

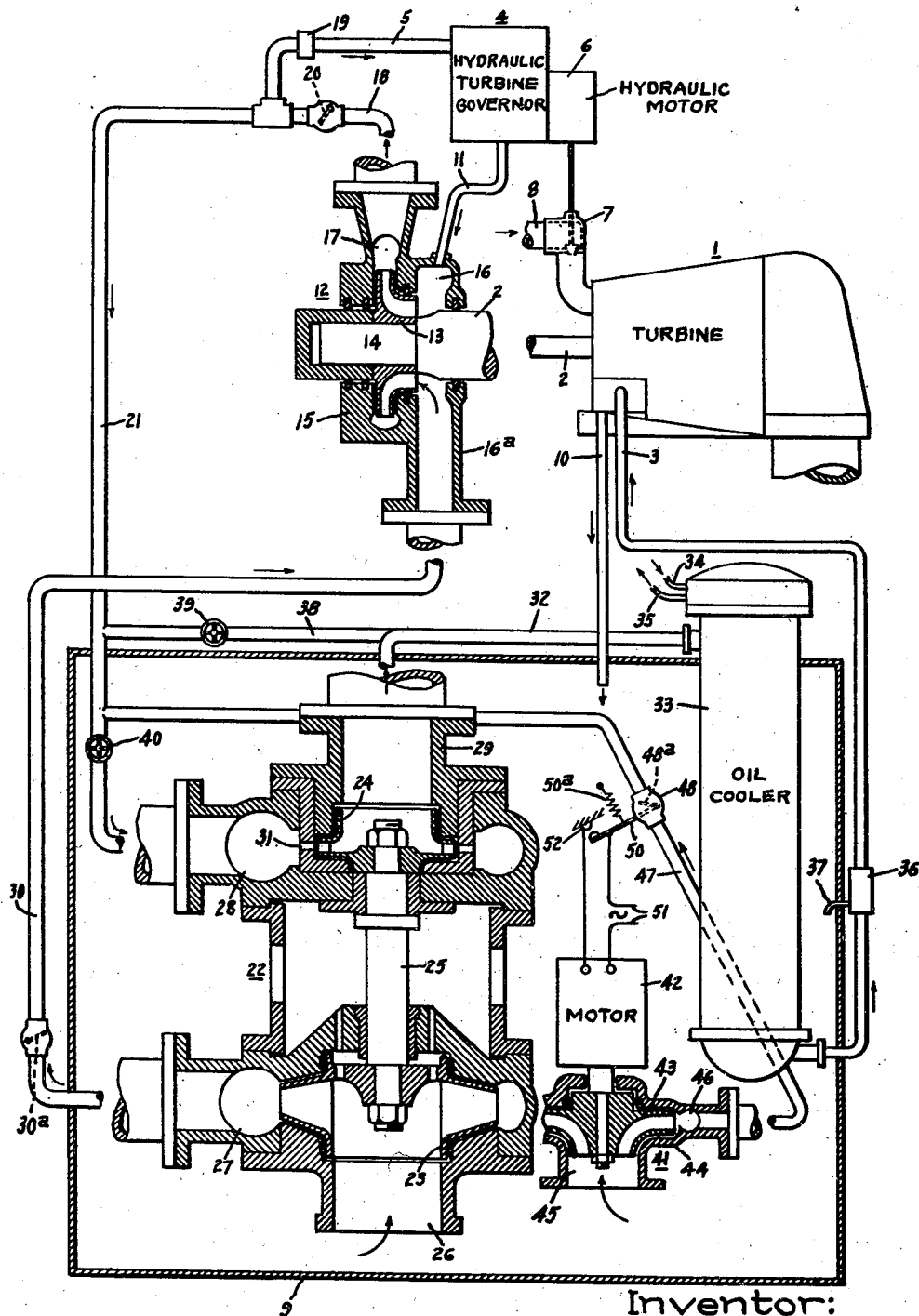
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TURBINE OIL SYSTEM WITH PUMP PRIMING ARRANGEMENT

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TURBINE OIL SYSTEM WITH PUMP
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My invention relates to a system for supplying liquid under pressure to a rotating machine, particularly to a system for supplying oil to a prime mover such as a turbine. It is especially applicable to steam turbines which require considerable quantities of oil, both for lubrication and for operating auxiliary hydraulic devices such as a hydraulic governing system.

