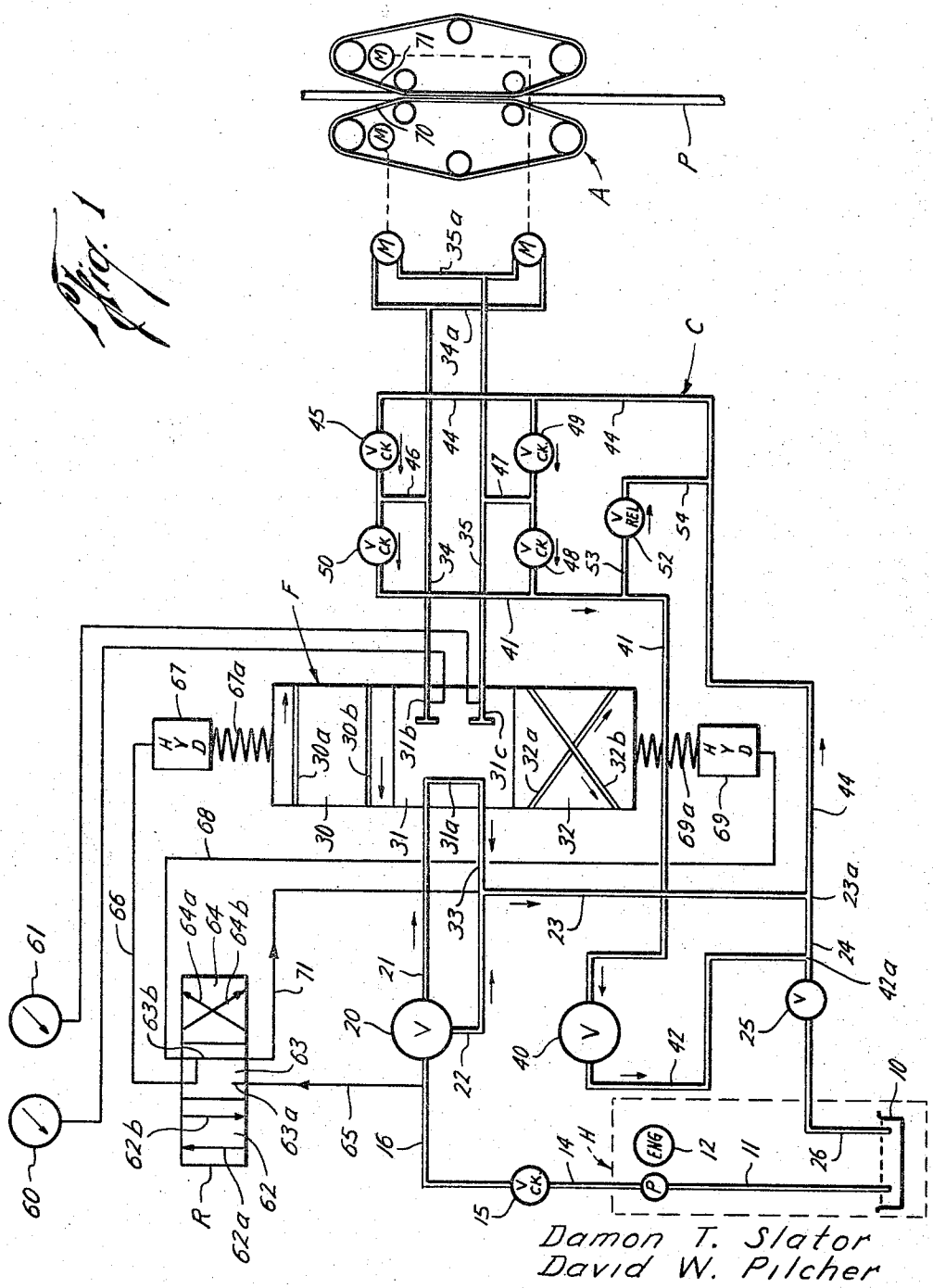
July 11, 1967 D. T. SLATOR ETAL 3,330,531

CONTROL SYSTEM FOR HANDLING VARYING LOADS

Filed April 22, 1964 4 Sheets-Sheet 1

Fig. 1



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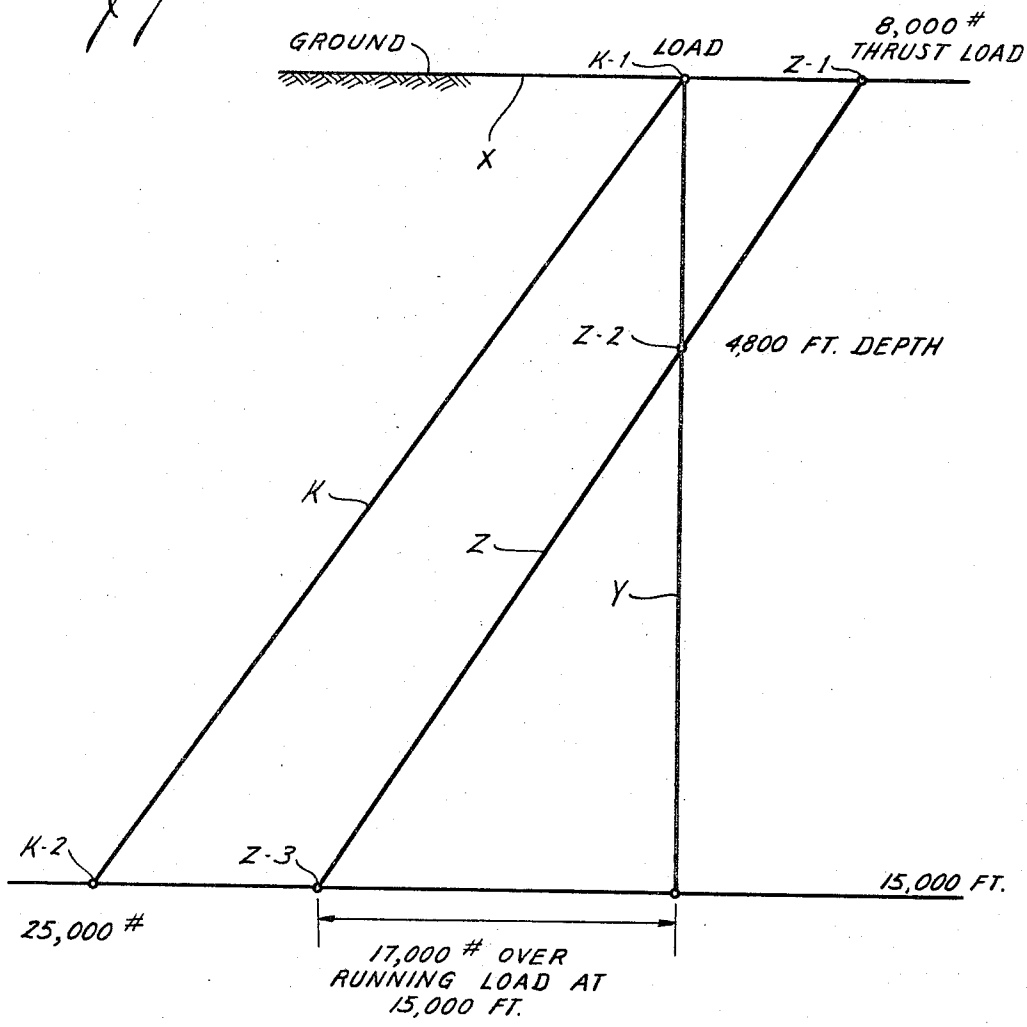
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CONTROL SYSTEM FOR HANDLING VARYING LOADS

