

Aug. 12, 1958

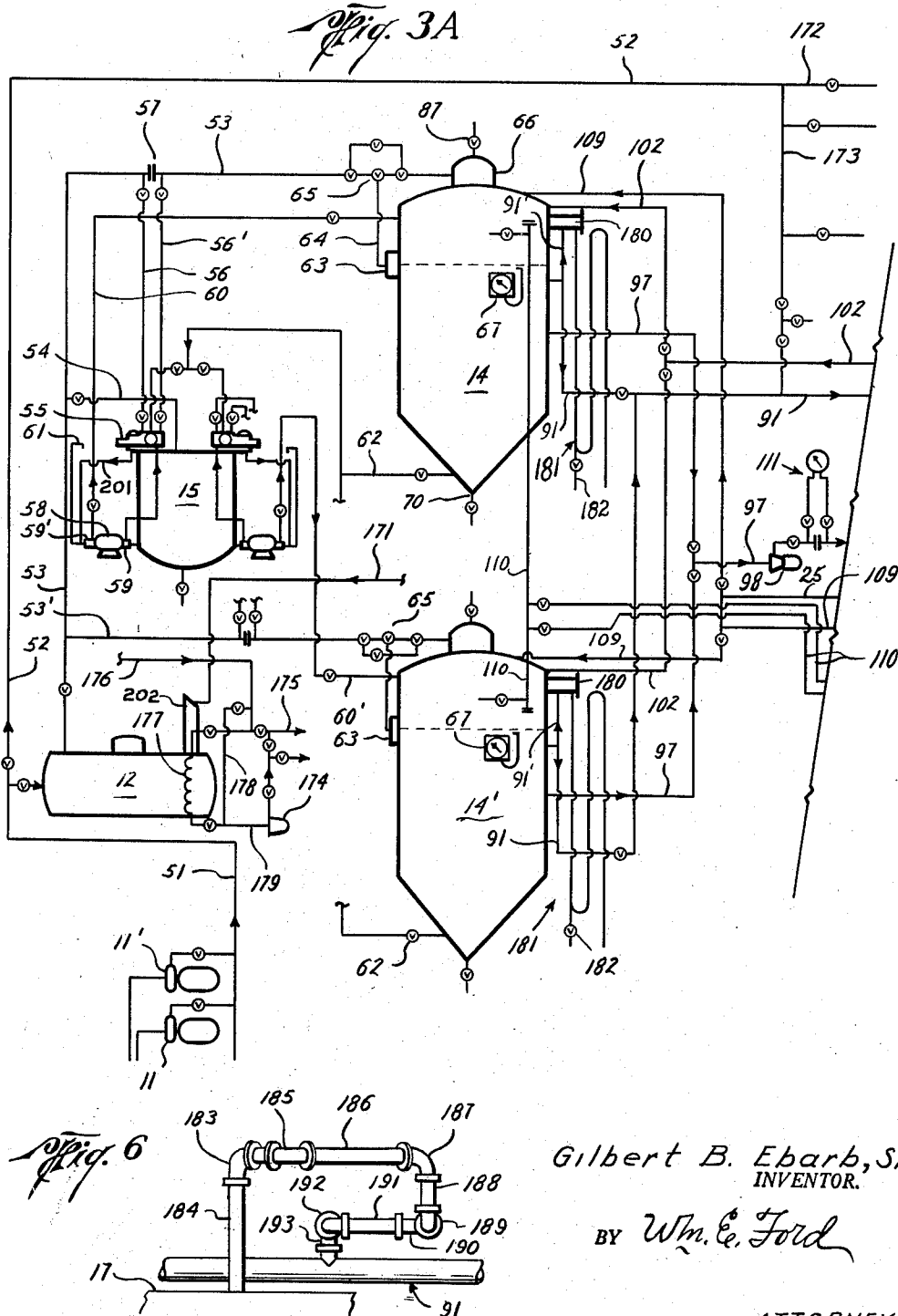
G. B. EBARB, SR

2,847,201

PORTABLE SULPHUR PLANT FOR USE IN A REGION OF SUBSIDENCE

Filed Nov. 9, 1954

4 Sheets-Sheet 2



Aug. 12, 1958

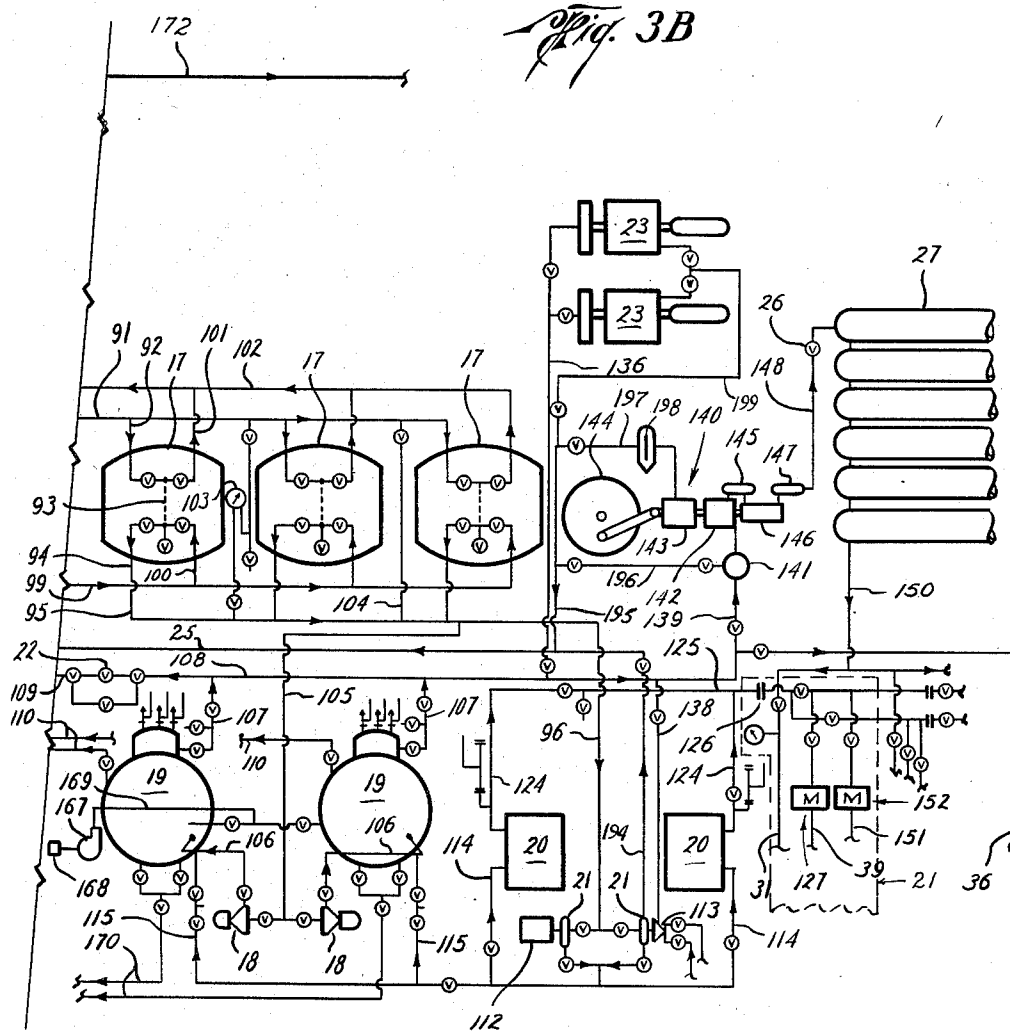
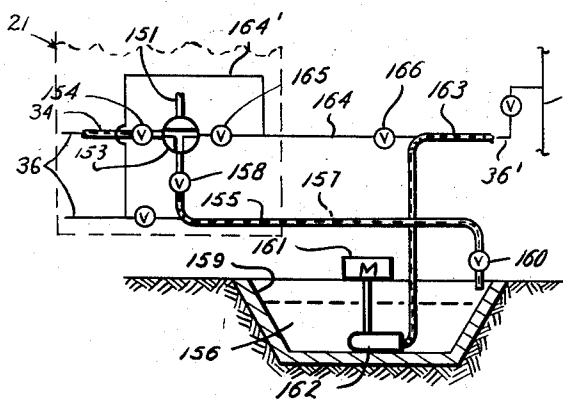
G. B. EBARB, SR

2,847,201

PORTABLE SULPHUR PLANT FOR USE IN A REGION OF SUBSIDENCE

Filed Nov. 9, 1954

4 Sheets-Sheet 3



Gilbert B. Ebarb, Sr.
INVENTOR.

