

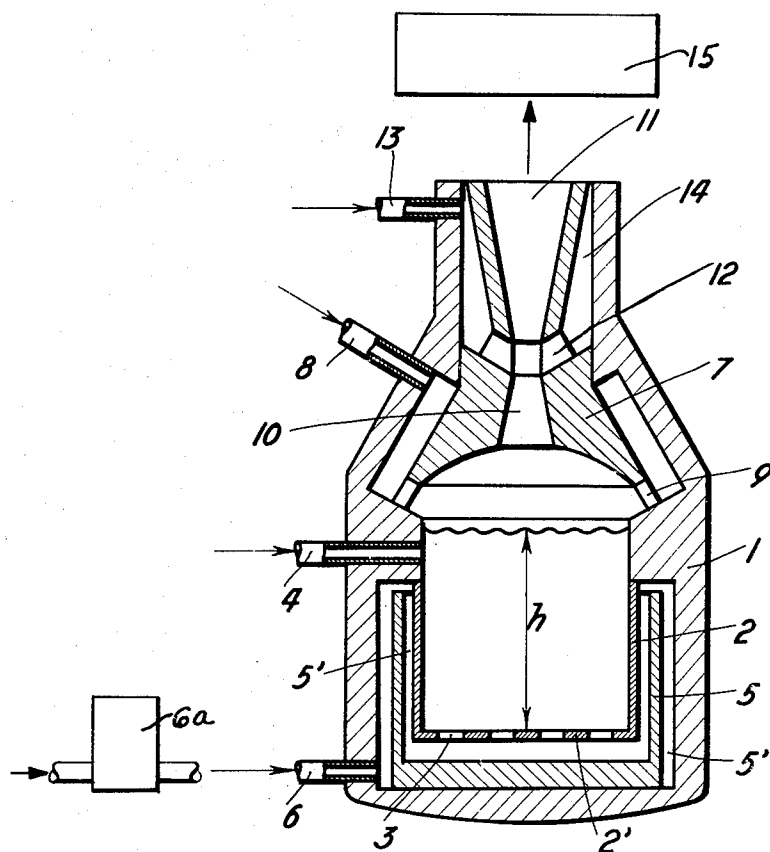
Oct. 19, 1965

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3,212,553

METHOD AND APPARATUS FOR BURNING LIQUIDS OF LOW VOLATILITY

Filed June 14, 1962



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3,212,553

METHOD AND APPARATUS FOR BURNING LIQUIDS OF LOW VOLATILITY

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Filed June 14, 1962, Ser. No. 202,475

Claims priority, application France, Dec. 14, 1961, 881,926

13 Claims. (Cl. 158—4)

This invention relates to a method for burning liquids of low volatility and to apparatus for performing the method. The invention likewise relates to certain industrial applications of the method and apparatus, both in the form of means for their utilization and in the new products resulting from the method and the apparatus.

It is commonly known that the use of low volatility combustible liquids, such as heavy heating oils, which can be so advantageously shipped and stored, encounters several difficulties. At the beginning of their introduction into industry, they were used according to a method of surface combustion, in which the fuel, kept at a constant level in a shallow bath, burns over its entire open horizontal surface, in exposure to air moved parallel to this surface. While acceptable for small installations, this scheme had to be abandoned for large installations, because, among other disadvantages, it was liable to a locally uneven combustion, with the attendant production of smoke and soot, and it required a large combustion chamber.

For this reason, in industrial heating plants, the various heavy heating oils (masut, fuel oil, etc.) are now burned in a nozzle, in which the liquid jet is "atomized," either by purely mechanical means or by being driven either by vapor or by compressed air. These nozzles, now and then noisy in operation, are delicate and do not guarantee a perfectly regular combustion at all rates of operation. They require a decidedly excessive amount of air, thereby substantially increasing the production of fumes and the attendant thermal losses. Any irregularity in operation entails the formation of droplets, which fall unburned in the ash-pit.

Finally, the "atomizing" of a low volatility fuel in the midst of the gaseous combustion supporting agent requires a large volume in order that the combustion chamber be sufficiently efficacious. But this requirement is particularly troublesome in modern installations requiring a high volumetrical efficiency, such as gas turbines and jet engines.

