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Dummer

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[54] **SYNCHRONIZED CONTROL SYSTEM FOR TELESCOPING BOOMS**

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[58] **Field of Search** ..... 60/97 E; 91/411, 91/412

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[57] **ABSTRACT**

A fluid control circuit for driving a plurality of double-acting linear fluid actuators at proportional, synchronized rates to extend and retract a multi-section boom has a flow divider assembly that meters proportional amounts of operating fluid into and out of each of the rod ends of the actuators to maintain the synchronization of the actuators. The flow divider assembly includes a plurality of relief valves, each of which are connected between a rod end of one of the actuators and the circuit reservoir to provide a means for resynchronizing the actuators with one another.

2 Claims, 2 Drawing Figures

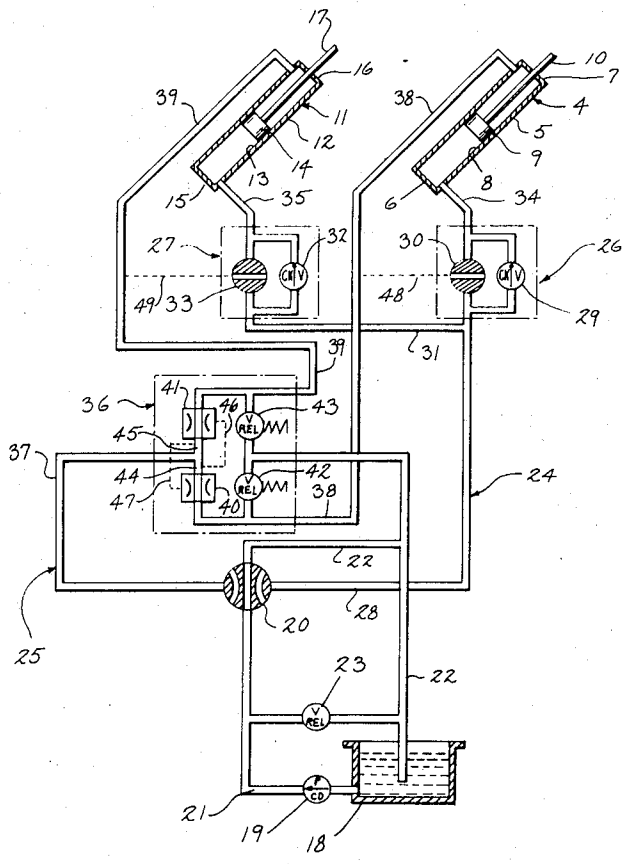
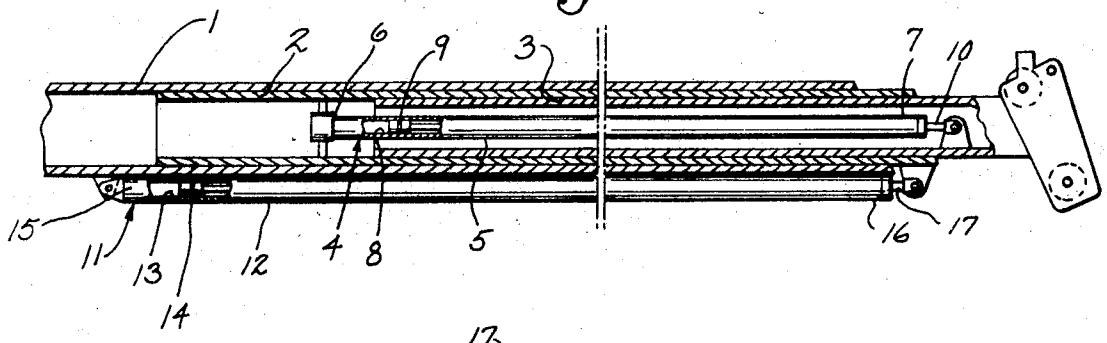


