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[54] RECIPROCATING FLUID MOTOR HAVING A VARIABLE DRIVE PISTON AREA

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[58] **Field of Search** .....91/305, 306, 314, 313; 92/59, 92/6, 6 D, 62, 63, 65

[56] **References Cited**

UNITED STATES PATENTS

1,132,424	3/1915	Arcus	92/6 D
1,165,400	12/1915	Dreisbach	92/6
1,819,947	8/1931	Lavaud	92/6 D
2,166,493	7/1939	Hill	92/6 D
2,433,221	12/1967	Huber	92/6 D
3,162,093	12/1964	Zoller	91/306

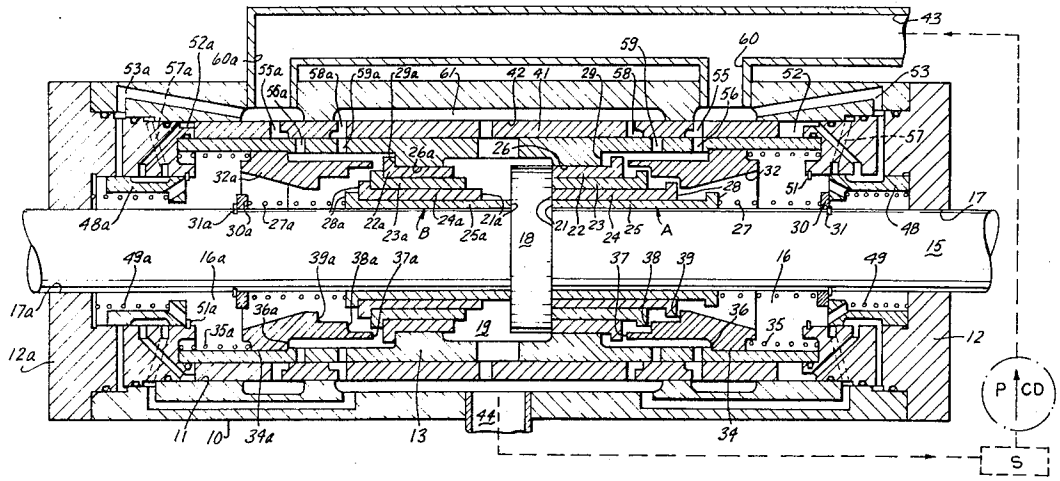
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[57] **ABSTRACT**

A reciprocating motor having a piston rod upon which a group of piston sleeves varying in length is hydraulically actuable against a shoulder of the rod to drive the rod in one direction. Arresting structure is provided to cause the sleeves to become successively arrested in their driving movement so that an initial large area of the combined sleeves which is subjected to the driving fluid is progressively decreased during the stroke. A second similar group of sleeves is similarly operable to return the piston. A separate re-setting element is arranged to automatically reset each group of sleeves to a driving condition preparatory to effecting the next driving stroke of the rod, and to also cushion overtravel of the rod. The rod is cooperably during its stroke with valve elements to cause automatic hydraulic feed alternately to each group of sleeves.

