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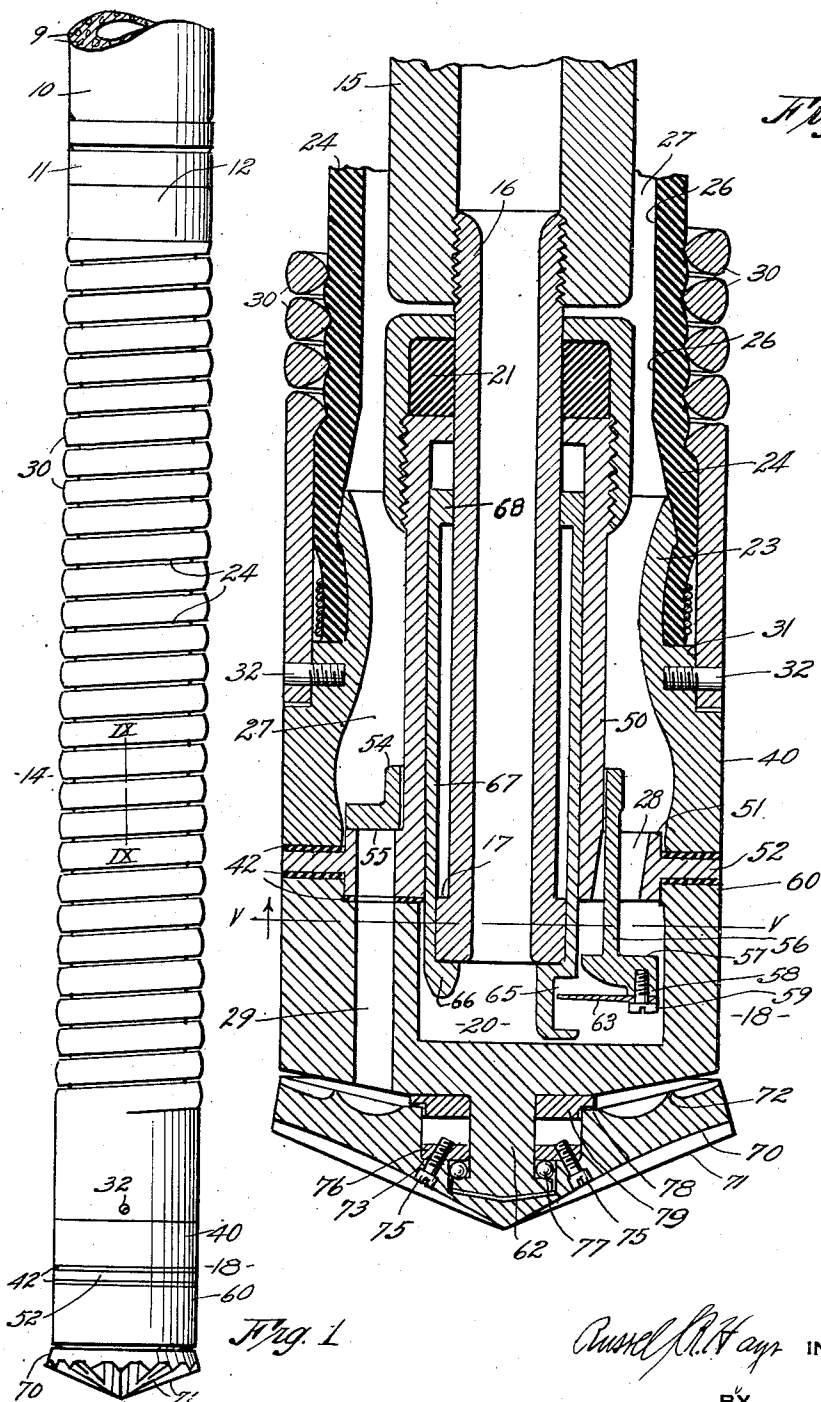
R. R. HAYS