An object of the invention is to provide an improved system for supplying a liquid such as oil under pressure to a rotating machine for lubrication and other purposes.

Another object is to provide a prime mover oil system which is comparatively free from service and maintenance troubles and has improved efficiency, so that a minimum amount of power need be taken from the shaft of the prime mover for operating the oil supply system.

A further object is to provide an improved turbine oil system having a main supply pump coupled directly to the turbine shaft and a separately driven booster pump for positively priming the main pump.

A still further object is to provide a system of the type described for supplying liquid to a rotating machine at two different pressures, in which the pressure drop from the higher to the lower pressure is utilized to furnish the energy required to drive the booster pump for priming the main oil pump.

Another object is to provide a liquid distribution system of the type described in which liquid can be supplied to the inlet of the main supply pump at any suitable pressure necessary for avoiding cavitation difficulties with that pump.

Other objects and advantages will be apparent from the following description taken in connection with the accompanying drawing, in which the single figure represents diagrammatically a steam turbine oil supply system arranged in accordance with the invention.

In the past it has been customary to lubricate large prime movers such as steam turbines by a positive displacement pump connected to the turbine shaft by mechanical gearing. Such geared pumps were a source of considerable trouble; therefore attempts have been made to devise supply systems having a main oil pump without mechanical gearing. It is of course possible to separate the oil pump entirely from the prime mover and drive it by an electric motor. This is not entirely satisfactory because the oil supply fails if the electric power fails; and loss of oil pressure is of course serious from the standpoint of damage to the bearings of the machine.

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Loss of oil pressure is doubly serious in the case of a steam turbine which relies upon oil pressure not only for lubrication but also to furnish the motive power for operating hydraulic devices such as a hydraulic governing system.

It has previously been suggested that the oil supply be furnished by a centrifugal pump impeller mounted directly on an extension of the prime mover shaft. This arrangement is subject to the objection that a centrifugal pump is not self-priming; therefore it is necessary to provide special means for insuring that the main oil pump shall always be primed with liquid at a positive pressure, to insure the required reliability. Centrifugal pumps have also been found to be subject to the objection that, when operated at the high speeds of modern steam turbines, they are susceptible to both performance and maintenance troubles caused by cavitation. This phenomenon results in series disturbances in the pump performance and shortens the life of the pump parts.

My invention provides an improved turbine oil supply system having a main centrifugal pump directly coupled to the turbine shaft and having a booster pump of novel arrangement for positively priming the main pump, which avoids the difficulties heretofore encountered with pumps of the type described.

Referring now to the drawing, my invention is disclosed as applied to a steam turbine indicated generally at 1 and having a shaft 2, a lubrication system to which oil is supplied under pressure through a conduit 3, and a hydraulic governor indicated generally at 4 to which oil is supplied under pressure through a conduit 5. As will be understood by those familiar with the turbine art, the hydraulic governor 4 is arranged to control a motor 6, which may be in the form of a piston slidably arranged in a cylinder, for positioning the turbine inlet control valve 7. Motive fluid is supplied to the turbine 1 through the inlet conduit 8, and the speed and output of the turbine are controlled by regulation of the valve 7 through the governor 4 and motor 6. Many types of such hydraulic governors for turbines are known in the art and the specific details of the governing system are not necessary to an understanding of the present invention.

Oil for lubricating the turbine and actuating the governing system is supplied from a reservoir 9, which is customarily located at a level below the turbine so that the oil supplied to the bearings and other components may conveniently be drained back to the reservoir by gravity. In the

drawing the turbine lubrication system is drained by means of the conduit 10.

