# United States Patent [19]

**Jacoby**

[11] **3,873,156**

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[54] **BEDDED UNDERGROUND SALT DEPOSIT SOLUTION MINING SYSTEM**


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[73] Assignee: **Akzona Incorporated,** Asheville, N.C.



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[21] Appl. No.: **445,975**

**Related U.S. Application Data**

[63] Continuation of Ser. No. 324,005, Jan. 15, 1973, abandoned.

[52] **U.S. Cl.** ..... **299/4,** 166/271, 175/61, 175/231, 175/422, 299/17

[51] **Int. Cl.** ..... **E21b 43/28**

[58] **Field of Search** ..... 299/4, 5, 17; 166/271; 175/61, 231



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*Primary Examiner*—Ernest R. Purser

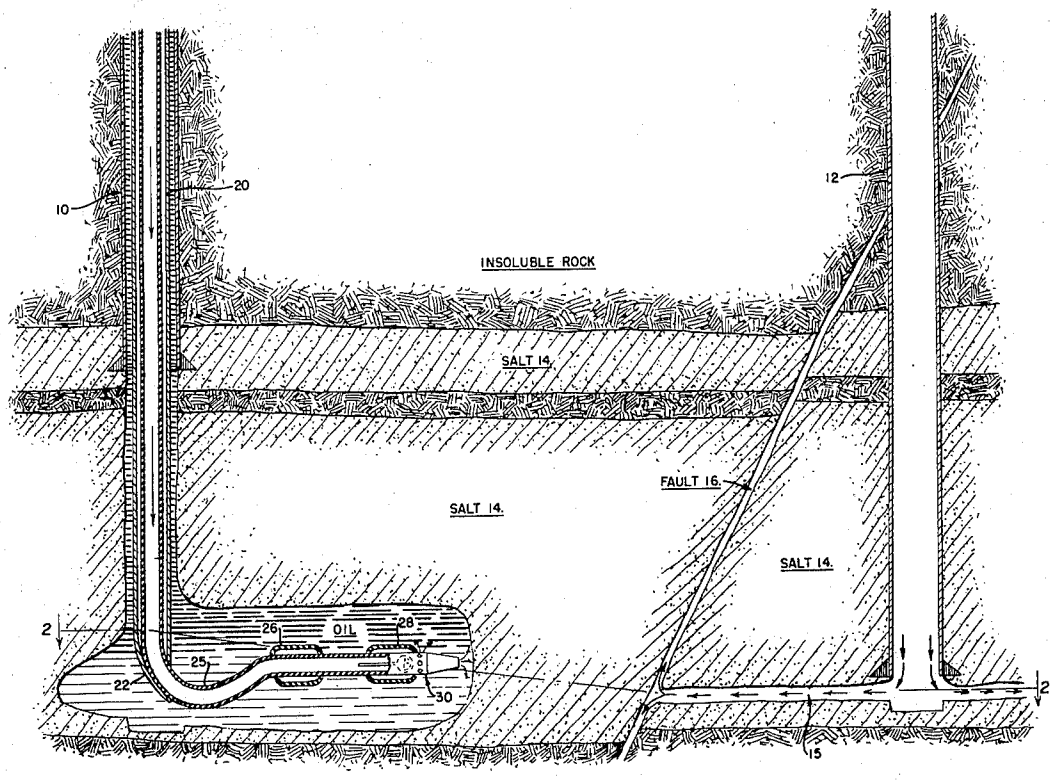
*Attorney, Agent, or Firm*—Bean & Bean



[57] **ABSTRACT**

An improved system for coalescing the nether ends of a group of spaced-apart bore holes intersecting a beded rock salt deposit, and for instituting and controlling progress of a solution-mining operation thereon. The invention is particularly useful in coalescing two or more bore holes extending into a bedded rock salt deposit whenever conventional hydraulic fracturing methods prove inadequate, such as by reason of the existence of faults or other anomalies existent intermediately of the bore holes. The system employs a flexible solvent delivery tube slip-fitted downwardly through one of the bore holes into the salt deposit; it being arranged that the delivery or nozzle end of the tube floats and travels horizontally along a gravitymonitored interface between the input solvent and resultant brine mixture and a thereabove maintained solvation insulating pad of oil or some other suitable hydrocarbon gas or air or the like, which at this stage operates to prevent undesirable upward progression of the solution mining process. The solvent delivering nozzle is at all times directionally controlled in an improved manner throughout the coalescing/mining operations in conjunction with an improved advancing/retreating mining method.