BY *Wm. E. Ford*

ATTORNEY

Aug. 12, 1958

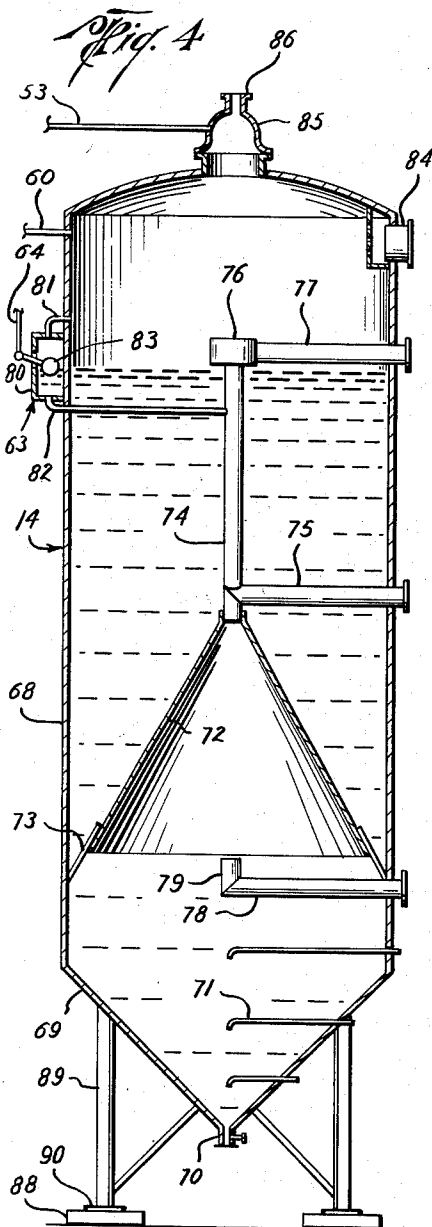
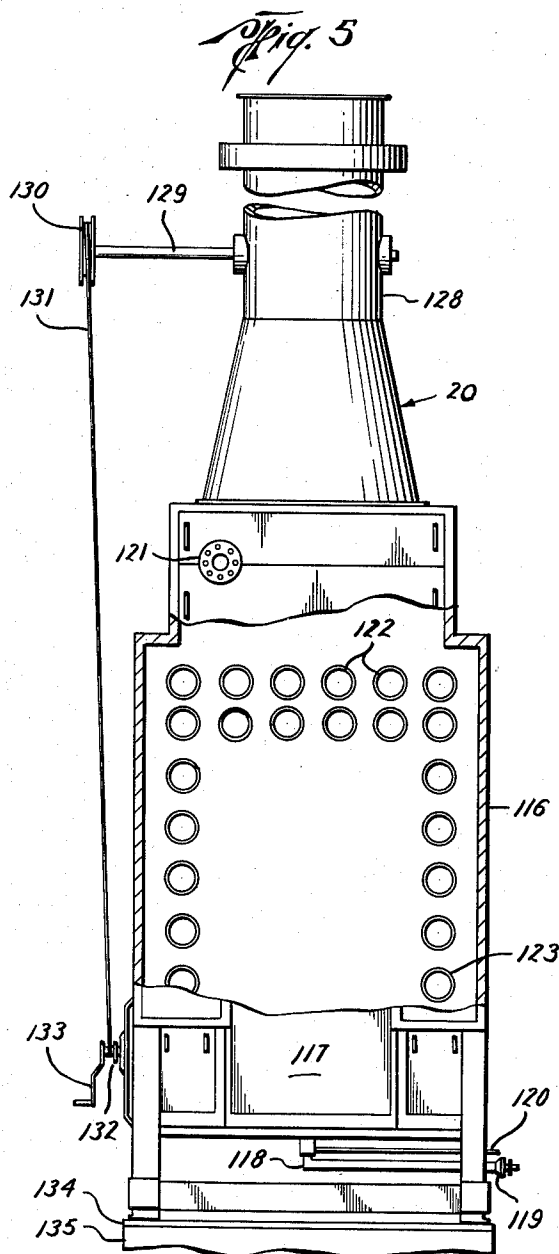
G. B. EBARB, SR

2,847,201

PORTABLE SULPHUR PLANT FOR USE IN A REGION OF SUBSIDENCE

Filed Nov. 9, 1954

4 Sheets-Sheet 4



Gilbert B. Ebarb, Sr.
INVENTOR.

BY *Wm. E. Ford*

ATTORNEY

1

2,847,201

PORTABLE SULPHUR PLANT FOR USE IN A
REGION OF SUBSIDENCEGilbert B. Ebarb, Sr., Rosenberg, Tex., assignor, by mesne
assignments, to Carroll R. Graham, Houston, Tex.

Application November 9, 1954, Serial No. 467,719

7 Claims. (Cl. 262—3)

This invention relates to a portable sulphur plant and method of its operation whereby the attendant advantage of proximity of plant to sulphur well may be obtained. Additionally it relates to such a method and plant which operates at higher thermal efficiency through employing treated water in the production of the well to thereby obtain a purer grade of sulphur, and it also relates to a method and plant operable at higher thermal efficiency, through applying gas heat directly to water containing tubes or through tubes surrounded by water whereby pressurized water at excessively high temperature may be employed as mine water to flow the sulphur. Furthermore the invention includes a more efficient method of flowing a sulphur well by localizing the producing sulphur to the area surrounding the producing area of the well bore and by drawing off cooling water from such area, with attendant increased thermal and operative efficiency. The invention also relates to a method of minimizing or counteracting the effects of "subsidence" resulting from the settling of the earth into the space from which the sulphur has been drawn.

Heretofore, in the production of sulphur wells, plants of permanent character have been established with the object of extending the hot water lines to the well as wells farther and farther from the plant are brought into production. This method of operation results in attendant heat losses along the line, requires excessive expensive insulation, and when the distance from plant to well has become sufficiently remote as a sulphur dome is drilled farther and farther from the plant, it is often necessary to install booster stations or plants where the water is re-heated. The costs of such booster stations or plants often rival the costs of constructing the initial plant, while requiring additional personnel and fuel consumption in operation.

Also, heretofore, it has been sulphur plant practice to treat only the water converted into steam and to extend such treatment only in degree sufficient to protect the boilers in operation, while employing the steam of the boilers to bubble through and heat the pressurized water to a sufficient temperature for sulphur well flowing. Thus the raw water heretofore employed as mine water has picked up as condensate only a small percentage of the steam into which the treated boiler feed water has been converted, and has consequently carried with it the impurities of the raw water to contaminate the sulphur in the well. The thermal efficiency of a plant of this type has been much less than the thermal efficiency of a plant which applies to treated water the excessive temperatures obtainable by gas consumption where such gas burns as it passes through tubes through the pressurized treated water, or else burns as it surrounds tubes through which the pressurized treated water passes.

