United States Patent [19]

Johnston et al.

[11] **3,726,191**

[45] **Apr. 10, 1973**

[54] **ELECTRICALLY CONTROLLED HYDRAULIC SYSTEM AND TRANSDUCER THEREFOR**

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[22] Filed: **Feb. 8, 1971**

[21] Appl. No.: **113,193**

[52] **U.S. Cl.** .....**92/5 R,** 92/113, 91/363 R

[51] **Int. Cl.** **F15b 9/03,** F15b 9/04

[58] **Field of Search**.....92/5 R, 363 R, 363 A, 92/113, 361, 362

[56] **References Cited**

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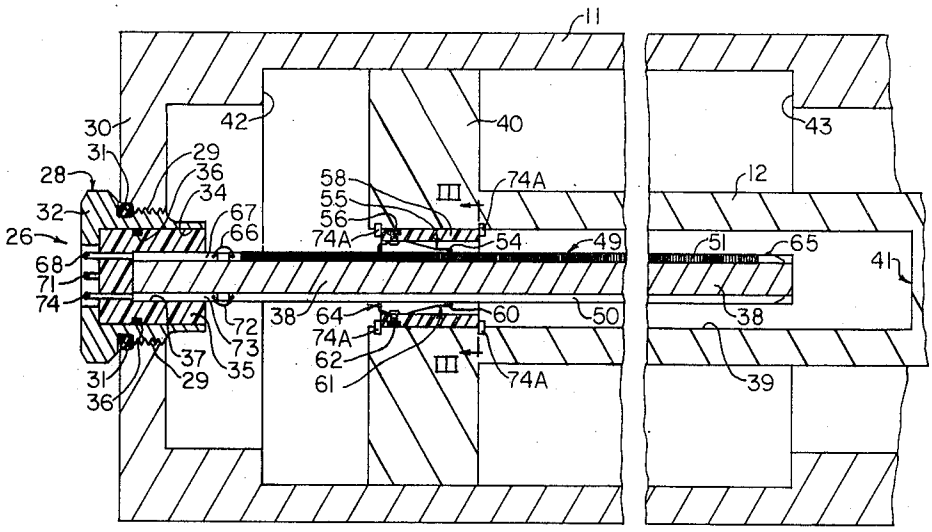
[57] **ABSTRACT**

Hydraulic system in which the application of fluid to a cylinder is controlled electrically by circuitry connected to an elongated resistance element mounted within a hydraulic cylinder and to a slider contact carried by a piston within the cylinder. The resistance element is part of a first assembly supported from one end of the cylinder and extending within a passage within a piston rod and is wound on and connected at a first end to a metal rod disposed in a longitudinal slot of an insulating support. A second metal rod is in a diametrically opposed slot and is engaged by a second slider contact, the contacts being part of a second assembly and being at the ends of resilient arms supported within the tubular insulating member which is mounted within the open end of the piston rod passage. Terminal means are connected to the metal rods and to a second end of the resistance element at one end of the first assembly which is at one end of the hydraulic cylinder.

