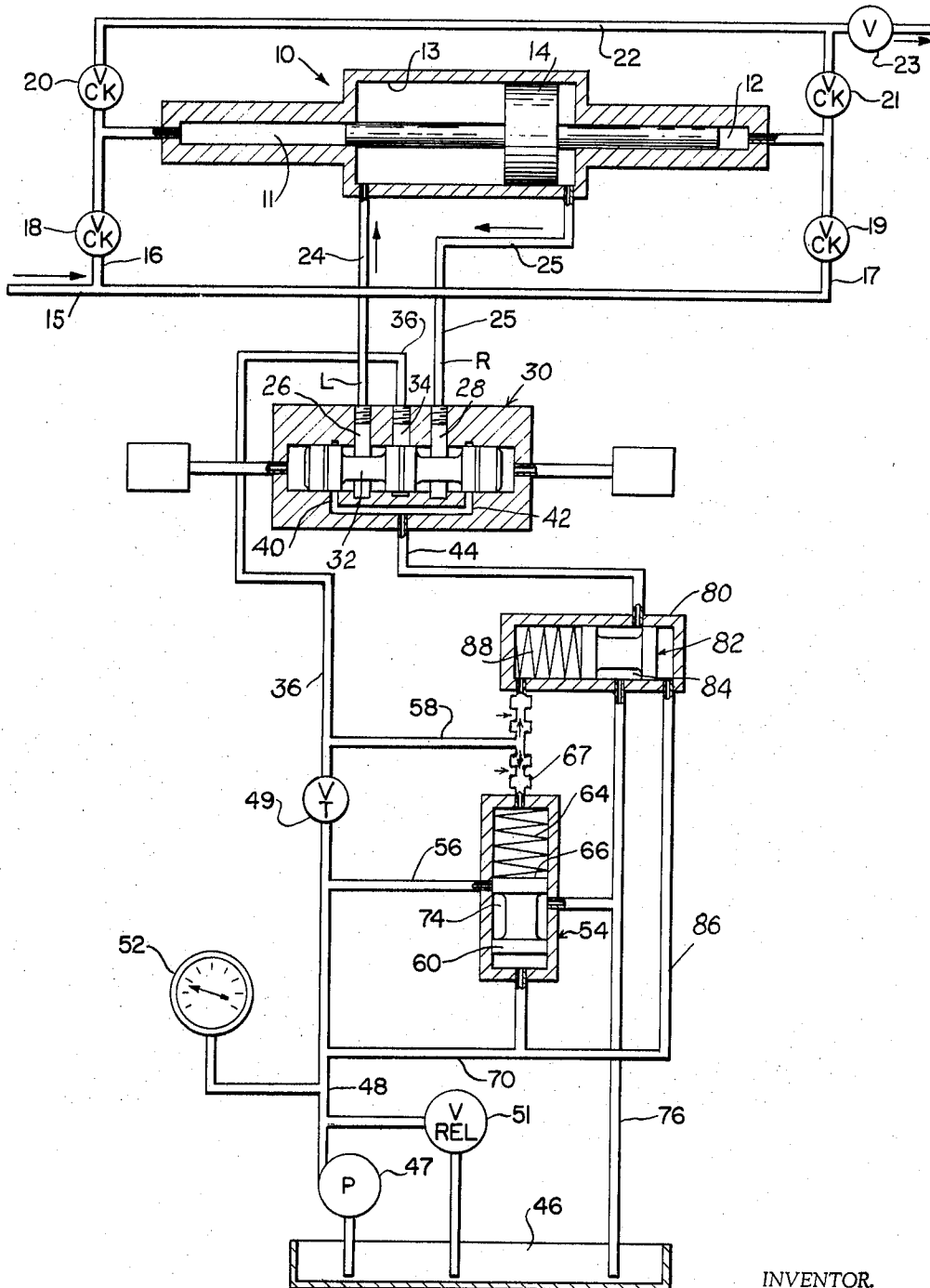


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SHOCK MODULATING DEVICE FOR A HYDRAULICALLY
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SHOCK MODULATING DEVICE FOR A HYDRAULICALLY DRIVEN GAS COMPRESSOR

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The present invention relates to an apparatus for smoothing out the action of hydraulically driven pumps when used to pump or compress gases and liquids which have compressibility.