During the course of his work and experimentation, seeking a solution to these problems, the Applicant was led to discover that, by bubbling the gaseous combustion supporting agent, at a sufficiently elevated temperature, through a layer (of appropriate depth) of the low volatility fuel used, it was possible to eliminate the atomizing of the fuel in a large volume of air or other gaseous combustion supporting agent. In other words the invention is based upon the obtaining of a partial vaporization of the fuel by preburning it in contact with a portion of the gaseous combustion supporting agent, which passes through it in the form of gaseous bubbles. Consequently, when a portion of the gaseous combustion supporting agent (that part called the "primary gaseous combustion supporting agent") is introduced, in the form of bubbles, at a temperature equal to or higher than the kindling temperature of the fuel, which has a known depth, all of the oxygen of the gas bubbles is used by the combustion that occurs in the midst of the fuel. All of the resulting heat is thereby stored in the fuel, the temperature of which consequently rises. The gas bubbles which clear the open surface of the fuel, and which no longer contain oxygen, are formed of residual nitrogen mixed with

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the combustion products. In the form of saturated vapor they carry along a very substantial quantity of fuel, which is volatilized at a precise temperature and can be burned in a secondary combustion chamber, in contact with a suitable and precisely controllable amount of the combustion agent.

It is an object of this invention to provide a method for burning slightly volatile liquids, such as heavy oils (liquid sulfur, for example), which, in its most general form, essentially consists of running through the liquid (kept at a substantially constant level) a gaseous combustion supporting agent in the form of gas bubbles and at a temperature at least equal to the kindling temperature of the liquid, and then to introduce into the liquid, thus vaporized and carried off, an additional amount of the gaseous combustion supporting agent substantially sufficient for a complete final combustion.

According to one form of the method, before effecting the final combustion by the required amount of gaseous combustion supporting agent (preferably heated), an additional amount of the agent is introduced next to the open fuel surface during the course of vaporization. There is thus obtained an intermediate-combustion, which causes, at the same time, a notable rise in the temperature of the primary gaseous mixture and a dilution of the combustible vapors therein contained, thereby preventing any condensation of the vapors while on their way to the final combustion. A portion or all of the gaseous combustion supporting agent required for the complete combustion advantageously can be circulated in a jacket surrounding the vaporization zone, the intermediate combustion zone, and the final combustion zone, in order to use a part of the calories which otherwise would be lost from these zones.

The apparatus for practicing the method will now be described with reference to the figure shown in section of the accompanying drawing.

The apparatus consists of a chamber 1 made of a refractory metal or any other suitable material and preferably insulated from the outside by one or more insulating jackets, not shown. Chamber 1 supports a vessel 2 having a bottom 2' perforated by a plurality of apertures 3. The slightly volatile liquid is introduced into 2 by means of inlet 4, so that it is kept substantially constant at some lever *h*, which depends upon the nature of said liquid and on the size and number of the apertures 3. This depth is generally between 5 and 10 centimeters.

Vessel 2 is separated from the wall of chamber 1 by one or more (one is shown) baffle walls 5, forming passages 5'. The gaseous combustion supporting agent is introduced through inlet 6 and reaches the bottom 2' after passing through passages 5'. Chamber 1 includes a dome or cover 7 made of metal or some other refractory material; an inlet 8 opens into the space between dome 7 and the wall of chamber 1 and is in communication with the interior of said dome by means of apertures 9 distributed along the circumference of dome 7, next to the open surface of the liquid. Dome 7 is axially pierced by a convergent passage 10 and a divergent passage 11 connected to each other by a short cylindrical passage or neck, so as to form a venturi tube. A series of apertures 12 is arranged about the circumference of said neck. The gaseous combustion supporting agent is conveyed through inlet 13 to the space or chamber 14 formed between the upper part of chamber 1 and the wall of divergent passage 11 and thence, after circulating through this space and thereby heated, through aperture 12 into the neck of the venturi. The burner proper consists of the outlet of venturi tube 10-11, and is the final combustion zone or chamber.

The operation of the device will now be described.

The gaseous combination agent (which can be air),

initially heated (by any suitable means diagrammatically indicated at 6a) to a temperature slightly above the kindling point of the fluid or fuel, is brought in through inlet 6. The liquid is then introduced into vessel 2 through inlet 4. The fluid, which is now burning, continues to be introduced until it reaches a desired level *h*, while the agent can now be brought directly from the outside and heated to the appropriate temperature while passing through passages 5'. The agent, thus heated, reaches the bottom 2' of vessel 2 and bubbles through the fluid, which burns in part. The bubbles, divested of their oxygen and carrying a large quantity of vapor saturated with the fluid, come into contact, at the level of the fluid, with the gaseous combustion supporting agent which has passed through inlet 8 and apertures 9 of dome 7. In this area or zone (which can be called the intermediate-combustion chamber), immediately above the level of the liquid, there is thus an intermediate-combustion. That gas which still carries along unburned liquid rises through convergent passage 10 until it reaches the neck, where it comes into contact with gaseous combustion supporting agent supplied by inlet 13 through apertures 12 and heated during its passage through space or chamber 14. The gas, thus mixed with the necessary amount of the agent to insure complete burning, burns in divergent passage 11, which forms the burner proper, and which is the final combustion zone or chamber.