**19 Claims, 6 Drawing Figures**



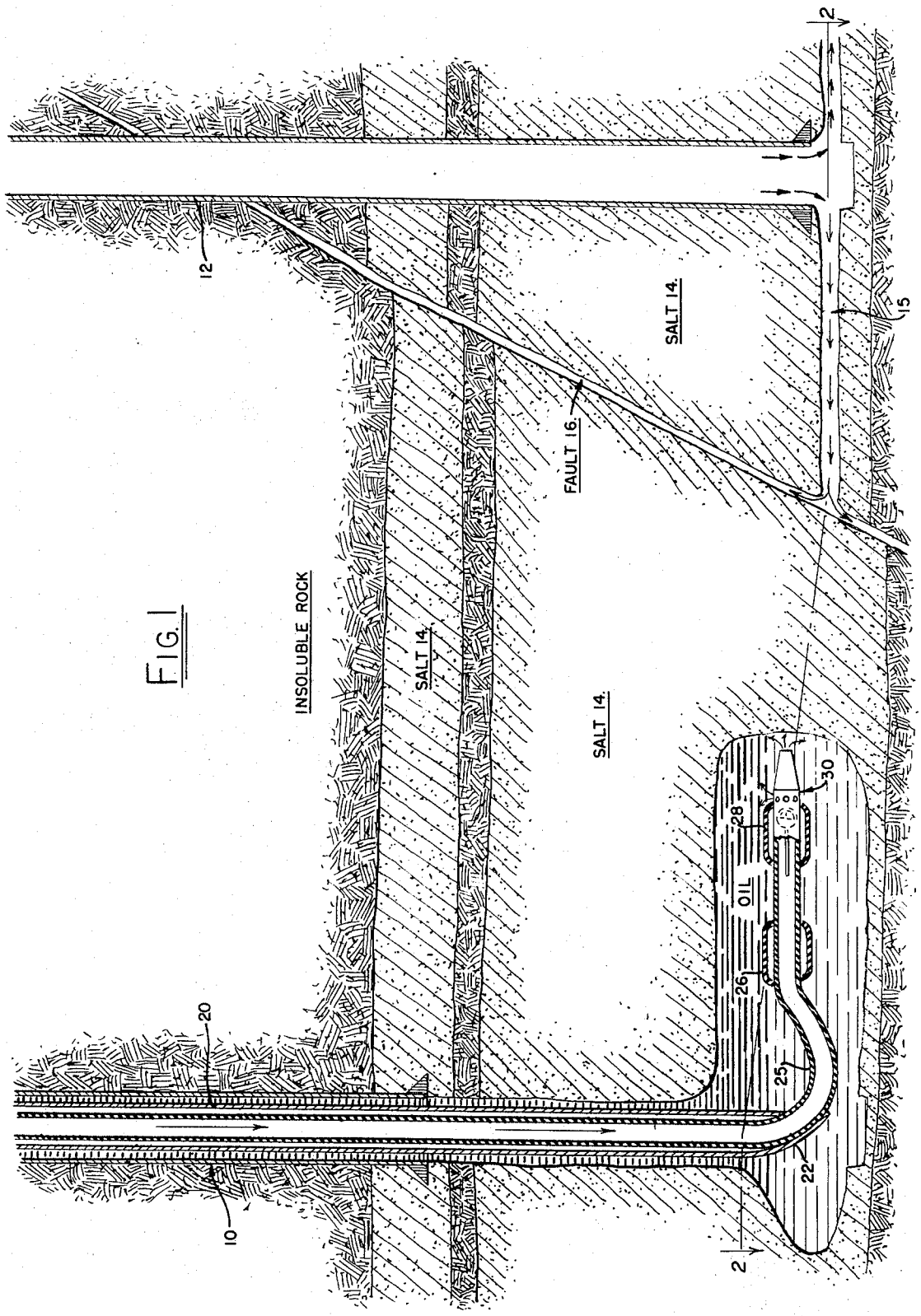
