

April 2, 1946.

H. HILLIER

2,397,664

LIQUID PUMP OF THE CENTRIFUGAL TYPE

Filed March 27, 1944

2 Sheets-Sheet 1

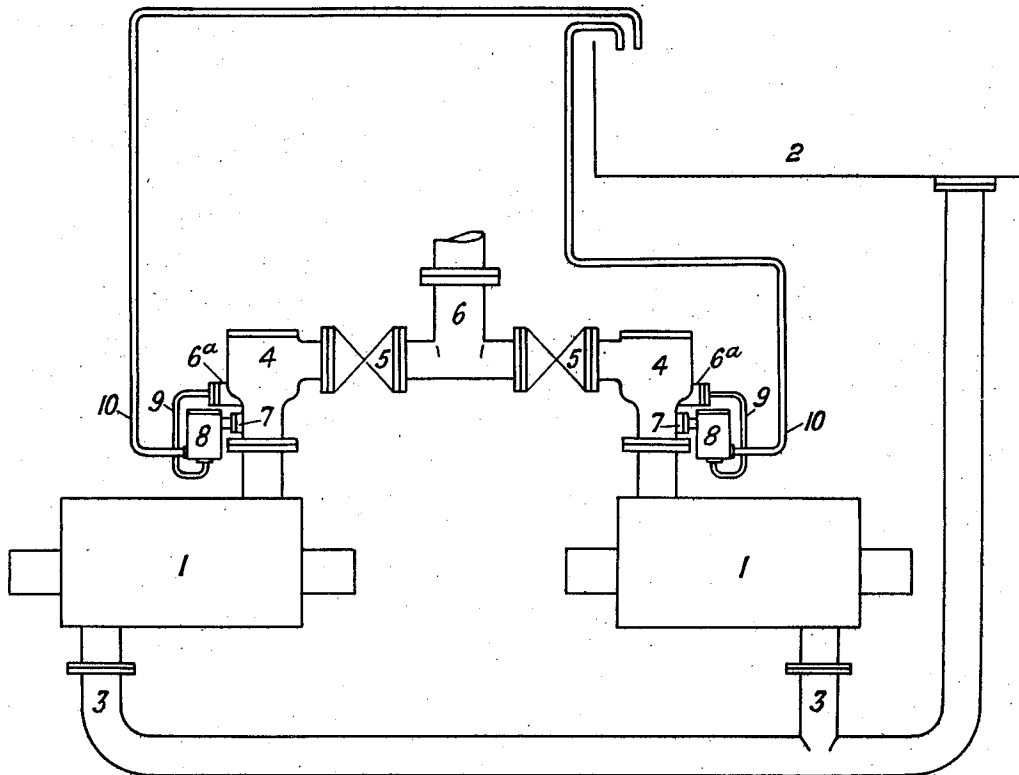


FIG. 1.

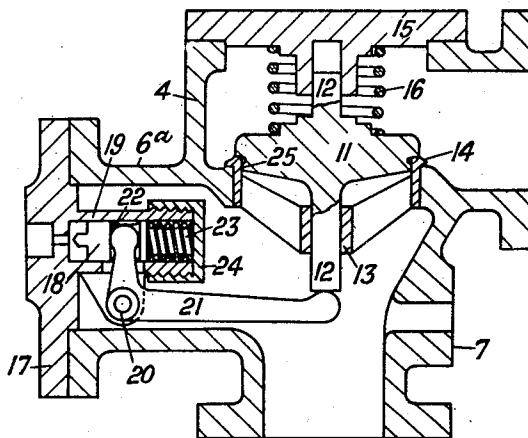


FIG. 2.

Inventor
Harold Hillier
By
Perris, O'Connell & Smith
Attorneys

April 2, 1946.

