ABSTRACT: The percussive forces are imparted to the drill rod by a hydraulically actuated reciprocating piston housed in a cylinder having fluid openings on opposite sides of the piston. Fluid under pressure is supplied alternately to the respective openings to reciprocate the piston in the cylinder from a multivalve control device. A timing mechanism is included in the multivalve control device to open and close the valve ports within the valve to supply pressurized fluid alternately to the openings in the cylinder on opposite sides of the piston and to alternately vent the pressurized fluid from the cylinders. Pressure accumulators are employed as surge devices for excess fluid supplied to the cylinder for each stroke of the piston.
1

ROTARY PERCUSSION DRILL HAVING A
HYDRAULICALLY ACTUATED PERCUSSION DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a hydraulically actuated reciprocating device and more particularly to a hydraulically actuated reciprocating piston percussion device with control means to supply fluid under pressure alternately to opposite faces of a piston.

2. Description of the Prior Art

In underground mines the roof of the entries or tunnels are supported by expansion-type roof bolts. The bolts are inserted in drilled holes that are arranged in predetermined spaced patterns. The drilling of the boleholes consumes a substantial amount of time and contributes substantially to the overall cost of the mining operation. The boleholes were, in the past, drilled by rotary drills and it was found by using a high rotary speed and imparting percussive forces to the drill rod that it was possible to increase the rate of penetration of the drill rod and thus reduce the time required to drill the boleholes. The percussive forces applied to the drill rod were imparted either by the conventional air-type reciprocating devices well known in the percussive drill art or imparted by the action of eccentric weights. The use of air underground, especially in coal mines, is discouraged because the exhaust air adjacent the drill rod increases the dust hazards. There have been several proposals in the past of imparting the percussive forces to the drill rod by a hydraulically actuated device. To the best of my knowledge none of these devices have been commercially successful. There is a need, therefore, for a hydraulically actuated percussive device that may be used with a percussion drill or associated with a high-speed rotary drill to impart percussive forces thereto.

SUMMARY OF THE INVENTION

The herein described invention relates to a hydraulically actuated reciprocating piston. Hydraulic fluid under pressure is supplied alternately to the piston cylinder assembly on opposite sides of the piston from a multivalve control device to open and close the valve ports within the valve to supply pressurized fluid alternately to opposite sides of the piston and to alternately vent the cylinder on opposite sides of the piston so that the timing device controlling the opening and closing of the valves thereby control the rate of reciprocation of the piston. The device may also be employed as a positive displacement pump to supply the fluid to the control valves. The piston cylinder assembly may be connected to either a percussive drill or to high-speed rotary drill to impart percussive forces to the rotating drill rod.

The principal object of this invention is to provide a fluid-actuated device that includes a multivalve control device which alternately supplies fluid under pressure to opposite sides of a reciprocating piston within a cylinder.

Another object of this invention is to provide a reciprocating device wherein the timing device for supplying pressurized fluid to opposite sides of a reciprocating piston within a cylinder also functions as a positive displacement pump.

Another object of this invention is to provide a reciprocating device in which the cylinders on opposite sides of the piston are connected to pressure ports and vent ports of a multivalve control device and accumulator devices are provided to displace the excess fluid supplied to the cylinder.

Another object of this invention is to provide a reciprocating piston in which the cylinder is provided with a liquid shock-absorbing means for the piston at opposite ends of its stroke.

Another object of this invention is to provide a percussion drill with a hydraulic actuated percussive device.

Another object of this invention is to provide a reciprocating device wherein the volume of liquid displaced by a timing and metering device will correspond with the volume of liquid required to displace the piston in the cylinder for a complete stroke of the piston.

These and other objects and advantages of this invention will be more completely disclosed and described in the following specification, the accompanying drawings and the appended claims.

5

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a view in elevation of the multivalve control device illustrating the plurality of inlet and outlet ports for the pressure and vent valves and the timing device.

FIG. 2 is a view in section taken along the line II-II of FIG. 1 illustrating in detail the plurality of valves in their operative positions and the gears of the timing device.

FIG. 3 is a view in section of a rotary percussion drill head with a cylinder housing the reciprocating piston and having pairs of openings on opposite sides of the piston.

FIG. 4 is a view in section of the pressure accumulators illustrated in FIG. 1. Connected to the vent or return conduit.

FIG. 5 is a view in section taken along the line V-V of FIG. 2 illustrating one of the pressure valves in open position.

