and has a closed upper end. The upper portion of the sleeve 44 is provided with splines 45 which mate with the splines 43 in the cylinder 40. The cylinder 40 thus forms a rotatable support for the sleeve 44, while the sleeve is free to slide axially relatively to the cylinder. The interior of the cylindrical housing 14 provides an inlet chamber 46. The fluid transfer member 44 is provided with a first set of transfer ports 47 and a second set of transfer ports 48; ports 47 of the first set being in communication with the inlet chamber 46. The transfer member is also provided with an external rib 49 and a compression coil spring 50 is interposed between the lower edge of the rib 49 and the upper surface of the upstanding boss 36 on the pump rotor 23.

The transfer member 44 is normally retained in a first position, as shown in Figure 1, by the spring 50. In this first position there is no communication between the ports 48 of the second set and the passages 32 of the pump rotor. However, fluid may be admitted into the interior of the cylinder 40 through the union 41 to move the transfer member downwardly to a second position, shown in Figures 2 and 3, in which the ports 48 of the second set are in communication with the radial passages 32 in the rotor.

Slidably mounted within the transfer member 44 for movement relatively thereto is a first valve member comprising a closely fitting piston 51 having ports 52 in its skirt. The piston has an internal depending boss 53 which is internally screw threaded to receive the screw threaded upper end of a rod 54. A second valve member 55, in the form of a poppet valve, is secured to the lower end of the rod 54 and co-operates with a valve seating 56 provided in the flanged plate 18. The second valve member 55 is movable between a first position, as shown in Figures 1 and 3, in which the valve is closed, and a second position, as shown in Figure 2, in which the valve is open.

The rod 54 is supported intermediate its ends by a fluid-tight plain bearing 57, which is supported by a diaphragm 58 in the interior of the transfer member 44, and by a further plain bearing 59 supported in a diaphragm 60 in the interior of the cylindrical portion 17 of the base plate 16. The diaphragm 60 is formed with a plurality of apertures 61 as is best seen in Figure 4. Intermediate its ends the rod 54 is formed with a reduced neck portion 62 for a purpose hereinafter to be described.

The first valve member 51 is biased to a first position, shown in Figure 1, relatively to the transfer member 44 by a compression spring 63 interposed between the depending boss 53 of the valve piston and the diaphragm 58 in the transfer member 44. Graphite washers 64 and 65 are interposed between the ends of the spring and the piston 51 and the diaphragm 58 respectively to permit relative rotation between the valve member 51 and the upper end of the spring 63 and between the lower end of the spring and the transfer member 44. The valve member 51 and the transfer member 44 are relatively movable so that the valve member may assume a second position relative to the transfer member as shown in Figure 3. In the first position of the valve member 51 relative to the transfer member, shown in Figures 1 and 2, the ports 52 are out of line with the ports 47 of the first set of ports in the transfer member, in the second position of the valve member 51 relative to the transfer member, shown in Figure 3, the ports 52 in the skirt of the piston are in line with the ports 47 of the first set of ports in the transfer member.

The turbine rotor 22 is mounted on a ball race 66 which is received on the outer periphery of the cylindrical portion 17 of the base plate 16. The cylindrical

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portion 17 is also provided with a series of ports 67 which place its bore in communication with the inner periphery of the turbine rotor. A pipe 68, having a screw threaded end, is received in the screw threaded boss 19 on the flanged plate 18 and provides an inlet for secondary fluid to be admitted to the turbine rotor when the second valve 55 is open. The drum 11 is provided with a plurality of circumferential apertures 69, best seen in Figure 4, to permit the exhaust of secondary fluid passed through the turbine, as will hereinafter be described.

A slotted plate 70 is received in the slots 30 in the upstanding boss 28 of the turbine rotor. Referring now to Figure 5, the plate 70 has an enlarged end 71 and a straight sided slot 72 so dimensioned as to closely embrace the reduced neck portion 62 of the rod 54 as shown in Figures 1, 2 and 5. The plate 70 is also provided with an enlarged aperture 73 through which the rod may pass. A tension spring 74 attached at one end to a pin 75 on the turbine rotor and at the other end to the slotted plate 70 biases the plate in a leftward direction as viewed in the drawings. A further compression spring 76 inserted between the plate 70 and an annular rib 17b on the turbine rotor biases the plate in an upward direction to the position shown in Figure 1.

The depending spigot 31 on the pump rotor is provided on its interior surface with splines 77 which mate with splines 78 in the lower outer peripheral surface of the transfer member 44. The transfer member 44 is thus caused to rotate with the pump rotor although it is free to slide axially thereof. The pump rotor and the member 44 are so assembled relatively to one another that, when the member 44 is in its second, or lower, position, the ports 48 line up with the inner ends of the passages 32.

The upper chamber 11a in the drum 11 is provided with an outlet port 79 leading to an outlet chamber 80. Located in the outlet chamber 80 is a drain valve 81 which is normally held open by a spring 82. A conduit 83 leads from the drain valve and is connected thereto by a union 84. Also located in the outlet chamber 80 is an outlet valve 85 which is normally retained closed by a spring 86. A conduit 87 is connected to the outlet valve by a union 88.

