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Byford

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[54] CIRCUIT BREAKER

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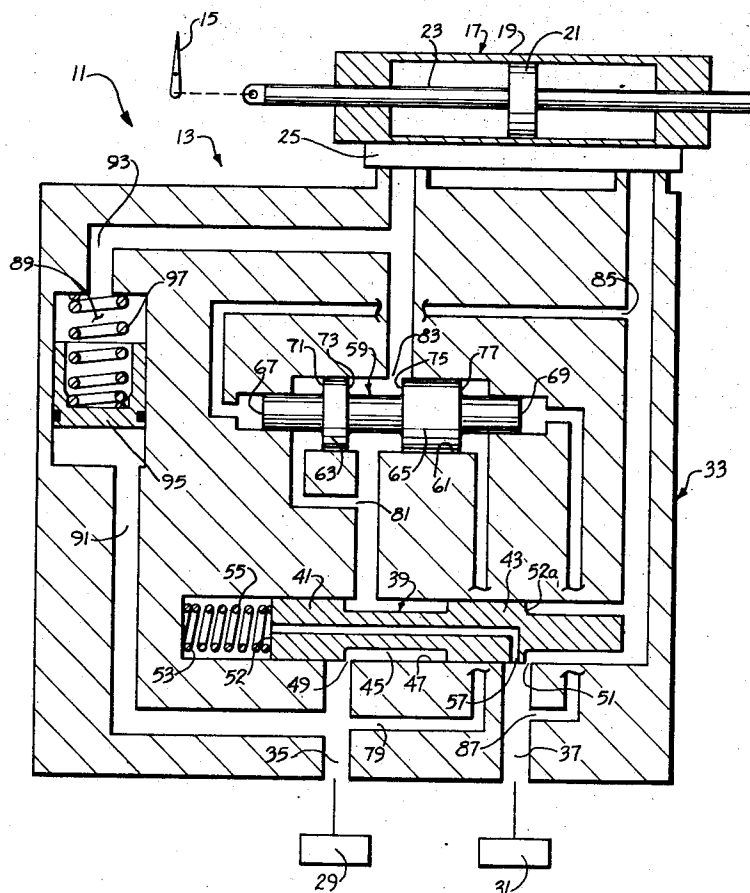
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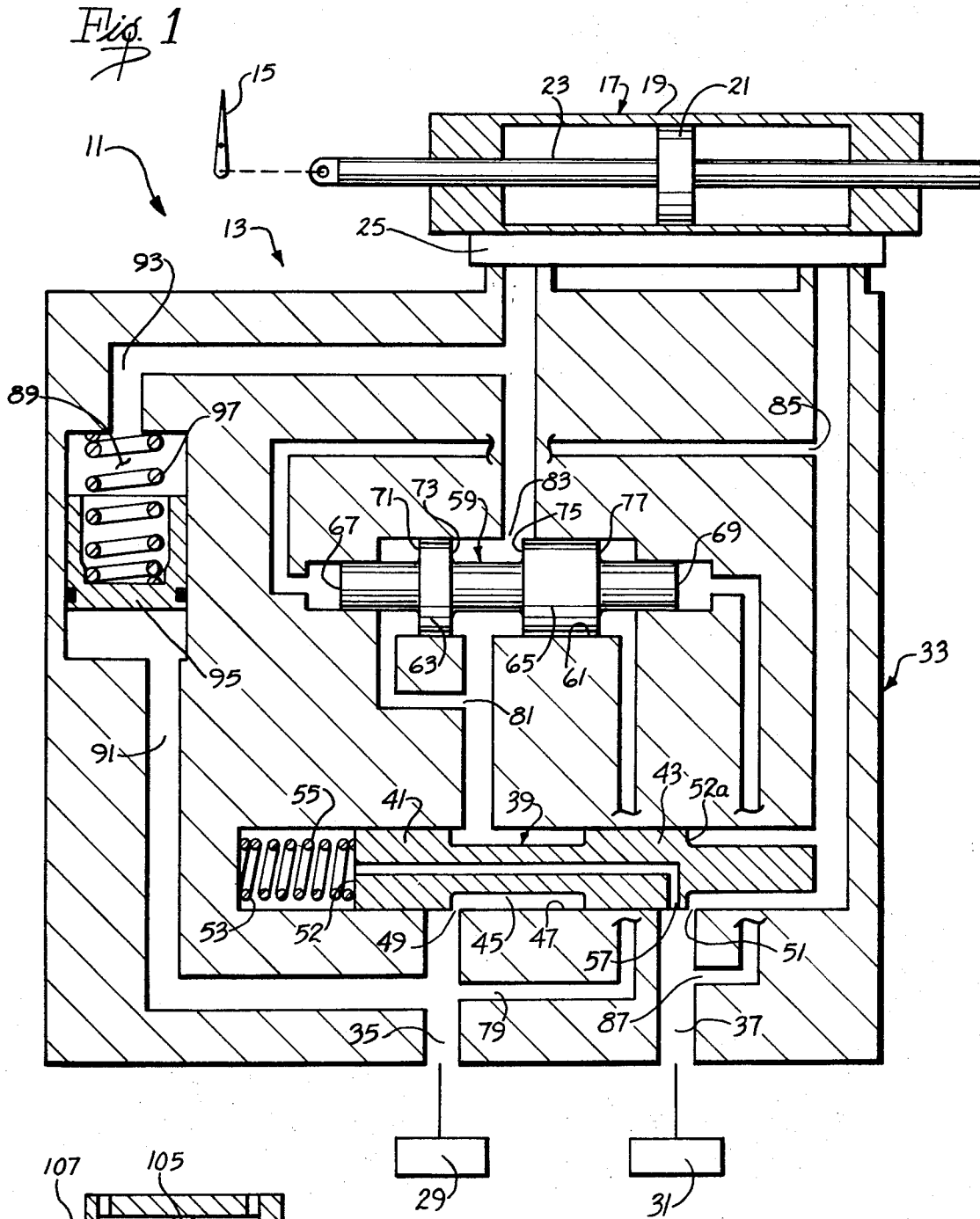
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[57] ABSTRACT

