(No Model.) 3 Sheets—Sheet 1.

# H. FRASCH.

## APPARATUS FOR MINING SULPHUR.

No. 461,430. Patented Oct. 20, 1891.

FIG.I.

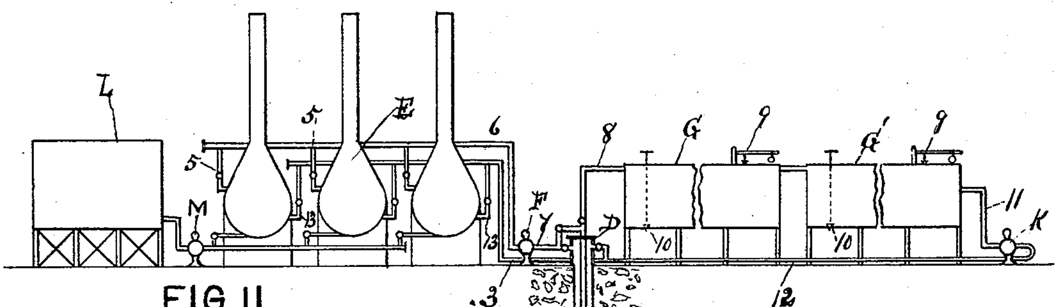



FIG.II.

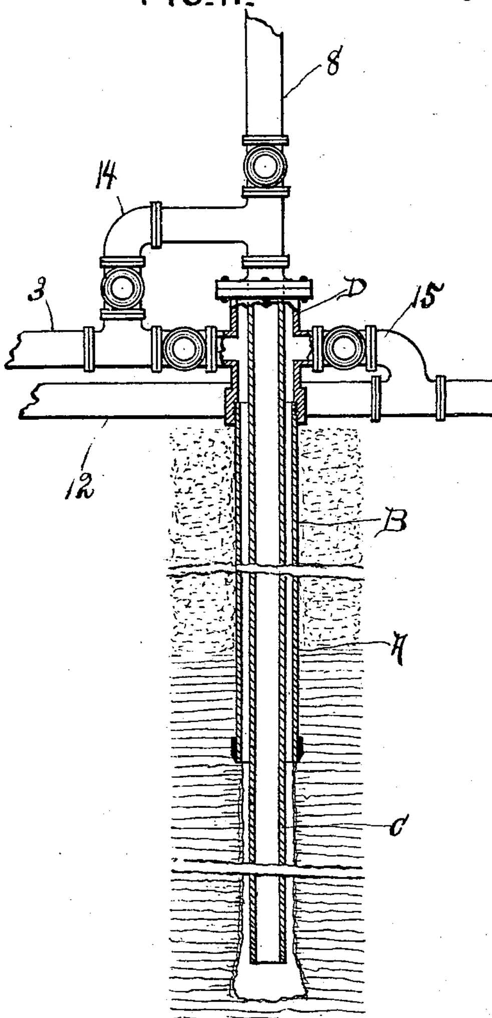
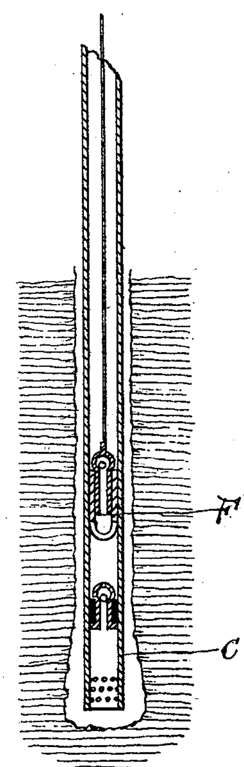



FIG.III.

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(No Model.)

3 Sheets—Sheet 2.

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## APPARATUS FOR MINING SULPHUR.

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FIG. V.

FIG. IV.

FIG. VI.

