United States Patent

[11] 3,561,542

[72] Inventors **Laurence B. Hanson**
Pine;
Arthur W. Wallace, Denver, Colo.

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[73] Assignee **Gardner-Denver Company**
Quincy, Ill.
a corporation of Delaware

[54] **CONTROL SYSTEM FOR ROCK DRILLS**
3 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **173/1,** 77/32.5; 173/5, 173/77, 173/112
[51] **Int. Cl.** **E21c 5/08,** E21c 5/16
[50] **Field of Search** ..... 173/1—11, 19; 91/37, 35; 77/32.5, 32.8

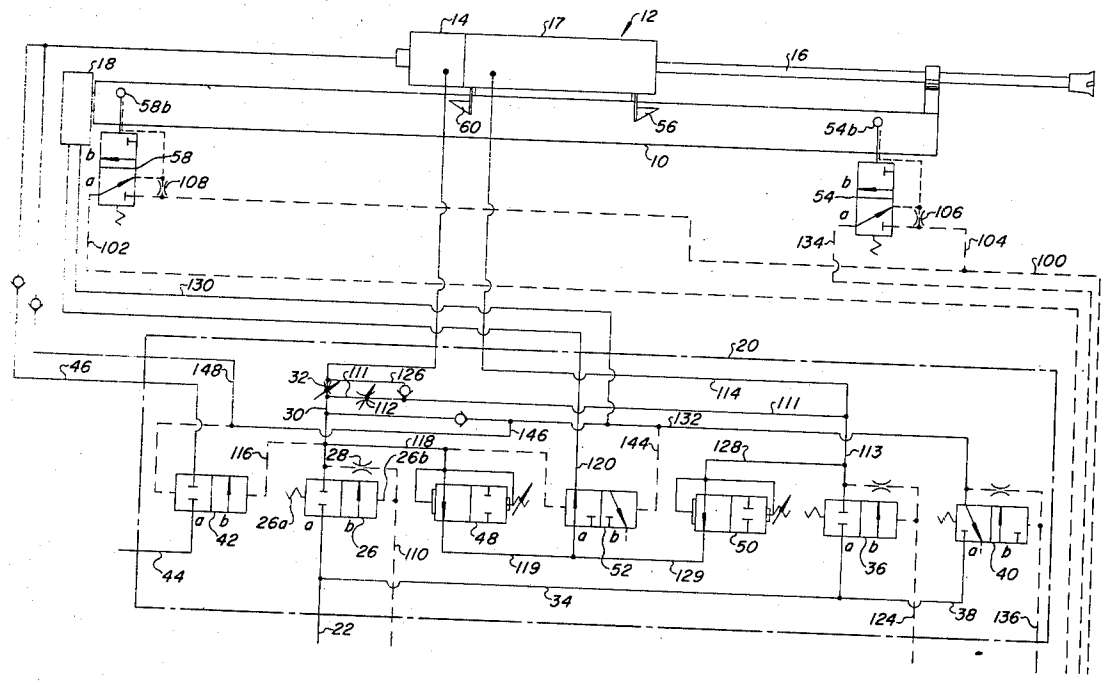
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1,787,781	1/1931	Galloway	77/32.8
3,381,761	5/1968	Hansson	173/19

Primary Examiner—Ernest R. Purser
Attorney—Michael E. Martin

ABSTRACT: An automatic control system for a guide shell-mounted rock drill including a control circuit having pneumatically operated valves for providing pressure fluid to the drill hammer, rotation motor and feed motor and for controlling drill hole flushing medium. Sensors mounted on the drill guide shell provide for reversal of the feed motor and reduced drill power upon reaching the forward end of the guide shell, and shutdown of the drill upon reaching the rearward end of the guide shell. The control circuit includes a series of control valves for selection, at will, by the drill operator of a particular operating sequence or condition of the drill. A control valve is included for providing an operating sequence which includes operation of the drill at reduced power for a predetermined period of time for collaring a drill hole. The control system also includes pressure proportioning valves for automatically regulating the feed motor pressure to be proportional to the drill percussion motor supply pressure.

