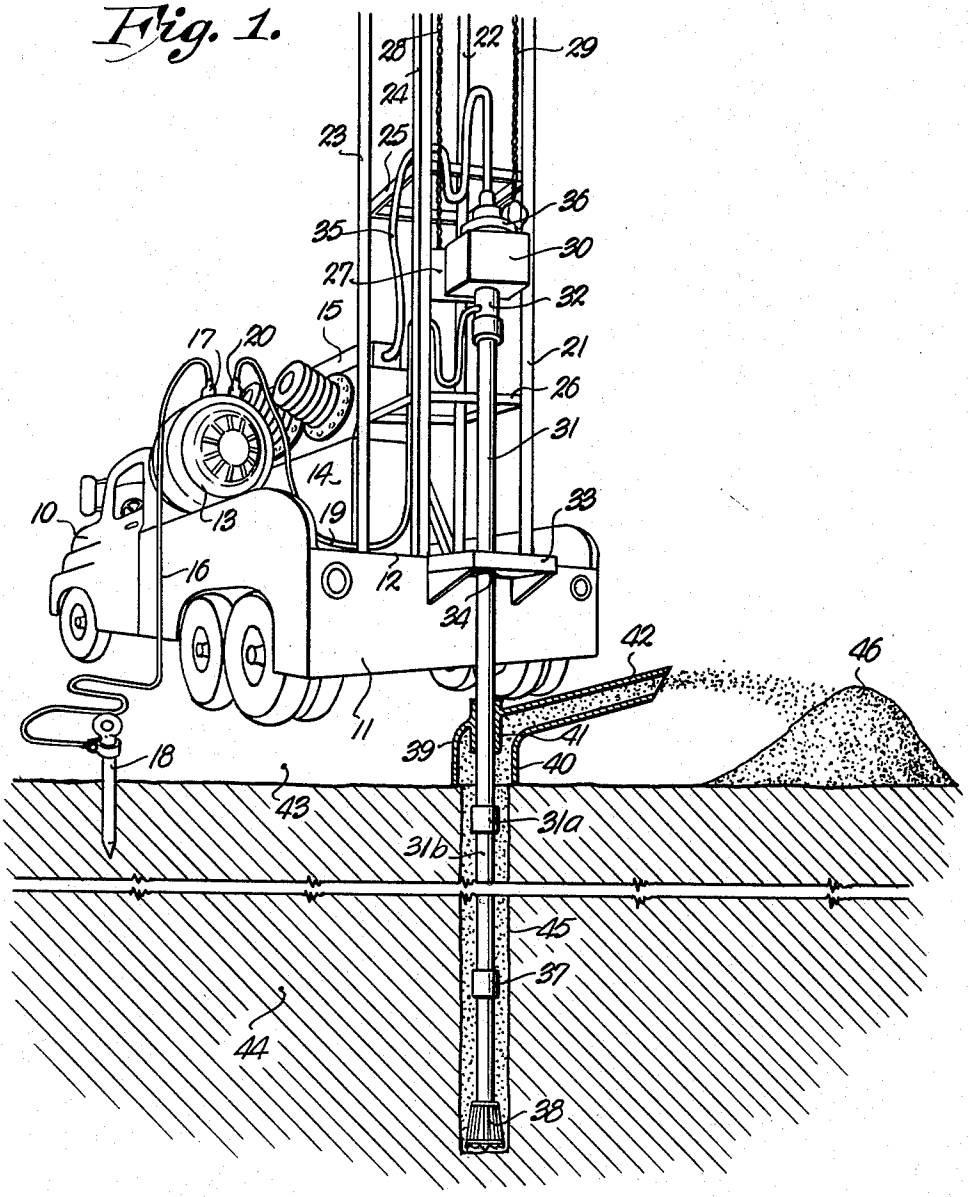
April 20, 1965 E. SARAPUU 3,179,187

ELECTRO-DRILLING METHOD AND APPARATUS

Filed July 6, 1961 4 Sheets-Sheet 1

Fig. 1.