FIG. 6 is a view in section taken along the line VI-VI illustrating one of the vent valves in a closed position.

FIG. 7 is a view in section taken along the line VII-VII in FIG. 2 illustrating in detail the timing gears that may also function as a positive displacement pump.

FIG. 8 is a view taken along the line VIII-VIII of FIG. 5 illustrating one of the rotary disc valve members with a peripheral fluid passage across a portion thereof.

FIG. 9 is a schematic view illustrating the motor-driven valve where the timing device also functions as a positive displacement pump.

FIG. 10 is a schematic view similar to FIG. 9 where the fluid under pressure is supplied from a separate source to the timing portion of the multivalve control device. The timing gears are employed as a motor to open and close the respective valves. The rate of percussion imparted by the piston may be controlled with a flow control valve controlling the rate of flow to the timing gears.

FIG. 11 is a schematic view similar to FIG. 9 in which separate drive members are provided for the timing device to open and close the respective valves. With this arrangement, the percussion rate can be varied over a wide range.

FIG. 12 is a perspective view of pairs of the disc valve elements with shafting connecting axially aligned pairs of disc valve elements.

FIG. 13 is a view partially in section of a percussion drill head with the cylinder housing and a reciprocating piston having pairs of openings on opposite sides of the piston.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings and particularly to FIG. 3, there is illustrated a drill head generally designated by the numeral 10 that includes a cup-shaped housing 12 with an annular open top portion 14 and a base portion 16. The sidewall of the housing 12 has an opening 18 in which bearings 20 are positioned to support a rotatable shaft 22. A bevel gear 24 is connected to the shaft 22 within the housing 12. Suitable means, not illustrated, are arranged to rotate the shaft 22 and thus impart rotation to a drill rod 26, as later explained. A top plate 28 encloses the housing opening 14 and is secured to the housing 12 by means of bolts 30. The plate 28 has an upwardly annular collar portion 32 with an annular passageway 34 connected to an outlet opening 36 for removing the dust and cuttings conveyed through the internal passageway 38 of the drill rod 26.

Positioned within the housing 12 is a drill rod support member 40 that has a base portion 42 and a cylindrical sidewall 44. A bevel gear 46 is secured to the outer portion of the cylindrical wall 44 and meshes with the bevel gear 24 to thereby rotate the drill rod support 40 within the housing 12. Suitable thrust bearings 48, 50 and 52 are arranged between the housing 12 and the drill rod support member 40 to permit rotation of the drill rod support member relative thereto. The upper portion of the drill rod support member has a socket 54.
for receiving a drill rod therein. The drill rod, however, is free to move axially in the socket 54 so that the percussive forces imparted thereto are transmitted through the drill rod to a drill bit connected the opposite end thereof.

The drill rod support member 40 has an opening 56 in the base portion 42 in which there is positioned a bearing 58. The support member 40 has an axial passageway 60 therethrough aligned with the opening 56 in which there is positioned a hammer shaft 62. The end portion 64 of the hammer shaft 62 extends through the opening 56 in the support member 49 into the inner portion of housing 12. The hammer shaft 62 has an enlarged other end portion 66 which is positioned in the upper portion of the drill rod support member and is in abutting relation with the base of the drill rod 26 and is operable upon axial reciprocatory movement to impart percussive strokes to the drill rod 26.

A cylinder generally designated by the numeral 68 has a body portion 70 and end flange members 72 and 74. The end flanges 72 and 74 are secured to the body portion 70 and to the housing base portion 16 by means of bolts 76 and are axially aligned with the hammer shaft 62. The body portion 70 has an inner cylindrical chamber 78 with an upper annular chamber portion 84 and a lower annular chamber portion 86 that provides upper and lower cylindrical chamber portions 84 and 86 of reduced diameter. Positioned within the cylindrical chambers of reduced diameter are annular bearings 88 and 90. A piston generally designated 92 has an annular recessed portion 94 in which a piston ring 96 is positioned. The piston 92 has substantially the same diameter as the cylindrical chamber 78 of cylinder 68 so that fluid under pressure acting on the upper annular surface 98 of piston 92 moves the piston 92 downwardly in the body portion 70. Similarly, fluid pressure acting on the lower annular surface 100 moves the piston upwardly within the cylinder body portion 78.

