

May 10, 1960

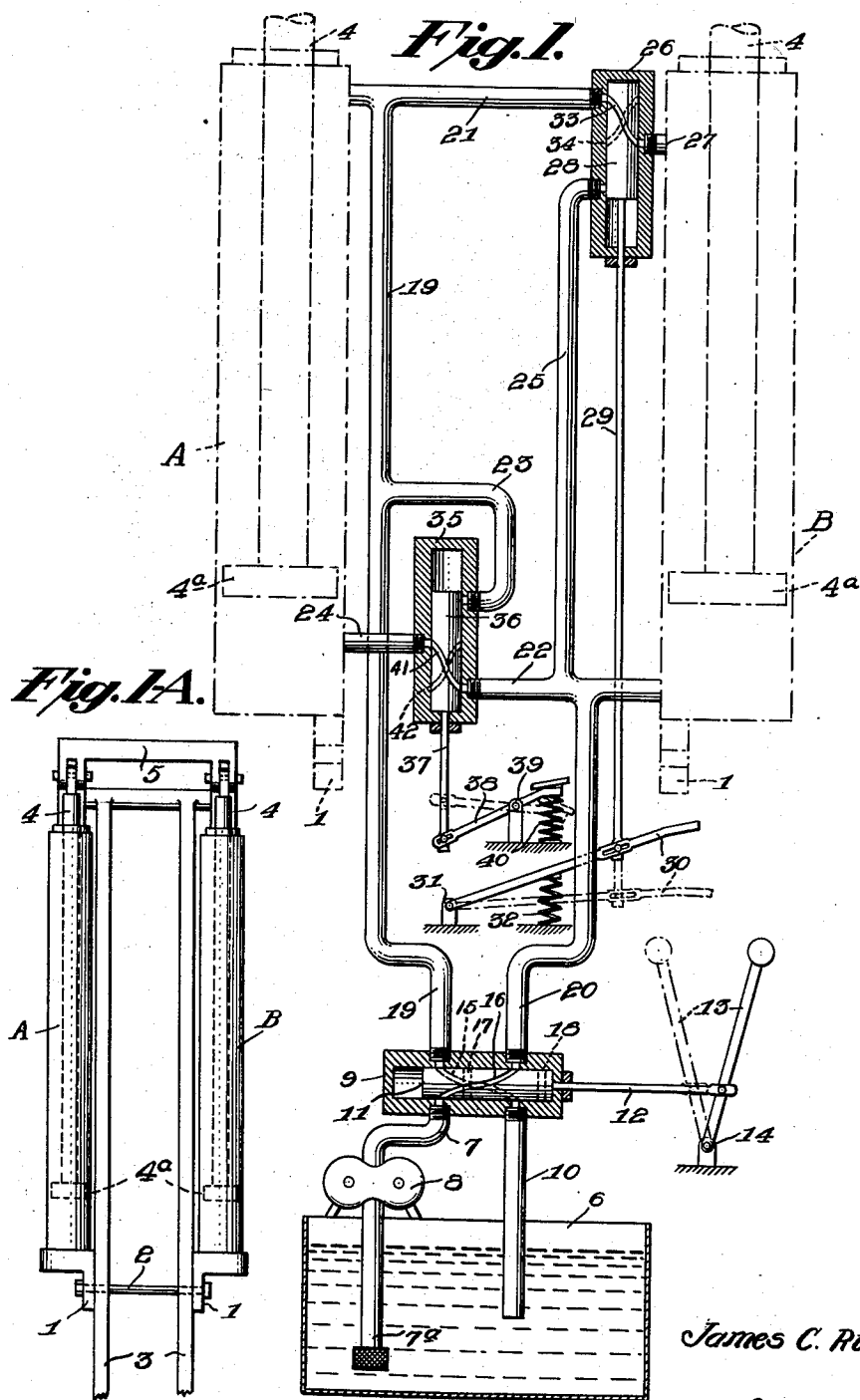
J. C. RUSSELL

2,935,852

MULTIPLE SPEED RECIPROCATING HYDRAULIC MOTORS

Filed April 16, 1957

4 Sheets-Sheet 1



INVENTOR
James C. Russell

BY *Stone, Boyden & Mack,*

ATTORNEYS

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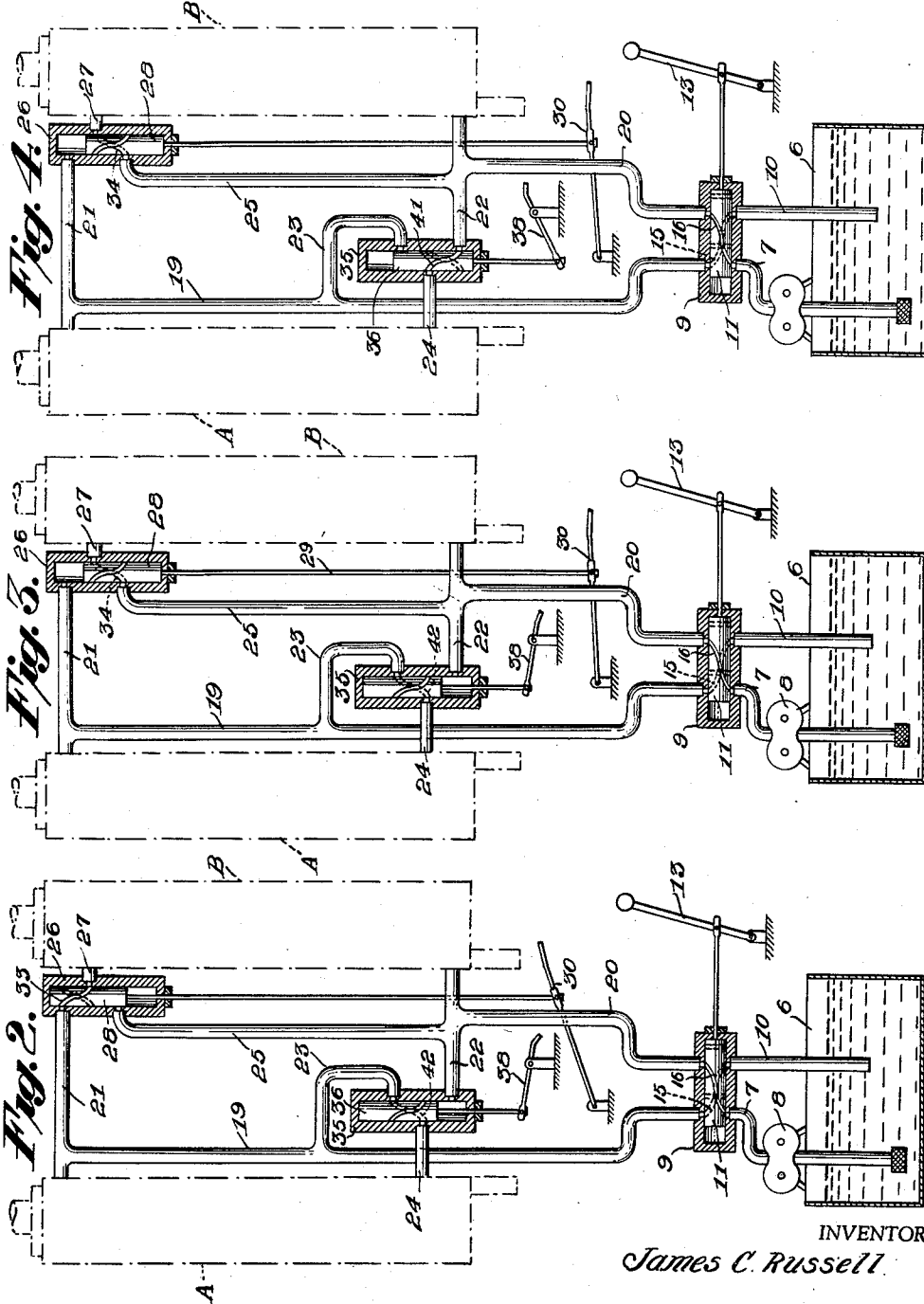
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MULTIPLE SPEED RECIPROCATING HYDRAULIC MOTORS

