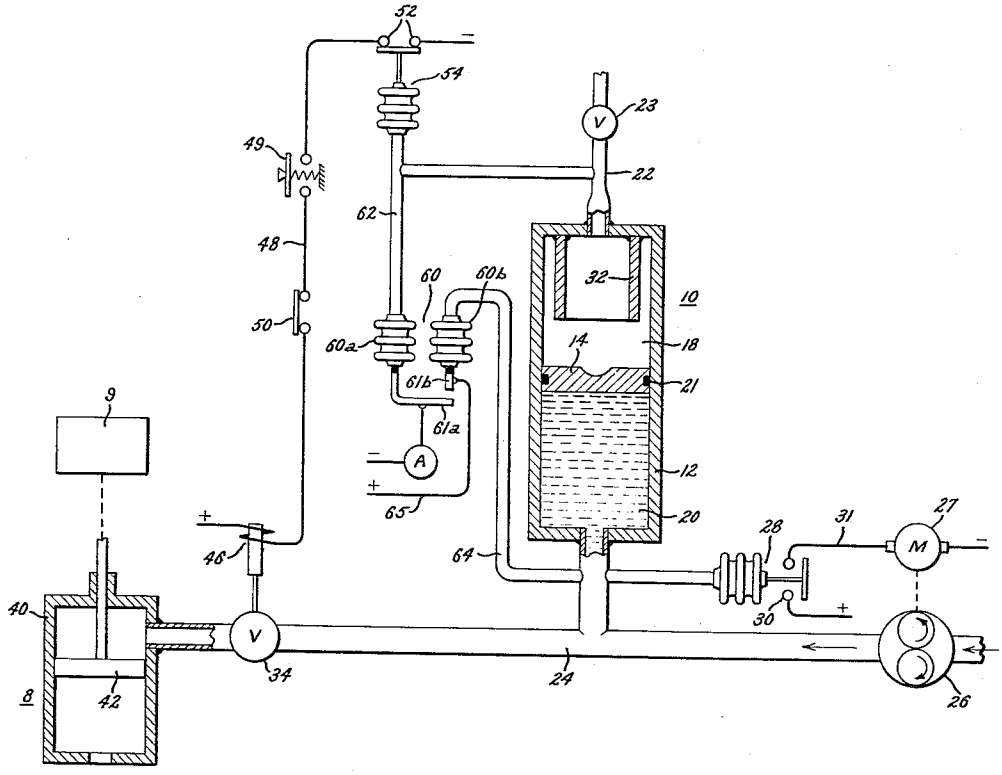
Aug. 21, 1962 U. R. TOGNELLA 3,050,079

HYDRAULIC OPERATING SYSTEM

Filed March 10, 1960



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United States Patent Office 3,050,079 Patented Aug. 21, 1962

3,050,079

HYDRAULIC OPERATING SYSTEM

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Filed Mar. 10, 1960, Ser. No. 14,017
6 Claims. (Cl. 137—568)

This invention relates to a hydraulic operating system that utilizes a pneumo-hydraulic accumulator as a source of energy and, more particularly, relates to means for providing a reliable indication of the amount of energy stored within the accumulator.

The usual pneumo-hydraulic accumulator comprises a pressure vessel containing a volume of gas that is compressed by pressurized liquid pumped into the pressure vessel. This compressed gas acts as a source of stored energy that forces pressurized liquid from the accumulator when the liquid is released. In my hydraulic operating system, release of the liquid is effected by means of a suitable controlling valve connected in a hydraulic line communicating with the pressurized liquid. Opening of this controlling valve allows the compressed gas in the accumulator to expand and force pressurized fluid through the line to perform a desired controlling operation.

In certain applications of hydraulic operating systems of this general type, it is of extreme importance that no attempt be made to perform the desired controlling operation if insufficient energy is available from the accumulator to complete the operation. For example, if the hydraulic system is being used for closing an electric circuit breaker against a faulted power line, insufficient available energy could result in stalling of the breaker in a partially closed position with possible serious damage to the breaker and connected apparatus resulting.