Fig. 1



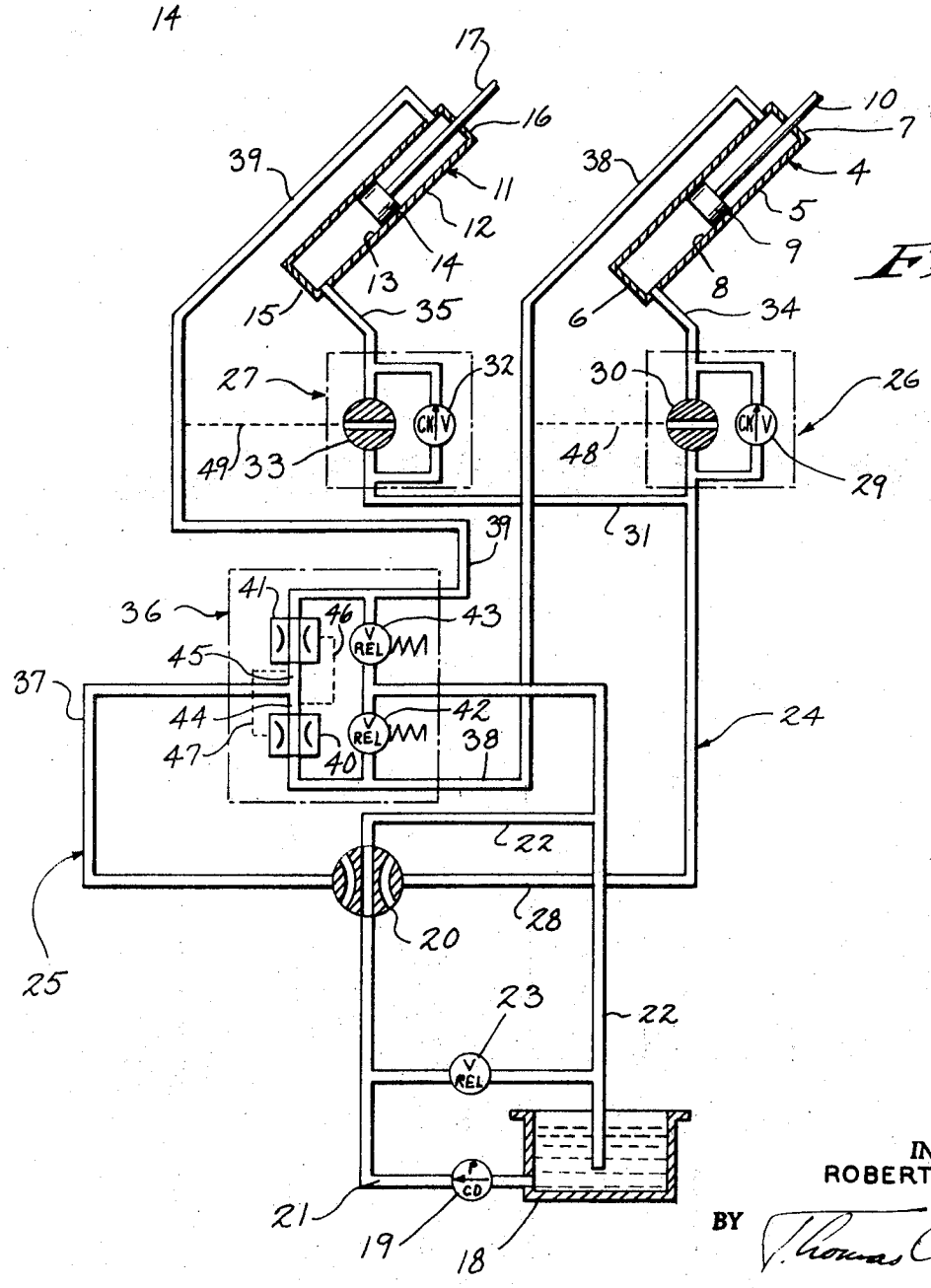


Fig. 2

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SYNCHRONIZED CONTROL SYSTEM FOR TELESCOPING BOOMS

BACKGROUND OF THE INVENTION

The present invention controls the extension and retraction of hydraulic telescoping cantilevered booms on truck cranes. These telescoping cantilevered crane booms generally have three or more sections, and are extended and retracted by telescoping the upper boom sections into and out of the lower boom sections. A long, double-acting hydraulic cylinder is used to extend and retract each boom section, and it is desirable that the sections simultaneously extend and retract at the same or a proportional, synchronized rate automatically. However, due to the wide range of speeds of extension and retraction normally employed in the operation of such cranes, the cylinders tend to desynchronize.

