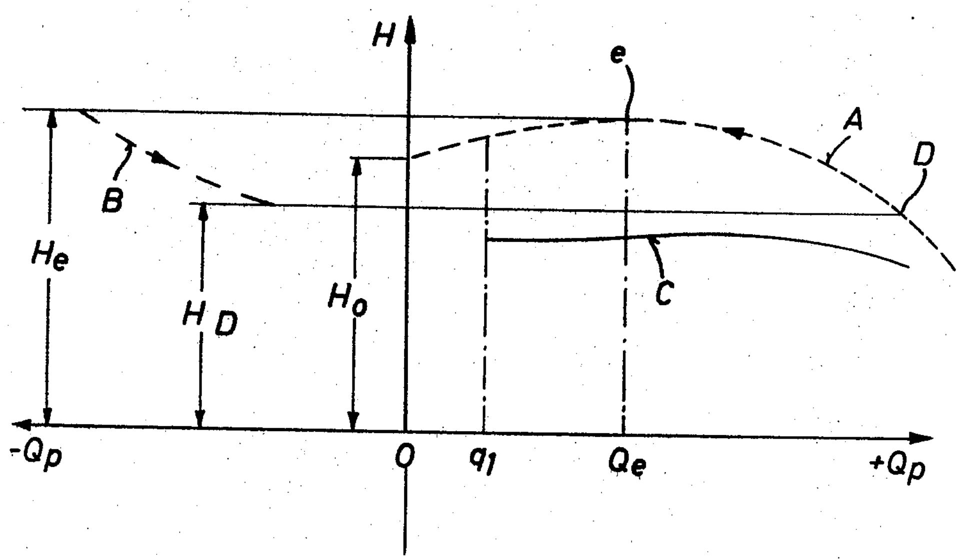
$H=f(Q)$

FIG.1



$\Delta H=f(Q)$

FIG.2

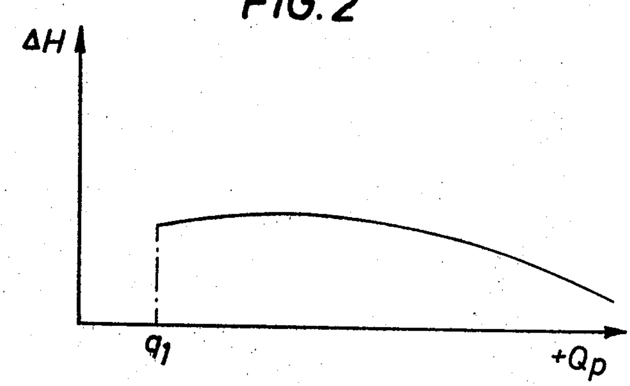


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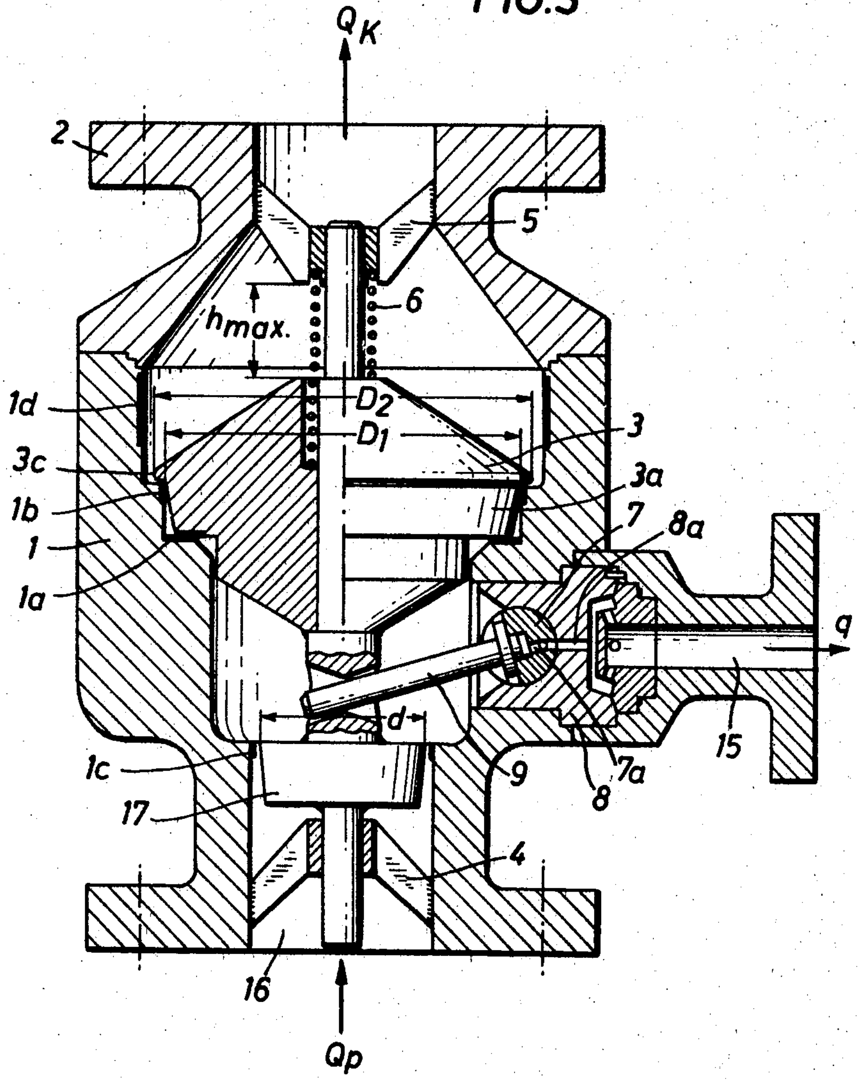
FIG.3