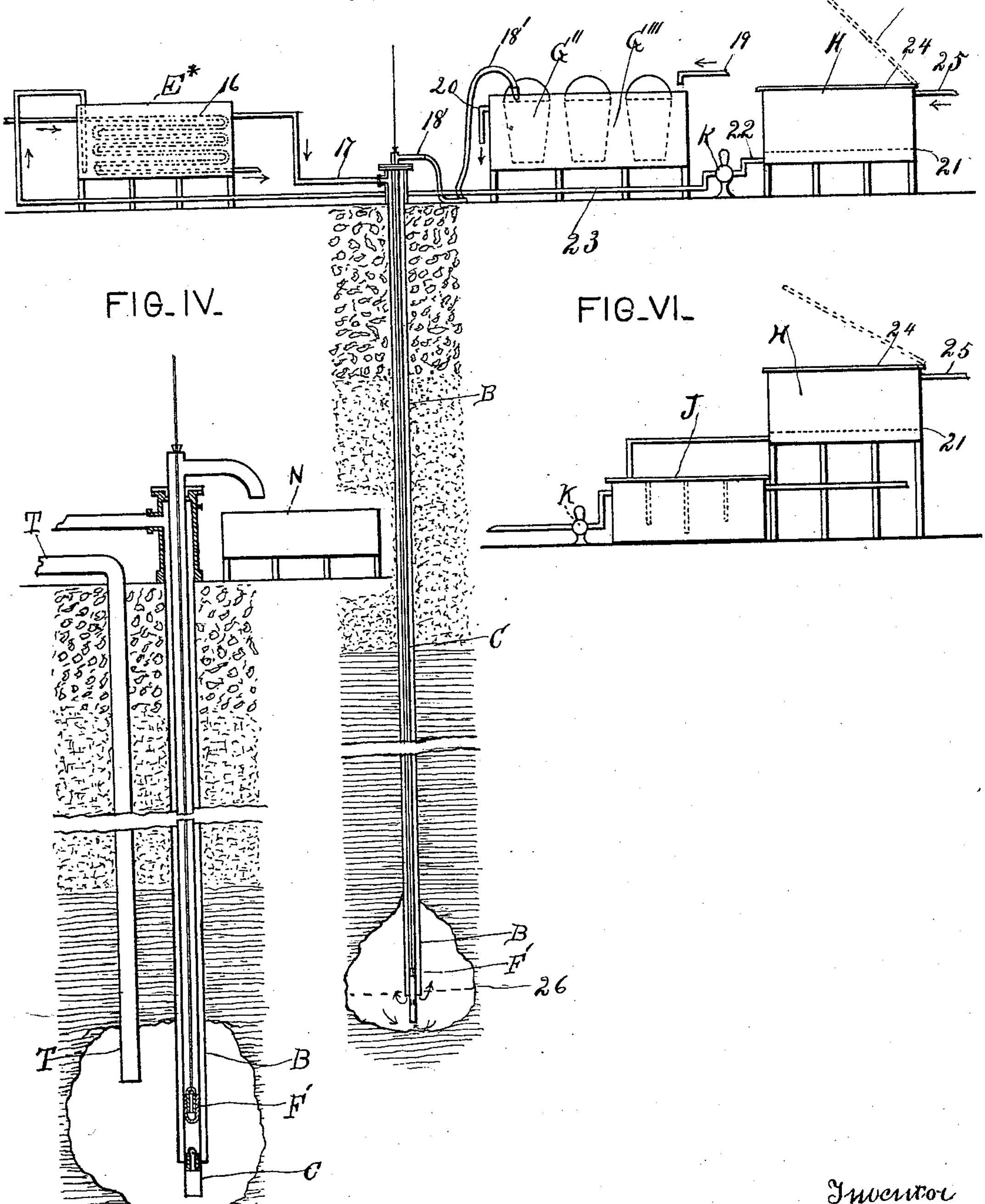


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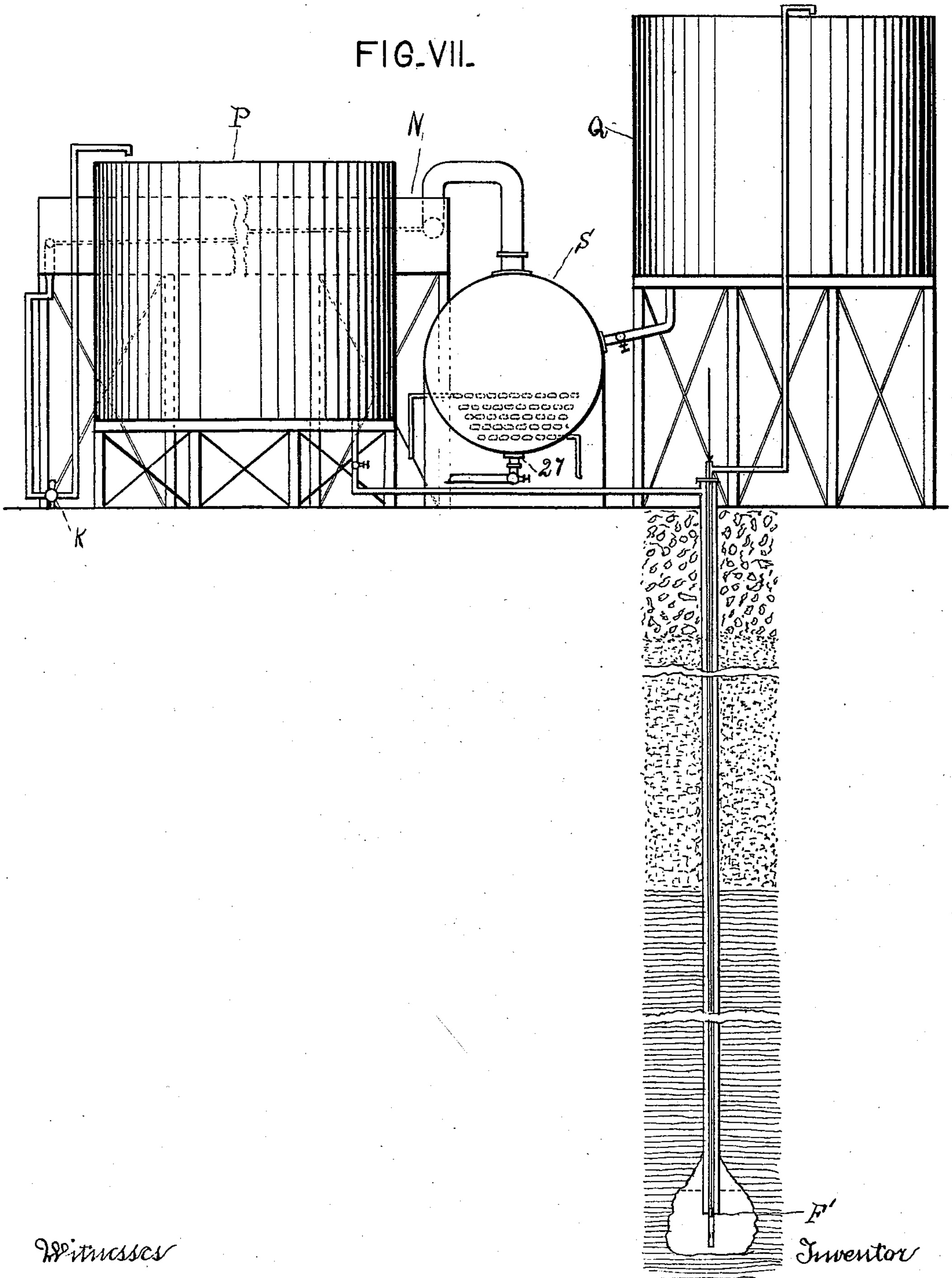
FIG. VII.

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# UNITED STATES PATENT OFFICE.

HERMAN FRASCH, OF CLEVELAND, OHIO.

## APPARATUS FOR MINING SULPHUR.

SPECIFICATION forming part of Letters Patent No. 461,430, dated October 20, 1891.

Application filed December 26, 1890. Serial No. 375,799. (No model.)

*To all whom it may concern:*

Be it known that I, HERMAN FRASCH, a citizen of the United States, residing at Cleveland, in the county of Cuyahoga and State of Ohio, have invented certain new and useful Improvements in Apparatus for Mining Sulphur, of which the following specification is a full, clear, and exact description.

