Nov. 4, 1958 J. C. HESSON ET AL 2,858,764

MEANS FOR EFFECTING SEQUENTIAL DISCHARGE OF A SERIES OF MATERIAL BREAKING CARTRIDGES

Filed Oct. 18, 1956 5 Sheets-Sheet 1

Fig. 1.

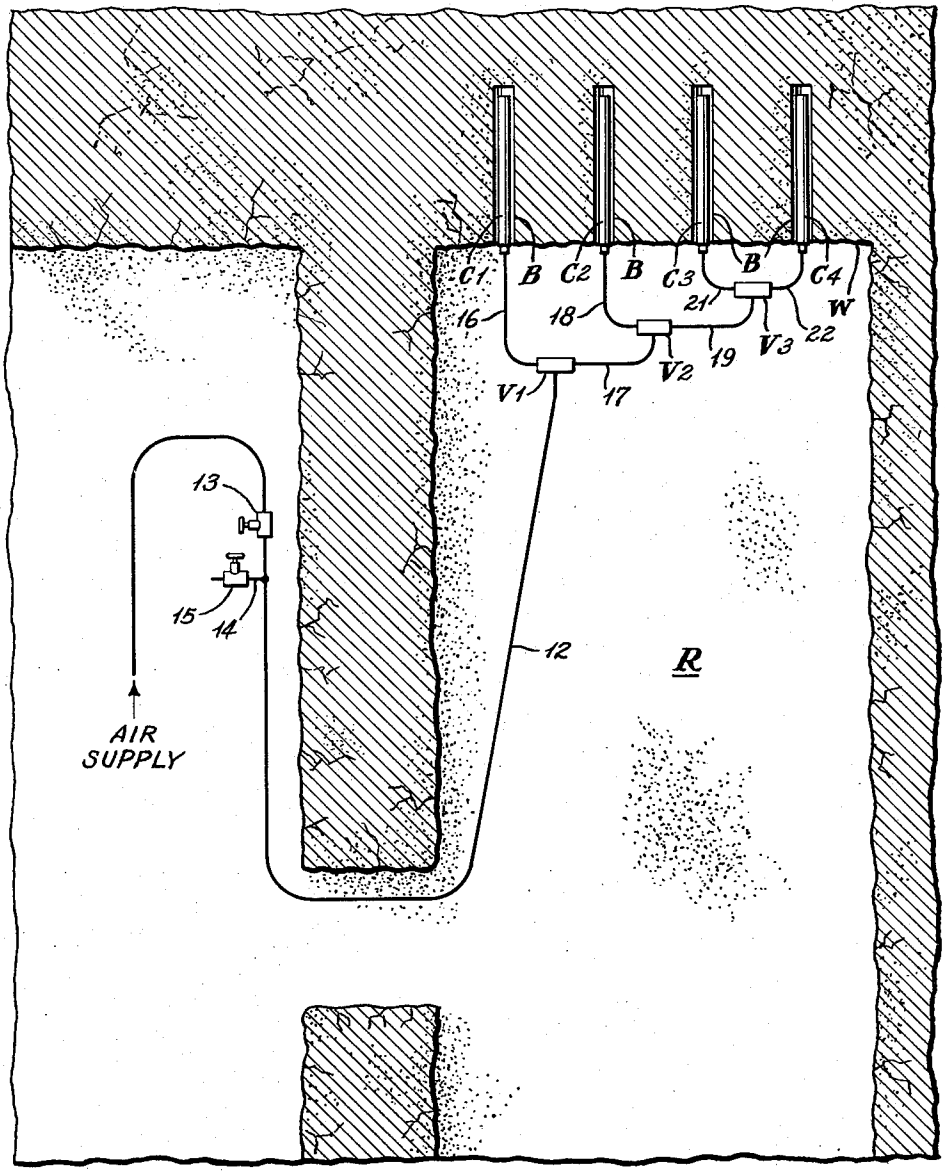

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Fig. 2.

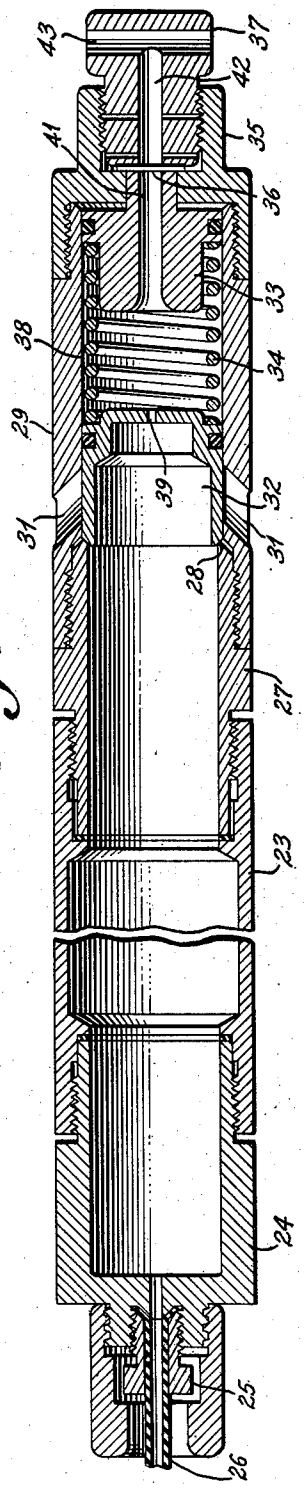

Fig. 3.

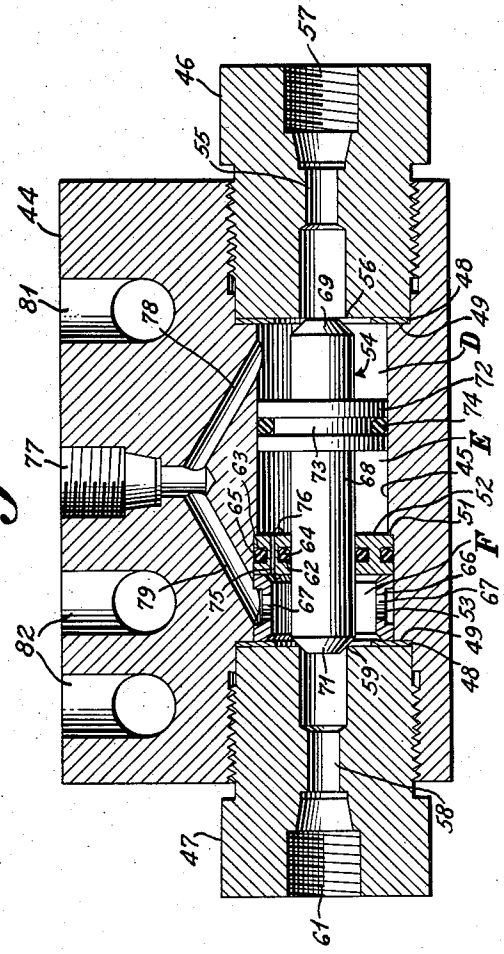

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Fig. 4.

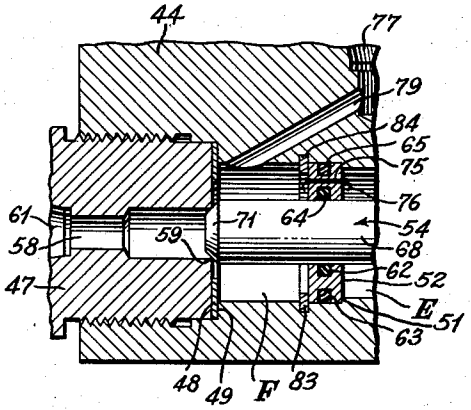

Fig. 5.

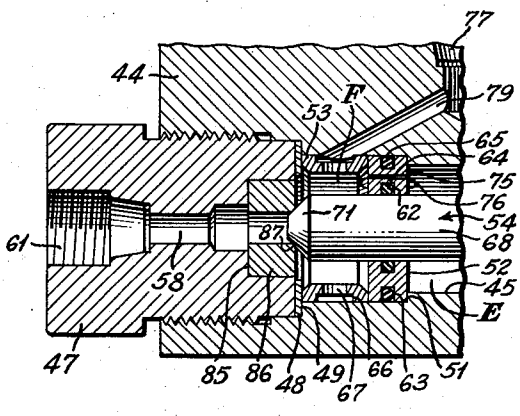

Fig. 6.

