March 3, 1970 H. E. PRUCHA ET AL 3,498,061

HYDRAULIC SUPERCHARGE AND COOLING CIRCUIT

Filed May 29, 1968 3 Sheets-Sheet 1

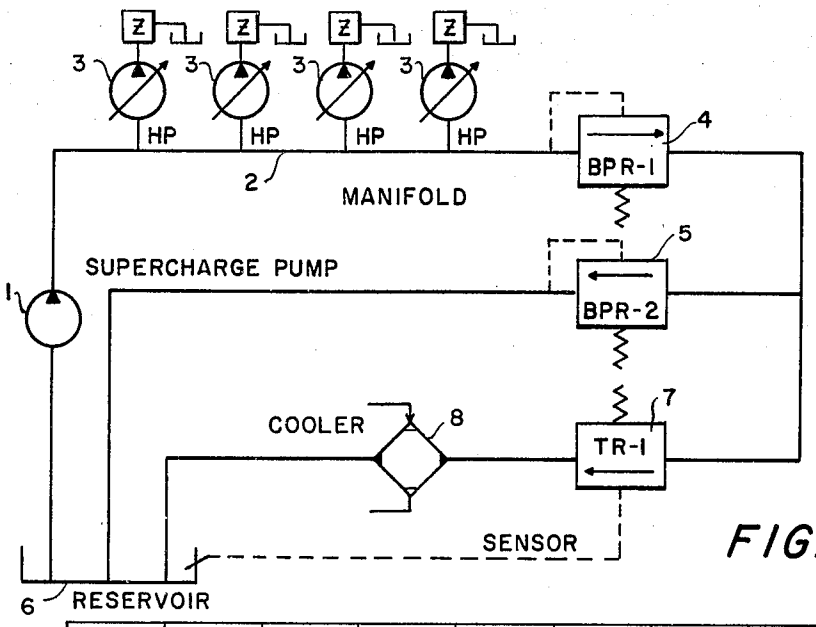


FIG. 1.

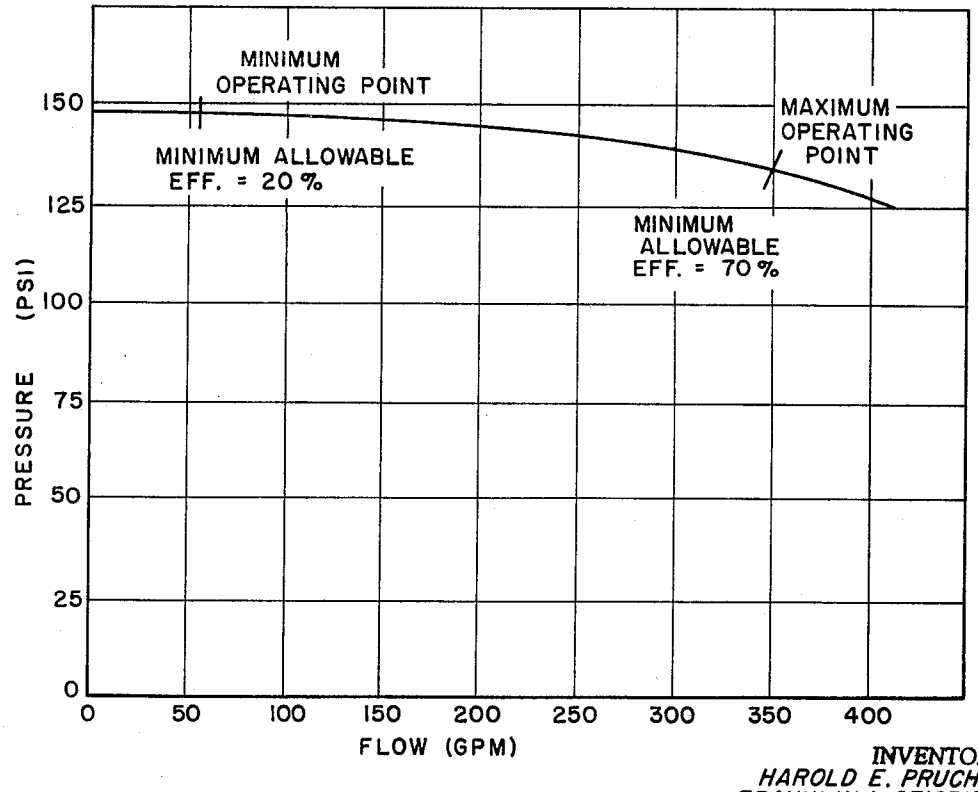


FIG. 3.