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Fig. 2



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CONTROL SYSTEM FOR HANDLING VARYING LOADS

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Fig. 3

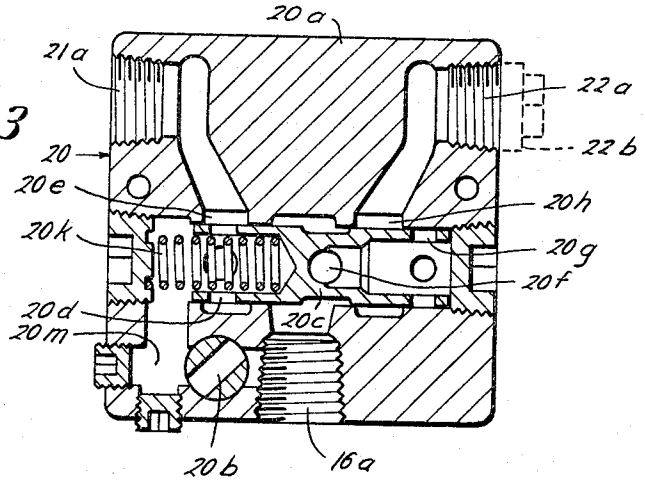


Fig. 4

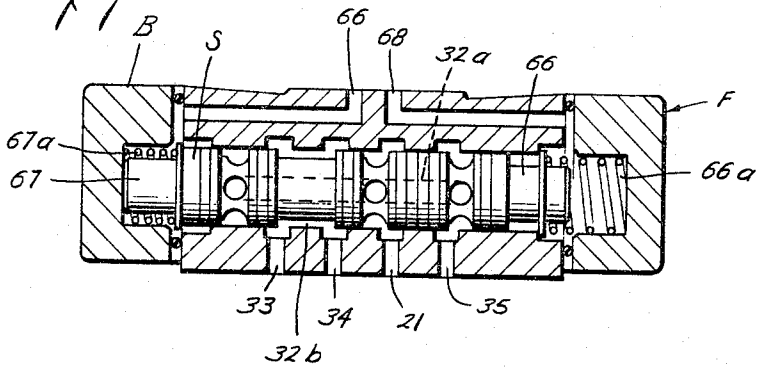


Fig. 5

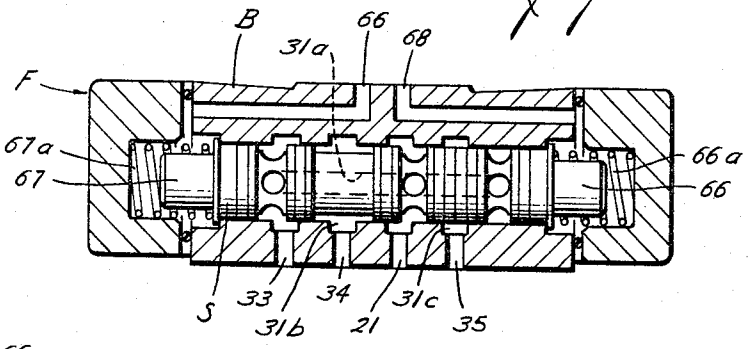
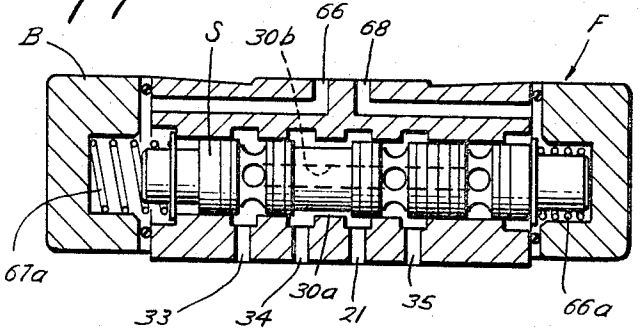


Fig. 6



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CONTROL SYSTEM FOR HANDLING VARYING LOADS

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Fig. 7

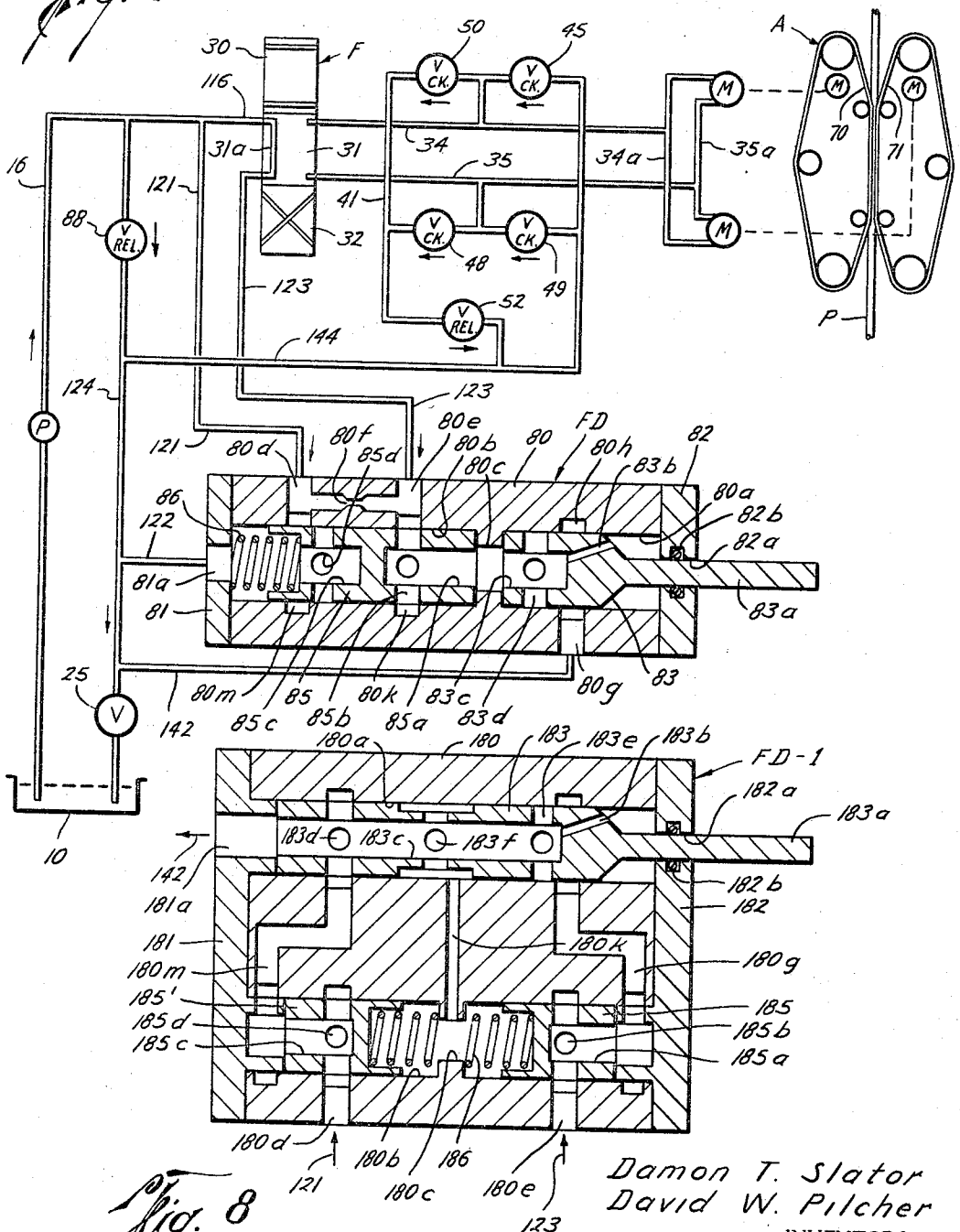


Fig. 8

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United States Patent Office 3,330,53
Patented July 11, 196

3,330,531

CONTROL SYSTEM FOR HANDLING VARYING LOADS

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Filed Apr. 22, 1964, Ser. No. 361,811
6 Claims. (Cl. 253—1)

This invention relates to control systems for handling varying loads, and particularly a hydraulic system for controlling the running in and raising of pipe in a well under pressure.