In such applications, it is therefore important that there be available some external indication of the amount of energy stored in the accumulator. It has heretofore been difficult to obtain such an external indication of the available energy primarily because in a conventional accumulator, pressure alone is not a reliable indication of this quantity. The difficulty with the usual system that relies simply upon a measurement of accumulator pressure is that it is not sensitive to leakage of gas from the accumulator. True, so long as no leakage has occurred, pressure alone is a reliable indication of available energy, but once leakage has begun to occur this reliability is lost. In this regard, the pump that is used for charging the conventional accumulator operates to maintain the pressure therein at a desired level irrespective of the amount of gas that is present. Even after leakage has reduced the amount of gas to an unacceptably low value, the pressure within the accumulator would still be at its normally high level due to the compensating action of the liquid pump.

Numerous proposals have been made for rendering such systems sensitive to a loss of gas from the accumulator, but these have usually involved undue complications. For example, it has been proposed to extend a rod from the piston through one end of the accumulator to provide an indication of piston position. This approach is disadvantageous in that it requires a seal about the rod which can be an added source of leakage. It has also been proposed to use electrical limit switches mounted inside the accumulator to provide an indication of piston position, but this is disadvantageous in that it requires high pressure lead-throughs for the wires leading to the limit switch. It has been further proposed to use an electronic piston position indicator, but such indicators are relatively complicated and expensive and can be a source of trouble.

Accordingly, an object of my invention is to provide,

in a hydraulic controlling system of this general type, simple, inexpensive, and reliable means sensitive to a loss of gas from the hydraulic accumulator for providing an indication of the amount of energy stored within the accumulator.

Another object is to provide energy-detecting means of this nature which can warn that a gas leak is present before the leak has rendered the hydraulic system unsafe or unsuitable for further operations.

Another object is to construct this energy-detecting means in such a manner that it is not susceptible to false operation as a result of normal operations of the hydraulic system.

In carrying out my invention in one form, I provide a hydraulic operating system that includes a pneumo-hydraulic accumulator comprising a cylinder and a piston movably mounted within the cylinder to divide the cylinder into a liquid chamber and a gas chamber at the respective opposite sides of the piston. The accumulator is charged by suitable pumping means that acts to force liquid into the liquid chamber. Operation of the pumping means is terminated when the pressure of the liquid exceeds a first predetermined value. A stop within the cylinder limits the travel of the piston in a direction to compress any gas within the gas chamber. The gas chamber normally contains sufficient gas to maintain the piston spaced from the stop when the pressure of the liquid equals this first predetermined value. So long as no gas leak is present in the accumulator, the piston will remain spaced from the stop, and the pressures on its opposite sides will be substantially equal. If a gas leak should occur, however, the pressurized liquid will eventually drive the piston into engagement with the stop, whereupon further gas leakage will produce a pressure differential on opposite sides of the piston. This pressure differential, and hence a gas leak, is sensed by differential pressure means which is sensitive to pressure differentials on opposite sides of the piston.

For a better understanding of my invention, reference may be had to the accompanying sheet of drawing, wherein:

The single figure is a schematic view of a hydraulic operating system embodying one form of my invention. The system is shown in a charged condition.

Referring now to the drawing, there is shown a fluid motor **8** that is arranged to operate a suitable utilization device shown in block form at **9**. The energy for operating the motor is derived from a pneumo-hydraulic accumulator **10** which comprises a cylindrical pressure vessel **12** and a piston **14** slidably mounted for vertical movement in the bore of the cylindrical pressure vessel **12**.

The piston **14** divides the cylinder **12** into a gas chamber **18** on the upper side of the piston and a liquid chamber **20** on the lower side of the piston. A suitable seal **21** provided about the outer periphery of the piston **14** prevents fluid from either of these chambers from leaking around the piston and assures that there will be no direct communication between these fluids. The gas chamber **20** is closed off at its upper end during normal operation of the accumulator **10** but is provided with a high pressure supply line **22** through which gas can be supplied to the gas chamber **18** to precharge the accumulator to the desired extent. Once the desired amount of gas has been supplied to the gas chamber **18**, the supply line **22** is closed by means of a suitable valve **23**.