Additionally, sulphur wells have been "mined" or flowed by injecting water into the well to melt the sulphur in the mine or sulphur producing formation, but with no effort being made to localize or isolate the producing sulphur or molten lode to the immediate area of the

2

well bore. Thus the hot water which is employed may flow from the area of the well bore and into remote crevices and faults in the formation to cool and thereby waste the heat therein in ineffectiveness. However, when a series of holes are drilled through the cap rock at spaced apart distances surrounding the well bore and a viscous liquid, as a drilling mud, is pumped or otherwise forced down these bores at a time after the sulphur surrounding the well or production bore has been placed in a molten state by the introduction of hot water, the heavier mud will flow at least in part below and around the sulphur to form a bowl or an inverted dome-shaped sheath within which the sulphur of production is confined or localized to the area of the producing bore.

In this manner most of the hot water ejected down the well bore acts effectively to melt the sulphur and very little heat content is lost therefrom in giving up heat at points too remote from the producing well bore to effect the upward flow of sulphur therein. As an additional feature of thermal efficiency a cold water draw off bore may be made at a distance from the well bore and near, but within the periphery of the localized area and that portion of the water in the localized area space remote from the well bore may be drawn off as it cools and before it can cool to any appreciable degree.

It is consequently a main object of this invention to provide a portable sulphur plant and method of use by installing the plant proximate each producing sulphur bore to thereby avoid the heat losses encountered where long lines extend from plant to well.

It is also a primary object of this invention to provide a sulphur plant and method of operation, wherein treated water is employed as the mine water, thereby obtaining a purer produced sulphur.

It is another important object of this invention to provide a light, moderately priced sulphur plant and inexpensive method of use wherein treated water under pressure is heated by gas directly applied through fire tubes surrounded by the treated water, or to tubes through which the treated water flows, thereby eliminating the use of boiler steam to heat the mine water, so that steam boilers are needed only to operate the plant equipment and for auxiliary purposes; an appreciable reduction in operation costs being achieved thereby.

It is still a further object of this invention to provide a plant and method of use whereby the heating of the mine water may be carried out by automatically operable means to a great degree, thereby reducing personnel requirements.

It is yet another object of this invention to provide a sulphur plant and method of use wherein treated water is heated in gas fired heaters in which pressures can be maintained in degree to obviate internal treatment of the water in the heater, the heated water then being deliverable from the heaters at high velocities by virtue of the pressures obtainable in the heaters.

It is yet another object of this invention to provide a sulphur plant and method of use wherein various items of installation may be individually skid mounted for portability so that the plant may be positively located proximate each new producing bore, flexible connections being provided in the connection means between the various items of equipment to thereby obviate breakage due to any "subsidence" of the earth beneath the plant location as the sulphur is removed.

It is also another object of this invention to provide a method of mining sulphur with the pure high temperature water obtained from a sulphur plant and method of use of this class in which the molten sulphur is localized to the area of the producing bore while the mine water is drawn off from the outer part of the producing area

before it can cool and by contact reduce the temperature of the incoming mine water.

Other and further objects will be apparent when the specification hereinbelow is considered in connection with the drawings in which:

Fig. 1 is a flow sheet of a portable sulphur plant for carrying out the teaching of this invention;

Fig. 2 is a sectional elevation through a sulphur mine in which the teaching of this invention is carried out;

Fig. 3A is a detailed flow sheet and piping diagram of part of the sulphur plant shown generally in Fig. 1;

Fig. 3B is a detailed flow sheet and piping diagram of the other part of the sulphur plant shown generally in Fig. 1;

Fig. 4 is a sectional elevation of a water softener tank shown generally in Figs. 1 and 3A; and

Fig. 5 is a sectional elevation of a water heater shown generally in Figs. 1 and 3B.

Fig. 6 is a plan view illustrating how flexibility may be obtained in piping connections.

Fig. 7 is an elevation, partially diagrammatic, of part of the relay station, and of the sulphur pit.

Reference may now be made to the drawings in which corresponding reference numerals are applied to corresponding elements in the various views.

In Fig. 1 the broad concept of a sulphur plant constructed after the teaching of this invention is shown. Beginning with a reservoir or water well as a source of raw water, a pump 11, which may be driven by a gasoline engine, electric motor, or by steam, delivers such raw water to storage, as to a storage tank 12. From the storage tank 12 the greater part of the water, as 95%, is delivered to a softener, as a water softening tank 14, while the remainder is delivered to a chemical mixer 15, where a chemical, as lime, is provided to be mixed with the water. A pump 16, which may be driven electrically, by a gasoline engine, or by steam, delivers the mixture of chemical and water to the softener 14 wherein, under steam pressure as will be hereinafter described, the added chemical and water are mixed with the raw water delivered to the softener from the storage tank 12, and the impurities are at least in part precipitated and the water otherwise treated and softened under steam contact, as will be described hereinbelow.

The water from the softener 14 is delivered to a filter 17 wherein suspended particles and other matter are filtered therefrom and then a part of the water is delivered by a boiler feed water pump 18 to a boiler 19 while the greater part of the water is delivered to a gas heater 20 by a pump 21, the pumps 18 and 21 being steam operated. A by-pass line 22' is provided so that in case of failure of either the pump 18 or the pump 21, the other pump may supply the water to both the boiler 19 and heater 20.

The heater 20 is gas fired and may be either of the water tube or fire tube type, it only being necessary that the heat imparted by gas combustion may be applied directly through the metal of the separating tubes to the water. In such a boiler the water remains in a closed system under pump pressure and thus may enter at say 180 p. s. i. and leave at say 160 p. s. i. Due to the thermal capacity gas thus burned in such a heater, the water may be raised to comparatively high temperatures; on an occasion temperatures in excess of 340° Fahrenheit having been obtained while the lower ranges obtainable include a temperature of 317° Fahrenheit. From the heater the water, now ready for employment as mine water, is delivered to the control or relay station 21 where its employment in the sulphur well, not shown, is controlled.

The live steam generated in the boiler 19 is delivered through a motor or reduction valve 22 to the softener 14 for use therein as low pressure steam, the reduction being from pressures of say 138 p. s. i. to pressures of 5 p. s. i. The live steam is also employed to run a generator 23

which generates the electricity required at location. Also steam at high pressure is conveyed to actuate a steam turbine or compressor rotor 144 which actuates an air compressor 24, and to actuate pumps of the plant, as the pumps 18 and 21. Additionally live steam, controlled at relay station 13, is employed in lines in a manner to keep the flowed sulphur from the well in molten condition. An exhaust steam line indicated in Fig. 1 as the line 25 extending from the pump 21 returns from the various steam operated items of equipment for employment in the softener 14 together with the reduced pressure steam passing through the motor or reduction valve 22. The use of the exhaust steam is designated by the fragmentary exhaust steam line 25 shown entering the softener 14.

The compressed air generated by the air compressor 24 passes through a reduction valve 26 where it is reduced from pressures of approximately 400 p. s. i. to pressures of approximately 30 p. s. i. and is then stored in a surge bottle or tank 27 prior to delivery to the relay station 21 where its use in the sulphur well is controlled.

In Fig. 2 there is shown a central well casing 28 which designates the casing for a producing sulphur well bore, as an 8" casing. The bore descends through the calcite rock cap generally indicating the presence of sulphur therebelow, and is shown penetrating a sulphur bearing calcite formation and extends into an anhydrite formation. The lower part of the casing 28 has perforations 29 therein extending from the bottom of the casing well up into the sulphur bearing calcite formation. Centrally within the casing 28 there extends a smaller diameter pipe 30, as a 3" pipe, which terminates at a spaced distance above the bottom of the casing 28 and at a spaced distance below the upper limit of the perforate part of the casing. Centrally within the pipe 30 there is located a smaller diameter pipe 31, as say a 1" pipe terminating at some substantial distance, as say 30 feet, above the lower end of the pipe 30.

