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METHOD OF BURNING FUEL

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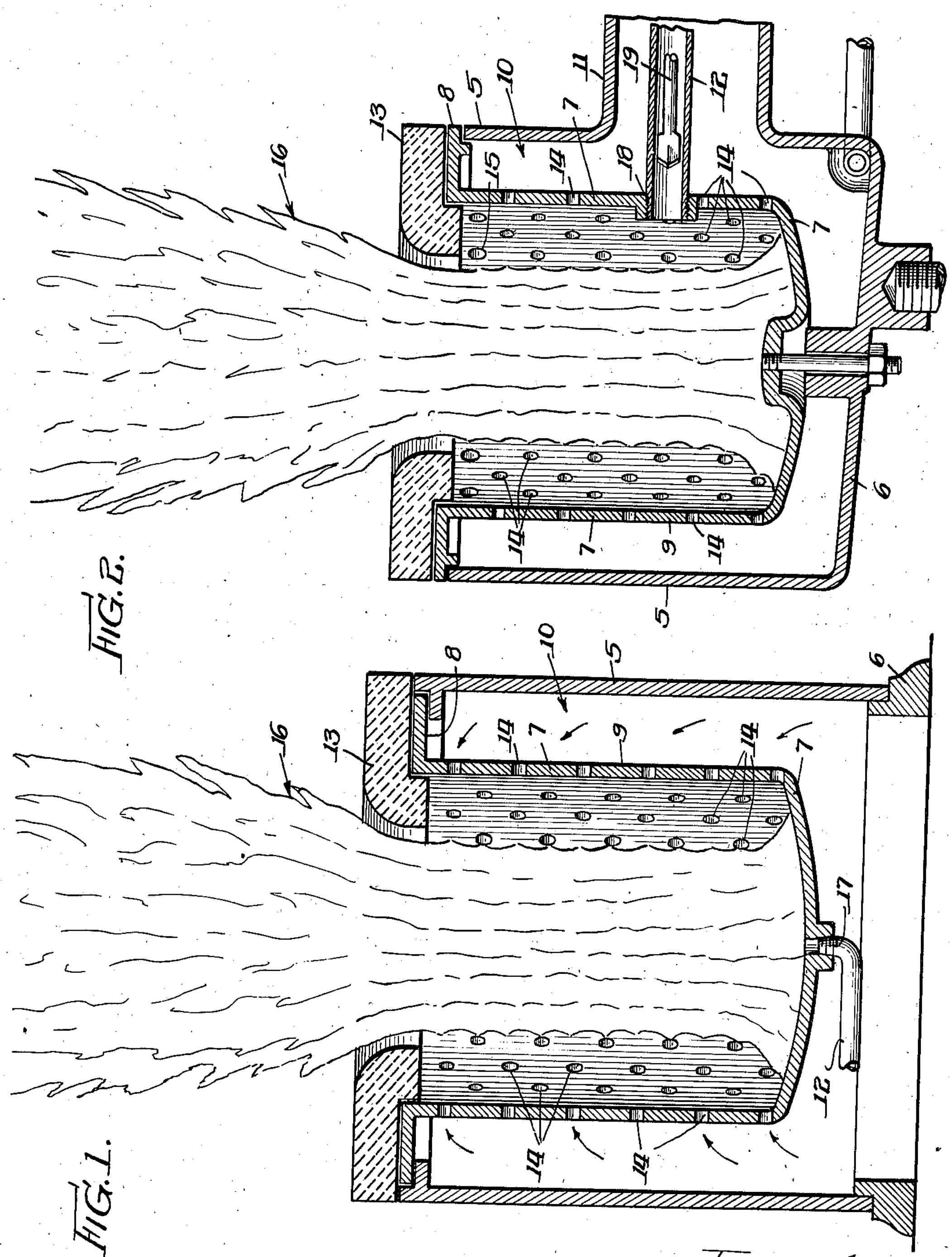

FIG. 2.

FIG. 1.

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METHOD OF BURNING FUEL

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This invention relates to processes of combustion and to processes or methods of burning fuel, particularly in the vaporizing type of oil burners and in perforated wall type burners.