Mounted on the upper surface of the flange 15 of the cylindrical housing 14 is an actuating and inlet valve assembly which includes a solenoid 89 having a movable core 90, the core being biased downwardly to the position shown in Figure 1 by a spring 91. A stem 92 extends upwardly from the core 90 and carries three lands 93, 94 and 95. The stem and lands are reciprocable in a cylinder 96 which is in communication with the conduit 42 towards the upper end of the cylinder, the lands being a sliding fit in the base of the cylinder. The cylinder 96 is also in communication with a source of high pressure fluid via a conduit 97 and with a source of primary fluid via a conduit 98. The cylinder 96 is connected to the cylindrical housing 14 and the inlet chamber 46 by an inlet union 99 providing an inlet for primary fluid into the inlet chamber. It will be noted that the conduits 42 and 97 are not in line with one another but that the conduit 98 is in line with the union 99. The top of the cylinder 96 is closed by a disc 100 and the stem 92 passes through a gland 101 at the lower end of the cylinder. A bleed passage 102 connects the conduit 98 to the cylinder 96 above the land 94 when the stem is in its lower position as shown in Figure 1. In the position of the valve assembly shown in Figure 1, primary fluid is prevented by the land 94 (constituting the inlet valve) from passing from the conduit 98 to the inlet union 99, and high pressure fluid is prevented by the land 95 (constituting the actuating valve) from passing from the conduit 97 into the conduit 42. However, fluid trapped in the cylinder 40 may pass through the union 41, and conduit 42 and bleed through the passage 102 into the conduit 98.

In the position of the actuating and inlet valve as-

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sembly shown in Figure 2, with the solenoid energized, high pressure fluid may pass from the conduit 97 into the cylinder 40 through the conduit 42 and the union 41, and primary fluid may pass from the conduit 98, between the lands 93 and 94 and into the inlet chamber 46 through the inlet union 99. Means, not shown, are provided to actuate the solenoid 89 and may be of any convenient conventional form. When the pump is used for a "hot-streak" injection ignition system, the means for actuating the solenoid would be a pulse switch, so that the solenoid could be continually energised and de-energised until the afterburner is lit.

The upper portion of the transfer member 44 is provided with bleed passages 102a for a purpose hereinafter to be described and the upper surface of the first valve member 51 is castellated at 103 also for a purpose hereinafter to be described.

To prevent the rotors from exceeding a predetermined rotational speed, the inner periphery of the turbine rotor is provided with overspeed flaps 104 hingedly mounted at the inner ends of the passages 25 and arranged to close the passages under predetermined conditions of rotational speed and fluid pressure. Referring now to Figure 8, one of the overspeed flaps is shown in detail. The lower member 24 of the turbine rotor is provided with an inwardly projecting rib 105, the lower surface of which rests upon the outer race of the bearing 66. The overspeed flaps are mounted on hinge pins 106, the lower ends of the pins being received in the rib 105 and the upper ends of the pins being received in the upper plate member 26 of the turbine rotor.

Each flap 104 is provided with an embossed portion 107 to enter the inner end of a passage 25 and also with a rolled over portion 108 to embrace the pin 106. A lug 109 is formed integrally with each flap and is bent at an angle thereto so that, when the flap is open, as shown in Figure 8, the lug lies against the inner peripheral wall 110 of the member 24. A spring 111 encircles the pin 106 and has one end 112 in engagement with the lug 109 and the other end 113 in contact with the wall 110. The spring tends to keep the flap in the open position as shown in Figure 8.

When the turbine rotor rotates, the flaps 104 tend to move outwardly against the action of the springs 111 and, at a predetermined rotational speed, the flaps move sufficiently for the embossed portions 107 to enter the inner ends of the passages 25 and seal the passages. The springs will be rated to take into account any fluid pressure within the turbine rotor and which will also tend to close the flaps.

The operation of the pump will now be described as it would be used in a "hot-streak" injection ignition system on a gas turbine engine. In such a system the pipe 68 would be connected to a source of compressed air which would constitute a source of secondary fluid to operate the turbine of the pump. Conveniently the air would be bled from the compressor of the gas turbine engine. The conduit 97 would be connected to a source of high pressure fuel and the conduit 98 would be connected to a source of fuel at a pressure lower than that of the fuel in the conduit 97. The fuel entering from the conduit 98 is considered to be the primary fluid to be operated on and is pumped by the pump out through the outlet valve into the conduit 87 from whence it would be fed to a combustion chamber to provide the necessary fuel for ignition of the after-burner. It will be appreciated, however, that the pump could be operated by other fluids in other applications and that the operation would still remain substantially the same.

In Figure 1 the parts are shown in the positions they occupy between successive operating cycles of the pump, the solenoid 89 is de-energised and the actuating and inlet valve assembly is in a position to cut off the supply of primary fluid to the inlet chamber 46 and also to cut off the supply of high pressure fluid to the cylinder 40.

