

Nov. 3, 1925.

1,559,709

M. A. KNAPP

ROCK DRILL

Filed Sept. 18, 1920

6 Sheets-Sheet 1

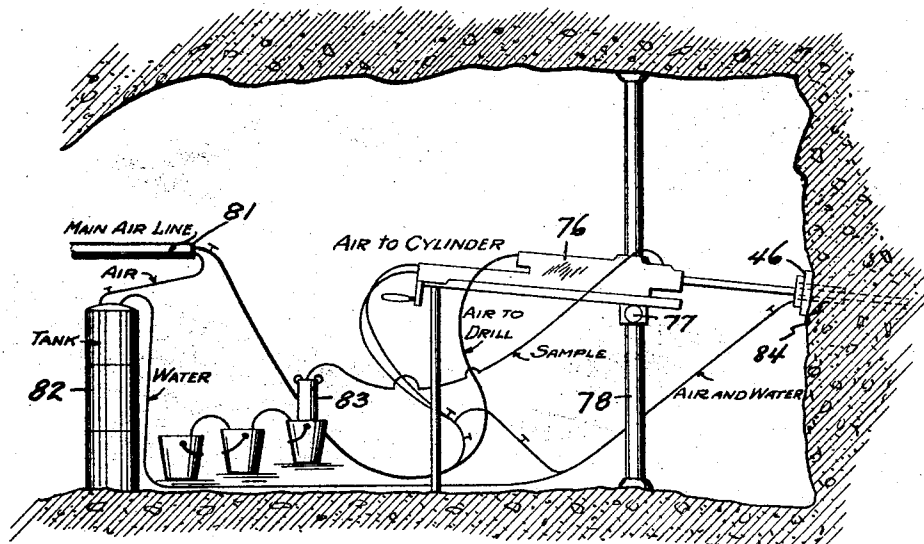


Fig. 1.

Fig. 28.

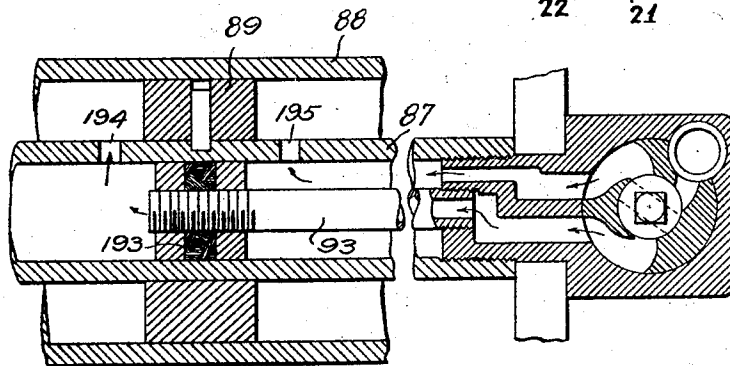
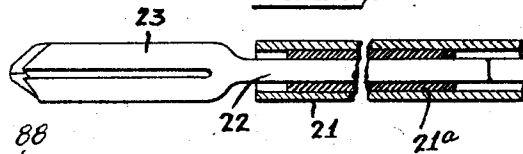


Fig. 27.

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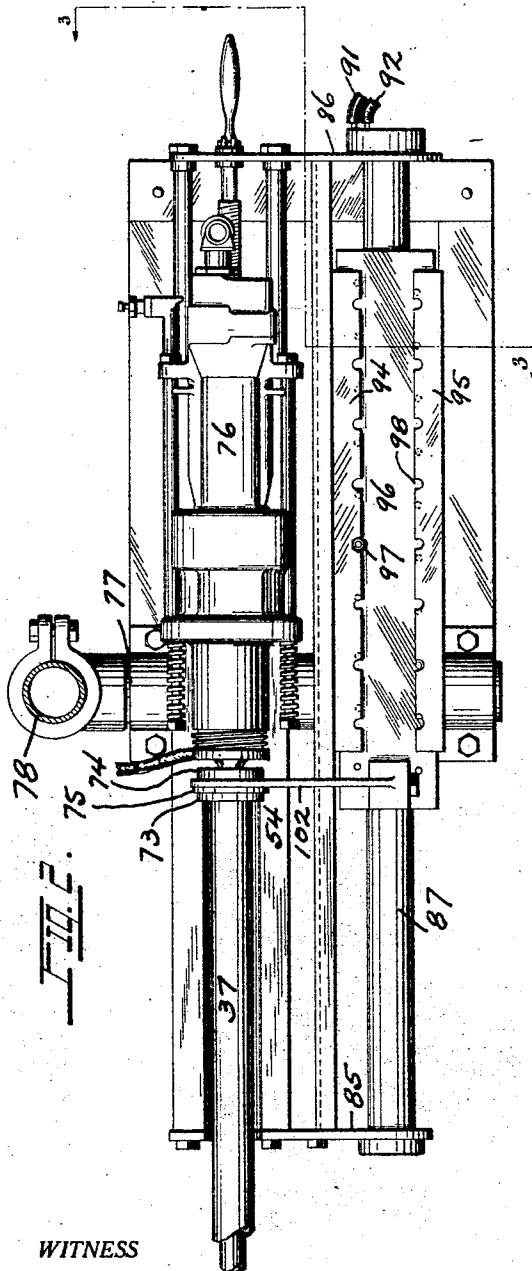
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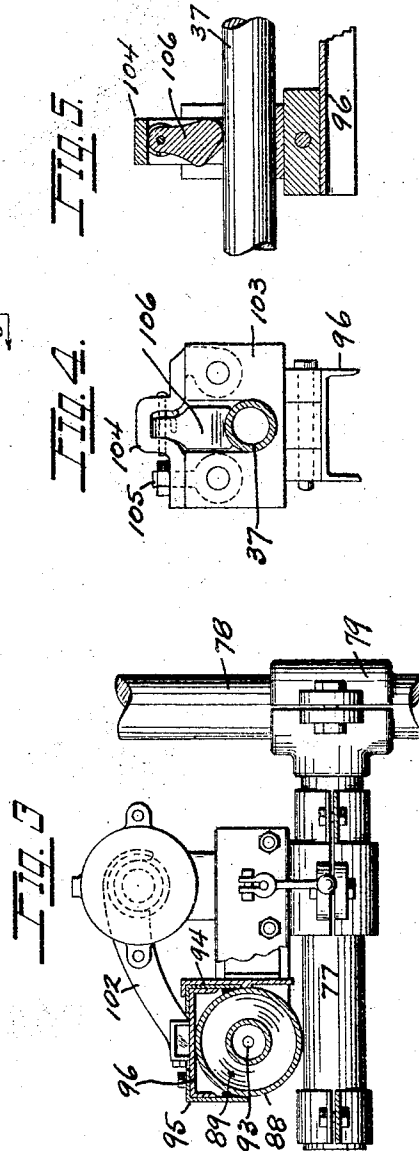
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6 Sheets-Sheet 2