At the top of the well the casing 28 is capped by a fitting 32 and the pipe 30 passes upward through the top of the fitting 32 and branches at a fitting 33 into a horizontal line 34 having a valve 35 therein adjacent thereto. Outwardly of the valve 35 a steam line 36 is sealably passed into the line 34 and extends centrally therein. The pipe 31 is sealably passed through the top of the fitting 33 and extends outwardly therefrom. Within the fitting 32 the pipe 30 branches and is sealably extended outwardly therethrough in a horizontal line 37 and turned to join the line 34 having the central line 36 therein, there being a valve 38 in the line 37 adjacent its junction with the line 34. The fitting 32 has connected thereto the line 39 opposite the line 37 and this line 39 has a valve 40 therein adjacent the fitting 32.

At usually substantially equally radially spaced distances from the producing bore, and at substantially equal angular distances apart, a plurality of bores 41 are drilled to pierce the calcite cap rock which almost universally is encountered above a sulphur producing area. Also, a bore 42 is drilled at a spaced distance from the producing bore and preferably slightly within the periphery of the bores 41.

In producing the well at first pressurized heated mine water is directed down the line 39, through the open valve 40, into the fitting 32, and down the casing 28. Also the heated mine water is directed down the line 34 through the open valve 38, the valve 35 being closed, and down the line 37 into the pipe 30, through which it flows to join the water flowing down the casing 28 and out through the perforations 29 into the sulphur bearing calcite.

As the pressurized mine water at temperatures in excess of 300° F. comes in contact with the sulphur in the calcite, it melts the sulphur so that it begins to form a molten sulphur pool in the lower part of the calcite formation. To avoid the molten sulphur running off

5

through lines of cleavage and faults in the calcite formation, a thick, heavy, viscous fluid as the fluid used in drilling oil wells and termed "drilling mud" is pumped under pressure down the cased bores 41 which extend into the calcite formation below the cap rock. The drilling mud, flows out of the cased bores 41 and at least in part, it flows into space in the upper calcite including space which the sulphur has vacated and arriving at the pool of molten sulphur the heavy viscous mud runs down under the pool of sulphur and forms an inverted dome-shaped encasement or a bowl to fill and plug the lines of cleavage, crevices, or faults through which the sulphur might otherwise flow away from the pool. Thus the sulphur is localized to a bowl shaped area surrounding the casing 28 as its central or focal point.

The mine water, lighter than sulphur, tends to stand on top of, or in the upper part of the sulphur. The water being supplied to the sulphur is at the high temperatures stated above at the point it leaves the pipe perforations 29 but loses temperature as its heat is expended in melting the sulphur and becomes cooler in the areas of the mud bowl more remote from the producing bore. In order that this cooler water at the periphery of the bowl may not act to cool the hot water arriving down the producing bore, a pump 200 is connected at the top of the pipe 42 to exert suction thereon and draws the cool water around this pipe and from the periphery of the mud bowl up the pipe 42 to be expelled at the surface or employed at the surface for other uses when so adapted. The process of drawing off this cool water is termed "bleeding" the well, and the pipe or line 42 is termed the "bleed" line.

After the hot water has been introduced into the producing bore for some time and the sulphur is in molten state and ready to flow, the valve 38 is closed and the valve 35 is opened. Also compressed air is introduced into the bore through the pipe 31 to place under pressure the liquid sulphur in the pool below. The molten sulphur may now flow up the pipe 30 around the compressed air pipe 31 and pass onto a subsequent stage of treatment through the line 34 as steam flows in the line 36 within the line 34 to supply heat to the sulphur and maintain it in molten state. The compressed air blows an open central core space through the upwardly passing sulphur in pipe 30 as the air passes downwardly to pressurize the molten sulphur in the pool below. This reaction is obvious if consideration is given to the fact that a hole blown by a gas into a liquid will cause an upward splashing of the liquid around the gas jet stream. Carried farther, especially when the spaces in the sulphur bearing calcite become pressurized, additional pressurizing gas must cause the sulphur to take the only egress possible when it cannot penetrate the cap rock, and when the pump 200 is shut down, and this egress is up the pipe 30 and around the compressed air pipe 31.

The plant shown in Figs. 3A and 3B follows in general the sequence of the flow diagram shown in Fig. 1 but the arrangement is shown in more detail in order that a fuller understanding may be had of the arrangement of the apparatus carrying out various stages of the process and the relation of such apparatus to the piping and auxiliary equipment required for the operation thereof.

The water from the reservoir is such water as may be obtained from any outdoor tank, artificial lake, or dammed stream and consequently such water will have substantial impurities therein and the degree and character of such impurities will vary seasonally, especially during rainy seasons. It is necessary to use this type of water as it would be otherwise prohibitive to pipe treated water from established water systems to the varying locations in remote areas at which sulphur may occur.

Thus because of outdoor service and because of the heavy usage to which the pumps which transfer the raw water must be subjected, alternately employable pumps

6

11 and 11' are shown, one of which may be driven by an electric motor and the other by a gasoline engine, the reservoir being omitted from the drawings. The raw water thus picked up by the pumps is transferred through a main 51 from the location of the reservoir to a storage tank 12 located as an element of a sulphur plant very proximate the location of a producing sulphur well. A service line 52 branches from the main 51 to supply service water for plant usage where purified water may not be needed.

From the storage tank 12 the raw water is supplied to a pair of softener tanks 14, 14' via the respective lines or header 53 and 53' and a small percentage, as 5%, of the water, is also supplied via the line 54 or header 15 to a chemical mixer 15.

Ordinarily the chemical employed in such a mixer is lime or calcium hydroxide but also other related products may be employed to precipitate the impurities in the water and in rainy seasons it has been found that copperas must be added to precipitate matter brought in by the rains.

A chemical proportioner 55 is mounted on the mixer for each softener. Lines 56 and 56' lead from the line 53 on opposite sides of an orifice plate 57 and record at the proportioner the rate of raw water flow in the line 53 which delivers the raw water to the softener. The operator observes this recorded rate of flow and adjusts a conventional means within the proportioner, which means is not shown because of scale difficulties, and this means adjusts the proportioner to deliver therefrom an amount of mixed chemical and water at a rate sufficient to precipitate and soften the raw water at the rate of volumetric delivery thereof. An electric motor 58, having pumps 59, 59' at the ends thereof, drives the pump 59 adjacent the lime mixer 15 to draw a mixture of chemical and water from the mixer and delivers it to the proportioner 55. That part of the mixture of water and chemical which is not passed overflows and returns to the mixer 15, while the part that is passed through is picked up by the pump 59' on the outer end of the motor 58 and delivered through a line or header 60 into the top of the softener 14. An air bleed line 61 is provided to bleed air from the suction line 201 to the pump 59'. Similar apparatus proportions mixed chemical and water delivered through a line 60' into the top of the softener 14'.

The impurities of the raw water are substantially precipitated in the softeners 14, 14' and a combination of water and sludge of precipitation is drawn off from the bottom of each softener through a line 62 and delivered into the chemical proportioner 55 to serve as an added ingredient in the lines 60 and 60' to avoid the deposit of chemicals within these lines, as it has been found that the presence of sludge keeps in solution matter which would otherwise encrust the pipes.

The precipitation and softening of the raw water in the softeners 14 and 14' is conducted under the pressure of reduced steam and exhaust steam at above 5 lbs. pressure. The source and path of access of this low pressure steam will be described hereinbelow. Automatic adjustment is provided to maintain the steam-water level in the softeners, a conventional float mechanism, not shown in detail, but generally designated by the numeral 63 being mounted on the exterior of each softener. The rise and fall of the float is imparted to a linkage 64 which controls a regulator valve 65 in the line 53 and thus regulates the amount of water delivered through the line 53 into a cap 66 at the top of each softener, to maintain a proper balance in such softeners between the steam and the water therein. A temperature recorder 67 registers the temperature of the water within a softener at approximately the steam-water level. The ordinary softener at slight overload can process approximately 14,000 gallons of water per hour so that three softeners of the type shown could process approximately 42,000 gallons of

raw water per hour. It has been found that such softeners when supplied with low pressure steam at approximately 5 p. s. i. pressure will raise the temperature of the water to about 220° Fahrenheit at its point of exit.