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The transfer member 44 is in its first state, in which the transfer ports 48 of the second set are out of line with the radial passages 32 in the pump rotor. The first valve member 51 is in its first position relative to the transfer member 44 in which the ports 52 in its skirt are out of line with the ports 47 of the first set of transfer ports in the transfer member 44, and the second valve member 55 is in its first, or closed, position. The drain valve 81 is held open by its spring 82 and the outlet valve 85 is held closed by its spring 86. The slotted plate 70 is held with the slot 72 closely embracing the reduced neck portion 62 of the rod 54.

To initiate a cycle of operation of the pump, the solenoid 89 is energised to raise the stem 92 of the actuating and inlet valve assembly to the position shown in Figure 2. Primary fluid is now permitted to enter the inlet chamber 46 through the inlet union 99 and high pressure fluid is enabled to enter the cylinder 40 from the conduit 97 through the conduit 42. The primary fluid in the inlet chamber 46 is unable to pass into the interior of the transfer member 44 since the ports 47 are blocked by the piston 51. As high pressure fluid is admitted to the cylinder 40 the transfer member 44 moves downwardly to its second position as shown in Figure 2. As the transfer member moves downwardly, the transfer ports 48 of the second set come into line with the radial passages 32 in the pump rotor. Also the lower edge of the transfer member contacts the slotted plate 70 and moves it downwardly against the action of the spring 76. As the slotted plate moves downwardly it moves the rod 54 downwardly due to the close embrace of the slot 72 on the reduced neck portion 62 of the rod. As the rod 54 moves downwardly the second valve member 55 is moved to its second, or open, position. During the downward movement of the transfer member 44 the relative positions of the valve member 51 and the sleeve 44 remain unchanged so that the valve member 51 remains in its first position relatively to the member 44, i.e. blocking the ports 47 of the first set.

With the second valve member 55 in its second position, the turbine rotor is in communication with the inlet for secondary fluid, in this case compressed air, provided by the pipe 68 and compressed air flows in to the interior of the cylindrical portion 17, through the apertures 61 in the diaphragm 60 and through the ports 67 into the bore of the annular turbine rotor. The secondary fluid then flows outwardly through the convolute passages 25 and causes the turbine rotor to spin, the secondary fluid being exhausted through the circumferential apertures 69 in the drum 11 of the housing.

Since the turbine rotor is rigidly connected to the pump rotor, the pump rotor also begins to spin. As the rotational speed of the rotors increases, the enlarged end 71 of the slotted plate 70 will tend to move outwardly due to centrifugal force. At a predetermined rotational speed of the rotors, the centrifugal force due to the weight of the enlarged end 71 will overcome the pull of the spring 74 and the slotted plate 70 will move to the right as shown in Figure 3. As the slotted plate moves to the right the enlarged aperture 73 will come into line with the rod 54 so that the assembly of first valve member 51, rod 54 and second valve member 55 may move upwardly relatively to the transfer member 44 under the influence of the spring 63 interposed between the diaphragm 58 and the valve member 51.

As the rod 54 moves upwardly the second valve member 55 will move back to its first, or closed, position thus halting the admission of secondary fluid to the turbine rotor. Simultaneously, the first valve member 51 will move to its second position relative to the transfer member 44 in which the ports 52 line up with the ports 47 as shown in Figure 3. As the member 44 continues to rotate the ports 47 will pass over the ports 52 and primary fluid will flow from the inlet chamber 46 through the ports 47 and 52, through the interior of the trans-

fer member 44, which constitutes a transfer passage, through the ports 48 and into the radial passages 32 of the pump rotor. Since the pump rotor is rotating, the primary fluid entering the passages 32 will be forced outwardly to the periphery of the pump rotor into the chamber 11a and will then pass through the outlet port 79 into the outlet chamber 80.

It will be seen that no primary fluid is admitted to the pump rotor until the rotors are rotating at a predetermined rotational speed which is arranged so that the rotors then possess considerable kinetic energy. Primary fluid is then admitted to the pump rotor which is rotating relatively quickly, and a high pressure is built up in the outlet chamber 80 thus closing the drain valve 81 and opening the outlet valve 85 so that the fluid permitted to enter the pump rotor will pass out through the conduit 87 to the combustion chamber of the gas turbine engine. After the rod 54 has moved upwardly, since the admission of secondary fluid to the turbine rotor has been cut off by the closing of the valve 55, the rotors will begin to slow down. When the pressure in the outlet chamber 80 falls below a predetermined value, the spring 86 will close the outlet valve 85 and the spring 82 will open the drain valve 81 so that any fluid remaining in the outlet chamber will be bypassed to the supply through the conduit 83. The cycle of pump operation is then completed by breaking the circuit through the solenoid 89 so that the actuating and inlet valve assembly moves to the position shown in Figure 1 under the influence of the spring 91. The spring 50 will then move the transfer member 44 upwardly expelling fluid from the cylinder 40 along the conduit 42, down the cylinder 96 and through the bleed passage 102 into the conduit 98. The spring 50 is strong enough to overcome the pressure in the conduit 98. A second cycle of operation of the pump is initiated by energising the solenoid 89 to admit fluid to the cylinder 40 and to repeat the cycle as hereinbefore described.