In the past, some systems have utilized a flow divider valve that meters fluid flow into the blind ends of two boom extension cylinders in an effort to maintain synchronization. In this type of system, resynchronization is achieved by diverting fluid from the blind end of a leading cylinder into the blind end of the lagging cylinder, as disclosed in U.S. Pat. No. 3,481,489. However, in the practical application of such systems certain problems emerge, particularly in larger machines.

Because of the comparatively large flow of hydraulic fluid associated with the blind end of an actuator, the flow dividing valves of the prior art systems require an extraordinary flow capacity to accommodate maximum flow and must work over a broad range of flow. Since valves are not available that can operate effectively across the entire flow range required in such systems, as a practical matter the valves are operated much of the time outside of their rated range, with a resulting decrease in effective control and stability. Also, resynchronization of these systems by diverting fluid under pressure from the blind end of the leading cylinder to the blind end of the lagging cylinder leaves something to be desired since the rate of resynchronization can be no more than twice the maximum rate of normal extension. In addition, relatively large back pressures are established in the circuit of such systems and act against the operating system pressure to decrease the effective pressure of the system. Manifestly, each of these problems becomes more acute as the crane booms increase in size, because the larger booms require larger cylinders which require larger capacity hydraulic systems.

The present invention provides a synchronizing control system that is designed to solve those problems.

SUMMARY OF THE INVENTION

The present invention relates to a control circuit for driving a plurality of double-acting linear fluid motors at proportional rates; and more specifically, the invention resides in the combination of a plurality of double-acting linear fluid motors each of which has a cylinder bore with a rod end and a blind end, a source of fluid under pressure, and a flow divider assembly which connects said source of fluid under pressure to said rod end of each of said linear fluid motors for metering fluid flow from said rod end of each of said plurality of fluid motors.

As a result, structures embodying the present invention manifest advantages heretofore unavailable with fluid systems known to the prior art. Specifically, the

salient objects and advantages of the present invention as set forth above may be summarized as follows:

To provide a control circuit for automatically driving at least two linear fluid actuators at predetermined proportional rates simultaneously;

To provide a control circuit for automatically driving at least two linear fluid actuators that substantially reduces circuit back pressure so that effective circuit pressure may thereby be increased;

To provide a control circuit for automatically driving at least two linear fluid actuators that will operate more consistently within the most efficient operating range of the circuit components;

To provide a control circuit for automatically driving at least two linear fluid actuators that may operate with the smallest components consistent with the size of the fluid actuators;

To provide a control circuit for automatically driving at least two linear fluid actuators capable of more rapidly resynchronizing the actuators; and

To provide a control circuit for automatically driving at least two linear fluid actuators that may allow for substantially increased stability if the rates of extension of the actuators are substantially equal to their rates of retraction.

In the attached drawings, which form a part of the description of this invention, and in the description which follows, there is disclosed an embodiment of the present invention which composes the best mode presently contemplated by the inventor for carrying out his invention. The invention is described in full, clear, concise and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected to make and use the same. However, the embodiment described and disclosed here in detail is not to be considered the invention itself. The subject matter which the inventor does regard as his invention is particularly pointed out and distinctly claimed in the claims at the conclusion of this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevation in section of a telescoping boom with two fluid actuator controlled inner sections and an outer foot section.

FIG. 2 is a schematic representation of a control circuit for extending and retracting the boom sections of FIG. 1 at proportional, synchronized rates.

DESCRIPTION OF THE PREFERRED EMBODIENTS

Referring now to the drawings, FIG. 1 is a view of a telescoping boom of a type that is normally cantilever mounted on a truck chassis to form a crane as described in U.S. Pat. No. 3,445,004. The boom is composed of three tube-like sections, an outer foot section **1**, an intermediate section **2** telescoped into the foot section **1**, and an inner top section **3** that in turn is telescoped into the intermediate section **2**.

The inner section **3** is moved into and out of the intermediate section **2** by means of a first double-acting linear fluid motor **4** that is located within the boom and has a cylinder **5** with a blind end **6** and a rod end **7**. The cylinder **5** defines a bore **8** in which a piston **9** is reciprocally mounted. A piston rod **10** extends from one side of the piston **9** through the rod end **7**. The outer end of the rod **10** is pinned to the interior of the inner section

3, and the blind end 6 is supported from the inside of the intermediate boom section 2.