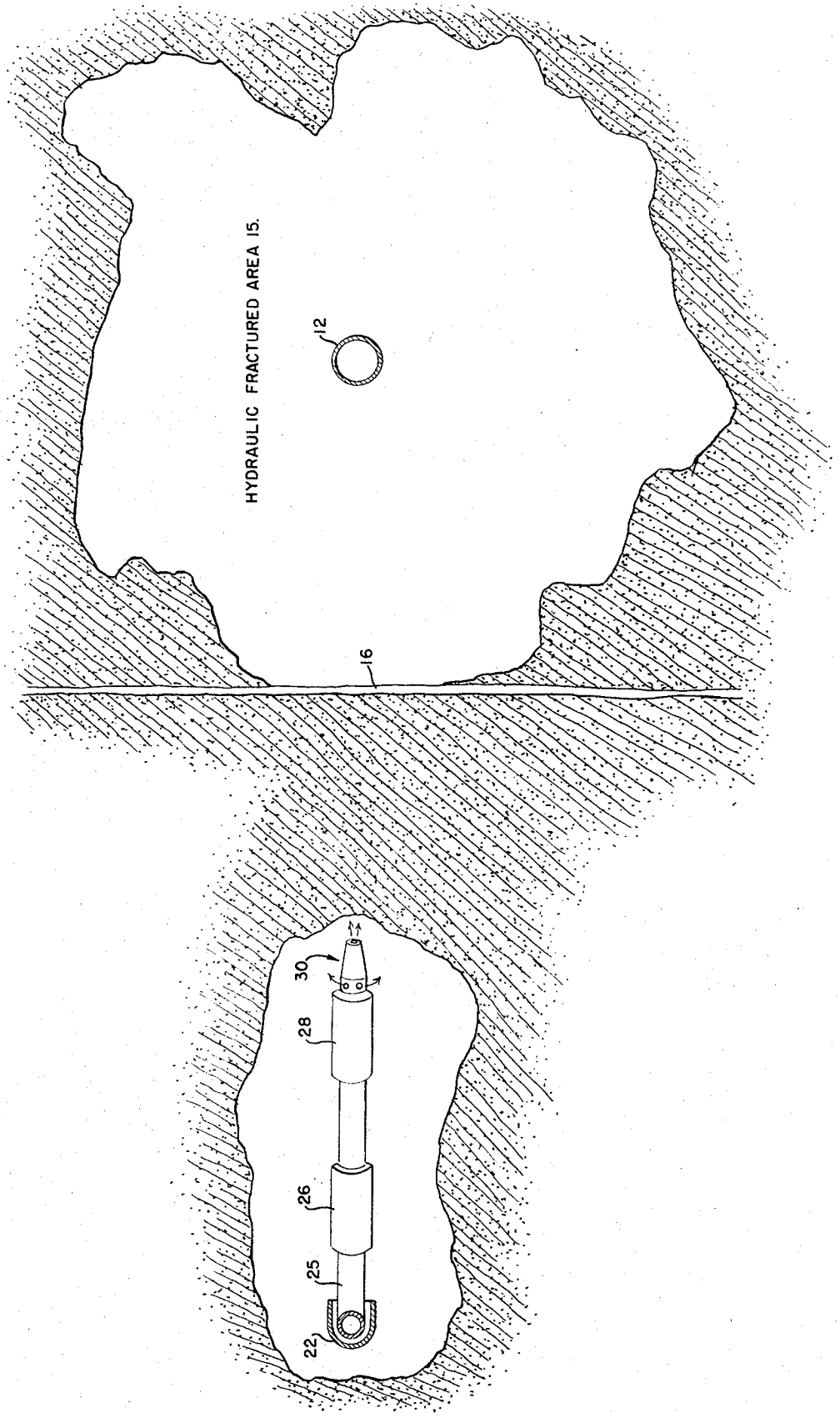