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HYDRAULIC SUPERCHARGE AND COOLING CIRCUIT

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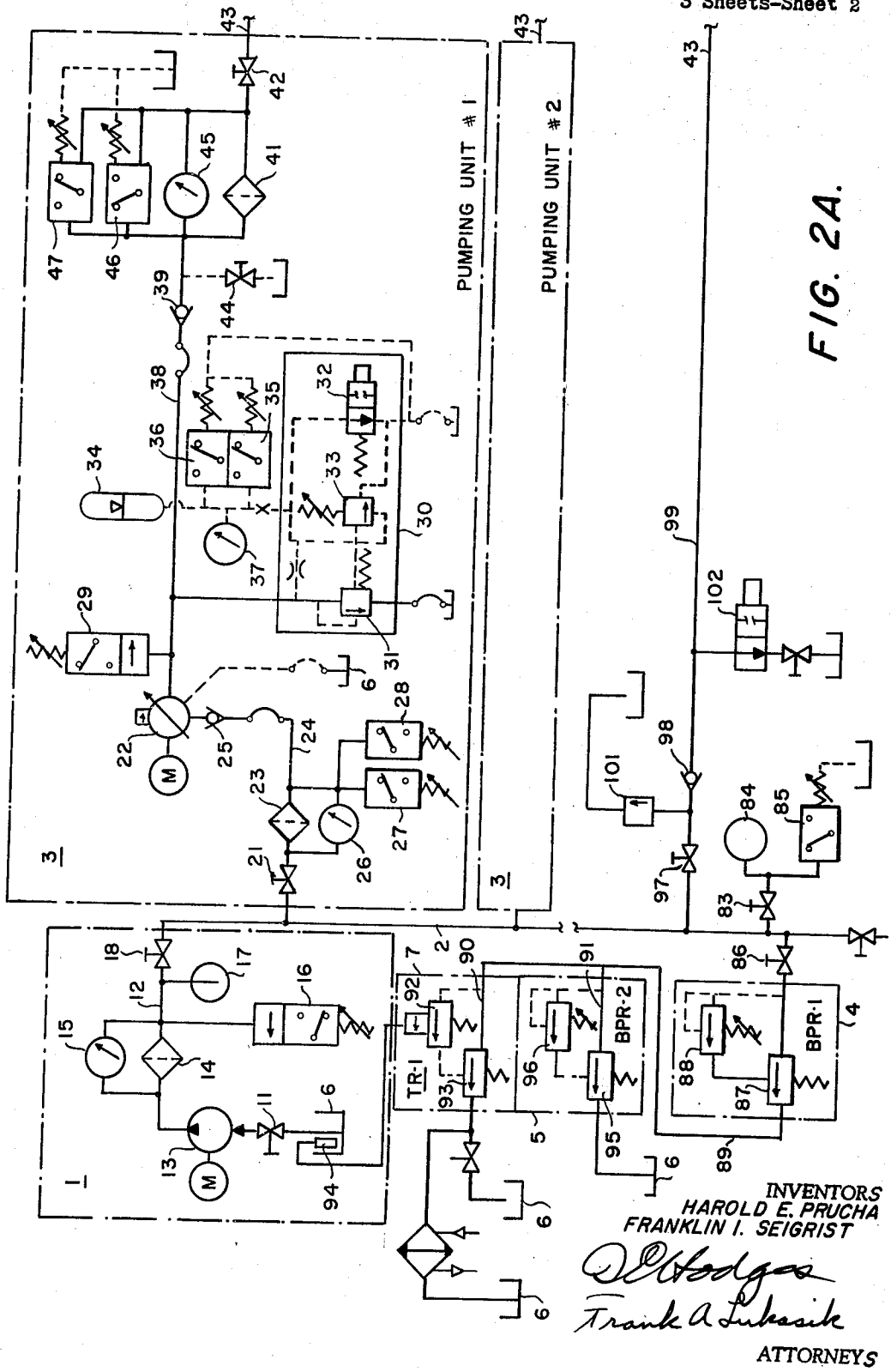


FIG. 2A.