It is possible that, during operation, fluid may leak into the space between the upper surface of the piston 51 and the closed end of the transfer member 44. It will be appreciated that, if there were a considerable amount of fluid in this space when the first valve member 51 was moved upwardly by the spring 50, the valve member might be halted by the fluid before the ports 52 came into line with the ports 47 in the member 44. To avoid this eventuality, the bleed passages 102a are provided so that any fluid trapped in the space referred to may pass out through the bleed passages as the piston 51 moves upwardly. The piston 103 is castellated to avoid closing off the bleed passages 102a as the piston nears the end of its upward movement.

The turbine rotor is prevented from assuming too high a rotational speed by virtue of the over-speed flaps 104. The springs 111 holding the over-speed flaps open are rated so that at a predetermined rotational speed of the turbine rotor the force of the springs will be overcome by the combined effect of the pressure of the secondary fluid acting on the flaps and the centrifugal forces also acting on the flaps, so that the flaps may close against the springs and cut off the inner ends of the convolute passages 25. When this occurs secondary fluid will no longer be able to flow through the passages 25 and the turbine rotor will be caused to slow down. As soon as the speed decreases below the predetermined value, the overspeed flaps will open to admit further secondary fluid to continue to drive the rotor.

It will be seen that the combination of the sleeve 44 and the first valve member 51 may be considered as a first valve means having a first state in which the inlet chamber 46 is cut off from the pump rotor, and a second state in which the inlet chamber 46 is in communication with the pump rotor. The valve means is shown in its first state in Figures 1 and 2 and in its second state in Figure 3. Similarly the valve 55 may be

considered as a second valve means having a first state, shown in Figures 1 and 3, in which the inlet of secondary fluid is cut off from the turbine rotor, and a second state, shown in Figure 2, in which the turbine rotor is in communication with the supply of secondary fluid.

It will also be seen that, since the first valve member remains in its second position as shown in Figure 3 during the time that the rotors are slowing down, it is possible that some primary fluid will collect in the pump rotor and transfer chamber at a pressure less than that which is required to open the outlet valve 85 against its spring 86. The drain valve 82 by-passes such fluid back to the supply. It is also possible that, at the end of the cycle, as the transfer member 44 is moved back to its first position, some fluid will be left in the pump rotor. Such fluid will pass into the outlet chamber 80 as soon as the rotors start rotating in the next cycle and before they have sufficient speed to deliver the fluid at a pressure sufficient to open the outlet valve 85. Such fluid delivered to the outlet chamber will then pass through the drain valve 81 and back to the supply.

It will thus be seen that the invention provides a "one-shot" pump capable of delivering discrete quantities of fluid at a predetermined pressure.

The pump of the invention is very compact, since it is designed on the basis that the residual kinetic energy of the rotors after the supply of secondary fluid has been cut off is utilised to pump fluid. There is, as it were, a deliberate mis-match between the size of the turbine and the size of the pump. Continuously to drive a pump rotor of the size shown in the drawings, the turbine would have to be much larger in relation to the pump rotor than is shown but, because it is desired to deliver the fluid in discrete quantities, the rotors can be rotated at a relatively high speed before any pumping is done and, as soon as the requisite kinetic energy is attained by the rotors, fluid is admitted to the pump rotor and is pumped through the outlet.

Although in the specification it has been stated that the conduit 97 connects the cylinder 96 with a source of "high" pressure fluid, it will be appreciated that the actual pressure of the fluid at the source will depend upon the geometry of the pump and the static friction to be overcome in moving the sleeve 44 downwardly. In any event the pressure at the source must be sufficient to be capable of moving the sleeve downwardly against the resisting forces.

It will be understood that the form of the invention herewith shown and described is a preferred example and that various modifications can be carried out without departing from the spirit of the invention or the scope of the appended claims.

What I claim as my invention is:

1. A pump for operation in successive separate operating cycles, comprising a housing, a first inlet in the housing for primary fluid, a pump rotor rotatably mounted in the housing, a turbine rotor rotatably mounted in the housing, coupling means interconnecting the rotors for synchronous rotation, an outlet for primary fluid in the housing, the outlet being in communication with the pump rotor, first valve means in the housing interposed between the inlet and the pump rotor, the valve means having a first state, in which it cuts off communication between the inlet and the pump rotor, and a second state in which the inlet is in communication with the pump rotor, the valve means being normally retained in its first state, a second inlet in the housing for secondary fluid, said second inlet leading to the turbine rotor, second valve means in the housing and associated with the second inlet, said second valve means having a first state, in which the second inlet is cut off from the turbine rotor, and a second state in which the second inlet is in communication with the turbine rotor, the second valve means being normally retained in its first state, means to move the second valve means from its first state to

its second state to initiate an operating cycle of the pump by admitting secondary fluid to rotate the turbine rotor, means associated with both valve means and operable at the attainment of a predetermined rotational speed of the turbine rotor to cause the first valve means to assume its second state and the second valve means to assume its first state, thus permitting primary fluid to flow from the first inlet to the pump rotor and also cutting off the supply of secondary fluid to the turbine rotor, the residual kinetic energy of the rotors after the cutting off of the secondary fluid being such as to deliver through the outlet a quantity of the primary fluid admitted to the pump rotor, and means associated with the first valve means to return the said means to its first state at the end of the cycle.

