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HYDRAULIC COMPENSATION SYSTEM

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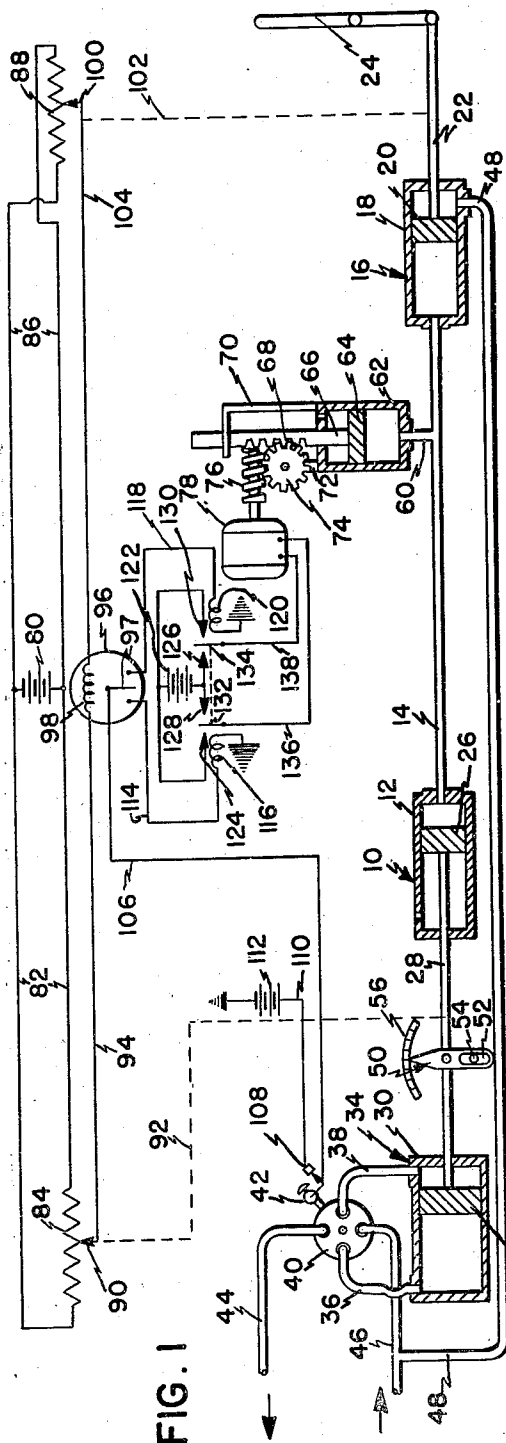