H. HILLIER

2,397,664

LIQUID PUMP OF THE CENTRIFUGAL TYPE

Filed March 27, 1944

2 Sheets-Sheet 2

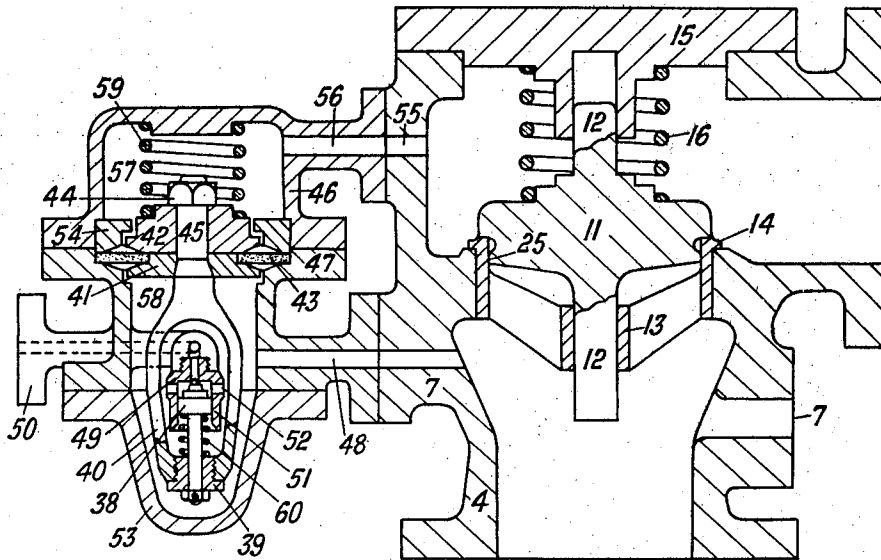


FIG. 4.

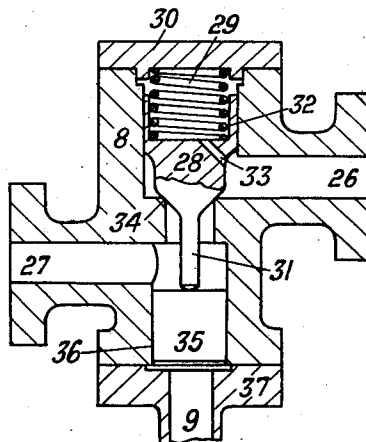


FIG. 3.

Inventor
Harold Hillier
By
Parrish, Davis, Mann & Clark
Attorneys

UNITED STATES PATENT OFFICE

2,397,664

LIQUID PUMP OF THE CENTRIFUGAL TYPE

Harold Hillier, Cathcart, Scotland, assignor to G. & J. Weir, Limited, a corporation of Great Britain

Application March 27, 1944, Serial No. 528,199
In Great Britain April 3, 1943

1 Claim. (Cl. 103—97)

This invention relates to means for the prevention of damage to liquid pumps of the centrifugal type when operating against a closed discharge valve or with a very small liquid flow from the discharge of the pump.

When a centrifugal pump is in operation, a proportion of the energy supplied to the pump by the driving unit is absorbed in friction, shocks, eddies and churning within the pump. The energy so absorbed is transformed into heat which increases the temperature of the liquid flowing through the pump. With a considerable flow of liquid through the pump, the temperature rise, due to these causes, is comparatively small and does not involve any serious consequences, but, when the pump is operating against a closed discharge valve or with a very small flow of liquid through the pump, the temperature rise through the pump can be very considerable and may be such that, in a few minutes, the temperature is raised to the boiling point of the liquid within the pump, and a portion of the liquid is evaporated. Such vaporisation may prevent the flow of water into the suction of the pump, thereby preventing the pump from discharging liquid, with the result that seizure or damage may occur between the rotating and the stationary parts due to the lack of an adequate supply of liquid for cooling and lubricating purposes.

The operating conditions of a large number of centrifugal pump installations are such that a certain minimum flow through the pump is necessary, in order to avoid such dangerous conditions arising, and provision is usually made to ensure that, whenever there is a danger of the flow through the pump falling below the minimum required to ensure safe operation, an emergency outlet from the discharge of the pump is opened, either by hand or automatically, to allow the pump to discharge a predetermined minimum quantity of liquid back to the source of liquid supply, such predetermined quantity being fixed as necessary to prevent a dangerous rise in temperature through the pump under any condition of operation.

The quantity of water passing through such emergency outlet is usually known as the bypass discharge.

