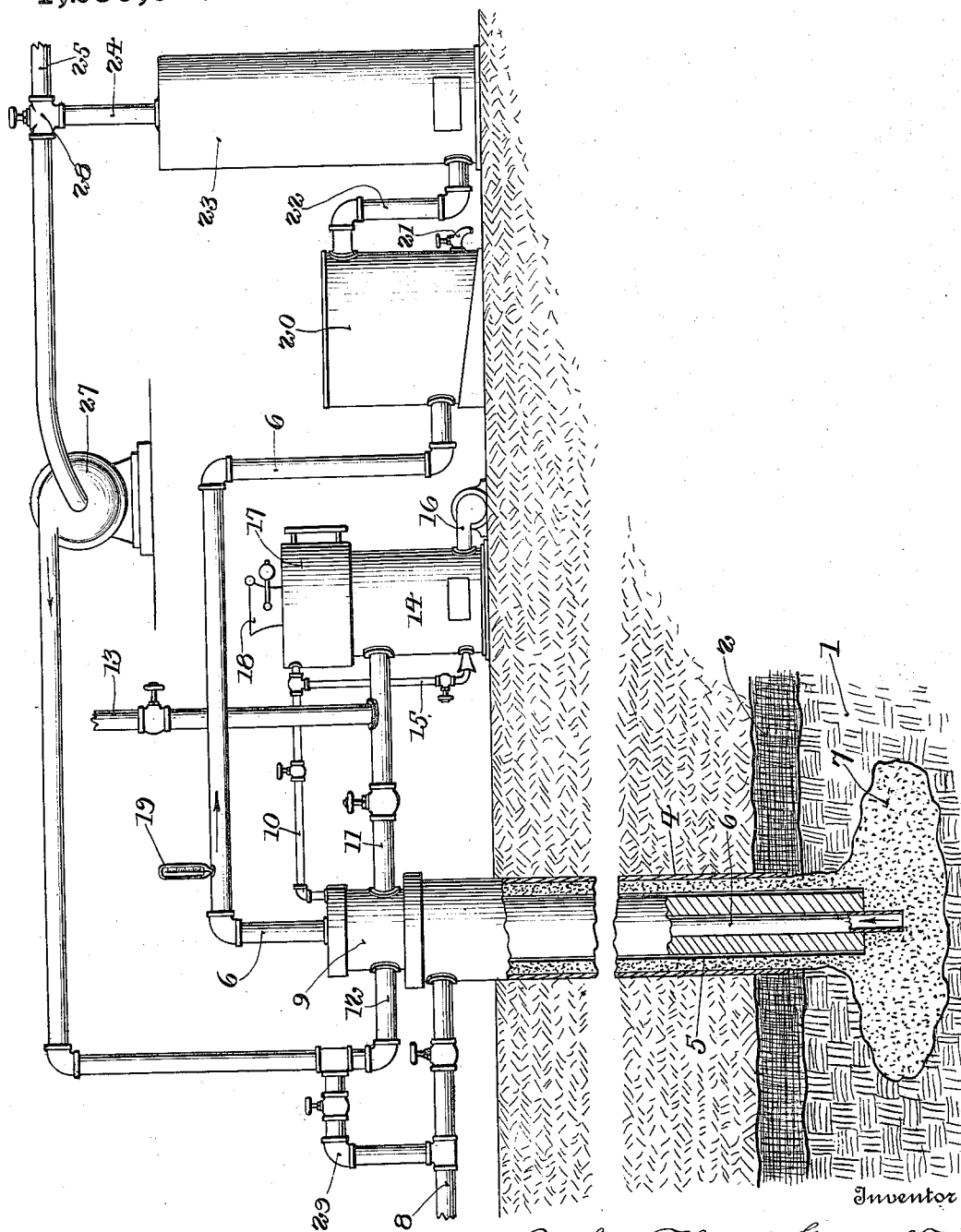


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MINING SULFUR.
APPLICATION FILED MAR. 9, 1917.

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MINING SULFUR.

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To all whom it may concern:

Be it known that we, ANTHONY F. LUCAS and GODFREY M. S. TAIT, residing at Washington, in the District of Columbia, have
5 invented certain new and useful Improvements in Mining Sulfur, of which the following is a specification.

