Dec. 3, 1940. W. P. MUIR 2,223,792

HYDRAULIC APPARATUS FOR OPERATING MACHINE TOOLS AND THE LIKE

Filed April 12, 1938 5 Sheets-Sheet 1

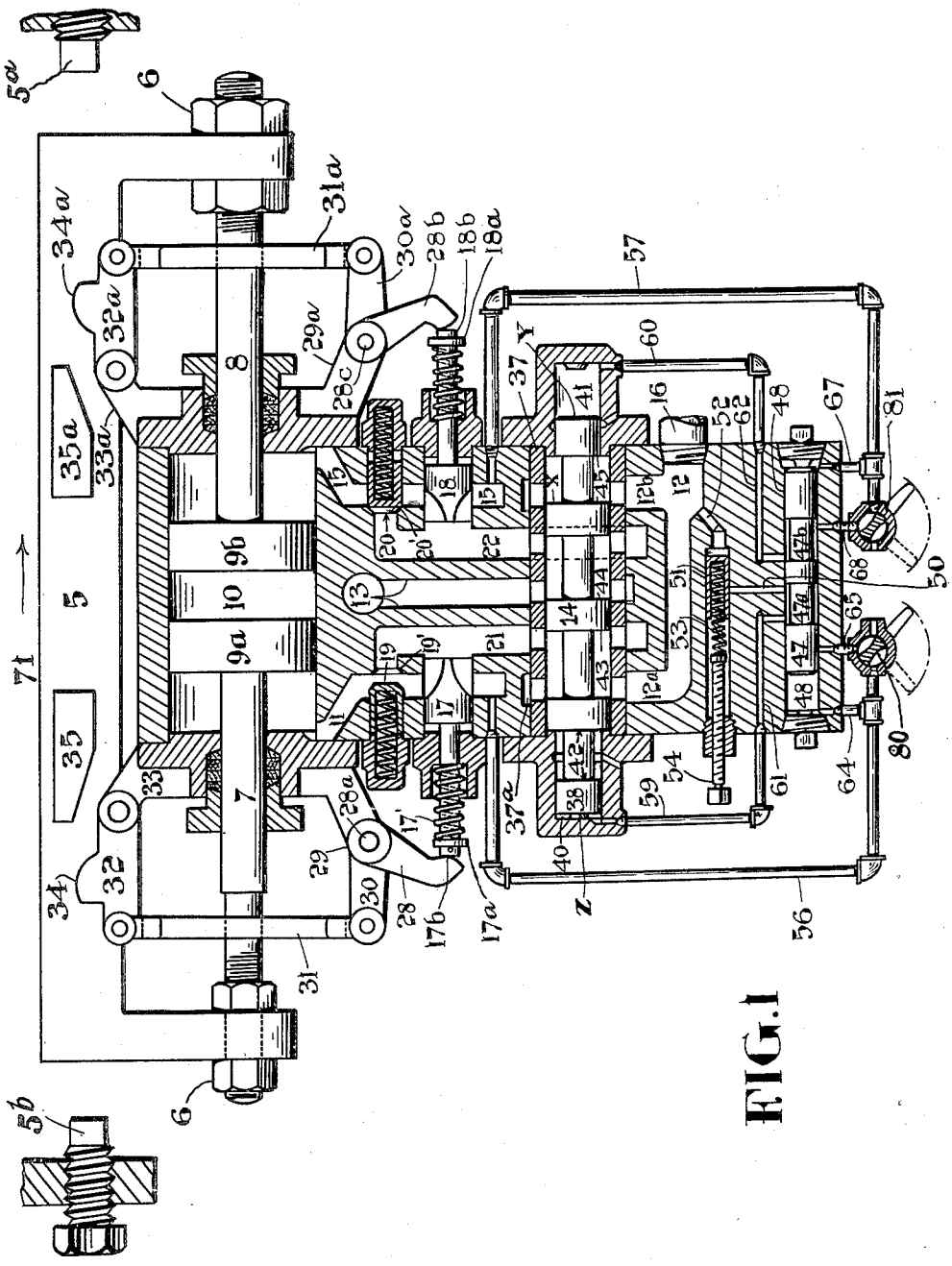

FIG. 1

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HYDRAULIC APPARATUS FOR OPERATING MACHINE TOOLS AND THE LIKE

