A method of solution mining and recrystallization recovery of solid sodium chloride salt from underground occurrences thereof, which utilizes the heat conductivity characteristics of an underground salt spine, spine, dome, or the like; whereby the latent heat of the earth's core may be efficiently employed in the recrystallization process. The highly (heat) conductive characteristic of a salt spine or the like such as has been formed by geologic plastic flow and vertical intrusion of a portion of a deep-seated "mother" bed of salt through the relatively heat-insulative overlying rock strata, is employed to draw heat from a high temperature geologic structure which is so deep-seated as to be economically inaccessible to modern drilling equipment. This heat energy is drawn into a "heat well" which is developed at an underground level which is readily within reach of modern earth bore drilling techniques; the heat energy flowing into the "heat well" being thereupon transmitted and utilized in the salt recrystallization process facility at or near the earth's surface.

BACKGROUND AND GENERAL DESCRIPTION OF THE PRESENT INVENTION

Whereas numerous proposals have been previously made whereby to employ so-called "underground heat" to useful purposes, certain practical limitations have invariably minimized the economic importance and/or commercial success of such efforts. This has been due to such factors as the relatively low and fluctuating temperatures available from so-called "hot" underground water or "steam well" sources such as have been suggested for such purposes, as well as their unreliability and depletion-prone characteristics. Also, the expense and difficulties attending attempted bore hole operations through ordinarily encountered geologic structures with a view to reaching such depths as would tap rock formations competent to support a constant and sufficiently high temperature heat abstracting operation have proved prohibitive. For examples of such prior proposals see Pats. 2,461,449; 3,140,986; 3,274,769; and 3,563,664.

The present invention derives from the discovery that certain geologic spines or spires or "domes" comprising solid masses of crystalline rock salt which are impervious to the passage of heat, this core structure, intrude upwardly from deep-seated "mother beds" towards the earth's surface to within reach of modern drilling equipment and are highly heat conductive compared to the surrounding and/or more ordinarily encountered underground strata. These geologic phenomena are sometimes integrally associated in the earth's crust structure, intruding upwardly from deep-seated "mother beds" of salt or other rock masses which are located at such great distances underground as to be far beyond reach of modern drilling techniques. Thus, in such cases these salt domes or spires are uniquely adapted to function as conduits for transmission of practically unlimited quantities of heat from the earth's core and into and through the earth's crust structure to the extent they penetrate the latter.

By virtue of the present invention a bore hole driven into a salt dome only to a depth of the order of 10,000 or 15,000 feet may tap a constant high temperature heat energy supply drawing from sources as deep as 50,000 or feet or more. Such results are attainable because of the fact that rock salt structures have heat conductivity coefficients many times higher than the coefficients of other geologic structures such as are usually encountered by underground drilling. See "Handbook of Physical Constants," revised edition, published by the Geological Society of America, Inc., pp. 461-466. Test data has established, for example, that a bore hole drilled into a Louisiana Gulf Coast salt dome to a depth of 12,000 feet will tap a practically unlimited source of heat at 270 to 310°F., depending upon the proximity of the bore hole to the edge of the dome. Such sources of heat are not obtainable at the same depth by drilling into the usually encountered underground geology.

This invention utilizes the existence of this rare heat supply and conduction facility in combination with the fact that a salt spine of the character described may be easily reached and penetrated to suitable depths by modern bore hole drilling equipment. A "heat cavity" may be thereby economically constituted to provide a suitable heat supply reservoir; such as for example by solution mining a desirably sized and shaped cavity in the rock salt mass. The subsequently emptied cavity or "heat well" may then be flushed for heat abstraction purposes by circulating a heat exchange fluid threethrough, such as any inert (to salt) gas or liquid. It is of particular importance that when the system contemplated by the present invention is properly managed, the "heat well" may be maintained to be leakproof and constant as to size and shape. Hence, a uniform and regulated rate of heat extraction and delivery to the surface facility should be maintained.

DETAILED DESCRIPTION

In accordance with one example of the present invention a "heat spine" in the form of virgin salt rock, is established in a "hot" portion thereof by drilling one or more bore holes into the spine to such depth as to reach a constant source of heat at the desired temperature. A heat exchange cavity is then formed in the spine, and is established in fluid circulation communication (at monitored rates) with conduit means extending from above such spine. Thus, a regulated supply of relatively cool fluid may be circulated through the cavity as to become suitably heated therein, and is then conducted back up to an aboveground (or perhaps underground) facility, for utilization of the heat energy abstracted by the fluid from the salt mass. The fluid may be in the form of any chemically neutral and non-dissolving (to the salt) heat exchange medium.

Inasmuch as competent (permanently sized and shaped and leakproof) cavities may be economically formed in such "salt domes" or "spires" by currently available solution mining techniques, and advantageously in close association with a field of solution mining salt wells, the heat abstracted by a heat cavity of the present invention may be most beneficially utilized in the process of evaporating or recrystallizing or otherwise processing the brines produced by the associated brine field. The invention further more contemplates improved techniques for transmission of a heat-exchange fluid through the heat cavity of the system.

