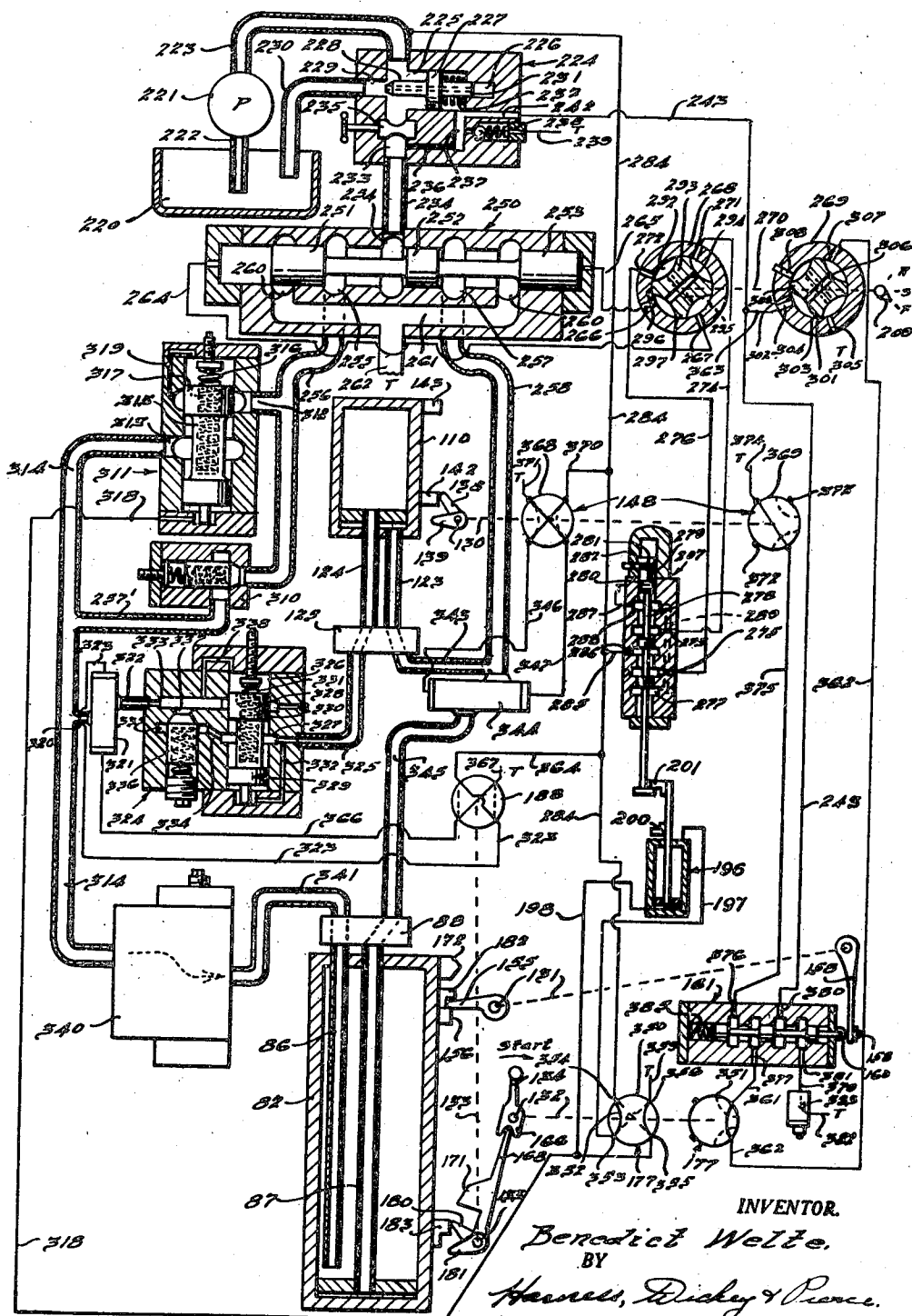


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OPERATION OF A PLURALITY OF POSITIVE
DISPLACEMENT HYDRAULIC MOTORS
OF DIFFERENT SIZES
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HYDRAULIC CIRCUIT FOR EFFECTING SEQUENTIAL OPERATION OF A PLURALITY OF POSITIVE DISPLACEMENT HYDRAULIC MOTORS OF DIFFERENT SIZES

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2 Claims. (Cl. 60—52)

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The present invention relates to an improved hydraulic circuit for operating a machine incorporating a plurality of successively operated positive displacement hydraulic motors, and this application is a division of applicant's application, Serial No. 495,856, filed July 23, 1943, now Patent No. 2,395,702, issued February 26, 1946. The particular embodiment of the invention illustrated is adapted for use in operating the cylinders of a pull-down broaching machine having a vertically-moving, broach-handling cylinder, a vertically-moving, broach-pulling cylinder, and a horizontally-moving cylinder for shifting the work into and out of broaching position.

In prior hydraulic machines incorporating positive displacement pumps for operating a plurality of positive displacement motors at different times, it has been customary to design the pump to supply the maximum flow required at any one time and to employ a safety by-pass relief valve to prevent the development of a destructive pressure in the system. As a result, when the flow requirements are low, the pump is operating against the maximum safe pressure for the system. This requires unnecessary power and results in objectionable heating of the liquid.

