

[54] SOLUTION MINING METHOD

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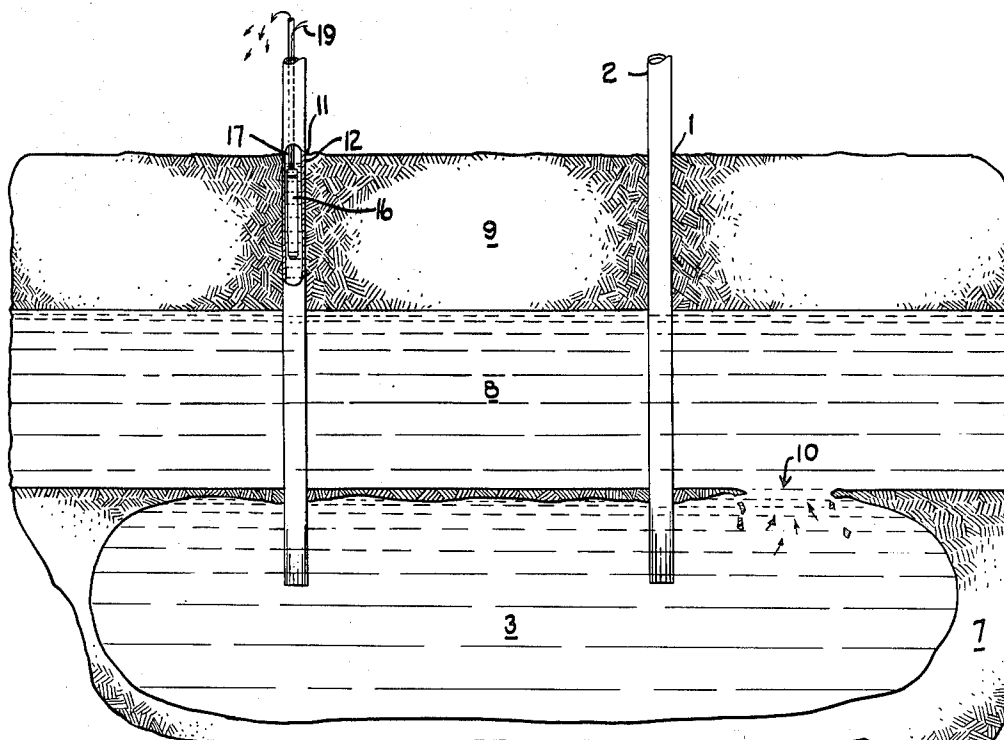
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[57]

ABSTRACT

A method of operating a solution mining cavity which has come into open contact or communication with an underground, water-bearing formation is described in which flow into and out of the cavity is controlled generally to provide a feed to the cavity slightly in excess of the fluid withdrawn from the cavity. Control is established by introducing solvent into and removing product solution from the cavity at a controlled rate to insure that the quantity of fluid fed into the cavity is in excess of the quantity of fluid removed from the cavity. The invention is described particularly with respect to the solution mining of KC1.