2,390,646

WELL DRILLING APPARATUS

Filed May 10, 1943

3 Sheets-Sheet 1



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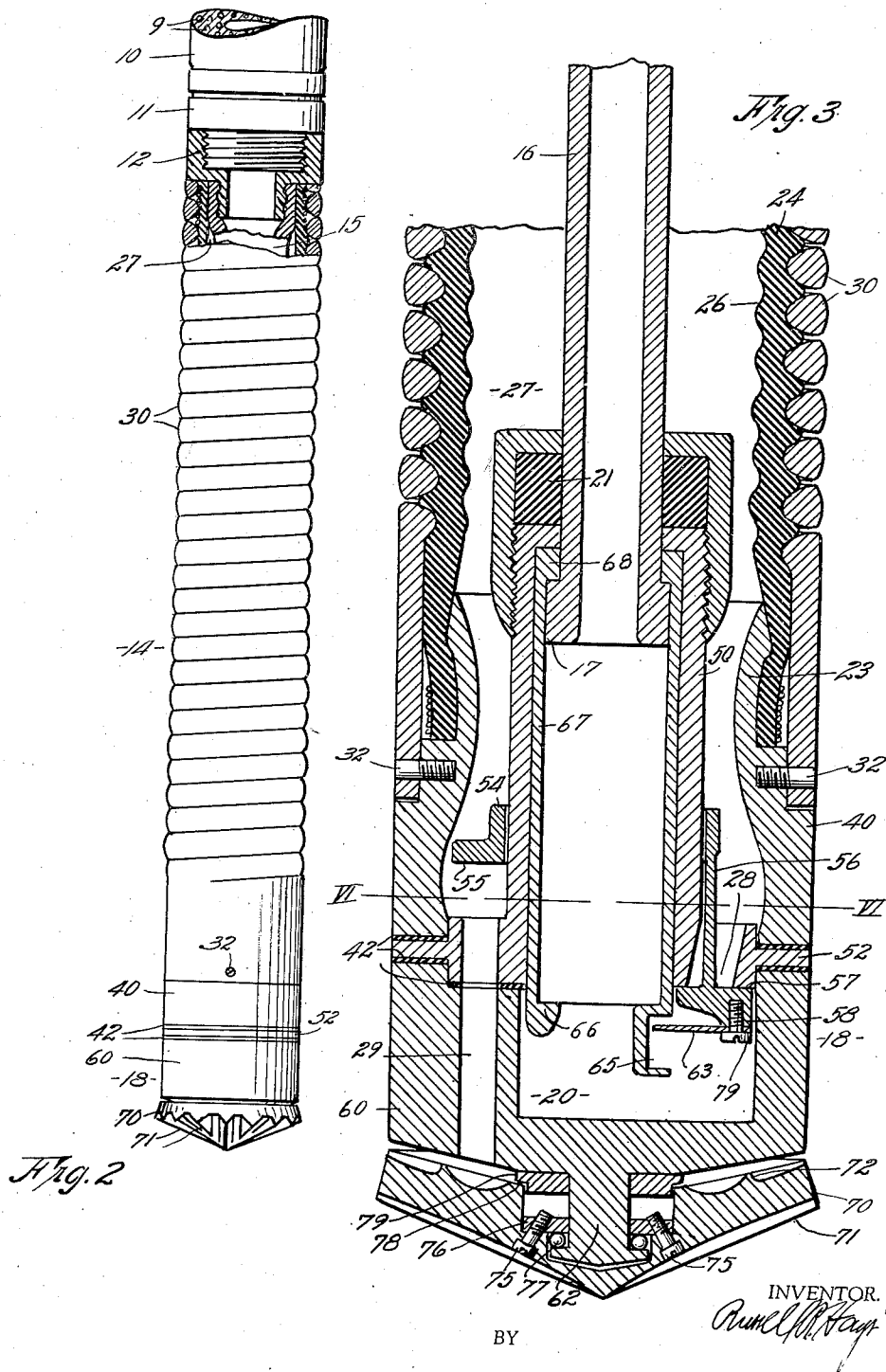
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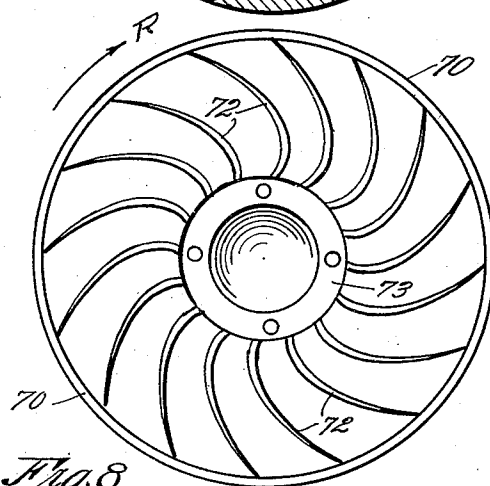
