July 5, 1938. C. A. FRENCH 2,122,684

VAPORIZING RELATIVELY HEAVY OILS

Filed Nov. 1, 1935 3 Sheets-Sheet 1

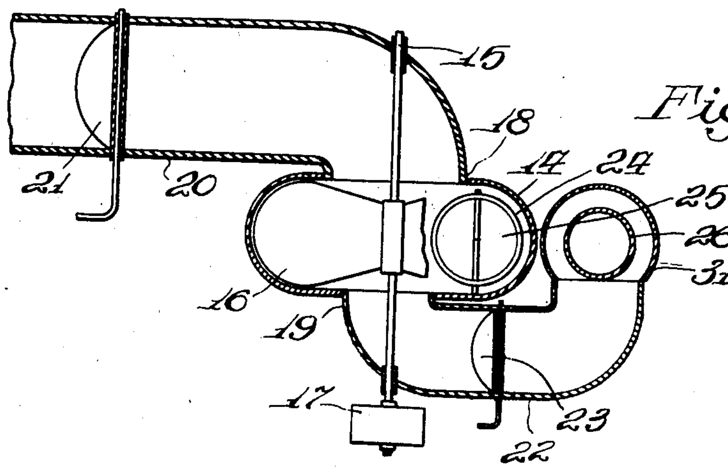

Fig. 2

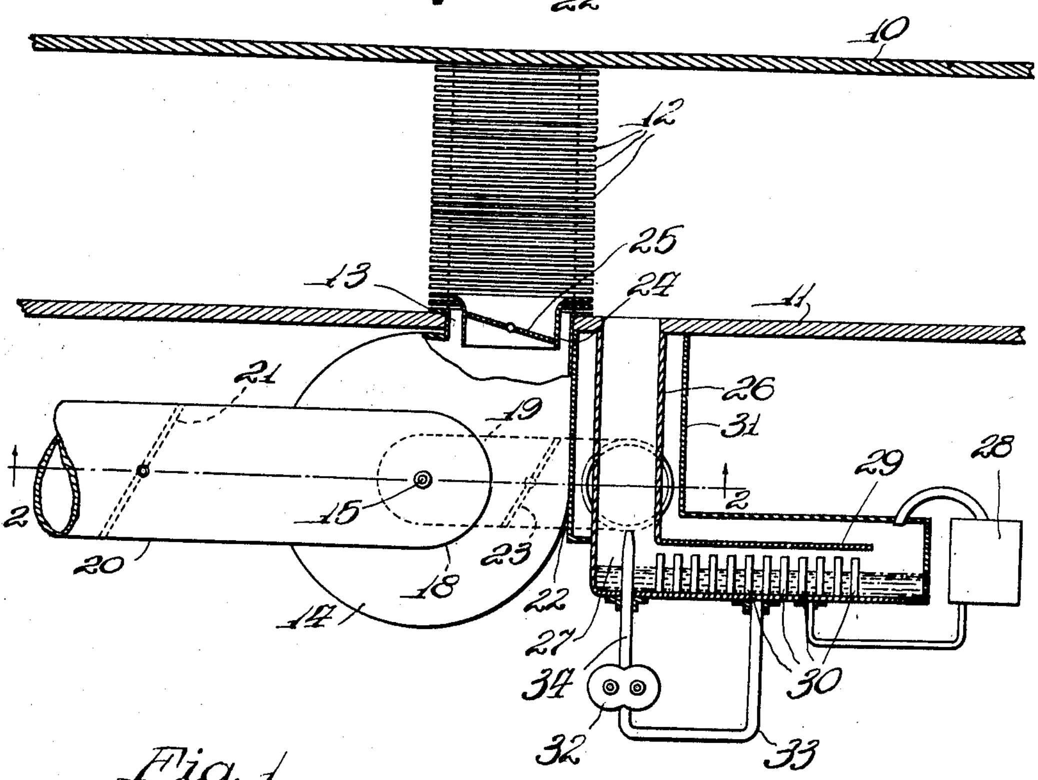

Fig. 1

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Fig. 3

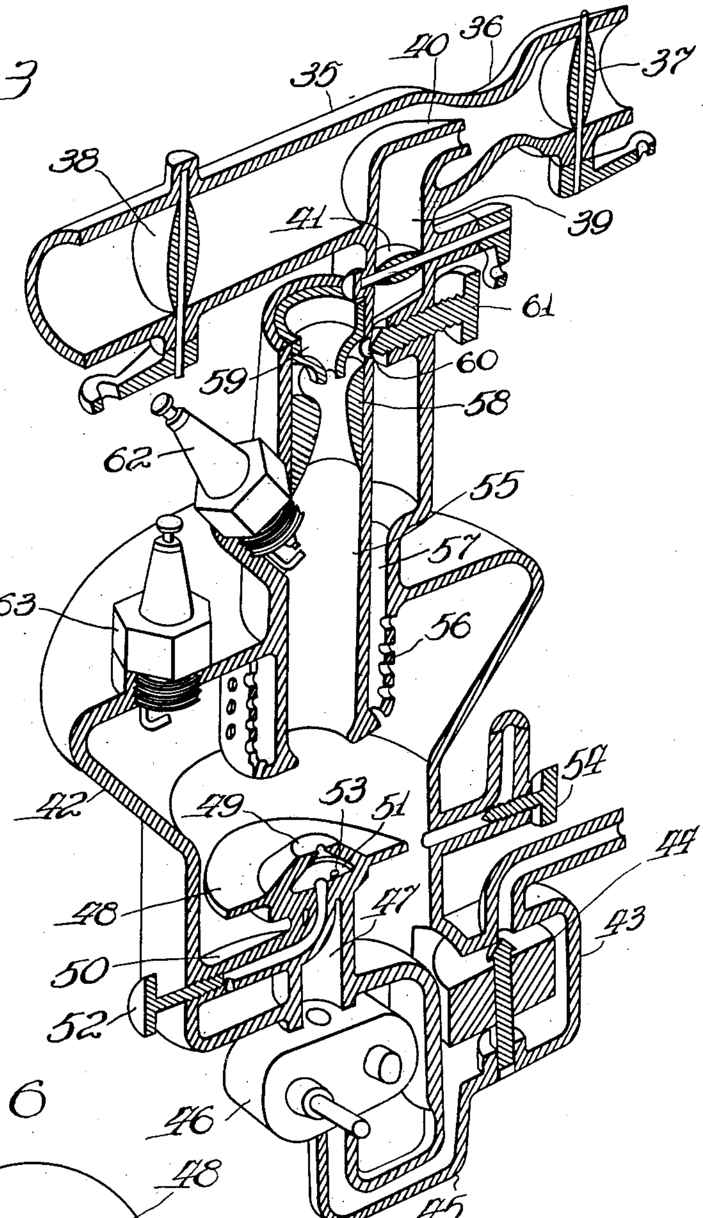
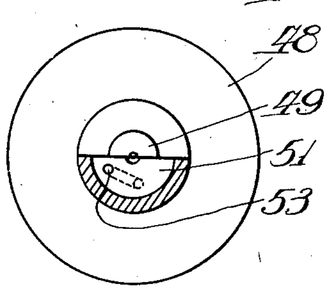