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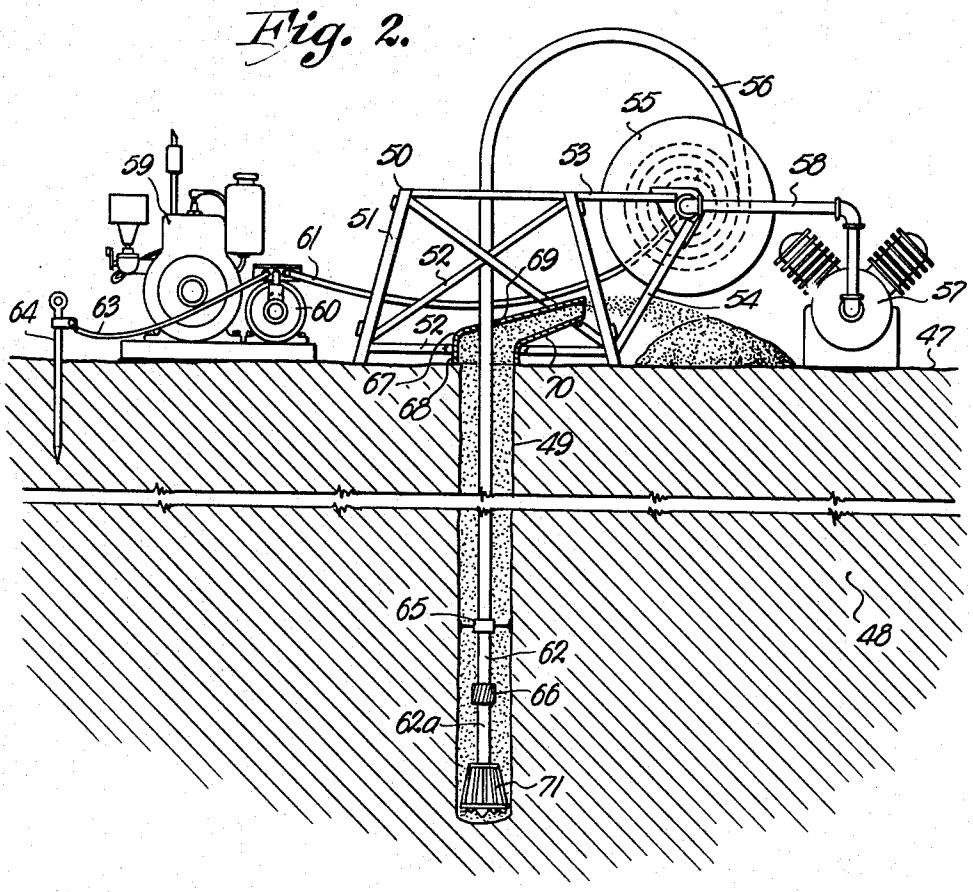
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April 20, 1965 E. SARAPUU 3,179,187

ELECTRO-DRILLING METHOD AND APPARATUS

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Fig. 2.



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ELECTRO-DRILLING METHOD AND APPARATUS

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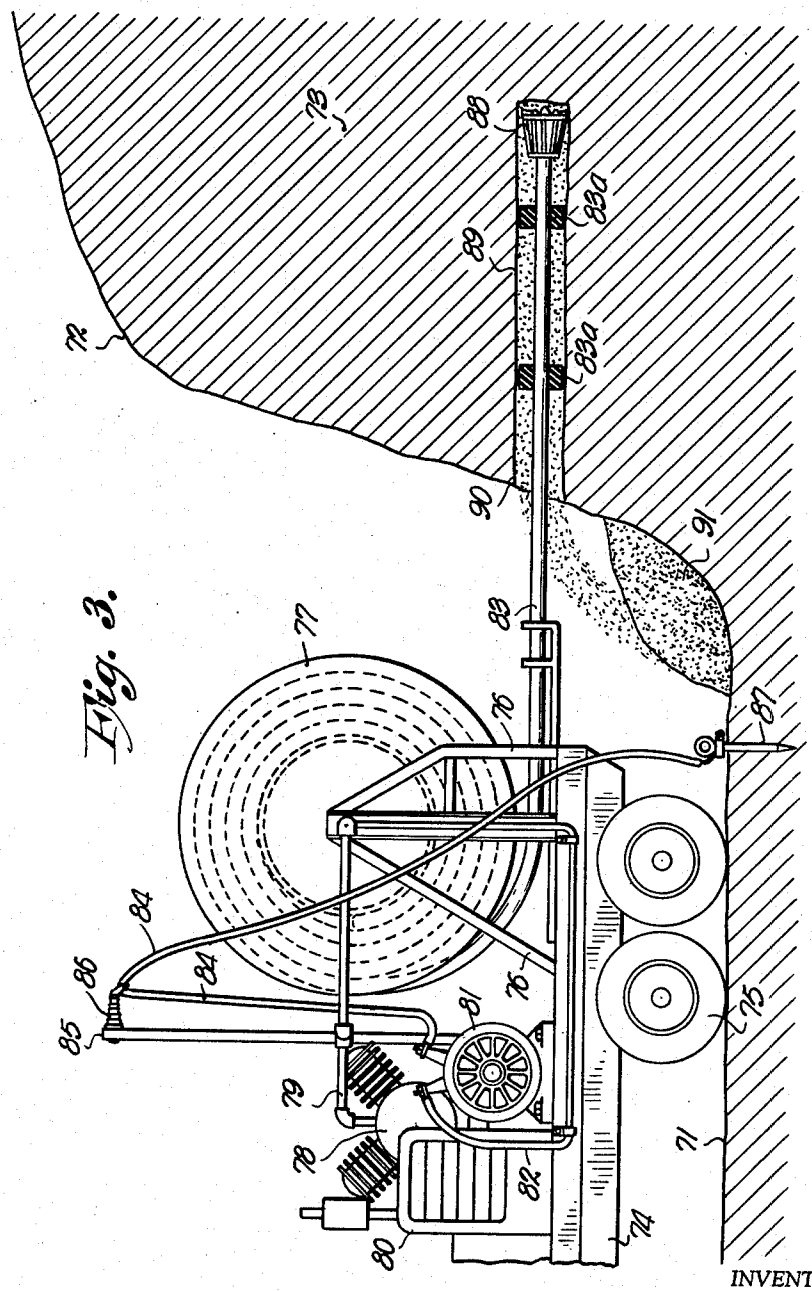


Fig. 3.