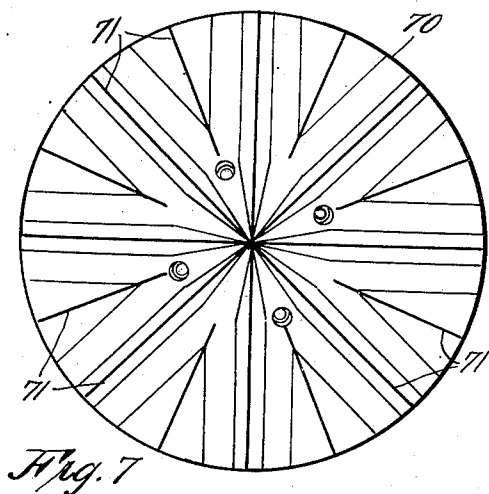
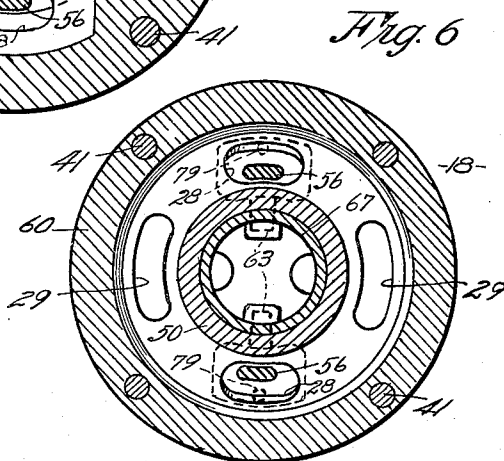
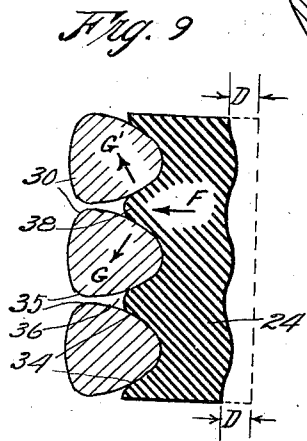
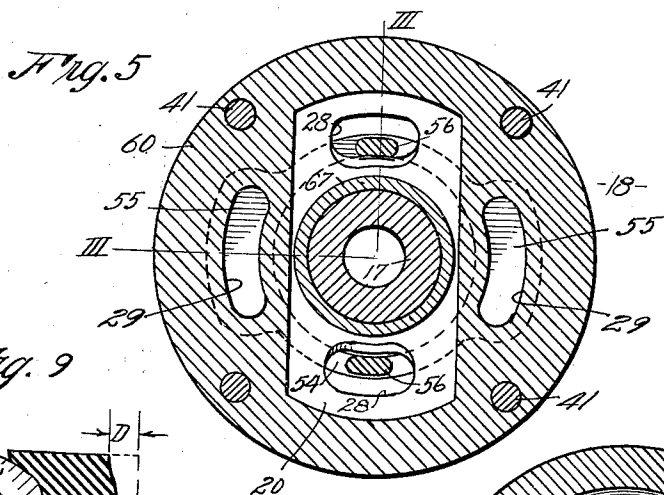
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,390,646