2
12
SALT 14.
15
FAULT 16
INSOLUBLE ROCK
SALT 14.
SALT 14.
30
28
OIL
26
25
22
20
10
2

FIG. 1

FIG. 2



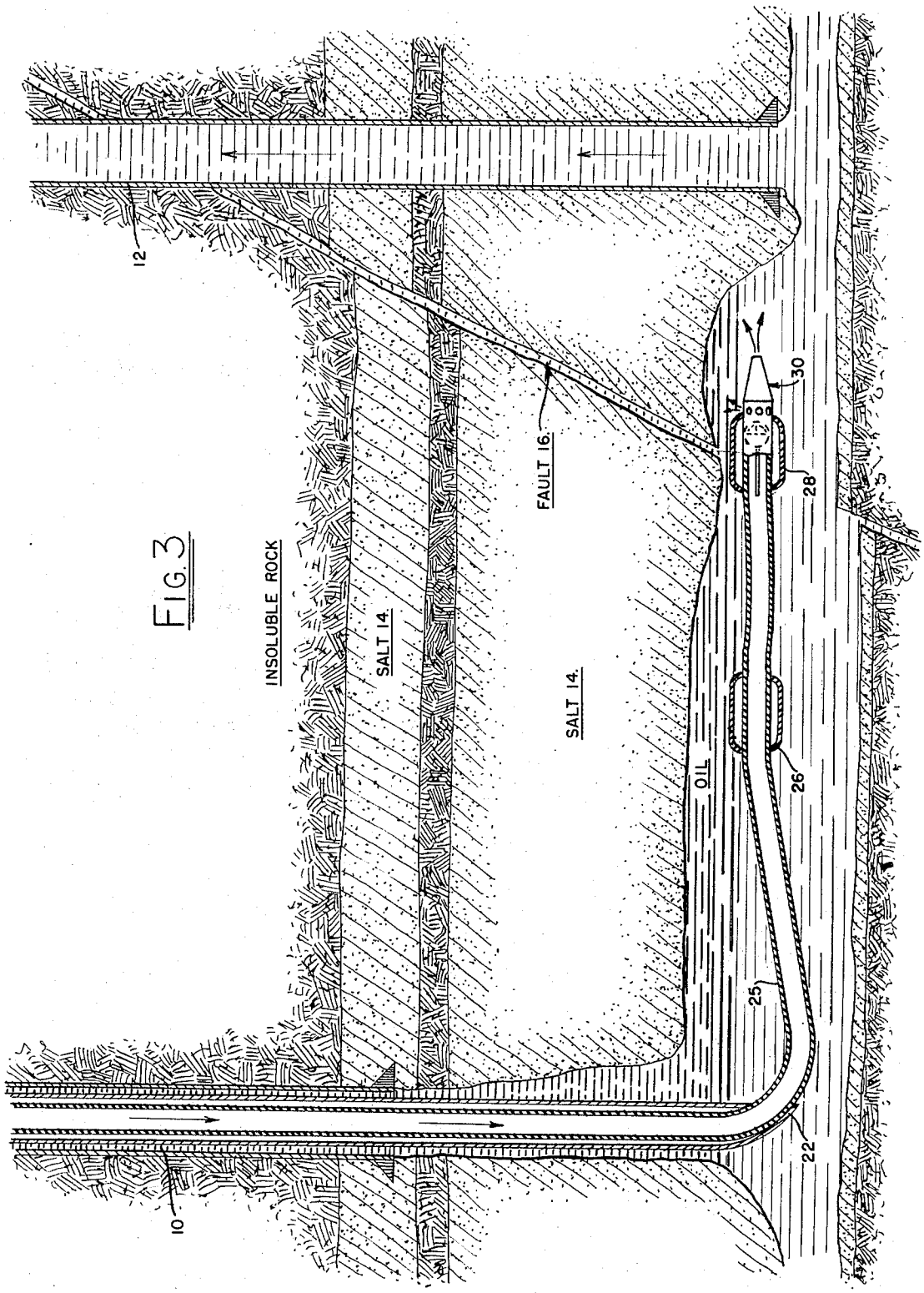



FIG. 3

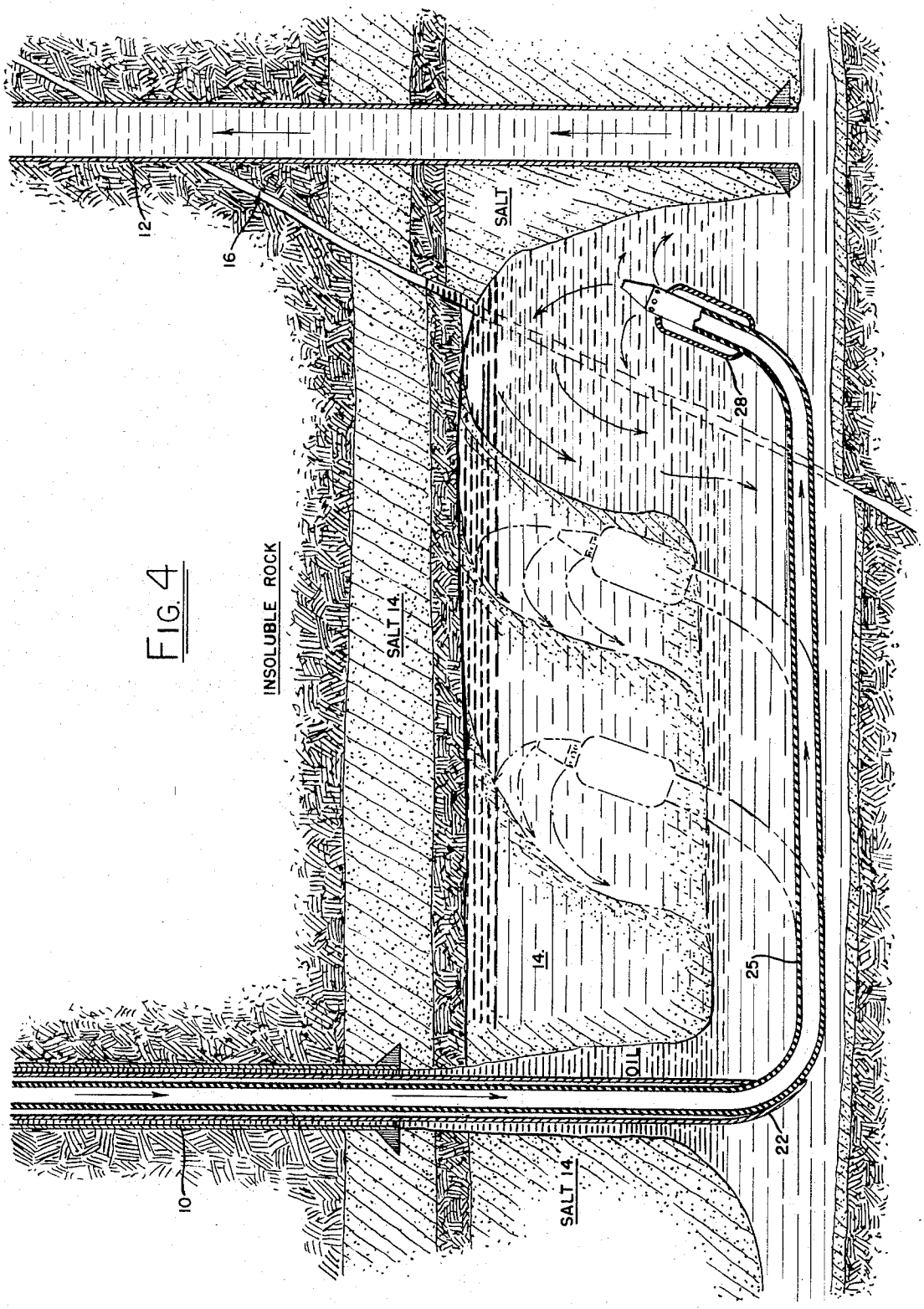



FIG. 4

FIG. 5

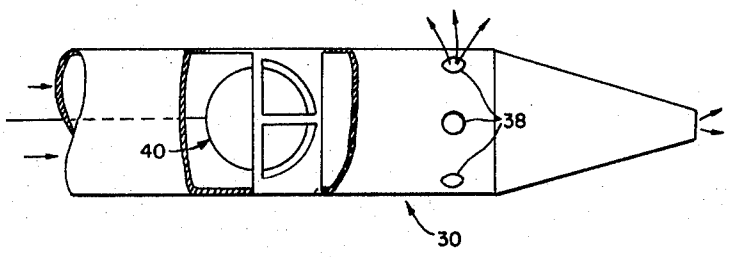
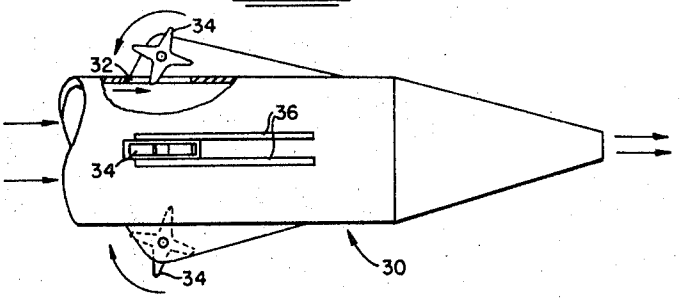



FIG. 6



# BEDDED UNDERGROUND SALT DEPOSIT SOLUTION MINING SYSTEM

This is a continuation of application Ser. No. 324,005, filed Jan. 15, 1973, and now abandoned.

## BACKGROUND AND BRIEF DESCRIPTION OF THE INVENTION

In solution mining operations, one or more bore holes are typically provided to penetrate the overlying geological formations so as to reach the subterranean "sought-for" or "product" mineral, and means are thereupon employed to establish therein an open "cavity" or passageway whereby the mineral may be extracted by circulation therethrough of a suitable solvent such as water, acid, steam, or some other solvent liquid or gas such as is unsaturated with respect to the sought-for mineral.

It is known that the efficiency of a solution mining cavity system is improved as the dimensions of the fluid travel path within the cavity increase. Such flow patterns are typically enhanced when initiatng a solution mining operation by establishing as soon as possible a cavity of substantial horizontal (as well as vertical) extent between the point of solvent injection and the point of effluent withdrawal; because such cavities inherently tend to automatically increase vertically. In a cavity which is in communication with a single duplex-cased bore hole the operation is of course at first limited to the vertical distance between the injection and withdrawal ports of the bore hole casing system; and therefore it is preferred to employ a plurality of bore holes and conventional hydraulic fracturing operations with a view to establishing solution conveying cavities therebetween. For example, reference is made to my prior U.S. Pat. Nos. 3,064,957 and U.S. Pat. No. Re. 25,682.