In copending United States application, Ser. No. 249,854, filed Jan. 7, 1963, and issued as U.S. Patent No. 3,182,877 on May 11, 1965, an apparatus is disclosed for forcing or feeding tubing or other pipe into a well under pressure, and for pulling such tubing from the well. The present invention is especially suitable for controlling the operation of the apparatus of said application Ser. No. 249,854, although it may be used for controlling other apparatus having varying loads.

An object of this invention is to provide a new and improved control system for controlling the speed of one or more fluid-driven motors under varying loads.

An important object of this invention is to provide a new and improved fluid control system for controlling the speed of lowering and raising well pipe with an apparatus of the type disclosed in said U.S. patent application, Ser. No. 249,854.

Another object of this invention is to provide a new and improved fluid control system wherein one or more fluid motors are adapted to be driven for feeding pipe into a well against pressure until the weight of the pipe overcomes the thrust on the pipe due to such pressure, at which time the motor or motors are operated as pumps to brake the downward travel of the pipe as the speed thereof tends to increase due to the increasing weight of the pipe as it continues to be lowered.

A further object of this invention is to provide a new and improved fluid control system wherein one or more fluid motors are adapted to be driven for pulling pipe out of a well under pressure until the weight of the pipe remaining in the well is insufficient to overcome the thrust of the pipe due to such pressure at which time the motor or motors are operated as pumps to brake the upward travel of the pipe as the speed thereof tends to increase due to the decrease in weight of the pipe as it continues to be removed.

A particular object of this invention is to provide a new and improved fluid control system for operating one or more fluid motors at substantially constant speeds as the load on such motors varies and even reverses in direction.

Still another object of this invention is to provide a new and improved fluid control system having one or more fluid motors driven by fluid from a fluid pump and wherein means are provided for reducing the volume of such fluid reaching the fluid motor or motors when such reduction becomes desirable and concurrently diverting the excess flow of such fluid without developing pressure in the system significantly in excess of that pressure required for the operation of said fluid motor or motors under the load prevailing by using two pressure-compensated flow control valves.

Yet a further object of this invention is to provide a new and improved fluid control system and a new and improved valve therefor wherein one or more fluid motors are subjected to varying loads and wherein the pressure of the fluid at the motors is automatically controlled in response to the varying loads on the motor or motors, such valve automatically diverting any excess

fluid flow from the fluid motor or motors without develo ing pressure in the system significantly in excess of th pressure required for the operation of said fluid mot or motors under the load prevailing.

The preferred embodiment of this invention will be d scribed hereinafter, together with other features thereo and additional objects will become evident from suc description.

The invention will be more readily understood fro a reading of the following specification and by referenc to the accompanying drawings forming a part thereo wherein an example of the invention is shown, an wherein:

FIG. 1 is a schematic illustration of the present inve tion;

FIG. 2 is a chart representing typical conditions of us of the control system of this invention;

FIG. 3 is a sectional view of one of the control valve for the control system of FIG. 1;

FIGS. 4, 5, and 6 are sectional views of a typical mult port valve in three operating positions for use in the sy tem of FIG. 1;

FIG. 7 is a schematic illustration of a modified forr of this invention, incorporating therein a sectional vie of a new and improved control valve; and

FIG. 8 is a sectional view of a modified form of th control valve illustrated in FIG. 7.

In the drawings, the letter A designates generally a apparatus adapted to lower and raise pipe P into an out of a well. Such apparatus A is schematically show in FIG. 1. A specific form thereof is illustrated in said co pending United States patent application Ser. No. 249,854 identified above. The control system of this invention i designated generally with the letter C, and as will be ex plained in detail hereinafter, such control system C i adapted to control fluid in the system when it is subjecte to varying loads. Thus, the control system C is particu larly adapted to control the lowering and/or raising o pipe P from a well with the apparatus A. The control sys tem C of this invention is also suitable for use in othe situations wherein the load on the motors M used wit the apparatus A varies. As will be explained, the spee of the motors M or similar fluid motors may be main tained substantially constant with the control system C of this invention even though the external loads thereo are varied in use.

Considering the invention more in detail, the contro system C illustrated in FIG. 1 includes a conventiona hydraulic power unit H, which is enclosed in dash lines Some of the components of such a conventional hydraulic power unit H are illustrated in FIG. 1 schematically so that the relationship of such power unit H to the rest o the control system C will be clear. Thus, as shown ir FIG. 1, the hydraulic power unit H includes a source o hydraulic fluid **10** which may be a tank or other simila container having connection with a pump P through a fluid line **11**. The pump P is driven by an engine **12** o any suitable type such as a gasoline engine, electric moto or similar prime mover.

The pump P discharges the hydraulic fluid through line **14** and check valve **15** to flow line **16**. The flow line **16** is connected to a pressure-compensated flow control valve **20** of known construction, one type of which is illustrated in FIG. 3 and which is described in detail hereinafter. The valve **20** has three ports, one connected to the incoming line **16**, a second connected to a normal flow line **21**, and a third connected to a bypass line **22**. The control valve **20** is of the type which maintains a constant volume flow through the normal flow line **21**, regardless of the changes in the pressure in the upstream line **16** and the downstream line **21**. Any excess volume from the pump P which does not flow through the line

1 is bypassed through the line **22** and returns through ine **23** and line **24** to a pressure-control valve **25** and hen to the sump return line **26** which discharges the luid back into the sump or source **10**. The valve **25** is onstructed as illustrated in FIG. 1 so that flow is possi- ble in the direction from the line **24** to the line **26**. Such alve **25** opens only when the pressure in the line **24** ex- eeds a predetermined amount which is preferably 100 ounds per square inch (p.s.i.). Such predetermined mount may of course vary so long as the back-pressure n the line **24** is maintained at a high enough level to vercome fluid pressure drops in the flow lines from the alve **25** back to the motors M when such motors M are perating as pumps, as will be more evident hereinafter. Therefore, the system is maintained at such predeter- mined minimum back-pressure by reason of the setting of he valve **25**.

For illustration purposes, a specific form of the valve **20** is shown in detail in FIG. 3, although it will be under- stood that other valves capable of performing the func- tions thereof may be used instead in the system of this invention. The valve body **20***a* has an inlet opening **16***a* which is connected to the line **16** (FIG. 1), a controlled flow opening **21***a* which is connected to the line **21** (FIG. 1), and a by-pass opening **22***a* which is connected to the line **22** (FIG. 1). The volume of fluid passing through the valve **20** to the outlet **21***a* is regulated with a rotatable plug valve **20***b*, or any other suitable volume control. Thus, if the valve **20***b* is fully open (horizontal open- ing in FIG. 3), the motors M will operate at the maxi- mum speed, but if the valve **20***b* is closed so that only fifty percent of the fluid from the line **16** flows through to the outlet **21***a*, the speed of the motors M is reduced to approximately one-half of the maximum speed.