FIG. 1

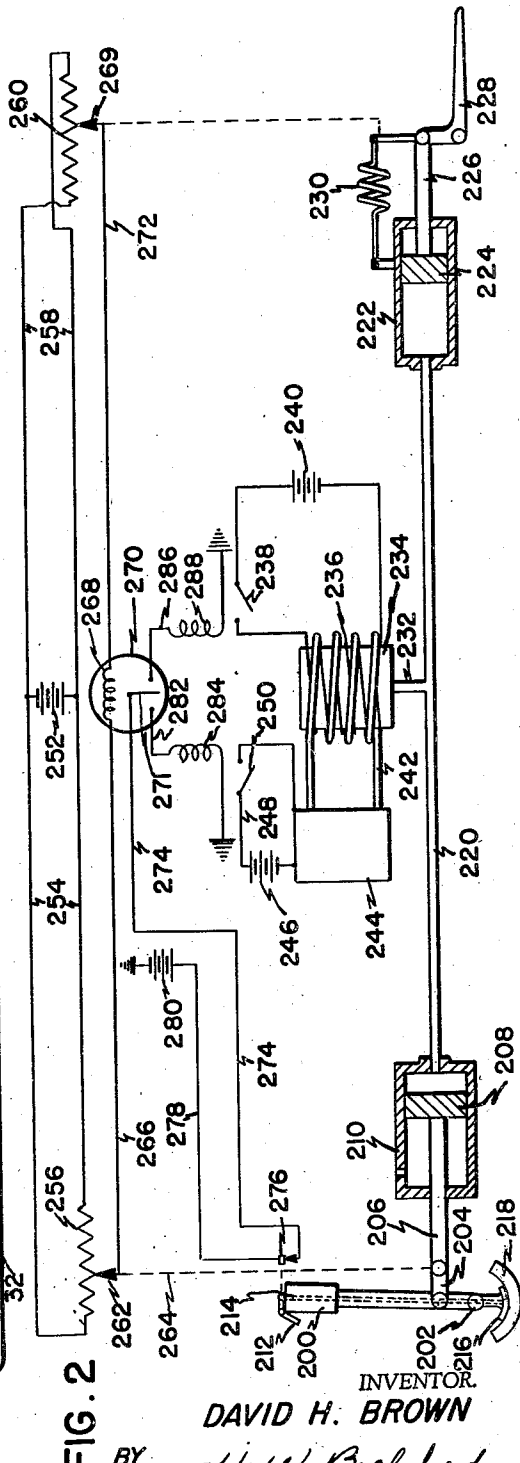


FIG. 2

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## HYDRAULIC COMPENSATION SYSTEM

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6 Claims. (Cl. 60—54.5)

This invention relates to fluid actuated remote control systems, and more particularly to a system having electrical means to compensate for fluid expansion, contraction or leakage.

In many instances it is desirable to actuate devices which are remote from the operator. For example, the driver of a truck may desire to apply a braking effort to the wheels of the truck, or an airplane pilot may desire to operate the throttle of an airplane engine located on a wing. For such purposes a direct mechanical connection between the operator and the actuated device may obviously be used. Mechanical connections ordinarily require straight line installations, and for this and many other reasons the more flexible and adaptable fluid mediums, either gaseous or hydraulic, are used. It is therefore desirable in many instances that the fluid system have position control as contrasted to full operation in one direction or the other.

One of the most common and practicable fluid control systems having position control is that having a master cylinder, either manually or power driven, which in turn operates a motor cylinder which may be remotely located. When the master cylinder is moved a given amount the motor cylinder moves a corresponding amount because of the fluid connection between them, and the operator can regulate the movement of the motor cylinder by movement of the master cylinder.

In all master cylinder-motor cylinder combinations, the registration of the motor cylinder with respect to the master cylinder is upset by fluid expansion, contraction or leakage. This renders such systems unfit for extremely accurate actuation such as control within hundredths and thousandths of an inch. Such regulation is required, for example, in the throttle control of aircraft engines where minute adjustments are needed to synchronize two or more engines.

The present invention provides means to compensate for hydraulic expansion, contraction or leakage by electrical means as contrasted to the mechanical and hydraulic means previously attempted to be used. The invention results in accuracies measured in thousandths of an inch, thus qualifying any fluid system for close regulation.

Briefly, the invention uses an electrical bridge with take-offs at both the operator's control and the actuated member. When the balance of the bridge is upset by one take-off moving out of synchronism with the other, means are actuated by the resulting current to return the system to synchronization or registration.

It is therefore an object of the invention to provide electrical means for compensating a fluid control system for expansion, contraction, or leakage of the fluid as well as any other causes

which might upset synchronism or registration between controls and the actuated member.

Another object of the invention is to compensate for expansion, contraction, and leakage of fluid in a hydraulic remote control system without producing false compensation during operative movement of the system.

Another object of the invention is to provide a power actuated system which is electrically compensated.

Still another object of the invention is to provide a manually powered fluid system which is electrically compensated.

Another object is to provide means responsive to an electrical energization for returning a fluid system to synchronization.

Other objects and advantages of the system will be apparent in the following description and claims.

In the drawing forming a part of this specification:

Figure 1 is a schematic view of a power operated master cylinder and a slave cylinder, in full section, with an electrical compensation system, all made in accordance with the invention; and

Figure 2 is a schematic view of a manually powered master cylinder, in full section, with an electrical compensation system, all made in accordance with the invention.

In this specification the word "synchronism" and its derivatives will be used to designate a state of corresponding movement of two members; for example, a master cylinder and a motor cylinder. When one member is stationary and the other moves, or when both are moving but at unrelated rates, this movement will be described as "asynchronous." The phase relation of stationary members will be referred to as "registration," the members being registered when in phase and lacking in registration when out of phase.

