

May 15, 1956

F. E. GILMORE

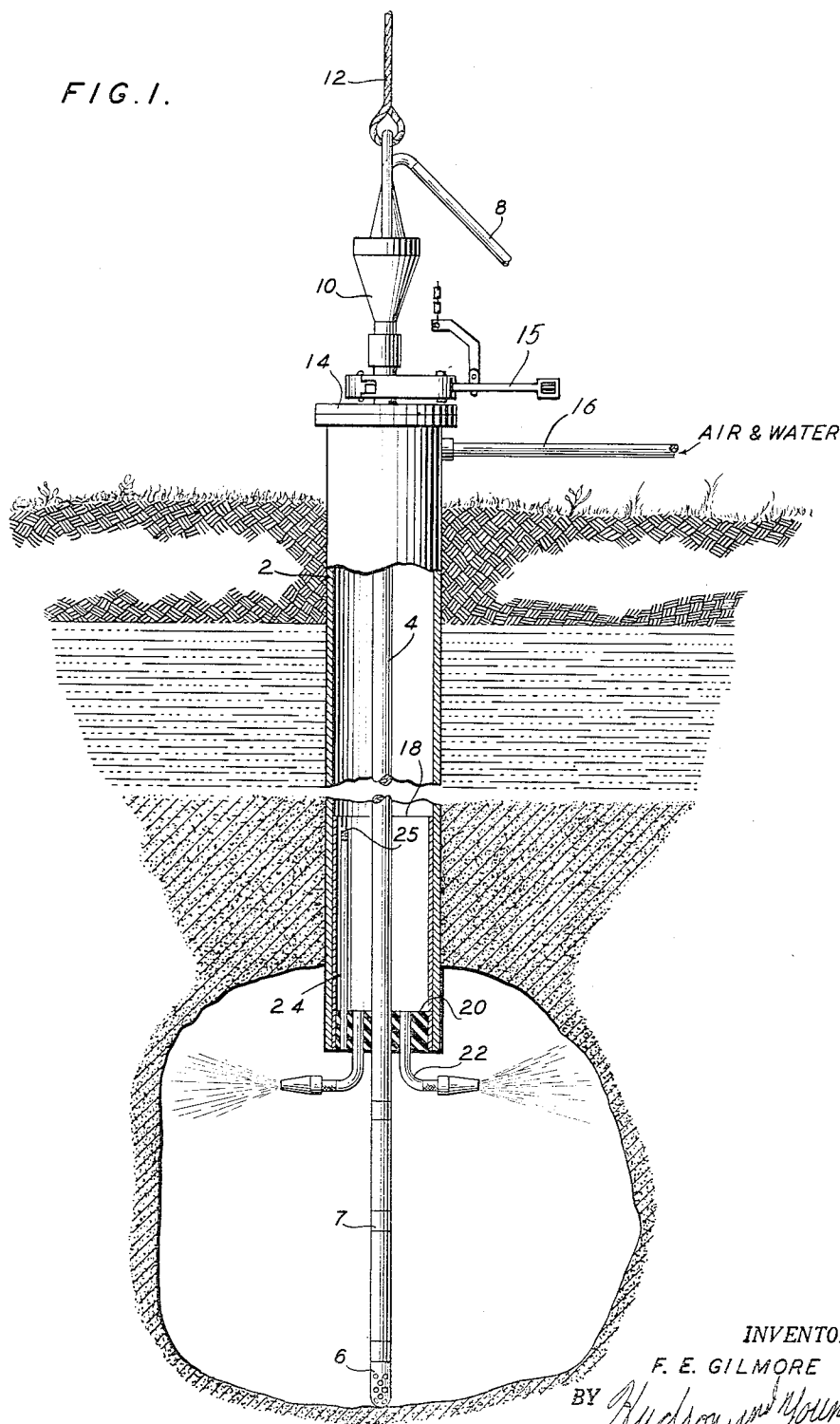
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PRODUCTION OF UNDERGROUND CAVITIES

Filed July 21, 1952

4 Sheets-Sheet 1

FIG. 1.