This invention relates to the removal of sulphur from deposits or mines in the earth which consist of or contain free sulphur, and is particularly useful in the removal of the sulphur from deposits which are overlaid with beds of quicksand, and which therefore cannot be mined in the usual way by sinking a shaft; but each of the improvements constituting said invention is included for all the uses to which it may be adapted. By means of the present invention, moreover, a refining of the sulphur is effected in the mining operation.

The present invention consists in apparatus whereby the removal of the sulphur from the mine or underground deposit in a liquefied state is effected or facilitated.

In accordance with the said invention a well is sunk into or through the underground sulphur deposit or mine, and a pump or other known or suitable means of forcing circulating or elevating liquids is employed to remove the liquefied sulphur or the liquefied sulphur and vehicle by which it is liquefied. Heaters are also used for raising the temperature of the liquefying-vehicle; also vessels for recovering the sulphur after it has been removed in a liquid state, together with other appliances, as hereinafter set forth.

In the accompanying drawings, which form part of this specification, Figure I is a diagram of a plant for mining sulphur in accordance with the invention. Fig. II is an enlarged diagram of the well. Fig. III is a view illustrating a modified arrangement of part of the apparatus. Fig. IV is a view illustrating a further modification. Figs. V and VII are each a diagram of a plant for mining the sulphur by means of a solvent vehicle, the form of the apparatus exhibited in Fig. I being especially adapted for use with a fusing-vehicle; and Fig. VI is a view of a modified arrangement of part of the apparatus of Fig. V.

Referring to Figs. I and II, a well A is drilled, as usual, in making salt and oil wells, a casing B (say ten inches in diameter) being brought to the rock above the sulphur, so as to shut off water and quicksand, and a smaller hole (say eight inches in diameter) being continued into or to the bottom of the sulphur deposit. Tubing C (say five inches in diameter) is introduced through the sulphur and sulphur-bearing rock nearly to the bottom of the well. The lower part of this tube may be provided with perforations at the side, or may otherwise be provided with a strainer, or it may be left more or less open. There are thus two passages opening at the bottom into the underground deposit. At the surface there is a casing-head D, having a lateral tube 3. The tubing C extends through the casing-head D. At E are boilers or hot-water heaters, which may be used to heat water under pressure to a suitable temperature to melt the sulphur when forced into the mine at the bottom of the well. A temperature of from 270° to 280° Fahrenheit, which requires a pressure of about thirty pounds to thirty-five pounds per square inch, will suffice with an appropriate flow. The water-spaces of the heaters are connected by branches 5 and a main 6 with the inlet of a force-pump F, whose outlet is connected by a pipe 7 with the tube 3 of the casing-head D. The pump has sufficient capacity to force a stream of water through the downflow-passage, consisting of the casing B and the hole in continuation thereof, and through the upflow-passage of the tubing C with less loss in temperature than will bring the water down to the melting-point of sulphur—say with a loss of about 35° Fahrenheit, supposing the water to enter the casing at a temperature of 280° Fahrenheit. The flow of the water and its temperature should be such that in the sulphur or sulphur-bearing rock and in passing up through the tubing C it remains at a temperature at which the sulphur is liquid. The pipe 8 forms a continuation of the tubing C to the sulphur-recovering vessels in the form of settlers, of which a series G G′ is shown, each settler or settling-tank being closed and provided with a safety-valve 9, loaded to, say, sixty-five pounds per square inch, and also with a draw-off 10 at the bottom of the sulphur. From the last settler a pipe 11 connects with the boiler-feed pump K, which discharges through the main 12 and branches 13 into the heaters E, or the last settler may be connected directly with the heaters, the duty of feeding the boilers or heaters being thrown upon the force-pump F. It will thus be seen that there is a closed circuit, which includes a chamber in the sulphur or sulphur-bearing rock and through which water at a temperature sufficient to fuse the sulphur is forced. This water imparts heat to the walls of the said chamber, melting the sulphur, which flows to the deepest portion of the well, where it collects and whence it is forced with the water through the tubing C and pipe 8 to the settlers G G′. In these it separates by reason of its greater specific gravity, and when a quantity has settled out it is drawn off in a liquid state by the draw-offs 10. The water from the settlers G G′ is pumped again while still hot into the heaters E, to be therein reheated or raised to its original temperature, and to be thence sent again into the well by the force-pump F. As the chamber in the sulphur deposit at the bottom of the well enlarges the quantity of water must be increased. The additional supply is drawn from the tank L, wherein it is kept at or near boiling temperature (212° Fahrenheit) and whence it is fed to the heaters by the feed-pump M to maintain the level in the said boilers.

