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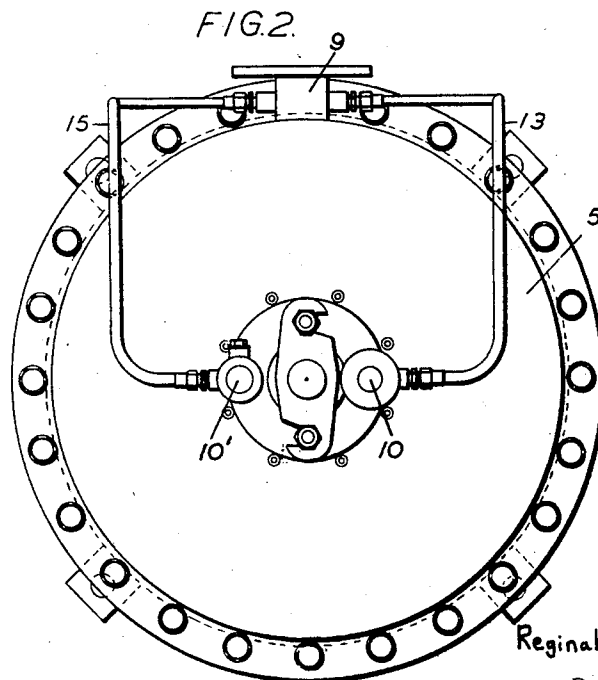
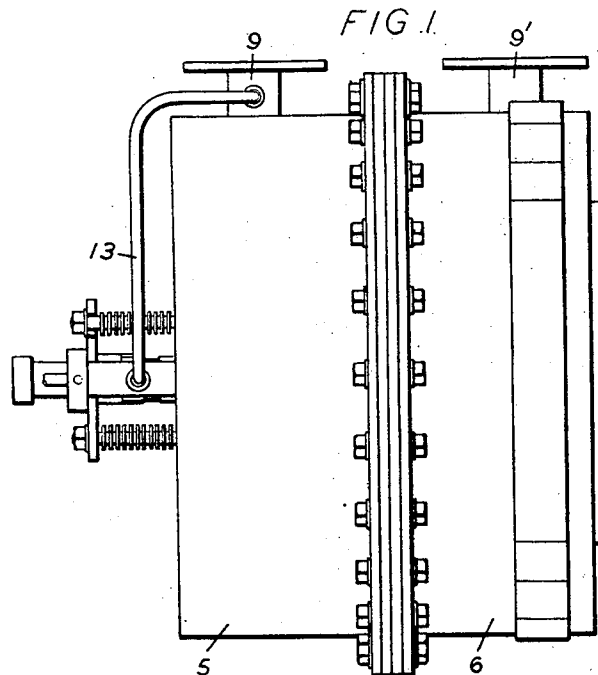
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2,923,348

FUEL COMBUSTION APPARATUS

Original Filed Oct. 11, 1951

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

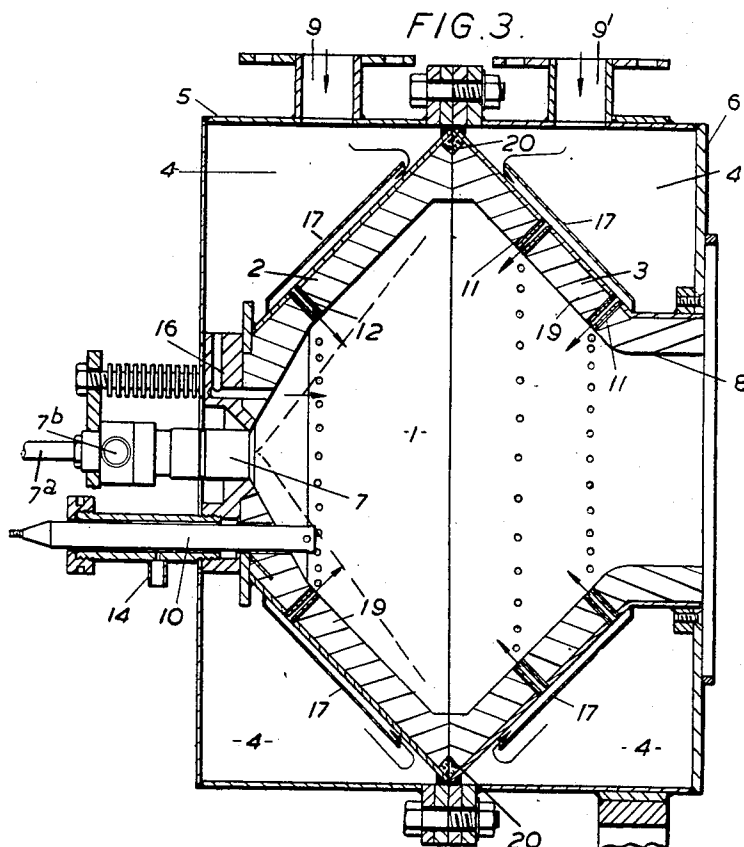
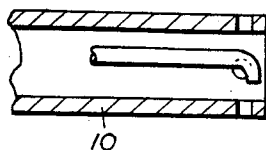


FIG. 4



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4 Sheets-Sheet 3

FIG. 5.

