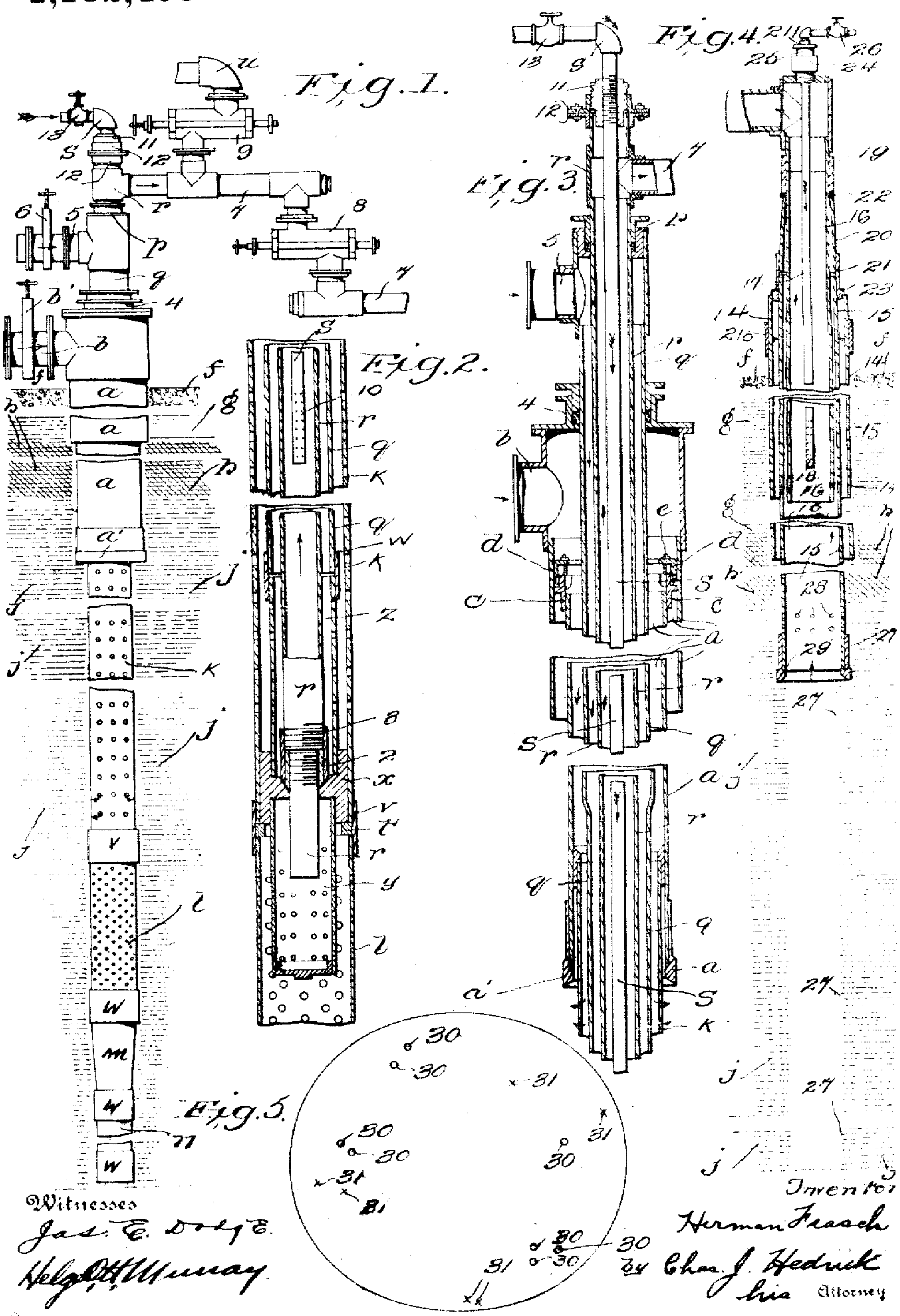
H. FRASCH.

MINING SULFUR.

APPLICATION FILED MAY 3, 1912.

1,152,499 Patented Sept. 7, 1915.



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MINING SULFUR.

1,152,499. Specification of Letters Patent. Patented Sept. 7, 1915.

Application filed May 3, 1912. Serial No. 695,008.

To all whom it may concern:

Be it known that I, HERMAN FRASCH, a citizen of the United States, residing at New York city, Manhattan borough, New York county, in the State of New York, have invented certain new and useful Improvements in Mining Sulfur, of which the following is a specification.

