Nov. 14, 1950 B. WELTE 2,529,718

BROACHING MACHINE

Filed Aug. 21, 1944 2 Sheets-Sheet 1

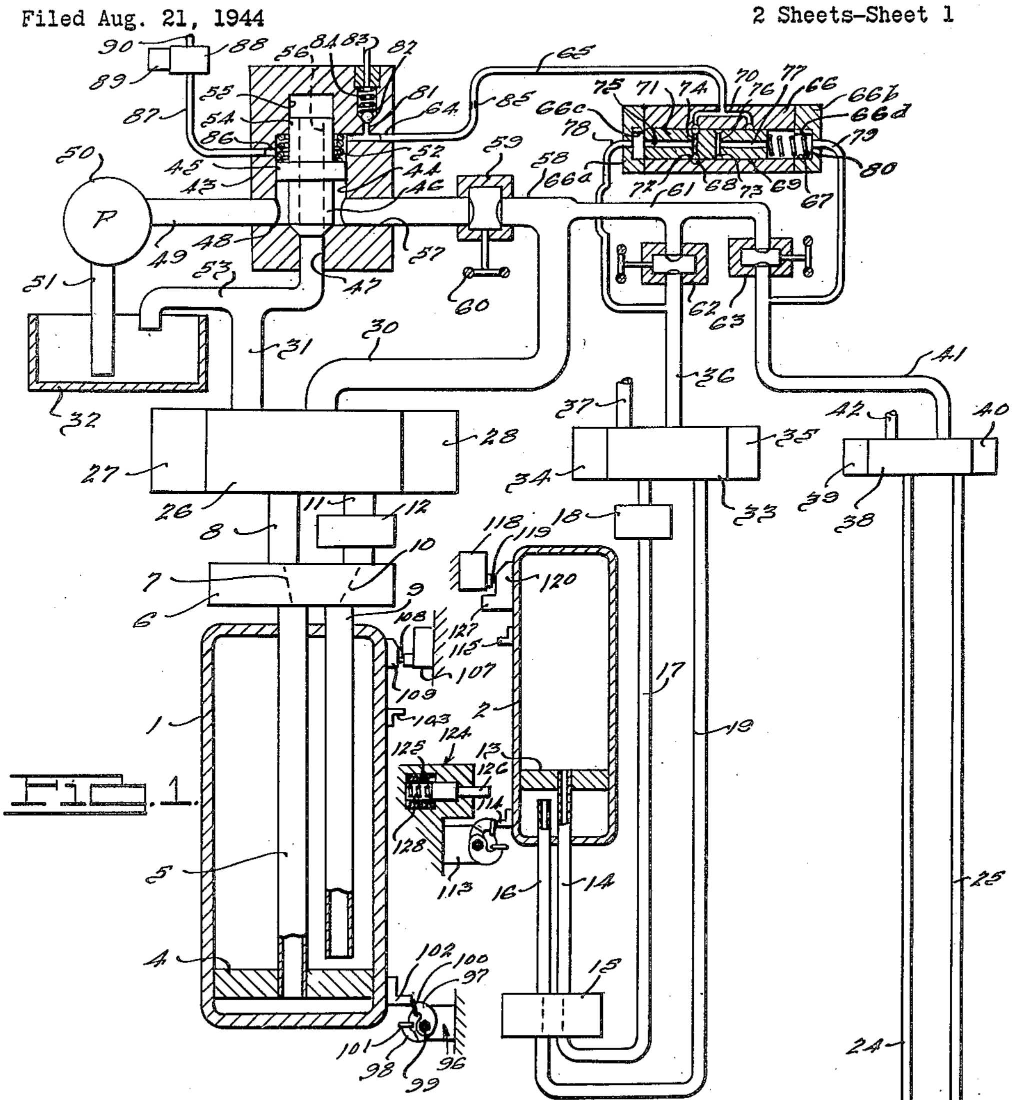

FIG. 1.

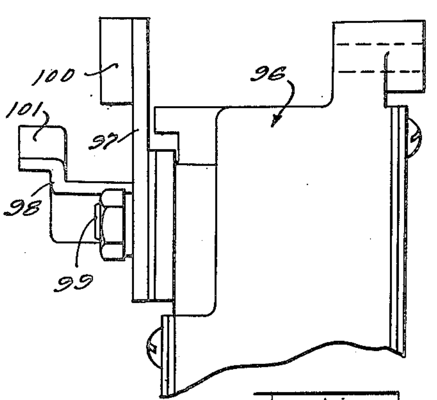

FIG. 2.

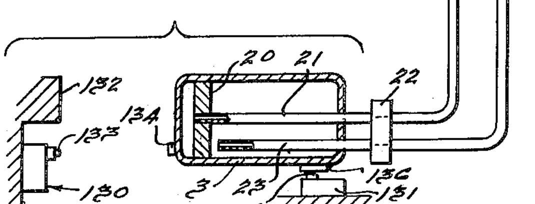

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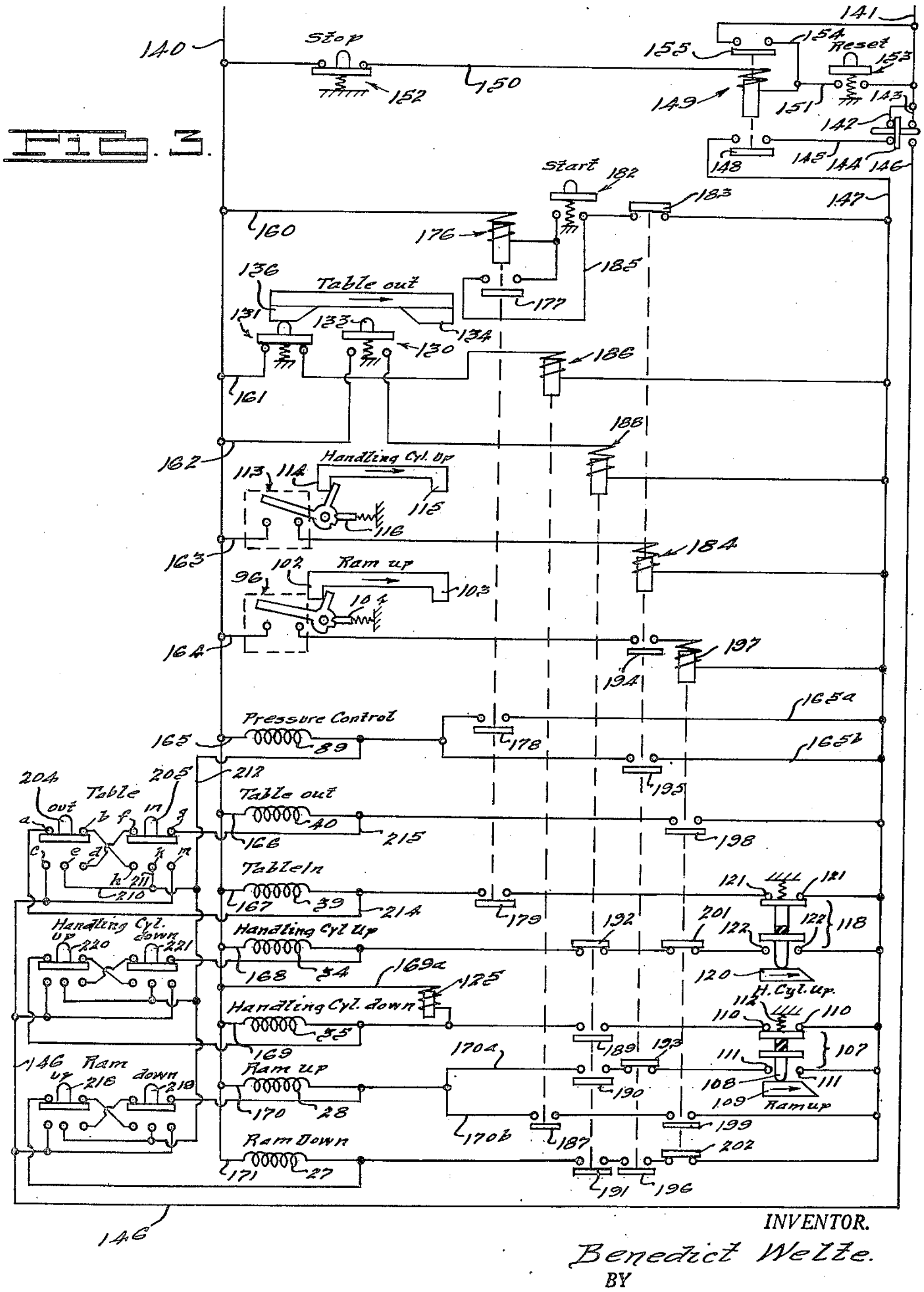
FIG. 3.



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Patented Nov. 14, 1950

2,529,718

UNITED STATES PATENT OFFICE

2,529,718

BROACHING MACHINE

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Application August 21, 1944, Serial No. 550,330

10 Claims. (Cl. 90—33)

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The present invention relates to an automatic-control mechanism for operating a plurality of positive displacement hydraulic motors in a hydraulically-operated machine through a complete cycle of operations.

One object of the present invention is to provide an improved and simplified type automatic-control mechanism for operating a plurality of hydraulic piston and cylinder units through a desired cycle of operations, which mechanism is readily adaptable to various types of machines.

Another object of the present invention is to provide an automatic-control mechanism of the type mentioned, in which safety interlocks are provided to prevent normal operation of any motor where another of the motors is in an improper position and which will automatically restore the improperly positioned motor or motors to their proper positions and then cause a resumption of the normal cycle of operations.

Another object of the present invention is to provide an automatic-control mechanism of the type mentioned having a simple, manually-operated means for selectively shifting each motor in either direction to facilitate machine set-up operations.