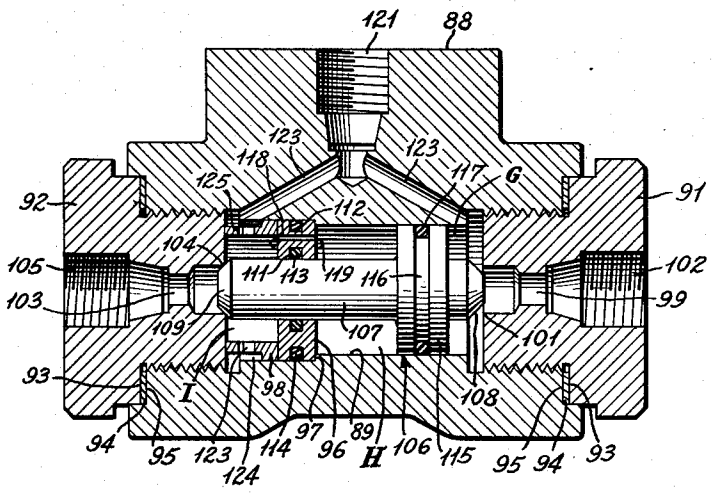

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Fig. 7.

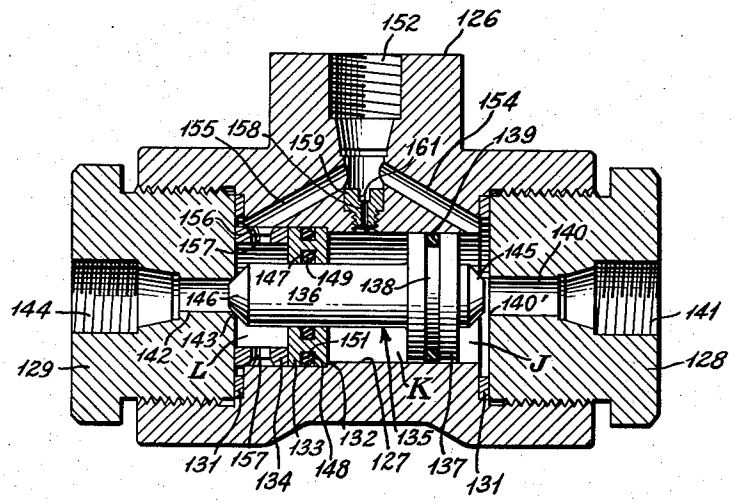

Fig. 8.

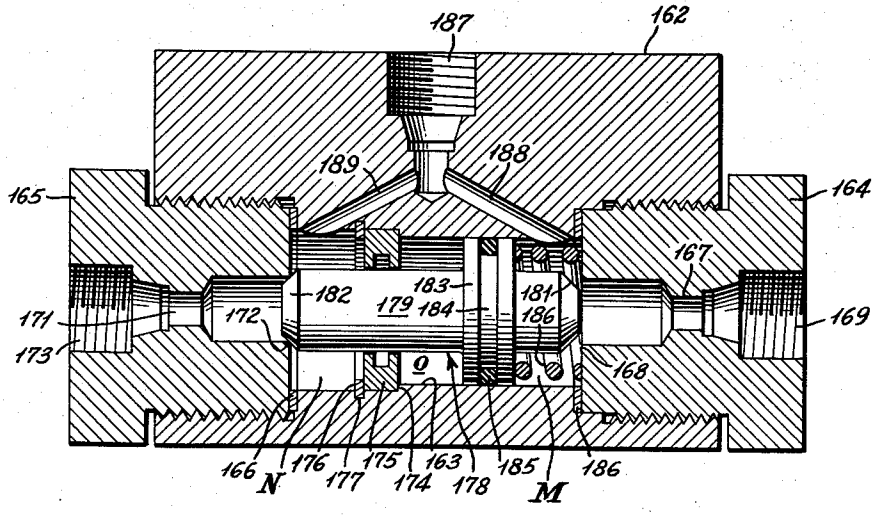

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Fig. 9.

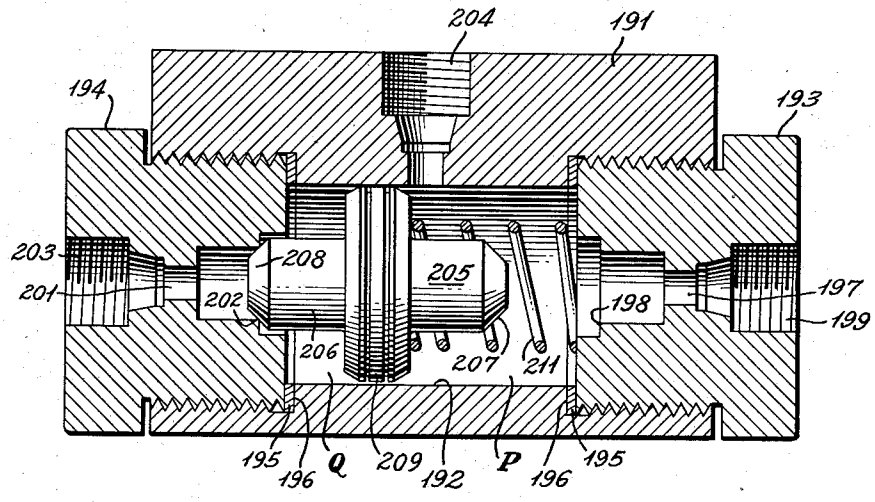


Fig. 10.

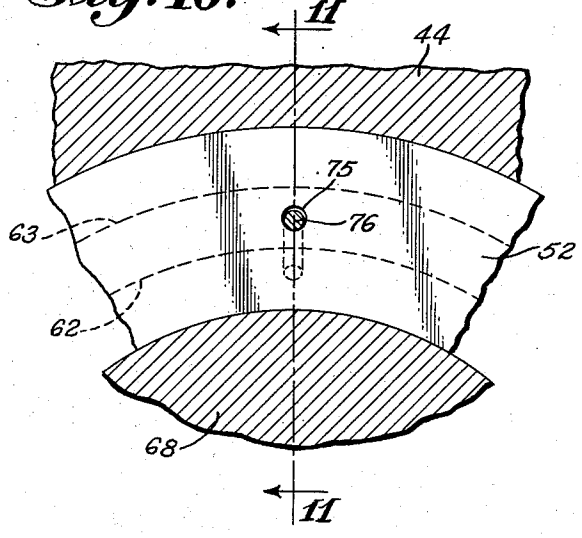
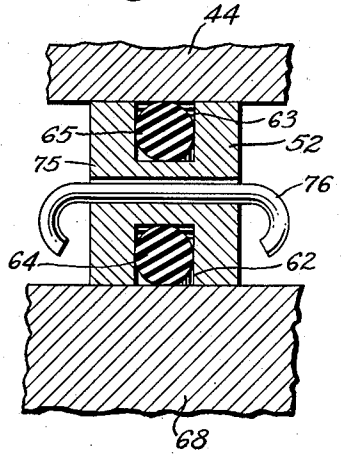


Fig. 11.



United States Patent Office 2,858,764 Patented Nov. 4, 1958

2,858,764

MEANS FOR EFFECTING SEQUENTIAL DISCHARGE OF A SERIES OF MATERIAL BREAKING CARTRIDGES

James C. Hesson, Riverdale, and James A. Swanson, Chicago, Ill., assignors to Cardox Corporation, Chicago, Ill., a corporation of Illinois

Application October 18, 1956, Serial No. 616,634

18 Claims. (Cl. 102—22)

This invention relates to new and useful improvements in apparatus for employing compressed gas blasting devices in mining operations and deals more particularly with systems in which the compressed gas is automatically directed from a main supply source successively to a plurality of blasting devices for sequential operation of the latter.

One conventional type of compressed gas blasting cartridge discharges automatically when the pressure of the gas charge within the cartridge reaches a predetermined value. When using such a cartridge for blasting down coal in a mine, the cartridge has been placed in a drilled hole in the working face of the mine and a tube for supplying gas to the cartridge extended from the latter around at least two right angle bends to a valve through which compressed gas was admitted from a main supply line. After the cartridge had discharged, the operator returned to the working face, reconditioned the cartridge for operation, replaced the cartridge in another drilled hole and returned to the valve for controlling the operation of the cartridge. These repeated trips between the working face and the valve were time consuming and, particularly in low seam mines, were very laborious.

The use of two or more cartridges attached to the same supply tube would have reduced the time and labor required in the trips between the working face and the control valve. This solution has been impracticable, however, because one cartridge always discharged first and vented the compressed gas so that the other cartridges would not discharge.