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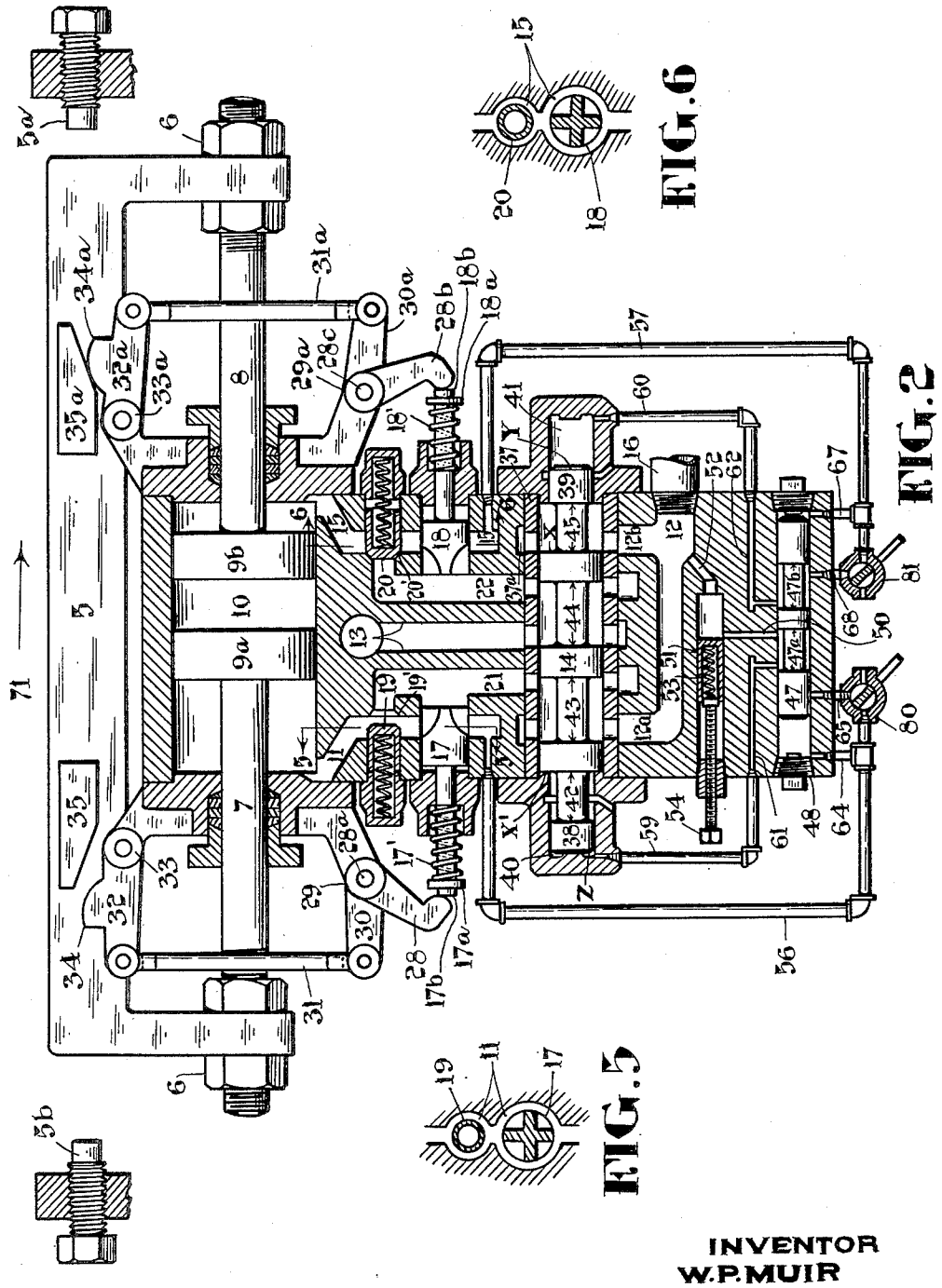

FIG. 2

FIG. 6

FIG. 5

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HYDRAULIC APPARATUS FOR OPERATING MACHINE TOOLS AND THE LIKE

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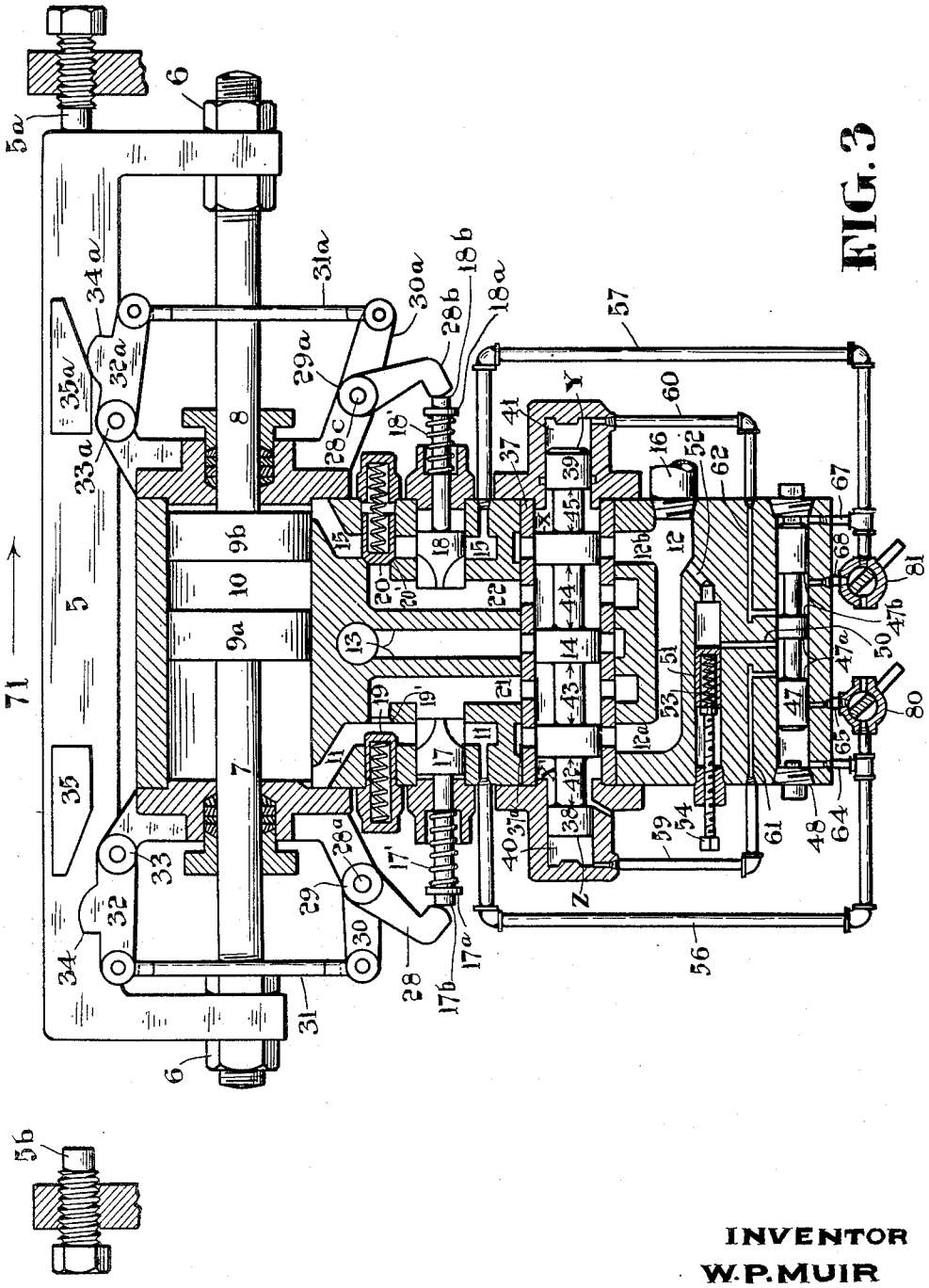