8 Claims, 4 Drawing Figures



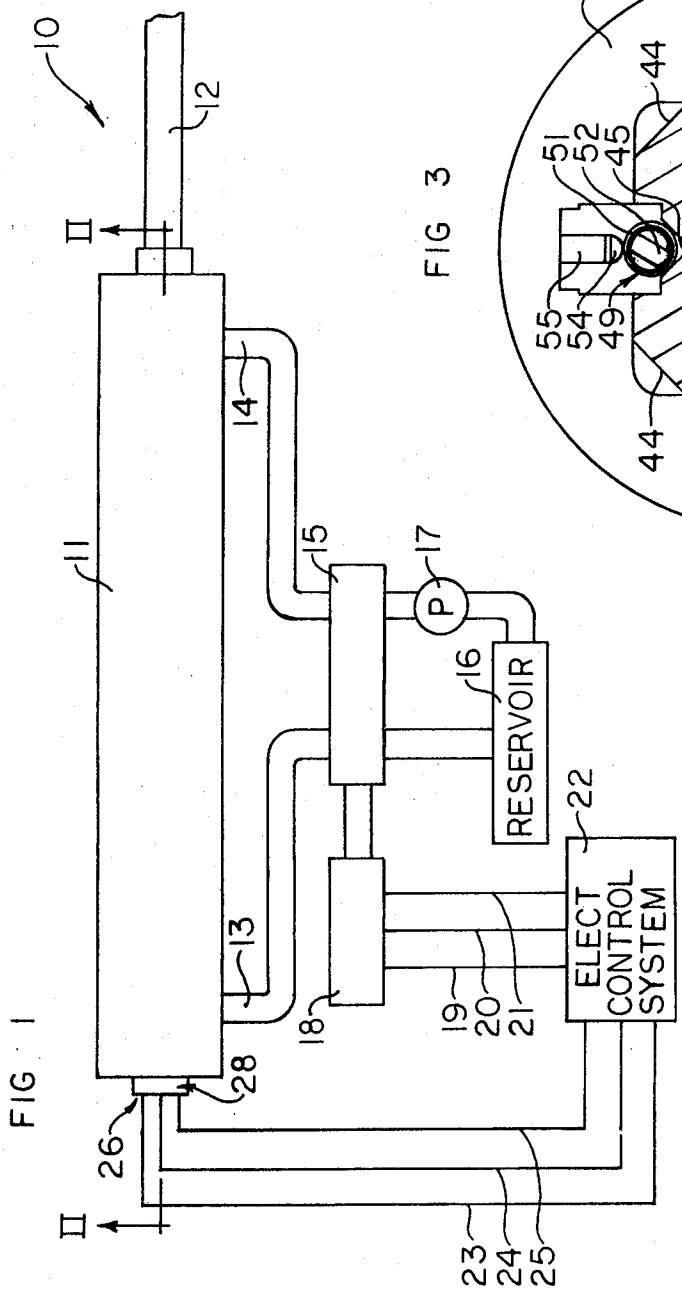


FIG. 1

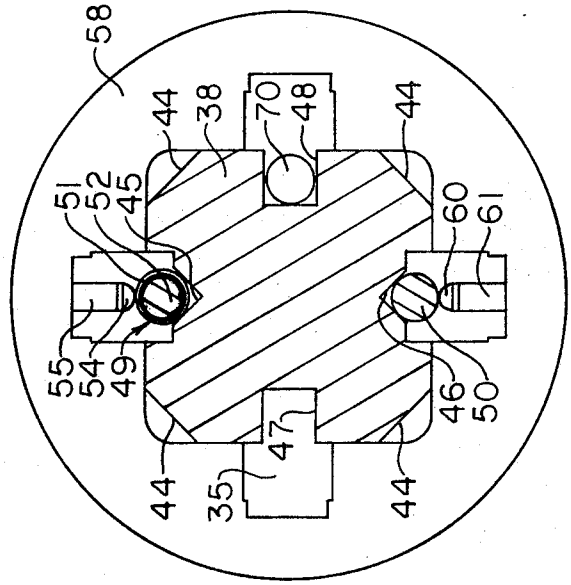


FIG 3

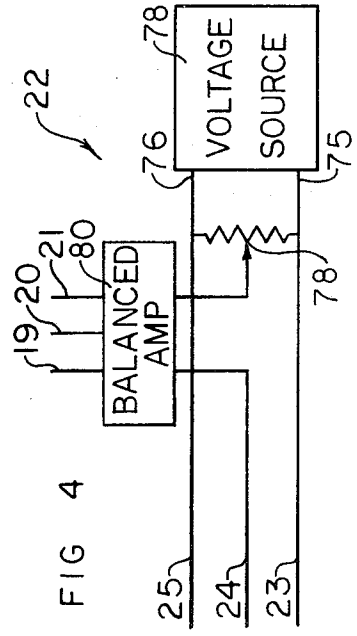


FIG 4

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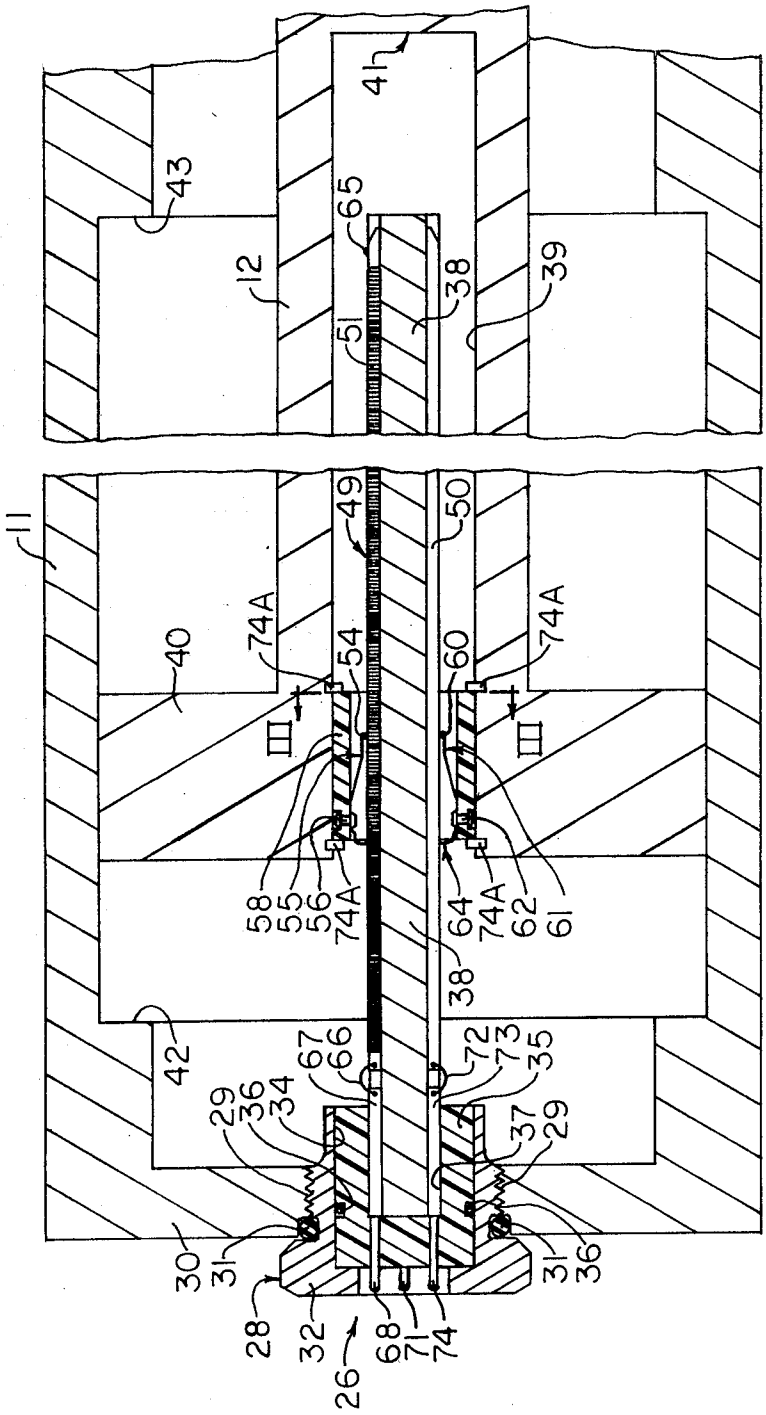

FIG 2

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ELECTRICALLY CONTROLLED HYDRAULIC SYSTEM AND TRANSDUCER THEREFOR

This invention relates to a hydraulic system and more particularly to a hydraulic system including a transducer mounted in a cylinder in a manner such as to prevent damage thereto and to obtain a high degree of reliability. The transducer is relatively simple in construction and readily and economically manufacturable.

Hydraulic systems have been proposed in which the movement of elements is sensed electrically to develop signals for monitoring such movements or for performing control functions. Conventional transducers, however, are not generally suitable for sensing movements in hydraulic systems because of difficulties in mounting of the units and because of the conditions to which they are exposed. In hydraulic systems for use in construction or in earth moving machines or the like, for example, relatively delicate instruments such as transducers can be easily damaged and become inoperable. With respect to safety, the problem can be particularly serious when the transducer performs a critical control function.