Within the valve body **20***a*, a valve spool **20***c* is mount- ed for axial movement to control the amount of fluid flowing to the outlet opening **21***a* and the flow line **21**. The spool **20***c* has openings **20***d* which are adapted to be fully or partially aligned or misaligned with a port **20***e* by an axial movement of the spool **20***c* for maintain- ing a constant volume flow of fluid to the opening **21***a* even though the pressure fluctuates. The spool **20***c* also has an opening or openings **20***f* in communication with openings **20***g* through the bore of the spool for the by- pass of fluid in accordance with the position of the open- ings **20***g* relative to a port **20***h*. A spring **20***k* urges the spool **20***c* to the right as viewed in FIG. 3, or towards a position in which the by-pass is closed, but the effect of such spring **20***k* depends upon its strength and the dif- ferential pressures between the fluid acting upon the ends of the spool **20***c*, as will be explained.

By the partial closing of the valve **20***b*, the pressure in the passage **20***m* to the left of the valve **20***b* to which the left end of the spool **20***c* is exposed, is lower than the incoming pressure at the inlet opening **16***a*, to which the right end of the spool **20***c* is exposed through ports **20***f* and the bore of the spool **20***c*, which tends to posi- tion the spool **20***c* in some intermediate position with a portion of the fluid flowing through the outlet **21***a* and the rest flowing through the outlet **22***a*. In such inter- mediate position, the force on the left end of spool **20***c* due to the fluid pressure in the passage **20***m* together with the force from the spring **20***k* is balanced by the force on the right end of spool **20***c* due to the fluid pres- sure from the inlet **16***a* acting to urge the spool **20***c* to the left (FIG. 3).

When the pressure in line **21** drops due to a decrease in load at the apparatus A, the flow of fluid through the valve **20***b*, passage **20***m* and ports **20***d* and **20***e* to out- let **21***a* and line **21** tends to increase. Any increase in flow through valve **20***b* causes a corresponding increase in the pressure drop therethrough and resultant decrease in the pressure in passage **20***m*, on the left side of the spool **20***c*, and thereby causes an unbalance of the forces affecting the position of said spool **20***c*. Such unbalance

of forces causes a movement of the spool **20***c* toward the left in FIG. 3, which adjusts the alignment of ports **20***d* with respect to ports **20***e* to restrict the flow there- through, and simultaneously adjusts the alignment of ports **20***g* with respect to ports **20***h* to reduce the restriction to the flow therethrough, such that a balance of forces affecting the spool **20***c* is re-established. It will be ap- parent to those skilled in the art that the effect of the above described action of spool **20***c* is to maintain a constant differential pressure across valve **20***b*, which, for a particular setting may be considered a fixed orifice, such that the flow through the valve **20***b* to the outlet **21***a* is maintained substantially constant, regardless of the decrease in the pressure at the outlet **21***a*. Since the re- striction to flow through the ports **20***g* and **20***h* is de- creased, the pressure at inlet **16***a* will decrease.

When the pressure in the line **21** increases, the flow through the valve **20***b* tends to decrease, causing an un- balance of forces on the spool **20***c* in the reverse direc- tion from that described hereinbefore, which causes a movement of the spool **20***c* toward the right thereby re- ducing the restriction to the fluid flow from inlet **16***a* to outlet **21***a* and simultaneously increasing restriction to flow from inlet **16***a* to outlet **22***a*, such that the flow to outlet **21***a* is again held substantially constant and the pressure at inlet **16***a* is increased.

Thus, the valve **20** provides a means for adjustable constant volume control of the fluid reaching the fluid motor or motors and concurrently diverting the excess flow of fluid without developing a pressure in the system significantly in excess of that pressure required for op- eration of said fluid motor or motors under the load prevailing.

A four-way valve F, one type of which is illustrated in FIGS. 4–6, is schematically illustrated in FIG. 1 as hav- ing three positions **30**, **31** and **32** which correspond with FIGS. 6, 5 and 4, respectively. Such four-way valve F is disposed in the system between the flow control valve **20** and the motor or motors M which are to be operated. In the "forward" valve position **30** of the valve F (FIG. 1), as illustrated also in FIG. 6, a port **30***a* communicates the flow passages **21** and **34** for imparting a driving move- ment to the motor or motors M. For the purposes of illus- tration, it is assumed that each motor M is a fluid-driven rotary motor of any known type, although the term "fluid- motor" as used herein may include any other device oper- able by fluid power such as double-acting pistons and reciprocatory motors. In the forward position **30**, a re- turn passage **30***b* communicates the flow lines **33** and **35** for a return of the fluid from the motors M when driving the motors M forwardly.

Thus, when it is desired to drive the motors M in the forward direction, which is clockwise for the upper or left motor M and counterclockwise for the lower or right motor M, the spool S of the valve F is positioned within the body B so that the passage or port **30***a* connects the flow conductors **21** and **34** while the return passage **30***b* connects the flow passages **33** and **35** (FIG. 6). Thus, the fluid from the control valve **20** passes through the lines **21** and **34** to the distributor line **34***a* and then to each of the motors M. The return fluid from the motors M passes through the distributor line **35***a* to the return line **35**, and then through the return port **30***b* to the conductor **33**. The fluid entering the conductor **33** returns to the sump **10** through the line **23**, the conductor **24**, the pressure-control valve **25** and the return line **26**.

In order to reverse the direction of rotation or move- ment of the motors M while still driving same as motors with the fluid, the four-way valve F is shifted to the re- verse position **32** (FIG. 4) so that a port **32***a* establishes communication from the line **21** to the line **35**, and at the same time establishes communication from the line **33** to the line **34** through the port **32***b*. With the four-way valve F thus positioned (FIG. 4), the direction of rotation of the motors M is reversed so that the upper or left

motor M is in a counterclockwise direction and the lower or right motor is in a clockwise direction. It is to be noted that the motors M are shown in the diagram as connected to the distributor lines 34*a* and 35*a*. The dotted lines show the actual locations of the motors M in the apparatus A so that the upper motor M of FIG. 1 is in fact located on the left-hand portion of the apparatus A for driving an endless belt 70, while the lower motor M of the control assembly C is located on the right-hand portion of the apparatus A for driving an endless belt 71, as will be more evident hereinafter.

In lowering the pipe P into a well under pressure, the motor on the left of the apparatus A is rotating clockwise to feed the pipe P downwardly against the well pressure whereas the motor M on the right of the apparatus A is rotated counterclockwise to also effect such downward feeding of the pipe P. When the amount of pipe P in the well is sufficient so that its weight overcomes the upward force exerted by the well pressure on the pipe P, the motors M then must begin to exert a braking action to control the lowering of the pipe P as the force of gravity gradually takes over and there is a tendency for the speed of the pipe P to increase due to the increase in weight of the pipe P being lowered into the well. When such condition occurs, the motors M actually function or serve as pumps to provide such braking action, as will be more fully explained hereinafter in connection with FIG. 2.

In order to obtain such braking action, the four-way valve F is shifted to the brake position 31 illustrated in FIGS. 1 and 5. In the brake position, lines 21 and 33 are connected through a port 31*a*, while the conductors 34 and 35 are closed off as indicated by the closed ports 31*b* and 31*c*, respectively. Thus, no flow occurs to or from the lines 34 and 35 through the valve F.