12 Claims, 2 Drawing Figures



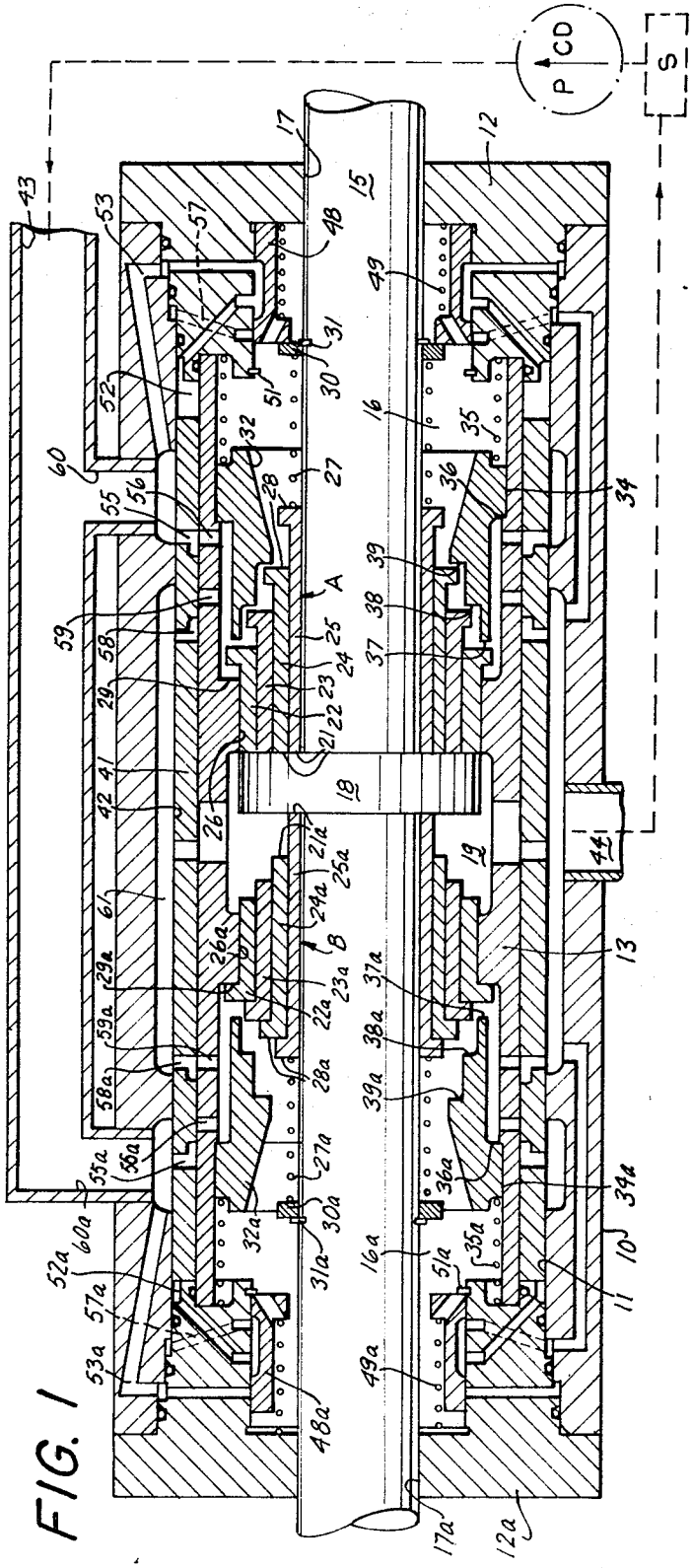


FIG. 1

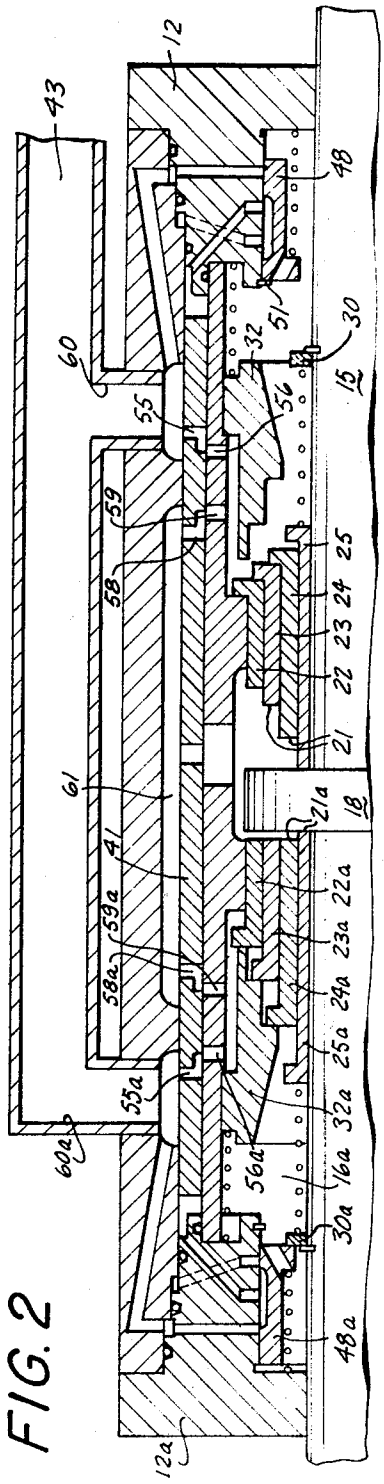


FIG. 2

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RECIPROCATING FLUID MOTOR HAVING A VARIABLE DRIVE PISTON AREA

BACKGROUND OF THE INVENTION

This invention is directed to an hydraulic reciprocating piston motor having a high cycling speed and having an hydraulic system in which fluid flow is substantially constant.

High speed reciprocating hydraulic motors present problems which are not encountered in motors using relatively compressible fluids such as air. Among these problems are shocks developing during acceleration and deceleration of the piston at the ends of its stroke because of the high forces customarily required to obtain this acceleration and deceleration. Another problem is concerned with reducing line losses due to moving viscous fluids at high velocities through the system. Wide fluctuations in hydraulic fluid flow rate, often ranging from maximum to zero, developing during valve shifting and during the reversal portion of the piston stroke result in high loads which strain various components of the hydraulic system.

The general objective of this invention is to provide a high speed reciprocating hydraulic motor in which these problems are substantially minimized. Toward this end, there is provided an advantageous hydraulic system design through which hydraulic pressure fluid flow is substantially constant; and in which flow paths are relatively short. There is further provided a work piston having a form which affords a variable area to which hydraulic work forces are applied. The variable area of the piston is at its maximum at the start of a stroke and progressively decreases during the progress of the stroke to a minimum at the end of the