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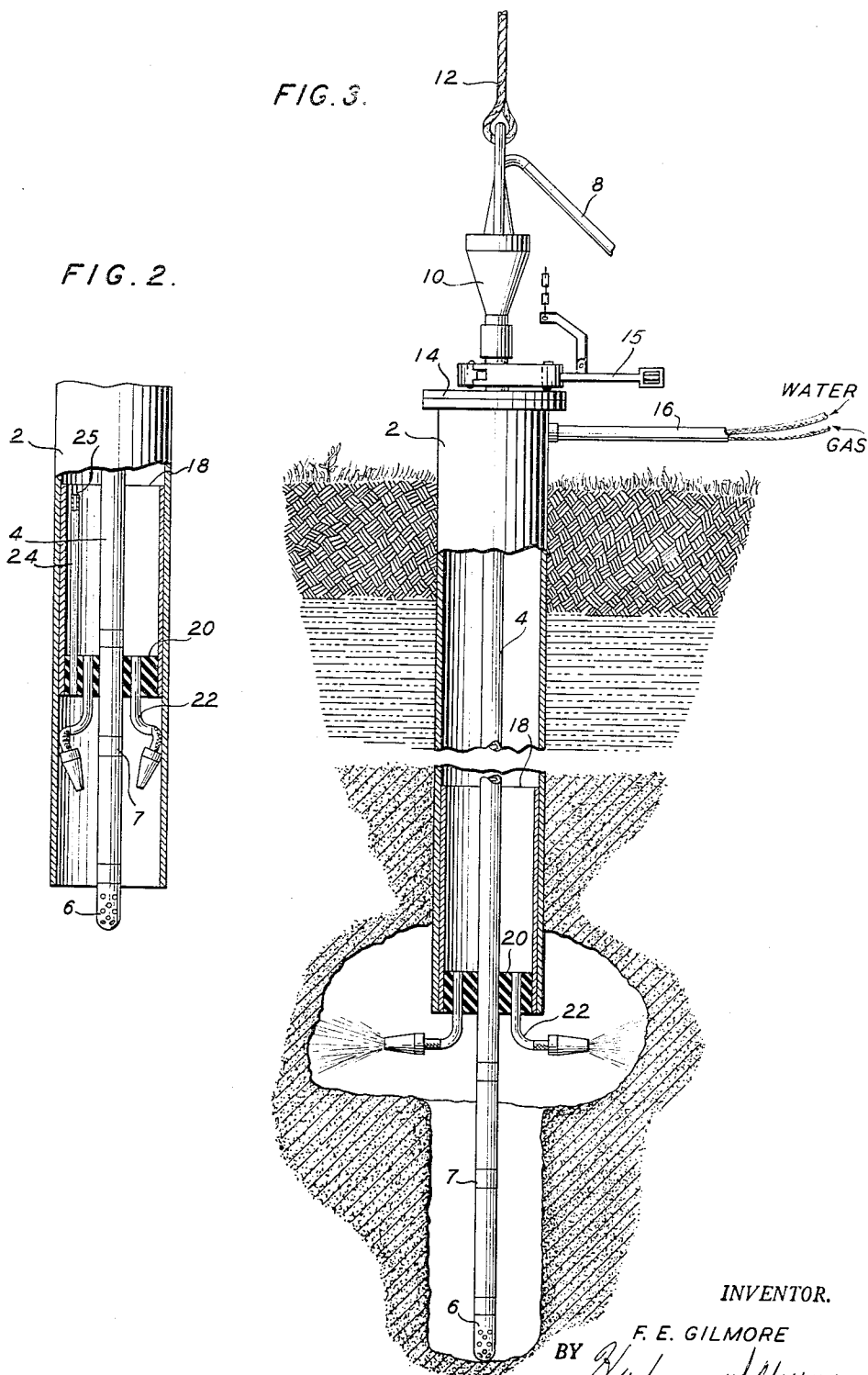
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FIG. 4.