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METHOD AND DEVICE FOR THE OSCILLATION-FREE OPERATION OF A ROTARY PUMP

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ABSTRACT OF THE DISCLOSURE

A valve device for stabilizing discharge from a pump. The valve device comprises a discharge throttling cone which throttling cone actuates an auxiliary by-pass relief valve member.

BACKGROUND OF THE INVENTION

With rotary pumps having unstable characteristics, oscillations often occur in the range of small feed rates. Consequently, proper operation of the rotary pump is impossible over a particular part of the characteristic curve. This is especially true in the unstable branch of the curve. The cause for the occurrence of oscillations is probably due to the pump pressure line acting as an elastic member under certain conditions. Tubular lines must be made extremely elastic in high pressure feed plants because of the high temperatures involved. Therefore, the pump pressure line contains a storage mass which can easily be subjected to oscillations. Due to all the circumstances surrounding such an operation, this storage capacity as an elastic member in the pump system cannot be avoided and therefore, as a practical matter, an oscillable mass has to be accepted. When these oscillations occur, the pump may sometimes cease to feed and the mass of fluid flows intermittently in a direction against the feed direction.

Various attempts have already been made to overcome these deleterious oscillations. However, in existing methods and devices the danger of oscillations occurring has not been completely avoided. One attempt to solve the problem has involved working with a stabilized discharge pressure characteristic curve. However, with this method, oscillations can still occur which are strong enough to necessitate the immediate stopping of the pump equipment. An increase of the natural frequency to over 5 cycles per second of an intermediately disposed by-pass relief valve cannot prevent the occurrence of oscillations. Even the increase of the natural frequency to 12 cycles per second for this particular valve cannot prevent such oscillations.

SUMMARY OF THE INVENTION

The object of this invention is to operate a rotary pump in an oscillation-free manner even in the unstable portion of the discharge pressure characteristic curve.

Another object of the invention is to provide a method to effectively obviate the propagations of oscillations by separating the pump from the source of oscillations.

A further object of this invention is to provide a device for maintaining a pressure drop from the pump to the elastic tubular line which acts as a storage member for oscillations. This results in the holding of the pressure of the fluid intended for the said tubular line to be held near the starting pressure of the pump to obtain a damping effect.

Another object of this invention is to maintain the pressure of the fluid intended for the tubular line acting as a storage member below the starting pressure of the pump when the pump is operating in the unstable region.

This method of pressure control completely removes the possibility of discharge fluid from flowing back to the pump.

Another feature of the invention is to provide a throttling of the fluid flow as a function of the pump feed rate. This throttling step takes place between the pump and the oscillable storage member in such a way that the maximum throttling lies in the unstable zone of the characteristic curve and the minimum throttling lies in the stable zone of the characteristic curve.

A still further object of this invention is to provide a degree of throttling in the unstable zone of the characteristic curve that is large enough for the pressure behind the valve to be below the pump starting pressure.

The method of the invention is preferably effected with a by-pass relief valve disposed beyond the pump. In this way a minimum feed quantity within a predetermined range is automatically drawn off. The by-pass relief valve of this invention includes an inlet, a main outlet and an auxiliary outlet. A stepped cone structure is provided in the main outlet region and operates in conjunction with an inlet cone structure and a slider controlling means for the auxiliary outlet. The use of the main inlet cone provides a drop in pressure over the whole discharge range from the minimum rate to a predetermined peak rate value so that the pump starting pressure is not exceeded in the oscillations storage mass. This pressure drop provided by the use of the main inlet cone completely prevents the pump starting pressure from being reached in the oscillations storage mass.

