



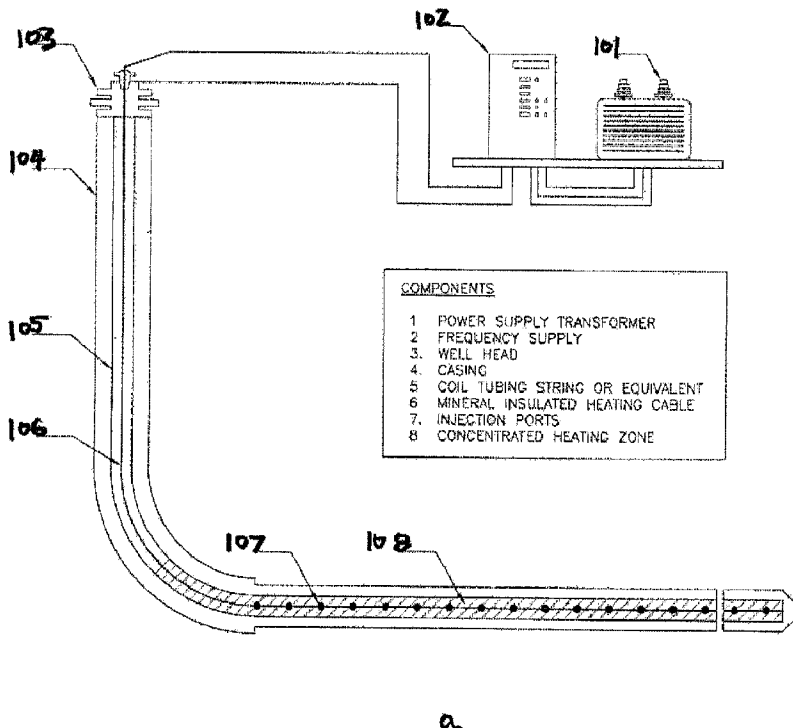
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(54) Title: DOWNHOLE HEATING METHODS FOR SOLUTION MINING



(57) **Abrégé/Abstract:**

A method for mining soluble minerals from a subterranean deposit that comprises injecting a mining solvent into an injection wellbore passing through or contacting the deposit, wherein a heating means is allowed to heat the mining solvent while downhole

(57) **Abrégé(suite)/Abstract(continued):**

and inside the wellbore thereby increasing the solvent temperature and reducing solvent heat loss is provided. The heated solvent is allowed to dissolve some of the soluble minerals from the deposit forming a mineral solution which is produced to surface.

Abstract

A method for mining soluble minerals from a subterranean deposit that comprises injecting a mining solvent into an injection wellbore passing through or contacting the deposit, wherein a heating means is allowed to heat the mining solvent while downhole and inside the wellbore thereby increasing the solvent temperature and reducing solvent heat loss is provided. The heated solvent is allowed to dissolve some of the soluble minerals from the deposit forming a mineral solution which is produced to surface.

DOWNHOLE HEATING METHODS FOR SOLUTION MINING

Field of the Invention

- 5 The present invention relates to subterranean solution mining, and specifically to heating methods for solution mining.

Background of the Invention

- 10 It is known in the mining industry that heat is useful for evaporite solution mining operations that employ an injected solvent. Typically, more desired minerals can be dissolved in a solvent when solvent temperatures are increased. Employing heated injected brine for solution mining, for example, allows for a more concentrated production brine (saturated or super-saturated) and lower processing costs. However, many mineral host formations are cooler than the optimum
15 formation temperature required to achieve maximum solubility of the evaporite minerals in the solvent brine, thus having a natural cooling effect upon the injected heated solvent brine.

To overcome the above-mentioned impediments to solution mining, solvent brine employed for secondary recovery (i.e., selective solution mining) is heated on the surface and injected at an
20 elevated temperature into an injection wellbore and into the mining beds. The solvent brine, however, must be heated on surface to temperatures sufficiently high to also account for the heat loss that can occur not only while being pumped on surface, but also while being injected into the injection wellbore and into a mining / dissolution zone.

- 25 Heat loss can occur in a formation containing the evaporite minerals to be mined, as the host formation is typically cooler than the temperature required to maintain maximum solubility of evaporite minerals in the solvent brine. Heat loss can also occur during the dissolution process itself due to endothermic processes occurring. It is estimated that this heat loss can be over 40 degrees C, suggesting that in order to recover a saturated mineral brine solution that is over 40
30 degrees C in temperature, the brine must be heated to over 80 degrees C on surface prior to injection into the wellbore in order for the brine to be at 40 degrees C once it reaches the

dissolution zone, as it will further cool during the dissolution process before being produced to surface. For some solution mining operations, such as those located in Saskatchewan, Canada, brine may need to be heated to 100 degrees C on surface before injection to compensate for anticipated heat loss. Such processes are inefficient and waste a considerable amount of energy.

5 This is especially a problem in regions having long and cold winters, such as Saskatchewan, Canada.

It is therefore contemplated that for solution mining operations that employ surface brine heating, brine must be heated about 20 degrees C to 60 degrees C warmer than the temperature
10 otherwise required for mineral dissolution at the mining zone. This is due to heat loss of the brine occurring while being pumped to the mining zone and the endothermic nature of potash dissolution. During the cold winter months, heat transfer from the brine to the atmosphere and surface casing can also be considerable, as the solvent brine may be exposed to surface ambient temperatures ranging from -20 degrees C to -30 degrees C.

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Summary of the Invention

Heating means such as brine heaters can be employed downhole in an injection well for heating a
20 mining solvent, such as brine, within the well but before the solvent enters the mineral zone. Downhole heating means can also be employed in a production well for heating mining solutions before the solution is produced to the surface from the mineral zone. Such heating means can also be useful in production wells to re-heat the formed mineral solution so that minerals, such as potassium chloride, do not crystallize out of solution as a result of temperature loss occurring at a
25 production wellbore casing or during piping to a processing facility. The heating means can be in one or any combination of the injection well, the production well and the mining solvent source well (described below). The heating means can also be physically located outside the wellbore(s) but operative to effect a temperature increase of the target fluids within the wellbore(s).

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A methods for heating a mining solvent, such as brine, employed for solution mining before entering a mining zone and/or a mining solution before being produced to the surface from the mining zone is provided. Underground solvent heating can reduce heat loss as compared to previous contemplated surface brine heating methods.

