

June 15, 1937.

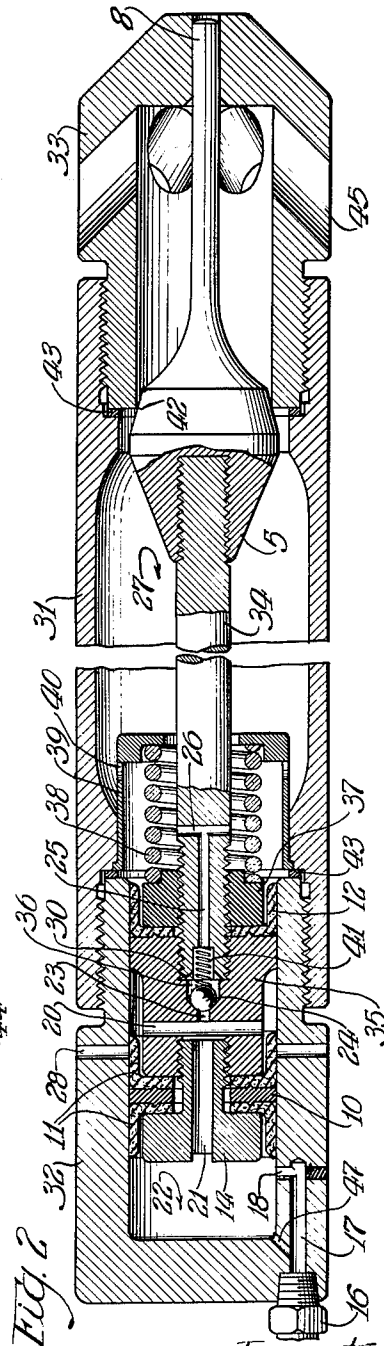
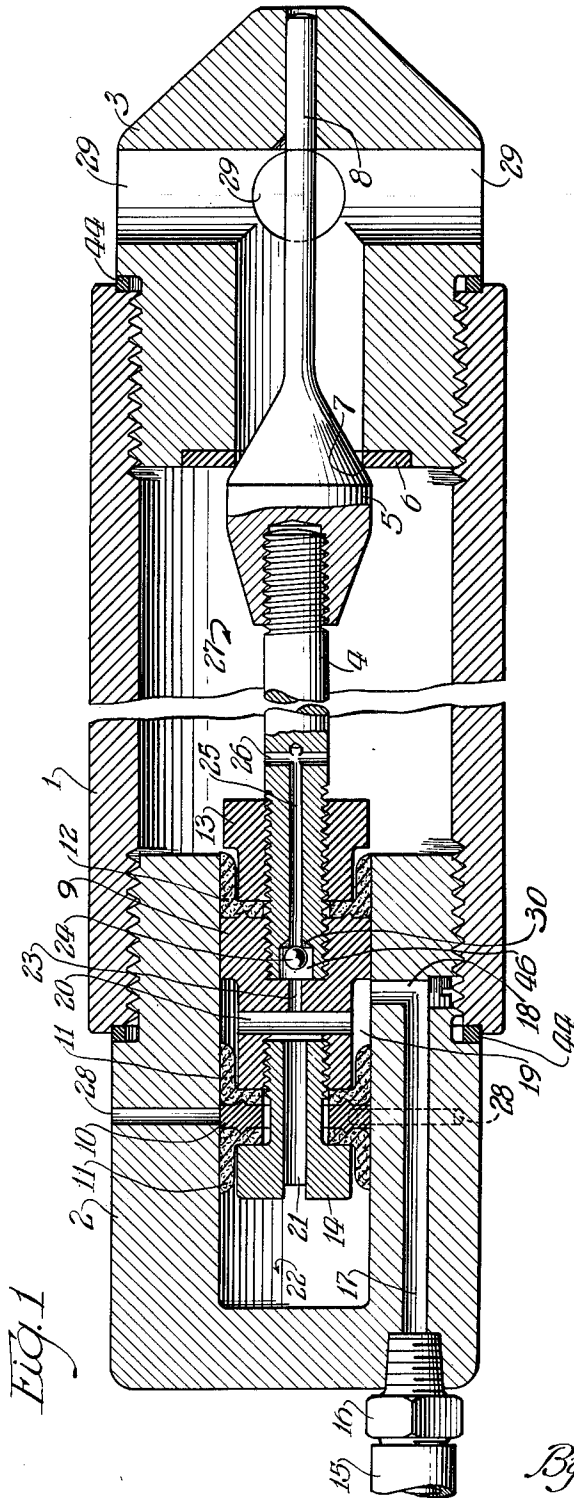
F. H. ARMSTRONG

2,083,976

MATERIAL BREAKING DEVICE

Filed March 30, 1934

5 Sheets-Sheet 1



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June 15, 1937.

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MATERIAL BREAKING DEVICE

2,083,976

Filed March 30, 1934

5 Sheets-Sheet 2

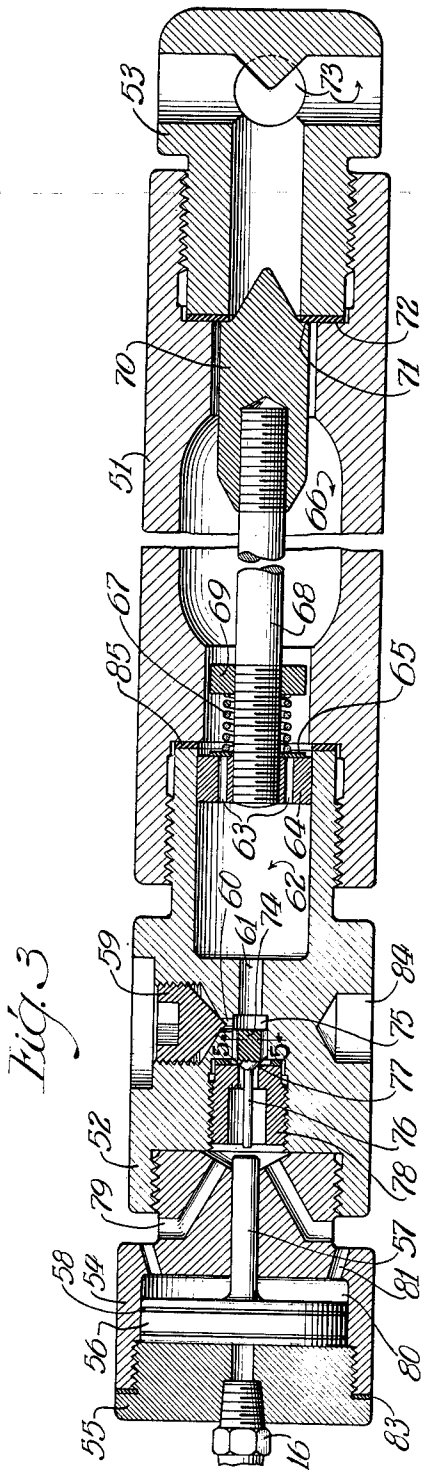


Fig. 4.



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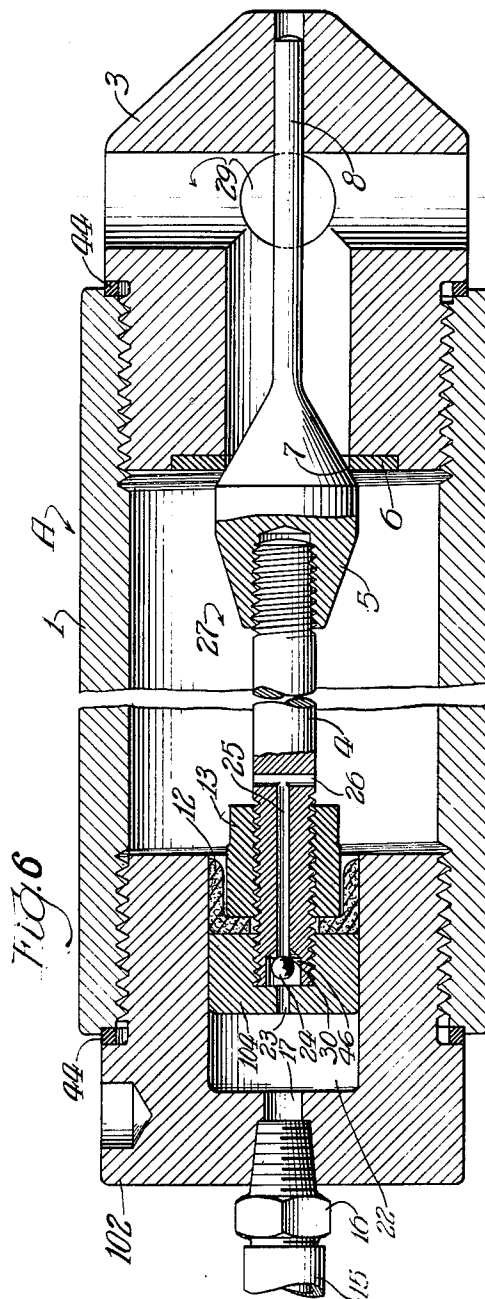
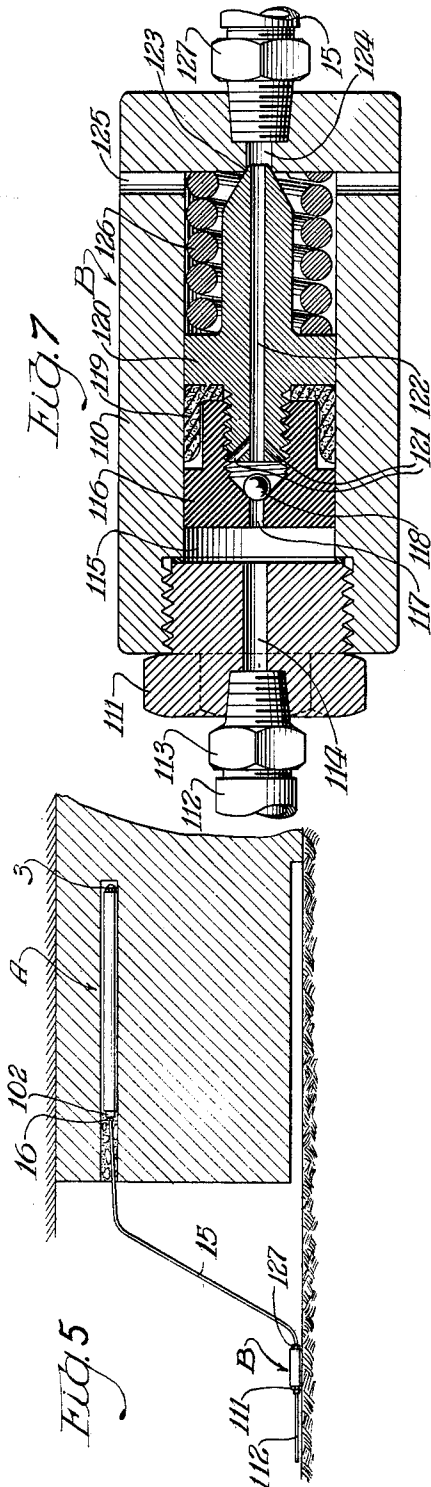
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2,083,976