stroke. The advantages of this hydraulic system and piston design are that large forces are enabled for acceleration of the piston at the start of its stroke; an increase in velocity progressively develops during the progress of the stroke as the piston area to which hydraulic forces may be applied decreases; and deceleration of the stroke develops near the termination of the stroke as the effective piston area is reduced to a minimum and as hydraulic fluid flow gradually shifts from one piston chamber to another. This desirable operation of the piston is obtained without substantial change in the volume flow of pressure fluid to the system.

The invention may be incorporated in a rock drill as the driving means for a work steel attachable to the piston. It could also find use in various other applications where reciprocating motion from an hydraulic power source would be desirable.

BRIEF DESCRIPTION OF THE DRAWING

In the accompanying drawing:

FIG. 1 is a schematic showing of a high speed reciprocating hydraulic motor embodying the invention, the piston rod being shown as having just completed its stroke to the right; and

FIG. 2 is a view similar to that of FIG. 1 but showing the slide valve as having reached the mid-point of its movement upon being shifted to the right and showing the piston rod as having almost completed its stroke to the left.

DESCRIPTION OF PREFERRED EMBODIMENT

The embodiment disclosed in the drawing includes a casing **10** having an inner cylindrical wall **11**. A plug **12** seals the right end of the casing, a similar plug **12***a* seals the left end. Coaxial with the casing wall **11** and in spaced relation thereto is a piston cylinder **13** having one end seated in an annular groove of plug **12** and having its opposite end similarly seated in plug **12***a*.