As shown in detail in Fig. 4, each softener 14 includes a cylindrical hull or housing 63 having a conical lower end 69 including a bottom blow-out vent 70 therein. Sample lines 71 extend from the lower end of the softener and sludge samples may be taken from these lines at various levels to obtain knowledge of the sludge constituency. Above the lower end of the tank an upstanding conical baffle 72 is provided therewithin and supported by a series of peripherally spaced connectors 73 which space the baffle from the inner wall of the housing and thus the baffle 72 serves as a deflecting guide member whereby the precipitating sludge may slide downwardly and through the annular space between baffle and housing to deposit in the lower portion of the housing.

A central pipe 74 upstands from the top of the baffle 72 and is transversely supported by a pipe 75 which extends through the shell of the housing 68 for connection to the outlet line to be hereinafter described through which the treated water from the softener 14 flows out to the filters 17. At the top of the upstanding pipe or riser 74, a cup or basin 76 is installed and transversely supported by a pipe or line 77 which extends outwardly through the hull 68. In order to back wash the filter 17 by means of a system to be hereinafter described, a pipe 78 is provided, having an inner inlet or upstanding elbow 79 to extend axially of the softener to an elevation approximate the base of the baffle 72. Suction is taken from the outer end of the pipe 78 and the treated water is passed through the filter 17 and returned by a back wash return line connected to the pipe 77. Thus the direction of back wash circulation passes through the pipe 77, the basin 76, down the riser 74, and from within the baffle 72 to the inner inlet 79 of the pipe 78.

The float mechanism 63 on the exterior of the shell 68 includes a housing 80 rigidly connected to the shell 68 and having a steam inlet 81 in the top thereof and a water conduit 82 connected into the bottom thereof, such conduit extending from the riser 74 through the shell 68. A float 83 within the housing 80 is connected to a pivoted linkage 64, hereinabove generally described, which transmits the rise and fall of the float 83 in results respectively operating to open and close the flow regulator valve 65 which controls the rate of raw water flow to the softener.

A baffled inlet 84 is provided at the top of the shell 68 through which reduced steam and exhaust steam from lines to be hereinafter described may enter the top of the softener to provide the steam which maintains the treated water in the softener under steam pressure. A bonnet 85 is installed on top of the softener and has connected thereto the line 53 through which raw water is supplied to the filter; also, the line 60 is connected into the top of the softener through which flows the mixture of lime and water from the lime mixer 15. The top of the bonnet 85 has a flange 86 thereon on which is mounted a conventional vent valve indicated as a valve 87 in Fig. 3A.

As has been generally stated hereinabove the condition known as "subsidence" exists at sulphur well locations, subsidence being defined as the subsiding of the earth into the cavities formed by the flowing out of molten sulphur from the space which the sulphur had previously occupied in its hardened solid state. Thus a different condition exists in the mining of sulphur than in the mining of liquid minerals as oil, since the oil and similar liquids occur in the earth in preexisting cavities within walls of hardened formation which confine the oil space and thereby support the overhead formation from caving in or subsiding when the liquid oil is withdrawn, whereas in sulphur mining, sulphur in its normal state constitutes a hard substance of supporting strength which augments the material calcite in supporting the earth formation thereabove. Therefore it can be seen that

when the sulphur is melted and changed from its normal hardened state, part of the original hard supporting structure is withdrawn from the formation mass thereabove so that in many cases the earth will sink or subside into the crevices from which the sulphur has flown under heat and the earth up to the top of the ground will subside.

To provide against such subsidence in a sulphur plant and to provide for the portability of each individual item of equipment employed, it is advantageous to provide a separate concrete base for each plant element and often it is advisable even to go further and provide separate footings for each individual leg of an element. Thus, as shown in Fig. 4, a footing 88 is provided for each leg 89 which supports the softener 14 and a base 90 is provided for each leg 89 of the softener, and lag bolts, not shown, connect the base 90 to the footing 88. In case of uneven subsidence such lag bolts may be withdrawn from any leg which may sink lower than the other supporting legs and proper shimming may be provided under such leg to raise it to the level of the others. To move the softener to another location it is obvious that it is only necessary to remove the lag bolts of the bases 90 and then, when the pipe lines to the softener are disconnected, the softener is ready to be lifted for transportation to a new site.

From each softener 14 a treated water outlet line or header 91 connects to the pipe 75 which receives the softened water in purified state, such water rising above the sludge to the top of the baffle 72. Such line 91 delivers the water to the filters 17 in which the water is further purified by the removal of suspended particles therefrom through deposit by impingement on the filter material within the filters. The filter employed may be provided from a range of commercially known apparatus and details of individual filters are not shown for this reason. An inlet line 92 from the general delivery or header line 91 delivers the treated water to each filter and the water passes through the filter medium therein generally denoted in Fig. 3B by the dotted line 93 and exists through a line 94 to a header 95, and flows therefrom through a line or header 96 to be picked up for further delivery as will be hereinbelow described.

Each filter 17 is connected to permit the bypassing of the filtering flow therethrough in order to allow the filters to be back washed or cleaned individually, one filter being cut out of the system at a time while the others continue in operation to handle the treated water delivered thereto. To this end a back wash line 97 is connected to the outlet of the pipe 78 from each filter and a suction pump 98 draws on the lines 97 and delivers back wash down the line 99 for distribution through a line 100 into each individual filter to be back washed. The line 97 has a suitable controlled orifice and gauge therefor provided at 111 to control the rate of flow to the filters.

The valves in the lines 92 and 94 are closed to back wash an individual filter and a valve in the back wash inlet 100 and a valve in back wash outlet 101 from the filter are opened. Thus the back wash courses through the line 100, through the filter material 93, and out the outlet 101 to a back wash return line 102 which delivers the back wash through the top of each softener to course therein for recirculation through elbow 79 and the pipe 78 to the back wash suction line 97.

The pressure drop across the filters may be measured by a suitable pressure gauge assembly 103 between the filter inlet header 91 and the filter return header 95. Also all of the flow from the header 91 may be directed to bypass the filters and flow through a line 104 for delivery by the line 96 for further circulation.

From the return header 95 a line or header 105 delivers water for distribution as boiler feed water to the pumps 18 which discharge through lines 106 into the boilers 19. Within the boilers, which may be either fire

tube boilers or water tube boilers, the treated water is converted into high pressure steam at approximately 160 p. s. i. and delivered through steam outlet lines 107 to a high pressure steam line or header 108. By means of the reduction valve 22 in the line 108 high pressure steam is reduced to approximately 5 p. s. i. and delivered via lines 109 to the softeners for employment in the softening process therein. Additionally steam employed in removing deposited material or boiler crud from the boilers is delivered via lines 110 to the softeners 14.

The treated water is delivered to the heaters 20 by means of pumps 21 which discharge through or header lines or conduit means 114 to such heaters. One of these pumps may be driven by a gasoline engine 112 and the other by a steam turbine 113 and thus a stand-by prime mover source is available in case of breakdown of one source. In case of a break down of the boiler pumps 18, boiler feed water may be supplied to the boilers by either or both of the pumps 21 via bypass lines 115. Conversely, in case of break down of either of the pumps 21, either or both of the pumps 18 may be employed to deliver treated water from the line 105 via the conduit means 115 to the discharge conduit means 114 to the heaters 20.