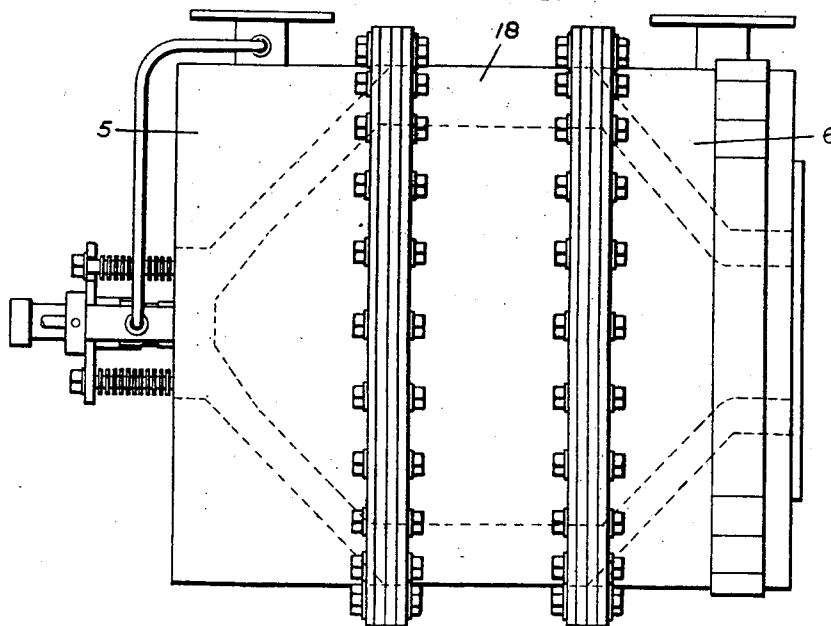
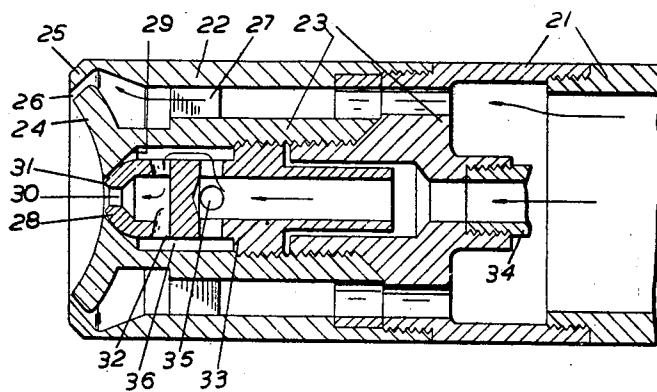


FIG. 6.