The high specific heat of water and the small amount of heat made latent by the melting of sulphur make water specially desirable as a vehicle to carry the heat for fusion of the sulphur, while the pressure of the pump furnishes the cheapest and most ready means of elevating the melted sulphur to the surface of the rock. In operating with a current of hot water the circulation may be of, say, three hundred barrels per hour. This amount of water at 280° Fahrenheit should furnish to the settlers G G′ about one hundred barrels of melted sulphur and two hundred barrels of water at 235° Fahrenheit, while one hundred barrels of the water would remain in the well in place of the sulphur removed therefrom in its melted condition. One hundred barrels of water should therefore be supplied to the boilers from the supply-tank L.

The pipe 7 from the force-pump F is connected by a branch 14 with the tubing C, so that the hot water may be forced down said tubing, if desired, in order to melt the sulphur in the mine. There is also a branch pipe 15 between the casing-head D and the main 12, so that the water which is expelled from the mine through the casing B may pass directly into the heaters E. These branch pipes have stop-cocks, as have also the pipes 7 and 8. This arrangement enables the water to be forced into the mine through either the casing B or the tubing C. One use of this arrangement is that in case the temperature should become so low in the well that the sulphur does not melt rapidly enough water of a higher temperature—say 300° Fahrenheit or over—may be pumped down the tubing C, and this water on its escape at the bottom of the well and during its ascent to and through the casing heats the mass and raises the average temperature. When this has reached the desired degree, the hot water, of, say, 280° Fahrenheit, is forced again down the casing B and sulphur is forced up the tubing C. By not allowing the temperature at the outlet of the tubing C to fall below 235° or 240° Fahrenheit the process may be continued as long as the water is supplied.

Instead of relying upon the pump F to force the melted sulphur and hot water up the tubing C, a pump F′ at the bottom of the well in the tubing C may be employed, as shown in Fig. III. By the use of this latter pumping arrangement it is not necessary to fill the cavity in the mine with hot water in order to remove the melted sulphur, since it can be raised by the pump in the tubing C. The mine might be filled with hot water, and after a quantity of sulphur had melted this could then be removed by the pump F′, thus making the operation of melting the sulphur and removing it periodical. The pump F′ is formed by a working barrel at the bottom of the well and a plunger operated by a sucker-rod with valves such as are commonly used in oil-wells where a similar arrangement of pump is employed. Instead of having casing B terminate at the rock above the sulphur, it may be extended into the mine and form a conduit for the introduction of the hot water.

Instead of employing hot water as a vehicle to fuse the sulphur in the mine, saline solutions of such concentration as to have suitable boiling-point above 235° Fahrenheit could be used with apparatus such as above described. Steam superheated or maintained under appropriate pressure, or other fluid, liquid, or gases adapted to be circulated at an appropriate temperature, could also be used.

In Fig. IV there is a third passage or pipe T extending into the mine, through which the hot water (or other fusing-vehicle) pumped down the casing B may be allowed to escape after having first melted the sulphur in the mine. The melted sulphur collects about the end of the tubing C, through which it is raised by the pump F′. Of course it could be forced up by the pressure in the mine by checking the outflow from the pipe T. The pipe T is (or may be) connected with the heaters E. The melted sulphur from the tubing C may be discharged into any convenient receiver—as, for example, a vessel N—kept full or partially full of cold water, so as to solidify the sulphur as it is run into the water. The sulphur settles to the bottom and the water runs off.