A piston rod **15** is hydraulically reciprocable in the casing. A right portion of the rod extends axially through a piston chamber **16** defined at the right end of the piston cylinder; and a left portion of the rod extends axially through a similar chamber **16***a* at the left end of the cylinder. An axial bore **17** in plug **12** provides a bearing surface and support for the right portion of the piston rod; and a similar bore **17***a* in plug **12***a* provides a similar arrangement for the left portion of the rod. As the piston rod reciprocates, a radial piston shoulder **18** about the rod is carried back and forth within an expansible chamber **19** defined centrally of the piston cylinder between the inner ends **21** and **21***a* respectively of a group of piston sleeves A and a similar group, B.

The sleeves **22** to **25** of group A are coaxial with one another and with the piston rod, and are reciprocable in chamber **16** at the right of the piston rod's shoulder **18**. The sleeves **22***a* to **25***a* of group B are similarly arranged on the piston rod at the left of the shoulder for reciprocation in chamber **16***a*. The sleeves of group A, upon being subjected to hydraulic pressure fluid admitted to chamber **16**, operate against the piston rod's shoulder to drive the rod to the left; and the sleeves of group B similarly act to return the rod to the right when subjected to hydraulic pressure fluid admitted to chamber **16***a*.

The group A sleeves are axially slidable relative to each other; and vary progressively in their length from one another. The longest sleeve **25** of the group bears upon the piston rod; the shortest sleeve **22** is outermost and bears at its periphery upon an internal land **26** of the piston cylinder. The inner end **21** of the longest sleeve is held in abutment with the shoulder **18** of the piston rod under the bias of a spring **27**. One end of the spring abuts a radial annular back flange **28** of the sleeve, and the other end presses a trip ring **30** against a retainer ring **31** mounted in the piston rod. By this means, the longest sleeve of the group moves together with the piston rod.

When the inner ends of the several sleeves of group A are in abutment with the piston rod's shoulder, as they will be preparatory to driving the piston rod to the left as appears in FIG. 1, the opposite flanged end **28** of each sleeve in the group is spaced rearwardly from the next outer sleeve; and the flanged end of the shortest sleeve is spaced rearwardly of a shoulder **29** of the related land **26**. This spacing, as appears in FIG. 1 at the right, progressively increases, being shortest with respect to the shortest sleeve, and longest with respect to the longest sleeve. It can thus be seen with respect to the sleeves of group A, which are now in a position preparatory to driving the piston rod to the left, that sleeve **22** will move a relatively short distance in driving the rod before limiting or bottoming its flange **28** upon the shoulder **29** of stationary land **26**. Sleeve **23** will move over a little longer distance before its flange **28** bottoms on the flange of sleeve **22** ahead of it; and each succeeding sleeve will in sequence move over a relatively longer distance than did the one next ahead of it. The driving action of the group A sleeves ends when the flange **28** of its longest sleeve **25** bottoms on that of the sleeve **24**, next ahead. It can be seen in this driving action that pressure fluid entering chamber **16** will initially act against the broad area defined by the combined flanged ends **28** of all of the sleeves of the group in driving the piston rod; and that as each sleeve bottoms out or is arrested in its driving action, the force of the pressure fluid will be applied to the remaining unarrested sleeves. Thus, the driving area of the sleeves to which the driving force of the pressure fluid is applied progressively decreases until the last or longest sleeve **25** has finally bottomed out or become arrested. Accordingly, the velocity of the moving piston rod increases as the sleeve driving area decreases, the volume of pressure fluid entering chamber **16** being substantially constant.

The piston sleeves **22***a* to **25***a* of group B are arranged on the piston rod symmetrically to those of group A. They are similar in structure and mode of operation. The shortest sleeve **22***a* of the group B bears at its periphery upon an internal land **26***a* of the piston cylinder; and the longest sleeve **25***a* bears upon the piston rod. Sleeve **25***a* also is held in abutment with the shoulder **18** of the piston rod under the bias of a spring **27***a*. One end of the spring abuts the radial flange **28***a* of the sleeve; its other end presses a trip ring **30***a* against a retainer ring **31***a* fixed in the piston rod. The sleeves of group B are shown at the left in FIG. 1 in the position which they obtained after having driven the piston rod to the right. In this position,

it is seen that the flanged end 28*a* of the shortest sleeve 22*a* has bottomed against the shoulder 29*a* of the related land 26*a*; and the flanged ends 28*a* of the succeeding sleeves have bottomed against one another.

