

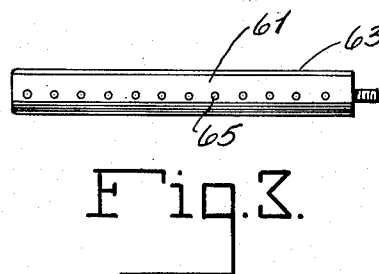
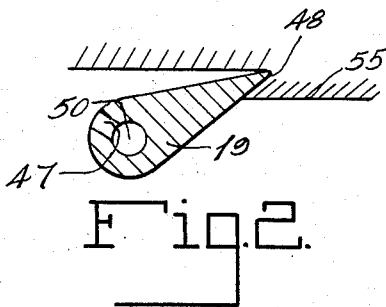
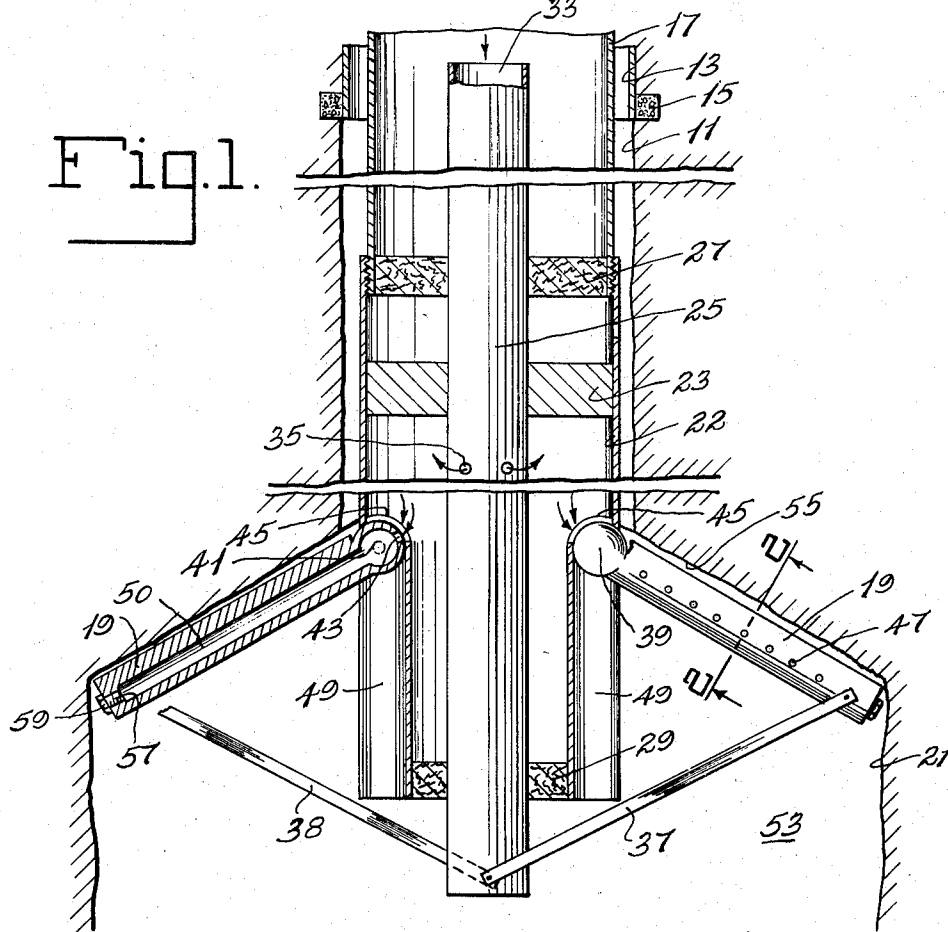
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APPARATUS FOR REAMING HOLES DRILLED IN THE EARTH

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APPARATUS FOR REAMING HOLES DRILLED IN THE EARTH

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4 Claims. (Cl. 255—76)

The present invention relates to a novel apparatus for reaming out a hole which has been drilled in the earth, from a relatively small diameter to a relatively large diameter. More particularly the invention concerns such an apparatus whereby an enlarged storage cavity can be formed below the surface of the earth for receiving liquids such as liquefied petroleum gases which are to be stored.