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Filed May 29, 1968 3 Sheets-Sheet 3

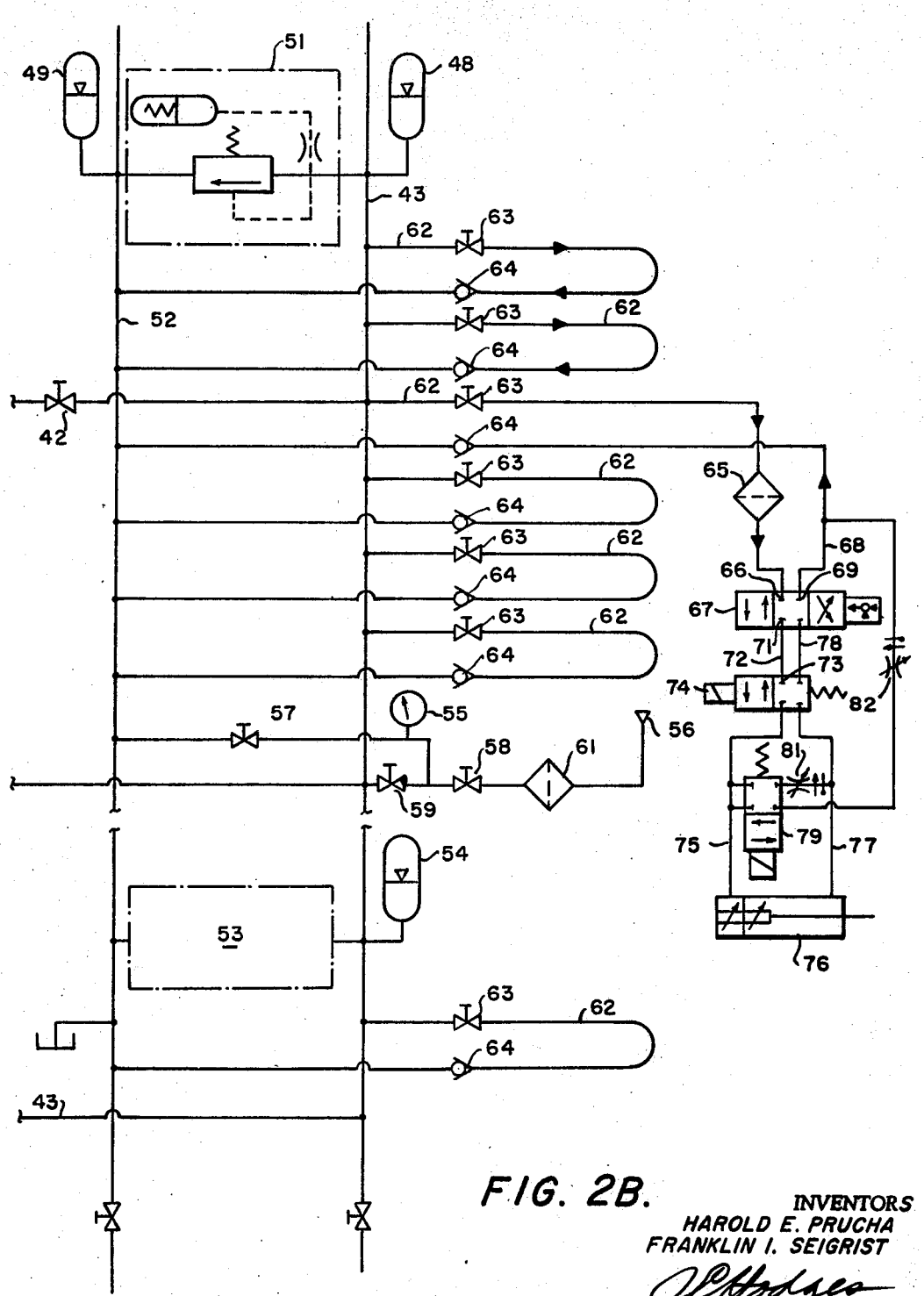


FIG. 2B.

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3,498,061

Patented Mar. 3, 1970

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HYDRAULIC SUPERCHARGE AND COOLING CIRCUIT

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Filed May 29, 1968, Ser. No. 732,979
Int. Cl. F15b 15/18
U.S. Cl. 60—52 12 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus which provides automatic control of the inlet pressure to high pressure pumps and simultaneously diverts excess fluid to a cooling unit as required to maintain the fluid temperature of the system at a specified value. A digital control monitors and controls a plurality of independent hydraulic actuators. A lock-up and release circuit provides a means for remotely holding a load on a hydraulic ram and a means for remotely releasing the load at a set rate.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

The present invention relates to a hydraulic system and more particularly to a system which provides automatic control of the temperature of the operating fluid in the system, and provides remote control of the working units.

In the field of hydraulic systems, prior art systems generally cooled all of the oil in a supercharge circuit in order to maintain cool oil under pressure at the inlet to the high pressure pumps. A disadvantage of this method is that cooling occurs only when flow is demanded at the high pressure pumps. This method resulted in oil remaining in the cooling system and thereby becoming excessively cold. Without adequate temperature control of the hydraulic fluid, surges of either hot or cold fluid may have harmful effects on hydraulic machinery and tend to reduce their useful life.

