

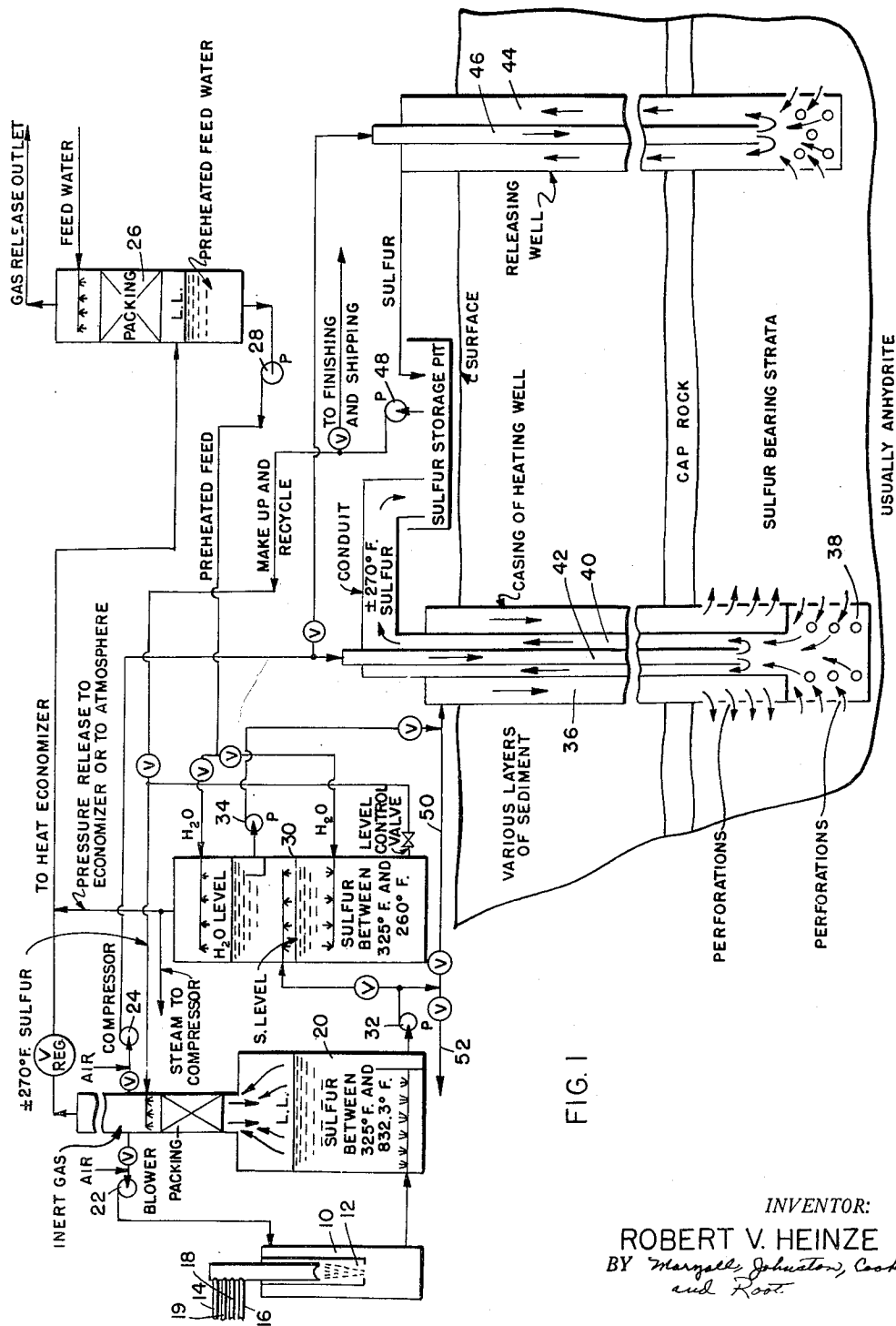
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PROCESSES FOR HEATING A MINING LIQUID AND MINING
THEREWITH A SUBSTANCE MODIFIED BY HEAT
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PROCESSES FOR HEATING A MINING LIQUID AND MINING THEREWITH A SUBSTANCE MODIFIED BY HEAT

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This invention relates to new and improved processes for direct introduction of heat into materials and to the utilization thereof in the mining or separation of sulfur and other heat-modifiable substances.

