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SOLUTION MINING SYSTEM USING HEAT EXCHANGE TUBES

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The present invention generally relates to solubilizing water-soluble minerals in a subterranean formation and removing the minerals so solubilized. In a particular aspect the present invention relates to a method for efficiently removing potassium chloride from a sylvinite ore panel.

A mineral soluble in water is sometimes mined by pumping water or other dilute aqueous solution into a subterranean formation containing the mineral, thereby dissolving the mineral in situ, and pumping out the resulting aqueous solution containing the dissolved mineral. The mining of alkali metal halides, carbonates, nitrates, sulfates and borates employing water illustrates this operation.

The most common method of dissolving the mineral in situ employs an arrangement of concentric pipes inserted into a well penetrating the mineral stratum, the inner pipe usually being the input conduit and the outer pipe being the output conduit. Another method employs two or more separate wells which penetrate the same soluble mineral bearing stratum, of which at least one well is an input well and at least one other well is an output well. Communication can be provided between the input and output wells by hydraulically fracturing the formation, i.e., by injecting a fluid into one of the wells at sufficient pressure to produce cracks or fissures in the formation, at least some of such fissures incepting both the input and output wells. Fluid is then circulated down the input well, along a fissure to the output well and out the output well.

Previously proposed processes for the solution mining of sylvinite have generally met with failure because, in the absence of heat, it was necessary to use water or a very dilute brine to dissolve sylvite from the formation. In the course of dissolving sylvite, substantial quantities of halite are dissolved which must be separated from the sylvite in relatively expensive evaporation and crystallization operations to obtain sylvite of commercial quality. For example, if the brine recovered from the solution cavity is saturated with sylvite and halite at 30° C., about six parts of water must be evaporated to produce one part of potassium chloride. Two parts of sodium chloride per part of potassium chloride are crystallized. This sodium chloride contaminant must be separated from the evaporated brine prior to crystallization of the potassium chloride.

In view of the above difficulties encountered in solution mining in the absence of heating it has been proposed to heat the incoming water or dilute brine. Such previously proposed processes have also generally failed. When the solvent brine, prior to being introduced into the solution cavity was heated to effect selective dissolution of the potassium chloride from the sylvinite ore body, a sufficiently high temperature inside the cavity could not be maintained because heat was dissipated throughout the sylvinite ore body. Also, the solution of potassium chloride is endothermic, that is, potassium chloride has a relatively high negative heat of solution (106 B.t.u./lb.), which also tends to cool the system substantially.

It is an object of the present invention to provide a new method for the solution mining water, soluble minerals in a subterranean formation.

It is another object of the invention to provide a method for efficiently removing potassium chloride from a subterranean sylvinite ore body.

It is a specific object of the present invention to provide a solution mining method for efficiently removing potassium chloride from a sylvinite ore panel.

These and other objects and advantages of the present invention will be apparent as the description of the invention progresses.

Briefly, the method of this invention comprises driving entries around the perimeter of a panel of soluble mineral, such as sylvinite, inserting an input conduit into one wall of the panel and an outlet conduit into another wall of the panel, passing an aqueous solvent which is unsaturated with respect to sylvite through the ore panel between the input conduit and the output conduit, inserting a plurality of heat exchange tubes preferably substantially parallel to the course of flow between the input conduit and output conduit, and forcing steam through the heat exchange tubes. The direction of flow of the steam is preferably countercurrent to the direction of flow of the solvent. By heat transfer between the steam and the solvent the temperature of the solvent is maintained at a suitable level, such as 90° C., for the solution mining of the mineral.

The invention is best described with reference to the drawing, of which,

FIG. 1 is a plan view, in section, of a substantially horizontal ore panel in which a solution mining operation is carried out in accordance with this invention.

FIG. 2 is an elevational view, in section, in the plane 2-2 of FIG. 1.

Ore panel 10 is bounded on one side by entry 12, and on the other side by entry 14. These entries are made by means of conventional mining machinery. A plurality of holes are drilled through the ore panel, input casing 16 being inserted at one end of a hole of relatively large diameter and output casing 18 is provided at the opposite end of the same hole. Two heating exchange tubes 20 and 22 are inserted in holes of smaller diameter than that provided for the inlet casing 16 and the outlet casing 18. A third heat exchange tube 24 passes through casings 16 and 18. These heat exchange tubes connect through riser tubes such as riser tubes 26 and 28 to output header 30 and input header 32.

