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(54) FAIL-SAFE FLUID PRESSURE EQUIPMENT

(71) I, JEREMY BARROW CHITTENDEN, a British subject of Lytes Cary Manor, Lytes Cary, Somerton, Somerset, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to apparatus for the supply of fluid pressure to actuating equipment which is operated by fluid pressure, and to such actuating equipment. It is an aim of this invention to provide such apparatus and equipment which will go to (or remain at) a predetermined state if a supply of energy is not maintained. This supply of energy may constitute a power supply for the equipment, the equipment automatically going to a fail-safe condition, if that power supply should fail, or remaining in that condition if it is already there.

According to the present invention there is provided apparatus for the supply of fluid pressure to fluid pressure operated actuating equipment, the equipment having at least one first chamber the supply of pressure to which induces actuation in one direction and a second chamber the supply of pressure to which induces actuation in the reverse direction, the apparatus including a first fluid line the supply of pressure along which effects, in use, the supply of pressure to the said first chamber of the actuating equipment and a second fluid line the supply of pressure along which effects, in use, the supply of pressure to the said second chamber; a fluid pressure reservoir; a valve controlling the supply of fluid pressure from the reservoir to the said first fluid line, and also the supply of fluid pressure to fluid pressure operable means for preventing the supply of fluid pressure along the said second fluid line the valve normally being maintained closed by a supply of energy, and opening automatically should that supply not be maintained, thereby supplying fluid pressure from the reservoir to the said first fluid line, and also supplying pressure to the said fluid pressure operable means for preventing supply along the said second line.

This automatic supply of pressure to the first fluid line can be utilised as a fair-safe operation. In this way the actuating equipment is commanded to go to the designated fail-safe state, and moreover that command cannot then be overridden e.g. by inadvertant operation of a manual control in ignorance of the interruption of the energy supply or by an automatic control which is continuing to function despite the interruption of the energy supply.

The invention also provides fluid pressure operated actuating equipment having a pair of chambers the supply of pressure to which induces actuation in respective reverse directions. The supply of pressure along the first said line of the apparatus can then effect, in use, the supply of pressure to one chamber of the actuating equipment - this being the chamber for actuation in the direction which gives fail-safe operation - while the supply of pressure along the second fluid line effects, in use, the supply of pressure to the other of the pair of chambers and consequent actuation in the reverse direction. During routine operation of the equipment it may utilise fluid pressure from the same reservoir as that used for fail safe operation, or from a different reservoir.

The fluid pressure used may be either positive pressure or negative pressure. The fluid pressure supplied to the fluid line need not be of the same type as that which it causes to be supplied to the chamber of the actuating equipment. In a preferred arrangement, the actuating equipment has at least one of its chambers supplied with hydraulic liquid from a reservoir for that liquid, the supply passing through valve means which are normally closed, but which are caused to open when pressure is supplied along either one of the fluid lines.

The fluid lines need not be long. They may be constituted by short connections between two components.

Actuating equipment for a gate valve or penstock and embodying this invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a diagram of a first embodiment;

Figure 2 is a diagram of a modification to Figure 1;

Figure 3 shows a possible general layout of the parts; and

Figure 4 shows a connection box.

Referring first to Figure 1 of the drawings, the equipment has a double acting hydraulic cylinder 101 which would be mounted above a gate valve or penstock (assuming that the travel of the gate is vertical). The cylinder has a piston 103, and a shaft 105 to be connected to the gate of the gate valve or penstock. The lower chamber 107 of the cylinder is supplied with hydraulic oil from an oil reservoir 109. Its upper chamber 127 contains air.

The upper chamber 127 can be pressurized to move the piston down by the supply of compressed gas, namely compressed air along line 123. To raise the piston the lower chamber 107 is pressurized with hydraulic oil delivered from the oil reservoir upon pressurization of this by the supply of air along line 121. When line 121 is pressurized air exhausts along line 123, and vice versa.