2. A pump for operation in successive separate operating cycles, comprising a housing, an inlet chamber for primary fluid in the housing, a pump rotor rotatably mounted in the housing, a turbine rotor rotatably mounted in the housing, coupling means interconnecting the rotors for synchronous rotation, an outlet for primary fluid in the housing, the outlet being in communication with the pump rotor, first valve means in the housing interposed between the inlet chamber and the pump rotor, the valve means having a first state, in which it cuts off communication between the inlet chamber and the pump rotor, and a second state in which the inlet chamber is in communication with the pump rotor, a second inlet in the housing for secondary fluid, the second inlet leading to the turbine rotor, second valve means in the housing and associated with the second inlet, said second valve means having a first state, in which the second inlet is cut off from the turbine rotor, and a second state in which the second inlet is in communication with the turbine rotor, means biasing the first valve means to its second state, means to move the second valve means from its first state to its second state, connecting means interposed between the first valve means and the second valve means to hold the first valve means in its first state as the second valve means moves from its first state to its second state to initiate an operating cycle of the pump by admitting secondary fluid to rotate the turbine rotor, disabling means associated with the connecting means and operable in dependence on the rotational speed of the turbine rotor to disable the connecting means and to cause the first valve means to assume its second state and the second valve means to assume its first state, thus permitting primary fluid to flow from the inlet chamber to the pump rotor and also cutting off the supply of secondary fluid to the turbine rotor, the residual kinetic energy of the rotors after the cutting off of secondary fluid being such as to deliver through the outlet a quantity of the primary fluid admitted to the pump rotor, and means associated with the first valve means to return the said means to its first state at the end of the cycle.

3. A pump for operation in successive separate operating cycles, comprising a housing, an inlet chamber for primary fluid in the housing, a pump rotor rotatably mounted in the housing, a turbine rotor rotatably mounted in the housing, coupling means interconnecting the rotors for synchronous rotation, an outlet for primary fluid in the housing, the outlet being in communication with the pump rotor, a fluid transfer member movably mounted in the housing and interposed between said inlet chamber and the pump rotor, a transfer passage in the transfer member, one end of the passage being in communication with the inlet chamber, means to move the transfer member reversibly between a first position and a second position, in the first position there being no communication between the transfer passage and the pump rotor while in the second position the pump rotor is in communication with the other end of the transfer passage, a first valve member mounted on the transfer member for movement relatively thereto between a first and a second position, in the first position the valve member

blocking fluid flow through the transfer passage, and in the second position the valve member permitting primary fluid to flow from the inlet chamber through the transfer passage, a second inlet in the housing for secondary fluid, the second inlet leading to the turbine rotor, a second valve member in the housing and associated with the second inlet, said second valve member being movable reversibly between a first position, in which the second inlet is cut off from the turbine rotor, and a second position in which the second inlet is in communication with the turbine rotor, means biasing the second valve member to its first position, connecting means interposed between the fluid transfer member and the valve members whereby movement of the transfer member from its first position to its second position holds the first valve member in its first position but moves the second valve member to its second position to initiate an operating cycle by admitting secondary fluid to rotate the turbine rotor, and disabling means associated with the connecting means and operable in dependence on the rotational speed of the turbine rotor to disable the connecting means and to cause the first valve member to assume its second position and the second valve member to assume its first position thus permitting primary fluid to flow from the inlet chamber to the pump rotor and also cutting off the supply of secondary fluid to the turbine rotor, the residual kinetic energy of the rotors after the cutting off of secondary fluid being such as to deliver through the outlet a quantity of the primary fluid admitted to the pump rotor.

4. A pump for operation in successive separate operating cycles, comprising a housing, an inlet chamber for primary fluid in the housing, a pump rotor rotatably mounted in the housing, a turbine rotor rotatably mounted in the housing, coupling means interconnecting the rotors for synchronous rotation, an outlet for primary fluid in the housing, the outlet being in communication with the pump rotor, a fluid transfer member movably mounted in the housing and interposed between the inlet chamber and the pump rotor, a transfer passage in the transfer member, one end of the passage being in communication with the inlet chamber, the fluid transfer member being movable between a first position and a second position, in the first position there being no communication between the transfer passage and the pump rotor while in the second position the pump rotor is in communication with the other end of the transfer passage, elastic means to bias the transfer member to the first position, means operable to overcome the elastic biasing means and move the transfer member from the first position to the second position, a first valve member mounted on the transfer member for movement relatively thereto between a first position and a second position, in the first position the valve member blocking fluid flow through the transfer passage, and in the second position the valve member permitting primary fluid to flow from the inlet chamber to the transfer passage, elastic means biasing the first valve member to the second position, a second inlet in the housing for secondary fluid, the second inlet leading to the turbine rotor, a second valve member in the housing and associated with the second inlet, said second valve member being movable reversibly between a first position, in which the second inlet is cut off from the turbine rotor, and a second position in which the second inlet is in communication with the turbine rotor, elastic means biasing the first valve member to its second position, connecting means interposed between the fluid transfer member and the valve members, the connecting means holding the first valve member in its first position during movement of the transfer member from its first position to its second position, the transfer member acting through the connecting means during said movement to move the second valve member to its second position to initiate an operating cycle by admitting secondary fluid to rotate

the turbine rotor, and disabling means associated with the connecting means and operable in dependence on the rotational speed of the turbine rotor to disable the connecting means allowing the first valve member to assume its second position and the second valve member to assume its first position under the influence of the elastic means and thus permitting primary fluid to flow from the inlet chamber to the pump rotor and also cutting off the supply of secondary fluid to the turbine rotor, the residual kinetic energy of the turbine rotors after the cutting off of secondary fluid being such as to deliver through the outlet a quantity of the primary fluid admitted to the pump rotor.