It has been suggested that liquefied petroleum gases be stored in large cavities formed in earth formations such as beds of salt, clay, or limestone below the surface of the earth. For example, such a cavity can be formed about 1,000 feet below the surface and can have dimensions such as 1,000 feet in length by 20 feet in diameter so as to store more than 50,000 barrels of liquid.

One method for creating such cavities involves first drilling a hole of relatively small diameter from the surface of the earth down into the formation within which the cavity is to be formed, then circulating water or other material-removing wash liquid down through the drilled hole to dissolve or otherwise remove material, and concurrently, and continuously withdrawing from the hole the liquid containing removed material in a dissolved or suspended state. Plain water can be used for removing salt. A material such as clay requires a deflocculant liquid such as water, preferably including a deflocculation promoter such as the molecularly dehydrated phosphates. Limestone requires an acid solution such as a water solution of hydrochloric acid.

While cavities have been successfully formed as described, the speed of the operation is often less than desired, and it is difficult to control the shape of the cavity so as to obtain a known uniform diameter throughout its length. Low speed may be partly attributed to the fact that when operating with a liquid-filled cavity it has not been possible to employ the eroding action of wash liquid jets impinging directly against the walls of the hole, since the pool of liquid arrests the motion of such jets after they leave a central wash pipe.

In accordance with the present invention there is provided a novel apparatus for enlarging the diameter of a hole drilled into a bed of salt, clay, or the like, for progressively scraping material from successive areas of an annular zone which extends laterally outwardly from the hole while concurrently directing one or more flowing streams of a material-removing wash liquid, such as water, against substantially the full width of the annular zone. The enlarged diameter is extended lengthwise of the hole by similarly removing material from successively exposed annular zones. During the scraping and washing action a pool of the wash liquid accumulates in the hole to receive the removed material and form a suspension or solution which is continuously discharged from the hole by the application of air or liquid pressure, by pumping mechanically, or in any other suitable way.

My novel apparatus comprises a stem which is secured on the lower end of a conventional hollow drill string,

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and one or more arms mounted adjacent the bottom of the stem for lateral movement transversely into contact with the wall of the hole. Each arm has a cutting edge extending longitudinally along one of its sides for scraping material from an annular zone extending laterally out from the hole, and also has one or more ports in the opposite side of the arm for projecting a fluid, such as water, at high velocity in a direction away from the cutting edge and against the annular zone. The fluid discharged from these ports not only acts to wash off loose material and to impregnate and soften the wall, but also supplies propulsive force for assisting rotation of the arm about the longitudinal axis of the stem.

The apparatus also comprises mechanism (not shown) for rotating the stem about a longitudinal axis, and for moving the stem longitudinally up or down so as to extend the reaming operation lengthwise of the hole. Mechanism of the type conventionally employed for rotating and advancing oil well drilling tools can be used.

In the drawings:

Fig. 1 is a vertical sectional view, parts being in side elevation, of apparatus embodying the invention, shown in position for reaming out a hole;

Fig. 2 is a cross-sectional view taken along the line 2—2 of Fig. 1; and

Fig. 3 is a side elevational view of an extension arm which may be added to the apparatus shown in Fig. 1.

More specifically in accordance with the invention a hole 11 is drilled in a conventional manner from the surface of the earth down into the formation of salt, clay or the like, in which a storage cavity is to be formed, and is lined with a casing 13 which is sealed by cement at 15 to the earth formation. After completion of the hole the drill string is removed and the drilling cutter on the end of the drill string is replaced with the reaming apparatus of the present invention, which includes a longitudinal stem 17 mounted on the lower end of the drill string and carrying a pair of oppositely disposed transversely movable reamer arms 19 adjacent its lower end for engaging the wall 21 of the hole.

Stem 17 includes a cylinder portion 22 within which works a longitudinally movable control piston 23 mounted on a hollow piston rod 25 which is journaled in sealing bearings 27 and 29 to prevent the leakage of liquid.