One manner in which the operator could have reduced the number of trips between the control valve and the working face in a given blasting operation would have been to provide a separate supply tube and valve for connecting each cartridge to the main supply line. The use of a number of relatively long supply tubes, however, would have been cumbersome and confusing and would have materially increased the amount of equipment to be hauled from place to place in the mine. Further, the compressed gas in the relatively long supply tube between each cartridge and its control valve would have been lost when the cartridge discharged.

It is the primary object of this invention to provide an apparatus for introducing compressed gas through a single supply tube to successively operate a plurality of blasting cartridges of the type that discharge automatically at a given pressure.

A further important object of the invention is to provide an apparatus for supplying compressed gas to automatically operate in a selected sequence a plurality of blasting cartridges.

Another important object of the invention is to provide an apparatus for discharging a plurality of compressed gas blasting cartridges whereby the flow of compressed gas to operate the cartridges is automatically directed from a single supply source to successive adjacently located cartridges.

Still another important object of the invention is to

provide a system for supplying compressed gas through alternate flow paths to adjacently positioned blasting cartridges, the flow paths being successively connected to and isolated from a source of compressed gas to effect sequential operation of the cartridges.

A further object of the invention is to provide a system for successively charging a plurality of automatically operated compressed gas blasting cartridges in such a manner as to prevent the loss of any substantial portion of the compressed gas flowing between a remotely located control point and the cartridges when the cartridges discharge.

Another object of the invention is to provide a valve which will automatically direct the flow of compressed gas therethrough into one flow path until there is a sudden reduction in the pressure in said one flow path and will thereafter direct the flow therethrough into a second flow path.

A still further object of the invention is to provide a valve responsive initially to the introduction of compressed gas to the inlet thereof for directing the flow of gas through a first outlet and responsive thereafter to a sudden reduction in the pressure of the gas therein for directing the flow of gas through a second outlet.

Other objects and the advantages of the invention will be apparent during the course of the following description.

In the accompanying drawings forming a part of this specification and in which like reference characters are employed to designate like parts throughout the same,

Figure 1 is a schematic view of a system embodying the invention as employed in a mining operation,

Figure 2 is a longitudinal sectional view of a blasting cartridge of the type with which the invention is adapted to be employed,

Figure 3 is a longitudinal sectional view of a valve embodying the invention,

Figure 4 is a fragmentary sectional view of a valve similar to that illustrated in Fig. 3 but employing a modified baffle plate retaining structure,

Figure 5 is a fragmentary sectional view of a valve similar to that illustrated in Fig. 3 but employing a modified valve seat,

Figure 6 is a longitudinal sectional view of a valve embodying a further modification of the invention,

Figure 7 is a longitudinal sectional view of a valve embodying still another modification of the invention,

Figure 8 is a longitudinal sectional view of a valve embodying a further modified form of the invention,

Figure 9 is a longitudinal sectional view of a valve embodying still another modification of the invention,

Figure 10 is a fragmentary view of the baffle plate employed in the valves of Figs. 3 to 6, inclusive, showing the manner in which the size of the bleed hole is limited, and

Figure 11 is a fragmentary sectional view taken on line 11—11 of Fig. 10.

In the drawings, wherein for the purpose of illustration are shown the preferred embodiments of the invention, and first particularly referring to Fig. 1, there is shown a room R in a mine having a working face W at one end thereof into which holes B have been drilled for receiving blasting cartridges C1, C2, C3 and C4 by means of which the coal is blasted down for removal from the mine. The cartridges C1 to C4, inclusive, may be of any conventional type which is adapted to receive a charge of compressed air and to automatically discharge the air when the pressure within the cartridges reaches a predetermined value. A preferred form of cartridge of this type is fully illustrated in Fig. 2 and will be fully described at a later point.

Leading from a source of supply of high pressure air, not shown, into the room R of the mine is a supply line 12. The flow of compressed air through the supply line 12 is controlled by a manually operated valve 13 which is located at a point that is remotely located around at least two right angle bends from the working face W. Adjacent the valve 13 and on the downstream side thereof is a bleeder line 14 the flow through which is controlled by a manually operated valve 15 so that the compressed air between the valve 13 and the working face W may be bled off at any time during a blasting operation.

The end of the supply line 12 adjacent the working face W is connected to the inlet of a switching valve V1 which has a first outlet connected through the branch line 16 to the cartridge C1 and a second outlet connected through the branch line 17 to the inlet of a second switching valve V2. The second switching valve V2 has a first outlet connected through branch line 18 to the cartridge C2 and a second outlet connected through the branch line 19 to the inlet of a third switching valve V3. The third switching valve V3 has its first and second outlets connected through branch lines 21 and 22, respectively, to the remaining two cartridges C3 and C4.

Each of the switching valves V1, V2 and V3 is constructed, as will be later described, so that when compressed air is admitted to the inlet thereof the flow of air will be directed initially to the first outlet of the valve and, when the pressure of the air at the first outlet of the valve is suddenly reduced, will switch the flow of air to the second outlet of the valve while closing the first outlet. It will be readily apparent, therefore, that when the valve 13 is opened by an operator at the control point, air willl flow through the supply line 12 and through the switching valve V1 into the branch line 16 and the cartridge C1 connected thereto. When the pressure within the cartridge C1 reaches a predetermined value, the cartridge will discharge and the pressure in the branch line 16 and at the first outlet of the connected switching valve V1 will be suddenly reduced. The flow of compressed air from the supply line 12 thereupon will be switched to the branch line 17, the first outlet of the valve being closed by the switching action thereof.

Air flowing through the branch line 17 will be directed by the second switching valve V2 to the first outlet of the latter and through the branch line 18 into the second cartridge C2 until the pressure therein has reached a predetermined value at which the cartridge will discharge. The switching valve V2 will thereupon close the branch line 18 and direct the flow of air from the line 17 into the line 19 for flow to the third switching valve V3. This valve will then direct the flow of air to its first outlet and through the branch line 21 to the cartridge C3 until this cartridge discharges, at which time the branch line 21 will be closed and the air from the line 19 will be directed through branch line 22 into the cartridge C4 for operation of this cartridge. When the last cartridge C4 has discharged the operator will close the valve 13, thereby completing the blasting operation.

It will be readily apparent that the operator may suspend the above described blasting operation at any time by closing the valve 13 and by bleeding the pressure from the portion of the system between the valve 13 and the working face W through the bleed line 14 and valve 15.

The preferred form of blasting cartridge illustrated in Fig. 2 is fully described in the James C. Hesson and John L. Smith application, Serial No. 242,724, filed August 20, 1951, now Patent Number 2,794,395, for Material Breaking Cartridge and will be only briefly described as follows:

By reference to Fig. 2, it will be seen that the blasting cartridge includes a tubular body portion 23 having a charging cap 24 threadedly connected in sealed relationship with one end portion thereof. Coupled to the outer end of the charging cap 24 by a coupling nut 25 is a compressed gas feed line 26 through which compressed gas is introduced into the chambered interior of the tubular body member 23.

Threadedly connected to the end portion of the body member 23 opposite the charging cap 24 is an adapter member 27 the outer end edge of which forms an annular valve seat 28.

A tubular discharge section 29 having an inner diameter slightly greater than that of the valve seat 28 is threaded onto the outer end portion of the adapter member 27. The discharge section 29 has formed therein a plurality of discharge ports 31 adjacent the valve seat 28.

A piston type main valve 32 is mounted in the discharge section 29 for longitudinal movement in sealed relationship with the inner surface of the discharge section between a closed position at which the inner end of the valve sealingly engages the valve seat 28 and the peripheral surface of the valve is in closing relationship with the discharge ports 31 and an open position at which the discharge ports are in open communication with the chambered interior of the body member 23. A plunger 33 is positioned in the outer end portion of the discharge section 29 for longitudinal movement in sealed engagement with the inner surface of the discharge section and a spring 34 is compressed between the plunger and the main valve 32. Threaded onto the outer end portion of the discharge section is a cap 35 having a central aperture through which a portion of the plunger 33 extends for engagement with the shear member 36 that is clamped against the outer end of the cap 35 by a plug 37.

The chamber within the discharge section 29 and between the main valve 32 and plunger 33 forms a control chamber 38 which communicates with the chambered interior of the body member 23 through an aperture 39 in the main valve 32. Extending longitudinally through the plug 33 is a passageway 41 the outer end of which is closed by the shear member 36. Formed in the plug 37 is a passageway 42, one end of which is aligned with the passageway 41 and lies on the opposite side of the shear member 36 therefrom and the opposite end of which communicates with the atmosphere through a venting passage 43.