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Filed Sept. 18, 1920

6 Sheets-Sheet 3

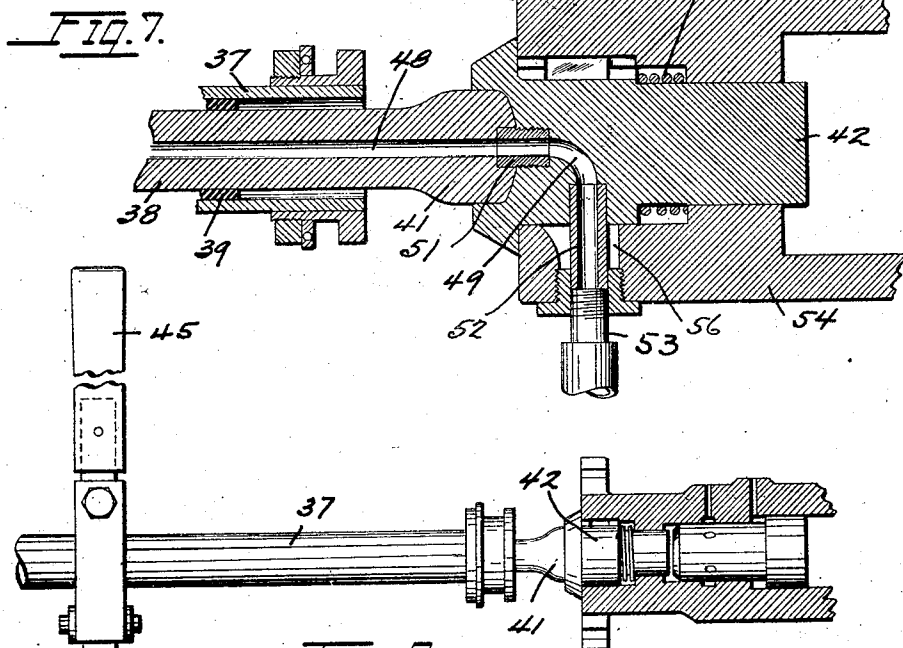
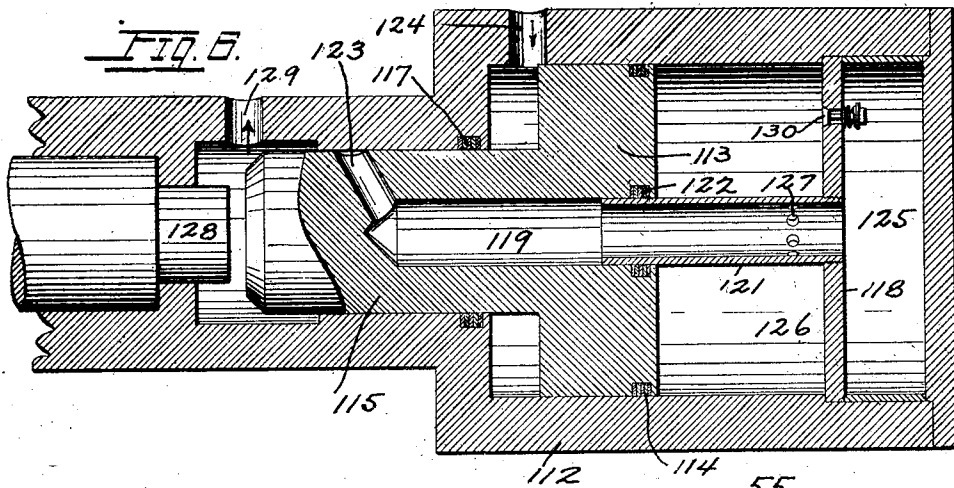


FIG. 8.

WITNESS

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Filed Sept. 18, 1920

6 Sheets-Sheet 4

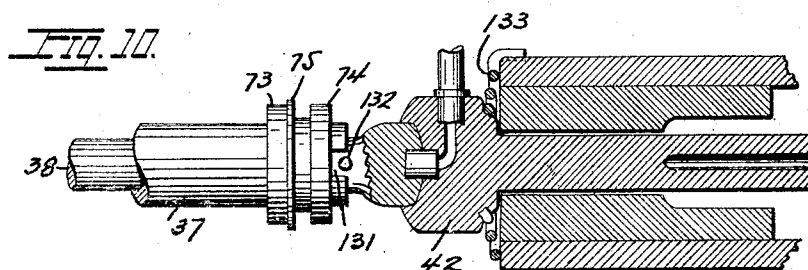
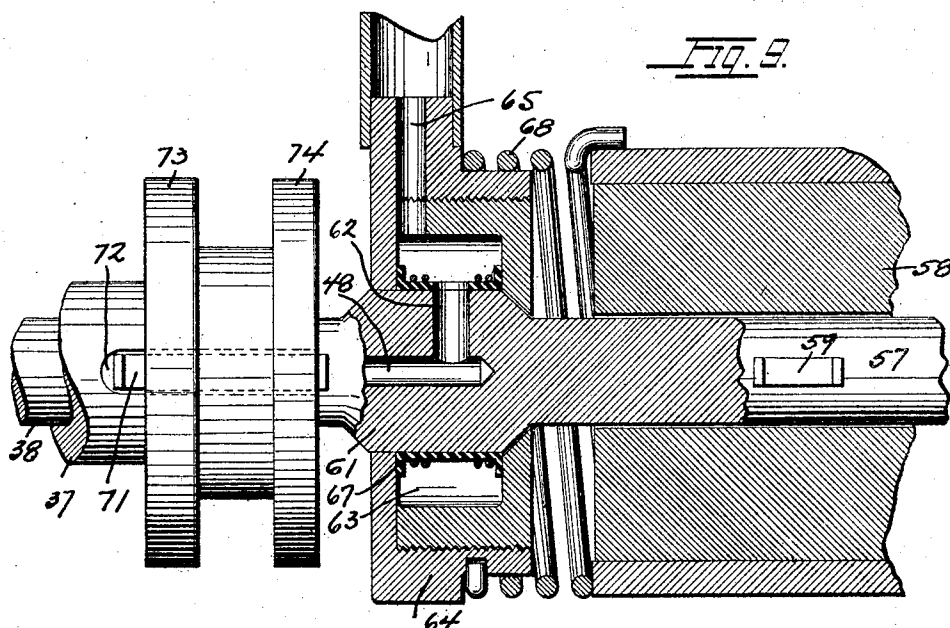


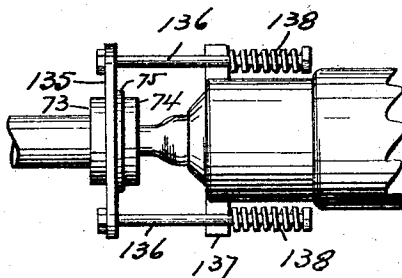
FIG. 12.



WITNESS

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FIG. 11.