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According to a first aspect, there is provided a method for mining soluble minerals from a subterranean deposit containing the soluble minerals, the method comprising the steps of:

- a. providing an injection wellbore contacting the subterranean deposit;
- 10 b. providing heating means in the injection wellbore;
- c. injecting a mining solvent into the injection wellbore;
- d. allowing the heating means to heat the mining solvent while inside the injection wellbore to form a heated mining solvent;
- e. allowing the heated mining solvent to enter into the subterranean deposit and dissolve a
15 portion of the soluble minerals from the subterranean deposit, thereby forming a mineral solution comprising the heated mining solvent and the portion of the soluble minerals;
and
- f. producing the mineral solution to surface.

20 In a further aspect, the method can include, before producing the mineral solution to the surface, the step of allowing the heating means to heat the mineral solution. Where the step of producing the mineral solution to surface comprises use of a production wellbore, the method may comprise providing a second heating means in the production wellbore.

25 In a further aspect, the injection wellbore comprises at least one of: a vertical section; and a horizontal section. The method may further comprise the step of allowing the heating means to heat the mining solvent while inside the at least one of: a vertical section; and a horizontal section.

30 In a second aspect, there is provided a method for producing liquid fluid from a subterranean deposit containing soluble minerals, the method comprising the steps of:

- a. providing a production wellbore contacting the deposit;
- b. providing heating means in the production wellbore;
- c. allowing the liquid fluid to flow into the production wellbore;
- 5 d. allowing the heating means to heat the liquid fluid while inside the production wellbore to form a heated fluid; and
- e. producing the heated fluid to surface.

10 In a further aspect, the liquid fluid is a mining solution comprising mined soluble minerals from the subterranean deposit.

In a further aspect, the production wellbore comprises at least one of: a vertical section; and a horizontal section. The method may further comprise the step of allowing the heating means to heat the liquid fluid while inside the at least one of: a vertical section; and a horizontal section.

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According to a third aspect, there is provided a method for mining soluble minerals from a subterranean deposit, the method comprising the steps of:

- a. providing an injection wellbore contacting the subterranean deposit;
- 20 b. providing a production wellbore contacting the subterranean deposit;
- c. providing first heating means in the injection wellbore;
- d. providing second heating means in the production wellbore;
- e. injecting a mining solvent into the injection wellbore;
- f. allowing the first heating means to heat the mining solvent while inside the injection
- 25 wellbore to form a heated mining solvent;
- g. allowing the heated mining solvent to enter into the subterranean deposit and dissolve a portion of the soluble minerals in the subterranean deposit, thereby forming a mineral solution comprising the heated mining solvent and the portion of the soluble minerals;
- h. allowing the mineral solution to flow into the production wellbore;
- 30 i. allowing the second heating means to heat the mineral solution while inside the production wellbore to form a heated mineral solution; and

- j. producing the heated mineral solution to surface.

In a further aspect, the injection wellbore comprises at least one of: a vertical section; and a horizontal section. The method may further comprise the step of allowing the first heating means to heat the mining solvent while inside the at least one of: a vertical section; and a horizontal section of the injection wellbore.

In a third aspect, the production wellbore comprises at least one of: a vertical section; and a horizontal section. The method may further comprise the step of allowing the second heating means to heat the mineral solution while inside the at least one of: a vertical section; and a horizontal section of the production wellbore.

According to a fourth aspect, there is provided a method for producing liquid fluid from a subterranean region containing the liquid fluid, the method comprising the steps of:

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- a. providing a production wellbore contacting the subterranean region;
- b. providing heating means in the production wellbore;
- c. allowing the liquid fluid to flow into the production wellbore;
- d. allowing the heating means to heat the liquid fluid while inside the production wellbore to form a heated fluid; and
- e. producing the heated fluid to surface.

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In a further aspect, the fluid is a mining solvent comprising water.

In a further aspect, the production wellbore comprises at least one of: a vertical section; and a horizontal section. The method may further comprise the step of allowing the heating means to heat the liquid fluid while inside the at least one of: a vertical section; and a horizontal section.

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A detailed description of exemplary embodiments of the present invention is given in the following. It is to be understood, however, that the invention is not to be construed as being limited to these embodiments. The exemplary embodiments are directed to particular

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applications of the present invention, while it will be clear to those skilled in the art that the present invention has applicability beyond the exemplary embodiments set forth herein.

Brief Description of the Drawings

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In the accompanying drawings, which illustrate embodiments of the present invention:

Figure 1a is a simplified schematic view of a first embodiment of the present invention;

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Figure 1b is a simplified schematic view of a second embodiment of the present invention;

Figure 2 is a simplified schematic view of a third embodiment of the present invention; and

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Figure 3 is a simplified schematic view of a fourth embodiment of the present invention.

Exemplary embodiments of the present invention will now be described with reference to the accompanying drawings.

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Detailed Description of Exemplary Embodiments

Throughout the following description specific details are set forth in order to provide a more thorough understanding to persons skilled in the art. However, well known elements may not have been shown or described in detail to avoid unnecessarily obscuring the disclosure. The following description of examples of the technology is not intended to be exhaustive or to limit the invention to the precise form of any exemplary embodiment. Accordingly, the description and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

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Throughout the following description, the terms "solvent brine", "solvent" or "mining solvent" should be interpreted to include aqueous solvents such as, but not limited to, fresh water, process

water, salt water, brackish water, saturated brine, brine saturated with potassium chloride, brine and any other solvent that could be employed for solution mining operations, as would be apparent to a person skilled in the art.

5 Throughout the following description, the terms "mining solution" and "mineral solution" should be interpreted to include solutions such as, but not limited to, solutions created wherein a mining solvent or solvent has dissolved minerals from a subterranean deposit that may be ultimately produced to surface, as would be apparent to a person skilled in the art.

10 Throughout the following description, the terms "mining zone" or "mineral zone" should be interpreted to include, but not be limited to, areas within a subterranean deposit wherein minerals can be mined.

15 Throughout the following description, the term "mining solvent source" should be interpreted to include, but not be limited to, a subterranean source of mining solvent.

The methods can involve downhole heating of solvent employed for solution mining, whereby the solvent is heated within the wellbore, thus potentially augmenting the naturally occurring geothermal temperature allowing for the possibility of a consistent and warmer solvent
20 temperature at the depth of the minerals to be mined. The methods can also involve downhole heating of fluids, such as mining solutions, as they travel inside a production wellbore to the surface.

The downhole heating means can be employed for heating a mining solvent and/or mining
25 solution while inside generally vertical injection and/or production wellbores. Perforations or ports along the injection wellbore may be provided allowing the injected heated mining solvent to enter into a subterranean deposit and dissolve some of the soluble minerals from the deposit, thereby forming a mineral solution that is produced to the surface.