Valve means, namely a valve 133 (referred to hereafter as a lock valve) are provided between the oil reservoir 109 and the lower chamber 107. The lock valve is normally closed to prevent the flow of hydraulic oil, and when it is closed it seals off the hydraulic volume constituted by the lower chamber 107, and the oil line 143. However, the lock valve 133 is opened if air is supplied along the line 135, which is connected via a shuttle valve 137 to each of the lines 121 and 123. The function of a shuttle valve is to select whichever of two input lines that is pressurized and connect it to an output line. The valve 137 thus connects whichever of the lines 121 or 123 that is pressurized to the line 135, and hence pressurized air is supplied to the lock valve 133 to open it and allow the gate to move. However, when neither line is pressurized the valve 133 closes, sealing off the hydraulic volume, and preventing oil from flowing into or out of the chamber 107. The valve 133 thus functions to lock the gate at any position which it is caused to assume. Hence the operating equipment can be used for penstocks and gate valves which it may be desired to open partially, and then maintain in that position, or where it is desired to hold the gate fully raised for long periods.

The operating equipment has two sets of control means for moving the piston 103, and hence the gate of the penstock or gate valve. The parts at the right hand side of Figure 1 are at the site of the valve or penstock, and include a manual control valve 117. The parts at the left hand side are at a remote location; they include control valves for automatic operation, and are connected along the air lines 189, 191.

Pressure along either of the lines 189, 122 is delivered via a shuttle valve 181 into a line 220 which leads (via a valve 221 to be described hereinafter) to the line 121. Correspondingly, pressure along either of the lines 191, 124 is delivered via a shuttle valve 183 into a line 218 which leads via a shuttle valve 219 (whose purpose will be explained below) to line 123.

Inlets for supplies of compressed air are provided at 111 and 112. The inlet 112 at the remote location is connected through a non return valve 114 to an air reservoir 116 at the remote location. The air inlet 111 feeds the manual control valve 117.

Normal operation of the equipment will now be described. The valve 117 has an operating knob with an inoperative normal position, but which can be pushed to either of two positions. The first position is used for raising the gate; the inlet 111 is connected to the line 121, while the line 124 is connected to an exhaust port 125 of the control valve. Air from the line 111 pressurizes the line 121, and the line 123 is free to exhaust either along the line 124 to port 125 or along line 191 which is connected to an exhaust port 192. The other operative position of the valve 117 is used for lowering the gate. Here the inlet 111 is connected to the line 124 and hence to the line 123 while the line 122 is connected to the exhaust port 125. Air can escape from the oil reservoir 109 along line 121 which exhausts along either of lines 122 or 189. In either case after the lock valve 133 has opened the speed of travel of the piston 103 and hence of the gate of the penstock or gate valve is governed by the rate at which hydraulic oil can be driven between the oil reservoir 109 and the chamber 107. If desired a flow restrictor can be incorporated in either of the oil lines 143 or 146 to reduce the speed of travel.

At the remote location there is the air reservoir 116 supplying control means in the form of a pair of solenoid operated two way valves 185, 186. The air lines 189, 191 lead from the remote location to the shuttle valves 181, 183 and constitute the connections between the control means at the remote location, and the actuating equipment.

The solenoid operated valves 185, 186 are connected to respective sequence timers 176, 177 which are connected to one or more sensors and/or timers, e.g. a 24 hour clock, indicated generally at 178. Connection to an electricity supply is indicated at 179.

Each of the valves 185, 186 has a port 187 and two ports 188. The port 187 of each valve is connected to one of the two ports 188 of that valve when the solenoid is energized and is automatically connected (by means of a return spring in the valve) to the valve's other port 188 when the valve is de-energized. It is desired that the gate should be lowered in the event of failure of electrical power, and for this purpose the valves 185 and 186 are connected differently.

The valve 185 is not normally energized, and in this condition the line 189 is connected to the port 190 which functions as an exhaust.

Energizing of the solenoid of valve 185 is effected by the sequence timer 177 under the command of the clock 178. The timer 177 will respond to a signal from the clock 178 by going through an operating cycle consisting of energizing the solenoid of valve 185, maintaining it energized for a predetermined period and then de-energizing it. When the valve 185 is energized, air from the reservoir 116 is supplied along the line 189 to pressurize the line 121 and hence raise the gate.

The valve 186, on the other hand, is normally energized, in which state the line 191 is connected to the port 192 and hence is free to exhaust to atmosphere, but when the valve 186 is de-energized the return spring in the valve causes the line 191 to be pressurized from the reservoir 116 so pressurizing the line 123 and the chamber 127 and thus closing the gate of the valve or penstock. The valve 186 is de-energized by a sequence timer 176 whose function is converse to that of the sequence timer 177. On receipt of a signal from the clock 178 the sequence timer de-energizes the solenoid valve 186, maintains it in a de-energized state for a predetermined period and then re-energizes it.