FIG. 3

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HYDRAULIC APPARATUS FOR OPERATING MACHINE TOOLS AND THE LIKE

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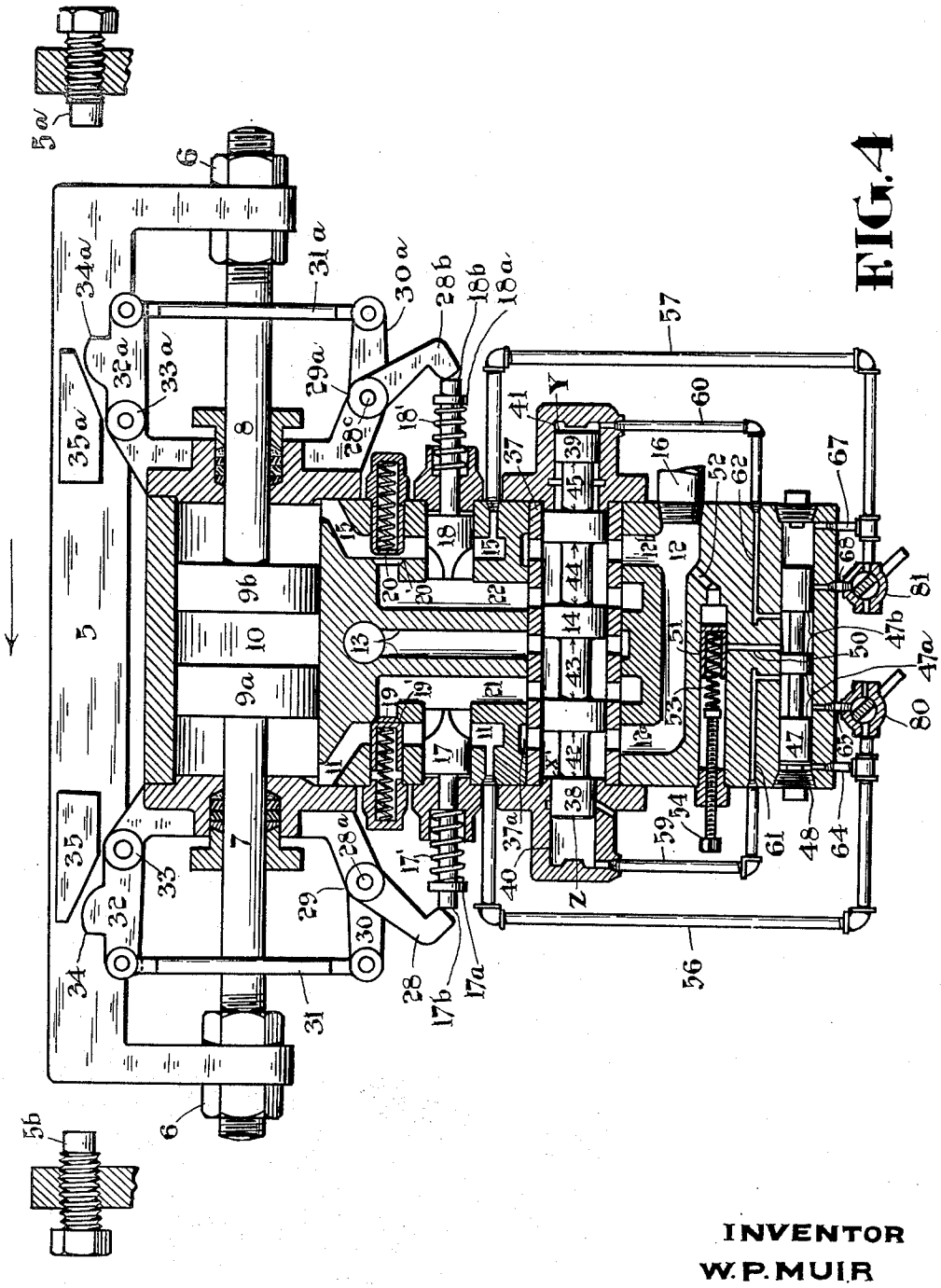