This invention relates to mining sulfur; and it comprises a method of extracting sulfur as such or in the form of its compounds, from deep seated sulfur deposits wherein a zone of active combustion is instituted in
10 such deposit, such combustion being either of the sulfur or of a combustible gas, or both, and sulfur carrying gases are led to the surface while new supplies of air or of air and gas, are led to the said deposit; all as more fully hereinafter set forth and as
15 claimed.

As is well known there are at various points in this country subterranean deposits of sulfur which can be exploited only with difficulty. The usual method now in use for such exploitation is to pass a system of
20 concentric pipes down to the deposit and through these pipes transmit air and superheated water. The heated water melts the sulfur in place and the air forces a mixture of water and melted sulfur to the surface.
25 This method has rendered these great deposits of sulfur available but it has a number of disadvantages. One is that the action of the water is only local; there is a chamber melted out but after a time the action
30 stops. Another is that the utilization of the heat is very small; only about half a per cent. or so of the total heat imparted to the hot water reaching the deposit and being employed in useful work. And the apparatus
35 equipment for extraction is very expensive.

In the present invention a simpler and more economical procedure is provided. In lieu of attempting to melt the sulfur and
45 lift it to the surface in the melted state by the use of heat generated on the surface of the ground and transmitted to the deposit by hot water, we produce a high heat in the sulfur deposit itself by producing combustion therein. This combustion may be either
50 that of the sulfur itself or may be the combustion of combustible gas of any kind. By this heat the sulfur is melted and burned, or melted and volatilized, or both, as the
55 case may be, giving gases and vapors which

are brought to the surface for utilization.

In practice, a series of concentric pipes is employed and gases are sent through one of these pipes into the deposit, combustion is there produced and gases and vapors are led
60 out through another pipe to a place of utilization. Within the limits of the described invention, many procedures are possible; but they all depend upon the central idea of producing a limited combustion in the de-
65 posit and utilizing the heat of this combustion in removing the sulfur of the deposit to the surface for utilization.

In one desirable embodiment of the present invention we provide, say, three concentric tubes, although more may be used; a central tube for the removal of sulfur carrying gases and vapors, a surrounding tube for the introduction of hot gases and
70 an outside tube for the introduction of air. Presuming that the sulfur is to be removed as such in the vapor form, the operation may be started by passing hot producer gas at a temperature of about 500° C. down through the middle pipe around the central
75 tube, the hot gases returning through this central tube. In so doing the innermost pipe becomes heated throughout to about 500° C. or somewhat above the boiling point of sulfur; which is of course a temperature
80 at which vapors of sulfur will not condense. Attainment of this temperature will be quickly shown by the appearance of hot gases and vapors of sulfur at the outlet of the center tube. A little air is now introduced through the outermost tube. This air
85 joins the combustible gas coming through the middle tube at the base of the tube assemblage and there ignites and burns, producing heat. The amount of heat of course
90 depends upon the amount of air so introduced. Sulfur being an excellent insulator of heat very little of the heat thus produced travels outward; it nearly all remains in the combustion chamber or crater which is
95 formed in the body of sulfur. The hot gases in this crater being at a temperature above the boiling point of sulfur, the sulfur evaporates freely and the sulfur vapors and such products of combustion as form go up-
100 ward through the central tube in admixture with the hot producer gas to a place of condensation of the sulfur. Advantageously the mixture of gases and vapors first goes through a cooling tube at such a
110

temperature that liquid sulfur will condense and deposit and goes thence to a larger cooler chamber for the production of flowers of sulfur. There is danger in this operation of the development of too high a temperature in the crater if too much air is introduced and for this reason the air is best limited in amount or diluted with inert gases such as products of combustion.

After the operation once starts, the gas currents flowing outward are used mostly to dilute and carry forward the sulfur vapors and it is the object to produce merely enough combustion in the crater to keep the temperature up to the required point while furnishing the heat necessary for melting and volatilizing the sulfur. To this end, while the total amount of gases introduced at the bottom of the tube assemblage may be rather great, there is merely enough air (or diluted air) for this limited combustion. The main volume of gases may be products of combustion or steam introduced with and diluting the air: or it may be mainly a harmless combustible gas such as producer gas with only enough air introduced to afford the temperature desired at the base of the tube assemblage. A more economical procedure is to introduce, after the first heating up, a mixture of air and products of combustion of such a nature that the burning of a limited amount of sulfur at the base of the tube assemblage will afford the heat desired. Instead of products of combustion steam may be employed as a neutral incombustible diluent.