This equipment can be operated either by means of the manual control valve 117, or remotely under the command of the clock 178 through the sequence timers 176, 177.

Lowering the gate upon failure of the electricity supply 179 is as follows. As explained above, the supply of air pressure along the line 123 will pressurize the chamber 127 and hence move the actuating equipment to its desired fail-safe state. The valve 186 which controls the supply of air from the reservoir to the line 191 and hence line 123 is normally maintained closed by a supply of energy, namely electricity supplied to the apparatus. In the event of failure of the electricity supply the solenoid of valve 186 will necessarily become de-energized, and the valve will open automatically so that air pressure from the reservoir 116 will pressurize upper chamber 127 through the lines 191 and 123 to lower the gate. The solenoid of valve 185 will also be de-energized, preventing pressurization of line 189.

It will be appreciated that to lower the gate the equipment uses energy which is already stored in it viz. pressure held in the reservoir 116 by its non-return valve 114.

If it were desired that the gate should be raised on failure of the electricity supply, the valve 185 would be connected so as to be normally energized, whereas the valve 186 would be connected so as to be normally de-energized.

The gate can be prevented from moving from the position to which it goes upon failure of the electricity supply 179 even if some while after movement the air pressure in the reservoir 116 were to fall to a level insufficient to hold the gate in position. To do this the pressure needed to open the lock valve 133 is arranged to be as great as (or slightly greater than) that needed to hold the gate in its fail-safe position. If the air pressure is insufficient the lock valve will close, and thus hold the gate.

In accordance with the invention, the equipment is responsive to failure of the air supply 112 which is of course a source of energy used by the equipment. More specifically, the equipment will automatically go to its required fail-safe state, with the gate lowered, in response to the pressure of the air supply delivered at the inlet 112 dropping below a predetermined level. Moreover, if this should happen the supply of fluid pressure along the line 121, which would cause the gate to move away from its fail-safe state, is positively blocked. For these purposes the air supply 112 is also connected through a line 211 which follows the lines 189 and 191 from the remote location to the location of the penstock or gate valve. At the penstock or gate valve the line 211 supplies the reservoir 115 through a non-return valve 213. It also supplies a pressure operated valve 215 which controls the outflow of air from reservoir 115. In this valve, the air pressure from the line 211 opposes the action of a return spring, which tends to open the valve 215 and allow discharge of compressed air into the line 217. As long as the pressure from the line 211 is greater than a predetermined value (which depends on the strength of the return spring used in the valve 215) the valve 215 is held closed and no air flows from the reservoir 115 into the line 217.

The line 217 is connected to a shuttle valve 219 which allows the line 123 to be pressurized either from the shuttle valve 183 or from the line 217. The line 217 is also connected to a further valve 221, in which pressure from the line 217 opposes a return-spring. The valve 221 has a port 223 supplied from the shuttle valve 181, a port 224 which is connected to the line 121, and a port 225 which is an exhaust. When the line 217 is not pressurized, the return spring causes the valve 221 to go to a condition in which the port 223 is connected to the port 224, so that the line 121 can be pressurized from the shuttle valve 181. However, when the line 217 is pressurized thus overcoming the action of the return spring the valve 221 goes to a condition in which the port 224 is connected to the exhaust port 225 and the line 121 is consequently free to exhaust. This condition is not affected by any pressure delivered from the shuttle valve 181, and consequently the line 121 cannot be pressurized. The valve 221 thus constitutes fluid pressure operable means to prevent the supply of fluid pressure along line 121.

The equipment functions as follows. As long as the pressure supplied along the line 211 exceeds the predetermined value, the valve 215 remains closed, the ports 223 and 224 are connected to each other and the equipment will function normally, as described above, provided the electricity supply 179 is maintained. It will be operable either automatically by the time clock 178 or by the manual control 117.

