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W. A. HOYER ET AL

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SULFUR MINING USING HEATING BY ELECTROLYSIS

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FIG. 1.

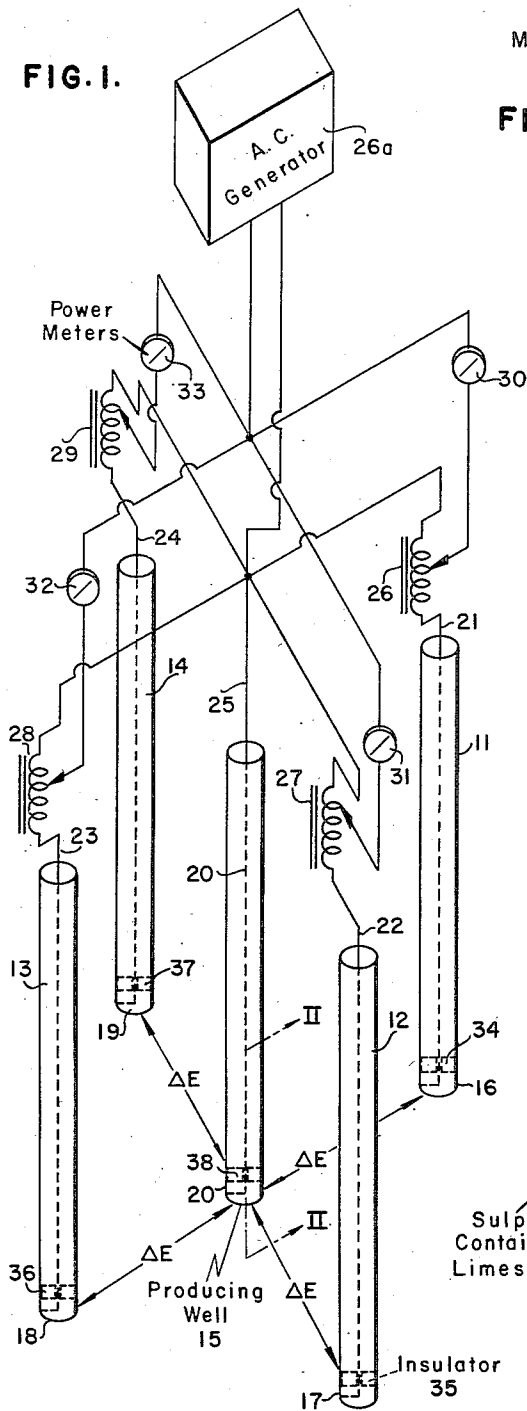
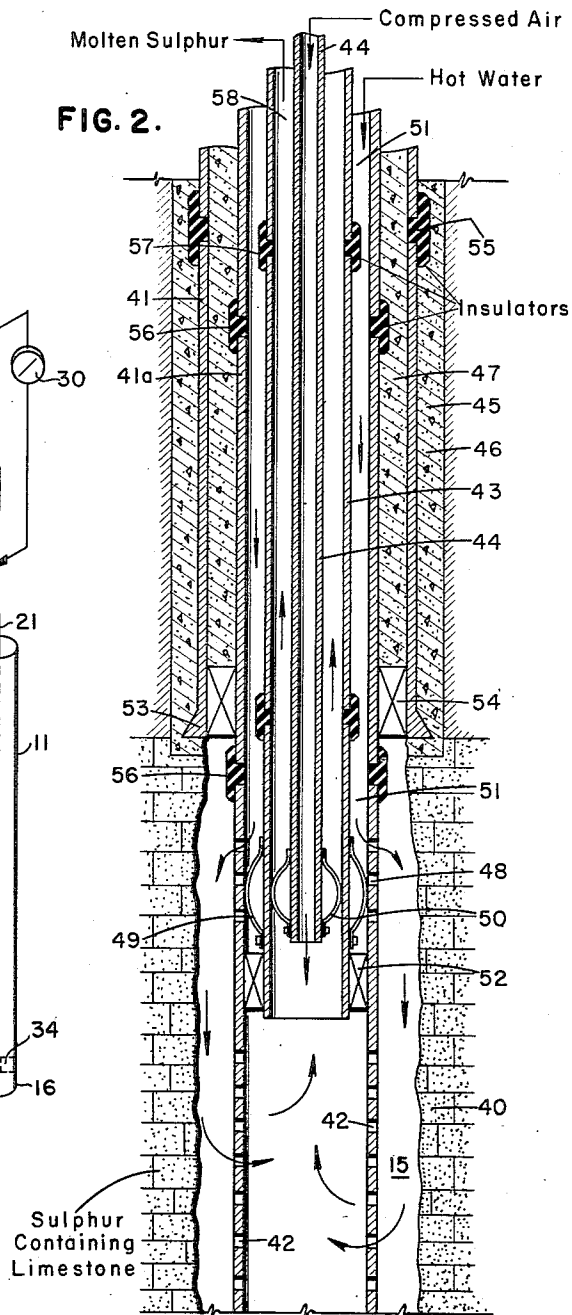