The operation of the cartridge C illustrated in Fig. 2 will be briefly described as follows.

Compressed air is admitted through the feed line 26 to the chambered interior of the body member 23 and from the body member through the aperture 39 in the main valve 32 to the control chamber 38. The pressures within the body member 23 and control chamber 34 are thereby maintained substantially equal during the charging of the cartridge and, since the effective cross-sectional area of the main valve 32 exposed to the pressure within the control chamber 38 is greater than that exposed to the pressure within the body member 23, the main valve will be held in its closed position against the valve seat 28 to prevent the escape of compressed air through the discharge ports 31. The pressure of the air within the control chamber 38 will also act upon the plunger 33 to maintain the plunger in sealing engagement with the shear member 36 so that no air will escape through the passageway 41. When the pressure of the compressed air within the body member 23 and the similar pressure within the control chamber 38 has reached a predetermined value, the portion of the shear member 36 lying between the aligned passageways 41 and 42 will be sheared and the pressure within the control chamber will be quickly reduced by the venting of compressed air through the passageways 41 and 42 and the venting passage 43. The force applied to the main valve 32 by the pressure of the gas within the body member 23 will thereupon exceed the force applied to the valve by the pressure of the gas within the control chamber 38 and the valve will move longitudinally in the discharge section to place the discharge ports 31 in open communication with the chambered interior of the body member. The cartridge C is thereby automatically discharged and

any additional air that is admitted to the cartridge will be quickly vented through the passageways 41 and 42 and the venting passage 43 to the atmosphere.

Referring now to Fig. 3 for a detail description of the switching valve illustrated therein, it will be seen that the valve housing 44 has formed therein a cylindrical bore 45 the opposite end portions of which are radially outwardly offset and internally threaded for receiving plugs 46 and 47 which are threaded into the opposite end portions of the bore until their inner end surfaces sealingly engage gaskets 48 which are clamped between the inner ends of the plugs and the radial shoulders 49 that are formed by the offset relationship of the end portions of the bore. A portion of the bore 45 adjacent the inner end of the plug 47 is formed with a slightly greater diameter than the remainder of the bore between the two plugs 46 and 47 to provide a shoulder 51 in spaced relationship with the inner end of the plug 47 and prior to the assembly of the plugs 46 and 47 to the housing 44 an annular baffle plate 52, retaining ring 53 and valve member 54 are positioned in the bore, as will be later described.

Extending longitudinally through the plug 46 in axial alignment with the bore 45 is a passageway 55 the inner end edge of which forms an annular valve seat 56 and the outer end portion of which is internally threaded to provide a first outlet port 57 which may be connected by a threaded coupler, not shown, to a compressed air line. The plug 47 is similarly provided with a passageway 58 the inner end edge of which provides an annular valve seat 59 and the outer end portion of which is internally threaded to provide a second outlet port 61 for the valve.

The annular baffle plate 52 is seated axially against the shoulder 51 and is held in this position by the spacer ring 53 which extends circumferentially around the bore 45 between the baffle plate and the gasket 48 at the inner end of the plug 47. Circumferentially extending grooves 62 and 63 are formed in the inner and outer peripheries of the baffle plate 52 for receiving O-rings 64 and 65, respectively, the latter of which forms a seal between the baffle ring and the bore 45. The spacer ring 53 is provided with a circumferentially extending groove 66 adjacent the bore 45 and a plurality of ports 67 pass radially through the ring for a purpose that will be later described.

The valve member 54 has a cylindrically formed body portion 68 which is shorter than the distance between the two plugs 46 and 47 and the opposite end edges of which are beveled to provide inclined seating surfaces 69 and 71. The body portion 68 extends through and is supported for longitudinal movement by the baffle plate 52 and a seal is provided between the baffle plate and the body portion by the O-ring 64 in the inner groove 62 of the baffle plate. Extending radially outwardly from the body portion 68 in axially spaced relationship with the baffle plate 52 is a piston portion 72 which slidingly engages the bore 45 and is provided with a peripheral groove 73 for receiving an O-ring 74 which functions as a seal between the piston portion and the bore.

It will be readily apparent that the bore 45 between the plugs 46 and 47 is divided into three chambers D, E and F by the baffle plate 52 and the piston portion 72 of the valve member 54. The chamber E which lies between the baffle plate 52 and the piston portion 72 functions as a control chamber and is sealed from communication with the end chamber D adjacent the plug 46 by the O-ring 74. The control chamber E, however, communicates with the end chamber F adjacent the plug 47 through a very small passageway 75 in the baffle plate 52. As illustrated in Figs. 10 and 11 the size of the passageway 75 is further restricted by a wire 76 which extends through the passageway and has its opposite end portions bent to maintain the wire in the passageway.

An inlet port 77 is formed in one side of the housing 44 and communicates tthrough branch passageways 78 and 79 with the chambers D and F, respectively. The passageway 79 enters its associated chamber F outwardly of the spacer ring 53 and communicates with the chamber through the groove 66 and ports 67 of the spacer ring.

Between the inlet port 77 and the end of the housing 44 into which the plug 46 is threaded, there is provided a single marker hole 81 and between the inlet port and the opposite end of the housing 44 there are provided two marker holes 82 so that an operator connecting the valve to its associated air supply and branch lines in total darkness can readily distinguish the first and second outlet ports 57 and 61, respectively.

The operation of the switching valve V will be described as follows:

Compressed air from any suitable source of supply is introduced to the inlet port 77 of the valve and will flow through the two passageways 78 and 79 into the chambers D and F. The control chamber E, however, will initially remain at a very low pressure due to the restricted size of the passageway 75 through the baffle plate. The maximum force applied to the valve member 54 in a direction to move the valve member toward the end plate 46 therefore, is equal to the pressure of the gas in the chamber F times the cross-sectional area of the body portion 68 of the valve member. On the other hand, the minimum force acting on the valve member 54 in a direction to urge the valve member toward the plug 47 is equal to the pressure of the gas in the chamber D times the cross-sectional area of the piston portion 72 of the valve member 54 which is greater than the cross-sectional area of the body portion 68. The valve member 54, therefore, will always initially move in a direction to cause the seating surface 71 to engage the valve seat 59 and thereby close the second outlet port 61. Since the body portion 68 of the valve member 54 is shorter than the distance between the two plugs 46 and 47, the seating surface 69 will at this time be spaced from the valve seat 56 and the passageway 55 to the first outlet port 57 will remain open. After the valve member 54 is initially moved to the position described above, it will remain in this position despite a gradual increase in the pressure within the control chamber E to a value substantially equal to the pressure in the chambers D and F. In other words, the pressure in the chamber D acts over the entire cross-sectional area of the piston portion 72 and the body portion 68 to maintain the valve member 54 in its above described position while the pressures in the chambers E and F acting in the opposite direction are prevented from acting on the end portion of the body member within the passageway 58 by engagement between the seating surface 71 and valve seat 59.

If the first outlet port 57, however, is connected to a blasting cartridge of the type illustrated in Fig. 2, the cartridge will discharge when the pressure therein reaches the predetermined value and the sudden reduction in the pressure within the cartridge will cause a rapid drop in the pressure of the air at the outlet port 57 of the valve and in the chamber D within the valve.

This sudden drop in pressure in the chamber D will permit the pressure of the gas in the control chamber E to move the valve member 54 to close the passageway 55 by engagement between the seating surface 69 and the seat 56 and to open the passageway 58 for the free flow of air from the inlet port 77 to the second outlet port 61. The pressures applied to the valve member 54 by the air within the control chamber E and the chamber F thereafter will act upon the combined cross-sectional areas of the piston 72 and body portion 68 and the oppositely applied pressure in the chamber D will be prevented from acting on the end portion of the body member 68 within the passageway 55. The compressed air introduced to the inlet port 77, therefore, will continue

to flow through the second outlet port 61 until such time as the flow of air to the inlet port 77 has been stopped, the pressure of the air within the valve reduced by a substantial amount and flow of air to the inlet port subsequently renewed.

From the above described operation of the valve, it will be readily apparent that the relative diameters of the piston and body portions 72 and 68 of the valve member 54 and of the valve seats 56 and 59 must be properly selected to provide the desired operation of the valve. In other words, the surface areas of the valve member 54 acted upon by the compressed air in chambers D, E and F must be so related that the forces applied to the valve member by the air pressure will be unbalanced in the proper direction during the different stages of operation of the valve.