Specifically, the invention contemplates automatically controlled circulation of the heat exchange fluid through the conduit and heat exchange system such as to cause delivery of the heat exchange fluid uniformly at the desired temperature to the heat utilization facility. In this respect the system will be automatically monitored by temperature sensors at the output end of the conduit...
system, controlling velocity of fluid flow through the heat
exchange cavity. Note that the conduit system may be
self-moving; the relatively cooler fluid in the down-hole
outweighing the relatively hotter fluid in the up-hole.

However, in order to positively establish and maintain cir-
culation, a priming pump may be employed and kept on
a standby basis and brought automatically into play
whenever needed by means of a motor control actuated in
response to signals from a rate-of-flow meter in the con-
duct line. It is also contemplated that if the heat utiliz-
ing facility is located near a source of brackish water such
as sea water or the like, this may be used as the solvent for
the solution mining operation; the evaporation vapor efflu-
ent thereupon providing good potable water.

Whereas the invention may be applicable to a variety of
solution mining systems, it is illustrated and described in
detail hereinafter by way of example in conjunction with
a sodium chloride rock salt solution mining opera-
tion; as will be more fully explained and as is illustrated
by the accompanying drawing wherein:

THE DRAWING

FIG. 1 is a vertical geologic section view, illustrating
a typical system installation in accordance with the
present invention;

FIG. 2 is a fragmentary enlarged scale view of an upper
portion of FIG. 1; and

FIG. 3 is a flow diagram of the system illustrated by
FIGS. 1-2.

As shown in FIG. 1, in accordance with the present
invention, a relatively rarely occurring geological phe-
nomenon known as a salt “spire” or “dome” as indicated at
10 occurring in thermal continuity with a deep-seated
“mother bed” is first located and then penetrated from an
appropriate location at the earth's surface by means of a
bore hole system which is designated generally at 12. The
penetration is conducted to a relatively great depth; say,
of the order of 10,000 to 20,000 feet below the earth's
surface, such as may be required to acquire a heat reser-
voir cavity as indicated at 14 at a level wherein tempe-
ratures approximating 300° F. or higher are encountered
within a substantial body of solid rock salt. It is essen-
tial that the reservoir be located in an integral struc-
ture having thermal continuity with the heat source
“mother bed”; all components of the system having such
thermal continuity and conductivity characteristics as will
insure continuous replacement of the anticipated heat en-
ergy abstraction from the reservoir.

The solubility characteristics of rock salt, the heat reser-
voir 14 may be conveniently and economi-
cally formed at the desired level in the spire 10 by flowing
a stream of water from the surface to the bottom of the
bore hole system, and then counterflowing the resultant
brine solution upwardly to the earth's surface for disposal.
A circulation system for this purpose may be established
either within a single bore hole as illustrated at 12 (FIG.
1) by use of concentric casings; or, alternatively it may
be arranged as shown in FIG. 2 by use of a pair of parallel
bore holes 16, 17, as explained for example in my earli-
er Pat's. Nos. 3,421,794; 3,348,883; 3,386,768; and
18, 25,682.

As previously stated, the invention contemplates partic-
ular advantages when employed in conjunction with a salt
mining operation such as may comprise one or more solu-
tion mining cavities as are illustrated in FIG. 1 at 18, 19.
As shown therein the mining cavities may be serviced as
indicated generally at 20-21 either by multiple cored single
bore holes, or by dual bore holes, as indicated at 22-24
(FIG. 2). The heat cavity bore hole system 12 is illus-
trated as being coupled to a surface facility which is indicated
generally at 25, while the salt brine production cavities are
illustrated by way of example as being arranged to be
serviced by earth surface facilities as are indicated gen-
erally at 26, 28, respectively.

It is a particular feature of the present invention that
the heat cavity 14 is located within a structurally solid por-
tion of the salt spire 16, and at such a depth therein as to
operate as a heat well for reception and transmission of
the heat energy which is constantly available for con-
duction from the earth's core for example by way of the
mother bed of salt forming the foundation for the spire
16. Thus, the cavity 14, after being suitably formed by the
solution mining process and then emptied, provides a heat
exchange chamber through which a heat exchange fluid
such as a suitable gas or liquid may be transported by
pumping it downwardly through the casing 16 (FIG. 2)
and permitting it to rise through the casing 17 after it
flows in heat exchange relation around and against the
walls of the “heat cavity.”