WELL DRILLING APPARATUS

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Application May 10, 1943, Serial No. 486,446

7 Claims. (Cl. 255—1.6)

This invention relates to well drilling apparatus and more particularly to improvements in mechanisms for cutting drainage channels transversely to a main drill hole.

Among the problems encountered in the development of cutting heads when a high pressure fluid carrying abrasives was projected against the face of an oil bearing sandstone, was one arising through the widely variegated nature of the cementing material with the result that the cutting head was held up or deflected by reason of the face of the sandstone being cut away unevenly ahead of it. A variety of cutting heads using a rotary grinding action and also a direct hammering action were tested individually and in combination with the use of abrasives in an effort to overcome this difficulty. With the introduction of such mechanical movements it soon became evident that two approaches to the problem were possible.

In the first, the power means might be contained within the main drill hole in which event a comparatively heavy motor or engine might be used for motivating the cutting head; but, it was then necessary to mechanically transmit either a twisting or a reciprocating movement through a 90° angle in order to drill transverse channels. In either case great inefficiency arose when flexible couplings were used to transmit power through an angle of this magnitude, while the use of gearing introduced great mechanical complexity and brought out the fact that with rotary drilling means a torque problem of first magnitude accompanied extension of the cutting head away from the main drill hole.

The second approach, which was the one chosen, was that of placing the drive mechanism for producing either a rotative or hammering action of the cutting head entirely within this head or immediately adjacent thereto, thereby making a unit which was projected into a transverse channel by means of a flexible conduit which would pass with comparative ease through a 90° turn at the bottom of the main drill hole and at the same time supply a high pressure fluid or gas for the operation of the mechanism it carried. The greatest drawback to a mechanism of this nature appeared to lie in the requirement of extraordinary compactness since it must be retractable into the main drill hole with the conduit by which it was carried.

Previous experiments have shown that to successfully force a flexible conduit through a 90° angle limits the diameter of the conduit to about one-fifth the diameter of the main drill hole.

Furthermore, it had been found that a solid section of the conduit longer than its diameter was difficult to force through a passageway making an arc the radius of which was defined by the same limitation. The mass of the movable parts of the drive mechanism being definitely restricted by such considerations, it was obvious that a very rapid energy exchange was necessary if work of any magnitude was to be performed. This in turn meant that a high pressure fluid stream or its equivalent must be used to operate the mechanism, and also that relatively large valves and very rugged construction of the moving parts would be required.

Space limitations and the requirement of flexibility mitigated against the use of drive mechanisms which would convert the energy of a high pressure stream to a rotary motion, and accordingly a program of experimentation was undertaken toward the end of developing a device or machine for transmitting a hammering or striking movement to the drill head. Investigation revealed that the ordinary reciprocating action of a piston carrying a drill head was useless for the purpose in mind and led to an analysis of the "hammering" action of such mechanisms as standard drilling tools, steam hammers, and the like. This revealed that such hammering or drilling tools were characterized by a rhythmic beat or stroke in which the mass of the tool in question accelerated during the major portion of the "striking" blow, and that the energy thus imparted was abruptly absorbed at the end of the stroke by a combination of impact against some solid object or formation and of damping by means of a powerful spring or its equivalent.

Accordingly the object of this invention is broadly the provision of a small hydraulically or pneumatically operated mechanism mounted on an extendible conduit and providing a rhythmic beat or stroke similar in character to that of standard drilling tools to a small bit or cutting head carried ahead of the mechanism in question.

Another object is the provision of a device of this nature which has a flexible expansion chamber and such compactness of unyieldable elements including inlet and exhaust valves of relatively large size, valve throw mechanisms, packing glands, and the like that the whole device can be retracted into a curved passageway having a radius not more than five times the diameter of a cross-section of the device.

Yet another object is the provision of a mechanism of the character described in which the drilling head has a throw at least as great as the

diameter of a cross-section of the conduit on which it is mounted.

Still another object is the provision of an assembly having the foregoing characteristics in which all the elements with the exception of a fluid supply tube are mounted for travel with the cutting bit of head thereby increasing the mass subject to movement and hence the work which can be performed by it.

Ancillary objectives such as a simple arrangement of direct throw valves, a single direct reversal of the fluid supply stream, use of a single packing gland, automatic damping means to arrest the motion of the drill head assembly at the end of each stroke, means for imparting a rotary motion to the cutting bit, all in conjunction with a rugged construction of parts capable of standing up under work of this nature will be made clearer from a consideration of the following detailed description taken in connection with the accompanying drawings in which:

Fig. 1 is an elevational view of a drill mechanism in the expanded position embodying this invention.

Fig. 2 is a view similar to that shown in Fig. 1 with the parts shown retracted and partly broken away.

Fig. 3 is an enlarged irregular sectional view of the drilling head assembly taken on line III—III of Fig. 5 with the parts expanded.

Fig. 4 is an irregular sectional view similar to that shown in Fig. 3 with the position of the valves changed.

Fig. 5 is a cross sectional view taken on line V—V of Fig. 4.

Fig. 6 is a reduced cross sectional view taken on line VI—VI of Fig. 3.

Fig. 7 is an end elevation of the bit showing the cutting edges.

Fig. 8 is a top side view of the bit.

Fig. 9 is an enlarged fragmentary sectional view taken on line IX—IX of Fig. 1.

Referring to Figures 1, 2, and 3, a section of high pressure hose 10 which, with the exception of the fact that its walls are impregnated with lead 9 to increase its weight, is identical with that projected transversely from a drill hole by means of a slip-joint and flanged rolled arrangement such as is described in the co-pending Patent No. 2,345,816. In this instance the extending end of the hose 10 is fitted with a conventional male hose coupling 11 which screws into the female coupling 12 of the hydraulically operated drilling mechanism 14. The coupling 12 is swedged down to carry the flexible conduit 15 which is similar to those used on high pressure grease guns in that although laterally flexible it does not change its shape longitudinally when pressure is applied to its inner wall. The outer end of the fluid conduit 15 is also swedged and carries the fluid supply tube 16 which has a collar 17 solidly affixed to its free end.