If the pressure in the line 211 drops below the predetermined value, however, the valve 215 opens and the pressure which is already in reservoir 115 (and retained there by virtue of non-return valve 213) is admitted via valve 215 to line 217 and consequently pressurizes line

123 moving the piston 103 and hence the gate of the gate valve or penstock to the fail-safe position. The port 224 of the further valve 221 is connected to the port 225, thus providing an exhaust from the oil reservoir 109 via line 121. This valve 221 prevents the line 121 from being pressurized whether by operation of the manual control valve 117 in ignorance of the air pressure failure which prompted the equipment to proceed to its fail-safe condition, or by operation of the automatic control equipment at the remote location. It will be appreciated that the air reservoir providing the supply of fluid pressure to move the piston to the fail-safe position is constituted by the reservoir 115 which is amongst parts sited at the location of the penstock or gate valve. This provides protection against destruction of the communicating lines between that location and the remote location. Should these lines be destroyed, e.g. by mechanical damage or an outbreak of fire between the penstock or gate valve and the remote location, the destruction of them (causing loss of pressure in line 211) will cause the equipment to go to its fail-safe state even though communication with the remote location has been cut.

It could be arranged, if desired, for the fail-safe state to be with the gate raised; the valves 219 and 221 would then be interchanged, the valve 221 then connecting shuttle valve 183 with the line 123 and the valve 219 delivering into the line 121.

In either case, it may be arranged that the air pressure to open the lock valve 133 is as great as (or slightly greater than) that needed to hold the gate in its fail-safe position. Then if the air pressure from the reservoir 115 were to prove insufficient to hold the gate in its fail-safe position after it has been driven to that position, the gate would nevertheless be held by virtue of the closure of the lock valve 133 to seal off the oil-filled line 143 and the lower chamber 107.

Numerous modifications are possible. The equipment could use a pair of oil reservoirs so that both the lower and the upper chambers of the cylinder 101 are filled with oil. The manual control valve 117 could be dispensed with if not needed, in which case the shuttle valves 181 and 183 would not be required and the lines 189 and 191 could be directly connected to the valves 219, 221. The solenoid operated valves could be at the site of the gate valve or penstock with electrical connection to the remote location, although for equipment to be used in a hazardous environment it may well be preferable for connection to be by means of air (or other gas) lines rather than electric cables. Additional control equipment could be incorporated. For example, detectors could be fitted to the shaft 105 to detect whether or not the gate had achieved its desired travel, and additional control valves could be incorporated in an operating equipment assembly mounted above the gate to cause the equipment to repeat its opening and closing cycle in the event of failure to achieve the desired travel at the first attempt.

It would be possible to dispense with the use of timers and the lock valve 133. The two solenoid operated valves 185, 186 would be connected to a control for simultaneously energizing the valve 185 and de-energizing the normally de-energized valve 186. On operation of this control the gate of the valve or penstock would be raised fully, and kept raised with the chamber 107 under pressure. At all other times the gate would be fully lowered with the chamber 127 under pressure. Such an arrangement would be suitable where it would only be required to open the gate occasionally and for short periods.

The line 211 could be supplied from the reservoir 116, in which case the equipment would go to its fail-safe state if the pressure in reservoir 116 fell below a pre-determined value rather than if the pressure at the supply 112 fell below a pre-determined value.

Figure 3 shows one modification. The valve 186′ is not normally energized, and the sequence timer 176′ has the same manner of operation as timer 177. When the solenoid of valve 186′ is energized, pressure from the reservoir 116 is delivered via line 231 to shuttle valve 233 and hence into the line 191.

An additional solenoid operated valve 235 is provided. This is normally energized, but when it is de-energized through failure of the electricity supply 179 it delivers air pressure from the reservoir 116 into a line 237 which also leads to the shuttle valve 233, and so delivers into the line 191 and hence into the line 123 to move the piston 103 to its fail-safe position.

Figure 3 shows a possible layout for the equipment shown in either of Figures 1 or 2. An assembly 196 is mounted above a gate valve 195. The assembly has a cylinder 101 disposed centrally with the oil reservoir 109 at one side of it and the air reservoir 115 at the other side. All three are mounted on a common supporting structure having a base plate 194 supported on a block 197 which is attached to the gate valve and through which the shaft 105 passes. This shaft is attached to the gate 198.

A manual control valve 117 (whose operating knob is shown at 118) the lock valve 133, and the valves 113, 137, 181, and 183 (these not shown in Figure 3) as well as any valves 213, 219 and 221 (also not shown in Figure 3) are suspended beneath the plate 194.

