May 25, 1926. 1,585,664

G. H. GILMAN

METHOD OF AND APPARATUS FOR BREAKING OUT ROCK

Filed Nov. 24, 1920 5 Sheets-Sheet 1

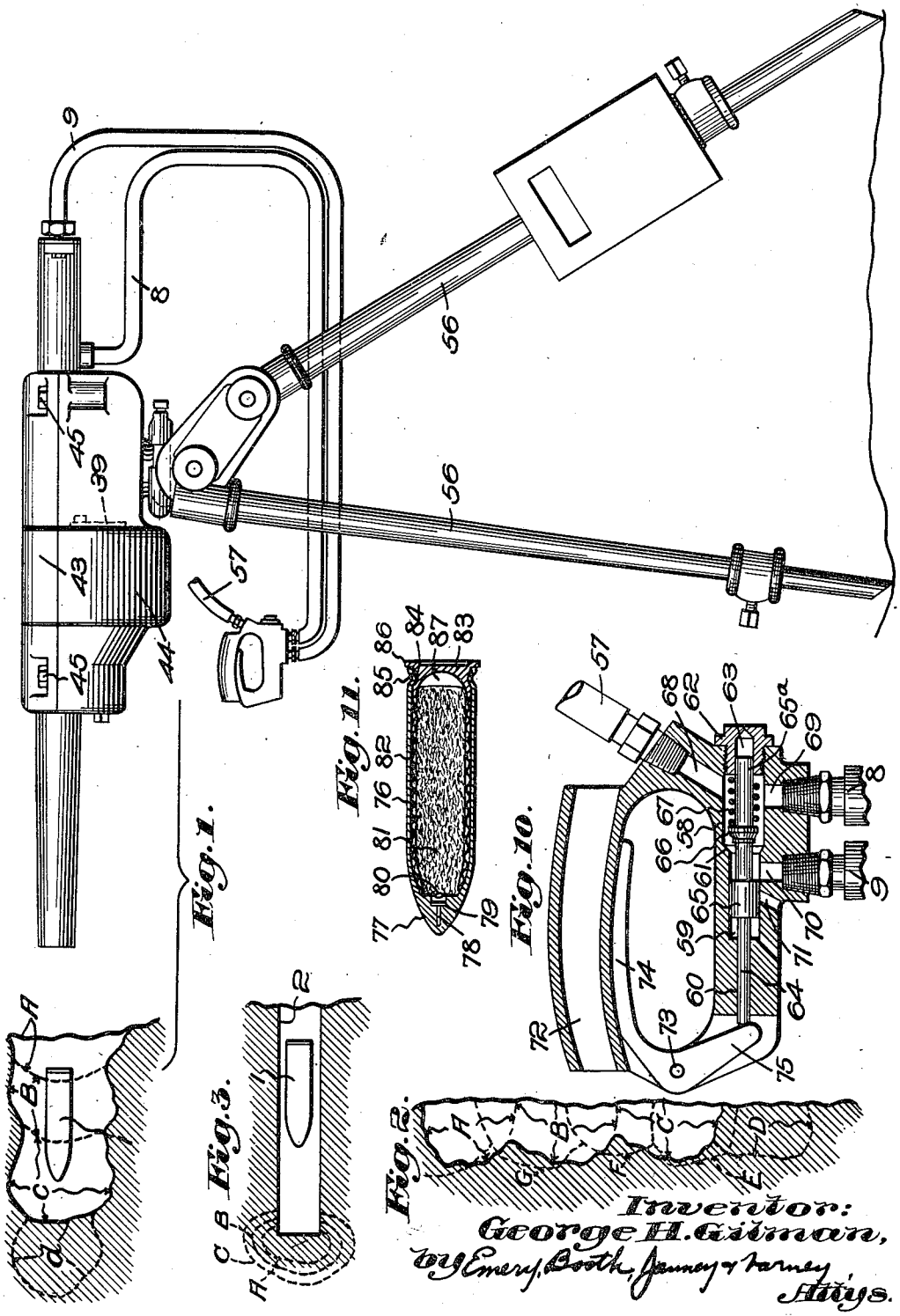

Fig. 1.

Fig. 3.

Fig. 11.

Fig. 10.

Fig. 2.

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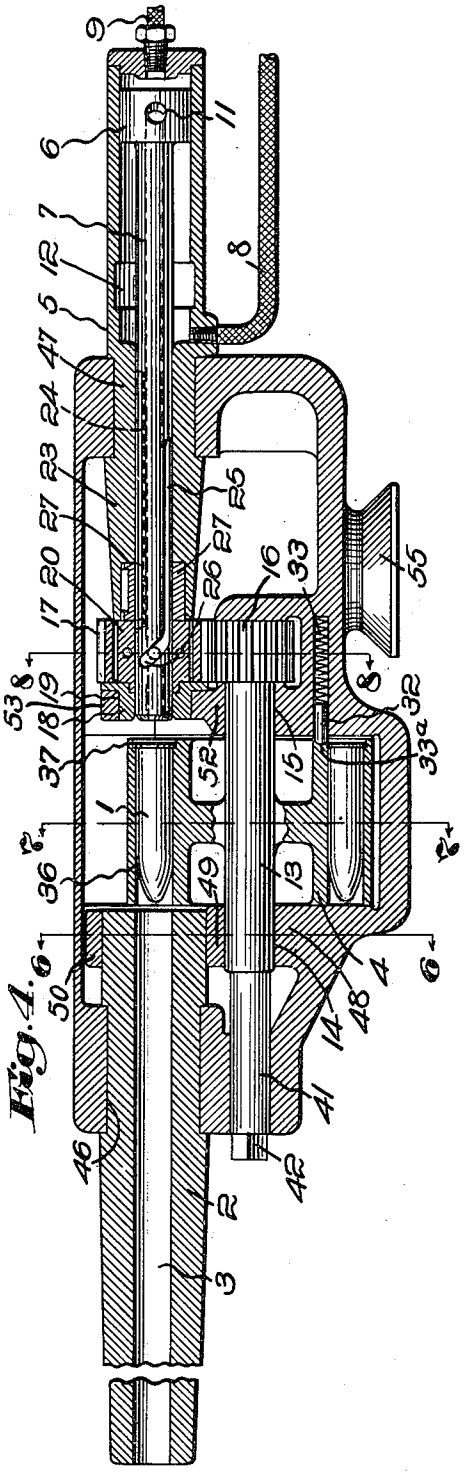

Fig. 4.