However, in many cases it is found to be impossible to satisfactorily coalesce the bottoms of two or more bore holes by such hydraulic fracturing methods because of the intervention of geological anomalies therebetween. The present invention provides an improved method for rapidly coalescing the lower ends of two or more such bore holes when driven into a rock salt bed and when encountering such an anomalies, thereby establishing solvent passageways therethrough which are oriented in generally horizontal direction between the bottoms of such bore holes, and for subsequently conducting an improved technique for solution mining the salt bed.

## THE DRAWING

FIG. **1** is a fragmentary vertical geological section illustrating compositely successive stages of a coalescing operation in accordance with the present invention; designed specifically to overcome encounter with a fault system such as typically forestalls successful completion of a conventional hydraulic fracturing fluid passageway forming operation;

FIG. **2** is a horizontal sectional view taken as indicated by line **2—2** of FIG. **1**;

FIG. **3** is a view corresponding to FIG. **1** but illustrating completion of a solution-flow passageway between the two bore holes such as may be established by my new process;

FIG. **4** is a view corresponding to FIGS. **1** and **3**; illustrating progressive stages of the subsequently employed solution mining technique in accordance with the invention;

FIG. **5** is a fragmentary illustration of one form of a directionally controllable solvent delivery nozzle such as may be used in conjunction with the invention; and

FIG. **6** illustrates another form of self-motivating solvent delivering nozzle such as may be used in accordance with the invention.



## DETAILED DESCRIPTION OF THE INVENTION

By way of example and referring now to FIGS. **1** and **2** of the drawing herewith, a pair of bore holes **10, 12** may be driven to intersect a soluble deposit **14** of bedded salt or the like, and cased preferably to a level close to the bottoms thereof. The drawing illustrates a geologic condition typically encountered when bore holes are driven into a bedded salt deposit with a view to interconnecting their bottom ends as by means of a hydraulic fracturing operation (such as illustrated and described in detail in my prior U.S. Pat. Nos. 3,064,957 and Re. 25,682).

In the illustration herewith the hydraulically fractured zone **15** which radiates from the bottom of bore hole **12** has encountered a geological fault **16**; whereby the attempt to interconnect the bore holes **10–12** by means of a "propped fracture" has failed. Such geological anomalies often occur for example throughout the great Appalachian Salt Basin beds which underlie many of the Eastern States; and may appear in the form of open or closed faults; sharp foldings; crevices filled with insoluble debris; and/or the like. The present invention provides an improved method for completing a solvent fluid flow passageway between bore holes such as are described hereinabove, and also provides an improved solution mining system as illustrated at FIGS. **3** and **4** herewith.

In accordance with this invention, assuming that an attempt to hydraulically fracture the lower portion of the salt bed **14** to provide a "propped" passageway from bore hole **12** to bore hole **10** has met with a fault zone such as is shown at **16,** the bore hole **10** is thereupon fitted with a casing **20**; the lower end of the casing **20** being provided with a smoothly curved laterally directed outlet cuff as is illustrated at **22.** A solvent delivery tube of flexible nature as illustrated at **25** is then slide-fitted downwardly through the casing **20** so as to project at the lower end thereof through the exit cuff **22** in the desired horizontal direction. A solvent fluid is then pumped through the tube **25** to jet therefrom in a horizontal direction against the opposing salt "face," whereby the jetted fluid dissolves the salt away while returning it to the earth surface recovery facility in the form of brine, through the annulus surrounding the tube **25.**

In order to direct the solvent jet action so as to progress horizontally from the bore hole **10** toward the bore hole **12** until such time as the solvated cavity eroded through the fault zone **16** and connects with the previously hydraulically fractured passageway **15,** one or more floats such as are shown at **26–28** are fixed upon the nozzle end **30** of the tube **25** in spaced-apart relation thereon in such manner as to cause the nozzle end of the tube to float horizontally at or near the top of the solvent-brine mixture within the cavity. Thus, the jet nozzle is prevented from dipping or rearing upwardly so as to direct the solvating process on a down-

wardly or upwardly on an inclined path, such as would miss connection with the fractured zone **15.**

As a further assist at this stage in preventing any undesirable upward erosion of the salt body above the level of the intended channel to be eroded toward the fault zone, a solvation insulatng "pad" or blanket of oil or air or gas or the like may be introduced and maintained to float on top of the desired level of the solvent/brine solution throughout the operation. For this purpose the oil (or the like) may be simply added in proper proportion to the solvating liquid as the latter is furnished through the bore hole **10.** The floats **26–28** are fabricated so that the tube-float combination is of slightly greater specific gravity than the material comprising the pad, while being of lower specific gravity than that of the solvent/brine mixture at the bottom of the cavity. For example, the floats may be made of any suitable solids such as wood, foamed plastic, glass or the like; and/or may be of inflatable form, such as may be preferred.