Further, the volume of the control chamber E and the flow rate of the compressed air through the passageway 75 past the wire 76 must be carefully controlled so that the pressure within the chamber E will closely approach the value of the pressure within the chamber D before the sudden reduction in the latter at a selected operating pressure for a cartridge. More specifically, the pressure in the control chamber E must increase to a value substantially above the pressure to which the air in the chamber D will be reduced before the pressure in the chamber D is reduced. On the other hand, the flow through the passageway 75 cannot be too rapid or the pressure within the control chamber E will drop concurrently with the pressure in the chamber D and the valve member 54 will remain in its initial position despite the sudden reduction in the pressure in the chamber D when the cartridge discharges.

The valve illustrated in Fig. 3 has been constructed to operate properly with cartridges which release their charges at from 5,000 to 10,000 pounds per square inch, gauge, the diameters of the piston and body portions 72 and 68 of the valve member 54 being one inch and one-half of an inch, respectively, and the diameters of the valve seats 56 and 59 each being three-eighths or one-fourth of an inch. The diameter of the passageway 75 was .0275 of an inch and the diameter of the wire 76 was .0270 of an inch. The length of the control chamber E with the valve member 54 in its initial position was five-eighths of an inch. These dimensions, of course, are given by way of example only and it is to be understood that the valve may be made to operate properly despite variations, within reasonable limits, in one or more of the dimensions given.

As a further consideration in the proper operation of the valve for controlling the supply of air to a blasting cartridge, it should be noted that the rate of pressure drop at the first outlet port 57 of the valve decreases in proportion to increases in the length of the branch line connecting the port to a cartridge. In other words, a reduction in the length of the branch line between the first outlet port 57 and the cartridge will increase the pressure change available at the outlet port to effect shifting of the valve member 54 when the cartridge discharges. Also, the pressure change available at the outlet port 57 increases as the rate at which the air is introduced to the cartridge decreases. When the charge introducing time is increased, therefore, a longer branch line may be used between the valve and cartridge. As an example of the length of branch line and charging time employed, it has been found that with a charging time of from nine to fourteen seconds a branch line preferably of ten feet but up to twenty-five feet in length may be employed with a considerable factor of safety with respect to shifting of the valve member 54.

Referring now to Fig. 4 for a detailed description of the modification illustrated therein, it will be noted that the construction of this valve is identical to that of the valve illustrated in Fig. 3 except that the baffle plate 52 is retained in its seated position against the shoulder 51 by a snap ring 83 which is seated in a groove 84 that is formed circumferentially around the bore 45 immediately adjacent the side of the baffle plate 52 opposite the shoulder 51. The snap ring 83 projects radially inwardly from the groove 84 along the side of the baffle plate 52 to prevent axial movement of the baffle plate.

The operation of this valve is identical to that of the valve illustrated in Fig. 3 and previously described.

Referring now to Fig. 5 for a detail description of the modification illustrated therein, it will be noted that this modification of the valve is identical to that illustrated in Fig. 3 and previously described except that the plug 47 is rabbeted at the inner end of the passageway 58 to provide a radially arranged shoulder 85 that is spaced from the inner end of the plug 47. Pressed in to the offset portion of the passageway 58 is an annular insert 86 which seats against the shoulder 85 and provides a valve seat 87 in radial alignment with the inner end of the plug 47. The use of a separately formed plug 47 and insert 86 permits the two parts to be formed of different materials so that the materials selected for each part may be best suited to the particular function which the part performs.

Referring now to Fig. 6 for a detail description of the modification of the invention illustrated therein, the valve housing 88 is provided with a cylindrical bore 89 the opposite end portions of which are radially outwardly offset and internally threaded for receiving the plugs 91 and 92. These plugs are each threaded into the housing 88 to a position at which a radial shoulder 93 on the head of the plug sealingly engages a gasket 94 that is clamped between the shoulder 93 and a radial shoulder 95 formed by a rabbeted groove at the outer end of each threaded portion of the bore. The portion of the bore 89 adjacent the inner end of the plug 92 is slightly radially enlarged for receiving a baffle plate 96 that is seated axially against the shoulder 97 formed at the inner end of the enlarged portion. The spacer ring 98 extends circumferentially of the bore 89 between the baffle plate 96 and the inner end of the adjacent plug 92 to hold the baffle plate in a seated position against the shoulder 97.

Extending longitudinally through the plug 91 in axial alignment with the bore 89 is a passageway 99 the inner end edge of which forms an annular valve seat 101 and the outer end portion of which forms a first outlet port 102 for the valve. The plug 92 is similarly provided with a passageway 103 the inner end edge of which forms an annular valve seat 104 and the outer end portion of which forms a second outlet port 105 for the valve.

Positioned in the bore 89 between the two plugs 91 and 92 is a valve member 106 having a cylindrical body portion 107 which is slightly shorter than the distance between the two plugs. The body portion 107 extends through the baffle plate 96 for longitudinal movement to cause the beveled seating surfaces 108 and 109 at opposite ends thereof to alternately engage and be moved away from their associated valve seats 101 and 104, respectively.

The baffle plate 96 is provided with circumferentially extending inner and outer grooves 111 and 112, respectively, for receiving O-rings 113 and 114. The O-ring 113 forms a seal between the baffle plate and the body portion 107 of the valve member 106 and the O-ring 114 forms a seal between the baffle plate and the bore 89.

Extending radially outwardly from the body portion 107 of the valve member 106 is a piston portion 115 which slidingly engages the bore 89 and is provided with a circumferentially extending groove 116 for receiving the O-ring 117 which provides a seal between the piston portion and the bore.

The bore 89 between the two plugs 91 and 92 is divided into three chambers G, H and I by the baffle plate 96 and the piston portion 115. The control chamber H

between the baffle plate 96 and piston portion 115 communicates with the chamber I adjacent the plug 92 through a very small passageway 118 that extends through the baffle plate. This passageway is further restricted by a wire 119 which extends therethrough and has its opposite end portions bent over to prevent the wire from being dislodged from the passageway.

An inlet port 121 is formed in one side of the housing 88 and communicates with the chamber G through a passageway 122. A second passageway 123 extends from the inlet port 121 to the bore 89 at a point adjacent the inner end of the plug 92 and outwardly of the spacer ring 98. Communication is provided between the passageway 123 and the chamber I through a groove 124 which extends circumferentially around the ring 98 and a plurality of ports 125 which pass radially through the ring.

The operation of the valve illustrated in Fig. 6 is identical to the operation of the valve of Fig. 3 and will not be described again.

The modification of the invention illustrated in Fig. 7 includes a housing 126 having a bore 127 formed therein with its opposite end portions radially enlarged and internally threaded to receive plugs 128 and 129. Each of the plugs 128 and 129 is seated in sealing relationship with a gasket 131 at the inner end of the radially enlarged portion of the bore into which the plug is threaded.

A portion of the bore 127 adjacent the inner end of the plug 129 is slightly radially enlarged to provide a shoulder 132 that is spaced from the inner end of the plug and an annular baffle plate 133 is positioned in the bore and axially seated against the shoulder 132. A spacer ring 134 extends circumferentially of the bore 127 between the baffle plate 133 and the inner end of the plug 129 to clamp the baffle plate against the shoulder 132.

Positioned in the bore 127 is a valve member 135 having a cylindrical body portion 136 which extends through the baffle plate 132 and is supported thereby for longitudinal movement. Extending radially outwardly from the body portion 136 in spaced relationship with the baffle plate 133 is a piston portion 137 which slidingly engages the bore 127 and is provided with a circumferentially extending groove 138 for receiving the O-ring 139 which provides a seal between the piston portion and the bore.

Extending longitudinally through the plug 128 in axial alignment with the bore 127 and the body portion 136 of the valve member 135 is a passageway 140 the inner end edge of which forms an annular valve seat 140' and the outer end portion of which forms the first outlet 141 for the valve. A similar passageway 142 is formed in the plug 129 to provide an annular valve seat 143 and a second outlet port 144 for the valve. The body portion 136 of the valve member 137 has its opposite end edges beveled to provide seating surfaces 145 and 146 and the length of the body portion is less than the spacing between the two plugs 128 and 129 so that longitudinal movement of the valve member 137 will alternately move the seating surfaces 145 and 146 into engagement with and spaced relationship from their associated seats 140' and 143, respectively.

The baffle plate 133 is provided with circumferentially extending inner and outer grooves 147 and 148 for receiving the O-rings 149 and 151, respectively, which provide seals between the baffle plate and the bore 127 and between the baffle plate and the longitudinally movable body portion 136.