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ELECTRO-DRILLING METHOD AND APPARATUS

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4 Sheets-Sheet 4

Fig. 4.

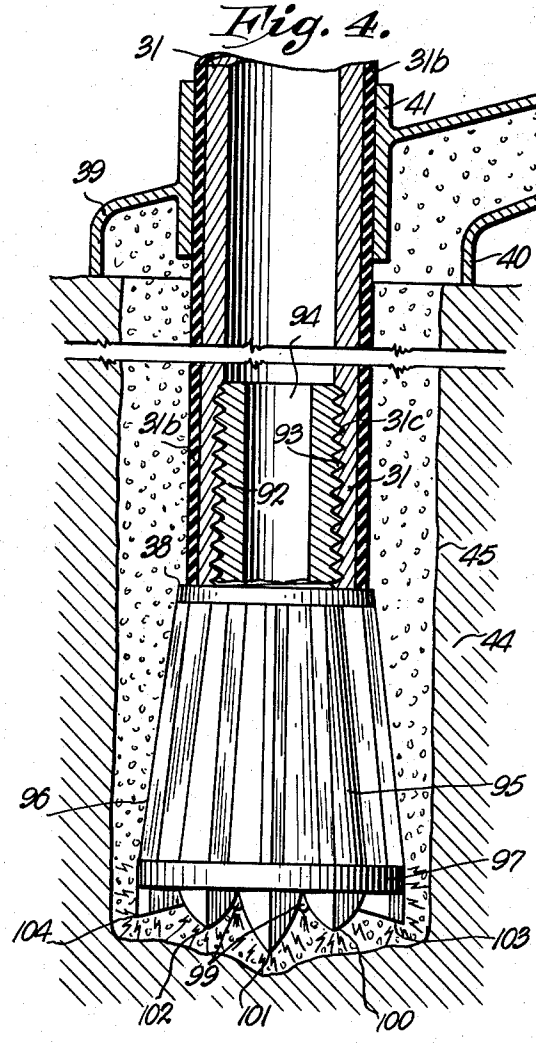


Fig. 6.

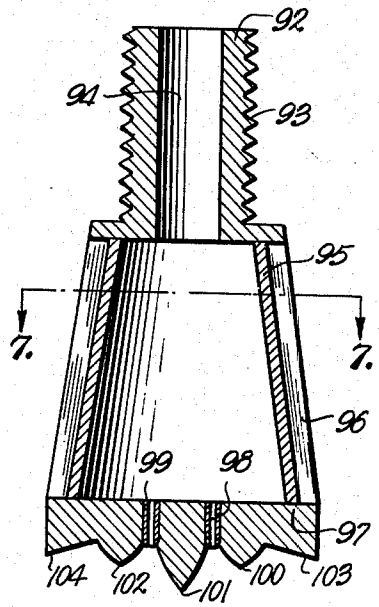


Fig. 5.

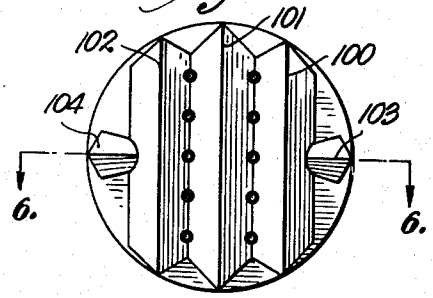
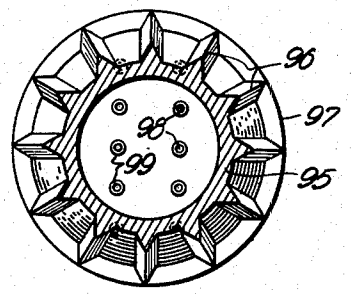


Fig. 7.



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United States Patent Office 3,179,187 Patented Apr. 20, 1965

3,179,187

ELECTRO-DRILLING METHOD AND APPARATUS

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Filed July 6, 1961, Ser. No. 122,172
5 Claims. (Cl. 175—16)

This invention relates to electrical drilling devices and processes and refers more specifically to such devices and processes utilizing thermal shock (successive heating and cooling) rather than heat alone whereby to effect the rock and drilling penetration.