16 Claims, 2 Drawing Figures



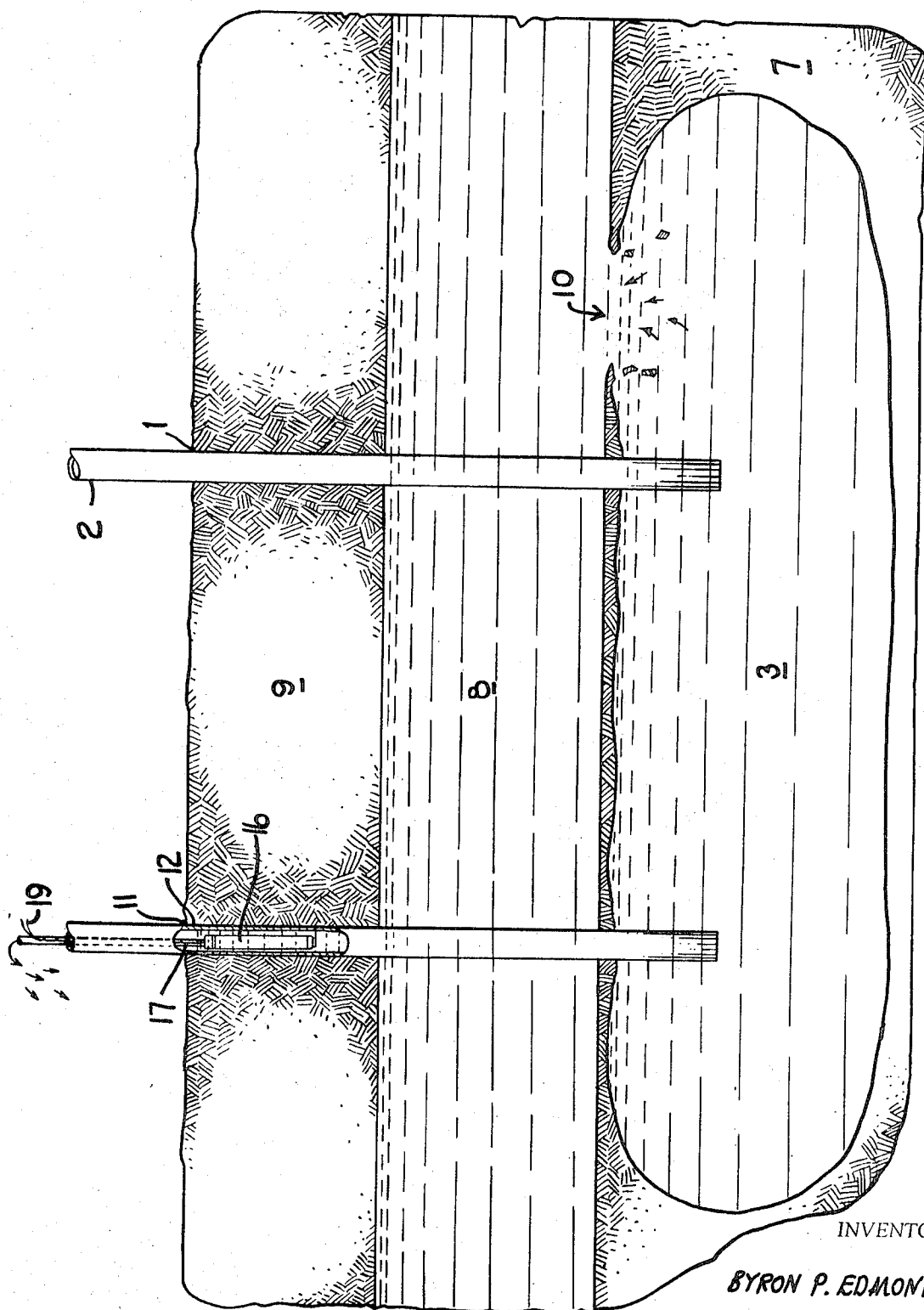


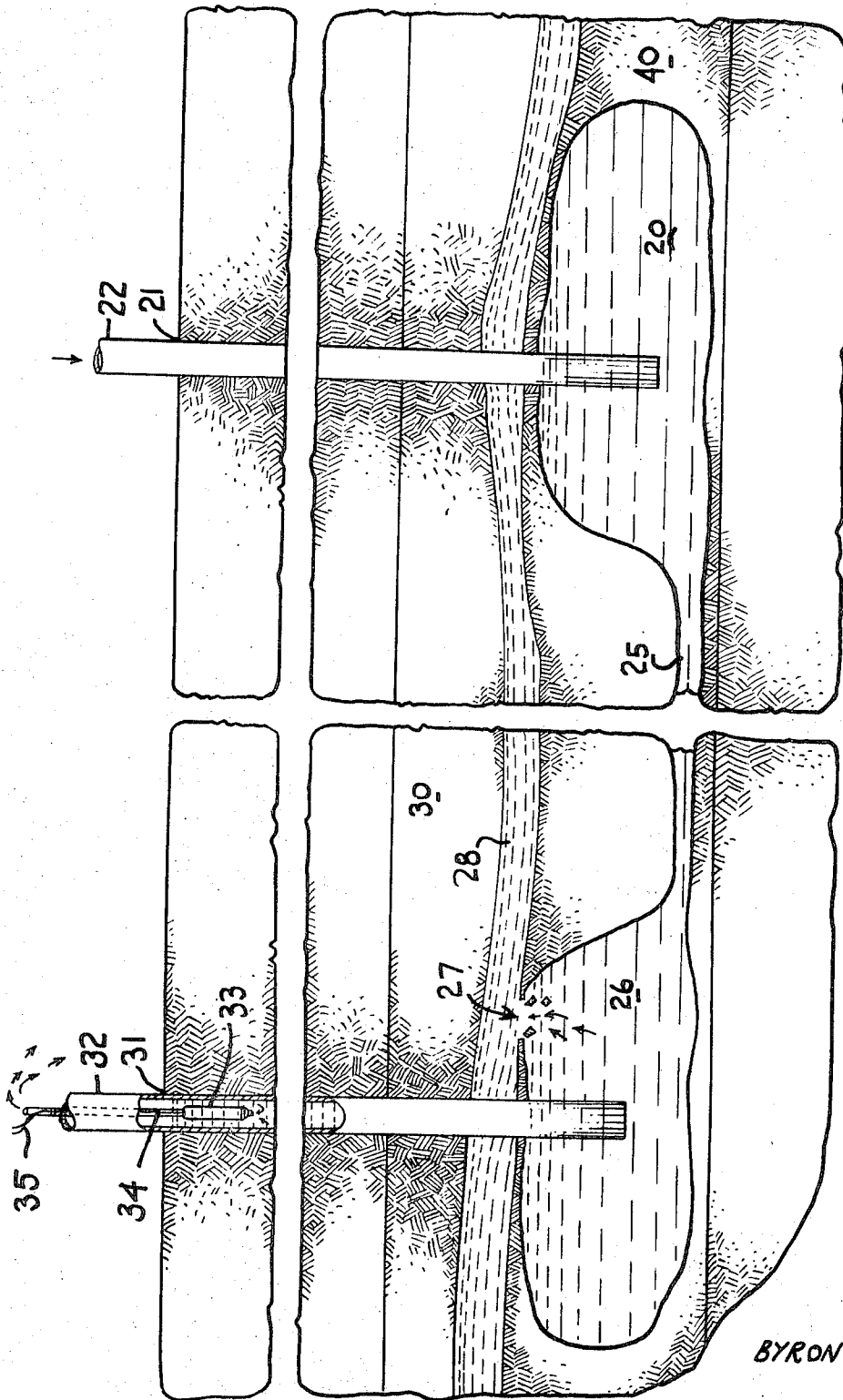
FIG. 1

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SOLUTION MINING METHOD

BACKGROUND OF THE INVENTION

Solution mining is employed today in many commercial operations to recover soluble minerals of various descriptions from mineral deposits located below the surface of the earth. In a typical solution mining application to recover a specific salt from a mineral deposit, for example, a solvent for that salt is introduced into the mineral deposit located below the earth's surface through a bore hole drilled into that deposit. A solution of the desired salt is formed as the salt is dissolved from the deposit. The resulting salt solution is withdrawn through the same or a second bore hole. The salt solution is then processed to recover the specific salt desired from the solution. These general techniques may be used to recover NaCl and KCl, for example, from such minerals as Kalinite, Sylvite, Carnallite and the like using water and weak brines, (both KCl NaCl and mixed brines) as the solvent. They may also be used to recover salt (NaCl) from Halite using water or weak brines as the solvent and many other salts or minerals from an underground deposit using a suitable solvent.

In typical solution mining applications the mineral deposit in which the desired compound or salt is located is generally positioned a substantial depth below the earth's surface. By substantial depth is meant a depth below the surface of the ground of at least 250 feet. Typically, these mineral deposits in which solution mining operations are conducted are located between 250 to 8,000 feet or more below ground level.