This invention relates more particularly to obtaining sulfur by melting the same in a natural deposit underground and removing it therefrom in the melted state; but each of the improvements composing the invention is intended to be secured for all the uses to which it can be applied, with or without modification. On October 20, 1891, Patents 461,429 and 461,430 were granted to me for, respectively, the process of and the apparatus for such mining by fusion, a fusion fluid (more particularly, but not necessarily exclusively, water heated under pressure to above the melting point of sulfur) being introduced into the deposit and the melted sulfur being raised to the surface of the ground by the pressure of said fusion fluid in the deposit or by pumping. At that time I believed that sulfur deposits were tight, or, in other words, of such nature that on boring a well hole into a deposit and introducing fusion fluid through such hole said fusion fluid would be confined by the surrounding material of the deposit to the well hole or its immediate vicinity; except as an enlarged cavity should be formed by the removal of the sulfur; and I described in said patents the introduction into the deposit of water of a temperature of about 35° F. above the melting point of sulfur, the removal of the water while still above said melting point, but after such loss of temperature as should result from the melting operation, and the reintroduction of the water after again raising its temperature to about 35° F. above said melting point. Subsequently when I found that the sulfur deposit, which I had specially in mind when I made the so patented inventions, was not tight, but porous, and that it was flooded with water, it became necessary to overcome the difficulties thus presented. Moreover, in working said deposit new difficulties have arisen with the progress of the mining operations. The difficulties have been greater by the fact that engineering furnished no precedents for dealing with most of them, and by the further fact that the operations were (and are) performed underground away from direct observation, the control of said operations being exercised entirely above ground by men who none of them enter or can enter the deposit.

As described in my patents of September 19, 1905, Numbers 799,642 and 800,127, and as recited in some of my claims therein, the highly heated water introduced as fusion fluid into the deposit flows away underground instead of returning to the surface as set forth in my said Patents 461,429 and 461,430; and in actual working enormous volumes of such highly heated water thus introduced into the deposit have been flowing away underground during a number of years. This water has always carried into the deposit many times as much heat as would suffice to melt the amount of sulfur actually obtained; and heretofore, notwithstanding an evident accumulation of heat in the ground, the quantity of heat necessary to be sent into the deposit in order to obtain therefrom a given amount of sulfur became larger and larger with the progress of exploitation; while the tonnage producible in a given time with a given plant became less and less.

I have conceived that the increasing quantity of heat required per ton of sulfur obtained and the decreasing production per well per day might be due, in part at least, to a restriction of the fusion fluid (water of melting temperature) to certain parts of the deposit, the fusion fluid being crowded upward by water of lower temperature or excluded thereby from certain cavities in the sulfur bearing rock and so kept away from much of the sulfur, and that by withdrawal from the deposit of water of a temperature below the melting point of sulfur the fusion fluid could be better distributed in the deposit and could consequently be utilized to better advantage than heretofore. Following out this conception, I have, in fact, been able not merely to check the increase in the amount of heat required per ton of sulfur produced, but to lower such amount below the average of previous operations (carried on without such withdrawal of water) and to attain a higher production per well per day than the average of said previous operations and even to increase the production per day from particular wells in operation under my prior methods. Further, I believe that I can profitably obtain (if I have not, in fact, already so obtained) sulfur which could not otherwise be obtained profitably, if at all.

In accordance with the present invention, therefore, water of a temperature below the melting point of sulfur is withdrawn from a porous water flooded deposit of sulfur, into which an appropriate fusion fluid (more particularly, but not necessarily exclusively, water heated under pressure to above the melting point of sulfur) is introduced, and from which sulfur is removed in melted state. The three operations would best be performed contemporaneously; although it is believed that advantage over the prior state of the art might be obtained without contemporaneous performance of all or even of any two of them; since the effects of said water withdrawal and said introduction of fusion fluid, each of them, continue for a certain time after stoppage of the operation itself. Care should be taken to insure against the solidification of the sulfur in the piping through which the melted sulfur is removed and to keep the sulfur melted which is to supply said piping; for which purposes fusion fluid would best be conveyed through appropriate piping of the sulfur raising wells and be introduced into the deposit near the sulfur intakes continuously during the melting and sulfur removing operations. All the fusion fluid might be so introduced near the sulfur intakes; but it is considered better to introduce the bulk of such fluid elsewhere.

I have, in attaining the results stated, withdrawn water of lower temperature at the rate of about eighty per cent. by volume of the water of melting temperature introduced contemporaneoulsy into the deposit, millions of gallons per day being so withdrawn from a deposit with a superficial area estimated at less than seventy five acres; but a higher or a lower percentage can be withdrawn within the limits of the invention; the volume of withdrawn water may even exceed that introduced as fusion fluid; and variations can be made in the amounts per day so withdrawn. By withdrawing the said cooler water at a lesser rate than that at which water of melting temperature is introduced (after allowing for enlargement of the cavities of the deposit as the result of removing sulfur) a portion at least of the water introduced as fusion fluid must necessarily flow away underground; and this portion may be more than corresponds with the difference in the respective rates of withdrawal and introduction; since water entering the deposit from subterranean sources may constitute a part (if not all) of the so withdrawn water. By causing water introduced as fusion fluid to flow away underground, the inflow of water from outside into the part of the deposit occupied by said fusion fluid is checked or prevented. This checking is desirable, but it is not necessarily essential to the invention in its broader aspects.