The piston 92 has a pair of oppositely extending cylindrical shafts with intermediate portions 102 and 104. The diameter of the intermediate portions 102 and 104 is substantially the same as the diameter of the cylindrical chamber portions 84 and 86. There is approximately .002 inch clearance between the surfaces of intermediate portions 102 and 104 and the inner cylindrical wall of chamber portions 84 and 86. With this arrangement, as the cylinder 92 is reciprocated so that the intermediate shaft portions 102 and 104 are moved into the cylindrical chamber 84 and 86 and the fluid entrapped within the chamber portions serves as a liquid cushion for the piston. Because of the slight clearance between the intermediate shaft portions 102 and 104 and the side walls of the chamber portions 84 and 86 the fluid is slowly displaced to thereby provide a fluid cushion for the piston 92. There are provided passageways 106 and 108 in the flanges 72 and 74 to receive and return to the tank, the fluid that has leaked past the bearings 88 and 90.

The oppositely extending shafts of piston 92 have end shaft portions 110 and 112 extending therefrom. The end shaft portions are suitably positioned in the annular bearings 88 and 90 to maintain the piston 92 axially aligned within the cylinder 68. The shaft end portion 110 extends through an opening 114 in the drillhead housing bottom portion 16 and has an end surface 116 in abutting relation with the end portion 64 of hammer shaft 62. With this arrangement, upward movement imparted to the piston 92 is transmitted through the shaft end portion 110 to the end surface 116 which, in turn, strikes the end portion 64 of hammer shaft 62 and moves the hammer shaft upwardly within the drill rod support member 40. Since the upper portion 66 of hammer shaft 62 is in abutting relation with the base of drill rod 26 this upward percussive force or motion is transmitted to the drill rod 26. Since the drill rod is continually urged against the base of the hole being drilled by the drilling machine, the drill rod 26 and hammer shaft 62 are moved downwardly in the drill and support 40 when the piston 92 is moved downwardly within the cylinder 68. Thus, each upward movement of the piston 92 imparts an upward percussive blow to the drill hammer 62 which is, in turn, transmitted to the drill rod 26. Positive fluid pressure is employed to move the piston 92 downwardly away from the drill hammer end portion 64.

The cylinder body portion 70 has an upper inlet port 118 opening into the cylindrical passageway 78 within the body portion 70 and an upper outlet port 120. It should be noted in the particular embodiment illustrated, the inlet port 118 and outlet port 120 both communicate with the cylindrical chamber portion 86. An inlet conduit 122 is connected to inlet port 118 and vent conduit 124 is connected to outlet port 120. Similarly, the cylinder 68 has a lower inlet port 126 below the piston 92 and an outlet port 128. Conduits 130 and 132 are connected to the respective inlet and outlet ports 126 and 128. With this arrangement, fluid supplied through inlet conduit 122 will fill the annular chamber between the cylindrical intermediate shaft portion 102 and the cylindrical walls of chamber 78 and displace or move the cylinder 92 downwardly. Since the lower portion of the cylinder is vented through outlet conduit 132, fluid remains in the annular chamber between the shaft 112 and the cylindrical wall of chamber portion 86. The intermediate shaft member 104 has a shoulder or secondary piston face 135 that contacts the fluid end of other designated intermediate shaft portion 102 and, with the clearance between the surface of intermediate shaft portion 104 and wall 86, the fluid slowly flows therebetween and prevents metal-to-metal contact on the upward and downward strokes of the piston.

Referring to FIGS. 1 and 2, there is illustrated a multiport control device generally designated by the numeral 136 that has an upper vent valve 140, a lower pressure valve 142, a lower vent valve 144 and a timing device pump combination 146. The upper vent valve 140 has a port 148 to which conduit 124 is connected. The other end of conduit 124 is connected to vent port 120 of cylinder 68 (FIG. 3). A pressure accumulator generally designated by the numeral 150 is connected in series with the conduit 124 and port 148. The upper pressure valve 140 has a port 152. Conduit 122 is connected to port 152 and to port 118 of the cylinder 68 (FIG. 3).

The lower pressure valve 142 has a port 154 connected to conduit 130. The other end of conduit 130 is connected to the lower pressure port 126 in cylinder 68. The lower vent valve 144 has a port 156 that is connected to conduit 132. The other end of conduit 132 is connected to lower vent port 128 in cylinder 68. A pressure accumulator 158 is connected in series with the conduit 132 and port 156 of vent valve 144.

