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ADJUSTABLE STROKE RECIPROCATORY FLUID PRESSURE MOTOR

Filed July 10, 1957

4 Sheets-Sheet 1

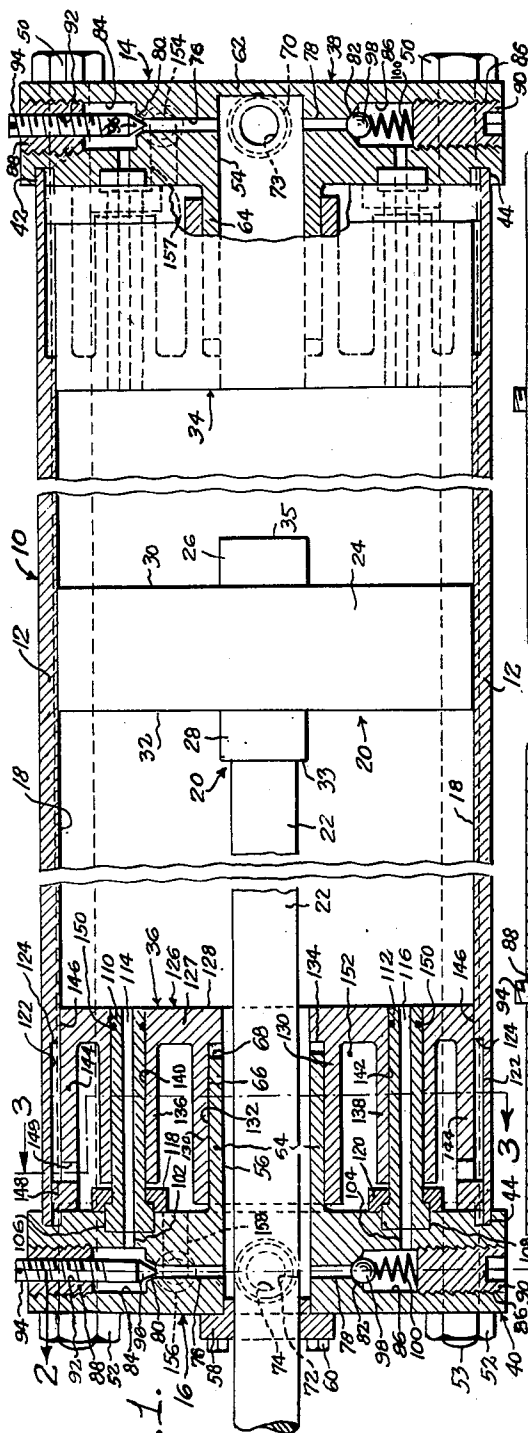


Fig. 1.

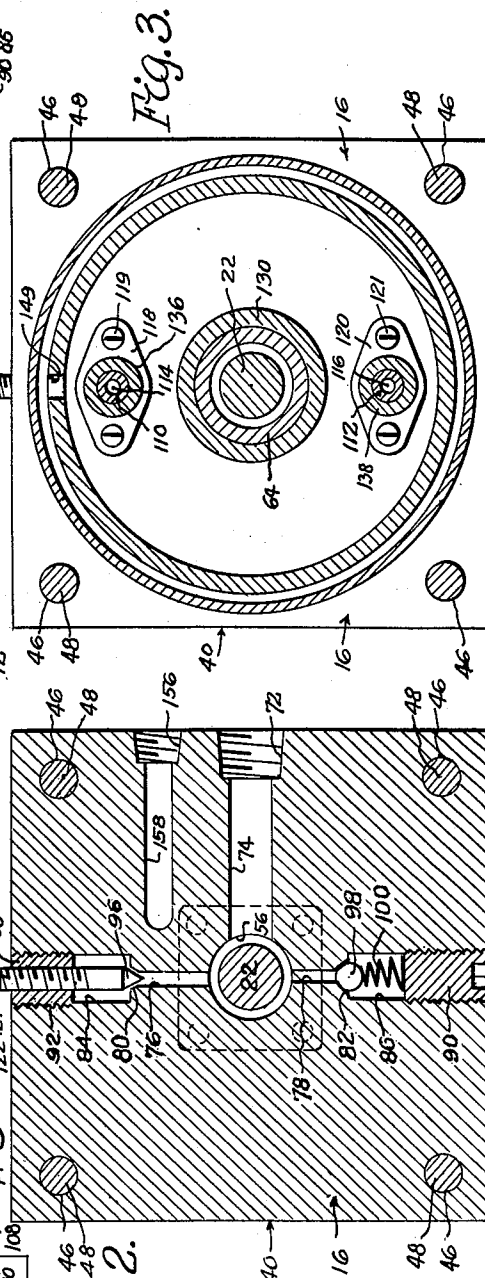


Fig. 2.

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4 Sheets-Sheet 2

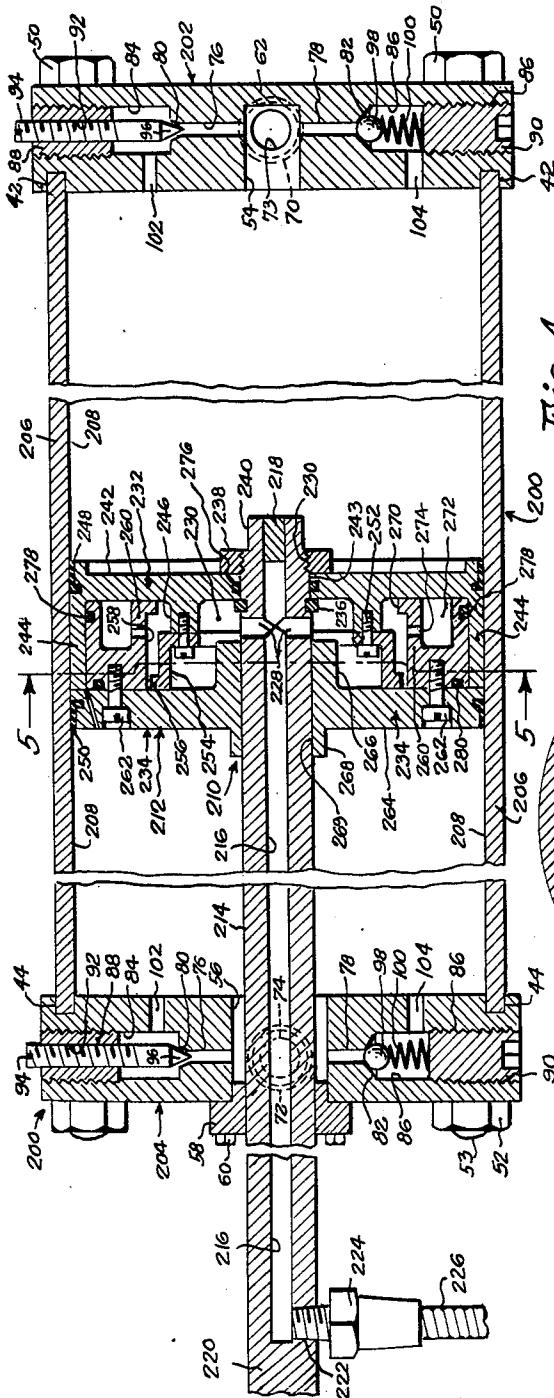


Fig. 4.