The sequence timers 176, 177, the time clock 178 and the solenoid operated valves 185, 186 are contained in a control box 199 at a remote location 200. The lines 189 and 191 lead from this remote location to the assembly 196. For equipment having a third solenoid operated valve 235 as described with respect to Figure 2, this valve and the shuttle valve 233 would also be contained in the control box 199. The line

211 here extends from downstream of valve 114.

The section of the line 211 between the remote location 200 and the assembly 196 (and which is shown in chain dotted lines) is provided by tubing 241. This is of larger bore than the tubing used for the lines 189 and 191, and contains these two lines. In consequence it would be virtually impossible to damage either of the lines 189 or 191 at some point along the pathway between the remote location 200 and the assembly 196 without also damaging the line 211 (as constituted by tubing 241) which would then cause the equipment to go to its fail-safe state.

The tubing 241 is terminated by air tight boxes 243 with fittings for leading out the lines 189 and 191. One such box is indicated diagrammatically in Figure 3; another (not shown) would be provided in the assembly 196. Air tight boxes would also be used for connecting together lengths of the tubing 241.

A termination box 243 is shown in Figure 4. It is sealed to the tubing 241, and is provided with three bulkhead fittings 245. One of these connects the line 211 with the air space in the box, the other two connect the lines 189, 191 with continuations of those lines which run within the tubing 241.

WHAT I CLAIM IS:

1. Apparatus for the supply of fluid pressure to fluid pressure operated actuating equipment, the equipment having at least one first chamber the supply of pressure to which induces actuation in one direction and a second chamber the supply of pressure to which induces actuation in the reverse direction, the apparatus including a first fluid line the supply of pressure along which effects, in use, the supply of pressure to the said first chamber of the actuating equipment and a second fluid line the supply of pressure along which effects, in use, the supply of pressure to the said second chamber; a fluid pressure reservoir; a valve controlling the supply of fluid pressure from the reservoir to the said first fluid line, and also the supply of fluid pressure to fluid pressure operable means for preventing the supply of fluid pressure along the said second fluid line the valve normally being maintained closed by a supply of energy, and opening automatically should that supply not be maintained, thereby supplying fluid pressure from the reservoir to the said first fluid line, and also supplying pressure to the said fluid pressure operable means for preventing supply along the said second line.

2. Apparatus according to Claim 1, wherein said supply of energy is a supply of fluid under pressure, said valve being normally maintained closed thereby and opening automatically if that pressure drops below a predetermined value, said valve being connected both to the said first fluid line and to said fluid pressure operable means, so that, in use, on opening of said valve fluid pressure from the reservoir is supplied to said first fluid line and to the fluid pressure operable means.

3. Apparatus according to Claim 2, wherein the supply of fluid under pressure feeds the said reservoir through a non return valve, the said valve being normally maintained closed by the pressure upstream of the non return valve.

4. Apparatus according to any one of Claims 1, 2 or 3, wherein the fluid pressure operable means is a further valve which is connected to the said other line so that any fluid pressure supplied to that line must pass through the further valve and which operated to block such passage, should fluid pressure be supplied to it from the first said valve.

5. Fluid pressure operated actuating equipment having a pair of chambers the supply of pressure to which induces actuation in respective reverse directions, and apparatus according to any preceding Claim connected such that, in use, supply of pressure to a respective chamber of the actuating equipment.

6. Actuating equipment according to Claim 5 having apparatus according to Claim 2 or Claim 3, or to Claim 4 when appendant to either Claim 2 or Claim 3, the apparatus being located proximate to the actuating equipment with control means for the actuating equipment at a location remote therefrom, the control means being connected to the equipment by connections which run in close proximity to a supply one for the said supply of fluid under pressure.

7. Actuating equipment according to Claim 6, wherein the connection of the control means to the equipment are contained within the supply line.

8. Actuating equipment according to any one of Claims 5 to 7, which has at least one of its chambers supplied with hydraulic liquid from a reservoir for that liquid, the supply passing through valve means which are normally closed, but which are caused to open when pressure is supplied along either one of the said fluid lines.

9. Fluid pressure operated actuating equipment substantially as herein described with reference to Figure 1, or Figures 1 and 2 of the accompanying drawings, either alone or in combination with Figure 3.

10. Apparatus for the supply of fluid pressure to actuating equipment substantially as herein described, with reference to Figure 1, or Figures 1 and 2 of the accompanying drawings.