Fig. 6



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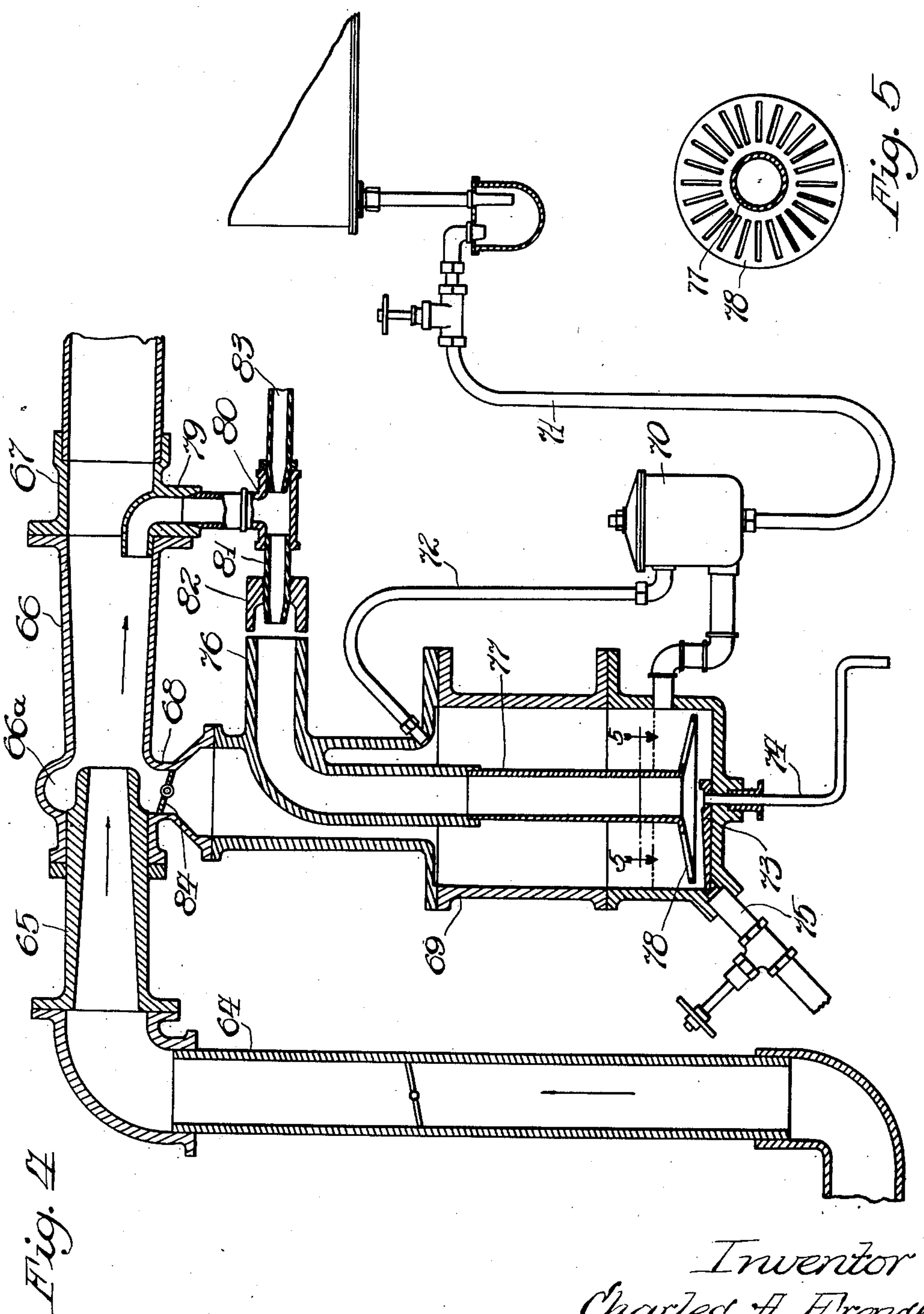

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2,122,684

UNITED STATES PATENT OFFICE

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VAPORIZING RELATIVELY HEAVY OILS

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Application November 1, 1935, Serial No. 47,910

19 Claims. (Cl. 48—213)

My invention relates in general to the vaporization of liquid fuels and forming combustible gaseous mixtures therefrom. It relates more in particular to the vaporization of relatively heavy hydrocarbon liquids preliminary to burning the same.

In the burning of relatively heavy liquid fuels, whether for the primary purpose of deriving heat therefrom or in the operation of internal combustion engines of any of the usual types, considerable difficulty has been encountered, principally in that air is not brought into such intimate contact with the fuel during burning as to obtain satisfactory efficiencies and complete blue flame combustion. For purposes of analysis, the burning of the relatively heavy hydrocarbon fuels, the function in which I am most interested in the present invention, will be considered.

It is known that fuels heavier than kerosene, particularly fuels of the grade of so-called No. 1 furnace oil and heavier, do not burn well in ordinary "oil burners". It is very difficult to obtain any flame other than a smoky, radiant flame which will deposit carbon on surfaces with which the flame or hot gases therefrom come in contact. Such flames are not readily controlled and are objectionable from many standpoints, particularly where accurate control of temperature or furnace atmosphere is desired. Substantially perfect combustion, evidenced by an essentially neutral furnace atmosphere, has been considered substantially impossible of attainment with such fuels.

Attempts have been made to obviate the disadvantages of direct burning of relatively heavy fuel oils by preliminarily vaporizing such fuels and subsequently burning the vapors either by precommingling the vapors with air or effecting the combination at the burner orifice. Methods heretofore employed for vaporization of relatively heavy liquid fuels, that is, those heavier than kerosene, have not been satisfactory. Vaporization of the fuel and the utilization of the resulting vapors require some metering device or method whereby the amount or character of vapor delivered to a manifold can be controlled. This has been accomplished in the past by measuring or metering the liquid fuel as it has been delivered to a vaporization chamber. This principle has very serious disadvantages, principally because the viscosity of a relatively heavy hydrocarbon fuel changes greatly with change in temperature, and change in viscosity requires a correction in the measuring orifice or valve through which the liquid fuel is delivered. The relatively small volume occupied by the liquid fuel also complicates the problem of measurement, as a relatively small volumetric error as applied to the liquid is translated into a relatively high percent of error when the liquid has been vaporized.

Methods of vaporization employed in the past have utilized hot surfaces which contacted the liquid fuel or have resulted in the proximity of hot surfaces of metals to said fuels, which metals acted catalytically and otherwise to cause a cracking of the heavy fuel and a consequent deposition of carbon in and around the vaporization chamber and conduits leading therefrom. Employment of radiant heat, hot conducting surfaces, and the like, seem to produce a chemical action resulting in the objectionable formation of carbon to which reference has been made.

When I refer to heavy liquid fuels, or relatively heavy liquid fuels, or relatively heavy hydrocarbon fuels, or employ similar expressions indicating that the product considered is heavy or relatively heavy, whether hereinabove or in the following part of this specification, I mean a fuel or hydrocarbon having a specific gravity of 42 Bé. or heavier, unless otherwise indicated; and where reference is made to hydrocarbons directly, it is understood that, so far as the present invention is concerned, present commercial "kerosenes" and lighter fractions are excluded from the class of substances to which my invention relates. The relatively light fractions, as a rule, volatilize so readily that no unusual vaporization problems are involved.

The principal object of my present invention is to provide a method of substantially completely vaporizing heavy liquid fuels and intimately mixing the vapors therefrom with air.

Another object is the provision of an improved method for metering relatively heavy liquid fuels during a vaporization step preparatory to combining the vapors with air.

Another object is to avoid metering fuel in the liquid phase when burning the same.

Another object is to vaporize relatively heavy liquid fuels with a minimum of decomposition, and thereby reduce carbonaceous deposits and detonation and the troubles ordinarily caused thereby.

Another object is to provide vaporization heat in exact proportion to the requirements of heat for vaporization.

Another object is to provide a combustible vaporous product at substantially constant temperature and quality over a wide range of operation for a given device with which the method may be practiced.

Another object of this invention is to provide combustible gases of different B. t. u. value, within limits, under the control of the operator.

Another object is to avoid condensation so that gaseous fuel only will be delivered to the burner or other means utilizing the gases.

Another object is to provide a constant ratio of fuel to air in any quantity required by a burner or other device utilizing the same.

Another object is to burn relatively heavy hydrocarbon fuels with a clear, transparent, sootless, blue flame.

Another object is to vaporize relatively heavy hydrocarbon fuels and combine the vapor with air in such proportions and in such a manner that the products of combustion of said vapors and oxygen content of the air are substantially only carbon dioxide and water.

Another object is the provision of a vaporized product from relatively heavy fuel which can be used instead of conventional supplies of gas for many purposes, can be piped short distances, and can generally be controlled in the manner in which gas is controlled.

Another object is to so surround each molecule of fuel vapor with hot inert gas that it will immediately be swept out of contact with the liquid fuel, and initial condensation and cracking will be greatly retarded or entirely avoided, and the vapor thereafter can be conveyed through a manifold at a much lower temperature without appreciable condensation.

Another object is to provide a gaseous product that burns with the same type of clean, blue, non-radiant, sootless flame as premixed natural or water gas, and which has a lower hydrogen content, making it valuable for metallurgical, ceramic, and drying processes where water vapors in furnaces must be kept at a minimum.

A further object is to provide a more efficient method for burning heavier fuels.

A still further object is to provide a method of and means for effecting the non-destructive vaporization of hydrocarbons heavier than kerosene.

The objects of the invention as above set forth and other more specific objects are accomplished generally by maintaining an excess of fuel at the point of vaporization thereof and passing into intimate contact with said excess of fuel, hot inert gases of substantially complete combustion and constant composition, controlled in a manner illustrated more in detail hereinafter. The amount of fuel vaporized and the amount of fuel vapor produced is proportional to the amount of hot gases supplied (these gases being of constant quality); that is to say, for a given amount of heat as the sensible heat of hot inert gases of constant temperature, the same amount of vapor is always produced. Therefore, instead of metering or measuring the liquid fuel, the amount of vapor produced is controlled by metering the hot gases brought into contact with the fuel, whereby the difficulties attending the metering of the liquid fuel are eliminated.