The fuels used in burners of the type to which the invention refers are petroleum products which are commonly referred to as hydrocarbons. These hydrocarbons are found in a gaseous state, a liquid state, and a solid state. For example, if a crude oil is subjected to heat and distillation is effected, hydrocarbons known as methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), etc., are derived. These latter are all gaseous hydrocarbons and follow the formula C_nH_{2n} plus 2, and while these might conceivably be used in burners of the type embodying the invention, it is not commonly done and operation is usually with liquid hydrocarbons.

Liquid hydrocarbons generally start with pentane (C_5H_{12}), hexane (C_6H_{14}), heptane (C_7H_{16}), etc., according to the formula C_nH_{2n} plus 2 until the solid group is reached, such as paraffin ($C_{30}H_{62}$).

Combustion, or the burning of fuel oil, consists essentially in heating the liquid to a sufficiently high temperature and adding sufficient oxygen to break down the hydrocarbon into carbon dioxide and water with the consequent liberation of heat.

There are two distinct processes by which this can be done, and in either case, the hydrocarbon is subjected to a sufficiently high temperature and sufficient oxygen must be present. The two methods of burning a hydrocarbon, such as fuel oil ($C_{20}H_{42}$), are separate and distinct and produce different chemical reactions, although in either case complete combustion may be secured provided sufficiently high temperatures are employed and sufficient oxygen is present.

The first method, or the method commonly used in connection with pot type burners, is characterized by the absence of flame in the lower portion of the bowl. Here the fuel is admitted, vaporized at a relatively low temperature and mixed with air as it rises upwardly. The amount of air admitted and the temperature at which this mixture of air and gases is maintained, is insufficient to cause effective combustion. As this mixture nears the top or outlet of the pot, it is struck by a comparatively large amount of air, causing combustion or burning to take place. The type of pots or bowls used are provided with openings in the side wall. These openings are few and widely scattered, starting relatively high from the bottom of the pot. Near the top of the pot are larger holes and a comparatively larger number of them which admit a large amount of air at this point. In some instances, a slot or gap around the outlet is used to obtain the same effect. This commonly used method uses a limited oxygen supply, that is, insufficient oxygen is present to cause complete combustion when the vaporized fuel combines chemically with the oxygen present. Thereafter a large amount of oxygen is added, at which time complete combustion will occur. Before combustion occurs, the hydrocarbon, in combining with the oxygen present, undergoes three chemical changes. The first of these is known as the formation of alcohols and is represented by the formula:

$$2C_{20}H_{42} \text{ plus } O_2 = 2C_{20}H_{41}OH$$

As this product rises higher in the burner pot and more oxygen is added, a second chemical change occurs known as the formation of aldehydes, as is represented by the following formula:

$$2C_{20}H_{41}OH \text{ plus } O_2 = 2C_{19}H_{39}CHO \text{ plus } 2H_2O$$

Continuing this process, these aldehydes form acids in accordance with the following formula:

$$2C_{19}H_{39}CHO \text{ plus } O_2 = 2C_{19}H_{39}COOH$$

Upon addition of the final large air supply, these acids burn, or break down, to form carbon dioxide and water as follows:

$$2C_{19}H_{39}COOH \text{ plus } 59O_2 = 40CO_2 \text{ plus } 40H_2O$$

These changes represented show the formation of H_2O and CO_2 from $C_{20}H_{42}$ as the hydrocarbon passes through the alcohol, aldehyde and acid stages previous to burning.

The second known method of burning a hydrocarbon in a pot type burner consists in adding all the oxygen necessary for complete combustion at one time. This method causes rapid combustion, and great noises and extremely high temperatures occur in the pot. These high temperatures cause the pot to deteriorate rapidly, and due to the serious drawbacks of the method and the construction used in connection therewith, apparatus using this second method has practically disappeared from the market. The entire reaction of adding a large initial amount of air to the hydrocarbon to cause immediate combustion as is inherent in this second method can be shown by a single formula, inasmuch as the hydrocarbon starts burning immediately. This formula is as follows:

$$C_{20}H_{42} \text{ plus 61 oxygen atoms} = 20CO_2 \text{ plus } 21H_2O$$

This shows the formation of H_2O and CO_2 from $C_{20}H_{42}$ as the hydrocarbon passes directly through the process of burning.

The differences between the two methods, the construction of the burner equipment, and the type of flames produced are apparent even to the most uninitiated.

The present invention utilizes certain preferred elements and characteristics relating to the burner construction as set forth in the first method, but employs certain principles of the method of burning as related in the second method. In other words, the second method of burning fuel oil with certain modifications, is used in connection with certain preferred modifications of perforated wall pot-type of burner as set forth in the first method.