Operating in the manner just described the temperature in the sulfur chamber is of course higher than the melting point of sulfur and the walls are constantly melting down, the sulfur flowing down as liquid or vapor to the bottom of the crater. Now if the gases be introduced as they may be, under considerable pressure, the melted sulfur in the margins of the chamber will be forced outward effectually sealing any cracks or crevices there may be and preventing the entrance of water. Sometimes the entrance of water may be desired since its evaporation in the heating chamber may be utilized to moderate the temperature to that which is desired. The steam formed may be utilized as a carrier vapor. In this event, of course, such high pressure of the gases forced in is not desirable.

In the method of operation just described, the product of the operation is sulfur itself; sulfur being delivered as a vapor carried by a mixture of gases. This sulfur may be condensed and regained as such. If the heat at the base of the tube assemblage is afforded by combustion of sulfur there will be more or less SO_2 mixed with the gases and this may be recovered in suitable ways.

If combustible gas, such as producer gas,

be introduced as a carrier, the SO_2 will be reduced, or not formed, as the case may be. The carbon monoxid and the hydrogen of ordinary combustible gas both reduce SO_2 to sulfur.

Instead of producing sulfur as such with only a minor proportion, if any, of SO_2 , the operation may be so conducted as to afford SO_2 as a main product. In so doing, after the central tube is at the heat desired, (and this heat may be a much lower one), the supply of combustible gas is cut off and the heat thereafter maintained by introduction of air. In order to prevent development of too much heat in the combustion chamber it is ordinarily useful to dilute the air more or less with products of combustion. The gases discharged are rich in SO_2 and may be used for making sulfuric acid. Or they may be passed through heated charcoal, may be mingled with producer gas and heated, etc., to regain free sulfur as flowers of sulfur. The gases coming forward may be rich in SO_3 and H_2SO_4 if the structure of the bottom of the tube assemblage be such as to permit a tolerably direct passage of the air from the inlet pipe to the outlet pipe. In such event they may be passed through the ordinary fume collecting devices to regain these bodies. By adding more or less steam to the air a fog of sulfuric acid may be produced.

Very many other results may be produced by changing conditions somewhat. These sulfur deposits may carry more or less salt or salt deposits may be in close proximity to the deposit and be, or made to be, in communication with such deposit; and if the temperature in the combustion chamber be maintained at a high temperature there may be a production of chlorin, or of HCl in the event that steam is employed. This chlorin or HCl comes forward through the outlet pipe and may be regained.

In the accompanying illustration we have shown, more or less diagrammatically, an embodiment of apparatus elements within the present invention and adapted for the performance of the described process. In this showing,

1 indicates a deposit of sulfur capped by overlying rock 2, while 3 is the surface of the ground. As shown, there extend from the surface of the ground to this deposit three concentric pipes, 4 being a casing or air pipe while 5 is a midpipe forming within it a conduit for hot gases. Concentrically located is a central outlet pipe 6. As shown, these three pipes are of somewhat different length, the outermost pipe being the shortest and the central pipe the longest. This central pipe may be provided with means for extending it to the depth desired. Around the base of these pipes is shown what may be here termed crater 7. Connected to the

outermost pipe is a source of air 8. Head 9 communicating with the midpipe is provided with steam inlet 10 and valved inlet 11 for hot gases. A third inlet 12 is for the introduction of waste gases, as hereinafter described. The valved inlet for hot gases has a valved branch 13 through which products of combustion may escape to the atmosphere and is connected to a source of hot gases 14, shown as a gas producer. As shown this gas producer is provided with a steam blowing means 15 for introducing air and with fan blower 16 for the same purpose. Either or both may be used. As shown it is surmounted by a steam generator 17 for utilizing waste heat. Hopper 18 provides for the introduction of fuel. This gas producer and accessories are of a common type. Any other type may be substituted. The innermost or vapor outlet pipe is provided with thermometer 19 and leads to hot condensing chamber 20 kept at such a temperature that sulfur will condense in a molten state. Outlet 21 is provided for draining off liquid sulfur from time to time. From this chamber another conduit 22 leads uncondensed sulfur and gases to another cooling and condensing chamber 23 wherein flowers of sulfur may condense and be collected. Waste gases from this chamber leave through 24 and all or a portion may be sent to a place of utilization or disposition through 25. A portion of the waste gases may be returned through 26 by means of fan 27 to the waste gas inlet previously described. Two-way valve 28 allows for a return to the head 9 of such gases as remain after the extraction of the sulfur contents. This is accomplished by means of blower 27 driven from some source of power not shown.