MATERIAL BREAKING DEVICE

Filed March 30, 1934

5 Sheets-Sheet 3



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2,083,976

MATERIAL BREAKING DEVICE

Filed March 30, 1934

5 Sheets-Sheet 4

Fig. 11

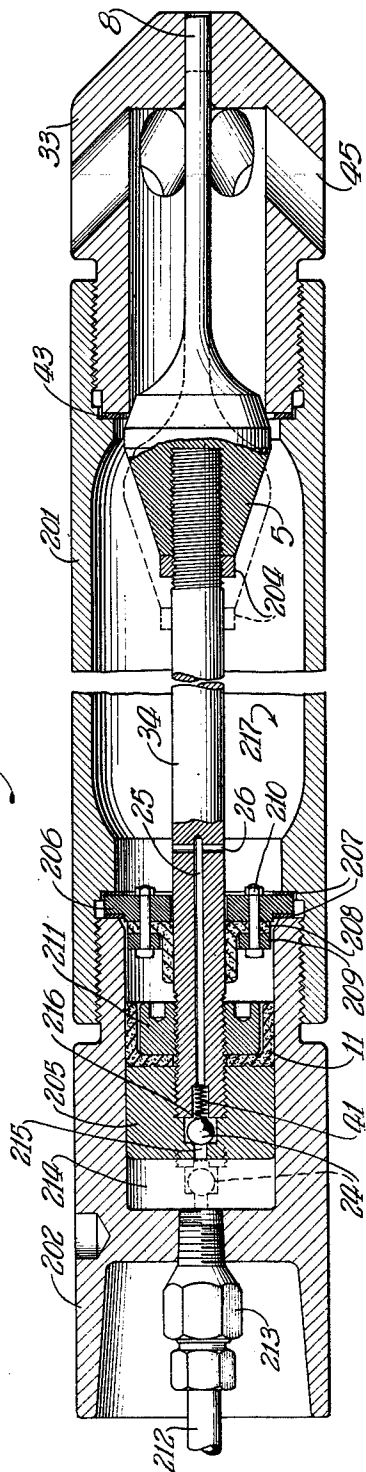


Fig. 8.

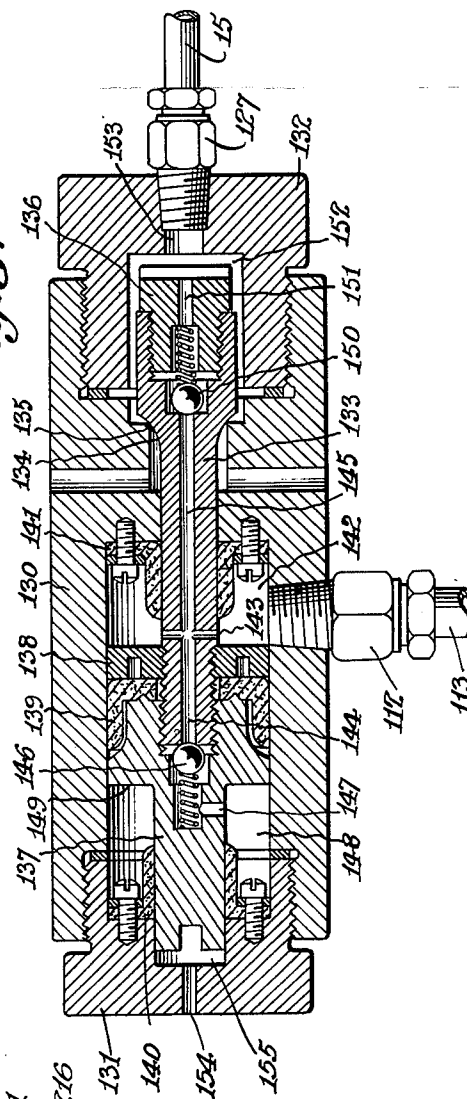
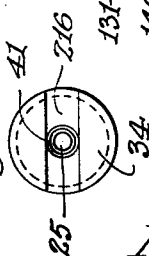


Fig. 12.



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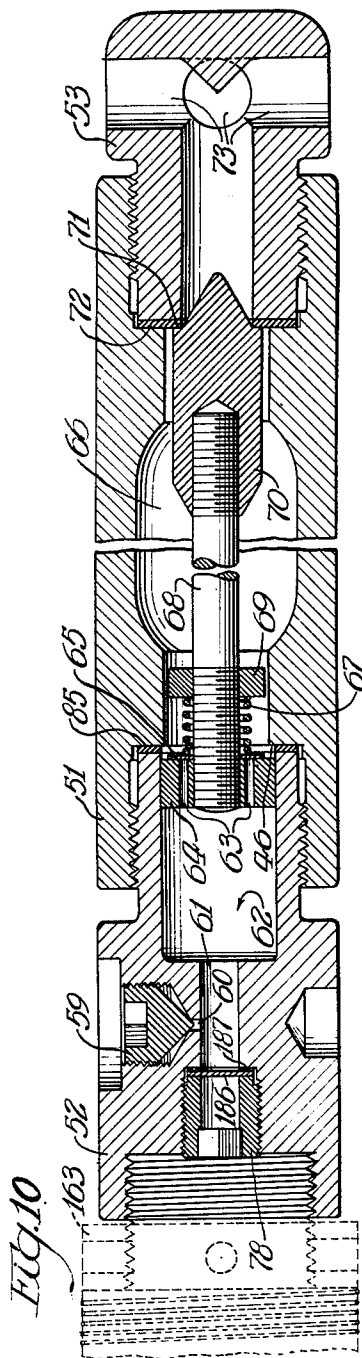
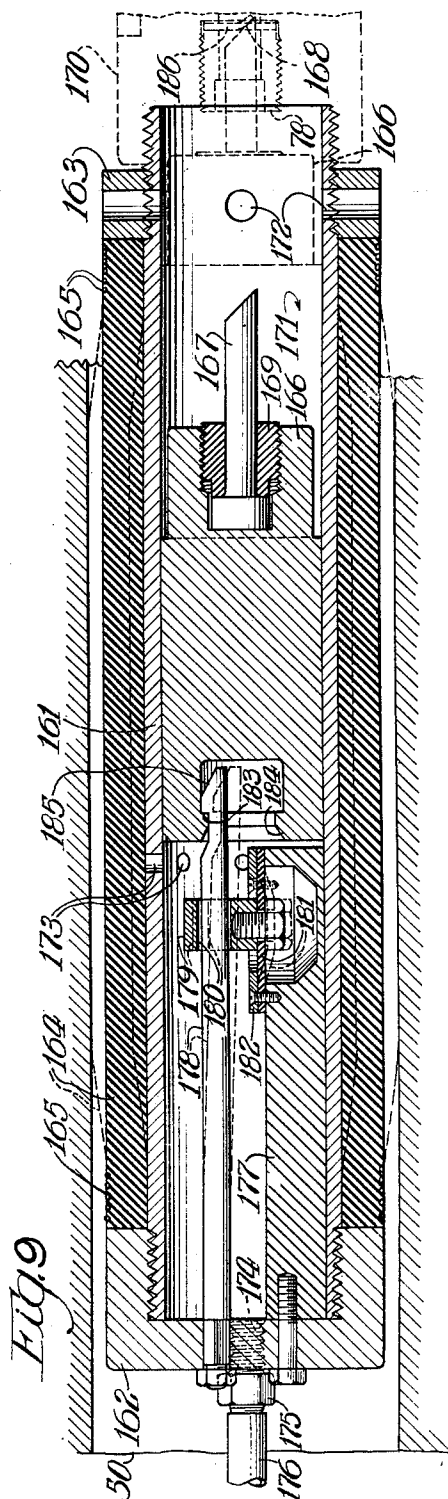
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MATERIAL BREAKING DEVICE

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5 Sheets-Sheet 5



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UNITED STATES PATENT OFFICE

2,083,976

MATERIAL BREAKING DEVICE

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Application March 30, 1934, Serial No. 718,175

37 Claims. (Cl. 102—6)

There has been developed a commercially successful method and apparatus designed to perform the classes of work for which explosives are ordinarily required and used, which method involves merely a proper handling and application of compressed air or other gas at pressures quite low in relation to the pressures developed by explosives ordinarily used in such work. Broadly speaking, the difference in pressure between explosives as ordinarily used and the compressed air or other gas as used in the performance of this method is compensated by the use of a large volume of the compressed air or other gas. In other words, the compressed air method relies upon the application of a minimum amount of force required in a particular situation coupled with the expansion of a large volume of the compressed air or gas. One of the important factors in the practice of this new method is the relationship between the volume of the charge, the pressure of the charge and the speed with which the charge is applied to the work at hand.