FIG. 4

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HYDRAULIC APPARATUS FOR OPERATING MACHINE TOOLS AND THE LIKE

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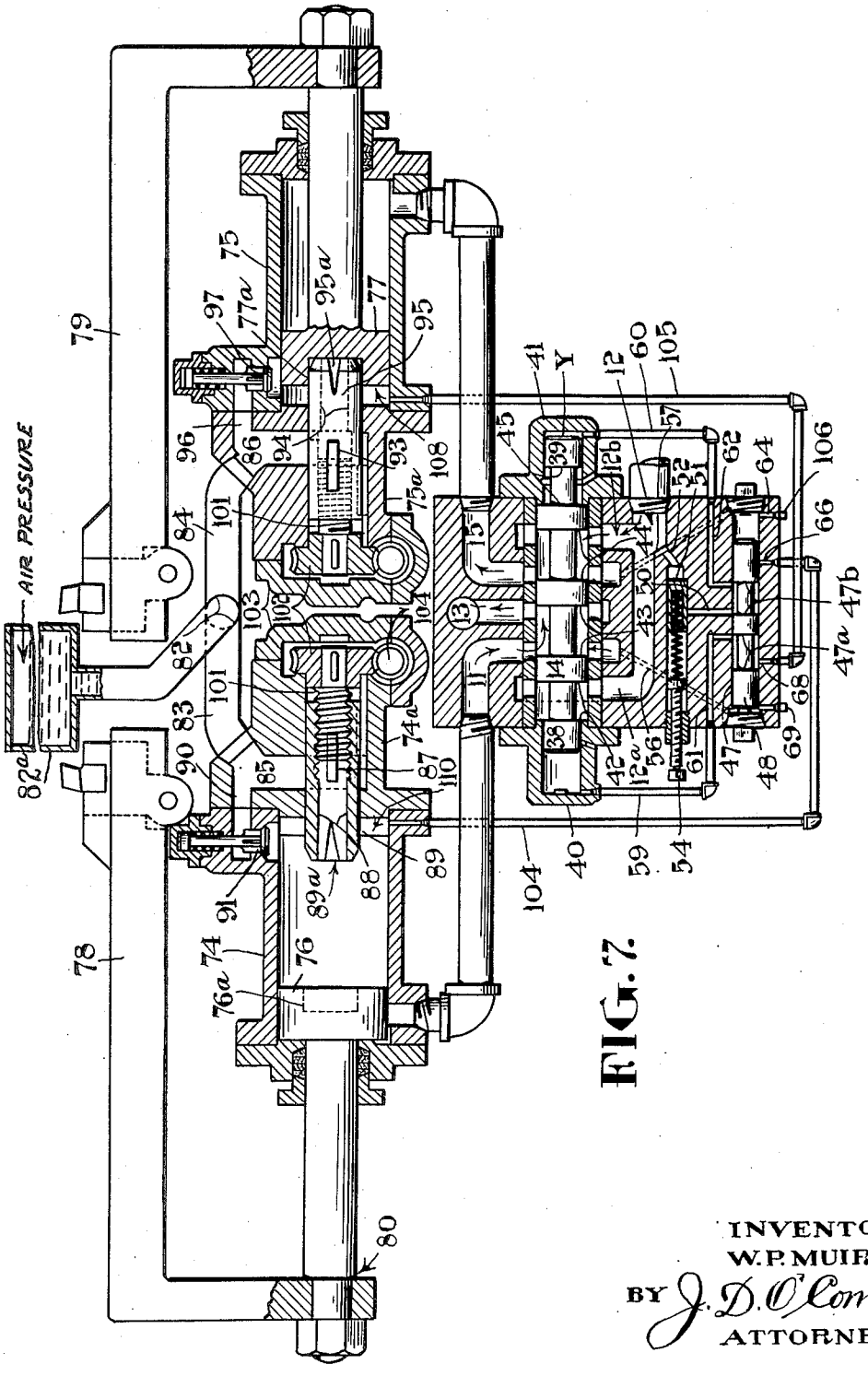

FIG. 7.

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UNITED STATES PATENT OFFICE

2,223,792

HYDRAULIC APPARATUS FOR OPERATING MACHINE TOOLS AND THE LIKE

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Application April 12, 1938, Serial No. 201,576

8 Claims. (Cl. 121—45)

This invention relates to hydraulic apparatus for operating machine tools and the like.

The said apparatus is characterized by a novel mode of operation which comprises applying pressure to move the tool in a given direction; increasing said pressure when the tool has travelled a predetermined distance, and utilizing the increased pressure to reverse the direction of travel of the tool. This method may be applied to effect either immediate or delayed reversal of the tool in response to the rise of working pressure acting thereon. In the case of immediate reversal the increased pressure is preferably utilized to open a normally closed passage leading to a reversing valve which then operates in direct response to such pressure to establish hydraulic connections resulting in reversal of the direction of travel of the tool. In the case of delayed reversal, operation of the reversing valve by the increased working pressure is prevented by an opposing hydraulic pressure until the travel of the tool is halted by a mechanical stop. When this occurs the opposing pressure is released or decreased sufficiently to permit operation of the reversing valve by the working pressure acting thereon.

Hereto the movement of tables on machine tools actuated by hydraulic means has been limited by the inability of the hydraulic system to control the movements up to a predetermined point in the travel with absolute accuracy. The control of reversal of travel of the table was by means of cams reversing the main control valve directly or through a pilot valve, and it has been found impracticable to use a definite mechanical stop for the table travel with the positive assurance that the table will contact this stop every time and not reverse its motion until it does so.

With the system described herein, definite assurance that the table will come to some positive accurate stop so that it will be possible to mill, plane or grind right up to a shoulder or radius without leaving a relief or undercut for the tool to work into and thereby eliminating the extra operation to machine this relief or undercut and the weakness to the piece entailed by the undercut.

Several samples of apparatus, illustrating different ways of effecting hydraulic operation of machine tools or tables in accordance with the novel principles of this invention, are shown and described in the present application. It will be understood, however, that the principles involved may be embodied in various other forms of apparatus for operating machine tools, tables or any other movable elements to which the invention is usefully applicable.

In the preferred embodiment of the invention, the working pressure moves the tool against an opposing hydraulic pressure which is automatically increased when the tool has travelled a predetermined distance. This increase of pressure opposing movement of the tool causes a corresponding increase of working pressure which is utilized, as previously explained, to effect either immediate or delayed reversal of the direction of movement of the tool. When the increased working pressure is to be utilized for effecting immediate operation of the reversing valve the increase of pressure opposing movement of the tool by the working pressure merely serves to cushion the movement of the tool toward the end of its stroke and to cause the necessary increase of working pressure. When reversal of the tool is to be delayed until the tool is halted by a mechanical stop the increase of pressure opposing movement of the tool is utilized to prevent operation of the reversing valve by the increased working pressure until such time as the tool actually engages the stop.

A characteristic feature common to several forms of apparatus disclosed herein is the application of hydraulic pressure to move a tool against a mechanical stop which, in addition to halting the tool after it has travelled a predetermined distance, also serves, by its resistance to further movement of the tool, to promote establishment of pressure conditions resulting in hydraulic reversal of the tool. This employment of a mechanical stop controlling both the working stroke and the reversal of the tool enables the point to which the tool is advanced at the end of the working stroke to be predetermined within sufficiently close limits to meet the demands of any operating conditions likely to arise.