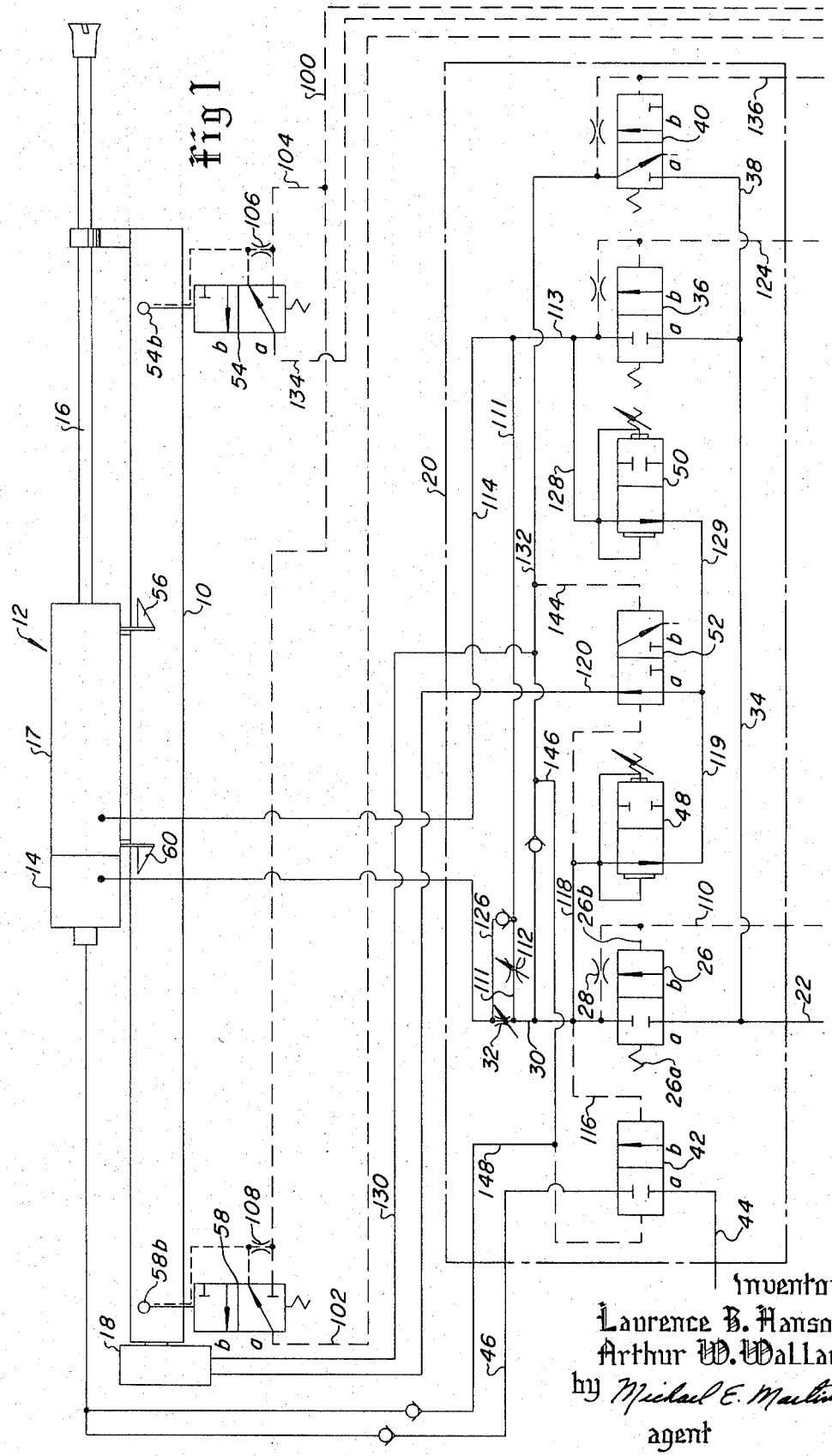


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SHEET 1 OF 3

Fig 1



Inventors

Laurence B. Hanson

Arthur W. Wallace

by Michael E. Martin

agent

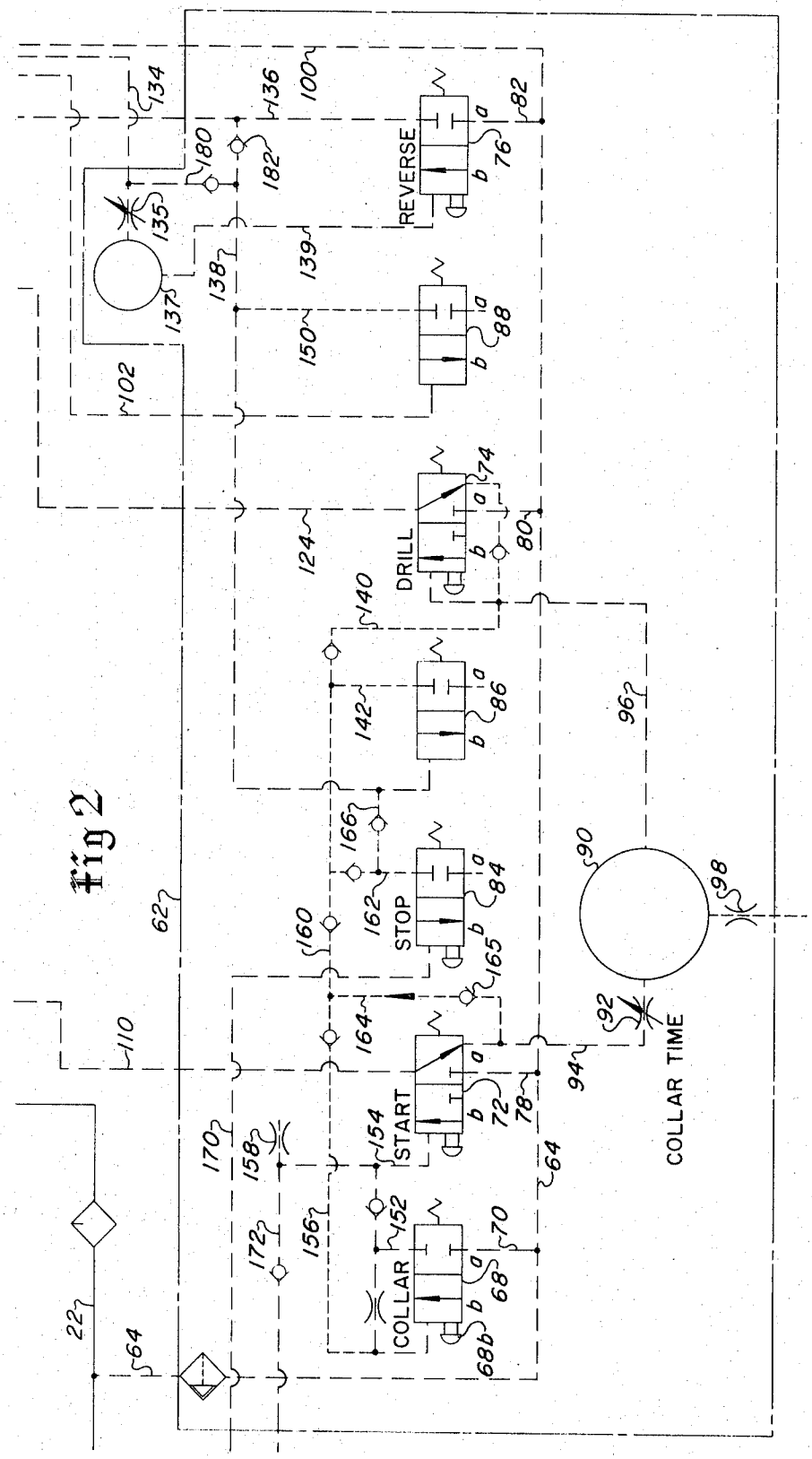

REVERSE
DRILL
STOP
START
COLLAR
COLLAR TIME
22
62
64
68
70
72
74
76
78
80
82
84
86
88
90
92
94
96
98
100
102
110
124
134
135
136
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170
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180
182

Fig 2

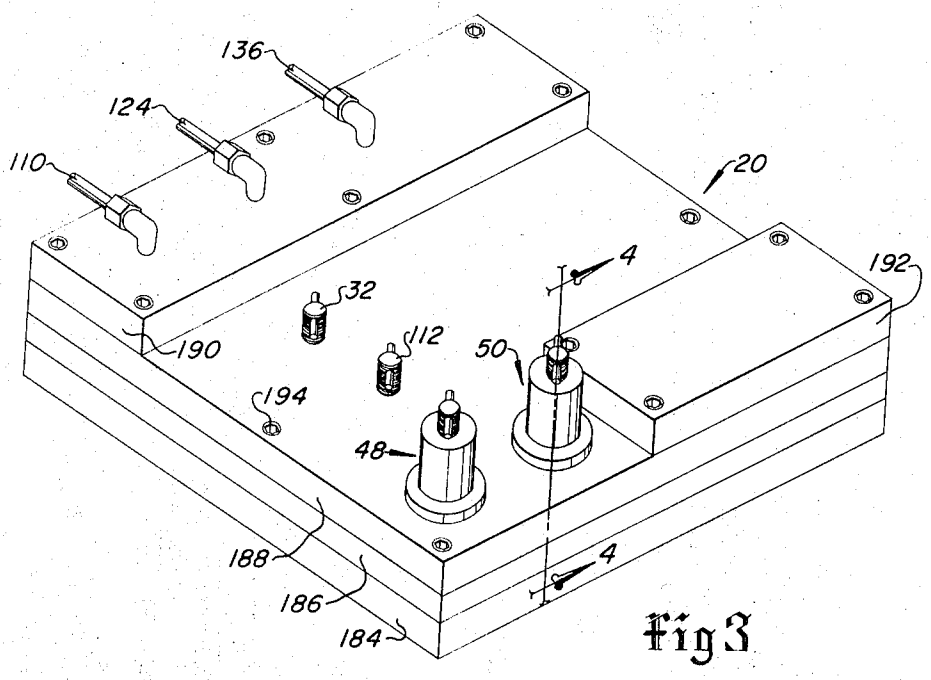


Fig 3

Fig 4

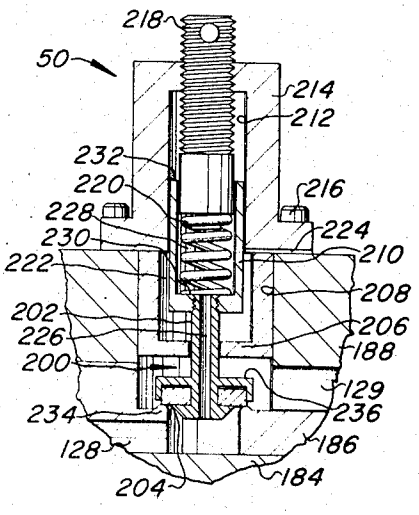
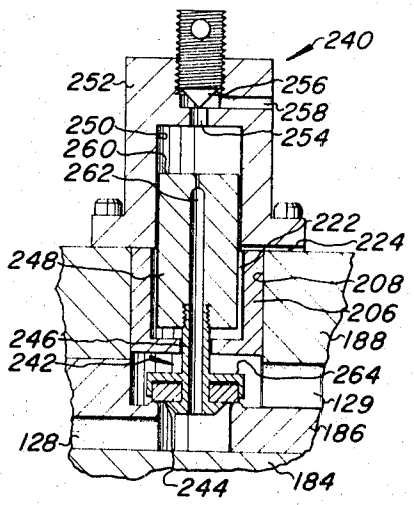


Fig 5



CONTROL SYSTEM FOR ROCK DRILLS

BACKGROUND OF THE INVENTION

In underground mining and tunnel construction it is common practice to drill blast holes with multiple rock drill units commonly known in the art as jumbos. Jumbos usually comprise a plurality of pressure fluid operated percussion rock drills slidably mounted on elongated supports known as guide shells which in turn are mounted on positionable booms. Operation of the rock drills is normally controlled from a remote operator station or control panel mounted on a vehicle or undercarriage carrying the boom and drill assemblies.

Heretofore control of plural drills has been largely a manual operation carried out by manipulation of a number of control valves located on the operator control panel to feed and retract the drills along their respective guide shells and to regulate feed pressure and drill motor impact and rotation. As the number of drills mounted on a jumbo is increased, it becomes difficult for an operator to monitor and control all drills simultaneously and accordingly drilling rates decrease and efficiency is impaired. It therefore becomes desirable to provide an automatic control system for each drill so that a greater number of drills can be monitored by one operator.