Another object of the present invention is to provide an automatic-control mechanism of the type mentioned which is peculiarly adapted for use with an independent source of operating liquid for each motor, such as is provided when use is made of the multiple flow-control valve mechanism of applicant's copending application, Serial No. 548,294, filed August 5, 1944.

A further object of the invention is to provide a control mechanism of the type described which incorporates means for independently adjusting the speed of operation of each of the motors.

Another object of the invention is to provide an automatic-control mechanism of the type mentioned, in which an improved and simplified electrical circuit is employed to control the operation of the main valves of the hydraulic system with resulting simplification of the interlocking mechanism.

Another object of the invention is to provide an automatic-control mechanism having the above mentioned advantages for cycling the cylinder and piston units of a shuttle-type pull broaching machine having a work moving cylinder which is simple in construction and positive and fool-proof in operation.

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

Referring to the drawing in which like numerals are applied to like parts in the several views, Figure 1 is a diagrammatic illustration of the mechanical and hydraulic portions of a shuttle-type pull broaching machine having a moving table and incorporating a portion of the control means of the present invention.

Figure 2 is a fragmentary side elevation of a portion of one of the mechanically operated electric switches illustrated in Figure 1.

Figure 3 is a diagrammatic illustration of the electrical circuit employed to control the operation of the mechanism illustrated in Figure 1.

While the invention is applicable to various types of hydraulically operated machines the particular embodiment illustrated is specially designed and arranged to control the operation of the shuttle-type pull-down broaching machine having a work moving table or fixture which moves the workpiece into and out of broaching position. Such machines incorporate at least three positive displacement piston and cylinder units or motors. One of these units operates what is generally referred to as the broach-handling chuck; the second operates the broach-pulling chuck, and the third operates the table or fixture which moves the workpiece into and out of broaching position. These piston and cylinder units may either be of the type embodying a stationary cylinder and a movable piston or of the type embodying a stationary piston and a movable cylinder. The particular mechanism illustrated in Figure 1 is of the latter type, in which the pistons are stationary and mechanical features of the machine in general may be of the type illustrated in greater detail in applicant's copending application, Serial No. 495,856, filed July 23, 1943, and now Patent No. 2,395,702, granted Feb. 26, 1946. In this connection it may be noted that the broach-handling and pulling chucks are preferably of the conventional type which contain means to positively lock the broach in the chuck and which have a release sleeve which engages a fixed abutment at the end of the inward stroke of the chuck and is thereby shifted axially to release the broach. A chuck of this type is shown in Fig. 3A of Hart Patent 2,162,814.

Referring to Figure 1 there is illustrated a movable broach-pulling cylinder 1 to which is secured in any desired manner, not illustrated, the broach-pulling chuck, a movable broach-handling cylinder 2, to which is secured in any desired manner the broach handling chuck and a movable worktable operating cylinder 3. Cylinder 1 contains a piston 4 which is secured by means of a hollow piston rod 5 to a stationary manifold 6. The interior of the hollow piston rod 5 communicates through the manifold in the manner indicated by the dotted line 7 with a pipe 8. The hollow piston rod 5 and the manifold provide means for conducting liquid under pressure to the lower end of the cylinder 1. Likewise, fixed to the manifold 6 is a second pipe 9 which projects into the cylinder 1 and provides means for conducting liquid under pressure to the upper end of the cylinder 1. Pipe 9 communicates through the manifold, as indicated by the dotted line 10, with a pipe 11, which contains a conventional foot valve 12. The foot valve 12 serves to offer sufficient resistance to flow of liquid from the upper end of the cylinder 1 through the pipe 11 to prevent cylinder 1 from moving down under the influence of gravity. The foot valve offers no appreciable resistance to flow in the opposite direction. The valve may be of any desired construction, such as that indicated generally by the numeral 324 in Figure 9 of applicant's aforementioned copending application, Serial No. 495,856, now Patent No. 2,395,702.

While, for purposes of illustration, the pipe 9 and piston rod 5 are shown as separate pipes leading to opposite ends of the movable cylinder 1, it is preferred, in the actual construction, that these two pipes be concentrically arranged in the manner shown in Hart Patent No. 2,190,067.

The handling cylinder 2 is similarly provided with a stationary piston 13 having a hollow piston rod 14 connected to a stationary manifold 15. The hollow piston rod 14 provides a path for fluid communication to the upper end of the handling cylinder 2. A second pipe 16, also connected to the manifold 15, supplies fluid to the lower end of cylinder 2, the arrangement of the pipes 14 and 16 being similar to that referred to above in connection with pipes 5 and 9 in cylinder 1. Pipe 14 communicates through the manifold with a pipe 17 which contains a foot valve 18 similar to the foot valve 12, previously mentioned. Pipe 16 communicates through the manifold with a pipe 19.

The work handling cylinder 3 is likewise provided with a stationary piston 20 having a hollow piston rod 21 which is fixed to a stationary manifold 22 and supplies fluid to the lefthand end of the cylinder 3. The cylinder also has a stationary pipe 23 fixed to the manifold 22 which supplies fluid to the righthand end of the cylinder. Piston rod 21 communicates with pipe 24, and pipe 23 communicates through the manifold with the pipe 25.

It will be apparent from the above that the six pipes 8, 11, 17, 19, 24, and 25 serve to conduct the operating fluid to and from the three motors, each pipe being effective when it conducts pressure fluid to effect a movement of one of the cylinders in one direction. The present invention requires that each of these pipes be provided with a valve which is effective in one position to conduct liquid under pressure to the pipe, and in the other position to connect the pipe to a low-pressure reservoir. In order to realize the full advantage of the improved control and mechanism, which constitutes one feature of the present invention, it is essential that these valves be provided with valve-shifting means incorporating a solenoid which, when energized, effects a shift of the valve in one direction in combination with suitable means to return the valve when the solenoid is not energized. The six lines illustrated may, if desired, be provided with individual valves of this type, but in the embodiment of the invention illustrated each pair of pipes is connected to a four-way valve having a single source of liquid under pressure, and a single pipe line leading to the low-pressure reservoir. Such four-way valves are in effect two individual three-way valves combined in a single valve.

The particular four-way valves employed in the preferred embodiment of the invention illustrated are conventional four-way valves of the type having an axially shiftable spool, a pair of solenoids each effective when energized to shift the spool in one of its two directions of movement, respectively, and a spring-centering device which is effective when neither solenoid is energized to shift the spool to a central position in which it blocks all flow through the valve. The solenoids may either act directly on the valve spool or control a pilot valve which supplies hydraulic pressure to shift the valve spool. Since such valves are old and well known, they are merely indicated diagrammatically in the drawings. As hereinafter pointed out, the spring centering device may be omitted from valve 38, if desired, in which event the valve is preferably provided with any conventional form of spring-pressed detent which will hold the valve spool against displacement from either of its two positions of adjustment when neither solenoid is energized.

Pipe lines 8 and 11 for the main cylinder 1 are connected to a spring-centered blocking center four-way valve 26 having a pair of solenoids 27 and 28. The construction is such that when the solenoid 28 is energized the spool of the valve shifts to its lefthand position, in which it connects pipe 11 to the pressure supply line 30 and simultaneously connects pipe 8 to a pipe 31, which is in communication with the low-pressure reservoir 32. When solenoid 27 is energized the spool of the valve shifts to its right-hand position, in which pipe 11 is connected to the low-pressure pipe 31 and pipe 8 is connected to the pressure-supply line 30. When neither solenoid is energized all flow through the valve is blocked.

The pair of pipes 17 and 19 for the broach-handling cylinder 2 is provided with a similar four-way valve 33 having a pair of operating solenoids 34 and 35, a pressure supply line 36 and a pipe 37, which is in fluid communication, not shown, with the low-pressure reservoir. Likewise the pair of pipes 24 and 25 are provided with a similar four-way valve 38 having a pair of operating solenoids 39 and 40, a pressure-supply line 41, and a low-pressure reservoir return line 42.

While in a broad sense the pressure-supply lines 30, 36, and 41 may receive a suitable supply of pressure fluid from any desired source, in accordance with one aspect of the invention these lines receive fluid from a multiple flow-control valve mechanism which may be any one of the various forms of such mechanism disclosed in applicant's copending application, Serial No. 548,294, filed August 5, 1944.

The particular form of multiple flow-control mechanism illustrated includes a valve housing

43 provided with an internal cylindrical chamber 44 in which is slidable a piston 45 carrying a valve plunger 46 which controls a discharge port 47 in the housing. The chamber 44 is provided with an inlet port 48 connected by pipe 49 to a positive constant-displacement pump 50, the intake line 51 of which is connected to the low-pressure reservoir 32. A spring 52 acts on the piston 45 to force it in a direction to cause the plunger 46 to close the outlet port 47, which outlet is connected to the low pressure reservoir 32 by a pipe 53. The tapered end of the plunger 46 is preferably tapered at a slightly steeper angle than the tapered seat at port 47 in accordance with common practice so that the effective seating area is equal to the full cross-sectional area of plunger 46. The piston 45 has an upwardly projecting cylindrical plunger 54 which fits a reduced cylindrical chamber portion 55. The entire valve element including the piston 45 and the plungers 46 and 54, is provided with an axial opening indicated in dotted lines at 56, which opening extends entirely through the element.

The valve housing is provided with an outlet port 57 which is in communication with the inlet port 48 at all times, regardless of the position of the plunger 46. The outlet 57 is connected to a pipe 58, in which is positioned an adjustable throttle valve 59. The valve 59 constitutes a restriction in the line 58, which restriction can be adjusted by manipulation of the handle 60. The degree of restriction provided by the valve 59 is preferably that required to cause a relatively small pressure drop in line 58 when the quantity of liquid passing through the valve is that required to operate the main cylinder 1 at its desired speed. For example, in a system having a maximum operating pressure of 1000 pounds per square inch, the valve 59, when fully opened, may cause a pressure drop of approximately twenty pounds per square inch during passage of the full discharge of pump 50. By adjusting the valve 59 to increase its restricted effect, the amount of flow for the given pressure drop may be reduced.