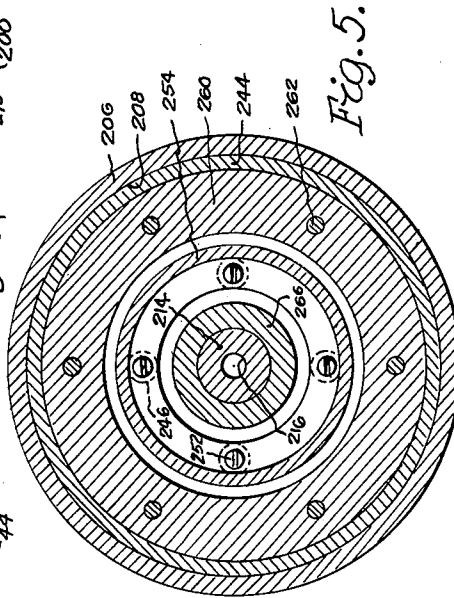


Fig. 5.

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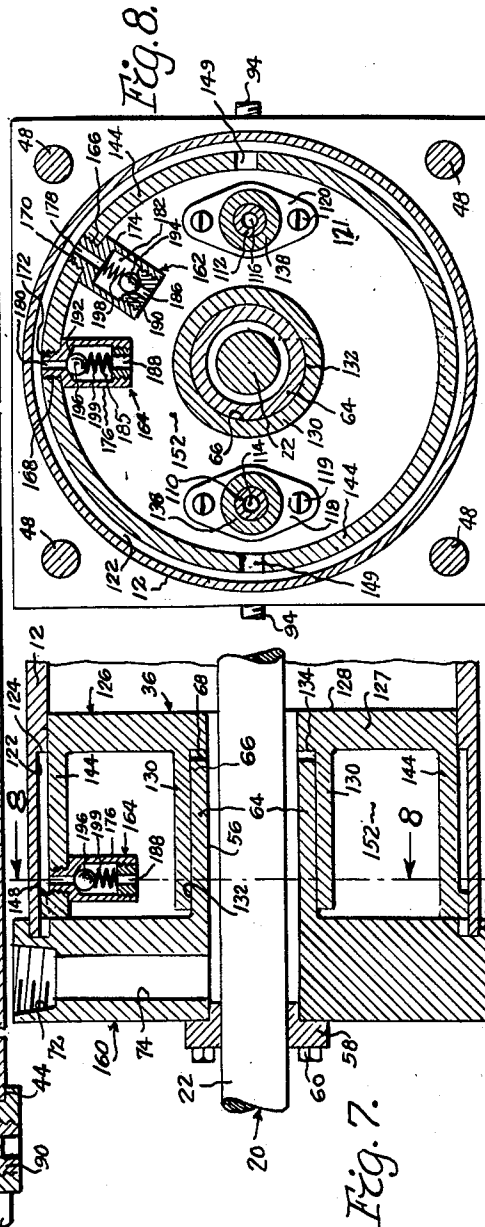
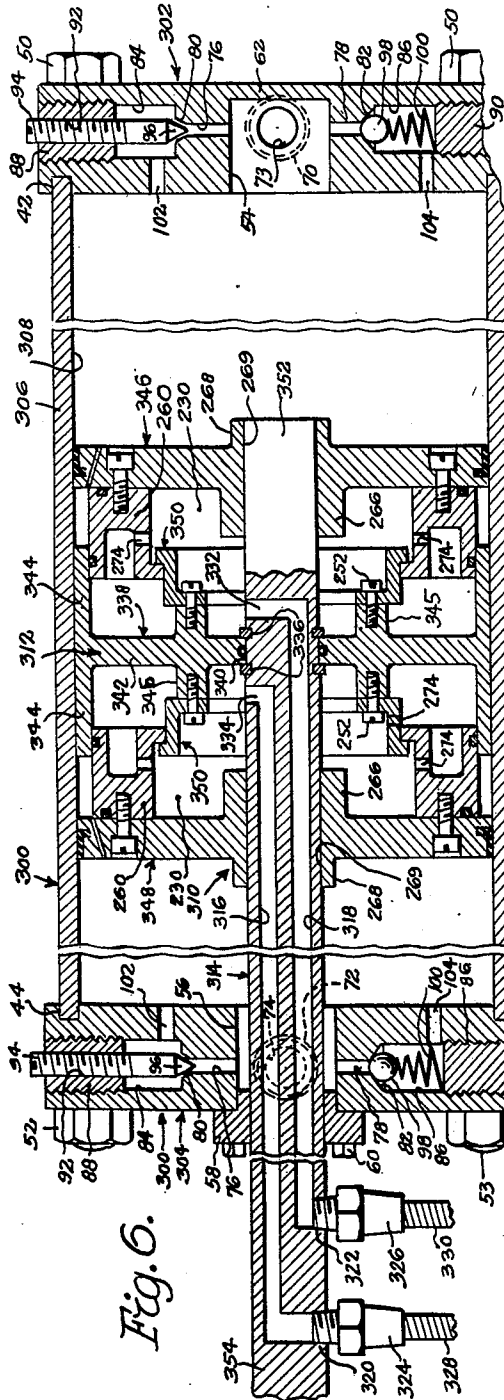
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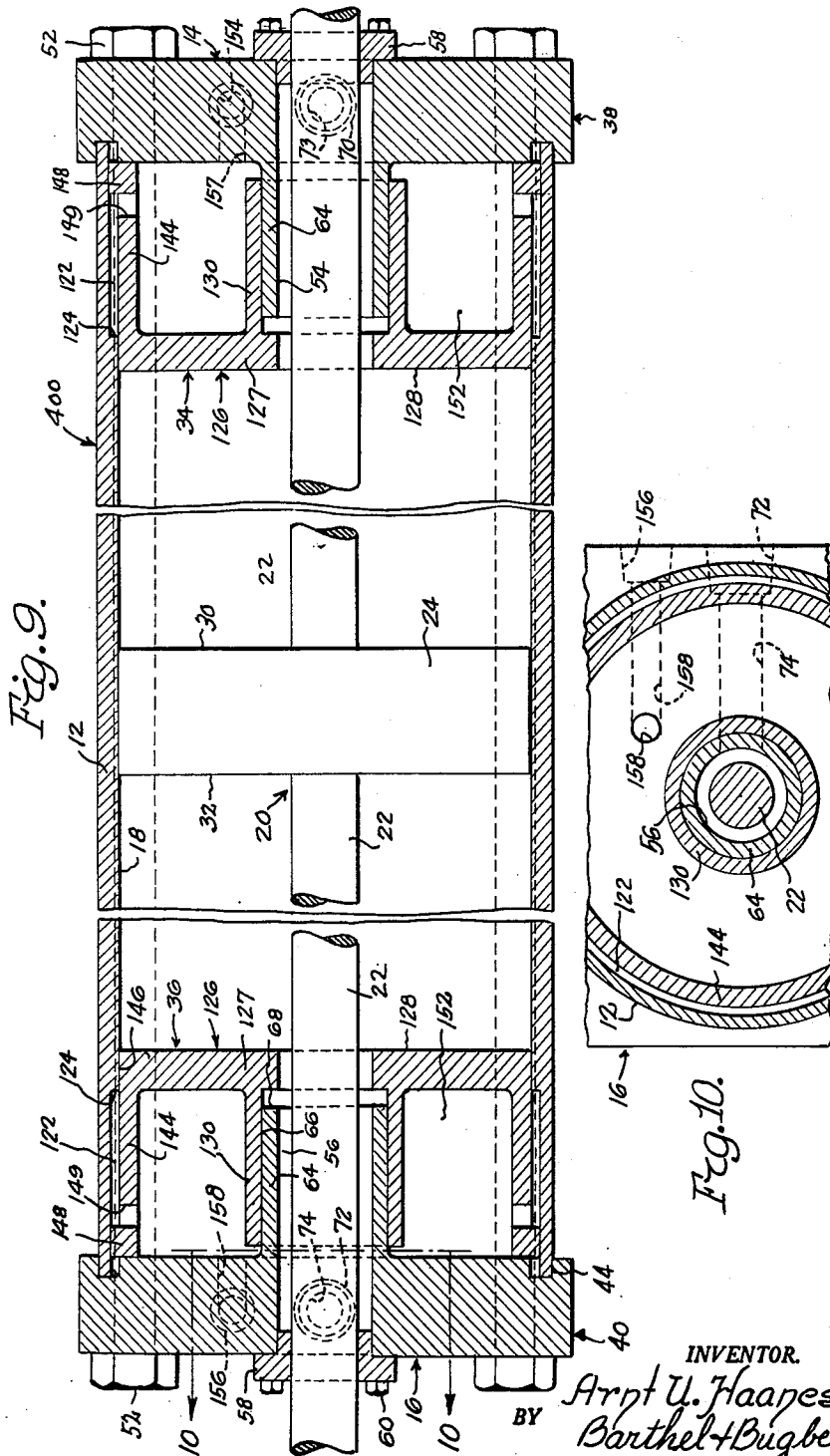
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2,922,397