This new method is practiced in two general ways. One is to introduce into a suitable cartridge or container a charge of compressed air or gas of proper volume and at a proper pressure for the particular work at hand and to then suddenly liberate the charge. According to a second method, a cartridge or container may be positioned in or in operative relation to the material to be acted upon and may be connected by piping to a source of compressed gas at some remote point, suitable means being provided for permitting the flow of compressed gas from the source of supply into the cartridge or container and for suddenly liberating this charge when it has reached a desired value.

The present invention relates to the new method briefly characterized above. The principal object of the invention is to provide the most efficient forms of apparatus for practicing the method under different conditions.

It is also an object of the invention to provide certain reliable safety characteristics in equipment of this kind.

It is a further and very important object of the invention to provide a form of apparatus designed to operate with a minimum of expense and preferably without any element of recurring expense other than normal maintenance.

Referring to the drawings,

Figure 1 is a view in longitudinal section through one form of cartridge or container designed to fulfill the objects of this invention.

Figure 2 is a similar view through a slightly modified form of cartridge.

Figure 3 is a view in longitudinal section through a cartridge which will be hereinafter referred to as the precharged type as distinguished from the type represented in Figures 1 and 2, which is designed to be charged from a remote point after being placed in or in operative relation to the material to be acted upon.

Figure 4 is a sectional detailed view taken along line 4—4 of Figure 3.

Figures 5, 6 and 7 relate to a form of the remote charged cartridge and more particularly to a method and means for effecting the charging and discharging of such a cartridge. Figure 5 illustrates the cartridge in a position in a drill hole formed in a face of coal to be broken down. Figure 6 is a view in longitudinal section illustrating the construction of the cartridge in its simplest form, and Figure 7 is a view in longitudinal section illustrating the construction of the valve B which governs the charging and discharging of the cartridge.

Figure 8 is a view in longitudinal section illustrating a modified form of valve for use in the situation illustrated in Figure 5.

Figures 9 and 10 relate to a further alternative form of the precharged cartridge, Figure 10 illustrating in longitudinal section the cartridge itself and Figure 9 illustrating the construction and method of operation of the device used in conjunction with the cartridge for effecting the discharge thereof and also for anchoring the cartridge against displacement.

Figure 11 is a view in longitudinal section illustrating the preferred and perfected form of cartridge design for charging and discharging under control from a remote point.

Figure 12 is a detailed view of a part shown in Figure 11.

In Figure 1, there is shown a complete cartridge or container consisting of a long tubular body 1 of any desired volumetric capacity. It will be understood, of course, that the mechanism of the cartridge may be the same, regardless of the capacity for which it is designed, the matter of capacity being determined entirely by the requirements of the work to be performed. In the use of this method and apparatus to replace ordinary explosives in the mining of coal and similar materials, it has been found that a cartridge of approximately 200 cu. in. of volumetric capacity is quite adequate. Such a cartridge will ordinarily take the form of a relatively long tube having an outside diameter of approximately 3".

The relation between length and diameter for any desired volumetric capacity is largely a matter of economics to be developed in relation to particular conditions.

5 The tube 1 is provided with caps 2 and 3, which for convenience will hereinafter be referred to as terminal cap and discharge cap respectively. The discharge cap 3 is of a familiar form such as has been used rather extensively in connection with material breaking cartridges employing carbon dioxide and a chemical heater unit as their source of energy. The cap is formed with an axial bore and a plurality of radial discharge openings 29 communicating therewith. The circular line defined by the end of the axial bore in the discharge cap is used in conjunction with a conical valve for sealing the charge of compressed gas within the cartridge. The valve may engage directly with the discharge cap or there may be provided as is shown a special sealing member 6 designed to have engagement with the valve as indicated at 7. This member may be made of a metal different from that of which the valve itself is made or it may be made of the same metal and serve simply as a readily renewable seat for the valve. The valve 5 has an axial extension 8 which, together with a suitably formed bore in the end of the cap, serves to center and guide the valve.

30 The valve 5 is secured to one end of the valve rod 4 which extends throughout the length of the cartridge and which carries on its opposite end a control mechanism governing the introduction and release of compressed gas to and from the interior of the cartridge. This mechanism consists of a plunger 9 having a snug sliding fit in the bore 22 formed in the terminal cap 2. A suitable cup leather 12 is provided inwardly of the plunger 9 and is held in position by a retaining nut 13. On the opposite end of the plunger 9 there is carried a secondary plunger assembly consisting of the nut 14, opposed cup leathers 11 and intermediate supporting disc 10. 45 It will be noted that a bore 21 extends through nut 14, placing the chamber 22 in communication with a transverse bore 20 and the chamber 19, the latter being formed between the two plunger assemblies. There is also a short bore extending from the transverse bore 20 into the pocket 46 of a ball check valve 24. Leading from the seat 30 of the ball check valve is a passage 25 and a communicating transverse passage 26 which opens into the main chamber of the cartridge. 50 It will be noted that the terminal cap 2 is provided with a plurality of radial ports or bores 28 which, with the parts in normal closed position, lie directly opposite the center of the plunger assembly consisting of the cup leathers 11, the disc 10 and nut 14. The main supply pipe 15 and nipple 16 are secured to the terminal cap 2 in communication with a charging passage 17 which communicates through a short passage 18 with the chamber 19 formed between the two plunger assemblies. Suitable sealing gaskets 44 are provided between the ends of the cartridge body and the terminal and discharge caps.

70 In utilizing a cartridge of this type it is customary to first position it in a drill hole formed in the material to be broken, with a supply pipe extending therefrom to a suitably remote point and there connected to a source of compressed gas. The source, of course, may be of any desired form, either a receiver charged with high

pressure air or other gas, or a suitable high pressure compressor.

The operation of this device will best be understood by tracing the flow of air from the supply pipe into and through the various passages formed in the valve and plunger mechanism of the cartridge. Thus, the air flows initially from the supply pipe 15 and nipple 16 through passages 17 and 18 into the chamber 19, thence through radial passage 20 and axial passage 21 into the chamber 22. In connection with this particular device, chamber 22 may be designated as a control chamber. High pressure air also flows from the radial passage 20 through axial passage 23 into ball check valve pocket 46 and past the ball check valve through passages 25 and 26 into the main chamber 27 of the cartridge. Analyzing the effect of the flow of air through the channels just mentioned, it will be observed that immediately upon the introduction of high pressure air into the chamber 22, a force will be exerted upon the end of plunger assembly consisting of the nut 14 and the outermost cup leather 11, this force acting in an axial direction and resulting in axial movement of the entire valve assembly, thus bringing the valve head 5 into sealing engagement with the discharge cap as indicated at 7. With the parts in this position, it will be observed that the several radial discharge ports 28 formed in the terminal cap 2 are effectively sealed against the escape of high pressure air both from the pocket 22 and the chamber 19 by virtue of the two opposed cup leathers 11. In this connection it should be mentioned that the cup leather 12 serves to prevent the flow of high pressure air from the main chamber 27 into the small chamber 19 between the two plunger assemblies. The flow of high pressure air from the supply pipe 15 into the main chamber of the cartridge through the various passages, as mentioned above, may be permitted to continue until the pressure value of the charge formed in the main chamber of the cartridge has reached a desired point, which will usually be determined by the judgment of the operator as to the amount of energy required to do the particular work at hand. When the charge within the cartridge has reached a desired value, the flow of high pressure air into the cartridge through the various channels mentioned may be discontinued by operation of a cut-off valve positioned in the supply pipe 15 at a point adjacent the source of supply. In order to effect discharge of the cartridge it is merely necessary to vent the supply pipe 15 to the atmosphere, which results in the following sequence of events:

The reduction in pressure within the supply pipe 15 results instantaneously in a corresponding pressure reduction in chamber 19, passages 20 and 21 and control pocket 22. It should be observed, however, that this reduction in pressure within passage 20 and passage 23 will naturally result in movement of the ball check valve 24 in a manner to seal the passage 23 against the escape therethrough of any high pressure air from passages 25, 26 and from the main chamber of the cartridge. The reduction of pressure in the control pocket 22 immediately results in an axial movement of the entire valve and plunger assembly in a direction to remove the valve 5 from sealing engagement with the discharge cap, due entirely to the preponderating force acting in that direction by reason of the pressure contained in the main chamber 27 acting upon the exposed

head of the nut 13. Simultaneously with the complete opening of the valve assembly, the several discharge ports 28 are placed in communication with the chamber 19, thus providing an auxiliary vent to the atmosphere for the entire system of passages and for the control pocket 22 and the chamber 19. The purpose of the auxiliary vent passages 28 is to insure against any tendency toward closing of the valve assembly as a result of a more rapid drop in pressure in the main chamber 27 than in control pocket 22. Thus, once the opening movement of the valve assembly is initiated, it is certain to remain open, thereby permitting the free and unrestricted discharge of the entire volume of high pressure air contained in the chamber 27 through the several radial discharge ports 29.