Accordingly, it is the general object of the present invention to provide in a machine of the type mentioned, means to limit the pressure on the system to a maximum value when the flow requirements of the machine are high in combination with means operative when the flow requirements of the machine are low to limit the pressure on the system to a lower value.

A more specific object of the invention is to provide, in combination with a by-pass valve for the outlet of the positive displacement pump, means operative in response to the development of a given pressure for opening the by-pass valve and thereby limiting the pressure to said given value, in combination with other means operative only when the flow requirements of the machine are low to cause said valve to limit the pressure to a lower value.

Other objects and advantages of the invention will become apparent from the following specification, the accompanying drawing, and the appended claims.

The drawing illustrates diagrammatically one suitable embodiment of the invention particularly adapted for use in operating a hydraulic broaching machine of the type mentioned.

As shown in the drawings, the machine incorporates a broach pulling cylinder 82 adapted to move vertically with respect to a fixed piston car-

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ried by a stationary hollow piston rod 87. The piston rod 87 communicates with a manifold 88, and the manifold also supports a conduit 86 which projects into the cylinder 82 and communicates with the space above the piston. The machine also incorporates a similarly constructed broach-handling cylinder 110 containing a fixed piston carried by a hollow piston rod 124. A second conduit 123 communicates with the lower end of the cylinder 110, and the piston rod 124 and conduit 123 are fixed to a manifold 125. It will be appreciated that the illustration of the above described structure is purely diagrammatic and that the two conduits leading to the opposite ends of the cylinder may be concentric, as pointed out in greater detail in the aforementioned copending application. The machine also incorporates a positive displacement hydraulic motor 196, the movable piston rod of which is connected in any desired manner to the worktable of the machine.

The drawing is further simplified by illustrating the valve operating rods as dotted lines and by omitting most of the lines which run from the tank to the low pressure reservoir. These lines are indicated by the letter T at their termination.

As shown in the drawing, the hydraulic system includes a tank or low pressure liquid reservoir 220 and a fixed displacement pump 221 having its inlet pipe 222 extending into the tank and its discharge pipe 223 extending to a speed and pressure control valve mechanism indicated generally at 224. The valve 224 has an internal cylindrical chamber 225 having a reduced end portion 226. The cylindrical chamber 225 contains a piston 227 which fits the cylinder and carries at one side a valve plunger 228 which controls a port 229 leading, by means of pipe 230, to the tank. The opposite side of the piston carries a plunger 231 which fits the reduced bore 226 and a spring 232 normally acts upon the piston 227 to shift it in a direction to close port 229. The valve plunger 228 and the plunger 231 are of the same diameter, and the entire piston and plunger assembly is provided with a longitudinal opening from one end to the other, as best shown in dotted lines in the drawing.

The chamber 225 is in constant communication with the pump discharge line 223 and also with a passageway 233 which connects with an outlet pipe 234. The passageway 233 contains an adjustable throttle valve 235. The valve 235 is so constructed that it will not entirely close the passageway 223 but may be adjusted to provide a variable restriction to the flow of liquid in the

passageway. The passageway 233 at a point beyond the throttle valve 235 is in constant communication with the right-hand end of the cylindrical chamber 225 by means of a small bleed passageway 236 and a communicating passageway 237. The passageway 237, in turn, communicates through a ball check valve 238 to the tank line 239.

The structure of the speed and pressure control valve so far described forms no part of the present invention, since it is conventional. The operation of the valve is as follows.

Fluid from the pump, which may flow unrestricted through the line 223 and chamber 225 to the passageway 233, is subject to a restriction at the throttle valve 235 which causes a drop in pressure between that existing in the chamber 225 and that existing at the discharge end of passageway 233. Consequently, the pressure at the discharge end of the passageway, which is communicated through passageway 236 and 237 to the right-hand end of the cylindrical chamber 225 and acts on the right-hand side of the piston 227, is lower than the pressure acting on the left-hand side of the piston 227. As a result, the difference in fluid pressure tends to force the piston to the right and open the port 229 to the tank, and this tendency is resisted by the spring 232. The spring 232 is relatively light and is constructed to permit opening of port 229 on a relatively small difference in pressure at the opposite sides of the piston, such as a difference in pressure in the order of eighteen pounds per square inch.

As a result of this arrangement, the piston 227 will shift to the right, thus opening port 229 at any time the pressure drop across the throttle valve 235 tends to exceed the pressure difference for which the spring 232 is set. This opening of port 229 by-passes a part of the constant flow of liquid from the pump to the tank and, consequently, reduces the flow across the throttle valve 235 and thereby reduces the pressure drop across the throttle valve until the pressure drop falls to or below that for which the spring 232 is set. Accordingly, the structure so far described functions to maintain automatically a flow through passageway 233 of sufficient fluid to cause a given pressure drop determined by spring 232 across the throttle valve, regardless of the pressure existing in the passageway 233. Since the only way in which the pressure drop across the valve 235 can be maintained uniform is by maintaining the quantity of liquid which flows past the valve uniform, the function of the valve mechanism so far described is to maintain a uniform rate of flow from passageway 233 to pipe 234, regardless of the resistance against which the pressure is flowing. The valve 235 is adjusted to pass the quantity of liquid necessary to operate the broaching ram at the desired cutting speed; consequently, the ram will move at that speed, even though the resistance to its movement is variable.