An important object of the present invention is to provide a burner which utilizes advantages of the methods and apparatus used in the two aforesaid methods, and which eliminates the disadvantages inherent to those methods.

Another object of the invention is to provide an oil burner of the pot type which is provided with openings in the wall thereof, said openings being of a sufficient size to permit entry of sufficient air to allow partial combustion of the fuel to occur at the bottom of the pot, the burner having additional openings in the wall to admit air sufficient to complete the process of combustion; and which is constructed and arranged so that the temperature in the bottom of the pot, during normal operation of the burner, is higher than the end point of any of the fuels used.

Another object of the invention is to provide a burner of practically noiseless operation and which, during operation, permits a flame to burn upwardly from the bottom of the pot.

A further object of the invention is to provide a process of burning relatively heavy fuel oils without the formation of excess residual carbon and coking, and which is not limited to the lighter fuels, such as kerosene, range oil and distillate as recommended in conventional methods.

Still another object of the invention is to provide a process for maintaining a normal operating temperature in the pot which is beyond that required to vaporize the heaviest hydrocarbon present, adding sufficient air so that combustion occurs immediately as the hydrocarbon is vaporized, and then adding additional air so that complete combustion of all the fractions of the hydrocarbons will occur at the rate at which fuel is being supplied to the combustion bowl.

The process consists generally in introducing hydrocarbon fuel into a vaporizing zone, maintaining said zone during normal operation at such a temperature that vaporization of lighter hydrocarbons and heavier hydrocarbons occurs simultaneously, mixing the hydrocarbons with a sufficient amount of atmospheric oxygen at the point of vaporization to maintain such a temperature, and supplying additional oxygen progressively to complete the process of burning whereby excess carbon and coke formations will be practically eliminated.

Numerous other objects and advantages will be apparent throughout the progress of the following specification.

The accompanying drawing illustrates a selected embodiment of the invention and the views therein are as follows:

Fig. 1 is a detail vertical sectional view through one form of burner embodying the invention.

Fig. 2 is a similar view of a similar type of burner including slight modifications in arrangement of the parts.

In the present construction a perforated wall type of pot is used. The openings start relatively close to the bottom and are of such size as to admit only sufficient air to cause active combustion to occur in the bottom of the pot, or, in other words, at the point of vaporization. Additional holes are provided along the side walls of the pot above the lower openings, and these additional holes are of such size and in such numbers as to add air progressively to the burning mixture so that sufficient air for complete combustion has been added when the top or upper row of holes is reached. The lower holes directly adjacent to the bottom of the pot are of greatest importance and the amount of air which they admit determines the temperature in the vaporizing area. The greater the amount of air admitted at this point, the more complete will be the combustion at the bottom of the pot and consequently the higher will be the temperatures at this point. If these holes are relatively large, the temperatures will rise higher than is necessary. Also if these holes are made excessively large the noise of combustion will become noticeable. It is, therefore, important that these holes be of proper size so that only sufficient air is allowed to enter to cause active combustion to start. Air is then added progressively through the remaining holes in the side walls of the pot as the burning mixture rises upwardly so as to complete the process of burning. Tests show that by varying the lower row of holes any desired temperature in the vaporizing area can be secured. For practical purposes it has been determined that approximately 1100° F. is ample to completely vaporize any of the fuels commonly used for domestic heating purposes and yet prevent disturbing noises from occurring.

Typical burner designs embodying the above principles, and which have been found very satisfactory in commercial use comprise a suitable outer casing or jacket 5 mounted on a suitable supporting base 6. A burner bowl or pot 7 having an exteriorly positioned annular flange 8 is supported by the outer surrounding side walls of the jacket 5. The surrounding walls 9 of the bowl or pot 7 are spaced a predetermined distance from the surrounding jacket or casing 5 to provide a space, or air passage 10, which may completely surround the bowl 7. Air is supplied to the passage 10 through the duct 11, and a fuel inlet 12 supplies the liquid hydrocarbon to the interior or combustion chamber of the bowl 7. A refractory ring 13, preferably made of ceramic material, is arranged above the burner and overhangs the bowl 7 at its upper end as clearly shown in the drawing. A plurality of relatively large holes 14 are made in the walls of the bowl 7, and these openings 14 may be larger and greater in number than the conventional arrangement now in use. The holes 14 may be carried down the side of the bowl to a point just above the bottom of the bowl. Air entering the lower holes or openings blows directly across the top of the liquid hydrocarbon and causes initiation of combustion to occur at that point. As the flame in the bowl rises, additional air is supplied progressively in sufficient quantity to complete the process of burning. In Fig. 2 the holes in the uppermost row are shown larger, as indicated at 15, whereby it is possible to shorten the height of the bowl.