The construction described above may be broadly characterized as a differential valve mechanism. Perhaps it is well to explain at this point the important relationships between the areas of the various parts which are effectively subjected to pressure and to point out wherein the differential relation exists. Considering first the closing of the valve assembly, the principal factor in this movement is the area of the end plunger assembly consisting of the nut 14 and its associated cup leather 11. This area is in effect the same as the cross sectional area of the cylindrical bore 22. Thus, the pressure of the gas introduced into the pocket 22 is effective upon an area equal to the cross sectional area of the bore, the result of which is an axial movement of the plunger assembly 14 and all connected parts in a direction to bring the valve 5 into sealing engagement with the discharge cap. During the entire charging operation and until such time as the discharging operation is initiated, this full force acts to hold the valve in sealed position. Under these circumstances, we have not only the pressure acting upon the plunger assembly 14, but also a like pressure acting upon the effective exposed area of the nut 13 and the valve head 5. The effective exposed area of the nut 13 is the full cross sectional area thereof less the cross sectional area of the valve rod 4. The effective exposed area of the valve head 5 is equal to the cross sectional area of the axial bore formed in the discharge cap, also less the cross sectional area of the rod 4. Thus, the force acting upon the nut 13 is in a direction tending to unseat the valve, while the force acting upon the valve head 5 is in a direction tending to seat the valve. It is recalled, however, that until discharge of the cartridge is actually initiated, there is full pressure acting upon the full cross sectional area of the plunger assembly 14. Hence, under these conditions, the forces acting in opposite directions upon the nut 13 and valve head 5 respectively are of no consequence. As soon, however, as the pressure in control pocket 22 has been reduced substantially or exhausted, the relationship between forces acting upon nut 13 and valve head 5 becomes very important. In this connection it is pointed out that the cross sectional area of the nut 13 less the area of the valve rod is slightly greater than the cross sectional area of the bore in the discharge cap, less the area of the rod, resulting in a preponderating force tending to move the valve assembly toward open position. Thus, there is a definite differential between the opposed forces acting upon nut 13 and valve head 5 and when the pressure in control pocket 22 has been reduced to a point below the value of this

differential, then the entire assembly moves into open position.

The form of cartridge shown in Figure 2 is fundamentally the same as that shown in Figure 1. This form, however, has some minor changes and some rather important additions which will be described. Referring to the terminal cap 32, it will be noted that the discharge ports 28 occupy a different position in relation to the normal position of the valve and plunger assembly. As here shown, these passages are just barely covered by one of the cup leathers 11, the arrangement being such that they are immediately placed in communication with the chamber between the two plunger assemblies upon initial movement of the plunger. The purpose of this is to provide a more rapid auxiliary release for the control pocket 22. It will also be noted in this connection that the supply of compressed gas is introduced in advance of the plunger assembly 14 as indicated at 18 and that the port 18 is arranged to be covered and sealed by the forward cup leather 11 upon initial movement of the valve and plunger assembly. There is provided, however, a secondary port 47 communicating with the supply passage 17 and the control pocket 22 for the purpose of permitting introduction of gas from passage 17 should the plunger be overlying port 18.

Aside from the above changes, the terminal cap and plunger assemblies are practically identical to those of Figure 1. There is added to this form of cartridge, however, a device calculated to insure that the valve mechanism remains in fully open position at each discharge. This device consists of a spring 38 acting upon the nut 37 and supported by a spring cage 39. The cage 39 is perforated as indicated at 40 to permit the passage of air into and through the same. The spring 38 is compressed when the valve is in closed position and constantly tends to move the valve toward open position. The same area differentials exist in connection with this design as in that described above, the spring being provided merely to assist in the opening movement of the valve and to insure against possible closing movement thereof. The necessity for the spring 38 or some equivalent device lies in the fact that under certain conditions the pressure in the main chamber 27 may reduce more rapidly than that in the control pocket 22, thereby causing a reversal of the resultant force acting upon the valve assembly. A further reason for this special provision is that the flow of air at high velocity from the main chamber 27 around the enlarged valve head 5 and out through the passage cap creates a considerable friction drag on the valve head which tends to draw the entire valve assembly toward closed position. The effectiveness of the application of high pressure gas at the pressures and volumes contemplated for use in the cartridges herein described is dependent to a considerable extent upon the speed with which this energy is applied to the work. It is therefore particularly important that the valve be moved quickly and positively to fully open position and that it be retained in that position until the passage has been completed. The spring device illustrated in Figure 2 has been found to be a satisfactory solution for this problem.

Figures 3 and 5 relate to a form of cartridge and method of use somewhat different from the methods and constructions above described. According to this phase of the invention, the

cartridge is designed to be charged at some central charging point and then transported to the point of use, at which, after being placed in operative relation to the work, a suitable device is attached for effecting discharge of the cartridge by remote control.

Referring to Figure 3, the body 51 of the cartridge is equipped with terminal and discharge caps 52 and 53 respectively. The discharge cap is sealed on a gasket 72 and is provided with a plurality of discharge ports 73. A valve head 70 is designed to have sealing engagement with the end of the discharge cap and is carried by the valve rod 68 which has on its opposite end a plunger assembly slidably fitting the bore 62 formed in the terminal cap 52. In this case the main chamber of the cartridge is indicated at 66. The plunger 64 is formed with two or more gas passages 63 which communicate with the control pocket 62 and with the main chamber 66 of the cartridge. These ports 63, however, are under the control of a disc type check valve consisting of the disc 65, spring 67 and nut 69. A suitable valve 59 is provided in the terminal cap 52 to permit the cartridge to be charged with the aid of a suitable charging clamp. The present invention is not particularly concerned with the form of the charging apparatus, although perhaps it should be pointed out that this consists broadly of a charging nozzle designed to have sealing engagement with the surface immediately surrounding the valve 59 and which is provided with a suitable packed wrench designed to operate the valve 59. When the cartridge is positioned in such a charging clamp and the valve 59 is moved to open position, high pressure gas is permitted to flow through the ports 60 and 61 into the control pocket 62. From the control pocket 62 the gas passes through the several ports 63, past the check valve 65 and into the main chamber 66. It will be observed, however, that the gas cannot pass in a reverse direction from the chamber 66 to the chamber 62. This design provides the same general relationship of vital areas as explained above. The introduction of high pressure gas into the control pocket 62 results instantly in the closing of the valve assembly. Likewise a reduction in pressure in the chamber 62 results in opening movement of the valve assembly owing to the differential relation of the areas of the valve head 70 and the surface of plunger 64 which is exposed to the pressure in chamber 66.

Centrally positioned in the outer end of the terminal cap 52 is a nut 78 which provides a sealing surface as indicated at 77 for a pressure operated valve 74. This valve has a sliding fit within chamber 75 and is fluted as indicated at 82 in Figure 5 to permit the passage of air from the control pocket 62 through passage 61, around the valve and out through the central opening in the nut 78. The pressure in pocket 62 and passage 61 acts alone to force the valve 74 into sealing engagement with the nut 78.

The above description covers the complete cartridge in the form in which it is charged and thereafter transported to the point of use. When the cartridge is ready to be placed in or in operative relation to the material to be acted upon, an actuating unit 54 is screwed into the end of terminal cap 52. This unit consists of a suitable housing in which is positioned a plunger 56 having an extended stem 57 designed to engage the stem 76 of the pressure operated release

valve 74 for the purpose of opening the latter and permitting the escape of high pressure air from pocket 62. With the valve 74 in open position the high pressure air escapes from the pocket 62 through a plurality of escape ports 79. The head 55 of the actuating device may be provided with a connection as indicated at 16 for conveying into the actuating device any suitable form of energy transmitting medium. In other words, the plunger 56 may be actuated hydraulically, pneumatically or otherwise. The cylinder 80 in which the plunger 56 operates is provided with several vent ports to prevent the trapping of air. Thus, the cartridge may be discharged from a point as remote as may be desired by simply transmitting compressed air or hydraulic pressure to the actuating device 54.

Figures 5, 6 and 7 illustrate a slightly different construction and method of operation. In Figure 5 the cartridge A is shown positioned in a drill hole formed in the material to be broken down, with tubing 15 extending from the cartridge and having connection at 127 with a remote control valve B. A supply line 112 is connected at 111 to the opposite end of this remote control valve.

Referring first to the cartridge as shown in Figure 6, it will be noted that the discharge cap, valve and valve rod are essentially the same as corresponding parts shown in Figure 1. The plunger assembly contained within the terminal cap 102, however, is somewhat different. A plunger 104 has sliding fit in the bore 22 formed in the terminal cap and has threaded connection with the end of the valve rod 4. A cup leather assembly consisting of cup leather 12 and keeper 13 serves to prevent the passage of high pressure air from the main chamber 27 into the control pocket 22. The plunger 104 is provided with a port 23 which is normally in communication with passages 25 and 26 and consequently with the interior of the cartridge. A ball check valve 24 is provided to permit the flow of high pressure air from chamber 22 into the main chamber 27, but to prevent flow in the reverse direction. The terminal and discharge caps are suitably sealed on the body of the cartridge by gaskets 44. A suitable connection 16 is provided in the terminal cap for the supply pipe 15.