In prior art hydraulic ram systems, when remote operation was desired, hydraulic lines were run from the ram assemblies to a remote operator's control unit. This resulted in a large number of high pressure fluid lines entering an area frequented by operating personnel, thus constituting a safety hazard and additional expense. Prior art control systems generally utilized analog chart records of the desired commands, utilizing each recorder to command a plurality of actuators through a scaling process. This method resulted in inaccurate loading spectrums and yielded false data.

SUMMARY

The general purpose of this invention is to provide a hydraulic system that has all of the advantages of similarly employed systems and has none of the above described disadvantages. To attain this, the present invention provides a hydraulic supercharge and cooling circuit which automatically controls the inlet pressure to high pressure fluid pumps and which simultaneously diverts excess fluid flow to air-oil coolers as required to maintain the oil temperature of the system at a specified value. The present invention also provides a lock-up and release circuit for holding or maintaining a load on a hydraulic ram by remote control. A control system provides digital control of a plurality of independent hydraulic actuators while monitoring the load at each of the actuators to verify that the required loads or commands are being followed.

An object of the present invention is to provide a hydraulic system that is simple, economical and trouble free.

Another object is to provide a hydraulic system having an automatic fluid temperature control.

A further object of the invention is to provide a hydraulic system for driving servo-controlled hydraulic actuators.

A still further object of the invention is to provide a hydraulic system for static, dynamic, and fatigue testing structural members.

With these and other objects in view, as will hereinafter more fully appear, and which will be more particularly pointed out in the appended claims, reference is now made to the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a simplified circuit diagram of a practical embodiment of the invention.

FIGS. 2A and 2B taken together comprise a complete circuit diagram of a preferred embodiment of the invention.

FIG. 3 is a chart of pressure versus flow of a pump unit of the preferred embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 which shows a simplified schematic diagram of an embodiment of the present invention may be easily understood by following three distinct fluid paths of the system. The first fluid path begins with a supercharge pump unit **1**, providing fluid under pressure to a supercharge manifold **2**. High pressure pump units **3**, attached to supercharge manifold **2**, raise the input pressure to a higher level and provide the high pressure necessary to operate the working units to be described below.

A second fluid path may be traced from the supercharge pump unit **1**, to the supercharge manifold **2**, through the first back pressure regulator unit **4**, through a second back pressure regulator unit **5** and into a reservoir **6**.

A third fluid path may be traced from the supercharge pump unit **1**, to the supercharge manifold **2**, through back pressure regulator unit **4**, through temperature control unit **7**, through a heat exchanger **8** and into the reservoir **6**.

The supercharge pump unit **1** may preferably be a centrifugal pump having an output flow versus downstream pressure drop characteristics as shown in FIG. 3. The plot in FIG. 3 shows that for a small change in downstream pressure drop, a large change in output flow from supercharge pump unit **1** will result. This flow characteristic is used as follows:

High pressure pump units **3** may preferably comprise piston pumps which require a positive pressure on their inlet or suction ports. The pumps may also have a variable output and therefore require fluid only part of their operating time. In order to maintain the positive pressure on the inlets of high pressure pump units **3** and to maintain sufficient fluid availability, the following fluid circuits may be established.

Back pressure regulator unit **4** senses the pressure in the supercharge manifold **2** and automatically adjusts its pressure drop to maintain the supercharge manifold **2** at a fixed pressure level. Because of the fact that supercharge pump unit **1** supplies more fluid than required by the high pressure pump units **3** and because of the fact that back pressure regulator unit **4** requires fluid flow therethrough to maintain and regulate the pressure in manifold **2**, fluid flowing through back pressure regulator unit **4** is available for other uses. For example, as described above in the third fluid path, fluid is directed through a conduit to a temperature control unit **7** which detects the fluid temperature in reservoir **6** and determines the amount of fluid passing through heat exchang-

er 8 for cooling. As the temperature in reservoir 6 rises, a valve in temperature control unit 7 opens and as the temperature in reservoir 6 drops, the valve in temperature control unit 7 closes thereby regulating the temperature in reservoir 6.

Back pressure regulator unit 5 may preferably be similar to back pressure regulator unit 4, however, back pressure regulator unit 5 is set at a higher pressure. If temperature control unit 7 closes completely, all excess fluid from the supercharge manifold 2 is bypassed back to the reservoir 6, thereby forming the second fluid path. Furthermore, the rise in pressure in the supercharge circuit due to control by back pressure regulator unit 5 will cause the supercharge pump unit 1 to reduce its output to that amount necessary for the high pressure pump units 3 and back pressure regulator unit 5.