A circuit breaker including a first orifice positionable in a first fluid stream, a second orifice positionable in a second fluid stream, and a valve responsive to the pressure drops across the orifices being in a predetermined ratio for at least substantially reducing the flow rate of the first fluid stream.

21 Claims, 2 Drawing Figures





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CIRCUIT BREAKER**BACKGROUND OF THE INVENTION**

It is often necessary or desirable to provide an indication, or to take remedial action, when a leak of predetermined magnitude develops in a hydraulic system. To accomplish this purpose, it is necessary to continuously monitor the condition of the hydraulic system even through portions of such system may be remotely located.

Leak detection is particularly important in hydraulic systems used on aircraft. As is well known, hydraulic systems are utilized on many aircraft to control the control surfaces of the aircraft. To insure reliability, the systems are often redundant so that if one system or a component thereof malfunctions, the other system or component is operative to provide the necessary control motion.

If a leak of predetermined magnitude develops in one of the hydraulic systems, it is absolutely essential that such system be shutoff from the source of hydraulic fluid under pressure to prevent complete loss of the hydraulic fluid and ultimate destruction of the aircraft. A circuit breaker or hydraulic fuse is utilized to accomplish this detection and shutoff function. In order to be useful for aircraft applications, the hydraulic fuse must be very reliable.

SUMMARY OF THE INVENTION

The present invention provides a reliable circuit breaker which compares fluid flows to and from a device and shuts down the supply flow if the supply and return flows reach a predetermined ratio. The circuit breaker is usable with any liquid operated or handling device if such device utilizes supply and return flows in a predetermined ratio, and the hydraulic system shown and described herein is merely illustrative. Thus, as used herein the expression "hydraulic fuse" is not limited to a device usable only with hydraulic oil but rather it includes devices usable with many other liquids. In a typical hydraulic system the return flow is a function of the supply flow if there are no leaks in the system. For example, the supply flow and return flows to many hydraulic components such as a balanced hydraulic actuator should be substantially equal except for minor factors such as bulk modulus. Thus, the difference between supply and return flows indicates the amount of leakage in the system.

To accomplish flow measurement, the present invention provides supply and return orifices in the supply and return conduits, respectively. The areas of both of the orifices are known and bear a predetermined relationship to each other. Preferably the areas of the orifices are equal so that the pressure drops thereacross for equal flow rates are also equal. Accordingly, the leakage of the system is a function of the difference in the pressure drops across the orifices.