I have introduced fusion fluid and removed sulfur from a number of producing wells, which are separated each of them from the nearest water withdrawing well by a horizontal distance of between about two hundred and about eight hundred feet; but such distances may be shorter than two hundred feet and longer than eight hundred feet within the limits of the invention. It is important to have a number of water withdrawing wells within influencing distance of each other and a number of melting wells each of them within influencing distance of at least one of said water withdrawing wells; although such disposition of wells is not necessarily essential to the invention in its broader aspects.

Water of a temperature below the melting point of sulfur may be withdrawn at one or more levels; and it is considered advantageous to withdraw it at places below a level at which a large part at least of the fusion fluid is introduced into the deposit, and even below the intake of a sulfur raising pipe. To insure such withdrawal, piping can be provided with water intakes so located; but passages in the deposit, naturally existing therein or formed artificially by working or by boring, may also conduct water from such places at such lower level or levels to piping that terminates at a higher level or levels; and within the limits of the invention water may be withdrawn from any place or places at which it is of a temperature below the melting point of sulfur.

Withdrawal of water might be effected within the limits of the invention where the pressure in the deposit is sufficient, by allowing the water to escape from the deposit through piping, open at both ends, without employing special agencies to expedite the flow; but it would ordinarily (if not always) be at least advantageous to employ such agencies, whether the pressure in the deposit should or should not be able (unaided) to raise water therefrom to the surface of the ground. A pump connected with the piping and located at the surface of the ground could be used; but it is considered important to accelerate the flow to a greater extent than could be effected thereby, appropriate accelerating agencies being applied to the water column underground. It is considered best to force air into the column of water in such quantity and at such distance below the surface of the ground as to reduce the pressure of the overlying column (reaching to the surface of the ground) to the extent of a number of atmospheres.

The particular deposit herein above mentioned is flooded with naturally present water; but the invention includes also the working of porous deposits which have been flooded with water artificially. The general expressions "water flooded porous deposit" and the like as used hereinafter apply to and are intended to include both sorts. In the case of a porous deposit not naturally flooded with water, it is believed that advantage over attempts otherwise to work the same would be obtained by first flooding the deposit artificially with water and then mining the sulfur therein by the operations and appliances which would be suitable for obtaining sulfur by fusion from porous deposits naturally flooded with water or by any appropriate part of said operations and appliances. The artificial flooding with water of a porous deposit preparatory to mining the same by underground fusion can be resorted to when such mining is to be performed in any known or suitable way; and deposits not naturally flooded with water can, therefore, be mined in accordance with the present invention by first flooding the same with water artificially and then proceeding to melt the sulfur therein and to remove it in the melted state therefrom, with or without withdrawal of water of a temperature below the melting point of sulfur as herein set forth.

In the accompanying drawings: Figures 1, 2 and 3 illustrate a form of sulfur producing well (or combined melting and sulfur raising well) which it is considered best to employ, but which may be replaced by other forms of producing wells or by separate wells for introducing fusion fluid and for removing melted sulfur, Fig. 1 showing in elevation the piping of such well with gaps therein at intervals and indicating in section beds of earthy or rocky material, penetrated by such piping, and Figs. 2 and 3 showing on a larger scale and in central vertical section the lower and the upper parts of such piping, respectively, certain valves shown in Fig. 1 being omitted from Fig. 3; Fig. 4 illustrates a form of water withdrawing well which it is considered as advantageous as any to employ and which may be replaced by other forms, said well being shown on the scale of Fig. 1 in central vertical section in connection with beds of earthy or rocky material penetrated thereby and containing gaps similar to those of Figs. 1, 2 and 3, except that Fig. 4 shows the well between certain levels which are included in one of the gaps of Figs. 1 and 3; and Fig. 5 is a diagram in plan showing the superficial area of a deposit and the locations of the two kinds of wells thereon, such locations being merely by way of example. The portion of piping omitted at each gap in Figs. 1, 2, 3 and 4 is the same as is represented above and below the same gap.