Referring now to FIGS. 2A and 2B there is shown an embodiment in accordance with the principles of the present invention. The symbols used in the drawings to represent the various hydraulic components are "ASA Proposed Standard Graphic Symbols." The fluid circuit begins at a reservoir 6 which is connected through a ball valve 11 to a pump 13. The ball valve 11 may also serve to isolate the reservoir 6 for draining. The pump 13 provides supercharge pressure for the high pressure pumps and the cooling circuit. Pump 13 may preferably be a unidirectional, centrifugal pump having an electric motor as an integral part of the pumping unit.

To further aid the understanding of the terminology used in this description, the valve terminology will be explained. This includes hand valves, relief valves, solenoid valves, back pressure valves and thermally-controlled valves.

The following definitions and operatings parame'ers are included merely as examples to aid in understanding the operation of the invention and are not to be considered as limiting factors in the practice of the invention.

A "high pressure" valve is one that is designed for continuous operation at not less than 3500 p.s.i. at temperatures ranging from 50° to 150° F., and have a burst pressure of not less than 13,500 p.s.i.

A "low pressure" valve is one that is designed for continuous operation not less than 150 p.s.i. at temperatures ranging from 50° to 150° F., and has a burst pressure of not less than 1200 p.s.i.

A high pressure "check valve" is a poppet type, spring loaded valve which allows flow in only one direction.

A "relief valve" is a pilot operated valve which will open or relieve pressures above a preselected pressure setting.

A "solenoid-operated" valve is a valve which has an electrical operator which allows operation of the valve when excited with 120 volts AC, 60 cps.

A high pressure "surge valve" is a valve which responds to a rate of pressure rise but does not act as a pressure relief valve.

A low pressure "check valve" is either a poppet type or swing type valve, which allows flow in only one direction.

A "back pressure" valve is a pilot operated valve which has a normally closed "sliding-gate" and operates to maintain the pressure on the upstream side at a relatively constant value up to the limit of the valve's rated capacity.

A "thermally-operated" valve is a pilot operated "sliding-gate" valve which operates with a change in temperature at its sensor.

A "servo-valve" is a valve which is pilot operated, closed center, four-way sliding spool type designed to control the flow of hydraulic oil proportionally to input current.

A "manual flow control valve" is a valve which is manually set, temperature and pressure compensated to maintain set flow within ±5% over the full flow range.

In the outlet line of pump 13 is a filter 14, for cleaning the fluid, and a pressure gage 15 across filter 14 to indicate cleanliness of the filter 14. As the filter 14 becomes clogged, the pressure drop will increase. Gage 15, as well as the gages described below may be of any suitable well known construction, e.g. a "Bourdon" tube gage. The filter 14 may be of any suitable well known construction. A temperature responsive switch 16 of any suitable well known construction is connected across the filter 14 to indicate the temperature of the fluid exiting from pump 13 and shuts the system off if the oil exceeds a specific set temperature. Also located in the output line 12 is a temperature gage 17 which indicates oil temperature for purposes of operation and maintenance. Ball valve 18 is connected between output line 12 and supercharge manifold 2 to isolate the supercharge pump unit 1 from the supercharge manifold 2.

Connected to the supercharge manifold 2 are the high pressure pump units 3 in a quantity determined by the capacity of supercharge pump unit 1. In a model arranged in accordance with the invention, eight high pressure pump units 3 were connected into supercharge manifold 2 in two sets of four each. A ball valve 21 connected between high pressure pump units 3 and supercharge manifold 2 is used to isolate the units. High pressure pump 22 is connected to ball valve 21 through filter 23, conduit 24 and check valve 25.

Pressure gage 26 is connected across filter 23 to indicate the cleanliness of the filter 23 as discussed above with regard to filter 14. A first pressure switch 27 is set at a pressure lower than a second pressure switch 28, pressure switch 27, giving a warning signal that the filter 23 is becoming dirty or the supercharge pressure at this point is low, and pressure switch 28 being used to shut down the system. Check valve 25 prevents fluid from flowing back through the high pressure pump 22 if the pump 22 is shut off.

The high pressure pump 22 may preferably be a variable displacement, pressure compensated pump. The pressure compensator normally operates such that any drop in pressure at the outlet port starts the pressure compensator to stroke the pump towards increasing delivery. The pressure compensators may be matched to provide satisfactory operation at any desired pressure ranging from 2,000 to 3,500 p.s.i. without resorting to pressure offsets to maintain stability.