The bore 127 between the plugs 128 and 129 is divided into three chambers J, K and L by the baffle plate 133 and the piston portion 137 of the valve member 135.

Formed in one side of the housing 126 is an inlet port 152 which communicates through passageways 154 and 155 with the chambers J and L in the end portions of the bore adjacent the plugs 128 and 129, respectively. The passageway 155 intersects the bore 127 outwardly of the spacer ring 134 and communicates with the chamber L through a groove 156 that extends circumferentially around the outer surface of the spacer ring and through a plurality of ports 157 which extend radially through the spacer ring.

The inlet port 152 is also in restricted communication with the control chamber K between the baffle plate 133 and the piston portion 137 through a very small passageway 158 that is formed in a plug 159 which is threaded into an opening between the inner end of the inlet port and the control chamber. The passageway 158 is further restricted by a wire 161 which is positioned in the passageway and has its opposite end portions bent to prevent the wire from becoming dislodged from the passageway.

The operation of the valve illustrated in Fig. 7 is identical to that of the valve illustrated in Fig. 3 with the exception that compressed air is admitted at a restricted rate to the control chamber K through the passageway 158 in the plug 159 rather than through the restricted passageway 75 that is formed in the baffle plate 52 of the valve illustrated in Fig. 3.

Referring now to Fig. 8 for a detail description of the modification of the invention illustrated therein, the valve housing 162 has formed therein a bore 163, the opposite end portions of which are radially outwardly offset and internally threaded for receiving the plugs 164 and 165 which are threaded into the housing to a position at which their inner ends sealingly engage and clamp a gasket 166 against the shoulder that is formed at the inner end of the radially enlarged portion of the bore. Extending longtiudinally through the plug 164 in axial alignment with the bore 163 is a passageway 167 the inner end edge of which forms an annular valve seat 168 and the outer end portion of which forms a first outlet port 169 for the valve. The plug 165 is provided with a similar passageway 171 the inner end edge of which forms an annular valve seat 172 and the outer end portion of which forms a second outlet port 173 for the valve.

A portion of the bore 163 adajcent the inner end of the plug 165 is formed with a slightly greater diameter than the remaining portion of the bore between the two plugs 164 and 165 to provide a radial shoulder 174 in spaced relationship with the inner end of the plug 165. Seated axially against the radial shoulder 174 is a baffle plate 175 which is retained in its seated position against the shoulder by the snap ring 176 that is mounted in a circumferentially extending groove 177 adjacent the side of the baffle plate.

Positioned in the bore 163 is a valve member 178 having a cylindrical body portion 179 the length of which is slightly less than the spacing between the two plugs 164 and 165. The body portion 179 extends through the baffle plate 175 and is supported thereby for longitudinal movement to alternately position the beveled seating surfaces 181 and 182 at opposite ends of the body portion in sealing engagement with and in spaced relationship from the associated valve seats 168 and 172, respectively. Extending radially outwardly from the body portion 179 in spaced relationship with the baffle plate 175 is a piston portion 183 which slidingly engages the bore 163 and is provided with a circumferentially extending groove 184 for receiving the O-ring 185 which provides a seal between the piston portion and the bore.

Compressed between the piston portion 183 and the adjacent end cap 164 is a spring 186 which urges the valve member 178 in a direction to effect seating engagement between the surface 182 and the valve seat 172.

An inlet port 187 is formed in one side of the housing 162 and communicates through passageway 188 with the chamber M that is formed between the plug 164 and the piston portion 183 and through passageway 189 with the chamber N that is formed between the plug 165 and the

baffle plate 175. The chamber O which lies between the baffle plate 175 and piston portion 183 of the valve member 178 functions as a control chamber and communicates with the chamber N through the very slight clearance space between the inner periphery of the baffle plate and the body portion 179 of the valve member.

The operation of the valve illustrated in Fig. 8 will be described in detail as follows:

Compressed air from any suitable supply source is admitted to the inlet port 187 and will flow through passageways 188 and 189 into the chambers M and N. At this time the valve member 178 will have been moved to seat the surface 182 against the valve seat 172 by the spring 186 so that the compressed air admitted to the chamber N will exert a longitudinally acting force on the valve member which is very small compared to the force applied to the valve member by the pressure of the air in the chamber M acting on the entire cross-sectional area of the piston and body portions thereof. Further, the pressure within the control chamber O will be initially less than the pressures in the chambers M and N due to the retarded flow of gas between the closely spaced inner surface of the baffle plate and the body portion 179 of the valve member.

It will be noted that the valve member 178 would be moved to seat the surface 182 against the valve seat 172 by the pressure of the gas in the chamber M even if the spring 186 were omitted from the device. The spring 186, however, insures proper seating of the valve member 178 to close the passageway 171 and the outlet port 173 and permits a slightly greater latitude in the cross-sectional area of the clearance space between the baffle plate 175 and the body portion 179 of the valve member.

The compressed air admitted to the inlet port will initially flow to the chamber M and through the passageway 167 and first outlet port 169 to a point of use. During this period of flow of compressed air from the first outlet port 169, however, the pressure within the control chamber O will increase to a value substantially equal to the pressures in the chamber M and N and any subsequent sudden reduction in the pressure of the compressed air at the first outlet port 169 will permit the increased pressure within the control chamber O acting on the piston portion 183 of the valve member 178 to move the valve member to a position at which the surface 181 sealingly engages the valve seat 168 and the surface 182 moves away from the valve seat 172. The valve member 178 will thereafter remain in this second position due to the fact that the forces exerted on the valve member in one direction by the pressure of the gas within the control chamber O acting on the entire cross-sectional area of the piston portion 183 and by the pressure of the gas within the chamber N acting on the entire cross-sectional area of the body portion 179 are greater than the forces applied to the valve member in the opposite direction by the spring 186 and by the pressure of the gas in the chamber M acting on the cross-sectional area of the piston portion of the valve. In other words, the reduced pressure at the first outlet port 169 and within the passageway 167 acting on the end area of the body portion 179 within the passageway will create an unbalanced condition in the forces acting on the valve member 178 so that the valve member will be maintained in a position to close the first outlet port 169 and open the second outlet port 173.

The valve member 178 will return to its initial position when the supply of air to the inlet port 187 is stopped and the forces exerted by pressures within the control chamber O and the chamber N are reduced to a value below the opposed forces exerted by the spring 186 and by the pressure of the gas within the chamber M acting on the piston portion 183.

Referring now to Fig. 9 for a detail description of the modification of the invention illustrated therein, it will be seen that the valve housing 191 has a cylindrical bore 192 formed therein with the opposite end portions of the bore radially enlarged and internally threaded for receiving plugs 193 and 194 which are threaded into the bore into sealing engagement with the gaskets 195 which are clamped against the shoulders 196 formed at the inner ends of the radially enlarged end portions of the bore. The plug 193 has a passageway 197 extending longitudinally therethrough axially of the bore 192 and the inner end portion of the passageway is rabbeted to provide an annular valve seat 198. The outer end portion of the passageway 197 forms a first outlet port 199 for the valve. The plug 194 is similarly provided with a passageway 201 the inner end portion of which is rabbeted to provide an annular valve seat 202 and the outer end portion of which provides a second outlet port 203 for the valve.

At one side of the housing 191 there is provided an inlet port 204 which opens into the bore 192 at a location that is centered longitudinally of the bore.

Mounted in the bore 192 is a valve member 205 having a cylindrical body portion 206 the opposite end edges of which are beveled to provide seating surfaces 207 and 208 for sealingly engaging the valve seats 198 and 202, respectively. The valve member 205 is also provided with a piston portion 209 which is centered longitudinally of the body portion 208 and extends radially outwardly therefrom for sliding engagement with the bore 192 with sufficient clearance therebetween to permit a restricted flow of gas past the piston portion. The piston portion 209, therefore, divides the bore into chambers P and Q which are in restricted communication with each other and which vary inversely in size in accordance with the position of the piston portion.

It will be noted at this point that the length of the body portion 208 of the valve member 205 is such that when the seating surface 208 engages the valve seat 202 the piston portion 209 will lie on the side of the inlet port 204 adjacent the end plug 194. Similarly, when the seating surface 207 sealingly engages the valve seat 198, the piston portion 209 of the valve member 205 will lie on the side of the inlet port 204 adjacent the end plug 193. In other words, when either of the outlet ports 199 or 203 is closed by the valve member 205 the other outlet port will be in open communication with the inlet port 204.

Compressed between the end plug 193 and the adjacent side of the piston portion 209 of the valve member 205 is a spring 211 which urges the valve member in a direction to cause the seating surface 208 to sealingly engage the valve seat 202 and to thereby close the second outlet port 203.