The pipe *a* (Figs. 1 and 3) is best in telescoping sections (see Patent 977,444 granted on December 6, 1910, to my assignee). The branch *b*, provided with valve *b'*, supplies fusion fluid thereto; best in the form of water heated to corresponding temperature by direct condensation in it of steam at a pressure of from ninety to a hundred pounds to the square inch (see my said Patents 799,642 and 800,127). The lower section of pipe *a* fits for a large part of its length within said upper section; and projects below the latter to such distance as may be desired. A stuffing box between them is composed (as shown in Fig. 3) of an externally flanged ring *c* fast on the lower pipe section and a follower *d* which is held by nuts on bolts *e* (anchored in ring *c*) and compresses the packing between itself and the flange of ring *c* and against the wall of the inclosing pipe section.

The upper section is represented in Fig. 1 as passing through beds *f g* (the upper bed say of clay and the lower say of sand or of mixed sand and gravel) to a bed of nonproductive rock *h;* while the lower section proceeds on down to the deposit (or bed of producing rock) *j* and into the same to such extent, if any, as may be desired. Beds respectively of from fifty to two hundred feet in thickness may be assumed by way of example. It will, of course, be understood that the character and thickness of beds composing or overlying different deposits, and even different parts of the same deposit will naturally vary. A shoe *a'* is shown at the bottom of the lower section of pipe *a*.

Below the pipe *a* is a stout perforated lining *k;* which fills the well hole at least approximately (see Patent 1,008,319 granted to my assignee on November 14, 1911) and is provided with a strainer section *l* that is connected through a swaged nipple *m* with a supporting pillar *n* of smaller diameter; whose foot rests on the bottom of the bore hole. The latter may terminate either at or above or below the bottom of the deposit, as may be considered best in each instance. The pillar *n* would be of a suitable length to locate the strainer section *l* in the best position or what the operator may consider to be such; and said pillar may be omitted if not desired.

Inside the pipe *a* and well hole lining *k* are the inner fusion fluid pipe *q*, the sulfur raising pipe *r* and the air pipe *s*. At the top of strainer section *l* is a ring *t* interposed between the said strainer section and the next higher length of lining *k;* which are connected with each other by the screw collar *v*. Other collars connecting lengths of pipe are shown at the points *w*.

Upon the ring *t* rests the casting *x*. The interior strainer *y* (of perforated pipe closed at its lower end by a screw plug is screwed into and depends from the bottom of said casting. The perforated (or outlet) section *z* of the inner fusion fluid pipe *q* is screwed into the top of said casting. The latter forms a perforated partition or plug which shuts off the interior strainer *y* from the inner fusion fluid pipe *q* so long as the collar (composed of bushing 2 and coupling 3) near the lower end of the sulfur raising pipe is seated on said casting (see Patents 799,642 and 800,127, hereinbefore referred to). The lower end of the sulfur raising pipe (of reduced diameter as shown) projects through the casting *x*. This upholds ordinarily the sulfur raising pipe *r* as well as the inner fusion fluid pipe *q*; but the pipe *r* can be raised above the casting by appliances at the surface of the ground whenever it may be desired to put said pipe *q* into communication through said casting *x* with the strainer *y*. The pipes *q* and *r* pass, the former through a stuffing box 4 on the head of pipe *a*, and the latter through a stuffing box *p* on a T at the upper end of pipe *q*. A branch pipe 5, with valve 6, supplies fusion fluid to pipe *q*. A branch pipe 7, with valve 8, conveys melted sulfur from pipe *r* to a suitable receptacle (not shown) for the sulfur. The branch pipe *u*, with valve 9, supplies fusion fluid when desired to the sulfur raising pipe *r* for conveyance by the latter into the deposit; branch 7 being closed at such time beyond the junction with it of branch *u* (see Patent 870,620 granted on November 12, 1907, to my assignee). The valves 8 and 9 in said branches would best be adapted for the interior disks or closures thereof to be loosened by a blow should they stick fast (see Patent 988,994 granted on April 11, 1911, to my assignee).

The air pipe *s* has at the bottom a section 10 which is perforated with small holes so that the escaping air will mingle in bubbles with the melted sulfur. Portions of pipe *s* otherwise detached from each other are screwed (as shown) from above and below respectively into the plug 11; which supports said pipe *s* and is secured to the T at the top of pipe *r* through the flanged couplings 12 and a nipple. At 13 is a valve.

The pipe 14 of each water withdrawing well (Fig. 4) passes (as shown through the beds *f g* to the non-productive rock *h* overlying the deposit (producing rock) *j;* while the pipe 15 extends through the pipe 14 to, and for such distance (if any) as may be desired into, the deposit *j*. These pipes are each of them upheld by the rock on which it rests. The pipe 15 projects above the top of pipe 14.