A drill head assembly 18 is mounted upon the tube 16 for reciprocating movement during which the tube 16 telescopes into the chamber 20 of the drill head. The inner end of the drill head carries a packing 21 which rides on the tube 16 and prevents leakage of fluid from one side to the other of the drill head during travel thereon. Concentric with the packing 21 the inner end of the drill head has a reduced section 23 over which is solidly affixed the inner end of a soft rubber tube 24 with fairly heavy sidewalls. This tube 24 fits loosely over the flexible conduit 15 and its inner end is fixed to the inner end of the conduit

adjacent the coupling 12 so that a sealed chamber 27 is formed between the conduit 15 and the inner wall 26 of the tube 24 with the exception of the fluid supply port 28 and the fluid exhaust port 29 carried in the forward part of the drill head 18.

The coiled spring 30 completely covers the tube 24 and its ends extend slightly beyond corresponding ends, the inner end being solidly affixed to a suitable shoulder on the supply hose coupling 12 and the outer end being fixed to the reduced section 31 at the rear end of the drill head 18 by means of screws 32 (see Figure 5), which restrain longitudinal movement at the end of the spring relative to the drill head but permit a slight lateral flexing sufficient to permit retraction of the head and spring into a curved passageway having a relatively small radius.

The wire of which the coiled spring 30 is made is pre-formed before coiling to give its inner face 34, Fig. 9, a wedge shape so that related wedge shaped grooves 36 lie between successive coils of the spring which contact at rounded shoulders 35. When the exhaust port 29 is closed and the inlet port 28 opened, a high pressure fluid stream enters the expansion chamber 27 and exerts a radial force F against the inner wall 26 of the soft rubber tube 24 with the result that it is forced outward through a distance D whereupon the outer face of the tube is extended as ridges 38 into the wedge shaped spaces 36 inside the coiled spring 30. Since the integrated coils of the spring 30 provide tensile resistance to outward expansion it follows that the direction of action of the force F is changed through the medium of the ridges 38 thereby providing a longitudinally effective force G and G' tending to push consecutive coils of the spring apart. This force G and G' is resisted only by the longitudinal tension inherent to the spring and hence when the force G and G' exceeds this tension the spring extends longitudinally.

The main portion of the drill head assembly 18, Fig. 5, consists of a circular section 40 carrying the reduced faces or shoulders 23 and 31 at its inner end upon which are mounted the forward ends of the expansion tube 24 and the coiled spring 30 respectively; a tube 50 concentric with and telescoping on the supply tube 16 which carries the packing gland 21 on its inner end and on its outer end a wide flange 51 containing the exhaust ports 29 and the inlet ports 28, this flange 51 being reduced in thickness at its outer periphery to form a flange 52 by means of which it is properly positioned relative to the other parts of the head assembly; and, a head piece 60 containing an extension of the exhaust port 29 and carrying a stud or pins 62 at its outer end on which is mounted the bit plate 70. These three sections, 40, 50, and 60 are concentrically aligned and fixed solidly together by bolts 41 through the holes 61, suitable gaskets 42 being placed between the faces of the sections before assembly to render the joints fluid tight.

The valve assembly consists of a ring 54 slidably mounted on the tube section 50 behind the flange 51 and carrying the exhaust valves 55 on one section of its rearward edge and the inlet valve stems 56 on alternate sections of its forward edge. The valve stems 56 pass through the inlet ports 28 to carry the inlet valves 57 at their outer end. The forward faces of the valves 57 have a projection 58 upon which is mounted a throw spring 63 by means of a screw 59. The inner end of the throw spring 63 projects into a groove 65 in the

flange 66 carried at the outer end of the valve throw tube 67 which telescopes between the valve section tube 50 and the fluid supply tube 16, being caused to travel with the head assembly 18 by reason of the tension spring 63 contacting the shoulder of groove 65, and being restrained from traveling with the drill head assembly at either end and the end flange 66 at its outer end contacting the end 17 of the supply tube 16. When the valve throw tube 67 is restrained from traveling with the head assembly 18, a tension is applied to the valve throw spring 63, and when this tension becomes greater than the hydrostatic head holding either the inlet or the exhaust valves in a closed position, this tension serves to throw the valves, simultaneously opening one and closing the other, the arrangement of parts being such that a hydrostatic head is always available to hold any valve in a closed position. Since throwing of the valves reverses the direction of fluid movement in the expansion chamber 27, it follows that throwing of the valves in the same direction as the head assembly's travel acts to reverse the direction of this travel.