It has been found that with a cartridge such as shown in Figure 6, the discharging action is not reliable in cases where it is necessary to use a considerable length of small diameter supply pipe between the cartridge and the source of supply of high pressure air or gas. The reason for this is simply that the volume of high pressure air introduced in the chamber 22 during the charging operation cannot be exhausted through a considerable length of tubing having a small inside diameter as rapidly as the pressure in the main chamber 27 of the cartridge can be exhausted through the discharge cap when the valve moves toward open position. Thus, if the supply pipe 15 is vented to the atmosphere at a point quite remote from the cartridge, the pressure in chamber 22 will immediately begin to drop and the valve assembly will move toward open position. However, the instant the valve opens, the more rapid escape of high pressure air from the chamber 27 through the discharge cap results in the lowering of the pressure in that chamber more rapidly than the pressure can be lowered in the chamber 22, thus resulting in a reversal of the resultant forces acting upon the

valve and the valve will move or tend to move toward closed position. In order to prevent this uncertain action, there has been provided an automatic supplemental release valve designed to be positioned in the supply pipe line at a point near the cartridge as indicated at B in Figure 5.

The supplemental release valve B consists of a cylindrical casing 110 in which there is provided a plunger assembly consisting of plungers 116 and 120 with an interposed cup leather 119. The plunger 120 is provided with a reduced axial extension which is tapered as indicated at 123 to form a valve for sealing the passage 124. Axial passages 117 and 122 are provided in the plungers 116 and 120 respectively. A ball check valve 118 is interposed between the passages formed in these two members and serves to permit flow of high pressure air from the supply line 112 to the supply line 115, but to prevent flow in a reverse direction. A spring 126 acts upon the plunger 120 tending to move the entire assembly to the left, thus carrying the valve 123 out of engagement with the seat surrounding the passage 124. At the right end of the valve casing 110 there is provided one or more radial ports 125, placing the interior of the casing in communication with the atmosphere. The supply pipe 15 leading from the cartridge communicates with the passage 124 through fitting 127. The main supply pipe 112 leading from the source of supply of high pressure air to the valve communicates with a passage 114 through connector 113 having threaded connection with the end plug 111 secured in the valve casing.

The operation of the remote control valve B is in many respects similar to the operation of the cartridges described in Figures 1 and 2. High pressure air from the source of supply passes through the supply pipe 112, passage 114 into a chamber 115 which may be termed a control pocket having much the same functions as the control pockets 22 of Figures 1 and 2. The first result of the introduction of high pressure air into the chamber 115 is to act upon the exposed area of the face of plunger 116, thereby moving the entire assembly axially toward the right to bring the valve 123 into sealing position. This movement is accomplished by the pressure of the gas against the resistance of the spring 126. Simultaneously with this action the high pressure air passes through passage 117, past check valve 118, through passages 121, 122 and 124 into the pipe 15, which carries the air on into the control pocket 22 in the cartridge. When it is desired to effect discharge of the cartridge, it is merely necessary to open a relief valve in the supply pipe 112 at a point adjacent the source of supply, thereby venting the supply pipe 112 to the atmosphere and causing a pressure reduction in the control pocket 115. With the pressure reducing in pocket 115 a point is soon reached at which the pressure acting upon the small exposed area of the valve 123, plus the force of the spring 126 results in axial movement of the entire plunger and valve assembly toward the left. It will be appreciated that as soon as this movement occurs, the chamber occupied by the spring 126, as well as the passage 124, the supply pipe 15 and the control pocket 22 of the cartridge are placed in communication with the atmosphere through the several exhaust ports 125. Thus, there is provided a rapid outlet for the high pressure gas in pocket 22 and the piping connected therewith which, of course,

results in a rapid reduction of pressure in the pocket 22 and also in rapid and reliable opening of the valve assembly in the cartridge. It should be understood, of course, that the remote control valve B may be placed at any desired point in the supply line extending between the cartridge and the source of supply or that it may even be attached directly to the end of the cartridge. The only limitation is that it be sufficiently closed to avoid the interposition of too much resistance to the escape of high pressure air from the control pocket of the cartridge to the atmosphere. The friction of the air flowing at high velocity through piping of small inside diameter is the vital consideration in this matter.

An alternative form of remote control valve is illustrated in Figure 8. In principle this form of construction involves merely the substitution of air pressure for the coil spring of the preceding form for moving the valve and plunger assembly to open position. In this case the pipe 15 extends between the remote control valve and the cartridge and the pipe 113 extends between the valve and the source of supply of high pressure air, nipples 127 and 112 respectively being employed to connect these pipes to the valve. The movable assembly of this valve mechanism consists of a valve member 133 having secured to one end thereof a plunger assembly consisting of plunger 149, cup leather 139 and cup leather keeper 138. The stem 137 of the plunger 149 extends into a pocket 155 formed in the end plug 131. This pocket is vented to the atmosphere as indicated at 154 to avoid the trapping of air in the pocket. The stem 137 of the plunger is effectively sealed at the point where it passes into pocket 155 by means of a suitable hat leather 140. Thus, the cross sectional area of the stem 137 is not exposed to whatever pressure may exist in chamber 148. The valve 133 is provided with gas passages 143 and 145, the former being in communication with the gas chamber 142 at a point adjacent the inlet. The passage 145 communicates with the interior of chamber 148 through a ball check valve 146 and a radial passage 147. At its opposite end the passage 145 communicates with the outlet 153 through a check valve 150, passage 151 and chamber 152. During charging operation the valve 133 is sealed on the valve casing as indicated at 135. At a point just inwardly of the valve seal 135 the casing 130 is provided with a plurality of radial exhaust ports. A hat leather 141 is positioned within chamber 142 and serves to prevent leakage of high pressure gas from this chamber.

With this remote control valve positioned in the supply line at some point between the source of supply and the cartridge to be charged, high pressure air may be permitted to flow from the source of supply through supply pipe 113 into the chamber 142 of the remote control valve. As an immediate result of the introduction of high pressure air or gas into the chamber 142, the entire valve and plunger assembly will move to the extreme right by reason of the pressure acting upon the exposed face of keeper 138. Simultaneously, the high pressure gas will flow into the axial passage 145 of the valve through ports 143 and in opposite directions therefrom, a portion of it passing around the check valve 146 and into the chamber 148 and another portion passing around check valve 150 and into chamber 152. It will be observed that the initial axial movement of the valve and plunger assembly to-

ward the left brings about an immediate seal at the point 135, thus preventing the escape of high pressure gas from the chamber 152 other than to the pipe 15 leading to the cartridge. It should be pointed out in this connection that the face area of plunger 149 which is exposed to pressure existing in chamber 148, is somewhat less than the exposed area of the keeper 138 on which pressure is acting in an opposite direction. It should also be pointed out that during the charging operation the pressure in chamber 152 acts upon the effective cross sectional area of the head of the valve member disposed therein, tending to supplement the force acting upon the valve and plunger assembly in a direction toward the left. As pointed out above, the cross sectional area of the plunger stem 137 is not exposed to the pressure within the chamber 148 by reason of the fact that this stem enters what may be termed a dead end pocket, which is effectively sealed by the hat leather 140. Thus, during the charging operation the high pressure air will flow through passages 143, 145, around ball check 150, through passage 151, into chamber 152 and thence through pipe 15 to the cartridge. When a desired charge has been introduced into the cartridge in this manner, the discharge may be effected by merely exhausting the supply pipe 113 to the atmosphere by means of a suitable release or venting valve positioned in the line 113 at a point adjacent the source of supply. As the pressure in chamber 142 drops, the check valves 146 and 150 move to closed position, thus preventing the flow of high pressure air from chambers 148 and 152 back into the chamber 142. When the pressure valve in chamber 142 has dropped to some predetermined point, then the force acting upon that face of the plunger 149 which is exposed to the pressure in chamber 148 will serve to move the entire valve and plunger assembly toward the right, thus breaking contact at 135 and permitting escape of high pressure gas from the pocket 152 outwardly through the several exhaust or discharge ports. The end 136 of the valve head is transversely slotted in order to avoid blocking the flow of high pressure gas from the pipe 15 into the chamber 152 and thence outwardly to and through the several exhaust ports. It should be pointed out that immediately upon the breaking of the sealed relation as indicated at 135, the pressure which had previously been acting upon the head of the valve tending to move it toward the left, is immediately lowered, thus eliminating this force as a factor in the positioning of the parts. This leaves the device with a trapped quantity of high pressure gas in chamber 148 which acts constantly upon the exposed face of the plunger 149 to hold the plunger and valve assemblies to the extreme right, with the valve 133 in open position, thus providing a rapid escape for the high pressure air flowing back from the control pocket of the cartridge into the chamber 152.

Figures 9 and 10 deal with a cartridge which is essentially the same as that illustrated in Figure 3, the principal difference being that instead of the pressure operated valve 74 of Figure 3, there is employed a suitable disc 186 of steel, fibre or other suitable material, for sealing the exhaust passage 61 leading from the control pocket 62. In this case discharge of the cartridge is effected by puncturing the disc 186, thus permitting escape of the high pressure air from control pocket 62 outwardly to the atmosphere. For this purpose there is provided an air gun or equivalent

device as shown in Figure 10. This device consists of a cylinder 161 which is capped at one end as indicated at 162 and which is provided at its opposite end with a suitable threaded collar 163. Positioned between the cap 162 and the collar 163 is a flexible sleeve 164 which is suitably secured at its ends as indicated at 165. The cylinder 161 is provided with several ports 173 which permit the passage of compressed fluid through the cylinder to cause expansion of the flexible sleeve 164. The purpose of this arrangement is to effectively seal and anchor the cartridge and air gun in the bore hole formed in the material in which the apparatus may be used.