It will be noted that in addition to operating as a speed control valve the valve 224 also performs the important function of insuring that the pressure against which the pump is discharging during the broaching and broach return strokes of the ram never exceeds the pressure required to move the broaching ram at the desired speed plus the small constant pressure drop across the throttle valve 235. This follows from the fact that the pressure in the pump discharge line 223 is always equal to the pressure in line 234 plus the drop in pressure across the throttle valve 235, and the pressure in chamber 225 is automatically

maintained at a sufficient level to pass the desired quantity of liquid through the valve 235 regardless of the resistance to ram movement. This is an important feature inasmuch as during a considerable portion of the cycle little resistance is offered to the movement of the broaching cylinder, and it is undesirable to have the pump operating at a high pressure during those periods since it would waste power and, moreover, that power would show up in the form of heat in the liquid.

The check valve 238 is a safety release device, and the spring which normally holds the check valve closed is set to open at the maximum allowable pressure, which may be in the order of a thousand pounds per square inch. If at any time the resistance is sufficiently great to build up a pressure in pipe 234 and passageway 233 sufficient to open the check valve 238, the fluid in passageway 237 will immediately flow to tank through line 239 and at a faster rate than it can be supplied through the small bleed passageway 236. As a result, the pressure in passageway 237 and, therefore, the pressure at the right-hand side of piston 227 will drop, allowing the pressure at the right-hand side of piston 227 to shift the piston to the right and open port 229, thus relieving the pressure on the system.

It will be understood that since the broach handling cylinder and the work table moving cylinder are much smaller than the broaching ram cylinder, they will require a smaller flow of liquid. Since valve 235 is set for the flow required to operate the ram cylinder, the valve 224 will not operate automatically as a speed or pressure control valve during the movements of the handling cylinder and table cylinder.

However, means are provided for limiting the pressure developed by the pump during movements of the broach handling cylinder and the table cylinder. This means includes a port 242 in valve 224, which connects passageway 237 and a pressure control line 243 and means hereinafter described for controlling the pressure in line 243.

The fluid from line 234 is conducted to a four-way valve, indicated generally at 250, which is provided with a spool having three lands 251, 252 and 253, respectively. The valve housing is provided with a port 254 connected to the line 234, a port 255 connected to a discharge line 256, a port 257 connected to a discharge line 258, and a pair of ports 260 at the ends of the housing which is connected by a passageway 261 to tank line 262. The valve is a pilot operated valve, being provided with a pair of pilot lines 264 and 265 leading to opposite ends of the valve. On admission of pressure to pilot line 264 and connection of line 265 to the tank, the valve spool is shifted to the right into the position shown in the drawing, while it is shifted in the reverse direction if pilot pressure is applied to line 265 and line 264 is connected to the tank.

Pilot lines 264 and 265 are connected to ports 267 and 266 of a rotary four-way valve 268. The rotary valve 268 comprises one portion of a dual reversing valve, the other portion being indicated at 269. The two valves are connected by a shaft 270, indicated in dotted lines, to the reverse control handle 209, which may be mounted in any convenient location on the machine. The reversing valves 268 and 269 are illustrated in their forward or normal position, at which time port 266 communicates with port 271 and port 267 communicates with port 272. Port 271 is con-

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nected to port 273 of the four-way valve 207 by means of a line 274, and port 272 of valve 268 is connected to a port 275 of valve 207 by means of a line 276.

As previously indicated, the valve 207 is a four-way valve controlled by trip dogs 200 and 201 connected to the piston of a movable work fixture, piston and cylinder unit 196. The spool and ports of valve 207 are generally similar to those of valve 250 except that the spool 278 is provided with an enlarged end portion 279 having a pair of spaced notches 280 and 281 adapted to co-operate with a spring-pressed detent 282, which acts to hold the spool against accidental displacement from either of its two positions of adjustment. When the spool is in the position shown in the drawing which it occupies when the piston is at the lower end of cylinder and piston unit 196 and the work fixture is in its loading position, pressure is transmitted from line 284, which is connected to the pump discharge pipe 223 through line 285 to port 286, which is in communication with port 275. At the same time the tank line 287, which is connected to port 288, is in communication with port 273 and line 274. Pilot pressure is thus transmitted through valve 207 to line 276 and thence through valve 268 from port 272 to port 267 to pilot line 264 to the left-hand end of the main four-way control valve 250. At the same time, the right-hand pilot line 265 of valve 250 is connected to the tank through ports 266 and 271 of valve 268, line 274, port 273 and port 288 of valve 207, and line 287. This serves to hold the spool of valve 250 in the right-hand position shown in the drawing.

When the work table is shifted to its broaching position, the spool 278 of valve 207 is shifted to its upper position, thus reversing the connections to lines 274 and 276. At that time the pilot pressure flows from port 286 to port 273, through line 274, from port 271 to port 266 of valve 268, and thence to the pilot line 265 at the right-hand end of valve 250. At the same time, the pilot line 264 at the left-hand end is connected with the tank through valve 268, line 276, and by communicating ports 275 and 277, passageway 289, and port 288 of valve 207.