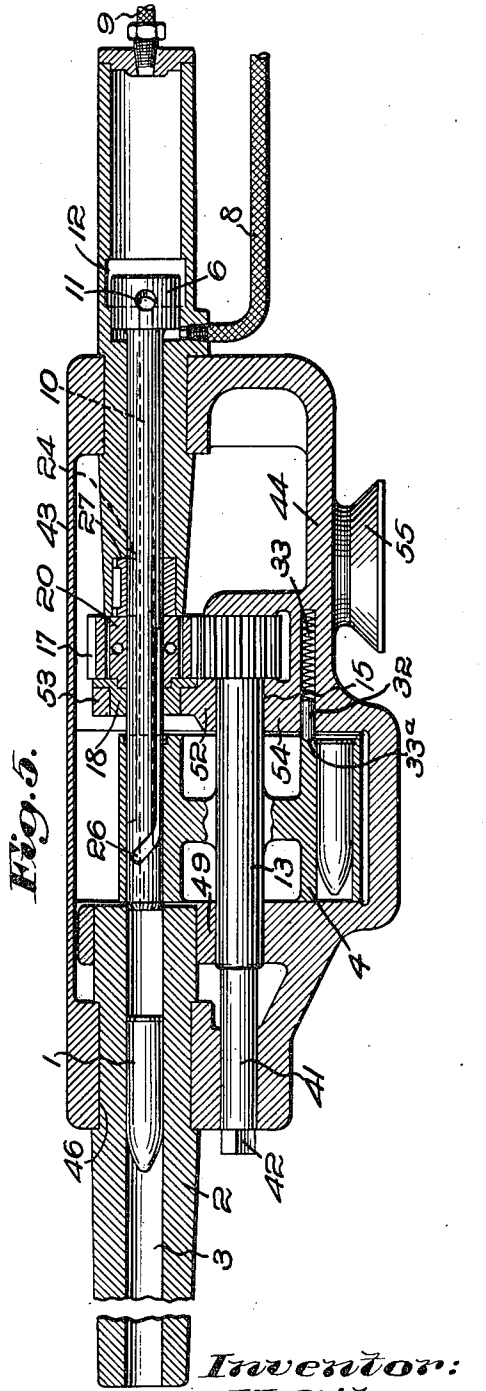

Fig. 5.

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Fig. 8.

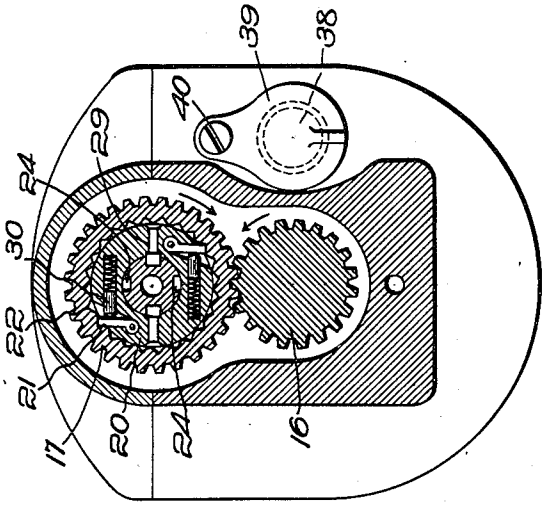


Fig. 2.

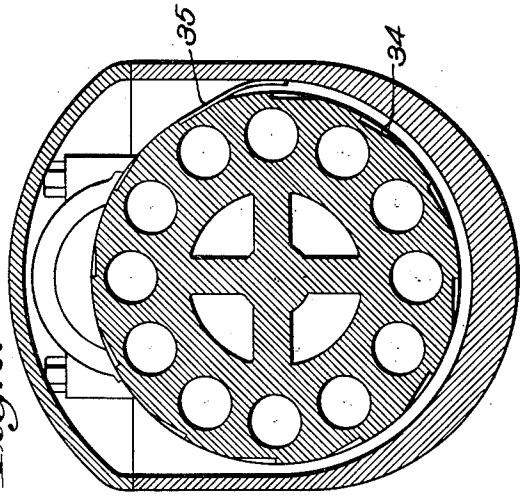


Fig. 9.

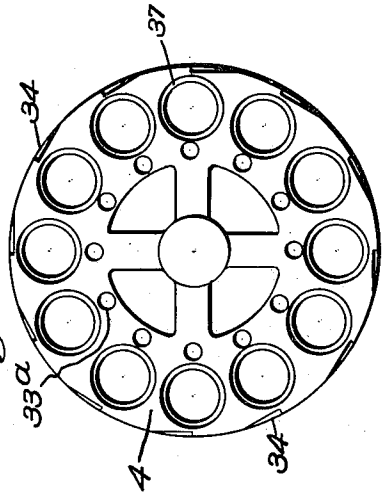
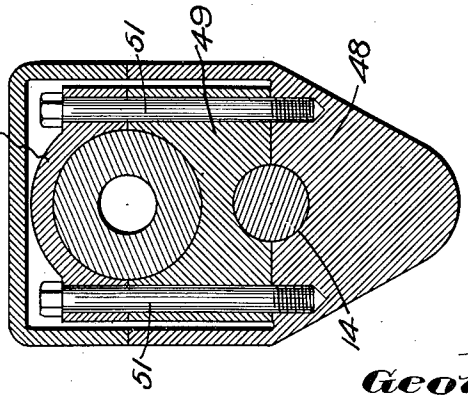


Fig. 6.