Within the upper portion of pipe 15 and projecting above it is the pipe 16; and within the latter is the air pipe 17, having a perforated bottom section 18. The pipe 16 as shown is supported by the pipe 15 by means of a collar (coupling) 19 which rests on the upper end of a swaged nipple 20. At 21, 210 and 211, respectively, other collars (couplings) are shown. Between the collar 19 and nipple 20, packing 22 is shown; and packing 23 is also shown between the overlying collar 21 and the top of pipe 14. If desired, the space between pipes 14 and 15 can be filled (for packing purposes) with earth or clay; which can be mixed with water and introduced in the form of mud. The air pipe 17 passes through a stuffing box 24. It is upheld by a collar 21 of said pipe resting on the follower 25 of the stuffing box. At 26 is a valve.

The bore hole 27 of the well is continued below the pipe 15 to such depth as may be desired. The pipe 15 could also be provided with a perforated or an unperforated extension; say, for example, a well hole lining such as shown at *k* in Figs. 1, 2 and 3, but without perforations, if so preferred. As shown in Fig. 4, there are a few holes at 28 near the bottom of pipe 15 to provide for the ingress of water in case the wall of well bore 27 below said pipe should fall in and so obstruct the opening in the bottom of pipe 15. A shoe 29 is shown at the bottom of pipe 15.

In Fig. 5 the superficial area of a deposit of the character of that in Calcasieu parish, Louisiana, is represented, with locations 30 (each represented by a small circle) for producing wells and locations 31 (each represented by a cross) for water withdrawing wells indicated thereon. Said area of a general elliptical form in plan, as shown, may be taken as about two thousand feet across at its major axis and about eighteen hundred feet across at its minor axis. The locations of wells shown are by way of an illustrative example only. It is not expected that producing wells should yield indefinitely; and new wells would be sunk and equipped and exploited as may be considered best at the time. Water withdrawing wells would apparently last indefinitely, unless lost by caving in of the ground or other accidental occurrence; but their locations can be changed at will. When a producing well ceases to yield, it can (if uninjured) be converted into a water withdrawing well.

As already stated, it is necessary that the water withdrawing wells withdraw water of a temperature below the melting point of sulfur; and it is considered advantageous to withdraw water of as low a temperature as practicable. It is considered best to extend the bore holes of the water withdrawing wells not only below the level at which fusion fluid is introduced into the deposit, but also below the level from which melted sulfur is removed. With the producing well of Figs. 1, 2 and 3 the bulk of the fusion fluid would be forced down the pipe *a* and would be introduced into the deposit *j* through perforations in the well hole lining *k* near the upper end of said lining and the melted sulfur would be taken in through the bottom of the pipe *r*. The water withdrawing well shown in Fig. 4 has its water intake at the bottom of pipe 15 at a level which may be above or below the bottom of pipe *a* of any given producing well, although with the bottoms of pipes *a* and 15 at the same level water may reach the pipe 15 through the bore hole 27 from a level even below the lowest sulfur intake. The water intakes (or places at which the water is taken into the piping of the water withdrawing wells) could be at any desired level appropriate to receiving water of a temperature below the melting point of sulfur.

The fusion fluid conveyed through the pipe *q* and introduced into the deposit a short distance above the sulfur intake insures against solidification of sulfur in pipe *r* and keeps the sulfur melted which is to supply said pipe. After the fusion fluid is once liberated it tends to rise, being hotter and consequently lighter than the water by which the lower part of the producing well is surrounded; so that a melting temperature would not necessarily exist even a few feet away from said well. It is believed that the withdrawal of water of a temperature below the melting point of sulfur operates to enlarge the fusion zone of each producing well, or at least of each producing well within influencing distance of such withdrawal.

In normal working, while sulfur is being removed through the pipe *r* of each producing well, water of a temperature above the melting point of sulfur (constituting the fusion fluid) is introduced into the deposit through pipes *a* and *q* of each producing well; and water of a temperature below the melting point of sulfur is withdrawn from the deposit through pipes 15 and 16 of each water withdrawing well; the three operations being performed contemporaneously. The fusion fluid is introduced as fast say as it will flow through said pipes *a* and *q* under pressure of between ninety and a hundred pounds to the square inch in the heaters (not shown herein, but illustrated in Patents 799,642 and 800,127 herein above mentioned) connected with said pipes. The well hole linings of the producing wells may be say eight inches in internal diameter and the inner fusion fluid pipe say five inches where it is inclosed by said lining, the sulfur raising pipe being say three inches in internal diameter. The water is withdrawn at such rate as to equal say about eighty per cent. more or less of that introduced as fusion fluid. The bottom of the air pipe 17 of each water withdrawing well would advantageously be placed so far below ground (say three hundred feet, more or less, where the pressure in the deposit would bring water to the surface) that the back pressure of the overlying column would be reduced by a number of atmospheres and the flow of water from the deposit through such well would be correspondingly expedited.