The output of high pressure pump 22 has a temperature response switch 29 to indicate possible pump failure which generally results in a rise in fluid temperature. The high pressure pump 22 may then be shut down to prevent complete failure.

Also connected to the output of high pressure pump 22 is a pressure relief and dump unit 30 which comprises a standard valve 31, a small solenoid valve 32 and a pilot valve 33. When the solenoid valve 32 is energized, the unit 30 acts as a standard relief valve set at approximately 4,000 p.s.i. When the solenoid valve 32 is de-energized, the pump flow is passed directly to reservoir 6, thus performing the function of a dump valve. Connected to the pressure relief and dump unit 30 is accumulator 34. When solenoid valve 32 is energized, a shock wave of pressure is created by the high pressure pump 22. Accumulator 34 prevents the shock wave by slowly closing the main pressure relief and dump unit 30 as the pressure builds up in the accumulator 34. Connected to the line from accumulator 34 are pressure switches 35 and 36 and a pressure gage 37 for indicating the pressure on the high pressure pump line 38. Pressure switch 35 may be set at a low pressure value and if the pump pressure drops below a pre-determined value it causes a warning. Pressure switch 36 may be set at a higher pressure and when this pressure is exceeded the system will be shut down.

Pump line 38 is connected through check valve 39, through filter 41 and ball valve 42 to the high pressure manifold 43. Check valve 39 prevents high pressure fluid flow back into the pump 22 when the pump is shut off. Also connected to the line 38 is drain valve 44 for draining this section of the line. Pressure gage 45 and pressure

switches 46 and 47 give a warning if the filter 41 becomes partially clogged and will shut down the system if a predetermined pressure is exceeded. Ball valve 42 serves to isolate the filter 41 and pump 22 from the high pressure manifold 43.

Referring now to FIG. 2B there is shown the high pressure manifold 43 having accumulators 48 and 49 for shock compression and a transient protection valve 51 between the high pressure manifold 43 and a low pressure manifold 52. A second transient protection valve 53 with accumulator 54 may also be used. The accumulators and transient protection valves are arranged to absorb any shocks which may be sent back from equipment connected across the manifolds. Also connected across high pressure manifold 43 and low pressure manifold 52 is a pressure gage 55 which may be conveniently located on the test floor area. Vent 56 and by-pass 57 are provided for venting and draining the high and low pressure manifolds. Ball valves 58 and 59 are provided to isolate the manifolds as desired. Filter 61 in the conduit to vent 56 further purifies the hydraulic fluid.

Connected across high pressure manifold 43 and low pressure manifold 52 are the fluid conduits to the working units. High pressure lines 62 may be isolated from the working units by ball valves 63. Check valves 64 are also used to isolate the high and low pressure circuits. High pressure fluid is fed through line 62, through filter 65 which is connected to the input 66 of servo-valve 67. Control current for servo-valve 67 may be provided by a hybrid process controller in accordance with the desired response. Since servo-valve 67 is used to control high and low pressure fluid flow, fluid conduit 68 connected to outlet 69 may be provided for return fluid flow through check valve 64 to low pressure manifold 52.

Outlet 71 of servo-valve 67 is connected through conduit 72 to an inlet port 73 of lock-up valve 74. Lock-up valve 74 is connected through conduit 75 to one end of a hydraulic ram 76, and through conduit 77 to the opposite end of hydraulic ram 76. Conduit 78 connects the lock-up valve 74 through servo-valve 67 to the low pressure manifold 52.

A release valve 79 is connected by conduit 75 to the high pressure fluid side. On the low pressure side, a first flow circuit through release valve 79 is connected through manual flow control valve 81 to conduit 77. A second flow circuit through release valve 79 is connected through manual flow control valve 82 to conduit 68, the low pressure side of servo-valve 67, thereby by-passing the lock-up valve 74 and servo-valve 67.

During normal operation of hydraulic ram 76, the servo-valve 67 controls the position and load on the hydraulic ram 76. The solenoid on lock-up valve 74 is energized and the solenoid on release valve 79 is de-energized. Interrupting electrical power to lock-up valve 74 will nearly instantaneously block both fluid ports on hydraulic ram 76 and hold the ram position and load, regardless of the action of servo-valve 67. To return the hydraulic ram 76 to a neutral position at no load, release valve 79 is energized and hydraulic fluid flow will commence through the flow control valves 81 and 82. The rate of unloading will be governed by the setting of flow control valves 81 and 82.