This invention was evolved with the general object of overcoming the disadvantages of prior proposed systems and of providing an electrically controllable hydraulic system and a transducer therefor in which the possibility of damage is minimized and in which a high degree of reliability is obtained.

Another object of the invention is to provide a transducer which is comparatively simple in construction and readily and economically manufacturable.

In a hydraulic system according to the invention, an electrically controllable system controls the supply of hydraulic fluid to a cylinder to control the position of a piston in the cylinder, a transducer connected to the electrical system being responsive to movement of the piston in a manner such as to obtain highly accurate control. The transducer comprises an elongated resistance element and a contact element engaged therewith, both mounted within the cylinder and supported from the cylinder and the piston in a manner such that relative rectilinear movement of the contact element along the resistance element is effected in response to movement of the piston. Preferably, the resistance element is supported from the cylinder while the contact element is supported from the piston. With this arrangement, the position of the piston relative to the cylinder is directly and accurately sensed and since the elements are mounted within the cylinder, rather than on the outside, the possibility of damage from externally applied impacts is obviated.

The elements are exposed to the hydraulic fluid which is an advantage rather than a disadvantage when the fluid is an oil, as is normally the case, having good dielectric properties and offering protection against any possible arcing, as the contact element moves along the resistance element. Since the transducer is completely protected and enclosed, there is no danger when the system is used in an explosive atmosphere.

According to an important feature, a piston rod has an internal passage open at the end thereof which supports the piston and at least a portion of the resistance element is disposed in the passage. The length of the passage is preferably such as to allow travel of the piston throughout substantially the full length of the cylinder while at the same time providing continuous sensing of the position of the piston in the cylinder.

Further important features relate to the construction of the transducer in a manner such that it can be readily mounted in the cylinder and such that it is readily and economically manufacturable while being highly reliable. In a preferred construction, the resistance element is wound on but insulated from a metal rod disposed in a slot along one side of a support member of insulating material and a second metal rod is disposed in a slot along the opposite side of the support member with the assembly of the rods and the support member being arranged for support from the end of the cylinder opposite that from which the piston rod extends. One end of the resistance element is electrically connected to one end of its supporting rod, the opposite end of the rod being connected to an electrical terminal extending to the outside for connection to an external circuit. The other end of the resistance element is connected to another terminal and the second rod is also connected to a terminal. A slider assembly is provided which preferably comprises a tubular member of insulating material and a pair of resilient arms supported at diametrically opposed points therewithin, contact elements being on the free ends of the resilient arms and being held in pressure engagement with the resistance element and the second metal rod. The tubular member is preferably arranged to be inserted in the open end of the passage in the piston rod.

This invention contemplates other objects, features and advantages which will become more fully apparent from the following detailed description taken in conjunction with the accompanying drawings which illustrate a preferred embodiment and in which:

FIG. 1 is a view illustrating diagrammatically and constructed in accordance with the invention and including a transducer unit according to the invention;

FIG. 2 is a sectional view of a hydraulic cylinder of the system, also showing in cross-section the construction of the electrical transducer disposed therewithin;

FIG. 3 is a sectional view, on an enlarged scale, taken substantially along line III-III of FIG. 2; and

FIG. 4 is a schematic electrical diagram.

Reference numeral **10** generally designates a hydraulic system in accordance with the invention. The system **10** comprises a hydraulic cylinder **11** from which a piston rod **12** extends. Opposite ends of the cylinder **11** are coupled through lines **13** and **14** and through a valve **15** to a reservoir **16** and the outlet of a pump **17** having an inlet connected to the reservoir **16**. The valve **15** is arranged to connect the line **13** to the reservoir and the line **14** to the pump outlet or the line **13** to the pump outlet and the line **14** to the reservoir, so as to move the piston rod **12** in either direction. The valve **15** is controlled by a solenoid unit **18** which is connected through lines **19**, **20** and **21** to an electrical control system **22** which is connected through lines **23**, **24** and **25** to terminals of a rectilinear transducer generally designated by reference numeral **26**. In the operation of the system, the electrical control system **22** responds to a signal indicating the position to which the piston rod **12** should be moved, which signal may be developed by a manual control or from other electrical control apparatus. In response to the signal so applied, the system **22** through the lines **19–21** energizes the