The pressure drops across the orifices are used to control a shutoff valve. If the difference in pressure drop exceeds a predetermined magnitude, the valve shuts off the supply of hydraulic fluid. The pressure drop across the supply orifice tends to close the valve while the pressure drop across the return orifice tends to open the valve. Accordingly, if the pressure drop across the return orifice decreases, as it would if return flow decreased, the system has a leak, and the valve

would shut off the supply of hydraulic fluid. The valve can advantageously take the form of a slide valve having pressure responsive faces thereon against which the pressure drops across the supply and return orifices can act.

The present invention provides means for opening the shutoff valve during start up of the system, if at that time, the shutoff valve is closed. This function is performed by a reservoir which provides a small quantity of fluid to the supply conduit intermediate the shutoff valve and the hydraulic device to operate the hydraulic device and to thereby initiate fluid flow in the return conduit. This results in a pressure drop across the return orifice, and this pressure drop is utilized to open the shutoff valve.

The volume of the reservoir is very small in relation to system volume. The reservoir may contain a piston exposed to hydraulic fluid at supply pressure upstream of the supply orifice. This drives the piston to cause expulsion of the fluid in the reservoir into the supply conduit. To permit recharging of the reservoir when the fluid therein is depleted or partially depleted, biasing means are provided to retard movement of the piston in a direction tending to expel the fluid from the reservoir into the supply conduit. The spring permits the reservoir to be recharged by hydraulic fluid which is under a pressure slightly less than the supply pressure upstream of the supply orifice. Although the reservoir can be recharged in various different ways, the manner disclosed herein is preferred because of its simplicity.

The areas of the supply and return orifices are difficult to control. Preferably the supply orifice is of slightly larger area than the return orifice so that for a given pressure drop more fluid can flow therethrough than through the return orifice. Stated differently, supply flow can slightly exceed return flow and this additional supply flow can be utilized to recharge the reservoir and to make up for minor leaks which the system can readily tolerate. Although the supply and return orifices are described herein as being of substantially equal area, it should be understood that this expression encompasses a supply orifice being of slightly larger diameter than the return orifice.

Another function of the reservoir occurs when the hydraulic device is an unbalanced actuator. In this event, the flow input to the actuator may be different from the flow output from the actuator, and hence the reservoir will add to or subtract from the flow supplied through the supply orifice to make up for the differential.

Another problem relates to the sizing of the orifices. It is generally desirable to maintain pressure drops in a hydraulic system at a minimum, and this would seemingly dictate sizing of the orifices for the desired pressure drop at maximum flow rates. However, if the orifices are sized for maximum flow rates, the pressure drops thereacross at low flow rates may not produce sufficient force to operate the shutoff valve.

To overcome this problem, the present invention provides variable area supply and return orifices. The area of the supply and return orifices vary together so that the areas thereof are substantially the same. The areas of the orifices vary with the pressure drop across the return orifice with an increase in such pressure drop resulting in increasing the areas of the orifices. In

this manner, the area of the return orifice is varied so that the pressure drop thereacross is substantially the same over a range of flow rates. Moreover, the area of the supply orifice is correspondingly varied so that for a no leak condition, the pressure drop thereacross remains substantially constant even though the supply flow rate may change.

The variable orifice concept can be advantageously implemented by utilizing a slide valve positionable in both the supply and return conduits. The slide valve partially defines both of the orifices and by moving the slide in the appropriate direction, the area of the orifices can be increased or decreased simultaneously. This slide valve also serves as a check valve.

The invention can best be understood by reference to the following description taken in connection with the accompanying illustrative drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 of the drawing is a schematic view partially in section illustrating a preferred form of hydraulic fuse constructed in accordance with the teachings of this invention.

FIG. 2 is a schematic view of an unbalanced actuator.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a hydraulic fuse 11 constructed in accordance with the teachings of this invention. It should be understood that FIG. 1 of the drawing is schematic and that the configuration and construction of the components can be varied by those having ordinary skill in the art. Moreover, elements such as seals having no relationship to the concept of the invention have been omitted for clarity, it being understood that such elements can readily be provided as necessary or desired by those having ordinary skill in the art.

The hydraulic fuse 11 is part of a hydraulic control system 13 usable to control a control surface 15 of an aircraft (not shown), although it may be utilized in other environments. The position of the control surface 15 is controlled by a hydraulic actuator 17 which includes a housing 19, a piston 21 and connecting linkage 23 drivingly connecting the piston and the control surface. Movements of the piston 21 within the housing 19 are controlled by a servo valve 25 which controls the flow of hydraulic fluid to and from the faces of the piston 21. Of course, the actuator 17 and the servo valve 25 can be of various designs and function in various ways.