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4 Sheets-Sheet 2



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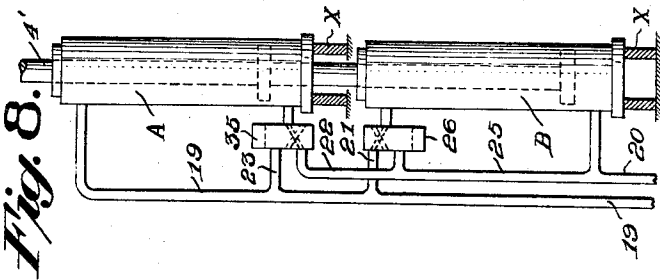
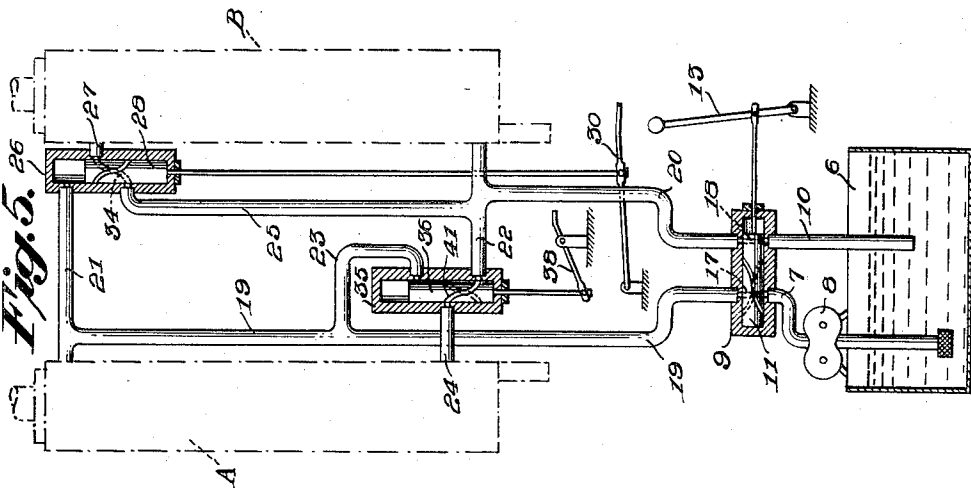
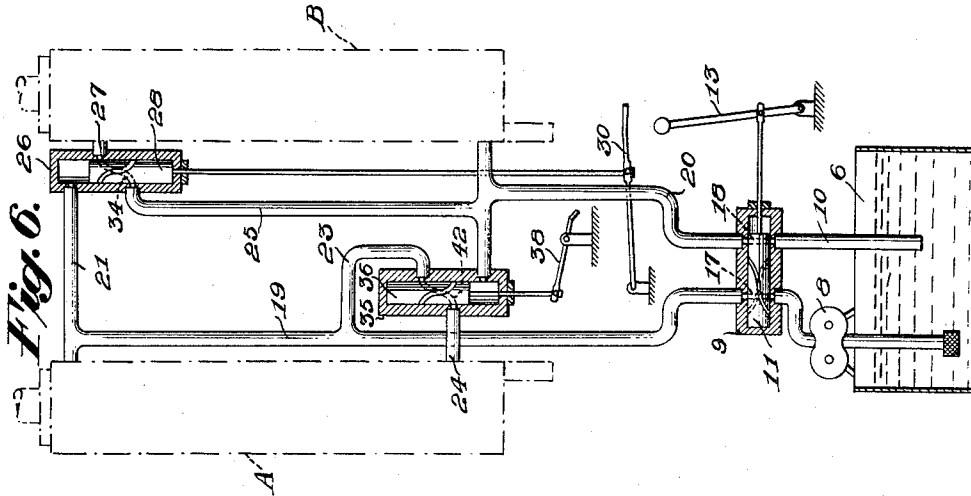
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MULTIPLE SPEED RECIPROCATING HYDRAULIC MOTORS