The diagrammatically shown apparatus is susceptible of use in a variety of different ways within the purview of the present process.

In one such use the gas producer 14 is placed in operation and discharges producer gas or water gas or semi-producer gas through 11. The temperature of this gas may be anywhere from 500° to 1000° C. The temperature may be reduced if necessary by steam from 10. The hot gas is passed downwardly through the midpipe 5, whence it reaches the crater and passes upward through pipe 6. The object of this operation is to bring 6 to a temperature above the boiling point of sulfur (450° C.). Ordinarily, we try to heat 6 to about 500° C. Since the hot gases pass through 5 and 6 in a sort of return bend or U-conduit, heating of 6 may be made uniform throughout. When the temperature at 19 is about 500°, vapors of sulfur begin to appear in 20 and condense. The operation may now be continued in this manner, the hot gases going down into the deposit and melting and va-

porizing the sulfur which then passes upward through 6. By extending 6 downward the end may be kept near the bottom of the crater so as to pick up the heavy vapors of sulfur. In this operation, the fumes delivered by 6 are a mixture of sulfur vapors and combustible gas. After depositing the sulfur in 20 and 23, the combustible gas passing through 25 may be utilized in any suitable manner. In this manner of operation, the development of heat is wholly on the surface in gas producer 14. No combustion takes place in the deposit. But as sulfur is a very poor conductor of heat there is little waste of heat by conduction beyond the surface of the crater 7. Obviously, instead of using producer gas from 14 in this embodiment of our invention, 14 may be run to produce ordinary combustion, 11 then supplying hot products of combustion. It is immaterial in this embodiment of our invention whether the hot gases, which are merely a heat carrier, passing through 11 to 7 are combustible gases or products of complete combustion. Both are inert as regards sulfur.

In another embodiment of our invention, after the central pipe 6 is heated up a little air may be admitted through 8 and passed downward into the crater. Here it produces combustion either of the sulfur or of combustible gas from 14, or of both, as the case may be. This combustion is in crater 7 and develops the heat required to produce melting and vaporization, the vapors being then taken forward through 6. In this modification of our invention, the gases passing through 6 and 20 may or may not contain sulfur dioxid. It is of course possible, after heating up and starting combustion in the crater, to develop all the heat there by means of air from 8, introduction of combustible gas through 11 being discontinued. This, however, we do not regard as being so advantageous as furnishing at least some other gas for the reason that the temperatures are apt to go too high and for the reason that too great a proportion of the sulfur goes forward as SO₂. To obviate this great amount of combustion and high temperature, the air sent through 8 may be diluted by waste gases from 12, using valved by-pass 29. These waste gases may be according to the operation either products of combustion, if fuel is completely burnt in 14, or the waste gases may be simply a mixture of sulfur dioxid and nitrogen. Mixture of waste gases from 5 and air from 8 may be in the crater. By an adjustment of the amount of gas coming in through 12 and 8 the temperature in the crater may be kept at any desired degree.

Where we have hereinbefore spoken of the introduction of gases as heat carriers we of course mean to include the use, where

it is desired, of greater or less proportions of steam through 10.

Where combustion is produced in the crater with development of SO_2 , the SO_2 passing outward at 25 may be utilized in any desired manner, as for making sulfuric acid. For this purpose, the gases from 25 may be sent to a chamber or through an ordinary "contact" apparatus.

10 The apparatus may be used for producing a gas mixture rich in fumes of H_2SO_4 or SO_3 , as the case may be. In so doing, it is merely necessary to raise pipe 6 somewhat so that air coming from 8 need not pass next the bottom of the crater but has a short path to 6. In so doing, high temperature combustion will take place at the base of the pipe assemblage, sulfur vapors mixing with the air and burning to form SO_2 and SO_3 . If steam is introduced from 10, a fog of H_2SO_4 may be formed and suitably collected by means not shown.