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1603301 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

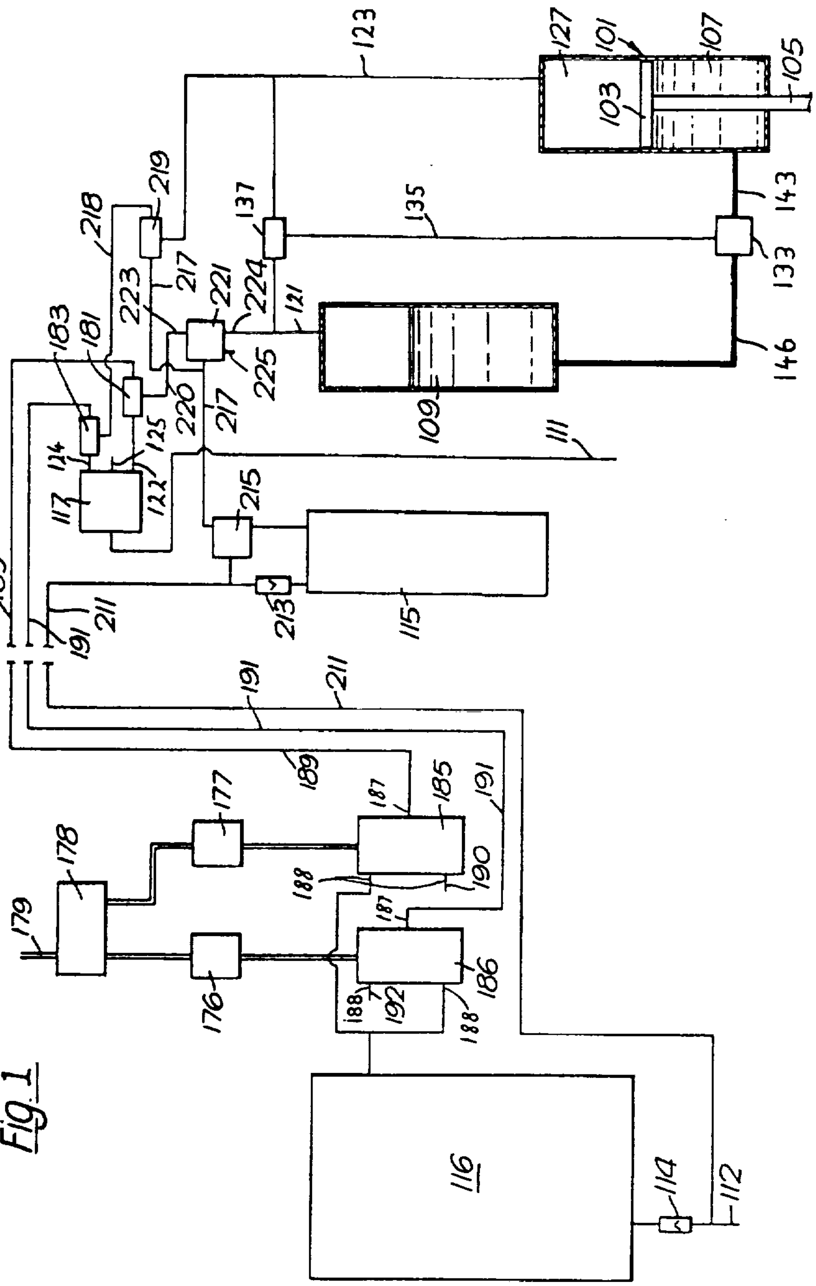

Fig.1

Fig. 2

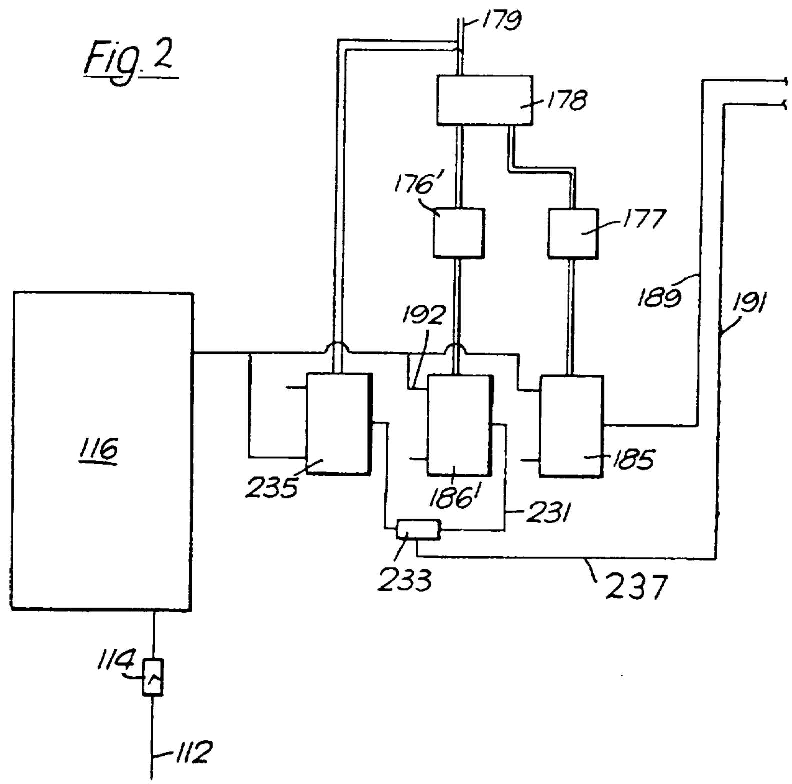