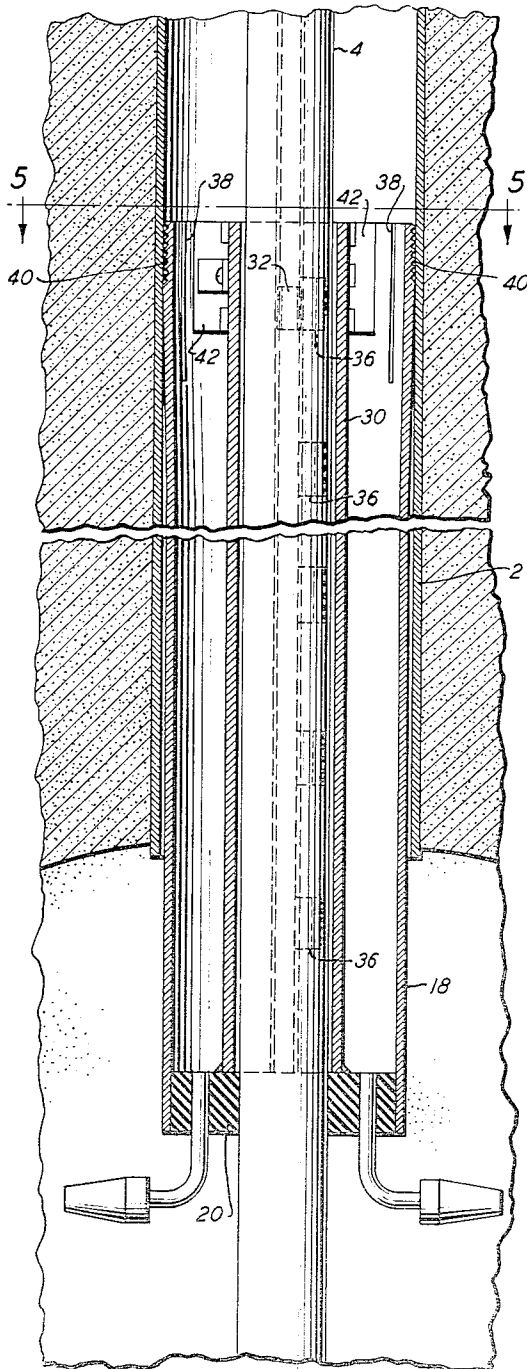


FIG. 5.

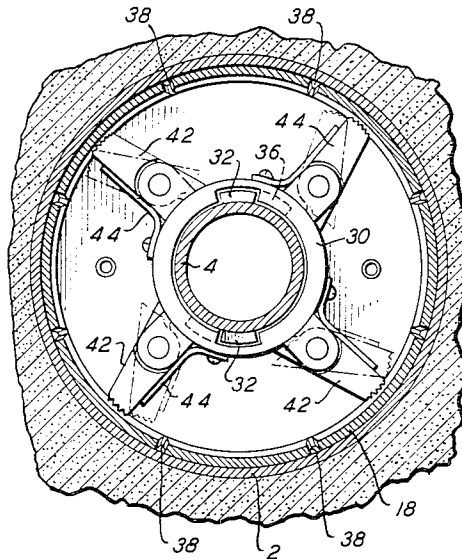
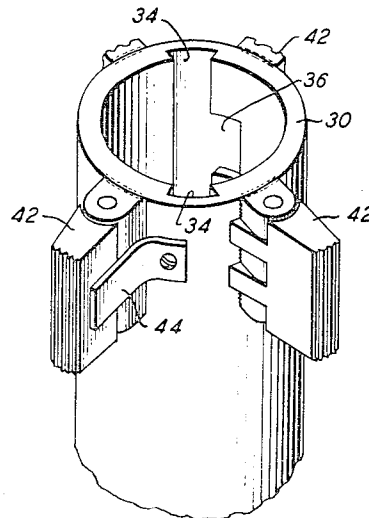


FIG. 6.



