Aug. 13, 1963 H. C. FOSTER 3,100,446

GAS OPERATED DEVICES

Filed Dec. 9, 1960 4 Sheets-Sheet 1

FIG. 1

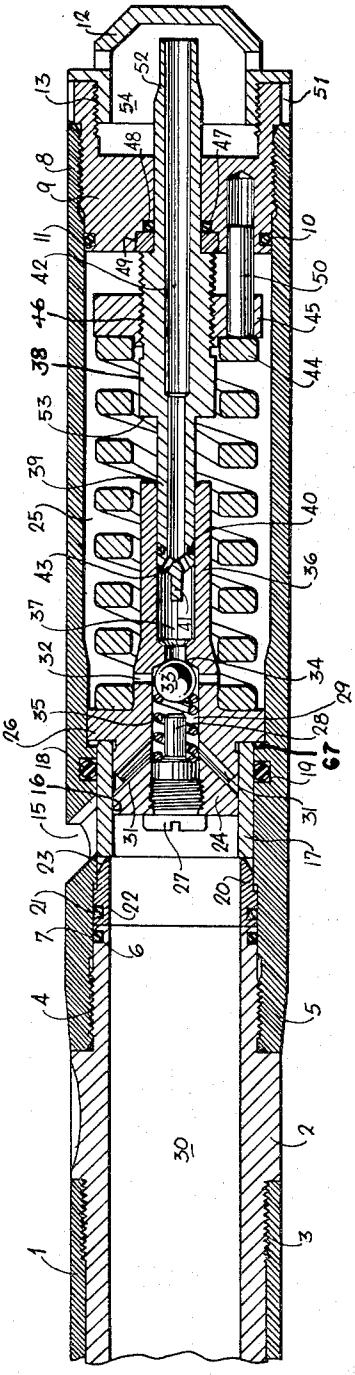
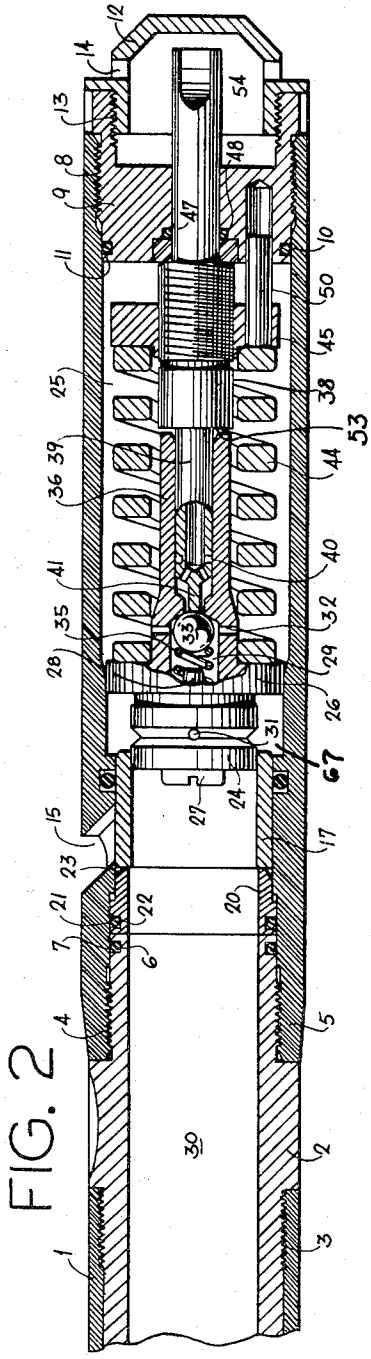


FIG. 2



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GAS OPERATED DEVICES

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FIG. 3

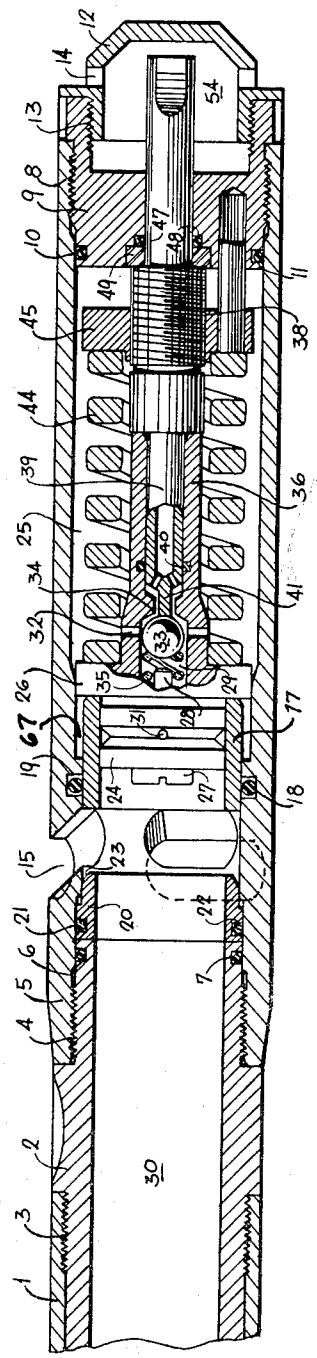
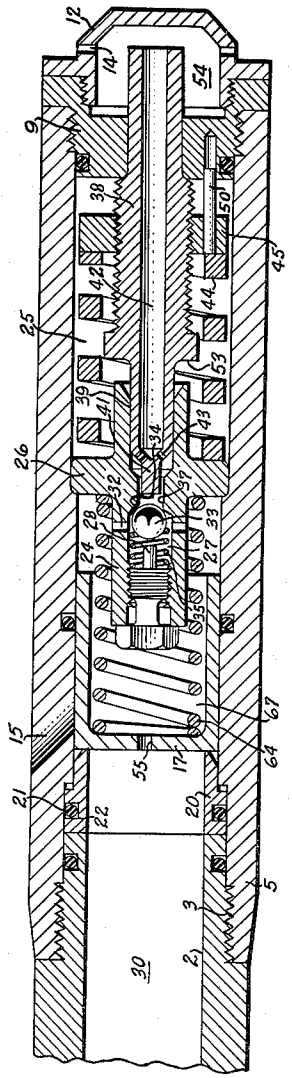