The multivalve control device 136 includes an end plate 160 with a plurality of longitudinal bolt passageways 162 therethrough adjacent the circumferential edge portion and a pair of recurred cup-shaped portions 164 and 166. Annular bearings 168 and 170 are positioned in the recessed portions 164 and 166. The upper vent valve 138 includes a pair of disc-like valve members 172 and 174 with peripheral grooved portions 176 and 178 extending around about 180° to 190° of the periphery. The member 172 has oppositely extending shaft end portions 180 and 192. The shaft end portion 192 is positioned in the bearing 168 in recess 164. Similarly, the member 174 has oppositely extending shaft end portions 184 and 186. The shaft end portion 184 is rotatably positioned in bearing 170 in recessed portion 176. An annular valve housing 188 having port 148 therein extends around the pair of disc-like members 172 and 174 and has a central chamber therein. The housing is similar to that illustrated in FIGS. 5 and 6. The valve housing 188 has longitudinally extending bolt apertures 190 aligned with the bolt apertures 162. The valve housing has one planar end wall 192 in abutting relation with a mating end wall of the end plate 160 to form a seal therebetween. A support housing 194 has a plurality of bolt passageways 196 aligned with bolt passageways 190 and 162 and has a pair of longitudinal passageways 198 and 200 with enlarged end portions 202 and 204 adjacent the opposite end wall 207 of valve housing 188. Bearings 206 and 208 are positioned in enlarged portions 202 and 204 and shaft end portions 182 and 186 of
3,547,206

The disc valve members 172 and 174 are rotatably supported in the bearings 206 and 208. The passageways 198 and 200 have enlarged portions 210 and 212 in which bearings 214 and 216 are positioned.

The upper pressure valve 140 has a pair of disc valve members 218 and 220 which are similar to the disc valve members 172 and 174 previously described. The disc valve member 218 has a shaft portion 222 positioned in the recessed portion 210 of support member 194 and disc valve member 220 has a shaft end portion 224 positioned in the enlarged portion 212. The disc valve members 218 and 220 have recessed peripheral portions 226 and 228 similar to the recessed portions 176 and 178 that extend around 190° of the periphery of both of the valve members 218 and 220. The shaft end portions 182 and 222 have axial passageways 230 and 232 therein with suitable keyways 234 and 236. A shaft 238 is positioned in the passageway 198 of support member 194 and extends into the recessed portions 230 and 232 and is suitably keyed to the end shafts 182 and 230 so that valve members 172 and 218 rotate in timed relation to each other.

The disc valve member 220 is similarly connected to disc valve member 174 by means of shaft 240 keyed to the shaft end portions 186 and 224. As illustrated in FIG. 2, the upper vent valve 138 is open in that the peripheral recessed portions 178 are facing each other and the parts extending therefrom are in a passage therewith. The upper pressure valve 140 is closed in that the recessed portions 226 and 228 are spaced from each other. The upper pressure valve 140 has an external housing 242 which is similar in construction to the external housing 188 of the vent valve 138. The housings 188 and 242 and the disc valve members housed therein are exchangeable.

Abutting the wall of the housing 242 is a support member 244 which is similar to the support member 194 and is interchangeable therewith. The support member 244 has passageways 246 and 248 extending therethrough in which shafts 250 and 252 are positioned and extend into recessed portions within the shaft end portions of disc valve members 218 and 220.

The lower pressure valve 142 is positioned adjacent the support member 244 and has a housing 254 which is similar to the housings 242 and 188. Within the housing 254 there are positioned a pair of disc valve members 256 and 258 which have peripheral recessed portions 260 and 262. The disc valve members 256 and 258 are of the same construction as the disc valve members 172 and 174, and have shaft end portions 264 and 266, 268 and 270. The shaft end portions 264 and 268 extend into enlarged passageways in the support member 244 and have recessed portions 272 and 274 in which the shafts 250 and 252 are positioned and non-rotatably keyed thereto so that the disc valve members 256 and 258 rotate in timed relation with the other previously described disc valve members. A support member 276 similar to support members 244 and 194 is positioned in abutting relation with the upper pressure valve housing 254 and has passageways 278 and 280 therethrough in which shafts 282 and 284 are positioned. The shafts 282 and 284 extend into recessed portions of disc valve member shaft end portions 266 and 270 and are keyed thereto.

The lower vent valve 144 has a housing 286 in which a pair of disc valve members 288 and 290 are positioned with recessed peripheral portions 292 and 294. The disc valve members have shaft end portions 296, 298, 311 and 302. All of the shaft end portions have recessed portions therein and shafts 282 and 284 extend into the recessed portion of shaft end portion 308 and are keyed therein to rotate therewith so that the disc valve members 288 and 290 to the disc valve members 256 and 258 and the other previously described valve members. It should be noted that the disc valve members 256 and 258 of the lower vent valve have their recessed portions 260 and 262 abutting each other to form a passage therebetween so that the lower vent valve as illustrated in FIG. 2 is open, whereas the lower pressure valve 144 is closed because the recessed portions 292 and 294 are spaced from each other.