Referring to Figure 1, a master cylinder 10 including a closed cylinder 12, is connected by a conduit 14 to the left end of a motor cylinder 16 including a closed cylindrical housing 18. Placed within cylinder 18 and adapted for reciprocation is a piston 20 having a piston rod 22 projecting through the end wall of cylinder 18. Any suitable actuated device such as a throttle lever 24 may be connected or actuated by the piston rod 22.

Placed within cylinder 12 is a piston 26 having a piston rod 28 which passes through the left end of cylinder 10 through the right wall of a closed power cylinder 30. The left end of piston rod 28 is connected to piston 32 adapted to reciprocate within the cylinder 30.

Cylinder 30 and piston 32 form a power cylinder 34 which is double acting. Leading from the

ends of cylinder 30 are conduits 36 and 38 connected to a four-way valve 40 having exhaust line 44 and pressure line 46 also connected to it. Actuation of a handle 42 of valve 40 connects selectively conduit 36 to exhaust and conduit 38 to pressure, or vice versa. Normally, valve 40 is in a neutral position, preventing flow through the valve. Connected to pressure line 46 is a conduit 48 leading to the right end of motor cylinder 18.

It will be noted that power cylinder 30 is of a greater diameter than master cylinder 12 and that the motor cylinder 18 is the same diameter as master cylinder 12. The pressure transmitted by master piston 26 is therefore in excess of the unit pressure found in pressure line 46. This pressure is transmitted to the left face of motor piston 20. This increase in pressure, together with the smaller area of the right side, or rod side, of motor piston 20, insures that the actuating pressure will always be greater than the pressure transmitted through conduit 48. The line pressure in conduit 48 therefore acts as a spring to move motor piston 20 to the left whenever power piston 32 is moved to the left by actuating valve 40.

Pivoted to rod 28 is an indicator 50 having a slot 52 in the lower end through which a pin 54 passes. As rod 28 moves in response to power cylinder 34, the indicator makes known the position of the master piston 26 with respect to a scale 56.

Connected to conduit 14 is a branch conduit 60 leading to a cylinder 62 in which may reciprocate a piston 64. Connected to piston 64 is a piston rod 66, having a rack 68 formed thereon, and having the upper end guided by an arm 70 connected to cylinder 62. Projecting from cylinder 62 is a support 72 to which is pivoted a worm-wheel 74 engaging rack 68 and driven in turn by a worm 76 connected to the drive shaft of a reversible electric motor 78. The electric motor is controlled by means which will next be described, and moves the piston 64 downwardly or upwardly to add or subtract fluid from the fluid system as a whole, to compensate for contraction, expansion or leakage.

The electrical circuit includes a source of potential such as a battery 80 having two parallel connections from one terminal to the other. One connection is a wire 82 including a resistance 84, and the other is a wire 86 including a resistance 88. The resistances are made high enough so that the current drain is small from the source 80. At resistance 84 is a take-off or wiper point 90 mechanically connected to piston rod 28 as shown by the dotted line 92. A wire 94 connects point 90 to one side of a polar relay 96 having a coil 98. The other resistance has a similar wiper point 100 mechanically connected to the motor piston rod 22 as shown at 102. A wire 104 connects wiper point 100 to the other end of coil 98 in polar relay 96.

The principle of operation of the bridge is that the potential drop across both resistances 84 and 88 will be the same, regardless of whether the resistances are equal. Likewise, at any given proportion of the resistors the voltage will be the same. But if one take-off is at a different point on the length of its resistor than the other, then a difference of potential will exist between the two points, and if a wire connects them current will flow from the point of higher voltage to the point of lower voltage. Thus it may be seen that when wiper points 90 and 100 are at dif-

ferent distances along their respective resistances, the current will flow through relay 96 in a direction depending upon the relative position of the two wipers.

Relay 96 contains an armature 97, the pivot end of which is connected to a wire 106 leading to a push button switch 108 in the handle 42 of valve 40. A wire 110 connects switch 108 to a battery 112, the other terminal of which is grounded. Switch 108 is normally closed and only when the operator is actuating valve 40 is the switch 108 open, rendering the compensating system inactive during this period.