The mechanism of the air gun consists of a suitable plunger which carries at its outer end a chisel 167 designed to engage and rupture the sealing disc 186. This plunger is normally retained in starting position by a spring latch 178. This latch is in turn controlled by a pressure responsive release mechanism consisting of diaphragm 181 and trip finger 179. The end of the latch is formed with a notch 183 designed to engage a shoulder 184 formed in the plunger and the tip of this spring latch member is tapered as indicated at 185 to facilitate the entering and engagement thereof with the plunger. A supply pipe 176 is connected to the cap 162 and is in communication with the interior of the cylinder 161. The air gun assembly is adapted to be screwed into the end of a cartridge as illustrated in Figure 10.

With the parts assembled as indicated and positioned in suitable drill hole, the first operation is to permit the flow of a suitably compressed fluid into the cylinder 161 through pipe 176. The development of pressure within the cylinder 161 results in the building up of a force on the plunger tending to project it forcefully in an axial direction toward the end of the cartridge with which the gun is associated. Movement of the plunger, however, is delayed until the pressure has reached a desired predetermined value. In the meantime this fluid pressure passes through the several ports 173 and causes the flexible sleeve 164 to expand into firm sealing and gripping engagement with the walls of the drill hole in which the apparatus is positioned. When the pressure in the cylinder has reached the desired predetermined value, then the diaphragm 181 will be flexed, thus causing the spring latch 178 to be tripped and releasing the plunger which is then forcefully projected, together with the chisel 167 toward the end of the cartridge. The chisel 167 serves to rupture the disc 186 and the high pressure gas in control pocket 62 of the cartridge passes outwardly through a plurality of exhaust ports 172 formed in the end of the air gun. The only conditioning required for a repetition of this operation is the removal of the ruptured disc 186 and the substitution of a new disc for sealing the outlet opening. The cartridge may then be recharged and used in the manner described.

In Figures 11 and 12 there is shown a preferred form of cartridge of the type designed to be charged and discharged after being positioned in the material to be acted upon. This form of cartridge is fundamentally the same as that illustrated in Figure 2, the chief difference being that the exhaust ports 28 are omitted as unnecessary in this design and the function of the spring 38 of Figure 2 is performed by high pressure air. The discharge end of this cartridge is sufficiently like that of Figure 2 that further description is unnecessary. As regards the terminal cap end, 75

it will be observed that there is positioned between the end of the terminal cap and the shoulder provided in the end of the cartridge a heavy steel plate 206 to which is secured a hat leather 208, surrounding and adapted to seal on the surface of the valve rod 34 which passes therethrough. The plunger assembly is considerably simplified as compared with that of Figure 2 and consists of a steel plunger 205, a cup leather 11 and a keeper 211. A suitable ball check 24 with check spring 41 is provided in the plunger 205 as a means for permitting the flow of high pressure air from chamber 214 into the main chamber 217 of the cartridge, but preventing flow in the reverse direction.

The supply line 212 extending from the cartridge to a suitable source of supply permits the introduction of high pressure gas into the control pocket 214. This results, as in the designs previously described, in axial movement of the valve and plunger assembly to bring the valve into firm sealing engagement with the end of the discharge cap 33. At the same time, the high pressure air flows from control pocket 214 through passage 215, around check valve 24, through slots 216, passages 25 and 26, into the main chamber 217. It is important to note that as the pressure builds up in the main chamber 217, the high pressure gas is permitted to escape from the main chamber rearwardly along the valve rod 34 into the pocket formed between the disc 206 and the cup leather 11, the hat leather 208 functioning merely as a check valve under these circumstances. In other words, the pressure of the charge in chamber 217 acting along the valve rod 34 tends to expand the hat leather from sealing engagement with the rod, thus permitting the passage of high pressure gas into the small chamber between the disc 206 and the cup leather. It will be observed, however, that a reversal of the flow cannot occur when the pressure in chamber 217 falls below the pressure which is trapped in the small pocket. When a charge of desired value has been introduced into the main chamber 217, the discharge is effected, as usual, by venting the supply pipe 212 to the atmosphere by means of a valve positioned in the supply line at a point adjacent the source of supply. This results immediately in the lowering of the pressure in control pocket 214 and, bearing in mind that the pressure trapped in the pocket formed between the cup leather 11 and disc 206 is the same as that of the charge introduced into the chamber 217, it is apparent that this reduction of pressure in chamber 214 immediately results in axial movement of the valve and plunger assembly toward the left. The initial opening of the main discharge valve 5 naturally results in an immediate and extremely rapid drop in pressure within the chamber 217 and it is therefore apparent that the pressure trapped between disc 206 and cup leather 11 will be maintained owing to the differential pressures acting upon the hat leather 208. Thus, the air trapped in the pocket between the disc and cup leather serve to positively move the valve and plunger assembly toward open position and to maintain them in that position. This arrangement provides a positive and extremely rapid discharge of the high pressure air contained in the chamber 217 and eliminates the necessity of an auxiliary remote control valve as illustrated in Figures 5, 7, and 8 and also eliminates the necessity of the double plunger arrangement with auxiliary exhaust ports as illustrated in Figures 1 and 2. At the same time, the air

pocket arrangement replaces the somewhat cumbersome spring arrangement illustrated in Figure 2.

The various designs, structures and methods disclosed herein represent to some extent the succession of improvements one over the other but for the most part, are calculated to meet a variety of conditions which cannot be conveniently met by any single construction or method of operation. For example, there are conditions where it is impractical to carry right up to the point of use a suitable source of high pressure air. Under such conditions it is desirable to provide a form of device which can be brought to the point of use in a charged condition, ready for use. The nature of the source of supply of high pressure air also is an important consideration in determining the type of mechanism to be used. In some cases, it may be advantageous to charge the various devices from a source of high pressure gas maintained at a constant pressure. In other cases, it may be desirable to generate and introduce the charge in a progressive manner, starting from atmospheric pressure. These and many other considerations have important bearing on the selection of the design and type of mechanism and the method to be practiced under the wide range of conditions to be encountered.

The present invention has been developed primarily in relation to the problem of mining coal with a view to providing a method and apparatus which will afford the maximum of safety and which will at the same time accomplish the work in a most economical manner and without destroying in any appreciable degree the essential qualities of the coal produced. It should be understood, however, that the invention in all of its aspects is applicable to a wide range of other uses. The entire absence of heat, flame and electricity and the complete safety of the apparatus will commend it to many old and new uses.

Attention is directed particularly to the form of the discharge cap in the constructions illustrated in Figures 2 and 11. As here shown, the discharge ports 45 are inclined rearwardly from the outermost end of the discharge cap. The purpose of this arrangement of the discharge ports is to utilize the force of the discharging gas to produce a reaction tending to hold the cartridge to its work. For example, if the cartridge is placed in a drill hole formed in a face of coal with the discharge end adjacent the closed end of the drill hole, the high pressure gas issuing out of the rearwardly inclined discharge ports at high velocity will react upon the surrounding walls of the drill hole, producing a resultant force tending to project the entire cartridge farther inwardly toward the closed end of the drill hole. It will be appreciated, of course, that in cases where it is found desirable to reverse the position of the cartridge in the drill hole, that is, position it with the discharge end toward the open end of the drill hole, then the discharge ports 45 should be inclined in the reverse direction in order to provide the desired resultant force tending to hold the cartridge in the drill hole until its work has been accomplished. This matter of holding the cartridge to its work is of greater importance where relatively low pressures are employed than is the case where relatively high pressures are employed, for the reason that the lower pressures act more slowly and hence provide a greater time interval within which the cartridge may be projected from the drill hole by reason of the building up of a pressure between the innermost end

of the cartridge and the inner closed end of the drill hole. Thus, where air pressures ranging from 4000 or 5000 pounds up to 10,000 or 12,000 pounds per square inch are used, it is desirable that some means be provided other than the tamping ordinarily employed for retaining the cartridge in the drill hole. It has been found that this requirement is largely satisfied by inclination of the discharge ports as shown. It will be appreciated, of course, that the angle of inclination may be varied to meet different conditions.

The variety of structures disclosed may be regarded as indicative of a much wider range of structural and functional variations of which the invention is susceptible. It should be appreciated, therefore, that many variations of the principles and structural features disclosed are contemplated as within the scope of the invention, it being impractical to make anything like an exhaustive disclosure of even those variations which have been actually and specifically contemplated.

I claim:—

1. In combination, a cartridge having provision for storing a charge of gas under a high pressure, a supply line therefor, means for releasing the charge to a point of use upon a reduction of pressure in the supply line, means between the ends of said supply line for providing a vent orifice larger than the minimum cross-sectional area of the supply line, upon pressure reduction in said supply line.

2. In combination, a cartridge having provision for storing a charge of gas at high pressure, a supply line therefor, means for releasing the charge to a point of use upon a reduction of pressure in the supply line, means between the ends of said supply line and adjacent to but spaced from the cartridge for venting the latter upon pressure reduction in said supply line.

3. In a material breaking apparatus in which a charge of gaseous medium is stored at high pressure in a casing and is released suddenly to a point of use by the venting of a control chamber which is filled with high pressure gaseous medium while the casing is charged, a pressure control device for effecting quick venting of such control chamber comprising a vent valve, and means for quickly opening said valve comprising a cylinder having a bore, a piston reciprocable in said bore, means for supplying compressed gas to said bore at one side of said piston, a check valve for controlling flow of gas from said bore to the cartridge, and means actuated by said piston for venting the chamber to effect charge release.