Very many other methods of recovering and utilizing the sulfur from underground deposits by the described method may be devised.

In another application Serial No. 139,193, filed December 27, 1916, we have described and claimed a method of recovering sulfur from underground deposits wherein combustion is produced in the deposit by a draft current containing air forced thereinto, the temperature caused by the combustion being sufficient to fuse sulfur and the pressure of the draft current being sufficient to force sulfur in a molten condition to the surface. In the method as there described and claimed at least a portion of the sulfur is recovered in the molten state.

40 What we claim is:—

1. In the mining of subterranean sulfur, the process which comprises establishing a combustion chamber in such a deposit, supplying air to support combustion therein while withdrawing sulfur containing gases, at least part of such sulfur being in the form of vapors of elemental sulfur, and collecting the sulfur contained in such gases for utilization.

50 2. In the mining of subterranean sulfur, the process which comprises establishing a combustion chamber in such a deposit, supplying air and a combustible gas to support combustion therein while withdrawing sulfur containing gases and collecting such sulfur containing gases for utilization.

3. In the mining of subterranean sulfur, the process which comprises establishing a combustion chamber in such a deposit, supplying air diluted with an inert gas to produce a moderated combustion therein while withdrawing sulfur containing gases and collecting such sulfur containing gases for utilization.

65 4. In the mining of subterranean sulfur,

the process which comprises establishing a combustion chamber in such a deposit, supplying air diluted with products of combustion to support combustion therein while withdrawing sulfur containing gases and collecting such sulfur containing gases for utilization.

5. In the mining of subterranean sulfur, the process which comprises establishing and maintaining a plurality of concentric conduits between the deposit and the surface, heating the central conduit to a temperature around 450°C . by means of hot inert gases passed therearound and back there-through, instituting a limited degree of combustion in the sulfur deposit, removing vapors of sulfur, products of combustion and other gases through the heated central tube and collecting the sulfur containing vapors.

6. In the mining of subterranean sulfur, the process which comprises melting and volatilizing the sulfur in the deposit by producing limited combustion in such deposit, removing products of combustion therefrom and condensing vapors of elemental sulfur carried forward by such products of combustion.

7. In the mining of subterranean sulfur, the process which comprises melting and volatilizing the sulfur in the deposit by combustion heat imparted to a draft current sent thereto and removing and condensing vapors of elemental sulfur carried by gases removed therefrom.

8. In the mining of subterranean sulfur, the process which comprises melting and volatilizing the sulfur in the deposit by combustion of a combustible gas therein and removing and condensing vapors of sulfur.

9. In the mining of subterranean sulfur, the process which comprises establishing and maintaining a flow of hot gases at a temperature above the vaporizing point of sulfur to and from the deposit in adjacent conduits in heat equalizing relationship while maintaining in such deposit a temperature sufficient to melt and volatilize sulfur and carrying forward vapors of sulfur by outgoing gases.

10. In the mining of subterranean sulfur, the process which comprises establishing and maintaining a flow of hot gases at a temperature above the vaporizing point of sulfur to and from the deposit in adjacent conduits in heat equalizing relationship while maintaining in such deposit a temperature sufficient to melt and volatilize sulfur by means of a limited combustion taking place in the deposit and carrying forward vapors of sulfur by outgoing gases.

11. In the mining of subterranean sulfur, the process which comprises establishing and maintaining a flow of hot gases to and from the deposit in adjacent conduits in heat equalizing relationship while maintaining

in such deposit a temperature sufficient to melt and volatilize sulfur by means of a limited combustion taking place in the deposit, the flow of hot gases including sufficient combustible gas and air to maintain such combustion.

12. In the mining of subterranean sulfur, the process which comprises establishing and maintaining a flow of hot gases to and from the deposit in adjacent conduits in heat equalizing relationship while maintaining in such deposit a temperature sufficient to melt and volatilize sulfur by means of a limited combustion taking place in the de-

posit, the flow of hot gases including only sufficient air to maintain such combustion to produce such temperature, and carrying forward sulfur vapors by outgoing gases.

13. In the working of subterranean sulfur deposits the step which comprises subjecting the ignited sulfur to restricted combustion in the presence of a mixture comprising oxygen, nitrogen and substantial proportions of carbon dioxide.

In testimony whereof, we affix our signatures.

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GODFREY M. S. TAIT.