The bit assembly is terminated by a thick conical bit plate 70, the point of which extends away from the head assembly and the rim of which extends beyond the sides of the head assembly to form a conventional bit head flange. The center of the inner face of the bit plate 70 is recessed to receive and provide clearance for the head of the pin 62 over which it fits. The plate 70 is farther recessed to provide a shoulder 73 upon which is fixed a heavy washer 76 by means of screws 75 to form a ball race between the washer 76 and head of the pin 62 in which are held ball bearings 77. The inner edge of this recessed portion of the bit plate forms a shoulder 78 which contacts the outside flange of the shouldered washer 79 which restrains the bit plate from tilting relative to the pin 62 yet still permits it to swivel freely thereon. The inner face of the bit plate 70 lying outside the shoulder 78 is grooved to form the deflection vanes 72, Figs. 4 and 8, against which the exhausted fluid from the expansion chamber 27 impinges and in being deflected radially acts to set up the rotation R of the bit plate. The outer face of the bit plate 70 is also grooved, Fig. 7, to provide cutting edges 71 or ridges which are faced with extremely hard alloys.

In operation, the movement of the cutting head 18 is essentially the same as the drilling action of a string of tools on a standard rig. This should not be confused with the reciprocating action of a piston operating in a cylinder against a constant load. In the latter instance the objective is to apply a more or less constant pressure against the face of the piston toward the end of producing uniform movement of a drive wheel. With a string of drilling tools, on the other hand, the objective is to produce a maximum impact of the tools against the formation to be drilled. To achieve this end the tools are swung from a walking beam which provides a reciprocating movement to a resilient drilling rope or cable, which carries the drilling tools on its free end.

With this picture clearly in mind it is evident that to obtain an effective hammering action of the drill head of a device for cutting transverse drainage channels, the energy exchange by which the drill head is motivated should parallel that which experience has shown to be effective. Since gravity is not available to accelerate the drill head on the out stroke or to damp its move-

ment on the back stroke, it follows that the general nature of the "drilling" stroke must be obtained by other means.

The first step in this adaptation is that of utilizing a relatively heavy spring 30, Figs. 1 and 2, intermediate the drill head 18 and the fluid supply hose 10 so that when the head is extended by whatever means are used, this spring will be available to arrest the outward movement of the cutting head; at which time the force thus absorbed by the spring acts directly against the supply hose rather than being transmitted to the valve assembly and restraining flanges carried by the head. It is then apparent that if the mass of the supply hose is very great relative to the mass of the drill head, which in this instance is achieved by leading the former, then elements equivalent to those effective at the end of the down stroke of standard tools have been supplied.

However, it is equally apparent that a single spring in itself does not duplicate the action of standard tools since with the latter the walking beam drops the tools and the spring tension of the drilling cable becomes effective in arresting or damping their downward action only at the end of the stroke. It is desirable therefore to nullify the tension of the spring during the major portion of the out-stroke, but to retain the full force of its resistance to damp the cutting head at the very end of this stroke. This is accomplished by what is in effect another spring placed under compression at the beginning of the stroke, specifically, the rubber fingers 38 of the expansion tube 24, which act to spread consecutive coils of the spring 30 apart until the head is nearly to the end of its outward stroke. As long as fluid pressure is applied to the chamber 27 to the extent that the forces G and G', Fig. 9, approach the tension inherent to the spring 30, and the force required to expand the spring will be only the difference between the two, and when the fluid pressure is released at any time during expansion of the chamber 27 the entire tension of the spring 30 will be available to resist outward movement of the drill head.

Hence, after the fluid pressure in the expansion chamber 27 is released, the entire outward inertia of the drill head 18 is absorbed by the spring 30 under "off bottom" conditions, and this kinetic energy is then available to bounce the head backwards. Fluid meanwhile being exhausted from the ports 29 thereby releasing the compression against the walls 26 of the expansion chamber 27 and hence nullifying the force G and G', the entire tension of the spring 30 is available to return the drill head 18 to its initial position. And it will be further apparent that by closing the exhaust port 29 before the spring 30 has completely contracted, any residual tension in it will be absorbed by recompression of the resilient fingers 38 imposed in the wedged recesses 36.