## ADJUSTABLE STROKE RECIPROCATORY FLUID PRESSURE MOTOR

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Application July 10, 1957, Serial No. 670,978

13 Claims. (Cl. 121—38)

This invention relates to reciprocatory fluid pressure motors, commonly known as "cylinders" and, in particular, to adjustable-stroke reciprocatory fluid pressure motors.

One object of this invention is to provide a reciprocatory fluid pressure motor in which the stroke of the motive piston is limited and the halting point thereof varied by an adjustable abutment device mounted within the cylinder of the motor and movable back and forth to precisely fix the stroke and limit the halting point of the motive piston.

Another object is to provide a reciprocatory fluid pressure motor of the foregoing character wherein the abutment device not only regulates the length of stroke and halting point of the motive piston in one or both directions, but also fixes the exact location at which the mechanism, such as a workpiece handling device, operated by the motive piston will begin or end its action in one or both directions.

Another object is to provide a reciprocatory fluid pressure motor of the foregoing character wherein the stroke-limiting abutment device for the motive piston is mounted on either or both cylinder heads of the cylinder so as to thereby limit the stroke and fix the halting point of the motive piston at either or both ends of its stroke.

Another object is to provide a modified reciprocatory fluid pressure motor of the foregoing character wherein the stroke-limiting abutment device is mounted upon one side or upon both sides of the motive piston head rather than upon one or both cylinder heads of the cylinder.

Another object is to provide a reciprocatory fluid pressure motor of the foregoing character wherein the stroke-limiting abutment device is moved to its adjusted position and locked therein by hydraulic fluid supplied thereto.

Another object is to provide a reciprocatory fluid pressure motor of the foregoing character wherein the stroke-limiting abutment device or devices are moved and locked in position by hydraulic pressure fluid but wherein the motive piston is reciprocated by elastic pressure fluid, such as by compressed air, in order to provide rapid action, means being provided for cushioning the halting of the motive piston head immediately prior to its arrival at the abutment surface of the stroke-limiting device.

Another object is to provide a further modified reciprocatory fluid pressure motor of the foregoing character wherein a spring-loaded pressure-fluid release valve is provided to defer the release of hydraulic fluid from a locking chamber for the stroke-limiting abutment device until the attainment of a predetermined pressure therein, whereby to reduce noise and knocking and counteract the frictional drag effect of the piston.

Other objects and advantages of the invention will become apparent during the course of the following description of the accompanying drawings, wherein:

Figure 1 is a longitudinal section through a reciprocatory fluid pressure motor provided with an adjustable

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stroke-limiting abutment mounted at each end of its cylinder;

Figure 2 is a cross-section taken along the line 2—2 in Figure 1;

Figure 3 is a cross-section taken along the line 3—3 in Figure 1;

Figure 4 is a longitudinal section through a modified reciprocatory fluid-pressure motor provided with an adjustable stroke-limiting abutment mounted on one side of the motive piston head and shown in its retracted position;

Figure 5 is a cross-section taken along the line 5—5 in Figure 4;

Figure 6 is a longitudinal section through a further modified reciprocatory fluid pressure motor provided with an adjustable stroke-limiting abutment mounted on each side of the motive piston head and shown in their extended positions;

Figure 7 is a fragmentary longitudinal section through one end of a still further modified reciprocatory fluid pressure motor provided with an adjustable stroke-limiting abutment having pressure-responsive hydraulic fluid release means associated therewith;

Figure 8 is a cross-section taken along the line 8—8 in Figure 7;

Figure 9 is a longitudinal section through a still further modified reciprocatory fluid pressure motor similar to that of Figure 1, but omitting the cushioning arrangement and using a "through" piston rod; and

Figure 10 is a fragmentary cross-section taken along the line 10—10 in Figure 9.

### *Reciprocatory fluid pressure motor with stroke-limiting abutment at end of cylinder*

Referring to the drawings in detail, Figure 1 shows an adjustable-stroke reciprocatory fluid pressure motor, generally designated 10, according to one form of the invention, as consisting generally of a cylinder or cylinder barrel 12 having cylinder heads 14 and 16 secured to the opposite ends of the cylinder 12 and closing the cylinder bore 18 within the cylinder 12. Reciprocably mounted in the cylinder bore 18 is a motive piston, generally designated 20, including a piston rod 22 carrying a piston head 24 on one end thereof. Annular cylindrical portions 26 and 28 of slightly larger diameter than the piston rod 22 and coaxial with the piston rod 22 project axially from the piston head 24 on the opposite sides 30 and 32 thereof respectively. The cylindrical portion 28 has an annular shoulder 33 between it and the surface of the piston rod 22 (Figure 1), whereas the cylindrical portion 26 has an end surface 35.