The hot inert gases employed to vaporize the hydrocarbon fuel are supplied in several ways, the only requirement being that the proportion of such hot gases be controllable in order to permit control of the amount of vapor produced. I may, for example, withdraw a definite portion of the vapors and burn the same in a pilot burner with a quantity of air sufficient for complete combustion, and then deliver all of the products of combustion from said pilot burner to the vaporization chamber. I may also combine the vapors produced in the vaporization chamber with a fixed proportion of air, burn the same in a main burner, and withdraw a fixed proportion of the hot products of combustion of the main burner for delivery to the vaporization chamber.

The method described may be practiced with many different types of equipment which may be modified considerably. The three types of devices illustrated show three embodiments of the invention which secure the objects described and employ the general features of the invention pointed out. The general steps of the method will be described more in detail after description of the devices with which the method can be practiced, said devices being shown in the accompanying drawings, wherein

Fig 1 is a sectional view somewhat diagrammatic illustrating the essential elements and their relative arrangement of a vaporizer and burner particularly adapted for high pressure steam boilers;

Fig. 2 is a cross section taken on the line **2—2** of Fig. 1;

Fig. 3 is a perspective sectional view showing a vaporizer particularly adapted for internal combustion engines;

Fig. 4 is a sectional view, somewhat diagrammatic in nature, illustrating a modified form of vaporizer;

Fig. 5 is a sectional view of a gas and liquid contacting means utilized in the vaporizer shown in Fig. 4; and

Fig. 6 is an enlarged detail view, partly in section, showing the sprayer nozzle section utilized in the vaporizer shown in Fig. 3.

In the device shown in Fig. 1, the two walls **10** and **11** are spaced apart to form a combustion chamber, such as shown in my United States Patent No. 1,466,709. This type of combustion chamber is particularly adapted for use in the generation of steam for high pressure boilers, as illustrated in said patent. Between the walls **10** and **11**, a plurality of spaced annular plates **12** are arranged to form a burner grating. The stack of plates extends into contact with the lower wall, and an opening **13** is formed therein for delivering combustible gases to the space within the plates. A fan housing **14** communicates with the lower wall **11**, having a flange which fits within the opening **13**. A transverse shaft **15**, extending through the fan housing, carries impeller blades **16** and a pulley **17** by which power is transmitted through a belt for driving the fan. The fan housing is provided with an air intake **18** at its center on one side and a combustible gas inlet **19** at its center on the other side.

A conduit **20** communicating with the air intake **18**, is provided with a damper **21** for regulating the flow of air therethrough. A conduit **22**, communicating with the inlet **19**, is provided with a damper **23** for regulating the flow of gas therethrough. The outlet from the fan, communicating with the interior of the grating, is provided with a cylindrical member **24** spaced from the walls of the outlet and flanged at its upper end to extend outwardly to the plates of the grating. The outwardly extending portion is somewhat above the bottom of the stack of plates. A damper **25** is positioned in the cylindrical member **24** for regulating the flow of gas therethrough. The annular space around said member is at all times in communication with the portion of the grating below the outward extension on said member.

A conduit 26 communicates with the lower wall 11 adjacent the flame side of the burner grating. Said conduit extends downwardly into communication with the vaporization chamber 27. Said chamber, as illustrated, is a somewhat shallow vessel in which liquid fuel is maintained at the indicated level by a float chamber 28 to which the liquid fuel may be supplied in any conventional manner. A horizontal partition 29 in the vaporization chamber directs the flow of gases into close proximity to the surface of the liquid. A plurality of heat conducting elements 30 are mounted in the vaporization chamber and extend above the liquid level into close proximity to the partition 29. A cylindrical wall 31 surrounds the conduit 26 in spaced relation with respect thereto, thereby forming an annular chamber. This chamber is in communication with the vaporization chamber 27. The partition 29 is so arranged that incoming gases passing through the conduit 26, must pass along the surface of the liquid in contact with the elements 30 before passing out into the annular chamber formed by the wall 31. The conduit 22, previously referred to, is in communication with the chamber formed by the wall 31.

A pump 32, illustrated as a gear pump, is connected by an inlet pipe 33 with the bottom of the vaporization chamber. A discharge pipe 34, connected with the pump, extends into the vaporization chamber and up into the conduit 26, terminating in a nozzle for spraying the fuel oil.

The operation of the burner shown in Figs. 1 and 2 will be understood from the above detailed description. The fan 16 is put into operation, whereby suction is created at the center, drawing air in through the conduit 20 and gases in through the conduit 22 in a ratio determined by the setting of the dampers 21 and 23. The air and gases are discharged from the fan into the center of the stack of plates forming the burner grating, being discharged therefrom in a radial direction in flat streams. The suction on the conduit 22 draws gases downwardly from the flame side of the burner grating through the conduit 26, over the heat conducting elements 30 and through the annular chamber formed by the conduit 26 and the wall 31. As previously stated, the liquid fuel may be maintained at the indicated level in the vaporization chamber 27 by a conventional float actuated means. In operating the device, the gear pump 32 is put into operation, whereby fuel is sprayed from the nozzle at the upper end of the pipe 34 into the conduit 31. As an essential feature in a device of this kind, the pump is so constructed and driven that during any rate of operation of the burner a considerable excess of fuel is sprayed into the conduit 26, that is, more fuel than can be vaporized by the hot gases contacting therewith.

To initiate operation of the burner and for operating at low loads, that is, with the circulation and combustion of a small amount of gas, the member 24 is provided in order to confine the combustible gas being supplied to a small area of the grating. With the damper 25 in closed position, the discharged gas is delivered from a very small area of the burner grating. By utilizing this construction, a mixture can be obtained at a concentrated point which can easily be ignited by any suitable means. As soon as heat is supplied by actual burning of gases being supplied from the lower part of the grating or from an independent torch or other means, an increased amount of vaporization takes place in the conduit 26, to which a spray of liquid fuel is delivered. A sufficient amount of combustible gas is, therefore, in a short time after ignition available for full operation of the burner. The damper 25 may then be opened and the dampers 21 and 23 controlled to provide a blue flame combustion, which is very desirable in burners of this type.

The vaporizer particularly adapted for internal combustion engines shown in Fig. 3 differs somewhat from the vaporizer for the burner above described. In this vaporizer a portion of the hot products of vaporization is completely burned to supply heat for vaporization. As shown in Fig. 3, a conduit 35 is provided with a restriction 36 which forms a Venturi throat. Other conventional means, such as a volute, fan or system of valves, may also be used to provide the suction and metering. A throttle valve 37 is positioned beyond said Venturi throat, and a choke valve 38 is provided at the inlet end of the conduit 35 ahead of the Venturi throat. A conduit 39, extending through the wall of the conduit 35, terminates in a nozzle 40 positioned in the Venturi throat. A valve 41 is positioned in the conduit 39 for a purpose which will be hereinafter described. A vaporizing chamber 42 is particularly formed to carry out the principle of vaporization utilized. A substantially cylindrical bottom portion of the casing forms a receptacle into which excess fuel is drained. A fuel reservoir 43 is formed integral with the chamber 42 and communicates with the bottom thereof. A float controlled inlet valve 44 regulates the flow of fuel to the reservoir and maintains the fuel level therein substantially constant. A fuel conduit 45 communicates with the fuel reservoir and with the inlet of a gear pump 46 which is provided with suitable driving means. The outlet of said pump communicates with a conduit 47 which extends centrally upwardly into the bottom of the vaporizing chamber 42. A plate 48, connected to the top of the conduit 47, extends horizontally therefrom and terminates closely adjacent the wall of the vaporizing chamber, leaving, however, an annular opening between the plate and wall. A particular type of nozzle 49 is provided at the top of the conduit 47 positioned to discharge a conical spray above the plate 48.

The nozzle 49 is provided interiorly at the top of the conduit 47 with a conical chamber 51. The conduit 47 and the chamber 51 are connected by angularly inclined passages 53. As best shown in Fig. 6, the passages 53 are arranged at such an angle with respect to the axis of the conical chamber 51 that the flow of liquid through the passages tends to create a whirling movement of the liquid within the chamber. A bypass conduit 50 communicates with the conical chamber at the lower side and centrally thereof. Said conduit extends out into the base of the vaporizer and is provided with a control valve 52. The nozzle 49 is provided with a small discharge opening at the apex of the conical chamber 51.

The top of the vaporizing chamber is flared out in the nature of an inverted cone, thereby providing a suitable space for the conical discharge from the nozzle 49. The top of the chamber is substantially flat. Centrally of the top, a conduit 55 extends downwardly into the vaporizing chamber. Within the chamber, a perforated sleeve 56 surrounds the conduit in spaced relation thereto, joining the open end of the conduit and the top of the chamber.