Polar relay 96 has two terminal connections with a wire 114 leading from one and connected to ground through a relay solenoid 116. The other terminal is connected to a wire 118 also connected to ground through a relay solenoid 120. A battery 122 supplies current for motor 78, and each end of battery 122 has two contacts, contacts 124 and 126 forming a pair for passing current and contacts 128 and 130 forming another pair. Relay armatures 132 and 134 are mechanically interconnected to move together and are electrically connected respectively to wires 136 and 138 leading to the reversible electric motor 78. Thus it will be noted if polar relay armature 96 is connected to wire 114, current will flow in motor 78 in one direction and when it is connected to wire 118 current will flow through motor 78 in the opposite direction, reversing itself. Since relay armatures 132 and 134 are normally in a neutral position, no current will normally flow.

The operation of the system of Figure 1 is as follows. The operator grasps valve control handle 42 and operates it in one direction or another, connecting power cylinder 34 to pressure and exhaust to move power piston 32 in one direction or another. If pressure fluid is admitted on the left side of piston 32, that piston will move to the right until the desired position is reached as indicated by pointer 50. At the desired position the operator returns handle 42 to neutral, locking the piston 32 by trapping fluid.

The movement of power piston 32 to the right causes a corresponding movement of master piston 26 to the right because of the connecting rod 28. This movement forces fluid through conduit 14 into cylinder 18, and since cylinders 12 and 18 are the same size, motor piston 20 moves exactly as far as master piston 26 is moved. Pressure fluid also acts on the right face of piston 20, but since that area is less than the left side and since power cylinder 34 is larger than master cylinder 10, pressure in conduit 48 will be less than the driving pressure in conduit 14 and will merely act as a spring.

Once having set the hydraulic system in a given position, there may be changes in temperature between the different parts to cause expansion or contraction of the fluid. For example, if motor cylinder 16 is in the wing of an airplane, it might become colder than master cylinder 10. In this event the fluid in motor cylinder 16 will contract and line pressure on the right face of motor piston 20 will force that piston to the left. This action or any other cause of asynchronous movement will cause wiper 100 to move to the left, causing a difference of potential between it and wiper 90.

This difference of potential causes a current to flow through relay winding 98, causing polar armature 97 to contact wire 118. This contact causes current to flow from battery 112 through

relay winding 120 to ground. Winding 120 causes relay armatures 132 and 134 to contact points 128 and 130, passing current to motor 78 in a direction to force piston 64 downwardly. This piston movement adds fluid to conduit 14 and cylinder 18, forcing motor piston 20 to the right. When motor piston 20 reaches its original position, wiper 100 will reach its original position, and there will no longer be a difference of potential between points 90 and 100. Polar relay 96 will then return to its neutral position, cutting off current and stopping the operation of the motor 78.

If the motor cylinder 16 should become hotter than master cylinder 10, its liquid would expand and pointer 100 would move to the right with respect to pointer 90. This would cause current to flow in the opposite direction through polar relay 96 and its armature would contact wire 114. Current would then flow through relay solenoid 116, which would actuate armatures 132 and 134 to contact points 124 and 126, causing current to flow to motor 78 in the opposite direction. Piston 64 would then move upwardly removing fluid from conduit 14 and motor cylinder 18. Under the urging of line pressure from conduit 48 acting on the right face of motor piston 20 this piston then moves to its original position, stopping the compensating action.

Any fluid may be used in the system, either gaseous or hydraulic. When accurate work is required, however, an incompressible fluid such as actuating oil is preferably used.

It will be noted that during the times the fluid system is not in operation, the master cylinder should be locked. Otherwise, when the compensating fluid is added or subtracted to the system the master cylinder may move rather than the motor cylinder which is intended.

When the fluid system is operated, the operator cuts off the operation of the compensating system by opening switch 108 on control handle 42. When the master cylinder is moved, wiper 90 moves a corresponding distance on its resistance 84. Ordinarily the motor cylinder 16 will respond exactly to the movement of the master cylinder and its wiper 100 will be in exact registration, or synchronization, with the master cylinder and its wiper 90 since there is no time for heating and cooling. Once the operator releases switch 108, the compensating system will act to register the motor with the master cylinder and maintain it regardless of expansion, contraction or leakage. The switch 108 is provided to eliminate unnecessary operation of the compensating system such as might occur during operation of the fluid system.