During the solution mining of mineral deposits located at these depths, cavities having substantial dimensions in both vertical and horizontal planes are formed in the mineral deposit being mined. Occasionally these cavities during formation and development encounter and openly communicate with underground water-bearing formations or aquifers. When this situation arises, the ability to pump fluid from the cavity is usually lost. Cavity solution is further subject to contamination by salts occurring in the solutions contained in these aquifers when solution from the aquifer enters the cavity. Contamination of cavity solution with any appreciable amount of undesirable salt is to be avoided in most solution mining operations. Where a controlled solution mining operation is being conducted, i.e., where the solvent is balanced in its solute content to provide a selective extraction of a specific salt from the deposit, this contamination is particularly undesirable. Often the salt contaminants contained in the water of such formations are undesirable materials, such as sodium sulfate and calcium sulfate. In a KCl or NaCl solution mining operation these undesirable materials being soluble in the solvent used to dissolve product salts substantially contaminate the product solutions. Further should uncontrolled amounts of water enter a cavity from an aquifer, undue dilution of product solutions can occur rendering the economic recovery of the desired product no longer possible.

THE PRESENT INVENTION

In accordance with the present invention a method is provided for operating solution mining cavities which have come into open communication with underground water-bearing formations or aquifers in such a manner that contamination of cavity solutions is substantially avoided and a minimum loss of solvent fed to a solution mining cavity is encountered. In accordance with this invention when an aquifer has been contacted by a solution mining cavity so that the cavity solution communicates with the water in the aquifer, solvent in the effluent conduit of the solution mining cavity is removed from that conduit by a pump associated with that effluent conduit. The pumping of fluid from the effluent conduit is furthermore regulated with the quantities of solvent fluid being fed to the cavity through the influent conduit to the solution mining cavity so that a slight excess of fluid (0.5 per cent or more by volume) is fed to the cavity over the quantity of fluid being removed from the cavity through the effluent conduit. Operating in this manner solvent containing product can be removed

from the solution mining cavity continuously and the amount of fluid loss to the aquifer minimized while the aquifer itself is effectively sealed off from the cavity.

In a solution mining cavity, for example, one in which KCl-NaCl salt mixtures are being dissolved with water from a formation, fluid pressures of about 0.52 pounds per square inch per foot of depth are exerted on the walls and ceiling of the cavity. Overburden pressure on the cavity is typically equal to about 1 pound per square inch per foot of depth on the average. The pressure on any aquifer is hydrostatic and thus dependent upon the point of entry into the ground and the depth at which it is measured. In most instances when an aquifer is entered by a solution mining cavity, the cavity pressures greatly exceed those of the aquifer. This situation results in the loss of fluid to the aquifer from the cavity and a loss in the ability to pump fluid out of the cavity. Typically, the conduit from which fluid is removed from the cavity will establish a level of fluid governed by the hydrostatic head of the aquifer. In those rare instances where the aquifer is artesian, the hydrostatic pressure of the aquifer may well exceed the cavity pressure and result in the admission of fluid to the cavity from the aquifer. While in these instances the ability to pump fluid from a cavity is not lost, control of the solution mining cavity is lost in that flow rates in and out of the cavity are effected by the influence of the aquifer waters entering the cavity. Even a short circuit of the aquifer water from the break in the cavity to the exit conduit can occur which results rapidly in a nonproductive cavity solution being removed from the cavity.

In accordance with the instant invention, careful control of inflowing and outflowing solutions to and from a solution mining cavity permit the operation of an underground cavity, when it encounters an aquifer and communicates openly with it, in an economical, productive way. To accomplish this result the nature of the aquifer in part determines the procedure to be employed though either procedure hereinafter described proceeds on the same basic principle.