30 The downhole heating means can be employed for heating a mining solvent and/or mining solution while inside generally horizontal portions of injection and/or production wellbores. As

described below, the horizontal portion of the injection wellbore may comprise perforations or injection ports to ensure even amounts of mining solvent are injected into the targeted mining zone through each of the injection ports. Such solution mining well arrangements are well known in the art.

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By heating of the mining solvent in the wellbore and at the mining bed depth rather than at surface, the heat loss can be reduced from the solvent, and can re-heat the mining solution in the production well before it is produced and piped to a processing plant. A consistent temperature regime can be produced in a wellbore and at the mining level that is significantly warmer than
10 the surface ambient temperature, as opposed to the typical practice in the solution mining industry whereby the solvent fluid is heated at surface either in close proximity to the injection wellbore or at the processing plant.

Heat loss found in conventional surface solvent-heating systems caused by convection and heat
15 transfer between the hot solvent fluid and the typically cool ambient surface temperatures at the near surface wellbore regions can also be reduced. The heat energy lost to the formation during the dissolution of soluble minerals, such as evaporite minerals, may also be used to replaced as dissolution is typically an endothermic process.

20 Means for heating The mining solvent/solution within an injection and/or production wellbore can be heated with a variety of devices including, but are not limited to, mineral insulated heating cables, other heating cables, heating devices employing electromagnetic energy, heating devices employing radiofrequency energy, electric heating devices, or other types of heating or heat conduction systems that would be well suited for solution mining using a wellbore that has
25 at least one vertical section and preferably also a horizontal section.

The mining solvent can be heated just before entering the mining zone by using a mineral-insulated ("MI") cable such as those manufactured and described by MCAAA Ltd. (<http://www.mcaaa.eu>).

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MI cable can be used to heat the solvent near the mining zone so that heat loss can be controlled and reduced due to a more consistent geothermal temperature regime in the wellbore, at depth. In some embodiments, MI cable can be provided in 2,000 meter spools so that cable can be run as a continuous string into injector wells or production wells to augment, and take advantage of, the naturally occurring geothermal temperature at the mining depth, which should minimize the energy needed to keep the brine at an optimal temperature.

Controlled downhole heating through the use of the downhole heating means, such as a MI cable, can heat the injected mining solvent travelling down an injection wellbore until immediately before the solvent reaches the mining zone. In cases where both the injection and production wellbores are both being heated, heat may be transferred to the mining zone helping to ensure that the solvent brine is at, or above, the geothermal formation temperature so that the efficiency of the mineral dissolution process is maximized.

Soluble minerals or mineral compounds with the aid of a suitable solvent brine heated downhole can be mined with use of a heating means, such as a MI cable placed within the horizontal and/or vertical injection and/or production well as required. This can facilitate the recovery of chloric, nitric and sulphatic minerals, and particularly potassium chloride (potash) minerals such as sylvinite/sylvite or carnallite.

For conventional techniques that provide heating to the solvent brine only at the surface, the solvent brine is typically heated to temperatures well above the geothermal temperature of the mining zone to compensate for the anticipated conductive heat loss to be experienced by the solvent as it travels from the surface down to the mining zone. Similarly, fluids, such as mining solution, can experience heat loss as they are produced to the surface from the mining zone. This can be quite costly in colder climates like those found in Saskatchewan, Canada. Previous heating techniques also compensate for the anticipated heat loss caused by the dissolution processes, occurring in the mining zone, as these processes are typically endothermic when, for example, sylvite or carnallite minerals are dissolved.

The present process can be used to help reduce recrystallization of sylvite, carnallite, or sodium chloride in an injection/production wellbore and above-surface piping. Recrystallization of such minerals can reduce the flow of liquid fluids into and out of the mining zone. This is often caused by the cooling of a saturated or super-saturated mining solution as it is being withdrawn from the mining zone and transported to the processing facility. This unintended recrystallization can have a detrimental effect on the mining process by further cooling the brine and mining solution, restricting flow in dissolution cavities or the mining plane/zone, and causing crystal build-up and flow restrictions within the production and injection wells and production piping system.

10 Non-selective or selective solution mining can be carried out by a continuous injection of a heated solvent, such as water or brine, more particularly of a brackish to saline brine type, into a potash-bearing stratum. The amount of water or brine that is required to be injected and its capability to dissolve minerals from the host rock is dependent on the ratio of soluble minerals within the host rock, the naturally occurring geothermal temperature of the host rock, and the temperature of the injected water or brine. Downhole heating can be an efficient method to control the temperature of the injected water or brine thereby potentially increasing the efficiency of the dissolution process.

20 Following the principles of thermodynamics, the methods can involve running a MI cable with up to 2000 meters of continuous cable (i.e., no splices) into an injection wellbore so that once a certain temperature is achieved within the wellbore, the MI cable can easily maintain the temperature of a heated injected solvent or process brine so that the desired dissolution temperature is achieved and maintained within the mining zone. A MI cable downhole heating means can also be installed in the vertical and/or horizontal portions of a production well so that the mining solution produced from the mining zone through the production well is at an appropriate temperature before being piped to a refinery plant to reduce the risk or amount of recrystallization.

30 The injected mining solvent may be composed of a combination of fresh brine from deeper deposits and spent plant effluent. The ratio of the components forming the mining solvent may

be adjusted according to the prevailing ore ratio in the mineral bed to be mined. The heat content of the injected solvent may be determined by considering the relative proportions of the components used to form the injected solvent and their temperatures. The amount of downhole heating required to cause an injected solvent temperature to be at or greater than the geothermal formation temperature at the mining zone can then be determined based on the determined heat content of the injected solvent.

While the heat content of the process brine employed in most cases is equal to or higher than the geothermal temperature of the mining horizon, the heat content of a mixture with effluent may be either higher than, equal to, or lower than that of the mineral stratum to be mined. A downhole MI cable heater can be used to more consistently regulate the temperature of the mining solvent (composed, for example, of process brine and effluent) being injected from the injection wellbore into the mining zone and control the temperature of the mining solution as it is produced from the mining zone to the surface and sent to a refinery plant.

Brine, solvent or process water can be heated in the wellbore before being injected from the wellbore and into the mining zone containing the desired minerals to be solution-mined, such as desired evaporite minerals. This can be achieved by placing a MI cable into a coil tubing string or other suitable tubing string and allowing the MI cable to be inside the coil tubing string as it is inserted into a vertical or horizontal injection well to a desired location. Alternatively, a coil tubing sting or suitable tubing string may also be already run inside the well. In such cases, the MI cable may be pushed or pulled to the end of the wellbore with the assistance from an injected solvent.