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METHOD OF AND APPARATUS FOR BREAKING OUT ROCK

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Fig. 13.

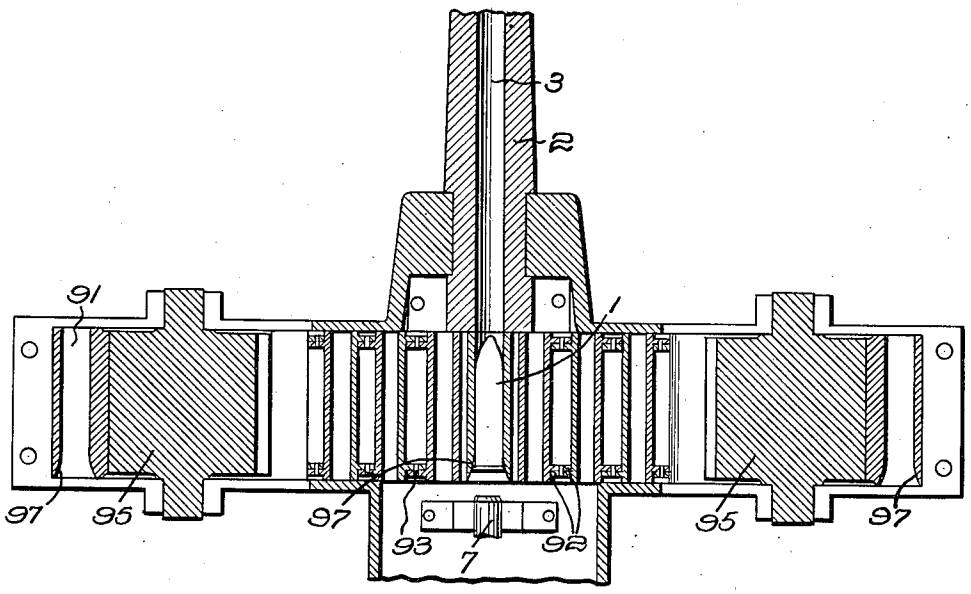

Fig. 12.

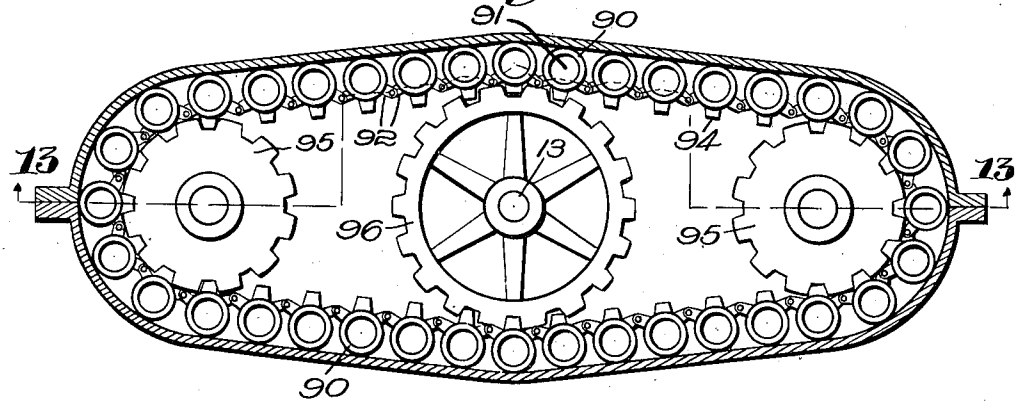

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Fig. 14.

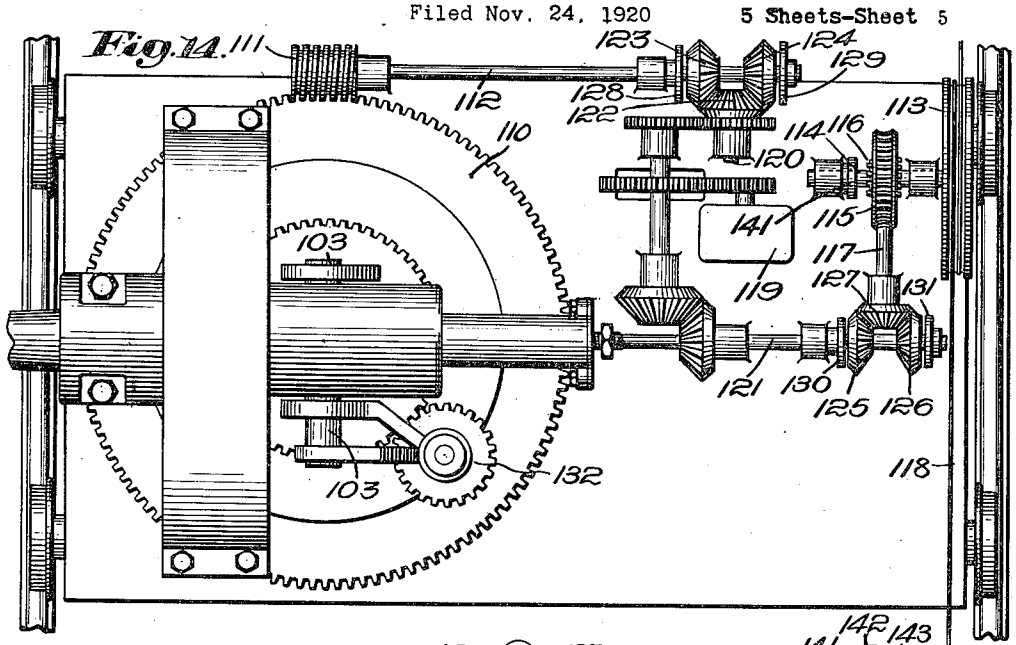


Fig. 16.