An example of an automatic control system for a guide shell-mounted rock drill is disclosed in U.S. Pat. No. 3,381,761 to C.A. Hansson. In addition to the automatic functions performed by the Hansson system it is desirable to provide for operating the drill at reduced percussion motor impact power, feed rate, and drill steel rotation rate at the beginning of the drilling cycle to collar or spot the hole.

Another problem associated with the operation of a guide shell-mounted drill is the regulation of the feed force to prevent overfeeding or underfeeding the drill during penetration of the rock face. In large mines and tunneling operations the pressure fluid supply systems from which jumbo units operate are often subject to supply pressure fluctuations which in turn make necessary the adjustment of the supply pressure to the feed motor to keep the feed rate of the drill at a proportional rate relative to the drill percussion motor power which will prevent overfeeding or underfeeding of the drill.

SUMMARY OF THE INVENTION

The present invention provides for a rock-drilling apparatus having a control system which is operable to control automatically a predetermined operating cycle of the drill. The control system of the present invention provides for an operating cycle which commences with operation of the drill percussion motor, feed motor, and drill steel rotation motor at reduced power for a predetermined period of time to collar or spot a hole. After the collaring operation is completed, the drill is automatically fed to the desired hole depth, then retracted along the support while operating at reduced power, and finally shut off upon being fully retracted along the support.

The present invention also provides for control valve means which may be actuated to provide for continuous operation at reduced power to the drill. The present invention also provides for control means operable to provide full power to the drill percussion motor at any phase of the drill operating cycle, reversing of the drill feed motor at any point in the forward feed phase of the operating cycle, and stopping all functions at any phase in the drill operating cycle.

An important aspect of the present invention is the provision of valve means for automatically maintaining a regulated pressure to a drill feed motor which is proportional to the drill percussion motor supply pressure to prevent underfeeding or overfeeding the drill due to variations in pressure of the working fluid supply system.

Another aspect of the present invention is the provision of automatic time delay means operable to delay the retraction of the drill upon completion of the drill hole until sufficient hole cleansing medium has been provided to flush the drill hole completely free of drill cuttings which could interfere with removal of the drill steel and bit, and so that a clean hole is provided for ease in placing blasting charges therein.

The apparatus of the present invention further provides for an improved method of drilling blast holes wherein a complete cycle comprising collaring, drilling, cleaning the hole, and withdrawal of the drill steel is accomplished automatically with predetermined time intervals for the collaring and hole cleaning phases.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** and FIG. **2** comprise a schematic view of the automatic control system and are intended to be read together.

FIG. **3** is a perspective view of an enclosure for the pilot operated supply valves.

FIG. **4** is a sectional view of an embodiment of a proportional pressure regulator valve for controlling pressure to a rock drill feed motor.

FIG. **5** is a sectional view of an alternate embodiment of a proportional pressure regulator valve.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The schematic representation of the automatic control system shown in FIGS. **1** and **2** is for the purpose of ease in understanding the circuitry of the system. Generally, diagrams of valve and flow control elements are in accordance with accepted standards for graphic symbols for fluid power diagramming. Exceptions have been made for nonstandard components and where standard symbols are not particularly descriptive.

Referring to FIG. **1** an elongated drill support **10** is shown having slidably mounted thereon a pressure fluid operated rock drill **12**. The rock drill **12** includes a fluid operated rotation motor **14** operable to rotate a hollow drill steel **16**. The rock drill **12** is of a well-known type which operates to deliver percussion blows to the drill steel **16** by means of a fluid actuated percussion motor **17** housed within the drill. The drill **12** is operable to use compressed air as the working fluid although the present control system with obvious modifications could be used with hydraulic-working fluid. The drill support **10** also includes a fluid operated feed motor **18** which is operable to feed the drill **12** reversibly along the support **10** by one of several well-known mechanisms, not shown.

A portion of the automatic control system of the instant invention is diagrammatically shown as being contained in an enclosure **20** which could take many forms. One practical embodiment of such an enclosure is described later herein in some detail.

The enclosure **20** has a main pressure air supply conduit **22** (see FIG. **2**) leading from a source, not shown, into a first supply valve **26** having a position *a* and a position *b*. All two position valves will be designated as having a position *a* and position *b*. As an example to define the symbols, the valve **26** has a spring actuator **26***a* to maintain the position *a* and a pilot actuator **26***b* to maintain the position *b* when energized with pressure fluid. When pressure fluid is exhausted from the pilot actuator to deenergize the valve the spring actuator returns the valve to the position *a*. Quite conceivably, the pilot actuated valves of FIG. **1** could have pilot actuators using a hydraulic or electric signal if the control circuit were so designed to operate with these mediums. Numeral **28** designates the flow restrictor and conduit which comprises an internal pilot supply for pilot actuator **26***b*. A conduit **30** leads from supply valve **26** through an adjustable flow control valve **32** to the drill rotation motor **14**. The main supply air conduit **22** has a branch **34** which supplies a second supply valve **36** comprising means to supply the drill **12** with fluid at substantially supply pressure. The valve **36** is also pilot air actuated and has an internal pilot conduit. The branch **34** is also in communication via conduit **38** with a third pilot actuated supply valve **40** having an internal pilot conduit. The valve **40** comprises means for operating the drill and feed motor in the reverse condition. Also mounted in the enclosure **20** is a two-position pilot-actuated valve **42** for controlling the supply of drill hole-flushing water to the drill via conduits **44** and **46**. Drill hole-flushing water is supplied internally through the drill **12** to the hollow drill steel **16** in a manner well-known.