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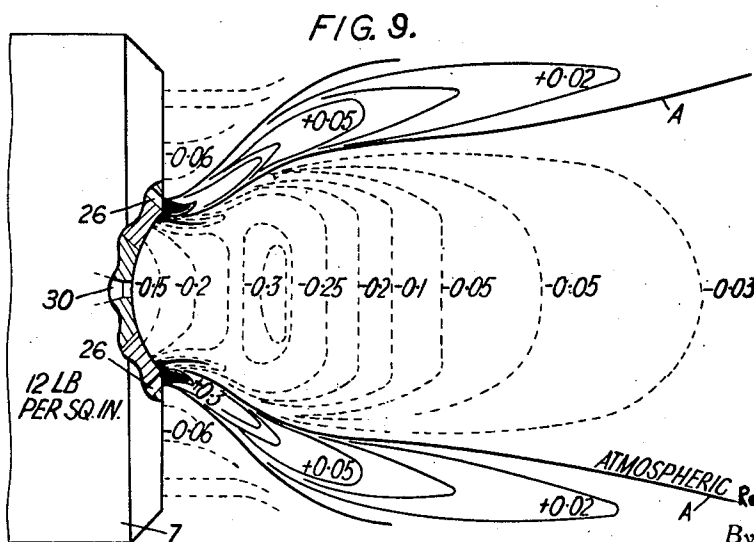
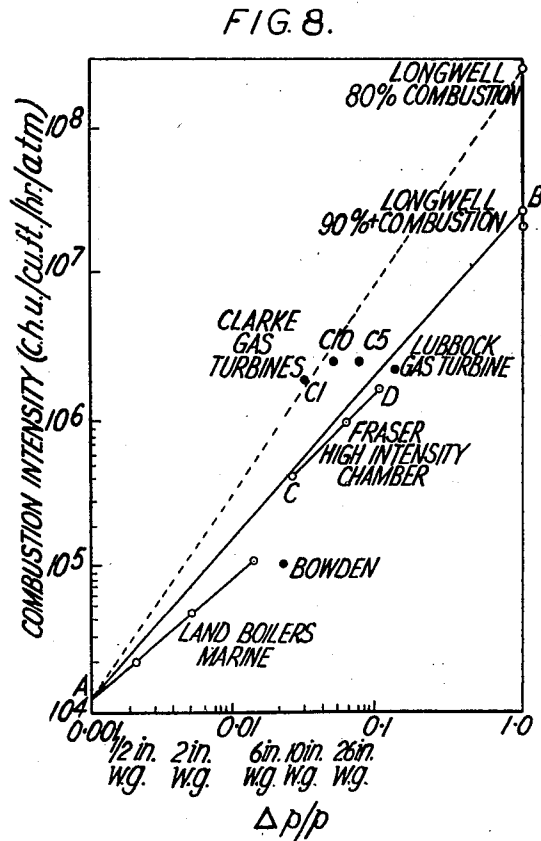
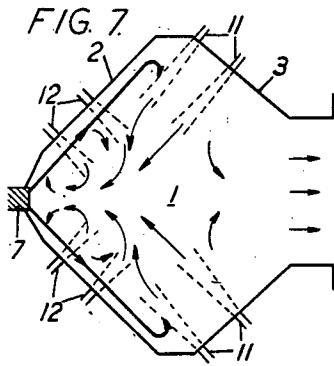
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2,923,348

FUEL COMBUSTION APPARATUS

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Continuation of application Serial No. 250,890, October 11, 1951. This application April 24, 1958, Serial No. 730,674

Claims priority, application Great Britain
October 17, 1950

3 Claims. (Cl. 158—4)

This invention relates to the production of hot gases for industrial use by the combustion of relatively heavy liquid fuel, and to fuel combustion apparatus for producing such hot gases. The invention has for its chief object the provision of improved apparatus for the efficient production of clean hot gaseous currents, such as the production of a clean stream of the gaseous products of combustion of residual fuel oils by the use of oil atomisers. Such hot streams of combustion products and air have various industrial uses, as for example the bulk drying of materials and the concentration of liquors.

This application is a continuation of my application Serial No. 250,890, filed October 11, 1951, now abandoned.

In apparatus for achieving the object of the present invention, the basic consideration is the completeness or perfection of combustion combined with a high rate of heat liberation per cubic foot of combustion space, and various factors are involved from the practical aspect, such as controllability of size in relation to known apparatus, and life of the combustion chamber.

The combustion chambers of industrial boilers using fuel oil work at a rate of heat liberation of about $.05 \times 10^6$ British thermal units per cubic foot per hour per atmosphere. Furnaces in drying equipment work at about $.1 \times 10^6$ B.t.u., and marine boilers under forced draught conditions work at up to about $.3 \times 10^6$ B.t.u., and all of them have to work with some excess air as otherwise carbon and smoke are produced. These rates might be classified as a low rate of combustion per cubic foot. On the other hand, gas turbine combustion chambers work with high amounts of excess air at relatively high rates i.e. between 3.0×10^6 and 9.0×10^6 British thermal units per cubic foot per hour per atmosphere. Rockets using oxygen or an oxidant develop still higher burning intensities.

A specific object of the present invention is the provision of a combustion chamber for industrial use capable of working at an intermediate rate of heat liberation ranging between about 0.5×10^6 to 3.0×10^6 British thermal units per cubic foot per hour per atmosphere, and yet using much less than the usual quantities of excess air or even using no excess or a slight deficiency of air.

The combustion of liquid fuels in furnaces and boiler combustion chambers employing normal diffusion flames is always carried out with some excess air.

The combustion conditions in a boiler using a fuel oil are defined by the CO_2 content and carbon content of the flue gases and the determination of the excess air employed.

A satisfactory excess air figure generally accepted for boiler operation is 45 percent, giving 11 percent CO_2 and about 13 grains of carbon per 1,000 cubic feet of exhaust gases (namely Shell Smoke Meter No. 5). The best operating practice is represented by 12.5 to 13 percent CO_2 ; that is to say 27 percent to 20 percent excess air and no more carbon than the above figure; namely no visible smoke.

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Just visible smoke is given by carbon in excess of 22 grains per 1,000 cubic feet.