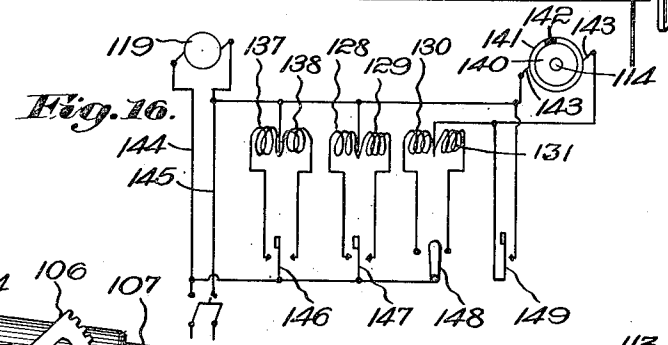
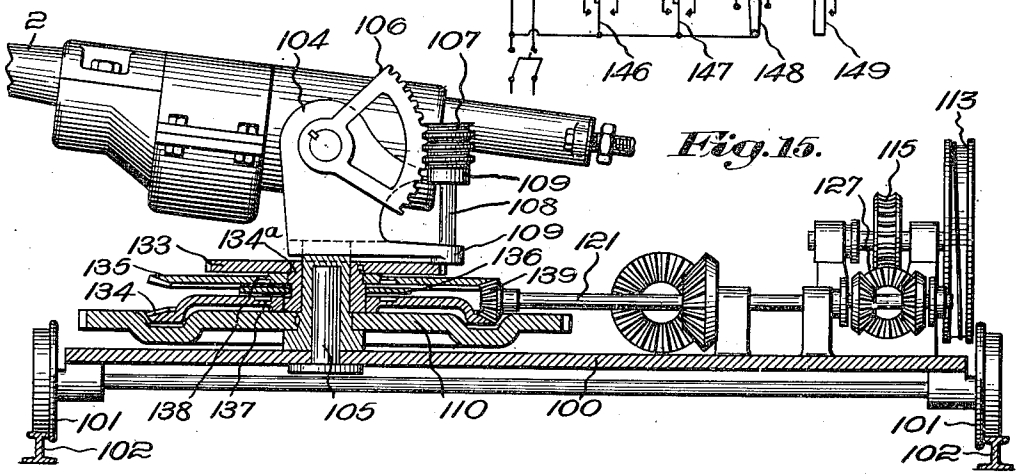


Fig. 15.



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Patented May 25, 1926. 1,585,664

UNITED STATES PATENT OFFICE.

GEORGE H. GILMAN, OF BOSTON, MASSACHUSETTS.

METHOD OF AND APPARATUS FOR BREAKING OUT ROCK.

Application filed November 24, 1920. Serial No. 426,214.

My invention relates to a method of and apparatus for breaking down rock, coal, or other earth formations or deposits, and particularly but not exclusively to the forming of recesses such as holes or kerfs and to the springing of drill holes.

The invention will be best understood from the following description when read in connection with the accompanying drawings of several examples of apparatus for use in practicing the invention, while its scope will be more particularly pointed out in the appended claims.

In the drawings:

Figure 1 illustrates a gun mounted before the face of a heading, and more or less diagrammatically the steps of forming a hole;

Fig. 2 illustrates more or less diagrammatically the steps of forming a kerf or like recess;

Fig. 3 illustrates more or less diagrammatically the steps of springing a drill hole;

Fig. 4 is a longitudinal section through the gun illustrated by Fig. 1 and showing the parts in one position;

Fig. 5 is a view corresponding to Fig. 4 and showing the parts in another position;

Figs. 6, 7 and 8 respectively are sections on the lines 6—6, 7—7 and 8—8 of Fig. 4;

Fig. 9 is a view of the end of the magazine according to Figs. 4 and 5 looking from the back of the machine;

Fig. 10 is a longitudinal section illustrating the controlling valve;

Fig. 11 is a longitudinal section through an example of the shell fired by the gun;

Fig. 12 illustrates a modified form of magazine;

Fig. 13 is a section on the line 13—13 of Fig. 12;

Fig. 14 illustrates the invention applied to a machine for undercutting coal;

Fig. 15 is an elevation corresponding to Fig. 14, parts being shown in section; and

Fig. 16 is a diagrammatic representation of the wiring of the machine according to Figs. 14 and 15.

Heretofore it has been customary to form holes with power drills, and to form kerfs with power operated picks or chain-cutters, while drill holes have usually been sprung by means of powder charges exploded at the end of the drill hole after plugging the portion of the hole immediately above the charge. My improved method comprises breaking out the rock, for example to form holes or kerfs, or to spring drill holes, by subjecting the rock to charges of explosive material and causing the same to explode when in contact therewith. For these purposes I preferably project against the rock percussion shells containing the explosive, and although in carrying out my method I may employ other means for projecting the shells, I preferably employ a gun operated by compressed air. As employed herein the term "rock" is used to indicate any earth formation or deposit.

The following examples are illustrative of the practice of my method. Fig. 1 shows my invention as applied to the process of forming a hole. The gun is shown as mounted before a rock heading and the shell 1 as passing into a hole in the rock, which shell when it reaches the end of the hole is adapted to explode by percussion and thereby to break out additional material and deepen the hole, while the material thus broken down is forcibly ejected, in a more or less pulverized state, from the hole by the gases resulting from the explosion. As illustrated more or less diagrammatically by Fig. 1, the first shell fired against the rock has removed the material represented by the line indicating the cavity A, the second shell the material represented by the line indicating the cavity B, the third shell that indicated by the line C, while the fourth shown passing into the hole thus formed will remove the material represented by the dotted lines indicating the cavity D.