The enclosure 20 further includes valves 48 and 50 which comprise proportional pressure regulator means for regulating pressure fluid to the feed motor. Valves 48 and 50 are shown schematically in FIG. 1 and structurally in FIGS. 4 and 5. A forward feed supply valve 52 which is pilot actuated to be in positions *a* or *b* is also included in the enclosure 20.

FIG. 1 also illustrates schematically a front position sensing element comprising a two-position mechanically actuated valve 54 having an actuator 54*b* engageable by the projection 56 on the drill 12. A rear position sensing valve 58 similarly has an actuator 58*b* engageable by the projection 60. The sensing valves 54 and 58 may be positioned as desired along the length of the drill support 10 and mounted thereon for actuation by the drill projections 56 and 60 to limit the forward and rearward movement of said drill by the automatic control system as explained below.

Referring to FIG. 2, the remainder of the automatic control system is schematically illustrated as comprising a plurality of control valves and associated circuitry housed within an enclosure 62 which would preferably be mounted at the drill operator control station of the rock-drilling unit, not shown. The enclosure 62 has a branch conduit 64 leading thereto which is in communication with the main air supply line 22 and leads to the several control valves to be described. The operator control enclosure 62 houses a two-position valve 68 labeled COLLAR which receives supply air at line pressure from conduit 70 connected to branch supply conduit 64. A typical manual operator or push button is depicted by the symbol 68*b*. The valve 68 may be actuated manually to the position *b* or by a supply of pilot pressure fluid. Release of operator force or pilot pressure will result in the return to the position *a*. The control enclosure 62 similarly includes two-position manual and pilot actuated valves 72, 74, and 76 labeled START DRILL and REVERSE, respectively. The valves 72, 74 and 76 are respectively connected to the branch supply conduit 64 by conduits 78, 80 and 82. A manual and pilot actuated valve 84 labeled STOP is also within the enclosure 62 for actuation by the operator. The enclosure 62 further includes a pilot-actuated exhaust valve 86 and a similar exhaust valve 88.

An important aspect of the present invention includes a variable timing means which is provided for by the reservoir 90 and the adjustable timing valve 92 labeled COLLAR TIME. The reservoir 90 is in communication with the start valve 72 via the conduit 94, and with the pilot actuator of the drill control valve 74 by way of the conduit 96. The reservoir 90 also includes an orificed exhaust line 98. The conduit 164, in communication with conduit 94, includes a typical check valve 165. Flow is one way only as indicated by the arrow in conduit 164.

The circuitry can be easily traced and the control system can be best understood by an explanation of the improved operating cycles which the drill can be controlled to perform. From the accompanying drawings it will be evident how the circuitry is interconnected to the various components. Referring to FIGS. 1 and 2 a normal drilling cycle begins with the drill 12 retracted over the rear position sensing valve 58 so that the valve is actuated to be in the position *b*. All valves labeled for positions *a* and *b* will be in position *a* except as noted. Water control valve 42 is assisted to the position *a* by water pressure in line 44 due to internal construction of the valve.

With pressure air supplied to conduit 22 and its branch conduit 64, air will flow through conduit 100 to the rear sensing valve 58 and through conduit 102 to the pilot actuator of exhaust valve 88 to hold the same in position *b*. Conduit 104 leading from conduit 100 to the front position sensor 54 will be bleeding through orificed conduit 106 to continually air wash the actuator 54*b* to prevent debris from collecting thereon. Air washing of the rear sensing valve actuator 58*b* occurs similarly through orificed conduit 108. To commence a complete drill operating cycle the operator will momentarily manually actuate the START valve 72 shifting the same to position *b* which permits pilot air to flow from conduit 78 through conduit 110 to shift the first or collaring supply valve 26 to position *b* (FIG. 1). Valve 26 then supplies air through its internal pilot 28 to maintain position *b* and pressure air flows through conduit 30 to operate the drill rotation motor at reduced speed as controlled by the adjustable valve 32. Pressure air will also flow through conduit 111 through an adjustable flow control valve 112 to conduit 114 and to the drill 12 for operation of the percussion motor 17 at reduced power. Valve 26 also supplies pilot air through conduit 116 to hold the drill hole-flushing water valve 42 open in position *b* to provide water to the drill hole, and through conduit 118 to hold the forward feed valve 52 in position *a*. Supply air from conduit 118 also flows through the proportional pressure regulator 48 and conduit 119 to supply fluid at proportionately reduced pressure through the forward feed valve 52 and conduit 120 to the feed motor 18. Referring to FIG. 1 it appears that air can flow through conduit 111 and conduit 113 to operate the internal pilot of the second or drilling supply valve 36 to shift same to position *b* and provide full power to the drill. However, the pilot actuator of valve 36 is set to operate at line pressure only and therefore will not actuate at the reduced pressure set by the adjustable valve 112. The drill 12 thus commences to operate at reduced forward force feeding for collaring the hole. Such operation is particularly desired to prevent deflection of the drill steel when the steel and bit are inclined to the surface of the rock face. As the projection 60 moves off the actuator 58*b* of the rear sensing valve 58, said valve returns to position *a* and exhaust valve 88 returns to position *a*.

As previously mentioned the operator need only actuate the START valve 72 momentarily whereupon release of the manual actuator the start valve returns to position *a*.