In the art of drilling into or penetrating earth formations and rock structures, it is well known to utilize electric arcs to melt into the structure desired to be penetrated. Additionally, it is known to utilize circulating fluids in conjunction therewith to clear the arc area and carry off cuttings, spallings, etc. It is further old to drill electrically while maintaining a pressure in the wellbore in excess of the rock pressure whereby to drive molten rock back into the formation. Withdrawal of molten, electrically drilled material from the wellbore is additionally known by fluid circulation of same to the surface. Still further, it is known to utilize electrical arc cutting means with air blowing or water supply means associated therewith to simultaneously heat and cool the rock surface to disintegrate same.

The above-noted electrical arc drilling art finds its reflected counterpart in the older flame blast, gas flame or burner drilling art, which is of more ancient derivation. It has been long known to alternately apply gas blast and a cooling medium against a rock face whereby to disintegrate the rock by thermal shock in this manner. Circulation of liquids to carry cuttings and spallings out of the way of the cutting operation is also well known in this art. Mechanical means are often employed with the flame blast drilling means to aid in breaking up slag created by the drilling blast. It is additionally known to utilize, in a drill bit, air blast nozzles or cooling fluid nozzles spatially alternated with heated gas blast nozzles whereby flame contact is followed by cooling fluid contact with circulation of mud or the cooling fluid to remove cuttings. Mechanical cutters may also be associated with such a drill head. Rotating flame blow pipes with simultaneous water injection to carry away slag are additionally known.

An object of the invention is to provide an improved electrical drilling device which utilizes a heating-cooling cycle which operates to distintegrate the rock or earth formation through which the drill is passing and provide an effective drilling or coring means.

Another object of the invention is to provide an improved electrically driven forced heating and cooling cycle which powders or disintegrates the rock particles away from the natural cementing material therebetween instead of electrically melting it.

Another object of the invention is to provide an improved electrical drilling device whereby electrical currents are discharged from the drill bit through direct contact between the drill bit and the rock or ground structure.

Another object of the invention is to provide an improved electrical disintegrating drilling device wherein the electrical currents being discharged against the bottom hole structure create electrical shock waves which

physically tend to fracture, pulverize and break up the rock formation.

Another object of the invention is to provide such a device which provides a heating zone under certain limited portions of the bit, whereby, upon rotation of the bit, to provide alternate heating and cooling of the rock thereby tending to disintegrate the material drilled from successive thermal shocks.

Still another object of the invention is to provide a device for electrically drilling earth horizons and zones wherein the drill bit includes cooling means superimposed behind rotating heating means whereby to cause the alternate expansion and contraction of the heated and cooled rock zones and members whereby to effectuate heat shock disintegration of the material being drilled.

Still another object of the invention is to provide means for imposing heating and cooling cycles on the rock structure being drilled without requiring rotation of the drill bit.

Another object of the invention is to provide means for electrical drilling wherein electrical disintegration effects extend laterally, to a certain extent, of the drill bit as well as downwardly therefrom.

Another object of the invention is to provide an electrical disintegrating drilling device wherein a fluid medium passed centrally of the tubing or other means supporting the drill bit serves to carry cutting and debris out of the way of the drilling operation.

Another object of the invention is to provide an electrical disintegrating drilling means which permits effective drilling and coring with actual contact between the bit and the material or formation being drilled.

Another object of the invention is to provide electrical disintegrating drilling means which are suitable for commercial application and which provides high speed drilling penetration into hard rock formations.

Another object of the invention is to provide electrical current drilling means which may be designed slightly eccentric in form whereby to wabble rotation, if rotation is employed, whereby to drill a much larger diameter borehole than one might expect from the bit diameter and wherein undercutting may also be achieved, if desired.

Another object of the invention is to provide an electrical current drilling means wherein sufficient electrical discharge takes place laterally in the borehole whereby to encrust or fuse the sides or walls of the borehole as drilling or coring proceeds.

Other and further objects of the invention will appear in the course of the following description thereof.

In the drawings, which form a part of the instant specification and are to be read in conjunction therewith, embodiments of the invention are shown and, in the various views, like numerals are employed to indicate like parts.

FIG. 1 is a view above and cross sectionally through a portion of an earth horizon illustrating a first form of electrical drilling apparatus penetrating the horizon with the means for operating the drilling apparatus positioned on the surface.

FIG. 2 is a sectional view through an earth horizon showing a second form of electrical drilling apparatus penetrating the said horizon, the apparatus for operating same positioned at the surface.

FIG. 3 is a sectional view through an earth formation showing apparatus for drilling laterally thereinto pene-

trating same, the apparatus for operating this modification of the electrical drilling apparatus positioned on the surface to the side of the structure being drilled.

FIG. 4 is a cross-sectional view through an earth formation showing an enlarged partly sectional view of the drill head and surface debris and cutting conduit of the drilling means.

FIG. 5 is a view of the underside of the drilling head of FIG. 4.