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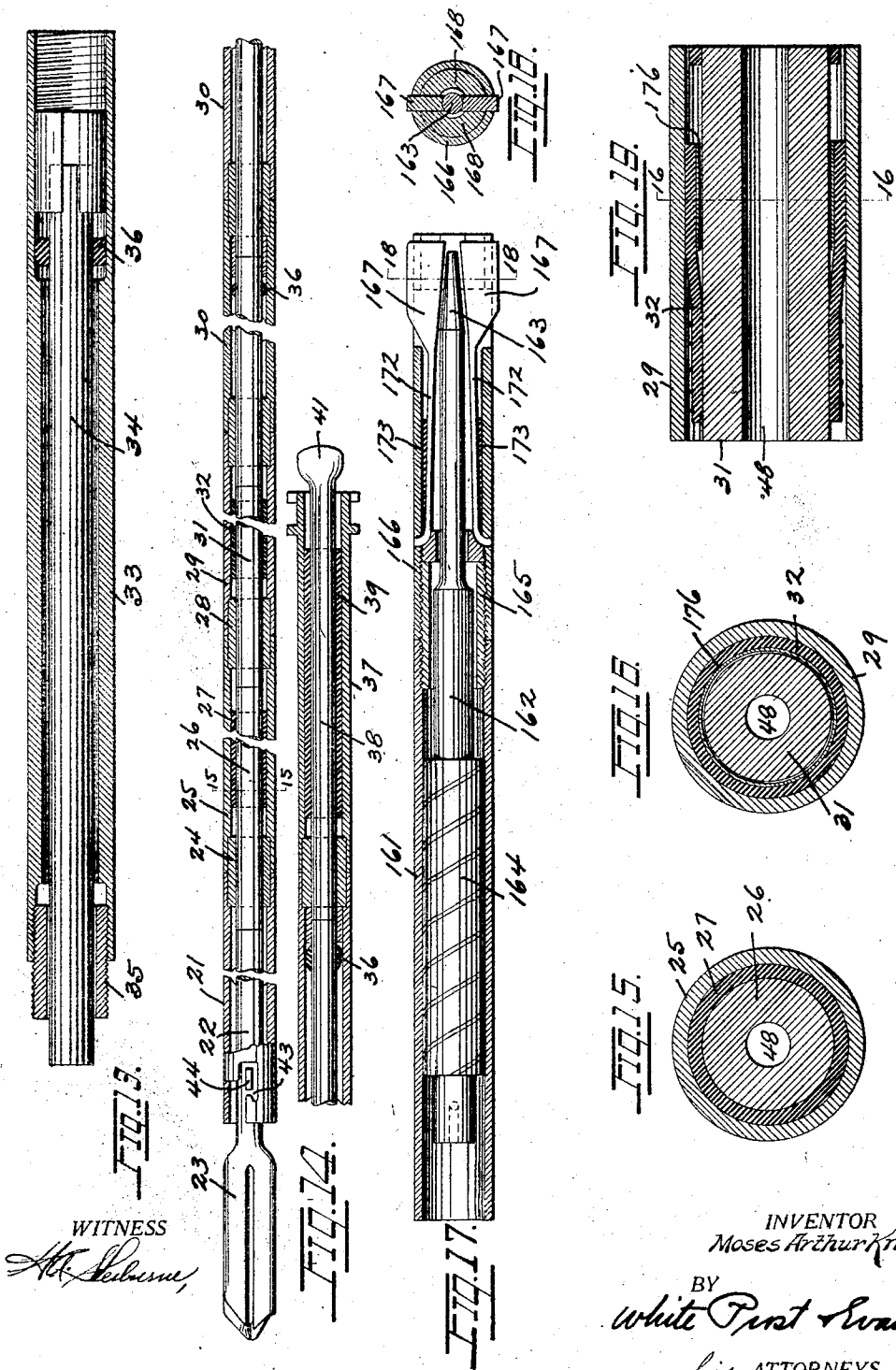
M. A. KNAPP

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ROCK DRILL

Filed Sept. 18, 1920

6 Sheets-Sheet 5



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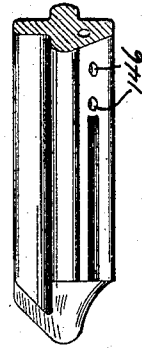
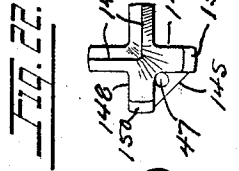
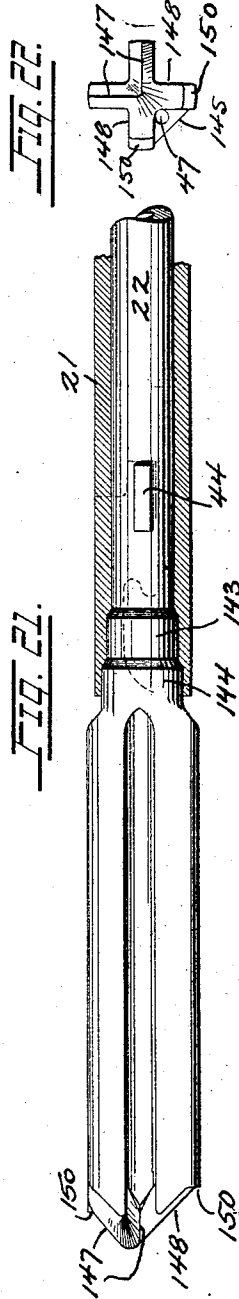
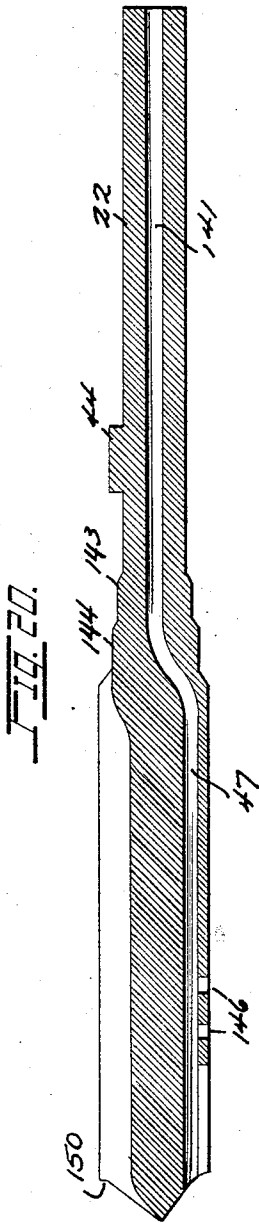
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ROCK DRILL

Filed Sept. 18, 1920

6 Sheets-Sheet 6



WITNESS

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UNITED STATES PATENT OFFICE.

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ROCK DRILL.

Application filed September 18, 1920. Serial No. 411,064.

To all whom it may concern:

Be it known that I, MOSES ARTHUR KNAPP, a citizen of the United States, and a resident of Oakland, county of Alameda, State of California, have invented certain new and useful Improvements in Rock Drills, of which the following is a specification.

The invention relates to rock drills and especially to drill rods used with hammer rock drills which are operated by a series of heavy percussive blows delivered in rapid succession by a compressed air operated hammer.

An object of the invention is to provide means for transferring a high percentage of the energy of the hammer blow of a rapidly striking hammering machine external to the drill hole to a light rock cutting drill bit wholly inserted in the drill hole and free to move forward under the impulses of the hammer blows.

Another object of the invention is to provide means for aligning the drill hole and for maintaining it at the necessary diameter.

A further object of the invention is to provide means for taking a fairly consecutive sample of the rock cuttings continuously from the drill holes to determine the location of ore bodies cut by the holes.

A further object of the invention is to provide means for rotating the drill bits in the drill hole for inserting and withdrawing the drill rods and for sustaining them while drilling.

A further object of the invention is to provide a new form of hammering machine whereby a plurality of heavy percussive blows may be delivered in very rapid succession.