Liquid such as water is supplied through the hollow drill string to the interior of stem 17, flows down through the open top 33 of piston rod 25, and thence is discharged into cylinder 22 through a plurality of apertures 35 in the side walls of the piston rod between piston 23 and lower bearing 29.

Piston rod 25 extends down to a position below bearing 29 where it is connected to the reamer arms 19 by a pair of oppositely extending links 37 and 38. Links 37 and 38 are pivotally secured at their inner ends to opposite sides of piston rod 25, and at their outer ends are pivotally secured to arms 19 near their outer ends.

Arms 19 are pivotally connected at their inner ends to the stem 17 by leak-proof ball and socket joints 39 and 41 which have apertures 43 registering with connecting slots 45 through which liquid flows from the inside of cylinder 22 to the insides of the arms. This liquid is then discharged through a plurality of upwardly tilted closely spaced ports or orifices 47 along one side of each arm as a substantially continuous sheet to impinge against substantially the entire area swept over by the arm. The opposite side of the arm 19 is provided with a sharp cutting edge 48 which is tilted up to cut into the roof of the cavity 53 being formed. Cutting edges 48 of the two arms 19 both point in the direction of rotation, and orifices 47 point in the opposite direction to add the propulsive force of the liquid jets to the force rotating stem

17. As shown in Fig. 2 the ports 47 lie above the bisector of the angle included by the sides of cutting edge 48.

When the reaming apparatus is inserted in the hole 11 the piston 23 is in lowered position so that the arms 19 are folded into a pair of longitudinal recesses 49 in the sides of stem 17. Once the reaming apparatus has reached the position at which enlargement is to begin, liquid such as water is introduced into the stem 17 from the drill string, passes down through the piston rod 25, and forces the piston 23 upwardly so as to raise the arms 19 into scraping contact with the side walls of the hole. Meanwhile liquid flows through the passages 50 inside arms 19 and is discharged with considerable force from the orifices 47 against the walls of the hole to wash away material and to soften material in preparation for the action of the scraping edges 48 of the arms 19 as the stem 17 is rotated.

The washing and scraping action is extended around the circumference of the hole to remove material from successive areas of an annular zone extending laterally outwardly from the hole by rotating the stem 17 while maintaining the liquid pressure on piston 23 to hold out the arms 19. As material is removed the arms 19 are gradually forced out farther until they are fully extended.

To extend the reaming operation lengthwise of the hole once the arms 19 have expanded to their fullest extent the stem 17 is raised so that the arms remove material from successively exposed annular zones. Upward movement of this type is required when the cutting or scraping edges 48 of the blades are tipped upwardly in the direction of rotation, so that an enlarged cavity 53 is formed having a conical roof 55 from which the scraper edges 48 remove material. Continuous raising of stem 17 causes arms 19 to pursue a spiral path, which is an advantageous procedure. However, intermittent upward movement of stem 17 in small increments can also be used successfully.

The orifices 47 are so designed in the modification illustrated that they are inclined upwardly and rearwardly with respect to the direction of rotation so as to discharge high velocity liquid jets against the roof 55 in a direction opposite the edges 51. The liquid should be discharged from orifices 47 with sufficient force and velocity to assist in propelling the arms 19 around within the hole.

It is evident that similar apparatus could be used to enlarge a cavity in a downward direction by providing a scraping edge 48 which is inclined downwardly so as to scrape the floor of the cavity; and by tilting the orifices 47 downwardly so as to wash the floor of the cavity. Relocation of links 37 and 38 obviously would then be required to clear the arms.

The liquid injected from the orifices 47 gradually accumulates until it forms a deep pool filling the enlarged cavity 53 and the portion of the hole 11 surrounding the stem 17 and the drill string. The continued addition of liquid under pressure then forces liquid from the pool to the surface of the earth where it is discharged. If the material of the formation is soluble, for example salt, the dissolved salt is carried to the surface in solution as a concentrated brine. If the material is insoluble, for example clay, the finely divided removed particles are carried to the surface as a suspension in the liquid.