Referring now to FIG. 2*a* the automatic temperature control previously described with reference to FIG. 1 will be described in detail. Ball valve 83 is connected between supercharge manifold 2 and pressure gage 84 with its associated pressure switch 85. Pressure switch 85 may be interlocked with the high pressure pump 22 to prohibit its operation until the supercharge manifold 2 reaches a pre-determined level. Also connected to supercharge manifold 2 through a ball valve 86 are back pressure regulator valves 87 and 88. In a particular model utilizing the principles of the invention, valve 88 may be set to maintain the supercharge pressure at 110 p.s.i. as long as the system is in a cooling mode. Conduit 89, forming a fluid circuit from valve 87, branches into conduits 90 and 91. Conduit 90 is connected to the inlet of temperature regulating valves 92 and 93 whose temperature sensor 94 is located in reservoir 6. The temperature control unit 7, containing temperature regulating valves 92 and 93 is modulated to maintain the temperature of the hydraulic fluid at a specific value.

The second branch, conduit 91, forms a fluid circuit through back pressure regulator valves 95 and 96 and into reservoir 6. If the temperature control unit 7 is closed, e.g. fluid temperature below 110° F., back pressure regulator unit 5 regulates the pressure in the supercharged line at 125 p.s.i. This regulation in effect throttles the supercharge pump unit 1 back to a lower output flow.

Connected across supercharge manifold 2 and high pressure manifold 43 is a fluid circuit comprising a ball valve 97, a check valve 98 and a conduit 99. Ball valve 97 and check valve 98 are provided to isolate the two circuits from each other. Also connected to conduit 99 is a pressure relief valve 101 which may be used to take up leakage through the check valve 98. On the opposite side of check valve 98, there may be connected to conduit 99 a solenoid operated dump valve 102 which may be used for emergencies. Operation of dump valve 102 will immediately dump all of the fluid out of the high pressure manifold 43 and in effect reduce the pressure to a less dangerous value. Dump valve 102 may also be used for flushing purposes and also as a by-pass of the high pressure pump units 3 when a lower pressure may be useful for setup of the hydraulic rams 76.

When operating a closed loop control system, as shown in FIG. 2B, the system may begin to oscillate because of excessive gain in the system. The release valve 79 may be energized or manually positioned to a flow-through position. Flow control valves 81 and 82 may be adjusted to cause a small amount of hydraulic fluid to leak across hydraulic ram 76, effectively reducing gain and stopping oscillation.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. The method of supplying hydraulic fluid to a hydraulic system, the method comprising the steps of:
   - controlling the inlet pressure to a high pressure system by diverting a quantity of hydraulic fluid in excess of the fluid required by said high pressure system through a pressure regulating system which is automatically responsive to said inlet pressure; and
   - regulating the temperature of said hydraulic fluid by diverting a quantity of said excess fluid through a heating and cooling system which is automatically responsive to the temperature of said hydraulic fluid.

2. The method of supplying hydraulic fluid at a relatively constant pressure and temperature to a hydraulic system, the method comprising the steps of:
   - raising the pressure of said hydraulic fluid to a first pressure level;
   - providing said hydraulic fluid at a first pressure level to a distribution system, raising the pressure of the hydraulic fluid in the distribution system from said first pressure level to a second pressure level;
   - supplying said hydraulic system with hydraulic fluid at said second pressure level;
   - regulating the first pressure level of said hydraulic fluid to maintain the first pressure level in response to the fluid input required to maintain said second pressure level; and
   - regulating the temperature of the fluid circulating at said first pressure level,
   - whereby the hydraulic fluid circulating through said distribution system is maintained at a constant desired temperature and pressure by utilizing excess fluid

flow through a temperature and pressure regulating system.

3. A hydraulic system comprising:
first pressure means for supplying fluid at a first pressure level;
second pressure means adapted to raise the pressure of said hydraulic fluid to a second pressure level and adapted to supply fluid at said second pressure to a plurality of output devices;
first pressure responsive means for detecting and automatically adjusting said first pressure level thereby maintaining a substantially fixed pressure level;
temperature responsive means adapted to detect and automatically regulate the temperature of said fluid in said system; and
second pressure responsive means adapted to form a fluid bypass for said temperature responsive means when said fluid is at a desired temperature,
whereby said first and second pressure responsive means and said temperature responsive means control the output of said first pressure means in response to the fluid requirements of said output devices.

4. A hydraulic system according to claim 3 wherein said first pressure means comprises:
a unidirectional, centrifugal pump.