Communicating with the liquid chamber **20** beneath the piston **14** is a hydraulic line **24** located at the lower end of the accumulator. Liquid is forced through this line **24** into the liquid chamber **20** by means of a suitable

source of pressure such as pump 26. This pump 26 is operated by means of a suitable electric motor 27 that is controlled by a conventional pressure sensitive switch schematically shown at 28. The controlling portion of the pressure sensitive switch 28 communicates with the liquid chamber 20 and is sensitive to the pressure therein. When the pressure in liquid chamber 20 falls below a predetermined minimum value, the switch 28 closes its contacts 30 to complete an energizing circuit 31 for the motor 27. The motor responds by operating the pump 26, thereby causing the pump to force liquid into the accumulator through the line 24. This pumping action continues until a predetermined maximum pressure is reached, whereupon the pressure sensitive switch 28 responds by opening its contacts 30 to interrupt the energizing circuit 31 for the motor, thereby terminating pump operation when this maximum pressure is reached. In the drawing, the system is depicted just after the pressure responsive switch 28 has opened to terminate pumping action.

The pump 26, in forcing liquid into the liquid chamber 20, forces the piston 14 upwardly to compress the gas in chamber 18, thereby storing energy in this gas for subsequent utilization, as will soon appear. A stop 32 is interposed in the path of movement of the piston to limit its upward travel under certain abnormal conditions, which will soon be described, but normally there is sufficient gas present within the gas chamber 18 to prevent the piston 14 from reaching stop 32. In other words, under normal conditions, the previously-mentioned maximum pressure is reached before the piston 14 has reached the stop 32, and, thus, the pressure sensitive switch 28 terminates operation of the pump 26 while the piston 14 is still spaced from the stop 32.

For controlling the release of energy from the accumulator 10, a controlling valve 34 is interposed in the line 24 between the accumulator 10 and the motor 8. This valve 34 is normally closed and thus normally prevents any pressurized liquid from flowing from the accumulator 10 to the motor 8. When the valve 34 is operated to open position, the compressed gas above the piston 14 is free to expand and, in so doing, forces the piston 14 downwardly, driving pressurized liquid through the then-open valve 34 into the cylinder 40 of the motor. The pressurized liquid entering the cylinder 40 drives the piston 42 of the motor downward to produce the desired operation of device 9. When the piston 42 of the motor has completed its downward operating stroke, the valve 34 is returned to its closed position to block the further flow of liquid from the accumulator to the motor 8. Preferably, the valve 34 is a three-way valve that vents the motor 8 to a low pressure sump when valve 34 is returned to its closed position. A suitable valve of this nature is shown and claimed in application Serial No. 856,122, Coggeshall et al., filed November 30, 1959, now Patent No. 2,972,337, and assigned to the assignee of the present invention.

In the disclosed operating system, the valve 34 is electrically controlled by means of a suitable solenoid 46, which is connected in an energizing circuit 48. This energizing circuit 48 also includes a manually-controlled operation-initiating switch 49, a limit switch 50, and the normally-closed contacts 52 of a pressure sensitive interlock switch 54, all connected in series with each other and the solenoid 46.

Assuming that the limit switch 50 and the contacts 52 of the pressure sensitive switch 54 are closed, operation of the solenoid 46 can be effected simply by closing the switch 49 to complete the energizing circuit 48 for the solenoid. When the piston 42 of the motor has completed its working stroke in response to energization of solenoid 46, the energizing circuit 48 is opened by the limit switch 50, thus causing the valve 34 to return to its closed position. When the motor piston 42 is returned at least partially to its position shown in the drawing, the limit switch 50 is reclosed and the circuit 48 is again prepared for another operation. Any suitable conventional means may be used for controlling the limit switch in this manner. The pressure sensitive portion of interlock switch 54 is connected to the gas chamber above the piston 14 of the accumulator 10 and is arranged to open its contacts 52 when the gas pressure falls below a predetermined minimum value. In a preferred form of my invention, this minimum value is a pressure slightly above the minimum pressure capable of producing a complete operation of the motor piston 42 if the accumulator piston 14 was resting against the stop 32 when the valve 34 was opened. Thus, the switch 54 opens to block operation of the valve 34 whenever insufficient gas pressure is present within the accumulator to assure successful completion of the desired controlling operation.