As illustrated diagrammatically at FIG. 3, a typical
rock salt solution mining and recrystallization recovery
system as contemplated in conjunction with the present
invention will comprise a solution mining cavity 19 into
which a solvent liquid such as water or dilute brine may
be introduced by means of a pump, whereby a concen-
trated brine from the cavity 19 will be forced to flow up-
wardly through the well bore conduit 24 (FIG. 2) to
the surface. Here it is delivered into the evaporator
apparatus for recovery of the salt product therefrom in
accordance with any preferred form of a variety of

technologies, such as are discussed for example in my ear-
er Pat's. 3,348,883; 3,386,786; and 3,421,794. Still
further by way of example the vapor effluent from the salt
recovery apparatus may then be passed through a con-
denser for recovery of a fraction of the pure water there-
from; the residual effluent being returned to the conduit
supplying the pump servicing the injection well bore 22.
Dilute brine effluent from the recovery system and/or
make up fresh water may be added to the pump supply
conduit, as needed. Furthermore, as stated hereinabove,
if the solution mining and salt recovery facility is located
in the region of a supply of nonpotable water such as sea
water or other brackish water or the like, and if the im-
portances therein would not add prohibited contaminants to
the salt product of the system such nonpotable water may
be utilized as whole or part of the solvent in the solution
mining operation. In such case the condenser unit will
then deliver a potable water supply such as may be of
economic importance.

In any case, in accordance with the present invention
the heated fluid ascends the output well bore conduit
17 from the heat exchange cavity 14 will be utilized to
heat power the evaporator apparatus referred to herein-
above; thereby eliminating need for any auxiliary
heat generating facility. As illustrated in FIG. 3, the spent
heat exchange fluid exiting from the evaporator
apparatus is recirculated through the heat recovery well
14 by means of a pump delivering fluid to the well bore
conduit 16.

It is a particular feature of the present invention that
the heat exchange fluid to be used is of such nature as to
be non-dissolving and chemically inert as to the rock salt
wall structure of the heat cavity 14, and that the fluid is
circulated through the cavity at such rate as to abstract
heat from the walls thereof at such rate that when the
fluid passes through the evaporator apparatus it delivers
heat energy thereto uniformly at the desired rate and tem-
perature. Accordingly, in order to suitably regulate the
rate of heat exchange fluid flow a meter system is arranged
in conjunction with the heated fluid delivery conduit.
Rate of fluid flow and temperature sensors deliver signals
to a monitoring mechanism, the output from which is
arranged to regulate the performance of the pump. It will
be appreciated that the overriding parameter controlling
the monitoring operation for most effective operation of
the evaporator apparatus will be the permissive input tem-
perature fluctuation range of the fluid as it enters the
evaporator apparatus.
As stated hereinabove, the heat exchange fluid may comprise any medium of high heat transfer characteristics. Accordingly, some of the relatively expensive organic chemical compositions may be preferred for this use, and in such case the fluid circulating conduit system will of necessity be maintained in leak-proof condition. The rock salt wall structure of the heat cavity being outstandingly competent in regard to its fracture-free and leak-proof characteristics, renders such a closed circuit system fully feasible and practical. Examples of liquids contemplated as being suitable for this purpose are: ethylene glycol, carbon tetrachloride, propylene glycol, hexane, diethylene, diphenyl ether, polyoxyethylene glycols, mineral oils, kerosenes, block copolymers of ethylene glycols and propylene glycols, glycol, polypropylene diols, and suitable higher fatty acids, alcohols, esters and ethers. Also, condensible gases may be employed, such as dichlorodi-fluoromethane and other Freons® propane, carbon dioxide and chlorine. These may be employed alone or in mixture with other such fluids to produce the desired operative heat transfer means.

I claim:

1. The method of solution mining and recovering solid sodium chloride from an underground occurrence thereof, which method comprises the steps of:
   (a) determining the location of a rock salt formation which extends to a depth inaccessible by bore drilling techniques and into thermal continuity with a bed of elevated temperature material;
   (b) driving a bore hole into said rock salt formation to a selected accessible depth of at least 10,000 feet at which the temperature of the rock salt and the rate of heat transfer therefrom are selected, the elevation of elevated temperature material are of selected values;
   (c) dissolving said rock salt through said bore hole for a time sufficient to produce, at said selected accessible depth, a cavity of selected size having a heat transfer area which will provide a selected rate of heat energy due to said selected values of temperature and heat transfer rate specified in (b);
   (d) flushing said cavity through said bore hole with a fluid which is non-soluble and inert chemically with respect to said rock salt formation to terminate the dissolution and retain said selected size of the cavity;
   (e) driving a second bore hole into said rock salt formation to an accessible depth therein at which the temperature of the formation is insufficient to cause evaporation of brine obtained therefrom;
   (f) solution mining through said second bore hole to form an ever-expanding cavity and directing the brine so-obtained back to the earth's surface at a selected rate;

(g) circulating heat transfer fluid which is non-soluble and inert with respect to said rock salt formation through the bore hole of step (b) at a rate sufficient to evaporate the brine of step (f);

(h) thermally contacting the heat transfer fluid of step (g) with the brine of step (f) to evaporate the latter; and

(i) recovering solid sodium chloride from the evaporation of step (h).

2. The method according to claim 1 including the step of condensing vapor obtained from step (h) and recycling same as solvent for step (f).

3. The method according to claim 1 wherein the heat transfer fluid of step (g) is circulated in a closed path and including the step of controlling the return flow of said heat transfer fluid in accord with its emergent temperature.

4. The method according to claim 3 including the step of condensing vapor obtained from step (h) and recycling same as solvent for step (f).

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