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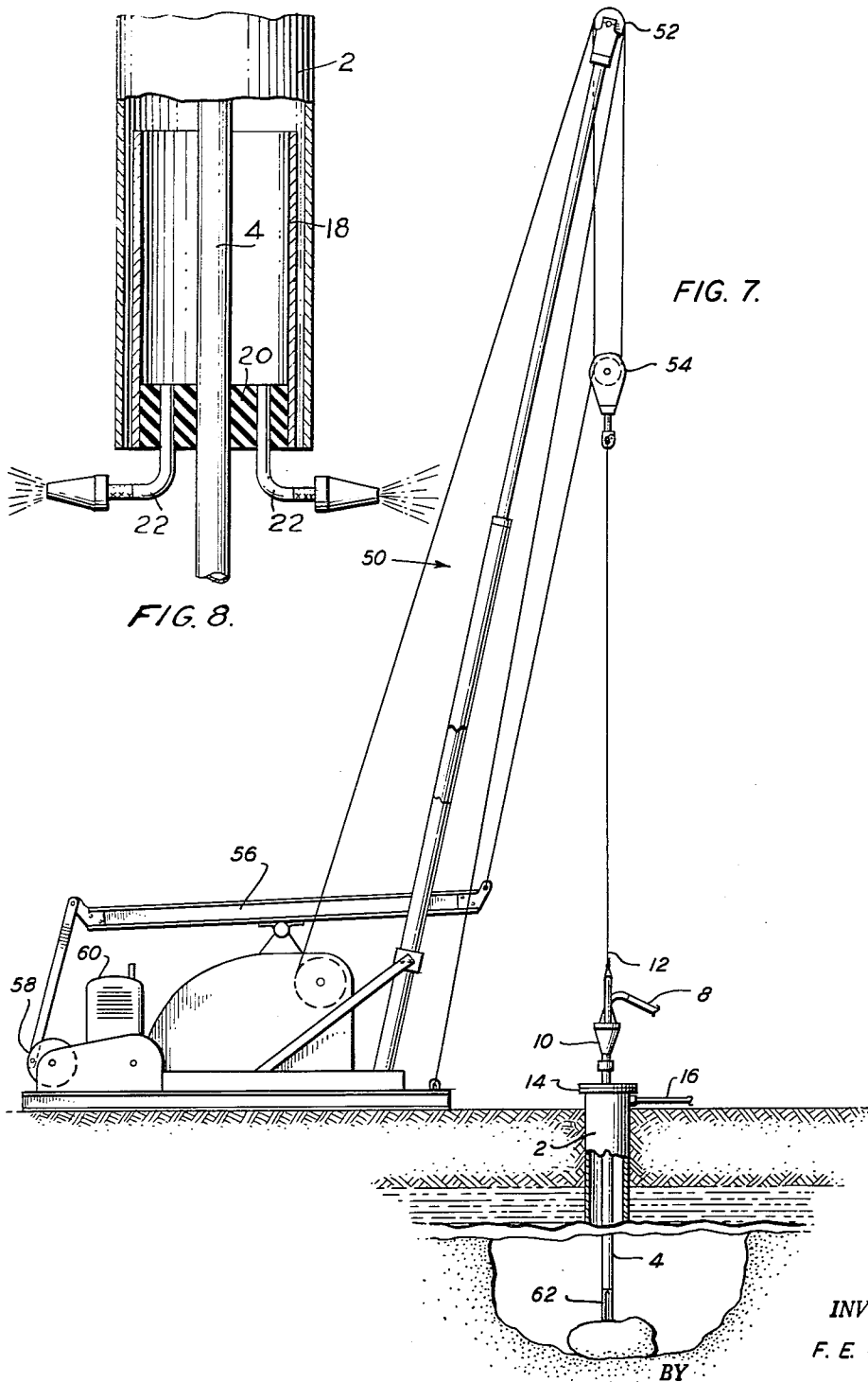
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4 Sheets-Sheet 4



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2,745,647

PRODUCTION OF UNDERGROUND CAVITIES

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Application July 21, 1952, Serial No. 300,000

11 Claims. (Cl. 262—3)

In one of its embodiments this invention relates to the enlargement of well bores. In another of its aspects the invention pertains to the formation of underground storage cavities, e. g. for liquefied petroleum gases. Still another aspect of the instant invention relates to the recovery of sediments or of soluble materials from subterranean deposits.

It is known that the sale of liquefied petroleum gas has been limited by the fact that supply could not be provided where demand existed because of high cost of pressure storage vessels. The practice which developed as a consequence has been to provide underground storage cavities for the storage of liquefied petroleum gases. The apparatus of this invention is particularly adapted for the development of underground storage cavities suitable for the storage of liquefied petroleum gases, diesel fuel, kerosene, furnace oil and other refined products. However, the apparatus of the invention can also advantageously be used in various petroleum production and mining operations, e. g. hydraulic mining of solids, i. e., eroding of solids and lifting a slurry instead of a solution of solids.

In the development of underground storage cavities for liquefied petroleum gas ground formations are selected such as salt beds, certain sands and shales, etc. which are susceptible to dissolving or leaching by water or other mechanical solvents. A well is drilled with ordinary equipment to the top of the formation and the casing set in accordance with practices well known to the art.

To enlarge well bores in accordance with the practice of this invention, jets of a mixture of air and liquid are directed laterally against the sides of a well bore from an annular space formed by a casing and a smaller tubing within the casing through nozzles extending outwardly from an annular plate connected to the tubing and to a cylindrical sleeve slidable within the inside wall of the casing. Alternately, the jet may comprise water alone while air is added separately in a quantity and at a pressure necessary to maintain desired operating conditions, as more fully described hereafter. Detrital material dislodged by jet action is withdrawn through the tubing within the casing.