A further object of the invention is to provide a rock drill comprising a plurality of rods interposed between the drill bit and the hammering machine with means for holding the rods in longitudinal contact so that a high percentage of the energy of each of the high frequency hammer blows delivered to the outermost rod is transferred through the rod series to the drill bit. The drill bit is generally separate from the energy transmitting means and is carried by a tube surrounding the rods and the drill bit is mounted so that it is capable of longitudinal movement independent of the tube.

The invention possesses other advantageous features, some of which, with the foregoing, will be set forth at length in the following description where I shall outline in full that form of the invention which I have selected for illustration in the drawings accompanying and forming part of the present specification. In said drawings I have shown several embodiments of the rock drill of my invention, but it is to be understood that I do not limit myself to the embodiments shown since the invention as set forth in the claims may be embodied in a plurality of other forms.

Generally considered the invention comprises a series of abutting rods enclosed in a tube or pipe and elastically held in the pipe at the forward end or at both ends of the rod series, and very strongly held in contact at their ends by the tensile strength of the pipe; and a self-aligning, self-clearing drill bit loosely held at the forward end of the pipe and adapted to receive the impulses transmitted through the rod series from the rapidly reciprocating hammer arranged external to the drill hole; together with means of collecting consecutively the sample cuttings and of rotating and handling the rods and pipe sections and other accessory apparatus necessary to the complete operation.

Referring to said drawings:

Fig. 1 is an elevation of the general arrangement of the drilling apparatus in a mine drift when drilling a slightly down-cast hole.

Fig. 2 is a plan view of the hammer drill on its shell showing the means for handling the rods.

Fig. 3 is a section taken on the line 3—3, Fig. 2.

Fig. 4 is an elevation of the rod-pulling clamp.

Fig. 5 is a longitudinal section of the rod-pulling clamp.

Fig. 6 is a longitudinal section through the drilling machine showing the reciprocating hammer.

Fig. 7 is a horizontal section through the hammering machine showing the tappet and the end rod of the rod series, and showing an outlet for the sample from the drill hole.

Fig. 8 is a plan and partial horizontal sec-

tion of a portion of a hammer drilling machine in operative position against the rear rod of the composite drill rod showing means for rotating the rod tube by hand.

5 Fig. 9 is a longitudinal section through a portion of a drilling machine showing the outlet for the sample from the drill rod through a swivel in front of a self-rotating hammer drill adapted to rotate the composite rod series by power.

10 Fig. 10 is a longitudinal section of a modified form of tappet adapted to enter the front end of a standard hammer drilling machine and to be used in connection with hand rotation of the rod allowing the drill chuck to rotate freely.

Fig. 11 is an elevation of the end of the drilling machine showing means to connect the rods and the drilling machine.

20 Fig. 12 is an elevation of the yoke used in the structure shown in Fig. 11.

Fig. 13 is a longitudinal section through one section of the composite drill rod.

25 Fig. 14 is a longitudinal section through the composite drill rod showing a plurality of rods in series, the drill rod being broken away at parts thereof to reduce the length of the figure.

30 Fig. 15 is a cross section taken on the line 15—15, of Fig. 14.

Fig. 16 is a cross section taken on the line 16—16, of Fig. 19.

35 Fig. 17 is a longitudinal section through a reamer for use in connection with the rock drill of my invention.

Fig. 18 is a cross section taken on the line 18—18, Fig. 17.

40 Fig. 19 is a longitudinal section on a larger scale of a connection means between the tube and the forward rod shown in Fig. 14.

Fig. 20 is a longitudinal section of the drill bit of my invention.

45 Fig. 21 is a plan view of the drill bit of my invention inserted in the rod tube.

Fig. 22 is a view of the cutting face of the drill bit of my invention.

Fig. 23 is an elevation of a modified form of drill bit.

50 Fig. 24 is a cross section of the bit shown in Fig. 23.

Fig. 25 is an elevation of the cutting end of the drill bit shown in Fig. 23.

55 Fig. 26 is a front elevation of the form of drill bit shown in Fig. 21.

Fig. 27 is a longitudinal section of a portion of the feed cylinder, showing the air conduits and control valve.

60 Fig. 28 is a longitudinal section through the drill tube showing the drill secured thereto by a rubber filler.

65 The rock drill of my invention comprises a drilling engine of the hammer type, a drill bit wholly inserted in the drill hole and energy transmitting means interposed be-

tween the hammer and the drill bit for transmitting the energy of hammers' blows to the drill bit. The energy transmitting means comprises a composite drilling rod composed of a plurality of sections of pipe or tubing securely fastened together and a plurality of rods disposed in longitudinal engagement within the pipe. The drill bit is carried by and rotated by the pipe and the impact of the hammer blow is transmitted from the hammer to the drill bit through the rod series in the pipe. The rods in the series are in tight abutting engagement and the end of the leading rod is in abutting contact with the shank of the drill bit, so that the energy of the hammer blow is transmitted to the drill bit with the minimum energy loss. The pipe and rods are formed in sections, and additional sections are added to the composite drill rod as the drilled hole deepens, rendering the drill particularly adaptable to the formation of deep holes. Each section preferably comprises a pipe section and a contained rod section of the same length as the pipe section, so that when a composite section is screwed in place, the rod in the added section is brought into tight abutting contact with the ends of the adjacent rods. The various composite rod sections are preferably of different form, as will be hereinafter set forth.

In Fig. 14, I have shown a composite drilling rod formed of four sections, although it is to be understood that any desired number of sections may be employed, depending upon the depth of the hole. Means are provided within the composite rod for holding the rod sections pressed tightly together under heavy pressure, so that the vibration of the rods due to the rapidly recurring hammer blows, will not cause the rods to separate. The rod section in the outer composite section usually extends sufficiently forward of its containing pipe section, so that when the outer composite section is screwed into place the rod section therein contacts with and is displaced longitudinally by the contiguous rod section, thus indicating that all of the rod sections are in pressing contact. The leading rod sections are firmly and resiliently held to the containing pipe sections and these sections are displaced slightly longitudinally when the sections are screwed together thus placing the entire rod series under longitudinal pressure.

The leading pipe section 21 comprises a socket for the shank 22 of the drill bit 23 which has a limited longitudinal motion with respect to the pipe, to permit the drill bit to spring forward against the face of the rock, under the transmitted impulses of the hammer. Firmly and tightly screwed to the pipe section 21 by a nipple 24 is the second pipe section 25 in which is disposed

a rod section 26 which is resiliently held to the pipe section so that it is capable of longitudinal vibration, without permanent longitudinal displacement. This rod section, which I have termed the rebounding rod section, springs forward from the following or contiguous rod section, under the impulses of the hammer blows, and strikes and imparts the energy of the blow to the drill bit. The rod section may be resiliently held to the pipe section in any suitable manner, such as by the introduction of a cylinder of rubber 27 into the annular space between the rod and the pipe. The rubber is introduced into the annular space in such manner that it is under pressure and in tight contact with the rod and pipe, permitting the rod to move slightly with respect to the pipe, but preventing it from being permanently displaced. The rubber may be in the form of a cylinder, or may comprise a strip of rubber wrapped spirally around the rod or may comprise longitudinal strips or may be otherwise suitably formed and inserted, as will be hereinafter set forth. I prefer to use rubber, rather than a metallic spring, since the rubber will not transmit the vibration of the rod to the pipe and since the rubber will remain "live" under vibration, whereas metal may crystallize.