When the valve F is moved to the brake position illustrated in FIGS. 1 and 5, a second pressure compensated flow control valve 40 is opened manually or by any suitable automatic control. Such valve 40 receives the discharge flow from conductor 41 and conveys such flow through line 42 to line 24 at connection point 42*a* which is between the connection point 23*a* and the valve 25. The valve 40 is basically a duplicate of the valve 20 and is of conventional construction, except that the valve 40 has only the two ports for connecting to the lines 41 and 42, as will be described more in detail hereinafter. A constant volume of the hydraulic fluid is thus discharged through the line 42 regardless of the pressure of such hydraulic fluid in the flow conductor 41. As will be more evident hereinafter, the pressure of the fluid in the line 41 varies depending upon the load of the motor or motors M, but by controlling the discharge of the fluid through the line 42 with the valve 40 so as to maintain such discharge at a constant volume, the speed of the motors M is kept substantially constant even though the load thereon is increasing due to the increasing amount of pipe in the well.

Since the valve 40 may be a duplicate of the valve 20, except for the number of ports, reference is now again made to FIG. 3, wherein the valve 20 is illustrated. When using the valve 20 as the valve 40, the outlet port 22*a* is closed by a plug 22*b* (shown in dotted lines), the inlet port 16*a* is connected to line 41, and the outlet port 21*a* is connected to line 42. Then, as the pressure in the line 41 fluctuates, the spool 20*c* is shifted for maintaining a constant volume flow through the opening 21*a* to the line 42. Thus, if the pressure in the line 41 increases, the spool 20*c* is shifted to the left to reduce the extent of the openings 20*d* open to the port 20*e*, but if the pressure in the line 41 decreases, the spool 20*c* shifts to the right, at all times maintaining a constant volume discharge to the line 42.

When the valve F is in the braking position 31 (FIGS. 1 and 5), the incoming fluid from the line 21 is bypassed through the passage 31*a*, is returned to the line 33 and then to the line 23. Also, the fluid bypassed through valve 20 to conductor line 22 is discharged to line 2: From there, the flow of the incoming fluid is directe through flow line 44 to a one-way check valve 45. Th check valve 45 is adapted to permit the flow from the lin 44 to an intermediate line 46 which connects with th line 34 and thus supplies the fluid to the motors M. Whe the motors M are actually being driven as pumps b reason of the external load of the pipe P pulling dowr wardly thereon during the running in of such pipe P, th valve 45 is merely allowing fluid to flow into the line 3 to replenish the fluid pumped by the motors M. By reaso of the predetermined minimum back-pressure which i maintained in the system by the valve 25, as previousl explained, there is always an adequate supply of fluid fo the motors M to prevent cavitation thereof. The flui which is pumped by the motors M is forced under pres sure through the distributor line 35*a* to the line 35 an then to the intermediate line 47 which connects with one-way check valve 48. The one-way check valve 4 allows the fluid to flow therethrough to the line 41. It i to be noted that the check valve 49 prevents the flui under pressure coming from the motors M from backin up into the line 44. It should also be noted that th check valve 50 prevents the fluid in the line 41 from back ing up into the line 46.

In the event the pressure of the fluid in the line 41 be comes excessive, for example in the neighborhood o 2500 p.s.i., it is necessary to relieve such pressure an therefore a pressure relief valve 52 is provided in a lin 53 which is connected to the flow line 41. Thus, whe the pressure in the line reaches a point above the maxi mum set for the relief valve 52, the fluid from the lin 41 is recirculated through line 54 to the line 44 so as t relieve such excessive pressure.

The four-way valve F may be manually shifted by a operator who is observing the pressure gauges 60 and 61 Thus, the pressure gauge 60 indicates the pressure of th fluid flowing in the line 34 while the gauge 61 indicate the pressure of the fluid flowing in the line 35. When th valve F is in the forward position, with the conductor 21 and 34 connected by the port or passage 30*a* and th conductors 33 and 35 connected by the port or passag 30*b*, the pressure in the line 34 will initially be at a relatively high value, for example, about 1500 p.s.i., and the pressure in the line 35 will be at about 100 p.s.i. o slightly above. Such readings will be reflected on the gauges 60 and 61, respectively. As the pipe P is lowered into the well, less feeding force is required with respect to the motors M since the weight of the pipe is gradually assisting the lowering operation. Therefore, the gauges 60 and 61 will reflect such condition by a gradually decreasing reading on the gauge 60.

When the pressure gauge readings on the gauges 60 and 61 become substantially the same, and the operator observes that the pipe P is increasing in speed during the lowering thereof, the valve F is shifted to the breaking position illustrated in FIGS. 1 and 5. During the braking action, the gauge 60 is indicating the pressure of the fluid replenishing the motors M as they are being driven as pumps and therefore such pressure will be approximately 100 p.s.i., or such other amount as is set by the valve 25. The pressure gauge 61 will have a varying reading which will increase as the pipe P is lowered due to the increased pressure developed during the lowering of the pipe P.

When the four-way valve F is in the reverse position (FIG. 4), the gauges 60 and 61 will have reverse readings as compared to the readings obtained when the motors M are being driven forwardly.

If desired, the four-way valve F may be shifted with a remote hydraulic unit which is schematically indicated at R as containing three operating positions 62, 63 and 64. Such unit R is basically the same as the valve F, and may be of the spool type as illustrated in FIGS. 4–6. When the valve R is in the operative position 62, a flow

port or passage 62*a* establishes communication from the line 65 to the line 66 for operating a hydraulic piston 67 (FIGS. 4–6) to shift valve F so as to move it to the forward position of FIG. 6. Also, a flow passage 62*b* communicates return lines 68 and 71 to reduce fluid pressure acting on a second hydraulic piston 69 on the opposite end of the four-way valve F from the hydraulic piston 67. The return fluid flows through the lines 71 and 23 for discharge to the sump 10.

The central position 63 of the valve R closes off the flow from the line 65 to the line 66 by the dead-end 63*a*. Also, a T-line 63*b* in the section 33 communicates the lines 66 and 68 with each other so as to equalize the pressure acting on the pistons 67 and 69. In such case, the spring mechanisms 67*a* and 69*a* for the pistons 67 and 69, respectively, or any other suitable return means, is utilized to move the valve F to its braking position.

When the valve R is moved to left as viewed in FIG. 1 to the shifting position 64, the passage 64*a* connects the lines 65 and 68 while the passage 64*b* connects the passages 71 and 66. Thus, the fluid under pressure is admitted to the hydraulic unit 69 to shift the valve F from the brake position (FIG. 5) to the reverse position (FIG. 4). It can thus be seen that by shifting the remote valve R which is in itself a conventional four-way valve, the operating four-way valve F may be shifted to any of the three desired positions.

In the operation or use of the control system C of this invention with the apparatus A of the type disclosed in said copending application Ser. No. 249,854, the pipe P is initially forced into the well which is ordinarily under pressure. For illustration purposes, the chart shown in FIG. 2 is provided. Thus, the vertical axis line of the chart indicated by the letter Y starts from the ground level at the top and is shown as terminating at 15,000 feet, which is an assumed depth for the well into which the pipe P is inserted. The X-axis indicates the load on the pipe P at the various elevations, with zero load being indicated at the intersection of the Y-axis therewith. The inclined line Z in FIG. 2 is representative of typical conditions in which the pipe P is inserted in a well. Thus, with the well pressure at 6,000 p.s.i., the pipe is inserted at the ground level which is indicated at Z–1 with approximately 8,000 pounds of thrust load being applied by the apparatus A in a downward direction for the feeding of a pipe P against the 6,000 p.s.i. well pressure acting upwardly on such pipe P. The apparatus A of FIG. 1 is of course illustrated merely schematically, but includes the endless belts 70 and 71, which are driven by the motors M with the pipe P therebetween so as to force or feed the pipe P downwardly, all as more fully explained in said co-pending application Ser. No. 249,854.