In accordance with the invention, a main oil pump, indicated generally at 12, is directly coupled to an extension of the turbine shaft 2. As shown, this main oil pump consists of a centrifugal impeller 13 mounted directly on the shaft extension 14. The impeller is surrounded by a casing 15 which defines an annular pump inlet chamber 16 and a discharge scroll 17. Any suitable type of centrifugal pump may be employed, provided it has a "flat" characteristic operating curve, which is required for reasons which will appear hereinafter.

The pump inlet chamber 16 communicates with a supply pipe 16a. The discharge scroll 17 communicates with a discharge pipe 18, to which is connected the governor supply conduit 5. A suitable pressure regulating valve 19 is incorporated in the conduit 5 to maintain constant at a preselected value the pressure of the oil supplied to the governor. Spent liquid from the governor 4 and motor 6 returns through conduit 11 to the inlet 16 of pump 12, as noted hereinafter. A suitable check valve 20 is provided in conduit 18 to prevent flow of liquid in a reverse direction through pump 12. Arranged in the oil reservoir 9 for priming the main pump 12 is a booster pump indicated generally at 22 and consisting of a centrifugal pump impeller 23 and a liquid pressure turbine rotor 24 mounted on a common shaft 25. The casing of the booster pump 22 defines an inlet opening 26 for admitting oil from the reservoir to the pump impeller 23, a pump discharge scroll 27, a turbine inlet scroll 28, and a turbine discharge conduit 29. A conduit 30 containing a check valve 30a delivers oil from the booster pump discharge scroll 27 to the inlet 16a of the main oil pump 12. Another conduit 21 supplies oil under pressure from the discharge scroll 17 of pump 12 to the inlet scroll 28 of turbine 24.

Arranged in the housing of the booster pump 22 and surrounding the turbine impeller 24 are a plurality of circumferentially spaced liquid inlet nozzles 31. It will be understood by those skilled in the art that the capacity of the liquid turbine may be varied by properly selecting the size of the ring of nozzles 31, or the nozzles may be provided around only a portion of the circumference of impeller 24, so as to provide "partial arc admission." Oil discharged from the turbine through the outlet 29 is led by a conduit 32 to a suitable oil cooler 33, through which cooling water is circulated by means of the inlet pipe 34 and an outlet pipe 35. From the oil cooler, lubricating oil is supplied to the turbine 1 through conduit 3. A pressure relief valve 36 is arranged to return excess oil to reservoir 9 through a drain line 37 so as to maintain constant at a preselected value the oil pressure in conduit 3.

In order to readily adjust the output of the turbine impeller 24 and the pressure maintained in conduit 32, a bypass conduit 38 provided with a throttle valve 39 is provided connecting the turbine inlet conduit 21 with the turbine discharge conduit 32. The amount of liquid supplied to the turbine can be adjusted by suitably controlling the throttle valve 39 so as to vary the amount of liquid bypassed around the turbine. Additional control of the liquid pressure turbine may be obtained through a suitable inlet control valve 40. By adjusting valve 40, the speed of turbine 24, and hence the discharge pressure in conduit 30, can be regulated. Then by adjusting valve

39, the pressure in conduit 32 can be brought to a value suitable for lubrication purposes.

From the above description of the apparatus, it will be seen that during normal operation of the turbine 1, oil is delivered by the main pump 12 to the conduit 18 at a pressure suitable for operation of the hydraulic governing mechanism 4. This pressure may be of the order of 200 pounds per square inch, which is considerably higher than is ordinarily used for lubrication purposes. Therefore it becomes necessary to reduce the pressure in some manner to a value suitable for the turbine lubrication system, which may be of the order of only 25 pounds per square inch. This could of course be done simply by means of an ordinary throttling valve, but the resulting throttling process would wastefully dissipate an appreciable amount of the power abstracted from the turbine shaft 2 for driving the oil supply system.