The usual method by which sulfur is mined is to force hot water, heated in conventional boilers, into a conduit which is positioned in the sulfur-bearing ore body. The conduit is provided with perforations in its side walls adjacent the end which is in the sulfur-bearing ore body. A baffle is provided between these perforations and other perforations farther down in the side wall of the conduit so that the hot water flows into the sulfur-bearing ore body where the heat in the water is transferred to the sulfur, which then becomes molten. Because it is heavier than the water, the molten sulfur gravitates downwardly and flows into the perforations in the conduit below the baffle. The molten sulfur in the lower end of the conduit is conducted to the surface by means of another conduit disposed centrally within the first conduit. A third conduit containing compressed gas is disposed centrally in the second conduit, and the column of molten sulfur inside the second conduit is lifted to the surface by means of the compressed gas.

This process is made costly by the fact that the hot water is heated in conventional type boilers. That is to say, the water is heated by the transfer of the heat of combustion through metallic walls. Furthermore, the air is separately compressed and then released without having rendered any other function than that of lifting the molten sulfur from subsurface regions to the surface where it is handled for further disposition. One factor in the high cost is that fresh, carefully treated water is essential in conventional type boilers. Additionally, even with fresh water, the water deposits scale on the metal surfaces which must be cleaned at frequent intervals in order to facilitate heat transfer through the metallic walls of the boiler.

It is an object of this invention to provide economical processes for heating by direct heat exchange.

A further object is to provide processes wherein brackish, alkali, or salt water may be heated.

A further object is to provide economical processes for heating mining water wherein a variety of different kinds of heating fuels may be used.

A still further object is to provide methods wherein molten sulfur may be used as a mining liquid.

Another object is to provide processes for mining sulfur.

Still another object is to provide processes for utilizing brackish, alkali, or salt water in mining a heat-modifiable substance.

A still further object is to provide methods for mining or separating from accompanying gangue materials substances such as heavy oils, asphalts, metals and other

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liquefiable or gasifiable materials either beneath or above the earth's surface.

Another object is to provide processes for the introduction of heat by direct contact with hot gases into a moving material and conducting the heat in the moving material into other secondary stationary or moving materials in a manner that permits separation of combustion gases and vapors before the secondary release of heat is utilized.

Other objects will appear hereinafter.

In the drawing:

FIG. 1 is a diagrammatic illustration of apparatus used in mining a heat-modifiable substance such as sulfur.

Briefly, the heating process of this invention and apparatus therefor involves the heating of a liquid, in most instances water, by direct contact with a heating liquid which has, in turn, been raised to the desired heating temperature by direct heat exchange with a preheated gas, usually including the products of combustion. The heating fuel may be any of the combustible gases, combustible liquids, combustible solids such as coal particles, mixtures of gases and vapors, or liquids admixed with solid particles. After the gases have been heated, they, and usually the products of combustion, are passed into a body of a heating liquid in which direct heat exchange occurs. The heating liquid may be molten sulfur, molten metals, mixtures of molten metals, or high boiling liquid hydrocarbons having a relatively high flash point such as petroleum stocks. After the gases have passed through the heating liquid, they are withdrawn from the direct heat exchange vessel and recycled for reheating. Excess gases produced through combustion are withdrawn and preferably sent to a heat economizer for preheating feed water or other processing liquids or materials.

The heating liquid is pumped from the heating vessel to a second vessel containing both the heating fluid and a liquid to be heated. Direct heat exchange occurs between the two fluids. The two fluids may be immiscible and thus separate into two layers, or they may be separated after heat exchange by vaporization of one of the fluids. In the case of sulfur as the heating liquid and water as the mining liquid, the two liquids separate—the sulfur as the lower layer and water as the upper layer. A level control valve or other regulating device provides for the withdrawal of the heating liquid, whence it is recycled to the first heating vessel. Also, a regulating device provides for withdrawal of the desired amount of the upper layer of liquid. The second heating vessel is provided with pressure release apparatus for withdrawing steam from the vessel. High pressure air is obtainable by using steam flashed from the second vessel. This steam is free from fixed gases and can be used to drive a high pressure air or gas compressor without going through a reheater and without the difficult separation of fixed gases and steam prior to using steam to drive the compressor. The compressed air or gas is pumped into the mining zone to aid in lifting the molten mined sulfur to the surface. Where sulfur is burned as the fuel, the compressed sulfur dioxide gas may be collected as liquid sulfur dioxide or may be used in the manufacture of sulfuric acid.