The operation of the valve illustrated in Fig. 9 will be described as follows:

With the valve member 205 initially positioned as illustrated in Fig. 9 by the spring 211, compressed air is admitted to the inlet port 204 and will flow through the chamber P into the passageway 197 and out of the first outlet port 199 of the valve. During this flow of air to the first outlet port 199 the restricted flow of air past the piston portion 209 of the valve member 205 will cause the pressure within the chamber Q to gradually increase to a value substantially equaling the pressure in the chamber P. A sudden reduction in the pressure of the air at the first outlet port 199 and in the chamber P, therefore, will permit the pressure of the air in the chamber Q to move the valve member 205 to a position at which the seating surface 207 will sealingly engage the valve seat 198 and the first outlet port will be closed. Further, since the end area of the body portion 208 within the passageway 197 is sealed from the pressure of the air within the chamber P, the unbalance in the forces applied to the valve member by the pressures of the gas in the chambers P and Q will cause the valve member to remain in a position to close the first outlet port 199 while compressed air continues to flow from the inlet port 202 through

the chamber Q and into the passageway 201 and second outlet port 203. When the pressures within the chambers P and Q are bled down, however, the force exerted on the valve member 205 by the spring 211 will cause the valve member to return to its initial position as illustrated in Fig. 9.

It will be readily apparent that any of the above described switching valves may be employed in the system illustrated in Fig. 1 to effect sequential operation of the cartridges C1 to C4, inclusive. When so employed, the inlet port of the valve V1 is connected to the supply line 12, the first outlet port of the valve V1 is connected to the cartridge C1 by the branch line 16 and the second outlet port of the valve V1 connected by the branch line 17 to the inlet port of the valve V2. Similarly, the first outlet port of the valve V2 is connected by the branch line 18 to the cartridge C2 and the second outlet port of the valve V2 is connected by the branch line 19 to the inlet port of valve V3. The first and second outlet ports of the valve V3 are connected by branch lines 21 and 22 to cartridges C3 and C4, respectively.

When the valve 13 at the control point is opened by the operator, therefore, compressed air will flow through the supply line 12 and from the first outlet port of the valve V1 into the cartridge C1 until a predetermined pressure is reached at which the cartridge will discharge. The valve V1 will thereupon automatically close the first outlet port of the valve and direct the flow of compressed air from its second outlet port into the branch line 17 for flow from the first outlet port of the valve V2 into the branch line 18 and cartridge C2. When the air within the cartridge C2 reaches a predetermined value, this cartridge will automatically discharge and the valve V2 will automatically switch the flow of air from its first outlet port to its second outlet port for flow into the branch line 19 and to the inlet port of the valve V3 which will direct the air from its first outlet port into the branch line 21 and cartridge C3. When the pressure of the air within the cartridge C3 reaches a predetermined value, this cartridge will discharge and the valve will automatically switch the flow of air to its second outlet port and through the line 22 into the cartridge C4. After the pressure of the air within the cartridge C4 has reached a predetermined value and the cartridge has automatically discharged, the operator will close the valve 13 to prevent any unnecessary loss of air from the supply line 12. Since the branch lines 16, 18 and 21 are relatively short, only a small amount of air will be lost from the system upon the discharge of each of the three cartridges C1, C2 and C3 so that the total loss of compressed air after discharge of the four cartridges is only slightly greater than the amount of compressed air which would be lost by the operation of a single cartridge from the control point 13.

It will be readily appreciated that the switching valves of the invention may be employed to control the operation of any practical number of blasting cartridges in a mining operation. For example, a single switching valve might be employed to control the operation of two cartridges which would be connected to the first and second outlet ports of the valve. Any greater number of valves might also be employed, the first valve having its inlet port connected to an air supply line and each valve having its first outlet port connected to one cartridge and its second outlet port connected to the inlet port of the succeeding valve except the last valve which would have both its first and second outlet ports connected to cartridges. It will also be apparent that the blasting operation may be suspended at any point during a cycle of operation by closing the valve 13 at the control point and bleeding the pressure from the supply line 12 and from the various branch lines and cartridges by opening the valve 15 in the bleeder line 14.

It is to be understood that the forms of this invention herewith shown and described are to be taken as preferred examples of the same, and that various changes in the shape, size, and arrangement of parts may be resorted to without departing from the spirit of the invention or the scope of the subjoined claims.

Having thus described the invention, we claim:

1. Apparatus for blasting down coal in a mine, comprising a source of compressed gas, a gas supply line leading from said source to a point adjacent the coal to be blasted, a valve mounted in said supply line at a point remote from the coal to be blasted for controlling the flow of gas through the supply line, a pressure fluid operated flow directing device having an inlet port connected to said supply line at said point adjacent the coal and having a pair of outlet ports, valve means in said pressure fluid operated device movable to a first position by the admission of compressed gas to said inlet port to permit the free flow of gas from the inlet to a first outlet port and to close the second outlet port, means responsive to a sudden decrease in the pressure of the gas at said first outlet port to move said valve means to a second position to close said first outlet port and to permit the free flow of gas from the inlet to the second outlet port, a blasting cartridge arranged in blasting relationship with the coal for receiving a charge of compressed gas and for releasing said charge when the pressure thereof reaches a predetermined value, and a branch line connecting said first outlet port to said cartridge for introducing said charge to the latter.

2. Apparatus as defined in claim 1 further characterized by a second blasting cartridge arranged in blasting relationship with the coal for receiving a charge of compressed gas and for releasing said charge when the pressure thereof reaches a predetermined value, and means connecting said second outlet port of the pressure fluid operated device to said second cartridge for introducing the charge to the latter.

3. Apparatus as defined in claim 1 further characterized by a second pressure fluid operated flow directing device having its inlet port connected to said second outlet port of the first pressure fluid operated device, a pair of additional blasting cartridges each arranged in blasting relationship with the coal for receiving a charge of compressed gas and for releasing said charge when the pressure thereof reaches a predetermined value, a branch line connecting the first outlet port of said second device to one of said additional cartridges for introducing the charge thereto, and means connecting the second outlet port of said second device to the other additional cartridge for introducing the charge thereto.

4. Apparatus for blasting down coal in a mine, comprising a source of compressed gas, a gas supply line leading from said source to a point adjacent the coal to be blasted, a valve mounted in said supply line at a point remote from the coal to be blasted for controlling the flow of gas through the supply line, a plurality of pressure fluid operated flow directing devices each having an inlet and a pair of outlet ports, valve means in each of said flow directing devices movable to a first position by the admission of compressed gas to the inlet port to permit the free flow of gas from the inlet to a first outlet port and to close the second outlet port, means responsive to a sudden decrease in the pressure of the gas at said first outlet port to move said valve means to a second position to close said first outlet port and to permit the free flow of gas from the inlet to the second outlet port, one of said pressure fluid operated devices having its inlet port connected to said supply line at said point adjacent the coal and successive ones of the remaining pressure fluid operated devices having their inlet ports connected to the second outlet port of the preceding device, a plurality of blasting cartridges each arranged in blasting relationship with the coal for receiving a charge of compressed gas and for releasing said charge when the pressure thereof reaches a predetermined value, and a plurality of branch lines connecting the first outlet port

of each of said devices and the second outlet port of the last of the successively connected devices to associated ones of said cartridges for sequentially introducing the gas charges to the cartridges.

5. Apparatus for controlling the operation of blasting cartridges which are to be charged with compressed gas and which automatically release their charge when the pressure thereof reaches a predetermined value, comprising a chambered valve housing having an inlet port and first and second outlet ports, a valve member mounted in said housing for movement between first and second positions at which the first and second outlet ports, respectively, are in open communication with the inlet port and the other outlet port is closed, said valve member having opposed surface areas subjected at different rates to the pressure of gas admitted to said inlet port to cause the higher pressure initially acting on one of said surface areas to move the valve member to said first position and to cause the pressure acting on the other surface area to move the valve member to said second position when the pressure on said one surface area is suddenly reduced, a compressed gas supply line connected to said inlet port for the controlled admission of compressed gas thereto, a branch line connected to said first outlet port for supplying compressed gas therefrom to a blasting cartridge until the pressure in the latter is suddenly reduced, and a second branch line connected to said second outlet port for supplying compressed gas therefrom to a point of use.