An important feature of the invention is that the reduction of the oil pressure from the value required for operation of the governor 4 to that required for the turbine lubrication system is accomplished in a manner which makes use of the energy represented by this pressure drop. This is effected by causing the pressure drop to occur across the nozzles 31 and impeller 24 of the liquid pressure turbine which serves to drive the priming pump 23. This method of conserving the energy in the liquid is found to make an important contribution to the overall efficiency of the prime mover by reducing the power needed to drive the oil supply pump 12. In the case of a 100,000 kilowatt steam turbine, this saving may amount to roughly 100 horsepower.

In an oil supply system for a 100,000 kilowatt steam turbine arranged in accordance with the invention, the quantity of liquid normally discharged from the main pump 12 for lubrication may be of the order of 350 gallons per minute. Of this quantity, 250 gallons per minute may flow through the liquid pressure turbine 24 to drive the booster pump impeller 23, while 100 gallons per minute is bypassed through the conduit 38. The combined flow of 350 gallons per minute from the bypass 38 and turbine discharge 29 is supplied to the turbine lubrication system through conduits 32, and cooler 33, neglecting any small amount that may be dumped by the relief valve 36.

The functioning of the hydraulic governing mechanism 4 and the valve control motor 6 requires that the quantity of liquid discharged from pump 12 be capable of increasing suddenly from the normal rate of 350 gallons per minute required for lubrication to a magnitude of the order of 750 gallons per minute. This large momentary increase in the quantity discharged by the main pump 12 must take place without any material change in the pump discharge pressure, in order to avoid disturbances in the governor 4. It is for this reason that the pump 12 must have a "flat" characteristic curve, so that it is capable of delivering a quantity of liquid which varies over a wide range without appreciable change in the discharge pressure.

It should be noted that spent liquid from the governor 4 and motor 6 is returned by conduit 11 to the inlet chamber 16 of main oil pump 12. Thus, when operation of the governor and motor 4, 6 requires a large increase in the liquid discharged by pump 12, that amount required to actuate the governing system circulates only in the conduits 17, 18, 5, 11, 16 without materially altering the flow through conduit 21 to the liquid

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pressure turbine 24 and the lubrication supply pipe 3.

In starting the turbine 1, an auxiliary source of liquid under pressure is required in order to prime the system. This source may comprise a second auxiliary pump indicated generally at 41 and consisting of a motor 42 driving a centrifugal pump having an impeller 43 and a casing 44. The casing 44 defines an inlet opening 45 arranged to admit oil from reservoir 9 to the impeller 43, and a discharge scroll 46. A conduit 47 supplies liquid under pressure from the discharge scroll 46 through a suitable check valve 48 to the conduit 21 at a point upstream from the turbine control valve 40. It will be apparent to those skilled in the art that the starting pump motor 42 may be of any suitable type, such as an electric motor or a small steam turbine.

To start the system the motor 42 is energized and liquid supplied by the starting pump impeller 43 through conduits 47 and 21 past control valve 40 to the turbine impeller 24. Check valve 20 prevents this priming liquid from flowing backwards through the main pump 12. Liquid is also supplied to the governor 4 through conduit 5. Rotation of the turbine 24 causes the booster pump to increase the pressure in scroll 27, until check valve 30a opens when the pressure in 27 exceeds that in conduit 30. Oil is then supplied through pipe 30 to the inlet chamber 16a of main pump 12; while the discharge from oil turbine 24 and bypass 38 proceeds to the lubrication system of turbine 1 by way of the pipe 32, oil cooler 33, and conduit 3. When the pressure in the oil system rises to the proper value for actuating the governor 4, turbine 1 may be started and brought up to speed, during which the discharge pressure of the main oil pump 12 will increase to its normal operating value so that check valve 20 is caused to open. It will be apparent that when the pressure in conduits 18, 21, produced by the rotation of the main oil pump impeller 13, rises above that produced in conduit 47 by the starting pump impeller 43, the check valve 48 will act to prevent any leakage of oil from conduit 21 backwards through conduit 47.