When operating within a geologic deposit of the type where the sought-for soluble mineral rests upon an underlying insoluble rock sill along a substantially flat and clean parting plane, and jet nozzle **30** may be provided with a self-motivating traction device such as is illustrated at FIG. **6** of the drawing herewith. As shown herein at **32** the casing of the jet nozzle is slotted to accommodate pinwheels **34** which are pivotally mounted as by means of fins **36** on the nozzle casing so as to extend into the slots **32.** Thus, as the solvent fluid jets through the nozzle device, the pinwheels are driven hydrodynamically whereby whenever their outside portions engage the cavity floor surface they tend to drag the nozzle forwardly in the direction of the jet discharge. It is to be understood however that any other suitable mechanism for forwardly propelling the nozzle end of the tube **25** may be employed, such as for example a remotely controlled motor unit.

To provide suitable directional control of the nozzle progress within the horizontal plane parameters established by the aforesaid devices; it is contemplated that a variety of means may be employed for such purpose. For example, the progress of the nozzle **30** may be guided from above ground by simply twisting the upper end of the tube **25** where it exists above ground from the bore hole casing. Or, the nozzle may be constructed to include an automatically or remotely controlled guidance device such as my include alternatively operable jet-exit side ports **38** as shown in FIG. **5**; or an electronically operated guidance mechanism such as may cause the nozzle to "seek" or "home-in" on a target device placed in the bottom end of the bore hole **12.** In any case the mechanism would be under remote control by the process operator and/or monitored automatically; as for example by a bore hole surveying type device or the like, such as is indicated at **40** (FIG. **5**).

FIG. **4** illustrates how the soluble mineral deposit is preferably mined subsequent to coalescing the bottom ends of the bore holes **10–12** as explained hereinabove. Operation of the float **28** at the nozzle end of the solvent delivery tube **25** is altered so as to overcome the prior tendency to maintain the nozzle **30** in horizontally directed attitude and to permit it to point upwardly; thereby causing the solvent jet discharge to sweep the salt bed **14** in an upwardly directed path. This may be readily managed either by inflating the float **28** to a larger volume or by substituting a more buoyant float for the one originally mounted on the nozzle end of the tube; the tube **25** being temporarily withdrawn back up the bore hole **10** to enable such an exchange to be made. Then, as the upturned nozzle operates to direct the solvent fluid to mine the salt bed up to the desired ceiling level the delivery tube may be slowly retracted (by pulling upon its outer end) so as to cause the upturned nozzle to drive the solvent fluid against the overlying salt bed in accordance with a progressively retreating solution mining operation such as is diagrammatically illustrated at FIG. **4.**

I claim:

**1.** The method for solution-coalescing the nether ends of two or more bore holes intersecting a bedded rock salt deposit which includes a geologic anomaly preventive of effectively coalescing said bore holes by means of a hydraulic fracturing technique, and for conducting a solution mining operation throughout said deposit, said method comprising:

driving two or more bore holes in spaced apart relation into the lower level of said deposit at opposite sides of said anomaly,

hydraulically fracturing said deposit from one of said bore holes as far as feasible towards one other of said bore holes, thereby providing a first horizontally extending passageway for fluid flow,

then solution-mining a second horizontally extending passageway from the nether end of the other of said bore holes through said salt bed and through said anomaly into communication with said first passageway, thereby providing a solution mining cavity,

and then solution mining said deposit intermediately of said bore holes by passing a solvent fluid through said cavity from one of said bore holes and withdrawing brine out of the other of said bore holes whereby said cavity enlarges and said deposit is mined.

**2.** The method for coalescing the nether ends of two or more bore holes intersecting a bedded rock salt deposit and for conducting a solution mining operation throughout said deposit as set forth in claim **1,** wherein said solution mining operation is conducted by means of solvent liquid delivered through a flexible hose slidefitted into and advanced through one of said bore holes and having guide means thereon to cause the nozzle end thereof to point substantially horizontally towards the nether end of the other of said bore holes.

**3.** The method of coalescing the nether ends of two or more bore holes intersecting a bedded rock salt deposit and for conducting a solution mining operation throughout said deposit as set forth in claim **1,** wherein said solution mining operation is conducted under a solvent-insulating pad of fluid at the ceiling of the solution mining cavity.