As shown in Fig. 5 each heater 20 includes a shell 116 having a fire box 117 in the lower end thereof to receive gas through a gas inlet 118 which is provided at 119 with a suitable gas flow adjustment, also an air intake 120 is provided for the gas inlet 118. The type of heater employed is of the water tube class and generally water enters at approximately 220° F. into the intake 121 to which is connected the pump discharge line 114 shown in Fig. 3B. The water courses downward through water tubes 122, leaving the heater at a temperature of approximately 320° F. from the lowermost tube 123 as shown in Fig. 5, where connection is made to the heater discharge line or header 124. As shown in Fig. 3B, this water is delivered to the mine water line or header 125 having the orifice plate 126 therein by means of which the rate of mine water flow is measured. From mine water line 125 the line 39 extends to deliver the heated water to the sulphur well bore casing 28, as has been hereinabove described in detail in connection with the description of Fig. 2 relating to the mining operation. A suitable conventional manometer assembly 127 is provided in the line 39 for measurement.

An adequate stack 128 is provided as shown in Fig. 5 having a damper not shown therein and mounted on a shaft 129 which is journaled in the stack and has a pulley 130 on the outer end thereof to which is attached a line 131 which extends downward to a reel 132 mounted on the side of the fire box. By turning the reel handle 133, adjustment of the damper can be made to control the exhaust of gas of combustion. A suitable base or skid 134 is provided to support the heater 20 and such base is removably mounted on a concrete foundation 135 which is adequate to support the heater but which is not connected to the foundation of any other element or item of plant process equipment.

As shown in Fig. 3B the high pressure steam generated in the boilers 19 is delivered in the line 108 to the line 136 which is shown extending to operate generators 23 which are required to supply power to the plant as the power which operates the lighting circuits required for night operation. Such generators 23 may also be gas driven and this is generally the practice in areas where most sulphur mines are located, it being generally found that oil and gas is produced in the same localities where sulphur may be found. Thus gas can be inexpensively obtained for the purposes of operating certain apparatus in sulphur plants.

Steam from the main steam line 108 is also carried by a line 138 to operate the steam turbine 113 which drives one of the pumps 21; also such high pressure steam is carried by a steam line 139 to operate a compressor 140

employed to compress the air required in flowing the sulphur from the sulphur well as has been hereinabove described.

The line 139 is connected to the steam separator 141 of the compressor 140 and from the separator high pressure steam is delivered to the compressor steam chest 142 to operate the compressor rotor 144. The compressor compresses air in two stages by means of a low stage compressor 145, an intercooler 146 and a high stage compressor 147 from which compressed air, at say 400 p. s. i. is delivered by the line 148 to the reduction valve 26 where it is reduced to say 30 p. s. i. and delivered to a number of series-connected air receivers or bottles 27. From the last bottle of the series the compressed air is drawn via a discharge line 150 for delivery to the line 31 hereinabove described and shown in Fig. 2 in its use in flowing the sulphur well. The storage of the compressed air in the number of large volume bottles results in dampening surge in the compressed air delivery line 150 so that compressed air flows evenly therein and at substantially uniform pressure.

Exhaust steam, as that from the steam turbine 113 which actuates the pump 21, returns via a line 194 to the exhaust steam header 25 which joins the reduced steam lines 109 which connect to the baffled inlets 84 of the softeners 14, 14'. Such exhaust steam header 25 also is joined by an exhaust steam line 195 which transports the exhaust steam from a line 196 from the compressor steam trap 141 and by an exhaust steam line 197 from the compressor piston 143 and from a compressor oil separator 198. Additionally this line 195 carries off exhaust steam from a line 199 from the generators 23 when such may be steam operated.

The delivery of treated water to the sulphur well in the early stages of operation before the sulphur begins to flow has been described hereinabove in connection with the description of the lines 34 and 37 at the top of the well. The treated water is supplied to the line 34 from the line 151 which extends from the mine water line 125 and as shown in Fig. 3B a suitable manometer assembly 152 is provided in the line 151 for flow measurement. High pressure steam is taken from the high pressure steam line 108 via the line 36 for central installation in the line 34 to keep molten the sulphur from the mine as has been described hereinabove in the description of Fig. 2.

The line 39 has also been described hereinabove in relation to its usage in supplying hot water to the sulphur well, such line being of a larger diameter than the line 34 with which it supplies the earlier part of the hot mine water used in first melting the sulphur. The supply from line 39 must pass down the casing 28 which has a much larger cross-sectional area externally of the pipe 30 than does the pipe 30 itself which is the conduit for the volume of early hot water from the line 34.

The shift from supplying hot water down the lines 151 and 34 to the pipe 30 to the clearing of the pipe 30 for the upward passing of sulphur therein is effected by means of a 4-way valve 153, such valve being shifted to the position shown in Fig. 7 which completes communication with a line 155 through which molten sulphur is delivered to a sulphur pit 156. The line 155 has a steam line 157 installed therein to supply heat to the sulphur and keep it in molten condition. To effect delivery of steam from the line 36 to this line 157 a valve 154 within the line 36 adjacent the 4-way valve 153 having a stem rotatably and sealably extending through the line 34 is opened and also a valve 158 within the line 157 adjacent the 4-way valve 153 having a stem rotatably and sealably extending through the line 155, is opened. This effects steam communication through the 4-way valve between line 36 within line 34 and line 157 within line 155.

The line 155 has a longitudinally extending slot, not shown, but of a length comparable to the distance across the pit 156. To insure that the molten sulphur delivered

through the pipe 155 is all received within the pit, the pit has upper walls sloped as indicated at 159. A motor 161 mounted at ground level adjacent the pit 156 operates pump 162 in the bottom of the pit which discharges the molten sulphur through the line 163 to the location of a conventional sulphur stack, not shown.

In order to blow out any sulphur which may harden in the line 163 a steam line 164 is provided which extends from its valve 165 adjacent the 4-way valve 153 to a valve 166 which is sealably connected to the line 163. Thus with the 4-way valve in the position shown in Fig. 7, the valves 165 and 166 are opened, as is the valve 154, so that the steam from the line 36 may blow through the 4-way valve 153 and down the line 164, into the line 163. The line 163 is heated by a line 36' which branches from the steam line 36 and extends down the line 163 centrally therewithin to terminate at the pump 162.

The sulphur plant has various additional features which are described hereinbelow to better set forth the complexity of this operation. Some of the special equipment items employed in such a plant include a pump 167 which draws anti-corrosion and treatment material from a supply source 168 and delivers it via lines 169 to the boilers 19. In order to blow off or drain the boilers 19 suitable drain lines 170 are provided which may be opened for waste flow or which may deliver into a make-up line 171 shown in Fig. 3A which is adapted to deliver such drainage water, as well as water from other sources, into a stand pipe 172 which extends above the water storage tank 12.

The raw water delivered to the line 52 for service purposes may be used for a number of functions such as the supply for fire extinguishing water 172. Also service water may be taken through filters 17 when the softeners 14 are shut down as indicated by the line 173 which connects the line 52 with the filter supply header 91.

A general supply pump 174 is provided to deliver water through lines 175 for purposes such as cooling the bearings of the plant equipment. A return line 176 from such plant equipment connects into a cooling line or coil 177 which extends within the storage tank 12 to be cooled by the contact of the cold raw water in the storage tank and stand 202 with the surface of the pipe or coil 177. In cases when it may not be desired to employ the storage tank 12 for cooling purposes the line 176 may be bypassed via the line 178 which connects into the suction line 179 of the general service pump 174.

A casting or pipe 180 extends from each softener 14, 14' and has connected thereto a branch line 91' from the line 91 also a loop seal line 181 extends from the casting 180 which communicates with the low pressure steam in the top of the softener and as a consequence of opening a valve 182 in the loop seal, water may be blown out through the loop seal 181 to lower the water in the softener.

The feature of portability is strongly stressed in sulphur operation employing the equipment hereinabove described and all items of equipment and all individually supported apparatus have skids or bases which are removably mounted on individual concrete foundations or footings. Thus the sulphur plant may be moved with a minimum of difficulty, as has not heretofore been the case when larger equipment has been employed, such as larger filters, larger boilers, larger softeners, and larger storage tanks. This portability is obtained through employing a number of corresponding items of equipment of a smaller size than have been employed heretofore in these conventional plants.