A solvent for the ore to be recovered from ore panel 10 is introduced through input casing 16 into the ore panel. The solvent is removed from the ore panel through output casing 18, and conveyed to an ore recovery plant from which it is recycled to input casing 16. The circulation in the panel of solvent which is unsaturated in the mineral to be produced causes the dissolution of mineral and the growth of a cavity such as cavity 36. Steam is introduced through input header 32 and cooled steam and water is removed through output header 30. The flow of heating medium, steam, is in a direction substantially parallel with, but countercurrent to, the direction of solvent flow in the ore panel.

As an example of the production of soluble ores in accordance with a method of this invention, the application of the invention to the recovery of sylvite from a sylvinite ore panel will be described. The ore panel is first provided with input and output casings as shown in FIG. 1, and with a plurality of heat exchange tubes which lie in a substantially horizontal plane. One of the heat exchange tubes is preferably concentric with the input and output casings, as is the heat exchange tube 22, shown in FIG. 1. Sylvinite generally occurs in substantially horizontal strata of large horizontal dimensions but of small vertical dimensions. Thus, a typical stratum may be only five feet in height. Such narrow strata are difficult to mine by means of conventional mining machinery. Since the sylvite contained in the sylvinite ore is substantially more soluble in water at elevated temperature than is the halite contained in the sylvinite ore, an aqueous brine

is injected into the sylvinite panel by means of input conduit 16. The aqueous solvent is preferably injected at a suitable high temperature, such as 90° C. The temperature of the solvent on reaching the output conduit would be substantially less, say 50° C., if not heat were supplied to the solvent in the ore panel. This is due to the dissipation of heat by conduction and also because of the cooling effect which the relatively high negative heat of solution which sylvite exerts upon the solvent.

In accordance with this invention steam at a temperature of 150° C. and 30 p.s.i.a. is introduced into input header 32 and circulated through the heat exchange tubes. Some steam at about 100° C. and 15 p.s.i.a. and condensate is removed through output header 30. The steam rate is controlled by means of a valve, not shown, to maintain the temperature of the aqueous solvent in the ore panel at about 90° C. The brine recovered through output conduit 18 is conveyed to a salt recovery plant in which the temperature of the brine is reduced to about 30° C. In this operation about nine tons of sylvite, substantially uncontaminated with halite, are recovered from each 100 tons of brine circulated through the ore panel. After recovery of the sylvite from the brine, the brine is again heated to 90° C. and introduced into the sylvinite ore panel through casing 16.

A number of possible variations in the operation of the processes of this invention will at once be apparent to those skilled in the art. For example, the invention is applicable to the mining of any soluble mineral by utilizing a suitable solvent in which the mineral displays the requisite solubility. While the invention has been described with reference to the recovery of sylvite from a sylvinite ore panel, which ore panels generally lie in substantially horizontal planes, it will be apparent that the method of this invention is applicable to the recovery of minerals from ore panels disposed at any conventional dip and strike, or even from substantially vertical ore panels. It will be found most convenient to place the input and output conduits to provide circulation in the direction of the greater dimension of the ore panel. While it is preferred that the heat exchange tubes be in a direction parallel to the direction of flow of solvent in the ore panel, such is not necessary. It will also be apparent that the direction of flow of steam through the heat exchange tubes need not necessarily be countercurrent to the direction of flow of solvent, although a more

even heating of the solvent and more economical utilization of heat can be obtained by countercurrent flow. It will also be evident that heating fluids other than steam can be utilized.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method for the solution mining of a sylvinite ore panel which comprises driving entries around the perimeter of the panel to thereby define a panel having substantially vertical walls, inserting a plurality of heat exchange tubes substantially horizontally through said panel, inserting an inlet casing into one wall of said panel and an outlet casing in a wall of said panel substantially opposite to the wall into which said inlet casing is inserted, passing a fluid at an elevated temperature through said heat exchange tubes, introducing an aqueous solution substantially unsaturated with respect to potassium through said inlet casing into said panel and withdrawing an aqueous solution containing more potassium than the incoming solution through said outlet casing thereby forming a solution cavity within said panel as potassium is dissolved in the aqueous solution and withdrawn from said panel, at least one of said heat exchange tubes passing through said solution cavity and maintaining substantially all of the solution in said solution cavity at an elevated temperature by heat exchange with the fluid in said heat exchange tubes.

2. The method in accordance with claim 1 in which said heat exchange tubes extend substantially parallel to the direction of solution flow between said inlet and outlet casings.

3. The method in accordance with claim 2 in which the flow of fluid through said heat exchange tubes is countercurrent to the direction of flow of said solvent.

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