The spring 52 is of such stiffness that it will just balance a pressure differential on opposite sides of the piston 45 equal to the pressure drop through valve 59, when the desired amount of liquid is flowing through the latter valve. Thus, in the example given, the spring 52 would balance a pressure differential on opposite sides of the piston 45, of twenty pounds per square inch. The design and construction of the spring should be such that no material increase in pressure is exerted by it when the valve plunger 46 moves from fully closed to fully open position.

Pipe 58 is connected directly to the pipe 30 which supplies the pressure fluid to the main four-way valve 26, and it is also directly connected to a pipe 61 which in turn is connected to previously described pipes 36 and 41 through adjustable throttle valves 62 and 63 located, respectively, in the pipes 36 and 41. The adjustable throttle valves 62 and 63 are identical in construction to the valve 59 except that in the particular embodiment of the invention they are of smaller size, being so designed as to produce the same pressure drop as the valve 59 but for the smaller quantity of liquid required to operate the smaller cylinders 2 and 3 at the desired speeds.

The space within the chamber 44 above the piston 45 is connected by means of a port 64 and a line 65 to a low-pass valve 66, having an internal chamber 67 provided with a pair of axially spaced internal annular grooves 68 and 69 which are connected by means of a passageway 70 to each other and to the line 65. The chamber 67 contains a movable plunger or spool 71 having a pair of annular channels 72 and 73. The annular channel 72 is connected by cross passageway 74 and an axial passageway 75 to the lefthand end of the spool, while the channel 73 is connected by a cross passageway 76 and an axial passageway 77 to the righthand end of the spool. The spool is so constructed that when it is in the lefthand position illustrated, channels 72 and 68 are in communication with each other and the spool blocks channel 69. When the spool is in the righthand position, channels 73 and 69 are in communication with each other and the spool blocks channel 68. The ends of the valve housing 66 are connected by means of a pair of pipes 78 and 79, respectively, to the pipes 36 and 41 at points in the latter located beyond the adjustable throttle valves 62 and 63, respectively. As a result of this arrangement, the upper end of chamber 44 and pipe 65 are in fluid communication with and subject to the pressure in that one of the two pipes 78 and 79 which is at the lowest pressure. Thus, when the pressure in line 78 is less than the pressure in line 79, the spool 71 will be forced to the left into the position shown in which it connects pipes 65 and 78. When pipe 79 is subject to a lower pressure than pipe 78, the spool will shift to the right and connect lines 65 and 79. As shown in the drawing, the end closure plates 66*a* and 66*b* of the housing 66 are recessed and each recess is provided with an inwardly projecting lug 66*c* and 66*d*, respectively, for limiting endwise movement of the spool 71. The lugs are of limited radial and circumferential extent in order that substantially the entire end areas of the spool will be subject to the pressure from lines 78 and 79. If desired, a spring 80 may be provided for normally holding the spool 71 in its lefthand position illustrated when the pressures in the lines 78 and 79 are equal. The spring 80 preferably exerts sufficient force on the spool 71 to overcome a pressure differential between the lines 78 and 79 equal to approximately half of the pressure differential which would be balanced by the spring 52 of valve 43.

Valve chamber 43 contains a countersunk passageway 81 in communication with the port 64. The passageway 81 contains a spring-pressed ball check valve 82 which normally closes communication between the passageway 81 and a line 83 which is connected to the low-pressure reservoir 32 in any desired manner, not illustrated. The spring 84 of the ball check valve is of such stiffness as to permit opening of the check valve 81 only when the pressure in line 65 exceeds the safe operating pressure for the system. The check valve thus limits the pressure which can act on the upper side of piston 45 to a safe maximum with the result that the valve plunger 46 will move upwardly and discharge oil from the pump 50 to the reservoir through line 53 when the pressure below the piston 45 exceeds that maximum plus the small additional pressure necessary to overcome spring 52. The existence of a pressure drop necessary to overcome spring 52 is insured by the bleed restriction 85 provided in the line 65. This mechanism, therefore, provides a safety over-pressure relief for the system.

The space within the chamber 44 above piston 45 is also connected by means of a port 86 and a line 87 to a blocking valve 88 which is operated by means of a solenoid 89. The blocking valve 88 may be of any desired or conventional construction, it being sufficient only that it block flow through line 87 except when the solenoid 89 is energized. The valve 88, when opened, permits unrestricted flow through the line 87 to a line 90 which is connected to the low pressure reservoir. Consequently, the valve 88 serves as means for venting the space above the piston 45 and thereby entirely relieving the pressure on the system when desired.

The mechanism so far described operates in the following manner. If it be assumed that the pump 50 is running and that none of the solenoids 27, 28, 34, 35, 39, or 40 is energized, the lines 30, 36, and 41 will be blocked by the blocking four-way valves 26, 33, and 38, and there will be no outlet for the fluid delivered to the valve housing 43 except through the outlet port 47. The pressure in line 49 will be transmitted without change through the valve 43 and through lines 58, 61, 36, 78, the low-pass valve 66, line 65, and port 64 to the upper end of the valve chamber 44. There being no outlet for the fluid delivered, the pressure will immediately build up to open the ball check valve 82, thus venting the fluid in the valve chamber above piston 45 and causing the valve plunger 46 to open fully and discharge all of the fluid delivered by the pump to the reservoir through the line 53 at the maximum safe operating pressure of the system. Under these circumstances the pressure drop through the bleed restriction 85 will be sufficient to overcome the action of spring 52 and, consequently, the pump discharge pressure will exceed the pressure in the ball check valve line 81 by the relatively small pressure drop required to overcome spring 52.

If it is desired to relieve the pressure upon the pump this may be done by energizing solenoid 89 and thus opening valve 88. This immediately connects the upper end of chamber 44 directly to the low-pressure reservoir and, consequently, the pressure above the piston 45 will be substantially zero. Under these circumstances the valve plunger 47 will open fully and discharge all the fluid delivered by the pump to the reservoir through line 53 at the relatively low pressure required to overcome spring 52. Under these circumstances the bleed restriction 85 prevents the flow of liquid to the upper end of the valve chamber as rapidly as it can be withdrawn through the line 87, and consequently prevents transmission of the pressure existing in the lower end of the chamber 44 to the upper end of the chamber 44. Means hereinafter described for automatically controlling the cycle of operation of the machine, incorporates means to energize the solenoid 89 when the machine is stopped and means for de-energizing the solenoid 89 when any motor of the machine is in operation. Thus there is no idle period during which the pump is required to act against a high pressure.

It will be apparent that to cause any desired cylinder of the three cylinders 1, 2, and 3 to move in either of its two directions of movement it is only necessary to energize one of the solenoids 27, 28, 34, 35, 39, and 40. Consequently, any desired sequence of operations of the three cylinders may be accomplished by simply energizing the solenoids in the proper sequence.

If it is desired to have the table cylinder 3 move the workpiece into broaching position, which is accomplished by moving the cylinder to the left, as viewed in the drawing, solenoid 39 is energized, thus connecting the line 41 to line 24 and at the same time connecting line 25 to the low-pressure discharge line 42. Under these conditions a portion of the fluid from the pump will pass through valve 43, pipe 58 containing valve 59 and pipe 61 to the line 41, during which flow it will pass through the adjustable throttle valve 63 in line 41. The throttle valve 63 will cause a pressure drop which will result in a lower pressure in line 79 than that existing in line 78, due to the fact that no flow is occurring in pipe 36 and, consequently, there is no pressure drop through valve 62. The high pressure in line 78 will shift the spool of the low-pass valve to the right, thereby connecting line 79 to line 65 and subjecting the upper end of the valve chamber 44 to the pressure existing in the pipe 41 below the valve 63. As a result of these connections piston 45 with the plunger 46 will automatically adjust itself to by-pass to the low-pressure reservoir through line 53 all of the fluid delivered by the pump except that amount which will produce the predetermined pressure drop through valve 63 required to overcome the spring 52. Since the mechanism maintains a uniform pressure drop through a fixed opening the rate of flow of liquid through the line 41 will remain constant, independent of variations in the resistance to movement of cylinder 3. The total pressure against which the pump discharges under these circumstances will be the pressure required to move the cylinder 3 at its desired speed plus the relatively small pressure drop through valve 63. If it is desired to adjust the speed of movement of the cylinder 3 it is only necessary to adjust the degree of opening of the throttle valve 63. If the opening is reduced a smaller quantity of the liquid will pass for the given pressure drop maintained by spring 52 and, consequently, the speed of the cylinder will be reduced and vice versa. It is apparent that the mechanism will operate in a similar manner to cause reverse or return movement of the cylinder 3 when solenoid 40 is energized in place of solenoid 39.

When it is desired to effect movement of the broach-handling cylinder 2 in downward direction, solenoid 35 is energized, thus connecting lines 36 and 19 and at the same time connecting lines 37 and 17. The valve mechanism previously described will, under these circumstances, maintain the speed of cylinder 2 at a uniform rate in exactly the manner described in connection with the cylinder 3, except that in this case the pressure in line 78 will be lower than that in line 79, and the low-pass valve will assume the position illustrated in the drawings in which it connects the upper end of valve chamber 44 with the pipe 36 at a point below the adjustable restriction 62. As in the previous case, the rate of flow through the line 36 may be adjusted by adjusting the degree of opening of the throttle valve 62.

Return or forward movement of the cylinder 2 is effective in the same manner by energizing the solenoid 34 instead of the solenoid 35.