During the operation of a compressor the advancing stroke of the piston forces the compressed fluids into a high pressure system through a check valve or similar holding device. In the pressure end of the compressor there is always some space above and beyond the piston travel up to the check valves comprising a volume that is unswept by the piston. The stored energy released from said unswept volume when the hydraulic drive is reversed causes the hydraulic system of the intensifier to undergo a very considerable shock with resulting wear and risk of breakdown of the system.

It is a principal object of the invention to provide a control means responsive to any unbalance which may appear in the system produced by an initial surge or impulse of the hydraulic piston in the reverse direction at reversal, which will act automatically and without delay to diminish and absorb the shock in the system produced by said surge, and to restore the entire system to normal operating condition.

With the above and other objects in view as may hereinafter appear, the several features of the invention consist in the devices, combinations and arrangement of parts hereinafter described and claimed which together with the advantages to be obtained will be readily understood by one skilled in the art from the following description taken in connection with the accompanying drawing which is a diagrammatic disclosure of a double acting intensifier including a hydraulic operating system therefor provided with a control means in accordance with the invention for diminishing and dissipating shock produced by the unswept volume of the compressed fluid upon reversal of the hydraulic piston.

A double acting intensifier unit 10 is provided which consists of an outer shell having at the two ends thereof high pressure compression chambers 11, 12 of relatively small diameter, and an intervening low pressure chamber 13. Mounted within the shell is a piston having two end portions of small diameter slidably fitted within the high compression chambers 11, 12 and a middle portion 14 of larger diameter which is fitted to slide within the low pressure chamber 13.

The high pressure compressible fluid output system for the intensifier as shown in the drawing comprises an input line 15 through which a compressible fluid or gas is supplied at a predetermined input pressure. Branch portion 16 and 17 of the input line 15 are connected respectively through check valves 18 and 19 with the high compression chambers 11 and 12, and through check valves 20 and 21 with a high pressure manifold 28. The delivery pressure of the system is determined by the back pressure of the process to which the compressed fluid is supplied. In order to indicate this arrangement a discharge back pressure valve 23 is shown in the drawing.

The two ends of the low pressure chamber 13 are connected by pipe connections 24, 25 with ports 26, 28, respectively, formed in the casing of a four-way reversing valve 30. The casing of valve 30 is formed with a cylindrical aperture to receive a movable valve body 32. The valve 30 is also provided with a centrally disposed

pressure inlet port 34 which is connected by means of a pipe 36 with a pressure hydraulic fluid supply system hereinafter more fully described. Two exhaust ports 40, 42 in the valve 30 connect with one another and with an exhaust pipe 44 through which the hydraulic fluid is returned to a reservoir or sump 46.

The valve body 32 is formed with spool portions at each end and midway of the valve 32, said spools being separated by two land portions. The valve body 32 is constructed and arranged so that the movement of the valve body 32 to the right from the theoretical neutral position shown in the drawing causes the pipe connection 25 with the right hand end of the low pressure chamber 13 to be connected with the exhaust port 42, and the pipe connection 24 with the left hand end of the low pressure chamber 13 to be connected with the supply port 34. Under these conditions piston element 14 of the intensifier unit is moved to the right. Movement of the four-way valve body 32 to the left operates in the reverse manner to move the piston element 14 of the intensifier unit to the left.

The hydraulic control system employed for supplying a relatively noncompressible fluid through the low pressure chambers of the intensifier unit will be described in connection with the single figure of the drawing as follows:

Fluid pressure is supplied to the low pressure chambers of the intensifier unit 10 from the reservoir 46 by means of a pump 47 and a supply line 48 which is connected with a throttle valve 49 which is in turn connected by the pipe line 36 with the inlet port 34 of the four-way reversing valve 30. A relief valve 51 is provided in line 44 to prevent overloading of the pump. A pressure gage 52 provides a visual reading of the driving or upstream pressure in the pipe 48 connecting with the throttle valve 49.