For many centrifugal pump installations, the operating conditions are such that a hand-operated bypass meets all requirements, but, in other installations, such as centrifugal pumps used for boiler feed purposes, it is necessary to operate two or more centrifugal pumps discharging in parallel, and such pumps are so designed

as to share proportionally the total quantity of water discharged. With extremely small liquid flows, it is barely practicable to ensure that each pump discharges its due share of the total, and operating occasions may arise in which the flow is completely stopped. Such conditions arise in a haphazardous fashion, and it is not possible to anticipate them by manual operation of the bypass, so that it is necessary that the bypass should be opened automatically whenever the flow falls below the necessary minimum.

Centrifugal pumps are usually provided on the discharge side with a non-return valve which closes in the event of there being any tendency for liquid to flow back from the discharge line through the pump. The closing motion of the non-return valve in the discharge line has been used to open a bypass, but, with pumps operating at high discharge pressures, the dynamic forces of the flow of liquid across the bypass discharge device are very considerable and sometimes are such as to prevent the satisfactory closure of the non-return valve, with the result that high pressure water passes from the discharge line, through the centrifugal pump, into the suction line, which is usually of comparatively light construction, and damage to the suction line results when it is subjected to the pressure of the discharge line. There is a further disadvantage that such a bypass device permits leakage of water through the bypass connection when the bypass valve is in closed position. In boiler feeding installations, this is objectionable because such leakage water must be pumped again, whereby meter readings in the feed system may be vitiated; further, water passing through the boiler feed pump is very often at a high temperature and the leakage of hot feed water through the bypass connection results in undesirable heating of the feed supply tank and suction system and a loss of heat potential.

The primary object of the present invention is to provide an improved apparatus for controlling the flow of bypass liquid from a centrifugal pump in such manner as to prevent any flow through the bypass connection when the pump is in normal operation and the bypass is closed, and to eliminate, or reduce to a minimum, the resistance to the closing motion of the non-return valve on the discharge of the pump. For this purpose, the bypass valve is remotely hydraulically actuated by means of liquid taken from the discharge of the pump, the flow of such actuating liquid being controlled by a small pilot valve, the primary operating force controlling

the bypass discharge being thereby reduced to a minimum.

I may use the closing motion of the non-return valve in the discharge line of the pump to open the bypass pilot valve which may be provided with a spring operative to close the bypass pilot valve during the opening motion of the non-return valve, or I may arrange that the opening movement of the non-return valve will close the bypass pilot valve through a flexible link connection whereby the opening motion of the non-return valve can continue after the bypass pilot valve is closed. I may provide the non-return valve on the pump discharge with a spring to assist in closing the non-return valve and to ensure that sufficient force is available to ensure the opening of the bypass pilot valve and the complete closure of the non-return valve. I may obtain the force for the operation of the pilot valve from a diaphragm one side of which is subject to the discharge pressure of the pump on the underside of the discharge non-return valve, while the other side of the diaphragm is subject to the discharge pressure in the discharge line on the outlet side of the said non-return valve, in conjunction with the load of a spring. I may provide the non-return valve on the pump discharge with a spring to assist the closing movement of the non-return valve, with the object of providing a definite pressure drop across the valve, such pressure drop bearing a predetermined relation to the quantity of liquid flowing through the valve, so that the same predetermined pressure drop is available across the diaphragm for the movement of the diaphragm in operating and opening the pilot valve for the bypass discharge valve.

To ensure that there is no leakage across the bypass discharge valve under normal operating conditions, the bypass valve is of the seated type. A spring may be provided to exercise a force holding the valve on its seat, the spring load plus the discharge pressure of the pump acting on the top of the valve maintaining the valve closed and thereby ensuring absence of leakage through the bypass valve under normal operating conditions of the pump. On the underside of the bypass valve there may be provided a piston having an area considerably in excess of the bypass valve area. The underside of the piston is in communication with the bypass pilot valve, so that, when the bypass pilot valve opens, the discharge pressure of the pump is applied to the remote side of the piston, causing the piston to move upwards and lift the bypass valve from its seat, thereby permitting the bypass discharge liquid to pass through the bypass valve to the source of liquid supply. When the bypass pilot valve is closed, the water in the chamber under the piston leaks through the clearance between the piston and the chamber to the source of liquid supply, so that the piston is balanced and the spring load, plus the pump discharge pressure, acting on the top of the bypass valve, causes the bypass valve to return to the closed position.