6. A flow directing device, comprising a chambered housing having an inlet port for the admission of pressure fluid thereto and first and second outlet ports for the flow of pressure fluid therefrom, and a valve member mounted in said housing for movement between first and second positions at which said first and second outlet ports, respectively, are placed in communication with said inlet port and the other outlet port is closed, said valve member having a first surface directly exposed to the pressure of the fluid admitted to said inlet port for moving the valve member to its first position and an opposed surface, means for subjecting said opposed surface to the pressure of the fluid admitted to the inlet port at a rate retarded in respect to the rate at which said first surface is exposed to said pressure for moving the valve member to its second position when the pressure at said first outlet port is suddenly reduced.

7. A flow directing device, comprising a housing having a cylindrically formed bore therein and first and second outlet ports for the flow of pressure fluid axially from opposite ends of the bore, an annular baffle plate mounted to extend radially inwardly from the cylindrical bore surface in axially spaced relationship with said second outlet port, and a valve member extending through and supported by said baffle plate for movement axially of said bore to alternately close said first and second outlet ports, said valve member having a radially outwardly extending piston portion slidingly engaging the cylindrical bore surface, said baffle plate and piston portion forming end chambers in said bore axially outwardly thereof and a control chamber therebetween, said housing having an inlet port in open communication with said end chambers and in restricted communication with said control chamber.

8. A device as defined in claim 7 further characterized by said baffle plate having a passageway therethrough to provide communication between the end chamber adjacent said second outlet port and the control chamber, and a restrictor member positioned in said passageway to limit the flow of pressure fluid therethrough and to retard variations in the pressure of the fluid in said control chamber relative to variations in the pressures of the fluid in said end chambers.

9. A device as defined in claim 7 further characterized by said baffle plate being mounted in sealing engagement with the cylindrical bore surface, means providing a seal between the baffle plate and the portion of said valve member supported thereby, means providing a seal between the cylindrical bore surface and the slidingly engaged piston portion of the valve member, and means forming a restricted passageway between said inlet port and the control chamber.

10. A flow directing device, comprising a housing having a cylindrically formed bore therein and first and second outlet ports for the flow of pressure fluid axially from opposite ends of the bore, a valve member positioned in said chamber for movement axially thereof to alternately close said first and second outlet ports while opening the other outlet port, said valve member having a radially outwardly extending piston portion, and a spring engaging the side of said piston portion facing said first outlet port to urge the valve member into closing relationship with said second outlet port, said piston portion dividing said bore into chambers, and the chamber on the opposite side of said piston portion from said spring having restricted communication with said inlet port for the retarded admission of pressure fluid thereto to move the valve member into closing relationship with said first inlet port against the force of said spring when the pressure of the fluid at said first outlet port is suddenly reduced.

11. A flow directing device, comprising a housing having a bore therethrough with enlarged and internally threaded end portions and a portion adjacent one threaded portion radially outwardly offset to provide a shoulder in the bore, an annular baffle plate positioned against said shoulder in sealing relationship with said offset portion, means retaining said baffle plate against said shoulder, a valve member having a cylindrical body portion supported for axial movement through and in sealing engagement with said baffle plate and a radially outwardly extending piston portion in sealing engagement with said bore to provide a control chamber between said piston portion and said baffle plate, and a pair of plugs threaded into sealing relationship with the enlarged and threaded end portions of the bore, said plugs each having an outlet port extending axially therethrough and being engageable by the body portion of said valve member to alternately close the outlet ports, said housing having an inlet port for introducing pressure fluid to the chambers formed at opposite end portions of said bore between the baffle plate and piston portions and their adjacent plugs, and said baffle plate having a restricted passageway therethrough for introducing pressure fluid at a relatively retarded rate to said control chamber.

12. A device as defined in claim 11 further characterized by said plugs each having a rabbeted groove formed therein around the inner end of its outlet port, and the portion of each plug engageable by the body portion of the valve member comprising a separately formed annular valve seat pressed into the groove at the inner end of the plug.

13. A flow directing device, comprising a housing having a cylindrical bore therein with first and second outlet ports extending axially from opposite ends of the bore, an annular baffle plate mounted to extend radially inwardly from the cylindrical bore surface, a valve member having a cylindrical body portion extending through said baffle plate for axial movement in sealing relationship therewith to alternately close said first and second outlet ports, said valve member having a radially arranged portion extending outwardly from its body portion into sealing relationship with the bore surface, said baffle plate and radially arranged portion of the valve member dividing said bore to provide a control chamber therebetween and a chamber at each end portion of the bore, and said housing having an inlet port in open communication through separate branch passageways with the chambers at opposite end portions of the bore, and means providing a separate restricted passageway from the inlet port to said control chamber.

14. Apparatus for controlling the operation of blasting

cartridges which are to be charged with compressed gas and which automatically release their charge when the pressure thereof reaches a predetermined value, said apparatus comprising an axially bored valve housing having an inlet port, a compressed gas supply means connected to said inlet port for the controlled admission of compressed gas thereto, a valve member mounted in the bore of said housing having a movable piston portion defining a first chamber in open communication with said inlet and a second chamber in restricted communication with said inlet, said piston being movable in response to differences in the gas pressures in the said two chambers acting on said piston portion, a first and a second outlet port in said housing, a first branch line connected to said first outlet port for conducting compressed gas therefrom to a blasting cartridge, a second branch line connected to said second outlet port for conducting compressed gas therefrom to a point of use, an elongated body portion mounted on said valve member for movement between first and second positions at which the first and second outlet ports, respectively, are in open communication with the inlet port and the other outlet port is closed, said first outlet port being in open communication with said first chamber when the valve member is in said first position for effecting a sudden reduction in the pressure in the first chamber when the pressure in said first branch line is released to cause the pressure in said second chamber to move the valve to said second position.

15. A flow directing device comprising a chambered housing having an inlet port for the admission of pressure fluid thereto and first and second outlet ports for the flow of pressure fluid therefrom, said housing having a cylindrical bore therein with said first and second outlet ports being axially aligned and at opposite ends of the bore, a valve member having an elongated body portion arranged axially of said bore for alternate movements in opposite directions to position the opposite end portions thereof in closing relationship with said first and second outlet ports, and a piston portion extending radially outward from said body portion to divide said cylindrical bore into a first chamber in open communication with said inlet port and a second chamber in restricted communication with said inlet port, the difference in the pressures acting on opposite sides of said piston portion effecting said alternate movement of said valve member.

16. Apparatus for blasting down coal in a mine, comprising a source of compressed gas, a gas supply line connected to said source and having a discharge end located adjacent the coal to be blasted, means for controlling the flow of gas through said supply line, a plurality of branch lines extending to different blasting locations, gas confining means connected to said branch lines at each of said blasting locations, means associated with each of said confining means for releasing gas from the confining means at selected release pressures, and means for connecting each of said branch lines to said supply line to supply compressed gas to the respective confining means in a predetermined sequence, said connecting means including means for shifting the flow of compressed gas from each one of said branch lines to the next succeeding branch line after the gas in the confining means connected to the preceding branch line has reached its release pressure.

17. Apparatus for blasting down coal in a mine comprising a source of compressed gas, a gas supply line leading from said source to a discharge end located adjacent the coal to be blasted, a valve mounted in said supply line at a point remote from the coal to be blasted for controlling the flow of gas through said supply line, first and second branch lines connected to the discharge end of said supply line, means connected at the end of each of said branch lines for confining the gas flowing through the branch lines in blasting relationship with the coal, means associated with each of said confining means for releasing the confined gas from the respective confining means at selected pressures, and means for automatically directing the flow of gas from said supply line into said first branch line until the gas is released from the confining means connected to said first branch line and then directing the flow of gas from said supply line into said second branch line.

18. Apparatus for blasting down coal in a mine, comprising a source of compressed gas, a gas supply line leading from said source to a discharge end located adjacent the coal to be blasted, a valve connected in said supply line at a point remote from the coal to be blasted for controlling the flow of gas through said supply line, a first and a second branch line, valve means connected to the discharge end of said supply line for automatically directing the flow of gas from said supply line into said first branch line, first cartridge means connected to said first branch line for confining the gas flowing through said first branch line in blasting relationship with the coal, means associated with said first cartridge means for automatically releasing the confined gas from said first cartridge means when the pressure thereof is at a predetermined value, said valve means including means for automatically shifting the flow of gas from said first branch line into said second branch line after the pressure of the confined gas in said first cartridge means is at said predetermined pressure, second cartridge means connected to said second branch line for confining the gas flowing through said second branch line in blasting relationship with the coal, and means associated with said second cartridge means for automatically releasing the confined gas from said second cartridge means when the pressure thereof is at a predetermined value.

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