The space formed by said sleeve and the conduit **55** comprises a lateral passage **57** formed at one side of the conduit **55**, to the conduit **39** which communicates with the suction producing Venturi throat previously described. The conduit **55** is substantially cylindrical in shape. A member **58**, forming a venturi, is fitted inside said conduit at the top thereof. A second member **59** is fitted into the conduit above the member **58** and is provided with a nozzle portion extending into the suction creating area of the member **58**. An annular space formed between the members **58** and **59** is connected by an opening **60** formed in the wall of the conduit **55** to the passage **57**. Said opening is controlled by an adjustable valve **61** extending outside the casing which, as illustrated, makes up the entire device. A spark plug **62** is inserted in a boss formed at one side of the conduit **55**. The conduit **55**, as will be described in connection with the operation of the device, forms a combustion chamber. The lower end of the conduit **55** is restricted to form a high velocity discharge from the combustion chamber. A spark plug **63** is mounted in a boss formed in the top of the chamber **42**.

In the operation of a vaporizer, as shown in Fig. 3, it is to be understood that the conduit **35** is connected to the manifold of an internal combustion engine. In starting the vaporizer and engine when cold, suitable electric current is furnished to the spark plug **63**. The pump **46** is put into operation and a spray is produced in the chamber **42** by the nozzle **49**. Air may be admitted through the inlet **54**. Even with a comparatively heavy grade of oil, sufficient combustion takes place in the vaporization chamber by reason of the spray formed by the nozzle **49** to produce combustible gases. These gases pass out through the perforated sleeve **56**, through the passage **57**, the conduit **39**, and the nozzle **40**, into the Venturi throat **36**. When the device is first put into operation, the choke valve **38** is closed and the throttle valve **37** is partly or all the way opened. The closing of the choke valve **38** puts a high suction upon the nozzle **40** and substantially all of the gases drawn into the engine cylinders come from said nozzle. Although the gases first produced are low in heat value, the fact that the gases are without dilution with air makes them combustible in the engine. As soon as some vaporized products are formed and pass up the passage **57**, a certain portion regulated by the needle valve **61** is drawn into the annular space formed in the combustion chamber between the Venturi member **58** and the member **59**. These gases are thoroughly mixed with the incoming air and are discharged with a considerable velocity into the combustion chamber. Ignition is supplied to the spark plug **62**, thereby igniting the combustible gases passing through the conduit **55**. The members **58** and **59** are so related that, during normal operation over the entire range for which the device is adapted to operate, a substantially constant ratio of air and combustible gas will be drawn into the combustion chamber formed by the conduit **55**. The proportion is such that a clean blue flame combustion is obtained. The hot products of combustion are projected through the restricted inner end of the conduit **55** into the apex of the conical spray formed by the nozzle **49**. The mixture in **36** may be lean, neutral, or rich, depending upon the adjustment of the valve **41**, without affecting the mixture in the conduit **55**. An intimate contact is thereby obtained between the hot gases and the liquid particles of fuel in suspension. A substantially complete utilization of all the sensible heat carried by the hot gases is realized. As previously stated, the fuel pump **46** is of a capacity considerably greater than required for any amount of fuel ever vaporized in the chamber **42**. This condition is desired as an excess of fuel should be supplied at all times to the vaporization chamber. The excess fuel drains to the bottom of the vaporization chamber and returns to the float bowl where it mixes with the new fuel and is again sprayed into the vaporization chamber. By this means, at the most only a very small amount of decomposition takes place.

The vaporized fuel passing out through the perforated sleeve **56** projects against the conduit **55** and is superheated thereby. In this condition the vapor can be carried a considerable distance without any appreciable condensation of the vapor particles.

As the quantity of gas becomes somewhat uniform, an amount of combustible gas is drawn into the Venturi member **58** proportional to the amount of vaporized gases desired. The complete combustion of this gas, which is very uniform, qualitatively furnishes the heat for vaporization. By this construction, it will be understood that there is no metering of the liquid fuel, the metering to obtain a constant quality of gas being obtained by the injector action of the members **58** and **59** and by the adjustment of the vapor controlling needle valve **61**. This is a very important feature of the invention as there are a great many difficulties encountered when attempting to meter liquid fuel when the proportion by volume of liquid fuel to the air required for combustion is very small, as is the case with the fuels which my invention is intended to handle.

The particular construction of the nozzle **49**, as previously described, provides a fine spray, particularly suitable for the purpose of obtaining an intimate contact with the hot vaporizing gases. Fuel being delivered from the pump **46** through the inclined passages **53** produces a whirling movement of the liquid within the chamber **51**. This results in the discharge of a fine conical spray from the edges of the orifice formed in the nozzle **49**. In order to prevent the building up of static pressure in the chamber **51** which would reduce the whirling action therein and the centrifugal force resulting from the whirling action, the bypass conduit **50** is provided. The valve **52** in said conduit provides a means for regulating the bypass of fuel from the central zone of the conical chamber. In addition to assisting in maintaining a whirling action in the chamber, whereby an appreciable centrifugal force is obtained, the removal of a large quantity of fuel from the center of the chamber **51** permits the use of a comparatively large orifice in the nozzle **49**.

This is a very important feature in a burner of this type, which is designed to handle heavy fuels. Small orifices are always undesirable where such fuels are to be handled as they clog much easier and therefore interfere with the operation of the device. Ordinarily, the use of large orifices with a small quantity of fuel to be discharged therefrom would result in a very coarse, narrow spray. By using the bypass construction, a very fine spray may be obtained from a large orifice with a comparatively small fuel line pressure and with a small quantity of fuel being discharged.

The modification shown in Fig. 4 is somewhat the same in general construction as the vaporizer shown in Fig. 3. By the use of either suction at the outlet end or pressure at the inlet end or, in other words, by a pressure differential, air is caused to flow through an air inlet **64**, a nozzle **65** which is surrounded at its discharge end by a Venturi shaped member **66**, and a discharge conduit **67**. The member **66** is so shaped and arranged with respect to the nozzle **65** as to set up aspirating action in a chamber **66a** formed around the nozzle by an enlargement on the member **66**. A conduit **68**, communicating with the chamber **66a**, joins said chamber with a vaporizing chamber **69**. The vaporizing chamber is formed in three sections secured together in a gas-tight manner. The uppermost section is comparatively small and provides a means for connection of the vaporizer to the conduit **68**. The middle section is cylindrical in form and provides the main part of the vaporizing chamber. The lowermost section, in addition to being a part of the vaporizing chamber, forms a reservoir in which liquid is maintained at the indicated level by a conventional float chamber **70**. The float chamber is provided with a liquid fuel pipe **71** and a balancing conduit **72** for maintaining the pressure above the liquid in the float chamber, the same as the pressure in the vaporizing chamber. The bottom of the liquid reservoir is formed with a flat surface over which a scraping member **73** is adapted to be rotated by a crank shaft **74** extending through the bottom of the reservoir. A valve controlled draining conduit **75** is connected to the bottom of the reservoir.

A conduit **76** of a substantial internal diameter extends into the uppermost section of the vaporizing chamber and centrally downwardly therethrough into the main body of the chamber. A cylindrical member **77**, connected to the lower interior end of the conduit **76**, extends below the normal level of the liquid in the reservoir and is provided with a radially extending flange **78**. As best shown in Figure 5, the flange **78** is provided with a plurality of small openings which, as illustrated, are in the form of radially extending narrow slits. This flange, with the openings formed therein, provides a bubble plate for intimately contacting gases with the liquid in the reservoir.

In the conduit **67**, a small elbow **79** is formed with its interior open and extending toward the nozzle **65**. Said elbow extends out through the conduit **67** and is joined with a T-shaped connection **80**. Said connection forms, in effect, a mixer for the pilot light or vaporizing flame of the device. One end of the T member is connected to a discharge nozzle **81** which terminates a short distance away from the open end of the conduit **76**. A member **82**, threaded on the nozzle **81**, is adjustable toward and away from the end of the conduit **76**. A fuel line **83**, which may be used to conduct any type of fuel, is fitted into the third end of the T connection **80**. Air or gaseous fuel may also be forced in through **83** to lean or enrich the flame from **81** in case a modified character of flame is wanted on the main burner, as will be considered later.

A valve **84** is mounted in the conduit **68** in a position to regulate the flow of gas through said conduit. A valve is also mounted in the conduit **64** and serves as a throttle valve to regulate the output of mixture from the vaporizer.