I shall now proceed to describe in detail practical embodiments of the invention as illustrated in the accompanying drawings in which the same reference numerals denote similar parts in the several views.

Fig. 1 shows diagrammatically the arrangement of two centrifugal liquid pumps with automatic bypass valves in accordance with the invention.

Fig. 2 is a sectional elevation of the discharge

non-return valve and a bypass pilot valve in accordance with the invention.

Fig. 3 is a sectional elevation of a pilot-operated bypass valve in accordance with the invention.

Fig. 4 is a sectional elevation through a diaphragm-operated bypass pilot valve.

Referring to Fig. 1, each centrifugal pump 1 draws liquid from a tank 2 through suction piping 3 and discharges the liquid through a non-return discharge valve 4, and an isolating valve 5, to a common discharge line 6. The two pumps are required to operate in parallel and to share the total liquid flow, but it is difficult so to manufacture and arrange the pumps that each pump handles its proper share of liquid at very small liquid flows, so that it is always possible at small flows for one pump to discharge the whole flow and prevent any flow of liquid passing through the other pump. The non-return valve 4 prevents any possible back discharge through the said pump but it is essential to ensure a flow through the pump under such conditions as to prevent overheating of the pump and possible damage to the rotating and the stationary parts of the pump.

For this purpose, I provide a branch 6a on the non-return valve 4 for a bypass pilot valve which controls the supply of operating water through a pipe 9 to a bypass valve 8 which controls the flow of bypass liquid from the branch 7 on the non-return valve 4 to the liquid tank 2 by way of the pipe 10.

Referring to Fig. 2, the non-return valve 4 has a valve element 11 which is provided with a central extension spindle 12 which is guided below the valve in a bush 13 formed in the valve seat 14. The extension spindle 12 above the valve is guided in a bush formed in the valve box cover 15.

A spring 16 is provided between the valve 11 and the cover 15, so that the bias of the spring exercises a force to close the valve 11. On the underside of the non-return valve seat 14, there is provided a branch 6a into which is inserted a cover 17 containing a seat for the bypass pilot valve 18.

An extension of the cover plate 17 forms a guide 19 for the pilot valve 18 and centres the pilot valve 18 in relation to its seat in the cover plate 17.

The guide 19 is provided with a fulcrum 20 on which is mounted a bell-crank lever 21, the end of one arm of which passes into a slot 22 formed in the pilot valve 18. The other arm of the bell-crank lever 21 is extended so that its extremity lies immediately under the spindle extension 12 of the non-return valve 11. The guide 19 for the bypass pilot valve 18 forms housing for a spring 23 which is retained in position by a cap 24 threaded on the guide 19. The spring 23 exercises a force to close the bypass pilot valve 18 against its seat in the cover 17. The liquid discharge pressure of the pump assists the spring 23 in closing the pilot valve 18.

The extremity of the lever 21 under the non-return valve spindle 12 is so arranged in relation to the non-return valve spindle 12 that closing motion of the non-return valve 11 causes contact to be made between the non-return valve spindle 12 and the extremity of the bell-crank lever 21 at a predetermined position before the non-return valve 11 reaches its seat 14. After contact is made between the spindle 12 and the bell-crank lever 21, further motion of the non-return valve 11 towards its seat 14 opens the

pilot valve 18. The non-return valve 11 is provided with a skirt 25 and contact is made between the spindle 12 and the bell-crank lever 21 at the position in the travel of the non-return valve 11 when the skirt 25 enters the seat 14. It will be seen that, when the flow of liquid past the non-return valve 11 falls to a small amount, the skirt 25 will be entering the seat 14 and the bypass pilot valve 18 will be commencing to open. Further movement of the non-return valve 11 to the completely closed position will ensure that the bypass pilot valve is moved to the full open position. When the centrifugal pump discharges an appreciable quantity of liquid into the discharge line, the non-return valve 11 will lift until its skirt 25 leaves the valve seat 14, at which point the pilot valve spring 23 will cause the pilot valve 18 to seat on the cover 17 and cut off the flow of liquid through the cover 17. As all further liquid flows through the centrifugal pump up to the maximum, the pilot valve 18 is maintained in the closed position by the spring 23 and the discharge pressure of the pump.