The characteristic flame of a burner having the type of bowl in accordance with the present invention is long and narrow as indicated at 16. The flame starts from the bottom of the bowl and is spaced from the side walls thereof, passing up through the center opening to a maximum height of probably several times the depth of the bowl. The amount of oil capable of being burned in a given size bowl is several times as great as in conventional burners, depending of course, upon the temperatures in the vaporizing area during normal operation. For example, a standard 8-inch bowl of the conventional low temperature type of burner, such as is obtainable on the open market, is rated by the manufacturer as having a maximum burning capacity of one quart an hour; while an 8-inch burner of the type made in accordance with the present invention has a capacity of eight quarts of oil per hour. The average rate of vaporization in the conventional low temperature types of burners as set forth in the two known methods is approximately 1/60th of a quart per hour per square inch of vaporizing surface as compared to approximately 1/8th of a quart per hour in the present new high temperature type of burner.

The exact temperature at which the bottom of the fire bowl or pot should be maintained is important, and, of course, this temperature will depend on the fuel to be burned. In any event the temperature in the vaporizing area must be kept higher, during normal operation, than the end point of the fuel used because such temperature is essential if continuous operation is to be had without the formation of residue. Fuel oil #2, American Oil Burner Association specification, sets forth the minimum flash point as being 125° F.; the maximum flash point 190° F.; and the 10% point 440° F.; the 90% point 620° F., and the end point as 660° F. In order to completely burn this fuel, it is essential that temperature in excess of 660° F. be maintained in the vaporizing area during continued normal operation.

If the temperature in the vaporizing area is kept below 660° F., a portion of the fuel will remain unvaporized, and if operation is continued indefinitely under these conditions, unvaporized fuel will accumulate and as the heavier ends become heated in an insufficient amount of air for complete combustion, residual carbon or coke will be formed. In a similar manner if a burner is operated under forced conditions, that is, for long periods of time at a high percentage of its maximum burning capacity, the reflected heat of the flame causes the temperatures within the bowl to increase substantially. Vaporization would then occur at a rapid rate and without increase in the amount of oxygen being supplied to the lower portion of the bowl, leaving it without sufficient oxygen to cause burning. Under these latter conditions temperatures in the vaporizing area will become sufficient to break down the hydrocarbon, with the formation of coke.

Therefore, in order to have continuous normal operation without the accumulation of residual formations in the vaporizing area of the bowl, it is essential to have temperatures in this area in excess of the end point of the fuel being burned, so that the fuel will become completely vaporized, and sufficient oxygen must be present at the initiation of vaporization to cause active combustion to occur at the point of vaporization, and at any rate of vaporization within the capacity of the bowl. When such is the case and the flame rises in the bowl, further oxygen may be added by means of the additional openings in the side wall of the bowl to complete the process of burning. It is, therefore, a fundamental principle of the present invention that the temperature in the vaporizing area during normal operation be at all times higher than the end point of the fuel being burned with sufficient oxygen at the point of initiation of vaporization to cause immediate burning without the formation of the various gaseous compounds which are formed in the successive intermediate steps previously described in connection with the conventional process. In other words, this is a direct process of burning, whereas the conventional might be termed indirect. This relatively higher vaporizing temperature is determined by the holes 14 in the burner side walls, the location of the holes, and the number thereof. By increasing the size of the holes 14 and placing them closer together, as well as keeping them close to the bottom of the bowl, the vaporizing temperature can be increased. It is well known that any petroleum product or byproduct will completely burn if vaporized at a sufficiently high temperature and given enough oxygen, with the exception of the mineral deposits found present. Actual tests made with crude oil, hard carbon (or coke) formations, and tar, show these materials capable of burning completely, except for a few fine minerals which form mineral ash and which are usually so light that the air currents cause them to be blown away.