As the pipe P is fed downwardly into the well, the weight of the pipe gradually assists in the feeding operation since its weight is being pulled downwardly by gravity and tends to partially overcome the upward force exerted by the well pressure. Such gradual reduction in the thrust load is reflected by the pressure reading on the gauge 60 and this is indicated by the inclined line Z in FIG. 2. Such inclined line Z ultimately reaches a zero load condition, which is indicated at 4,800 feet in FIG. 2. At that point, which is designated Z–2 in FIG. 2, the weight of the pipe which is in the well is sufficient to overcome the upward thrust of the well pressure. Then, as the pipe continues to move into the well, the additional weight of the pipe reverses the load on the motors M and actually begins to pull on the motors to exert an external load on such motors and operate them as pumps rather than motors. The load developed, as the pipe P is lowered, gradually increases as indicated by the graph line Z in FIG. 2 until at an elevation of 15,000 feet in the well, there is approximately 17,000 pounds of an over-running load on the pipe as indicated at the point Z–3 in FIG. 2.

As previously explained, the valve F is in the forward position 30 aligned with the incoming passage 21 during the time that the pipe is traveling from the position Z–1 to the position Z–2 on FIG. 2. The valve 40 is closed during such travel of the pipe P. When the pipe P has reached the 4,800 foot depth as indicated at the point Z–2 on the FIG. 2 chart, the valve F is shifted to the braking position indicated in FIG. 1 with the section 31 lined up with the conduit 21 as shown. At that point, the valve 40 is opened and the motors M operate as brakes or pumps to retard the downward travel of the pipe P which is being pulled downwardly thereafter by its own weight due to gravity. The pressure which is developed in the line 41 gradually increases as is reflected by the increasing loads from Z–2 to Z–3 on the FIG. 2 chart due to the flow control valve 40 which maintains the constant volume discharge through the line 42, as previously explained. Thus, the pipe P is lowered at a substantially constant speed from the ground level to its lowest elevation.

On the return trip or removal of the pipe P from the well, the valve F is shifted to the reverse position so that the section 32 is lined up with the inflowing fluid line 21. The valve 40 is closed when the valve F is thus shifted. Assuming the reversal of the motors occurs at the 15,000 foot elevation indicated at Z–3 of FIG. 2, the motors M will thus be driven so as to move the belts 70 and 71 for lifting the pipe P. The maximum pressure developed for lifting will thus occur at the 15,000 foot elevation, or such other elevation at which the pipe P is located upon the beginning of the removal step. The amount of pressure in the line 35 is gradually decreased as indicated by the line Z in moving from the point Z–3 to the point Z–2. When the pipe P reaches the point Z–2, it is again in a neutral load condition at which time the weight of the pipe is balanced against the force of the well pressure tending to push the pipe upwardly. Thereafter, the pipe P must be restrained from being forced out of the well by the fluid pressure. Therefore, when the pipe P reaches the point at the 4,800 foot elevation, or such other elevation at which the pressure is balanced against the weight of the pipe as indicated at Z–2, the control valve F is shifted to the braking position 31 and the valve 40 is again opened.

At that time, the motors are again operated as pumps and retard the upward movement of the pipe so that such pipe can travel upwardly at a substantially constant speed by reason of the upward force of the well pressure acting thereon. The braking forces are indicated on the chart of FIG. 2 as gradually increasing from the point Z–2 to the point Z–1, at which time the pipe P has been fully retrieved from the well.

During the travel of the pipe from the point Z–2 to the point Z–1, the fluid from the incoming line 21 flows through the braking section 31 to the flow conductor 33 which then joins with the by-pass flow from the line 22 for flow to the flow conductor 23. Since the motors M had been operating on a reverse cycle prior to the braking action, the motors M are actually rotating in a reverse direction to that direction in which they roate for the downward feeding of the pipe P. Therefore, coming out of the well with the pipe, the motor M on the left for the conveyor 70 is rotating counterclockwise and the motor M on the right for the conveyor 71 is rotating clockwise as the pipe P is retracted or removed from the well. Thus, when the motors M are being operated as pumps on the withdrawal of the pipe P, the higher pressure is developed in the line 34 so that the fluid supplied through the line 44 enters the check valve 49 and flows to the line 47 and then to the line 35 for replenishing the fluid discharged from the motors M. The check valve 45 is not utilized since the higher pressure in the line 46 prevents its opening. The fluid which is being pumped by the motors M is discharged through the line 46, the check valve 50 and is then returned to the discharge line 41. The control valve 40 functions in the same way as heretofore de-

scribed in connection with the braking action during the feeding of the pipe into the well so that as the pressure in the line **41** increases, the flow through the valve **40** becomes more restricted so that a constant volume of discharge through the line **42** is maintained, as described above and as will be understood by those skilled in the art.

For purposes of illustration, FIG. 2 also shows another chart line indicated at K which shows the insertion of a pipe P into a well in which there is no pressure. Because of mechanical and frictional forces normally tending to restrain downward movement of the pipe, a small amount of initial downward feeding force is generally required, but for illustration, this factor has been ignored. Thus, the pipe starts at the point K–1 which is at zero pressure and the gravity then is pulling the pipe downwardly into the well. In such case, the control system C is started with the apparatus in the position shown in FIG. 1, namely, with the braking section **31** in operating position. As the weight of the pipe P increases down to the depth of 15,000 feet, the overrunning loading increases until it reaches the 25,000 pounds indicated in FIG. 2 at the point K–2, which in fact is the weight of the 15,000 feet of pipe P.

When removing the pipe from the well, the valve F is shifted to the reverse position with the reverse section **32** in operating position, and the pulling force is exerted for the entire travel from the point K–2 to the point K–1, but such pulling forces is necessarily decreased as indicated by the slope in the line K due to the decreasing weight of the pipe P in the hole.

It will be appreciated that other conditions in the well may occur, but the conditions illustrated in the graph lines Z and K in FIG. 2 are believed sufficient to clearly describe the functioning and operation of the control system C of this invention in connection with the apparatus A.

In FIG. 7, a modified control system is illustrated wherein a pressure-compensated flow divider and controller FD is incorporated in place of the valves **20** and **40** of FIG. 1, but otherwise the system of FIG. 7 basically is the same as that disclosed in FIG. 1. The controller FD includes a body **80** having a first bore **80** and a second bore **80***b* with a counterbore **80***c* interconnecting same at an intermediate point within the body **80**. The body **80** has fluid inlet ports **80***d* and **80***e* which communicate with the bore portion **80***b* and which are interconnected preferably by a small orifice **80***f*. An outlet **80***g* is provided in the body **80** for establishing communication with the bore **80***a* as will be explained.

The body **80** is closed at its left end by a closure **80** which is suitable secured to the body **80** and which is provided with an outlet opening **81***a* from the bore **80***b*. The body **80** is closed on its right-hand end by a closure plate **80** which is secured by any suitable means to the body **80** and which has a central guide opening **82***a* therein with a suitable seal ring **82***b* such as a rubber O-ring mounted therein.

For setting the flow through the controller FD from line **123** to line **142** at a predetermined flow, a valve element **83** having a valve stem or handle **83***a* is provided. Such valve element **83** is indicated to be movable back and forth within the bore portion **80***a* for purposes of illustration but could be constructed movable in a rotary or other fashion to provide an adjustable restriction to flow from the bore **80***c* to line **142**. The release port **83***b* is provided to prevent a fluid lock during such adjustment. The element **83** has an inner bore **83***c* which is in communication with the counterbore **80***c* and which is also in communication with one or more ports **83***d*. The ports are adapted to be aligned with the port **80***g* which preferably has an annular portion **80***h* to facilitate such alignment. Thus, the extent to which the openings **83***d* are open relative to the annular port **80***h* and the outlet port **80***g* determines the flow through the port **80***g*. If the openings **83***d* are fully aligned with the port **80***g*, th maximum flow through the controller FD to port **80***g* : provided, whereas a movement of the valve element **8** to the left to partially close the openings **83***d* with respec to the port **80***g* restricts the flow and reduces the volum of the fluid passing through the controller FD to outle **80***g*. The valve element **83** is therefore initially set a a desired opening when the controller FD is put into use but until that time, the controller FD may be kept close by positioning the element **83** to the extreme left positio indicated in FIG. 7.