The cylinder 62 and its piston may be regarded as a reversible pump adding or subtracting fluid to the fluid system. Alternatively, these parts may be regarded as a closed chamber capable of expanding or contracting. Both of these concepts are within the scope of the invention.

The wire forming the resistances 84 and 88 may be quite fine, and in normal practice are windings with several hundred turns per inch. For more accurate work, with a correspondingly more sensitive polar relay, several thousand effective turns per inch may be used. An increased voltage at source 80 may, of course, be used instead of a more sensitive relay.

The device of Figure 2 differs from that of Figure 1 in that it is manually powered and the compensating chamber has no movable parts. The operator grasps a handle 200 pivoted at 202

and having a link connection 204 to a piston rod 206 connected to a master cylinder piston 208 reciprocable in a cylinder casing 210. Handle 200 has a thumb lever 212 which lifts a rod 214 connected to a brake shoe 216 normally urged against a braking surface 218. Thus the handle 200 and its connected master piston 208 are locked when not in use.

Master cylinder casing 210 is connected by a conduit 220 to a motor cylinder 222 which is of lesser diameter but longer than cylinder 210 to have the same volume. Within motor cylinder 222 is a reciprocable piston 224 connected to a piston rod 226 pivoted to an actuated flap 228. A coil spring 230 urges piston 224 to the left.

Branching from conduit 220 is a conduit 232 leading to a closed chamber 234. A heating coil 236 of resistance wire surrounds chamber 234 and is connected by a relay armature 238 to a battery 240. A cooling coil 242 also surrounds chamber 234 and leads from a refrigerating unit 244 energized by a battery 246 connected to a wire 248 and a relay armature 250.

In the upper part of Figure 2 is a battery 252 having parallel connections between its terminals, one through a wire 254 including a resistance 256 and the other through a wire 258 including a resistance 260. A wiper 262 contacts resistance 256 and is mechanically connected to link 204 by a connection indicated at 264. Connected to wiper 262 is a wire 266 leading to a coil 268 of a polar relay 270. A wiper 269 contacts the resistance 260 and is connected by a wire 272 to the other end of relay coil 268.

A polar relay armature 271 is connected by a wire 274 to a handle switch 276 connected by a wire 278 to a battery 280, the other terminal of which is grounded. Relay armature 271 is normally centered but when the relay is energized it may contact either a wire 282 connected to ground through relay solenoid 284 or a wire 286 connected to ground through a relay solenoid 288.

The operation of the device of Figure 2 is as follows. The operator grasps the handle 200 and depresses thumb lever 212 releasing brake 216. The same operation opens switch 216 rendering the compensation system inoperative. The handle 200 is then moved to the desired position and the thumb lever released, locking the lever and closing switch 216. For example, the lever 200 may be rotated to the right, moving master piston 208 to the right and causing fluid to be forced through conduit 220 to motor cylinder housing 222. This fluid then forces motor piston 224 to the right against the tension of spring 230 and actuating the device 228 for which the system is designed.

When handle 200 is rotated, the wiper point 262 moves along its resistance 256 a corresponding amount. Ordinarily the motor piston 224 will move an amount equal to the exact proportion of the movement of the handle 200 or the attached master piston 208 which that movement bears to their respective total operating stroke. Thus there will ordinarily be no unbalance in the bridge circuits and to prevent operation of the compensation system during operation of the fluid system, the switch 216 is opened rendering the compensation system inoperative.

After the movement of the fluid system any lack of registration between the master piston 208 and the motor piston 224 will be reflected by the positions of their respective wipers 262 and 269. A current will then flow through polar relay 270. If the motor piston 224 is in advance of the

master piston 208, the polar relay 270 will connect wire 274 to battery 280, actuating relay armature 250 and starting the refrigerating unit 244. When the fluid in container 234 starts to cool, its volume becomes smaller, permitting fluid from conduit 220 and cylinder housing 222 to flow into it under the urging of spring 230. When the motor piston 224 returns to registration with master piston 208, their respective wipers will be equalized proportionately on the resistances and no current will flow through polar relay 270, returning the system to neutral.