The stop 32 performs the highly desirable function of rendering the pressure responsive device 54 sensitive to the leakage of gas from the accumulator. Without the stop 32, gas could leak from the accumulator 10 without any significant effect on the pressure to which the device 54 is exposed. This would be the case because the pump 26 would maintain the pressure within the accumulator 10 above the minimum pressure setting of switch 54 despite any gas leakage. The pump would simply force additional liquid into the accumulator to compensate for the loss of gas through leakage. With the stop 32 present, however, the pump 26 can force liquid into the accumulator only until the piston 14 encounters the stop. Thereafter, any gas leakage that occurs will not be compensated for by the pump and will reflect itself in falling gas pressure. When this gas pressure has finally fallen to a level that is too low to assure successful operation of the device 9 by the motor 8, the pressure sensitive switch 54 will open its contacts 52 and prevent the controlling valve 34 from being opened to initiate operation of the motor 8.

The pressure setting of the pressure responsive switch 54 is sufficiently low to prevent the switch 54 from opening its contacts to disable the valve 34 in response to the pressure drops resulting from one or even several normal operations of the motor 8. For example, accumulator 10 of the disclosed system is designed so that it has sufficient capacity to provide for six closely-successive operations of the motor B. Five such operations would substantially lower the gas pressure in the accumulator 10, but if the accumulator were initially fully charged, these five operations would not lower the pressure sufficiently to open the pressure responsive switch 54. A closely successive sixth operation would result in opening of the switch 54, but this sixth operation could take place without hindrance from the pressure-responsive switch 54. Thus, it will be apparent that the pressure within the accumulator is normally maintained at pressures considerably higher than the setting of switch 54 to provide for a series of closely successive normal operations.

Since the switch 54 is insensitive to normal pressure drops within the accumulator, it cannot warn of a loss of gas from the accumulator 10 until the loss has reduced the gas pressure to a value substantially below the normally-occurring minimum pressure. By this time, the gas pressure might be too low to assure successful operation of the motor 8, and the operator would then have had no opportunity to prepare for this situation, even though the leak might have first begun days or even weeks earlier.

It is therefore desirable that some warning be given of a gas leak well ahead of the time that the leak renders the system inoperative through opening of the pressure sensitive switch 54. For providing this early warning, I provide a conventional differential pressure switch 60 which is sensitive to a difference in pressure on opposite sides of the piston 14. This differential

pressure switch **60** is schematically depicted as comprising a pair of pressure sensitive bellows **60***a* and **60***b*, one **60***a* connected to the gas chamber **18** of the accumulator through a line **62** and the other **60***b* connected to the liquid chamber **20** of the accumulator through a line **64**. Contacts **61***a* and **61***b* are respectively carried at the lower, or movable, ends of these bellows **60***a* and **60***b*. So long as the liquid and gas pressures are equal the contacts remain spaced apart, but if the liquid pressure should exceed the gas pressure by a predetermined amount, the contact **61***b* will overtake the contact **61***a* and thus complete an alarm circuit **65**, energizing and sounding a suitable alarm A connected in this circuit **65**. The switch **60** is so adjusted that the pressure differential required to effect this operation is considerably less than the difference between the opening setting of the pressure-responsive switch **28** and the opening setting of pressure-responsive switch **54**. For reasons which will soon be apparent, operation of the differential pressure switch **60** is indicative of a gas leak in the accumulator. Sounding of the alarm A thus informs the station attendant that a gas leak is present and that appropriate preparations and steps should be taken for its correction.

This gas leak might very well be a slow one which would not impair the ability of the accumulator to produce a successful operation of the motor for days or even weeks, and it would therefore be premature at this time to render the motor **8** inoperative through opening of the switch **54**. Since the switch **54** remains closed until there is insufficient accumulator pressure to assure completion of a motor operation, it will be apparent that the attendant is not precluded from initiating any operation that the accumulator is then capable of carrying through to completion, even though a gas leak is present.