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4 Sheets-Sheet 4

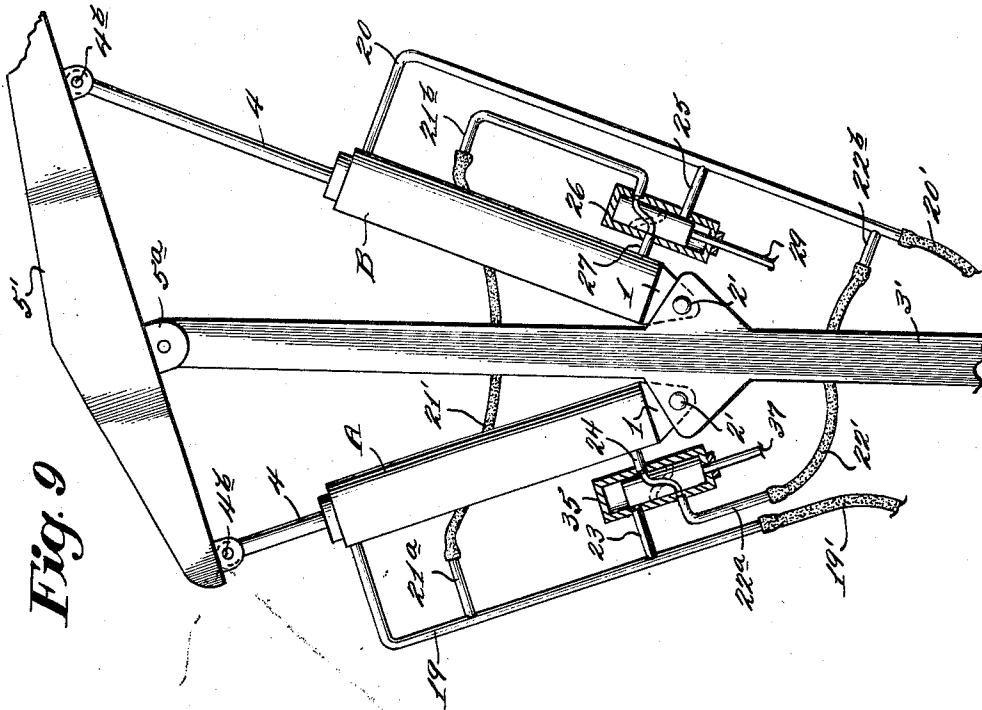


Fig. 9

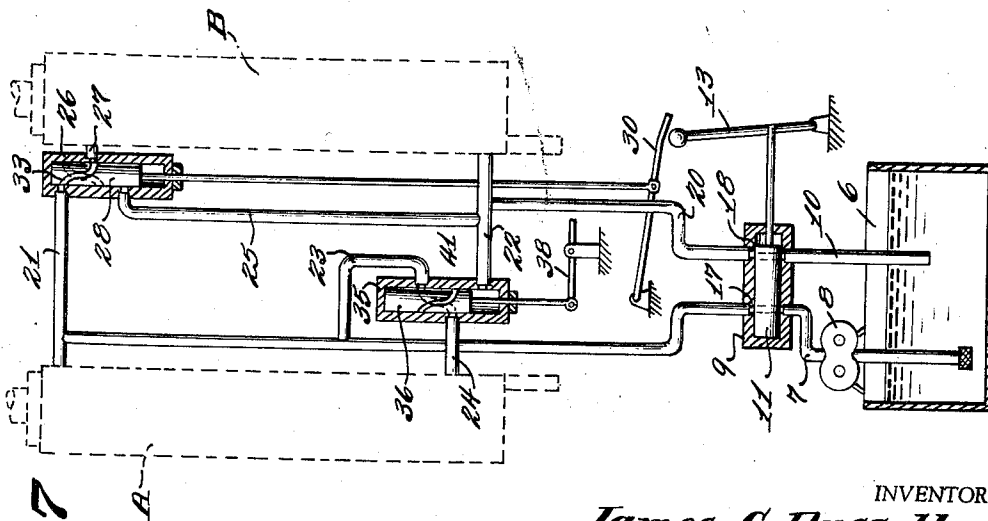


Fig 7

INVENTOR

James C. Russell,

BY *J. Hanson Boyden*

ATTORNEY

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2,935,852

MULTIPLE SPEED RECIPROCATING HYDRAULIC MOTORS

James C. Russell, Yakima, Wash.

Application April 16, 1957, Serial No. 653,167

8 Claims. (Cl. 60—97)

This invention relates to hydraulic motors and methods of controlling the same, and more particularly to motors comprising a pair of cylinders, having pistons which are mechanically connected so that they move together.

The present application is a continuation-in-part of my prior co-pending application S.N. 481,851, filed January 14, 1955, now abandoned.

In systems employing motors of this kind, the hydraulic fluid may be delivered under pressure from any suitable source, but is usually supplied to the cylinders by means of a continuously operating pump, the admission of fluid to the cylinders being controlled by a "master" valve, and it is common practice to govern the speed of movement of the pistons in the cylinders by opening this valve to any desired extent. When the valve is only partially open, the flow of fluid from the pump is more or less throttled, thus slowing down the movement of the pistons, and when the valve is fully open, fluid flows freely from the pump to the cylinders, thus causing the pistons to move at their maximum rate.

Where the cylinders are double-acting, the "master" valve is in the nature of a four-way valve, and is so constructed that it may direct fluid to either end of the cylinders while simultaneously permitting fluid to escape from the other end.

In many cases it is highly desirable to cause the pistons to travel in one direction at a much higher speed than in the other. Thus, for example, in hydraulically operated earth working machines such as a "backhoe," it is desirable, in the interest of efficiency, to move the dipper stick faster during the dumping stroke, where less power is required, than during the digging stroke, and in a power shovel it is desirable to move the shovel, on the back stroke at substantially greater speed than on the forward stroke.

Furthermore, to achieve still greater efficiency, it is highly desirable to be able to change the speed of travel of the pistons, when moving in either direction, at any time, so as to save time by completing a stroke faster whenever the power demand is reduced.