Thus, in an instance where a solution mining cavity has encountered an aquifer of a lower pressure than is exerted on the cavity walls, the result will be that production solution from the cavity can no longer be recovered despite the fact that solvent is being pumped into the cavity for the dissolution of minerals. When this has occurred, the liquid in the effluent conduit will reach a level equivalent to the hydrostatic head of the aquifer in contact with the cavity. This liquid must be assisted in being removed from the effluent conduit to establish a satisfactory liquid working cycle in the cavity and reestablish production therein. To accomplish this a submersible pump is positioned below the liquid surface and the fluid in the column is pumped therefrom. In instances where other than a submersible pump is employed the eductor is positioned below the surface of the liquid. In the preferred embodiment of this invention a submersible pump is positioned a substantial distance below the surface of the normal hydrostatic head in the effluent column after the contact is made with the aquifer. A substantial distance in this instance is at least 10 feet below the surface, preferably 20 to 60 feet or more. Once the pump is in position, fluid is then pumped from the cavity until it reaches ground level. Solvent for dissolution of the minerals associated with the cavity is also pumped into the cavity but at a different rate than the solution being removed. Typically, a differential is maintained between the two pumping rates. This differential insures that on a volume basis less material is removed through the effluent conduit than is introduced through the influent conduit. Generally, 0.5 per cent or more fluid is fed to the cavity than is removed typically between 1 and 10 per cent. Thus, by a controlled volume balance between fluid input to the cavity and fluid output from it the aquifer is effectively sealed off from the cavity. In this manner it can neither feed fluid to the cavity to contaminate it nor take fluid from it at a rate such that the operation becomes nonproductive. Simple adjustment of the pump in the effluent conduit to a flow rate slower than the feed pump rate renders the influence of the aquifer negligible.

In instances where the aquifer is artesian in nature an application similar to the above is made in that the effluent conduit is controlled by throttling to control volume withdrawal therefrom. A control is also maintained on the influent conduit. In this instance, it will be understood, a pressure greater than the fluid pressure on the cavity walls before the aquifer was encountered has resulted in the inrush of fluid from the aquifer when the cavity encountered it. Cavity solution is being diluted with water from the aquifer and contaminated with whatever salts are in that water if they differ from those being mined in the cavity. In general the tendency will be for the aquifer to cause an increase in the effluent fluid flow. To control this situation the general concept remains the same. Thus, a differential in the volume of fluid entering the cavity and the volume of fluid leaving the cavity is established so that the quantity entering is at least 0.5 per cent greater than that being removed. This is readily accomplished by continuing to introduce fluid to the cavity while throttling the effluent conduit to establish sufficient pressure in the cavity to overcome the aquifer hydrostatic head. Once this pressure is overcome, and fluid from the influent conduit enters the aquifer, the rate of flow in and out can be adjusted by the throttle on the effluent conduit to maintain 0.5 per cent more fluid volume entering than is leaving the cavity through the effluent conduit. Once again the result is an effective sealing of the aquifer from the cavity.

For a more complete understanding of the instant invention, reference is made to the accompanying drawing in which:

FIG. 1 is a diagrammatic illustration of the process of the instant invention applied to a single hole cavity with a separate influent conduit and effluent conduit, and

FIG. 2 is a diagrammatic illustration of the process of the instant invention applied to a multiple cavity operation in which one cavity is used as an injection cavity and one is used as a product withdrawal cavity.

In FIG. 1 a bore hole 1 is shown having positioned in it an influent conduit 2 for the introduction of fluid to a cavity 3 located in a deposit 7. Cavity 3 is in communication with the bore hole 1. Positioned above the cavity 3 and the deposit 7 is an aquifer 8 and overburden 9. In FIG. 1 cavity 3 has been extended upwardly to a point where a portion of the roof of cavity 3 has broken away as indicated at 10.

A second bore hole 11 is shown in communication with cavity 3 and contains a conduit 12 therein. Inside of conduit 12 is a pump 16 with means 17 to discharge fluid upwardly therefrom. Electrical power supply lines 19 are shown which supply power to pump 16 when connected to a switch power supply (not shown).

In the operation of the instant invention in the cavity 3 of FIG. 1, typically the break 10 in the roof of cavity 3 results in the loss of fluid pumping ability from the cavity 3. Thus, in normal operation, pump 16 is not present in conduit 12 and fluid is pumped into cavity 3 through conduit 2 and removed from conduit 12 at essentially the same rate ignoring contraction due to dissolution. When the break 10 occurs, fluid in conduit 12 stands at a height therein representing substantially the hydrostatic head of the aquifer 8 regardless of the feed rate of solvent introduced into conduit 2. Feed is discontinued at this point. The pump 16 is then placed in conduit 12 at a point typically at least 10 feet below the liquid level in that conduit. The discharge conduit 17 of the pump is passed to the surface and carries in it the wiring 19 which is connected to a suitable power source. The pump 16 can be regulated to discharge at any given rate within its design capacities and the discharge conduit 17 can also be regulated to discharge liquid at given rates.