The extension and retraction of the intermediate boom section 2 into and out of the foot section 1 is powered by a second double-acting fluid motor 11, shown mounted on the exterior of the boom. However, the motor 11 may also be mounted within the boom if desired. The motor 11 includes a cylinder 12 that defines a bore 13, with a piston 14 reciprocally mounted therein. The bore 13 has a blind end 15 and a rod end 16. A piston rod 17 protrudes from one side of the piston 14 through the rod end 16 and is pinned at its outer end to the intermediate boom section 2. The blind end 15 of the motor 11 is supported from the foot section 1. The fluid hoses generally associated with the motors 4 and 11 are not shown in FIG. 1 for purposes of clarity but it is to be understood that the motors 4 and 11 are typical double-acting motors that are powered by an operating fluid.

The motors 4 and 11 are driven by a common hydraulic circuit, schematically illustrated in FIG. 2, to proportionally synchronize their rates of extension and retraction. The circuit has a source of pressurized fluid which is comprised of a fluid reservoir 18, a constant displacement pump 19 and an operator's control valve 20. The pump 19 draws fluid from the reservoir 18, supplying it under pressure to the control valve 20 through a line 21. The valve 20 is connected to the return side of the reservoir 18 by a return line 22. Bridging between the lines 21 and 22 is a system pressure relief valve 23 that acts to limit the maximum pressure of fluid supplied by the fluid source to the remainder of the circuit. The fluid branch is connected to the blind ends 6 and 15 of the cylinders 5 and 12, respectively by a first fluid circuit branch 24, and to their rod ends 7 and 16 by a second fluid circuit brand 25.

The first fluid circuit branch 24 includes a pair of counterbalance valves 26 and 27 that are connected to the cylinder blind ends 6 and 15 respectively. A line 28 leads from the fluid source control valve 20 to the counterbalance valve 26 (enclosed by broken lines) that is functionally represented by the parallel combination of a check valve 29 and a pilot-operated valve 30. A line 31 connects the line 28 to the counterbalance valve 27 (also enclosed by broken lines) that may also be functionally represented by the parallel combination of a check valve 32 and a pilot-operated valve 33 as illustrated in the drawing. The pilot-operated valves 30 and 33 are pressure responsive 2-way valves that are closed in an unactuated state and allow no fluid flow through the counterbalance valves 26 and 27. The check valves 29 and 32, on the other hand, are designed to permit flow through their respective counterbalance valves 26 and 27 but only in the direction of the cylinder blind ends 6 and 15. The first fluid circuit branch 24 terminates with lines 34 and 35 which respectively connect the counterbalance valves 26 and 27 to the cylinder blind ends 6 and 15.

The second fluid circuit branch 25 primarily consists of a flow divider assembly 36 (enclosed by broken lines) that is connected to the control valve 20 of the fluid source by a line 37, and to the cylindr rod ends 7 and 16 by a pair of lines 38 and 39 rspectively. The function of the flow divider assembly 36 is not only to synchronize the motors 4 and 11 to provide proportional extension and retraction of the piston rods 10 and 17, but to also resynchronize the motors 4 and 11 with one another. The flow divider valve assembly 36 is functionally represented by a pair of pilot-operated flow control valves 40 and 41, and a pair of spring biased relief valves 42 and 43. The line 37 forms a "T" with lines 44 and 45 that respectively lead to the valves 40 and 41. A first pilot line 46 communicates with the line 44 and the valve 41, and a second pilot line 47 communicates with the line 45 and the valve 40. Respectively communicating with the lines 38 and 39 are the relief valves 42 and 43, which also communicate with the reservoir 18. The relief valves 42 and 43 are normally closed, but they are each set to open when a predetermined fluid pressure is present in their respective associated lines 38 and 39 to permit direct flow to the reservoir 18.

Bridging between the first and second fluid circuit branches 24 and 25 are a second set of pilot lines 48 and 49. The pilot line 48 communicates with the line 38 and the pilot-operated valve 30. Similarly, the pilot line 49 communicates with line 39 and the pilot-operated valve 33. The function of the pilot lines 48 and 49 is to transmit the pressure realized in their respective lines 38 and 39, when fluid is supplied to the cylinder rod ends 7 and 16, to actuate their respective pilot-operated valves 30 and 33 and open them to fluid flow.