Each cylinder head 14 or 16 has connected to the inner side thereof an adjustable piston stroke-limiting abutment device 34 or 36 respectively. These abutment devices 34 and 36 are of substantially identical construction, hence the same reference numerals are used on their corresponding parts and a single description will suffice for both. Furthermore, Figure 1 shows the most versatile application of the present invention where it is desired to limit the stroke and halting point of the piston head 24 at both ends of its stroke—a condition which is not always necessary. In installations where the limiting of the stroke and alteration of the halting point of the piston head 24 is required only at one end of the stroke, it will be evident that only one of the cylinder heads 14 or 16 needs to be equipped with a stroke-limiting device 34 or 36, the other cylinder head being devoid of such a device, as in the plain cylinder heads shown in Figures 4 and 6 as described below.

The cylinder heads 14 and 16 include rectangular end plates or blocks 38 and 40 (Figure 2) with annular grooves 42 and 44 on their inner surfaces for receiving

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the opposite ends of the cylinder 12, the plates 38 and 40 being drilled as at 46 near their corners for the passage of elongated tie bolts 48 having heads 50 engaging the end plate 38 and nuts 52 threaded onto the threaded rod ends 53 engaging the end plate 40. The end plates 38 and 40 are of almost identical construction, differing from one another in the necessity for providing means for the passage of the piston rod 22 through the end plate 40 of the cylinder head 16. The end plate 38 has a blind central bore 54 therein, whereas the end plate 40 has an enlarged axial bore 56 spaced radially away from the piston rod 22 and of substantially the same diameter (with the necessary clearance for reciprocation) as that of the annular cylindrical portion 28. The passage of the piston rod 22 through the outer end of the bore 56 is sealed by an annular gland 58 secured to the end plate 40 as by the bolts 60. For purposes of simplification, the gland 58 is shown as also forming a packing or gasket for preventing leakage between it and the piston rod 22, whereas in actual practice, the gland 58 would be provided with an annular recess containing such a packing or gasket. The outer end of the bore 54 in the end plate 38 of the cylinder head 14 is of a diameter suitable to snugly but slidably receive the piston rod enlargement 26 and terminates in an end wall 62. Each of the bores 54 and 56 also passes through a tubular projection 64 extending inwardly from its respective end plate 38 or 40 and having a substantially cylindrical external surface 66 coaxial with the bores 54 or 56 and an annular end surface 68.

The piston 20 is preferably reciprocated by a compressed elastic fluid, such as compressed air or other suitable gas, which is admitted to the space on one side of the piston head 24 and discharged from the space on the opposite side thereof. For this purpose, each end plate 38 and 40 is provided with a threaded service port 70 or 72 respectively. Leading from each port 70 or 72 is a passageway 73 or 74 respectively, the inner ends of which terminate at the bores 54 and 56 respectively.

Also leading radially outward from the bores 54 and 56 in line with one another but at right angles to the passageways 73 and 74 are upper and lower passageways 76 and 78, each having a conical seat 80 or 82 opening into an enlargement or counterbore 84 or 86 (Figure 1), the outer end of which is threaded to receive an externally-threaded plug 88 or 90. The upper plug 88 is centrally bored and threaded as at 92 to receive a needle valve member 94 in the form of a headless set screw having a tapered point 96 or corresponding bevel to the seat 80. Accordingly, when the needle valve member 94 is screwed upward or downward in its threaded bore 92 in the plug 88, its tip 96 closes or opens the space within the seat 80 so as to control the volume of fluid passing therethrough. The counterbore 86, on the other hand, contains a ball check valve member 98 yieldably urged into the conical seat 82 by a helical spring 100, the opposite end of which abuts the inner end of the threaded lower plug 90.

Extending inward at right angles to the counterbores 84 and 86 are upper and lower passageways 102 and 104 respectively (Figure 1), the rearward ends of which open into sockets 106 and 108 containing the enlarged heads of upper and lower tubular stems 110 and 112 having bores 114 and 116 aligned with the passageways 102 and 104 respectively. The upper and lower stems 110 and 112 are mounted with their axes parallel to the axis of the piston rod 22 and bores 54 and 56 and their heads are secured in their respective sockets or counterbores 106 and 108 by retaining members 118 and 120 (Figures 1 and 3) bolted or otherwise secured as at 119 and 121 to the end plates 38 or 40.

At its opposite ends, the cylinder bore 18 is enlarged into an end bore 122 of slightly larger diameter, separated from the cylinder bore 18 by an annular shoulder 124. Reciprocably mounted in the cylinder bore 18

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at each end of the cylinder 12 is a hollow roughly cup-shaped abutment member 126 with an end wall 127 having an exposed abutment surface 128 against which the surface 30 or 32 of the motive piston 24 abuts at the opposite ends of its stroke. The abutment member 126 is the movable part of the abutment device 34 or 36, and has a central tubular extension 130 containing a bore 132 snugly but slidably receiving and engaging the outer surface of the central stem 64 containing the bore 56. The tubular extension 130 is slightly shorter than the length of the central stem 64 and the two tubular portions 130 and 64 telescope with one another. In a similar manner, the abutment member 126 is also provided with a pair of marginal inwardly-extending upper and lower tubular stems or projections 136 or 138 terminating slightly short of the retaining members 118 and 120 and having bores 140 and 142 snugly but slidably receiving the outer surfaces of the upper and lower tubular stems 110 and 112 in telescoping relationship.

Each abutment member 126 has a cylindrical outer wall 144 with a cylindrical outer surface 146 snugly but slidably engaging the cylinder bore 18. Each such side wall 144 terminates at an outwardly-extending annular flange 148 snugly but slidably engaging the counterbore 122. The flange 148 serves as a stroke-limiting stop on the cylinder head 14 or 16 in one direction and the abutment member 126 when it engages the annular shoulder 124 between the cylinder bore 18 and end counterbore 122 in the other direction. One or more ports 149 are provided in the side wall 144 adjacent the flange 148 and opens into an auxiliary hydraulic fluid chamber 152 within the abutment member 126. The various telescoping members or stems described above are preferably annularly grooved and provided with conventional O-rings therein to prevent leakage. To simplify the drawing, these conventional leak-preventing devices have been omitted except on the upper and lower stems 110 and 112 which are externally annularly grooved to receive O-rings 150 for that purpose.

In order to supply hydraulic pressure fluid to the auxiliary hydraulic fluid chamber 152 within the movable abutment 126, the end plates 38 and 40 of the cylinder heads 14 and 16 are provided with threaded hydraulic service ports 154 and 156 leading by way of L-shaped passageways 157 and 158 (Figures 1 and 2) to the chamber 152 for the inlet or discharge of hydraulic pressure fluid, such as oil under pressure to or from the chamber 152.

In the operation of the adjustable-stroke reciprocatory fluid pressure motor 10 of Figures 1 to 3 inclusive, the threaded service ports 70 and 72 are connected by pipes to a suitable conventional control valve (not shown) which in turn is connected to a source of compressed air or other elastic fluid. When such fluid is supplied to the bore 54 in the right-hand cylinder head 14, air is discharged to the atmosphere from the space at the left-hand end of the cylinder bore 18 adjacent the abutment device 36 by way of the bore 56 in the left-hand cylinder head 16, the service port 72 and the piping and air control valve (not shown) connected thereto. Accordingly, the air pressure thus applied to the surface 30 of the piston head 24 causes the piston 20 to move to the left until its cylindrical enlargement 28 enters the end of the bore 56 and closes the entrance thereof.