When it is desired to cause the downward movement of the main cylinder 1, solenoid 27 is energized, thus connecting pipe 30 to pipe 8 and at the same time connecting pipe 11 to pipe 31. Under these circumstances, the liquid from the pump will pass through valve 43 and the adjustable throttle valve 59 to line 30, and thus causing a downward movement of the cylinder 1; and the mechanism in valve housing 43 will serve to maintain the flow in pipes 58 and 30 at the uniform rate required to maintain the pressure drop across valve 59 equal to the differential pressure required to overcome spring 52. Since under these circumstances no liquid will be flowing in lines 36 or 41, the low pass valve 66 will, under the influence of spring 80, assume the position illustrated in the drawings in which it connects line 78 to line 65. Thus, the upper end of valve chamber 44 will be subject to the pressure in pipe 56 beyond the adjustable throttle valve 59. As in previous instances, the quantity of liquid supplied through the main cylinder 1 may be adjusted by adjusting the degree of opening of the throttle valve 59 since for the fixed pressure drop maintained by the mechanism in valve 43 the quantity of liquid which will pass valve 59 is a function of the size of the opening provided therein.

Reverse or upward movement of the cylinder 1 is effective in the same manner by energizing solenoid 28 in place of the solenoid 27.

It will be noted that successful operation of the flow control mechanism depends upon the fact that flow occurs in only one of the lines 30, 36, and 41 at a time. This requires the presence of some means to block flow in the lines to the cylinders which are not operating at any given time, or at least so reduce flow that no appreciable pressure drop will occur through the throttle valves of the inoperative cylinders. In certain machines, such as broaching machines, it is possible to prevent such flow by moving each operating cylinder unit against a mechanical abutment in each direction to stop the movement and consequently the flow of liquid to the unit upon completion of its stroke even though the position of the four-way valve leading to the cylinder does not change. In that case, it is unnecessary to employ a blocking valve in the fluid line to the cylinder. In broaching machines of the type herein disclosed, it is a common practice to limit the stroke of the table cylinder in both directions by positive abutments and consequently the spring centering device may be omitted from valve 38 if such an arrangement is employed without affecting the mode of operation of the machine. While the same practice may be employed with the cylinders 1 and 2, it is preferred to employ a blocking valve in lines 30 and 36 to facilitate adjustments in the stroke of the cylinders. As previously indicated, the four-way valves 26 and 34 perform the necessary blocking function when neither solenoid is energized by reason of the action of the spring centering device.

It will be observed that the adjustable throttle valve 59 is connected in series with the adjustable throttle valves 62 or 63, the latter being connected in parallel with respect to each other. Consequently, when liquid is supplied to either the broach-handling cylinder 2 or the table-moving cylinder 3, it will also flow through the adjustable throttle valve 59. In the particular embodiment of the invention illustrated and described, it is assumed that the quantity of liquid required to operate the cylinders 2 and 3 at their desired speeds is so much smaller than that required to operate the larger broach pulling cylinder 1 that the flow required to operate the cylinders 2 and 3 will cause no appreciable pressure drop on passage through valve 59. Consequently, adjustment of valve 59 made for the purpose of adjusting the speed of operation of the cylinder 1 will not appreciably affect the speed of operation of the cylinders 2 and 3. The valves 62 and

63 are connected in parallel because of the fact that the amount of fluid required to operate the cylinders 2 and 3 is more nearly in the same order and, consequently, a parallel connection is desirable to enable adjustments of the speed of one of these two cylinders to be made without affecting the speed of the other. It is apparent that, if desired, all three of the restriction valves may be connected in parallel in a manner more fully disclosed in applicant's copending application, Serial No. 548,294, filed August 5, 1944. Reference may be had to that application for more detailed description of the multiple flow control mechanism and the preferred form of adjustable throttle valve employed therein.

The cycle of operation of the three cylinders is controlled by means of an electrical circuit, hereinafter described in combination with a plurality of limit switches operated by the three cylinders. As best shown in Figure 1, the limit switches include a switch 96 having a pair of operating arms 97 and 98 fixed to a rotatably mounted switch contact operating shaft 99. The contacts and internal mechanism of the switch, being conventional, are not illustrated or described, it being sufficient to note only that the switch incorporates a pair of contacts which, in one rotative position of the shaft 99, are electrically connected together and in another rotative position are disconnected. As best shown in the fragmentary side elevation of Figure 2, the arms 97 and 98 are axially offset with respect to each other and are provided, respectively, with flanges 100 and 101 adapted to engage, respectively, lugs 102 and 103 which are fixed to the broaching cylinder 1. The housing of the switch 96 is fixed in any suitable manner to a stationary portion of the machine in such position that the flanges 100 and 101 will be engaged by the lugs 102 and 103. Lug 102 is displaced downwardly from the plane of Figure 1 with respect to lug 103, with the result that lug 103 will not engage flange 100 of the arm 97, while lug 102 will not engage flange 101 of arm 98, the latter flange being engaged by the lug 103. The construction and arrangement of the lugs and the limit switch 96 are such that when the ram 1 approaches its upper position illustrated, lug 102 will engage the flange 100 of arm 97 and rotate the shaft 99 with its attached arms 97 and 98 into the position illustrated in Figure 1 in which position the contacts of the switch are broken. When the ram approaches its lower position, the lug 103 will engage the flange 101 of arm 98 and rotate the shaft 99 counterclockwise approximately 90° to close the electrical circuit between the two contacts of the switch. The switch 96 and the operating means therefor are indicated diagrammatically in Figure 3 in which the double arms 97 and 98 are represented as a single arm engaged alternately by the lugs 102 and 103 for the sake of simplicity. The switch is of the snap-acting type so that it will be held in each of its two positions of adjustment. This is represented diagrammatically in Figure 3, by the spring pressed detent 104.

The broaching ram 1 is also provided with a limit switch 107, which is fixed to a stationary portion of the machine. Switch 107 contains a reciprocating plunger 108 which is depressed by a camming lug 109 carried by the broaching ram when the ram reaches the top of its stroke. The limit switch 107 contains, as illustrated diagrammatically in Figure 3, two pairs of contacts 110 and 111. When the plunger 108 is depressed, contacts 110 are electrically connected, and contacts 111 are disconnected. When, on downward movement of the ram, the cam lug 109 is withdrawn from contact with the plunger 108, a spring 112 forces the plunger outwardly disconnecting contacts 110 and making an electrical connection between the contacts 111.

The handling cylinder 2 is provided with a limit switch 113 which is identical in construction and operation to the limit switch 96 previously described and which is operated by a pair of lugs 114 and 115 carried by the handling cylinder 2. As best shown diagrammatically in Figure 3, when the handling cylinder is up, lug 114 operates the switch to break electrical communication between the two contacts of the switch. When the handling cylinder reaches the bottom of its downward stroke, the lug 115 operates the switch in the opposite direction to make an electrical connection between the contacts. The switch 113 is also snap acting as indicated diagrammatically by a spring-pressed detent 116 in Fig. 3.

The handling cylinder 2 is also provided with a limit switch 118 having a plunger 119 adapted to be depressed by a cam lug 120 on the handling cylinder when the cylinder reaches the upper end of its stroke. The switch 118 is similar in construction and mode of operation to the switch 107 previously described and contains two pairs of contacts 121 and 122, as indicated diagrammatically in Figure 3.

For reasons which will appear more fully hereinafter, the handling cylinder 2 is also provided with a solenoid operated latch mechanism indicated generally at 124 which serves, when the machine is idle, to prevent the handling cylinder, if it should sink by gravity, from completing the last few inches of its downward stroke. The latch mechanism includes a housing containing a solenoid 125 and a latch plunger 126 adapted to engage a lug 127 on the handling cylinder to limit downward movement of the cylinder when the plunger is in its outermost position illustrated in Figure 1. The plunger is normally held in its outermost position by means of a spring 128 and is retracted on energization of the solenoid 125. The arrangement of the lug 127 is such that when the cylinder 2 is in its lowermost position the lug prevents latch plunger 126 from projecting outwardly under the influence of spring 128.

The table cylinder 3 is provided with a pair of limit switches 130 and 131 which are identical in construction and mode of operation to limit switch 107, except that they incorporate only one pair of contacts, as best shown diagrammatically in Figure 3. The limit switch 130 is mounted in such a position that when the table cylinder reaches the end of its stroke in the direction in which it moves the table into broaching position and engages (or the table engages) a fixed abutment 132, the plunger 133 of the switch 130 will be depressed by any suitable means fixed to the cylinder or table, such as the projection 134. Such depression closes the circuit between the pair of contacts of the switch 130, as indicated diagrammatically in Figure 3. The switch 130 is of the type which will close upon a very minute inward movement of the plunger 133 and in which the closing position can be set with great accuracy to coincide with the point at which the cylinder or table engages the fixed abutment. The limit switch 131 contains a similar plunger 135 which is depressed by means of a cam lug 136 on the cylinder 3 when the cylinder reaches the opposite end of its stroke, as indicated diagrammatically in Figure 3. Both are opened by constantly acting springs.

Figure 3 is a diagrammatic illustration of the circuit employed to control the operation of the cylinders of the machine. As there shown, the circuit comprises a pair of main line conductors 140 and 141 connected to any suitable source of electrical power. The line 141 is divided into two lines, 142 and 143, which are connected, respectively, to one contact of the two pairs of contacts in a double pole, double throw switch 144. When the switch 144 is in the position illustrated, line 142 is connected to line 145 and the circuit is broken between line 143 and a line 146. The electrical connection of line 145 with a line 147 is controlled by means of the normally open contact 148 of a relay 149, the coil of which is connected between the line 140 and 141 by means of a line 150 and a line 151. The line 150 contains a normally closed emergency stop switch 152, and the line 151 contains a normally open cycle reset switch 153. The coil of the relay 149 is provided with a holding circuit 154 connected in parallel with the line 151 and containing a normally open contact 155 of the relay 149. When the relay 149 is energized, contacts 148 and 155 close. If switch 146 is in the position illustrated, closing of contact 148 connects line 141 with the line 147, and closing of contact 155 closes the parallel holding circuit 154 which maintains the energization of the relay 149 until such time as the emergency stop button 152 is depressed.