4. In a material breaking apparatus in which a charge of gaseous medium is stored at high pressure in a casing and is released suddenly to a point of use by the venting of a control chamber which is filled with high pressure gaseous medium while the casing is charged, a pressure control device for effecting quick venting of such control chamber comprising a vent valve and means for quickly opening said valve comprising a cylinder having a bore, a piston reciprocable in said bore, means for supplying compressed gas to said bore at one side of said piston, a check valve for controlling the flow of gas from said bore to the cartridge, and means actuated by said piston for venting the chamber to effect charge release, said check valve closing automatically when said vent valve is opened.

5. In a material breaking apparatus in which a charge of gaseous medium is stored at high pres-

sure in a casing and is released suddenly to a point of use by the venting of a control chamber which is filled with high pressure gaseous medium while the casing is charged, a pressure control device for effecting quick venting of such control chamber comprising a vent valve and quick acting pressure control means for actuating said valve, said means acting to close quickly said valve when compressed gas is supplied to the cartridge, and to open quickly said valve when the supply of compressed gas to the cartridge is cut off and the cartridge is vented.

6. In a material breaking apparatus, the combination with a blasting cartridge having a casing in which a charge of gaseous medium is stored at high pressure and embodying means for releasing suddenly the charge including a valve, and controlling means for said valve including a control chamber which is filled with high pressure gaseous medium while the casing is charged and adapted to be vented to effect opening of said valve, of a pressure controlled device for effecting quick venting of such control chamber comprising a vent valve, and means for quickly opening said vent valve having pressure responsive controlling means.

7. In a material breaking apparatus, the combination with a blasting cartridge having a casing in which a charge of gaseous medium is stored at high pressure and embodying means for releasing suddenly the charge including a valve, and controlling means for said valve including a control chamber which is filled with a high pressure gaseous medium while the casing is charged and adapted to be vented to effect opening of said valve, of a pressure controlled device for effecting quick venting of such control chamber comprising a vent valve and pressure actuated means for quickly opening said valve comprising a cylinder having a bore, a piston reciprocable in said bore, and valve actuating means operated by said piston.

8. In a material breaking apparatus, the combination with a blasting cartridge having a casing in which a charge of gaseous medium is stored at high pressure and embodying means for releasing suddenly the charge including a valve, and controlling means for said valve including a control chamber which is filled with high pressure gaseous medium while the casing is charged and adapted to be vented to effect opening of said valve, of a pressure controlled device for effecting quick venting of such control chamber comprising a vent valve and pressure actuated means for opening and closing said valve comprising a piston-actuated valve actuating means operated to close said valve by the charge of gaseous medium flowing to said casing.

9. In a material breaking apparatus, the combination with a blasting cartridge having a casing in which a charge of gaseous medium is stored at high pressure and embodying means for releasing suddenly the charge including a valve, and controlling means for said valve including a control chamber which is filled with high pressure gaseous medium while the casing is charged and adapted to be vented to effect opening of said valve, of a pressure controlled device for effecting quick venting of such control chamber comprising a vent valve and pressure responsive mechanism for actuating said valve effective to cause closing movement of said vent valve when gas is supplied to charge the casing.

10. A material breaking device of the character described, comprising a cartridge embody-

ing a charge receiving chamber having a discharge orifice, a differential valve mechanism for controlling said discharge orifice, a control pocket containing a reciprocable piston for governing the action of said differential valve mechanism, means for venting said control pocket to the atmosphere, and means consequent upon movement of the differential valve mechanism and having a vent control valve element embodied in and movable with said piston for accelerating the venting of said control pocket.

11. In a blasting cartridge, a container having a charge receiving chamber and a discharge opening through which the charge may be released, a differential valve within said chamber for controlling said discharge opening, means for effecting initiation of the opening movement of said differential valve, and means including a valve element movable with said last mentioned means for thereafter effecting rapid movement of the valve into its wide open position.

12. In a blasting cartridge, a container having a charge receiving chamber, a discharge orifice, a valve adapted to seal said orifice, fluid actuated means governing said valve, and means associated with said governing means and automatically operative upon initial opening of said valve for causing said fluid actuated means suddenly to open widely said orifice sealing valve and including a vent control valve embodied in said fluid actuated governing means.

13. A blasting cartridge comprising a casing having a chamber for receiving a charge of high pressure air or gas, release means for said charge comprising a discharge control valve, pressure responsive means for effecting opening of said discharge control valve when a predetermined blasting pressure is attained within the cartridge and including a pressure-actuated piston connected to said valve for holding the latter closed during building up of the blasting pressure within the cartridge and for opening said valve when said blasting pressure is attained, and means controlled by movement of said piston and rendered active upon initiation of movement of said valve toward its open position including a vent control valve movable with said piston for accelerating movement of said piston suddenly to move said discharge control valve into its wide open position.

14. A blasting cartridge comprising a casing for receiving a charge of high pressure air or gas and a control chamber, releasable valve means for discharging the blasting charge from said charge receiving chamber, a piston in said control chamber for controlling said valve means, means for supplying pressure fluid to said control chamber, valve controlled passages in said piston for supplying pressure fluid from said control chamber to said charge receiving chamber, means operative to effect venting of said control chamber upon attainment of a predetermined blasting pressure within the blasting chamber, said passages in said piston being automatically closed when said control chamber is vented, and the pressure in said charge receiving chamber effecting movement of said piston in said control chamber to release said valve means when said control chamber is vented, and valve means movable with said piston automatically operative upon initiation of opening movement of said first mentioned valve means for further and more freely venting said control chamber to effect acceleration of movement of said control

piston to move said first mentioned valve means toward a wide open position.

15. A blasting cartridge comprising a casing having a chamber for receiving a blasting charge and a discharge orifice, a valve for closing said orifice, controlling means for said valve governable to effect exertion of a valve closing and holding pressure on said valve or to effect relief of said pressure to effect valve opening upon attainment of any one of a wide range of blasting pressures in said chamber, and means operative automatically upon a predetermined opening movement of said valve to effect complete relief of said holding pressure including a vent control valve movable with an element of said controlling means.

16. In a blasting cartridge, a casing having a chamber for receiving a charge of blasting pressure, a control chamber, and a discharge orifice, a piston reciprocable in said control chamber for actuating said valve, means for supplying pressure to said control chamber at the outer side of said piston for holding said valve closed, check valve controlled passage means for supplying pressure from the control chamber at the outer side of the piston to said charge receiving chamber, and check valve controlled means for conducting pressure from said charge receiving chamber to said control chamber at the inner side of said piston, said control chamber at the outer side of said piston adapted to be vented when a predetermined blasting pressure is attained in said charge receiving chamber, the pressure in the control chamber at the inner side of said piston acting on the latter when said control chamber is vented to move said piston in a direction to open said orifice controlling valve to release the blasting charge from said charge receiving chamber through said discharge orifice.

17. In a blasting cartridge, a casing having a chamber for receiving a charge of blasting pressure, a control chamber and a discharge orifice, a valve for controlling said discharge orifice, a piston reciprocable in said control chamber having a piston rod connected to said valve for actuating the latter, means for supplying pressure to said control chamber at the outer side of said piston for holding said valve closed, check valve controlled passage means for supplying pressure from the control chamber at the outer side of the piston to said charge receiving chamber, a cup packing sealingly engaging said piston rod for conducting pressure fluid from said charge receiving chamber to said control chamber at the inner side of said piston while preventing flow of pressure from the control chamber to said charge receiving chamber, said control chamber at the outer side of said control piston adapted to be vented when a predetermined blasting pressure is attained in said charge receiving chamber, the pressure in the control chamber at the inner side of the control piston acting on the latter when said control chamber is vented to move the piston in a direction to open said orifice controlling valve to release the blasting charge from said charge receiving chamber to said discharge orifice.

18. In a blasting cartridge, a casing having a chamber for receiving a charge of blasting pressure and a discharge orifice, a member secured to said casing and having a control chamber, a plate interposed between said casing and member for separating the control chamber from said charge receiving chamber and having an

axial opening, a valve in said casing for controlling said discharge orifice, a piston reciprocable in said control chamber and having a piston rod extending through said plate opening into connection with said valve for actuating the latter, means for supplying pressure to said control chamber at the outer side of said piston for holding said valve closed, check valve controlled passage means in said piston and piston rod for supplying pressure from the control chamber at the outer side of said piston to said charge receiving chamber, and a cup packing secured to said separating plate for sealingly engaging the piston rod, said cup packing permitting flow of pressure from said charge receiving chamber to the control chamber at the inner side of the control piston while preventing flow of pressure from the control chamber to said charge receiving chamber, said control chamber at the outer side of said control piston adapted to be vented when a predetermined blasting pressure is attained in said charge receiving chamber, the pressure in the control chamber at the inner side of said piston acting on the latter when said control chamber is vented to move the piston in a direction to open said orifice controlling valve to release the blasting charge from said charge receiving chamber through said discharge orifice.

19. In a blasting cartridge, a container having a chamber to receive a charge of gas under high pressure and a discharge opening through which the charge may be released, a valve for controlling said discharge opening, a control chamber within the container which is supplied with high pressure gas when the main chamber is charged, a differential pressure plunger in the control chamber, a valve rod threadedly connected to the valve and the plunger, a cup leather for packing said plunger, a retaining nut for said cup leather threaded on the valve rod, said plunger and stem having a passageway therethrough to connect the main and control chambers, a check valve in said passageway, and means for feeding high pressure gas to said main and control chambers and for venting gas from said control chamber.