In mining of heat-modifiable substances such as sul-

fur, the heated liquid is then pumped into the sulfur-bearing strata where it serves to heat the sulfur as previously described. The mining fluid pumped into the well is replaced by preheated feed water fed either into the top of the second heating vessel or below the surface of the heating liquid in the second vessel, as is desired.

The invention is illustrated in FIGURE 1 by schematic diagram. The apparatus comprises an inert gas heating chamber 10 having a combustion chamber 12. In the burner illustrated wherein a fuel gas such as natural gas or other suitable type of fuel gas is used, the apparatus has a pilot gas conduit 14 and a main gas conduit 16. Support for combustion is provided through a main air conduit 18 and a pilot air conduit 19. The heated gases and products of combustion are forced into a first heating vessel 20 below the surface of the heating liquid. The hot gases pass through the body of heating liquid, such as sulfur, in direct heat exchange therewith and are withdrawn from the heating vessel 20 in any one of several ways. The gases may be recycled through blower 22 for reheating and recycling through the heating vessel 20. Alternatively, the gases may be withdrawn from the vessel 20 into compressor 24 and pumped into the well to serve as the lifting gas for the mined molten sulfur. In either instance the inert gas may be mixed with air supplied in the takeoff lines. In the case of the gas recycled through blower 22 the oxygen in said air is employed to oxidize the sulfur or other heating liquid in the heating vessel 20—thus providing additional heat to said heating liquid. Air may also be mixed with the inert gases used as the lifting gases; the air in this case functions in the customary manner.

Excess gases are released through the pressure regulator valve and may be passed to heat economizer 26 wherein the gases flow upwardly through packing in the heat economizer and counter-currently through downwardly flowing feed water. The feed water is thus preheated by the gases. The cool gases are then released to the atmosphere or, as circumstances may warrant, they are processed through conventional apparatus for further conservation of material.

The preheated feed water is pumped by pump 28 into water heating vessel 30. The feed water may either be fed under the surface of the heating liquid or sprayed in near the top of the water heating vessel 30. The heating vessel 30 is a pressure vessel. Steam produced by the heat exchange between the heating liquid and water is taken off to drive the compressor and for any other power or heating purpose as may be desired. Excess steam is passed to the heat economizer in a manner similar to the excess gases. A pressure safety pop-off valve is provided on the vessel 30 to prevent build-up of excessive steam pressures.

The heating liquid in the first heating vessel 20 is pumped by pump 32 into the pressure vessel 30. The heating liquid in the pressure vessel 30 is recycled through the level control valve to the first heating vessel.

The superheated mining liquid in pressure vessel 30, in most instances water, is pumped by pump 34 into the casing of the heating well. It passes down the annular chamber 36 and into the sulfur-bearing strata through perforations as illustrated. The molten sulfur, being heavier than water, sinks to the bottom of the sulfur-bearing strata and is drawn into the bottom chamber 38 and is then lifted to the surface of the well through annular passage 40 with the assistance of the lifting gases which are pumped into the well through conduit 42. The molten mined sulfur is deposited in a sulfur storage pit.

Preferably, the molten sulfur is moved at temperatures either between its melting point, about 235° F., and 340° F. or above 446° F. At 340° F. and lower, molten sulfur is sufficiently fluid to be pumped. Between about 340° F. and 446° F. molten sulfur is relatively viscous and difficult to pump. If molten sulfur is heated appreciably above 446° F., even up to its boiling point of 832.3° F., or hotter if pressure is applied, the viscosity

is decreased so that the molten sulfur is once again pumpable.

In situations where a releasing well is employed to recover a portion of the sulfur, molten sulfur is lifted to the surface through casing 44 having perforations in the lower end thereof and into which lifting gases are pumped through conduit 46. The sulfur in the storage pit may be pumped by pump 48 into the heating vessel 20.

Once the ore strata has been heated so that the sulfur is molten between the heating wells and the adjacent release wells, it is then possible to blow heated, inert gases through the heating well into the sulfur-bearing strata. By including in the hot inert gases a controlled percentage of oxygen and heating the inert gases and oxygen at least as high as the kindling temperature of sulfur, approximately 502° F., controlled amounts of sulfur may be oxidized. The resulting heat of oxidation is then used to control the temperature of the sulfur in the sulfur-bearing strata so that it readily flows to the bottom ends of the wells for lifting to the surface as production product.