For a better understanding of the present invention and objects thereof, reference is made to the following discussion taken in connection with accompanying drawings. The drawings are, of course, illustrative and the invention is not intended to be limited thereby.

In Figures 1 and 3 are shown, partially in section, two embodiments of the instant invention.

Figure 2 is a partial view showing a tubing and sleeve combination at the time the tubing and the sleeve connected thereto are being lowered into the casing.

Figures 4, 5 and 6 are a modification of Figures 1 and 3 and are partial views showing means for lowering or raising the tubing without removing the sleeve.

Figure 7 is a further modification showing means for lowering and raising tubing 4 and associated parts.

Figure 8 is a further modification wherein tube 24 is omitted and sleeve 18 fits loosely within casing 2.

In Figures 1 and 3, numeral 2 is a casing cemented in place in a well which is drilled to the formation to be excavated or mined. Tubing 4 of smaller diameter than casing 2 is disposed within casing 2 to form an annular space therebetween. Tubing 4 has a perforated end 6 extending some distance below the casing into the bore. Alternately, the tubing 4 may have an open end with no perforations in the side of the tube. Tubing 4 has a discharge pipe 8 attached thereto by swivel 10. Swivel 10 is attached to a mast of a hoisting rig as shown in Figure 7, at 12 so that it can be raised or lowered. The tubing can also be adapted for rotation by means of a power tongs 15 or a rotary table. A casing head 14 closes the top of the casing securely and prevents leakage of water and air from the annular space between casing 2 and tubing 4. Water and air, or other gases and liquid solvents, are together passed into the top casing 2 through connection 16. Tubing 4 carries with it a sleeve 18 so that said sleeve during operation will be disposed in the lower part of casing 2 and in substantially air tight connection therewith. Sleeve 18 is connected to tubing 4 by means of plate or packer 20. A central perforation is provided in plate or packer 20 where plate 20 and tubing 4 are rigidly attached to each other. Plate 20 is also provided with other perforations which are adapted for attachment of nozzles 22. There are means available for attaching nozzles 22 to plate 20 so that they will automatically move outwardly when sleeve 18 reaches the bottom of casing 2. For example, the L connection can be made of a rigid material while the rest of the nozzle is flexible and can be bent as shown in Figure 2. Thus the nozzles may be made of rubber so that they will spring outwardly when they pass through the casing or springs may be provided if desired. In addition, rollers can be attached to the nozzles so that the sleeve 18 can more easily move down through the casing.

Referring now to Figure 1 a tube 24 is provided to allow air or gas to be applied to the surface of the liquid in the hole without spraying it through the nozzles with water as is done in the operation illustrated in Figure 3. In the formation of cavities where the nature of the formation is such that more jet action is necessary, or the head of water in sleeve 18 is not sufficient to provide an effective jet, my preferred embodiment is to use a restriction 25 in tube 24 so that there will be a pressure drop through the tube. In this preferred embodiment there will be applied to the surface of the liquid in the bore hole sufficient air or gas to provide the air-lift, but there will also be additional pressure on the head of water in the sleeve for more effective jet action. In operation in accordance with the embodiment illustrated in Figure 1 air and water together are supplied under pressure to the annular space between tubing 4 and casing 2. The water passes through nozzles 22 in the form of a jet against the sides of the cavity while air passes through small tube 24 to provide an air lift. When the air reaches the cavity it passes through perforations 6 in the bottom of tubing 4 carrying with it water having salt dissolved therein or water and detrital material. After the cavity is mined to the largest diameter permissible with one length of hose or the like, other lengths can be provided to place the nozzles closer to the wall of the cavity being mined or enlarged. Further, as a cavity or mine becomes deeper additional sections of tubing can be added by collars 7 so that perforation 6 will always be on the floor of the cavity. In other words as the mine or cavity progresses in size the tubing can be lowered. Addition of lengths of hose to nozzles 22 and addition of sections of tubing to tube 4 can be done in Figures 1 and 3 by raising tube 4 by means of the hoisting rig shown in Figure 7. Tube 4, packer 20 with nozzles 22 attached and sleeve 18 are all raised to the surface where the additions to nozzles 22