It is therefore an object of the present invention to provide means in addition to the "master valve," and operable at will, by which the speed of travel of the pistons of a two-cylinder motor, where the cylinders are of the same size, may be increased at any desired point of the stroke up to at least double the maximum normal speed produced by shifting the "master valve" to wide open position.

A further object is to provide means, in connection with motors having two similar cylinders of the double-acting type, for increasing the speed of travel of the pistons in one direction up to several times the maximum normal speed, and, in a case where the effective area of the piston rod is one half that of the piston, up to approximately four times normal speed.

A still further object of the invention is to devise means in connection with a double acting, two-cylinder motor,

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for fractionally increasing the speed of travel of the pistons over the normal maximum speed.

From the foregoing, it will be understood therefore, that the invention contemplates the provision of a multiple-speed hydraulic cycle arrangement for two-cylinder motors, and, as will hereinafter appear, these multiple speeds are achieved without sacrificing any of the piston area which is normally available for producing power.

The cylinders may be disposed either side by side or in tandem relation, as conditions may require, and the pistons may be arranged to move simultaneously in either the same or opposite directions, as desired.

In order that the invention may be readily understood, reference is had to the accompanying drawings, forming part of this specification, and in which:

Fig. 1 is a view illustrating my improved control system in its entirety, parts being shown in section and the cylinders being shown in broken lines;

Fig. 1-A is an elevational view on a smaller scale illustrating one method in which the cylinders may be mounted in actual practice;

Figs. 2 to 7, inclusive, are a series of views similar to Fig. 1, but on a smaller scale, illustrating different possible combinations of valve positions for giving various speeds of piston movements;

Fig. 8 is an elevational view showing a modification in which the cylinders are arranged in tandem instead of in parallel; and

Fig. 9 is a partially diagrammatic elevational view showing a further modified arrangement in which the pistons of the two cylinders move simultaneously in opposite directions.

Referring to the drawings in detail and first to Fig. 1-A thereof the two cylinders are shown at A and B and are shown as having lugs 1 at their lower ends, supported by means of a pivot bolt 2 on the boom 3 of a special type of excavating machine known as a "backhoe." The cylinders are of the double acting type and in each works a piston 4^a carried by a piston rod 4. The upper ends of the piston rods are shown as pivotally connected to a cross-head 5 which may be secured to the dipper stick of the machine. Thus, it will be seen that the two cylinders are mounted on a common support and that the piston rods 4 are mechanically connected so that the pistons must move together. The essential thing, so far as the present invention is concerned is that the two cylinders are mounted on a common support and that the pistons are mechanically connected so as to move together, and it will be obvious that many other possible arrangements, in addition to that illustrated by way of example in Fig. 1-A can be employed, dependent upon the particular type of machine to which the cylinders are applied.

By the term "double acting cylinders" as used in the specification and claims, I mean cylinders having both ends sealed, and associated with means by which motive fluid can be supplied to either end as desired, so that the pistons may be driven in either direction.

Although, of course, each cylinder is of the same diameter throughout its length, it is obvious that the fluid capacity of that end of the cylinder through which the piston rod does not extend is much greater per unit of length than that of the end containing the piston rod. For convenience, therefore, to distinguish between the two ends of the cylinder, I shall refer to the end through which the piston rod passes as the "rod end" and the other end as the "big end," that is, the end having the greater fluid capacity, and the fluid in which acts upon a larger piston area.

Referring now to Fig. 1, my improved hydraulic system for controlling the speed of the pistons in the cylinders A and B comprises a tank 6 containing oil or

other suitable motive fluid. Associated with this tank is a rotary pump 8, driven by a suitable motor (not shown) and illustrated as of the gear type. An intake pipe 7^a extends from the pump down into the tank, and a delivery pipe 7 is connected with the outlet side of the pump.

In connection with the pump I employ a "master" valve 9 of a well known type. The delivery pipe 7 connects with this valve and an exhaust pipe 10 extends from the valve into the tank 6.

The valve 9 comprises a reciprocating valve member 11 connected by a rod 12 to an operating lever 13 pivoted at 14 to a fixed support. The valve 9 is of the type known as a four-way valve, and in addition to the pipes 7 and 10 another pair of pipes 19 and 20 are connected with this valve on the opposite side.

The valve member 11 has formed therein a pair of diagonally extending ports 15 and 16 and also a pair of transversely extending ports 17 and 18. When the valve member 11 is in the position shown in Fig. 1, it will be seen that the pipe 19 is connected through the port 15 with the exhaust pipe 10, while the pipe 7 is connected through the port 16 to the pipe 20. When, on the other hand, the valve is shifted to its left hand position as indicated by the broken line position of lever 13, the port 17 connects the pipes 7 and 19 while the port 18 connects the pipes 10 and 20.

The pipes 19 and 20 serve to deliver motive fluid to the cylinders A and B and may be called the supply pipes. In the conventional arrangement of twin cylinder motors of the type to which the invention relates, it is the common practice to have one supply pipe such as 19 connected with an equalizing pipe 21 extending between the upper ends of the two cylinders and to have the other supply pipe 20 connected with a second equalizing pipe 22 extending between the lower ends of the cylinders.

With such an arrangement it will be seen that when the pump 8 is running and the master valve is in full line position, as shown in Fig. 1, motive fluid is delivered from the pipe 7 to the supply pipe 20, and thence to the bottom of both cylinders, thus forcing the pistons upwardly. This will be referred to as the "extend" stroke. At the same time the fluid which is in the cylinders above the pistons will be forced out through the equalizing pipe 21 and pipe 19 to the exhaust pipe 10 leading to the tank. This is the normal operation of conventional twin cylinder motors.

In carrying out the present invention I modify the conventional arrangement by providing between upper and lower ends of each cylinder what I shall call a by-pass pipe or conduit, each of such by-pass pipes being controlled by what I shall term, a "diversion" valve. By reference to Fig. 1 it will be seen that a by-pass conduit connecting the opposite ends of cylinder A comprises the pipe 23, and that this by-pass conduit is controlled by a diversion valve 35, preferably located near the lower end of the cylinder. It will be further seen that this diversion valve is interposed in the equalizing pipe 22, 24.