The servo valve 25 may include numerous control system components such as an electrohydraulic valve, a modulating piston, etc. Fluid under pressure is supplied from a source 29 and return fluid returns to a sump 31.

The hydraulic fuse 11 includes a body 33 having a supply passage or conduit 35 and a return passage or conduit 37 extending therethrough. A slide valve 39 having lands 41 and 43 defining an annular groove 45 therebetween is mounted for sliding movement in a bore 47 which extends transversely between the supply passage 35 and the return passage 37. The land 41 cooperates with the supply passage 35 to define a variable area supply orifice 49. Similarly, the land 43 cooperates with the return passage 37 to define a

return orifice 51. The orifices 47 and 51 are of substantially equal area with the supply orifice 49 being slightly larger in area than the orifice 51.

The slide valve 39 has pressure responsive end faces 52 and 52a. The face 52 and one end of the bore 47 cooperate to define a chamber 53. A spring 55 acts between one end of the bore 47 and the face 52 to urge the slide valve 39 in a direction tending to reduce the areas of the orifices 49 and 51. A passage 57 provides communication between the chamber 53 and the return conduit 37 downstream of the return orifice 51 to thereby permit fluid pressure to act on the face 52. Although the passage 57 in the embodiment illustrated extends through the slide valve 39, it should be understood that this is merely for convenience of illustration and that the passage 57 may physically take other routes in reaching the chamber 53.

A shutoff valve 59 is mounted in a bore 61 which extends transversely of the supply passage 35 downstream of the orifice 49. The shutoff valve 59 has axially spaced lands 63 and 65 and pressure responsive and faces 67 and 69. The land 63 has pressure responsive annular faces 71 and 73 and the land 65 has pressure responsive annular faces 75 and 77. In the embodiment illustrated, the areas of the faces 67, 69, 71, 73, 75 and 77 are equal.

The shutoff valve 59 is controlled by the pressure drops across the orifices 49 and 51. Thus, fluid under pressure from upstream of the orifice 49 is supplied to the face 77 by a passage 79, and fluid under pressure from downstream of the orifice 49 is supplied to the pressure responsive face 71 by a passage 81. Thus, the net force as a result of the pressure drop across the orifice 49 urges the shutoff valve 59 toward a closed position in which the land 65 closes off a port 83.

Fluid under pressure from upstream of the return orifice 51 is supplied to the pressure responsive and face 67 by a passage 85, and fluid under pressure from a location in the return conduit 37 downstream of the orifice 51 is supplied to the pressure responsive end face 69 by a passage 87. Thus, the pressure drop across the orifice 51 acts, in effect, on the shutoff valve 59 in a direction tending to open the latter, i.e., to increase the area of the port 83. In this manner, the shutoff valve 59 is controlled by the pressure drops across the supply orifice 49 and the return orifice 51.

A reservoir 89 is provided in the body 33. A passage 91 provides communication between one end of the reservoir 89 and a location in the supply conduit 35 upstream of the supply orifice 49. A passage 93 provides communication between the other end of the reservoir 89 and a location in the supply conduit 35 downstream of the port 83. A piston 95 is mounted in the reservoir 89 for sliding movement therein, and a spring 97 urges the piston downwardly as viewed in FIG. 1, i.e., toward the passage 91.

Movement of the piston 95 upwardly as viewed in FIG. 1 by the fluid pressure supplied through the passage 91 expels hydraulic fluid from the reservoir 89 into the supply conduit 35 downstream of the port 83. Similarly, under other operating conditions, hydraulic fluid can be supplied through the passage 93 to urge the piston 95 downwardly as viewed in FIG. 1 thereby charging the reservoir. The spring 97 is of such a strength that under certain operating conditions the

force supplied by the spring and the force exerted by the fluid under pressure supplied through the passage 93 is sufficient to move the piston 95 downwardly for recharging.

OPERATION

The position of the shutoff valve 59 at start up is unknown. Moreover, the valve 59 is in equilibrium prior to start up because no hydraulic fluid is flowing through the orifices 49 and 51.

Assuming that the shut-off valve 59 is in a position to completely close off the port 83 at start up, fluid under pressure from the supply conduit 35 and the passage 91 acts on the piston 95 in the reservoir 89 to move the latter to expel hydraulic fluid through the passage 93 and into the supply conduit 35 downstream of the closed port 83.