Troubles heretofore encountered in subsidence are minimized when smaller equipment is used even though a larger number of individual items of apparatus may be required. As shown in Fig. 6, provision is also taken to avoid breakage of connecting lines between various equipment due to the consequences of subsidence. In

this regard, the filter supply header 91 is shown in relation to a filter 17. The support for the header 91 is not shown but it is a separate support from the filter foundations for the filter 17. Thus if the filter 17 should subside as the molten sulphur in the earth therebelow is withdrawn by melting, while the header 91 does not undergo similar subsidence, breakage would occur in any rigid pipe connecting header and filter. However, the line 92, employed to connect header 91 and filter 17, consists of an assembly of elbows, pipe sections, and nipples which, as shown, will permit compensation in three dimensions for any relative subsidence between the elements 17 and 91.

In detail an elbow 183 is connected to the outer end of a pipe section 184 which extends outwardly from the filter 17. The elbow 183 extends upwardly in an angular direction and is connected by a short nipple, not apparent in Fig. 6, to an elbow 185 which extends downwardly at an angle and has a pipe section 186 connected thereto. An elbow 187 is connected to the lower end of the pipe section 186 and its inner leg extends with axis horizontal. A nipple 188 connects the elbow 187 with an elbow 189 which extends vertically downward. An elbow 190 is connected to the lower leg of elbow 189 by a short nipple, not apparent, and a pipe section 191 is connected to the elbow 190 to extend horizontally for connection at its other end to an elbow 192. Such elbow 192 in turn is connected to an elbow 193 by a nipple, not apparent, and the elbow 193 in turn extends horizontally outwardly from the header 91. Thus regardless of the degree and direction of relative subsidence, the assembly of elbows, nipples, and pipe sections can pivot to allow three dimensional adjustment to the new relative positions between filter and header.

A plant as hereinabove described and its method of use together with the method of using the treated water therefrom in an improved mining operation has amounted to a revolutionary contribution to the art of sulphur mining. Especially opportunistic is this discovery as the increased demand for sulphur and the scarcity of new producing areas makes it necessary to work old domes and parts of producing areas which may heretofore have been considered in the category of marginal producers from an economic viewpoint.

In past years the presently nationally known large sulphur producers have grown to their present stature due to the fact that their earliest producing wells have been located centrally of lodes or producing areas of vast extent so that production could be continued from a well over a long period as the producing area therebelow was progressively exploited. To this end permanent plants were installed with boilers, softeners, filters, and auxiliary equipment of large size so that the costs of moving the plant were prohibitive.

As a comparatively large area below a well within the heavy producing central lode was gradually brought to marginal production, other wells were drilled in the heavy producing zone at considerably spaced distances from the first producing means, and spaced to fall centrally of new zones whose peripheries were calculated to extend to the periphery of the earlier, depleted zone.

The plant having been constructed for permanency, could not be moved, so the mine water lines from such plant were extended with attendant heat losses due to radiation which could not be compensated for by extensively insulating the extended lines. The cost of the pipe lines necessary to make these extensions also mounted, and when extension to the remoter wells was made it became necessary to install booster stations to reheat the mine water, and such stations could amount in costs to figures comparable with the costs of initial installation.

By arriving at a plant which could be portable from one location to another and which also could be constructed to counteract subsidence, a plant could be lo-

cated proximately on top of a sulphur well, so that the shortest mine water lines were required. Also, as the plant could be moved at little expense, plans could be made to produce wells which could be located outwardly of the center of a heavy producing zone, and even on the borders of such a zone or lode. The area of production could be calculated to be of substantially lesser area than those formerly worked from a single bore, as the more frequent intervals of shifting from well to well were counter-balanced with increased efficiency of operation at each site and inexpensive cost of moving the plant.

The ability to work smaller zones outwardly toward the rim of a heavy producing area made it more effective to employ the "mud bowl" method of isolating the molten sulphur to a smaller area with the consequence that less mud and fewer mud bores were required to carry out such isolation. Following this advantage the hot mine water in the well could give up a much larger percentage of its heat content to heating the molten sulphur so that much more sulphur could be produced per gallon of mine water. Also, the added safeguard of a bleeder well at the periphery of the producing area to draw off the cooling water added to the increased effectiveness of the hot mine water.

Additionally, the speed of the upward flow of the molten sulphur in the well was increased by elevating the compressed air pipe within the producing pipe to some distance above the bottom of the producing pipe so that the pressure exerted upon the upward passage of the molten sulphur was increased by the downward passage of the central core of compressed air therethrough for say, the first 30 feet of the upward travel of the sulphur. This result of increased speed is obvious since the compressed air passing down through the center of the sulphur exerts an outwardly acting pressure on the surrounding sulphur which causes it to move in the direction of discharge in the manner that a liquid in a primed pump continues to flow in the direction of discharge.

To these advantages the present invention adds that of increased purity of the sulphur produced through employing fully treated water as mine water rather than raw water through which steam produced by the plant boilers was bubbled in the conventional process heretofore conventionally employed. The increased purity of the sulphur was obtained at an increased rate of production as by the old method of bubbling boiler steam through the raw or partially treated mine water, where mine water left the boilers at a reduced velocity consequent upon the substantial pressure drop in the steam-water contact stage.

It has been found that gas fired heaters, when maintained under the operating pressures obtainable by this invention, require no internal treatment to prevent the occurrence of scale and corrosion when treated water is used therein, and this is an added improvement. But of far greater importance is the saving in plant operation costs which can amount to the production of mine water on occasion, at gas consumption costs approximately one-half the costs per gallon occurrent with conventional methods. Such cost reduction is obtainable due to the fact that the heat of gas consumption in the heater fire boxes is applied directly against the surface of the water tubes in water tube boilers, and radiated out through the fire tubes in fire tube boilers, to the treated water therein as the products of combustion pass upwardly to the stack. Adjustment and control is obtainable between the inlet gas and the stack damper setting so that almost complete combustion, when desired, may take place within the heater. Such adjustment can be made as an incident to the duties of a plant operator so that the duties of full time boiler operators are not required and thus a saving in operating costs is also involved.

On the other hand, boilers require expensive controls and individual attention, and special pumps are required to circulate treatment materials to the boiler to prevent

scale and pipe corrosion, such pumps being required in addition to boiler feed water pumps.

Specific comparison has been made between the performance of a sulphur plant operated under the conventional methods where boilers were required to generate steam to heat the mine water as well as for auxiliary plant purposes and a plant operative after the disclosure herein in which treated water was heated in gas heaters for mine water and boilers were only employed to generate the steam to operate the softeners and certain other items of plant equipment.

In a conventional type plant 5 boilers were employed, each of maximum 1500 H. P. rating and the boilers were operated at approximately 85% capacity to produce approximately 1,000,000 gallons of heated mine water per day. With a plant constructed after the principles of this invention the same approximate amount of 1,000,000 gallons of mine water was produced employing 3 heaters each of 250 H. P. rating and 3 boilers each of 500 H. P. rating and operated at 75% capacity. Thus for a comparable delivery in mine water gallonage this plant employed equipment operated at total effective H. P. of approximately 1640 as compared with approximately 6375 total effective H. P. for the equipment of a conventional plant.

The total gas consumption of the conventional plant was approximately one third greater than the gas consumption of the plant of this invention and the amount of gas consumed in this novel type of plant which went directly to the production of heated mine water was approximately one half the amount consumed in the conventional plant to produce approximately the same gallonage of mine water. Additionally the mine water from the novel plant arrived at the mine under a greater pressure and velocity, at higher temperature, and in a purer state than the water of the conventional plant, and the labor cost of the novel plant were comparably lower due to the substantially automatic operation of its heaters.