FIG. 6



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FIG. 4

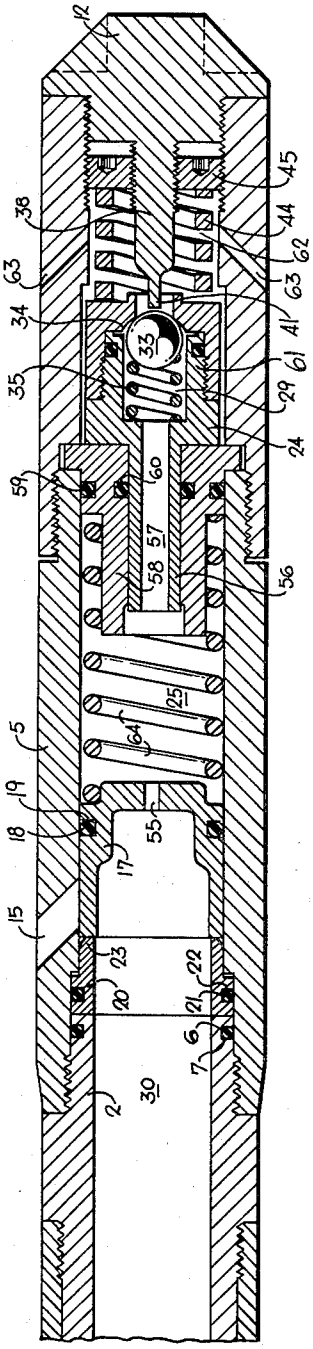
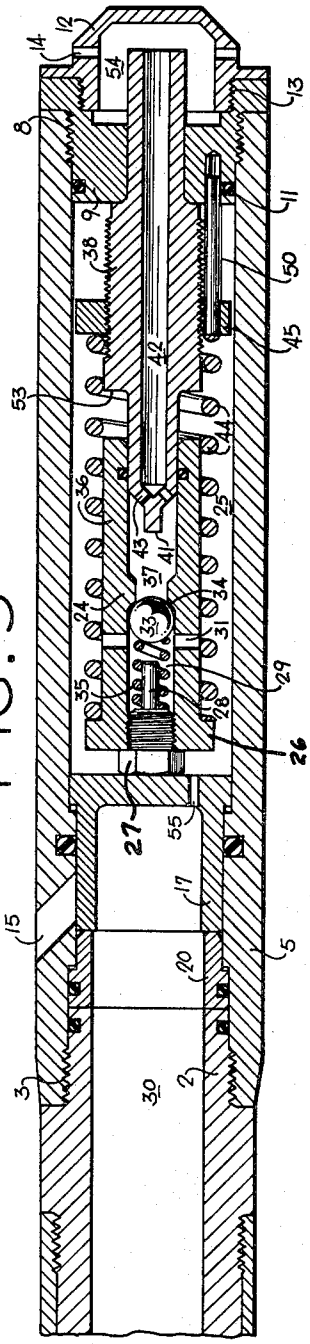


FIG. 5



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GAS OPERATED DEVICES

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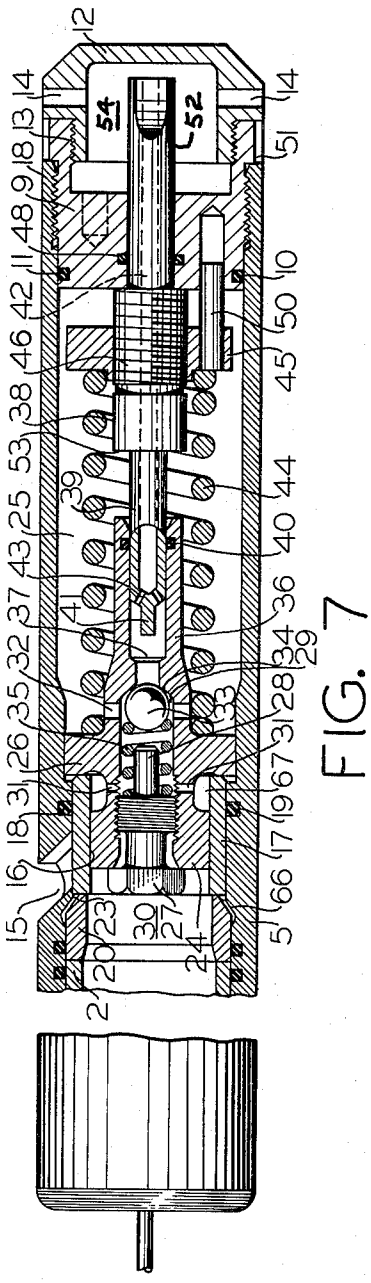


FIG. 7

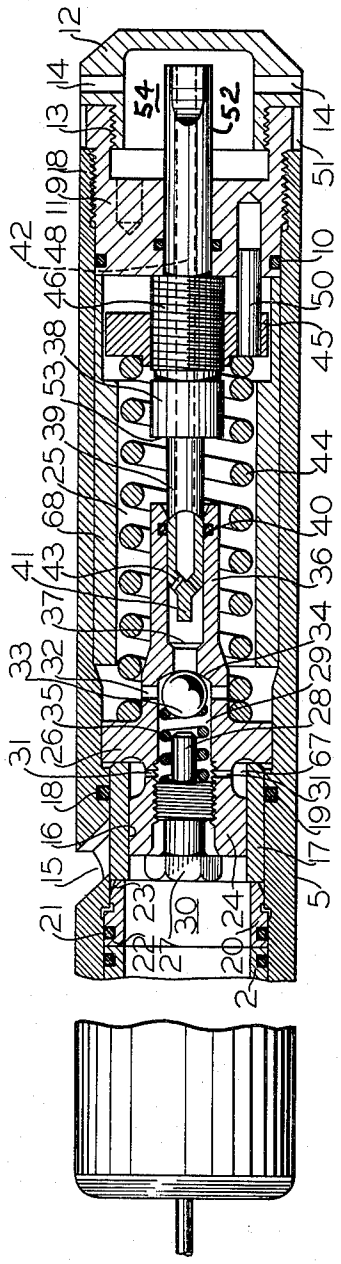


FIG. 8

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United States Patent Office 3,100,446 Patented Aug. 13, 1963

3,100,446

GAS OPERATED DEVICES

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Filed Dec. 9, 1960, Ser. No. 75,033
10 Claims. (Cl. 102—25)

This invention relates to gas operated devices and more particularly to such devices adapted to effect the sudden release of a charge of compressed gas to serve as a work performing medium. While such devices are applicable to many commercial applications, the present invention will be described with particular reference to blasting cartridges utilizing a gas under pressure. This application is a continuation-in-part of application Serial No. 14,440, filed March 11, 1960, now abandoned, which in turn is a continuation-in-part of parent application Serial No. 842,082, filed September 24, 1959, and now abandoned.