To extend or retract the cylinder piston rods 10 and 17, operating fluid from the fluid source must be supplied to the first or second fluid circuit branches 24 and 25, respectively, by switching the operator's control valve 20 to one of its actuated positions. The control valve 20 is a manually controlled, three-position, 4-way valve that serves as a directional device for alternately connecting the line 21 and the return line 22 to the first and second fluid branches 24 and 25 when actuated, and for connecting the line 21 directly to the return line 22 when in a neutral position. In addition, the valve 20 may also be controllable to regulate the amount of flow supplied by the fluid source; pressure compensation of the valve 20 may be employed to automatically regulate the amount of flow so that the extend rates of the piston rods 10 and 17 are substantially equal to the retract rates thereof. In a first actuated position, which produces the extension of the piston rods 10 and 17, the valve 20 connects the line 21 with the line 28 of the first fluid circuit branch 24 and also connects return line 22 with the line 37 of the second fluid circuit branch 25. In a second actuated position, which produces the retraction of the piston rods 10 and 17, the valve 20 reverses these connections and joins the line 21 with the line 37, and the return line 22 with the line 28.

When the valve 20 is switched to its first actuated position to extend the piston rods 10 and 17, the fluid source supplies operating fluid under pressure to the line 28. This fluid is divided between the counterbalance valves 26 and 27 to flow through the check valves 29 and 32 and into the cylinder blind ends 6 and 15. As the fluid is fed to the cylinder blind ends 6 and 15, their respective pistons 9 and 14 are impelled forward. As a result, operating fluid in the cylinder rod ends 7 and 16 is displaced respectively into the lines 38 and 39 of the second fluid circuit branch 25. The fluid in lines 38 and 39 flows to the flow divider assembly 36 to enter the flow regulating valves 40 and 41, respectively, wherein the fluid flow is regulated to provide proportional synchronization of the motors 4 and 11.

To proportionally synchronize the motors **4** and **11** the flow regulating valves **40** and **41** respectively monitor the line pressures in the lines **45** and **44** via the pilot lines **47** and **46**, respectively. In correspondence to the pressure readings, the valves **40** and **41** are piloted to control automatically the flow into the lines **44** and **45**, respectively. The pressure that the valve **40** senses in the line **45** acts to increase or decrease the amount of fluid flow through the valve **40**. In like fashion, the flow through the valve **41** is regulated by the pressure in line **44**. Hence, there is a correlation between the fluid flow through the valves **40** and **41** and the lines **45** and **44** respectively to provide the appropriate extension or retraction of the piston rods **10** and **17** that is necessary to maintain the proportional synchronization of the motors **4** and **11**. The function of the two flow regulating valves **40** and **41** may also be performed by a single integral spool type device.

As previously pointed out, normally the relief valves **42** and **43** of the flow divider assembly **36** are closed so that they do not affect the flow in the lines **38** and **39**. However, if one of the motors **4** or **11** completes its extension stroke before the stroke of the other motor is completed the relief valves **42** and **43** come into play. For example, if motor **4** is first to complete its extension stroke, the fluid flow in the line **38** will terminate and, consequently, the line pressure in line **38** will decrease. This decrease in pressure will be transmitted to the flow control valve **41** via pilot line **46**. Thereupon, the valve **41** will be piloted so that it will attempt to curtail flow in the line **39**. As the valve **41** reduces the flow in line **39**, fluid pressure in the line **39** will rise substantially until it reaches the release setting of the relief valve **43**. The relief valve **43** will then open, allowing direct flow from the line **39** to the reservoir **18**, to bypass the flow control valve **41** and complete the extension stroke of motor **11**. Since the relief valve **43** exhausts directly into the reservoir **18**, exhaustion of the line **39** is almost instantaneous. Thus, a rapid resynchronization of the motors **4** and **11** is achieved. In like manner, the relief valve **42** will actuate to resynchronize the motors if the motor **11** completes its stroke before the motor **4** is fully extended. Once the motors **4** and **11** are resynchronized the spring biasing of the relief valves **42** and **43** will return the valves to their normal unactuated state.