The hydraulic fluid in the reservoir 89 is supplied to the actuator 17. Because the actuator 17 is a balanced actuator, this results in a substantially equal flow of hydraulic fluid from the actuator into the return passage 37 and through the return orifice 51. The flow of hydraulic fluid through the return orifice 51 produces a pressure drop which acts on the shutoff valve 59 to move the latter to open the port 83 to permit additional fluid to be supplied to the actuator 17. Specifically, the end face 67 is supplied with fluid under pressure upstream of the return orifice 51 via the passage 85, and the pressure responsive face 69 is supplied with fluid from downstream of the return orifice 51 via the passage 87. The net effect is a force on the valve 59 tending to open the port 83.

At start up the slide valve 39 is moved by the spring 53 to completely close the ports 49 and 51. The pressure of the return fluid in the return conduit 37 acting on the face 52a is sufficient to move the valve 39 to open the orifices 49 and 51.

With fluid flowing through the orifices 49 and 51, the shutoff valve 59 seeks a position which is a function of the pressure drops across the orifices 49 and 51. Because the supply orifice 49 is of slightly larger area than the return orifice 51, the flow through the supply orifice can slightly exceed the flow through the return orifice without making the pressure drop across the orifice 49 larger than the pressure drop across the orifice 51. This increased flow can be utilized to recharge the reservoir 89 as the combined effects of the pressure of the fluid from the passage 93 and the spring 89 are sufficient to overcome the force of the fluid from the passage 91 acting on the piston. Once the reservoir 89 is fully charged, the flow through the orifice 49 reduces slightly until it equals the flow through the return orifice 51. Accordingly, the pressure drop across the orifice 49 is then less than the pressure drop across the orifice 51 with the result that the shutoff valve 59 is held in the fully open position.

If the actuator 17 requires increase quantities of fluid, the flow through the supply passage 35 and the return passage 37 increase. This produces an increased pressure drop across the return orifice 51 with the result that the slide valve 39 is moved to increase the areas of the orifices 49 and 51 until the predetermined pressure drop across the return orifice 51 has been reestablished. Similarly, if the flow through the return orifice 51 decreases, the slide valve 39 is repositioned

to reduce the size of the orifices 49 and 51 to reestablish the predetermined desired pressure drop across the orifice 51. Thus, the slide valve 39 maintains the pressure drop across the return orifice 51 at a preset value over a relatively wide range of flow rates.

Because the supply orifice 49 is of a larger area than the return orifice 51, minor leaks in the system 13 can be tolerated without causing shut down of the system. If a leak, for example, in the supply conduit 35 downstream of the passage 93 exceeds the minor amount permissible, the pressure drop caused thereby will permit the piston 95 to supply the needed makeup. In this event the flow through the orifices 49 and 51 will be substantially equal and substantially no effect will be felt on the slide valve 39 or the shutoff valve 59.

However, the reservoir 89 is of relatively small volume and the fluid therein would be quickly exhausted by a major leak. Once the fluid therein was exhausted, a continuing leakage would result in a reduction in the flow rate through the return orifice 51. However, because the demand of the actuator 17 still exists, flow through the supply orifice 49 would continue and would exceed the flow through the return orifice 51. The result is that the pressure drop across the supply orifice 49 would exceed the pressure drop across the return orifice 51, and this would cause the shutoff valve 59 to move in a direction tending to close off the port 83. Specifically, the relatively high pressure acting in the face 77 would cause movement of the shutoff valve 59 to close the port 83.

The reduction in flow through the return orifice 51 would also result in repositioning of the slide valve 39 to reduce the areas of the orifices 49 and 51. However, in normal operation the shutoff of the supply flow through the conduit 35 would be accomplished by the shutoff valve 59. With the shutoff valve 59 in the closed position, there is no flow through the supply and return passages and the slide valve 39 is moved by the spring 55 to completely close the orifices 49 and 51. The slide valve 39 also serves a check valve in that it closes the orifices 49 and 51 if pressure downstream of the return orifice 51 equals or exceeds the pressure upstream of the return orifice.