FIG. 6 is a view taken along the line 6—6 of FIG. 5 in the direction of the arrows.

FIG. 7 is a view taken along the line 7—7 of FIG. 6 in the direction of the arrows.

Referring first to FIG. 1, at 10 is generally designated the cab housing of a truck having a body 11 adapted to carry and mount the electrical drilling means to be described. Positioned upon deck 12 of the truck body 11 is an electrical generator 13 which is driven from power source 14 which may be any suitable internal combustion motor. Positioned on top of the motor 14 is air compressor 15. Ground lead 16 from connection 17 on generator 13 passes to a suitable ground means 18 such as a steel bar which may be of any desired shape or size necessary to handle the electrical load in the process to be described. A flat surface plate of steel with a plurality of depending ground penetrating spikes will also suffice. A second output electrical lead 19 is connected to the generator by connection 20.

A suitable derrick construction having vertical legs 21–24, inclusive, and horizontal support bars 25 and 26 connecting the same to one another is fixed to the rear deck of the truck. A steel plate or panel 27 slides vertically between vertical legs 21 and 24 controlled in such motion by chains 28 and 29 connected to a suitable power source such as an electric motor or gasoline winch at the top of the derrick (not shown). Fixedly connected to plate 27 is shown any suitable conventional gear box and power means for rotating drill pipe designated 30. Drill pipe rotating device 30 may be electrically or otherwise powered from any conventional power source. Drill pipe or tubing 31 passes from its upper end connection to the rotating means downwardly through nonrotating lower fitting 32 on rotating device 30. Platform 33 receives drill pipe 31 therethrough for vertical and rotational motion whereby to stabilize same. An opening 34 defined by an insulating bushing is formed through platform 33 of sufficient size to permit passage of the drill pipe joints 31*a* and/or centralizers therethrough. The bushing insulates the drill pipe from the truck body. Suitable means (not shown) may be provided for gripping the drill pipe sections already in the hole to stabilize them while another section of drill pipe is added on thereabove or other suitable conventional means in the manner of a conventional oil derrick may be provided adjacent the top of the derrick on the truck for adding and removing sections of drill pipe to and from the drill string.

A compressed air hose 35 passes from air compressor 15 into upper nonrotating conventional pressure fitting 36 of drill pipe rotating device 30 and is received in any conventional pressure seal fitting therewithin whereby compressed air or other fluid may be passed into the rotating drill pipe 31 for purposes to be described. Power lead 19 passes from the generator into lower nonrotating fitting 32 and connects electrically to rotatable drill pipe 31 by a conventional brush power take-off or the like whereby the rotating drill pipe can carry the electrical current required in the electrical drilling operation. The drill pipe joints 31*a* may be themselves covered by electrically insulating material for centralizing purposes or additional insulating centralizers of ceramic or other electrical insulating material may be provided as at 37 to avoid lateral tubing-wall arcing and contact. The drilling head construction detailed in FIGS. 4–7, inclusive, is designated 38 at the lower end of drill pipe 31.

A deflector for passing rock particles, cuttings, etc. to the side of the borehole is generally designated 39 and has wellbore capping hood 40 at the lower end thereof, optionally electrically insulated passage or fitting 41 through the upper portion thereof extending axially of hood 40 and ejection pipe 42 extending laterally thereof. This construction or the equivalent thereof may also be employed with a conventional wellhead structure in cooperation with suitable well casing, if the depth of the drilling warrants. In adidtion to insulating fitting or passage 41, which receives drill pipe 31 therein for rotation thereof, the drill pipe itself may be insulated in its entire length on the outside thereof as seen in FIG. 4 alone, or in addition to insulation of the inside surface of fitting 41. The entire means 39 may be made of electrically insulating material, if desired. Means 39 may additionally be formed in joinable halves to put around the top of the drill pipe after insertion of the drill pipe in the ground with the centralizers 31*a* and 37 thereon.

In FIG. 1, ground surface is designated 43, the earth formation therebelow 44 and the wellbore drilled therethrough 45. Cuttings and debris from the wellbore are designated at 46.

Referring to FIG. 2, therein is shown an earth formation with ground level 47, formation proper 48 and wellbore 49 already partially drilled thereinto. A derrick generally designated 50 having vertical legs 51 with lateral bracing members 52 thereon is positioned above the wellbore, has a hollow center and carries, on arms 53 and 54 thereof, a reel or spool 55. A hollow, semi-rigid, fluid tight cable or hose of reinforced plastic, plastic coated woven metal or the like is shown at 56. Spool 55 is mounted on a suitable horizontal shaft (not seen) whereby to reel up and unreel cable 56 thereon. Cable 56 must be fluid tight under high gas or liquid internal pressure. Alternatively, cable 56 may be a hollow flexible conductor coated or clad with electrically insulating material.