Suitable governing mechanism may be provided for the starting motor 42, so arranged that it is automatically deenergized when the pressure in conduits 18, 21 rises to a preselected value. Specifically, motor 42 may be automatically shut off when the pressure produced by the main pump 12 exceeds the pressure in conduit 47 produced by the starting pump 41. When an electric motor is used, energized from a suitable source of current 51, the control system may conveniently consist of a contact arm 50 coupled to the pivoted valve disc member 48a, so that arm 50 moves away from the stationary contact 52 and thus breaks the circuit to motor 42 when liquid tries to flow in the reverse direction through check valve 48. A spring 50a biases the contacts to closed position so that motor 42 will be energized whenever the pressure in conduit 21 falls below a preselected value.

It will be seen that my improved liquid supply system provides oil at a comparatively high pressure for operating hydraulic devices such as a governing mechanism, and also supplies oil at a much lower pressure for lubrication purposes, by means of a high speed main oil pump of a non-self-priming type coupled directly to the shaft of the prime mover without intermediate gearing and having an oil booster pump arranged to positively prime the main pump and driven by

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energy derived from the drop in pressure from the high value required for the hydraulic devices to the lower value required for lubrication. With this improved arrangement, a minimum quantity of oil need be handled by the main oil pump, so that the power required for operating the system is kept to a minimum. By using the pressure drop inherent in the system to furnish energy for driving the booster pump, a further important improvement in the power consumption of the system is obtained. With my invention, a very much smaller quantity of oil need be pumped, than in other previously suggested systems. By thus reducing the volume flow in the system, aeration of the oil is minimized and the life of the oil is considerably extended. Furthermore because of its efficiency and flexibility, my system makes it possible to obtain at the inlet of the main oil pump any pressure which may be found to be required in order to overcome or avoid cavitation in that pump. Thus the performance of the system is improved and the life of the main oil pump may be greatly extended.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. In a liquid supply system for a machine requiring a primary supply of liquid at a comparatively high pressure and a secondary supply at a lower pressure, the combination of a liquid reservoir, a main pump located at the machine and arranged to be driven thereby, a booster pump located at the reservoir and including a second pump arranged to receive liquid from the reservoir and driven by a liquid pressure motor, first conduit means for supplying liquid from the discharge of the main pump to the inlet of the liquid pressure motor and to the machine at a high pressure, second conduit means for supplying liquid from the discharge of the second pump to the inlet of the main pump, and third conduit means for supplying liquid from the discharge of the liquid pressure motor to the machine at a lower pressure, whereby the pressure differential between said first and third conduit means is utilized to drive the booster pump.

2. In a liquid supply system for a machine requiring a primary supply of liquid at a comparatively high pressure and a secondary supply at a lower pressure, the combination of a liquid reservoir, a main pump located at the machine and arranged to be driven thereby, a booster pump located at the reservoir and including a second pump arranged to receive liquid from the reservoir and driven by a liquid pressure motor, first conduit means for supplying liquid from the discharge of the main pump to the inlet of the liquid pressure motor and to the machine at a high pressure, second conduit means for supplying liquid from the discharge of the booster pump to the inlet of the main pump, third conduit means for supplying liquid from the discharge of the liquid pressure motor to the machine at a lower pressure, and fourth conduit means connected to the first conduit and the third conduit whereby liquid not required for driving the liquid pressure motor can be bypassed around said motor.

3. In a liquid supply system for a machine requiring a primary supply of liquid at a comparatively high pressure and a secondary supply at a lower pressure, the combination of a liquid reservoir, a main pump located at the machine and arranged to be driven thereby, a booster pump located at the reservoir and including a second pump arranged to receive liquid from the reservoir and driven by a liquid pressure motor, first

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conduit means for supplying liquid from the discharge of the main pump to the inlet of the liquid pressure motor and to the machine at a high pressure, second conduit means for supplying liquid from the discharge of the second pump to the inlet of the main pump, third conduit means for supplying liquid from the discharge of the liquid pressure motor to the machine at a lower pressure, and means for priming the system including motor means driving a pump arranged to receive liquid from the reservoir and deliver it to the inlet of the liquid pressure motor.