As previously set forth, the present invention is not limited to the lighter fuels, such as kerosene, range oil, and distillate, but includes the heavier fuels. If the principles of the present invention are adhered to, and a burner is designed for the particular fuel intended, in accordance with the present invention, the heavier fuel will become completely burned.

In certain tests it was found necessary to maintain vaporizing temperatures as high as 1600° F., but these very high temperatures cause rapid deterioration of the bowl and in some cases crack the walls of the bowls, therefore necessitating replacement. Also, if the size of the openings is too greatly increased, the noise of combustion would likewise greatly increase. However, for practical purposes it has been found that a vaporizing temperature of 1100° F. will burn #1, #2 or #3 oils of the American Oil Burner Association specification with entire satisfaction without in any way causing deterioration of the bowl or increasing the noise of combuston. Tests have proven that the life of the burner bowl is indefinite when the vaporizing temperature of the bowl is approximately 1100° F. This temperature is sufficiently beyond the end point of these fuels to give complete vaporization and yet prevent excess noise of combustion. Deterioration and shortening of the life of the bowl is prevented if this temperature is not exceeded.

A practical illustration, to further explain the invention, was made with a combustion bowl five (5) inches in diameter and six (6) inches deep. The lower row of openings, or the initial air supply, consisted of a band of holes .136 of an inch in diameter spaced on 3/8 inch centers and located 3/8 of an inch from the bottom of the pot. The remaining holes throughout the balance of the pot were .113 of an inch in diameter, starting one inch above the initial row and spaced on half-inch centers with each succeeding row one-half inch above.

The particular construction just described shows a normal operating temperature when operating at aproximately its maximum output of 1100° F. at various points in the vaporizing area, and that it is capable of successfully burning oil of extremely low gravity and high end point. The actual combustion occurs slowly and is extremely quiet. It is impossible to form carbon under any reasonable adjustment inasmuch as sufficient air is admitted in the lower row of holes to cause initiation of combustion at this point, avoiding the possibility of decomposing the fuel in an insufficient supply of oxygen with the resultant formation of carbon.

It is apparent that this construction can be altered and still cause combustion to occur as above described. For example, instead of the lower row of openings consisting of a row of holes of .136 inch in diameter, two rows of holes forming the same total opening might be employed and give practically identical results. Likewise, the remaining holes could be changed without necessarily changing the results.

Bowls of larger or smaller diameters, depending upon the amount of fuel to be burned per hour, may have the sizes of the holes, spacing and arrangement thereof proportioned accordingly.

Tests with a thermocouple placed at various points throughout the vaporizing area of a bowl of the size and construction referred to show temperature around 1100° F. with the exception of that portion directly around the point of oil entrance. At the point of oil entrance a cooling effect is encountered due to the relatively cold oil entering and due to the feed pipe fastening in the bowl tending to conduct heat away from the bowl. This relatively cool area cannot be maintained at temperatures beyond the end point of the fuel being burned. Therefore, some carbon is likely to accumulate at this point. If the fuel inlet to the burner is at the bottom floor of the bowl as indicated at 17 in Fig. 1, carbon will eventually cover over the opening and clog the fuel inlet. If the oil inlet to the bowl is placed in the side wall of the bowl below the lowermost row of holes 14, a slight improvement is obtained as the carbon must first build up over the entire opening before it will be completely clogged. The arrangement of a rod within the feed line to dislodge the carbon would be of some assistance, but eventually the carbon would form over the path of the rod and completely envelop it and therefore render it ineffective.

By bringing the oil feed line into the side walls of the bowl as indicated at 18 in Fig. 2, the carbon area is confined to a point directly over the oil inlet and immediately surrounding it, leaving the bottom of the bowl free and clear of any accumulation. By localizing this carbonizing effect, the carbon may be dislodged by means of a rod 19, Fig. 2, inserted in the feed line. The dislodged carbon formation, which will only occur directly over the end of the feed line, will drop to the bottom of the bowl where it will be struck by the incoming jets of air in the lowermost row of holes and be subjected to the heat of combustion causing it to be burned. By this arrangement the entire vaporizing area in the bottom of the bowl is maintained at a uniformly high temperature. The location of the feed line in the side wall of the bowl with the air openings completely surrounding it, causes the carbon formation to localize, leaving the vaporizing area free and clear.