Coincident with this automatic release of the force G and G' near the end of the out-stroke and the replacement of it at the end of the in-stroke subsequent to the opening and closing of the inlet and exhaust ports 28 and 29 respectively, the hydrostatic head of the expansion chamber 27 exerts a force, tending to thrust the cutting head 18 outward, equal to the cross-section of the chamber times the hydrostatic head in the same fashion that such force is effective upon a conventional piston operating in a cylinder. To be sure, this force acts both fore and aft, but since the mass of the head 18 is only a fraction of that

of the leaded supply hose 10, it results primarily in movement of the drilling head only.

The action of the reciprocating movement of the drilling head 18 on the supply tube 16 in opening and throwing the valve assembly 54 to 58 follows along conventional lines. A high pressure fluid stream entering the recessed portion 20 of the drill head 18 through the supply tube 16, passes through the inlet port 28 into the expansion chamber 27. Since the exhaust port 29 is closed, the exhaust valve 55 being integral with the inlet valve 57, the hydrostatic head of the supply line is applied to the inside of the expansion chamber. Two actions occur simultaneously; first, pressure is created on the walls of the chamber, thereby nullifying the tension of the spring 30; second, the pressure acting outwardly tends to force the cutting head 18 outward over the supply tube 16. As this movement continues, the flange 68 of the valve throw tube 67 contacts the flange 17 at the end of the fluid supply tube 16, with the result that outward movement of the valve throw tube with the drill head assembly is stopped. Since the head 18 continues to move outward, tension is applied to the valve throw spring 63 by reason of its end being retained in the groove 65 of the flange on the valve throw tube. When the tension on this spring becomes greater than the force holding the exhaust valve 55 closed, this being the cross-section of the exhaust port times the hydrostatic differential between the chamber 27 and the fluid outside it, the exhaust valve is thrown open and the inlet valve 57 is closed, being held in position by the pressure differential between the fluid supply stream and the now exhausting expansion chamber 27.

Since the greatest force to be overcome by the tension in the spring 63 occurs at the instant of opening either the valve 55 or 57, it follows that the tension therein will serve to throw the valve with considerable force to the position in which the opposite ports are closed. By reason of this throw, or distance through which the valves move, the inner end of the spring 63 which had contacted the face of the groove 65 at the time it was being placed under compression, travels with the valve which has moved relative to the valve throw tube 67 so that now the inner end of the spring is clear of the face of the groove 65 and no longer under tension. Inasmuch as the width of the groove 65 is equal to the throw of the valves 55 and 57, it follows that the drill head 18 may, through inertia, continue moving outward after throwing of the valves for a distance equal to the width of the groove 65, without having any effect on the valve throwing mechanism. During this time however, its outward movement is arrested either by the tension of the coiled spring 30, or by reason of the bit contacting the formation to be cut, or by both.

While the head is continuing on outward and reversing its direction of travel, the fluid contained in the expansion chamber 27 is already exhausting through the now open port 29. This relieves the pressure on the sidewalls and hence decreases the forces G and G' effective against the inside face of the spring 30. As the expansion chamber continues to exhaust, the drilling head 18 is withdrawn on the supply tube 16 by the tension in the coil spring 30 until the outer flange 66 of the valve throw tube 67 is contacted by the outer side of the flange 17 on the supply tube 16. When this occurs tension is again applied to the valve throw spring 63 through farther withdrawal

of the drill head, but this time in the opposite direction. Consequently, when this tension becomes greater than the hydrostatic differential holding the inlet valve 57 closed, which differential has now increased upon exhausting of the chamber 27 so that it approximated that which held the exhaust valve shut at the other end of the stroke, the inlet valve is thrown open and the exhaust valve closed. This acts to retain any fluid in expansion chamber and to give it the pressure of the supply stream. As a result any farther rearward movement of the drilling head by reason of its rearward inertia is damped through the medium of the wedged faces of the spring 30 contracting on the fingers 38 of the expansion tube 24. The expansion chamber now begins to fill again and the process is repeated.