The foregoing comprises the basic apparatus of this invention. There are, however, other refinements which adapt the apparatus to economic conditions of various localities. For example, if it is desired to use the heat in the molten sulfur in heating vessel 20 for mining purposes the molten sulfur may be pumped by pump 32 through line 50 into the casing of the heating well. In this instance, sulfur heated substantially above its melting point may be used as the mining liquid or as a part of the mining liquid to facilitate the liquefaction and separation of additional sulfur from the gangue materials in the subsurface strata. Further, under conditions wherein the available fuels are expensive or where they impart undesirable contaminants into the heating liquid such as sulfur, the sulfur may be cycled through line 52 into a burner for heating the inert gases.

While the drawing illustrates only one gas heating vessel 10, multiples of the vessel 10 may be installed around the heating vessel 20. Such multiples provide a simple method for varying the amount of heat which can be introduced into the heating vessel 20.

In any operation where fixed gases should be kept to a minimum, oxygen can be used in place of air. For example, when sulfur is the fuel, oxygen may be preferred to avoid contamination of the resulting oxidized sulfur gases, which are basic materials to be made into valuable by-products. Alternatively, they may be reverted back to sulfur.

The temperatures of the sulfur in the vessels 20 and 30 may be outside the ranges shown on the drawing without departing from the invention. The temperature ranges shown are illustrative ranges for practicing the invention, and are not intended to be all-inclusive. For example, the lower temperature (325° F.) of the sulfur in the vessel 20 was selected as being an approximate minimum temperature at which it is economically feasible to circulate molten sulfur for heat exchange—particularly when the molten sulfur is utilized as a mining liquid. Obviously, however, the minimum temperatures of the molten sulfur may be below 325° F. if one so chooses. Similarly, the temperature of the molten sulfur in vessel 30 may be above or slightly below the practical range shown on the drawing.

It is not always necessary to have the burner in the heating vessel 10 pointing vertically down. The burner may be in a horizontal position or it may point vertically upward or at any other angle. The position of the burner depends upon the processing conditions involved. The burner illustrated is a submerged combustion-type burner which is eminently suitable for heating the gases. Other types of gas burners may also be used. Further, the burner need not necessarily burn gas only. By variations in construction, the burner can be caused to burn vapors, fluids, dust or solid particles or mixtures of these materials. For instance, in a case where it is advantageous to burn solid particles of sulfur, these particles are con-

ducted to the burner plate through a concentric, annular space designed to conduct sulfur to the burner plate in proper proportions with the oxidizing agents. The same is true where solid particles of coal such as lignite are used. An example of a mixture of combustible solids and liquids is lignite particles and catalytic cycle stock from petroleum refinery catalytic cracking stills which, when admixed with each other, generate intense heat above the burner plate area as the mixture emerges upwardly from the vertical conduit.

Combustible liquids such as molten sulfur or a liquid hydrocarbon may be burned in a reaction chamber by spraying or otherwise discharging the combustible liquid into the chamber through a conduit. Support for combustion is provided by supplying air or oxygen to the chamber by an annular conduit surrounding the conduit for the combustible liquid. An ignition wire is provided for igniting the mixture of liquid and air or oxygen as they are discharged into the chamber.

High boiling liquid hydrocarbons such as petroleum stocks is not always burned to completion. A small amount of hydrocarbon not completely burned usually passes on with the gases of combustion. Such hydrocarbon is not desired in the sulfur even in small amounts. For that reason, only liquid hydrocarbons that have been specially prepared and gasified prior to burning are used for sulfur recovery from ores. For such products as asphalts, petroleum oils, oil from shales, most metals, liquid hydrocarbons may be used as fuel. Usually sulfur and fuels with a high sulfur content are not desirable for asphalts, petroleum oils, oil from shales and most metals. Sulfur and sulfur bearing fuels are used only in those instances where sulfur is not injurious to the products involved.