A valve spool **85** is disposed in the bore portion **80** for axial movement with respect to the body **80**. The spoc **85** has a right bore **85***a* which is open for communicatio to the counterbore **80***c* and which also communicate with one or more ports **85***b*. The port **80***e* has an annula channel or port **80***k* which makes it possible for each o the ports **85***b* to communicate with the port **80***e* so tha the incoming fluid from the port **80***e* passes through th ports **85***b* and flows through the counterbore **85***a* for ulti mately discharging at the outlet port **80***g* as will be mor evident hereinafter.

The spool **85** has a left bore **85***c* which is open on th left end for allowing fluid to flow through the outlet **81***a* Also, one or more ports **85***d* are provided for communi cating the bore **85***c* with an annular groove or passag **80***m* and a port **80***d* when the port or ports **85***d* are aligne with the port **80***d*. The spool **85** is urged to the right whe no pressure is acting thereon by a spring **86** or othe similar resilient means.

In FIG. 7, the parts which are identical with thos heretofore described in connection with FIG. 1 are indicated with the same numerals and/or letters, but th modified parts bear new designations. Thus, the four-wa valve F is schematically illustrated in FIG. 7 with th three positions **30**, **31**, and **32** corresponding to the identical positions of FIG. 1. FIG. 7 also has the identica check valves **45**, **50**, **48**, and **49**, and also the relief valve **52** as described and illustrated heretofore in connectio with FIG. 1. The motors M are also illustrated in FIG. 7 in the same manner as in FIG. 1, and the apparatus A with which the control system of this invention may be used is likewise illustrated in FIG. 7 or correspond with the illustration in FIG. 1. The various interconnecting pipes or lines are identified with the numerals corresponding to those used in FIG. 1 where applicable as will be more evident hereinafter.

In the operation or use of the control system of FIG. 7 with the controller FD therein, and with the four-way valve F in the forward position **30**, the normal flow of fluid is from the pump P through the lines **16**, **116**, and **34** to the motor or motors M which are being operated by such fluid. The pump P is generally a constant volume pump or other source of fluid supply in the same manner as described heretofore in connection with FIG. 1. The fluid returns from the motor or motors M through the line **35** to the line **123** and then to the controller FD. It is to be noted that the flow line **121** is connected to the line **116** so that a portion of the fluid from the pump P may be directed through the line **121**, the amount depending upon the setting of the valve element **83** in the controller FD. Thus, after the controller FD is in its initial balanced condition and is operating properly, the line **116** will carry approximately one-half of the volume of fluid from the pump if the valve element **83** is set so that approximately one-half of the extent of the openings **83***d* is in register with the port **80***g*. Other proportions may likewise be obtained by the corresponding settings of the valve element **83**.

With the valve element **83** thus set at the desired amount of flow, the pressure initially developed in the line **123** is greater than the pressure in the line **122** so that the spool **85** is urged to the left as seen in FIG. **7** resulting in a partial opening of the openings **85***d* and a partial closing of the openings **85***b*. The spool **85** thus assumes

a position in which the force on the spool **85** due to the pressure within the bore **85***c* plus the force of the spring **86** are balanced by the force due to the pressure of the fluid within the bore **85***a* of the spool **85** so that there is flow through the controller FD from both of the lines **121** and **123** at relative volumes as determined by the setting of the valve element **83**.

When the load on the motors M decreases, such as during the forcing of the pipe P into the well as explained heretofore, the volume of the fluid will start to increase in the flow lines **116** and **123**. Such increase in flow will only be instantaneous since it will cause an increased pressure drop through the openings **83***d* which will increase the pressure acting upon the valve spool **85** in a direction tending to move the valve spool **85** to the left. The movement of the spool **85** to the left restricts the openings **85***b* to thereby restrict the volume and actually prevent any increase in the fluid flow thereby maintaining the volume of the fluid flowing from the line **123** to the discharge line **142** at a constant value.

Should the volume of the fluid flowing in the line **123** tend to decrease, the opposite effect would be produced and the valve element or spool **85** would move to the right to thereby open the openings **85***b* to a greater extent until there was again a balance of forces acting in opposite directions on such spool **85** and so as to again maintain a constant volume of fluid flow through the lines **123** and **142**.

When the motor or motors M start to operate as pumps, there will be a tendency to increase the volume flow through the line **123** which will again increase the pressure drop through the openings **83***d*. Such pressure drop increase will increase the force acting on the spool **85** so as to move the spool **85** to the left to restrict the openings **85***b* until the forces acting in opposite directions on the spool **85** are again balanced and so as to maintain the constant volume flow through the controller FD at the outlets **123** and **142**.

It will thus be appreciated that the controller FD of FIG. 7 provides for an automatic maintenance of the constant flow or volume while also providing for the changes in pressure within the system to accommodate the varying loads on the fluid motor to motors M. Additionally, it is important to note that the motors M are thus maintained at a constant regulated speed automatically and without the necessity for the hand manipulation of the valve FD after it has been set to the desired flow volume. By using the valve FD in the flow system of FIG. 7, the fluid flow is divided and at the same time it eliminates the development of any pressure in the system significantly in excess of that required for operation of the motor or motors under the load prevailing since the fluid pressure from the pump P is adjusted automatically in accordance with the load on the fluid motor or motors M. As a safety factor, a relief valve **88** is provided in the system in line **124**, but in normal operation, such valve **88** is unnecessary.

It will also be noted that through the use of the controller FD of FIG. 7 it is unnecessary to shift the four-way valve F for braking the load when the load changes and the motor or motors M start operating as pumps or vice versa, since the controller FD is automatically regulating the desired flow volume leaving the motor or motors M while concurrently diverting any excess fluid flow leaving the pump P without developing pressure in the system significantly above that pressure required for the operation of motor or motors M under the load prevailing.

Heretofore, the control system of FIG. 7 has been described with the four-way valve F in the operating position **30**. When the flow is through the valve F in the reverse position **32**, the controller FD will function in the same manner as heretofore described, except that the forces from the motors M will be in the opposite direction since the motors themselves are operated in the opposite direction. When the valve F is in the center position **31**, the fluid in the flow line **116** actually passes directly to the flow line **123** through the passage or port **31***a* in the valve F, and the flow of fluid to the motors M is blocked to prevent operation of the motors M in either direction. Such center section **31** could be eliminated from the valve F in the system of FIG. 7, if desired.

When the valve F is in the center position **31**, line **124** is in communication with the motor or motors M through the line **144** and either of the check valves **45** and **49**. As explained in connection with such valves **45** and **49** in FIG. 1, the flow therethrough depends upon the pressures in the lines **34** and **35**. If the pressure in line **34** is higher than in line **35**, the flow from line **144** is to the motors M through check valve **49** and line **35**. Fluid returns from the motors M through the higher pressure line **34** to the check valve **50**. If the pressure in line **35** is higher than in line **34**, the flow from line **144** is through the check valve **45** and line **34** to the motors M and the return from the motors M is through the check valve **48**. The relief valve **52** is set at a pressure slightly above the normal maximum working pressure so that when the valve F is shifted to the center position **31**, the maximum working pressure will be applied to the motors M to bring them to a smooth stop without developing excessive pressures and the load on the motors M will be held.