Material breaking cartridges using compressed gas to execute the required work are well known and widely used in the mining industry. Such cartridges or blasting devices are all reliant upon the sudden release of compressed gas to give a quasi explosive effect. The predecessors of this type of blasting cartridges consisted essentially of a cylindrical gas containing cartridge having venting means. The cartridges were charged with gas under considerable pressure, sealed and then conveyed to the face to be worked. The compressed gas within these cartridges was released by elaborate remote control means. More recently, the practice has been to place an uncharged cartridge in the bore hole and pump gas through a suitable conduit into the cartridge in situ. Conventionally, these cartridges are formed of high strength materials and are provided with a relatively weak member which shears or ruptures so as to liberate the gas from the cartridge body. Since the amount of pressure that can be built up in the cartridge body is dependent upon the strength of the expendable member, the quantity of energy developed by the liberation of the gas can be controlled only within relatively wide limits. Such cartridges are generally satisfactory but have one serious inherent drawback. After each shot, operations must be interrupted to permit removal of the expendable portion which has ruptured or sheared and to replace it with a new one.

This shortcoming has been well recognized and has led to a concerted effort for the development of automatic shells. While many so-called automatic shells have been presented, they have met with only a modicum of success. The previous types of automatic cartridges are operable, but they are very heavy, complex and unreliable. Although the expendable portions of the shell have been eliminated, this elimination has introduced new and more serious problems. Normally, the known automatic shells rely upon a series of two or more control or pilot valves to initiate the main release valve. Such complexity of design leads to cartridges that are difficult to control and exceedingly difficult to discharge at a desired predetermined pressure. In addition, the great number of moving parts in the automatic shells prior to the advent of the present invention has confronted the industry with a formidable sealing problem.

Therefore, it is an object of this invention to provide new and improved automatic material breaking devices utilizing compressed gas. A further object is to provide a device of this character having novel gas release means. Another object of this invention is to provide a simplified automatic shell overcoming the disadvantages of the prior art. It is also an object of this invention to provide an improved automatic gas operated device that is readily adjusted to discharge at different pressures.

The manner in which these and other objects are accomplished will be apparent from the following specification together with the drawing in which:

FIGURE 1 is a longitudinal sectional view of a blasting device illustrating an embodiment of the present invention;

FIGURE 2 is a longitudinal view partially in section of the device of FIGURE 1 in condition immediately prior to discharge;

FIGURE 3 is a similar longitudinal view partially in section of the same device in an open position;

FIGURE 4 is a longitudinal sectional view of a blasting device illustrating another embodiment of the present invention;

FIGURE 5 is a longitudinal sectional view illustrating another modification of the invention;

FIGURE 6 is a longitudinal sectional view illustrating another blasting device encompassed by the present invention;

FIGURE 7 is a longitudinal sectional view of an additional embodiment of the invention; and

FIGURE 8 is a longitudinal sectional view illustrating other modifications encompassed by the present invention.

Referring to FIGURES 1, 2 and 3 of the drawing, an elongated tubular body formed of metal of a strength to contain gas under high pressure, for example 6,000 to 20,000 pounds per square inch, is indicated generally at 1. Suitable means, not shown, are provided at one end of the body for introducing compressed gas into it. The outer diameter of the body is such that it may be freely set within a bore drilled in the face of the material to be mined. The end of the body remote from the gas inlet is screw threadedly attached to an adapter 2 as indicated at 3. The adapter in turn is screw threadedly attached as indicated at 4 to a head cylinder 5. The adapter is provided with a groove 6 proximate one end to accommodate a resilient sealing means such as O-ring 7 to complete the seal between the adapter 2 and head cylinder 5. The end of the head cylinder remote from the adapter terminates in an internally threaded portion 8 by means of which it is connected to cylinder plug 9. The joint between the head cylinder 5 and cylinder plug 9 is sealed by means of resilient O-ring 10 positioned in groove 11 of the fixture. The external portion of the assembly is completed by nose cap 12 which is screw threadedly attached to cylinder plug 9 as shown at 13. The nose cap is provided as shown with one or more vents 14, and plug 9 is provided with indentations 51 to accommodate a spanner wrench or the like.

The head cylinder 5 is provided with a plurality of lateral exhaust ports 15 which are normally spanned and closed by sleeve valve 17, the seal being completed by O-ring 18 in groove 19 of the head cylinder. Sleeve valve seat 20 is slidably mounted within head cylinder 5 and is in sealing engagement with head cylinder 5 by means of O-ring 21 and groove 22. The end of the sleeve valve seat in contact with sleeve valve 17 is in the form of a modified knife edge 23. Thus, the internal faces of the sleeve valve and sleeve valve seat are both cylindrical with the internal diameter of the sleeve valve being slightly smaller than the internal diameter of the sleeve valve seat. It will be readily appreciated that the terminal portion 23 of sleeve valve seat 20 can assume any desired configuration to provide a metal-to-metal seal between these two members.