Once the pump 16 is in place, it is actuated to begin discharging fluid from conduit 12. The feed of solvent to cavity 3 via conduit 2 is now begun again at a rate of at least 0.5 per cent greater than the pumping rate maintained in conduit 12 ignoring contraction due to dissolution, and usually between 1 and 10 per cent greater. This provides for a slight volume excess of fluid going into the cavity 3 and forces fluid against the fluid in the aquifer thus effectively sealing it off from cavity 3 despite the break 10 in the ceiling of the cavity.

In FIG. 2 a multiple cavity operation is shown in which an injection cavity 20 located in a deposit 40 has positioned therein a bore hole 21 housing a conduit 22. Conduit 22 is used to feed fluid to cavity 20.

Cavity 20 communicates via fluid connection 25 with a second cavity 26 which as shown in the drawing has a break 27 in the roof thereof. An aquifer 28 is shown above deposit 40 and below overburden 30. A bore hole 31 communicates with cavity 26 through a conduit 32 positioned therein. In conduit 32 there is shown a submersible pump 33 and a discharge conduit 34 connected thereto. Conduit 34 carries the wiring 35 which is connected to a suitable power source, not shown.

Prior to the use of the instant invention in the multiple cavity situation depicted in FIG. 2, solvent is pumped into cavity 20 via conduit 22 and is removed from cavity 26 via conduit 32 at substantially the same rate ignoring contraction due to dissolution. Pump 33 at this point is not present in conduit 32. When the break 27 occurs in the roof of cavity 26, the ability to remove product solution from conduit 32 is normally lost. A liquid level is established in this conduit 32 at a level substantially equivalent to the hydrostatic head of the aquifer 28. The feed to cavity 20 is discontinued and the pump 33 is lowered into conduit 32 to a level therein, typically 10 feet or more below the surface of the liquid standing therein. Pump 33 is then actuated and fluid is pumped from the cavity 26. Feed is again started to cavity 20 via conduit 22 and at a rate in excess of the rate of fluid leaving conduit 32. This rate is at least 0.5 per cent by volume in excess. In this manner a slight volume excess of fluid is pumped into the cavity system shown so that a small quantity of fluid is passed to the aquifer 28 from cavity 26 and thus the aquifer is effectively sealed therefrom.

While the invention has been described in reference to the accompanying drawings and with respect to situations where cavity pressure has exceeded aquifer pressures, the same concepts are employed in situations where the aquifer is artesian. Thus, by throttling the conduits 34 of FIG. 2 and 17 of FIG. 1 and introducing fluid at sufficient rates through conduits 22 and 2, respectively, excess fluid will be passed to the aquifer once the pumping rate differential has been established. The major distinction in these artesian water situations will be in the effluent conduit since water may not stand therein when a break occurs between a cavity and an aquifer. Indeed the water from the aquifer may cause fluid to continue to be removed at the same, a lesser or more probably a greater rate depending upon the hydrostatic head of the aquifer.

Thus, in FIG. 1, should aquifer 8 be artesian and break 10 result in the substantial flow of fluid from aquifer 8 into cavity 3, the invention still may be practiced. In this instance if pumping action is not lost and fluid is continuously being removed from conduit 12, pump 16 need not be employed. In lieu of pump 16 the volume differential of fluid into and out of the cavity 3 is established by throttling conduit 12 so that a slight excess of fluid is introduced into cavity 3 via conduit 2 over the amount being removed via conduit 12. This causes a fluid back pressure on break 10 and a slight feed of fluid from cavity 3 to aquifer 8 thereby effectively sealing the aquifer 8 from the cavity.

Similarly in FIG. 2, by throttling conduit 32 and feeding fluid through conduit 22 at a ratio greater than the rate it is removed via line 32 to thereby provide a volume excess feed over withdrawal in the system shown, the aquifer 28 is effectively sealed from the cavity 26. A slight amount of cavity fluid is continuously fed through the break 27 to the aquifer 28 to maintain this seal.

Submersible pumps are preferred in carrying out the instant invention but other pumps such as shaft driven pumps can be employed. In any case the eductor of the pump should be positioned below the surface of the solutions in the effluent conduit in those instances where withdrawal of fluid from the cavity has ceased. Thus, the pump or its eductor is generally placed below the surface of the liquid standing in the effluent conduit under operating conditions. For the purpose of maintaining high pumping rates, it is preferred that the distance below this liquid surface be at least 10 feet.

While the invention has been described with reference to certain specific embodiments, it is not intended to be limited thereby except insofar as appears in the accompanying claims. I claim:

1. A method of solution mining an underground deposit in which solvent is introduced at one point into a cavity in said deposit and solvent enriched in solute from said deposit is removed from another point therein and wherein the cavity openly communicates with an aquifer, the improvement comprising introducing into the solvent removal conduit a pump, pumping fluid from the solvent removal conduit while introducing solvent into the cavity and regulating the feed of solution into the cavity and the withdrawal of solution therefrom to provide on a volume basis at least 0.5 per cent more fluid into the cavity than is being removed.

2. The method of claim 1 wherein the fluid fed to the cavity exceeds the fluid removed therefrom on a volume basis by between 1 to 10 per cent.

3. The method of claim 1 wherein the deposit is a KCl-containing deposit.

4. A method of operating a solution mining cavity which has come into contact with an aquifer and from which fluid can no longer be withdrawn comprising introducing into the effluent conduit from said cavity pumping means, pumping the fluid standing in the effluent conduit to the surface of the ground while introducing into the cavity solvent capable of dissolving the desired mineral, and regulating the flow of fluid into the cavity and the flow of fluid pumped from the cavity to provide on a volume basis at least 0.5 per cent by volume more fluid into the cavity than is being pumped out.

5. The method of claim 4 wherein the fluid fed to the cavity exceeds the fluid removed therefrom on a volume basis by between 1 to 10 per cent.

6. The method of claim 4 wherein the deposit is a KCl-containing deposit.

7. A method of reestablishing production from an underground solution mining cavity which has encountered an aquifer and from which production liquor can no longer be pumped from the effluent conduit by pumping fluid through the influent conduit comprising introducing below the surface of liquid in the effluent conduit pumping means, pumping fluid from the effluent conduit using said pumping means at a given rate, pumping fluid to the cavity through the influent conduit at a rate greater than the pumping rate used in the ef-

fluent conduit to thereby provide on a volume basis to the cavity at least 0.5 per cent more liquid going into it than is being removed from it to thereby effectively isolate the aquifer from the cavity.

8. The method of claim 7 wherein the influent conduit to the said cavity includes a second cavity in communication with the said cavity.

9. The method of claim 7 wherein the pumping means is positioned at least 10 feet below the surface of the liquor in the effluent conduit.

10. The method of claim 7 wherein the fluid fed to the cavity exceeds the fluid removed therefrom on a volume basis by between 1 to 10 per cent.

11. The method of claim 7 wherein the deposit is a KCl-containing deposit.

12. A method of solution mining an underground deposit in which solvent is introduced at one point into a cavity in said deposit and solvent enriched in solute from said deposit is removed from another point therein and wherein the cavity openly communicates with an aquifer, the improvement comprising establishing on a volume basis a differential between the solvent introduced and the solvent removed from the cavity to thereby provide a feed of solvent into the cavity on a volume basis at least 0.5 per cent greater than the quantity of solvent being removed.

13. The method of claim 12 wherein the differential is established by maintaining solvent flow into the cavity constant while throttling the conduit from which solvent is removed.

14. The method of claim 12 wherein the deposit is a KCl-containing deposit.

15. A method of solution mining an underground deposit in which solvent is introduced at one point into a cavity in said deposit and solvent enriched in solute from said deposit is removed from another point therein and wherein the cavity has openly communicated with an aquifer, the improvement comprising feeding solvent to the cavity and removing fluid from the cavity at controlled but different rates to thereby establish a feed to the cavity of solution on a volume basis which is at least 0.5 per cent greater than the solution removed therefrom.

16. The method of claim 15 wherein the deposit is a KCl-containing deposit.

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