When my invention is employed for cutting a kerf, as for example, for undercutting the face of a heading, the gun may be manipulated to cause the shells to strike the rock at separate points along the direction in which the kerf is to be formed. Fig. 2, which represents a longitudinal section through the rock, shows diagrammatically the process of forming a kerf. In this figure the first shell has removed material to form the cavity indicated by the line A and the second and third the cavities indi-

cated by the lines B and C, while the next shell will remove material to form the cavity indicated by the dotted line D.

It will be understood that in the above example of the practice of my method the gun may be pointed between shots to form a kerf in other than in a straight line, as for example, when it is desired to cut a kerf around the edge of a coal heading, and that in both examples of kerf cutting more than one shell may be fired to form a cavity before the gun is repointed.

Fig. 3 illustrates the process of springing a drill hole. This hole which may be formed by any of the usual methods, as for example by drilling with a drill steel, is indicated at 2 and the shell 1 is shown as projected into the hole and travelling towards the bottom thereof. When the shells strike the bottom of the hole, the first shell will for example break down material to form the cavity indicated by the dotted line A and the material thus removed will be blown from the hole by the gases resulting from the explosion. The second shell and the third respectively will progressively break down and remove material as indicated by the lines B and C progressively to enlarge the original cavity. Successive shells may be fired into the hole until the cavity at the bottom thereof is sufficiently enlarged.

It will be understood by suitably pointing the gun between successive shots the entire face of the heading or any suitable portion thereof may be broken down, for example as indicated by Fig. 2, the gun after forming the cavities A, B, C and D may be used to form the cavities indicated by the lines E, F and G, which operation may be continued until the entire face of the heading is covered.

Referring particularly to Figs. 4 and 5, which show one embodiment of the gun for firing the shell, a barrel 2 is provided having a bore 3, and rearwardly of the barrel is mounted a carrier as shown for the shells, which carrier is in the form of a revolving magazine 4 having chambers adapted to receive and carry the shells 1 into alignment with the breech. In alignment with the bore 3 and rearwardly of the magazine is mounted a cylinder 5 in which is reciprocably mounted a plunger having a head 6 and a plunger rod 7 of substantially the same diameter as the magazine chambers. This plunger is normally biased to its rearward position by pressure fluid preferably compressed air admitted into the forward end of the cylinder through the conduit 8, while the plunger is caused to overcome this pressure and move forwardly by pressure fluid admitted through the conduit 9 into the rearward end of the cylinder. It will be appreciated that the rearward side of the head 6 has a greater effective area than the forward side and consequently whe fluid under the same unit pressure acts o opposite sides of the head 6, the plunge will move forwardly. For permitting th fluid on the forward side of the head 6 t move the plunger rearwardly I have show means hereinafter described for causing th motive fluid admitted to the rearward en of the cylinder to be exhausted to the at mosphere.

When the plunger moves forwardly fro the position illustrated by Fig. 4 to tha illustrated by Fig. 5, it enters the magazin chamber and pushes the shell 1 from th magazine into the bore 3 and at this tim admits motive fluid from the rearward en of the cylinder to project the shell from th barrel. For conducting this fluid to the gu barrel I have shown the plunger rod as pro vided with an axial bore 10 which extend from the front face of the plunger rea wardly and opens through a radial passag 11 to the exterior of the head 6. Near th forward end of the plunger cylinder i formed an enlargement 12 which when th plunger is at the forward end of its strok serves as a conduit to permit fluid to ente the passage 11 whence it passes into th bore 3 and discharges the shell. It will b noted that so long as the plunger is retaine in the position illustrated by Fig. 5, air wi continue to discharge through the bore By maintaining the plunger in this positio after the shell is discharged, a powerful je of air is discharged through the bore whic prevents rock and earth particles blow from the rock by the explosion from enter ing the bore.

The magazine in the illustrative embodi ment shown by Figs. 4 and 5 is provide with a suitable spindle 13 revolvably mount ed in the bearings 14 and 15. Preferably in this embodiment of my invention th magazine is turned by motion imparte thereto by the reciprocations of the plunger For converting the reciprocatory movemen of the plunger into this rotary movement herein provide a gear 16 rigidly carried b the spindle 13 and meshing therewith gear 17 provided with a hub 18 mounted i suitable bearing 19. The gear 17 is recesse to receive a cylindrical member 20 carrying suitable pawls 21 adapted to cooperate with ratchet teeth 22 formed on the interior sur face of the gear wheels 17, spring presse plungers 30 being provided to hold the pawls in engagement with the teeth. The member 20 and the hub 18 of the gear wheels 17 are provided with axial bores of the same diameter as the plunger 7, the plunger there by being permitted to slide through these members, being supported by the hub 18 and affording a bearing for the member 20 Providing a further support for the plunger rod and for holding the member 20 and the

gear wheel 17 in position, the cylinder 5 is herein provided with a forward extension 23, the forward end of which abuts the rearward face of the member 20.

The plunger illustrated is provided with a pair of oppositely disposed straight grooves 24 and intermediate these grooves are formed other grooves having a straight portion 25 and a helical portion 26. The extension 23 of the plunger cylinder carries a pair of keys 27 which enter the grooves 24 and thereby prevent the plunger from rotating but permit it to reciprocate. The member 20 carrying the pawls is provided with oppositely disposed pins 29 which enter the grooves having the portions 25 and 26. By this construction when the plunger is forced rearwardly the pins 29 are caused to enter the helical grooves 26 and thereby to rotate the pawl carrying member 20 and by means of the pawls the latter to rotate the gear 17 in the direction of the arrow shown in Fig. 8. When the plunger is forced forwardly from the position illustrated by Fig. 4, the member 20 is turned by the action of the helical slots on the pins 29 in a direction opposite to the arrow in Fig. 8 and this does not turn the gear wheel 17 by reason of the fact that under such conditions the pawls ride over the teeth 22. The helical slot 26 is so positioned and proportioned with relation to the other parts of the machine that the magazine is turned sufficiently to bring a new shell into alignment with the bore 3 when the plunger is moved from its forward position, illustrated by Fig. 5, to its rearward position illustrated by Fig. 4.