Secured to the pipe section 25 by the nipple 28 is another pipe section 29 containing a rod section 31 which is held firmly and resiliently to the pipe by a rubber retainer 32, of similar construction as the retainer 27, or more strongly made so that it holds the rod more firmly to the pipe. This rod section I have termed the rubber held section, in distinction to the rebounding section 26. The rod section 31 is held so firmly that while it is capable of longitudinal displacement, the pressure tending to return it to normal position is so great that there is no relative movement of the rod section 31 with respect to the succeeding rod sections of the composite rod. In some instances, it may be advisable to employ two rebounding rod sections between the rigidly held rubber held rod 31 and the drill bit, but in most instances, one rebounding rod section is sufficient. The remainder of the composite rod comprises combined pipe and rod sections 30, the number used depending upon the depth of the drill hole. These successive sections are shown in Fig. 13, and each section comprises a pipe section 33, a rod section 34 of the same length and a nipple 35. The rod is held against accidental displacement in the pipe by a ring 36 of rubber or other conformable or resilient material holding back of a split bushing slipped past the pipe threads, to prevent the rod from falling from the pipe in handling. The outer section of the composite rod, usually comprises a pipe section

37, a rod section 38 and a rubber retainer 39 inserted and compressed in the annular space between the rod and the pipe. The rod 38 is firmly held in the pipe in substantially the same degree as the rod section 31, so that when the pipe sections are screwed together tightly, the rod section 38 will be displaced backwardly to the same extent as the section 31 is displaced forwardly, thereby indicating the pressure with which the rods of the series are held together. It is advisable that this pressure be such that there is no separation of the rods during the operation of the hammer. Means other than the rubber insertion may be used for holding the rear rod pressed forward, as will be set forth hereinafter. The rear rod 38 extends from the pipe 37 at the rear, and is provided with an upset head 41 which is held in firm contact with the tappet 42 of the drilling engine.

The forward section 21 of the composite drill rod is provided with a bayonet slot 43 in which a lug 44 on the shank of the drill bit 23 is disposed. The slot is longer than the lug so that the drill bit has a free longitudinal movement with respect to the pipe, but is at the same time rotatable with the pipe. The pipe may be rotated in any suitable manner, such as by the handles 45, secured to the rear length of pipe, as shown in Fig. 8, or may be rotated by power operated means, as will be hereinafter set forth. In operation, the drill bit is held close to the face of the rock being cut and the pipe is continuously rotated.

Fitted into the drill hole at the outer end is a flanged bushing 46, through which the composite drill rod extends and with which it forms a turning fit. Air and water under pressure are entered into the drill hole at the bushing for the purpose of keeping the hole clean and the air and water flows through the space between the pipe and the drilled hole to the drill bit and in high angle holes is flowed inward through the hollow rods. For the purpose of removing the drilled rock and obtaining fairly consecutive samples of the rock cut, the drill bit is provided with a passage 47 opening on the side of the bit adjacent the cutting face and disposed axially of the shank of the bit. The rod sections are hollow, forming a continuous passage 48 through the composite rod series for the discharge of the air, water and cut rock. The upset end 41 of the rear rod 38 seats in the tappet 42, which is provided with a sample exit passage 49, one end of which opens on the end of the tappet in alinement with the passage 48. A short rubber nipple 51 forms a connection between the passages 48 and 49. At its other end the passage 49 opens on the side of the tappet and is connected by a short rubber nipple 52 with the discharge

conduit 53, secured to the shell 54 of the drilling engine. The tappet is held pressed forward against the end rod 38, by a spring 55 and is vibrated or reciprocated longitudinally by the hammer of the drilling engine. The shell 54 is provided with an enlarged pocket 56 surrounding the nipple 52, to permit the nipple to move laterally freely as the tappet and machine are separated by the hammer vibrations.

In Fig. 9, I have shown a modified form of means for rotating the drill rod and extracting the sample. In this construction the rear rod section 38 is provided with a shank or extension 57 which extends into the rotary chuck piece 58 of the drilling engine, the rod being provided with a lug 59 which engages a slot in the chuck piece, so that it rotates therewith. The rod 38 is provided with a thickened or upset portion 61 adjacent its rear end and the longitudinal passage 48 in the rod, terminates in this portion in communication with the transverse passage 62, opening on the side of the rod. The passage 62 opens into a chamber 63 in the casing 64 surrounding the enlarged portion of the rod and the chamber is provided with a sample discharge outlet 65. Inside the chamber and wired down to the surface of the rod is a rubber flange ring 67 closing the joints between the walls of the casing and the surface of the rod, to prevent leakage. The aperture in the rear wall of the casing through which the rod extends is beveled to correspond to the bevel on the enlarged portion of the rod and a spring 68 is interposed between the shell of the drilling engine and the casing, to hold the rod series pushed forward and away from the drilling engine. The rubber connection between the rod and the surrounding pipe is not sufficiently strong to be relied on in continuous operation, to transmit the rotary motion of the rear rod to the pipe and for this purpose the rod is provided with a lug 71 seated in a slot 72 in the rear pipe section.

Secured to the rear pipe section are two spaced rings 73—74 between which is disposed a loose thrust bearing 75 and the means for inserting and removing the composite drill from the drill hole engages between one of the rings and the thrust bearing, depending upon the direction of movement of the composite drill rod.

The hammer drilling engine 76 is mounted on the arm 77 of a drill column 78, to which it is held by the clamp 79. The composite drill rod extends from the drilling engine into the drill hole, through the air tight bushing 46. Compressed air is supplied to the apparatus by the pipe 81, which is connected to the drilling engine, to the cylinder for handling the rod series and to the water tank 82, from which water under pressure

flows into the drill hole. The sample, with its mixed water, is discharged from the rods through the conduit 53 into the sample receiving sack 83 from which the water drains. The bushing 46 at the mouth of the drill hole is screwed to a short length of pipe 84 fixed securely and tightly in the enlarged mouth of the drill hole.

The drilling engine 76 is mounted on the drill shell 54. Across the ends of the shell are bolted two plates 85 and 86, between which is fastened a stationary piston rod 87 along which reciprocates a cylinder 88 over a piston 89 secured to the piston rod. Air is supplied to both ends of the cylinder in front of and in back of the piston through conduits 91 and 92, one of the conduits connecting with a passage 93 extending through the piston rod and opening in front of the piston, the other conduit opening into the cylinder in back of the piston. The conduit 93 is secured by a packing ring 193 to the stationary piston rod 87, which is provided with ports 194—195 on opposite sides of the ring 193, to permit the passage of air into the cylinder 88 on either side of the piston 89, which is arranged in the same plane as the ring 193. The conduits 91 and 92 are connected to the compressed air supply pipe 81 and a four-way valve 196 is arranged in the conduit to control the introduction of and discharge of air from the cylinder. The cylinder is thus movable longitudinally over the fixed piston rod. Secured to the cylinder preferably by welding are two angle irons 94—95 and slidable between the angle irons is a channel iron 96 which may be secured to the angles in adjusted position by pins or bolts 97 extending through seats 98 in the angle irons and apertures in the channel iron. In this manner the position of the channel with respect to the angles may be varied as desirable to produce a movement of the channel of greater extent than the stroke of the cylinder.