In the embodiment illustrated in FIG. 1, the actuator 17 is a balanced actuator, i.e., one in which the return flow from the actuator equals the supply flow to the actuator excluding the relatively minor effects of bulk modulus. In an unbalanced actuator, there is some disparity between the supply flow to the actuator and the return flow from the actuator, although these flows may be considered as substantially equal. FIG. 2 shows an unbalanced actuator 101 which includes a housing 103, a piston 105 and a connecting rod 107 for drivingly connecting the piston to the control surface 15.

The piston 105 has opposed faces 109 and 111. It is apparent that with fluid at supply pressure being supplied to the face 109 to move the piston to the right as viewed in FIG. 2 the return flow will exceed the supply flow. This is because the connecting rod 109 reduces the volume of the cylinder 103 on the left side of the piston 105. Conversely, with fluid under pressure being supplied to the face 111 to move the piston 105 to the left, supply flow will exceed the return flow.

The reservoir 89 compensates for the disparity in supply and return flows caused by the differential actuator 101. Thus, with the actuator 101 substituted for the actuator 17 of FIG. 1, the reservoir 89 supplies additional fluid when the piston 105 is being driven to the left and absorbs excess fluid supplied through the orifice 49 when the piston 105 is driven to the right. Specifically, when a high demand for fluid is made, there is a pressure drop intermediate the port 83 and the servo valve 25 which permits the pressure in the conduit 91 to move the piston 95 upwardly to expel fluid therefrom to supply the excess needed by the unbalanced actuator. Should the actuator then be moved in the reverse direction so that return flow exceeds supply flow, there is a pressure increase downstream of the port 83 because the requirements of the actuator are fully met thereby permitting the piston 95 to be driven downwardly to recharge the actuator. Thus, the piston 95 breathes in unison with the unbalanced actuator 101. The volume of the reservoir should equal the differential volume of the unbalanced actuator 101 plus a slight excess volume to allow for bulk modulus and other effects that may cause inadvertent bottoming of the piston 95 in the reservoir 89.

Although an exemplary embodiment of the invention has been shown and described, many changes, modification, and substitutions may be made by one having ordinary skill in the art without necessarily departing from the spirit and scope of this invention.

I claim:

1. A circuit breaker comprising:

means defining a first orifice positionable in a first fluid stream so that the fluid of such stream can pass therethrough and undergo a first pressure drop;

means defining a second orifice positionable in a second fluid stream so that the fluid of such stream can pass therethrough and undergo a second pressure drop;

means responsive to the ratio of said pressure drops reaching a predetermined value for at least substantially reducing the flow rate of the first fluid stream;

means responsive to the pressure drop across at least one of said orifices for automatically varying the area of said second orifice to maintain the pressure drop thereacross substantially constant over a range of flow rates therethrough;

means for correspondingly varying the area of said first orifice so that the pressure drop thereacross is substantially constant; and

said orifices being open during normal operation of the circuit breaker.

2. A circuit breaker as defined in claim 1 wherein said orifices are of substantially equal area whereby said pressure drops are substantially equal for substantially the same flow rates of said fluid streams, and said predetermined ratio is about one to one.

3. A circuit breaker as defined in claim 1 wherein said means responsive to the ratio of the pressure drops includes a shut off valve.

4. A circuit breaker as defined in claim 1 wherein the areas of said orifices are variable from substantially completely closed positions to open positions.

5. A circuit breaker as defined in claim 1 wherein said means for varying includes a slide valve, said circuit breaker including means responsive to the pressure downstream of said second orifice exceeding the pressure immediately upstream of said second orifice for closing said slide valve whereby said slide valve also serves as a check valve.

6. A circuit breaker as defined in claim 1 wherein said means responsive to the ratio of the pressure drops includes a valve member, said first orifice being of slightly larger area than said second orifice whereby for equal flow rates the pressure drop across the second orifice is greater than the pressure drop across the first orifice, the pressure drop across the second orifice being used to hold the valve member open whereby the valve member need not be spring biased open.