Two practical examples of the invention will now be described.

EXAMPLE ONE

In a burner of the invention, heavy heating oil having a heating value equal to 10,500 kcal./kg. was burned. The hydrogen-carbon ratio was 14.8/85.2, and the boiling point was about 350° C. The combustion equation showed that one kilogram of this fuel would require 14.85 kg. of dry air, containing 3.46 kg. of oxygen, and would produce 15.85 kg. of fumes containing 3.12 kg. of carbon dioxide and 1.34 kg. of steam. The combustion tests were conducted at atmospheric pressure.

The air was heated by taking up the heat of the walls of the combustion chamber, and the temperature of the fuel, through which the hot air was bubbled, was stabilized at 275±2° C. In order to completely avoid vapor condensation, the amount of intermediate-combustion air used was identical to that of the primary air; and the temperature of the outlet of the vaporization zone was raised from 250° C. to about 525° C. By carefully adjusting the secondary air, the percentage of oxygen relative to nitrogen in the fumes was lowered to 0.26%. Calculation showed that the amount of primary air required for burning one kilogram of heavy fuel oil would be charged with 44 kg. of fuel vapor.

Experiments have confirmed that the amount of fuel vaporized by complete combustion of a portion of the heavy heating oil in the vaporization chamber or zone depends on the pressure under which the burner operates. Using the same heavy heating oil, as above, the temperature of the fuel during vaporization rises to 320° C. under two atmospheres and to 475° C. under 3.5 atmospheres; the amount of fuel vaporized per unit amount burned falls from 44 kg. at atmospheric pressure to 40 kg. at two atmospheres and to 38 kg. at 3.5 atmospheres.

This example clearly demonstrates that the instant method of pre-burning heavy-hydrocarbons, by bubbling through a hot gaseous combustion supporting agent, is also particularly economical for vaporizing under pressure similar substances. When burning approximately 1 kg. of heavy heating oil under 3.5 atmospheres, 38 kg. of it are vaporized, mixed with less than 15 kg. of fumes, consisting of 11.4 kg. of nitrogen, 3.12 kg. of CO₂, and 1.34 kg. of steam. By adding oxygen to the primary air, or even by substituting pure oxygen, it is possible to obtain an even greater vaporization under pressure. It can be worthwhile, before their final combustion, to physical-

ly or chemically treat these vapors under pressure to change their composition, after possibly having separated from them particular constituents.

EXAMPLE TWO

Liquid sulfur, which today can often be considered as a source of heat, since its combustion gives off 2020 kcal./kg., was burned in accordance with the invention.

Liquid sulfur, through which air under pressure was bubbled, was burned in a burner of the type described above; and there was obtained gas containing 19.5% or more of sulfurous anhydride. It can also be remarked here that the quantity of sulfur vaporized per unit of sulfur burned, and the temperature of the liquid sulfur bath, depend on the pressure used. Experiments give the following results:

Pressure, kg./cm. ²	Bath temperature, ° C.	Ratio of sulfur vapor sulfur burned
1.-----	370	14.0
5.-----	455	9.5
6.-----	465	8.8
7.-----	485	8.2

It is interesting to remark, in addition, that the temperature of the liquid sulfur bath, even at atmospheric pressure, remained sufficiently high so that it returned to its normal viscosity.

In this method, the partial combustion of the liquid sulfur can be used to produce sublimed industrial sulfur having a high surface activity. By vaporizing 14 kg. of sulfur for each kilogram of sulfur burned and immediately cooling the vapors issuing from the vaporization zone by continuously circulating residual nitrogen (charged with SO₂) and then recovering the solids, thus condensed, in some customary mechanical separating means (diagrammatically indicated at 15), such as a filter or a cyclone, one obtains an economical sublimation for condensing flowers of sulfur. By substituting pure oxygen for ordinary air and circulating pure sulfur dioxide to condense the sulfur vapors, it is possible to produce in the same operation both sublimed sulfur and pure sulfurous anhydride. For this operation; the vaporization rate can be raised to around 30 kg. of vapor for each kilogram of sulfur burned.