FIG. 2.



INVENTORS.

Wilmer A. Hoyer,
Millard S. Taggart Jr.,

BY

James B. McCallum

ATTORNEY.

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SULFUR MINING USING HEATING BY ELECTROLYSIS

Wilmer A. Hoyer, Bellaire, and Millard S. Taggart, Jr., Houston, Tex., assignors, by mesne assignments, to Ezzo Research and Engineering Company, Elizabeth, N. J., a corporation of Delaware

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The present invention is directed to the mining of liquefiable minerals contained in subsurface earth formations. More particularly, the invention is directed to sulfur mining by means of a well bore penetrating a sulfur-containing formation. In its more specific aspects, the invention is directed to the mining of sulfur without the use of large amounts of water.

The present invention will be briefly described as a method for producing liquefiable mineral from a subsurface earth formation containing the mineral and an aqueous electrolyte. In the practice of the present invention an electrode is placed in the formation in contact with the electrolyte and an electric current is then passed through the electrode and conducted through the electrolyte whereby the formation is heated by the electrical resistance of the electrolyte which causes the liquefiable mineral to be rendered fluid. The mineral is then flowed from the formation through a well penetrating the formation. The liquefiable mineral is sulfur or crude petroleum which may be too viscous to flow easily from the pores in the rock containing same.

The aqueous electrolyte employed in the practice of the present invention is either connate saline water which may be contained in the interstices of the formation or may be a saline water introduced from the surface of the earth where the electrical resistance of the connate water is insufficient to provide the amount of heat necessary to raise the temperature of the formation to render the mineral liquefiable.

In the practice of the present invention, it is contemplated that a plurality of wells, such as five wells, may be drilled to penetrate the formation. One of the wells surrounded by four of the wells may be used as the producing well with the potential of selected wells being controlled at substantially the same potential such that current flows from the producing well to the selected wells whereby the formation adjacent the producing well is heated to its maximum extent, the liquefied mineral being flowed from the producing well and, if desired, also from the selected wells.

In the practice of the present invention, it is contemplated, especially where the liquefied mineral is sulfur, that air or other gasiform material, such as inert gases and the like, may be introduced into the well to aid or assist in lifting the fluid or liquefied mineral.

In the practice of the present invention a plurality of pipes are arranged in the well with one of the pipes being employed as an electrode and other of the pipes being electrically insulated therefrom. To achieve this end, it may be desirable to cement a well casing in the bore hole employing an electrical resistant cementing material, such as a high density Portland cement and the like, or a plastic material, such as phenol-formaldehyde resin or urea-formaldehyde resin, and the like.

The several pipes which are arranged in the well are suitably insulated electrically above the point of contact at the lower end thereof with each other and with the

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electrolyte to prevent current flow up the well bore and the pipes.

The present invention will be further illustrated by reference to the drawings in which:

Fig. 1 shows a schematic arrangement of a plurality of wells surrounding a producing well and the electrical connections therefor; and

Fig. 2 is a view taken along the lines II—II of Fig. 1.