As the piston 20 continues to move to the left, air can henceforth escape only through the passageway 114 in the upper stem 110 through the counterbore 84 and member 94 through the restricted opening between the conical tip 96 of the needle valve member 94, and the conical seat 80 through the passageway 76 into the outer end of the bore 56, the inner end of which is temporarily closed by the piston rod enlargement 28, thence escaping through the port 72 to the atmosphere. Air attempting to escape through the lower passageway 116 in the lower tubular stem 112 is prevented from so doing by the ball check

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valve member 98 urged against its seat 82 by the spring 100 and the pressure of this air. This sudden restriction on the release of the air from the left-hand end of the cylinder bore 18 causes the air therein to become slightly compressed for the remainder of the stroke of the piston 20, slowing down the speed of the piston 20 and cushioning the impact of the piston head surface 32 with the abutment surface 128 of the abutment member 126 which terminates the stroke of the piston 20.

To shorten the stroke of the piston 20 to the left and move its halting point nearer the mid point of the cylinder 12, hydraulic pressure fluid is admitted through the port 156 and L-shaped passageway 158 to the chamber 152 within the abutment member 126, acting against the inner side of its end wall 127. This action causes the abutment member 126 to move to the right in the cylinder bore 18 as long as hydraulic pressure fluid, such as oil under pressure, is supplied to the port 156 from a pump or other source thereof by way of a conventional four-way hydraulic pressure control valve (not shown). The hydraulic pressure fluid fills the chamber 152 and also passes through the port or ports 149 in the cylindrical side wall 144 of the abutment member 126 into the counterbore 122. When the hydraulic control valve is closed, locking the hydraulic fluid in the chamber 152 and L-shaped passageway 158, as well as in the counterbore 122, the abutment member 126 stops moving and its abutment surface 128 halts. Henceforth, the piston head 24 and piston rod 22 of the piston 20 temporarily perform a shortened stroke to the left because the piston surface 32 now sooner engages the abutment surface 128 of the now advanced end wall 127 of the abutment member 126. Thus, not only is the stroke of the piston 20 shortened to the left, but its piston head 24 and piston rod 22 are caused to halt at a precisely-positioned point determined by the then-attained location of the abutment surface 128 on the abutment member 126.

The stroke of the piston head 24 and piston rod 22 to the right toward the abutment device 34 takes place in a similar manner when the motive pressure fluid control valve is reversed so that compressed air or other pressure fluid enters the service port 72 in the left-hand cylinder head 16 and is discharged from the port 70 in the right-hand cylinder head 14. The abutment member 126 of the abutment device 34 is also adjusted in the manner described above for the abutment device 36, and the speed of reciprocation of the piston 20 is retarded and cushioned in the manner also described above.

To reciprocate the piston 20 in the opposite direction to that described above, namely to the right, the main pressure fluid or motive fluid control valve is reversed, thereby supplying pressure fluid, such as compressed air, to the service port 72 in the cylinder head 16 and venting the service port 70 in the cylinder head 14 to the atmosphere. Since at this time the cylindrical portion 28 of enlarged diameter is closing the inner end of the bore 56, the sole piston area exposed to the entering motive pressure fluid is the annular shoulder 33 between the cylindrical portion 28 and the piston rod 22. However, the pressure of the motive fluid, such as compressed air, within the temporarily closed bore 56 is bypassed through the passageway 78, counterbore 86 and passageways 104 and 116 (the latter within the lower stem 112) when the pressure of the motive fluid overcomes the thrust of the spring 100 and moves the ball 98 off its seat 82. Thus, the motive pressure fluid emerging from the passageway 116 is enabled to act against the entire area of the surface 32 of the piston head 24, moving the latter to the right until the consequent travel of the cylindrical portion 28 out of the bore 56 reopens communication between the latter and the cylinder bore 18.

To lengthen the piston stroke at one or both ends of its stroke, the hydraulic control valve is operated to release hydraulic fluid from one or both ports 154 and

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156. The elastic fluid control valve is then operated to apply pressure to the surface of the piston head 24 at the opposite end of the cylinder 12, moving the piston head 24 against one of the movable abutments 126 so as to expel hydraulic fluid from the chamber or chambers 152 thereof to effect retraction thereof and consequently lengthen the stroke of the piston 20.

#### *Modified adjustable stroke motor with check valve cushioning*

The modified adjustable stroke motor, generally designated 160, of Figures 7 and 8, is substantially identical to the reciprocatory motor 10 of Figures 1 to 3 inclusive with the addition of a lightly-spring-loaded inlet check valve 162 and a relatively heavily-spring-loaded outlet check valve 164 leading respectively to and from the peripheral chamber 122. The views of Figures 7 and 8 have a slightly different appearance from the corresponding views of Figures 1 and 3 because the motor 160 has been rotated 90 degrees in a clockwise direction in order to bring out more clearly the check valves 162 and 164, which are located out of the vertical longitudinal section plane of Figure 1. Corresponding parts in Figures 7 and 8 are designated with the same reference numerals as in Figures 1 to 3 inclusive. This arrangement is of especial importance with relatively small diameter cylinders, where the enlargement 26 or 28 on the piston rod 22 exerts a relatively more powerful frictional drag upon the wall of the bore 54 or 56 in leaving these bores than in cylinders with relatively large diameter pistons 24. Under such circumstances with the arrangement shown in Figure 1, the sudden exposure of the entire piston head surface 30 or 32 to the motive pressure fluid may occasionally cause a knock or other noise due to the sudden reaction imposed upon the end wall 127 of the abutment member 126. This knock may also occur when the piston rod 22 is operatively connected at its outer end to a crank mechanism. The addition of the spring-loaded outlet check valve 164 locks the hydraulic fluid in the chamber 122 until it overcomes the spring pressure and prevents movement of the abutments 126 and thus greatly reduces such noise or knock.

To install the check valves 162 and 164, the peripheral wall 144 of the abutment member 126 is provided with a pair of threaded ports 166 and 168 respectively (Figure 8) into which the threaded stems 170 and 172 of the hollow check valve casings 174 and 176 are threaded. The stems 170 and 172 have passageways 178 and 180 leading out of the valve chambers 182 and 185 into which lead passageways 186 and 188 in the plugged outer ends of the casings 174 and 176. The inlet check valve 162 contains a valve seat 190 at the inner end of the passageway 186, whereas the outlet check valve 164 has a valve seat 192 at the inner end of the passageway 180, these seats being engaged by valve balls 194 and 196 urged against their respective seats by compression springs 198 and 199 respectively. The spring 198 is of relatively light pressure so as to permit the ball 194 to be moved easily off its seat 190 but the spring 199 is of relatively heavy pressure so as to hold the outlet ball valve member 196 closed against its seat 192 until a relatively heavy pressure is exerted against it by fluid in the peripheral chamber 122.