The connection of line 147 with line 141 places the circuit in a condition to start the normal cycle of operation of the machine, since all of the control switches and relays and the valve-operating solenoids are connected in parallel between the lines 140 and 147. Thus, there are provided the following lines connected in parallel between the lines 140 and 147; lines 160, 161, 162, 163, 164, 165 (the latter being divided into a pair of parallel lines 165a and 165b), 166, 167, 168, 169 (the latter having a parallel branch 169a), 170 (the latter being divided into a pair of parallel lines 170a and 170b), and line 171. Line 160 contains the coil of a relay 176 having three normally open contacts 177, 178, and 179, and also contains a normally open starting switch button 182, and the normally closed contact 183 of a relay 184. The coil of relay 184 is connected in line 163. The contact 177 of relay 176 controls a relay holding circuit 185 connected in parallel across the contacts of the starting switch 182, as a result of which, on depression of the starting button, the relay 176 will be energized, thus closing all of its contacts, and the contact 177 will maintain the relay 176 energized after the starting button is released. Contact 178 of the relay 176 is located in the line 165a, and contact 179 is located in the line 167. Line 161 contains the limit switch 131 and also the coil of a relay 186, having a normally open contact 187 located in line 170b. Line 162 contains the limit switch 133 and also the coil of a relay 188, having three normally open contacts 189, 190, and 191, and a normally closed contact 192. Contact 189 is in line 169; contact 190 is in line 170a; contact 191 is in line 171; and contact 192 is in line 168. Line 163 contains the limit switch 113 and also the coil of the aforementioned relay 184. Relay 184 has two normally closed contacts, namely, contact 183 in line

160 and 193 in line 170*a*, and three normally open contacts, namely, contact 194 in line 164, 195 in line 165*b*, and 196 in line 171. Line 164 contains the limit switch 96 and also the coil of a relay 197 having two normally open contacts, namely, contact 198 in line 166 and 199 in line 170*b*, and two normally closed contacts, namely, contact 201 in line 168, and 202 in line 171.

Line 165 contains the solenoid 89 of the pressure control valve 88 shown in Figure 1. As previously indicated, the line 165 is connected to the line 147 through the two parallel lines 165*a* and 165*b*. Line 166 contains the solenoid 40 of valve 38. Line 167 contains the solenoid 39 of valve 38 and also contains the contacts 121 of switch 118. The line 168 contains the solenoid 34 of valve 33 and also the contacts 122 of switch 118. Line 169 contains the solenoid 35 of valve 33 and also the contacts 110 of switch 107, and the parallel branch 169*a* contains the latch solenoid 125. Line 170 contains the solenoid 28 of valve 26 and is connected to the line 147 by a pair of branch lines 170*a* and 170*b*, the former branch line containing the contacts 111 of the switch 107.

The electrical circuit so far described constitutes the complete circuit necessary to operate the broaching machine through its normal cycle. It also serves to interlock the position of the various cylinders to prevent the operation of any cylinder when the cooperating cylinders are in an improper position, and it further operates to automatically correct any improper positioning of the cylinders, and thereafter permit automatic resumption of the cycle of operation.

The operation of the circuit is as follows: In Figure 3, all of the relays are illustrated in the position they assume when the cylinders of the machine are in their starting positions and no power is supplied to the lines 140 and 141. This will be the theoretical position assumed when the power supply is cut off after the machine has stopped at the end of its cycle of operation. Actually, as hereinafter pointed out, if the machine is left idle for any appreciable period of time one or more of the vertically positioned cylinders may sink down by gravity and assume an improper position. While the foot valves 12 and 18 serves to hold the cylinders in their upper positions, unavoidable leakage will often permit a gradual sinking of the cylinders during long idle periods. The result of such occurrences will be dealt with hereinafter.

If the lines 140 and 141 are energized when the parts are in the position illustrated, no power will be supplied to the line 146 because the jogging switch 144 is in the position it assumes when the machine is set for normal operation. Likewise, no power will be supplied to the line 147 because of the open contact 148 of relay 149. Consequently, no power is supplied to any of the parallel lines connecting lines 140 and 147, and none of the valve solenoids will be energized.

The machine is placed in condition to be started by connecting lines 140 and 141 to a suitable source of electrical power and by depressing the reset button 153, which establishes a circuit through the coil of relay 149, thus causing contacts 155 and 148 of that relay to close. Contact 155 establishes a holding circuit through line 154 for maintenance of the energization of the relay 149 and contact 148 closes communication from line 141 through branch line 142, switch 144, and line 145 to the line 147. As the result of this operation, the opposite ends of all the parallel lines 160 and 171, inclusive, are subject to a voltage differential which will cause a current flow through any parallel line which forms a closed path for the flow of the electric current. After the reset button is depressed to energize line 147, the only one of the parallel lines which is closed to the passage of electric current is the line 161 which contains the coil of relay 186. Consequently, as soon as the reset button is depressed relay 186 is energized and closes its contact 187. The contact 187 is in line 170*b* which contains the open contact 199, and thus the closure of contact 187 does not affect line 170*b* when the parts are in the position illustrated in the drawing. Since none of the remaining parallel lines 160 and 162 to 171, inclusive, provide a closed circuit, it is necessary to depress the starting button 182 to start the machine.

As soon as the starting button is depressed, a circuit is established through the coil of relay 176 causing that relay to close its contacts 177, 178, and 179. The contact 177 establishes a holding circuit for the relay 176 through the branch line 185 and, consequently, the relay remains energized after the starting button is released. Contact 178, on closing, establishes a current flow through line 165*a*, line 165, the pressure control solenoid 89, thus establishing pressure in the hydraulic system in the manner previously described in connection with the mechanism illustrated in Figure 1. At the same time, current flow is established through line 167 by reason of the closure of relay contact 179. This energizes the solenoid 39 of the table control valve 38, and shifts the valve to the position in which it effects inward movement of the table. Such movement shifts the workpiece into broaching position.

In this connection, it will be observed that injury to the broach or to the work would result if, on inward movement of the table, the handling cylinder had sunk down during a previous idle period to a point in which the lower end of the broach was below the top of the workpiece. It is for this reason that the switch 118 is provided. It will be noted that, as long as the handling cylinder is in its uppermost postion, the switch 118 will be in a position in which its upper contact closes communication between the contacts 121 in line 167. If, however, the handling cylinder is not at the top of its stroke, communication between the contacts 121 will be broken and no current will be supplied to the solenoid 39. When this state of affairs exists, the switch 118 closes communication between contacts 122 in line 168, thus energizing solenoid 34 of the handling cylinder valve 33. This energization of solenoid 34 causes the valve to shift to a position in which the handling cylinder 2 is returned to its uppermost starting position. This energization of solenoid 34 is possible because relay 188 is de-energized and, therefore, its contact 192 is closed. As soon as the handling cylinder reaches the top of its stroke, switch 118 returns to the position illustrated in Figure 3, in which it closes the circuit through line 167 to effect the aforementioned inward movement of the worktable.

As soon as the table begins to move in, switch 131 is opened, breaking the circuit through line 161 and de-energizing relay 186, with the result that the previously closed contact 187 is then opened. When the table reaches its innermost position, switch 130 is closed, establishing a circuit through line 162 and energizing relay 188, thus closing relay contacts 189, 190, and 191, and opening contact 192. If at this time the broaching cylinder is in its uppermost position, as it should be, switch 107 will be in the position illustrated in which it opens the connection between contacts 111 in line 170*a*, and, consequently, the closure of contact 190 will have no effect. Similarly, the closure of contact 191 will have no effect because contact 196 in line 171 is open. However, the closure of contact 189 closes the circuit through line 169 to energize solenoid 35 of valve 33, thus causing the handling cylinder to move downwardly. At the same time, the parallel branch line 169*a* is energized, thus causing retraction of the latch 126.

In this connection, it will be noted that it is undesirable to have the handling cylinder move downwardly unless the broaching cylinder is in its uppermost position, since otherwise the automatic chuck on the broaching cylinder will not be open to receive the broach when it is released by the handling chuck, and in the subsequent step in the cycle the broaching cylinder will move downwardly without the broach. This in turn would result in breaking the broach when the table moved outwardly at the end of the downward movement of the broaching cylinder. It is for this reason that the switch 107 is provided. It will be noted that if the broaching cylinder is not at the top of its stroke, the switch will be in its lowermost position, in which it breaks the circuit between contacts 110 in line 169 and thus prevents energization of the solenoid 35. At the same time, the switch 107 connects contacts 111 of line 170*a* (thus completing the circuit through line 170*a* and the solenoid 28, which in turn shifts the main valve 26 into a position in which it returns the broaching cylinder to the top of its stroke. As soon as the cylinder reaches the top of its stroke, switch 107 returns to the position illustrated in Figure 3, thus permitting energization of solenoid 35 and downward movement of the broach-handling cylinder.

Since the switch 130 is of the type which can be very accurately adjusted to close only when the worktable is in its extreme innermost position against abutment 132, no downward movement of the broach-handling cylinder can occur unless the table is in its full inward position because as soon as it leaves that position, switch 130 de-energizes solenoid 188 and opens contact 189 in line 169. This insures that the workpiece will be in the proper position to receive the broaching tool.

During the downward stroke of the broach-handling cylinder, the switch 118 shifts downwardly from the position shown in Figure 3, breaking the circuit through line 167 and connecting contacts 122 of line 168. No current will flow through line 168 at this time, due to the fact that the table is in, and consequently relay 188 is energized, thus opening contact 192.