With the apparatus of Figs. I and II, after hot water of any appropriate temperature has been forced down the tubing C and out of the casing B long enough to melt a supply of sulphur, the melted sulphur, which will on reversing the circulation be forced up the tubing C, can be received in a vessel of water, as N, Fig. IV, or in any appropriate receiver.

Referring to Fig. V, the casing B extends nearly to the bottom of the tubing C, and the pump F′ is placed at the lower end of the said tubing, as in Fig. IV. At E* is a heater with steam-pipes 16 for raising the temperature of the solvent which is to be introduced into the mine. A pipe 17 conducts the hot fluid from the heater E*, and discharges it into the mine through the casing B. A feeding-pump could be interposed in this pipe, (like the pump F, Fig. I,) instead of the solvent being allowed to run from the heater into the mine by gravity alone. The lateral pipe 18, forming a continuation of the tubing C, delivers the sulphur solution into vessels for recovering the sulphur. These vessels, as shown, are coolers G″, in the form of large frusto-conical buckets, which are set in a vat G‴, supplied with cooling medium, as cold water entering by pipe 19 and escaping by pipe 20. The pipe 18 is supplied with a flexible hose 18′, such as used for oil, (petroleum,) by which the sulphur solution can be run into any cooler G″ in the vat G‴. At H is a strainer for drawing off the solvent from the sulphur which has been separated by cooling in the buckets G″. It consists of a vessel having a perforated false bottom 21, which is covered with a cloth. A pipe 22 connects the space under the false bottom with the inlet of a pump K, whose outlet is connected by the pipe 23 with the heater E*. The straining-vessel H has a close-fitting removable cover 24, and a pipe 25 enters just below said cover for admitting into the said vessel a fluid for removing the last traces of solvent from the sulphur.

In order to use the apparatus just described, the heater E* may be filled with petroleum distillate of, say, 36° Baumé, which is then heated to, say, 250° Fahrenheit, at which temperature it is capable of dissolving one hundred per cent. of sulphur. When this oil has been raised to the proper degree of heat, it is introduced through the casing B into the bottom of the well. There it comes in contact with the sulphur or sulphur-containing walls of the cavity, which it dissolves, forming a sulphur solution. This solution is pumped up by means of the pump F′ and discharged through the tubing C and pipe 18 into one or other of the vessels G″. Here it is allowed to cool and deposit the sulphur. At 60° Fahrenheit the oil will contain about four per cent. of sulphur. When this temperature is reached, the buckets G″ are emptied into the strainer H. This oil, lightly charged with sulphur, passes through the false bottom 21 and is returned by the pump K into the heater E*. When its temperature has been raised, it is again introduced into the well. As the cavity in the mine increases it is not necessary to increase the quantity of solvent used, since the solvent may be allowed to only partially fill the cavity, as indicated by the dotted line 26. By introducing the hot solvent at or near the bottom of the cavity it naturally rises as soon as it escapes from the casing B and creates a circulation, which flows over and comes in contact with the sulphur, dissolving the same, so that it can be pumped out in a liquid condition. It is evident that the hot solvent could be introduced considerably above the bottom of the tubing C or at the upper part of the cavity in the mine. The solvent can be introduced continuously at the same time that the sulphur solution is pumped out, thus making a continuous operation, or the solvent can be introduced, allowed to stand, and then the sulphur solution be pumped out. Instead of raising the oil to the temperature indicated, it may be raised to a less temperature or to a higher temperature. The cooling also might be to a temperature other than 60° Fahrenheit. It is possible, also, to employ it in a cold state; but this is not considered advantageous. The portion of the solvent which adheres can be removed by washing the sulphur with a volatile solvent of the oil, like bisulphide of carbon or benzine. The cover 24 can be closed when this is effected, the solvent being introduced through the pipe 25. It passes with the heavy oil through the false bottom 21 and may be allowed to pass through the pump K into the heater E*. Only a small quantity is required. When the sulphur is removed from the straining-vessel H, any of the light solvent which may adhere passes off as vapor.

Instead of using a light solvent to wash off the heavy oil, this may be effected by the introduction of steam into the vessel H through the pipe 25. To separate the water of condensation from the oil, a separator or trap J, Fig. VI, may be inserted between the vessel H and the pump K. This is a common appliance in oil-refineries and needs no description here.