As a general rule it is not necessary that the return stroke of a hydraulically actuated tool be controlled and predetermined within the same close limits as the working stroke. Consequently, apparatus provided in accordance with this invention may be designed so that the travel and reversal of the tool during a working stroke is closely regulated by a mechanical stop, as previously explained, while the reversal of the tool at the end of a return stroke is controlled solely by an increase of the pressure then acting to move the tool. In other cases, where the limits within which both the working and return strokes must be predetermined are fairly wide, the re-

versal of the tool after it has travelled a predetermined distance in either direction may be made dependent solely on an automatic increase of the pressure which is then acting on the tool. In still other cases, where extreme accuracy is required in respect to controlling both the working and return strokes of the tool, the latter may be operated against a stop at each end of its travel so that the resistance of the stop serves, as previously explained, to control both the stroke and the reversal of the tool within very close limits.

Proceeding now to a more detailed description reference will be had to the accompanying drawings in which—

Figure 1 is a view, mainly in vertical section, of one form of apparatus by which the invention may be reduced to practice.

Figures 2 to 4 inclusive are views similar to Fig. 1 but showing other positions to which the valves and other component parts are shifted during operation of the apparatus.

Figure 5 is a vertical sectional view along the line 5—5 of Fig. 2.

Figure 6 is a vertical sectional view along the line 6—6 of Fig. 2.

Figure 7 is a view similar to Fig. 1 but showing a modified form of apparatus.

In the construction shown in Figs. 1 to 6 inclusive, 5 represents a work table such as the table of a planer or milling machine. This table is rigidly secured, as indicated at 6, to the piston rods 7 and 8 of pistons 9*a* and 9*b* working in cylinder 10. The left hand end of cylinder 10 communicates with a port 11 which is alternately connected to fluid pressure supply passage 12 and exhaust passage 13 through the agency of a reversing valve 14. The right hand end of cylinder 10 communicates with a port 15 which is alternately connected to passages 12 and 13 by the valve 14. Passage 12 is connected to a pump or other source of pressure fluid by pipe 16.

Cylinder port 11 is connected, through throttle valve 17 and check valve 19, to valve port 21 leading to reversing valve 14. Cylinder port 15 is connected, through throttle valve 18 and check valve 20, to valve port 22 also leading to reversing valve 14. Check valves 19 and 20 are spring loaded to close against the valve seats 19′ and 20′. These valves open when the flow is from the valve ports 21 and 22 to the cylinder ports 11 and 15 respectively, but close when the direction of flow through the cylinder and valve ports is reversed. Throttle valves 17 and 18 are normally biased to open position by valve springs 17′ and 18′ acting, respectively, against suitable abutments 17*a* and 18*a* carried by the outer ends of the valve stems 17*b* and 18*b*. When table 5 approaches the end of its stroke in one direction, an arm 28 acts against the outer end of stem 17*b* to shift the throttle valve 17 to the right from the open position shown in Figure 1. Arm 28 is carried by a pin or shaft 28*a* rotatably mounted in a suitable bracket 29. This pin or shaft 28*a* is connected, by arm 30 and vertical link 31, to one end of a horizontal link 32 having its opposite end pivoted to a bracket 33. Link 32 is provided with a cam lug or projection 34 disposed in the path of an operating cam 35 carried by table 5. When the table 5 approaches the end of its stroke in the opposite direction the throttle valve 18 is moved inwardly or to the left by an arm 28*b* fixed to a pin or shaft 28*c* journalled in bracket 29*a*. This pin or shaft 28*c* is connected, by arm 30*a* and vertical link 31*a*, to the outer end of a horizontal link 32*a* having its opposite end pivoted to a bracket 33*a*. Link 32*a* is provided with a lug 34*a* disposed in the path of an operating cam 35*a* carried by the table.

Reversing valve 14 is slidably mounted in a suitably ported valve liner 37 arranged in passage 37*a* intersecting the main cylinder ports 21 and 22; exhaust port 13; and branches 12*a* and 12*b* of fluid pressure supply port 12. The ends of this valve are formed to provide operating pistons 38 and 39 working in cylinders 40 and 41. The body portion of valve 14 is provided with annular ports 42, 43, 44 and 45. Port 43 is the port through which main cylinder port 11 is alternately connected to exhaust port 13 or to branch 12*a* of fluid pressure supply port 12 through valves 17 and 19 and port 21. The port 44 is the one through which main cylinder port 15 is alternately connected to exhaust port 13 or to branch 12*b* of pressure supply port 12 through valves 18 and 20 and port 22.

The positioning of reversing valve 14 is controlled by a cylindrical pilot valve 47 slidably mounted in pilot valve cylinder 48. This cylinder is connected through port 50, valve 51 and port 52 to the fluid pressure supply port 12. Valve 51 is normally biased to closed position by a spring 53 and is automatically opened when fluid pressure in supply port 12 exceeds a predetermined value. The closing pressure applied through spring 53 is regulated by adjusting screw 54. The ends of pilot valve cylinder 48 are also connected to the main working cylinder ports 11 and 15 by suitable pipes 56 and 57. Reversing valve cylinders 40 and 41 are also connected to pilot valve cylinder 48 by pipes 59 and 60 and passages 61 and 62, said passages opening into cylinder 48 at points between the ends of the cylinder and the central port 50. A port 64, communicating with the extreme left hand end of cylinder 48, is connected through a valve controlled bypass to a port 65 formed in the cylinder wall below and somewhat to the left of the cylinder end of passage 61. Cylinder 48 is also provided with additional ports indicated at 67 and 68, the former communicating with the extreme right hand end of the cylinder and the latter being located below and slightly to the right of the adjacent end of passage 62. Ports 64 and 65 are connected together by a three-way valve 80 so arranged that when the valve lever is turned to the right as shown, port 64 is blocked and port 65 is open through valve 80 to atmosphere. Ports 67 and 68 are similarly connected by valve 81 except that valve 81, as shown with the valve lever turned to the right, affords direct communication between said ports 67 and 68.

In describing the operation it will be assumed that table 5 and pistons 9*a* and 9*b* are making a working stroke to the right as indicated by arrow 71. In this case port 11 of working-cylinder 10 is connected to branch 12*a* of fluid pressure supply port 12 through annular port 43 of reversing valve 14 and valves 17 and 19. The remaining working-cylinder port 15 is connected to exhaust passage 13 through annular port 44 of valve 14 and valve 18, valve 20 being closed by its spring.