A suitable air compressor generally designated 57 passes compressed air through pipe 58 which passes into the hollow center of the shaft rotatably mounting spool 55. Cable 56 is connected to said hollow center shaft at its end whereby to receive the air under pressure. Any suitable internal combustion engine 59 drives conventional electrical generator 60. Power lead 61 from generator 60 passes through a nonrotating seal fitting in the other end of the hollow shaft rotatably mounting spool 55 from the air supply entrance of line 58 and thence into cable 56. Any suitable cable conductor is received in the length of cable 56 to connect with the drill head 71 or a metallic pipe segment 62 carrying the drill head supporting and rotating means. Ground lead 63 connects to any suitable metallic ground such as a steel bar 64. A conventional connection 65 between resilient cable 56 and rigid hollow tube 62 removably supports the latter on the former. A conventional fluid turbine 66, driven by air or well fluids moving upwardly therepast may be fixed at the lower end of member 62 whereby to permit rotation of lower hollow, rigid member 62*a*, separate from member 62 and rotatably connected thereto by the turbine fittings. Rotation of the drive portion of turbine 66 rotates member 62 and drill head 61 (see FIGS. 4–8). The upper portion of member 62 (not rotating) must be fixed relative to the wellbore as by laterally extending jack legs.

Cutting deflecting means generally designated 67 has wellbore capping hood 68 at the lower end thereof, a suitable passage 69 in the upper portion thereof centrally of hood 68 whereby to pass cable 56 therethrough and lateral flowing tube 70. This means may be employed at the top of a conventional wellhead, if such is employed, and may be halved to fit around the tubing 56 after the drilling head 71 and its upper fittings are passed therebelow. Centralizers (not shown) of insulating material may be mounted on tube 56 if desired.

Referring to FIG. 3, therein is shown an earth forma-

tion having a level ground surface 71 adjacent a hill or cliff structure 72 with earth formation 73 therewithin. A truck bed 74 mounted on wheels 75 carries support frame 76 mounting spool or reel 77 for rotation upon a hollow shaft (not seen). Air compressor 78 passes compressed air through line 79 to a seal fitting on the hollow shaft rotatably mounting wheel or spool 77. Conventional internal combustion motor or other suitable power source 80 drives electrical generator 81. Power lead 82 from generator 81 passes centrally of the hollow shaft mounting spool 77 through a nonrotating seal fitting and connects to a conductor within tubing 83. Ground lead 84 from generator 81 is elevated by frame 85 carrying insulator 86 and passes to earth ground 87 lower in the earth structure than the wellbore to be drilled.

Spool 77 mounts a coil of tubing 83 which is of the character previously described relative to FIG. 2, namely, sufficiently rigid to be substantially self-supporting in lateral orientation, hollow, compressed air or fluid tight and carrying an electrical conductor from power lead 82 to the drilling head generally designated 88. Tubing 83 is, however, sufficiently resiilent to permit winding on spool 77. Wellbore 89 drilled into earth formation 73 does not require a deflecting housing over the opening thereof at 90 as the cuttings and debris can fall below the opening as seen at 91. Insulating spacers 83*a* may be employed as desired.

Referring now to FIGS. 4–7, inclusive, it will be assumed that the application of the drill head to be described is in the well drilling construction of FIG. 1. Wellbore 45 is drilled into earth formation 44. Deflection means 39 has been previously described and will not be redescribed. In the structure shown, the drill pipe or tubing 31 has an insulating sheath of plastic or other electrically insulating material 31*b* passing downwardly the length of the drill pipe or tubing to the drill head generally designated 38.

Referring to the detailed construction of the drilling head, it is entirely constructed of electricity-conducting material such as steel. The upper end 92 is externally threaded as at 93 whereby to engage the internally threaded lower end of the drill pipe 31 at 31*c*. Upper portion 92 has hollow fluid carrying passage 94 axially thereof. An intermediate portion 95 of truncated cone form in transverse vertical section is connected to the lower end of portion 92 and has tapered vertical wedges 96 extending vertically on the outer surface thereof, tapered outwardly to sharp edges and angled outwardly downwardly. The outer edges of wedges 96 pass current discharges to the lateral walls of the wellbore and the valleys therebetween permit the passage of cuttings upwardly therethrough. Drilling surface or plate 97 has a plurality of passages 98 therethrough lined with hard steel tubes 99. Plate 97 may be notched to correspond with wedges 96. A plurality of parallel, transverse, sharp-edged wedges 100, 101 and 102 extend across the lower face of the drill plate. Wedges 100 and 102 are of equal downward extension from plate 97, while wedge 101 has greater downward extension, preferably, than both. The openings or passages 98 are preferably positioned in parallel lines between wedges 100 and 102 and wedge 101, as seen in FIG. 5. A pair of minor wedges 103 and 104 are preferably positioned normal to the wedges 100 and 102, outboard thereof, and centrally thereof.