7. A hydraulic fuse for use with a hydraulic device comprising:

means defining a supply conduit for supplying hydraulic fluid under pressure to the hydraulic device;

means defining a return conduit for carrying hydraulic fluid away from the hydraulic device;

means defining a supply orifice in said supply conduit through which the fluid can flow, the flow of fluid through said supply orifice causing a first pressure drop;

means defining a return orifice in said return conduit through which the fluid can flow, the flow of fluid through said return orifice causing a second pressure drop;

a valve member at least partially in said supply conduit and movable between an open position in which the valve member leaves the supply conduit open and a closed position in which the valve member substantially shuts down flow through the supply conduit;

means for applying a first force to said valve member having a magnitude which is a function of the first pressure drop and tending to move the valve member to said closed position;

means for applying a second force to said valve member having a magnitude which is a function of the second pressure drop and tending to move the valve member to said open position whereby the valve member is controlled by said first and second pressure drops;

reservoir means for supplying additional fluid under pressure to said supply conduit downstream of said supply orifice; and

said reservoir means including a reservoir, a piston in said reservoir movable in a first direction to expel the fluid in the reservoir toward the hydraulic device, means for retarding movement of said piston in said first direction and conduit means for conducting the fluid from the reservoir to the supply conduit downstream of the supply orifice.

8. A hydraulic fuse as defined in claim 7 including means for maintaining the pressure drop across both of said orifices substantially equal for equal flow rates to and from the hydraulic device, said supply orifice being slightly larger in area than said return orifice whereby for the same pressure drop supply flow can exceed return flow.

9. A hydraulic fuse for use with a hydraulic device comprising:

means defining a supply conduit for supplying hydraulic fluid under pressure to the hydraulic device;

means defining a return conduit for carrying hydraulic fluid away from the hydraulic device;

means defining a supply orifice in said supply conduit through which the fluid can flow, the flow of fluid through said supply orifice causing a first pressure drop;

means defining a return orifice in said return conduit through which the fluid can flow, the flow of fluid through said return orifice causing a second pressure drop;

a valve member at least partially in said supply conduit and movable between an open position in which the valve member leaves the supply conduit open and a closed position in which the valve member substantially shuts down flow through the supply conduit;

means for applying a first force to said valve member having a magnitude which is a function of the first pressure drop and tending to move the valve member to said closed position;

means for applying a second force to said valve member having a magnitude which is a function of the second pressure drop and tending to move the valve member to said open position whereby the valve member is controlled by said first and second pressure drops;

second valve means responsive to the flow rate through the return orifice for correspondingly varying the areas of said orifices so that the pressure drops across each of said orifices will be substantially the same over a range of flow rates when the flow rates to and from the actuator are substantially the same; and

the valve member being downstream of the supply orifice and all of the fluid flowing in the supply conduit to the valve member passing through said supply orifice.

10. A hydraulic fuse as defined in claim 9 wherein said hydraulic fuse includes biasing means for resisting the opening of said second valve means.

11. A circuit breaker comprising:

a body having first and second fluid passages therein; first means defining a first orifice in said first passage; second means defining a second orifice in said second passage, said orifices being of about the same area so that the pressure drops across said orifices are about the same for equal flow rates;

a slide valve in said first fluid passage having first and second sets of pressure responsive faces, each of said sets of pressure responsive faces including generally opposed pressure responsive faces;

first passage means for supplying fluid under pressure from upstream and downstream of said first orifice to the opposed faces, respectively, of said first set of pressure responsive faces with the net effect being the urging of the slide valve toward a closed position in which substantially no fluid can flow through said first passage;

second passage means for supplying fluid from upstream and downstream of said second orifice to the opposed faces, respectively, of said second set of pressure responsive faces with the net effect being the urging of said slide valve toward an open

position in which fluid can flow through said first passage;

a reservoir in communication with the first fluid passage downstream of said slide valve; and

means for expelling fluid from the reservoir into the first passage downstream of said slide valve.

12. A circuit breaker as defined in claim 11 wherein said first and second means includes a second slide valve movable in said first and second fluid passages to partially define said orifices and to vary the areas thereof.

13. A circuit breaker as defined in claim 12 including means responsive to the pressure drop across said second orifice for controlling the position of said second slide valve to increase the areas of said orifices in response to an increase in the pressure drop across said second orifice and to decrease the areas of said orifices in response to a reduction in the pressure drop across said second orifice.

14. A circuit breaker as defined in claim 13 including resilient means for urging said second slide valve in a direction to reduce the areas of said orifices, said means for expelling including a piston movable in at least one direction in said reservoir and biasing means for retarding the movement of said piston in said one direction.