The operation of the thus-modified adjustable stroke reciprocatory motor 160 is for the most part the same as that of the motor 10 of Figures 1 to 3 inclusive described above, hence requires no repetition. As the abutment member 126 of either the abutment device 34 or 36 is reciprocated in response to the admission of hydraulic pressure fluid into its chamber 152, such fluid passes through the inlet port 186 of the inlet check valve 162, lifting the lightly loaded ball 194 off its seat 190 and permitting the fluid to pass through the outlet passageway 178 thereof into the peripheral chamber 122,

Meanwhile, the ball 196 of the outlet check valve 164 is maintained against its seat 192 both by its spring 199 and the pressure of the hydraulic pressure fluid reaching it through the passageway 188 of the outlet valve casing 176 (Figure 8).

When, however, the abutment member 126 has been moved to such an extent that its abutment surface 128 has arrived at the desired location for halting the stroke of the piston 20, the valve controlling the supply of hydraulic fluid is closed, entrapping the hydraulic fluid both in the chamber 152 within the abutment member 126 and also in the peripheral chamber 122 surrounding the outer wall 144 thereof. When, now, compressed air or other motive pressure fluid is supplied to the service port 72, passageway 74 and bore 56 around the piston rod 22 of the piston 20, it pushes the piston rod enlargement 28 out of the outer end of the bore 56, thereby suddenly exposing the entire areas 32 and 128 of the piston head 24 and abutment member 126 to the action of the pressure fluid. This action, however, is incapable of forcing the abutment member 126 backward because of the hydraulic liquid locked in the chamber 152 and in the peripheral chamber 122. When the hydraulic fluid control valve is opened, however, to permit discharge of oil from the abutment member chamber 152 in response to the pressure of the piston head 24 thereagainst, the release of fluid from the peripheral chamber 122 into the abutment member chamber 152 is effected by its forcing the ball 196 off its seat 192 by overcoming the thrust of the spring 199, since the hydraulic pressure in the chamber 122 is increased proportionally as the area 128 is to the area 124.

#### *Reciprocatory fluid pressure motor with single stroke-limiting abutment in piston head*

The further modified reciprocatory fluid pressure motor, generally designated 200, shown in Figures 4 and 5 differs from the motors 10 and 160 of Figures 1 and 7 principally by having a single stroke-limiting abutment associated with and mounted on a single-movable-abutment motive piston head. The motor 200 accordingly has plain cylinder heads 202 and 204 respectively similar in construction to the outer portions of the piston heads 14 and 16 of Figure 1 without their portions forming parts of their respective movable abutment devices 34 and 36. Consequently, a repetition of description is deemed to be unnecessary, and corresponding parts are designated with the same reference numerals. Reciprocably mounted in the cylinder bore 208 of the cylinder barrel 206 of the motor 200 is a compound adjustable-stroke motive piston, generally designated 210, having a compound motive piston head, generally designated 212, mounted on a hollow piston rod 214 containing a longitudinal bore or passageway 216 closed at its inner end by a plug 218 and at its outer end by the solid outer portion 220.

The piston rod 214, like the piston rod 22 of Figure 1, passes slidably through the gland 58, closing the enlarged bore 56 around the piston rod 214. The latter, near its outer end, is provided with a threaded port 222 threadedly receiving the threaded pipe coupling 224 of a flexible hydraulic hose or conduit 226. The latter is connected through a suitable hydraulic control valve to a source of hydraulic pressure fluid. The ports 70 and 72, as in Figure 1, are connected by suitable piping through a suitable conventional reversing valve (not shown) to a conventional source of elastic pressure fluid, such as compressed air, which is preferred to hydraulic pressure fluid as a motive fluid because of its more rapid response.

The bore 216 of the hollow piston rod 214 near its inner end is provided with radial ports 228 which lead into a chamber 230 between the stationary and movable piston head components 232 and 234 of the motive piston 210. In order to hold the stationary component 232 in a fixed position on the piston rod 214, the latter

is grooved to receive a snap ring 236 against which it is held by a nut 238 threaded upon the threaded portion 230 near the inner end of the piston rod 214. The extreme inner end portion 240 of the piston rod 214 is of slightly reduced diameter in order to snugly but slidably enter the bore 54 in the piston head 202. The end wall 242 of the stationary piston head component 232 is centrally bored as at 243 to receive the piston rod 214 and is provided with an outer or peripheral cylindrical wall 244 and four spaced intermediate circular bosses 246 (Figure 5) located between the bore 243 and the wall 244. Packings 248 and 250 respectively prevent leakage of elastic fluid past them during reciprocation of the piston head 212 along the cylinder bore 208.

Secured to the bosses 246 as by the screws 252, is an approximately cup-shaped open-centered annular member 254 having an outwardly-projecting flange 256 spaced away from the inner surface 258 of an annular side wall 260 secured as by the screws 262 to the radial or disc portion 264 of the movable piston head component 234. The latter has an axially-elongated hub 266 on its inner side and a tubular boss or projection 268 on its outer side snugly but slidably engageable with the bore 56 in the cylinder head 204. The hub 266 and projection 268 contain an axial bore 269 slidably engaging the piston rod 214. The side wall 260 has an inwardly-projecting flange 270 engageable with the flange 256 to limit the maximum separation of the stationary and movable piston head components 232 and 234 respectively. The side wall 260 is also provided with an annular recess 272 extending axially away from the end wall 242 of the stationary piston head component 232, and is preferably provided with ports 274 communicating with the chamber 230 so as to facilitate flow of hydraulic fluid in the recess 272. The piston head portions 242, 234 and 260 are annularly grooved to receive conventional O-rings or gaskets to prevent leakage at the points 276, 278 and 280 respectively. In the operation of the reciprocatory motor 200 with single-movable abutment, adjustable limitation of the stroke of the motive piston 210 takes place only on the left-hand side thereof where the relatively movable piston head component 234 is mounted for sliding motion along the piston rod 214. The action of the compressed air or other motive fluid in entering one of the service ports 72 while being discharged from the other service port 70 to reciprocate the piston head 212 in the cylinder bore 208 is similar to that described above in connection with Figure 1, and a similar cushioning action takes place at the opposite ends of its stroke by reason of the entry of the portions 240 and 268 on the piston rod 214 into their respective bores 54 and 56, as described below. The movable component 234 of the piston head 212 is adjusted relatively to the stationary component 232 thereof by admitting hydraulic pressure fluid to the chamber 230 through the flexible conduit 226, piston rod passageway 216 and radial ports 228, thereby moving the movable component 234 away from the stationary component 232.

Consequently, the piston head 212 is, in effect, thickened toward the left away from the outer end portion 240 of the piston rod 214, thereby shortening the stroke between the piston head 212 and the cylinder head 204. The reversal of the hydraulic control valve (not shown) to permit hydraulic fluid to be discharged from the chamber 230 through the piston rod bore 216 and flexible conduit 226 enables the movable component 234 to be pushed toward the stationary component 232 when the former comes into engagement with the cylinder head 204 at the end of the left-hand portion of the stroke of the piston 210.