The collaring supply valve 26, having shifted to position *b*, now also supplies air at line pressure from its internal pilot conduit 28, through conduit 110, valve 72 and conduit 94 to the reservoir 90 at a rate controlled primarily by the timing valve 92. The setting of valve 92 will regulate the amount of time required for pressure to increase in the reservoir sufficiently to cause the drill control valve 74 to shift to position *b*. The reservoir 90 may take many forms including being embodied in conduit 96 depending on the volume thereof. When the control valve 74 has shifted to position *b* air at line supply pressure will flow through conduit 80 and conduit 124 to actuate the drilling supply valve 36 to position *b* to supply air at substantially line supply pressure to the drill percussion motor 17 through conduits 113 and 114. Air at line supply pressure will also flow through conduit 111 and bypass conduit 126 to conduit 30 to operate the drill rotation motor 14 at full power. Conduit 113 will also supply air through conduit 128 and the proportional pressure regulator 50 which in turn will provide a regulated supply of pressure air through conduit 129, the forward feed valve 52, and conduit 120 to the feed motor 18. The feed motor will be exhausting through conduits 130 and 132 and the third or reverse supply valve 40 which is in position *a*.

The drill 12 will proceed to operate at full power and will feed forward along the support 10 until the projection 56 strikes actuator 54*b* causing the front position sensing valve 54 to shift to position *b* which in turn will provide pressure air to flow through conduit 134. Conduit 134 is in communication with an adjustable flow control valve 135 and a reservoir 137 located in the control enclosure 62. A conduit 139 leads from the reservoir 137 to the pilot actuator of the REVERSE control valve 76. The flow control valve 135 and the reservoir 137 comprise a variable time delay means to delay the shifting of the control valve 76 to position *b* for reasons to be explained below. The REVERSE control valve 76, when shifted to position *b* by pilot pressure fluid from conduits 134 and 139, will cause pressure air to flow through conduits 82 and 136 to the pilot actuator of reverse supply valve 40 shifting same to position *b*. The REVERSE control valve 76 will also cause a pressure signal in conduit 138 to shift the exhaust valve 86 to position *b* exhausting air from the pilot actuator of the DRILL control valve 74 by way of conduits 140 and 142 causing valve

74 to shift to position *a* which will cause a shift of the drilling supply valve **36** to position *a* interrupting the full power supply to the drill percussion motor, rotation motor and proportional regulator **50**. Collar supply valve **26** will also actuate to position *a* having exhausted its pilot actuator through conduit **110**, START valve **72** in position *a*, conduit **165**, **160**, and **142** to the exhaust valve **86**. The reverse supply valve **40** will also now supply pressure air through conduit **132** to conduit **144** shifting the forward feed supply valve **52** to position *b* exhausting conduit **120**. Pressure air will also now flow through conduit **130** at full supply pressure to the feed motor **18** running the same in reverse to retract the drill along the support. Pressure air is further now being supplied to conduit **146** and **148** simultaneously shifting the flushing water valve **42** to position *a* shutting off the flow of water and changing the flushing medium to air for drying the hole as the drill steel is withdrawn. Hole cleaning air is not required to be controlled by valve **42** with the system of the present invention. The drill **12** is now also being supplied with a reduced supply of air through conduit **132** to adjustable valves **32** and **112** to operate the rotation motor **14** and drill percussion motor **17** at reduced power to facilitate withdrawal of the drill steel from the hole. After the drill projection **56** moves off the front position sensing actuator **54***b* the valve **54** returns to position *a* causing the pilot actuator of the REVERSE control valve **76** to exhaust through conduit **134** and a shift of said valve to position *a*. The reverse supply valve **40** remains in position *b* due to its own internal pilot supply.

The drill **12** continues to retract along the support **10** until the projection **60** strikes the rear position sensing actuator **58***b* causing the valve **58** to shift to position *b* which in turn will send a pressure signal through conduit **102** to the pilot actuator of the exhaust valve **88** shifting the same to position *b*. The reverse supply valve **40** will now shift to position *a* having exhausted its pilot actuator through conduits **136**, **138**, and **150** and the exhaust valve **88**. All supply air to the drill and feed motor is now interrupted and the drill is shut down. The exhaust valve **86** will also return to position *a* having exhausted its pilot actuator through conduits **138**. The drill thus have operated through a completely automatic cycle of operation with regulated pressure on the feed motor **18** automatically compensating for variations in supply line pressure during the collaring and drilling phase of the cycle.

Various other operational modes are selectable, at will, by the operator with the control system of the present invention. For example, if it is desired to prolong operation of the drill at collaring power, that is prior to the drill engaging the front position sensing valve **54**, manual actuation of the COLLAR control valve **68** to move to position *b* will operate the pilot actuator of the START valve **72** by supplying pressure air through conduits **70**, **152**, and **154** to move the START valve to position *b*. The collaring supply valve **26** will then be actuated as previously described and the drill will operate at collaring power. Upon actuation of the exhaust valve **86** to position *b*, caused by the drill actuating the front position sensing valve **54**, the collar control valve pilot actuator would be exhausted through conduits **156**, **160**, **142** and the valve **86** and the START valve **72** would return to position *a* after bleeding its pilot actuator through conduit **154** and orifice **158**. During any operating mode of the control system, full power to the drill percussion motor and rotation motor may be applied by manual actuation of the drill control valve **74** to position *b* which will supply line pressure air to the pilot actuator of the drill supply valve **36** as previously described.

If the drill is in the reverse feed mode, however, the DRILL control valve **74** must be manually held in position *b* to operate the percussion motor and rotation motor at full power, otherwise the drill supply valve pilot actuator would exhaust through the DRILL control valve, in position *a*, and conduits **140** and **142** and the exhaust valve **86** which, during reverse feed of the drill, is in position *b*.

The control system may also be operated to commence the reverse feed mode at any point in the forward collaring or drilling mode by manual actuation of the REVERSE control valve **76** to position *b*. Such actuation would cause a pressure signal to be sent to the reverse supply valve **40** and via conduit **138** to exhaust valve **86** shifting both valves to position *b* and resulting in operation previously described. With the control system of the present invention only one control valve is required for reversing the feed motor which thereby eliminates the need for a so-called five-port four-way valve as found in certain prior art systems.