As a result of this arrangement, it is apparent that the main four-way valve 250 is reversed at each end of the stroke of the work fixture cylinder and piston unit 196. If at any time during the cycle of operation it is desired to reverse the machine, the dual valve 268 and 269 is shifted to its reverse position. This reverses the connections between lines 264 and 265, on one hand, and lines 274 and 276, on the other, and thus reverses the position of the spool of valve 250 with respect to the position of spool 278 of valve 207. In the reverse position of the valve 268 port 272 is in fluid communication with port 266 through the space 292 in the valve stem formed in the rotatable plug 293 of valve 268, and port 267 is in communication with port 271 through the opening 294 in the valve plug. In the position shown in the drawing, the communication between ports 267 and 272 is through the opening 295 in the valve plug, shown in dotted lines. When the reversing handle 209 is shifted to the stop position, indicated by S in the drawing, the lands 296 and 297 block ports 266 and 267, with the result that no fluid can flow through the valve 268.

The valve 269, which forms part of the dual reversing valve, is identical in construction to valve 268 except that the lands 300 and 301 on

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the valve plug have cut-away corners at 302 and 303, with the result that when the valve is in its central or stop position fluid may flow from port 304 and port 305 through the passageway 306 in the valve plug to port 307. When valve 269 is in the forward position, shown in the drawing, port 305 is blocked because of the fact that port 308 is plugged, while port 304 is connected to port 307 through passageway 306. When the valve is shifted to reverse position, ports 305 and 307 are connected through passageway 306 and port 304 is blocked.

All of the parts in the drawing are in the position they assume when the machine is automatically stopped at the end of a broaching cycle and is in condition to be started on a new cycle of operation of the starting handle 134.

In the stop position illustrated, the valves are in such a position that fluid from pipe 234 may flow through valve 250 from port 254 to port 255 and thence to pipe 256. Pipe 256 is connected to a check valve 310, which is so arranged as to permit relatively free flow from pipe 256 to a pipe 257', but no return flow. Pipe 256 is also connected to a valve 311. Valve 311 is provided with a pair of ports 312 and 313. Port 312 is connected to pipe 256, while port 313 is connected to pipe 314 which, in turn, is joined by previously mentioned pipe 257'. The spool 315 of valve 311 is normally urged by spring 316 into the position shown in the drawing, in which the land 317 of the spool blocks communication between ports 312 and 313. However, when pilot pressure is applied to the pilot line 318, which is connected to the lower end of the valve, the spool will be lifted, permitting communication between the ports 312 and 313. During the upward movement of the valve spool the fluid trapped above the land 317 is discharged through a small passageway 319 to the port 312. From pipe 314 the fluid may flow through a short branch line 320 to a pilot operated valve 321, which, in turn, is connected to a pipe 322. Valve 321 operates to block the flow of fluid from pipe 320 to pipe 322 except when pilot pressure is applied to the pilot line 323 leading to the upper end of the valve.

Valve 321 may be of any desired construction; for example, it may be identical in construction to valve 250 except that the ports corresponding to ports 255 and 260 are blocked and the pipes 320 and 322 are connected to the ports which correspond to the ports 254 and 257 of valve 250.

Pipe 322 connects to a foot valve 324, which functions to permit relatively free flow from line 322 to line 325 but offers sufficient resistance to return flow from line 325 to 322 to prevent the fluid trapped in the upper end of the cylinder 110 from discharging through the piston rod 124 and pipe 325 under the influence of gravity acting on the cylinder and broach handling slide. The interior of valve 324 contains a cylindrical housing 326 provided with a pair of ports 327 and 328 and a spool 329 provided with a land 330 which, when the spool is held in its lower position illustrated by spring 331, blocks communication between ports 327 and 328. Port 327 is connected by means of a passageway 332 to the space at the lower end of the valve spool 329. Consequently, when the pressure in line 325, which is connected to port 327, reaches an amount sufficient to overcome the influence of spring 331, spool 329 will lift, allowing flow from port 327 to port 328 and thence through passageway 333 to line 322. The tension of spring 331 is adjusted so that it will not open until the pressure in pipe

325 exceeds the pressure which is induced by the force of gravity acting upon the broach handling slide. Port 327 is also connected by passageway 334 to a channel 335 of a spring-pressed check valve 336 which normally blocks a port 337 connected to passageway 333. The check valve 336 will permit relatively free flow from line 322 through passageways 333 and 337 to channel 335 and through passageway 334 to port 327 and thence to pipe 325. When spool 329 is moved upwardly, the fluid trapped at the upper end is discharged to passageway 333 through passageway 338.

Pipe 314 is also in communication with the upper end of the broaching cylinder 82 through a foot valve 340, which is identical in construction to foot valve 324, and through pipe 341.

Port 257 of valve 250 is in constant communication with the lower end of the broach handling cylinder 110 through pipe 258, branch pipe 343, and pipe 123. Pipe 258 may also be connected through valve 344 and pipe 345 to the lower end of the broaching cylinder 82 through piston rod 87. Valve 344 is identical in construction and mode of operation to valve 321, previously described, being controlled by pilot pressure in pilot lines 346 and 347.