For better insuring the proper positioning of the shell in alignment with the bore I herein provide the plunger 32 carried by the casing and pressed forwardly by means of a spring 33. This plunger is provided with a spherical end which is adapted to snap into spherical recesses 33ª formed in the rearward face of the magazine, when the shell is brought into alignment with the gun barrel. For insuring against reverse rotation of the magazine I herein provide the same with notches 34 which serve as ratchet teeth for the spring pawl 35 carried by the casing.

The magazine illustrated is provided with a series of chambers 36 having bores of such diameter as will fit the exterior surface of the shells, which bores are slightly counterbored at one end to form an enlarged diameter portion 37. In alignment with the rearward end of these chambers is an opening 38 formed in the casing through which the shell may be inserted. This opening is normally closed by means of a flap 39 hinged to a pivot 40 carried by the casing. For rotating the magazine while the same is being filled I herein provide the spindle 13 with a projection 41 having on the end thereof exterior of the casing of the machine a head 42 adapted to receive a suitable key or other handle for turning the magazine. It will be noted in this connection the ratchet mechanism illustrated by Fig. 8 permits the turning of the gear 17 by the key in the same direction the gear is turned by the plunger.

For securing the parts in assembled relation I herein provide a casing having the upper portion 43 and lower portion 44, which portions are bolted together by means of suitable bolts 45 as illustrated by Fig. 1. The barrel 2 has a reduced diameter portion 46 and the plunger cylinder extension a reduced diameter portion 47, each adapted to be received by the end portions of the casing and to be clamped in position when the halves of the casing are assembled. Rearwardly of the front end the machine is provided with a boss 48 which supports a block 49. The adjacent portions of the block and boss are provided with semi-cylindrical recesses which form the bearing 14 for the magazine spindle, while the upper portion of the block is provided with a semi-circular recess to support the extreme rearward end of the barrel. For clamping the barrel in position herein is provided a suitable cap 50 and for assembling the cap and block to the boss are provided the through bolts 51. The bearing 15 for the rearward end of the magazine spindle and the bearing 19 for the gear 17 are provided by the block 52 and cap 53 similar to the block 49 and cap 50. The block 52 and cap 53 are secured to a boss 54 in the same manner that the block 49 and cap 50 are secured to the boss 48.

As illustrated, on the lower portion of the casing is carried a conical projection 55 which serves to connect the machine to the usual tripod or mine column. Such a tripod is shown at 56 in Fig. 1 and provides a mounting for the gun enabling it to be pointed in any direction.

For controlling the air for operating the plunger, I herein provide a suitable valve, the casing of which is connected to the conduits 8 and 9 and to the conduit 57 conducting motive fluid from a suitable source of supply. This casing provides a base provided with a bore 58, an intermediate bore 59 of smaller diameter and the bore 60 of still smaller diameter. On the shoulder connecting the bores 58 and 59 is formed the conical valve seat 61 and closing the bore 58 is provided a plug 62 having a bore 63 closed at one end and opening at the other into the bore 58 of the casing. Mounted for reciprocation in the respective bores of the casing is a valve member provided with a stem 64, a cylindrical head 65 fitting the bore 59 and a second stem 65ª which enters the bore 63 to provide a rearward support for the member. The stem 65 has formed

therewith a puppet valve 66 adapted to cooperate with the seat 61. Surrounding the stem 65a is a spring 67 which abuts the plug 62 at one end and the valve 66 at the other and thereby tends to force the valve member to the left as viewed in Fig. 10. Connecting the bore 58 with the conduits 57 and 8 respectively are passages 68 and 69 and connecting the bore 59 with the conduit 9 and the atmosphere respectively are passages 70 and 71. The casing is formed with a handle grip portion 72 and carries a trigger pivoted to the casing at 73. This trigger is provided with a finger portion 74 and an arm 75 against which the end of the stem 64 is forced by the spring.

As will be obvious, the hand of the operator which grasps the handle 72 may operate the trigger by the fingers of such hand to hold the valve in the position illustrated by Fig. 10 or by releasing the trigger to permit the spring and the pressure of the air on the head 65 to force the valve to the left sufficiently to permit the valve 66 to seat and the head 65 to uncover the port 71. It will be noted that in all positions of the valve, the conduit 8 is connected to the source of motive fluid supply and therefore continually supplies motive fluid to the front end of the plunger cylinder. In the position of the parts shown by Fig. 10 motive fluid is admitted into the conduit 9 which conducts the same to the rearward end of the plunger cylinder and when the valve member is permitted to move to the left the valve 66 seats and the passage 71 is opened, which interrupts the supply to the conduit 9 and opens the same to the atmosphere. This exhausts the rearward end of the plunger cylinder and permits the pressure supplied to the conduit 8 to move the plunger to its rearward position.