Instead of employing "petroleum-gas oil," as the product above mentioned is called, aniline or phenol might be used or other appropriate solvent.

Instead of raising the solution of sulphur by means of a pump at the bottom of the well, a pump which discharges the solvent from the heater E* into the casing B may be utilized for that purpose by introducing enough solvent or other fluid to fill the cavity in the mine. By introducing the casing B into the cavity—say to the dotted line 26—air can be pumped in to fill the space (or part of the space) above the end of the casing, thus confining the solvent to the lower part of the cavity.

Instead of using a solvent non-volatile at the melting-point of sulphur, like petroleum-gas oil, aniline, or phenol, a volatile sulphur solvent, like benzol, (coal-naphtha,) benzine, (petroleum-naphtha,) or bisulphide of carbon may be used. This would preferably be employed in the cold state, but may be heated. It can be introduced into the mine through the casing B either at the top or bottom of the cavity, and when it has become saturated or charged with sulphur is removed by the pump F′ (see Fig. VII) and discharged into a suitable steam-heated still S, in which the solvent is evaporated from the sulphur. The temperature at the bottom of the still is preferably sufficient to melt the sulphur, so that it can be drawn off at 27 in a liquid state. The evaporated solvent is recovered in a condenser N, and is reused for the liquefying of the sulphur in the mine. As shown, the pump K discharges the condensed solvent into the tank P, from which it flows into the well or mine, and the sulphur solution from the mine is discharged into tank Q, from which it is drawn into still S. The volatile solvent could be made to fill the cavity in the mine; but preferably it would be introduced so as to only partially fill the same, as described, for the non-volatile solvent. It can be forced into and out of said cavity by a pump at the surface of the ground, as exhibited in Fig. I.

It will be understood that the various forms of apparatus described or suggested are all within the invention. In each of the forms it will be perceived that there is a well extending into (part way or it might be wholly through) an underground sulphur deposit, in connection with vessels from which a sulphur-liquefying vehicle or fluid adapted to liquefy sulphur by fusion or by solution may be introduced into the mine, and also with a pump for raising the liquefied sulphur, and with sulphur-receiving vessels for receiving the sulphur raised from the mine and, if necessary, separating it from the liquefying-vehicle. Moreover, in the apparatus of Figs. I and V one or more heaters are shown combined with the sulphur-well, so as to raise the temperature therein, and the still S of Fig. VII may also serve as a heater, provided the vapors when condensed are not so cooled but that they otherwise retain heat imparted in said still, and a separate heater could of course be placed between the tank and the casing B, a pump being used or not, as may be necessary or desirable. In both Figs. I and VII closed vessels are provided for recovering the sulphur—namely, the settlers G G′ of Fig. I and the still and condenser of Fig. VII. In Figs. I, V, and VII conduits or connections are shown for returning the vehicle to the mine. In Figs. I, II, IV, V, and VII this well is shown as closed, so as to allow the production of pressure therein. This pressure may have one or more of the following objects, namely: to prevent the vaporization of the sulphur-liquefying vehicle in case a volatile liquid is used as such vehicle, to enable a higher degree of heat to be imparted to the water or other volatile liquid or a vapor or gas in the mine, or to force the vehicle or sulphur, or both, to the surface of the ground.

It will further be understood that the use, in place of a pump or pumps and other appliances described, of a known or appropriate substitute is within the invention—as, for example, the use of other fluid-moving means, as a column of liquid in place of a pump—and is covered in the claims hereinafter written by the mention of said appliances without further specification herein.

I do not herein claim any process or processes herein described, but reserve the same to concurrent applications. I have heretofore filed two such applications—namely, Serial No. 369,072, filed October 23, 1890, and Serial No. 375,800, filed December 26, 1890—which describe but do not claim apparatus illustrated in the drawings hereof.

I claim as my invention or discovery—

1. A sulphur-mining well comprising a well extending into an underground sulphur-mine and adapted for the introduction of a sulphur-liquefying vehicle into the said mine and provided with a pump for raising the liquefied sulphur, substantially as described.