The fluid for operating the work fixture cylinder and piston 196 is supplied through line 284 to valve 350, which forms one of the valves of the dual valve unit 177, the other valve being indicated at 351. Valve 350 is identical in construction and mode of operation to valve 268, previously described, and hence need not be described in detail, while valve 351 is of the same construction except that two of the ports are plugged.

In the drawing, the flow through valves 350 and 351 is indicated diagrammatically. Thus, in valve 350 the solid line 352 connecting ports 353 and 354 indicates that in the position of the valve illustrated in the drawing ports 353 and 354 are in fluid communication with each other. At the same time, as similarly indicated, ports 355 and 356 are in communication. As a result of this, line 284 is connected through valve 350 to line 197, which leads to the upper end of the work fixture cylinder and piston unit 196, while the line 198, which is connected to the lower end of the cylinder and piston unit 196, is connected through ports 355 and 356 of valve 350 to tank line 359. When valve 350 is shifted by clockwise rotation of the starting handle 134 to start the machine, port 353 is connected to port 356 and port 354 is connected to port 355, as indicated by the dotted lines in the drawing, thus supplying fluid pressure to the lower end of the piston and cylinder unit 196 and connecting the upper end to the tank. This immediately starts movement of the work fixture from its loading to its broaching position. The pilot line 318 of valve 311 is connected to line 198 and hence pilot pressure is applied to valve 311 when the starting valve is shifted to starting position.

When the machine is in the stop position illustrated, valve 351 connects a line 361 with a line 362, which, in turn, is connected to port 307 of valve 269 and thence through passageway 306 to port 304, from which it is connected by line 363 to the pressure control line 243. Consequently, when the valve 351 is shifted to its starting position, flow of fluid under pressure in line 362 is blocked, as indicated by the dotted lines on valve 351 in the drawing. The dual valve 177 is returned to starting position, as pre-

viously indicated, at the end of the downward stroke of the broaching cylinder 82 by reason of the engagement of the trip dog 172 with the projection 171 on lever 168.

The pilot pressure for controlling valve 321 is controlled by valve 188, which is also identical in construction to the valve 268, previously described. When the parts are in the stop position illustrated, the pressure line 284 is connected by a branch line 364 through valve 188 to the pilot line 323 leading to the upper end of valve 321, while the pilot line 366 to the lower end of valve 321 is connected through valve 188 to the tank line 367 and, consequently, valve 321 is open.

Valve 188 is operated by rod 133, which, in turn, is rotated by the arms 180 and 181 and trip dogs 182 and 183. When the broaching ram reaches the bottom of its downward stroke, trip dog 182 engages arm 181 and rotates shaft 133 and thus valve 188 to a position in which the pressure line 284 is connected to pilot line 366, as indicated in dotted lines on valve 188, and the tank line 367 is connected to pilot line 323, thus shifting the spool of valve 321 and blocking communication between pipes 320 and 322. When the broaching cylinder 82 reaches its uppermost position on its broach return stroke, trip dog 183 engages and rotates arm 180, thus returning valve 188 to the position shown in the drawing.

The pilot lines 346 and 347, which control valve 344, are controlled by valve 368, which is one of the valves of the dual valve 148, the other valve of the dual valve being indicated 369. Valve 368 is identical in construction to valve 268 and, in the position illustrated in the drawing, connects pilot line 346 through line 370 to the pressure line 284 and at the same time connects pilot line 347 to the tank line 371. Under these circumstances, valve 344 is closed. When the broach handling cylinder 110 reaches the end of its downward stroke, trip dog 143 engages arm 139, thus rotating valve 148 counterclockwise until pilot line 347 is connected to line 370 and thence to the pressure line 284, while pilot line 346 is connected to the tank line 371, as indicated in dotted lines on valve 368. This shifts valve 344 and opens communication between pipes 258 and 345.

When the broach handling cylinder 110 returns to its top position, trip dog 142 engages arm 138 and returns dual valve 148 to the position shown in the drawing. The other valve 369 of dual valve 148 is also identical in construction to valve 268 except that ports 372 and 373 are plugged. In the stop position illustrated, valve 369 connects the tank line 374 to a line 375 which leads to port 376 of valve 161. When the dual valve 148 is shifted at the bottom of the downward stroke of the broach handling cylinder 110, communication between the tank line 374 and line 375 is blocked by valve 369.

Valve 161, in the position shown in the drawing, provides a communication between port 376 and port 377, the latter being connected to the aforementioned line 361. It also provides communication between the pressure control line 243 and a line 379, this connection being from port 380 to port 381. Line 379 is connected to tank line 382 through a pressure relief valve 383, which is identical in construction to the check valve 310 except that the spring which normally holds the check valve closed will not permit the valve to open until the pressure in line 379 ex-

ceeds a predetermined pressure necessary to operate both the broach handling cylinder 110 and the work fixture cylinder and piston 196. The purpose of this valve is to prevent the pressure in pressure control line 243, and, consequently, the pressure discharged by the speed control valve 224 to line 234, from exceeding a predetermined pressure during the movements of the broach handling cylinder 110 and the work table cylinder and piston unit 196 in view of the fact that these elements are not subject to the automatic speed and pressure control operation of valve 224. The pressure setting of valve 383, and, consequently, the pressure delivered to pipe 234 during the movements of the broach handling cylinder 110 and the work table is substantially less than the pressure required to operate the broaching cylinder 82.