Referring now to the drawing, wherein identical numerals will be designated to designate identical parts, numerals 11, 12, 13 and 14 designate boreholes drilled in the earth's surface to penetrate a subsurface earth formation and numeral 15 designates a well which was drilled in the earth's surface to penetrate the same formation surrounded by wells 11, 12, 13, 14. The wells 11, 12, 13, 14 and 15 are each provided, respectively, with electrodes 16, 17, 18, 19, and 20 which suitably are pipes as will be described with respect to Fig. 2. The electrodes 16, 17, 18, 19, and 20 are each connected by electrical connecting means 21, 22, 23, 24, and 25 to a source of electrical energy indicated by an A. C. generator schematically shown by numeral 26a, the electrical connecting means 21, 22, 23, and 24 each containing a power equalizer therein designated by the numerals 26, 27, 28, and 29 for control of the electrical potential to the electrodes 16, 17, 18, and 19. The electrical connection means 21, 22, 23 and 24 also have power meters 30, 31, 32, and 33 in order to monitor the potential and the current being applied to the several electrodes.

It is to be noted that each of the wells 11, 12, 13, 14, and 15 are provided with insulators 34, 35, 36, 37, and 38.

Referring now to Fig. 2 the wellbore 15 penetrates a subsurface earth formation 40 which is illustrated schematically as a sulfur-bearing formation which also contains limestone. The wellbore 15 has a casing 41 arranged therein and a tubing 41a which is perforated in the formation 40 by perforations 42. Arranged within the tubing 41a is a pipe string 43 and arranged within the pipe string 43 is an inner pipe string 44. The casing 41 is cemented in the borehole 15 with a high density cement 45 which fills the annulus 46 between the casing 41 and the borehole 15 and also fills the annulus 47 between the casing 41 and the tubing 41a. The tubing 41a has, as indicated, perforations 42 and also is provided with upper perforations 48.

The pipes 43 and 44 are provided with electrical contact means 49 and 50, respectively, which suitably may be spring biased contact means to form an electrical contact between the pipe 44 and the pipe 43 and between the pipe 43 and the tubing 41a.

It is to be noted that the annulus 51 between the pipe 43 and the tubing 41a is closed in by a packing means 52 and further it is to be noted that the annulus 46 is closed in by a casing seat or other means 53 cooperating with the cement 45. Also the annulus 47 is closed in by a closure means 54 which serves to maintain the cement 47 in place until it has set.

The casing 41 is provided with a plurality of insulators 55 and the tubing 41a is also provided with a plurality of insulators 56. The pipe 43 also has a plurality of insulators 57.

The pipe 44 provides a conduit for introducing compressed air into the well while the annulus 58 between the pipes 43 and 44 serves as a passageway for molten sulfur.

The annulus 51 serves as a passageway for hot water which may be saline water introduced into the well bore 15 and the perforations 48.

In practicing the present invention, especially with reference to Fig. 1, a five-spot plan of wells is drilled in the earth's surface with the well 15 being the producing

well. The flow of current from the generator 26 is started and the potential is adjusted by the power equalizers so that the voltage drop is from the producing well 15 to the peripheral wells 11, 12, 13 and 14 which allows the formation 40 to be heated most adjacent the producing well 15. Thus electrical current is conducted from the center pipe 44 through the contact 50 to the pipe 43 and thence by the contact 49 to the tubing 41a which serves as an electrode. The wellbore 15 contains saline water which serves as an electrolyte and the formation 40 also contains saline water. Since the current is carried by the electrolyte and since the electrolyte has a higher resistance as compared to the metallic conductors, an appreciable amount of heat is produced in the formation. By continuing to apply the current to the system, as shown in Fig. 1, the formation 40 is heated to a point that the sulfur contained therein is liquefied and flows in the direction of the borehole 15 and is lifted to the surface by the air introduced through pipe 44.

At the beginning of the operation, hot water may be injected through the annulus 58 and the perforations 48 to aid in melting the sulfur in the formation 40. However, it may be desirable also to introduce saline water and force same into the formation to increase and/or decrease the electrical resistance of the water in the formation.

In the practice of the present invention, 100,000 kw. will yield a temperature rise in a 40 acre section 300 feet thick of 1° F. for every 9.8 days.