When the handling cylinder reaches the end of its downward stroke, switch 113 is closed by lug 115 on the cylinder, thus energizing relay 184. Engerization of relay 184 closes contacts 194, 195, and 196, and opens contacts 193 and 183. The closing of contact 194 has no effect because line 164 is open at switch 96. The closing of contact 195 completes a circuit through the branch 165*b* of the pressure control solenoid line 165. The opening of contact 193 does not affect the circuit through line 170*a* because that circuit is already opened by the switch 107. The opening of contact 183 breaks the circuit through the starting button line 160, thus de-energizing relay 176 and opening its contacts 177, 178, and 179. The opening of contact 178 dos not interrupt the current through the pressure control solenoid 89 because of the simultaneous closing of contact 195, which closes the circuit through the branch line 165*b*, thus maintaining the pressure control solenoid energized. The opening of contact 177 breaks the holding circuit for relay 176. The opening of contact 179 has no effect because line 167 is open at contacts 121. However, the closing of contact 196 completes the circuit through line 171 and energizes solenoid 27 of the main valve 26, thus shifting the valve to a position in which it causes downward movement of the broaching cylinder 1 to effect the broaching stroke of the machine. During this state in the cycle of operation, line 166 is open at contact 198; line 167 is open at contact 179 and contacts 121; line 168 is open at contact 192; line 169 is open at contacts 110 as soon as the broaching cylinder starts down; line 170*a* is open at contact 193; and line 170*b* is open at contacts 187 and 199. As a result of these conditions, none of the other cylinders of the machine can move during the broaching stroke.

When the broaching cylinder 1 reaches the end of its downward broaching stroke, lug 103 closes switch 96, thus energizing relay 197 (contact 194 having previously closed). This opens contacts 201 and 202 and closes contacts 198 and 199. At this point, line 167 is open at contacts 179 and 121; line 168 is open at contacts 192 and 201; lines 169 and 169*a* are open at contact 110; line 170*a* is open at contact 193; line 170*b* is open at contact 187; and line 171 is open at contact 202. Line 166, however, is then closed, thus energizing solenoid 40 of valve 38 and shifting the valve to a position in which it causes an outward movement of the worktable. It will be observed that such outward movement occurs after the broaching cylinder has reached the end of its downward stroke. As soon as the table leaves its innermost position, switch 130 is opened, de-energizing relay 188, thus opening contacts 189, 190, and 191, and closing contact 192. The opening of contacts 189, 190, and 191 does not affect the lines in which they are located because at this stage in the cycle those lines are opened at contacts 110, 193, and 202, respectively. Closing of contact 192 does not affect line 168 because that line is open at contact 201. When the table reaches the end of its outward stroke, switch 131 is closed, thus energizing relay 186 and closing its contact 187. The closing of contact 187 closes the circuit through line 170*b* and line 170, thus energizing solenoid 28 of valve 26 and shifting that valve into the position in which it causes upward or return movement of the broaching cylinder. During the return movement of the broaching cylinder, switch 96 is held in its closed position by the detent 104. This insures that the relay 197 will remain energized and that, therefore, the table cannot move in or the broach handling cylinder up. When the broaching cylinder reaches the upper end of its stroke, switch 107 is shifted into the position illustrated in the drawing, and switch 96 is opened by lug 102. This shift of the microswitch 107 opens the circuit between contacts 111 of line 170*a*, which line is already open at contacts 190 and 193, and connects contacts 110 in line 169 which is already open at contact 189. The opening of switch 96 de-energizes relay 197, thus breaking contacts 198 and 199 and closing contacts 201 and 202. The opening of contact 198 de-energizes solenoid 40. The opening of contact 199 completes the de-energization of the solenoid 28 and thus relieves the broaching cylinder of operating pressure. The closing of contact 202 has no effect on line 171 because that line is open at contact 191. However, the closing of contact 201 completes the circuit through line 168 and energizes solenoid 34 of valve 33, thus shifting the valve to a position in which it effects upward movement of the broach handling cylinder 2. As soon as the cylinder 2 leaves its lower position, latch 126 is projected by spring 128 because line 169*a* is broken at contact 189.

During upward movement of the broach-handling cylinder, switch 113 is held closed by the detent 116, but when the handling cylinder reaches the end of its upward stroke, switch 113 is opened by lug 114, thus de-energizing relay 184. This opens contacts 194, 195, and 196, and closes contacts 183 and 193. In addition, when the handling cylinder reaches the upper end of its stroke, the switch 118 shifts to the position illustrated in the drawings, in which it closes communication between contacts 121 and breaks the connection between contacts 122. These changes complete the cycle of operation and bring the machine to a stop, inasmuch as line 166 is open at contact 198; line 167 is open at contact 179; line 168 is open at contact 122; lines 169 and 169*a* are open at contact 189; line 170*a* is open at contacts 190 and 111; line 170*b* is open at contact 199; and line 171 is open at contacts 191 and 196. It will be noted also that the pressure on the machine is relieved by reason of the breaking of both branches 165*a* and 165*b* of the pressure control line 165.

It will be observed that throughout the cycle described above, the latch solenoid 125 was retracted only when the handling cylinder was caused to move down. At all other times, including the stop position, the latch solenoid is de-energized and the latch advances under the influence of spring 128 into retaining position. The object of the latch 126 is to prevent the handling cylinder from moving downwardly under the influence of gravity during idle periods to such a point that the automatic broach handling chuck secured to the broach handling cylinder will release the broach. In this connection, it will be understood that the latch is so positioned as to stop the cylinder just before the chuck release mechanism contacts the release abutment.

The latch also prevents the handling cylinder from falling by gravity during idle periods sufficiently far to insert the broach, if carried by the handling cylinder chuck, into the chuck carried by the broaching cylinder 1 or to prevent the broach, if carried by the broaching cylinder chuck, from being projected into the broach-handling chuck. It further prevents downward movement of the cylinder during idle period from closing switch 113 since such closure would result in injury to the broach if the machine was started following an emergency stop after the worktable moves in, if, during the idle period, the handling cylinder sank all the way to the end of its stroke and the broaching cylinder also sank all or part way down.

It will be understood that in accordance with the conventional practice the downward stroke of the broach-handling cylinder, the inward stroke of the work fixture cylinder, and the upward stroke of the broach cylinder are limited by fixed abutments in all cases, with the result that it is immaterial whether the operating pressure is maintained after the cylinders reach the positive abutment. The length of the upward stroke of the broach-handling cylinder may be readily adjusted by adjustment of the lug 114 on the cylinder and similarly the downward stroke of the broaching cylinder 1 may be adjusted by adjusting the position of lug 103 on the cylinder. Such adjustments are desirable in order to adjust the stroke of the two cylinders to correspond to the length of the broach employed.

If, after the machine is automatically stopped in the above described manner at the end of the broaching cycle, the broach handling cylinder should sink down by gravity, the switch 118 will shift to its lower position, thus closing the circuit through line 168 and energizing the solenoid 34 of valve 33 to shift that valve to a position in which it returns the broach-handling cylinder to its uppermost position as soon as the machine is restarted. The worktable cannot move in until the handling cylinder returns to its uppermost position and shifts the switch 118 to the position illustrated in Figure 3. As a result there is no possibility, on restarting the machine, that the work moving table will collide with the broach.

It will be noted that if, during the idle period following an automatic stop at the end of a cycle, the broaching cylinder sinks downwardly by gravity, switch 107 will be shifted downwardly closing the circuit between contacts 111 and opening the circuit between contacts 110. These changes do not have any immediate effect because line 169 is already open at contact 189, and line 170*a* is already open at contact 190. However, when, during the subsequent cycle, the table moves inwardly to broaching position, it will close switch 130, thereby energizing relay 188 and closing contacts 189, 190, and 191. Consequently, line 170*a* will be energized and line 169 will be disconnected at contacts 110, with the result that the broaching cylinder will return to its upper position and the handling cylinder will not move down. As soon as the broaching cylinder reaches its upper position, the switch 107 is returned to the position illustrated, and the cycle is resumed by downward movement of the handling cylinder.

To restart the machine following an automatic stop, it is only necessary to depress the starting button 182, thus energizing relay 176 to initiate a repetition of the previously described cycle of operation.

At anytime during a cycle of operation, the machine can be stopped by depressing the emergency stop button 152. This de-energizes relay 149 and opens contacts 148 and 155, thereby disconnecting line 147 from the source of electrical energy. To reinstate the machine in condition to operate following an emergency stop, it is necessary to depress the cycle reset button 153, which re-energizes relay 149 and returns the contacts 148 and 155 to a position in which line 147 is connected to the electrical source. If the machine were stopped during a portion of the cycle subsequent to the end of the downward movement of the broach handling cylinder, the cycle will resume a depression of the reset button 153. If the machine was stopped at an earlier portion of the cycle, it is necessary to depress first the reset button 153 and then the starting button 182 to restart the machine. If, during the intervening idle period, the positions of the remaining switches and relays remained unchanged the machine, on restarting, will resume its cycle where it left off.

It will be appreciated that by reason of the possibility of stopping the machine at any point during its cycle by the emergency stop button and by reason of the possible sinking by gravity of the cylinders 1 and 2 during idle periods, the three moving cylinders may assume a wide variety of relative positions when the machine is restarted. The control circuit provided in accordance with the present invention automatically prevents any movement of any of the three cylinders which will result in injury to the broach, work fixture, or machine when the machine is restarted, regardless of the relative positions of the three cylinders at the time of starting. A few possible relative positions of the cylinders and the means by which they were cured during the cycle have been described above. However, many other relative positions are possible. For example, if the machine is stopped while the worktable is part way in during the beginning of the cycle and thereafter the broach-handling cylinder, which is then carrying the broach, sinks down by gravity before the machine is restarted, then, on restarting, the handling cylinder will return to its upper position and the movement of the worktable will not be resumed until after the work handling cylinder reaches its upper position. This result is achieved by reason of the fact that downward movement of the broach-handling cylinder shifts the switch 118 downwardly, thus breaking the circuit through line 167 and closing the circuit through line 168. As soon as the handling cylinder is fully returned, switch 118 returns to the position illustrated and inward movement of the table resumes.