Also, at any operating condition of the control system all pressure air to the drill and feed motor may be interrupted by manual actuation of the STOP control valve **84** to position *b* which will cause the COLLAR control valve **68** to exhaust its pilot actuator through conduits **156**, **160** and **162**. The START valve **72** will exhaust through conduits **164**, **160** and **162** and the DRILL control valve **74** will exhaust its pilot actuator through conduits **140** and **162**. The valves **68**, **72**, and **74** will thus return to position *a*. The collar supply valve **26** and drill supply valve **36** will, with their respective control valves **72** and **74** in position *a*, exhaust their pilot actuators through STOP valve **84** and return to position *a*. Reverse supply valve **40** will also exhaust its pilot actuator through conduits **136**, **138**, **166** and **162**, and through the STOP valve to return to position *a*. Therefore, regardless of the operating mode, actuation of the STOP valve to position *b* will result in the interruption of the flow of pressure fluid to the drill, rotation motor, and feed motor. As shown in FIG. **2** the STOP valve may be operated from a remote pilot pressure air supply through conduit **170** as may the START valve **72** by way of a pilot supply through conduit **172**.

As previously mentioned, the adjustable valve **135** and reservoir **137** operate as a variable time delay means to delay the pressure signal necessary to shift the REVERSE control valve **76** to position *b* when the drill projection **56** has actuated the position sensing valve **54** to position *b*. This delay in operation of the REVERSE control valve and, consequently, the reverse supply valve **40** permits thorough flushing of the drill hole to assure the removal of all drill cuttings while the drill steel is still at the bottom of the hole. As pressure fluid flows through conduit **134** into the reservoir **137** the pressure would eventually increase to a predetermined value required to operate the pilot actuator of the REVERSE control valve **76** to shift said valve to position *b* and the drill would be operated to retract along the support as hereinbefore described. A conduit **180** is connected to conduits **134** and **138** so that pilot pressure fluid is supplied to the actuator of exhaust valve **86** to effect the closure of the drilling supply valve **36** without delay when the front sensing valve **54** is actuated to position *b*. A check valve **182** prevents pressure fluid from flowing into conduit **136**.

A preferred construction of the enclosures **20** and **62** is illustrated in FIG. **3**. The enclosure **20** is shown as consisting of a series of flat plate elements **184**, **186**, **188**, **190** and **192** assembled and fastened together by fasteners **194**. All of the hereinbefore described conduits within the enclosure **20**, as shown on the schematic of FIG. **1**, would be drilled or machined into the matching surfaces of the plates. All valve elements would also be housed within the enclosure formed by the assemblage of plates. This construction provides for a compact arrangement of valves and conduits and also eliminates a large number of tube and pipe fittings. The operator adjustment handles for valves **32** and **112** are shown protruding from plate **188** and the connections of pilot actuator conduits **110**, **124**, and **136** are shown. The remaining eight connections required as shown by the schematic of FIG. **1** would be made on the bottom of plate **184**, not shown.

The section view of FIG. **4** illustrates an embodiment of the proportional pressure regulator valve **50** previously described and illustrated schematically in FIG. **1**. The valve **48** of FIG. **1** is of similar construction. Referring to FIG. **4**, the valve **50** comprises a movable closure member **200** having a stem portion **202** and a resilient seating member having an area forming a pressure surface **204**. The closure member **200** is inter-

posed between conduits 128 and 129 formed by plates 184, 186, and 188. The upper end of stem 202 projects through the end wall of a spacer 206 pressed into the bore 208 in plate 188 and is threadedly secured to a hollow piston 210. The piston 210, forming a part of member 200, extends into the bore 212 of a cap 214 which is secured to plate 188 by fasteners 216. An adjusting screw 218 is operative to vary the compression of a coil spring 220 which is operable to bias the closure member 200 in the closed position. The space 222 within the spacer 206 is vented to atmosphere through passage 224. A passage 226 in the stem of closure member 200 communicates pressure fluid from conduit 128 to the interior space 228 of the hollow piston 210 and to the bore 212 of the cap 214. The piston 210 is slidably housed in the bore 212 in close fitting relationship thereto and leakage of pressure fluid into space 222 is desirably kept to a minimum. The piston 210 includes an area 230 and an annular area 232 forming a second pressure surface operable to oppose the pressure acting on the surface 204 bounded by the seat 234. An annular area 236 formed on the closure member 200 comprises a third pressure surface and is operable to bias the closure member to the closed position under the action of pressure fluid at the reduced pressure in conduit 129 acting thereon.

As previously mentioned it is desirable to maintain the feed motor pressure at a proportional value to the supply pressure to the drill percussion motor to prevent underfeeding or overfeeding the drill when fluctuations in supply pressure occur. In prior art drills it is often a problem which requires the constant attention of the drill operator to adjust a manual valve to maintain the proper proportion. However, with the use of the proportional pressure regulator 50 in the feed control system of FIGS. 1 and 2 feed motor pressure is automatically maintained at the desired proportional value. The valve 50 or its equivalent may, of course, be used with other rock drill control systems.

A single proportional pressure regulator valve of the type disclosed could be used in the control system shown in FIG. 1. However, a system of the type disclosed, having provisions for operating the drill at reduced pressure for collaring the hole, desirably has a separate pressure regulator due to the fact that the proportionality or percentage value of feed motor pressure to supply pressure for collaring a hole is usually less than the value desired for operation at full drilling power. The provision of two regulator valves is therefore desirable in a completely automatic system to eliminate the need for adjustment of a single valve after the collaring phase of operation.