When the machine is stopped, it will be noted that the pressure control line 243 is connected through line 363, ports 304 and 307 of valve 269, line 362, valve 351, line 361 through ports 377 and 376 of valve 161, line 375, and valve 369 to the tank through tank line 374. Consequently, in the stop position there is no pressure in line 243 and, therefore, valve plunger 228 will be fully opened and the pump will discharge through line 230 to the tank at a very low pressure.

When the machine is shifted to starting position, valve 351 is shifted to disconnect line 362 from the tank. This enables the pressure to build up in line 243 and, consequently, during the operation of the work fixture the pressure supplied by the pump will be limited only by the setting of valve 383.

If at any time while the machine is stopped the broaching cylinder 82 sinks down by gravity, spring 385 in valve 161 will shift the spool of valve 161 to the right and thus block all flow through valve 161. This not only disconnects the line 362 and, therefore, line 361 from line 375, which is connected to tank when the machine is stopped, but it also disconnects line 243 from the pressure relief valve 383, thus enabling the pressure to build up in line 243. As soon as the pressure builds up in line 243, the valve 224 will close and raise the pressure supplied to the upper end of the broach cylinder 82, thereby returning it to its upper position. This insures that the broaching cylinder will not sink downwardly by gravity while the machine is in its stop position and the pump is operating. It also insures that the cylinder will be returned to starting position as soon as the pump is started after an idle period.

The machine operates in the following manner. With the parts in the stop position shown in the drawing and the pump running, passageway 237 in the speed and pressure control valve 224 will be connected directly to tank by lines 243, 363, valve 269, line 362, valve 351, line 361, valve 161, line 375, valve 369, and tank line 374. Consequently, the pressure in chamber 225 at the left-hand side of the piston 227 will not exceed the low pressure required to collapse spring 232, and all of the oil discharged by the pump will flow through port 229 to the tank through line 230 except the very small amount which will flow through the bleed passageway 236.

It will be noted that if while the machine is in the stop position illustrated the broaching cylinder 82 sinks down by gravity, trip dog 156 will leave arm 155 and allow the spring 385 of valve 161 to shift the valve spool to a position in which it blocks all flow through the valve. This immediately disconnects line 243 from the tank and

allows the speed and pressure control valve 224 to build up a high pressure in the discharge pipe 234. Since, as previously indicated, in the stop position fluid under pressure in pipe 234 is in communication with upper ends of the broach handling cylinder 110 and the broaching cylinder 82, the broaching cylinder will be returned to the top of its stroke. This arrangement, therefore, constitutes an automatic means for refilling the broaching cylinder so that it will be at the top of its stroke when the machine starts. At the same time, this arrangement will automatically insure that the broach handling cylinder remains at the top of its stroke. Incidentally, it may be noted that the foot valves 324 and 340 normally serve to prevent either of the cylinders 110 and 82 from falling by gravity when the machine is in its stop position. Consequently, the prefill arrangement need only take care of sinking movements due to unavoidable leakage.

It being assumed that the workpieces are secured to the moving worktable by any suitable work holding fixture, not shown, the machine is started by rotating lever 134 in a clockwise direction. This rotates the dual valve 177 from the position in which the flow conditions are illustrated in solid lines in the drawing to the position in which the flow conditions are illustrated in dotted lines. One of the valves of the dual valve 177, namely valve 351, is thus shifted to a position to block flow through the previously mentioned path from line 243 to the tank. This follows from the fact that line 362 is then no longer connected to line 361. When this occurs, the pressure in line 243 then becomes subject to the control of the pressure relief valve 383, being connected by means of valve 161 to line 379 and thence through the pressure relief valve 383 to the tank line 382. The setting of the pressure relief valve 383 is such that the discharge to the tank will occur at a pressure in excess of that required to operate the work handling cylinder and piston 196 and sufficient to operate the broach handling cylinder 110.

Fluid will then flow from line 284 through the other valve 350 of the dual valve 177 in the dotted line path to line 198, which is connected to the lower end of the work handling piston and cylinder unit 196, thus causing the piston to move upwardly, as viewed in the drawing, and shift the work table into broaching position. During this movement the liquid in the upper end of the cylinder and piston unit 196 returns to tank through line 197, valve 350 and line 359.

When the broaching fixture reaches broaching position, trip dog 200 on slide 191 shifts the spool 278 of valve 207, thus reversing the pilot connections to valve 250, in the manner previously described. When the spool of valve 250 thus shifts to the left, fluid under pressure in line 234 is transmitted to pipe 258 and flows unrestricted through line 343 and outer piston rod 123 to the lower end of the broach handling cylinder 110, causing it to move downwardly. At the same time, the fluid in the upper end of the cylinder returns to tank through the inner piston rod 124, pipe 325, foot valve 324, which then opens to permit flow from port 327 to port or channel 328, and thence through valve 321, pipes 320 and 314, valve 311, pipe 256, and line 262. At this time the pilot line 318 of valve 311 is connected to line 198 which, in turn, is connected to pressure through valve 350 and line 284, and, consequently, valve 311 is open to permit the above described return flow.