#### *Reciprocatory fluid pressure motor with double-stroke-limiting abutments in piston head*

The still further modified reciprocatory fluid pressure motor, generally designated 300, shown in Figure 6 is

generally similar to the motor 200 shown in Figures 4 and 5, but differs principally therefrom by having double movable-stroke-limiting abutments associated with and forming parts of and mounted on a double-movable-abutment motive piston head on opposite sides thereof. The motor 300, like the motor 200, accordingly has plain cylinder heads 302 and 304 respectively similar in construction to the outer portions of the piston heads 14 and 16 of Figure 1, without their portions forming parts of their respective movable abutment devices 34 and 36. For this reason, a repetition of the description of the cylinder heads 14 and 16 in connection with the cylinder heads 302 and 304 is deemed to be unnecessary, and corresponding parts are designated with the same reference numerals.

The motor 300 is provided with a cylinder barrel 306 having a cylinder bore 308 in which is reciprocally mounted a compound adjustable stroke motive piston, generally designated 310, and having a compound motive piston head, generally designated 312, mounted on a hollow piston rod 314 containing a pair of longitudinal bores or passageways 316 and 318 respectively. The piston rod 314, like the piston rods 22 of Figure 1 and 214 of Figure 4, passes slidably through the gland 58 which closes the enlarged bore 56 around the piston rod 314. The latter, near its outer end, is provided with a pair of threaded ports 320 and 322 respectively, receiving the threaded pipe couplings 324 and 326 of flexible hydraulic hoses or conduits 328 and 330 respectively. The service ports 70 and 72 in the cylinder heads 302 and 304, as in Figures 1 and 4, are connected by suitable piping through a suitable conventional reversing valve (not shown) to a conventional source of elastic pressure fluid, such as compressed air, which is preferred to hydraulic pressure fluid as a motive fluid because of its more rapid response.

The passageways 316 and 318 in the hollow piston rod 314 at their inner ends are provided with longitudinally-spaced radial ports 334 and 332 respectively leading into the interior of the compound double movable abutment motive piston head, as described below. The portion of the piston rod 314 between the ports 332 and 334 is grooved to receive spaced snap rings 336 between which is mounted the stationary component 338 of the compound motive piston head 312. The opposite sides of the stationary component 338 are similar in construction to the stationary component 232 of the single-sided abutment motive piston head 212 but the component 338 is double-sided instead of single-sided, hence similar parts are designated with the same reference numerals. In other words, the stationary component 338, as is seen by a comparison of Figure 6 with Figure 4, has a transverse wall 342 centrally bored at 340 to receive the hollow piston rod 314 and is provided with a pair of outer or peripheral cylindrical walls 344 extending in opposite directions from the transverse wall 342, together with a plurality of spaced intermediate circular bosses 345 projecting axially in opposite directions from the transverse wall 342 between the bore 340 and the peripheral walls 344.

The remainder of the construction of the motive piston 310 is substantially the same on opposite sides of the stationary component 338 as the motive piston 210 of Figure 4, with the exception that the movable components, generally designated 346 and 348 are doubled in that they are located on both sides of the stationary component 338. The movable components 346 and 348 therefore as to their component parts are designated with the same reference numerals as the movable component 234 of Figure 4, and are retained in connection with the stationary component 338 by open-centered cup-shaped members 350 of substantially the same construction as the cup-shaped member 254. It will be observed by a comparison of Figure 6 with Figure 4, however, that the inner end portion 352 of the hollow piston rod 314 is of

substantially the same diameter as the outer portion 354 thereof and of portions therebetween, with the result that the bore 54 in the cylinder head 302 is of substantially the same diameter as the bore 56 in the cylinder head 304, rather than being of slightly reduced diameter as at 240 in Figure 4.

In the operation of the reciprocatory motor 300 with double movable abutments 346 and 348 on its motive piston head 312, Figure 6 shows the abutments 346 and 348 extended to their maximum-positions of separation from the stationary component 338, with the result that the motive piston 310 possesses the minimum stroke as it is reciprocated to and fro within the cylinder bore 308 by the admission of compressed air or other motive fluid through one of the service ports 70 or 72 while the other service port 72 or 70 is vented to the atmosphere. In Figure 6, the movable abutments 346 and 348 have been slid along the piston rod 314 by supplying their internal chambers 230 with hydraulic pressure fluid, such as oil under pressure, from a conventional source of hydraulic pressure fluid, such as a pump, controlled by a conventional hydraulic control valve. Under such an arrangement, hydraulic pressure fluid proceeding through the pipes 328 and 330, passageways 316 and 318 and ports 334 and 332 respectively, into the chambers 230 on opposite sides of the transverse wall 342 of the stationary piston component 338 reacts against the latter to push the movable abutments 346 and 348 axially in opposite directions away from the stationary component 338.

Accordingly, as the motive piston 310 is reciprocated in the cylinder bore 308 in the manner described above, the movable components 346 and 348 engage their respective cylinder heads 302 and 304 after their respective tubular axial projections 268 enter their respective cylinder head bores 54 and 56, causing the cushioning and retarding action described above in connection with the operation of the motor 10 of Figure 1 and motor 200 of Figure 4. The subsequent engagement of the movable components 346 and 348 with their respective cylinder heads 302 and 304 halts the compound piston head 312 and consequently the piston 310 at the opposite ends of its shortened stroke.

To retract either or both of the movable abutments 346 and 348, the operator merely opens the conventional hydraulic control valve (not shown) in the pipe line 328 or 330 or both leading to the source of hydraulic fluid and permitting discharge of hydraulic fluid from the chambers 230 on either or both sides of the transverse wall 342 of the stationary piston head component 338. Thus, the stroke of the compound piston head 312 can be changed by infinitesimally small increments on either side of the stationary component 338 merely by adjusting either of the movable components 346 or 348 in this manner. When a movable component 346 or 348 is being retracted by applying suction to its respective port 332 or 334, the engagement of the movable component 346 or 348 with its respective cylinder head 302 or 304 assists this retraction by providing an additional push to the movable component 346 or 348 which is then in engagement with its respective cylinder head 302 or 304.

#### *Reciprocatory fluid pressure motor without cushioning arrangement but with through piston rod*

The still further modified reciprocatory fluid pressure motor, generally designated 400, shown in Figures 9 and 10, is generally similar to the motor 10 of Figures 1 to 3 inclusive, except that the cushioning arrangement consisting of the needle valve 94 and ball check valve 98, together with their tubular stems 110 and 112 is omitted. Also omitted are the corresponding tubular portions 136 and 138 of the abutment members 126 telescoping with the tubular stems 110 and 112. Furthermore, the piston rod of Figure 9 is shown as a "through" piston rod in that both ends of it pass through corresponding bores in the cylinder heads, so that both ends of the motor 400

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in this respect have constructions similar to the left-hand end of Figure 1. It will be obvious, however, from a comparison of Figures 1 and 9 that the through piston rod of Figure 9 is equally applicable to the motor 10 of Figure 1 and that the one-ended piston rod of Figure 1 is also equally applicable to Figure 9, depending upon the conditions and demands of the particular installation. Due to the above-mentioned identical or similar features of construction, and also due to the fact that the differences of the motor 400 of Figure 9 from the motor 10 of Figure 1 consist almost entirely in omission rather than changes or additions, the same reference numerals are used for the corresponding parts in Figure 9 as in Figure 1, and hence no repetition of the description of the construction is deemed necessary.