To operate the form of vaporizer above described, air pressure is applied to the conduit **64** whereby suction is created in the chamber **66a** around the nozzle. This suction or depression is also transmitted to the vaporizing chamber, valve **84** being open, whereby gases are drawn in through the conduit **76** and are contacted with the liquid in the reservoir at the bottom of the vaporizing chamber by bubbling through the slits formed in the bubble plate. Heat in the form of hot gases is delivered to the conduit **76** to initiate vaporization. This heat may be supplied in any suitable manner as, for example, by holding a blow torch between the members **76** and **82**. However, as illustrated, it may be supplied by delivering any readily ignitible fuel, such as gasoline or city gas, through the conduit **83** and igniting the mixture formed at the end of the nozzle **81**. The member **82** is a shield to prevent air being drawn into **76** after the burner is in operation. The hot products of combustion pass through the outer portion of the conduit **76** downwardly through the inner vertical portion of said member, through the member **77** and out through the bubble plate. The intimate contact obtained by bubbling the hot gases through the liquid assures a substantially complete transfer of the sensible heat in the hot gases to the fuel in the reservoir. The vaporization continues in the chamber above the fuel level with equalization of temperature. The unvaporized particles of fuel carried up are dropped out in the low velocity zone formed by the large vaporizing chamber and the vaporized gas is superheated to a certain extent by contact with the member **77** and the conduit **76** as said vaporized gas is drawn out through the conduit **68** into the Venturi member **66**. The valve **84** regulates the proportion of vapor being drawn out with relation to the amount of air supplied through the nozzle **65**. The vaporized fuel and air are thoroughly mixed in the Venturi member **66** and a portion of said mixture enters the elbow **79**. This combustible mixture is discharged through the nozzle **81** and is completely burned in the conduit **76**. It will, therefore, be understood that, after vaporization has been initiated, the necessary heat is supplied by complete combustion of a portion of the vaporized gases.

There are several methods of starting vaporizers of the type above described, all of which are based upon the fact that, if a small enough amount of cold air be brought into intimate contact with enough fuel and immediately removed from further contact, an ignitible mixture will result with any liquid hydrocarbon at any ordinary temperature. To make such an efficient surface carburetor requires a contacting means and space that is unduly large for practical purposes, so a compromise is made which, by the use of a little heat, permits the contacting means to be of reasonable size.

Any of the following methods may be used:

1. Air is drawn through the fuel and ignited at or above the surface of the fuel, developing heat enough to vaporize a portion of the excess of fuel present. The vapors, as produced, may be mixed with more air and burned in the burner or pilot flame to continue operation.

2. A more volatile and lighter fuel, such as gasoline, may be used initially in the vaporizing chamber and thus permit the burners to be lighted in the regular manner without any initial heat. The devices may be started on gasoline alone or the gasoline may be mixed with the regular fuel and the device will operate in the

regular manner without any other preparation. When operation has been established, the regular fuel may be substituted for the gasoline.

3. A lighted torch may be held at the pilot or gas inlet before admitting fuel to the device. If heated while empty, the vaporizer starts operation when fuel is turned on. This affords more rapid starting than other methods, except of course the gasoline starting method.

4. An electric heater may be used to heat either the fuel or the air. If the fuel is heated, the burner starts more slowly; if the air is heated, it starts at once.

In the preferred embodiment shown in Figs. 4 and 5, where a bubble plate is used for promoting more intimate contact between the hot gases and the liquid to be vaporized, the bubble plate should have a much larger capacity than is necessary for normal operation in order to start the burner readily. The slits formed in the bubble plate, or other means which might be employed to finely subdivide the heating gases into fine streams whereby intimate contact with the liquid is obtained, assure an almost complete transfer of heat from the gases to the liquid fuel. In order to start the burner when the liquid is cold and when the amount of heat supplied may be less than that supplied when the device is in operation, a complete transfer of heat from the gas to the liquid should be assured. This is obtained, as previously stated, by making the bubble plate of a larger capacity than necessary for normal operation in order to get the proper surface carburetion for starting.

All three of the devices described hereinabove utilize the same general method and secure, in general, substantially the same results. All of them employ a fuel heavier than kerosene, that is, having a gravity greater than 43 Bé. and preferably greater than 41 Bé. The combustible mixture in each case may be made to burn with a clear, blue, transparent, sootless flame, and the products of combustion, once the controls are set properly, are substantially only carbon dioxide and water vapor. In either form, a reducing or oxidizing flame may be produced. There are several features common to each of the devices and several terms employed which may require further explanation. The devices all are capable of uniform operation over a considerable range of capacity. While the products of combustion employed for vaporization in each case are substantially inert, the fuel vapors and air may be mixed in such proportions as to produce either a reducing flame or an oxidizing flame; or, stated in another way, either an oxidizing furnace atmosphere or a reducing furnace atmosphere. The device being once set for a particular type of operation, for example, to produce a reducing flame at the burner, will continue to produce the same type of operation over its operating range. It will be understood that, while only a minimum number of controls is shown, additional controls may be employed, particularly in the device shown in Fig. 4, to increase greatly the range of operation as to capacity.

For reasons made clear hereinafter, neither a strongly reducing flame nor a strongly oxidizing flame preferably is used at the pilot burner if excessive carbon and sludge formation is to be avoided in the vaporizing chamber. To produce an oxidizing flame, additional air may be admitted at the burner. If the gaseous mixture from which the pilot burner is supplied is too rich in oxygen or too rich in hydrocarbon vapors, the character thereof may be corrected. For instance, in the device of Fig. 4, either additional air, or an additional supply of gaseous fuel may be admitted through pipe **83** to produce a substantially neutral pilot flame.

In each of the modifications shown, approximately 5% of the vaporized products are employed for vaporization purposes. Stating this in another way, about 5% of the total heat units in the fuel are employed for vaporizing that fuel. Referring to Fig. 4, for example, the robber outlet **79** withdraws from the Venturi member **66** about 5% of the combustible mixture passing therethrough.

It has been established that such gases as carbon dioxide and water vapor begin to dissociate at temperatures above 1600 degrees F. The percentage of dissociation increases rapidly up to 3800 degrees F., which is the temperature of the pilot flame. While I produce substantially perfect combustion at the pilot flame in the device shown in Fig. 4, for example, at the temperatures of the blue flame produced, the gases have a definite chemical action due to the dissociated H_2+O content as well as the $CO+O$. I control the process which I employ, however, so that the hot gases of combustion are not brought into contact with the excess of fuel until they are reduced in temperature to substantially 1600 degrees F. For practical purposes, the gases may be as hot as 2000 degrees F., because up to this point, dissociation is not great enough to be serious. The gases should be above 1000 degrees F., however, because below this temperature difficulties arise in design of equipment, etc., although some results can be obtained.

As shown in Fig. 1, the hot gases of combustion have some considerable distance to travel before coming into contact with the spray from the pipe **34**. The conduit **26** is cooled by the relatively cooler vapors passing around it on their way to intake pipe **22**. In this form of device, there is also considerable expansion of the gases of combustion and this produces a very marked cooling effect. The result is that when the gases come into contact with the excess of fuel oil to be vaporized, they are at about 1600 degrees F. or somewhat lower, depending upon the capacity at which the device is being operated. This avoids tarring and carbonizing of the portion of the oil not vaporized. The gases, however, are well over 1000 degrees F. when the device is in operation, so that an amount of heat ample for vaporization is provided.

The construction, distribution of metal and direction of flow of gases is such, in the device shown in Fig. 3, as to produce substantially the same effect as described in connection with Fig. 1. In the device of Fig. 3, however, a portion of the vaporized products are burned for the sole purpose of vaporizing the remaining portion of the products. In this form, the temperature of the gases, when they come into contact with the excess of fuel sprayed in cone fashion from the nozzle **49**, are at about or slightly above 1600 degrees F.

In the device of Fig. 4, the gases produced at the pilot flame have little opportunity for expansion before contacting the fuel in the bottom of the vaporizing chamber. The distance from the pilot burner to the oil supply, however, is designed to permit cooling of the products of combustion down to substantially 1600 degrees F. It is to be noted that the hot gases pass through the center conduit which is cooled by the rising vapors from the puddle of oil in the vaporizing chamber. This has a cooling effect upon the combustion gases and also a favorable heating effect upon the products of vaporization.

I have found that if the products of combustion are brought into contact with the body of oil while still at a high temperature, by suitable means, such as shortening the pipe 77 shown in Fig. 4, the oil will, in a very short time, become tarry and the operation of the device will be substantially stopped. If the pipe is made too long, that is, if the gases are at a relatively much lower temperature, there will not be sufficient heat to vaporize relatively heavy hydrocarbon fuels.

I described hereinabove that during operation and after the starting period, approximately 5% of the vaporized products are utilized most efficiently for the vaporization of the fuel oil. In some cases, as low as 3 or 4% of the fuel may be used for vaporization, and, at times, as high as 10%. In general, however, the preferred range is between 5 and 10%.