The differential pressure switch **60** will remain inactive, or open, so long as the accumulator piston **14** is spaced from the stop **32** inasmuch as the pressures on opposite sides of the piston **14** will be equal under these circumstances. It is only when the piston **14** reaches the stop **32** that a pressure differential can build up on opposite sides of the piston **14**. The pressure responsive switch **28** that controls the pump **26** is so adjusted that if no gas leak is present, the piston **14** will remain spaced from the stop **32** inasmuch as the pressure in the accumulator will normally be sufficiently high to open the switch **28** and terminate pumping prior to the piston's reaching the stop **32**. Only when a gas leak is present, will the pump **26** be capable of forcing the piston **14** into engagement with the stop **32** before the switch **28** opens to terminate pumping action. In summary, the establishment of a pressure differential on opposite sides of the piston **14** indicates that the piston has engaged stop **32**, and the piston's engaging stop **32** indicates that a gas leak is present.

Because the pressure differential switch **60** operates in response to a much smaller differential in pressure than the difference in the settings of total pressure switches **28** and **54**, the switch **60** can respond much more quickly to the presence of a gas leak than can the pressure responsive switch **54**, thus providing the desired early warning of the gas leak.

As examples of the pressure settings of the various switches, in one typical embodiment of my invention the pump-controlling switch **28** is arranged to close its contacts whenever the liquid pressure falls below 2950 p.s.i. and to open on rising pressure whenever the liquid pressure reaches 3000 p.s.i. The gas pressure switch **54** is arranged to open on falling pressure whenever the gas pressure falls below 2500 p.s.i. and to close on rising pressure at about 2550 p.s.i. The pressure differential switch **60** is arranged to close whenever the pressure differential exceeds about 100 p.s.i. There is thus a 500 p.s.i. difference between the opening settings of switches **28** and **54** as compared to the 100 p.s.i. value for which the differential pressure switch is set. Accordingly, a 100 p.s.i. pressure differential sounds the alarm A, but a 500 p.s.i. differential is normally required to cause the switch **54** to disable the controlling valve **34**.

It is to be noted that the pump-controlling pressure switch **28** is located in communication with the liquid chamber **20** instead of with the gas chamber **18** of the accumulator. This location of the pressure switch **28** is advantageous in that it assures that the pumping action will be terminated whenever the liquid pressure reaches a desired maximum value. If the switch **28** were located in communication with gas chamber **18** instead of liquid chamber **20**, it would be insensitive to liquid pressure after the piston encountered stop **32** and would allow the pump to raise the liquid pressure to an undesirably high level.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects, and I, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. In a hydraulic operating system, a pneumo-hydraulic accumulator comprising a cylinder and a piston movably mounted within said cylinder to divide the cylinder into a liquid chamber and a gas chamber at the respective opposite sides of said piston, means including a source of pressure connected to said liquid chamber and operable to force liquid into said liquid chamber, pressure responsive means operatively connected to said cylinder for effectively terminating operation of said source of pressure when the pressure of the liquid in said liquid chamber exceeds a first predetermined value, a stop arranged within said cylinder for limiting the travel of said piston in a direction to compress any gas within said gas chamber, said gas chamber normally containing sufficient gas at a sufficient pressure to maintain said piston spaced from said stop when the pressure of said liquid equals said first predetermined value, differential pressure responsive means operatively connected to said liquid and gas chambers and sensitive to a pressure differential between the gas and the liquid on opposite sides of said piston for providing a controlling signal when said pressure differential exceeds a predetermined amount.