On each stroke of the piston rod, the then driving group of sleeves moves from a driving condition at the start of the stroke to a bottomed condition at the end of the stroke; and simultaneously during the stroke the sleeves of the other group are moved or re-set from a previously obtained bottomed condition to a driving condition preparatory to effecting the next driving stroke.

In chamber 16 is disposed a sleeve stripper or re-setting member 32 which, together with the shoulder 18 of the piston rod, cooperates during a piston stroke to re-set the sleeves of group A from a bottomed condition to a driving condition. A similar sleeve re-setter 32*a* is disposed in chamber 16*a* to serve the sleeves of group B. Each re-setting member also serves in cushioning any overtravel of the piston rod that might occur in its direction.

The sleeve re-setter 32 has a cylindrical open ended body which coaxially surrounds the piston rod with a clearance. Its body has a peripheral land 34 slidably bearing upon the surrounding wall of the piston cylinder. A spring 35 biases the re-setter inwardly to a normal position where its land abuts an internal shoulder 36 of the piston cylinder. The inner end of the re-setter is axially stepped inwardly to define a group of three concentric annular shoulders or fingers 37, 38 and 39, stepped axially inwardly from one another. The three fingers 37, 38 and 39 are disposed axially opposite the flanged ends 28 respectively of sleeves 22, 23 and 24 of group A. It can be seen that, as the sleeves of group A are carried toward the re-setter 32 as a group by the piston rod because of the viscous film coating frictionally adhering one to the other, the fingers of the re-setter will cooperate with the corresponding sleeves to slide them sequentially relative to one another until they are re-set to their driving condition. No finger is required on the re-setter with respect to the longest sleeve 25 since this sleeve will automatically obtain its driving condition as the next adjacent sleeve 24 is being re-set. The annular axial clearance provided between the body of the re-setter and the piston rod allows for movement therein of the longest sleeve 25 during the re-setting operation.

What has been described with respect to the structure, arrangement and operation of the re-setter 32 similarly applies to the re-setter 32*a* serving the sleeves of group B, the corresponding structures being identified by the same reference numerals, but with the small letter *a* appended thereto.

Each re-setter also functions to cushion or dampen overtravel of the piston rod that might occur in its direction at the termination of a stroke. In this respect, at about the time that the several sleeves of a group are re-set to their driving condition, their inner ends will abut the piston rod's shoulder 18 and the flanged ends of the three outermost sleeves will be limited upon the corresponding fingers of the related re-setter. Should overtravel of the piston for some reason develop at this time, the piston rod will be cushioned in its movement by the spring load of the re-setter.

Hydraulic reciprocation of the piston rod is obtained by means of a shiftable sleeve valve 41 controlling both escape from and feed of hydraulic fluid to the chambers 16 and 16*a*. The valve is disposed in the annular space or chamber 42 defined between the casing 10 and the piston cylinder 13. The valve has a shifted position to the left, as in FIG. 1, in which it communicates chamber 16 with a hydraulic pressure fluid feed line 43; and communicates the opposite chamber 16*a* with a drain line 44. And the valve has a position shifted to the right in which it communicates chamber 16 with the drain line; and communicates chamber 16*a* with the feed line. The center chamber 19 is at all times in communication through the valve with the drain line so as to allow fluid that might leak past the group of sleeves into the center chamber to be drained away and thereby prevented from retarding reciprocation of the piston rod. The pressure and drain lines 43, 44 are connected to a common sump S from which fluid is drawn by a motorized constant delivery pressure pump P-CD into the pressure line and circulated through the hydraulic system back to sump, the circulation being constant as long as the pump is operating.