The present invention has great utility and advantages since it is no longer necessary to use hot water in the mining of sulfur since in the Frasch process molten sulfur must run countercurrent to the flow of water to reach the wellbore. In such operations, the sulfur may be forced ahead of the water and be lost. Also the prior art sulfur mining processes requiring large volumes of water raise the formation pressure to dangerous levels and require the drilling of expensive wells to bleed off the pressure. Such disadvantages are obviated in the practice of the present invention since the heat required to melt the sulfur is produced by passing the electric current through an appreciable horizontal section of the producing formation. In this connection, the wells may be spaced from about 100 to about 1500 feet apart and yet realize the advantages of the present invention.

The present invention has numerous advantages over the prior art processes in that the heat by the electrical resistance of the electrolyte is introduced only into the ore body and large bodies of hot water are not required and, therefore, will not be lost into distant parts of the caprock. Also the molten sulfur may flow to the well without interference of a countercurrent flow of hot water. In the practice of the present invention, formation pressures are not raised to dangerous levels and also auxiliary wells to bleed off pressure are not required. The present invention is, therefore, quite useful.

In the present invention formation pressure may be maintained by injecting water, which may be hot water, to aid in the liquefaction of the liquefiable mineral. Since the electric current around the wellbore is conducted primarily by the saline formation water, relatively more heat may be generated in the less porous fresh formation ore than in the highly porous depleted rock due to the electrical resistance of the dispersed water. Therefore, once the rock has been depleted of its mineral, the heating will take place in the mineral-containing rock by the electrical resistance of the water therein.

While the present invention has been described primarily with respect to the production of sulfur, it is equally applicable to the production of crude oil where-

in viscous bodies of crude petroleum are contained in rock and the like.

The nature and objects of the present invention having been completely described and illustrated, what we wish to claim as new and useful and to secure by Letters Patent is:

1. A method for producing a liquefiable mineral from a subsurface earth formation containing said mineral and an aqueous electrolyte which comprises drilling a well to penetrate said formation, placing an electrically insulated pipe in said well, placing a plurality of electrodes in said formation surrounding said well and in contact with said electrolyte, passing an electric current through said electrodes and the insulated pipe and conducting said current through said electrolyte, the input current to selected of said electrodes surrounding said well and to said insulated pipe being controlled such that current flow is from the well to said selected electrodes, whereby said formation is heated to its maximum extent adjacent the well by the electrical resistance of said electrolyte and said mineral is rendered fluid, and then flowing said mineral from said formation through said well penetrating the formation.

2. A method in accordance with claim 1 in which the mineral is sulfur.

3. A method in accordance with claim 1 in which the mineral is crude petroleum.

4. A method in accordance with claim 1 in which the aqueous electrolyte is connate saline water.

5. A method in accordance with claim 1 in which the aqueous electrolyte is saline water introduced into the formation.

6. A method for producing a liquefiable mineral from a subsurface earth formation containing said mineral and an aqueous electrolyte which comprises drilling a plurality of wells to penetrate said formation, placing an electrically insulated pipe in each of said wells in contact with said electrolyte, passing an electric current through said pipes and conducting said current through said electrolyte, the input current to selected of said wells surrounding a producing well being controlled at substantially the same potential such that current flow is from the producing well to said selected wells whereby the formation is heated to its maximum extent adjacent the producing well by the electrical resistance of said electrolyte and said mineral is rendered fluid, and then flowing said mineral from said formation at least through said producing well.

7. A method in accordance with claim 6 in which a gasiform medium under pressure is injected into at least said producing well to assist in lifting the fluid mineral.

8. A method in accordance with claim 6 in which the mineral is sulfur.

9. A method in accordance with claim 6 in which the mineral is crude petroleum.

10. A method in accordance with claim 6 in which saline water is introduced into said formation to provide said electrolyte.

11. A method in accordance with claim 6 in which a casing is cemented into each of said wells, prior to placing said pipes, with an electrical resistant cementing material.

12. A method in accordance with claim 6 in which the aqueous electrolyte is connate saline water.

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