The combination timing device and positive displacement pump 146 has a housing 314 positioned in abutting relation with the support member 304. The housing has longitudinal bolt passageways 316 and a pair of meshing gears 318. The gears 318 are positioned in the housing 314. The gear 318 has shaft end portions 322 and 324. Similarly, the gear 320 has shaft end portions 326 and 328. The shaft end portions 322 and 326 are positioned in the enlarged portions of passageways 306 and 308 and shafts 310 and 312 extend into recessed portions of the respective gears 318 and 320 and are keyed thereto so that the gears 318 and 320 are connected to the previously described disc valve members.

An end plate 330 has bolt-receiving apertures 332 and a cup-shaped recessed portion 334 for receiving the shaft end portion 324 of gear 318. The end plate 330 has a passageway 336 with an enlarged portion 338. The shaft end portion 326 of gear 336 is supported in the enlarged portion 338 of passageway 336. A drive shaft 340 has an end portion extending into an axial passageway 342 of gear 320 and is keyed thereto so that rotation of shaft 340 rotates both gears 318 and 320 and by the previously described connections all of the disc valve members within the multidrop control device 136.

The previously described valve members are positioned in stacked relation as illustrated in FIGS. 1 and 2 and are secured in this position by the elongated bolts 346 extending through the bolt apertures previously described. Referring to FIG. 1, the support member 194 has an outlet port 348 therein and an internal passageway 350 that is connected to an internal passageway 352 in the upper vent valve housing 188. The support member 244 has a port 354 that opens into passageway 256. The passageway 356 is connected to passageways 358 and 360 in valve housing 242 and 254 of the upper and lower pressure valves 140 and 142 respectively. The support member 276 has a port 362 opening into passageway 364 which is connected to a passageway 366 in the housing 280 of the lower vent valve 144. The support member 304 has a pair of ports 368 and 370 that open into respective passageways 372 and 374. The housing 314 has passageways 376 and 378 that are connected to the passageways 372 and 374 respectively.