In operation of the devices of the figures, the drilling head is lowered into the wellbore by means of a drilling tubing or pipe or flexible cable as shown in the various forms described previously. Once the drilling head approaches the bottom of the wellbore, the electrical current is turned on from the generator and its power source and, additionally and simultaneously, circulation of fluid under pressure is begun downwardly through the drill pipe or cable. The air or fluid flows through passage 94, through intermediate head portion 95 and out through the passages or openings 98. As the drill plate 97 and the wedges 100–104, inclusive, closely approach the bottom of the wellbore, electrical discharges to the rock take place by virtue of ionization of the gaseous medium passing out of the openings 100 of the drill head to the wellbore bottom and also through ionization of earth moisture. Due to the continuous flow of high pressure air or other cooling medium, each electrical discharge at a given spot is followed by a blast of air or other fluid medium whereby a heating-cooling cycle is set up, whether the drill head is rotated or not. It is preferred that the drill head be rotated to vary the pattern of electrical and fluid impacts in the bottom of the wellbore.

When the drill head contacts the rock in rotation, electrical discharges take place. Rotation alone of the drill head permits more or less continuous bottom hole contact. It is preferred to vertically oscillate the drill head sufficiently far upwardly from the bottom of the wellbore that free passage of the fluid ionizing medium between the drilling head and the rock being drilled occurs if there is any problem of fluid circulation. This also permits the picking up of the debris and rock particles by the fluid medium and passing of same up the wellbore and out therefrom. In the event that the drilling head approaches the wellbore side wall, or perhaps to a certain extent in any case, there are lateral discharges which serve to fuse and coat the wellbore wall, as well as disintegrate same laterally.

If the drilling head is canted on the end of the cable or drill pipe, rotation of same will cause the formation of a larger diameter wellbore than the diameter of the drilling head itself. When the drilling head is rotated as in certain of the modifications described, the wedges 100–102 precede, as well as the wedges 103 and 104, the following air blast jets so that, in addition to the time sequential heating-cooling cycle, there is also a space-sequential heating and cooling cycle attacking the wellbore wall and bottom. The inward tapering of the drilling head as seen at 96 upwardly concentrates the electrical discharges at the lower end of the drill head. By having the central wedge 101 of greater depth than the adjacent wedges, the greatest depth of drilling is accomplished centrally of the wellbore bottom whereby the particles of the debris may be blasted upwardly past the inwardly tapering drilled surface. A stronger concentration of electrical force is also obtained from the greater depth wedge. However, this is preferred, not required.

As the rock conductively varies and also the quantity of earth and bottom hole moisture, it may be desirable to circulate steam, water or drilling mud through the head to aid ionization. In such case, the casing must be sheathed with insulation.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth together with other advantages which are obvious and which are inherent to the structure.

It will be understood that certain features and subcombinations are of utility and may be employed without reference to other features and subcombinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

Having thus described my invention, I claim:

1. A process of electrically drilling subsurface wellbores comprising positioning an electrical current carrying drill head in a wellbore with a portion of said drill head in physical contact with the bottom or terminus of said wellbore, said drill head carried by a drill stem extending downwardly into the earth formation from the surface, continuously flowing electrical current through said drill head into the said wellbore terminus in at least one narrow transverse strip zone extending across the bottom

of the wellbore, the drill head portion contacting the wellbore terminus comprising a substantially continuous elongate edge or line element mounted on the underside of said drill head and extending substantially across the bottom of said wellbore, said electrical current continuously flowed through said edge or line element in quantities sufficient to strongly heat the said terminus transverse strip zone in a substantially continuous manner throughout its entire extent by the electrical phenomenon of contact resistance of a ground electrode, rotating said drill head and line or edge element thereon around a central axis substantially corresponding to the central axis of the wellbore and simultaneously flowing an elongate narrow transverse stream of cooling fluid through said drill head in such manner that said transverse stream of cooling fluid follows and contacts in close sequence the said heated transverse terminus strip, whereby a substantially circular, continuous, sequent heating and cooling pattern is initiated and maintained in a circular zone at the bottom or terminus of the wellbore, said circular zone penetrating continuously deeper into the earth formation as the drill head underside-wellbore terminus contact, rotation of the drill head and line element thereon, and electrical current and fluid flow through the drill head are maintained.

2. A process of drilling subsurface wellbores comprising positioning an electrical current carrying drill head in a wellbore with a limited portion thereof in physical contact with the bottom or terminus thereof, said drill head carried at the end of a drill stem communicating the length of the wellbore from the surface, continuously flowing electrical current through said drill head into the earth formation at the wellbore terminus in a plurality of narrow substantially parallel transverse strip zones extending substantially across the terminus or bottom of the wellbore, the drill head portion contacting the terminus comprising a plurality of substantially continuous line or edge elements on the underside of said drill head each extending substantially entirely across the drill head underside and bottom or terminus of the wellbore, said electrical current continuously flowed through said drill head and line or edge elements thereon in quantities sufficient to markedly heat the said narrow transverse strip zones in a substantially continuous manner across their entire extent by the electrical phenomenon of contact resistance of ground electrodes, rotating said drill head and line or edge elements thereon around a central axis substantially corresponding to the central axis of the wellbore and simultaneously flowing a plurality of elongate transverse bands of cooling fluid through the underside of said drill head in such position and pattern as to closely follow and contact in following sequence the electrically heated transverse earth formation strip zones, whereby a circular, continuously moving, sequent, transverse earth formation heating and cooling action is initiated and maintained in a circular zone at the bottom of the wellbore, said circular zone penetrating continuously deeper into the earth formation as the drill head underside-wellbore contact, rotation of the drill head and line or edge elements thereon and current and fluid flow therethrough are maintained.