Employing the hot gases of combustion of a pilot flame, or of the main burner, for vaporizing the liquid fuel has several advantages. The burned gases, being substantially inert, have no chemical or catalytic action which will result in carbon or sludge formation, but have a physical action in separating the oil molecules as the oil is vaporized, particularly after some superheat has been imparted thereto. Just above the oil level, some oil particles of relatively large size are entrained, but near the top of the vaporization chamber less "atomized" particles are present and much more oil particles of molecular or substantially molecular size are present separated from each other by layers of hot inert gas. This separation of the oil molecules by layers of inert gases retards condensation greatly and serves so to dilute the vapors as to make possible the complete combustion of the vapors, which has already been described. When burning heavier fuels by vaporization, this method automatically compensates for the difficulties encountered when proceeding to employ successively heavier fuel oils through the practical range. Dilution of the vapors with burned gases retards condensation of the heavier gas molecules and the increased amount of heat available from a somewhat increased amount of hot gases of combustion serves to vaporize the more difficultly vaporizable, larger hydrocarbon molecules.

The following figures show the effect of modifying the percentage of fuel vapor burned for vaporization. When employing No. 1 furnace oil, 5% of the products burned are normally utilized to vaporize all of the oil burned. When employing this oil, 10.95 cubic feet of the products of combustion are associated with and employed to vaporize one pound of fuel. The mixed gas has a B. t. u. content of 1540. If 6% of the products of vaporization are utilized for vaporization purposes, the amount in cubic feet of vapor associated with one pound of fuel is 13.3 and the gas has a B. t. u. content of 1300. When 7% of the vapors are employed for vaporization, the vapor of one pound of fuel is diluted with 15.7 cubic feet of the products of combustion and the gas has a B. t. u. content of 1130. Additional figures are 8%, 18 cubic feet, 1000 B. t. u.'s.; 9%, 20.6 cubic feet, 880 B. t. u.'s. In general, not less than 5% nor more than 10% of the fuel should be used for vaporization.

It must not be assumed that the process of my invention involves the mere boiling of the fuel to vaporize portions thereof. There is no boiling in the ordinary sense, the temperature of the excess of fuel always being substantially below the boiling point. As an example, if a fuel having a boiling point of 460 degrees F. is employed, and vaporized according to the method of my invention, the maximum temperature of such fuel is approximately 390 degrees F. It is, of course, understood that a liquid boiling at 460 degrees F. has a relatively high vapor pressure at 390 degrees. By removing the vaporized products rapidly with a relatively large amount of hot inert gases, in accordance with my method, the equilibrium between the vapor and liquid is destroyed in such a manner as to favor more rapid vaporization. This is not explainable by the presence of sub-atmospheric pressure above the level of the liquid. Although some loss in pressure is manifest, it is by no means sufficient to explain the extremely rapid vaporization which occurs. In all forms of device employed, particularly the form shown in Fig. 4, the products of combustion at the point of thorough contact with the liquid are permitted to move upwardly, thus promoting and facilitating combination with the hydrocarbon vapors, which in themselves tend to rise.

That the process of my invention is not merely one of vaporization by heat equivalent to boiling is demonstrable by comparison of carbon residue by the two methods. If ordinary No. 1 furnace oil be vaporized by direct application of heat to the exterior of a vessel in which it is contained, the carbon or tarry residue left will be equivalent by weight to approximately 1½% or more of the original oil. The amount of residue produced when the process of my invention is employed cannot be determined accurately, because there is not sufficient carbonaceous residue deposited in the vaporization chamber to make an accurate determination. The closest approximation shows that in some test cases under commercial operating conditions the residue is only about of the order of one to two parts per million parts of oil vaporized.

I am aware that carburetors for vaporizing gasoline have been suggested wherein the exhaust gases of an internal combustion engine have been passed through a pool of gasoline in order to entrain gasoline vapor. This method is not entirely satisfactory for carbureting gasoline, but is particularly objectionable when heavier fractions are vaporized such as those to which my present invention relates. In the first place, the exhaust gases are not uniform in temperature or pressure as are the gases used in my method. Moreover, the exhaust gases from an internal combustion engine are not inert but contain relatively large amounts of chemically active constituents. If these burned exhaust gases at high temperatures are brought into contact with a liquid hydrocarbon, they will produce distinct cracking with a relatively large production of tar and carbonaceous residues. If the gases are allowed to cool to a great extent, they will have substantially no effect on relatively heavy fuels. They may be employed, however, to vaporize gasoline, because it is known that even air at ordinary room temperature, if bubbled through gasoline, will vaporize the same. Burned gases at temperatures of 200 to 300 degrees F. might be employed with gasoline with some increase of vaporization, but these relatively low temperatures cannot be employed successfully to vaporize heavy fuel oils unless the amount of surface of fuel oil in contact with the gas is so great as to make its use substantially impractical, and in no case could a vaporous product of high B. t. u. value be produced. It is, of course, known that surface carburetion is theoretically possible with any liquid fuel if a sufficiently great amount of surface is exposed.

Another disadvantage of the method described above is that it produces a pulsating flow of gases which substantially prevents satisfactory operation. If the vaporous mixture produced be conveyed to an open burner, the gases, to burn at such burner, must flow substantially evenly and at a uniform rate; otherwise, the burner will be extinguished. More objectionable, however, is the fact that a mixing device such as the venturi and forcing nozzle combination shown in Figs. 3 and 4 will not function satisfactorily under these conditions.

While I may deliver the products of vaporization of my invention to an internal combustion engine, as shown in one form of the device, this may be accomplished in such a way as to avoid pulsating flow of gases which would interfere with the practice of the method. In this form, I employ a separate pilot burner with its own aspirator, and there is such a damping of the pulsations that the incoming air at the pilot burner aspirator is substantially uniform and constant.

Still another disadvantage of employing an engine exhaust for vaporization is that a low temperature must be employed and, as a consequence, the vapors of the relatively heavy hydrocarbon will be at a low temperature. Furthermore, there will be little tendency for the air and vapors to combine in all proportions and propagation of a clear blue flame, where desired, will be substantially impossible and "complete combustion" cannot be obtained. This may be contrasted with my device wherein the gases brought into contact with the fuel are at a low enough temperature to prevent appreciable dissociation of their inert constituents, but at high enough temperature to be avid for moisture (which may be oil). The vapor tends to remain in vaporized form without condensing and, in addition, the gaseous mixture is at a high enough temperature so that the vapor substantially follows the gas laws. Moreover, the large volume of air is raised to a sufficiently high temperature so that the resulting mixture will still follow the gas laws and a very intimate commingling of all of the gaseous constituents obtained. This promotes the clear, blue flame combustion which is obtained herein.

In this connection, another feature and advantage of the present invention should be noted. In the burning of hydrocarbons, of the type known as No. 1 and No. 3 furnace oil, the proportion of air to fuel is approximately 98 to 99%. It is substantially impossible, by ordinary methods, to get a thorough mixing of 1 to 2% of the oil with 98 to 99% of the air. By diluting this fuel in vapor form with the inert gas, and then combining the air under such conditions that the entire resulting mixture is at a relatively high temperature, much better commingling of the products is obtained, even though the products might fail to obey the gas laws. In other words, the problem of mixing alone is solved by the use of the present method.

When practicing the method of my invention, the B. t. u. content of the gas produced can be modified by changing the area of contact between the hot gases and the liquid fuel. In the form of device shown in Figs. 1 and 3, for example, the character of the spray may be changed; that is to say, a relatively fine spray will afford a greater contact between gas and liquid and will produce a higher calorific value than if a relatively coarser spray is employed. Mechanical means for changing the character of the spray are relatively simple. In the form of device shown in Fig. 4, the level of the oil in the vaporization chamber may be raised or lowered, the former producing a greater area of contact and higher B. t. u. value.

When discussing the B. t. u. value of the gas produced, it is understood, of course, that the mixture of vapors and inert gases before the commingling of air therewith is what is referred to. It is obvious that the B. t. u. character of the final combustible mixture, under all circumstances, will be substantially the same. The B. t. u. character of the mixture of combustible and inert gases and fuel vapor can also be modified somewhat by increasing or decreasing the proportion of the vaporized products employed for vaporization and by changing the temperature at which they come in contact with the fuel.

In several places hereinabove, I have employed the term "excess of fuel" and terms having equivalent meaning. The meaning of this term seems to be clear from a consideration of the three forms of device shown. In all cases and at all times, there is in the vaporization chamber more liquid fuel than can be vaporized if all of the available heat generated and/or stored by the heat source were used at 100% efficiency to vaporize the fuel. As shown in Fig. 1, the sprayed fuel comes into contact with the hot gases descending initially downwardly through the conduit **26**. Not all of the sprayed liquid is vaporized, but a portion thereof falls back into the puddle maintained in the vaporization chamber. In addition, there is the puddle in the vaporization chamber providing an extended surface and a greater proportion of fuel than can be vaporized if all of the heat available at any one instant were employed. Indeed, it is obvious that, without supplying any additional fuel, the vaporizing device could be operated for some little time and continue to function, although, due to the gradual diminishing amount of fuel present, some change in the B. t. u. character of the gas would be manifest.