4. In a liquid supply system for a machine requiring a primary supply of liquid at a comparatively high pressure and a secondary supply at a lower pressure, the combination of a liquid reservoir, a main pump located at the machine and arranged to be driven thereby, a booster pump located at the reservoir and including a second pump arranged to receive liquid from the reservoir and driven by a liquid pressure motor, first conduit means for supplying liquid from the discharge of the main pump to the inlet of the liquid pressure motor and to the machine at a high pressure, second conduit means for supplying liquid from the discharge of the second pump to the inlet of the main pump, third conduit means for supplying liquid from the discharge of the liquid pressure motor to the machine at a lower pressure, means for priming the system including motor means driving a pump arranged to receive liquid from the reservoir and deliver it to the inlet of the liquid pressure motor, and means for automatically stopping the flow of liquid from the priming means to the liquid pressure motor when the main pump is in normal operation.

5. In an oil supply system for a prime mover requiring a primary supply of oil at a comparatively high pressure for operating hydraulic devices and a secondary supply at a lower pressure for lubrication, the combination of an oil reservoir, a main pump located at the prime mover and arranged to be driven thereby, a booster pump located at the reservoir and including a second pump arranged to receive oil from the reservoir and driven by a liquid pressure motor, first conduit means for supplying oil from the discharge of the main pump to the inlet of the liquid pressure motor and to the prime mover at a high pressure, second conduit means for supplying oil from the discharge of the second pump to the inlet of the main pump, and third conduit means including an oil cooler for supplying lubricating oil from the discharge of the liquid pressure motor to the prime mover at a lower pressure, the pressure differential between said first and third conduit means being utilized to drive the booster pump.

6. In an oil supply system for a prime mover requiring a primary supply of oil at a comparatively high pressure for operating hydraulic devices and a secondary supply at a lower pressure for lubrication purposes, the combination of an oil reservoir, a main oil pump located at the prime mover and arranged to be driven thereby, a booster pump located at the reservoir and including a second pump arranged to receive oil from the reservoir and driven by a liquid pressure motor, first conduit means for supplying oil from the discharge of the main pump to the inlet of the liquid pressure motor and to the prime mover at a high pressure, second conduit means for supplying oil from the discharge of the second pump to the inlet of the main pump, third conduit means for supplying oil from the dis-

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charge of the liquid pressure motor to the prime mover at a lower pressure, and fourth conduit means including a flow regulating device and connected to the first conduit and the third conduit in parallel with the liquid pressure motor for bypassing that oil which is required by the prime mover at the lower pressure in excess of the quantity of oil required to operate said motor.

7. In an oil supply system for a prime mover requiring a primary supply of oil at a comparatively high pressure for operating hydraulic devices and a secondary supply at a lower pressure for lubrication purposes, the combination of an oil reservoir, a main pump located at the prime mover and arranged to be driven thereby, a booster pump located at the reservoir and including a second pump arranged to receive oil from the reservoir and driven by a liquid pressure motor, first conduit means for supplying oil at a high pressure from the discharge of the main pump to the inlet of the liquid pressure motor and to the prime mover during normal operation of the latter, second conduit means for supplying oil from the discharge of the second pump to the inlet of the main pump, third conduit means for supplying oil from the discharge of the liquid pressure motor to the prime mover at a lower pressure, means for priming the system including a motor-driven pump arranged to supply oil to the inlet of the liquid pressure motor at a pressure sufficient to operate the latter, and means for interrupting the supply of priming oil from said motor-driven pump when the pressure of the oil delivered by the main pump is adequate to operate the liquid pressure motor.