solenoid 18 to move the valve 15 in the proper direction, fluid under pressure being applied either to the line 13 or the line 14 while the other line is connected to the reservoir 16. The rectilinear transducer 26 responds to movement of the piston rod 12 to apply a feed-back signal to the system 22 through the lines 23–25 and when the piston rod 12 is moved to the desired position, the solenoid 18 is deenergized to actuate the valve 15 to a position such that lines 13 and 14 are disconnected from the reservoir 16 and pump 17 so as to lock the rod 12 in position.

Referring to FIGS. 2 and 3, the transducer 26 comprises a fitting 28 which is threaded into an opening 29 in an end wall 30 of the cylinder 11, preferably with a seal ring 31 in an annular groove between the outside of the wall 30 and an enlarged head portion 32 of the fitting 28. The fitting 28 is of generally cup-shaped configuration and defines a generally cylindrical chamber 34 therewithin which receives a block 35 of insulating material, an O-ring 36 being disposed in an annular groove in the outer surface of the block 35 for pressure engagement with the internal cylindrical surface of the chamber 34. The block 35 also is generally cup-shaped to define a generally cylindrical chamber 37 into which an end portion of an elongated support member 38 is tightly fitted. Member 38 extends centrally into the cylinder 12 and into a central passage 39 of the piston rod 12. The support member 38 preferably extends to the opposite end of the cylinder 11 and the passage 39 has a closed end 41 with a length sufficient to allow the piston 40 to move to a position close to the end wall 30. Such movement may be limited by any suitable stop means such as by an internal shoulder 42 in the cylinder 11. Movement in the opposite direction may similarly be limited by an internal shoulder 43, in the cylinder 11.

The support member 38 has a cross-sectional configuration as shown in FIG. 3, being generally square, except with four bevelled edges 44 and except with longitudinal grooves or slots 45 and 46 in the top and bottom faces thereof and a pair of longitudinal grooves or slots 47 and 48 in the side faces thereof. A resistance unit 49 is disposed in the slot 45 while a conductive rod 50 is disposed in the slot 46. Member 38 is preferably of metal such as aluminum and is coated with an insulating material, preferably by means of an electrostatic powder coating operation. Resistance unit 49 comprises a resistance wire 51 such as a nichrome wire, for example, which is wound on a rod or mandrel 52 to extend for nearly the full length thereof, a suitable insulation material being disposed on the mandrel to insulate the wire from the mandrel. The wire 51 forms the resistance element of the transducer.

The wire or resistance element 51 is engaged by a contact 54 carried at the free end of a resilient arm 55 the opposite end of which is secured by means of a crimped metal grommet 56 to an inner surface portion of a tubular support member 58 of insulating material. Similarly, a contact, 60, engaged with the bare metal rod 50, is carried at the free end of a resilient arm 61 the opposite end of which is fixed by a grommet 62 to an inside surface portion of the support 58, the contacts 54 and 60 and associated support arms 55 and 61 being in diametrically opposed relation. The contacts 54 and 60 are electrically connected together as by means of a wire 64 interconnecting the grommets 56 and 62. One end of the resistance element wire 51 is connected to the rod 52 as by means of a weld indicated by reference numeral 65, at the free end of the support member 38. At the opposite end, the rod 52 is connected through a wire or strap 66 to the end of a pin 67 disposed in the slot 45 and having a reduced diameter portion 68 extending through a passage in the block 35, the portion 68 forming an electrical terminal accessible from the outside of the cylinder 11. The left-hand end of the resistance element wire 51 as viewed in FIG. 2, is connected to a pin 70, similar to the pin 67 which is disposed in the side slot 48 of the support member 38 and which has a reduced diameter portion 71 extending through an opening in the block 35 to form a second terminal. The rod 50 is connected by a wire or strap 72 to the end of a pin 73, similar to the pins 67 and 70 and having a reduced diameter portion 74 extending through an opening in the block 35 to form a third electrical terminal. Thus, pin portions 68 and 71 are connected to opposite ends of the resistance wire element 51 while pin portion 74 is connected to the slider contact 54.