A compensating valve 54 is connected across the throttle valve 49 being connected by an input line 56 with the pressure line 48 upstream from the throttle valve 49 and by a sensing line 58 with the pressure line 36 downstream from the throttle valve 49. The compensating valve includes a valve spool 60 vertically movable in a valve chamber 62, and a spring 64 which acts upon the spool 60 in a direction to keep the valve closed. A resistance 67 is provided in sensing line 58 between the spring supporting portion of the chamber 66 and the downstream pressure line 36. Under normal operating conditions the downstream pressure supplied to the upper end of the valve spool 60 through the sensing line 58 added to the pressure of spring 64 balances the pressure exerted against the bottom end of the spool 60 by the upstream pressure supplied to the lower end of the spool 60 through connections 70 from the pump 47 so that the valve spool 60 is normally held in a throttling resistance position, spilling to exhaust any excess flow from pump 47 not required by the setting of throttle 49, at a pressure in upstream line 48 higher than that in downstream line 36, by a differential equivalent to the spring pressure at 66. If for any reason the pressure in the downstream side of the throttle valve 49 is decreased, the spool 60 immediately starts to rise causing the flow in upstream line 48 to spill to exhaust at a lower pressure but again at the same, constant, differential pressure higher than that now in downstream line 36. This spill as before is through input line 56, then through a modulating resistance in spool 60 and on into return line 76 to the reservoir 46.

In the operation of the apparatus described, which is adapted for the pumping of compressible fluids or gases at high pressures which may be in the order of 30,000 p.s.i. or more, a very substantial amount of energy is stored in the unswept volume between the high pressure head and the adjacent check valves, for example, 19 and 21 as

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shown in the drawing. Since the unswept volume in an apparatus of the type shown may amount to anywhere from 4 to 6 cubic inches, the energy stored acts upon reversal of the hydraulic drive to provide a substantial push to the intensifier piston 14 in the reverse direction. The tendency is thus to cause the piston to be pushed suddenly ahead as the flow of hydraulic fluid formerly supplied at delivery pressure to the left side of the low pressure chamber 13 is suddenly reversed and shunted at a low exhaust pressure back to the reservoir. This in turn causes instantly reduced pressure on the downstream side of the throttle 49, cavitation, and abnormally increased flow therethrough, which filling the void in the hydraulic cylinder suddenly comes against the energy of the now nearly stalled pistons causing heavy surge and shock. While the differential compensating valve will attempt to adjust to this situation by dumping upstream pressure in line 48 to exhaust, the reaction comes too late to effectively correct for the aberration described for the reason that the jump-ahead of the piston is caused by a negative force external to the hydraulic system. In fact the operation of the compensating valve 54 increases the shock by trying to follow these sudden extreme changes in pressure.

The apparatus employed for smoothing out the action of the hydraulically driven pump upon reversal here provided comprises a flow shut-off valve 80 which is located in the exhaust line 44 between the reversing valve 30 and the reservoir 46. This valve is similar in construction and in operation to the compensating valve 54 except that the back pressure valve 80 is normally maintained at its open position. The valve comprises a spool 82 having formed therein an annular groove 84 for the open position of the valve spool to the right as shown in the drawing which provides an open connection between exhaust line 44 and the downward extension thereof 76 to the reservoir 46. The spool 82 is biased to the left to close by means of the upstream pressure from the line 48 supplied through an extension 86 of the line 70. A normally overbalancing bias in the opposite direction to open is supplied by means of a spring 88 and an extension of the sensing line 58 connected with the downstream pressure line 36.

The operation of the compensating valve 54 and the flow shut-off valve 80 to smooth out the action of the hydraulically driven pump or intensifier upon reversal is as follows: As the piston 14 of the pump reaches the limit of its movement to the right as shown in the drawing the reversing valve 30 is reversed so that the delivery pressure comprising the downstream pressure contained in supply line 36 is now supplied to the right hand end of the low pressure chamber 18 of the intensifier unit 10. The hydraulic fluid in the left hand end of the low pressure chamber 13 is now shunted to exhaust through line 24 and reversing valve 30 to the exhaust line 44. The stored energy of the highly compressed fluid in the unswept volume contained between the end of the cylinder and the check valves 19, 21 causes the piston to be forced suddenly to the left tending, as above noted, to create cavitation in the driving connections including supply lines 25 and 36 and a high flow transient through the newly opened exhaust line 25, 44. The drop in pressure in the line 36 at the downstream side of the throttle valve 49 produces a sudden movement of the spool 60 of the compensating valve 54 and of the spool 82 of the back pressure valve 80, causing the compensating valve 54 to open so that the upstream pressure in line 48 is shunted to exhaust, and simultaneously the back pressure valve 80 to close so that a direct resistance is interposed to the movement of the piston 14 of the intensifier unit to the left. Thus a rapid snubbing action is added circumventing most of the reverse jump-ahead and effectively preventing objectionable cavitation and surge. The compensating valve 54 and the flow shut-off valve 80 then return auto-

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atically to their usual operating positions as normal operating conditions are restored in the system.