In the apparatus of the present invention combustion of heavy residual fuel oils can be accomplished at the stoichiometric ratio of fuel to air giving 15.8 percent CO_2 with a carbon content in the exhaust gases under 3 grains per 1,000 cubic feet (Shell Smoke Meter No. 1). With distillate fuels the carbon content is nil. This contrasts with many jet engine combustion chambers using kerosene, where the percentage of unburnt matter is 1 or 2 percent, when operating with 40 percent excess air in the primary combustion zone.

It will, therefore, be understood that the combustion chamber of the present invention is not intended for jet propulsion for flight but has its main application as a stationary component of engineering and chemical engineering plant.

In industrial driers using the products of combustion to heat air, there is usually used relatively large combustion chambers with a low rate of heat liberation per cubic foot, giving a comparatively long life to the refractory of the combustion chamber. The secondary air passing through such combustion chambers is usually controlled by dampers on the combustion plant controlling the flow induced by the main fans on the drying equipment. To burn the heavier residual fuels successfully in such chambers it is essential to control the secondary air for combustion within reasonably close limits to obtain high flame temperatures. In industrial drying plants this is not easily accomplished by dampers because the air requirements of the combustion chamber are not independent of the main fans of the drier.

A further specific object of the present invention, therefore, is to provide a combustion chamber capable of successfully burning the heavier fuel oils for the production of clean combustion products with complete control over secondary combustion air, independent of the variations of flow or pressure of the dilution air required in commercial driers.

In apparatus where the products of combustion are blown directly into a liquor for the purpose of concentrating it, a positive pressure and higher rate of combustion is required in the combustion chamber. In such apparatus, known as submerged combustion chambers, the source of heat has usually been gas. In order to burn the heavier fuel oils for this purpose, it is essential that the combustion should occur at the above mentioned intermediate rate and be as immaculate as possible so that no fuel oil or fuel oil vapour passes into the liquor. A still further specific object of the invention is, therefore, to provide a medium high-intensity combustion chamber of small size to allow the heavier residue fuels to be used for the above purpose.

Because the industrial use of hot combustion products is very varied, it is desirable to construct the combustion chamber in such a manner that its component parts can be renewed in a simple manner from time to time; and because the heat output requirement is very varied, this combustion chamber should also be so arranged that the combustion space or volume of the chamber can be easily increased within limits by the addition of unit components without altering the form or manner of assembly of the essential mechanical parts and ancillaries.

For the efficient atomisation of the heavier liquid fuel oils and their efficient admixture with air, well designed oil atomisers and burners are necessary and many constructions of oil atomisers and burners therefor are known. By means of such atomisers, suitably mounted in a bulkhead or furnace end wall and supplied with air for combustion, a stream of hot products of combustion can be maintained having as its origin a flaming mass of fuel oil particles and air. Such so-called "diffusion"

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flames can differ as between a long pencil flame of small initial cone angle, say 12° to 30° , suitable for use in long narrow furnaces, and a flame of wide initial cone angle giving a substantially tulip-shaped flame. In such diffusion flames the surrounding air or atmosphere of the combustion chamber is entrained casually in an uncontrolled turbulent manner towards the axis of the flame. Nevertheless the process is quite rapid. As a result a fuel-rich region lies near the axis of the spray cone, and, regardless of the initial angle of spray, the flame is drawn out and lengthened.

In order to achieve the high intensity burning desired, therefore, it is necessary to provide oxygen in this fuel-rich region. If this were the only problem, there might well be a simple and obvious solution. However, there is the problem of supplying the fuel in such a dispersed condition that rapid burning can take place. With gaseous type fuels this is also a relatively simple problem, but with residual fuel oils the problem must be solved by the use of a specific type fuel atomiser. A third problem, and from a practical standpoint perhaps more important problem than the two problems just mentioned, is the problem of insuring a constant aerodynamic pattern to insure good flame stability over a relatively wide range of fuel throughputs. The present invention provides a solution to all of these problems.

According to the present invention, I provide a stationary fuel combustion apparatus comprising a liquid fuel atomiser in combination with a combustion chamber having a front wall and a coaxial rear wall, the said atomiser being mounted axially in the apex region of the front wall of said chamber and being capable of dispersing into said chamber finely divided liquid fuel in the form of a widely spread forwardly divergent cone of spray of at least 45° degrees and preferably 90° or 120° degrees or more initial cone-angle, the front wall of the chamber being correspondingly conical and correspondingly wide-spread, and the said rear wall being of corresponding conicity and size but disposed oppositely and having its apex region formed as an efflux duct, the peripheries of the said walls being secured together either directly or by a short cylindrical bridge member, at least one group of circularly disposed air inlets to the chamber being provided through the said rear wall for directing combustion air under pressure convergently towards the apex region of the cone of fuel spray. By this combination of features, highly efficient mixing of the fuel particles with the air takes place by turbulence that is not indiscriminate and uncontrolled but which on the contrary develops and maintains a constant aerodynamic pattern of circulation which remains steady notwithstanding metering of the fuel and air supplies incidental to change of load.