2. A sulphur-mining well extending into an underground sulphur-mine and adapted for the introduction of a sulphur-liquefying vehicle into the said mine and provided with a pump for raising the liquefied sulphur, in combination with a vessel, as described, for supplying to the mine a sulphur-liquefying vehicle, substantially as set forth.

3. A sulphur-mining well extending into an underground sulphur-mine and adapted for the introduction of a sulphur-liquefying vehicle into the said mine and provided with a pump for raising the liquefied sulphur, in combination with a sulphur-receiver, substantially as described.

4. A sulphur-mining well extending into an underground sulphur-mine and adapted for the introduction of a sulphur-liquefying vehicle into the said mine and provided with a pump for raising the liquefied sulphur, in combination with a vessel, as described, for supplying to the mine a sulphur-liquefying vehicle, and a sulphur-receiver, substantially as set forth.

5. A sulphur-mining well extending into an underground sulphur-mine and adapted for the introduction of a sulphur-liquefying vehicle into the said mine and provided with a pump for raising the liquefied sulphur, in combination with a vessel, as described, adapted for the separation of the vehicle and sulphur, substantially as set forth.

6. A sulphur-mining well extending into an underground sulphur-mine and adapted for the introduction of a sulphur-liquefying vehicle into the said mine and provided with a pump for raising the liquefied sulphur, in combination with a vessel, as described, for supplying to the mine a sulphur-liquefying vehicle, and a vessel, as described, adapted for the separation of the vehicle and sulphur, substantially as described.

7. A sulphur-mining well extending into an underground sulphur-mine, and adapted for the introduction of a sulphur-liquefying vehicle into the said mine and provided with a

pump for raising the liquefied sulphur, in combination with a vessel, as described, for receiving the sulphur, and a conduit returning the liquefying-vehicle to the mine, substantially as set forth.

8. The combination, with the sulphur-mining well having downflow and upflow passages opening below into the underground sulphur-mine, of the heater and pump adapted to supply a hot sulphur-liquefying vehicle and to remove the liquefied sulphur, substanstantially as described.

9. The combination, with the well having downflow and upflow passages opening below into an underground sulphur-mine, of the heater, pump, and means for maintaining pressure in the well, substantially as described.

10. The combination, with the well having downflow and upflow passages opening below into an underground sulphur-mine, and the means for liquefying the sulphur in the mine and removing it in a liquefied state, of a closed vessel for recovering the sulphur connected with the outlet from the well, substantially as described.

11. The combination, with the sulphur-mining well having downflow and upflow passages, of the heater, pump, and sulphur receiver or recovering vessel, substantially as described.

12. The combination, with the sulphur-mining well having downflow and upflow passages, of the heater, pump, sulphur receiver or recovering vessels, and conduit for returning a vehicle through the heater to the well, substantially as described.

13. The combination, with the sulphur-mining well having downflow and upflow passages, of the heater, pump, and closed receiver or sulphur-recovering vessel, substantially as described.

14. The combination, with the sulphur-mining well having downflow and upflow passages, of the heater, pump, closed vessels for recovering sulphur, and conduit for returning a vehicle through the heater to the well, substantially as described.

15. The combination, with the sulphur-mining well having downflow and upflow passages, of the heater, means for maintaining pressure in the well, pump, and vessel for separating the vehicle and sulphur, substantially as described.

16. The combination, with the sulphur-mining well having two or more passages, of a heater for liquid and a liquid-pump, substantially as described.

17. The combination, with the well having downflow and upflow passages adapted to retain a fluid therein under pressure, of a heater, and a pump for introducing a hot fluid into said well under pressure, and a vessel for separating the sulphur from the liquefying-vehicle, substantially as described.

18. The combination, with the sulphur-mining well having downflow and upflow passages, of a heater, a liquid-forcing pump, and a vessel for separating the sulphur and liquefying-vehicle, substantially as described.

In testimony whereof I have signed this specification in the presence of two witnesses.

HERMAN FRASCH.

Witnesses:

G. W. BOUDINOT,

F. W. LOTHMAN.