In operation of the valve 50, pressure fluid at supply pressure introduced into conduit 128 would act on surface 204 to open the valve closure member 200 permitting flow past the valve seat 234 to be throttled to a reduced pressure into conduit 129. Pressure fluid at supply pressure would also flow through passage 226 into space 228 and between the adjusting screw 218 and the inner wall of piston 210 into the bore 212 to act on the annular area 232. Fluid at supply pressure acting on areas 230 and 232 and fluid at the reduced pressure in conduit 129 acting on area 236 will operate to close the closure member 200. By an algebraic summation of pressure forces acting on the valve closure member 200 it may be seen that the areas 230, 232, and 236 may be proportioned such that the closure member will move to throttle flow across the orifice formed by the closure member and the seat 234 until a balanced position is reached. Accordingly, the pressure in conduit 129 may be regulated to a fixed percentage of the supply pressure in conduit 128 regardless of what value the supply pressure may be. For example, if the sum of areas 230 and 232 is 70 percent of area 204 and the area 236 is 90 percent of area 204 by setting the pressure forces on area 204 equal to the pressure forces acting on the reduced areas 230, 232, and 236 it may be realized that pressure will be regulated to be 33 percent of supply pressure. The areas 230, 232 and 236, of course, may be altered in proportion to alter the reduced pressure. The spring 220 is used to provide a light biasing force to overcome friction of the close fitted piston 210 to close the valve. The biasing force of the spring 228 may be increased by the adjusting screw to reduce the value of the reduced the value of the reduced pressure, however, increasing the biasing force of the spring 220 will also change the proportionality from a fixed percentage to a variable percentage. However, within the range of supply pressures normally encountered the variation in the reduced pressure will not adversely affect drill performance.

An alternate embodiment of a proportional pressure regulator valve is illustrated in FIG. 5. The proportional pressure regulator valve 240 includes a closure member 242 having a resilient seating member forming pressure surface 244 and a stem portion 246 threadedly attached to a piston 248 slidably housed in the bore 250 of cap 252. A passage 254 leads from the bore 250 past an adjustable needle valve 256 to a passage 258 opening to the exterior of cap 252. The piston 248 includes an area 260 forming a second pressure surface, and an orificed passage 262 opening into the bore 250 from the conduit 128. The principle of operation of the valve 240 is similar to the valve 50, that is, a force caused by pressure fluid acting on area 244 of the closure member is opposed by pressure fluid acting on the piston area 260 and pressure fluid in conduit 129 acting on the annular area 264 forming a third pressure surface on the closure member 242. In operation, if the needle valve 256 is closed the pressure in the bore 250 will be equal to supply pressure, and the reduced pressure in conduit 129 will be a fixed percentage of the supply pressure in conduit 128 as determined by the proportioning of areas 260 and 264. If the needle valve 256 is opened to bleed pressure fluid from the bore 250 the pressure therein will be reduced and the proportionality of the reduced pressure in conduit 129 to the supply pressure in conduit 128 will be changed and will no longer be a fixed percentage, but as with the proportional regulator valve 50 in the range of pressures normally encountered the proper feed pressure can still be obtained. Moreover, some adjustment of the proportionality must be provided for so that the drill operator can change the feed pressure for a given supply pressure to compensate for variations in the drillability of different rock formations.

However, it should be noted that the biasing means of the respective regulator valves 50 and 240, that is, the spring 220 and the adjustment screw 218, and the pressure chamber and needle valves 256 operate in a somewhat different manner. The maximum value of reduced pressure that can be obtained with the valve 50 occurs when no biasing force is applied by the spring 220, and an increase in the bias force acting to close the member 200 will reduce the value of the regulated pressure which the valve 50 will operate to produce in conduit 129. In the valve 240 the minimum value of reduced pressure is obtained when the needle valve 256 is closed and the pressure acting on the surface 260 is equal to the supply pressure in conduit 128. By opening the needle valve to reduce the pressure in the chamber formed by the bore 250 the valve closure member 242 will operate to balance at a higher value of reduced pressure in conduit 129.

We claim:

1. An improved operating cycle for a rock drill to drill a hole in rock or the like comprising:

providing a rock-drilling apparatus including a pressure fluid operated rock drill movably mounted on a support and operable to actuate a hollow drill steel, and a pressure fluid operated feed motor operable to feed said drill reversibly along said support, the operating cycle comprising;

supplying pressure fluid to said drill and said feed motor at reduced pressure for a predetermined period of time for collaring said hole;

automatically supplying pressure fluid to said drill at substantially supply pressure at the expiration of said collaring time period and simultaneously supplying pressure fluid to said feed motor to feed said drill forwardly for drilling a hole to a predetermined depth;

supplying flushing liquid to said hollow drill steel during collaring and drilling of said hole;

automatically supplying pressure fluid to said feed motor to retract said drill along said support upon completion of the drilling of said hole and simultaneously supplying pressure fluid to said hollow drill steel, and upon retraction of said drill a predetermined distance along said support interrupting the supply of pressure fluid to said feed motor.

2. The operating cycle set forth in claim 1 together with the step comprising: automatically delaying, for a predetermined time period, the supplying of pressure fluid to said feed motor to retract said drill upon completion of the drilling of said hole, and continuing the supply of flushing liquid to said drill steel during said predetermined time delay.

3. The operating cycle set forth in claim 1 wherein: the supply of pressure fluid to said feed motor during drilling of said hole is automatically maintained proportional to the pressure of said fluid supplied to said drill.