**4.** The method of coalescing the nether ends of two or more bore holes intersecting a bedded rock salt deposit and for conducting a solution mining operation throughout said deposit as set forth in claim **2,** wherein said nozzle end of said hose carries a motivating device powered under remote control and operating to advance the nozzle end of said hose toward said other bore hole.

**5.** The method of coalescing the nether ends of two or more bore holes intersecting a bedded rock salt deposit and for conducting a solution mining operation throughout said deposit as set forth in claim **2,** wherein

the solution mining operation upon said deposit is initially conducted proximate to said other bore hole and is then caused to retreat progressively throughout the deposit intermediately of said bore holes by progressive retraction of said hose.

**6.** The method of coalescing the nether ends of two or more bore holes intersecting a bedded rock salt deposit and for conducting a solution mining operation throughout said deposit as set forth in claim **3,** wherein said guide means comprises a float device carried adjacent the nozzle end of said hose, said float device being operable to cause the nozzle end of said hose to float at substantially the elevation of the interface between the brine and the solution insulating pad fluid occupying the solution cavity.

**7.** The method of coalescing the nether ends of two or more bore holes intersecting a bedded rock salt deposit and for conducting a solution mining operation throughout said deposit as set forth in claim **4,** wherein said motive device comprises a traction wheel system powered by flow of fluid through said nozzle.

**8.** The method of coalescing the nether ends of two or more bore holes intersecting a bedded rock salt deposit and for conducting a solution mining operation throughout said deposit as set forth in claim **2,** wherein said guide means comprises multi-radially directed reaction jet ports exiting through the wall of said nozzle, said ports being selectively controllable from remotely of the operation.

**9.** The method of coalescing the nether ends of two or more bore holes intersecting a bedded rock salt deposit and for conducting a solution mining operation throughout said deposit as set forth in claim **3,** wherein said solvent insulating pad comprises a fluid of lower specific gravity than brine and which is introduced into the solution mining cavity as an additive to the solvent fluid.

**10.** The method of coalescing the nether ends of two or more bore holes intersecting a bedded rock salt deposit and for conducting a solution mining operation throughout said deposit as set forth in claim **2,** wherein said guide means comprises a plurality of float devices spaced apart longitudinally on said hose so as to stabilize a substantial length thereof in horizontal attitude.

**11.** The method of solution-coalescing the nether ends of two or more bore holes intersecting a bedded rock salt deposit which includes a geologic anomaly preventive of effectively coalescing said bore holes by means of a hydraulic fracturing technique, said method comprising:

driving two or more bore holes in spaced apart relation into said deposit at opposite sides of said anomaly;

hydraulic fracturing said deposit from one of said bore holes as far as feasible towards another of said bore holes, thereby providing a first extending passageway for fluid flow; and

solution mining a second extending passageway from said another of said bore holes through said salt bed and through said anomaly into communication with said first passageway.

**12.** The method for coalescing the nether ends of two or more bore holes of claim **11** wherein said solution mining is conducted by means of solvent liquid delivered through a flexible hose advanced through said another bore hole, said flexible hose being fitted with a nozzle having means for guiding the nozzle end substantially towards said first passageway.

**13.** The method of coalescing the nether ends of two or more bore holes as set forth in claim **12** wherein said guide means include reaction jet ports exiting throught the wall of said nozzle, said jet ports being selectively operable.

**14.** The method of coalescing the nether ends of two or more bore holes as set forth in claim **12** including inserting a target device in said first passageway and wherein said guide means include an electronically operated guidance mechanism to home-in on said target device.

**15.** The method of coalescing the nether ends of two or more bore holes as set forth in claim **12,** wherein said guide means include a directional and inclination surveying device.

**16.** The method of coalescing the nether ends of two or more bore holes as set forth in claim **11,** including forming a solvation insulating pad at the ceiling of said second passageway.

**17.** The method of coalescing the nether ends of two or more bore holes as set forth in claim **16** wherein said solvation insulating pad comprises a fluid of lower specific gravity than brine, including the step of introducing said pad fluid into said second passageway as an additive to the solvent fluid for said solution mining.

**18.** The method of coalescing the nether ends of two or more bore holes as set forth in claim **16** including floating the nozzle substantially at the interface between said solvation insulating pad and the brine/solvent mixture formed in the lower part of said second passageway.

**19.** The method of solution mining a bedded rock salt deposit between two or more bore holes comprising the steps of coalescing the nether ends of said bore holes by the method of claim **11** and thereafter solution mining said deposit beginning in the region of said first passageway and retreating progressively toward said second passageway and said another bore hole.

* * * * *