The present invention provides for normal operating temperatures higher than the end point of the fuel supplied, and inasmuch as the fuel is vaporized as rapidly as it is being admitted, no residual fuel will remain in the bowl. Also, all fractions of the fuel will be distilled at the same time and this condition exists as long as fuel is being supplied in amounts within the vaporizing capacity of the particular bowl used. In other words, distillation of the lighter ends followed by the heavier ends is not occurring, but all fractions of the fuels are being volatilized at once. The present process, therefore, may be distinguished from others by the fact that all the fractions of the hydrocarbons are burned coincidentally.

By a temperature above the "end point" is meant to define such a temperature in the firepot and particularly in the zone where the oil is added as would cause the continuous vaporization of substantially all the fractions of the oil as they are added.

Many of the so-called fuel oils now being supplied are blends or mixtures of a relatively light volatile fuel and heavier fuel so as to produce a resultant fuel of the gravity desired. The mixing or blending of the various oils causes certain difficulties in the conventional types of burners because of the heavy hydrocarbons present. These mixtures or blends are, however, readily burned in an apparatus constructed in accordance with the present invention as proven by actual practice, because heavier hydrocarbons are burned simultaneously with the lighter hydrocarbons as soon as admitted to the burner bowl.

The present invention, therefore, eliminates many of the disadvantages inherent in the conventional modes and methods now used and causes complete volatilization of all the fractions of the fuel used.

Changes may be made in the herein disclosed process of combustion within certain limits without departing from the spirit of the invention or sacrificing any of the advantages thereof, and the right is hereby reserved to make all such changes as fairly fall within the scope of the following claims.

The invention is hereby claimed as follows:

1. The process of combustion which consists in introducing a liquid fuel into the combustion zone of a burner adjacent the bottom thereof, maintaining the bottom of the combustion zone at a temperature higher than the end point of the liquid fuel introduced during normal operation of the burner, supplying sufficient air at the bottom of the zone to cause the liquid fuel to burn at such rate at the bottom of the zone as to maintain said temperature thereof, and finally adding additional air progressively toward the top of the zone to allow complete combustion.

2. The process of combustion which consists in vaporizing liquid hydrocarbon fuel at a temperature higher than the end point of the hydrocarbon, mixing sufficient air at the point of vaporization with the hydrocarbon fuel vapor to cause initiation of combustion and to cause such temperature to be maintained, and admitting air progressively to the burning hydrocarbon fuel vapor after initiation of combustion to complete the combustion of the fuel vapor.

3. The method of burning a liquid hydrocarbon fuel which comprises introducing the liquid hydrocarbon fuel into the bottom of a combustion space and supplying air to the bottom of said space in amount sufficiently restricted to cause

a portion only of the hydrocarbon fuel to burn substantially at the bottom of the space, maintaining the temperature at the bottom of said combustion space at a point sufficiently above the end point of the hydrocarbon fuel to cause continuous vaporization of substantially all the fractions of the hydrocarbon fuel, and maintaining said temperature by the combustion of said fuel.

4. The process of combustion which consists in introducing a liquid hydrocarbon fuel into an upstanding combustion space of a burner at the bottom of said space, maintaining the bottom of said combustion space at a temperature higher than the end point of the hydrocarbon fuel whereby to vaporize all fractions of the fuel, supplying sufficient air only at the bottom of the space to cause the hydrocarbon fuel to burn substantially at the bottom of said space, the air being in a quantity restricted sufficiently to permit burning of only a portion of the fuel vapor.

5. The process of combustion which consists in vaporizing a liquid hydrocarbon fuel at a temperature sufficiently higher than the end point to cause substantially simultaneous vaporization of all of the fractions of the hydrocarbon fuel, mixing a restricted quantity of air sufficient to support combustion of only a portion of the fuel vapors therewith at the time of vaporization to permit immediate initiation of combustion, allowing the residual vapors to move away from the point of vaporization, and admitting additional air progressively to the burning hydrocarbon fuel vapor as it moves to complete combustion, and maintaining said temperature by combustion of the fuel.

6. The process of combustion which consists in introducing a liquid hydrocarbon fuel into one end of a combustion space, introducing into said space adjacent the place of fuel introduction sufficient air to vaporize said fuel at a temperature higher than its end point by combustion of a portion of the fuel vapor sufficient to cause said temperature to be maintained, and afterward introducing additional air progressively into said combustion space to complete combustion of the fuel vapor.

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