FIG. 5 is a sectional view in elevation of the lower pressure valve 142 and illustrates the housing 254 with the peripheral
bolt passageways for bolts 346 and the disclike valve members 256 and 258 with the peripheral recessed portions 260 and 262. In FIG. 5, the recessed portions 260 and 262 are illustrated as extending around 180° of the disclike valve member periphery. In FIG. 6, however, the recessed portions 292 and 294 are, for illustrative purposes, illustrated as extending around about 190° of the disclike valve member periphery. It is understood that the same peripheral recessed portion for all the disclike valve members so that the plurality of valves will open and close in timed relation. Where the recessed portions extend around 180° of the periphery, the volume of liquid displaced by the timing gears 318 and 320 in one-half a revolution should be about 10 percent greater than the volume of liquid required to discharge the piston in the cylinder for a complete stroke of the piston. The excess fluid enters into the accumulator in the conduit connecting outer port 370 from the timing device pump combination 146 and the inlet port 354 for pressure valves 140 and 142. The accumulator is not shown but may be similar to the accumulators 150 or 158. With this arrangement, an accumulator must be provided in the conduit between ports 370 and 354 because all of the valves in the control device are closed and the excess volume of fluid supplied by the timing device pump combination 146 must be displaced in the accumulator. Where the recessed portions extend around 190°, the accumulator in the conduit connecting ports 370 and 354 is not necessary because there is an overlap where both pressure valves 140 and 142 are open for about 10° of the revolution. The timing gears should, however, be made larger to compensate for the loss of fluid while all valves are open during the 10° overlap. The dimension of the timing gears and the piston and cylinder may be varied to control the amount of fluid entering the accumulator 150 and the resilience of the spring 394 may be varied to control the force exerted by the piston in the cylinder. In FIG. 1, the ports 154 and passageway 360 communicate through the mating recessed portions 260 and 262 of the disclike valve members 256 and 258 when positioned as illustrated in FIG. 5 so that liquid supplied to passageway 360 flows through the openings formed by the mating recessed portions 260 and 262 to the port 154. The disclike valve member 256 is illustrated in FIG. 8 with the recessed portion 260 and the shaft end portions 264 and 266. The shaft 250 is illustrated as extending into a recessed portion of shaft end portion 264 and is keyed therein. Similarly, the shaft 282 extends into a recessed portion of shaft end portions 266 and is keyed thereto. FIG. 6 is a sectional view in elevation of the lower vent valve 144 and illustrates the disclike valve members 288 and 290 within the housing 286. The recessed portions 292 and 294 are spaced from each other and the passageway 266 does not communicate with the port 156 because the peripheral portions of the disclike valve members 288 and 290 are abutting each other and closing the opening between the passageway 266 and port 156. FIG. 7 is a sectional view in elevation of the metering pump device 146. The housing 314 has passageways 376 and 378 that open into a chamber 380 in which the gears 318 and 320 are positioned in meshing relation to each other. The gears 318 and 320 are arranged upon rotation to displace fluid between the meshing gear teeth and thereby positively displace fluid from one passageway to the other through chamber 380. The valve housing, as for example, valve housing 254 and 286, also include a chamber 382 that communicates with the opposed passageways. The disclike valve members, as for example, valve members 256 and 258 in valve 142, are positioned in the chamber 382 and upon rotation permit the flow of fluid through the chamber from one port to the other or when in the position as illustrated in FIG. 6, close the chamber 382 and prevent the flow of fluid therethrough from one passageway to the other. It should be noted as illustrated in FIG. 2, that the disclike valve members are so connected to the adjacent disclike valve members that when the upper vent valve is opened, as illustrated in FIG. 2, the upper pressure valve 140 is closed and the lower pressure valve 142 is open and the lower vent valve 144 is closed. With this arrangement, as illustrated in FIG. 2, fluid under pressure is being supplied through lower pressure valve 142, conduit 130, to the face 100 of piston 92 (FIG. 3) to move the piston 92 upwardly. When the lower vent valve 144 is closed, the upper vent valve 138 is opened to permit the fluid within the cylinder above the piston 92 to be displaced through conduit 124. The upper pressure valve 242 is closed so that fluid under pressure is not being supplied to the upper port of the cylinder 68. Where the peripheral recessed portions extend around more than 180° of the disclike valve member periphery, there is a slight offset where, for a short period of time, both the vent and pressure valves are open. A suitable pressure accumulator such as accumulator 150 or 158 is positioned in series with the conduits 124 and 132 and ports 148 and 156 of the vent valves 138 and 144 to displace fluid supplied to the cylinder in excess of the volume of the annular space between the piston and the cylinder. One of the pressure accumulators is illustrated in detail in FIG. 4 and includes a cylindrical housing 384 with a cylindrical body portion 388 that has a longitudinal passageway 388 that is connected in series with the conduit 124 and the port 148. The housing 384 has an opening 390 into the passageway 388. Within the cylindrical housing 384 there is positioned a piston 392 and a coil spring 394 that urges the piston toward the base 386. An adjusting device 396 is provided to increase or decrease the tension on spring 394. An exhaust port 398 is provided above the piston 392 to vent the slight amount of fluid that leaks past the piston 392 within the housing 384. The piston 392 is displaced upwardly by the excess fluid supplied to the cylinder 68 (FIG. 3). When the vent valve is opened the piston 392 displaces the fluid within the housing 384 into the conduit 124. In FIG. 13 there is illustrated a percussion drill that includes a piston cylinder assembly similar to that illustrated in FIG. 3. Similar numerals in FIG. 13 will designate similar parts of the piston cylinder assembly. The percussion drill in FIG. 13 is generally designated by the numeral 550 and includes a chuck housing 552, a piston cylinder assembly 554 and a drill indexing housing generally designated by the numeral 556. The chuck housing 552 and drill indexing housing 556 are secured to the cylinder 68 by the bolts 76 and are axially aligned. The chuck housing 552 includes a chuck 558 with a central bore 560 in which the base 562 of drill rod 564 is positioned. The drill rod 564 is movable vertically in the chuck 558 and is rotatable by means of the indexing housing 556, later described. The piston cylinder assembly 554 has the piston and port 110 in abutting relation with the end portion of drill rod 564. A sleeve member 566 nonrotatably secures the drill rod 564 to the piston end portion 110 so that rotation of piston 92 by means of indexing mechanism 566 is transmitted to the drill rod 564. The cylinder 68 has a pressure inlet port 118 and a pressure outlet port 120 above the piston 92 and pressure inlet port 126 and pressure outlet port 128 below the piston 92 as previously described in reference to FIG. 3. With this arrangement fluid supplied through conduit 122 to the cylinder 68 moves the piston 92 downwardly and moves the end of the drill rod 564 away from the base of the hole being drilled. Fluid supplied through conduit 130 moves the piston 92 upwardly to transmit through the shaft 110 upward percussive movement to the drill rod 564. Thus, reciprocation of piston 92 within cylinder 68 provides the percussive blows to the base of the drill rod 564 to thereby dislodge material in the hole being drilled. The end shaft section 112 has splined portions 568 which nonrotatably connect the piston 92 to an indexing mechanism generally designated by the numeral 570 that is housed within the drill indexing housing 556. The drill indexing mechanism 570 may be conventional and similar to the indexing mechanisms illustrated in U.S. Pat. No. 3,059,618 and U.S. Pat. No. 3,044,448. The indexing mechanism 570 is so arranged that on the return downward stroke of the piston 92
the piston rotates through a fraction of a revolution to thereby rotate and index the drill bit for the next percussive stroke. The rotation of the piston 92 is transmitted through the sleeve 566 to the drill rod 564. Thus, with the above-discussed arrangement, it is now possible to provide percussive forces to a reciprocating percussion drill with a fluid supplied to the piston cylinder assembly 554 from the multipurpose control device 136 illustrated in FIGS. 1 and 2.