In Fig. 11 is illustrated a form of shell for use in the gun just described. As illustrated the shell comprises a container carrying the explosive material and the mechanism for causing the same to explode. The body of the container I prefer to make of a material which will be disintegrated by the explosion and for this purpose I employ relatively soft material such as cardboard or moulded paper pulp. The shell as illustrated comprises a cylindrical member 76 having a thickened front end 77 which preferably is tapered. The front end carries a firing pin 78 which is provided with a head 79 in spaced relation to a percussion cap 80 carrying fulminate of mercury or other suitable detonating substance. It will be observed by this construction that the striking pin can only be brought into contact with the percussion cap when the point of the shell strikes the rock and thereby crushes the front head. This is done to guard against explosion due to the shell striking the sides of the hole before it reaches the bottom thereof and is particularly applicable when employed for springing drill holes. The cavity of the shell rearward the percussion cap is filled with gelatine or other suitable explosive as indicated at 81. For protecting the explosive from the effect of accidental blows I may support the same from the walls of the shell by means of a layer 82 of corrugated material, for example such material as paper. The end of the shell as illustrated is closed by means of a suitable plug 83 which preferably is of the same material as the remainder of the casing. For holding the plug in position I herein provide the same with an exterior annular groove 84 into which I bead the wall of the shell as indicated at 85. On the rearward end of the plug illustrated is formed a flange 86 of greater diameter than the cylindrical portion of the shell. This flange serves to position the shell when inserted into the chamber of the magazine, the flange entering the counterbored portions 37 thereof and collapsing when the plunger forces the shell into the bore of the barrel. In this end of the cap I preferably form a cavity 87 which forms a space separating the end of the shell from the explosive material therein. The explosive material may be moulded into shape or if not capable of this is enclosed in a suitable container of paper or silk. The particular character of the explosive and amount thereof constituting the charge for a single shell may be varied to suit the conditions of the rock and size of the recess to be formed.

For some uses of my gun, for example, when applied to the undercutting machine hereinafter described, it is desirable to employ a magazine having a greater capacity than that embodied in the machine illustrated by Figs. 4 and 5. Such a magazine may take the form of an endless conveyor as illustrated by Figs. 12 and 13, in which the links 90 are provided with recesses 91 for receiving the shells 1. The adjacent portions of the links are provided with lugs 92 hinged together by means of pins 93. On one face of the links are provided the teeth 94 for engaging the sprocket wheels 95 and 96. The sprocket wheel 96 is carried by the spindle 13 illustrated by Figs. 4 and 5 and is substituted for the revolving magazine 4 illustrated by these figures. The sprocket wheels 95 serve merely to guide the conveyor.

When the plunger 7 operates, the sprocket 96 is turned in the same manner as the magazine 4 hereinbefore described, a new link and cartridge being brought into alignment with the bore of the gun barrel on each stroke of the plunger and the latter pushing the cartridge into the bore as hereinbefore described. In this modification of the magazine I have shown the cartridge chambers

91 as flared as illustrated at 97. With this construction if movement of the sprocket does not accurately align the cartridge with the bore of the gun barrel, the head of the plunger by contacting with the flared surface 97 will move the conveyor slightly to bring the cartridge into alignment with the barrel, after which the plunger enters the cartridge chamber and pushes the cartridge into the bore.

Referring particularly to Figs. 14 and 15, the illustrative embodiment of the undercutting machine hereinbefore referred to comprises a carrier having a platform 100 provided with the wheels 101 adapted to roll along the tracks 102, which tracks may be arranged parallel to the face of the heading. On the platform may be mounted the gun hereinbefore described, provided with the magazine illustrated by Figs. 12 and 13 and which as herein illustrated has trunnions 103 formed with the casing for pivotedly supporting the gun on the pedestal 104, the latter being pivotedly mounted on the pin 105 fixedly carried by the platform.

For elevating the gun I herein key to one of the trunnions a worm sector 106 with which meshes the worm 107 carried by the shaft 108 rotatively supported in the brackets 109 carried by the pedestal. As will be obvious when the shaft 108 is rotated the gun will be elevated or depressed and when the shaft 108 is stationary the gun will be firmly locked against vertical movement of the muzzle.

As illustrated, for swinging the gun horizontally I key to the lower portion of the gun pedestal a worm wheel 110 which meshes with a suitable worm 111 carried by the shaft 112.

For moving the platform along the track I herein provide a drum 113 supported by the shaft 114 fixedly secured to which is the worm wheel 115 driven by the worm 116 carried by the shaft 117. About the drum is wrapped one or more turns of the cable 118, the opposite ends of which are anchored adjacent the opposite sides of the heading. As will be obvious, when the shaft 117 is rotated, the drum 113 will be turned and the platform caused to travel along the track in a direction depending upon the direction of rotation of the shaft.

For operating the gun pointing mechanism and the drum 113 I herein provide a suitable motor 119, which for purposes of illustration I have shown as an electric motor. As illustrated the motor by means of suitable gearing drives the shafts 120 and 121, the shaft 120 as shown being provided with a bevelled gear 122 in mesh with the oppositely disposed bevelled gears 123 and 124 while the shaft 121 is provided with the bevelled gears 125 and 126 in mesh with the gear 127 carried by the shaft 117.

For connecting the gears 123, 124, 125 and 126 to their respective shafts I herein provide the electro-magnetic clutches 128, 129, 130 and 131, and as will be obvious by means of these clutches, the shafts 112 and 117 may be revolved in either direction so as to enable the operator to properly swing the gun or cause the carriage to travel along the track.

For operating the worm 107 in order to elevate or depress the gun, I herein provide the lower end of the shaft 108 with the spur gear 132, which is permanently in mesh with the gear 133 keyed to a sleeve 134^a rotatively mounted on the lower portion of the gun pedestal. Below the gear 133 are provided the bevel gears 134 and 135, which are normally freely rotatable with relation to the sleeve. Between the gears 134 and 135 I mount a suitable armature 136, which as shown is in the form of a flat plate splined to the sleeve in order that it may rotate therewith, but is free to slide longitudinally thereon, while meshing with the gears 134 and 135 is a gear 139 carried by the shaft 121 and effective to rotate the gears 134 and 135 in opposite directions. Carried by the gears 134 and 135 respectively are the annular coils 137 and 138. By this arrangement is formed a clutch effective by selective energizing of the coils to connect the armature 136 to either of the gears 134 or 135 and thus the shaft 121 is enabled to rotate the worm 107 in opposite directions as may be desired in order to elevate or depress the gun. It will be noticed that when the gun is swivelled by the operation of the worm 111 the elevation of the gun is unchanged because under such conditions the worm 107 and worm sector 106 act to turn the gear 133 without producing any other effect.