5. A pump for operation in successive separate operating cycles, comprising a housing, an inlet chamber for primary fluid in the housing, a pump rotor rotatably mounted in the housing, a turbine rotor rotatably mounted in the housing, coupling means interconnecting the rotors for synchronous rotation, an outlet for primary fluid in the housing, the outlet being in communication with the pump rotor, a fluid transfer member mounted in the housing and interposed between the inlet chamber and the pump rotor for movement between first and second positions, a transfer chamber in the transfer member, first and second sets of transfer ports in the transfer member and in communication with the transfer chamber, the ports of the first set being in communication with the inlet chamber, means to bias the transfer member to the first position, means to move the transfer member to the second position, in the first position there being no communication between the ports of the second set and the pump rotor while in the second position the pump rotor is in communication with the transfer chamber through the ports of a second set, a first valve member mounted on the transfer member for movement relatively thereto between a first and a second position, in the first position the valve member blocking communication between the ports of the first set and the ports of the second set while in the second position the valve member permits fluid to flow from the inlet chamber to the transfer chamber and to the ports of the second set, means to bias the valve member to its second position, a second inlet in the housing for secondary fluid, the second inlet leading to the turbine rotor, a second valve member in the housing and associated with the second inlet, said second valve member being movable between a first position and a second position, in the first position the second inlet being cut off from the turbine rotor, and in the second position the second inlet being in communication with the turbine rotor, connecting means interposed between the transfer member and the valve member, the connecting means holding the first valve member in its first position, elastic means biasing the second valve member to its first position, movement of the transfer member from its first position to its second position acting through the connecting means to move the second valve member to its second position to initiate an operating cycle by admitting secondary fluid to rotate the turbine rotor, and disabling means associated with the connecting means and operable in dependence on the rotational speed of the turbine rotor to disable the connecting means and to allow the first valve member to assume its second position and the second valve member to assume its first position, thus permitting primary fluid to flow from the inlet chamber to the pump rotor and also cutting off the supply of secondary fluid to the pump rotor, the residual kinetic energy of the rotors after the cutting off of secondary fluid being such as to deliver through the outlet a quantity of the primary fluid admitted to the pump rotor.

6. A pump for operation in successive separate operating cycles, comprising a housing, an inlet chamber for primary fluid in the housing, an annular pump rotor having a central bore and rotatably mounted in the housing, a turbine rotor rotatably mounted in the hous-

ing, coupling means interconnecting the rotors for synchronous rotation, an outlet for primary fluid in the housing, the outlet being in communication with the pump rotor, a fluid transfer sleeve mounted in the housing for movement between first and second positions, the sleeve being mounted co-axially with the rotors and passing through the bore of the pump rotor, the interior of the sleeve providing a transfer chamber, first and second sets of transfer ports spaced apart along the transfer sleeve and in communication with the interior thereof, the ports of the first set being in communication with the inlet chamber, elastic means biasing the transfer sleeve to the first position, means to move the transfer sleeve to the second position, in the first position there being no communication between the ports of the second set and the pump rotor while in the second position the ports in the second set register with apertures in the base of the pump rotor, a valve piston mounted in the transfer sleeve for movement relatively thereto between a first position and second position, in the first position the valve piston blocking communication between the ports of the first set and the ports of the second set, while in the second position the valve piston permits fluid to flow from the inlet chamber into the interior of the transfer sleeve and to the ports of the second set, elastic means to bias the valve piston to its second position, a second inlet in the housing, for secondary fluid, the second inlet leading to the turbine rotor, a second valve member in the housing and associated with the second inlet, said second valve member being movable between a first position and a second position, in the first position the second inlet being cut off from the turbine rotor, and in the second position the second inlet being in communication with the turbine rotor, connecting means interposed between the transfer member and the valve members, the connecting means holding the first valve piston in its first position, elastic means biasing the first valve member to its second position, movement of the transfer member from its first position to its second position actuating the connecting means to move the second valve member to its second position to initiate an operating cycle of the pump by admitting secondary fluid to rotate the turbine rotor, and disabling means associated with the connecting means and operable in dependence on the rotational speed of the turbine rotor to disable the connecting means and to allow the valve piston to assume its second position and the second valve member to assume its first position, thus permitting primary fluid to flow from the inlet chamber to the pump rotor and also cutting off the supply of secondary fluid to the turbine rotor, the residual kinetic energy of the rotors after the cutting off of secondary fluid being such as to deliver through the outlet a quantity of primary fluid admitted to pump the rotor, and means associated with the disabling means to return the said means to its original state at the end of the cycle when the transfer sleeve has returned to its first position.