The invention will now be described more fully with reference to the accompanying drawings which illustrate two embodiments thereof. In these drawings—

Figure 1 is an external side view of one embodiment;

Figure 2 is an end view of the embodiment of Fig. 1;

Figure 3 is an enlarged axial sectional view of the embodiment of Fig. 1;

Figure 4 is a view of a detail of construction of an igniter used to start the furnace;

Figure 5 is an external side view of a further embodiment of the invention;

Figure 6 is a sectional view of a liquid fuel atomising burner suitable for use in the furnace;

Figure 7 is a diagrammatic representation of the aerodynamic pattern of the turbulence in the chamber of Fig. 3;

Figure 8 is a graph of the relation between the behaviour of a chamber according to the present invention and the behaviour of known combustion apparatus burning fuel oil, and

Figure 9 is a graph showing isobars of pressure in and around the conical fuel spray when issuing from a fuel atomiser of the kind shown in fig. 6. In this graph the isobar A of atmospheric pressure is shown in full lines;

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the dotted lines are isobars of subatmospheric pressure.

In its simplest although very practical form, the said combustion chamber of itself comprises two opposed right-angled cone walls connected together at their peripheries, the maximum diameter of the chamber therefore being substantially equal to or slightly greater than the distance between the orifice of the fuel atomiser mounted at the apex of the front wall and the centre of the exit in the opposite or rear wall.

Referring first to Figures 1, 2 and 3 which show the apparatus in its simplest form, it is seen that the fuel combustion apparatus comprises an inner chamber 1 constituted by the enclosure between two conical walls 2 and 3 each of which has about 90° degrees conicity, and an outer two-compartment chamber 4 constituted by the enclosure between the exterior of the two conical chamber walls 2 and 3 and the interior of two walls 5 and 6 which form a cylindrical outer shell or casing.

Fuel oil and air enter the chamber 1 with a divergent conical and preferably vortical motion by projection from a twin-fluid atomiser 7 mounted axially of the conical front wall 2 with its nozzle substantially at the apex of the wall. The edge of the front face of the atomiser 7 rests on a narrow seat on the front chamber wall so as to minimise transfer of heat from the chamber to the atomiser. Fuel oil under pressure enters the atomiser 7 through the pipe 7a and primary air under pressure enters through the pipe 7b. One embodiment of atomiser suitable for use with this invention will be described hereinafter. The air pressure conditions that prevail in and around the fuel spray from such an atomiser and which make it particularly suited to use in my combustion chamber are illustrated in Figure 9. It is of importance to notice the isobars of negative pressure in the axial region inside the cone of fuel spray and the consequent strong inducement for air to flow towards the atomiser into the axial region of the fuel spray.

The continuation or rear wall 3 of the chamber 1 has its periphery abutting the periphery of the front or entry wall 2 and has formed in its axial region an efflux duct 8 leading from the combustion chamber 1. The two peripheral edges of the two conical walls are secured together as shown.

Combustion or secondary air under pressure is supplied through inlet 9' to one of the two compartments of the outer chamber 4. The atomized oil and air spray from the two-fluid atomiser 7 is ignited by the electrical igniter 10 and the atomiser is designed and adjusted to produce a divergent conical spray following approximately the conical shape of the front wall 2 of the chamber.

The main stream of secondary air enters one compartment of the outer chamber 4 from the inlet 9' and then passes into the chamber 1 through two groups of circularly arranged air inlet passages 11 formed in the rear conical wall 3 and is therefore directed inwardly and rearwardly with respect to the forwardly directed conical fuel spray. The turbulence within the chamber 1 is thus of an orderly and controllable character and its aerodynamic flow pattern is illustrated by the arrows in Figure 7.

Since the combustion air from inlets 11 is mechanically directed toward the apex of the conical fuel spray, and since, due to the distributing character of the two-fluid atomiser used, the pressure near the apex of and within the cone of vortically whirling air and fuel spray is relatively low as hereinbefore explained with reference to Fig. 9, the combustion air directed through the inlets in the rear conical wall of the combustion chamber is strongly induced to flow towards the said apex, the stability of the aerodynamic flow pattern of the turbulence, and the stability of the ignition point of the atomised fuel and air mixture, is extremely high.

Another separately controlled part of the total air for combustion flows to at least one group of circularly disposed inlets through the front conical wall of the chamber. The air jets from these latter inlets impinge on the ex-

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ternal surface of the conical fuel spray and to some extent mix with it and to some extent penetrate it but are not such as to annul the oppositely directed jets. By this method of injecting the combustion air to cause internal circulation towards the fuel spray apex to cause intense fuel and air mixing and more than usually rapid combustion within the fuel spray cone, the fuel burns as a wide-angled compact turbulent flame within the chamber to a condition of completeness of combustion controllable exactly by the proportions of fuel and air.