For causing the carriage to stop at predetermined positions in its travel along the track I herein provide an interruptor for the clutches 130 and 131. Such interruptor may take the form of a disk 140 of insulating material keyed to the shaft 114 and carrying a ring shaped conductor 141 provided with the gap 142, while in contact with the ring are the brushes 143 placing the ring in the circuit of the clutches 130 and 131.

The operation of the illustrative embodiment of the controlling mechanism for my undercutting machine will be understood by reference to Fig. 16. In this figure I have shown the motor 119 energized by the leads 144, 145, while connected to one side of the line thus formed are the switch keys 146, 147 and 148. Each key is provided with a pair of contacts leading to the coils of the clutches, while adjacent ends of the coils are connected to the side of the line opposite that to which the keys are connected. Obviously, by throwing the key 146 to the left

as viewed in the figure, the coil 137 may be energized and similarly by throwing it to the right, the coil 138 may be energized. In a similar manner by means of the keys 147 and 148 the clutches controlling the motion of the carriage and the swinging of the gun may be controlled. It will be noticed that after either of the clutches 130 and 131 is energized by the key 148, and the drum has turned a predetermined distance, the circuit is interrupted by reason of the gap 142 moving opposite one of the brushes 143. Under such conditions the carriage stops moving and the operator may then discharge projectiles until the required amount of material has been removed. For causing the carriage to continue its movement, I provide the key 149 which when closed shunts out the interruptor. This key may also be used to cause a continuous movement of the cariage from one end of the track to the other. By suitably proportioning the speed of the interuptor and the number of brushes and gaps, the carriage will be caused to automatically stop at the proper places necessary to space the cavities blown out by the gun to form the kerf or undercut.

It will be noticed that the clutches, keys and interruptor may be of any usual or suitable construction and are so well known that no further description need be given.

It is to be understood that the foregoing descriptions of specific embodiments of apparatus and shell and the descriptions of several examples of the practice of my method are submitted as examples of my invention and that extensive deviations may be made therefrom within the spirit of my invention.

Claims.

1. The method of breaking down rock and earth formations which comprises projecting against the same successive charges of explosive each sufficient to break out a limited quantity of material and each exploding by impact when in free contact with the formation.

2. The method of breaking down rock and earth formations which comprises projecting against the same successive charges of explosive each sufficient to pulverize a limited quantity of material, each charge exploding by impact when in free contact with the formation, and the interval between explosions being sufficient to allow the explosion gases to remove the material pulverized.

3. The method of breaking down rock and earth formations which comprises projecting against the same successive charges of explosive each sufficient to form a cavity and in so placing said explosives that the cavities so formed are in communication, each charge exploding by impact when in free contact with the formation.

4. The method of breaking down rock and earth formations which comprises projecting against the same successive charges of an explosive adapted to explode by impact when in free contact with the formation and each being of limited size to form a cavity without shattering said formation.

5. The method of advancing a recess in rock and earth formations which comprises breaking and removing limited amounts of the material by the explosive action of successive charges of explosive projected against the formation and exploding upon impact.

6. The method of forming holes in rock and earth formations which comprises successively breaking down limited quantities of material by the explosive action of successive charges of explosive projected against the formation and exploding upon impact, and in which the interval between explosions is sufficient to permit the explosion gases to remove such material from the hole.

7. The method of forming holes in rock and earth formations which comprises successively pulverizing and removing from the bottom of the hole limited quantities of material by the explosive action of successive charges of explosive projected against the formation and exploding upon impact.

8. The method of forming holes in rock and earth formations which comprises projecting into the hole being formed successive charges of explosive adapted to explode upon impact at the end of the hole and break down a limited quantity of material.

9. The method of forming holes in rock and earth formations which comprises projecting into the hole being formed successive charges of explosive adapted to explode on impact at the end of the hole, and in so timing the projection of successive charges to permit the explosion gases resulting from the explosion of a charge to remove the material broken down before the projection of the next successive charge.

10. The method of springing drill holes which comprises projecting into the hole successive charges of explosive material adapted to explode upon impact at the end of the hole and break down a limited quantity of material.

11. The method of springing drill holes which comprises projecting into the hole successive charges of explosive material adapted to explode upon impact at the end of the hole, and in which the interval between the projection of successive charges is sufficient to permit the explosion gases to clear the hole of material broken down by the explosion of the charge.

12. The method of springing drill holes which comprises projecting into the hole successive charges of explosive material

which explode upon impact at the bottom of the hole, and in timing the explosions at intervals sufficient to permit the explosion gases to clear the hole before the projection of the next successive charge.

13. The method of undercutting the face of a breast or like wall which comprises breaking out material by successively projecting against the said face explosive adapted to explode upon impact, and in causing the cavity made by one explosion to be enlarged in a direction transverse to said face by successive explosions.

14. The method of breaking down the face of a breast or like wall which comprises forming an undercut by successively projecting quantities of explosive adapted to be exploded upon impact against said face, and then breaking down the material above said undercut by successively projecting explosive against said material.

15. The method of breaking down the face of a breast or like wall which comprises forming a cavity at the lower portion of said face by successively projecting explosive adapted to explode upon impact against said face, and then breaking down the material above said cavity by successively projecting similar explosive against said material.

16. The method of breaking down the face of a breast or like wall which comprises successively projecting against said face explosive adapted to explode upon impact and form a cavity in said face, and in enlarging the cavity formed by one explosion by successively projecting explosives until the entire face is broken down.

17. The method of breaking down the face of a breast or wall which comprises first forming an undercut and in breaking down the material above said undercut by projecting thereagainst successive charges of explosive, each charge adapted to explode upon impact.

In testimony whereof, I have signed my name to this specification.

GEORGE H. GILMAN.