In the form shown in Fig. 3, more fuel is sprayed up through the nozzle than can be vaporized and this excess falls down and passes through the float chamber back into the pump **46** where it is again delivered to the spray nozzle. In the form shown in Fig. 4, there is always a pool of oil at the bottom of the vaporization chamber **69** through which the hot inert gases pass during vaporization. It is obvious, therefore, that I employ the phrase "excess of fuel" in a strict sense and my use of an excess of fuel is not to be compared with methods wherein, at a particular or given point or location in a vaporizing device, there may be more fuel than is vaporized.

I have employed the term "metering" hereinabove to describe the means employed for controlling the amount of vapors produced. The metering utilized in the practice of my invention is substantially automatic, as will be explained for convenience by reference to Fig. 4.

The mixture of gaseous products and air moves through the outlet of the Venturi tube **66** in the direction indicated by the arrow. The member

79 is in effect an impact pipe and is so arranged that, assuming uniform resistance to the passage of gas through the member 67 and through the outlet of member 79, the proportion of gas passing through the member 79 will be exactly proportional to the cross-sectional area thereof as compared with the cross-sectional area of the pipe 67. There are some differences in resistance, however, and these being calculated and determined in part also by test, the impact pipe is arranged to take a definite percentage of the gases passing to the manifold. Assuming this member to be designed to withdraw the proper amount of the combustible mixture, then the necessary amount of the gases produced will always be burned at the pilot burner independently of the amount of vapor generated within the limits of design of the apparatus employed. In other words, by withdrawing a definite proportion of the combustible mixture and burning that combustible mixture, the amount of burned gases delivered into contact with the fuel and, therefore, the amount of fuel vaporized is determined.

To illustrate the metering principle which I employ, reference may also be made to Fig. 1. In this form of the device for carrying out the method, the amount of vaporous mixture delivered through the opening 13 need not be controlled accurately for satisfactory operation because, due to the relative position of the part, any proportion of the hot gases of combustion which may be required for vaporization may be drawn through conduit 26. At any given time, therefore, more hot gases are available for vaporization purposes than are required. The apparatus is designed, however, so that from 5 to 10% of the hot gases are withdrawn, even though such gases are burned, not in a pilot burner, as in the other forms, but in the main burner. This relationship exists whether the entire burner is being operated, or only the lower section thereof. In all cases, therefore, a definite quantity of hot products of combustion, proportional to the quantity of fuel evaporated, is drawn into the vaporization chamber from either a pilot flame or main burner flame. These products of combustion are of essentially constant composition and temperature, and, therefore, the ratio between the products of combustion utilized and the amount of oil vaporized is substantially constant.

In the form of apparatus shown in Fig. 4, it is not absolutely necessary that all of the hot gases produced by the pilot burner be delivered to the vaporization chamber. In practical operation, some small amount of hot gases are usually forced out through the annulus between members 76 and 82 to avoid any possibility of entraining free air which might introduce carbonizing difficulties if present in appreciable amounts. This condition is maintained, usually, when the products of combustion of the pilot burner are substantially neutral due to the character of combustible mixture withdrawn.

This relationship, being established, holds when the device is operated at varying capacities, as further consideration will show. As will be explained, no matter how rapidly or how slowly vapor is withdrawn (within the capacity of the device), the relation of air to vapor will remain constant. Assuming a mixture such as will afford complete combustion, leaving no unburned hydrocarbon nor uncombined air, this gas burning at the pilot burner will always produce the same heat per unit volume. For practical purposes, therefore, the products of combustion will always be at the same temperature. This statement disregards the radiating action of metal surfaces, but within comparatively wide limits, the difference in temperature of gases delivered to the vaporization chamber is very slight. Since the temperature of these gases remains the same, the amount of fuel vaporized is purely and naturally proportional to the amount of hot gases delivered. This, as previously shown, is proportional to the amount of combustible mixture flowing to the manifold and this, in turn, is determined by the amount of gaseous mixture burned.

This arrangement makes for automatic operation and stabilization of the process of my invention when employed with suitable apparatus over a relatively wide range of capacities without making it necessary to employ any controls whatsoever, except those established by the structure of the device itself. This is in part made possible by inherent characteristics of the venturi forcing nozzle combination which I employ, or the definite action of the blower shown in Fig. 1. While, in the form shown in Fig. 4, air is delivered to the forcing nozzle under pressure and the mixture of vapor and inert gases is delivered to the venturi around the periphery of the forcing nozzle, the reverse arrangement shown in Fig. 3 in which suction is employed functions in substantially the same way.

With this form of apparatus and employing normal size equipment, the suction exerted on the vapors is at all times substantially proportional to the amount of air passing the vaporization chamber outlet orifice. For example, if, in the suction type, one plots absolute pressures on the two portions of the ejector and mixer assembly against each other, there is obtained substantially a straight line; straight at least over the greater portion of its length; and, assuming a relatively small size piece of equipment with perfect operating conditions, the curve will be a straight line running down to a point where both values are zero. Accordingly, in the absence of some complicating condition, the proportion of air to gaseous mixture remains the same independently of the output of the device, but, of course, assuming its operation within its expected capacity. In the form shown in Fig. 4, however, with a given body of fuel in the vaporization chamber, there is a fixed or constant friction to overcome when gases are passed through the body of oil, as they must be, unless a partial vacuum is to be built up above the vaporization chamber, such as to prevent the automatic mixing operation of the air and gaseous products in definite proportions. This fixed resistance is more manifest in its effect at low velocities than at high velocities. To overcome this resistance, the damper 84 is operated. In general, it is necessary to operate this damper only when starting, since, within the usual operating range, the modifying effect of the fixed resistance of the oil can be disregarded. For accurate control of the process, the damper 84 can be regulated automatically in response to the combustible mixture delivered to a manifold.

A feature of my invention is that it is unnecessary at any time for the liquid fuel to come into contact with highly heated surfaces which cause the production of tar and carbon. Nor do such products come in contact with a radiant flame, which seems to have an undesirable effect by producing tarriness and relatively large proportions of carbon residue.

The fact that highly heated surfaces do not come in contact with the oil is clear from a consideration of the devices with which the method is practiced. It is obvious that it is possible so to proportion and arrange the vaporization chamber and means for delivering hot gases to an excess of fuel therein as to avoid local superheating of the liquid. At the same time, however, the inert gases and vapor, which may be termed a "vaporous mixture", while being relatively cooler, extract heat from moderately hot surfaces in such a manner as to avoid local overheating in any particular place. It appears that the vaporous mixture may be subjected to much higher temperatures without cracking than the liquid product.

My present invention is a continuation in part of my prior copending application, Serial No. 603,491, filed April 6, 1932.

What I claim as new and desire to protect by Letters Patent of the United States is:

1. The method of vaporizing a relatively heavy liquid hydrocarbon fuel which comprises providing hot gases of substantially perfect combustion, said gases possessing a regulated amount of sensible heat, intimately contacting said gases with an excess of the fuel whereby to vaporize a portion only of said fuel, and withdrawing the resulting mixture of vaporized fuel and burned gases.

2. A method of vaporizing a relatively heavy liquid hydrocarbon fuel which comprises providing in a vaporizing chamber an excess of said fuel, continually delivering hot inert gases to said chamber into intimate contact with said fuel, continually withdrawing a resulting mixture of inert gases and vaporized fuel from said chamber, and controlling the vaporizing rate by regulating the amount of inert gases delivered to said vaporizing chamber.

3. A method of vaporizing a relatively heavy liquid hydrocarbon fuel which comprises providing in a vaporizing chamber an excess of said fuel, continually delivering hot inert vaporizing gases resulting from complete combustion of a portion of said fuel to said chamber into intimate contact with said excess of fuel whereby to vaporize a portion thereof, continually withdrawing the resulting mixture of fuel vapor and inert gases of complete combustion, and varying the vaporizing rate with the rate of withdrawal of vaporization products by producing the inert vaporizing gases by complete combustion of a predetermined percentage of the products of vaporization.

4. The method defined in claim 3, wherein the percentage of the products of vaporization utilized for effecting vaporization of said liquid fuel is between approximately 5 and 10%.

5. A method of vaporizing heavy liquid hydrocarbon fuels which comprises providing hot vapors of said fuel, taking off a metered portion of said hot vapors and completely burning said portion with air sufficient for complete combustion whereby to produce substantially inert gases resulting from said complete combustion, delivering the hot inert gaseous products of complete combustion to a vaporization chamber, supplying fuel in intimate contact with said gaseous products in amounts in excess of the amount which can be vaporized by the available heat, and withdrawing the gaseous products of vaporization, said products comprising an intimate mixture of fuel vapor and inert combustion gases.