This part of the secondary air may enter the chamber 1 as shown by way of the air inlet 9 and the other compartment of the outer chamber 4 and through the group of circularly disposed inlet passages 12 formed in the front or entry wall 2 of the chamber 1, so that the aerodynamic flow pattern of the controlled turbulence is that illustrated by the arrows in Figure 7.

A part of the air from inlet 9 passes through a branch pipe 13 (Figure 2) to an inlet connection 14 (Figure 3) on the housing of the igniter 10 so as to circulate around the igniter (before escaping into the chamber 1) thereby keeping the igniter body cool. The igniter is withdrawable into its housing so that its tip does not remain exposed to the direct heat of the chamber after ignition has been effected.

Another part of the air from the inlet 9 passes through a branch pipe 15 to circulate similarly around and through an inspection tube 10' mounted similarly to the igniter 10. A small controlled portion of the air entering the chamber 1 passes through passages 16 (Figure 3) and is thereby directed on to the rear surface of the atomised oil and air spray from the atomiser 7.

The air passing from the outer chamber 4 to the combustion chamber 1 by way of the inlet passages 11 and 12 is guided by inlet directing plates 17 forming pockets over said inlet passages.

For many purposes the combustion chamber 1 is advantageously of the form constituted by two conical walls connected face to face as shown in Figure 3. If the chamber is constructed with two opposed right circular cones, then the maximum diameter of the chamber is equal to its length. If a chamber of larger volume but of the same diameter is desired this may readily be obtained without materially impairing the aerodynamic pattern of turbulence by introducing a cylindrical component between the two conical walls as shown at 18 in Figure 5, provided that the length of the cylindrical component is not greater than the height of one of the cone walls. If the space enclosed by two opposed right circular cones is considered as unit volume then an increase of length of the chamber by 50 percent by the addition of a cylindrical portion between the cones, increases the volume 2.5 times. Thus considerable changes of combustion chamber volume are possible without any great change in the general form of the chamber or in the aerodynamic pattern of the turbulence within it and without any change whatever in the end cone units carrying respectively the atomiser and the efflux duct.

It will be understood that the temperature inside the combustion chamber 1 is high and that the combustion chamber wall may therefore be lined with refractory material 19 as shown, asbestos composition also being used as packing 20 at the junction of the wall components.

It will also be understood that heat passing through the walls of the combustion chamber 1 will preheat the secondary air in the compartments of the outer chamber 4. On the other hand the incoming cold secondary air in these compartments helps to keep down the temperature of the refractory walls of the combustion chamber.

The secondary air or gas supply passages 11 and 12 extending through the refractory lined walls of the combustion chamber may be constituted by refractory lined steel tubes or by refractory tubes, and such tubes, with or without nozzles, may be arranged in a circular row

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or in two or more such rows as shown, the tube axes intersecting on the longitudinal axis of the chamber or being set at a small inclination preferably such that the injected air streams augment any rotational component in the flame gases.

The liquid fuel atomiser employed may be of the simple pressure type, namely a single orifice swirl-spray pressure nozzle producing a conical sheet of liquid fuel which becomes a conical spray of fuel particles having the desired spray angle, or it may be and preferably is of the twin-fluid or blast type using air or steam as an atomising medium, in which case the said medium supplied under pressure to the interior of the atomiser assists in atomising and spreading the liquid fuel as a wide-angled cone of spray of admixed fuel particles and atomising medium. When using a twin-fluid atomiser with air as the atomising medium the atomising air also serves as combustion air and may be termed primary air and may comprise up to 10 percent of the total combustion air required; but at least 40 percent of the total air required for combustion is supplied through the rear conical wall of the chamber. One form of preferred twin-fluid atomiser capable of producing a high degree of vortical motion in the fuel spray and relatively low pressure conditions near the fuel cone apex inside the cone serving to further aid the axial circulation towards the apex of the fuel cone spray is hereinafter described.

The oil atomiser, as shown in Figure 6, comprises a tubular outer body or shell 21 with terminal cap 22, and an inner hollow body member 23 having an externally dish-shaped head piece 24 co-operating at its periphery with an internally conical lip 25 on the forward end of the cap 22 to form a gap 26 of predetermined size so that air or steam supplied to the shell at its rear end will emerge as a conically converging stream from the said gap 26. Inclined vanes 27 on the cylindrical wall of the hollow body member 23 serve to impart a swirling motion to the stream of air or steam before it reaches the said gap.