7. A pump for operation in successive separate operating cycles, comprising a housing, an inlet chamber for primary fluid in the housing, a pump rotor rotatably mounted in the housing, a turbine rotor rotatably mounted in the housing, coupling means interconnecting the rotors for synchronous rotation, an outlet for primary fluid in the housing, the outlet being in communication with the pump rotor, a cylinder in the housing, a fluid transfer member slidable in the cylinder and interposed between the inlet chamber and the pump rotor, a transfer passage in the transfer member, one end of the passage being in communication with the inlet chamber, the transfer member being movable between first and second positions, elastic means biasing the transfer member to the first position, means for introducing fluid under pressure into the cylinder to move the transfer member against the biasing means to the second position, an actuating valve to control the admission of fluid to the cylinder,

in the first position of the transfer member there being no communication between the transfer passage and the pump rotor, while in the second position the pump rotor is in communication with the other end of the transfer passage, a first valve member mounted on the transfer member for movement relatively thereto between a first position and a second position, in the first position the valve member blocking fluid flow through the transfer passage, and in the second position the valve member permitting primary fluid to flow from the inlet chamber through the transfer passage, a second inlet in the housing for secondary fluid, the second inlet leading to the turbine rotor, a second valve member in the housing and associated with the second inlet, said second valve member being movable reversibly between a first position, in which the second inlet is cut off from the turbine rotor, and a second position in which the second inlet is in communication with the turbine rotor, means biasing the second valve member to its first position, connecting means interposed between the fluid transfer member and the valve members whereby movement of the transfer member from its first position to its second position holds the first valve member in its first position but moves the second valve member to its second position to initiate an operating cycle by admitting secondary fluid to rotate the turbine rotor, and disabling means associated with the connecting means and operable in dependence on the attainment of a predetermined rotational speed of the turbine rotor to disable the connecting means and to cause the first valve member to assume its second position and the second valve member to assume its first position, thus permitting primary fluid to flow from the inlet chamber to the pump rotor and also cutting off the supply of secondary fluid to the turbine rotor, the residual kinetic energy of the rotors after the cutting off of secondary fluid being such as to deliver through the outlet a quantity of the primary fluid admitted to the pump rotor.

8. A pump according to claim 7 including an inlet valve to control the admission of primary fluid to the inlet chamber, the actuating valve and the inlet valve being interconnected for synchronous operation, the inlet valve permitting primary fluid to flow into the inlet chamber when the actuating valve permits fluid to flow into said cylinder and the inlet valve preventing primary fluid flowing into the inlet chamber when the actuating valve prevents fluid flowing into said cylinder.

9. A pump according to claim 8 including bleed means associated with the actuating valve and the inlet valve to enable fluid to bleed from said cylinder when both said valves are closed.

10. A pump for operation in successive separate operating cycles, comprising a housing, a first inlet in the housing for primary fluid, a pump rotor rotatably mounted in the housing, a turbine rotor rotatably mounted in the housing, coupling means interconnecting the rotors for synchronous rotation, an outlet port in the housing in communication with the pump rotor, an outlet chamber in communication with the outlet port, a drain valve in the outlet chamber, elastic means normally holding said drain valve open, an outlet valve in the outlet chamber, elastic means normally holding said outlet valve closed, the attainment of a predetermined pressure in said outlet chamber overcoming the elastic means associated with the outlet valve and the elastic means associated with the drain valve to open the former and close the latter, first valve means in the housing interposed between the inlet and the pump rotor, the valve means having a first state, in which it cuts off communication between the inlet and the pump rotor, and a second state in which the inlet is in communication with the pump rotor, the valve means being normally retained in its first state, a second inlet in the housing for secondary fluid, the second inlet leading to the turbine rotor, second valve means in the housing

and associated with the second inlet, said second valve means having a first state, in which the second inlet is cut off from the turbine rotor, and a second state in which the second inlet is in communication with the turbine rotor, the second valve means being normally retained in the first state, means to move the second valve means from its first state to its second state to initiate an operating cycle of the pump by admitting secondary fluid to rotate the turbine rotor, means associated with both valve means and operable on the attainment of a predetermined rotational speed of the turbine rotor to cause the first valve means to assume its second state and the second valve means to assume its first state, thus permitting primary fluid to flow from the first inlet to the pump rotor and also cutting off the supply of secondary fluid from the turbine rotor, the residual kinetic energy of the rotors after the cutting off of the secondary fluid being such as to deliver primary fluid to the outlet chamber at a pressure above said predetermined pressure thereby closing said drain valve and delivering said primary fluid through said outlet valve.