The invention has many advantages in the mining of sulfur and other materials found in subsurface regions and which are capable of being melted, dissolved or modified by a mining liquid or by hot gases and vapors. By means of the invention the cost of mining sulfur is reduced materially because the water does not need to be fresh water; the water does not have to be specially prepared and treated before heating; there are no boiler tubes required and for that reason tube cleaning is unnecessary. Additionally, the invention makes it possible to mine sulfur and other materials in subsurface regions with greatly reduced quantities of compressed air because the gases of combustion assist in lifting the molten sulfur or other material to be mined from the subsurface regions. The cost of equipment required to practice the invention is much less than that required where stationary boilers are used instead to heat the mining fluid. The space requirements for the apparatus used in the practice of the invention are smaller than the space requirements where stationary boilers are employed to heat the mining fluid. The invention is readily applicable therefore to the mining of sulfur by means of apparatus located on barges from sulfur deposits located beneath bodies of water. The operation of the process has the additional advantage that the apparatus can easily be moved from one location to another and is applicable in small units for the working of smaller deposits which would not ordinarily be mined by conventional methods because of the high capital investment requirements for equipment.

While the invention has been described largely with reference to the mining of sulfur, the procedures and apparatus herein described may be utilized in the recovery of asphalts and heavy crude oils and other hydrocarbon deposits. The heated mining liquid may be utilized to release more crude oil from petroleum deposits. This is true because the mineral aggregate can be heated sufficiently to cause expansion of oil occluded in crystalline and other pockets. This expansion breaks open the occluding mineral aggregate jackets so that the oil and gases can be brought to the surface as production products.

The method for heating herein disclosed may also be employed to separate a heat modifiable substance from gangue materials above the earth's surface in a manner similar to the mining procedures heretofore described.

For example, sulfur is found in pockets where it has been condensed as it rose to the surface after its natural alteration and distillation in the bowels of the earth. For the reason that these scattered pockets are located in mineral aggregate that is too broken and porous, the sulfur ore is brought to the surface for heating so as to melt and drain off the sulfur in the ore. Similarly, when molten metal heated substantially above the melting point of the metal mixtures in metal bearing ore is contacted with the metal bearing ore, the metals in the ore melt and, along with the molten metal used for introducing heat to the ore, are drained away from the gangue. This method applies for ore either on the surface or for ore beneath the surface. However, very often metal bearing ore bodies beneath the surface are lodged in pockets which are broken and widely separated due to previous shiftings in the earth's crust. To cite one example, a site in Arizona contains large quantities of silver-lead ore originally placed in seams and veins. The original placements have been shifted in every direction. Because of this shifting and relocating of the original deposits into a great number of separated pockets, it is impractical to heat the ore in place. For that reason, the ore is brought to the surface for heating so as to melt and drain off the metals in the ore. Thus, the molten liquid in the vessel 20 may be employed at temperatures substantially above the melting point thereof to melt additional material in an ore—the molten liquid used for introducing heat to the ore and the material in the ore which is liquefied by the heating being drained away from the gangue.

The invention is hereby claimed as follows:

1. A process for mining a substance modified by heat which comprises heating a mining liquid selected from the group consisting of brackish, alkali and salt waters by direct heat exchange with a heating liquid immiscible with said mining liquid and which has, in turn, been heated in a separate zone by direct heat exchange with hot gases; passing the heated mining liquid into a subsurface region containing the substance to be mined wherein said substance is rendered flowable by said heated mining liquid; and lifting said substance to the surface.

2. A process for mining sulfur which comprises heating a mining liquid selected from the group consisting of brackish, alkali and salt water, by direct heat exchange with a heating liquid immiscible with said mining liquid and which has, in turn, been heated in a separate zone by direct heat exchange with hot gases; passing the heated mining liquid into a subsurface region containing the sulfur to be mined wherein the sulfur is liquefied; and lifting the liquefied sulfur to the surface.

3. A process for mining sulfur which comprises heating molten sulfur by direct heat exchange with hot gases in a first vessel; removing the gases from said first vessel; passing said heated sulfur into a second vessel containing water selected from the group consisting of brackish, alkali and salt waters in contact with said water whereby direct heat exchange is effected between said heated sulfur and water; pumping said water heated to a temperature above the melting point of sulfur and a portion of said heated sulfur, the latter at a temperature in the range of 235° F.—340° F. or 446–832° F., into a sulfur-bearing subsurface region wherein the sulfur is liquefied; and lifting the liquefied sulfur to the surface.

4. A method for releasing petroleum oil and gases in subterranean strata which comprises heating a mining liquid selected from the group consisting of brackish, alkali and salt waters by direct heat exchange with a heating liquid immiscible with said water which has, in turn, been heated in a separate zone by direct heat exchange with hot gases; pumping the heated mining liquid into a

subsurface region containing the petroleum oil; and re-
covering the released petroleum oil.

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