Detachably secured to the channel iron at its forward end is an arm 102 having a bifurcated end adapted to engage the outer pipe section between the rings 73—74 thereon for the purpose of moving the composite rod longitudinally. In the drilling operation the composite drill rod is advanced into the hole and the bit held up to the work by admitting air into the cylinder in front of the piston. This device is also used for inserting the composite rod into and removing it from a steep angle drill hole which has already been started and which may be of considerable depth as set forth below.

Means are provided for pulling the composite rod from the drill hole when necessary or desirable. To accomplish this the drill shell is shifted laterally on the arm

77 to bring the piston 88 into substantial alignment with the drill rod. The arm 102 is then removed and in its place there is attached a block 103 having an arm 104 pivoted thereto and adapted to be locked thereto by the bolt 105. Swinging from the arm 104 in a slot in the block is a spring held dog 106. The composite drill rod extends through the slot in the block and on the forward movement of the block the dog does not engage the pipe, but on the backward movement of the block the dog grips the pipe and pulls it from the drill hole.

Drilling is accomplished by blows in rapid succession delivered by the hammer of the drilling engine. This engine may be of any suitable type capable of producing percussive blows in rapid succession. In the drawings I have shown a valveless hammer drill since I am of the opinion that this type of drill is preferable for use in connection with the drilling apparatus of my invention, but it is to be understood that I do not limit myself to the use of a valveless hammer drill.

In Fig. 6, I have shown one form of valveless hammer drilling engine which is particularly adapted for use in connection with my invention. This hammer drill comprises a cylinder 112 in which there is disposed a differential piston or hammer 113, the piston is provided with piston rings forming a tight joint between the piston and the cylinder and these piston rings 114 are simple flat rings breaking joints in the ringed groove. The piston is provided with an extension 115 of lesser diameter than the body of the piston and this extension forms the hammer which strikes against the tappet. The hammer 115 forms a tight sliding joint in the shell 112 and piston rings 117 seated in the shell and engaging the face of the extension form a substantially air tight joint. The cylinder is divided into two parts longitudinally by an annular wall 118 which forms a cushion plate. The piston is provided with a bore 119 into which the cushion tube 121 extends, the tube being open at both ends and being secured at its rear end to the wall 118. Piston rings 122 seated in the piston form a tight sliding joint between the piston and the tube 121. The bore 119 extends into the hammer 115 and communicates with a passage 123 opening on the cylindrical face of the hammer. Air under pressure is admitted to the cylinder in front of the piston, through the inlet port 124, and drives the piston backward. The backward movement of the piston brings the opening of passage 123 into the cylinder, permitting air under pressure to pass through the passage 123, bore 119 and tube 121 into the reserve air chamber 125 behind the wall 118 and into the chamber 126 behind the piston, through the apertures

127 in the tube. This forms an air cushion, protected by piston rings 114 and 122 and the air cushion catches and rebounds the piston. The area of the rear face of the piston exposed to air pressure is greater than the area of the front face of the piston exposed to air pressure, so that the piston is thrown forward. As the piston moves forward, the compressed air in the reserve chamber 125 enters the cushion chamber 126 and accelerates the forward movement of the piston. The advantage of this construction lies in the very rapid rearward movement of the piston due to the large front shoulder on the piston combined with high speed of forward movement due to both the perfect rebound due to the air cushion and the expansion of the air in the reserve chamber. As the piston approaches the end of its forward movement, and the hammer 115 is in close relation to the tappet 128, the passage 123 opens into the exhaust port 129, permitting the air behind the piston to exhaust. The wall 118 is provided with a check valve 130 to permit the flow of air from the reserve air chamber 125 to the cushion chamber 126. The check valve is more of a precaution against sticking of the hammer or worn piston rings, than a necessary element in a well designed hammer.

In Fig. 10, I have shown the front end of a hammer drilling engine not adapted to rotate the rods of this drilling system. The tappet 42 is provided with a sample discharge which extends directly from the head of the tappet in front of the drilling engine so that the chuck may be rotated without interfering with the discharge of the sample. The rear section of pipe 37 is provided with a seat or pocket 131 in which a pin or lug 132 on the rear section of drill rod 38 is disposed. The tappet is held forward against the rear end of the drill rod by a spring 133 and this spring is secured to the tappet and to the shell of the drilling machine to prevent rotation of the tappet by the rotating chuck of the machine.

In the construction shown in Figs. 11 and 12, I have provided a yoke piece 135 which fits over the sleeve on the rear end of the composite rod between the rings 73 and 74 thereon. Two rods 136 are rigidly fastened to the yokes and these rods pass through the front head 137 of the drilling engine, springs 138 are interposed between the rear ends of the rods and the front head and pull the yoke and rod back against the machine. This yoke is used as will be hereafter explained in connection with a reamer or rubber held drill bit to hold the rods elastically against the machine when they are not supported as by the contact of the drill bit against the face of the rock. If quite long and properly adjusted springs are used on the yoke and the vibration of the machine is

not excessive, the yoke can be used without the pressure cylinder 88 to support the weight of the rods in rather high angle downcast holes. Similarly in drilling up-
 5 cast holes if a long spring is used to hold the yoke piece forward it may sustain considerable weight of the rod without allowing the vibration of the machine to interfere materially with drilling.

10 In Figs. 20, 21 and 22, I have shown a form of drill bit which is particularly adapted for use in connection with the drilling system of my invention. The drill bit has a round shank 22 having a passage 141
 15 extending axially therethrough and being deflected at the forward end of the bit to open on the face of the bit to one side thereof. The shank increases in size at the base of the bit and is provided with two cylindrical steps 143 and 144. The front end of the elongated head is cruciform in shape for about two inches back of the tip. Back of that three of the grooves of the cruciform shape continue for the length of the bit, but
 20 the fourth groove is filled level across as shown at 145. Fig. 22, the passage 142 in the bit extends through this filled in portion 145 and opens on the face of such portion about two inches back of the tip of the
 25 bit. In order to prevent the clogging of the opening of the passage 47 by the drilled material, a plurality of openings 146 are provided on the side of the drill bit and these openings communicate with the passage 47. The two ribs of the cruciform end
 30 of the bit opposite the passage 47 and opposite the filled in portion 145 are provided on their ends with 45 degree inclined V shaped cutting edges 147, the other two ribs end in practically square cutting edges 148
 40 which are positioned at about the base of the inclined cutting edges. The bit head may be straight and parallel with the shank or may be slightly tapered to be of slightly less width at the rear end. The forward
 45 pipe section 21 is counterbored so as to fit loosely about the cylindrical steps 143 and 144, thus supporting the oscillating bits in all positions even after the pipe section 21
 50 is badly worn.

In Figs. 23 and 24, I have shown a modified form of drill bit which is in general similar to that shown in Fig. 21, with the exception that its two sloping cutting edges
 55 151 are made materially thinner and are bounded by generally parallel planes at the opposite sides of such edges. The purpose of this shape of bit edge is to retain a high cutting speed until the whole edge is worn
 60 off. The result is only obtainable by special steel and careful tempering and is applicable in this form of bit since the outer portion of these cutting edges do not ream the drill holes as do the oblique edges of the points of
 65 the ordinary cross bit. By making the cut-

ting edges narrow they retain their sharpness until they are worn down and are not blunted rapidly as are the cutting edges of the ordinary cross bit. These two cutting
 70 edges are joined at the point of the bit in a rather smooth curve and the other two ribs of the bit are provided with the square cutting edges as described in connection with the bit shown in Fig. 21. The oblique cutting
 75 edges are preferably brought out as shown at 150 for a short distance at nearly right angles to the bit's axis. This aids materially in starting a new bit against a hard sloping face of rock that has worn out the
 80 bit previously used, but is not always used.