6. A method of vaporizing heavy fuel oil which comprises maintaining a pool of said oil in a chamber, initiating vaporization of a portion of said oil and burning said vaporized oil to effect substantially complete combustion thereof, passing at least a part of the resulting hot inert gases of combustion beneath the surface of the pool of oil whereby vaporization of a part only of said oil is effected proportional to the amount of hot inert gases passing therethrough, intimately commingling the vaporized oil with a relatively large volume of air to form a combustible mixture, withdrawing a minor proportion of said mixture and burning it to effect substantially complete combustion thereof, the hot gases of said latter combustion being utilized to effect the vaporization of additional amounts of the oil, the process being carried out in a manner such that there is substantially no direct contact of the liquid oil with heated surfaces, whereby deposition of carbon is effectually retarded and decomposition of the liquid oil is substantially prevented.

7. A method of vaporizing liquid hydrocarbon fuels heavier than kerosene which comprises providing hot inert gases resulting from the burning of combustible material, intimately contacting a metered amount of said hot inert gases with a quantity of the fuel in excess of that quantity which can be vaporized by said metered quantity of hot inert gases whereby vaporization of a portion only of the fuel is effected, intimately commingling the vaporized fuel containing said inert gases with a relatively large volume of air to provide a combustible mixture, substantially completely burning at least a portion of said mixture to provide a continuous, non-pulsating generation of hot inert gases of a substantially uniform temperature, and utilizing the hot gases resulting from said burning to vaporize additional quantities of fuel, the vaporization being continuous and being effected, at least after initiation of the process, by the intimate contact of said hot gases and an amount of fuel in excess of that which can be vaporized by said hot gases.

8. A method of vaporizing liquid hydrocarbon fuels heavier than kerosene which comprises providing hot inert gases resulting from the burning of combustible material, intimately contacting a metered amount of said hot inert gases with a quantity of the fuel in excess of that quantity which can be vaporized by said metered quantity of hot inert gases whereby vaporization of a portion only of the fuel is effected, intimately commingling the vaporized fuel containing said inert gases with a relatively large volume of air to provide a combustible mixture, burning at least a part of said mixture to provide hot substantially inert combustion gases and utilizing said hot gases to vaporize additional quantities of fuel, the vaporization being continuous and being effected, at least after initiation of the process, by the intimate contact of said hot gases and an amount of fuel in excess of that which can be vaporized by said hot gases, the generation of the hot inert gases which effect the vaporization of the fuel being continuous and non-pulsating.

9. A method of vaporizing liquid hydrocarbon fuels heavier than kerosene which comprises providing hot inert gases resulting from the burning of combustible material, intimately contacting a metered amount of said hot inert gases with a quantity of the fuel, in the form of a spray, in excess of that quantity which can be vaporized by said metered quantity of hot inert gases whereby vaporization of a portion only of the fuel is effected, intimately commingling the vaporized fuel containing said inert gases with a relatively

large volume of air to provide a combustible mixture, burning at least a part of said mixture to provide hot substantially inert complete combustion gases and utilizing said hot gases to vaporize additional quantities of fuel, the vaporization being continuous and being effected, at least after initiation of the process, by the intimate contact of said hot gases and an amount of fuel in excess of that which can be vaporized by said hot gases, the generation of the hot inert gases which effect the vaporization of the fuel being continuous and non-pulsating.

10. The method of providing a combustible mixture of air and heavy fuel oil vapor which comprises completely burning heavy fuel oil vapors with a blue flame in a constant volume space, passing the resulting hot inert gases of combustion into intimate contact with a proportion of the heavy oil to be vaporized greater than can be vaporized by said hot gases, withdrawing the resulting vapors and commingling said vapors with air in proportions to cause substantially complete blue flame combustion when ignited.

11. The method of vaporizing a relatively heavy liquid hydrocarbon fuel which comprises providing fuel oil vapors therefrom, burning a portion of said fuel oil vapors, passing the products of combustion therefrom downwardly through a closed passageway into intimate contact with an excess of the fuel to be vaporized, and continuously withdrawing the resulting vapors mixed with said hot gases from above the excess of fuel so that said vapors admixed with said hot gases move upwardly in contact with said passageway, said mixture of vapors and hot gases being heated by the hot gases passing through said passageway.

12. The method of vaporizing a relatively heavy liquid hydrocarbon fuel which comprises substantially completely burning a portion of said fuel to produce substantially inert hot combustion products, spraying an excess of said fuel into a vaporization chamber, passing the substantially inert hot combustion products resulting from said burning into contact with said excess of sprayed fuel, whereby to vaporize only a portion of the fuel so sprayed, and to dilute the resulting vapors with hot inert gases, and withdrawing the resulting mixture of vaporized fuel and hot inert gases from said vaporization chamber, hot gases resulting from the burning of at least a portion of said vaporized fuel being utilized for vaporization of said heavy liquid hydrocarbon fuel.

13. The method of vaporizing a relatively heavy liquid hydrocarbon, which comprises supplying a regulated amount of heat as the sensible heat of hot substantially inert gases of substantially perfect combustion, intimately contacting said hot inert gases while at a temperature between 1000 degrees F. and 2000 degrees F. with an excess of fuel whereby to vaporize only a portion of said fuel, and withdrawing the resulting mixture of fuel vapor and burned gases, at least a portion of said fuel vapor being burned with substantially complete combustion to supply said regulated amount of heat.

14. The method of vaporizing a relatively heavy liquid hydrocarbon fuel which comprises maintaining a puddle of said fuel in a vaporizing chamber, combining vapors withdrawn from the vaporizing chamber with air substantially sufficient for complete combustion, whereby to produce a combustible mixture, continuously withdrawing a minor portion of said mixture, burning said withdrawn portion so as to produce a substantially blue flame, delivering the products of said blue flame combustion to said vaporizing chamber beneath the level of liquid fuel maintained therein, and withdrawing from above said puddle of fuel the resulting mixture of fuel vapor and products of said blue flame combustion.

15. The method defined in claim 14, wherein said hot products of combustion are permitted to cool sufficiently to decrease materially the proportion of dissociated carbon dioxide and water vapor contained therein before coming in contact with the liquid fuel and wherein said puddle of liquid fuel is substantially maintained out of contact with metal surfaces having a temperature appreciably higher than that of the liquid fuel itself, and passing the vaporized fuel into contact with heated surfaces whereby to impart some superheat thereto.

16. The method of vaporizing a relatively heavy liquid hydrocarbon fuel which comprises substantially completely burning a portion of said fuel to produce substantially inert hot combustion products, spraying an excess of said fuel into a vaporization chamber, passing substantially inert hot combustion products resulting from said burning into contact with said excess of sprayed fuel, whereby to vaporize only a portion of the fuel so sprayed, and to dilute the resulting vapors with hot inert gases, and withdrawing the resulting mixture of vaporized fuel and hot inert gases from said vaporization chamber, hot gases resulting from the burning of at least a portion of said vaporized fuel being utilized for vaporization of said heavy liquid hydrocarbon, said inert hot products of combustion being at a temperature between approximately 1000 degrees F. and 2000 degrees F. when they come in contact with the fuel.

17. The method of vaporizing a relatively heavy liquid hydrocarbon fuel which comprises substantially completely burning a portion of said fuel to produce substantially inert hot combustion products, spraying an excess of said fuel into a vaporization chamber, passing substantially inert hot combustion products resulting from said burning into contact with said excess of sprayed fuel, whereby to vaporize only a portion of the fuel so sprayed, and to dilute the resulting vapors with hot inert gases, and withdrawing the resulting mixture of vaporized fuel and hot inert gases from said vaporization chamber, hot gases resulting from the burning of at least a portion of said vaporized fuel being utilized for vaporization of said heavy liquid hydrocarbon, hot inert products of combustion of between approximately 5% and 10% of the total vaporization products being utilized for vaporizing said fuel.

18. The method of vaporizing a relatively heavy liquid hydrocarbon oil which comprises providing in a vaporization chamber an excess of said oil, continually delivering hot inert gases to said chamber into intimate contact with said oil, continually withdrawing a resulting mixture of inert gases and vaporized oil from said chamber at a point above said excess of oil, the vaporization rate being controlled by regulating the amount of inert gases delivered to said vaporizing chamber, delivering the resulting oil vapors to a pipe whereby they may be utilized for a suitable purpose, the amount of oil vaporized being responsive to the amount of such oil vapors utilized.

19. The method of vaporizing a relatively heavy liquid hydrocarbon fuel, which comprises providing in a vaporization chamber an excess of said fuel, continually delivering hot inert vaporizing gases resulting from a complete combustion of a

portion of said fuel to said chamber into intimate contact with said excess of fuel, whereby to raise the temperature of the excess of fuel substantially and to vaporize a portion thereof, proportionate to the amount of gases delivered to said chamber and continually withdrawing the resulting mixture of fuel vapor and inert gases of complete combustion, the vaporization rate being varied with the rate at which the generated vapors are utilized, and vaporizing gases being produced by complete combustion of a predetermined percentage of the products of vaporization so withdrawn.

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