2. In a hydraulic operating system for effecting predetermined controlling operations, a pneumo-hydraulic accumulator comprising a cylinder and a piston movably mounted within said cylinder to divide the cylinder into a liquid chamber and a gas chamber at the respective opposite sides of said piston, means including a source of pressure connected to said liquid chamber and operable to force liquid into said liquid chamber, pressure responsive means connected to said cylinder for effectively terminating operation of said source of pressure when the pressure of the liquid in the liquid chamber exceeds a first predetermined value, a stop arranged within said cylinder for limiting the travel of said piston in a a direction to compress any gas within said gas chamber, said gas chamber normally containing sufficient gas at a sufficient pressure to maintain said piston spaced from said stop when the pressure of said liquid equals said first predetermined value, a controlling valve operatively connected to said liquid chamber for releasing liquid from said accumulator to effect said predetermined controlling operations, differential pressure responsive means connected to said liquid chamber and said gas chamber and sensitive to a pressure differential between the gas and the liquid on opposite sides of said piston for providing a controlling signal when said differential exceeds a predetermined amount, means operatively connected to said gas chamber for rendering said controlling valve incapable of releasing liquid from said accumulator when the pressure in said gas chamber is below a second prede-

termined value substantially less than said first predetermined value, said differential pressure responsive means operating in response to a substantially smaller pressure differential than the difference between said first and said second predetermined pressure values so as to provide an early warning of the loss of gas from said accumulator.

3. In a hydraulic operating system for effecting predetermined controlling operations, a pneumo-hydraulic accumulator comprising a cylinder and a piston movably mounted within said cylinder to divide the cylinder into a liquid chamber and a gas chamber at the respective opposite sides of said piston, means including a source of pressure connected to said liquid chamber and operable to force liquid into said liquid chamber, pressure responsive means operatively connected to said cylinder for effectively terminating operation of said source of pressure when the pressure of the liquid in said liquid chamber exceeds a first predetermined value, a stop arranged within said cylinder for limiting the travel of said piston in a direction to compress any gas within said gas chamber, said gas chamber normally containing sufficient gas at a sufficient pressure to maintain said piston spaced from said stop when the pressure of said liquid equals said first predetermined value, a controlling valve operatively connected to said liquid chamber for releasing liquid from said accumulator to effect said predetermined controlling operations, said accumulator having sufficient capacity to provide the energy for a series of said controlling operations occurring in close succession, means operatively connected to said gas chamber and responsive to a drop in the pressure in said gas chamber to a level below a second predetermined value for rendering said controlling valve incapable of releasing liquid from said accumulator, said second predetermined value being below the lowest value of pressure that results from two closely successive normal controlling operations of said system initiated when the liquid pressure is at least as high as said first predetermined value.

4. In a hydraulic operating system for effecting predetermined controlling operations, a pneumo-hydraulic accumulator comprising a cylinder and a piston movably mounted within said cylinder to divide the cylinder into a liquid chamber and a gas chamber at the respective opposite sides of said piston, means including a source of pressure connected to said liquid chamber and operable to force liquid into said liquid chamber, pressure responsive means operatively connected to said cylinder for effectively terminating operation of said source of pressure when the pressure of the liquid exceeds a first predetermined value, a stop arranged within said cylinder for limiting the travel of said piston in a direction to compress any gas within said gas chamber, said gas chamber normally containing sufficient gas at a sufficient pressure to maintain said piston spaced from said stop when the pressure of said liquid equals said first predetermined value, said accumulator having sufficient capacity to provide the energy for a series of said controlling operations occurring in close succession, means operatively connected to said gas chamber and responsive to a drop in the pressure in said gas chamber to a level below a second predetermined value for providing a controlling signal indicating a gas leak from said gas chamber, said second predetermined value being below the lowest value of pressure that results from one normal controlling operation of said system initiated when the liquid pressure is at least as high as said first predetermined pressure.

5. A hydraulic operating system of claim 4 in combination with differential pressure responsive means operatively connected to said liquid chamber and said gas chamber and sensitive to a pressure differential between the gas and the liquid on opposite sides of said piston for providing a controlling signal when said differential exceeds a predetermined value, said differential pressure responsive means operating in response to a substantially smaller pressure differential than the difference between said first and said second predetermined pressure values so as to provide an early warning of a loss of gas from said accumulator.

6. The hydraulic operating system of claim 1 in which said pressure responsive means for terminating operation of said source of pressure means comprises a pressure sensitive switch having a controlling portion communicating with the liquid chamber of said accumulator.

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