A control piston 24 is slidable within sleeve valve 17 with sufficient space 16 between them to permit flow of compressed gas around the control piston into secondary chamber 25. The control piston is provided with annular flange 26 which rests on sleeve valve 17 and forms a sliding fit with the internal diameter of head cylinder 5. The

control piston is provided with a plug **27** terminating in a portion **28** of reduced diameter within valve chamber **29**. Valve chamber **29** is in communication with main chamber **30** and secondary chamber **25** through annular space **16** and passageway **31**, and passageway **32**, respectively. Ball valve **33** is normally urged against valve seat **34** by helical spring **35**. That portion of the control piston remote from sleeve valve **17** terminates in a tubular section **36** having a central passageway **37**.

A control adjusting stem **38** is seated on cylinder plug **9**. A portion **39** of the control adjusting stem is of reduced diameter and is in telescopic engagement with terminal portion **36** of control piston **24**. The seal between control adjusting stem **38** and control piston **24** is completed by resilient O-ring **40**. The control adjusting stem terminates in a centrally positioned pin **41**. The stem has a passageway **42** substantially throughout its entire length and one or more orifices **43** provide communication between passageways **37** and **42**. Control spring **44** extends from flange **26** of control piston **24** to control spring seat **45**. The force of the control spring is readily adjustable by means of the screw threaded attachment **46** between the control adjusting stem **38** and spring seat **45**. The seal between cylinder plug **9** and control adjusting stem **38** is completed by resilient O-ring **47** in groove **48** of cylinder plug **9**. Groove **48** is preferably covered by stem thrust washer **49** on which the control adjusting stem rests.

The position of the control spring seat **45** is controlled and maintained by control seat pin **50** extending from the control spring seat into cylinder plug **9**. Also, that portion of the control adjusting stem **38** within nose cap **12** has a terminal portion of a flattened or polygonal shape to facilitate adjustment. This is indicated generally at **52**.

In operation, compressed air or other suitable gas is introduced into the main chamber **30** through an appropriate gas inlet. The compressed gas also enters chamber **25** by passing through the annular space **16** about the periphery of the control piston **24** and by means of passageways **31**, valve chamber **29** and passageways **32**. Therefore, the pressure in chambers **30** and **25** is substantially equal during the charging of the cartridge. Thus, during charging of the cartridge, both ends of the sleeve valve **17** and of the control piston **24** are subjected to substantially the same pressure.

However, since the effective cross-sectional area of that end of the sleeve valve facing nose cap **12** is greater than the effective area exposed at that end of the sleeve valve in contact with valve seat **20**, the valve is normally urged into a closed position as shown in FIGURE 1. As the pressure increases within the cartridge, the sealing pressure exerted on sleeve valve **17** also increases. On the other hand, pressure responsive control piston **24** has an effective differential cross-sectional area such that an increase in pressure urges the control piston away from the ports in the direction of the nose cap **12** in opposition to control spring **44**.

As the pressure within chambers **30** and **25** increases, the control piston is thus gradually forced to the right. Since piston **24** has a greater effective cross-sectional area in main chamber **30** than in secondary chamber **25**, it is the pressure within the main chamber alone that moves the control piston from its initial position as shown in FIGURE 1. It will be readily understood that the moving force exerted by the gas pressure in the main chamber tends to unseal the secondary chamber and opposes the sealing force exerted by the gas pressure in the secondary chamber. This sliding motion of the piston continues until ball valve **33** contacts pin **41**. At this point the seating pressure of ball valve **33** augments the force of control spring **44**. The movement of the control piston by the main chamber pressure is then interrupted with the tubular portion **36** of control piston **24** a short distance from shoulder **53** of control adjusting stem **38**. This position, which is shown in FIGURE 2 of the drawing, is

maintained until the predetermined discharge pressure is attained. It will be noted that when the control piston **24** is in this position that flange **26** of the control piston has traveled away from sleeve valve **17**. Thus, sleeve valve **17** is then maintained in a sealing position with relation to ports **15** only because of its differential effective cross-sectional area.

Upon reaching the predetermined discharge pressure, the pressure in the main chamber **30** is sufficient to move piston **24** further to the right so that the ball valve is unseated and the tubular portion of piston **24** abuts shoulder **53** of control adjusting stem **38** and secondary chamber **25** is vented to the atmosphere through vents **32**, passageway **37**, vent **43**, passageway **42** and vents **14**. The effective cross-sectional area of this venting system is much greater than the effective cross-sectional area of the passageway **16** from chamber **30** into chamber **25**. Thus, the pressure in chamber **25** is reduced, the pressure on the right side of sleeve valve **17** is also suddenly reduced through passageways **31** and pressure on the left side causes the valve to fly open, liberating through exhaust ports **15** the charge of compressed gas contained in main chamber **30**. Accordingly, the gas pressure in the main chamber **30**, upon reaching the desired discharge pressure, causes the ball valve to open reducing the pressure in chamber **25** with consequent discharge of the gas from chamber **30** through ports **15**. This is illustrated in FIGURE 3 of the drawing.

The cartridge of this invention is fully automatic. After the charge of compressed gas is substantially expelled from chamber **30**, sleeve valve **17** and control piston **24** are returned to their original closed position as shown in FIGURE 1 by control spring **44**. The cartridge is then in condition to be recharged.

The cartridges shown in FIGURES 4, 5 and 6 function in substantially the same manner as the cartridge shown in FIGURE 1. However, in these embodiments, the control piston and the ball valve are responsive to pressure within the control chamber rather than within the main chamber. While it is generally preferred to utilize cartridges in which the control piston moves in response to pressure within the main chamber, there are some instances in which it may be advantageous to have the venting means contained entirely within the control chamber. Such embodiments illustrated in FIGURES 4, 5 and 6 show the versatility of the present invention. The same numbers are employed to identify similar portions of the cartridge in the various embodiments.

In the embodiment illustrated in FIGURE 4, valve **17** is slidable within head cylinder **5** and divides the cartridge into main chamber **30** and control chamber **25** which are connected by vent **55** in valve **17**. As in the previous embodiments, the differential effective cross-sectional areas on either end of the valve normally urge it into a closed position spanning discharge ports **15** and into sealing abutting relationship with valve seat **20**. Control piston **24** is provided with a stem portion **56** having a central passageway **57** and being slidably mounted within fixture **58**. The juncture between the latter member and the head cylinder **5** is secured by O-ring **59** while a sliding seal between fixture **58** and piston stem **56** is obtained by means of O-ring **60**. That portion of the control piston **24** opposite stem portion **56** terminates in a cylindrical section **61** which accommodates valve chamber **29** and is screw threadedly attached to valve seat member **34**.