Reversing valve 14 is being held in the position shown in Figure 1 partly by pump pressure acting through branch 12*b* and valve port 45 against the annulus X and partly by exhaust pressure acting against the outer face Y of piston 39. In this connection it will be noted that exhaust

pressure in cylinder port 15 is transmitted to the outer end of reversing valve cylinder 41 through pipe 57, valve 81, port 68, passage 62 and pipe 60. Since valve 51 is closed there is no pressure in cylinder 40 of reversing valve 14. Pilot valve 47 is provided with ports 47a and 47b and is held in the position shown in Fig. 1 by pump pressure admitted to the left hand end of pilot valve cylinder 48 by way of port 11, pipe 56 and port 64.

As the table 5 nears the end of its stroke in the direction indicated by the arrow 71, cam 35a acting through links 32a, 31a and arm 28b serves to partially close throttle valve 18 as shown in Fig. 2. This restricts the flow from port 15 to port 22 and causes an immediate rise in pressure in port 11 and in the left hand end of cylinder 10 by the pump. There is a corresponding rise of exhaust pressure in port 15 and the right hand end of cylinder 10. The increased pressure thus established in passage 12 is sufficient to open valve 51 (Fig. 2) so that port 50 is placed in communication with port 52. This permits the pressure in passage 12 to be transmitted through ports 52, 50, and 47a, passage 61 and pipe 59 to reversing valve cylinder 40 where it acts against the outer face Z of piston 38. There is no reversal of valve 14 at this time since the pressure acting against the face Z of piston 38 is less than the sum of the opposing pressures acting against annulus X and face Y of piston 39, due to the rise in exhaust pressure in port 15, pipe 57, valve 81, ports 68, 47b and 62 and pipe 60.

As piston 9b reaches the end of its stroke (Fig. 3) and is held against further movement by engagement of table 5 with the right hand table stop 5a, the pressure in port 15 and reversing valve cylinder 41 drops to the point where the pump pressure acting against the face Z of piston 38 overcomes the pump pressure acting on annulus X and becomes effective to shift valve 14 to the right as indicated in Fig. 3. In this connection it will be noted that the pressure receiving area Z is larger than the area X. It may be noted here that when piston 9a reaches the position shown in Fig. 3 valve 18 is fully closed so that port 15 is isolated from port 22.

When valve 14 reaches to the extreme right hand position shown in Fig. 4 pressure fluid is supplied to the right hand end of cylinder 10 through ports 12, 44, 22, 15, and valve 20 and is exhausted from the left hand end of said cylinder through ports 11, 21, 43 and 13 and valve 17. As cam 35a moves away from link 32a on the return stroke of piston 9 cushioning valve 18 resumes its open position as shown in Fig. 4.

During the aforesaid reversal of valve 14 valve 51 closes and the right hand end of pilot valve cylinder 48 is connected to port 12 through port 67, pipe 57 and ports 15, 22 and 44. The left hand end of pilot cylinder 48 is simultaneously connected to exhaust port 13 through port 64, pipe 56, port 11, valve 17, and ports 21 and 43. Pump pressure is thus established in the right hand end of cylinder 48 and acts to shift valve 47 to the left. (Fig. 4.) This disrupts the communication previously established between pilot valve cylinder ports 50 and 61 through piston port 47a and places port 50 in communication with port 62 through piston port 47b as shown more particularly in Fig. 4.

As pistons 9a and 9b near the end of their return stroke cam 35 engages lug 34 and operates link 32 to shift cushioning valve 17 to the right, thus throttling the exhaust through port 11. The resulting rise in pump pressure in port 12 opens valve 51 so that port 50 is connected to port 12 through port 52. Since pilot valve 47 is now in the position shown in Fig. 4, port 50 is also connected to port 62 through piston port 47b so that pump pressure is established in cylinder 41 and acts against the face Y of piston 39 to shift reversing valve 14 to the left. Since valve 80 cuts off port 64 and exhausts ports 65 and 61 through port 47a there is no exhaust pressure acting against piston 38 in opposition to the pump pressure acting against piston 39. Consequently, valve 14 will reverse as soon as the pump pressure in port 12 is increased by the exhaust throttling action of valve 17.

From the foregoing it will be seen that table 5 operates against mechanical stop 5a at the end of the working stroke and against a hydraulic cushion at the end of the return stroke. On the working stroke the pressure conditions necessary for operating the reversing valve are established partly by the increased pump pressure due to choking of the exhaust near the end of the working stroke and partly by the drop in exhaust pressure which occurs in part of the system as the piston is halted by the stop 5a. This arrangement enables the reversal of table 5 at the end of the working stroke to be predetermined within very fine limits. On the return stroke the reversal is timed solely by the throttling action of valve 17 which, in addition to providing a hydraulic cushion against which the table 5 operates, also causes the rise in pump pressure which acts against piston 39 to reverse valve 14. This method of effecting reversal of the table at the end of the return stroke is satisfactory where it is not necessary for the table to work to a fine clearance at both ends of its travel. It will be understood, however, that the return stroke of table 5 may be adjusted, within limits, by changing the position of the cam 35.

If it is desired to have table 5 operate against a mechanical stop at each end of its travel this may be accomplished by providing the left hand table stop 5b and reversing the position of valve 80 to provide a communicating passage between ports 64 and 65, valve 81 being left in the position shown in the drawings. In this case throttling of port 11 by valve 17 does not result in immediate reversal of valve 14 from the position shown in Fig. 4. On the contrary, exhaust pressure transmitted to the face Z of piston 38, through pipe 56, valve 80, ports 47a and 61 and pipe 59 serves, in conjunction with the pump pressure acting against annulus X' (Fig. 4) to hold valve 14 against reversal until table 5 encounters stop 5b. When this occurs the resulting drop in exhaust pressure acting against face Z permits the pump pressure acting against face Y of piston 39 to overcome the pump pressure acting against annulus X' and thus effect reversal of valve 14.