The use of a coil tubing string can protect the MI cable from wear and tear as the cable is inserted inside a wellbore. A coil tubing string also allows for a MI cable to be safely placed inside either a generally vertical and/or generally horizontal portion of an injection and/or production well. The MI cable is allowed to increase in temperature thereby heating the solvent or solution inside the coil tubing string that has been inserted inside the injection or production well. The heated injected solvent inside the coil tubing string is allowed to be injected from the wellbore (through ports, perforations or other suitable means) into the mining zone.

A number of suitable arrangements for employing a coil tubing string within a well casing can be used. For example, a tubing string can be inserted inside a vertical wellbore casing and positioned above the perforations or frack ports on the casing which are positioned along the well casing portion that is inside the mining zone. The tubing string can be held in place with a packer or series of packers that also prevents the injected mining solvent from entering into the annulus between the tubing string and the casing. In some embodiments, a packer or series of packers may be employed on a horizontal wellbore for preventing the injected mining solvent from entering the annulus between the string and the casing, and instead ensuring that the mining solvent is injected directly into the mining zone through the injection ports on the casing. Such an arrangement may be employed with an injection control device as would be known to those skilled in the art.

The solvent that is heated can be derived from subterranean sources of naturally occurring brackish to saline water, refinery plant effluent brine, or mixtures thereof, that is derived mainly from:

- a subterranean source located close to the strata of the embedded soluble minerals,
- a subterranean source located under the strata of the embedded soluble minerals,
- a subterranean source located above the strata of the embedded soluble minerals, and
- a subterranean source located at or near the strata of the embedded soluble minerals, and is either a saturated or under-saturated salt solution or brine.

The solvent, such as mining solvent, can also be heated while being produced from a subterranean source (i.e., mining solvent source) such as, but not limited to, those described above.

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The voltage of the heating means, such as a MI cable, and the mining solvent injection rate can be adjusted to ensure that the desired temperature of the mining solvent is obtained. This solvent temperature may further be customized in the same way as previously described above.

5 In one aspect, the heated solvent can be injected through the mining zone to recover the desired minerals, such as potash (specifically the minerals that make up Potash), from the produced mineral solution and then repeating this procedure until the deposit is substantially exhausted. For example, a mineral selected from a group consisting of sylvite and carnallite can be recovered from subterranean deposits by injecting a solvent brine (i.e., mining solvent) into a
10 wellbore that may be initially heated geothermally and/or by artificial/mechanical means, and is (further) heated by a downhole heating means to a heat content equal to or higher than the naturally occurring heat of the mineral-bearing stratum. The solvent brine is then pumped (or injected) out through multiple injection points/ports along a wellbore while still being heated by the MI cable to ensure that all of the solvent brine exits the horizontal or vertical wellbore at
15 virtually the same temperature along the wellbore.

The injected solvent can be retained inside a mining zone for a time period required for the injected solvent to reach saturation of the desired minerals, and then recovering the saturated solution by means of production wells that are in fluid communication with the injection wells. A
20 MI cable can also be run into the entire producing well to heat the solution before recovery at surface.

Turning to Figure 1a, a first embodiment is illustrated. In this first arrangement, a MI cable 106 is employed for heating the injected mining solvent inside the injection wellbore, and more
25 specifically inside a coil tubing string 105 positioned inside a well casing 104 of an injection wellbore. The coil tubing string 105 is configured to allow the injected mining solvent to flow out the end of the string 105 and into the annulus between the string 104 and the casing 105. A packer or series of packers (not shown) may be employed to hold the injected mining solvent within the annulus that is within the mining zone.

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Other suitable arrangements for employing a coil tubing string within a well casing could be used. For example, a tubing string can be inserted inside a vertical wellbore casing and positioned above the perforations or frack ports on the casing which are positioned along the well casing portion that is inside the mining zone. The tubing string can be held in place with a packer or series of packers that also prevents the injected mining solvent from entering into the annulus between the tubing string and the casing (i.e., bullhead injection). In some embodiments, a packer or series of packers may be employed on a horizontal wellbore for preventing the injected mining solvent from entering the annulus between the string and the casing, and instead ensure that the mining solvent is injected directly into the mining zone through the injection ports on the casing (i.e., zonal isolation injection). Such an arrangement may be employed with an injection control device ("ICD"), as would be known to those skilled in the art.

A power supply transformer 101 is provided above surface in the vicinity of the vertical or horizontal wellbore. The power supply 101 is connected to a frequency supply device 102, which is connected to the wellhead 103 and a MI cable 106.

Power from the power transformer 101 is supplied to the frequency supply device 102 and converted to a frequency supply that is grounded by the wellhead 103 allowing the MI cable 106 to increase in temperature. The MI cable 106 increases to a temperature capable of heating the brine or water (i.e., the mining solvent) inside the coil tubing string 105, at the concentrated heating zone 108, to a temperature greater than the geothermal temperature of the mining zone.

The MI cable 106 shown is inserted into a coil tubing string 105 or equivalent, which is contained inside the wellbore casing 104. The coil tubing 105 may be run inside a wellbore comprising a limited entry injection system (not shown) or ICD (not shown), comprising a series of packers, to ensure that an even amount of brine or water is injected into the targeted mining zone through the injection ports 107 positioned along the wellbore casing 104. Such limited entry injection systems have been manufactured and sold by Packers Plus (<http://packersplus.com/>).

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As shown in Figure 1a, a concentrated heating zone 108 is created in the generally horizontal portion of the wellbore to heat up the brine or water contained within it to a temperature that is at or exceeds the targeted mining zone's geothermal temperature.

5 Turning to Figure 1b, a second embodiment is illustrated that is generally akin to that described with respect to the first arrangement. In this second arrangement, the heating zone 108 is created in both the generally vertical and horizontal portions of the wellbore.

As discussed above, the MI cable 106 can also be inserted into a vertical and/or horizontal
10 production well to heat the mining solution before it is recovered to the surface.

Turning to Figure 2, a third embodiment is illustrated. In this third arrangement, a MI cable 206 is employed for heating the mining solvent while inside a coil tubing string 205 positioned inside a well casing 204 of a production wellbore comprising an open-hole portion completion (i.e., no casing or cement) as shown in Figure 2. A packer may be employed to ensure that the mining
15 solvent and solution flows into the coil tubing string 205 when being produced and does not flow into the annulus between the tubing string 205 and well casing 204.