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and tube 4 are made and then all returned to the cavity. If the embodiment using the modification shown in Figures 4, 5, and 6 is used, these additions to nozzles 22 and tube 4 can be made without removal of sleeve 18 from casing 2, as will become apparent from the description of Figures 4, 5 and 6 to follow. Tubing 4 can also be rotated to attain the maximum mining effect by means of a power tongs 15 shown in Figures 1 and 3, or other well known drilling and mining equipment such as a rotary table. It is understood that the length of sleeve 18 will be determined by the vertical size of the desired cavity since during operation sleeve 18 extends below the casing. The distance below the casing to which sleeve 18 carries the nozzles will also depend somewhat upon the particular formation. If the formation can be easily eroded by the jet action of water or water and air the length of the sleeve can be less than the vertical size of the desired cavity. Usually the sleeve lengths will be approximately half of the depth of the required cavity. It is also understood that the cavity can be mined by starting at the top of the formation to be eroded and working downwardly or starting at the bottom and working upwardly.

Referring now to Figure 3, the embodiment shown in that figure is particularly suitable for the formation of underground storage cavities at depths which are not sufficient to permit the use of a head of water for effective jet action. In this embodiment small tube 24 is not used. Instead during operation a vortex forms at the entrance of each nozzle and air and water together pass through the nozzles. The mixture of air and water in this instance should be such that the effective hydraulic action is not lost because of too much air. However, if during operation, it is seen that the air-lift through tubing 4, and out discharge pipe 8, is becoming ineffective, the amount of water can be cut down to insure the formation of a vortex, thus also insuring that a sufficient quantity of air is passing through the nozzles with the water to provide the air lift.

It is now apparent that operation will vary with the depth at which the bore will be enlarged and whether salt, sand or shale etc. is to be mined. Thus, when subsurface cavities are being mined at relatively shallow depths for liquefied petroleum gas, say at 60 or 100 feet levels, a convenient and economical method to employ is that illustrated in Figure 3. The hydraulic head will be relatively unimportant. However, where underground cavities are being formed at greater depths, for example at the 1,000 foot level, a more desirable method of operation to employ is that illustrated in Figure 1 since the greater depth furnishes an adequate hydrostatic head to produce the desired jet action as the water leaves nozzles 22, without passing both air and water through nozzles 22 as is done in Figure 3. As was stated before, additional sections of tubing can be added to tube 4 to facilitate mining a cavern at greater depths below the surface. However, even in this instance operation in accordance with the present invention is more economical than prior art methods.

It was previously pointed out that as the cavity or mine becomes deeper additional sections of tubing can be added by collars 7 so that perforations 6 will always be on the floor of the cavity. Figures 4, 5, and 6 show a means provided for moving tubing 4 up or down without moving the sleeve so that the tubing will not have to be withdrawn to add or remove additional sections below the sleeve. Referring to Figure 4, an additional tube 30 slidably surrounds tubing 4, and packer 20 is attached thereto instead of to the tubing. Packer 20 is also attached to sleeve 18 as is shown and described in Figures 1 and 3. However, packer 20 fits closely around tube 4 to make a substantially air-tight connection. In this modification tubing 4 is provided with two bosses 32, shown more clearly in Figure 5 which slide in grooves 34 shown clearly in Figure 6. In these grooves 34 are a desired number of notches 36 into which bosses 32 fit to suspend the tubing when the tubing is turned clockwise. Notches 36 are longer ver-

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tically than bosses 32 (see Figure 4) so that the bosses can be more easily turned into the desired notch. Any number of notches can be provided to suspend tubing 4 at any desired level. Means are also provided for expanding the top of sleeve 18 so that it will stay in place while tubing 4 is raised or lowered. To allow the sleeve to be expanded more easily slots 38 are provided in sleeve 18. In addition sleeve 18 is provided with sharp saw-like teeth 40 around the sleeve at its upper end. To cause the upper part of sleeve to expand, tube 30, at its upper end at the level of said teeth 40, is provided with a plurality of dogs 42 (e. g. four) to engage the expansible upper part of sleeve 18. Spring 44 is also attached to tube 30 to hold dogs 42 against the inside of the sleeve as shown by the dotted lines in Figure 5 so that the sharp edges of the dog will cause it to assume the position shown in solid lines in Figure 5, thereby expanding the upper end of sleeve 18. Sleeve 18 and casing 2 are in substantially airtight connection. In Figure 4 the space therebetween has been exaggerated to show the expansion at the top of sleeve 18. The operation of this embodiment is now readily understood.