If it is desired to provide for instant reversal of the table at both ends of travel without the use of the mechanical stops 5a and 5b this may be accomplished by leaving valve 80 in the position shown in Fig. 1 and reversing valve 81 to a position blocking port 67 and venting port 68 to atmosphere. This prevents exhaust pressure being established in either of the cylinders 40 and 41. Thus any degree of accuracy in either direction may be had at the will of the operator.

Fig. 7 shows a modification in which provision is made for operating two tool slides alternately. In this case cylinder ports 11 and 15 are

respectively connected to the outer ends of cylinders 74 and 75. These cylinders contain the working pistons 76 and 77 to which the tool slides 78 and 79 are rigidly fastened as indicated at 80. The ports 11 and 15 are alternately placed in communication with pressure supply passage 12 and exhaust passage 13 through the agency of the main reversing valve 14 and pilot valve 48. In this instance the cushioning valve 17 is omitted from passage 11.

The pistons 76 and 77 are operated on their inward or working strokes by high pressure fluid pumped to the outer end of cylinders 74 and 75 through ports 12, 11 and 15. On their return stroke the pistons are operated by a relatively low, constant, push-back pressure obtained from a separate source such as an air loaded accumulator connected to the inner ends of cylinders 74 and 75. In Fig. 7 pipe 82 represents a push back pressure supply leading from the accumulator 82*a*. This pipe is provided with branches 83 and 84 communicating with pressure chambers 85 and 86 formed in the cylinder heads 74*a* and 75*a* of cylinders 74 and 75. Chamber 85 is in constant communication with cylinder 74 through the port 87 and bore 88 of a hollow stop pin 89. This pin is slidably mounted in cylinder head 74*a* so that its inner end projects into the inner end of cylinder 74. Chamber 85 and cylinder 74 are also connected by a bypass 90 provided with a check valve 91.

Chamber 86 is in constant communication with cylinder 75 through the port 93 and bore 94 of a hollow stop pin 95 slidably mounted in cylinder head 75*a* so that its inner end extends into said cylinder. Chamber 86 and cylinder 75 are also connected by a bypass 96 provided with a check valve 97.

The outer ends of pins 89 and 95 serve as piston stops which fit into the piston recesses 76*a* and 77*a* as the pistons 75 and 76 complete their working strokes, the length of which may be accurately predetermined by lengthwise adjustment of the pins 89 and 95 with reference to cylinders 74 and 75. In the present instance each stop pin is adjusted by means of an adjusting screw 101 in threaded engagement with the wall of the pin bore, said screw being keyed to a worm wheel 102 which is held against longitudinal movement in a gear casing 103 and is operated by a suitable worm 104. The outer ends of pins 89 and 95 are also provided with lateral slots 89*a* and 95*a* which serve to maintain restricted communication between the bores of the pins and the inner ends of cylinders 74 and 75 when the pistons 76 and 77 are at the ends of their working strokes. These slots are tapered so that they decrease in width toward the inner ends of the pins.

The pilot valve cylinder ports 66 and 68 are respectively connected to the inner ends of cylinders 74 and 75 by pipes 104 and 105. The remaining pilot valve cylinder ports are connected in the same way as described in connection with Fig. 1, with the exception that ports 64 and 69 are both plugged as indicated at 106.

In Fig. 7, piston 77 is shown at the end of its working stroke, the outer end of cylinder 75 being connected to the fluid pressure supply passage 12 through cylinder port 15 and reversing valve port 44. As the piston is stopped by pin 95 the pump pressure in passage 12 rises and opens valve 51 so that reversing valve cylinder 41 is placed in communication with port 12 through ports 52, 50, 47*b* and 62 and pipe 60. Pump pressure is thus established in cylinder 41 and acts against the face Y of reversing valve piston 39.

Valve 14 does not reverse at this time because the pressure in cylinder 41 is insufficient to overcome the corresponding increase of the opposing push back pressure which is transmitted from the push back annulus 108 of cylinder 75 to reversing valve cylinder 40 through pipe 105, pilot valve ports 47*a* and 61 and pipe 59. In this connection it may be explained that the escape of push back pressure from annulus 108 is through the bore of pin 95 and is choked or throttled as the inner end of this pin enters the piston recess 77*a*. When piston 95 comes to rest the extreme inner end of the pin port 95*a* is still uncovered by the piston and provides restricted communication between annulus 105 and the bore of pin 95. By virtue of this communication, the push back pressure in annulus 108 drops to normal as soon as the piston is halted by pin 95 and this drop is sufficient to permit reversal of valve 14 by the pump pressure acting against face Y of reversing valve piston 39. When valve 14 is reversed fluid pressure is exhausted from the outer end of cylinder 75 through cylinder port 15, reversing valve port 44 and exhaust passage 13. This permits the piston 77 to be operated on its return stroke by push back pressure supplied to the inner end of cylinder 75 through pin 95 and bypass 97. The purpose of the bypass 97 is to speed up the return stroke of the piston by permitting a more rapid flow of the push back pressure into the cylinder 75 than would be possible if all the push back pressure had to enter the cylinder through pin 95. The bypass 97 is not essential and may be omitted where speeding up of the return stroke is unimportant.

When valve 14 is reversed to connect cylinder port 15 to exhaust passage 13, the cylinder port 11 is connected to receive pressure fluid from port 12 through reversing valve port 43. At the same time the connections at the reversing valve ends of pilot valve passages 56 and 57 are reversed so that passage 56 is now connected to fluid pressure supply port 12 through cylinder port 11 and reversing valve port 43 while passage 57 is connected to exhaust passage 13 through cylinder port 15 and reversing valve port 44. Pump pressure is thus established in the left hand end of pilot valve cylinder 47 to shift pilot valve 48 to the right. This shifting of valve 48 disrupts communication between pipe 105 and pilot valve port 61 and establishes communication between pilot valve port 62 and the pipe 104 which is connected to the inner end of cylinder 74. The reversal of valve 48 also disrupts the communication previously established between pilot valve ports 50 and 62 and places port 50 in communication with pilot valve port 61 which is connected to reversing valve cylinder 40 as previously described.