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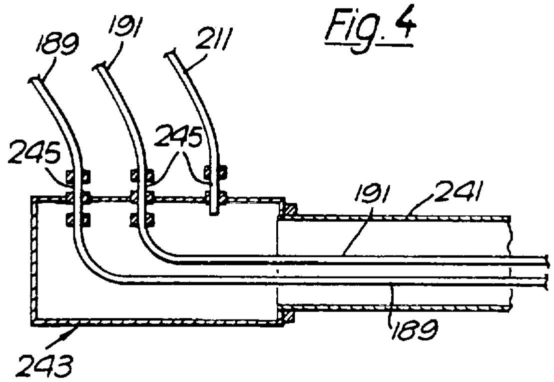
Fig. 4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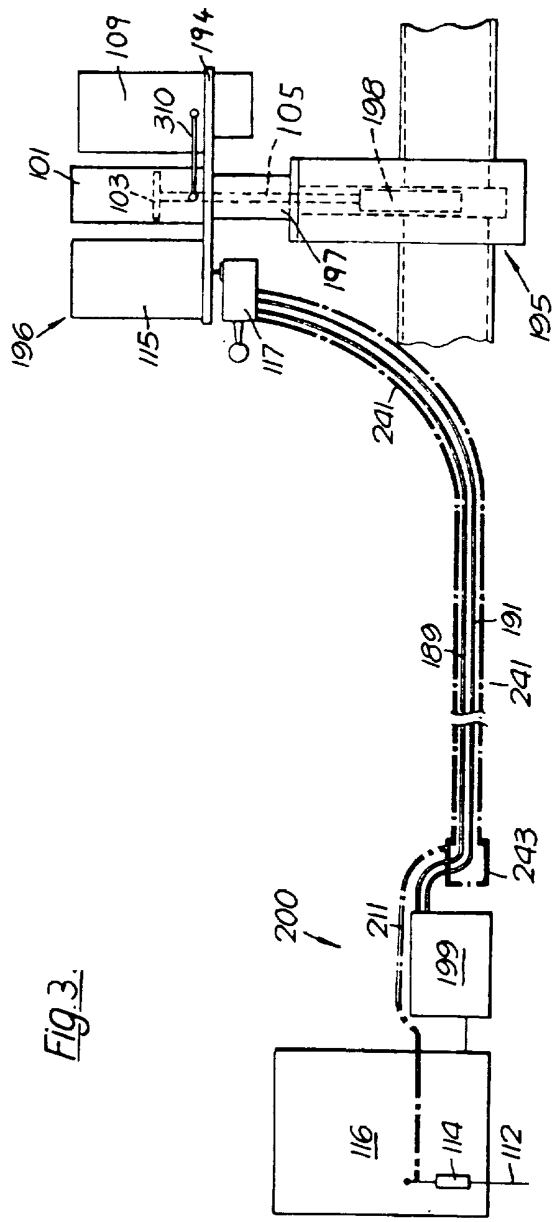
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Fig.3.