Another possibility is that the machine may be left idle following an automatic stop at the end of the cycle and that during the idle period the broaching cylinder will sink to the extreme lower end of its stroke, thus closing switch 96. However, closure of switch 96 cannot energize relay 197 because relay 184 is de-energized thereby breaking the circuit of relay 197 at contact 194. Relay 184 is energized only when the handling cylinder is at the lower end of its stroke and the latch prevents the handling cylinder from reaching that position during idle periods. Therefore, under the conditions stated, when the machine is started, the handling cylinder will move up if it is not at the top of its stroke and then the table will move in. At the end of the inward table stroke, the handling cylinder cannot move down because contacts 110 are open; but the circuit through line 170a is closed and, therefore, the broaching cylinder is returned to its upper position. From that point, the normal cycle resumes with a downward movement of the handling cylinder.

If the machine is stopped during the broaching stroke, it will, on restarting, resume the broaching stroke where it left off, since there is no possibility of a change of position of the work handling cylinder or table under those circumstances during the idle period. The same thing is true if the machine is stopped during the return movement of the broaching ram; that is to say, on restarting under these circumstances, the upward movement of the ram will resume.

A complete tabulation of all improper positions which may result, and the way they are automatically corrected before the normal cycle resumes, is given below. Each improper position assumed prior to restarting is indicated in the lefthand column, while in the right-hand column are listed the various cylinder movements which occur automatically in the order given when the machine is restarted and before the normal cycle is automatically resumed.

Improper Positions	Corrective Movements
A. Table Out	
1. Machine stopped at end of cycle	
a. Handling cylinder sinks	1. Handling cylinder returns
b. Broach cylinder sinks partially or fully	1. Table moves in 2. Broaching cylinder returns
c. Handling cylinder sinks and broaching cylinder sinks partially or fully	1. Handling cylinder returns 2. Table moves in 3. Broaching cylinder returns
2. Machine stopped during broach return by broaching cylinder	
a. Broaching cylinder sinks partially or fully	None required—cycle resumes
3. Machine stopped during broach return by handling cylinder	
a. Handling cylinder sinks	None required—cycle resumes
b. Broaching cylinder sinks partially	1. Handling cylinder returns 2. Machine stops 3. On restarting, table moves in 4. Broaching cylinder returns
c. Broaching cylinder sinks fully	1. Broaching cylinder returns
B. Table Intermediate Stroke	
1. Machine stopped during inward movement of table	
a. Handling cylinder sinks	1. Handling cylinder returns
b. Broaching cylinder sinks fully or partially	1. Table moves in 2. Broaching cylinder returns
c. Handling cylinder sinks and broaching cylinder sinks fully or partially	1. Handling cylinder returns 2. Table moves in 3. Broaching cylinder returns
2. Machine stopped during outward movement of table	None required—cycle resumes
C. Table In	
1. Machine stopped before handling cylinder moves down	
a. Handling cylinder sinks	None required—cycle resumes
b. Broaching cylinder sinks partially or fully	1. Broaching cylinder returns
c. Handling cylinder sinks and broaching cylinder sinks partially or fully	1. Broaching cylinder returns
2. Machine stopped during downward movement of handling cylinder	Same as for corresponding positions under C–1
3. Machine stopped during broaching stroke	None required—cycle resumes

It will be observed from the above table that the automatic corrective movements take place in such an order that no damage can occur to the broach, the workpiece, or the machine, and that every possible position that can result during operation or after an emergency stop at any point in the cycle is taken care of. In each case, the corrective movements listed leave the cylinders in a relative position they should assume during some point in the normal cycle. From that point on, the cycle resumes normally. It may be noted that no mention is made of the possibility of the handling cylinder sinking fully. This is due to the fact that a full sinking movement is prevented by the latch.

It should be noted that all of these functions are achieved by a very simple arrangement of parallel circuits, in which every single valve solenoid and relay operating coil is connected directly across the full line voltage. This basic arrangement insures that the full operating voltage is available to actuate each solenoid or coil at all times and greatly facilitates modification and adaption of the circuit to different types of machines.

The remaining portions of the circuit so far not mentioned, which are largely located in the lower lefthand portion of Figure 3, have no utility except for use in "jogging" the various cylinders during tool and fixture set-up. It is highly desirable in a machine of this type to provide manually controlled means for moving each cylinder in any desired direction to any desired extent, as such movements are required to facilitate attachment and adjustment of the tools and work holding fixtures during machine set-up operations. Accordingly, there is provided an auxiliary set of manual controls for use in such cases.

The jogging control circuit employs as its source of current the main conductor 140 and the branch 146 of the main conductor 141. When it is desired to operate the manual jogging controls, the previously mentioned switch 144 is shifted to break the connection between the lines 142 and 145 and to complete an electrical connection between the lines 143 and 146, thus energizing the latter.

In order to control movement of the table in either direction, a pair of manually operated push-button switches 204 and 205 are provided. Each of these switches has five contacts, those of the switch 204 being indicated by the letters *a*, *b*, *c*, *d*, and *e*, and those for the switch 205 being indicated *f*, *g*, *h*, *k*, and *m*. The contactor of switch 204 is spring-biased to a position in which it connects contacts *a* and *b*. When depressed it connects contacts *c*, *d*, and *e*. The contactor of switch 205 similarly connects contacts *f* and *g* in its normal position and connects contacts *h*, *k*, and *m*, when depressed. Contacts *c* and *m* are connected to line 146; contacts *d* and *f* are connected together; contacts *b* and *h* are connected together; contacts *e* and *k* are connected by lines 210, 211, and 212 to line 165 at a point to the right of the pressure control solenoid 89; contact *a* is connected by a line 214 to line 167 between solenoid 39 and the contact 179; and contact *g* is connected by a line 215 to line 166 between solenoid 40 and contact 198.

As the result of this arrangement, all of the circuits connected to switches 204 and 205 are normally open. However, when only switch 204 is depressed solenoid 40 is energized through line 146; contacts *c*, *d*, *f*, and *g*, and line 215, and the pressure control solenoid 89 is energized through line 146, contacts *c* and *e* and lines 210 and 212. Thus depression of switch 204 causes the work table to move out, and such movement continues only so long as the switch 204 is depressed. Likewise, the pressure control solenoid is energized only so long as the switch 204 is depressed, with the result that no pressure exists in the system except when the switch is depressed. This enables the operator to leave the pump running during the set-up operations without heating the oil and yet enables him to shift the table outwardly to any desired extent by the touch of the switch button. Switch 205, when depressed alone, operates in the same manner to energize solenoids 89 and 39 to build up pressure and effect an inward movement of the worktable.

If both of the switch buttons 204 and 205 are depressed simultaneously, no movement of the worktable results, but the pressure control solenoid is energized to subject the system to operating pressure.

A pair of manually operated switches 218 and 219 are provided for similarly energizing the solenoids 28 and 27 respectively of the ram control valve 26 to effect any desired upward or downward movement of the ram. These switches, being identical in construction and mode of operation to switches 204 and 205, need no further description.

A third pair of manually operated switches 220 and 221 are provided for energizing the solenoids 34 and 35 respectively of the handling cylinder control valve 33. These switches are likewise similar in construction and operation to the switches 204 and 205. It will be noted, however, that on depression of switch 221 both the solenoid 35 and the latch solenoid 125 are energized, whereas on depression of the switches 204, 205, 218, 219, and 220 the solenoids 40, 39, 28, 27, and 24 are energized, respectively, without energizing the solenoid 125 to release the latch. Thus the latch normally operates to limit downward movement of the handling cylinder during set-up operations. The only exception is when switch button 221 is depressed to cause downward movement of the handling cylinder.

It is apparent, therefore, that the hereinbefore described control circuit not only achieves an automatic positively interlocked and fool-proof control of maximum simplicity, but lends itself readily to an exceedingly simple and practical jogging control for use in tool set-up operations.

Preferably the jogging control buttons will be made inaccessible to the ordinary operator since they need be employed only by skilled machine set-up men. It is possible by manipulation of the jogging buttons to cause damage, but, as previously pointed out, it is impossible by any manipulation of the normal controls, namely, the starting button, the emergency stop button, and the cycle reset button, to cause any injury to the broach, work, or machine.

What is claimed is:

1. In a hydraulic shuttle pull-broaching machine, a double-acting positive displacement motor for operating a movable worktable between a retracted and a broaching position, a double-acting positive displacement motor for operating a broach-handling slide between a retracted and an advanced position, a double-acting positive displacement motor for operating a broaching ram through a broaching and a broach-return stroke, a separate four-way reversing valve for controlling admission of operating liquid to each motor, separate means for shifting each four-way valve, each said means including a pair of solenoids, energization of one of which causes a shift of the valve in one direction and energization of the other causes a shift in the opposite direction, and automatic means controlled by the position of the motors for energizing said solenoids one at a time in sequence to produce a complete cycle of operations including an advance of the table to broaching position, an advance of the broach-handling slide, a broaching stroke of the ram, a retraction of the table, a broach-return stroke of the ram, and a retraction of the broach-handling slide, said last-named means including automatic means operable to return the broach-handling slide to its fully-returned position before any advance of the table, automatic means to return the ram to fully-returned position before any advance of the broach-handling slide, automatic means to prevent advance movement of the broach-handling cylinder if the table is not fully advanced and automatic means to prevent a broaching stroke of the ram if the table is not fully advanced.