The high-speed rotary percussion drill illustrated in FIG. 3 operates as follows. The drill rod support member 40 and the drill rod 26 nonrotatably connected thereto is rotated at high rotary speed by means of drive shaft 22 transmitting rotation through bevel gears 24 and 46. The hammer shaft 62 and the piston 92 rotate at substantially the same speed as the drill rod support member 40. The percussive forces are imparted to the drill rod 26 by supplying fluid under pressure alternately through conduits 122 and 130 from the multipurpose control device 136.

It will be appreciated that the previously described multipurpose control device 136 can be utilized to provide reciprocating motion for the piston 92 within cylinder 68. FIGS. 9, 10 and 11 schematically illustrate various arrangements for supplying the fluid under pressure to the opposite faces of the piston 92 within the cylinder 68. Although not illustrated in FIGS. 9, 10 and 11, it should be understood that accumulators 150 and 158 are provided in the conduits 124 and 132 as illustrated in FIG. 1. In FIG. 9, a motor 500 is connected to shaft 340 and is arranged to rotate the gears 318 and 320 within the combined pump and timing device 146. In the embodiment illustrated in FIG. 9, the timing device pump combination 146 serves both as a timing device and as a positive displacement pump. The pump 370 is connected to a source of fluid by a conduit 502. The fluid displaced by the gears 318 and 320 flows through conduit 504 into passageways 360 and 358 of the upper and lower pressure valves 142 and 140 respectively. Where the recessed portions of the valves extend around 180° of the periphery, a pressure accumulator is positioned in conduit 504. The upper pressure valve 140 is connected by means of conduit 122 to the cylinder 68 and the lower pressure valve 142 is connected by conduit 130 to the cylinder 68 as previously described. The upper vent valve 138 is in turn connected by conduit 124 to the cylinder 68 and the lower vent valve 144 is connected by conduit 132 to the lower portion of cylinder 68. The vent valves 138 and 144 are connected by means of conduits 506 and 508 to a reservoir or tank 510. With this arrangement, the metering gears may be so sized that they will displace the same amount of fluid in one-half of a revolution as is displaced in one end of the cylinder. Where the metering gears have a greater displacement, a pressure accumulator must be positioned in conduit 504 to take up and displace the excess fluid supplied by the metering gears in one-half a revolution.

In FIG. 10, a separate pump 512 is provided, driven by the motor 500. The fluid under pressure from pump 512 is supplied through conduit 514 to the timing device 146. The fluid under pressure rotates the gears and opens and closes the valves as previously discussed and supplies the fluid under pressure through conduit 514 to the pressure valves 140 and 142. With this arrangement, the metering gears should have the same displacement in one-half rotation as the displacement in one end of the cylinder. Where the metering gears displace greater volumes of fluid, an accumulator should be positioned in conduit 504.

FIG. 11 illustrates an arrangement where fluid under pressure is supplied from the pump 512 directly to the pressure valves 140 and 142. A separate variable speed motor 516 is connected to a speed reducer 518 and the shaft 340 of the timing gears 318 and 320. A separate source of lubricant is supplied to the timing gears in this embodiment. With this arrangement, the motor 516 controls the opening and closing of the pressure and vent valves and also controls the number of percussive strokes per unit of time so that one can vary the speed of motor 516 and thereby vary the percussive strokes over a relatively wide range.