Hydraulic shifting of the sleeve valve 41 from one position to the other is automatically obtained by means of the cooperation of the reciprocating piston rod with a pair of pilot valves 48 and 48*a*. Valve 48 is axially slidable in a central recess of the right plug 12 in coaxial spaced relation to the piston rod. A spring 49 biases the valve to a normal position in abutment with a stationary ring stop 51. Toward the end of a piston rod stroke to the right, the trip ring 30 is carried by the rod to engage valve 48 and slide it away from stop 51. In its normal position, valve 48 connects the right end 52 of the slide valve chamber 42 with the drain line 44; and in its moved position, as in FIG. 1, the pilot valve 48 connects the said end of the slide valve chamber with the feed line 43. What has been described with respect to the structure, arrangement and mode of operation of the pilot valve 48 at the right is duplicated with respect to the pilot valve 48*a* at the left, the corresponding structure being identified by the same reference numerals but with the small letter *a* appended thereto. In its normal position, as in FIG. 1, the left pilot valve 48*a* connects the left end 52*a* of the slide valve chamber 42 with the drain line 44; and in its moved position connects the said end of the slide valve chamber with the feed line 43.

In summary of the operation of the device, assuming the piston rod has just completed its stroke to the right, as has occurred in FIG. 1, causing rightward displacement of pilot valve 48, and consequent feeding of pressure line fluid over passage 53 and through the pilot valve to the right end 52 of the slide valve 41 so as to shift the latter to its left position to register ports 55, 56. Pressure line fluid then flows through registered ports 55, 56 to chamber 16. Pressure fluid upon filling chamber 16 initially transmits its driving force over the combined areas of the flanges 28 of the several sleeves 22 to 25 in group A, causing a large initial driving force to be applied through the shoulder 18 to the piston rod. This large force rapidly overcomes the starting inertia of the piston rod and drives the rod to the left. As one by one of the sleeves of group A sequentially bottoms out, the effective flanged area of the sleeves through which driving force of the pressure fluid is transmitted to the piston rod decreases with a corresponding resultant increase in the velocity of the rod.

During the progress of the stroke, the sleeves of group B are progressively re-set to their driving condition as they are carried into abutment with the re-setter 32*a* at the left. Toward the end of the stroke, the left trip ring 30*a* moves the left pilot valve 48*a* away from its stop 51*a* causing feed line flow over passage 53*a* through pilot valve 48*a* to the left end 52*a* of the slide valve 41 so as to shift the latter to its position at the right and register ports 55*a*, 56*a*. The piston rod in moving to the left will have carried the right trip ring 30 away from the pilot valve 48 so as to allow the latter to restore to its normal position before the piston rod actuates the pilot valve 48*a* at the left. By this arrangement, the right end of the slide valve chamber at 52 is connected over passage 57 through the pilot valve 48 to the drain line 44 before pressure fluid is admitted to the left end of the slide valve chamber at 52*a*.

At about the end of the piston rod's stroke to the left, as the several sleeves of group B are re-set with their inner ends all in abutment with the piston rod's shoulder, the three outer sleeves of group B are pressed against the corresponding fingers of the re-setter 32*a* and the trip ring 30*a* of the piston rod is pressed against the now seated pilot valve 48*a*. In this action, the spring load of the re-setter spring 35*a*, as well as that 49*a* of the pilot valve, dampen and cushion the terminal portion of the piston stroke in the event of overtravel of the piston rod.

With the shifting of the sleeve valve 41 to the right, ports 58, 59 register to connect the right piston sleeve chamber 16 through an annulus 61 with the drain line 44 and ports 55*a*,

56*a* at the left register to connect the feed line **43** with the left piston sleeve chamber **16***a* to effect movement of the piston rod to the right. The operation of the pilot valves **48**, **48***a;* the shifting of the slide valve **41**; and the reciprocation of the piston rod **15** automatically continues until pumping of fluid into the feed line is terminated by the operator.