A quick counter-clockwise turn of tubing 4, as viewed in Figure 5, would cause dogs 42 to engage the expansible upper part of sleeve 18, forcing saw-like teeth 40 into casing 2 to hold sleeve 18 in place. The friction and inertia of the heavy sleeve 18 will keep it from turning. Then tubing 4 can be raised or lowered with the two bosses 32 on it sliding in the vertical grooves 34 inside the tubing sleeve 30. In these grooves are the desired number of notches 36 longer than the bosses into which the bosses fit when the tubing is turned clockwise. A further turn clockwise disengages dogs 42 and leaves the sleeve assembly supported by the tubing. A small dog or pawl can be attached to the casing sleeve to engage the casing in such a manner as to prevent it turning counter-clockwise if necessary, but friction and inertia will be sufficient to allow the expansion dogs to engage and expand the top expandable part of the casing sleeve when the tubing is snapped quickly counter-clockwise.

In the light of the the present disclosure modifications and variations will obviously occur to those skilled in the art. Thus besides creating cavities for underground liquid or gas storage the methods of the invention can be used to recover material such as sediments containing gold or precious metals.

An advantage of this invention is that, particularly in the case of salt formations, the water can be recirculated. The use of recirculated brine and the enlargement of a cavity by erosion alone is especially advantageous where no method of brine disposal is available. It has the additional advantage that much less water is required when brine is recirculated as the mining fluid.

A feature of this invention is that only sufficient air need be used to keep the water level down so that injected water can strike the walls freely. Also, in one of its embodiments this invention can be used without employing an air lift. In another embodiment, tube 24 is omitted, as in Figure 3, but sleeve 18 fits loosely within casing 2 to permit the flow of air through the system, as is illustrated in Figure 8. In addition a short drill bit can be attached at 6 instead of the perforated tip for pounding up any solid chunks accumulating in the bottom of the hole in response to a reciprocating action of the tubing 4 attained by connecting it to a walking beam of a standard drilling derrick or spudder. Also the tubing can be readily withdrawn for bailing out any heavy chunks accumulating in the bottom of the hole. In addition the elevation of the nozzles to approximately a horizontal position can be attained by means of mechanical contrivances such as springs which will lift the nozzles as they pass out of the lower end of the casing and as the erosion of the formation permits. The modifications described above are illustrated in Figures 7 and 8. In Figure 7 there is shown a hoisting rig 50 with a crown block 52 and a hoisting block 54. A walking beam 56 and band wheel 58, there-

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fore, is actuated by motor 60. Thus, tubing 4 and the parts associated therewith can be raised and lowered by attachment at 12 to the hoisting block 54. In Figure 7 a short drill bit 62 is shown attached to tubing 4 instead of the perforated tip 6 and when tubing 4 is reciprocated by means of the walking beam 56, bit 62 can pound up any solid chunks which accumulate in the bottom of the cavity. Also, the flexible hoses may be so constructed that they depend downwardly when not in use, but extend outwardly when fluid is flowing through the nozzles.

While certain preferred embodiments of this invention have been described for illustrative purposes the invention obviously is not limited thereto.

I claim:

1. An apparatus for the formation of an underground cavern comprising, in combination, a well casing projecting downwardly in a well bore, sealing means for said casing at its upper end, conduit means for introducing a gas and liquid into said casing, a tubing within and spaced from said casing, said tubing extending through said sealing means and at least to the bottom of said casing, a cylindrical sleeve within said casing and disposed about said tubing, said sleeve being not longer than the desired height of said cavern and being in substantially air-tight connection with said casing but moveable within said casing, an annular plate having a central perforation through which said tubing is disposed and having a plurality of other perforations, said plate being rigidly attached to said tubing and to the bottom circumference of said sleeve, flexible nozzles attached to said plate at said plurality of other perforations, and means for raising, lowering and rotating said tubing.

2. The apparatus in accordance with claim 1 wherein a pipe is disposed in the space between said tubing and said casing, said pipe extending through and being attached to said plate at its lower end and having a restriction in its upper end.

3. The apparatus in accordance with claim 1 wherein the lower end of said tubing has a perforated end extending below said casing.