With cylinder port 15 connected to exhaust port 13 and cylinder port 11 connected to pressure fluid supply port 12 by the described reversal of valve 14 the piston 76 will make a working stroke under pump pressure supplied through passage 11 as the piston 77 makes its return stroke under push-back pressure supplied from accumulator 82*a* through pipes 82 and 84, chamber 86, pin 95 and valve 97, such push-back pressure acting against piston 77 being increased to some extent by the discharge from cylinder 74 into the push-back pressure system. The return speed of piston 77 depends on the resistance offered by the work to the tool carried by tool slide

79. When piston 76 nears the end of its working stroke the escape of the push back pressure through pin 89 is choked as the inner end of the pin enters the piston recess 76a. The working stroke of piston 76 is thus cushioned and slowed down so that there is an immediate rise in both the pump pressure and the push back pressure in cylinder 74. The rise of pump pressure in port 12 is sufficient to open valve 51 so that port 11 is placed in communication with reversing valve cylinder 40 through ports 52, 50, 47a, 61 and pipe 59, it being remembered that pilot valve 48 is now in the opposite position to that shown in Fig. 7. The pump pressure thus established in reversing valve cylinder 40 becomes effective to shift valve 14 to the right when the opposing push back pressure in reversing valve cylinder 41 drops to normal as occurs when piston 76 is halted by pin 89. In this connection it will be noted that when pilot valve 48 is in the opposite position to that shown in Fig. 7 the push back pressure in annulus 110 of cylinder 76 is transmitted to reversing valve cylinder 41 through pipe 104, pilot valve ports 66, 47b and 62 and pipe 60. When valve 14 is reversed to resume the position shown in Fig. 7 the pilot valve 48 is also returned to the position shown in this figure by pump pressure acting through passage 57.

Having thus described my invention, what I claim is:

1. Apparatus for operating a machine tool or other translatable element by fluid pressure comprising means for applying working fluid pressure to move said element in a given direction against an opposing fluid pressure, means for increasing the opposing pressure to effect a corresponding increase of the working pressure when the element has travelled a predetermined distance, and means for reversing the direction of travel of the element in response to the increase of the working pressure.

2. Apparatus for operating a machine tool or other translatable element by fluid pressure comprising a mechanical stop, means for applying fluid working pressure to move said element toward said stop against the resistance of an opposing fluid pressure, means for automatically increasing said opposing pressure to effect a corresponding increase of the working pressure when the element has travelled a predetermined distance toward said stop, means for reversing the direction of travel of the element in response to said increase of working pressure, and means for preventing operation of said last mentioned means until the element is halted by said stop.

3. Apparatus for operating a machine tool or other element by fluid pressure comprising means for applying working pressure to move said element in a given direction against an opposing pressure, means for increasing the opposing pressure to cause a corresponding increase of the working pressure when the element has travelled a predetermined distance, means for reversing the direction of travel of the element in response to the increase of working pressure and means for utilizing said opposing pressure to prevent operation of the reversing means until the element has travelled to a predetermined point beyond the point at which the pressure increase occurs.

4. Apparatus for operating a machine tool or other translatable element by fluid pressure comprising a mechanical stop, means for applying fluid pressure to move said element into engagement with said stop against the resistance of an opposing fluid pressure, means for increasing the opposing pressure to cause a corresponding increase of the working pressure when the element has travelled a predetermined distance toward said stop, means for reversing the direction of travel of the element in response to the said increase of working pressure and means for utilizing said opposing pressure to prevent operation of the reversing means until the element is halted by engagement with said stop.

5. Apparatus for operating a machine tool or other element by fluid pressure comprising a mechanical stop, means for applying working pressure to move said element into engagement with said stop against the resistance of an opposing fluid pressure, means for increasing the opposing pressure to cause a corresponding increase of the working pressure when the element has travelled a predetermined distance toward said stop, a reversing valve arranged to operate in response to the increase of working pressure to establish connections resulting in reversal of the direction of travel of said element and means for utilizing said opposing pressure to prevent the aforesaid operation of the reversing valve until the element is halted by engagement with said stop.

6. Apparatus for operating a machine tool or other element by fluid pressure comprising means for applying working fluid pressure to move said element in a given direction against an opposing fluid pressure, means for increasing the opposing pressure to cause a corresponding increase of the working pressure when the element has travelled a predetermined distance and a reversing valve arranged to operate in response to the said increase of working pressure to establish connections resulting in reversal of the direction of travel of the tool.

7. Apparatus for operating a machine tool or other element by fluid pressure comprising means for applying working fluid pressure to move said element in a given direction, means for increasing said pressure when the element has travelled a predetermined distance, a reversing valve, means functioning in response to the said increase of working pressure for opening a normally closed passage through which said pressure is applied directly to the reversing valve to operate the latter to a position establishing connections resulting in reversal of the direction of travel of said element and means for preventing the aforesaid operation of the reversing valve in response to the opening of said passage until said element has travelled a predetermined distance beyond the point at which the pressure increase occurs.

8. Apparatus for operating a machine tool or other element by fluid pressure comprising a cylinder, a piston working in the cylinder and connected to said tool or other element, a reversing valve through which fluid working pressure is applied to one side of the piston to move the tool or other element on a working stroke against an opposing fluid pressure acting against the opposite side of the piston, a valve through which said opposing fluid pressure is discharged from the cylinder during the aforesaid movement of the piston, means for operating said valve to throttle the discharge of said opposing pressure from said cylinder when the tool has been moved a predetermined distance on its working stroke, said operation of the valve serving to increase

said opposing pressure and to thereby effect an increase in the working pressure acting on the piston, a passage through which the working fluid pressure is applied to shift the working valve to effect a return movement of the tool at the end of the working stroke and a valve normally closing said passage and arranged to be opened automatically by the working pressure when the latter is increased to a predetermined value by the aforesaid increase of the opposing fluid pressure.

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