A power supply transformer 201 is provided above surface in the vicinity of the vertical or
20 horizontal wellbore. The power supply 201 is connected to a frequency supply device 202, which is connected to the wellhead 203 and a MI cable 206.

Power from the power transformer 201 is supplied to the frequency supply device 202 and converted to a frequency supply that is grounded by the wellhead 203 allowing the MI cable 206
25 to increase in temperature. The MI cable 206 increases to a temperature capable of heating the brine or water (i.e., the mining solvent) inside the coil tubing string 205, at the concentrated heating zone 208, to a temperature greater than the geothermal temperature of the mining horizon.

30 The MI cable 206 shown is inserted into a coil tubing string 205 or equivalent, which is contained inside the casing 204 of the wellbore.

As shown in Figure 2, a concentrated heating zone 208 is created in the generally vertical portions of the wellbore to heat up the brine, water and/or solution containing mined minerals contained within the wellbore to a temperature that is at or exceeding the targeted mining zone's geothermal temperature.

Turning to Figure 3, a fourth embodiment is illustrated that is generally akin to that described with respect to the other arrangements above, however, it employs microwave emitters as a heating means instead of a MI cable.

In the fourth embodiment, a microwave downhole heating system employs a radio frequency source 301 to provide microwave frequency energy to microwave emitters or antennas 305, positioned along a vertical and/or horizontal wellbore, within a fluid that allows RF energy to be emitted from the emitters 305. The radio frequency source 301 provides energy to the microwave emitters or antennas 305 causing radiation to be produced which subsequently produces heat to increase the temperature of the mining solvent inside the casing 303 of an adjacent well and the mining zone.

A coaxial cable 304 is provided, run inside the adjacent well, for repositioning where the energy travels. This can be advantageous when horizontal wells are employed. The coaxial cable 304 may also allow for changes in how the configuration of the energy is emitted and may assist in ensuring that the wellbore is being heated as desired. The coaxial cable 304 may further allow for heat to radiate out into the mining zone, allowing for further heating of the mining solvent once the solvent has been injected into the mining plane/zone.

A wellhead 302 is provided that acts as a ground and can be employed for controlling the flow of certain fluids into and out of the wellbore which may assist in maintaining a desired temperature inside the wellbore.

Unless the context clearly requires otherwise, throughout the description and the claims:

• “comprise”, “comprising”, and the like are to be construed in an inclusive sense, as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

• “connected”, “coupled”, or any variant thereof, means any connection or coupling, either direct or indirect, between two or more elements; the coupling or connection between the elements can
5 be physical, logical, or a combination thereof.

• “herein”, “above”, “below”, and words of similar import, when used to describe this specification shall refer to this specification as a whole and not to any particular portions of this specification.

• “or”, in reference to a list of two or more items, covers all of the following interpretations of
10 the word: any of the items in the list, all of the items in the list, and any combination of the items in the list.

• the singular forms “a”, “an” and “the” also include the meaning of any appropriate plural forms.

15 Words that indicate directions such as “vertical”, “transverse”, “horizontal”, “upward”, “downward”, “forward”, “backward”, “inward”, “outward”, “vertical”, “transverse”, “left”, “right”, “front”, “back”, “top”, “bottom”, “below”, “above”, “under”, and the like, used in this description and any accompanying claims (where present) depend on the specific orientation of the apparatus described and illustrated. The subject matter described herein may assume various
20 alternative orientations. Accordingly, these directional terms are not strictly defined and should not be interpreted narrowly.

Where a component (e.g. a circuit, module, assembly, device, drill string component, drill rig system etc.) is referred to herein, unless otherwise indicated, reference to that component
25 (including a reference to a “means”) should be interpreted as including as equivalents of that component any component which performs the function of the described component (i.e., that is functionally equivalent), including components which are not structurally equivalent to the disclosed structure which performs the function in the illustrated exemplary embodiments of the invention.

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Specific examples of methods and apparatus have been described herein for purposes of illustration. These are only examples. The technology provided herein can be applied to contexts other than the exemplary contexts described above. Many alterations, modifications, additions, omissions and permutations are possible within the practice of this invention. This invention
5 includes variations on described embodiments that would be apparent to the skilled person, including variations obtained by: replacing features, elements and/or acts with equivalent features, elements and/or acts; mixing and matching of features, elements and/or acts from different embodiments; combining features, elements and/or acts from embodiments as described herein with features, elements and/or acts of other technology; and/or omitting combining
10 features, elements and/or acts from described embodiments.

The foregoing is considered as illustrative only of the principles of the invention. The scope of the claims should not be limited by the exemplary embodiments set forth in the foregoing, but should be given the broadest interpretation consistent with the specification as a whole.

Claims

1. A method for mining soluble minerals from a subterranean deposit containing the soluble minerals, the method comprising the steps of:
 - a. providing an injection wellbore contacting the subterranean deposit;
 - b. providing heating means in the injection wellbore;
 - c. injecting a mining solvent into the injection wellbore;
 - d. allowing the heating means to heat the mining solvent while inside the injection wellbore to form a heated mining solvent;
 - e. allowing the heated mining solvent to enter into the subterranean deposit and dissolve a portion of the soluble minerals from the subterranean deposit, thereby forming a mineral solution comprising the heated mining solvent and the portion of the soluble minerals; and
 - f. producing the mineral solution to surface.
2. The method of claim 1 further comprising, before producing the mineral solution to the surface, the step of allowing the heating means to heat the mineral solution.
3. The method of claim 1 wherein the step of producing the mineral solution to surface comprises use of a production wellbore.
4. The method of claim 3 further comprising the step of providing a second heating means in the production wellbore to heat the mineral solution.
5. The method of claim 1 wherein the injection wellbore comprises at least one of: a vertical section; and a horizontal section.
6. The method of claim 5 wherein the step of allowing the heating means to heat the mining solvent occurs while inside the at least one of: a vertical section; and a horizontal section.

7. The method of claim 1 wherein the soluble minerals comprise potassium chloride.
8. The method of claim 1 wherein the subterranean deposit comprises potash.
9. A method for producing liquid fluid from a subterranean deposit containing soluble minerals, the method comprising the steps of:
 - a. providing a production wellbore contacting the deposit;
 - b. providing heating means in the production wellbore;
 - c. allowing the liquid fluid to flow into the production wellbore;
 - d. allowing the heating means to heat the liquid fluid while inside the production wellbore to form a heated fluid; and
 - e. producing the heated fluid to surface.
10. The method of claim 9 wherein the liquid fluid is a mining solution comprising mined soluble minerals from the subterranean deposit.
11. The method of claim 9 wherein the production wellbore comprises: at least one of: a vertical section; and a horizontal section.
12. The method of claim 11 wherein the step of allowing the heating means to heat the liquid fluid occurs while inside the at least one of: a vertical section; and a horizontal section.
13. The method of claim 9 wherein the soluble minerals comprise potassium chloride.
14. The method of claim 9 wherein the subterranean deposit comprises potash.