The procedure wherein the roof of the cavity is scraped and the cavity is enlarged upwardly is particularly advantageous when operating with a cavity full of liquid because the material removed from the roof drops down into the liquid to become dissolved or suspended therein. When operating on the floor of the cavity the removed material may tend to accumulate as a mud.

Sometimes the diameter of the cavity 53 must be enlarged to a greater extent than is possible with the arms 19. Therefore provision is made for coupling an extension to each arm, which is accordingly provided with a threaded bore 57 in its outer end normally closed by a plug 59. The reaming apparatus is withdrawn from the

hole 11, the plugs 59 are removed, and an extension arm 61, shown in Fig. 3, is threaded into place in the end of each of the arms 19. The extension arm 61 is identical to the arms 19 with respect to the construction of its scraping edge 63 and the line of orifices 65, both of which are aligned with the corresponding parts of arms 19.

The apparatus is then reintroduced into the cavity 53 with the arms folded in, and the operation of further enlarging the diameter of the cavity proceeds by operating the piston 23 to raise the extended arms against the side walls of the cavity, rotating the stem 17 until the arms are fully extended, and then raising the stem 17 gradually.

Obviously, many modifications and variations of the invention as hereinbefore set forth may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated in the appended claims.

I claim:

1. Apparatus for reaming a hole drilled in the earth comprising a rotatable stem; an arm pivotally mounted at a near end on said stem for movement transversely thereof, said arm comprising a blade having sides inclined together at an angle and meeting in a cutting edge on the leading side of said arm, said cutting edge extending longitudinally from a position adjacent said near end to the far end, both of said sides also being inclined upwardly when said arm is in extended position; said arm also having a plurality of ports spaced longitudinally along said arm on the lagging side thereof opposite said cutting edge and above the bisectors of said angle, for projecting a fluid at high velocity therefrom in an upward direction transversely of said arm and away from said cutting edge when said arm is in extended position, said ports being inclined upwardly to the outlets thereof; and means for moving said arm transversely of said stem into and out of extended cutting position.

2. Apparatus for reaming a hole drilled in the earth comprising a rotatable stem; an arm having a near end pivotally mounted on said stem for movement transversely thereof, said arm having a cutting edge and a plurality of ports for discharging liquid therefrom, said arm having a far end and having coupling means at said far end constructed and arranged for connecting said arm to a hollow reamer extension having similar cutting edge and parts in axial alignment therewith, whereby the effective length of said arm for reaming is increased thereby to enlarge the diameter of said hole to a greater size than is possible with said arm, passage means in the far end of said arm in position for delivering liquid to such an extension after connection thereto, and means closing said passage means operable to open said passage means for the delivery of liquid therethrough.

3. An extension for reaming apparatus comprising a hollow arm having means at one end thereof for connection to a reamer arm, having passage means for receiving fluid from such a reamer arm, having a longitudinally extending cutting edge along one side thereof, and having orifice means for discharging fluid therefrom transversely of said arm and away from said cutting edge.

4. Apparatus for reaming a hole drilled in the earth comprising a rotatable tubular stem; an arm having a far end and having a near end pivotally mounted on said stem for movement transversely thereof, said arm having a cutting edge extending longitudinally from a position adjacent said near end to said far end; said arm also having port means for projecting a liquid therefrom; and means for moving said arm transversely of said stem into and out of cutting position, said last named means comprising a piston movable up and down within said stem, a tubular piston rod projecting downwardly from above said piston through said piston to a position below the bottom of said stem, said piston rod having apertures for liquid both above and below said piston within said

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stem, a first seal located between the top of said piston and the upper of said apertures, a second seal located between the lower of said apertures and the bottom of said stem, the construction and arrangement being such that when pressure liquid is introduced to the inside of said stem it passes in through the upper of said apertures, down through said hollow piston rod, and out through the bottom of said apertures and forces said piston upwardly; and linkage means connecting said piston rod below said stem to said arm; said arm and the interior of said stem below said piston having intercommunicating passages for conducting liquid to said port means.

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