Inside the front end of the hollow body member 23 is fitted a liquid spray forming member 28. The spray forming member 28 is externally hemispherical at its forward end to seat against a conical formation 29 behind the dish-shaped head piece 24. The said spray member is hollow with an exit orifice 30 in register with a central opening 31 in the head piece 24, and said spray member is formed with tangentially cut inlet slots 32 in its skirt portion which is seated on a tubular stem or plug 33, so that liquid fuel entering the interior of the said body portion will be whirled before escaping from the orifice 30. Liquid fuel reaches the inlet slots 32 of the spray forming member 28 from a supply pipe 34 connected axially to the base of the hollow body member. From the pipe 34 the liquid fuel passes into the interior of the body members 23 and along the interior of the aforesaid stem 33 at the rear of the spray member 28 and out through radial holes 35 into the annular space 36 existing between the forward end of the hollow body member 23 and the spray member 28 and thence to the said inlet slots 32. It will therefore be understood that the liquid fuel emerges from the exit orifice 30 and opening 31, while whirling air or steam emerges convergently from the annular gap 26.

Assuming that the atomiser 7 is supplied with fuel oil at a pressure of from 1-100 pounds per square inch and with primary air for atomising purposes at a pressure of 3-20 pounds per square inch (these pressures depending on the design of atomiser used), the secondary combustion air introduced through the tubes or nozzles in the wall of the combustion chamber 1 may be supplied at a pressure of say one to five pounds per square inch (above atmospheric pressure), in which case a steady stream of combustion products and air can be arranged to flow through the chamber outlet or efflux duct 8 at a pressure of about say 0.1 to 2.0 pounds per square inch.

(above atmospheric pressure). Effective turbulence in the chamber 1 can be obtained with a pressure drop across the tubes 11 and 12 varying from 0.4 to 5 pounds per square inch, as for example with a pressure drop from 0.5 to 0.1 pound per square inch, or from 5 pounds to 3.5 pounds, or from 10 pounds to 8 pounds, or from 20 pounds to 19 pounds, or from 50 pounds to 45 pounds.

Generally speaking the combustion air or a substantial proportion of the combustion air employed in carrying out the present invention has a flow component contra to the forwardly divergent cone of fuel spray so that it is projected to the region inside the said cone of spray. This high proportion of air within the spray cone causes the combustion to take place within the said cone, and not only externally on a narrow cone as in the usual diffusion flame.

As will be readily understood a hot gaseous stream of such a character has many industrial uses. When applied to apparatus for drying materials, the hot products issuing from the apparatus will be passed into a duct and mixed with further air to reduce the temperature. It is usual in such drying apparatus to employ suction fans to draw the hot air over or through the product, and an important feature and advantage of the apparatus above described is that it is substantially insensitive or indifferent to fluctuations of gaseous pressure that may occur beyond its delivery outlet due to varying conditions of industrial use of the stream at a point remote from the apparatus. Therefore, notwithstanding such varying conditions and varying requirements of industrial use of the delivered stream, the supplier of the apparatus can meet any supply requirements solely or mainly by consideration merely of the performance of his own apparatus. That is to say the quantity of secondary combustion air flowing through the combustion chamber can be arranged so that it is independent of changes of suction due to the fan on the dryer.

A further feature and advantage of the apparatus is that it is capable of burning efficiently furnace oils of high viscosity and that the products of combustion are clean. It has been found that with the apparatus according to the invention the heaviest fuel oils (3,000 secs. Redwood No. 1 at 100° F.) can be burned under conditions of complete control with either excess air or at theoretical proportions, or with a slight deficiency of air without the formation of carbon or smoke. Further, because of the particular aerodynamic flow pattern created in the chamber as shown in Figure 7, the stabilization of any particular degree of combustion is so good that the operator can make extremely rapid or instantaneous changes from combustion occurring with above the stoichiometric quantity of air to combustion occurring with slightly less than the stoichiometric quantity of air. As will be readily understood, the apparatus is extremely simple in construction and is composed of only a few readily assembled components and is easily convertible in capacity by addition of a simple component of construction.

A further surprising and unexpected feature of the apparatus is that it may be started instantaneously at full load when the combustion chamber is cold.

In illustration of the surprising results obtainable by the present invention it may be stated that the heat release rates using fuel oil in an ordinary domestic sectional boiler and in a combustion chamber according to the present invention are 0.04×10^6 British thermal units per cubic foot per atmosphere and 1.0 to 3.0×10^6 respectively (see transactions of the Institution of Chemical Engineers, London, vol. 35, No. 3, 1957 (page 224); also Proceedings of the Joint Conference on Combustion of the Institution of Mechanical Engineers (London), and The American Society of Mechanical Engineers Discussion in London on "Industrial Furnaces" (pages 220-221)). It is to be noted, therefore, that the heat release rate in a combustion chamber according to the

present invention is surprisingly high, namely, from 25 to 75 times as high as in an ordinary domestic boiler.