15. A method for mining soluble minerals from a subterranean deposit, the method comprising the steps of:

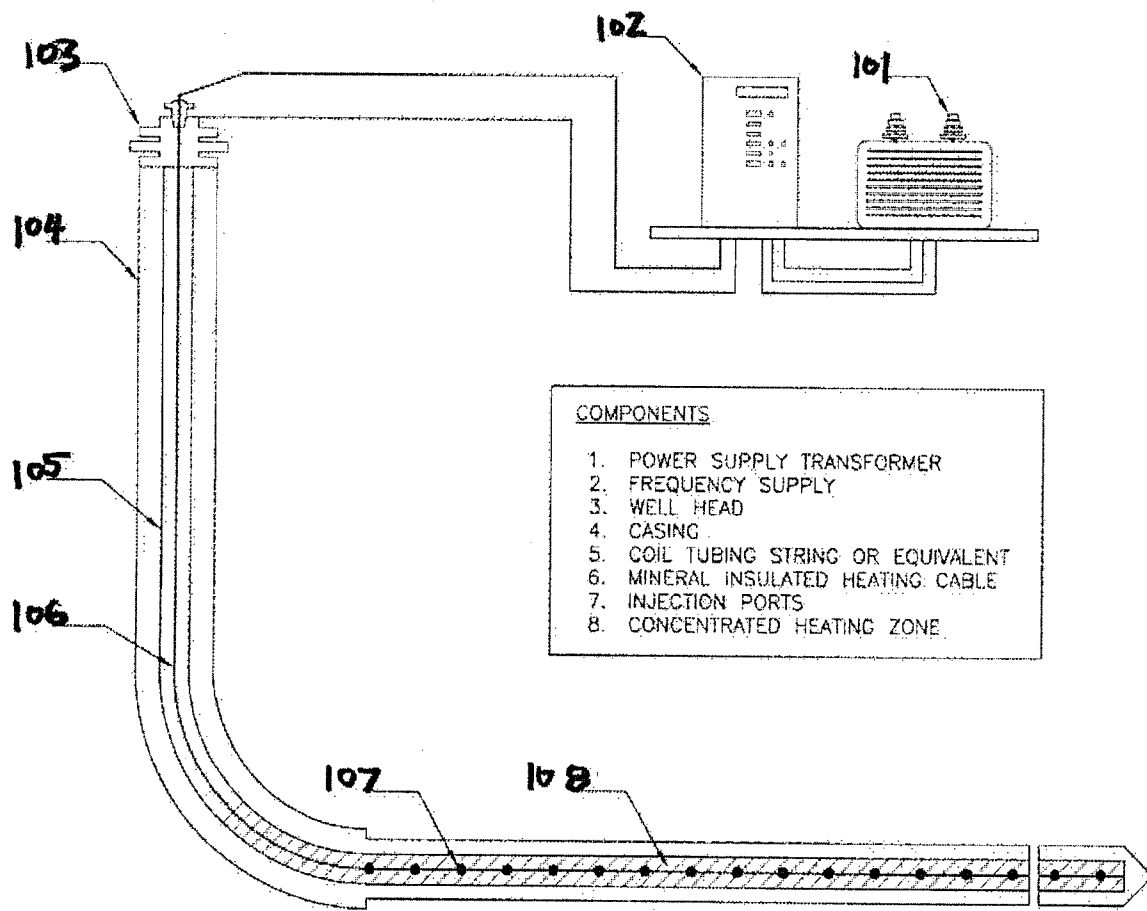
- a. providing an injection wellbore contacting the subterranean deposit;
- b. providing a production wellbore contacting the subterranean deposit;
- c. providing first heating means in the injection wellbore;
- d. providing second heating means in the production wellbore;
- e. injecting a mining solvent into the injection wellbore;
- f. allowing the first heating means to heat the mining solvent while inside the injection wellbore to form a heated mining solvent;
- g. allowing the heated mining solvent to enter into the subterranean deposit and dissolve a portion of the soluble minerals in the subterranean deposit, thereby forming a mineral solution comprising the heated mining solvent and the portion of the soluble minerals;
- h. allowing the mineral solution to flow into the production wellbore;
- i. allowing the second heating means to heat the mineral solution while inside the production wellbore to form a heated mineral solution; and
- j. producing the heated mineral solution to surface.

16. The method of claim 15 wherein the injection wellbore comprises: at least one of: a vertical section; and a horizontal section.

17. The method of claim 16 wherein the step of allowing the first heating means to heat the mining solvent occurs while inside at least one of: a vertical section; and a horizontal section of the injection wellbore.