BRIEF DESCRIPTION OF DRAWINGS

The invention will be described in relation to the embodiment in the drawing and the diagrams wherein:

FIG. 1 shows graphically a comparison of discharge pressure characteristic curves for a rotary pump having an unstable characteristic and provides a discharge procedure disclosed in accordance with this invention;

FIG. 2 shows graphically the throttling curve in relation to the pump discharge rate on applying the method of the disclosed invention;

FIG. 3 shows a longitudinal section of a by-pass relief valve for carrying out the method of the disclosed invention.

DESCRIPTION OF SPECIFIC EMBODIMENT

A discharge characteristic curve A is obtained in a system including a rotary pump of unstable characteristic and an elastic member in the discharge line. This discharge characteristic curve A shows that when the discharge is reversed on exceeding the peak point *e*, the characteristic curve B takes shape. The ordinates indicate the pressure head H while the discharge rate Q is shown along the abscissa. The said reversal means that the fluid already discharged is forced back into the pump. The oscillating storage member then gives up its energy in the form of a pressure reduction, and the pump begins to discharge again at its own starting pressure H_D on the stable branch A of the Q–H curve. The possibility of the discharge direction reversing is overcome by reducing pressure to H over the whole discharge range from the minimum rate to a peak point *e*. This pressure reduction is such that the pump starting pressure cannot be exceeded and cannot be reached in the storage member.

A by-pass relief valve as shown in FIG. 3 is disposed beyond the pump for providing the feature of the instant invention. The valve includes housing members **1** and **2** wherein a stepped cone **3** having diameters D_1 and D_2 is movably mounted in supports **4** and **5**. The stepped cone **3** is pressed against housing seat **1***a* by its own weight and the force of a spring **6**. The spring **6** which abuts both against support **5** and the cone **3** moves through a distance *h*. Another cone structure **17** having a diameter *d* is located in the valve inlet **16**. The cone structure **17** is connected to stepped cone **3** and is simultaneously movable up and down therewith.

The valve structure further includes an auxiliary outlet **15** controlled by a rotary slider **7** located in housing member **8**. The slider **7** is linked to cone **3** by way of a lever **9**. Parallel nozzel-like apertures **7***a* through which the pressure of the discharged water can be greatly reduced are located in the rotary slider **7**. The housing apertures **8***a* cooperate with and are of a greater diameter than the nozzle-like apertures **7***a*. The smallest diameter of the housing apertures **8***a* should exceed the smallest diameter of nozzle-like apertures **7***a*.

When the stepped cone portion **3** is seated on housing seating **1***a*, the minimum flow is established through the throttled point between the cone portion **17** having a diameter *d* and its corresponding housing seating **1***c*. Therefore, even with the discharge rate to the consumer point Q_k equal to zero, the pump pressure is reduced according to the function and is

$$\Delta p_1 = \frac{K}{d^2 \frac{\pi}{4}}$$

When a control valve is opened behind the by-pass relief valve, the discharge fluid from the pump can flow through the relief valve at a rate Q_p. This discharge fluid flow lifts the stepped cone **3** from its seating **1***a* due to the throttling of the flow at the two points between **3***a* and **1***a* and between **3***a* and **1***b*. The throttling between seat **1***a* and cone portion **3***a* is reduced as the feed rate Q_p increases further. The following equation of force applies:

$$\frac{d^2\pi}{4}\cdot\Delta p_1 + \frac{D_1^2\pi}{4}\cdot\Delta p_2 = G\left(1-\frac{\gamma Fl}{\gamma Fe}\right) + cf \pm R$$

In this equation:

Δp_1=pressure drop between **1***c* and **3***b*
Δp_2=pressure drop between **1***b* and **3***a*
G=cone weight
c=spring constant
γFl=specific gravity of fluid
γFe=specific gravity of cone material
f=spring traverse, formed by adding pre-tension fv and present cone movement h
R=friction force, produced partly by friction in supports **4** and **5** and partly at rotary slider **7** which is mounted in the slider head **8** and controls the auxiliary outlet.