It is to be noted that the arrangement, operation and structure of the shiftable sleeve valve **41** is such that in every position of this valve, fluid is constantly flowing from the feed line **43** to one or the other or to both piston chambers **16** and **16***a;* and is simultaneously flowing from one or the other or both chambers to the drain line **44**. This results in a smooth transition of hydraulic feed from one of the chambers **16** and **16***a* to the other; and thereby avoids undesirable hydraulic loads on the moving parts of the system that might otherwise develop. Toward this end, the ring of feed ports **55***a* at the left in the valve **41** is at all times connected with the feed line branch **60***a;* and the similar ring of feed ports **55** at the right in the valve is similarly connected with the feed line branch **60**. Also, the ring of drain ports **58***a* at the left in the valve **41** is at all times connected with the drain annulus **61**; while the similar ring of drain ports **58** at the right in the valve is similarly connected with the drain annulus. In addition, at the left, the two parallel rings of cylinder ports **56***a*, **59***a* open at all times into chamber **16***a;* and at the right, the two similar rings of ports **56**, **59** open into chamber **16**.

During shifting of valve **41** from the left to the right, the left feed ports **55***a* progressively register with the cylinder ports **56***a* to chamber **16***a*, as the right feed ports **55** progressively move out of register from the cylinder ports **56***a* relative to chamber **16**. The reverse occurs during shifting of valve **41** from the right to the left; and, as in FIG. **2**, when valve **41** reaches the instant of the mid-point of its shift in either direction, the right and left feed ports **55**, **55***a* will be in partial register with their corresponding cylinder ports **56**, **56***a;* and the right and left drain ports **58**, **58***a* will be in partial register with their corresponding cylinder ports **59**, **59***a*. It can be seen that in such an arrangement, the driving force of pressure fluid through the system will be at its maximum to one of the chambers **16** or **16***a* at the start of a piston rod stroke; and will be at its minimum toward the end of the stroke when the valve is at its mid-point and pressure fluid is flowing in and out of the closely spaced piston cylinder ports **56**, **59** and **56***a*, **59***a* of the respective chambers to the drain annulus **61**.

Accordingly, it can be seen that the piston rod will reciprocate smoothly through a cycle during which the piston rod readily changes from movement in one direction to reverse movement; accelerates rapidly during the stroke; and slows at the end of its stroke preparatory to reversing its direction, all occurring with a minimum of shock and strain to the system at the beginning and ends of the stroke.

It can also be seen that the motor may be provided with piston sleeves in one group which vary in size and number from those of the other group so as to obtain a high speed work stroke and a slower speed return stroke.

It is to be also noted that the flow paths from the main feed line **43** to the various hydraulically operable components; or from the latter to the drain line **44** are relatively short so that flow to or from the operable components is relatively rapid and with a minimum of interference.

What is claimed is:

1. In an hydraulic motor including a piston cylinder, a piston rod reciprocable axially of the cylinder having an annular radial shoulder between its ends, a first group of hydraulically actuable nested piston sleeves arranged coaxially one upon the other on the piston rod to one side of the shoulder in a first piston sleeve chamber defined at one end of the cylinder, the sleeves having when hydraulically actuated cooperation with the shoulder to drive the piston rod in one direction, a second similar group of sleeves similarly arranged upon the piston rod to the other side of the shoulder in a second piston sleeve chamber defined at the opposite end of the cylinder, the second group of sleeves having when hydraulically actuated cooperation with the shoulder to drive the piston rod in the opposite direction, means for feeding hydraulic pressure fluid alternately to the first and second chambers for actuating the sleeves therein, means in each of the chambers for determining the extent of driving cooperation of each of the sleeves therein with the shoulder, and means for draining spent hydraulic pressure fluid alternately from the first and second chambers; wherein a chamber is defined centrally of the piston cylinder between the inner ends of both groups of sleeves in which chamber the shoulder of the piston rod is carried as the piston rod is driven from one direction to the other.