As a consequence of the characteristics, heat content, and quality of water delivered, combined with the consequent benefits derived from the novel mining operation of this invention, including mud bowl and bleeder well, a substantially greater tonnage of sulphur was produced for the same delivered gallonage of mine water, although it could be said with logic that the conventional plant was located to operate a production bore which should have penetrated a much richer sulphur producing lode. An estimate of sulphur produced per volume of mine water for the performance of the novel plant and mining method indicated a ton of excessively pure sulphur was being produced per 1400 gallons of mine water introduced into the well.

The plant disclosed in the drawings and the methods of its use disclosed, as well as the disclosed methods of mining the well are not to be considered as defining or circumscribing the invention, which includes other plant arrangements and methods of use as well as other mining methods which fall within the broad spirit of the invention and within the broad scope of interpretation claimed and merited for the appended claims.

What is claimed is:

1. The process of inexpensively producing sulphur mine heating water in a plant adjacent a sulphur well in an area where formation subsidence may occur, comprising the steps of providing water for use in the plant in part as boiler feed water and in majority to be heated in the plant in a gas fired heater, using steam generated from the boiler feed water to operate plant equipment, heating the majority of water in the heater from an entering temperature of approximately 220° Fahrenheit at approximately 180 p. s. i. to approximately 320 to 340° Fahrenheit at approximately 160 p. s. i., such process including supporting plant equipment headers, including boiler and heater headers, respectively, separate from the plant equipment including separately supported units as

15

boiler and heater means, and connecting the headers respectively to the plant equipment including boiler and heater means by means permitting three dimensional adjustment for relative subsidence therebetween.

2. An inexpensive sulphur production process for employment in operating a succession of spaced apart sulphur wells comprising the step of erecting a portable plant adjacent a productive sulphur well adjacent an area where formation subsidence may occur, and including the additional steps of providing water for use in the plant in part as boiler feed water and in majority to be heated in the plant in a gas fired heater, using steam generated from the boiler feed water to operate plant equipment, heating the majority of water in the heater from an entering temperature of approximately 220° Fahrenheit at approximately 180 p. s. i. to approximately 320 to 340° Fahrenheit at approximately 160 p. s. i., employing the heated water in flowing the sulphur from the well, moving the plant adjacent a successive well to be produced, and repeating the hereinabove described steps, at each location such process including supporting plant equipment headers, including separately supported units as boiler and heater headers, respectively, separate from the plant equipment including boiler and heater means, and connecting the headers respectively to the plant equipment including boiler and heater means by means permitting three dimensional adjustment for relative subsidence therebetween.

3. The process of inexpensively producing sulphur mine heating water in a plant adjacent a sulphur well in an area where formation subsidence may occur, comprising the steps of providing water treated in the plant to be used in part as boiler feed water and in majority to be heated in the plant in gas fired heater means under pressures substantially in excess of 100 p. s. i. and wherein the heat of combustion is effectively and in largest percentage transmitted through the medium separating the water from the products of combustion to raise the water to temperatures at least 100° F. above the atmospheric boiling point of water, such process including supporting plant equipment headers, including boiler and heater headers, respectively separate from the plant equipment including separately supported units as boiler and heater means, and connecting the headers respectively to the plant equipment including boiler and heater means by means permitting three dimensional adjustment for relative subsidence therebetween.

4. A sulphur plant for producing a sulphur mine and comprising a source of raw water, a raw water storage means, a steam operated, raw water softener means, a chemical mixer means to mix in controlled quantities sludge precipitating chemical with a small portion of the raw water, means including header means to deliver the mixture to said softener means, means including header means to deliver the larger portion of said raw water to said softener means for sludge precipitation therefrom, filter means to remove particles from the softened water, means including header means to deliver the softened water to said filter means and to backwash said filter means into said softener means, boiler means, heater means, and an air compressor, means including header means to deliver a small part of the filtered water to said boiler means for conversion into steam to operate plant equipment including said delivery means, said compressor, and said softener means and to deliver the larger part of the filtered water to said heater means, said heater means being adapted to heat the water therein under pressure by applying the heat of combustion directly through the means separating the water from the products of combustion, means to produce said mine comprising means including header means to supply said heater water to said mine to melt said sulphur and to receive the molten sulphur therefrom, and also comprising means to supply compressed air to said mine to flow said sulphur, each header means being supported sepa-

16

ately from the separately supported plant units between which it extends and being respectively connected to such units by means permitting three dimensional adjustment for relative subsidence between such units, and between such units and said header means.

5. A method of employing a sulphur plant adapted to be rapidly transported to produce a succession of sulphur wells comprising the steps of providing plant equipment including individual boilers of approximately 500 H. P. capacity and individual heaters of approximately 250 H. P. capacity, pumps, chemical mixer means for water treatment, air compressor means, and pluralities of water softeners and filters of sizes comparable to the boilers and heaters, installing the individual items of plant equipment on separate foundation means closely proximate the well, providing separately supported header means extending between said units and connecting said headers to the units between which they extend by means permitting three dimensional adjustment for relative subsidence between such units and between such units and said header means, transferring a small part of a supply of raw water to the chemical mixer means and then to the softeners and the remainder directly to the softeners, operating the softeners to precipitate sludge from the water therein, filtering the softened water and employing the greater part thereof to be heated as mine water and the lesser part thereof as boiler feed water to be converted to steam to be employed in operating plant equipment including pumps, the compressor means and the softeners, and employing the mine water from the heaters and the compressed air conjointly to flow the sulphur well and with minimum heat loss due to short mine water lines between heaters and the well.

6. A method of employing a sulphur plant adapted to be rapidly transported in operating a succession of spaced apart sulphur wells comprising the steps of erecting a portable plant adjacent a productive sulphur well, providing water for use in the plant in part as boiler feed water and in majority to be heated in the plant in gas fired heater means, providing separately supported header means extending between the successively operative items of plant equipment including the boiler means and heater means, and connecting such header means to the respective units between which they extend by means permitting three dimensional adjustment for relative subsidence between such units and between such units and said header means, the water heated in said heater means being heated under pressures substantially in excess of 100 p. s. i. and wherein the heat of combustion is effectively and in largest percentage transmitted through the medium separating the water to temperatures at least 100° F. above the atmospheric boiling point of water, employing the heated water in flowing the sulphur from the well, and moving the plant adjacent a successive well to be produced, and repeating the herein above described steps.

7. The process of economically producing heated water for sulphur mining comprising the steps of erecting a portable plant adjacent the sulphur well including water storage, chemical mixer, water softener, filter boiler, gas fired heater, air compressor, air receiver, vat, stack, and pumps, supplying water to storage and delivering storage water in part to chemical mixer and in majority to softener, mixing lime with the water in the mixer and delivering it for addition to the water in the softener, treating the contents delivered to the softener, filtering the treated water in the filter, employing a part of the filtered water as boiler feed water to be converted to steam for operating the compressor and pumps while heating under pressure the greater part of the filtered water in the heater, the water entering at approximately 220° Fahrenheit and approximately 180 p. s. i. and leaving as water at approximately 320° to 340° Fahrenheit and at approximately 160 p. s. i., the flow processes through the successively operative separately supported items of plant

equipment being carried by separately supported header means extending therebetween and permitting three dimensional adjustment for relative subsidence between such units and between such units and said header means.

1,628,873
1,878,158
2,647,370
2,754,098
2,756,035

5

References Cited in the file of this patent

UNITED STATES PATENTS

461,429 Frsch ----- Oct. 20, 1891

Drachenberg ----- May 17, 1927
Lundy et al. ----- Sept. 30, 1932
Miller ----- Aug. 4, 1953
Henze ----- July 10, 1956
Axelrad et al. ----- July 24, 1956

OTHER REFERENCES

"Mining Engineer's Handbook," Peale 3rd ed., 1944,
vol. 1, 10-401 and 10-402.