20. In a blasting cartridge, a container having a chamber to receive a charge of gas under high pressure and a discharge opening through which the charge may be released, a valve for controlling said discharge opening, a control chamber within the container which is supplied with high pressure gas when the main chamber is charged, a differential pressure plunger in the control chamber, a valve rod threadedly connected to the valve and the plunger, a cup leather for packing said plunger, a retaining nut for said cup leather threaded on the valve rod, said plunger and stem having a passageway therethrough to connect the main and control chambers, a check valve in said passageway, and a quick acting venting device for venting said control chamber to effect movement of the plunger to open said valve.

21. In a blasting cartridge, a container having a chamber to receive a charge of gas under high pressure and a discharge opening through which the charge may be released, a valve for controlling said discharge opening, a control chamber within the container which is supplied with high pressure gas when the main chamber is charged, a differential pressure plunger in the control chamber, a valve rod threadedly connected to the valve and the plunger, a cup leather for packing said plunger, a retaining nut for said cup leather

threaded on the valve rod, said plunger and stem having a passageway therethrough to connect the main and control chambers, a check valve in said passageway, and means for effecting a change in pressure condition in said control chamber which will result in opening of said valve and which will maintain said valve open regardless of the speed of discharge from the main chamber.

22. In a blasting cartridge, a container having a chamber to receive a charge of gas under high pressure, a discharge cap for the container having discharge openings and a valve guiding opening, a valve for controlling said discharge openings and having an extension slidable in said valve guide opening, a control chamber within the container which is supplied with high pressure gas when the main chamber is charged, a differential pressure plunger in the control chamber, a valve rod threadedly connected to the valve and the plunger, a cup leather for packing said plunger, a retaining nut for said cup leather threaded on said rod, said plunger and stem having a passageway therethrough to connect the main and control chambers, a check valve in said passageway, and means for feeding high pressure gas to said main and control chambers and for venting gas from said control chamber.

23. In a material breaking device, the combination of a container adapted to be charged with high pressure gas at a material breaking pressure and having an outlet therefor, differential valve mechanism controlling said outlet for releasing the charge of material breaking pressure into the material to be broken, a control pocket for governing said differential valve mechanism, said container having inlet and exhaust ports, the former normally in communication with said pocket and the main chamber of said container and the latter normally sealed therefrom but communicable with said pocket consequent upon opening movement of said valve mechanism, the said inlet port being sealed consequent upon said movement, and means for reducing pressure in said control pocket to bring about such movement.

24. In a material breaking device, the combination of a container adapted to be charged with high pressure gas at material breaking pressure and having an outlet therefor, differential valve mechanism controlling said outlet for releasing the charge of material breaking pressure into the material to be broken, a control pocket for governing said differential valve mechanism, means for reducing pressure in said pocket to cause initial opening movement of said differential valve mechanism, and means yieldingly urging said valve mechanism toward open position.

25. In a material breaking device, the combination of a container adapted to be charged with high pressure gas at material breaking pressure and having an outlet therefor, differential valve mechanism controlling said outlet for releasing the charge of material breaking pressure into the material to be broken, a control pocket for governing said differential valve mechanism, means for reducing pressure in said pocket to cause initial opening movement of said differential valve mechanism, said container having an exhaust port normally sealed from said pocket but communicable therewith consequent upon opening movement of said valve mechanism, and means yieldingly urging said valve mechanism toward open position.

26. In a material breaking device, the combination of a container adapted to be charged

with high pressure gas at material breaking pressure and having an outlet therefor, differential valve mechanism controlling said outlet for releasing the charge of material breaking pressure into the material to be broken, a control pocket for governing said differential valve mechanism, means for reducing pressure in said pocket to cause initial opening movement of said differential valve mechanism, and means other than the pressure in said container for urging said valve mechanism toward open position.

27. In a material breaking device, the combination of a container adapted to be charged with high pressure gas at material breaking pressure and having an outlet therefor, differential valve mechanism controlling said outlet for releasing the charge of material breaking pressure into the material to be broken, a control pocket for governing said differential valve mechanism, means for reducing pressure in said pocket to cause initial opening movement of said differential valve mechanism, and means acting in conjunction with the pressure in said container for moving said valve mechanism toward open position and operative to retain the valve mechanism in open position notwithstanding the instantaneous pressure reduction in said container consequent upon the opening of said valve mechanism.

28. In a material breaking device, the combination of a container adapted to be charged with high pressure gas at material breaking pressure and having an outlet therefor, differential valve mechanism controlling said outlet for releasing the charge of material breaking pressure into the material to be broken, a control pocket for governing said differential valve mechanism, means for reducing pressure in said pocket to cause initial opening movement of said differential valve mechanism, said container having an exhaust port normally sealed from said pocket but communicable therewith consequent upon opening movement of said valve mechanism, and a spring for urging said valve mechanism toward open position.

29. In a material breaking device, the combination of a container adapted to be charged with high pressure gas at material breaking pressure and having an outlet therefor, differential valve mechanism controlling said outlet for releasing the charge of material breaking pressure into the material to be broken, a control pocket for governing said differential valve mechanism, said container having inlet and exhaust ports, the former normally in communication with said pocket and the main chamber of said container and the latter normally sealed therefrom but communicable with said pocket consequent upon opening movement of said valve mechanism, the said inlet port being sealed consequent upon said movement, and means for reducing pressure in said control pocket to bring about such movement, and a spring for urging said valve mechanism toward open position.

30. In a material breaking device, the combination of a container for receiving a charge of compressed gas at material breaking pressure and having a discharge orifice, a differential valve mechanism for controlling said orifice for releasing the charge of material breaking pressure into the material to be broken, said container embodying a control pocket, the pressure wherein governs the position and movement of said differential valve mechanism, a connection through which compressed gas may be introduced into and exhausted from said pocket, a

supply line extending from said connection to a source of supply of compressed gas, and means interposed in said supply line subject to remote control for venting said pocket to the atmosphere.

31. In a material breaking device, the combination of a container for receiving a charge of compressed gas at material breaking pressure and having a discharge orifice, a differential valve mechanism for controlling said orifice for releasing the charge of material breaking pressure into the material to be broken, said container embodying a control pocket, the pressure wherein governs the position and movement of said differential valve mechanism, a connection through which compressed gas may be introduced into and exhausted from said pocket, a supply line extending from said connection to a source of supply of compressed gas, and an exhaust valve subject to remote control for exhausting said pocket to the atmosphere, said valve being interposed in said supply line.

32. In a material breaking device, the combination of a container for receiving a charge of compressed gas at material breaking pressure and having a discharge orifice, a differential valve mechanism for controlling said orifice for releasing the charge of material breaking pressure into the material to be broken, said container embodying a control pocket, the pressure wherein governs the position and movement of said differential valve mechanism, a connection through which compressed gas may be introduced into and exhausted from said pocket, a supply line extending from said connection to a source of supply of compressed gas, and means interposed in said supply line subject to remote control for venting said pocket to the atmosphere, said means being positioned nearer to said container than to said source of supply.

33. In a material breaking device, the combination of a container for receiving a charge of compressed gas at material breaking pressure and having a discharge orifice, a differential valve mechanism for controlling said orifice for releasing the charge of material breaking pressure into the material to be broken, said container embodying a control pocket, the pressure wherein governs the position and movement of said differential valve mechanism, a connection through which compressed gas may be introduced into and exhausted from said pocket, a supply line extending from said connection to a source of supply of compressed gas, and means interposed in said supply line subject to remote control for venting said pocket to the atmosphere, said means consisting of a valve having two operative positions, one providing a continuous passage therethrough and the other placing said control pocket in communication with the atmosphere, said valve being controlled by differential pressures.

34. In a material breaking device, the combination of a container for receiving a charge of compressed gas at material breaking pressure and having a discharge orifice, a differential valve mechanism for controlling said orifice for releasing the charge of material breaking pressure into the material to be broken, said container embodying a control pocket, the pressure wherein governs the position and movement of said differential valve mechanism, a connection through which compressed gas may be introduced into and exhausted from said pocket, a supply line

extending from said connection to a source of supply of compressed gas, and means interposed in said supply line subject to remote control for venting said pocket to the atmosphere, said means consisting of a valve having two operative positions, one providing a continuous passage there-through and the other placing said control pocket in communication with the atmosphere, said valve being controlled by differential pressures and a spring.

35. In a material breaking device, the combination of a container for receiving a charge of compressed gas at material breaking pressure and having a discharge orifice, a differential valve mechanism for controlling said orifice for releasing the charge of material breaking pressure into the material to be broken, said container embodying a control pocket, the pressure wherein governs the position and movement of said differential valve mechanism, a connection through which compressed gas may be introduced into and exhausted from said pocket, and a secondary control pocket embodying means for permitting the introduction of and trapping high pressure gas therein, which trapped gas acts upon said differential valve mechanism with opposite effect to that of the first said control pocket.

36. In a material breaking device, the combination of a container for receiving a charge of com-

pressed gas at material breaking pressure and having a discharge orifice, a differential valve mechanism for controlling said orifice for releasing the charge of material breaking pressure into the material to be broken, said container embodying a control pocket, the pressure wherein governs the position and movement of said differential valve mechanism, a connection through which compressed gas may be introduced into and exhausted from said pocket, means governing said connection, and means subject to remote control for actuating said first means.

37. In a material breaking device, the combination of a container for receiving a charge of compressed gas at material breaking pressure and having a discharge orifice, a differential valve mechanism for controlling said orifice for releasing the charge of material breaking pressure into the material to be broken, said container embodying a control pocket, the pressure wherein governs the position and movement of said differential valve mechanism, a connection through which compressed gas may be introduced into and exhausted from said pocket, pressure actuated means governing said connection, and remote control means for operating said first means to exhaust said control pocket to the atmosphere.

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