Ball valve **33** is urged into seating position by helical spring **35**. In this embodiment, the control stem **38** is integral with and is an extension of solid nose cap **12**. Control piston **24** and the valve assembly is normally urged to the left by control spring **44**, the force of which can be regulated by the position of control spring seat **45**. Control spring chamber **62** to the right of ball valve **33** is exposed to the atmosphere through control vents **63**. The outside diameter of piston stem **56** is somewhat larger

than the contact diameter of ball valve seat 34 and the effective cross-sectional area of vent 55 is smaller than either of these values. This relationship is essential to the successful operation of the cartridge.

When a charge of compressed air or other gas is introduced into the cartridge of this embodiment, the pressure within main chamber 30 and control chamber 25 is substantially the same due to the passage of air through vent 55 between the chambers. As the gas pressure increases within the cartridge, valve 17 is urged with progressively increasing force against its valve seat 20 due to the effective differential cross-sectional areas on either end of the valve. Also, as the pressure in control chamber 25 increases, control piston 24 is gradually urged to the right in opposition to control spring 44. This movement of the control piston continues until ball valve 33 contacts centrally positioned pin 41 on the end of control stem 38. When the pressure is increased to adjusted discharge value, further movement of the control piston to the right results in the unseating of ball valve 33. Since the diameters of valve seat 34 and of central passageway 57 in stem portion 56 of control piston 24 are greater than the daimeter of vent 55 in valve 17, the pressure within control chamber 25 is rapidly reduced. When the ball valve is unseated the compressed gas in the control chamber passes into spring chamber 62 and thence to the atmosphere through vents 63. With the sudden reduction of pressure within control chamber 25, valve 17 is rapidly forced to the right, exposing lateral outlet ports 15 which permits rapid and efficient discharge of the compressed gas within main chamber 30. After the pressure has been relieved within main chamber 30, valve 17 is returned to its normal closed position by valve closing spring 64.

The structure of the cartridges illustrated in FIGURES 5 and 6 is quite similar to that of the cartridge illustrated in FIGURE 1. However, they differ from the embodiment of FIGURE 1 primarily in that the movement of the control piston is responsive solely to an increase in pressure within the control chamber instead of an increase in pressure within the main chamber. They also differ from FIGURE 1 in that the O-ring 47 is omitted and a metal-to-metal seal is shown where shoulder of stem 38 rests upon cylinder plug 9. With particular reference to FIGURE 5 of the drawing, valve 17 is slidable within head cylinder 5 between main chamber 30 and control chamber 25. Vent 55 in the bottom of the valve provides communication between the two chambers and has a smaller effective cross-sectional area than the venting passageways for the control chamber. When a charge of compressed gas is introduced into the main chamber 30, it passes through vent 55 at a slightly reduced rate into control chamber 25, thus maintaining the chambers at substantially the same pressure. Since valve 17 has a greater effective cross-sectional area in control chamber 25 than in main chamber 30, the sealing force between valve 17 and its valve seat 20 gradually increases to a maximum value immediately prior to the discharge of the cartridge. Likewise, control piston 42 has a greater effective cross-sectional area on its left hand end than on its right hand end. Thus, as pressure within control chamber 25 acting on end 27 is increased, the control piston is urged to the right in opposition to control spring 44. This gradual movement of the control piston continues until ball valve 33 contacts centrally positioned pin 41. At this point, the force of control spring 44 resisting movement of the control piston is augmented by the force necessary to overcome the seating pressure of ball valve 33. The movement of the control piston is then interrupted with the tubular portion 36 of control piston 24 a short distance from shoulder 53 of control adjusting stem 38. This condition with the ball valve in contact with seat 34 and pin 41 is maintained until the predetermined discharge pressure is attained. At that point, the control piston continues its movement to the right, unseating ball valve 33. When the valve is unseated, the control chamber is vented in much the same way as previously explained in connection with the embodiment illustrated in FIGURE 1 of the drawing. Thus, the control chamber is rapidly vented through passageway 31, valve chamber 29, central passageway 37, orifices 43, passageway 42, chamber 54 and vents 14. With the control chamber thus effectively evacuated and the control piston in its right hand position, valve 17 rapidly moves to the right, exposing lateral exhaust ports 15 and permitting discharge of the compressed gas in main chamber 30. After the cartridge has substantially discharged and the pressure therein has been reduced, valve 17 and control piston 24 are returned to their original positions by means of control spring 44. Likewise, ball valve 33 is returned to its seated condition by helical spring 35. The cartridge of this embodiment is thus completely automatic and is again in position to be charged.

The cartridge shown in FIGURE 6 of the drawing is quite similar to the one described immediately above but illustrates a modification in which a relatively short stroke control piston can be utilized. This modification permits placing the discharge ports closer to the nose cap than in the cartridge of FIGURE 5.

In this embodiment, the open end of valve 17 faces toward control chamber 25 rather than main chamber 30 and a separate valve closing spring 64 is employed. In all other respects, the operation of the cartridge illustrated in FIGURE 6 of the drawing is identical with that of FIGURE 5. Compressed gas entering main chamber 30 passes through vent 55 in the top of valve 17 into secondary chamber 25. As the pressure within the cartridge increases, the sealing force between valve 17 and its seat 20 increases to a maximum which is attained at the predetermined discharge pressure. Likewise, control piston 24 is gradually urged to the right against control spring 44 until ball valve 33 contacts pin 41, which position is maintained until the predetermined discharge pressure is reached. Then control piston 24 moves quickly to the right until its tubular section 36 contacts shoulder 53 of control adjusting stem 38. At this point, the control chamber is rapidly evacuated and the gas within main chamber 30 discharged in the same manner as described above. The cartridge is then returned to its original condition by control spring 44, valve closing spring 64 and helical spring 35.