Whenever occasion arises, the air is shut off from pipe *s*, thus allowing the melted sulfur in pipe *r* to sink to the level at which a column of melted sulfur (unmixed with air) would balance the pressure in the deposit. The valve 8 being closed and the valve 9 opened, water (fusion fluid) can then be forced through the sulfur raising pipe into the deposit, either for cleaning the strainers *y* and *l* or for increasing the melting. When thought best, the removal of melted sulfur can be resumed.

Operations and appliances appropriate to obtaining sulfur from water flooded porous deposits by underground fusion without the water withdrawal of the present invention (see patents herein above mentioned and, in addition, patents granted to my assignee, Number 928,036 on July 13, 1909, and Number 988,995 on April 11, 1911) can ordinarily, if not always, be used in connection with such water withdrawal.

In the case of a porous sulfur deposit which is not flooded with naturally present water and which can be flooded with water artificially it is considered advantageous to introduce water into the same until it is flooded to the depth desired and then to proceed as if dealing with a porous deposit flooded with naturally present water. For obtaining sulfur from such artificially flooded deposit it is considered that it would be best to withdraw water of a temperature below the melting point of sulfur therefrom contemporaneously with the introduction of fusion fluid thereinto and the removal of the melted sulfur therefrom as herein described; but it is believed that sulfur could be obtained therefrom as from a naturally flooded porous deposit by means of said three operations and appropriate appliances without contemporaneous performance of said three operations and also by introduction of fusion fluid and removal of melted sulfur without withdrawal of water of temperature below the melting point of sulfur. Producing wells of the character illustrated in Figs. 1, 2 and 3 or of other suitable character could be used in appropriate cases with or without water withdrawing appliances in order to mine by fusion a porous deposit flooded with water artificially.

Modifications either in process or apparatus for working a porous deposit either naturally or artificially flooded with water can be made indefinitely so long as the substance of any one or more of the hereinafter written claims is taken.

The expression "substance mined" means sulfur primarily, but not necessarily exclusively, in each of the claims in which the expression occurs. It is intended to include any fusible substance which can be mined in accordance with the recitals of the claims.

I claim as my invention or discovery:

1. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance through an artificially provided passage, introducing fusion fluid into said deposit, and removing the melted substance from said deposit, substantially as described.

2. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance through an artificially provided passage, introducing fusion fluid into said deposit, and removing the melted substance from said deposit contemporaneously with withdrawal of water of said non-melting temperature, substantially as described.

3. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance through an artificially provided passage, introducing fusion fluid into said deposit contemporaneously with withdrawal of water of said non-melting temperature, and removing the melted substance from said deposit, substantially as described.

4. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance through an artificially provided passage, introducing fusion fluid into said deposit, and removing the melted substance from said deposit, the three operations being performed contemporaneously, substantially as described.

5. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance through an artificially provided passage, introducing fusion fluid into said deposit and in part at least near an intake for the melted substance, keeping the piping through which the melted substance is removed at a temperature above the melting point of the latter by conveyance of fusion fluid in appropriate relation to said piping, and removing the melted substance from the deposit through said piping, substantially as described.

6. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance through an artificially provided passage, introducing fusion fluid into said deposit in main part elsewhere and in smaller part near an intake for the melted substance, keeping the piping through which the melted substance is removed at a temperature above the melting point of the latter by conveyance of fusion fluid in appropriate relation to said piping, and removing the melted substance from the deposit through said piping, substantially as described.

7. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance through a well located laterally a substantial distance from the point of introduction of fusion fluid into said deposit and yet within influencing distance of the same, introducing fusion fluid into said deposit, and removing the melted substance from said deposit, substantially as described.

8. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance through an artificially provided passage, introducing fusion fluid into said deposit in larger volume than that of the so withdrawn water of non-melting temperature after deducting from the former volume an amount equal to the volume of the removed substance, so that part at least of said fusion fluid must flow away underground, and removing the melted substance from said deposit, substantially as described.

9. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance through a number of water withdrawing wells in sufficient volume to influence the mining conditions within an extended area of said deposit, introducing fusion fluid into said deposit within said area, and removing the melted substance from said deposit, substantially as described.

10. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the sub-

stance mined from a water flooded porous deposit of such substance through a number of water withdrawing wells located within influencing distance of each other, introducing fusion fluid into said deposit by means of a number of melting wells located each of them within influencing distance of at least one of said water withdrawing wells, and removing the melted substance by means of wells distinct from said water withdrawing wells, substantially as described.

11. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance by means of at least one well whose bore hole extends below a level at which fusion fluid is introduced into the deposit, introducing fusion fluid into said deposit, and removing the melted substance from said deposit, substantially as described.

12. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance by means of at least one well whose bore hole extends below the level of at least one intake for the melted substance, introducing fusion fluid into said deposit, and removing the melted substance from said deposit, substantially as described.

13. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance through an artificially provided passage, accelerating the outflow through said passage relatively to that which would take place through the same under the pressure in the deposit, introducing fusion fluid into the deposit, and removing the melted substance from said deposit, substantially as described.

14. The process of mining by fusion, consisting in withdrawing water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance through an artificially provided passage, introducing aeriform fluid into the underground column of water, reducing by such introduction of aeriform fluid the pressure of the column which reaches from the place of introduction to the surface of the ground to the extent of a number of atmospheres, accelerating in this way the outflow through said passage relatively to that which would take place through the same against the unreduced pressure of said column, introducing fusion fluid into the deposit, and removing the melted substance from said deposit, substantially as described.

15. The process of mining by fusion, consisting in withdrawing during current working water of a temperature below the melting point of the substance mined from a water flooded porous deposit of such substance through an artificially provided passage, introducing fusion fluid into said deposit, and removing the melted substance from said deposit, substantially as described.

16. The process of mining by fusion, consisting in introducing fusion fluid into a water flooded porous deposit of the substance mined, withdrawing water through an artificially provided passage from outside the fusion zone of the so introduced fluid, and removing the melted substance from the deposit, substantially as described.

17. The process of mining by fusion, consisting in artificially flooding a porous deposit with water, and subsequently withdrawing water of a temperature below the melting point of the substance mined from the so flooded deposit, introducing fusion fluid into said deposit, and removing the melted substance from said deposit, substantially as described.

18. The process of mining by fusion, consisting in artificially flooding a porous deposit with water, and subsequently introducing fusion fluid into said deposit, and removing the melted substance from said deposit, substantially as described.

19. The process of preparing a porous deposit for mining by underground fusion, consisting in artificially flooding a porous deposit of water insoluble fusible substance with water preparatory to the fusion of said substance within the so formed artificial body of water, substantially as described.

20. Apparatus for mining by fusion, consisting of a water withdrawing well with its water intake at a place in a water flooded porous deposit of the substance mined at which water of a temperature below the melting point of said substance will be taken in, means for introducing fusion fluid into said deposit, and means for removing the melted substance from said deposit, substantially as described.

21. Apparatus for mining by fusion, consisting of a water withdrawing well with its water intake at a place in a water flooded porous deposit of the substance mined at which water of a temperature below the melting point of said substance will be taken in, means for introducing fusion fluid into said deposit, and means for removing the melted substance from said deposit contemporaneously with such withdrawal of water, substantially as described.

22. Apparatus for mining by fusion, consisting of a water withdrawing well with its water intake at a place in a water flooded porous deposit of the substance mined at which water of a temperature below the melting point of said substance will be taken in, means for introducing fusion fluid

into said deposit contemporaneously with such withdrawal of water, and means for removing the melted substance from said deposit, substantially as described.

23. Apparatus for mining by fusion, consisting of a water withdrawing well with its water intake at a place in a water flooded porous deposit of the substance mined at which water of a temperature below the melting point of said substance will be taken in, means for introducing fusion fluid into said deposit contemporaneously with such withdrawal of water, and means for removing the melted substance from said deposit contemporaneously with both the former operations, substantially as described.

24. Apparatus for mining by fusion, consisting of a water withdrawing well with its water intake at a place in a water flooded porous deposit of the substance mined at which water of a temperature below the melting point of said substance will be taken in, means for introducing fusion fluid into said deposit, and means for removing the melted substance from said deposit, said fluid introducing means being arranged for conveyance of fusion fluid in such relation to the piping which forms part of said means for removing the substance mined as to prevent solidification of said substance in said piping and for introduction of fusion fluid into the deposit near where the melted substance is taken in, substantially as described.

25. Apparatus for mining by fusion, consisting of a water withdrawing well with its water intake at a place in a water flooded porous deposit of the substance mined at which water of a temperature below the melting point of said substance will be taken in, means for introducing fusion fluid into said deposit, and means which include piping for removing the melted substance from said deposit, said fluid introducing means being arranged for conveyance of fusion fluid in such relation to the piping which forms part of said means for removing the substance mined as to prevent solidification of said substance in said piping and for introduction of fusion fluid into the deposit in main part elsewhere and in smaller part near an intake for the melted substance, substantially as described.

26. Apparatus for mining by fusion, consisting of a water withdrawing well with its water intake at a place in a water flooded porous deposit of the substance mined at which water of a temperature below the melting point of said substance will be taken in, means for introducing fusion fluid into said deposit at a well which is located a substantial distance from said water withdrawing well and is yet within influencing distance of the latter, and means for removing the melted substance from said deposit, substantially as described.