Similarly, the by-pass conduit connecting the opposite ends of cylinder B comprises the pipe 25 which is connected at its lower end with the pipe 22. This by-pass conduit is controlled by diversion control valve 26, which, in turn, is interposed in the equalizing pipe 21, 27.

The diversion valve 26 comprises a reciprocating member 28, in which are formed a pair of diagonally extending ports 33—34, and the diversion valve 35 comprises a reciprocating member 36 in which are formed diagonally extending ports 41 and 42. When in normal position the port 33 establishes a connection between pipes 21 and 27, and when in the actuated position as in Fig. 3, the port 34 establishes a connection between pipes 25 and 27. Similarly, when in normal position the port 41 of valve 35 establishes a connection between pipes 22 and 24, and when in its actuated position as in Fig. 2,

the port 42 establishes a connection between pipes 23 and 24.

The member 28 of valve 26 is reciprocated by means of a rod 29 connected at its lower end to a lever or foot pedal 30 pivoted at 31 to a fixed support and maintained in its elevated or full line position by means of a spring 32.

Similarly, the member 36 of valve 35 is reciprocated by means of a rod 37 connected at its lower end with a lever or foot pedal 38 pivoted at 39 on a fixed support and maintained in its lower or full line position by means of a spring 40.

Thus, the springs 32 and 40 serve to maintain the valve members 28 and 36 in what I shall call normal positions as illustrated in full lines in Fig. 1. When in such position, it will be seen that the port 33 in the valve member 28 connects the equalizing pipe 21 with pipe 27 set into the upper end of cylinder B, while the port 41 in valve member 36 connects the equalizing pipe 22 with the pipe 24 set into the lower end of cylinder A. Thus, when the valves are in this normal position, the equalizing pipes 21 and 22 connect the upper and lower ends of the two cylinders, respectively, thus resulting in an arrangement similar to the conventional arrangement of two cylinder motors as above described and operating in the same manner. In other words, with the arrangement shown in full lines in Fig. 1, the two cylinders operate in the normal conventional manner.

When operating in this manner, it will be noted that motive fluid is supplied to the two cylinders in parallel, that is to say, the fluid delivered by the pump divides between the two cylinders, part going to each. Since the pump when running at constant speed as is usual delivers motive fluid at a definite constant rate, this rate determines the speed at which the pistons will move, and in the following discussion this speed, when the cylinders are connected in parallel as shown, will be referred to as "normal" speed.

While, of course, the piston rods 4 may be made of any desired size, it is customary practice to make them of such size that their cross sectional area is equal to one-half the area of the piston 4^a. Thus, when fluid is admitted through pipe 20, to the lower or so called "big" ends of the cylinders, to produce the "extend" stroke, the pistons will move at a certain maximum speed. When, however, motive fluid is admitted to the upper or rod ends of the cylinders through pipe 19, the capacity of these ends is only one-half of the capacity of the big ends and thus, the rate of delivery of fluid from the pump being constant, the downward or "retract" stroke will take place at double the speed of the "extend" stroke. This is true of both the conventional arrangement and the arrangement shown in full lines in Fig. 1.

It is often desirable, however, to increase the speed of movement of the pistons, on either the "extend" or "retract" stroke, or both, and this may be accomplished by selectively and individually actuating the diversion valves 26 and 35 as desired, while at the same time manipulating the master valve to control the direction of movement.

Referring now to Fig. 2, I have shown the valve member 36 shifted from its lower to its upper position. When in this position, and when the master valve is in the "extend" position as shown, motive fluid will be delivered through supply pipe 20 directly into the lower end of cylinder B, but it cannot flow through any of the other pipes or conduits since the conduit 25 is blocked at its upper end by the valve member 28 and the equalizing pipe 22 is blocked by the valve member 36. Thus, the entire amount of fluid supplied by the pump is delivered into the big end of cylinder B alone, cylinder A being isolated. Since the output of the pump which was normally divided between the two cylinders is now delivered only into one cylinder, it will cause the piston to move at twice normal speed.

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The fluid trapped in the upper end of cylinder B escapes through pipe 27, port 33, and pipe 21 into pipe 19 and thence through port 15 of the master valve to the exhaust 10. At the same time the fluid trapped in the upper end of cylinder A also escapes through pipe 19. As the piston moves upward in cylinder A, however, it tends to create a void in the lower end of the cylinder and this void is filled by fluid coming down pipes 19 and 23 and flowing into the lower end of the cylinder through port 42 and pipe 24. Thus these last mentioned arrangements constitute a by-pass around the piston of cylinder A so that this piston may freely move, when pulled along by the motive fluid in cylinder B.

In Fig 3 I have shown another combination in which both valves 26 and 35 have been actuated by means of the foot pedals, and both have been moved to positions opposite the normal positions shown in Fig. 1.

Assuming the master valve to be in "extend" position as before, motive fluid will now be delivered through pipe 20 into the lower end of cylinder B and at the same time through pipe 25, port 34 and pipe 27 into the upper end of cylinder B. In other words, motive fluid is simultaneously delivered to both ends of this cylinder. Owing to the differential between the big end and rod end of the piston, however, the pressure on the big end will prevail and will move the piston upward as before. Notwithstanding that the pressure from the pump is endeavoring to deliver fluid into the upper end of cylinder B; as above explained, when the piston moves upwardly, the fluid trapped in the upper end thereof will be forced out through the port 34 and down through the pipe 25, where it will join the fluid being delivered into the lower end of the cylinder. Assuming for the sake of simplicity that the area of the piston rod is one-half that of the piston, then since cylinder A is isolated as before, not only will the fluid delivered by the pump into the big end of cylinder B tend to move the piston at twice normal speed, but the fluid forced out of the upper end and joining the fluid delivered by the pump into the lower end adds still further to the volume delivered and results in the piston moving upward at a speed which is approximately four times the normal speed. This is due to the so-called "differential circuit."