Fig. 3 shows the bypass valve chest 8 which is provided with an inlet branch 26 and an outlet branch 27. The branch 26 joins the branch 7 on the pump non-return discharge valve below its seat. The bypass valve 28 co-operates with a seat 34 to control the flow of liquid from the centrifugal pump discharge through the branch 26 to the outlet 27, whence it can flow to the liquid tank. A spring 29 is provided between the bypass valve 28 and the cover 30, the spring exercising a force to close the bypass valve 28 in conjunction with the discharge pressure of the pump, which passes to the top of the valve 28 by way of the hole 33 in the valve. The upper end of the valve 28 is provided with a piston 32 guided in the valve body 8 to maintain alignment of the valve 28 relative to its seat 34. A spindle extension 31 on the valve 28 passes through the valve seat and makes contact with a piston 35 which moves freely in a chamber 36 provided on the outlet side of the bypass valve seat. The chamber 36 is provided with a cover 37 from which a pipe 9 connects the bypass valve chest to the pilot valve outlet in the cover 17.

The area of the piston 35 is considerably in excess of the area of the bypass valve 28 so that, when the pilot valve 18 opens, liquid at the discharge pressure of the pump is applied to the under face of the piston 35 in the chamber 36. The force applied to the piston 35 considerably exceeds the force of the spring 29 and the discharge pressure of the pump applied to the top of the valve 28, so that the resultant force available causes the bypass valve 28 to move into the open position and permit the pump to discharge liquid through the bypass valve 28 to the liquid supply tank 2.

When the pilot valve 18 closes, the liquid present in the chamber 36 leaks through the clearance between the chamber 36 and the piston 35 to the outlet 27 until the pressures on both sides of the piston 35 are equalised. The resultant force on the bypass valve 28 is then composed of the load of the spring 29 and the discharge pressure of the pump applied to the valve 28 with the result that the bypass valve 28 moves into closed position and all flow through the bypass is cut off.

It will be recognised that, since both the bypass valve 28 and the pilot valve 18 are of the seated type, all leakage from the pump discharge

through the bypass arrangement is completely prevented when the pilot valve 18 is closed.

The bypass valve 28 may be of any desired size, and the pilot valve 18, due to the fact that it controls only a small quantity of water to actuate the bypass valve operating piston 35, can be made small, so that the force necessary to operate the pilot valve 18 is reduced to a minimum and is so small that it cannot interfere with the satisfactory closing of the non-return valve 11 in the centrifugal pump discharge line.

The pilot valve 18 may constitute a self-contained assembly mounted on the cover plate 17, the assembly being inserted through a branch 6a on the underside of the non-return valve 11, the cover plate 17 forming the closing member of that branch.

To ensure that the pilot valve 18 will close, under all operating conditions, even in the event of the pressure difference across the non-return valve 11 being negligible, a condition which may occur when two or more centrifugal pumps are operating in parallel at very light loads, the load of the spring 16 on top of the non-return valve 11 is made sufficient to ensure the opening of the pilot valve 18.

Referring to Fig. 4, the lower end of the pilot valve 38 is guided in a bush 39 which is screwed into a stirrup 40, the upper end of which passes through a lower diaphragm cover plate 41 and an upper diaphragm cover plate 42 between which is secured a diaphragm 43, the cover plates and diaphragm being held together by the nut 44 on the end of the spindle 45 formed at the upper end of the stirrup 40. The diaphragm is trapped between a branched cover 46 and a body 47 which contains the inlet branch 48 for the flow of the hydraulic operating liquid controlled by the pilot valve 38, such liquid entering by the branch 48, flowing through the pilot valve seat 49 and leaving by the outlet branch 50.