During the downward movement of the work handling cylinder 110, valve 344 blocks flow from line 258 to line 345 by reason of the fact that pilot pressure is connected to the left-hand pilot line 346 by means of valve 368.

During the broach delivering or downward stroke of the broach handling cylinder 110, line 243 limits the pressure delivered by valve 224 by reason of the connection of line 243 to tank through valve 161 and the pressure relief valve 383. During this movement of the broach handling cylinder, therefore, valve 224 does not act as a speed control valve, but simply as a pressure relief valve, due to the fact that the flow required to operate the broach handling cylinder is not sufficient on passing throttle valve 235 to cause a pressure drop sufficient to overcome the effect of spring 232. However, the pressure in valve chamber 225 cannot exceed the pressure determined by the setting of relief valve 383 plus the pressure required to overcome the spring 232 and, consequently, valve plunger 228 opens to a degree sufficient to maintain the desired pressure in the chamber 225 and line 234.

When the broach handling cylinder 110 reaches the lower end of its stroke, trip dog 143 engages arm 139 and shifts the dual valve 148. One portion of the dual valve, namely valve 369, is thus shifted into a position in which communication from line 375 to the tank line 374 is blocked. This insures that the pressure control line 243 and the branch thereof which includes line 363, valve 269, line 362, valve 351, line 361, valve 161 and line 375 will not be connected to tank when the valve 351 is subsequently returned to the position shown in the drawing. The other valve 368 of the dual valve 148 on such shift reverses the pilot connections to valve 344 and thus permits the fluid under pressure in pipe 258 to flow to pipe 345 and thence to the lower end of the broaching cylinder 82 in order to start the downward or broaching stroke of that cylinder. As soon as the broaching cylinder leaves its upper position, valve 161 is shifted into blocking position, disconnecting line 243 from the pressure relief valve 383 and tank line 382. This immediately eliminates control of valve 224 by the pressure relief valve 383 and enables the valve 224 to act as an automatic speed control and pressure relief valve during the remainder of the broaching or downward stroke of cylinder 82. During the broaching stroke, the return flow from the upper end of the cylinder 82 occurs through the outer piston rod 86, pipe 341, foot valve 340, pipe 314 and the open valve 311 to pipe 256 and thence through valve 250 to the tank line 262.

When the broaching cylinder reaches the end of its broaching stroke, the trip dog 182 engages arm 181 and thus shifts valve 188 to the position in which the flow is indicated in dotted lines in the drawing. In this position, pilot pressure is applied to the lower pilot line 366 of valve 321 and the valve spool assumes the position in which it blocks flow between pipes 320 and 322. At the same time, trip dog 172 engages the cam projection 171 on lever 168, thus returning the starting handle 134 in a counterclockwise direction to its stop position and, therefore, returning the dual valve 177 to the position shown in the drawing.

The return of valve 350, forming part of the dual valve 177, to the position shown in the drawing returns the valve to the solid line flow conditions illustrated in which the pilot line 318 from

the valve 311 is connected to the tank line 359 and, consequently, the valve 311 blocks the return of fluid from the upper end of the cylinder 82 and positively stops the broaching stroke at the point determined by the setting of the trip dog 182. This makes it possible to adjust the broaching stroke to suit the needs of any particular job. It will be understood, of course, that any adjustment of the position of trip dog 182 will be accompanied by corresponding adjustment of trip dog 172 since both must operate at the same time.

When the valve 350, which forms part of the dual valve 177, is thus returned to the position shown in the drawing, the fluid connections to the piston and cylinder unit 196 for the work fixture are reversed and fluid under pressure from line 284 flows through valve 350 to line 197 to the upper end of the cylinder, causing the piston to move downwardly as viewed in the drawing and retract the work from broaching position. During the return movement of the table the only pressure control effective is the high pressure relief action of valve 224 made possible by ball check valve 238.

When the piston of cylinder and piston unit 196 returns to the position shown in the drawing, it shifts the spool 278 of valve 207 into the position shown in the drawing in which it connects pilot pressure through valve 268 to the left-hand pilot line 264 of valve 250, thus shifting valve 250 to the right to the position shown in the drawing and initiating the broach return stroke of the broaching cylinder 82 by reason of the fact that fluid under pressure in line 234 then flows through valve 250 to line 256 through check valve 310, line 257, line 314, foot valve 340, pipe 341 and the outer piston rod 86 to the upper end of the broaching cylinder 82. The fluid in the lower end of the cylinder 82 returns to the tank through the inner piston rod 87, pipe 345, valve 344, pipe 258 and valve 250 to the tank line 262.

When the broaching cylinder reaches its uppermost position shown in the drawing, trip dog 183 engages and shifts arm 180 to the position shown, thus rotating valve 188 until it assumes the position in which the flow is indicated by solid lines in the drawing. In that position, pilot pressure is applied to the upper end of valve 321 by pilot line 323, thus causing the valve 321 to open and permit flow from pipe 320 to pipe 322 and thus through the foot valve 324 past the check valve 336 therein to line 325 and thence to the inner piston rod 124 of the work handling cylinder 110. This starts the broach return stroke of the work handling cylinder 110.