When the pressure drop increases according to the funtion

$$\Delta p = \zeta\frac{\gamma}{2g}\cdot v^2 = \zeta\frac{\gamma}{2g}\left(\frac{Q}{F_{gap}}\right)^2$$

where zeta is the resistance factor, the stepped cone **3** is also lifted into a higher equilibrium position as the flow increases. Stepped cone **3** and rotary slider **7** are connected by way of the lever **9**. Therefore, when the stepped cone **3** changes position it moves within a discharge range and the position of slider **7** is altered simultaneously. This causes aperture **8***a* to be covered to a lesser or greater extent by slider **7** in dependence on the cone lift *h*. This discharge range is subject to the conditions:

$$Q_p = Q_k + q, \text{ and}$$
$$q = 0.8\ Q_k + q_e$$

Here

Q_p=pump discharge rate
Q_k=discharge rate to consumer
q_e=by-pass feed rate
$q=f(Q_k)$ part—by-pass rate

On transposition and substitution we have

$$Q_p = 0.2Q_k + q_e$$

This equation provides mathematical evidence that the pump discharge rate Q_p cannot be less than the by-pass feed rate q_e. But since Q_p is always taken over the throttle point **1***c* to **17** and the pressure drop is a function of the square of the speed and therefore also a function of the square of the quotient Q_p/F_{gap}, even when $Q_k=0$ an appreciable pressure drop can be achieved with such a valve.

If the discharge rate reaches the value Q_e, the stepped cone **3** lifts so that the valve inlet cone **17** emerges from its throttle position **1***c*. That is, from this level upwards, the pressure drop Δp_1 will tend towards zero. In the equation of forces,

$$\Delta p_1\cdot\frac{d^2\pi}{4} + \frac{D_2^2\pi}{4}\cdot\Delta p_3 = K$$

where Δp_3=pressure drop between **1***d* and **3***c*, the first term will thus tend towards zero. Since the expression

$$d^2\pi/4$$

is appreciably smaller than

$$D_2^2\pi/4$$

Δp_3 must only increase slightly to balance the power equation, so that the total pressure drop

$$\Sigma\ \Delta p = \Delta p_1 + \Delta p_3$$

reduces to a minimum.

The arrangement and constuction of the individual throttle points as explained above mean that the maximum pressure drop lies in the unstable area and the minimum pressure drop in the stable area of the Q–H curves. The throttling curve $H=f(QP)$ for the valve is given in FIG. 2. If these values are deducted from the discharge pressure curve $H=f(Qp)$, the curve C shown in FIG. 1 is produced as a function of $H=f(Qp)$ behind the by-pass relief valve.

While the method and device for providing oscillation-free operation of a rotary pump has been shown and described in detail, it is obvious that this invention is not to be considered as being limited to the exact form disclosed, and that changes in detail and construction may be made therein in the scope of what is claimed, without departing from the spirit of this invention.

Having thus set forth and disclosed the nature of this invention, what is claimed is:

1. A valve device for providing oscillation-free operation of a rotary pump which discharges into a line and has an unstable discharge pressure characteristic comprising, in combination,

(a) means movably mounting a valve cone within a housing having an inlet opening for connection to said pump discharge, an outlet opening for connection to said line and an auxiliary discharge outlet located between said inlet and outlet openings,

(b) said valve cone including a return cone portion having a first throttling means to act on the flow of liquid through the device while said unstable line conditions exist,

(c) said valve cone carrying a second throttling means located at the inlet opening, said second throttling means always allows a quantity of liquid through the inlet opening,

(d) said second throttling means working in cooperation with said first throttling means so that when the first throttling means has stopped the flow of liquid through the outlet opening during unstable conditions in the line, the second throttling means restricts but does not stop the flow of liquid into the inlet opening and through the auxiliary discharge outlet located between the first and second throttling means,

(e) means mounted in said device to control the flow of liquid through the auxiliary discharge outlet,

(f) said discharge outlet control means allowing a maximum flow rate through said auxiliary discharge opening when said valve outlet opening is closed and allowing a minimum flow rate through said auxiliary discharge opening when said second throttling means allows a substantially free flow of liquid into the inlet opening.

2. A valve device as defined in claim 1 wherein said second throttling means includes a tapered cone member having a diameter that is always smaller than the inlet opening to allow a flow of liquid therebetween.

3. A valve device as defined in claim 2 wherein said cone member is displaceable to a point substantially free of said inlet opening to provide the pressure drop at said inlet opening to aproach zero.

4. A valve device as defined in claim 3 wherein said return cone portion and said tapered cone member are rigidly attached to each other to effect simultaneous up and down movement of said return cone portion and said cone member.

5. A valve device as defined in claim 4 wherein said discharge outlet control means includes a rotary slider means to control the size of the opening in the discharge outlet.

6. A device as defined in claim 5 wherein the said rotary slider means includes nozzle-like openings which control

the flow of discharge fluid through the auxiliary outlet.

7. A device as defined in claim 6 wherein the openings of said auxiliary outlet have a minimum diameter greater than the minimum diameter of the said nozzle-like openings.

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