While in the preferred embodiment of the invention shown regulation of the pressure differential across the throttle valve 49 is obtained by means of the compensating valve 54 which operates when the differential between upstream and downstream pressure increases abnormally to vent the upstream hydraulic pressure fluid from the pump 47 to exhaust, it will be understood that any suitable compensating valve may be employed which will compensate for such abnormal variations from, and will tend to restore to a desired value, the differential between the upstream and downstream hydraulic fluid pressures across the throttle valve 49.

The invention having been described what is claimed is:

1. In a hydraulically operated system for pumping compressible fluids, a hydraulically driven pump including a reciprocatory piston having hydraulically actuated opposed piston faces, and a driven fluid compressing piston face, a source of a hydraulic pressure medium, a supply line for supplying said hydraulic medium under pressure from said source to said hydraulically actuated faces including a throttle valve in said line providing differential upstream and downstream pressures at opposite sides of said throttle valve, a reversing valve in said supply line between said throttle valve and pump having hydraulic fluid supply and exhaust connections to said hydraulically actuated faces, exhaust connections from said reversing valve including a flow shut-off valve having a valve element shiftable between exhaust open and shut-off positions, a compensating valve providing a connection from the upstream side of said throttle valve to exhaust, and having a valve element shiftable between exhaust shut-off and open positions, and upstream and downstream connections responsive to an increased upstream, downstream pressure differential to move said compensating valve element to open position to discharge said upstream pressure to exhaust, said flow shut-off valve having connections channelling pressure from the upstream and downstream sides of said throttle valve against said flow shut-off valve element responsive to a said increased upstream, downstream differential to move said flow shut-off valve element to the shut-off position.

2. In a hydraulically operated system for pumping compressible fluids, a hydraulically driven pump including a reciprocatory piston having hydraulically actuated opposed piston faces, and a driven fluid compressing piston face, a supply line through which a hydraulic medium under pressure is supplied to said hydraulically actuated faces including a throttle valve in said line providing differential upstream and downstream pressures at opposite sides of said throttle valve, a reversing valve between said throttle valve and pump having hydraulic fluid supply and exhaust connections to said hydraulically actuated faces, exhaust connections from said reversing valve including a flow shut-off valve having a valve element shiftable between exhaust open and shutoff positions, a compensating valve connected between the upstream side of said throttle valve and exhaust having a valve element shiftable between exhaust shutoff and open positions, means channeling upstream pressure against said compensating valve element to open and against said flow shut-off valve element to close, spring means opposing the upstream pressure actuated movement of each said valve element, and means channeling downstream pressure against said respective valve elements in the same direction with said spring means, said spring means being of such strength so that said compensating valve element tends normally to close and said back pressure valve element tends normally to open.

3. In a hydraulically operated system for pumping compressible fluids having a hydraulically driven pump including a reciprocatory piston with hydraulically actuated opposed piston faces, and a driven fluid compressing piston face, a source of a hydraulic pressure medium, a revers-

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ing valve connected with said pump to drive said piston in reverse directions, and pipe connections connecting said reversing valve and pump with said supply source and with exhaust, a throttle valve in said pipe connections providing differential upstream and downstream pressures on opposite sides of said throttle valve, a flow shut-off valve in said pipe connections connecting with exhaust, having a valve element shiftable between exhaust open and shut-off positions, a compensating valve providing a connection between said pipe connection with supply and exhaust, and including a compensating valve element shiftable between supply pressure exhaust and closed positions, means channelling pressure from the upstream side of said throttle valve element against said compensating valve element to open and against said flow shut-off element to close, and means channelling pressure from the down-

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stream side of said throttle valve against said compensating valve element to close and against said flow shut-off element to open.

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