In Figs. 17 and 18, I have shown a reamer with side cutting bits which is particularly adapted for use in connection with my drilling system. This reamer comprises an enclosing tube or pipe 161 within which there
 85 is arranged a rod 162 having a pointed end 163. The rod is held firmly and resiliently to the pipe 161 by a rubber band formed by winding a strip of rubber 164 spirally about the rod. This rubber is under compression
 90 and permits the rod to move slightly longitudinally with respect to the pipe but prevents any permanent displacement of the rod. The pipe 161 is secured by a nipple
 95 165 to a forward pipe section 166 within which are arranged the laterally movable cutting blades 167. The pipe section 166 has two diametrically opposed slots through which the cutting blades 167 extend. The
 100 forward end of the pipe section 166 is strengthened and reinforced by two half-round sections 168 fitting into the end of the section on opposite sides of the cutting blades 167. The cutting blades are provided
 105 with thin spring steel extensions 172 which are turned outwardly at their ends and are secured in holes in the sides of the pipe section 166. The cutting blades are thus resiliently mounted and are free to move outwardly under the action of the inclined end
 110 163 of the rod 162. The cutting blades are normally held inwardly by the resiliency of the arms or extensions 172 and are forced outwardly by the pointed rods. Inserted
 115 between the extensions 172 and the pipe are rubber strips 173 which act partly as springs and partly as elastic bonds to return the cutters to proper position in the reamer without jar on the bent ends of the extensions 172.
 120

When this reamer is screwed onto the forward end of the composite drill rod ahead of the rebounding rod and in place of the bayonet clutch piece, the blows of the rebounding rod cause rod 162 to vibrate
 125 longitudinally and thus through its pointed end cause the side cutters 167 to fly against the sides of the drill hole and ream the hole the small amount required. When using the reamer the rod series is held to the drilling
 130

machine by the yoke shown in Fig. 11. Since the rod 162 is not permanently longitudinally displaced by the hammer blows but merely vibrates longitudinally under such blows and since the inner sides of the cutting edge of the cutting blades 167 are substantially parallel to the inclination of the pointed end 163, it is apparent that longitudinal vibration of the rod 162 will cause lateral vibration of the cutters 167.

When desired the drill bit 23 may be secured to its surrounding pipe 21 by rubber 21^a under compression inserted between the shank of the bit and the pipe, so that the bit is allowed to oscillate from one-eighth to one-quarter of an inch longitudinally under the hammer blows as delivered to it by the rebounding rod of the rod series, as shown in Figure 28.

In Fig. 19, I have shown a modified method of securing the rod to the pipe by means of the inserted rubber piece. In this construction a short length of rubber cylinder is wired down at one end to the rod and inside of the other end of the short rubber tube a thin hard steel ring 176 is inserted. The outer steel tube or pipe is then sprung or swaged down over the rubber about the ring 176. This forms an extremely elastic bond between the rod and the pipe through the rubber so that the rod may not be permanently displaced longitudinally with respect to the pipe. The surface of the rod, the ring, and the pipe touching the rubber are preferably roughened to increase the bond between the rubber and the metal. One or more of these rubber connections may be used between the rod and the pipe, depending upon the strength of bond that is required between the tube and the rebounding rod.

The action of this drilling apparatus is substantially as follows: The rapid blows of a heavy hammer in a modern hammer drilling engine when delivered upon the rear end of a rod series such as shown cause the rods to jump apart unless they are very strongly held together and such jumping apart rapidly lowers the percentage of energy of the hammer's blows that can be passed through such rod series. For that reason, by screwing the pipe together with a slightly greater total length of enclosed rods than that of the pipe, I extend the rubber bond of the rear rod and the front strongly held rod or both of them to produce a compressive strain on the rod series and I have obtained good results with a pressure of about 2000 pounds on the rod series.

With very light hammer drills striking slowly, that is about 600 per minute, it is possible to hold the rods effectively together by a forward pressure external to the drill hole forcing the bit against the rock. With modern high speed machines striking very

heavy blows 2000 to 3000 per minute, a very high pressure on the rods is absolutely necessary for effective work, which pressure is far too great to be sustained by the rotating bit point against the rock. Such pressure of the bit on the rock would make impossible its effective rotation and would cause it to dull very rapidly. In practice with this apparatus the bits are normally rebounding quite free from the rock and cutting at least four times as fast as if pressed continuously against the hard rock. The blows of the hammer so delivered upon the rear end of the rod series cause waves of compression to travel forward through the rod series. The rebounding rod is held elastically against the strongly held rod by its rubber bond and generally under a pressure of less than 500 pounds. These advancing waves of compression cause the rebounding rod to fly off from the strongly held rod with a velocity representing a high percentage of the energy of such compressive waves.

By proper handling of the feed screw of the machine, the bit, rebounding from the rock face, is caused to be so close to the forward end of the rebounding rod that its motion is not over $\frac{1}{16}$ of an inch or thereabout before it strikes the nearly equal length of drill bit. In this impact over 95 per cent of the energy of the rod is transmitted to the bit at each blow. With only the short distance of $\frac{1}{16}$ of an inch to return, the rod is at rest against the strong rod at the time of the arrival of the next compression wave.

The tappet is elastically held against the outer rod partially in order to avoid loss of energy by impact between them, also the spring holding forward the tappet or the rod and the spring acting to hold the rods away from the drilling engine act to eliminate any vibration of the drilling engine and to hold the rods elastically forward against the spring action on the rod series of the rebounding bit and shank. This elastic support of the rod series and bit between the rock and the drilling engine is very important in securing high drilling speed. In high angle holes the air pressure cylinder and its cross arms are used to support such portion of the weight of the rods as to allow the feed screw motion to freely adjust this pressure of the rods against the bit and the machine.

The action of the eccentric pointed bit is that the sloping cutting edges glance on the conical rock surface in the front end of the drill hole and throw the side ribs of the bit against the side of the drill hole. This action also throws the shovel or square edges of the bit into the angle of the hole cutting out the small shelf of oversize carried by this bit. The thin edges of the bit shown in Fig. 23 when worn down half their height are still cutting as fast as when only the first

$\frac{1}{16}$ of an inch had been worn off them and continue at the same speed until worn out. The V shaped edges on the bit shown in Fig. 20, on the contrary, cut slower as they wear back.

The offset bore hole of the drill bit head is of importance since it allows the working over of the metal of the ribs on this side to supply the wear of the edges on the other side.

In removing the bits from the drill hole while the hole is short, they may be pulled out by hand. When pulling long composite rods the drilling engine is slid along the column bar to alinement with the rods and the pulling clamp is then used to remove the rods from the drill holes.

What is claimed is:

1. In a rock drill, a composite drill rod comprising a tube, a rod disposed within said tube and means elastically holding the rod to the tube.

2. In a rock drill, a tube, a rod elastically held within said tube, a drill bit carried by the tube and a hammer associated with said rod.