It is noted that the support 58 is disposed in the passage 39 adjacent the open end thereof and suitable snap rings 74*a* are provided to hold it in place while allowing removal for servicing. Support 58 is free to rotate with the support 38 during installation of the assembly and the piston may rotate relative thereto during operation. A suitable epoxy cement, or the like may be used to securely hold the rods 49 and 50 in the slots 45 and 46.

It will be appreciated that as the piston 40 is moved from left to right, the electrical resistance between pin portions 73 and 71 is increased while the electrical resistance between pin portions 74 and 68 is decreased. If the wire 51 has a uniform resistance per unit length and is uniformly wound on the rod 49, as is generally preferred, the change in resistance is linear and provides an accurate indication of the position of the piston 40 within the cylinder 11.

A suitable electrical connector, not shown is provided for electrical connection of wires 23, 24 and 25 to the pin portions 68, 74 and 71, respectively. FIG. 4 is a schematic diagram of a simple type of electrical control system 22. Lines 23 and 25, which are connected to the pin portions 68 and 71 and hence to the opposite ends of the resistance element 51, are connected to terminals 75 and 76 of a voltage source 77 a potentiometer 78 being also connected between terminals 75 and 76. The movable contact of the potentiometer 78 and the line 24 which is connected to the pin portion 74 and hence to the contact 54, and are connected to input terminals of a balanced amplifier 80 having output terminals connected to lines 19–21 to the solenoid 18. The operation of the amplifier 80 is such that if the voltage between the input terminals thereof is of one polarity, an output signal is applied to the solenoid 18 in a direction such as to cause the hydraulic fluid to be supplied to the cylinder 11 in a direction such as to move the piston 40 and reduce the voltage differential at the input of the amplifier. With this arrangement, the position of the piston 40 is fixed by the position of the movable contact of the potentiometer 78 and by moving the contact of the potentiometer 78, the piston

position can be accurately adjusted. It will be understood, of course, that other types of electrical control systems may be used.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of this invention.

We claim as our invention:

1. In a hydraulic system including a cylinder and a piston reciprocable in said cylinder, an elongated resistance element within said cylinder, a contact element within said cylinder engaged with said resistance element, first support means supporting one of said elements from said cylinder, second support means supporting the other of said elements from said piston for relative longitudinal movement of said contact element along said resistance element in response to movement of said piston in said cylinder, first and second electrical terminal means accessible from outside said cylinder, first and second electrical connection means from said terminal means to said contact element and to one end of said resistance element, said first support means comprising a member of insulating material supported from one end of said cylinder and disposed centrally in said cylinder, said elongated resistance element being supported by said member of insulating material in a central region of said cylinder along the axis thereof,an elongated conductive member supported by said member of insulating material in said central region of said cylinder and along said axis thereof in spaced parallel relation to said elongated resistance element, and a second contact element engaged with said elongated conductive member and electrically connected to said first contact element.

2. In a system as defined in claim 1, saidmember of insulating material being an elongated member extending along the axis of said cylinder, said resistance element and said elongated conductive member being supported along said member of insulating material.

3. In a system as defined in claim 2, said resistance element and said elongated conductive member being supported along opposite sides of said member of insulating material.

4. In a system as defined in claim 3, said member of insulating material having a pair of diametrically opposed longitudinal slots receiving said resistance element and said elongated conductive member.

5. In a system as defined in claim 1, a piston rod connected at one end to said piston, said piston rod having an internal passage opened at one end thereof with said elongated resistance element and said elongated conductive member extending into said passage.

6. In a system as defined in claim 5, a generally tubular member of insulating material disposed in said passage adjacent said opened end thereof, and support means supporting said contact elements from said generally tubular member.

7. In a system as defined in claim 6, said support means comprising a pair of resilient arms.

8. In a system as defined in claim 7, a second elongated conductive member supporting said elongated resistance element, insulating means insulating said resistance element from said second conductive member along the length thereof, means electrically connecting one end of said resistance element to the adjacent end of said second conductive member, third terminal means accessible from outside said cylinder, and third electrical connection means from said third terminal means to said second elongated conductive member.

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