The cartridges shown in FIGURES 7 and 8 are quite similar in design and operation to the cartridge of FIGURE 1. However, they differ therefrom in a number of structural modifications. The more significant of these modifications will now be indicated.

With reference to FIGURE 7 it will be noted that the outside surface of sleeve valve seat 20 is not stepped but that this member is restrained in its movement to the right by constriction 66 of head cylinder 5. Also, piston 24 has been slightly elongated and cavitated or necked down adjacent shoulder 26 providing a larger annular recess 67. Passageway 31 extends transversely through piston 24 and provides a means of communication between annular recess 67 and spring chamber 29. As the control piston moves to the right cavity 67 is enlarged and upon unseating of the ball valve, the pressure in this cavity or portion of chamber 25 is reduced along with the pressure in the remainder of chamber 25 and the reduction in pressure in the cavity 67 causes the valve 17 to fly open and release the gas from main chamber 30 through ports 15. Depending upon the dimensions of the various passageways and clearances, opening of the ball valve can effect a more rapid reduction in pressure in the cavity 67 than in the remainder of chamber 25, in which event valve 17 will fly open earlier than would be expected from the residual pressure in the remainder of chamber 25. Where chamber 25 is large, this may be used to advantage. Here again, increased pressure in chamber 25 tends to maintain the ball valve closed, where-

as increased pressure in the main chamber **30** tends to unseat the ball valve.

The shell shown in FIGURE 8 is substantially the same as that shown in FIGURE 7. However, the cartridge of FIGURE 8 is provided with a cylinder liner **68**. This member is positioned around helical spring **44** and within the secondary chamber **25**. The liner has as its primary function the reduction of the volume in secondary chamber **25**. With such a reduction in volume of the secondary chamber, the ratio of the volume of chamber **25** to the volume of main chamber **30** is favorably reduced. The establishment of such a favorable minimum ratio renders the cartridge more responsive to the action of ball valve **33**. Since the volume of chamber **25** is greater with increasing shell diameter, the provision of cylinder liner **68** becomes increasingly significant with an increase in diameter.

The discharge pressure of cartridges made in accordance with this invention can be readily and precisely controlled. This control can be most easily achieved by controlling the relative cross-sectional areas at contact point of the ball valve seat and the diameter of that telescopic portion of the control piston which separates and seals the internal pressure from atmosphere. The cross-sectional area of the ball valve seat is necessarily smaller than the cross-sectional area of said telescopic portion so that there will be available a net force due to gas pressure tending to continue movement of the control piston to the right in opposition to the force of control spring **44**. As the size of the ball valve seat increases in relationship to the outside diameter of the telescopic portion, the force required of the control spring to obtain a desired discharge level is materially reduced and smaller, more easily adjusted springs can be employed. Thus, in accordance with the present invention, the force required to unseat the ball valve against air pressure is the major controlling force and the control spring with its adjustment serves in effect as a vernier to control discharge levels within relatively narrow limits. The discharge pressure of cartridges made in accordance with this invention can therefore be adjusted to increments of about 1% or less without relying upon major modifications or heavy springs.

The cartridge of the present invention is exceedingly durable and requires only about half as many moving parts as are normally necessary in automatic devices of this type. Also, the wear on the parts is reduced to a minimum because in most instances they are separated and in effect lubricated by a layer of high pressure gas. In addition, the normal heating tendency of such gas operated devices is obviated in accordance with present invention by the provision of an expansion chamber **54** within nose cap **12**. As the highly compressed gas within the device is vented through passageway **42** into chamber **54**, the expanding gas has a pronounced cooling effect upon the nose cap **12** and cylinder plug **9**. This cooling effect is carried by conduction substantially throughout the entire length of head cylinder **5**. This prevents any moving portion of the device from reaching temperature ranges which would result in binding of the moving parts or in deterioration of the sliding seals. It also permits handling of the device immediately after discharge. Expansion chamber **62** shown in the embodiment of FIGURE 4 provides similar cooling of that cartridge.

In some instances, nose cap **12** at the end of the shell has a tendency to become loosened and eventually to separate from the body of the shell. Such an occurrence can be avoided in a number of ways. For example, a compression spring having a reverse helix can be positioned in chamber **54** about terminal portion **52** of control adjusting stem **38** and in close association with the internal wall of the nose cap. If the nose cap is screwed to the shell by a right hand thread, a left hand helical spring is employed, and vice versa. Likewise, the nose cap position can be secured by a weld, bolt, spring latch, knurled mating surfaces or by any other suitable means. In such instances where the nose of the shell is sufficiently confined in the end of the bore hole to provide an expansion chamber about the nose equivalent in effect to chamber **54**, nose cap **12** may be omitted. Likewise, the cap may be otherwise constructed as long as the desired cooling effect is obtained.

While the pressure of the gas in the device of this invention is substantially the same in all pressure chambers until the discharge operation is initiated, perhaps the invention can be better understood by a consideration of what happens to the gas in each chamber and what its function is in the operation of the device. For instance, in the embodiments illustrated in FIGURES 1, 2, 3, 6, 7 and 8 it can be considered there are four gas chambers, namely the main chamber **30**, what might be called a control chamber **67**, what might be called a differential pressure chamber **25**, and what might be called a valve chamber **29**. The gas in chamber **30** is the large volume of gas which performs the work done by the device and which functions in the operation of the device in the embodiments of FIGURES 1, 2, 3, 7 and 8 to push the piston **24** to the right until the ball valve is unseated and the gas in chambers **67**, **29** and **25** flows through the respective passageways to the exterior of the shell and until the sleeve valve **17** moves to open ports **15**. The gas in chamber **30** thereupon flows out the ports **15** and accomplishes the work for which the device was designed. In the embodiment of FIGURE 6, the gas in chamber **30** follows the same pattern and performs the same functions except that it does not push the piston **24** to the right. In the embodiment of FIGURE 6 the piston is pushed to the right by the gas in the control chamber **67**.

The gas in chamber **67**, which chamber incidentally is enlarged by movement of the piston to the right, pushes sleeve valve **17** to the left to maintain the ports **15** sealed, pushes piston **24** to the right until the ball valve is unseated and then flows through vents **31** into the valve chamber **29** in the embodiments of FIGURES 1, 2, 3, 7 and 8. In the embodiment of FIGURE 6 upon unseating of the ball valve the gas in chamber **67** flows through vent **32** into valve chamber **29**.

The gas in valve chamber **29** pushes equally in all directions both to the right and to the left so that the gas in this chamber is not effective in moving the piston but is effective in holding the ball valve in its seat until the ball valve is unseated by movement of the piston whereupon the gas from the valve chamber flows through passageway **37** to the exterior of the cartridge.

The gas in the differential pressure chamber **25** is not effective to open the ball valve but tends to push the piston **24** to the left opposing the force of the gas in chamber **30** along with the main spring **44**. A main function of the gas in this differential pressure chamber is to add its force to that of the main spring **44** in opposing the force exerted by the gas in chamber **30** so that larger amounts of gas may be charged into chamber **30** with subsequently higher discharge pressures which would otherwise require an inordinately large spring force to prevent discharge at lower pressures. The gas in differential pressure chamber **25** upon unseating of the ball valve flows through vents **32** into the valve chamber in the embodiments of FIGURES 1, 2, 3, 7 and 8 and in the embodiment of FIGURE 6 flows between the edge of flange **26** and the head cylinder **5** into control chamber **67**. In the embodiment of FIGURES 1, 2, 3, 7 and 8 the gas in differential chamber **25** likewise tends to flow between the flange **26** on the piston **24** and the head cylinder **5** into control chamber **67** upon unseating of the ball valve **33**.

Thus it may be seen that in general the gas in chamber **30** does the work of the device. The gas in chamber **67** upon being vented to the atmosphere causes sleeve valve **17** to fly open and unseal ports **15**, the gas in valve chamber **29** holds the ball valve **33** in closed position and the gas in differential pressure chamber **25** adds its force to that of the spring opposing opening of the ball valve **33**

by the force of the gas in chamber 30. Any tendency of the gas in chamber 67 to push the piston 24 to the right is cancelled out by the force of the gas in differential pressure chamber 25, so that the gas in chamber 30 is solely responsible for unseating the ball valve 33. The embodiment of FIGURE 6 differs only in that the gas in control chamber 67 pushes the piston 24 to the right against the force of the gas in chamber 25 and the force of main spring 44. In these embodiments if the clearance between the flange 26 of the piston 24 and the head cylinder 5 is sufficiently great that no differential in gas pressure occurs between chambers 25 and 67 upon unseating of the ball valve 33, then for all practical purposes chambers 25 and 67 are but one chamber and the sleeve valve 17 will not move out of sealing position until the pressure in 25 and 67 has been sufficiently reduced. Where the clearance between flange 26 and head cylinder 5 and other gas passageways are insufficient to maintain the pressures in 25 and 67 equalized upon unseating of the ball valve, then the pressure in the chamber 67 will be controlling as regards movement of the sleeve valve 17 into unsealing position. The device of this invention may be so dimensioned and constructed as indicated above that the sleeve valve 17 moves into unsealing position when the gas pressure in chamber 67 is less than, or equal to, or greater than the gas pressure in chamber 25 with success and with advantages to be gained by each mode of operation, e.g. the residual pressure in chamber 25 upon discharge may be greater or less depending upon the mode of operation and somewhat more rapid discharge may be attainable if only the small volume of gas in chamber 67 is required to be vented in order to cause the sleeve valve 17 to move to unsealing position. In the embodiments of FIGURES 4 and 5 the chamber 67 is eliminated and the gas in chamber 25 pushes the piston 24 to the right effectively causing the ball valve to unseat.

While the invention has been described with particular reference to blasting or coal breaking cartridges, it will be readily appreciated that it is also applicable to any pressure release device in which a charge of compressed gas is suddenly liberated to act as a work preforming medium. Such devices include metal working and shaping devices, cutting devices, power cartridges, safety valves, and the like.

Although the invention has been described in considerable detail in the foregoing for the purpose of illustration, it is to be understood that such detail is solely for that purpose and that many modifications can be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A gas operated device comprising a cartridge having a substantially cylindrical main chamber adapted to receive a charge of compressed gas, gas inlet means at one end of the main chamber, lateral discharge outlets for the main chamber intermediate its ends, a control chamber positioned adjacent the other end of said main chamber, a pressure responsive valve positioned between the chambers slidable within the cartridge and normally positioned to span and seal the discharge outlets one end of said valve having a greater cross sectional area exposed to the pressure in the chambers than the opposite end of said valve, the differential effective cross-sectional areas of the valve urging the valve into a closed position during charging of the main chamber, a pressure equalizing passageway between the chambers, a slidable pressure responsive control piston normally positioned between the main chamber and the control chamber, one end of said piston having a greater cross sectional area exposed to the pressure in the chambers than the opposite end of said piston, the differential effective cross-sectional areas of the control piston urging it away from the valve, a ball valve in the control piston, a vent in the piston between the ball valve and the control chamber, resilient means urging the ball valve into its seat, the end of the control piston remote from the main chamber terminating in a hollow tube, said vent being open to the control chamber on one end and the hollow tube on the other end, a stationary hollow stem telescopically sealed within the hollow tube, the hollow tube and stem providing a passageway between the control chamber and the atmosphere, the passageway normally closed by the ball valve, the stem adapted to unseat the ball valve and open the passageway when the control piston has traveled a predetermined distance in response to pressure within the main chamber.

2. The gas operated device of claim 1 in which the cross-sectional area of the ball valve seat is smaller than the cross-sectional area of the stationary hollow stem.

3. A gas operated device comprising a cartridge having a substantially cylindrical main chamber adapted to receive a charge of compressed gas, gas inlet means at one end of the main chamber, lateral discharge outlets for the main chamber intermediate its ends, a secondary chamber positioned adjacent the other end of said main chamber, a pressure responsive valve slidable within the cartridge and normally positioned to span and seal the discharge outlets, one end of said valve having a greater cross sectional area exposed to the pressure in the chambers than the opposite end of said valve, the differential effective cross-sectional areas of the valve urging the valve into a closed position during charging of the main chamber, a pressure equalizing passageway through said valve and connecting the chambers, a pressure responsive control piston slidably mounted in said secondary chamber adjacent the valve, one end of said piston having a greater cross sectional area exposed to the pressure in the chamber than the opposite end of said piston, the differential effective cross-sectional areas of the control piston urging it away from the valve, resilient means in the secondary chamber urging the control piston towards the valve, vent means for said secondary chamber, said vent means including an opening in said piston communicating the interior of said piston with said secondary chamber and a tubular member mounted in said secondary chamber having one end opening in the interior of said piston and the other end opening to the atmosphere, a pressure responsive control valve mounted within the piston, the vent normally being closed by the control valve, and means to open said control valve when the control piston has traveled a predetermined distance in response to pressure within the main chamber.

4. A gas operated device comprising a cartridge having a substantially cylindrical main chamber adapted to receive a charge of compressed gas, gas inlet means at one end of the main chamber, lateral discharge outlets for the main chamber intermediate its ends, a secondary chamber positioned adjacent the other end of said main chamber, a pressure responsive sleeve valve slidable within the cartridge between the chambers and normally positioned to span and seal the discharge outlets, said valve having a greater cross sectional area at one end exposed to the pressure in the chambers than at the opposite end, the differential effective cross-sectional areas of the valve urging the valve into a closed position during charging of the main chamber, a slidable pressure responsive control piston adjacent the valve, the piston having a terminal portion with a diameter slightly less than the inside diameter of the sleeve valve and being provided with a shoulder having a diameter greater than the inside diameter of the sleeve valve, the difference in diameter between the inside of said sleeve valve and the terminal portion of said piston providing a passageway to equalize the pressure in said main and secondary chambers during charging of the cartridge, the terminal portion and shoulder of the piston being joined by a portion of reduced diameter, the terminal portion of the piston being normally positioned within the sleeve valve and the shoulder portion normally abutting said valve the cross sectional areas of the piston exposed to the pressure in the chambers being greater at one end than at the opposite end of said piston, the dif-

ferential effective cross-sectional areas of the control piston urging it away from the valve, an opening in said piston communicating the interior of said piston with said secondary chamber, means defining a passageway from the interior of said piston to the atmosphere, control valve means mounted within the control piston adapted to vent the secondary chamber through said opening and said passageway at a predetermined discharge pressure and means in the secondary chamber operative to open said control valve means at said predetermined pressure.

5. A gas operated device comprising a cartridge having a main chamber and a secondary control chamber, gas inlet means at one end of the main chamber and lateral discharge outlets in the side walls of the main chamber, said control chamber positioned adjacent the other end of said main chamber, a main valve slidably mounted in the cartridge between the main and secondary chambers and normally positioned to span and seal said discharge outlets, the end of the main valve remote from the gas inlet means having a greater cross sectional area exposed to the pressure in the chambers than the opposite end of said valve, this differential area being effective to urge the main valve into sealing engagement with the discharge outlets during charging of the cartridge, a pressure equalizing vent extending from the main chamber to the control chamber, a pressure responsive control piston slidably mounted in the control chamber, the end of the control piston adjacent the main valve having a greater cross sectional area exposed to the pressure in the chamber than the cross sectional area at the opposite end of said piston exposed to the same pressure, this differential area being effective to move the piston in a direction away from the main valve during charging of the cylinder, a spring positioned in the secondary chamber and urging the piston toward the main valve, means defining a passageway from said control chamber to the outside of said cartridge, a vent in said piston opening at one end to the control chamber and at the other end opening to said passageway, a ball valve and valve seat positioned in said passageway, spring means urging said ball valve onto the valve seat and sealing said passageway, and means positioned in the control chamber adapted to unseat the ball valve upon a predetermined movement of the piston in the control chamber and vent said control chamber to the outside.

6. The device of claim 5 in which the control piston has a reduced head portion which is slidably seated in the main valve and said pressure equalizing vent is located between the reduced head portion of the piston and the side walls of the main valve.

7. The device of claim 15 in which a sleeve is positioned in the secondary chamber to reduce the volume of the secondary chamber.

8. A gas operated device comprising a cartridge having a main chamber and a control chamber, gas inlet means positioned at one end of the main chamber, said control chamber positioned adjacent the other end of said main chamber, lateral discharge outlets in the side walls of the main chamber, a pressure responsive main valve slidably mounted in the cartridge between the main chamber and the control chamber and normally positioned to span and seal said discharge outlets, the end of the main valve remote from the gas inlet having a greater cross sectional area exposed to the pressure in the chambers than the opposite end of the valve, this differential area being effective to urge the main valve into sealing engagement with the discharge outlets during charging of the cartridge, a pressure equalizing passage positioned between the main chamber and the control chamber, a pressure responsive control piston slidably mounted in the control chamber, the end of the control piston adjacent the main valve having a greater cross sectional area exposed to the pressure in the chamber than the opposite end of the piston, this differential area being effective to move the piston in a direction away from the main valve during charging of the cartridge, a spring in the control chamber opposing the movement of the control piston, a hollow tube at one end of the control piston, lateral openings in the side walls of the piston communicating with the hollow tube, a hollow stem open at both ends mounted in the cartridge, one end of the hollow stem being in sealed telescopic engagement with the hollow tube and the other end of said stem being exposed to the atmosphere, said tube, stem, and lateral openings in the piston defining a passageway from the control chamber to the atmosphere, a spring biased ball valve closing the passageway between the lateral openings and the tube, and means on the stem adapted to contact and unseat the ball valve when the piston has moved a predetermined distance in the control chamber.

9. The device of claim 8 in which a spring seat is adjustably mounted on said hollow stem and the spring in the control chamber is positioned between the piston and the spring seat so that the tension in the spring can be regulated by adjusting the spring seat.

10. The device of claim 8 in which the passageway from the control chamber terminates in an expansion chamber vented to the atmosphere.

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