3. In a rock drill, a composite drill rod comprising a tube and a plurality of alined rods elastically held in tight longitudinal engagement in said tube.

4. In a rock drill, a composite drill rod comprising a sectional tube and a plurality of alined rods elastically held in tight longitudinal engagement in said tube.

5. In a rock drill, a composite drill rod comprising a tube and a hollow rod elastically held within said tube.

6. In a rock drill, a composite drill rod comprising a tube, a rod disposed within said tube and elastic material interposed between the rod and the tube whereby the rod has limited longitudinal movement with respect to the tube.

7. In a rock drill, a composite drill rod comprising a tube, a rod disposed within said tube and elastic rubber interposed between and forming an elastic connection between the rod and tube.

8. In a rock drill, a composite drill rod comprising a tube and a rod of substantially the same length as the tube, elastically held within said tube.

9. In a rock drill, a composite drill rod comprising a tube and a hollow rod of substantially the same length as the tube elastically held within the tube.

10. In a rock drill, a composite drill rod comprising a tube, a drill bit arranged at the front end of said tube and capable of longitudinal movement with respect to the tube and a rod cooperating with the drill bit and elastically held in said tube.

11. In a rock drill, a composite drill rod comprising a tube formed of tube sections secured together, a rod of substantially the

same length as each tube section disposed in each section and means for holding the rods in tight longitudinal engagement.

12. In a rock drill, a composite drill rod comprising a tube formed of tube sections secured together, a rod of substantially the same length as each tube section disposed in each section and means within the tube for holding the rods in tight longitudinal engagement.

13. In a rock drill, a composite drill rod comprising a tube formed of tube sections secured together, a rod of substantially the same length as each tube section disposed in each section and means elastically holding the rods against longitudinal displacement.

14. In a rock drill, a composite drill rod comprising a tube formed of tube sections secured together, a rod of substantially the same length as each tube section disposed in each section and means within the tube elastically holding the rods against longitudinal displacement.

15. In a rock drill, a composite drill rod comprising a tube formed of tube sections secured together, a rod of substantially the same length as each tube section disposed in each section and means elastically holding the rods against longitudinal displacement and in tight longitudinal engagement.

16. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous rods in said tube elastically held to said tube and a rebounding rod associated with said rod series.

17. In a rock drill, a composite drill rod comprising a tube, a rod elastically held in said tube adjacent the front end thereof, and a rod series elastically held in said tube behind and in contact with said rod, the rods in the rod series being in pressure contact.

18. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous rods in said tube, means for holding said rods in pressure contact and an elastically held rod associated with said rod series.

19. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous rods in said tube, means for holding said rods in pressure contact and substantially fixed with respect to said tube and an elastically held rod engaging the forward end of said rod series.

20. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous rods in said tube, means interposed between the rods and the tube for holding the rod series under longitudinal compression and an elastically held rod engaging the forward end of said series.

21. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous rods in said tube, means interposed between the rods and the tube for holding

the rod series under longitudinal compression and for preventing substantial longitudinal movement of the rods and an elastically held rod engaging the forward end of said series.

22. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous rods in said tube, means for holding the rod series under longitudinal pressure and a rubber-held rod engaging the end of the rod series.

23. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous rods in said tube, means for holding the rod series under longitudinal pressure, a drill bit arranged at the end of the tube and an elastically held rebounding rod interposed between and cooperating with the rod series and bit.

24. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous rods in said tube, means for holding the rod series under longitudinal pressure, a drill bit arranged at the end of the tube to move longitudinally with respect thereto and an elastically held rod interposed between and cooperating with the rod series and drill bit.

25. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous rods in said tube, means for holding the rod series under longitudinal pressure, a drill bit arranged at the end of the tube and a rubber held rod interposed between and cooperating with the rod series and drill bit.

26. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous rods in said tube, means in the tube for holding the rod series under longitudinal pressure, a drill bit arranged at the end of the tube and an elastically held rod interposed between the rod series and drill bit.

27. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous rods in said tube, means for holding the rod series under longitudinal pressure and substantially immovable longitudinally with respect to the tube, a drill bit arranged at the end of the tube and a rubber held rod interposed between the rod series and the drill bit.

28. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous rods in said tube, means for holding the rod series under longitudinal pressure and substantially immovable longitudinally with respect to the tube, a drill bit arranged at the end of the tube and an elastically held rod interposed between the rod series and the drill bit and adapted to be moved longitudinally.

29. In a rock drill, a composite drill rod comprising a tube, a series of alined contiguous

ous rods in said tube, means for holding the rod series under longitudinal pressure and substantially immovable longitudinally with respect to the tube, a drill bit arranged at the end of the tube and an elastically held rod interposed between the rod series and the drill bit and normally held in contact with the rod series.

30. In a rock drill, a composite drill rod comprising a tube, a series of contiguous alined rods in said tube, means for elastically holding the leading rod to the tube, means for holding the adjacent rod elastically and more firmly to the tube and means for similarly holding the rear rod to the tube.

31. In a rock drill, a composite drill rod comprising a tube, a series of rods in said tube and elastic means holding the end rods to the tube, said elastic means being under tension so that the rods are held together in pressure contact.

32. In a rock drill, a composite drill rod comprising a tube, a series of rods in said tube and means within the tube and engaging the end rods for holding the rods together under pressure.

33. In a rock drill, a composite drill rod comprising a tube, a series of rods held in tight longitudinal contact in said tube and substantially immovable longitudinally with respect to said tube, a rapidly reciprocating hammer arranged to impart the energy of its blows to said rod series, a drill bit arranged at the end of the tube opposite the hammer and an elastically held rod interposed between the rod series and the drill bit and adapted to reciprocate.

34. In a rock drill, a composite drill rod comprising a tube, a series of rods held in tight longitudinal contact in said tube and substantially immovable longitudinally with respect to said tube, a rapidly reciprocating hammer arranged to impart the energy of its blows to said rod series, a drill bit arranged at the end of the tube opposite the hammer and a rubber held rod arranged within the tube between the rod series and the drill bit.

35. In a rock drill, the combination with a hammer drilling engine arranged externally of the drill hole, of a tube extending from the engine into the drill hole, means on the engine for moving the tube longitudinally into and out of the drill hole, a drill bit arranged on the forward end of said tube and movable longitudinally with respect thereto and a series of elastically held rods in said tube adapted to transmit the energy of the hammer blows to said drill bit.

36. In a rock drill, a drill rod comprising a series of hollow rods pressed together longitudinally in tight abutting contact, a hammer drilling engine, a tappet having a passage therein registering with the passage

in the drill rod and means for holding the tappet pressed against the end of the drill rod.

37. In a rock drill, the combination with
5 a tube, of a drill bit shank extending into said tube and means elastically holding the shank to the tube.

38. In a rock drill, a tube, a drill bit
10 shank extending into said tube and means interposed between the shank and the tube for elastically holding the shank to the tube.

39. In a rock drill, a drill rod adapted to extend into the drill hole, a drilling engine, a rod handling device mounted on said engine, and an arm on which said engine is
15 mounted for longitudinal adjustment, whereby the rod handling device may be moved into alinement with the drill hole.

In testimony whereof, I have hereunto set my hand.

MOSES ARTHUR KNAPP: