United States Patent [19]

Messer et al.

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[45] **July 10, 1973**

[54] **APPARATUS FOR RECOVERING UNDERGROUND DEPOSITS OF SOLUBLE MINERALS**

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[21] Appl. No.: **201,000**

Related U.S. Application Data

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[30] **Foreign Application Priority Data**

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

[58] **Field of Search** ..... 299/2, 5, 11, 17, 299/22; 239/178, 286; 61/45 D

[56] **References Cited**

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[57] **ABSTRACT**

An apparatus for carrying out a method of recovering underground deposits of soluble minerals according to which an access shaft is sunk to the region of the deposit and a tunnel is driven from the shaft to the deposit, whereupon an upright working shaft is advanced from the tunnel into the deposit. From the working shaft a plurality of vertically spaced substantially horizontal and at least substantially parallel flushing passages are driven into the deposit, and intermediate these passages the deposit is formed with a plurality of slots each connecting two adjacent ones of the passages and inclined thereto. Water is forced through the passages and slots to dissolve soluble minerals from the deposit and the thus-obtained solution is collected in the respectively lower of the passages. The collected solution is at least substantially saturated with dissolved minerals by supplying it together with fresh water through the deposit to the next lower of the passages. The saturated solution is collected underground and thereupon pumped from below ground to above ground where the dissolved minerals are recovered and where residual water remaining after recovery of the minerals is returned into the passages.

5 Claims, 2 Drawing Figures

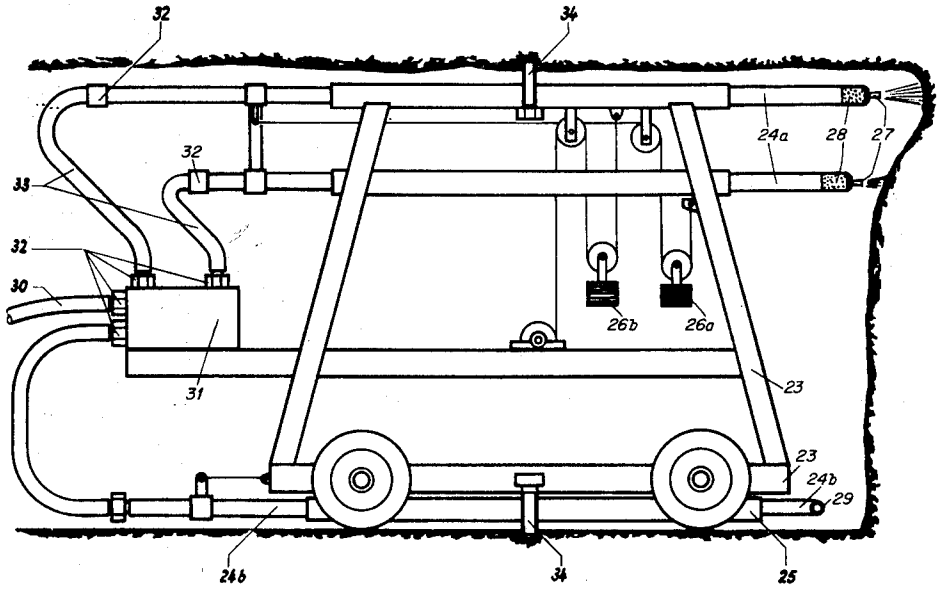
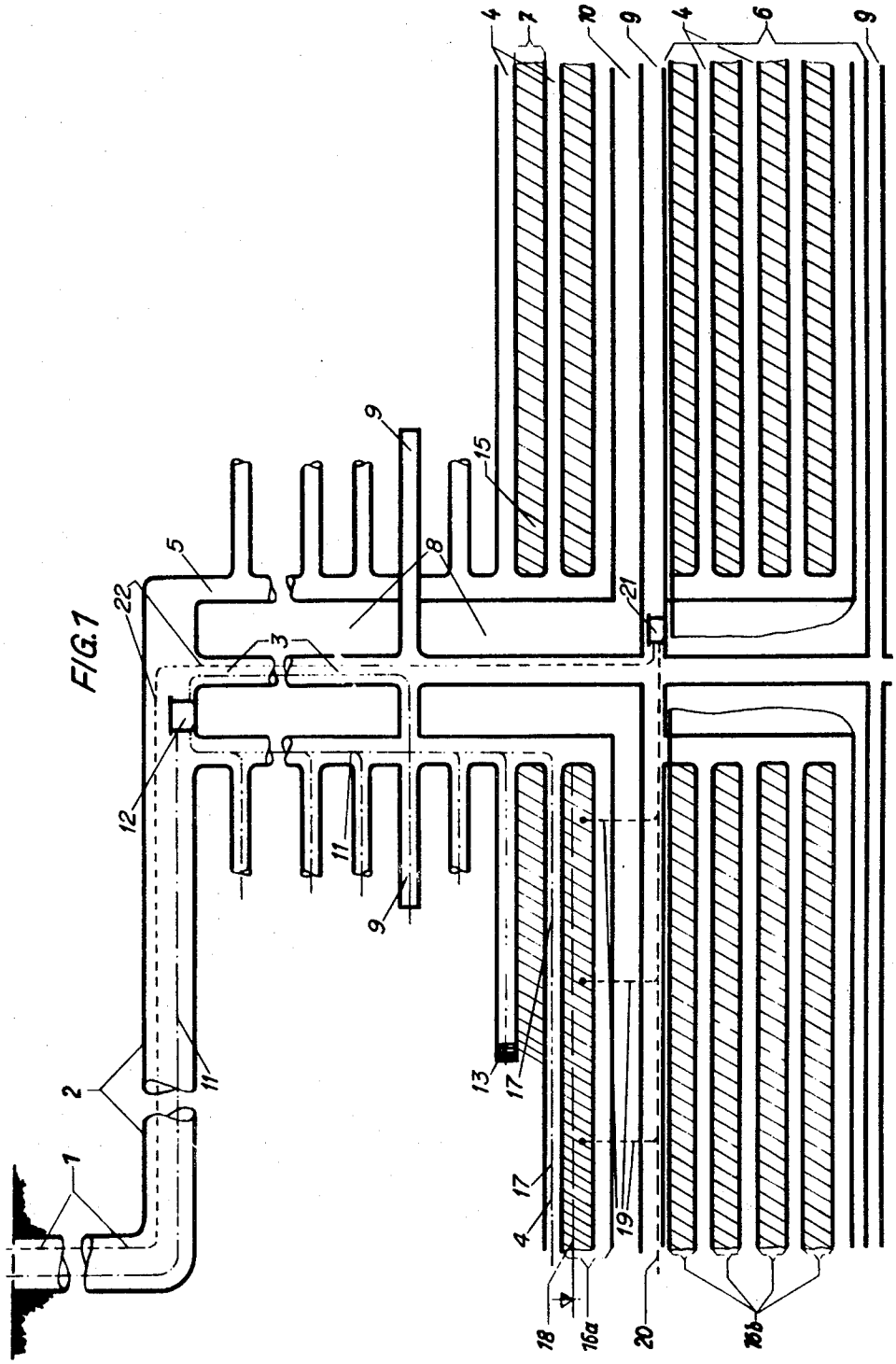


FIG. 1



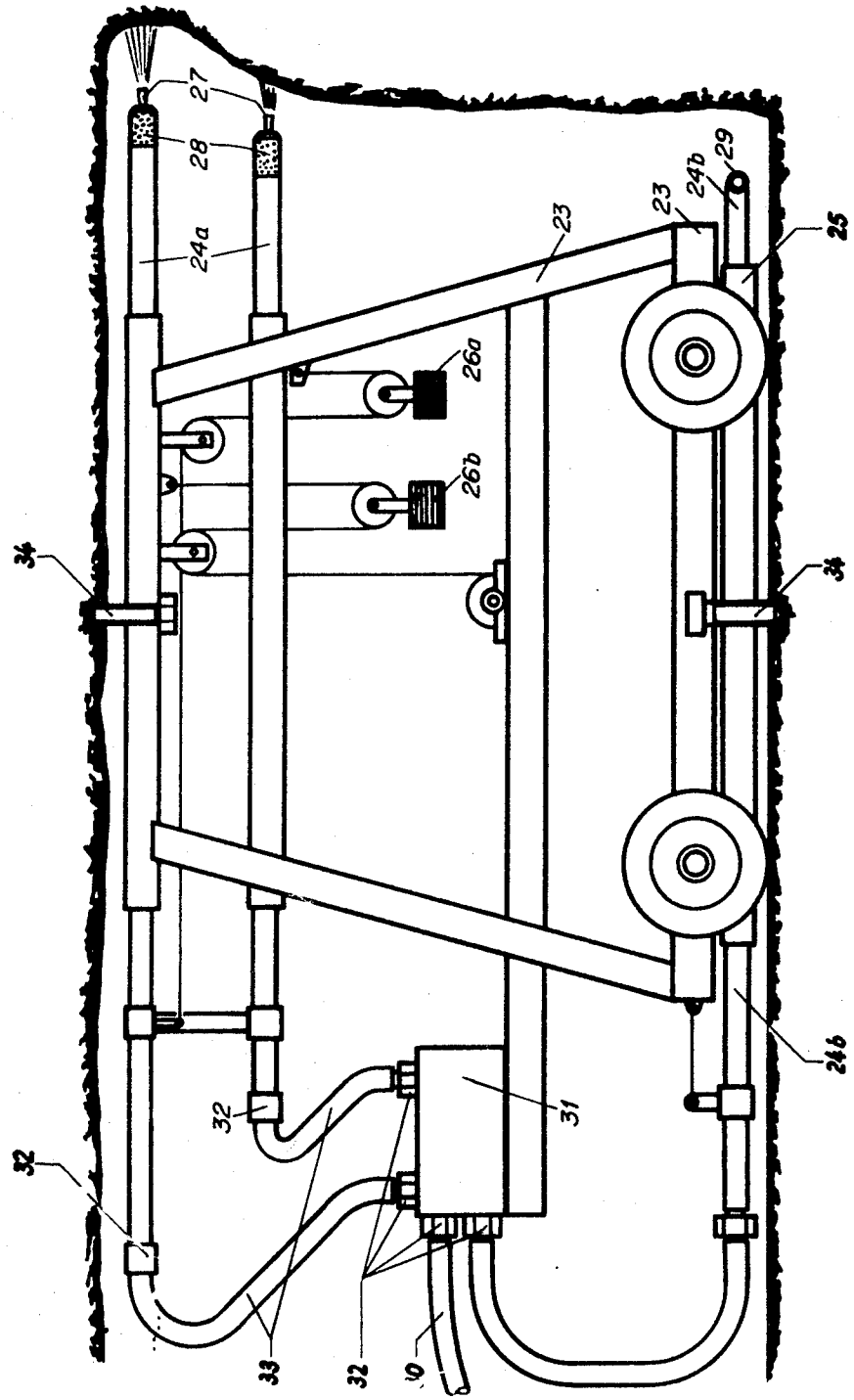


FIG. 2

APPARATUS FOR RECOVERING UNDERGROUND DEPOSITS OF SOLUBLE MINERALS

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a division of co-pending application Ser. No. 4,727, filed on Jan. 21, 1970.

BACKGROUND OF THE INVENTION

The present invention relates generally to the recovery of underground deposits of soluble minerals, and more particularly to an apparatus for effecting such recovery.

Different methods are known for recovering underground deposits of minerals, including of course the sinking of shafts into the deposit for opening up the latter. Such deposits include a variety of mineral deposits, for instance sylvin (KCl) which is usually admixed in granular form with rock salt (NaCl). Rock salt is also frequently found in almost pure deposits or in form of salt layers which contain relatively insignificant quantities of other minerals, such as anhydrite ($CaSO_4$), KCl and clay.

In addition to the conventional methods involving the physical removal of such deposits for processing above ground it is also known to recover such soluble minerals by a solution process. One method of this type which may be used for recovery both of pure salt deposits as well as mixed deposits of NaCl and KCl, requires that the deposit is made accessible by drilling into it an access shaft, into which water is introduced. The soluble salts of the deposit become dissolved in the water and after the latter has become saturated and forms a brine, the brine is pumped out and further processed. This is repeated until the entire mineral deposit near the access shaft has been leached out.

However, this known process has certain disadvantages. One of these is its limited applicability, particularly for the recovery of kalium-chloride (KCl). It is possible only to economically recover the minerals from deposits or layers which are horizontal or substantially horizontal and which are of regular and relatively significant thickness. Furthermore, it is very difficult and frequently possible only by utilizing expensive aids, to so carry out the solution process that the roof and/or bottom of the hollows which develop during the solution process, are protected against further solution when the limit of the deposit has been reached, that is that no solution of minerals other than those desired will occur. A further difficulty in this latter context is in the use of the additives which are used during the solution process and which have a higher or lesser specific weight than water or the brine and therefore tend to accumulate on the roof and/or floor of such hollows and thus to prevent solution of minerals from beyond the deposit which it is intended to recover. This, however, often is not an operational safeguard with the result that solution of minerals from outside the deposit —that is minerals not intended to be obtained— occurs. Aside from the recovery of minerals which are not intended to be obtained there is the further fact that this prevents an adequate saturation of the solution with KCl so that the process is not economical.

A further process of recovery by solution is known which is used for NaCl deposits which are of horizontal orientation. In this case solution passages are drilled horizontally through the deposit in parallelism with one another, and thereupon filled completely with water. The solution which forms is pumped out as soon as saturation has taken place. The process is repeated until recovery to the desired extend has taken place. However, this approach can be used only in compact deposits which are even and nearly horizontal. It has not been used to our knowledge for the recovery of KCl and appears to be impossible of utilization for irregularly configured deposits, particularly for those which are not horizontal but instead inclined, particularly those extending at a steep inclination.

Spackeler (Berg-und Aufbereitungstechnik, Vol. II/9*b*, 1957, pages 260–263) describes a solution process for rock salt deposit where galleries transversely of the deposit are spaced at 260 meter intervals, with chambers being formed of these galleries having a height of 9 meters, a width of 20 meters and a length of 80 – 100 meters. Between these chambers walls of salt remain. Each of the thus-obtained underground cavities was filled and the obtained solution pumped out for a requisite number of times until the final size was reached. Each filling period required several weeks if a saturated solution was to be obtained. While the publication specifies that the filling period can be reduced if instead of sweet water the water used for the solution process is partially enriched brine, it is to be understood that even than the filling period still requires weeks.

On pages 263–265 the publication deals with the solution of KCl-NaCl deposits. It states that it is possible only to obtain solutions of 40 and 85 g/l KCl although the saturation point is at 164 g/l. The publication points to the lack of controllability of the solution process and points out that the brine obtained did not come up to expectation because "it was not sufficiently saturated." It was thought that to obtain an adequately concentrated brine it would be necessary to use not water below ground, but instead to use steam. The solution process will thus always remain incomplete.

SUMMARY OF THE INVENTION

The present invention has a general object to improve the state of the art in the above field.

Particularly the present invention is concerned with an apparatus for carrying out an improved method of recovering underground deposits of soluble minerals.

According to one aspect of the invention, particularly for the recovery of KCl and NaCl, or NaCl alone from natural KCl and NaCl or NaCl-alone containing underground deposits, an access shaft is sunk to the region of the deposit, a tunnel or gallery is driven from the access shaft to the deposit, and from the gallery a working shaft or drill hole is driven into the deposit, following the inclination of the same. This working shaft is dissolved with water until it has a configuration of approximately 4–10 m^2. Subsequently, from this working shaft a plurality of vertically spaced substantially horizontal and at least substantially parallel flushing passages are formed in the deposit at predetermined distances from one another. This is accomplished by using water supplied via conduits and an apparatus according to tthe present invention. The spacing between the flushing passages varies in dependence upon the thickness of the deposit, being approximately 10 m if the thickness of the deposit is 3 m, and approximately up to 25 m if the deposit has a thickness of 10 m. Intermediate the passages a plurality of slots is formed each

connecting two adjacent ones of the passages and being inclined therein. The spacing of such slots is between substantially 0.5 and approximately 5 m and their number per 1 m length of deposit depends upon the thickness of the deposit, for instance two where the deposit is small and 3–5 if the deposit is large. Water is forced through the flushing passages and slots, and the unsaturated solution obtained and containing KCl and NaCl or NaCl alone passes through the slots into the next lower passage, or brining gallery becoming enriched in the process with additional KCl and NaCl, or NaCl alone, and simultaneously increasing the free surface of the next lower passage. The solution, and water emerging via valve controlled conduits are then advanced to the next lower passage where they arrive further enriched to the point of at least substantial saturation. The thus saturated solution is now passed via further valve controlled standpipes, located in the region of the brining gallery, and conduits to a collecting basin from where it is pumped upwardly above ground and further processed to obtain KCl and NaCl, or NaCl alone, and the water obtained on evaporation of the solution is recirculated into the flushing passages until the deposit has been completely recovered.

It has been found that the solution obtained by the use of this method on a sylvinite deposit containing 15% K_2O contains between approximately 30–40 g/l KCl and approximately 80–90 g/l NaCl, and that it becomes enriched by passage through an approximately 10 m long inclined slot and by the solution of further KCl and NaCl, whereupon the concentration is increased by approximately 10–15 g/l KCl and approximately 20–30 g/l NaCl.

It has further been found that fresh water can advantageously be sprayed against the face of the passage formed in the deposit containing KCl and NaCl, or NaCl alone, particularly under the influence of the natural hydrostatic pressure, and that the flushing passage can always be automatically extended for a length of approximately 2 m, with the KCl and NaCl or NaCl solution thus produced passing through the slots into the next lower passage.

The slots may be formed with known drilling machines or drilling carriages, or by means of length-adjustable steel tubes through which fresh water is supplied, utilizing hydrostatic pressure, and thus forming the slots by a leaching process. The accumulation of brine or saturated solution is advantageously held to approximately 1 m below the floor of the flushing passage, by regulating the supply of water. The flushing passages themselves can be arranged to form two or more groups in form of chambers which are separated by residual walls of the deposit which are not penetrated by passages and/or slots.

It is advantageous to provide three such groups arranged in form of chambers, which are operated in such a manner that in one of the chambers flushing takes place to obtain the initial solution, in a second of the chambers saturation of the solution takes place and in the third of the chambers pumping-out of the saturated solution takes place. If this is the case, and if above ground the further processing of the solution is carried out continuously, dwell-times for the solution in the chambers are on the order of 6–8 hours or longer.

The invention is also utilizable for the recovery of KCl, $MgCl_2$ and NaCl from carnallitite deposits which may be either rich or poor in natural rock salt. In this case, it will be KCl, $MgCl_2$ and NaCl which becomes dissolved in the water and is removed in the manner discussed above. Above ground the saturated solution is processed to obtain $MgCl_2$ and a crystalline by-product is obtained containing KCl and NaCl. In the passages where the solution is accumulated, bottom sludge deposits form which contain KCl and NaCl; these are flushed out by means of the saturated solution or are removed by mechanical means to be brought above ground for further processing.

The underground carnallitite deposits may have a kieserite content of up to 5 percent, especially between approximately 1 and 2 percent.

If, for instance, the rock salt poor carnallitite deposit has a composition of 93.8 percent carnallitite and 6.2 percent rock salt with the other aforementioned materials also included, then the saturated solution obtained in accordance with the method of the present invention will have a saturation of approximately 95 percent with reference to $MgCl_2$ and a composition of 320 g/l $MgCl_2$, 45 g/l KCl, 23 g/l NaCl at an operating temperature of approximately 30° at depth of approximately 500–600 m. The aforementioned sludge deposits contain approximately 70% KCl (44% K_2O), 29% NaCl and approximately 1 percent water unsoluble matter, such as $CaSO_4$ and clay.

If, on the other hand, the method is executed in a kieseritic carnallitite deposit rich in rock salt, for instance having a composition of 62.3 percent carnallitite, 29.5 percent rock salt, 0.6 percent sylvine, 0.5% $MgSO_4$, 4.2% $CaSO_4$, 2.9 percent water unsoluble, a saturated solution of approximately 94 percent saturation relative to $MgCl_2$ is obtained, having the composition of 360 g/l $MgCl_2$, 45 g/l KCl, 34 g/l NaCl at an operating temperature of 29.5% C at depths of approximately 750 m.

In this case, the aforementioned sludge which is obtained contains approximately 27.6% KCl, 57% NaCl, 8.5% $CaSo_4$, 0.9% $MgSO_4$ and 6% water unsoluble.

To produce 200 t $MgCl_2$ per day in form of the substantially saturated $MgCl_2$ solution with 320 g/l $MgCl_2$ corresponding to 0.32 t/m^3, a brine quantity of approximately 625 m^3/day is required. This contains 540 m^3 water, and an additional 360 m^3 fresh water per day is required. There is further obtained per day approximately 164 t KCl and 70 t NaCl in form of the aforementioned sludge.

The invention is also usable for recovery of KCl, NaCl, K_2SO_4, $MgSO_4$, $MgCl_2$ from deposits containing natural hard salts. Here, the water is used to dissolve KCl, NaCl, $MgSO_4$, $MgCl_2$. Again, fresh water may be sprayed under the influence of hydrostatic pressure as before.

If the deposit contains hard salts of the composition 34.1% KCl, 36.0% NaCl, 23.4% $MgSO_4$, 0.2% $MgCl_2$, 0.4% $CaSO_4$, a solution of approximately the following composition is obtained: 128 – 142 g/l KCl, 177 – 220 g/l NaCl, 11 – 22 g/l $MgCl_2$, 66 – 98 g/l $MgSO_4$, at an operating temperature of approximately 30° C at depths of approximately 500 – 600 m. The sludge obtained contains predominantly NaCl, KCl and $MgSO_4$, in smaller quantities of $MgSO_4$, $MgCl_2$ and $CaSO_4$.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages

thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a somewhat diagrammatic illustration showing the formation of the various passages and galleries in a deposit to be recovered; and

FIG. 2 is a somewhat diagrammatic illustration of an apparatus for carrying out the method.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIG. 1, there is first sunk an access shaft 1 to the region of the deposit to be recovered. From this access shaft 1 a tunnel or gallery 2 is driven to the deposit at the level of the upper region of the deposit. Once the deposit has been reached, an upright flushing shaft or drill hole 3 is driven in the deposit and has its size increased by flushing with water under pressure to between 4 and 10 m^2 cross section. It is now fortified in the usual manner of below ground shafts so that personnel and material can move through it.

A plurality of horizontal vertically spaced at least substantially parallel flushing passages 4 are driven outwardly from the shaft 3. The spacing of these passages 4 from one another is determined in accordance with the mean thickness of the deposit, for instance a 10 m spacing if the thickness is 3 m. The cross section of the passages 4 is approximately 3 – 4 m^2. The passages 4 are connected with the shaft 3 —which by now has been increased in cross-sectional dimension— via connecting passages or pits 5 having a length of at most 5 m. This permits the subdivision into sections or chambers 6 each having 1 – 4 layers or slices 7. Vertical pillars 8 of approximately 10 m thickness remain between the bore 3 and the passages 5. The individual chambers are horizontally limited by the pillars 10 located at opposite sides of the cross passages 9. The thickness of the pillars above the cross passages 9 is selected to be between approximately 5 and 10 m, that of the pillars below the cross passages 9 to be approximately 3 – 5 m. It has been found that the horizontal pillars are scarcely attacked when solution is removed from the region above them because, while the soluble salts are dissolved, the insoluble salts such as clay and anhydrite will sink and quickly form a bottom layer which provides protection against solution, and because in accordance with the specific weight the salt solution will immediately after entry become differentiated so that at the lowest locations there quickly develops saturated solution with the result that even at the beginning of the solution process and before formation of the protection bottom layer the hollowing out process on the bottom of the working area proceeds only slowly.

A down supply conduit 11 serves to supply fresh water from above, aand interposed in the conduit 11 are containers 12 at different heights which serve to regulate the flushing pressure.

The apparatus 13 according to the present invention is shown in FIG. 2. It comprises a movable support 23 with for instance two pairs of flushing tubes 24*a* arranged in parallelism and extend in the direction of elongation of the flushing passage, and with a spray or flushing tube 24*b* extending transversely of the passage. This support is advanced, with the tubes in withdrawn condition, to the leading end or face of a respective flushing passage (see FIG. 1, left-hand side) and arrested by means of the arresting device 34 with respect to the bottom and roof of the passage. Then the main feed conduit 30 is utilized, in conjunction with the distributor 31 and the feed hoses communicating with the tubes, to supply water to the latter. This water issues from the tubes in finely divided spray through the apertures 27, 28 and 29 and dissolves the soluble salts. The tubes are slidably guided in the guide tubes 25 and are automatically advanced to approximately 2 m lengths in accordance with the formation of hollow space ahead of them (resulting from the solution of the soluble salts) by the device 26*a* and 26*b*. The transversely extending spray tube serves to smooth the bottom wall. When the end position has been reached, the device 34 is operated to release the apparatus 13 so that it can be advanced by the available newly created hollow space, for instance approximately 2 m. If for instance the cross sectional area to be treated is 3 m^2 and 6 tubes 24*a* and 1 transvers tube 24*b* are utilized, a quantity of 50 – 60 m^3 water per hour must be sprayed and a rate of advancement of 20 – 30 cm/h is obtained.

Because of the spraying of the water against the leading wall or face of the respective flushing passage 4, the water dissolves salt such as 30 – 40 g/l KCl and 80 – 90 g/l NaCl in a sylvanite deposit containing 15% K_2O. The unsaturated solution 14 shown in FIG. 1 flows along the bottom of the respective passage 4 to the slots 15 and from them passes to the lowest location 16*a*, i.e., the actual brining gallery.

The inclined slots may be provided in conventional manner with suitable drilling apparatus, or with longitudinally extendable tubes through which water is driven to hollow out the material and form the slots in this way. In the same way as the flushing passages, they serve to open up the deposit for the solution process for further enrichment of the solution and, as initial cavities, permit a controlled brine formation. The spacing between the individual slots is selected in dependence upon the thickness of the deposit and within any one layer or slice it is approximately identical; usually the distance is between substantially 0.5 and 5 m.

The solution passing through the slots dissolves and absorbs further salts, for instance if the slots have a length of 8 – 10 m and an initial diameter of 30 – 40 mm, with the deposit containing 15% K_2O, the solution will absorb between approximately 10 – 15 g/l KCl and 20 – 30 g/l NaCl. This of course results in an increase of the diameter of the inclined slots. The location 16*a* receives not only the unsaturated solution coming through the inclined slots, but also additional fresh water which is supplied through the conduits 11*b*. The supply of such fresh water can be locally controlled by valves 17 so that the brine formation can be locally influenced in this manner. It is advantageous to maintain the level 18 of solution or brine approximately 1 m below the floor of the flushing passage to keep the head sections above the gallery accessible during brining-out. After the solution is saturated, with the dwell time in a deposit having a 15% K_2O content requiring approximately 6 – 8 hours, the solution is pumped above ground via valve controlled conduits or standpipes 19 which are cemented into the horizontal pillars located under the section and which communicate with the conduit 20 from where the solution is first passed to a collecting basin 21 to be pumped above ground through the riser conduits 22 from there.

Filling of the below-ground spaces just discussed with unsaturated solution and fresh water is repeated as many times as necessary to obtain the desired degree of mineral recovery. The water which is obtained on evaporation of the saturated solution above ground is continuously recirculated. It is advantageous to operate at least three different sections or chambers simultaneously and these may be located vertically or horizontally relative to one another. In this manner the operation above ground may be continuously supplied with saturated solution. Once the chambers **16***b* are hollowed out, they can be filled up in the manner usual in underground operations.

To obtain an annual yield of approximately 50,000 jato K_2O at 90 percent output and 250 working days, a daily production of 220 t K_2O is necessary which corresponds to a quantity of KCl amounting to 350 t. If the deposit contains 15% K_2O, the KCl quantity going into solution within the 6 – 8 hour dwell time amounts to 125 g/l and the NaCl quantity amounts to 255 g/l at 22° operating temperature at 500 m depth. A daily brine quantity of approximately 2,800 m^3 is required. At continuous operation the brine supply is to be approximately 120 m^3/h. At a slice spacing between adjacent layers of 10 m for a deposit having an average thickness of 3 m, 63 t of raw salt or approximately 8.2 t K_2O are obtained per running meter of length of the deposit, with a passage cross section of 3 m^2 for the flushing passages.

It follows that per day approximately 36 m advancement of the flushing passages is necessary. To obtain this a brine requirement of at least 1,500 m^3 is necessary, assuming an absorption factor of 35 g/l KCl and 85 g/l NaCl, and this total quantity used once for flushing absorbs approximately 52.5 t KCl and 33.2 t K_2O. These 1,500 m^3 unsaturated KCl and NaCl solution picks up on passing through the slots an additional 15 g/l KCl and 30 g/l NaCl, that is an additional 22.5 t KCl and 14.2 t K_2O. This is based on the assumption that two of the flushing passages **14** are simultaneously operated at three shifts with a brine supply of 35 – 40 m^3/h. The unsaturated solution, together with the remaining approximately 900 m^3 fresh water is supplied to the brining gallery, the fresh water passing through the valve-equipped conduits of the head section of the gallery, so that after approximately 6 – 8 hours dwell time a final content of approximately 125 g/l KCl and 255 g/l NaCl is obtained. The quantity of water to be circulated, including processing above ground, amounts to approximately 2,400 m^3, because at 125 g/l KCl and 255 g/l NaCl salt content the proportion of the water in the brine is 855 g/l.

It will be seen that with the present invention —and in contradiction to the statements of the aforementioned Spackeler publication— dwell times to saturation of only approximately 6 – 8 hours are necessary, as opposed to many weeks. In this time, and assuming that a deposit contains 15% K_2O, brine contents of approximately 125 g/l KCl and 255 g/l NaCl can be obtained. This considerable advantage in the state of the art is made possible by the fact that the inclined slots **15** arranged in slices for controlling the leaching process open up the deposit for easier dissolution of the soluble materials and simultaneously increase the free surface of the brining gallery for the process. In addition, the provision of the slots **15** in the deposits provides for a very advantageous relationship of the dissolving surface versus solution volume.

The present invention further affords the advantage that the solutions obtained in the flushing passages are passed to the lower portions of the cavities or brining galleries through the inclined slots **15** and in so doing further undergo enrichment with soluble matter.

A further advantage of the present invention with respect to the state of the art is to be seen in the fact that the locally regulatable supply of water quantities permits a control over the hollowing-out of the cavity or formation of the brining chamber, so that even deposits can be dissolved whose thickness is irregular.

Contrary to Spackeler which teaches as the state of the art that the solution approach is not economically practical, the present invention overcomes this heretofore existing prejudice and makes it possible to obtain, for instance, a daily recovery rate of 222 t K_2O continuously under recirculation of the solvent brine, at three-shift operation, with economic dwell times of the brine to solution, and with the possibility of controlling precisely the hollowing-out below ground.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of applications differing from the types described above.

While the invention has been illustrated and described as embodied in an apparatus for the recovery of underground deposits of soluble materials, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly consitute essential characteristics of the generic or specific aspects oof this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims.

1. An apparatus for recovering soluble minerals from underground deposits, comprising a movable support movable along an underground passage; a plurality of flushing tubes mounted on said support for shifting movement relative thereto and each having a leading outlet orifice and a plurality of radial orifices; guide tubes on said support and each accommodating one of said liquid tubes for shifting movement thereof; first shifting means for shifting said flushing tubes; at least one spray tube shiftable longitudinally of said flushing tubes and comprising rows of spray outlets; second shifting means for shifting said spray tube; arresting means for arresting said support with reference to said underground passage in a predetermined position; and conduit means for supplying liquid to said tubes.

2. An apparatus as defined in claim **1**, wherein said movable support comprises a wheeled frame.

3. An apparatus as defined in claim **1**, said spray tube extending transversely to the elongation of said underground passage.

4. An apparatus as defined in claim **1**, said conduit means comprising main conduit means and branch conduit means connecting said main conduit means with the respective tubes.

5. An apparatus as defined in claim **1**, said rows of spray outlets of said spray tube extending in longitudinal direction of said underground passage.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,744,847 Dated July 10, 1973

Inventor(s) Ernst Messer et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the cover sheet [73] "Kassel, Sweden" should read -- Kassel, Germany --.

Signed and sealed this 1st day of October 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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