To retract the piston rods **10** and **17**, the operator's control valve **20** is set in its second actuated position and operating fluid flows from the fluid source through the circuit in a reverse direction to that described during the extension stroke. The flow divider assembly **36** thereupon acts to control the rate of flow through the second fluid circuit branch **25** and into the cylinder rod ends **7** and **16**, just as it controlled the flow out of those rod ends. As fluid is pumped into the rod ends **7** and **16** the pistons **9** and **14** are impelled rearward toward the cylinder blind ends **6** and **15**. Due to the fluid operating pressure in the lines **38** and **39** the piloted valves **30** and **33** will be actuated by their respective pilot lines **48** and **49** to permit fluid to flow out of the cylinder blind ends **6** and **15** and through the first fluid circuit branch **24** to return to the reservoir **18**.

As is clear from the above description the present invention provides a highly efficient control circuit that proportionately synchronizes the rates of extension and retraction of at least two fluid motors, as well as providing a means for achieving rapid resynchronization of the motors. By employing the flow divider assembly **36** in the rod end side of the circuit the assembly **36** may be sized for a relatively small fluid flow. Thus, if the motors **4** and **11** are each driven so that the rates of extension of their piston rods **10** and **17** are substantially equal to the rates of retraction thereof, the assembly **36** will frequently be operating in the most efficient manner to produce highly effective flow control regulation and as a result, stability of the system will be substantially enhanced. In addition, the back pressure created by the flow restricting action of flow divider assembly **36** is considerably less than would be realized if the assembly **36** was employed in the blind end of the circuit, consequently, more of the system pressure is available for useful work, and less pressure is exerted on the circuit components when the motors **4** and **11** are out of synchronization. Thereto, by utilizing a direct feed back to the reservoir **18** from the lines **38** and **39** via the relief valves **42** and **43** resynchronization of the motors **4** and **11** is almost instantaneous.

I claim:

1. A hydraulic control circuit for simultaneously synchronously driving at least two double acting hydraulic cylinders, the combination comprising:

first and second double acting hydraulic cylinders, each cylinder containing a reciprocable piston with a rod projecting therefrom through one end of said cylinder, and each cylinder having a rod end enclosing said piston rod and a blind end on the opposite side of said piston;

a reservoir of operating fluid with a pump to impel fluid under pressure to drive said first and second hydraulic cylinder;

a directional control valve means connected to receive operating fluid under pressure from said reservoir and to return fluid to said reservoir, and adapted alternately to conduct said operating fluid under pressure out of either of at least two ports and to conduct fluid from the other of said two parts to said reservoir;

a first circuit branch connecting one of said two ports of said directional control valve means to said blind ends of said first and second double acting hydraulic cylinders;

and a second circuit branch connecting the other of said two ports of said directional control valve means to said rod ends of said first and second double acting hydraulic cylinder;

said second circuit branch including a first pilot operated flow control valve means connected between said rod end of said first double acting hydraulic cylinder and said other port of said directional control valve means, a second pilot operated flow control valve means connected between said rod end of said second double acting hydraulic cylinder and said other port of said directional control valve means said first and second pilot operated flow control valve means being responsive to operating fluid pressure between the other pilot operated flow control valve means and said directional control valve means to shut said pilot operated flow control valve means when said operating fluid pressure falls below a predetermined minimum, and pressure responsive valves connecting each of said rods ends of said first and second double acting hydraulic cylinders to said reservoir when operating fluid pressure exceeds a predetermined maximum.

2. A hydraulic control circuit as set forth in claim 1 wherein

said first circuit branch includes a first normally closed pilot operated on-off valve means connected between the blind end of said first double acting hydraulic cylinder and said directional control valve means responsive to operating fluid pressure in said second circuit branch to open when said operating fluid pressure exceeds a predetermined maximum and a one way valve connected to conduct operating fluid under pressure from said directional control valve means to said blind end of said first double acting hydraulic cylinder, and a second normally closed pilot operated on-off valve means connected between the blind end of said second double acting hydraulic cylinder and said directional control valve means responsive to operating fluid pressure in said second circuit branch to open when said operating fluid pressure exceeds a predetermined maximum, and a one-way valve means connected to conduct said operating fluid under pressure from said directional control valve means to said blind end of said second double acting hydraulic cylinder.

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