At the same time valve 188 is shifted, trip dog 156 returns arm 155 to the position shown in the drawing, thus rotating shaft 131 in a clockwise direction and returning the spool of valve 161 to the position shown in which it connects port 376 to port 377 and connects port 380 to port 381. As a result of the shift of valve 161, the pressure in line 243 during the broach return movement of the broach handling cylinder 110 is controlled by a pressure relief valve 383, in the manner previously described.

When the broach handling cylinder 110 reaches the upper end of its broach return stroke, trip dog 142 engages and shifts arm 138 and thus dual valve 148 to the position shown in the drawing in which line 375 is connected to tank through valve 369. This brings the machine to a stop because the next operation in the cycle must be the work advancing stroke of the table and that

can only be initiated by manual shift of the starting handle 134. When the machine thus stops, line 375 is connected through valve 161, line 361, valve 351, line 362, valve 269, line 363 to the pressure control line 243, thus causing the valve 224 to discharge to tank at negligible pressure. The shift of valve 368, which forms part of the dual valve 148, restores the pilot lines to valve 344 to the condition in which that valve blocks fluid flow from line 258 to line 345 and thus completes the return of all parts to the stop position illustrated.

The stop and reverse valve is a dual valve comprising two valves 268 and 269. The valve 268 serves, when the reversing handle 209 is shifted from the forward position indicated F to the reverse position indicated R in the drawing, to simply reverse the pilot connections to the main control valve 250 and, consequently, reverse the direction of operation of the broaching and broach handling cylinders with respect to the direction they normally operate for a given position of the work table. The valve 269 performs no function when the dual valve 268-269 is shifted to reverse position, but it is employed to stop the machine when the handle 209 is shifted to the intermediate stop position indicated S. In that position, the pressure control line 243 is connected through line 363 to the tank port 305 and, consequently, the valve 224 discharges to tank at low pressure. In the intermediate stop position, all ports of valve 268 are blocked and no function is performed by that valve.

Although only one form of the invention is shown and described herein, it will be appreciated that various modifications and alterations may be made in the machine without departing from the spirit of the invention or the scope of the appended claims.

What is claimed is:

1. In a hydraulic machine, a pair of hydraulically operated motors of different liquid flow requirements, a constant displacement pump, a reservoir connected to the intake of said pump, means including a liquid passageway connecting the pump discharge to said motors for automatically operating them successively through a cycle of operations, said passageway having a restriction therein, a by-pass valve for returning to the reservoir a portion of the liquid delivered by the pump, said by-pass valve being connected to said passageway between the pump and said restriction and having a cylinder, a piston in the cylinder, a valve plunger connected to the piston for controlling the by-pass, said piston being subject at one side to the pressure in the passageway between the pump and the restriction acting in a direction to open the valve, means including a conduit connecting the liquid at the opposite side of said piston with the passageway on the opposite side of the passageway restriction for maintaining the piston and valve plunger in such a position that a constant pressure drop is maintained across said passageway restriction, said pressure drop being that induced by a flow of liquid sufficient to operate the motor having the largest liquid flow requirement at the desired speed, a small bleed restriction in said conduit, a pair of pressure relief valves connected in parallel between the liquid in the valve cylinder at said opposite side of the piston and the reservoir, one of said pres-

sure relief valves being set to open when the pressure exceeds a predetermined maximum and the other being set to open at a lower pressure, said relief valves and their connections being less restricted when the relief valves are open than said conduit restriction, and means to block flow through said other relief valve when the motor having the largest liquid flow requirement is operating.

2. In a hydraulic machine, a pair of hydraulically operated motors of different liquid flow requirements, a constant displacement pump, a reservoir connected to the intake of said pump, means including a liquid passageway connecting the pump discharge to said motors for automatically operating them successively through a cycle of operations and bring the machine to a stop, said passageway having a restriction therein, a by-pass valve for returning to the reservoir a portion of the liquid delivered by the pump, said by-pass valve being connected to said passageway between the pump and said restriction and having a cylinder, a piston in the cylinder, a valve plunger connected to the piston for controlling the by-pass, said piston being subject at one side to the pressure in the passageway between the pump and the restriction acting in a direction to open the valve, means including a conduit connecting the liquid at the opposite side of said piston with the passageway on the opposite side of the passageway restriction for maintaining the piston and valve plunger in such a position that a constant pressure drop is maintained across said passageway restriction, said pressure drop being that induced by a flow of liquid sufficient to operate the motor having the largest liquid flow requirement at the desired speed, a small bleed restriction in said conduit, a pair of pressure relief valves connected in parallel between the liquid in the valve cylinder at said opposite side of the piston and the reservoir, one of said pressure relief valves being set to open when the pressure exceeds a predetermined maximum and the other being set to open at a lower pressure, said relief valves and their connections being less restricted when the relief valves are open than said conduit restriction, means to block flow through said other relief valve when the motor having the largest liquid flow requirement is operating, a third liquid connection between said liquid at the opposite side of the piston and the reservoir, manually operable means to close said third connection to start the machine, and means for automatically opening said connection for free flow to the reservoir when the machine completes a cycle of operations.

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