As the piston in cylinder A moves along with the other piston, the fluid trapped above it circulates to the lower end of the cylinder through pipes 19, 23 and port 42 as before. At the same time, the upward movement of the piston tends to create a void or vacuum in the lower end of the cylinder and, since the volume of the fluid expelled from the upper end is not sufficient to fill the lower end, the additional fluid necessary to fill such lower end and thus relieve the vacuum which would otherwise be created is sucked up through pipe 19 and exhaust pipe 10 from the tank.

In Fig. 4 I have illustrated another combination in which diversion valve 35 remains in its normal position as shown in Fig. 1 while diversion valve 26 has been actuated by the foot pedal to its lower position, the same as in Fig. 3. Assuming that the master valve remains in "extend" position as shown, fluid will again be delivered through supply pipe 20 to both ends of cylinder B as before. At the same time, it will be delivered through pipe 22, port 41 and pipe 24 into the lower end of cylinder A. As the pistons move up, the fluid trapped in the upper end of cylinder A is exhausted through pipes 19 and 10. Since the fluid from the pump is divided between the two cylinders, this arrangement gives a speed less than that of Fig. 2, but at the same time fluid expelled from the upper end of cylinder B comes down through pipe 25 and is added to the fluid being delivered by the pump. Consequently, with the valves in the position in Fig. 4, the cylinders move at about one-third greater speed than normal.

In Fig. 5 I have illustrated a combination in which

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the master valve has been thrown to "retract" position so that motive fluid from the pump is delivered into supply pipe 19. Valve 26 has been actuated so that the port 34 connects pipe 27 with pipe 25 and 20.

Under these conditions motive fluid flows directly into the upper end of cylinder A, all connection with cylinder B being blocked. Thus the entire output of the pump is delivered into cylinder A and the piston therefore moves downwardly therein at twice normal speed forcing the fluid beneath the piston out through pipe 24, port 41 and pipes 24 and 20 to exhaust. Meanwhile, in cylinder B the fluid beneath the piston is also forced out through pipe 20, and as this piston moves down it tends to create a vacuum at the upper end of cylinder B. This is relieved by part of the fluid ejected from the bottom of cylinder A flowing upward through pipe 25 and port 34 into the upper end of cylinder B.

In Fig. 6, I have shown still another combination which produces the same net results as that shown in Fig. 3. It will be noted that the master valve is in "retract" position, the same as in Fig. 5, and motive fluid therefore is supplied through pipe 19 directly into the upper end of cylinder A and, at the same time, through pipe 23, port 42, and pipe 24 into the lower end of this cylinder. Thus motive fluid is fed to both ends of the cylinder simultaneously giving rise to a differential action. The piston at the big end of the cylinder being of greater area, predominates and, although the master valve is in the "retract" position, it will be noted that the pistons will move in the "extend" direction. The same situation then exists in cylinder A as was explained in connection with cylinder B in Fig. 3, namely, the fluid from the upper end is forced out as the piston moves up, and joins the fluid flowing in pipe 23 from the pump thus increasing the amount of fluid delivered to the lower end of the cylinder. Thus, as in Fig. 3, the pistons move upwardly at four times normal speed. Meanwhile, the port 34 establishes a by-pass connection through pipe 25 between the two ends of cylinder B. At the same time, the upward movement of the piston tends to create a void or vacuum in the lower end of the cylinder, and, since the volume of fluid expelled from the upper end of the cylinder through pipe 25 is not sufficient to fill the lower end, the additional fluid necessary to fill such lower end and thus relieve the vacuum, is sucked up through pipe 20 and exhaust pipe 10 from the tank.

Finally, in Fig. 7, I have illustrated one more possible valve combination. In this combination, both valves 26 and 35 are in the upper position, the same as in Fig. 2, while the master valve is in the "retract" position, as in Figs. 5 and 6. This combination also produces a "differential circuit." The pressure of the fluid delivered through pipe 19 is applied to the big end of cylinder A and simultaneously to the rod ends of both cylinders. If the effective area of the pistons is twice that of the cross-sections of the rods, then this arrangement would give a "floating" situation in which the power is balanced, and there would be no movement. If, however, the ratio between the effective areas of the pistons and the rods is different from two-to-one, then, of course, the power would not be balanced, and movement would take place, one way or the other, at a speed dependent upon this ratio.

While in the figures above discussed, the two cylinders have been shown as mounted side by side in parallel relation, the same multiple speed results can be achieved when the cylinders are mounted end to end, in tandem relation. This is shown in Fig. 8.

In this figure, the cylinders A and B are shown as mounted co-axially on fixed supports X, although if desired they may be rigidly connected with each other in any suitable way. This arrangement differs from those previously described in that a common piston rod 4' extends through both cylinders, a piston being secured to this rod within each cylinder. The valves and con-

duits are employed as in the preceding figures, these being designated by the same reference numbers. In Fig. 8, the valves 26 and 35 are shown in the positions which they occupy in Fig. 1, namely, in positions which result in the motive fluid supplied through pipe 20 being divided between the two cylinders, thus giving the normal speed of movement of the pistons. It will, of course, be understood that the pipes 19 and 20 are connected with a master valve as before, and that this valve when shifted will cause the motive fluid to be supplied through pipe 19 into the upper ends of the cylinders.

Similar means (not shown) is, of course, provided for selectively shifting the position of the diversion valves, as in the other figures and the shifting of one or both of these valves results in producing various increased speeds of travel of the pistons. It is thought that this will be clear from what has gone before without the necessity of a detailed description. The resulting speed relations will, however, be slightly different in some cases from those heretofore described because of the fact that the piston area at both ends of cylinder A is the same and, consequently, no differential action can be obtained in this cylinder.

It will thus be seen that I have provided a control system including by-pass conduits and diversion valves and means by which these valves may be individually and selectively actuated as desired to cause the pistons to move at any one of several different speeds in either direction.

It will, of course, be understood that not only may any selected speed be maintained throughout the entire stroke of the pistons but the diversion valve may be actuated at any desired point in the travel of the pistons, thus causing them to travel at one speed during the first part of the stroke and at different speed during the last part of the stroke.

While I have shown and described the two cylinders as being of the same size, they do not necessarily have to be of the same size, but may be of different sizes.