5. A hydraulic system according to claim 3 wherein said second pressure means comprises:
a variable displacement, pressure compensated piston pump whereby a drop in outlet pressure causes the pressure compensator to vary the pump towards an increased output.

6. A hydraulic system according to claim 3 wherein said first and second pressure responsive means each comprises:
a pilot operated valve having a normally closed sliding-gate for maintaining pressure at a constant value.

7. A hydraulic system according to claim 3 wherein said temperature responsive means comprises:
a pilot operated valve having a sliding-gate responsive to a change in temperature at its sensor.

8. A hydraulic fluid power transmission system having a supercharge pump and a fluid reservoir, the system comprising:
a first fluid flow circuit from said reservoir, through said supercharge pump, through at least one high pressure pump, through at least one hydraulic ram and a return flow to said reservoir;
a second fluid flow circuit from said reservoir, through said supercharge pump, through a first and a second pressure regulator valve and a return flow to said reservoir; and
a third fluid flow circuit from said reservoir, through said supercharge pump, through a first pressure regulator valve, through a temperature regulator valve, through a cooling unit and a return flow to said regulator,
whereby hydraulic fluid flowing through said first, second and third flow circuits is continually recirculated and cooled thereby maintaining a relatively constant temperature and pressure and preventing sudden surges of potentially damaging temperature extremes.

9. A hydraulic fluid power transmission system comprising:
a fluid reservoir;
a unidirectional, centrifugal pump connected to said reservoir for pumping said fluid at a first pressure;
a supercharge manifold connected to said centrifugal pump for distributing said fluid at a first pressure;
at least two high pressure pumps connected to said supercharge manifold for raising the pressure of said fluid to a second pressure level;
a high pressure manifold connected to said high pressure pumps for distributing said fluid at a second pressure level;
control means connected to said high pressure manifold for applying loads to structural members for static, dynamic and fatigue testing said structural members;
a first back pressure regulator circuit connected to said supercharge manifold for detecting and automatically adjusting said first pressure level, said regulator circuit having a normally closed, sliding-gate pilot operated valve;
a temperature regulator circuit connected between said first back pressure regulator circuit and said reservoir for detecting and regulating the temperature of said fluid, said temperature regulating circuit having a pilot operated, sliding-gate valve responsive to the temperature of the fluid in said reservoir and having a cooling and heating unit to maintain the fluid temperature at a specified value; and
a second back pressure regulator circuit connected between said first back pressure regulator circuit and said reservoir thereby forming a fluid by-pass around said temperature regulator circuit,
whereby hydraulic fluid is circulated at a relatively constant pressure and maintaining at a constant safe temperature by utilizing excess fluid flow through a pressure regulator system.

10. A hydraulic system according to claim 9 wherein said control means comprises:
a servo-valve having a high and a low pressure side for controlling the flow of hydraulic fluid proportionally to input control current;
a hydraulic ram for applying loads to said structural members;
a lock-up valve connected to said high and low pressure sides of said servo-valve and adapted to provide fluid under pressure to said hydraulic ram, said lock-up valve also adapted for instantaneously blocking and holding fluid flow through said servo-valve in response to an external signal; and
a release valve connected across said hydraulic ram in parallel relationship to the fluid flow in said hydraulic ram, said release valve having fluid flow control valves controlling the rate of fluid flow therethrough.

11. A hydraulic system for remotely holding a load and remotely releasing the load on a hydraulic ram at a set rate, the system comprising:
a servo-valve having a high and a low pressure side for controlling the flow of hydraulic fluid proportionally to input control current;
a hydraulic ram for applying loads to structural members for static, dynamic and fatigue testing said structural members;
a lock-up valve connected to said high and low pressure sides of said servo-valve and adapted to provide fluid under pressure to said hydraulic ram, said lock-up valve also adapted for instantaneously blocking and holding fluid flow through said servo-valve in response to an external signal; and
a release valve connected across said hydraulic ram in parallel relationship to the fluid flow in said hydraulic ram, said release valve having fluid flow control valves controlling the rate of fluid flow therethrough.

12. A hydraulic circuit for holding a load and releasing the load on a hydraulic ram, the circuit comprising:
a release valve connected across said hydraulic ram and movable between an energized and a de-energized portion;
a solenoid operably connectd to said release valve and adapted to be actuated by an external signal to move said valve to an energized position; and
a flow control means connected to said release valve in an energized position for controlling the rate of fluid flow through said hydraulic ram and also adapted to cause hydraulic fluid to leak across said hydraulic

ram thereby effectively reducing gain and stopping oscillation.

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