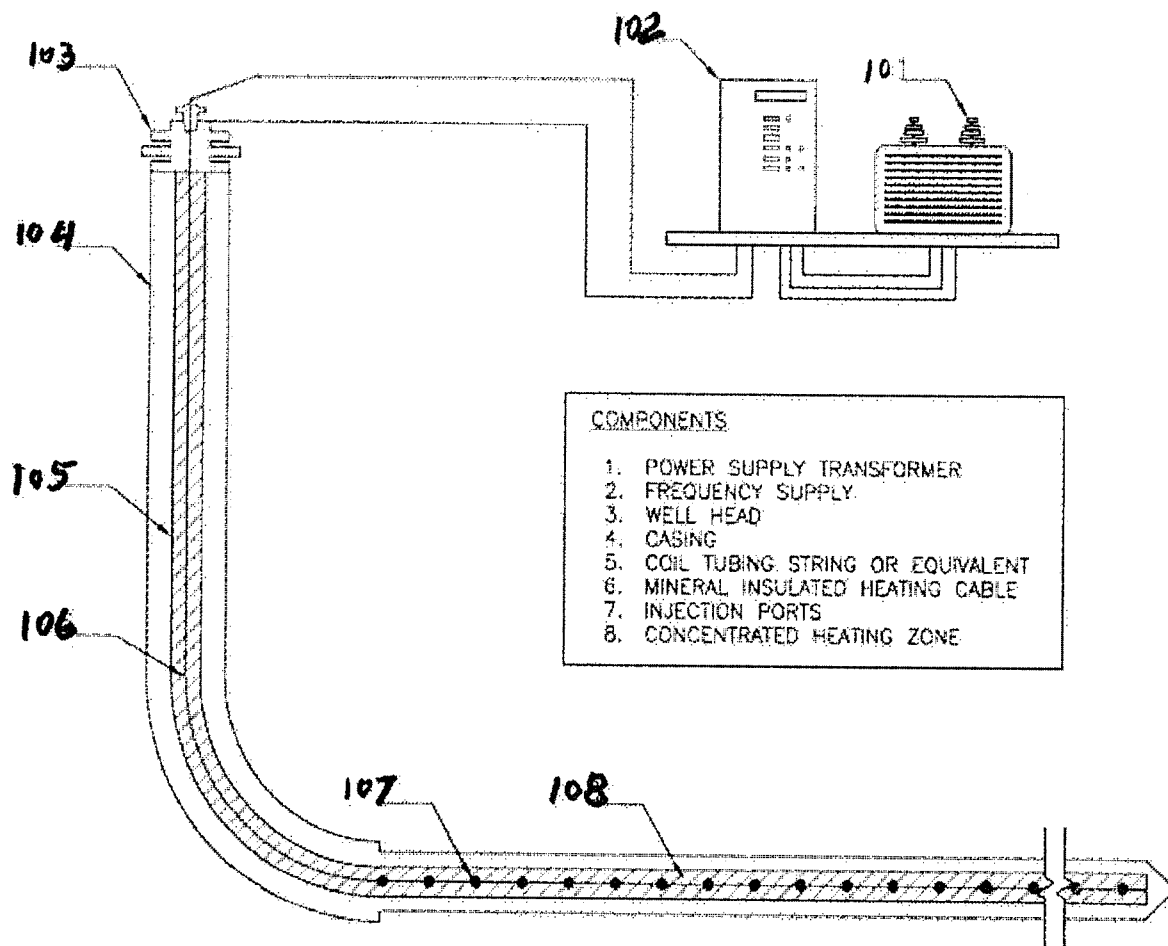
18. The method of claim 15 wherein the production wellbore comprises at least one of: a vertical section; and a horizontal section.

19. The method of claim 18 wherein the step of allowing the second heating means to heat the mineral solution occurs while inside the vertical section and/or the horizontal section of the production wellbore.
20. The method of claim 9 wherein the soluble minerals comprise potassium chloride.
21. The method of claim 9 wherein the subterranean deposit comprises potash.
22. A method for producing liquid fluid from a subterranean region containing the liquid fluid, the method comprising the steps of:
 - a. providing a production wellbore contacting the subterranean region;
 - b. providing heating means in the production wellbore;
 - c. allowing the liquid fluid to flow into the production wellbore;
 - d. allowing the heating means to heat the liquid fluid while inside the production wellbore to form a heated fluid; and
 - e. producing the heated fluid to surface.
23. The method of claim 22 wherein the fluid is a mining solvent comprising water.
24. The method of claim 22 wherein the production wellbore comprises: at least one of: a vertical section; and a horizontal section.
25. The method of claim 24 wherein the step of allowing the heating means to heat the liquid fluid occurs while inside at least one of: a vertical section; and a horizontal section.
26. The method of claim 22 wherein the soluble minerals comprise potassium chloride.
27. The method of claim 22 wherein the subterranean deposit comprises potash.



- COMPONENTS
1. POWER SUPPLY TRANSFORMER
 2. FREQUENCY SUPPLY
 3. WELL HEAD
 4. CASING
 5. COIL TUBING STRING OR EQUIVALENT
 6. MINERAL INSULATED HEATING CABLE
 7. INJECTION PORTS
 8. CONCENTRATED HEATING ZONE

Fig. 1a



- COMPONENTS
1. POWER SUPPLY TRANSFORMER
 2. FREQUENCY SUPPLY
 3. WELL HEAD
 4. CASING
 5. COIL TUBING STRING OR EQUIVALENT
 6. MINERAL INSULATED HEATING CABLE
 7. INJECTION PORTS
 8. CONCENTRATED HEATING ZONE