While for the purposes of simplicity and clearness I have described the area of the piston rods as being approximately equal to one-half that of the pistons, with certain definite resulting speed ratios, these rods may, of course, be of a size having any desired ratio to that of the pistons. Where sizes other than a 2:1 ratio are employed, the resulting relative speeds will, of course, be represented by fractions rather than even numbers, but in any event, in cases such as illustrated in Figs. 3, 6, and 7, in which a differential circuit is employed on one of the cylinders, the speed ratios will be a function of the differential between the areas of the piston rod and piston.

While in all of the preceding figures I have shown arrangements in which the cylinders are disposed either parallel or in tandem, and the pistons move simultaneously in the same direction in both cylinders, in Fig. 9 I have shown another modification in which the pistons move simultaneously in opposite directions in the two cylinders. In this Fig. 9, I have used the same reference characters to designate corresponding parts, so far as possible, but the use of some additional reference characters has been necessary.

In this modification, the boom of a power shovel or "backhoe" is shown at 3', and the dipper stick at 5'. This is pivotally connected to the end of the boom at 5^a and the piston rods 4 of the two cylinders A and B are pivotally connected at 4^b to the dipper stick 5', one on either side of the pivot 5^a. The cylinders A and B themselves are pivotally mounted at their lower ends on the boom 3', as shown at 2'.

The organization shown in Fig. 9 constitutes what I shall term a "push-pull" arrangement in which one piston goes in while the other goes out. This gives rise to a condition in which the power for producing "normal" speed is the result of the combined piston areas of the

rod end of one cylinder and the big end of the other cylinder.

The pipes through which motive fluid is supplied to the two cylinders are indicated at 19 and 20, as before, but owing to the fact that the cylinders move it will be necessary to connect the lower ends of these pipes with the master valve by means of flexible hoses 19' and 20'. Also, the pipe 19 is connected with the valve 26 by means of nipples 21^a and 21^b and a piece of flexible hose 21', while the pipe 20 is connected with the valve 35 by means of nipples 22^a and 22^b and a piece of flexible hose 22'. It will also be noted that the valve 26 is directly connected to the lower end of cylinder B by means of the pipe nipple 27, instead of with the upper end thereof, as shown in Fig. 1.

With this arrangement, when the master valve is in such a position as to supply motive fluid through the pipe 20, and with the valves 26 and 35 in normal position as shown in Fig. 1, fluid directly enters the rod end of cylinder B and through the connection 22^b, 22' and 22^a, the big end of cylinder A. The piston in cylinder A therefore extends while the piston in cylinder B retracts, thus rocking the dipper stick 5' on its pivot.

When the master valve is reversed, so as to supply motive fluid through the pipe 19, such motive fluid directly enters the upper or rod end of cylinder A and through the connection 21^a, 21' and 21^b the big end of cylinder B. This of course causes the piston in cylinder B to extend and the piston in cylinder A to retract, thus rocking the dipper stick in the opposite direction.

If the control valve 35 is now shifted to its uppermost position, as shown in Fig. 2, motive fluid from the pipe 20 enters only the rod end of cylinder B, while the big end of B is connected through the valve 26 to exhaust through the pipe 19 and the piston in cylinder A is bypassed through the valve 35. Thus the piston in cylinder B retracts and furnishes the sole power. The dipper stick will thus move with a speed about three times normal, assuming that the piston rods and piston areas have a ratio of 1:2, as previously assumed. When the master valve is reversed, pressure from pipe 19 is admitted to the big end of both cylinders simultaneously and to the rod end of cylinder A. The piston in cylinder A thus retracts at approximately the speed just mentioned.

Suppose now that both valves 26 and 35 are shifted from the position shown in Fig. 1 to the position shown in Fig. 3. In this position, motive fluid from the pipe 20 will enter both ends of cylinder B only. The piston in cylinder A will be by-passed and connected to exhaust 19. Since the big end of cylinder B has an effective area greater than the rod end, the piston in cylinder B extends. When the master valve is reversed and motive fluid admitted to pipe 19, such fluid enters both ends of cylinder A only, the piston in cylinder B being bypassed. This gives rise to a differential circuit which at this instance results in a speed about 2¼ times normal, in either position of the master valve.

Finally, let it be assumed that the valves 26 and 35, as well as the master valve, are shifted into the positions shown in Fig. 4. Motive fluid from the pipe 20 will then enter both ends of cylinder B and the big end of cylinder A, while the rod end of A is connected with exhaust. The piston in cylinder A extends. When the master valve is reversed, pressure from the pipe 19 enters the rod end of cylinder A only, the big end of this cylinder being connected to exhaust. At the same time, the piston in cylinder B is by-passed and connected with exhaust. As a result, the piston in cylinder A retracts, and the speed in both cases will be about three times normal, as described above when the valves are in the position shown in Fig. 2.

Although in Fig. 1 and in Figs. 2 through 8 I have shown valve 35 as being connected directly to the big

end of cylinder A and valve 26 connected directly to the rod end of cylinder B, and in Fig. 9 valve 35 piped directly to the big end of cylinder A while valve 26 is connected with the big end of cylinder B, it will be understood that either valve 26 or 35 may be piped directly to either end of either cylinder without departing from the principles of the invention. In some instances some different speeds than those speeds heretofore explained may result.

While I have illustrated and described diversion valves and by-pass conduits in connection with each of the two cylinders, it will of course be understood that they may be used in connection with one of the cylinders only. Thus, in Fig. 2, for example, the valve 26 may be omitted entirely, with the equalizing conduit 21 directly connecting the upper ends of the two cylinders, as in conventional practice. Nevertheless, with such an arrangement, when the valve member 36 is shifted to its upper position, as shown in Fig. 2, the entire output of the pump will be diverted to the lower end of cylinder B, while a by-pass is established around the piston of cylinder A, and the pistons will move upwardly at twice normal speed, as heretofore described.