27. Apparatus for mining by fusion, consisting of a water withdrawing well with its water intake at a place in a water flooded porous deposit of the substance mined at which water of a temperature below the melting point of said substance will be taken in, means for introducing fusion fluid into said deposit, and means for removing the melted substance from said deposit, said fluid introducing means being arranged to introduce into said deposit a volume of fusion fluid which is larger than that of the so withdrawn water of non-melting temperature after deducting from the former volume an amount equal to the volume of the removed substance, so that part at least of said fusion fluid must flow away underground, substantially as described.

28. Apparatus for mining by fusion, consisting of a number of water withdrawing wells arranged to withdraw water of a temperature below the melting point of the substance mined from a porous water flooded deposit of such substance in sufficient volume to influence the mining conditions in an extended area of said deposit, means for introducing fusion fluid into said deposit within said area, and means for removing the melted substance from said deposit, substantially as described.

29. Apparatus for mining by fusion, consisting of a number of water withdrawing wells located within influencing distance of each other and having their water intakes at places in a water flooded deposit of the substance mined at which water of a temperature below the melting point of said substance will be taken in, a number of melting wells for introducing fusion fluid into said deposit arranged each of them within influencing distance of at least one of said water withstanding wells, and means for removing the melted substance from the deposit at wells distinct from said water withdrawing wells, substantially as described.

30. Apparatus for mining by fusion, consisting of means for introducing fusion fluid into a water flooded porous deposit of the substance mined, a water withdrawing well whose bore hole extends below a level at which fusion fluid is so introduced into the deposit and which has its water intake at a place at which water will be taken in of a temperature below the melting point of said substance, and means for removing the melted substance from the deposit, substantially as described.

31. Apparatus for mining by fusion, consisting of means for introducing fusion fluid into a water flooded porous deposit of the substance mined, means for removing the melted substance from the deposit, and a

water withdrawing well whose bore hole extends below at least one intake for the melted substance and which has its water intake at a place at which water will be taken in of a temperature below the melting point of said substance, substantially as described.

32. Apparatus for mining by fusion, consisting of a water withdrawing well with its water intake at a place in a water flooded porous deposit of the substance mined at which water of a temperature below the melting point of said substance will be taken in, means for introducing fusion fluid into said deposit, and means for removing the melted substance from said deposit, said water withdrawing well having provision for accelerating the outflow of the water of said non-melting temperature as compared with the outflow which would take place under the pressure in the deposit, substantially as described.

33. Apparatus for mining by fusion, consisting of a water withdrawing well with its water intake at a place in a water flooded porous deposit of the substance mined at which water of a temperature below the melting point of said substance will be taken in, means for introducing fusion fluid into said deposit, and means for removing the melted substance from said deposit, said water withdrawing well having provision for accelerating the outflow of the water of said non-melting temperature by introducing aeriform fluid underground into the water column in such manner as to reduce the pressure of an overlying column reaching to the surface of the ground to the extent of a number of atmospheres, substantially as described.

34. Apparatus for mining by fusion, consisting of a water withdrawing well with its water intake at a place in a water flooded porous deposit of the substance mined at which water of a temperature below the melting point of said substance will be taken in during current working, means for introducing fusion fluid into said deposit, and means for removing the melted substance from said deposit, substantially as described.

35. Apparatus for mining by fusion, consisting of means for introducing fusion fluid into a water flooded porous deposit of the substance mined, a water withdrawing well with its water intake at a place outside of the fusion zone of the so introduced fluid, and means for removing the melted substance from said deposit, substantially as described.

36. Apparatus for mining by fusion, consisting of means whereby a porous deposit of the substance mined can be flooded with water artificially, a water withdrawing well with its water intake at a place in said deposit at which water of a temperature below the melting point of said substance will be taken in, means for introducing fusion fluid into said deposit, and means for removing the melted substance from said deposit, substantially as described.

37. Apparatus for mining by fusion, consisting of means whereby a porous deposit of the substance mined can be flooded with water artificially, means for introducing fusion fluid into said porous deposit, and means for removing the melted substance, substantially as described.

In testimony whereof I affix my signature in presence of two witnesses.

HERMAN FRASCH.

Witnesses:
C. M. Forrest,
A. F. Caffrey.

Correction in Letters Patent No. 1,152,499.

It is hereby certified that in Letters Patent No. 1,152,499, granted September 7, 1915, upon the application of Herman Frasch, of New York, N. Y., for an improvement in "Mining Sulfur," an error appears in the printed specification requiring correction as follows: Page 8, line 108, claim 29, for the word "withstanding" read *withdrawing;* and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 23d day of May, A. D., 1916.

[SEAL.]

J. T. NEWTON,

Acting Commissioner of Patents.

Cl. 83—78.