8. In an oil supply system for a prime mover requiring a primary supply of oil at a comparatively high pressure and a secondary supply at a lower pressure, the combination of an oil reservoir located at a level below that of the prime mover, a main pump of a non-self-priming type located at the prime mover and arranged to be driven thereby, a booster pump located at the reservoir and including a second pump arranged to receive oil from the reservoir and driven by a liquid pressure motor, first conduit means for supplying oil from the discharge of the main pump to the inlet of the liquid pressure motor and to the prime mover at a high pressure, second conduit means for supplying oil from the discharge of the second pump to the inlet of the main pump whereby the latter is positively primed during normal operation of the prime mover, and third conduit means for supplying oil from the discharge of the liquid pressure motor to the prime mover at a lower pressure, the pressure differential between said first and third conduits being utilized to drive the booster pump.

9. In an oil supply system for a prime mover having a lubrication system and a device requiring a supply of oil at a pressure materially higher than that in the lubrication system, the combination of an oil reservoir located at a level below that of the prime mover, a main pump of a non-self-priming type located at the prime mover and arranged to be driven thereby, a booster pump located at the reservoir and including a second pump arranged to receive oil from the reservoir and driven by a liquid pressure motor, first conduit means for supplying oil from the discharge of the main pump to the inlet of the liquid pressure motor and to said device at a high pressure suitable for operating said motor and device, second conduit means for supplying oil from the discharge of the second pump to

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the inlet of the main pump whereby the latter is positively primed during normal operation of the prime mover, and third conduit means for supplying oil from the discharge of the liquid pressure motor to said lubrication system at a lower pressure, whereby the pressure differential between said first and third conduits is utilized to drive the booster pump.

10. In an oil supply system for a prime mover having a lubrication system and a device requiring a supply of oil at a pressure materially higher than that in the lubrication system, the combination of an oil reservoir located at a level below that of the prime mover, a main pump of a non-self-priming type located at the prime mover and arranged to be driven thereby, a booster pump located at the reservoir and including a second pump arranged to receive oil from the reservoir and driven by a liquid pressure motor, first conduit means for supplying oil from the discharge of the main pump to the inlet of the liquid pressure motor and to said device at a high pressure suitable for operating said motor and device, second conduit means for supplying oil from the discharge of the second pump to the inlet of the main pump whereby the latter is positively primed during normal operation of the prime mover, third conduit means for supplying oil from the discharge of the liquid pressure motor to said lubrication system at a lower pressure, and a drain conduit for returning used oil from said device to the inlet of the main pump whereby the oil required to operate the device circulates from the main pump through the first conduit means and the drain conduit without materially affecting the flow in said third conduit to the lubrication system.

11. In a system for supplying oil to a prime mover having a lubrication system and to a device requiring a supply of oil at a pressure ma-

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terially higher than that in the lubrication system, the combination of an oil reservoir located at a level below that of the prime mover, a main pump of a non-self-priming type located at the prime mover and arranged to be driven thereby, a booster pump located at the reservoir and including a second pump arranged to receive oil from the reservoir and driven by a liquid pressure motor, first conduit means for supplying oil from the discharge of the main pump to the inlet of the liquid pressure motor and to said device at a high pressure, throttling means associated with the inlet to the liquid pressure motor for regulating the power output thereof, second conduit means for supplying oil from the discharge of the second pump to the inlet of the main pump whereby the latter is positively primed during normal operation of the prime mover, third conduit means for supplying oil from the discharge of the liquid pressure motor to said lubrication system at a lower pressure, fourth conduit means including a flow regulating device and connected to the first and third conduits for bypassing oil in excess of that required to operate the liquid pressure motor, a drain conduit for returning used oil from said device to the inlet of the main pump, means for priming the system including a motor-driven pump arranged to supply oil from the reservoir through a priming conduit to the inlet of the liquid pressure motor and control means for automatically interrupting the flow of priming oil into the system when the pressure of the oil delivered by the main pump is adequate to operate the liquid pressure motor, and check valve means in said first, second, and priming conduits for preventing reverse flow through said main pump, booster pump, and priming pump, respectively.

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