If motor piston 224 is retarded with respect to master piston 208, their respective wipers will be unbalanced in the opposite direction allowing current to flow in the opposite direction through polar relay 270. This causes relay armature 240 to be energized, completing the heating circuit. After the fluid container 234 starts to be heated, it expands into conduit 220 and slave housing 222 and moves motor piston 224 to the right until registered with master piston. At this point the wipers will be balanced, and current will cease to flow, returning the compensating devices to the neutral position.

It will be noted that Figure 2 discloses the use of unequal lengths of movement between master piston and motor piston while maintaining proportional synchronization throughout the entire movement. For this purpose, resistance 260 is made longer than resistance 256.

It will also be noted that the mechanical connection of wiper 256 is with link 204. Thus this connection may be construed either as a connection with control lever 200, or with master piston rod 206. It is contemplated within the invention, therefore, that the compensation system acts to synchronize or register the motor piston with the master piston or to synchronize or register the motor piston with the control lever 200.

Although this invention has been described with reference to particular embodiments thereof, it is not limited to these embodiments or otherwise except by the terms of the following claims.

I claim:

1. A fluid control system comprising driving means, driven means, fluid connection means between said driving and said driven means, a fluid chamber connected to one of said means, and electrically controlled temperature changing means for said chamber to register said driving and said driven means.

2. A fluid remote control system which is compensated for fluid volume changes including expansion, contraction and leakage, comprising a master cylinder, a motor cylinder, a fluid connection between said cylinders so that said motor cylinder moves in response to said master cylinder, a closed chamber connected to said cylinders and connection, electrically controlled means to cause fluid to be expelled from or received into said chamber, and electrical bridge means including a resistance varied by the actuation of said master cylinder and a resistance varied by said slave cylinder, to selectively control said electrically controlled means.

3. A fluid remote control system which is compensated for fluid volume changes including expansion, contraction and leakage, comprising a master cylinder, a motor cylinder, a fluid connection between said cylinders so that said motor cylinder moves in response to said master cylinder,

a closed chamber connected to said cylinders and connection, electrically controlled means to vary the volume of said chamber to cause the same to expel fluid to compensate for contraction or leakage, and to take in fluid to compensate for expansion, and electrical bridge means to control said electrically controlled means to obtain compensation, and including variable resistances at said master and motor cylinders, and a relay responsive to the voltage differential between said resistances.

4. A fluid actuating system comprising: driving means, driven means, a fluid connection between the driving and driven means whereby said driven means is moved in response to movement of said driving means, compensating means normally responsive to movement of said driven means to vary the volume of fluid in the system in direction to stop said movement, and means interlocked with said driving means for disabling said compensating means during movement of said driving means.

5. In a fluid actuating system comprising driving means, driven means, a fluid connection between the driving and driven means whereby said driven means is moved in response to movement of said driving means, and means for compensating for changes in volume of the fluid in the system comprising: a pair of potentiometers, a source of direct current connected across said potentiometers, said potentiometers having movable contacts positioned by said driving means and driven means respectively; a polar relay having a winding connected between said contacts whereby no current flows in said winding when said driving and driven members are in registration regardless of their positions, but whereby current flows through said winding in response to lack of registration, in one direction or the other according to whether the driven means is advanced or retarded with respect to the driving means; and means including contacts of said relay responsive to current flow in said winding for adding or subtracting fluid to said system according to the direction of flow of current, to neutralize changes in volume resulting from temperature changes or leakage.

6. A fluid actuating system comprising: a master cylinder and piston assembly; a motor cylinder and piston assembly; fluid connection means connecting said assemblies whereby the motor piston is moved in response to movement of the master piston; in which said master and motor assemblies have the same total displacement but different bores and strokes, whereby a given movement of the master piston produces a different movement of the motor piston in fixed ratio; electrical bridge means including a pair of potentiometers having resistance elements of lengths corresponding to the strokes of the master and motor pistons respectively and having movable contacts moved by the master and motor pistons respectively whereby departure from registration of the master and motor pistons produces a potential difference between said contacts of one polarity or the other corresponding to the direction of departure from registration; and means responsive to said potential difference for adding or subtracting fluid from said system to register said master and motor pistons.

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