According to the provisions of the patent statutes, I have explained the principle, preferred construction and mode of operation of my invention and have illustrated and described what I now consider to represent its best embodiments.

1. A hydraulically actuated rotary percussion drill comprising:
   a drill head housing;
   a rotary rod support positioned in said housing and having a central passageway therethrough opening into a drill rod receiver at one end and into said housing at the other end;
   a drill rod having an end portion nonrotatably secured in said receiver and extending longitudinally therefrom;
   means for rotating said drill rod support in said housing and thereby imparting rotary motion to said drill rod;
   a hammer shaft positioned in said drill rod support central passageway and having one end portion extend into said receiver and the other end portion extending into said housing;
   said housing having a cylinder portion with a cylindrical chamber axially aligned with said drill rod support central passageway;
   a piston positioned in said cylinder portion and having a rod end portion abutting said hammer shaft end portion;
   said cylinder portion having openings on opposite sides of said piston;
   a control valve assembly having an upper pressure valve, an upper vent valve, a lower pressure valve and a lower vent valve, said upper pressure valve and said upper vent valve connected to said cylinder above said piston, said lower pressure valve and said lower vent valve connected to said cylinder below said piston;
   means for supplying liquid under pressure to said upper and lower pressure valves and means for connecting said valves so that said upper pressure valve and said lower pressure valve alternately open and close to alternately supply fluid under pressure to the upper and lower portions of said cylinder and reciprocate said piston therein to thereby impart percussive blows to said drill rod through said hammer shaft by said piston rod end portion.

2. A hydraulically actuated rotary percussion drill as set forth in claim 1 in which, said means connecting said valves includes metering means to control the volume of liquid supplied through said pressure valves to said cylinder.

3. A hydraulically actuated rotary percussion drill as set forth in claim 1 in which, said means connecting said valves includes metering means to control the volume of liquid supplied through said pressure valves to said cylinder.

4. A hydraulically actuated rotary percussion drill as set forth in claim 1 in which, said means connecting said valves includes metering means to control the volume of liquid supplied through said pressure valves to said cylinder.

5. A hydraulically actuated rotary percussion drill as set forth in claim 1 in which, said means connecting said valves includes metering means to control the volume of liquid supplied through said pressure valves to said cylinder.

6. A hydraulically actuated rotary percussion drill as set forth in claim 1 in which, said cylinder portion includes:
   a chamber, a first pressure opening into said chamber above said piston and a first vent opening into said chamber above said piston, a second pressure opening into said chamber below said piston and a second vent opening into said chamber below said piston;
   said chamber means connecting said upper pressure valve to said first pressure opening, said upper vent valve to said first vent opening, said lower pressure valve to said second pressure opening and said lower vent valve to said lower vent opening;
3,547,206

11 liquid displacement means in said conduit means between said upper vent valve and said first vent opening and in said conduit means between said lower vent valve and said second opening.

7. A hydraulically actuated rotary percussion drill as set forth in claim 6 in which said liquid displacement means includes a pressure accumulator operable to receive fluid supplied to said cylinder in excess of the fluid required to displace said piston, said pressure accumulator having resilient means to exert a pressure on the fluid contained therein.

8. A hydraulically actuated reciprocating drill comprising: a drill head housing having a drill support portion, a cylinder portion having a cylindrical chamber, and a drill indexing portion; said drill support having a central drill rod receiving passageway; a drill rod having an end portion positioned in said receiving passageway; a piston positioned in said cylinder portion and having a rod end portion abutting said drill rod end portion; said cylinder portion having openings into said chamber on opposite sides of said piston; a control valve assembly having an upper pressure valve, an upper vent valve, a lower pressure valve and a lower vent valve, said upper pressure valve and said upper vent valve connected to said cylinder portion above said piston, said lower pressure valve and said lower vent valve connected to said cylinder portion below said piston; means to supply liquid under pressure to said upper and lower pressure valves; means connecting said valve members so that said upper pressure valve and said lower pressure valve alternately open and close to alternately supply liquid under pressure to the upper and lower portions of said cylinder and reciprocate said piston therein to thereby impart percussive blows to said drill rod end portion by said piston rod end portion; and means in said indexing portion of said drill head housing to rotate said piston and said drill rod a portion of a revolution with each stroke of said piston.