What I claim is:

1. The method of burning fuels of low volatility contained in an elongated vessel having a bottom with perforations spaced substantially throughout its area, the said vessel being contained within a housing, the method comprising the steps of initially heating a gaseous combustion supporting agent by external means to a temperature at least equal to the kindling temperature of said fuel, passing said gaseous combustion supporting agent between the inner surface of said housing and the exterior surface of said vessel, applying the said gaseous combustion supporting agent to the said perforated bottom of said vessel at sufficient pressure to prevent the exit of fuel from said vessel through said perforations, introducing said low volatility fuel into said vessel and maintaining said fuel at an adjusted level within said vessel, causing said combustion supported agent to pass through said perforations of said vessel bottom and to bubble throughout an elongated column of said fuel in said vessel whereby partial combustion of said fuel occurs in the bubbles of said gaseous combustion supporting agent leading to the vaporization of uncombusted quantities of said fuel at the surface thereof in said vessel, after said partial combustion of said fuel has begun, heating said gaseous combustion supporting agent by heat exchange with said exterior surface of said vessel, and maintaining a temperature of the column of fuel within said vessel sufficient to heat said gaseous combustion supporting agent to said kindling temperature by said heat exchange, and introducing additional quantities of gas into the vapors of

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the said fuel above said vessel whereby to cause at least a further combustion of said vapors.

2. The method of claim 1 in which the vapors of said fuel are caused first to enter a chamber above said vessel and within said housing, wherein the vapors of said fuel are subjected to partial combustion within said chamber by the addition of a secondary quantity of gaseous combustion supporting agent thereto, but short of that required for complete combustion, so that condensation of fuel does not occur within said chamber, the upper portion of said housing including a venturi tube the outlet end of which comprises a burner and including the step of mixing at said venturi with the gases passing from said chamber to said burner an additional quantity of gaseous combustion agent sufficient for complete combustion of any vapors of the said fuel remaining in said gases.

3. The method of claim 2 in which the quantity of gaseous combustion supporting agent bubbled through said fuel is substantially equal to the quantity of the secondary gaseous combustion supporting agent introduced into said chamber.

4. The method of claim 3 in which all quantities of gaseous combustion supporting agent are preheated by combustion in said housing.

5. The method of claim 1, in which the combustion agent and the pressure at which the combustion occurs can be varied and in which the rate of vaporization is controlled by control of at least one of the two.

6. The method of claim 1, in which said fuel is a heavy fuel oil.

7. The method of claim 1, in which said fuel is sulfur.

8. The method of claim 7 further comprising the steps of cooling and condensing the vapors, above said burning fuel, laden with the vaporized unburned sulfur.

9. The method of claim 8 further comprising the steps of separating the condensed solids to thereby obtain the sublimed sulfur.

10. The method of claim 9, in which the combustion supporting agent and the pressure at which the combustion occurs can be varied and in which the rate of vaporization is controlled by control of at least one of the two.

11. Means for burning liquid fuel of low volatility comprising an elongated chamber of refractory material, an elongated vessel located within said chamber, said vessel having side walls and a bottom provided with a plurality of perforations throughout its area, a first inlet means for filling said vessel with said fuel, a second inlet means in said chamber for admitting a combustion agent in heat

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exchange relationship to the walls of said vessel, structural means for confining said agent to a path that leads to said bottom of said vessel, a portion of said chamber extending above said fuel and having a dome interior over said fuel, a venturi, said venturi having a convergent inlet from said chamber, a cylindrical neck, and a divergent outlet, a plurality of apertures in said neck of said venturi, a third inlet means located in said portion of said chamber for admitting a gaseous combustion supporting agent downwardly and around said outlet of said venturi and in heat exchange relationship thereto, and structural means for confining the agent from said third inlet means to a path leading to the interior of said venturi through said plurality of apertures.

12. The means of claim 11, in which said dome has at its base a series of apertures; fourth inlet means, located between said first and third inlet means, for admitting a combustion supporting agent around said dome and in heat exchange relationship thereto; and structural means for confining the agent from said fourth inlet means to a path leading to the interior of said dome through said series of apertures.

13. The means of claim 11, in which at least one baffle within said chamber surrounds said walls of said vessel, so as to form a tortuous path for the agent from said second inlet means.

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