As in the fluid pressure motor 10 of Figures 1 to 3 inclusive, the threaded service ports 70 and 72 of the fluid pressure motor 400 of Figures 9 and 10 are connected by pipes through a suitable conventional control valve (not shown) to a source of compressed air or other elastic fluid. When such compressed gas is supplied to the bore 54 in the cylinder head 14 at the right-hand end of the cylinder bore 18, air is discharged from the space at the left-hand end thereof by way of the bore 56 in the cylinder head 16 and thence through the service port 72 by way of the piping and control valve to the atmosphere. Accordingly, the gas pressure thus applied to the right-hand surface 30 of the piston head 24 causes the piston 20 to move to the left until the left-hand piston head surface 32 engages the abutment surface 128 of the abutment member 126 of the stroke-limiting abutment device 36, terminating the leftward stroke of the piston 20.

The rightward stroke of the piston 20 is accomplished in the reverse manner by reversing the control valve so as to admit compressed gas through the threaded port 72 at the left-hand end of the cylinder 12 in the cylinder head 16 and discharge gas from the threaded port 70 at the right-hand end thereof in the cylinder head 14. The piston head 20 accordingly moves to the right, carrying with it the piston rod 22, until the right-hand piston surface 30 engages the abutment surface 128 on the right-hand abutment piston 126 of the right-hand stroke-limiting abutment device 34.

To shorten the stroke of the piston 20 to the left and move its halting point nearer the midpoint of the cylinder 12, hydraulic pressure fluid is admitted through the port 156 in the left-hand cylinder head 16 and thence passes through the L-shaped passageway 158 to the chamber 152 within the left-hand abutment member 126 of the stroke-limiting abutment device 36. This hydraulic pressure fluid, acting against the inner side of the end wall 127 of the left-hand abutment member 126 causes the latter to move to the right in the cylinder bore 18 as long as hydraulic pressure fluid is supplied to the port 156 from a pump or other conventional source by way of a conventional hydraulic circuit including a conventional hydraulic pressure control valve (not shown). This hydraulic pressure fluid fills the chamber 152 within the left-hand abutment member 126 and thence passes through the port or ports 149 in the cylindrical side wall 144 of the abutment member 126 into the counterbore 122 of the cylinder 12.

When the left-hand abutment member 126 of the stroke-limiting abutment device 36 has been moved inward to the right to shorten the stroke of the piston 20 to the desired extent, the hydraulic control valve is shifted to its shut-off position. This action locks or traps the hydraulic fluid in the chamber 152, L-shaped passageway 158 and counterbore 122, whereupon the left-hand abutment member 126 stops moving and its abutment surface 128 halts. Henceforth, under the previously-described mode of operation from compressed air or other elastic fluid, the piston head 24 and piston rod 22 of the piston 20 temporarily perform a shortened stroke to the left

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because the piston head surface 32 now encounters the abutment surface 128 of the left-hand abutment member 126 sooner than it previously did. In this manner, not only is the leftward stroke of the piston 20 shortened, but its piston head 24 and piston rod 22 are also caused to halt at a precisely-positioned point determined by the then attained position of the abutment surface 128 on the left-hand abutment member 126.

The limiting of the stroke of the piston head 24 and piston rod 22 of the piston 20 to the right toward the right-hand stroke-limiting abutment device 34 takes place in a similar but reversed manner. To accomplish this, the right-hand abutment member 126 of the right-hand stroke-limiting device 34 is supplied with hydraulic fluid through the port 154 to move it outward to a desired position of stroke limitation. When the motive fluid control valve is reversed, compressed air or other elastic pressure fluid is supplied to the service port 72 in the left-hand cylinder head 16 and fluid is vented from the service port 70 in the right-hand cylinder head 14 to the atmosphere. During its reciprocation, the piston head 24 will then halt at the end of its rightward stroke when its surface 30 engages the thus-advanced abutment surface 128 of the right-hand abutment member 126.

What I claim is:

1. An adjustable stroke reciprocatory fluid pressure motor comprising a cylinder having a cylinder bore therein, cylinder head structures secured to the opposite ends of said cylinder in closing relationship with the opposite ends of said bore, a piston having thereon a piston head structure reciprocally mounted in said bore and a piston rod connected thereto, one of said cylinder head structures having an enlarged bore therein of larger diameter than the piston rod and extending into said cylinder bore, said piston head structure having a central cylindrical projection movable into and out of said enlarged bore in snugly-fitting relationship therewith, a fluid flow-restricting device connecting said cylinder bore to said enlarged bore, and means for admitting pressure fluid to said cylinder bore for reciprocating said piston structure therein; one of said cylinder head structures having a fixed component, a movable abutment component reciprocally mounted in said cylinder and disposed adjacent said fixed component for axial motion relatively thereto and forming with said fixed component an auxiliary hydraulic fluid chamber therebetween, and means for passing hydraulic fluid into and out of said auxiliary chamber for adjustably moving said movable component axially relatively to said fixed component.

2. An adjustable stroke reciprocatory fluid pressure motor, according to claim 1, wherein the movable component is approximately cup-shaped and has a peripheral portion slidably engaging said cylinder bore.

3. An adjustable stroke reciprocatory fluid pressure motor, according to claim 1, wherein said pressure fluid admitting means includes telescoping tubular conduit members connected to said fixed and movable components respectively.

4. An adjustable stroke reciprocatory fluid pressure motor, according to claim 1, wherein said cylinder and said movable cylinder head component have axially-aligned shoulder portions engageable with one another at the maximum separation of said components.

5. An adjustable stroke reciprocatory fluid pressure motor, according to claim 4, wherein said shoulder portions in the retracted positions of said components define the opposite ends of a peripheral hydraulic fluid chamber and wherein means is provided for passing hydraulic fluid into and out of said peripheral hydraulic fluid chamber.

6. An adjustable stroke reciprocatory fluid pressure motor, according to claim 5, wherein a pressure-responsive fluid release valve is connected to said peripheral chamber for discharge into said main chamber.

7. An adjustable stroke reciprocatory fluid pressure motor, according to claim 6, wherein a uni-directional

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fluid intake valve is connected to said main chamber for discharge into said peripheral chamber.

8. An adjustable stroke reciprocatory fluid pressure motor, according to claim 1, wherein the fixed and movable components are connected to said piston structure. 5

9. An adjustable stroke reciprocatory fluid pressure motor, according to claim 8, wherein the piston rod has a hydraulic fluid passageway extending therethrough to the interior of said piston structure between the fixed and movable components thereof.

10. An adjustable stroke reciprocatory fluid pressure motor, according to claim 9, wherein the fixed and movable components have axially-extending telescoping peripheral walls. 10

11. An adjustable stroke reciprocatory fluid pressure motor, according to claim 10, wherein retaining means is provided between said components for limiting the maximum separation thereof. 15

12. An adjustable stroke reciprocatory fluid pressure motor, according to claim 1, wherein a uni-directional 20

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motive fluid inlet valve is disposed between said cylinder bore and said enlarged bore.

13. An adjustable stroke reciprocatory fluid pressure motor, according to claim 1, wherein said fluid flow-restricting device includes a valve seat and a flow-restricting valve member adjustably movable toward and away from said valve seat.

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