The seat 49 is provided with a cylindrical bore 51 which forms a guide for the pilot valve 38, and is provided with holes 52 for the passage of the liquid through the valve seat. A cover 53 provides access to the pilot valve 38 and the stirrup mechanism. An upper stopper ring 54 is trapped between the body 47 and the top cover 46, the body 47 and the stopper ring 54 being provided with stops to limit the movement of the diaphragm and the lower and upper diaphragm plates 41 and 42. In the extreme positions of the diaphragm, the diaphragm is fully supported by the corresponding diaphragm plate and the body 47 or the stopper ring 54.

The branch 48 is connected to the branch 7 on the non-return discharge valve body 4 so that liquid passing through the branch 48 is taken from the discharge of the centrifugal pump on the underside of the non-return valve 11. A branch 55 is provided above the non-return valve 11 and is connected to a branch 56 in communication with the space 57 on top of the diaphragm 43 so that the pressure of the feed main on top of the non-return valve 11 is at all times applied to the top of the diaphragm 43. The pressure on the underside of the non-return valve 11 is at all times applied to the space 58 on the underside of the diaphragm 43. The diaphragm is therefore subjected to the difference in pressure between the inlet and outlet sides of the non-return valve 11. In addition, a spring 59 is arranged between the cover 46 and the upper diaphragm plate 42, exercising a load in conjunction with the pressure on the top of the non-return valve 11, so

that the pressure difference across the diaphragm 43 is substantially the same as the pressure difference across the non-return valve 11.

When the non-return valve 11 is moved into the open position by the discharge pressure of the centrifugal pump exceeding the pressure in the discharge main, the pressure difference available across the valve 11 is exercised across the diaphragm 43 and causes the pilot valve 38 to seat on the valve seat 49, thereby stopping the flow of liquid through the pilot valve. A spring 60 is provided between the pilot valve 38 and the bush 39, so that, as the diaphragm 43 moves the stirrup 40 in the upward direction, immediately the pilot valve 38 seats itself, any further movement of the diaphragm compresses the spring 60 so that the load applied to the pilot valve 38 is limited to the compression load of the spring 60, until the diaphragm 43 reaches the stop provided by the ring 54 and the upper diaphragm plate 42. The arrangement is such that, when the pilot valve is closed by the movement of the diaphragm, further movement of the diaphragm is permitted by the spring 60 until it reaches the stop, in which position the diaphragm is fully supported so that possible rupture or damage to the diaphragm is thereby prevented.

Before the non-return valve 11 can open, the pressure on the underside must exceed the pressure on the top side as necessary to lift the non-return valve 11 against the spring 19. This pressure difference will also be exercised across the diaphragm 43, so that the diaphragm 43 will move at the same time and in the same direction as the non-return valve 11. Opening movement of the non-return valve 11 is therefore accom-

panied by closing movement of the pilot valve 38 and vice versa. I so arrange the loads of the springs 16 and 59 that, when the skirt 25 of the non-return valve 11 enters the seat 14, the resultant load acting on the diaphragm 43 causes the diaphragm to move downwards and open the pilot valve 38 so that liquid can flow through the branch 48, past the pilot valve 38, through the pilot valve seat 49 to the outlet branch 50, whence it passes to the bottom of the piston chamber 36, the liquid pressure being applied to the underside of the piston 35 so as to cause the necessary movement to open the bypass valve 28, thereby permitting the centrifugal pump to discharge liquid through the bypass connection to the liquid tank from which the centrifugal pump draws the supply of liquid.

I claim:

The combination with a non-return valve in the discharge line of a centrifugal pump, of a spring-urged by-pass valve of the seated type permitting when open the discharge by the pump of a predetermined minimum quantity of liquid for eventual return to the suction side of the pump, a pilot valve of the seated type serving to effect hydraulically the operation of said by-pass valve, a spring urging said pilot valve in closing direction, and a lever device having one arm engaged with said pilot valve, the other arm of said lever being free and in the path of motion of said non-return valve whereby said lever is rocked to open said pilot valve only in the final stage of closing movement of said non-return valve.

HAROLD HILLIER.