2. In an hydraulic motor as in claim **1**, wherein the central chamber is connected at all times with a drain conduit so that pressure fluid that might leak from the first and second chambers past the first and second groups of sleeves may escape.

3. In an hydraulic motor as in claim **2**, wherein a sleeve valve is axially shiftable in one direction so as to connect the first of the piston sleeve chambers with a hydraulic pressure fluid feed line and simultaneously connect the second chamber with the drain conduit.

4. In an hydraulic motor as in claim **3**, wherein the sleeve valve is axially shiftable in an opposite direction so as to connect the first piston sleeve chamber with the drain conduit and to simultaneously connect the second chamber with the feed line.

5. In an hydraulic motor as in claim **4**, wherein the sleeve valve has a mid-point shifted position in which the first piston sleeve chamber is connected to both the drain conduit and to the feed line, and in which the second chamber is also connected to both the drain conduit and to the feed line.

6. In an hydraulic motor as in claim **5**, wherein a first pilot valve means is provided at one end of the piston cylinder for causing hydraulic shifting of the sleeve valve in one direction and a second pilot valve means is provided at an opposite end of the piston cylinder for causing hydraulic shifting of the sleeve valve in the opposite direction.

7. In an hydraulic motor as in claim **6**, wherein the first pilot valve means has a normal position under the bias of a return spring in which a corresponding end of the sleeve valve is in communication through the first pilot valve means with the drain conduit, and has a shifted position against the bias of the spring in which the said corresponding end of the sleeve valve is in communication through the first pilot valve with the feed line.

8. In an hydraulic motor as in claim **7**, wherein the second pilot valve means has a similar normal position under the bias of a separate return spring similarly connecting a corresponding end of the sleeve valve with the drain conduit, and has a similar shifted position against the bias of its spring connecting its said corresponding end of the sleeve valve with the feed line.

9. In an hydraulic motor as in claim **8**, wherein the piston rod carries at an end portion thereof a trip ring having upon a predetermined movement of the piston rod in one direction engagement with the first pilot valve so as to shift the latter from its normal position; and the piston rod carries at an opposite end portion thereof a second trip ring having upon a predetermined movement of the piston rod in an opposite direction engagement with the second pilot valve so as to shift the latter away from its normal position.

10. In an hydraulic motor as in claim **9**, wherein the innermost sleeve in each group is greater in length than the others and is biased in abutment with a corresponding side of the shoulder by means of a separate spring, the spring being limited between an end of the related sleeve and the related trip ring.

11. In an hydraulic motor as in claim **10**, wherein the sleeves in one group are adapted to be carried along with the related longest sleeve during movement of the piston rod in the direction of said one group, and means is provided in the related piston sleeve chamber of said one group for arresting in sequence the extent of carried movement of each sleeve of the said one group.

12. An hydraulic piston motor including a piston cylinder, a piston rod reciprocable axially of the cylinder carrying a peripheral shoulder between its ends, a first expansible piston chamber defined to one side of the shoulder, a second expansible piston chamber defined to the other side of the shoulder, a first group of hydraulically actuable piston sleeves in the first chamber having when actuated cooperation with the shoulder to drive the piston rod in one direction, a second group of hydraulically actuable piston sleeves in the second chamber having when actuated cooperation with the shoulder to drive the piston rod in the opposite direction, valving means for causing feeding of hydraulic pressure fluid alternately to the piston chambers for actuating the piston sleeves therein, and abutment means in each piston chamber determining in sequential order the extent of driving cooperation of each of the sleeves therein with the shoulder; wherein a chamber is defined centrally of the piston cylinder between the inner ends of both groups of sleeves in which chamber the shoulder of the piston rod is carried as the piston rod is driven from one direction to the other.

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