2. In a hydraulic shuttle pull-broaching machine, a double-acting positive displacement motor for operating a movable work table between a retracted and a broaching position, a double-acting positive displacement motor for operating a broach-handling slide between a retracted and an advanced position, a double-acting positive displacement motor for operating a broaching ram through a broaching and a broach-return stroke, a separate four-way reversing valve for controlling admission of operating liquid to each motor, separate means for shifting each four-

way valve, each said means including a pair of solenoids, energization of one of which causes a shift of the valve in one direction and energization of the other causes a shift in the opposite direction, and automatic means controlled by the position of the motors for energizing said solenoids one at a time in sequence to produce a complete cycle of operations including an advance of the table to broaching position, an advance of the broach-handling slide, a broaching stroke of the ram, a retraction of the table, a broach-return stroke of the ram and a retraction of the broach-handling slide, means for rendering said automatic means inoperative, and manually controlled means effective when said automatic means is rendered inoperative for selectively energizing any one of said solenoids.

3. In a hydraulic shuttle pull-broaching machine, a double-acting positive displacement motor for operating a movable worktable between a retracted and a broaching position, a double-acting positive displacement motor for operating a broach-handling slide between a retracted and an advanced position, a double-acting positive displacement motor for operating a broaching ram through a broaching and a broach-return stroke, a constant displacement pump, branch conduits for conducting liquid from the pump to both sides of each motor, a separate four-way reversing valve for each motor associated with said branch conduits, automatic means for shifting said four-way valves one at a time in either direction to produce a complete cycle of operations including an advance of the table to broaching position, an advance of the broach-handling slide, a broaching stroke of the ram, a retraction of the table, a broach-return stroke of the ram and a retraction of the broach-handling slide, a by-pass valve for by-passing to low pressure a portion of the liquid discharged by the pump, and means for automatically controlling the degree of opening of said by-pass valve to maintain the rate of flow of liquid to each motor as that motor operates at a constant value which is different for each motor and which is independent of the resistance encountered by each motor, said last means including means in the conduits from the by-pass valve to said motors for imposing a different resistance to the flow to each motor, and means responsive to the pressure drop in each conduit as flow occurs therein for controlling the degree of opening of said by-pass valve.

4. In a hydraulic shuttle pull-broaching machine, a double-acting positive displacement motor for operating a movable worktable between a retracted and a broaching position, a double-acting positive displacement motor for operating a broach-handling slide between a retracted and an advanced position, a double-acting positive displacement motor for operating a broaching ram through a broaching and a broach-return stroke, a constant displacement pump, branch conduits for conducting liquid from the pump to both sides of each motor, a separate four-way reversing valve for each motor associated with said branch conduits, automatic means for shifting said four-way valves one at a time in either direction to produce a complete cycle of operations including an advance of the table to broaching position, an advance of the broach-handling slide, a broaching stroke of the ram, a retraction of the table, a broach-return stroke of the ram and a retraction of the broach-handling slide, a by-pass valve for by-passing to low pressure a portion of the liquid discharged by the pump, and means for automatically controlling the degree of opening of said by-pass valve to maintain the rate of flow of liquid to each motor as that motor operates at a constant value which is different for each motor and which is independent of the resistance encountered by each motor, said last means including means in the conduits from the by-pass valve to said motor for imposing a different resistance to the flow to each motor and means responsive to the pressure drop in each conduit as flow occurs therein for controlling the degree of opening of said by-pass valve, and means for independently adjusting the resistance to flow to each motor.

5. In a hydraulic broaching machine, a double-acting positive displacement motor for operating a movable worktable between a retracted and a broaching position, a double-acting positive displacement motor for operating a broaching ram through a broaching and a broach-return stroke, a constant displacement pump, branch conduits for conducting liquid from the pump to both sides of each motor, a separate four-way reversing valve for each motor associated with said branch conduits, automatic means for shifting said four-way valves one at a time in either direction to produce a complete cycle of operations including an advance of the table top broaching position, a broaching stroke of the ram, a retraction of the table, and a broach-return stroke of the ram, a by-pass valve for by-passing to low pressure a portion of the liquid discharged by the pump, and means for automatically controlling the degree of opening of said by-pass valve to maintain the rate of flow of liquid to each motor as that motor operates at a constant value which is different for each motor and which is independent of the resistance encountered by each motor, said last means including means in the conduits from the by-pass valve to said motors for imposing a different resistance to the flow to each motor and means responsive to the pressure drop in each conduit as flow occurs therein for controlling the degree of opening of said by-pass valve, and means for independently adjusting the resistance to flow to each motor.

6. In a vertical shuttle-type pull down broaching machine having a hydraulic motor for moving a work fixture into and out of broaching position, a hydraulic motor for moving a broach-handling chuck toward and away from a broach-pulling chuck, a hydraulic motor for moving a broach-pulling chuck toward and away from the broach-handling chuck, the combination of control means for automatically operating said units through a normal shuttle broaching cycle, said control means including, means operable automatically at any time during the cycle before the fixture is fully advanced to return the broach-handling motor to fully retracted position if it is not fully retracted and to prevent inward movement of the work fixture motor unit the broach-handling motor is fully retracted, means operable automatically at any time during the cycle before the broach-handling motor is fully advanced to restore the broach-pulling motor to its fully advanced position if it is not fully advanced, and means operable during operation of said last mentioned means to prevent advance movement of the broach-handling cylinder until the broach-pulling cylinder is fully advanced.

7. In a vertical shuttle-type pull down broaching machine having a hydraulic motor for moving a work fixture into and out of broaching posi-

tion, a hydraulic motor for moving a broach-handling chuck toward and away from a broach-pulling chuck, a hydraulic motor for moving a broach-pulling chuck toward and away from the broach-handling chuck, the combination of control means for automatically operating said units through a normal shuttle broaching cycle, said control means including; means operable automatically at any time during the cycle before the fixture is fully advanced to return the broach-handling motor to fully retracted position if it is not fully retracted and to prevent inward movement of the work fixture motor until the broach-handling motor is fully retracted, means operable automatically at any time during the cycle before the broach-handling motor is fully advanced to restore the broach-pulling motor to its fully advanced position if it is not fully advanced and to prevent advance movement of the broach-handling cylinder until the broach-pulling cylinder is fully advanced; means to prevent retraction of the work fixture motor after it has fully advanced unless the broach-handling motor is in its fully advanced position and the broach-pulling motor has previously been fully retracted during the cycle, means to prevent advance movement of the broach-pulling motor after it has completed the broaching stroke until after the work fixture motor is fully retracted, and means to limit advance movement of the broach-handling motor when the machine is idle.

8. In a vertical shuttle-type pull down broaching machine having a hydraulic motor for moving a work fixture into and out of broaching position, a hydraulic motor for moving a broach-handling chuck downwardly toward and upwardly away from a broach-pulling chuck, a hydraulic motor for moving a broach-pulling chuck upwardly toward and downwardly away from the broach-handling chuck, the combination of control means for automatically operating said units through a normal shuttle broaching cycle, said control means including: means operable automatically at any time during the cycle before the fixture is fully advanced to return the broach-handling motor upwardly to fully retracted position if it is not fully retracted and to prevent inward movement of the work fixture motor until the broach-handling motor is fully retracted, means operable automatically at any time during the cycle before the broach-handling motor is fully advanced downwardly to restore the broach-pulling motor to its fully advanced upward position if it is not fully advanced, and means operable during operation of said last mentioned means to prevent advance downward movement of the broach-handling cylinder until the broach-pulling cylinder is fully advanced upwardly.

9. In a vertical shuttle-type pull down broaching machine having a hydraulic motor for moving a work fixture into and out of broaching position, a hydraulic motor for moving a broach-handling chuck downwardly toward and upwardly away from a broach-pulling chuck, a hydraulic motor for moving a broach-pulling chuck upwardly toward and downwardly away from the broach-handling chuck, the combination of control means for automatically operating said units through a normal shuttle broaching cycle, said control means including means operable automatically at any time during the cycle before the fixture is fully advanced to return the broach-handling motor upwardly to fully retracted position if it is not fully retracted and to prevent inward movement of the work fixture motor until the broach-handling motor is fully retracted, means operable automatically at any time during the cycle before the broach-handling motor is fully advanced downwardly to restore the broach-pulling motor to its fully advanced upward position if it is not fully advanced and to prevent advance downward movement of the broach-handling cylinder until the broach-pulling cylinder is fully advanced upwardly, means to prevent retraction of the work fixture motor after it has fully advanced unless the broach-handling motor is in its fully advanced downward position and the broach-pulling motor has previously been fully retracted downwardly during the cycle, means to prevent upward advance movement of the broach-pulling motor after it has completed the broaching stroke until after the work fixture motor is fully retracted, and means to limit downward advance movement of the broach-handling motor when the machine is idle.

10. In combination, a plurality of positive displacement double-acting hydraulic motors each having a movable element, a separate four-way reversing valve for controlling admission of operating liquid to each motor, separate means for shifting each four-way valve, each said means including a pair of solenoids, energization of one of which effects a shift of the valve in one direction and energization of the other of which effects shift of the valve in the other direction, automatic means controlled by the position of the movable elements of said motors for energizing said solenoid one at a time in a predetermined sequence to cause said motor elements to perform a cycle of operations, said last-named means including a switch mechanism operated by one of said motors when said motor is away from the position it should occupy when a second motor which operates immediately prior thereto in said sequence is so operating, said switch mechanism having contacts in the circuit of the solenoid which on energization effect return of said one motor to said position and having contacts in the circuit of the solenoid which effect said prior operation of the second motor, said first-mentioned contacts being closed and the second-mentioned contacts being opened when said switch mechanism is so operated by said one motor.

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