In FIG. 8, a modified valve FD–**1** is illustrated which may be used in place of the valve FD in the control system of FIG. 7. The valve FD–**1** has a body **180** with a longitudinal bore **180***a* and another longitudinal bore **180***b* therebelow. The bore **180***b* is divided into two sections with a counterbore **180***c* therebetween of a smaller diameter. Inlet openings **180***d* and **180***e* are provided for connections with the lines **121** and **123**, respectively, as schematically indicated by the numbered arrows in FIG. 8. The body **180** has an end closure plate **181** having an outlet opening **181***a* which is adapted to be connected to either the line **142** or the line **122** in FIG. 7, but for purposes of illustration, the arrow is schematically indicated in FIG. 8 with the numeral **142**. At the opposite side of the body **180**, another end plate **182** is provided, such end plate **182** having an opening **182***a* with a resilient O-ring **182***b* disposed therein.

For controlling the percentage of volume flow through the flow divider FD–**1**, a valve element **183** having a handle **183***a* slidably positioned through the opening **182***a* is provided. Such valve element **183** is disposed for axial movement for purposes of illustration but it could be constructed for rotary or other movement within the bore **180***a*; it has a relief port **183***b* to prevent a fluid lock during such axial movement. The bore **183***c* of the element **183** is open on its left end for communication with the outlet port **181***a* and it has a plurality of ports **183***d*, **183***e* and **183***f*. As will be explained, by positioning the valve element **183**, the percentage of the volume provided by the pump P is constantly maintained to the motor or motors M.

In the form of the flow divider FD–**1** of FIG. 8, instead of having the single spool control valve **85** as shown in FIG. 7, the flow divider FD–**1** is provided with spool control valves **185** and **185'**. The valve **185** has a bore **185***a* therein with a port or ports **185***b* communicating with the passage **180***e*. Also, the bore **185***a* is in communication with a passage **180***g* through the body **180** so as to communicate with the port or ports **183***e*, as will be explained. A spring **186** urges the valve **185** to the right with a predetermined amount of force.

The valve **185'** has a bore **185***c* and one or more ports **185***d* which communicate with the inlet port **180***d*. The body **180** has a passage **180***m* which communicates with the inner bore **185***c* of the spool valve **185'** so as to communicate with the port or ports **183***d*, as will be more evident hereinafter. The valve element **185'** is urged to the left by a spring **186** with a predetermined amount of force.

A small relief port **180***k* is provided in the body communicating the space between the elements **185** and **185'** with the port or ports **183***f*.

In the use of the valve or flow divider FD–**1**, it is assumed that it is used in the control system of FIG. 7 in place of the controller FD and with the lines connected as indicated in FIG. 8 to control the flow of the fluid in basically the same manner as heretofore described in connection with the controller FD. Thus, the valve element **183** is initially positioned so that the percentage of the openings **183***d* exposed to the port **180***m* establishes the percentage of fluid flow in the line **121** and thus the percentage of flow to the motor or motors M. With the valve element **183** thus set at the desired volume percentage of the constant volume output from the pump P, the flow is divided as to volume between the two valve elements **185** and **185'**. If, for example, the openings **183***d* are opened for seventy-five percent of the volume from the pump P, the remaining twenty-five percent will flow through the port or ports **183***e*. Likewise, seventy-five percent of the volume will flow through the line **121** and the valve element **185'** while the remaining twenty-five percent will flow through the line **123** and the valve element **185**. In the event the flow in the line **121** increases due to a decrease in the load on the motor or motors M, the pressure within the valve element **185'** increases to cause the element **185'** to move to the right. Such movement to the right reduces the size of the exposed portion of the openings **185***d* to the inlet **180***d*, thereby restricting the flow and maintaining the volume through the openings **185***d* at a constant value. At the same time, the volume in the line **123** tends to decrease, causing a lower pressure in the valve **185** which moves it to the right. It will be understood that prior to such decrease, the valve **185** is positioned to the left of that shown in FIG. 8 so that there is room for its movement to the right. Such movement to the right tends to increase the extent of the openings **185***a* exposed to the inlet opening or port **180***e* so as to also maintain the volume through the valve element **185** at a constant amount. When the volume flow tends to decrease due to an increasing load on the motors M, the reverse action takes place with respect to such valve elements **185** and **185'**.

When the motor or motors begin to operate as pumps on the forward cycle, the flow of the fluid in the line **123** will tend to increase, thereby forcing the valve element **185** to the left to decrease the size of the openings **185***b* exposed to the port **180***e* so as to maintain the volume in the line **123** at a constant amount. The valve element **185'** will tend to open proportionately during such closing of the valve **185** so that the flow in the line **121** is also maintained substantially constant. It is to be noted that the valve or flow divider FD–**1** accomplishes the proper division of the fluid flow and maintains such flow volume constant in each of the lines **121** and **123** even though the pressures in such lines vary in accordance with the load on the fluid motor or motors M. Such control is accomplished automatically without the requirement for any manual manipulation of the flow divider FD–**1**, other than the initial setting of the valve element **183**. The motors M may pass from the stage in which they are feeding the pipe P into the well under pressure to the second stage in which they act as pumps, without requiring any manual manipulation of the flow divider FD–**1**, as was of course true with the controller FD. Therefore, the flow divider FD–**1** is a modification of the structure of the controller FD, both accomplishing similar results. It will be appreciated that other variations may be made in such structures within the skill of the art.

The foregoing disclosure and description of the invention is illustrative and explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made within the scope of the appended claims without departing from the spirit of the invention.

What is claimed is:

1. A control system for controlling operation of a fluid motor subjected to varying loads, comprising:
(a) a fluid motor,
(b) supply means for supplying fluid to the fluid motor,
(c) a first conduit means connecting said supply means to said fluid motor,
(d) a constant volume control valve in said first conduit means for maintaining a constant volume flow from said supply means to said fluid motor,
(e) means in said valve including passage means for diverting a portion of the fluid from flow to said fluid motor,
(f) a second conduit means for returning diverted fluid to said supply means,
(g) means in said passage means of said control valve for maintaining the inlet pressure thereto from said supply means substantially the same as the pressure of the fluid flowing to said fluid motor,
(h) a third conduit means for returning fluid from said fluid motor to said supply means, and
(i) means establishing fluid communication between the diverted fluid from said control valve and the returning fluid from said fluid motor.

2. The structure set forth in claim **1**, including:
(a) means communicating with said first and second conduit means for circulating any volume of fluid being pumped by the fluid motor which is in excess of the volume of fluid supplied to the fluid motor from the supply means.

3. The structure set forth in claim **1**, including:
(a) means for maintaining a predetermined back-pressure in said conduit means which is substantially lower than the pressure of the fluid supplied to said fluid motor.

4. The structure set forth in claim **1**, including:
(a) a second constant volume control valve connected in said third conduit means for maintaining a controlled volume discharge from the fluid motor when it is operating as a pump.

5. The structure set forth in claim **1**, wherein:
(a) said constant volume control valve includes therewith valve means for automatically maintaining a controlled volume discharge from the fluid motor when it is operating as a pump.

6. The structure set forth in claim **1**, wherein:
(a) constant volume control valve is a flow divider for dividing the volume of fluid flow from the supply means into selected percentages, and
(b) said flow divider having means for automatically maintaining such selected percentages substantially constant while varying the fluid volume from the supply means.

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