3. A process of drilling subsurface wellbores comprising positioning a current carrying drill head in earth formation contact at the bottom or terminus of a wellbore, said drill head mounted on a drill stem communicating from the surface to said wellbore terminus, continuously flowing electrical current into the earth formation at the wellbore terminus through the drill head contact therewith in a plurality of narrow transverse strip zones extending across the bottom of the wellbore, the underside of the drill head contacting the wellbore terminus through a plurality of substantially parallel and continuous line or edge elements thereon of such length as to extend substantially across the bottom or terminus of said wellbore, said current continuously flowed through said drill head and line elements thereon in quantities sufficient to markedly heat the said narrow transverse strip zones in a substantially continuous manner across their entire extent by the electrical phenomenon of contact resistance of ground electrodes, rotating said drill head and line or edge electrode elements thereon around a central axis substantially corresponding to the central axis of the wellbore and simultaneously continuously flowing an elongate transverse narrow stream of cooling fluid through the underside of said drill head and between each pair of said line elements in such quantity, velocity and manner as to continuously follow and contact the heated transverse strip zones with said fluid stream, whereby a circular, continuously rotating, sequent, earth formation heating and cooling action is initiated and maintained in a circular zone at the bottom or terminus of the wellbore, said circular zone penetrating continuously deeper into the wellbore terminus earth formation as the drill head underside-wellbore terminus contact, rotation of the drill head and line elements thereon, and current and fluid flow therethrough are maintained.

4. A process of drilling subsurface wellbores comprising positioning an electrical current carrying drill head in a wellbore with the underside thereof in physical contact with the earth formation at the bottom or terminus of said wellbore, said drill head carried by a drill stem extending from the surface the length of said wellbore, continuously flowing electrical current into the earth formation at said wellbore terminus through said drill head wellbore contact in at least one narrow transverse strip zone extending substantially across the diameter of the wellbore, the drill head underside portion contacting the wellbore terminus comprising at least one elongate, substantially continuous line or edge electrode element, said electrical current continuously flowed through said drill head line element into said zone in quantity sufficient to markedly and deeply heat same in a substantially continuous manner through and along its entire diametric extent by the electrical phenomenon of contact resistance of a ground electrode, simultaneously continuously flowing quantities of cooling fluid downwardly through the underside of said drill head, said fluid flow passing out of said drill head in an elongate continuous line positioned substantially parallel to and closely on one side of said line element whereby said earth formation transverse strip zone is subjected to continuous, juxtaposed electrical heating action and cooling fluid flow thereat, the flow of electrical current into the terminus earth formation through said drill head line element and the adjacent and coacting flow of cooling fluid also moving through said drill head effecting downward penetration of said drill head continuously deeper into the earth formation as the electrode-terminus contact, and electrical current and fluid flow are maintained.

5. A process of drilling subsurface wellbores comprising positioning an electrical current carrying drill head in a wellbore with a limited portion of the underside thereof in physical contact with the earth formation at the wellbore bottom or terminus, said drill head carried by a drill stem extending the length of the wellbore from the surface to said terminus, continuously flowing electrical current into portions of the earth formation at the wellbore terminus, said current flowed into a plurality of narrow transverse strip zones extending in substantially parallel array across the wellbore terminus, the drill head underside portions contacting the earth formation comprising a plurality of elongate substantially continuous line or edge electrode elements each extending substantially continuously across the drill head underside and also substantially across the entire bottom or terminus of said wellbore, said electrical current flowed into the earth formation through said line elements in quantities sufficient to markedly and penetratingly heat the said earth formation transverse strip zones throughout their entire extent by the electrical phenomenon of contact resistance of ground electrodes, simultaneously continuously flowing at least one transversely extending band or line of cooling fluid downwardly through the underside of said

drill head and between each pair of earth formation contacting drill head edge elements, said line of cooling fluid extending substantially parallel to said line elements and of transverse extent at least substantially as great as same, whereby continuously acting electrical heating and fluid cooling effects in the terminus earth formation are initiated and thereafter continuously maintained in a transverse zone at the wellbore terminus and whereby to cause said drill head to penetrate continuously deeper into the earth formation so long as the electrode-earth formation contact and current and fluid flow are maintained.

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