15. A circuit breaker for use with a hydraulic device comprising:

a supply conduit for supplying fluid under pressure to the hydraulic device;

a return conduit for carrying fluid away from the hydraulic device;

valve means in said supply conduit responsive to the quantity of fluid flowing through said supply conduit exceeding by a predetermined amount the quantity of fluid flowing through the return conduit for closing said supply passage;

reservoir means for providing a small quantity of fluid to said supply conduit intermediate said valve means and the hydraulic device to thereby cause fluid flow in said return conduit to cause opening of said valve means for start up; and

means responsive to the quantity of fluid flowing through said return conduit being at least about equal to the quantity of fluid flowing through the supply conduit for holding said valve means open.

16. A circuit breaker as defined in claim 15 wherein said reservoir means includes a reservoir, first conduit means providing communication between said reservoir and a location in said supply conduit upstream of said valve means, second conduit means for providing communication between said reservoir and a location in said supply conduit downstream of said valve means, a piston movable in said reservoir to expel fluid therein through said second conduit means into said supply conduit, and resilient means for retarding the movement of said piston in a direction tending to expel fluid from the reservoir through said second conduit means into said supply conduit.

17. A hydraulic device comprising:

a body having first and second fluid passages therein;

a valve member movable in both of said passages to define therewith first and second orifices of variable area in the first and second passages, respectively;

resilient means for urging said valve member in a direction tending to reduce the areas of said orifices; and

said valve member having first and second pressure responsive faces, said first pressure responsive face being exposed to fluid in said second passage upstream of said second orifice and said second pressure responsive face being exposed to fluid in said second passage downstream of said second orifice, said pressure responsive faces being arranged so that the pressure drop across said second orifice influences the position of said valve member with an increase in the pressure drop across said second orifice tending to move the valve member to increase the areas of said orifices;

said valve member being positioned to define said orifices at least during normal operation of the hydraulic fuse whereby all of the fluid flowing downstream of the valve member passes through said first orifice;

a shut off valve means in said first passage downstream of said valve member and responsive to the ratio of the pressure drops across said orifices being in a predetermined ratio for closing said first passage;

a reservoir;

first and second conduits for connecting said reservoir to locations in said first passage upstream and downstream, respectively, of said shut off valve means; and

means in said reservoir at least partially responsive to a pressure differential in said conduits for expelling fluid from the reservoir and through said second conduit to said first passage.

18. A circuit breaker for use with a hydraulic device comprising:

means defining a supply conduit for supplying hydraulic fluid under pressure to the hydraulic device;

means defining a return conduit for carrying hydraulic fluid away from the hydraulic device;

means defining supply orifice means in said supply conduit through which the fluid can flow, the flow of fluid through said supply orifice means causing a first pressure drop;

means defining return orifice means in said return conduit through which the fluid can flow, the flow of fluid through said return orifice means causing a second pressure drop;

a valve member at least partially in said supply conduit and movable between an open position in which the valve member leaves the supply conduit open and a closed position in which the valve

member substantially shuts down flow through the supply conduit;

means for applying a first force to said valve member having a magnitude which is a function of one of the pressure drops and tending to move the valve member to said closed position;

means for applying a second force to said valve member having a magnitude which is a function of the other of the pressure drops and tending to move the valve member to said open position whereby the valve member is controlled by said first and second pressure drops; and

means for increasing the effective areas of both of said orifice means automatically in response to an increase in pressure drop across at least one of said orifice means.

19. A circuit breaker as defined in claim 18 wherein said means for increasing the effective area of said first orifice means includes a valve member, said circuit breaker including spring means for biasing at least one of said valve members.

20. A circuit breaker as defined in claim 18 including means for supplying limited quantities of additional hydraulic fluid under pressure to the hydraulic device to thereby tend to increase return flow a limited amount.

21. A circuit breaker for use with a hydraulic device comprising:

a first conduit for supplying hydraulic fluid under pressure to the hydraulic device;

a second conduit for carrying hydraulic fluid away from the hydraulic device;

a shut off valve member movable to block said supply conduit;

means for normally urging said shut off valve member in an opening direction;

means including restricted passage means in said first and second conduits for measuring flow in said first and second conduits;

flow summing means associated with said shut off valve member for causing said valve member to move in a closing direction in response to said measuring means when the flow in said first conduit exceeds the flow in said second conduit by a predetermined amount; and

control valve means disposed in said first and second conduits and effective in response to small pressure differentials reflecting increases in flow demand by said hydraulic device to increase the flow through said circuit breaker and to maintain substantially constant pressure differentials across the restricted passage means as such flow through the circuit breaker is increased.

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