Fig 1b

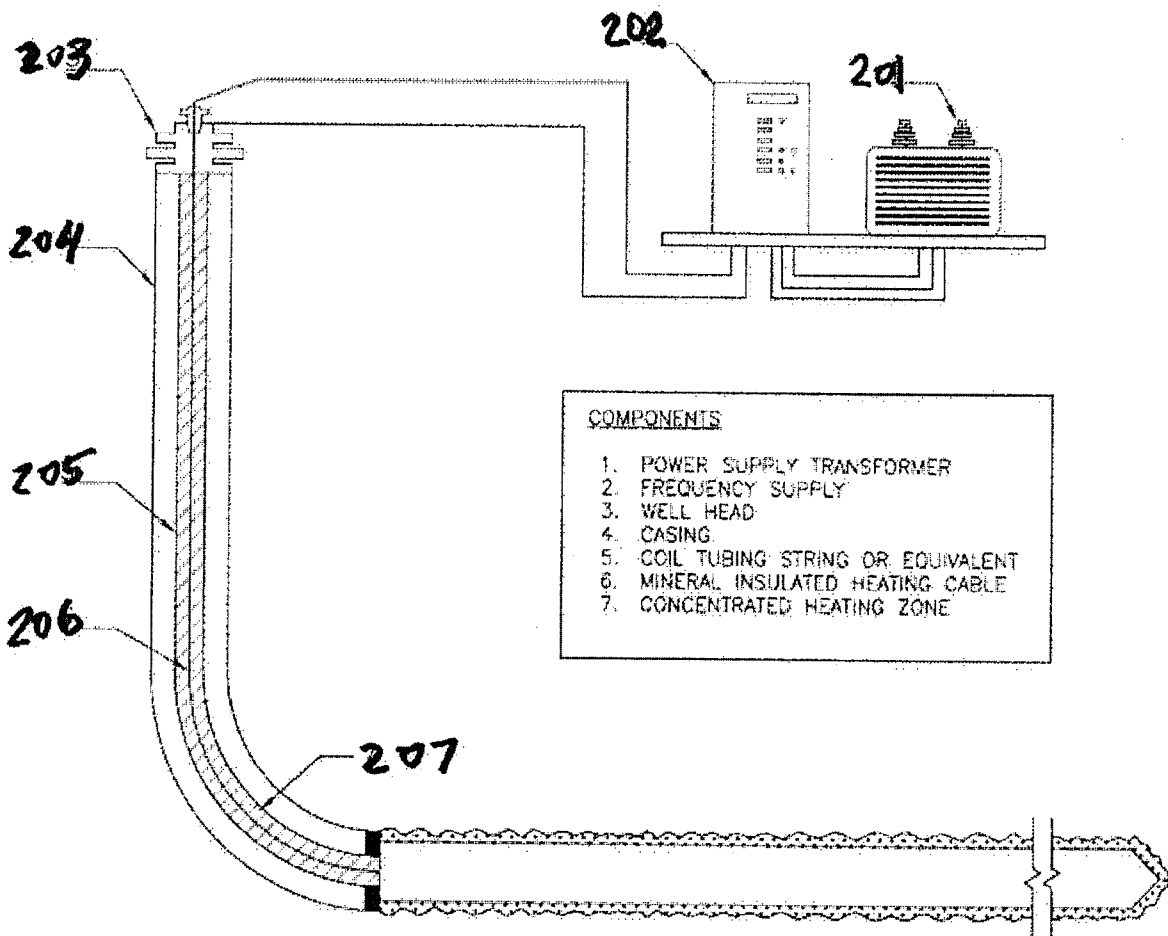


Fig 2

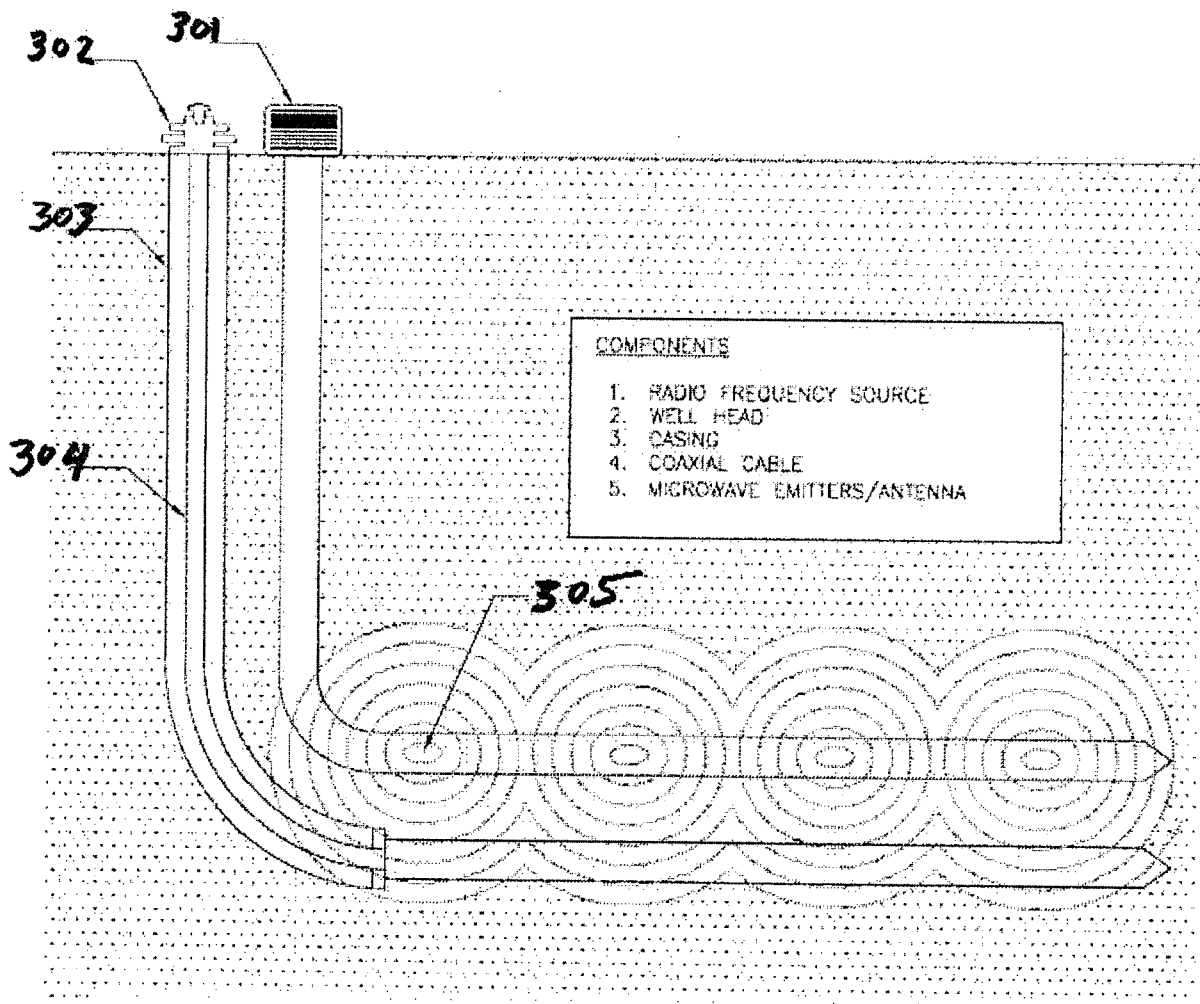
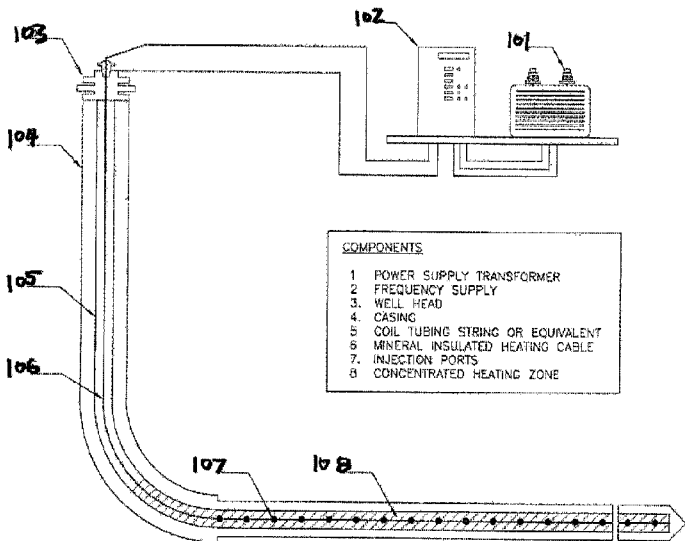


Fig. 3



COMPONENTS

- 1 POWER SUPPLY TRANSFORMER
- 2 FREQUENCY SUPPLY
3. WELL HEAD
4. CASING
- 5 COIL TUBING STRING OR EQUIVALENT
- 6 MINERAL INSULATED HEATING CABLE
7. INJECTION PORTS
- 8 CONCENTRATED HEATING ZONE