Similarly, in Fig. 5, the valve 35 may be omitted entirely, with the equalizing conduit 22 directly connecting the lower ends of the cylinders, as in conventional practice. Then, with such an arrangement, when the valve member 28 is shifted to its lower position, as shown, the entire output of the pump, flowing through pipe 19, will be diverted to the upper end of cylinder A, while a by-pass is established around the piston of cylinder B, and again the pistons will move, this time downwardly, at twice normal speed, as heretofore described.

Thus it will be seen that even though only one diversion valve and by-pass conduit is employed, the double speed result is achieved. Although not capable of producing as many speed changes as the two-valve arrangement, this one-valve embodiment is satisfactory in cases where so many different speeds are not required.

While, by way of example, I have described the invention as applied to earth working machinery such as a backhoe, it is obviously not by any means limited to such use but is equally applicable to press, lifts and hoists, and machine tools such for example as punching, shearing and milling machines, where it is desired to change the speed of travel during the whole or any part of the stroke in either direction.

It will of course be understood that the showing of the diversion valves in the drawings is purely schematic, for the sole purpose of illustrating the principle of operation, and that in actual practice the details of construction of these valves may well be different.

What I claim is:

1. In combination, a pair of double acting cylinders, a piston working in each cylinder, said pistons being mechanically connected so as to move together, means for delivering fluid under pressure at a constant, definite rate, equalizing conduits connecting the corresponding ends of said cylinders, a pair of by-pass conduits connecting said equalizing conduits, a two-position control valve at the connection point of each of said by-pass conduits with one of said equalizing conduits, and means for independently operating said valves in such manner that the fluid delivered may be directed thereby at will into one end of both cylinders in parallel, while allowing fluid to exhaust from the other end, or into either end of either cylinder alone, while maintaining the exhaust from the opposite end of the cylinder into which fluid is directed and establishing a by-pass around the piston of the other cylinder, whereby the speed of travel of said pistons may be varied as desired.

2. In combination, a pair of double acting cylinders, a piston working in each cylinder, said pistons being mechanically connected so as to move together, equalizing conduits connecting the corresponding ends of said

cylinders, a pair of by-pass conduits connecting said equalizing conduits, a pair of independent valves, each wholly controlling the flow of fluid between one by-pass conduit, one of said equalizing conduits, and the end of one cylinder to which the said equalizing conduit is connected, fluid supply means, and means for selectively directing fluid from said supply means into either of said by-pass conduits.

3. A hydraulic control system comprising a pair of cylinders, a piston positioned in each cylinder, said pistons being mechanically connected so as to move together, equalizing conduits connecting the corresponding ends of said cylinders, a diversion valve associated with each cylinder and interposed in each equalizing conduit, said valve being normally open so as to permit free flow of fluid through said equalizing conduit from one cylinder to the other a pair of supply conduits one of which is directly and permanently connected with one of said equalizing conduits and one of which is directly and permanently connected with the other, by-pass conduit means for each cylinder permanently connected at one end with one of said equalizing conduits and at the other end with the respective diversion valve means for delivering hydraulic fluid under pressure, control means for selectively directing the fluid from the delivery means into either one of said supply conduits, while leaving the other open to exhaust, so as to simultaneously move said pistons within said cylinders, and means for independently actuating said valves at will so as to close the associated equalizing conduit and simultaneously connect that end of the one of said cylinders adjacent the actuated valve with one of said supply conduits.

4. A hydraulic control system comprising a pair of cylinders, a piston positioned in each cylinder, said pistons being mechanically connected so as to move together, equalizing conduits connecting the corresponding ends of said cylinders, by-pass conduits extending longitudinally of said cylinders and fluid connected with both of said equalizing conduits, a two-way diversion valve at the connection point of each of said by-pass conduits with one of said equalizing conduits for controlling the flow of fluid between them, said valves being normally positioned to maintain said equalizing conduits open and said by-pass conduits closed, and means for independently operating each of said valves at will to close the associated equalizing conduit and simultaneously establish a fluid connection between opposite ends of the adjacent cylinder, fluid supply means, and means for selectively directing fluid from said supply means into either of said by-pass conduits.

5. In combination, a pair of similar double acting cylinders, a piston rod and piston working in each cylinder, said piston rods being mechanically connected so that they move together, means for delivering fluid under pressure at a constant, definite rate, means establishing a separate by-pass connection between the opposite ends of each cylinder, conduits and control means for either directing the fluid thus delivered simultaneously into one end of both said cylinders, while fluid is exhausted from the other end through one of said by-pass connections, whereby the pistons move at relatively slow, normal speed, or simultaneously connecting the same one of said by-pass connections with said fluid delivering means and the other with the exhaust, whereby the pistons move at substantially greater speed.

6. In combination, a pair of double acting cylinders, a piston and a single piston rod on one side only of said piston working in each cylinder, said piston rods being mechanically connected so that they move together, means for delivering fluid under pressure at a constant, definite rate, and conduits and control means for either directing the fluid thus delivered simultaneously into one end of both said cylinders, while fluid is exhausted from the other end, whereby the pistons move at relatively slow speed, or directing the entire amount of fluid si-

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multaneously into both ends of one cylinder, while establishing a fluid by-pass between the ends of the other cylinder, whereby the pistons move at substantially increased speed.

7. In combination, a pair of double acting cylinders, a piston and a single piston rod on one side only of said piston working in each cylinder, said piston rods being connected so that they move together, means for delivering fluid under pressure at a substantially constant, definite rate, and conduits and control means outside of said cylinders for selectively applying the fluid thus delivered to both sides of either piston at the same time and simultaneously establishing a by-pass around the other piston.

8. In combination, a pair of double acting cylinders, a piston and piston rod working in each cylinder, so that each cylinder has a "rod end" and a "big end," said piston rods being mechanically connected in such manner that they always move in opposite directions, means for delivering motive fluid under pressure at a definite constant rate, and conduits and control means for either directing the fluid thus delivered simultaneously into the rod end of one cylinder and the big end of the other, while fluid is exhausted from the opposite ends, whereby the pistons move at relatively slow speed, or directing

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the fluid delivered by said means simultaneously into the big ends of both cylinders and the rod end of one cylinder, while connecting the rod end of the other cylinder to exhaust, whereby the pistons move at increased speed.

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