Experience has shown that when any cutting bit having serrated edges on its face is used on a churn drill it is very desirable to rotate the bit with each stroke. Consequently, the bit plate is mounted for swiveling action upon the pin 62 and the exhaust stream utilized to whirl it during each return stroke of the head through the medium of the stream impinging against the vanes 72 carried on the inside of the bit plate 70. This also serves to flush the face of the drill hole with each stroke; the cuttings being picked up by this exhaust stream and floated to the surface as has been more fully described in the co-pending Patent No. 2,345,816.

The advantages of a drilling mechanism of this nature for cutting transverse channels in fluid bearing formations, or any other type of channel so situated that it cannot be reached by conventional drilled tools; being self-evident from the foregoing description, what is claimed is:

1. In pneumatic engines, a fluid pressure supply conduit, a longitudinally extensible chamber comprising a soft rubber tube surrounded by a helical spring, a head carried by the extending end of said coiled spring, inlet and exhaust ports carried by said head, a valve structure alternately operative to control said ports, a spring tension means carried by the extensible end portion of said chamber for throwing said valve structure, a restraining means integral with the relatively fixed end of said extensible cylinder and alternately contacting said spring tension means in response to reciprocating longitudinal movement of the extensible chamber whereby the operations of the valve structure are synchronized with the reciprocal movement of the head carried by the coiled spring, in response to tension thus induced in said spring tension means.

2. In a pneumatic engine, a fluid pressure supply conduit, a longitudinally extensible cylinder carried by and communicating with said conduit, a head carried by said cylinder having an inlet port and an outlet port for said cylinder, interconnected valves for said ports, a valve throw spring carried by said interconnected valves, means carried by said conduit in the path of travel of said throw spring, pneumatic means normally holding said interconnected valve members in fixed relation relative to said ports and for extending said cylinder, and a helical spring operable to contract said cylinder whereby fluid under pressure is intermittently delivered to said cylinder to cause a reciprocation of said head.

3. In a pneumatic engine, a fluid pressure supply conduit, a longitudinally extensible cylinder carried by and communicating with said conduit, a head mounted on the forward end of said extensible cylinder having an inlet port and an out-

let port for said cylinder, interconnected valves for said ports, a valve throw spring carried by said interconnected valves, means carried by said supply conduit to engage said throw spring, pneumatic means normally for holding said interconnected valve members in fixed relation relative to said ports and for reciprocating said head including a helical spring surrounding said extensible cylinder and resisting the extension thereof, whereby said valves are caused to operate as said head is reciprocated to cause said throw spring to overcome said pneumatic means.

4. In a well drilling mechanism for drilling lateral holes from a well bore, a pressure fluid supply conduit, an elastic tube constituting a longitudinally expansible and transversely flexible chamber communicating with and secured to said conduit, a drill head having an outlet port and carried on the free end of said chamber, and a valve responsive to the fluid flow in said chamber to open and close said outlet port whereby the fluid flow in said chamber is varied to cause expansion and contraction of said chamber whereby said drill head is reciprocated.

5. In a well drilling mechanism for drilling lateral holes from a well bore, a pressure fluid supply conduit, an elastic tube constituting a longitudinally expansible and transversely flexible chamber communicating with and secured to said conduit, a drill head having an outlet port and carried on the free end of said chamber, a valve responsive to the fluid flow in said chamber to open and close said outlet port whereby the fluid flow in said chamber is varied to cause expansion and contraction of said chamber where-

by said drill head is reciprocated, and resilient means for limiting outward movement of said drill head.

6. In a well drilling mechanism for drilling lateral holes from a well bore, a pressure fluid supply conduit, an elastic tube constituting a longitudinally expansible and transversely flexible chamber communicating with and secured to said conduit, a drill head having an outlet port and carried on the free end of said chamber, a valve responsive to the fluid flow in said chamber to open and close said outlet port whereby the fluid flow in said chamber is varied to cause expansion and contraction of said chamber whereby said drill head is reciprocated, a drill bit plate integral with said drill head, and vanes formed in said drill bit plate and obliquely disposed to the path of travel of fluid from said chamber whereby said bit plate is rotated.

7. In a well drilling mechanism for drilling lateral holes from a well bore, a pressure fluid supply conduit, an elastic tube constituting a longitudinally expansible and transversely flexible chamber communicating with and secured to said conduit, a drill head having an outlet port and carried on the free end of said chamber, a valve responsive to the fluid flow in said chamber to open and close said outlet port whereby the fluid flow in said chamber is varied to cause expansion and contraction of said chamber whereby said drill head is reciprocated, and a flexible non-extensible conduit extending into said chamber and operatively associated with said valve.

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