11. A pump for operation in successive separate operating cycles, comprising a housing, a first inlet chamber for primary fluid in the housing, a pump rotor rotatably mounted in the housing, a turbine rotor rotatably mounted in the housing, coupling means interconnecting the rotors for synchronous rotation, an outlet for primary fluid in the housing, the outlet being in communication with the pump rotor, a fluid transfer member movably mounted in the housing and interposed between the inlet chamber and the pump rotor, a transfer passage in the transfer member, one end of the passage being in communication with the inlet chamber, means to move the transfer member reversibly between a first position and a second position, in the first position there being no communication between the transfer passage and the pump rotor while in the second position the pump rotor is in communication with the other end of the transfer passage, a first valve member mounted on the transfer member for movement relatively thereto between first and second positions, in the first position the valve member blocking fluid flow through the transfer passage, and in the second position the valve member permitting primary fluid to flow from the inlet chamber through the transfer passage, a second inlet in the housing for secondary fluid, the second inlet leading to the turbine rotor, a second valve member in the housing and associated with the second inlet, said second valve member being movable between a first position, in which the second inlet is cut off from the turbine rotor, and a second position in which the second inlet is in communication with the turbine rotor, means biasing the first valve member to its second position, a rod interconnecting the first and second valve members, a neck portion of reduced diameter on said rod intermediate said valve members, a slotted plate mounted on the turbine rotor, the slot in the plate closely embracing the reduced portion of said rod, the slot in said plate having an enlarged aperture to accommodate the full diameter of the rod, spring means normally urging said plate to a position in which the slot closely embraces said neck portion and the enlarged aperture is clear of said rod, movement of the transfer member from its first position to its second position causing the transfer member to coast with the slotted plate to move the second valve member to its second position while holding the first valve member in its first position, movement of the second valve member to its second position initiating an operating cycle of the pump by admitting secondary fluid to rotate the turbine rotor, and means associated with said slotted plate and operable in dependence on the rotational speed of the turbine rotor to move said plate until said enlarged aperture is in register with said rod thereby permitting said rod to move relatively to the transfer member to cause the first valve member to assume its second

position and the second valve member to assume its first position, thus permitting primary fluid to flow from the inlet chamber to the pump rotor and also cutting off the supply of secondary fluid to the turbine rotor, the residual kinetic energy of the rotors after the cutting off of secondary fluid being such as to deliver through the outlet a quantity of the primary fluid admitted to the pump rotor.

12. A pump for operation in successive separate operating cycles, comprising a housing, a first inlet in the housing for primary fluid, an annular turbine rotor rotatably mounted in the housing, passages in the rotor extending between the inner and outer peripheries thereof, the rotor, flaps hingedly mounted at the ends of the passages opening into the inner periphery of the rotor, springs normally holding said flaps open, the flaps closing under the influence of a predetermined rotational speed and fluid pressure to prevent over-speed conditions of the turbine rotor, a pump rotor rotatably mounted in the housing, coupling means interconnecting the rotors for synchronous rotation, an outlet for primary fluid in the housing, the outlet being in communication with the pump rotor, first valve means in the housing and interposed between the inlet and the pump rotor, the valve means having a first state, in which it cuts off communication between the inlet and the pump rotor, and a second state in which the inlet is in communication with the pump rotor, the valve means being normally retained in its first state, a second inlet in the housing for secondary fluid and leading to the inner periphery of the turbine rotor, second valve means in the housing and associated with the second inlet, said second valve means having a first state, in which the second inlet is cut off from the turbine rotor, and a second state in which the second inlet is in communication with the turbine rotor, the second valve means being normally retained in its first state, means to move the second valve means from its first state to its second state to initiate an operating cycle of the pump by admitting secondary fluid to rotate the turbine rotor, means associated with both valve means operable at the attainment of a predetermined rotational speed of the turbine rotor to cause the first valve means to assume its second state and the second valve means to assume its first state, thus permitting primary fluid to flow from the first inlet to the rotor means and also cutting off secondary fluid from the turbine rotor, the residual kinetic energy of the rotors after the cutting off of secondary fluid being such as to deliver through the outlet a quantity of the primary fluid

admitted to the pump rotor, and means associated with the first valve means to return said means to its first state at the end of the cycle.

13. A pump for operation in successive separate operating cycles, comprising a housing, a first inlet in the housing for primary fluid, rotor means rotatably mounted in the housing, an outlet for primary fluid in the housing, the outlet being in communication with the rotor means, first valve means in the housing and interposed between the inlet and the rotor means, the valve means having a first state, in which it cuts off communication between the inlet and the rotor means, and a second state in which the inlet is in communication with the rotor means, the valve means being normally retained in its first state, a second inlet in the housing for secondary fluid, the second inlet leading to the rotor means, second valve means in the housing, and associated with the second inlet said second valve means having a first state, in which the second inlet is cut off from the rotor means, and a second state in which the second inlet is in communication with the rotor means, the second valve means being normally retained in its first state, means to move the second valve means from its first state to its second state to initiate an operating cycle of the pump by admitting secondary fluid to rotate the rotor means, means associated with both valve means and operable at the attainment of a predetermined rotational speed of the rotor means to cause the first valve means to assume its second state and the second valve means to assume its first state, thus permitting primary fluid to flow from the first inlet to the rotor means and cutting off secondary fluid from the rotor means, the residual kinetic energy of the rotor means after the cutting off of secondary fluid being such as to deliver through the outlet a quantity of primary fluid admitted to the rotor means, and means associated with the first valve means to return said means to its first state at the end of the cycle.

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