4. The apparatus in accordance with claim 1 wherein said nozzles are L shaped and are made of rubber.

5. An apparatus for the formation of an underground cavern comprising, in combination, a well casing projecting downwardly in a well bore, sealing means for said casing at its upper end, conduit means for introducing a gas and liquid into said casing, a first conduit means disposed in and spaced from said casing, said first conduit means extending through said sealing means, means for lowering, raising, and rotating said first conduit means, a second conduit means slidably fitting over said first conduit means, means for suspending said first conduit means within said second conduit means and for rotating said second conduit means in response to rotation of said first conduit means, a cylindrical sleeve within said casing and spaced from said first and second conduit means, said sleeve being in substantially air-tight connection with said casing but movable within said casing, said sleeve having an expandable upper portion with means on its outer surface for gripping the inner wall of said casing, means associated with the upper end of said second conduit for expanding said expandable portion of said sleeve in response to rotation of said second conduit means, an annular plate having a central perforation through which said first conduit means is disposed in substantially air-tight connection therewith, said plate being rigidly attached to the lower end of said second conduit means and to the lower end of said sleeve, said plate having a plurality of other perforations therethrough, and flexible nozzles attached to said plate at said plurality of other perforations.

6. An apparatus for the formation of an underground cavern comprising, in combination, a well casing projecting downwardly in a well bore, sealing means for said casing at its upper end, conduit means for introducing

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a gas and liquid into said casing, a first central conduit disposed within said casing and being of substantially smaller diameter than said casing, said first central conduit extending through said sealing means and at least to the bottom of said casing, means for lowering, raising and rotating said first central conduit, a second central conduit slidably fitting over said first central conduit, a pair of grooves in the inner wall of and extending the length of said second central conduit, a plurality of notches vertically spaced in the side of said grooves, a pair of bosses attached externally to said first central conduit, said bosses being adapted to slide vertically within said grooves and, when said first central conduit is rotated, to fit in said notches, thus providing means for suspending said first central conduit at varying positions within said second central conduit and means for rotating said second central conduit in response to rotation of said first central conduit, a cylindrical sleeve within said casing and about said first and second conduits, said sleeve being in substantially air-tight connection with said casing but movable within said casing, said sleeve being expandable in its upper portion by virtue of a plurality of slots therein and being capable of gripping the inner wall of said casing when its upper portion is expanded by virtue of a plurality of saw-like teeth around the outside of said slotted upper portion, means attached to the outer wall of said second central conduit for expanding the upper portion of said sleeve in response to rotation of said first and second central conduits, an annular plate having a central perforation through which said first central conduit is disposed in substantially air-tight connection therewith, said plate being rigidly attached to the lower end of said second central conduit and to the bottom circumference of said sleeve, said plate having a pair of other perforations therethrough, and flexible nozzles attached to said plate at each of said other perforations.

7. An apparatus according to claim 6 wherein said means for expanding the upper portion of said sleeve in response to rotation of said first and second central conduits comprises a plurality of saw-toothed dogs pivotally attached to the outer wall at the upper end of said second central conduit and a spring attached to each of said dogs and to the outer wall of said second central conduit, said springs being so biased as to hold one edge of the saw-teeth of said dogs against the upper portion of said sleeve and so that rotation of said first central conduit causing a corresponding rotation in said second central conduit causes said dogs to grip and expand the slotted upper portion of said sleeve.

8. An apparatus in accordance with claim 6 wherein a metal bit is attached to the lower end of said first central conduit and wherein said means for lowering and raising said first central conduit comprises a hoisting rig and a walking beam.

9. An apparatus for use in forming an underground cavern which comprises, in combination, a well casing projecting downwardly in a well bore, sealing means for said casing at its upper end, conduit means for introducing a gas and liquid into said casing, a first tubing within and spaced from said casing, said first tubing extending through said sealing means, a cylindrical sleeve within said casing and disposed about said first tubing, said sleeve being slidably positioned within said casing, an annular plate having a central perforation through which said first tubing is disposed and having a plurality of other perforations, flexible nozzles attached to said plate at said plurality of other perforations, said plate being rigidly attached to the lower end of said sleeve, means for movably supporting said sleeve and attached plate and nozzles within said casing, and means for raising, lowering and rotating said first tubing.

10. An apparatus in accordance with claim 9 wherein said means for movably supporting said sleeve and at-

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tached plate and nozzles within said casing is a rigid attachment of said plate to said first tubing.

11. An apparatus in accordance with claim 9 wherein said means for movably supporting said sleeve and attached plate and nozzles within said casing comprises a second tube slidably disposed about said first tubing, said plate being rigidly attached to the lower end of said second tube, means for detachably suspending said sleeve

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upon the inner wall of said casing, and means for detachably suspending said second tube upon said first tubing.

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