It is believed that these results can be attributed to the manner in which the apparatus solves the particular problems involved in the high intensity burning of heavy residual fuels. The supplying of air to the fuel-rich region in the centre of the spray cone is carried out by injecting a large portion of the secondary air into the centre of the spray cone in a direction contra to the spray cone. When additional secondary air is also injected through the front wall of the combustion chamber, this results in secondary air being applied to both sides of the spray cone, thus promoting an extremely high mixing and burning rate. The specific type of atomiser is also important, for it aids in solving two of the important problems. First it produces an extremely small particle size having an extremely short burning time. This promotes high intensity of burning and a resulting high rate of heat liberation. Perhaps more important, however, the atomiser produces a whirling conical spray at a constant spray angle at all fuel throughputs. The high rotary component of velocity producing the whirling keeps the spray cone stable and at the same time produces the lower pressure inside the vortex of whirling spray which aids the flow of secondary air into the spray cone as already described with reference to Figure 9. This stable spray cone together with the shape of the chamber which corresponds to the shape of the spray cone produces the stable aerodynamic pattern essential to the stability of the flame.

With this stability, high intensity combustion can be maintained by volumetric metering of the flow of fuel and air at various fuel throughputs.

Combustion apparatus as above described enables the combustion of liquid fuel to take place under such surprisingly good control that a stream of clean hot gases substantially free from carbon particles or smoke and consisting of carbon dioxide and nitrogen, but substantially no oxygen or only a limited and known constant quantity, can be maintained. Combustion using substantially the stoichiometric quantity of combustion air is in fact achieved which approximates theoretical perfection. Such hot clean gases can be put to a variety of industrial uses. Even when operating with a heavy fuel and with a fuel to air ratio somewhat richer than stoichiometric, hot gases containing no smoke can still be produced.

A graphic comparison between the performance of the combustion apparatus of the present invention and that of other combustion chambers is illustrated in Fig. 8 where the line AB is what is known in the art as "a best practice envelope," this being a line drawn between the rates of burning of different apparatus compared with the secondary air pressure drop used in them. The highest point B of the line AB is represented by the so-called "ideal combustion reactor" having near ideal mixing of vaporised octane, and the point A being the lowest or ordinary type of combustion equipment utilizing a low pressure difference. Apparatus of good design should lie as close to the line of the ideal envelope AB as possible, and the opposed cone chamber of the present invention is indicated on this figure by the line CD. This line CD is seen to be close and nearly parallel to the line AB.

From the extremely practical viewpoint of costs and suitability of the apparatus in its installation, the cost of running the auxiliary equipment necessary to give the fuel and air the necessary momentum is higher than with conventional low intensity equipment, but the capital cost of the apparatus is much less due to the small amount of material used in the combustion device itself. Moreover, because of the relatively small size, the apparatus may be more conveniently installed in a greater variety of locations, and its over-all cost is even further reduced because of the small plant space it occupies,

The overall apparatus is extremely cool in operation, being able to run with an outer shell temperature as low as 40° C., thus reducing the ventilating problems in the area surrounding the apparatus as well as increasing its over-all efficiency. From the standpoint of noise, an ever increasing industrial problem, when the apparatus is used at modest pressure drops of from 1 to 5 pounds, it is so quiet in its operation that in many cases it is necessary to provide visual means to indicate that the flame is lit.

I claim:

1. A stationary combustion apparatus for burning liquid fuel to produce a stream of hot clean gases at a rate of heat liberation ranging from 0.5×10^6 to 3.0×10^6 British thermal units per cubic foot per hour per atmosphere, said apparatus comprising a liquid fuel atomiser in combination with a combustion chamber having a front wall and a coaxial rear wall, the said atomiser being mounted axially in the apex region of the front wall of said chamber and being capable of dispersing into said chamber finely divided liquid fuel in the form of a widely spread forwardly divergent whirling cone of spray of at least 90 degrees cone angle, the front wall of the chamber being correspondingly conical and correspondingly wide-spread, and the said rear wall being of corresponding conicity and size but disposed oppositely and having its apex region formed as an efflux duct, the peripheries of the said walls being secured directly to one another, at least one group of circularly disposed air inlets to said chamber being provided through the said rear wall for directing combustion air under pressure convergently towards the relatively low pressure apex region of the cone of fuel spray, whereby a steady aerodynamic pattern of turbulence and mixing is maintained within the chamber, said apparatus also having at least one group of circularly disposed air inlets through said front wall for directing separately controlled combustion air under pressure to impinge on the external surface of the fuel cone spray, and a casing around said conical walls and spaced therefrom and forming an outer chamber around each conical wall of the combustion chamber for the supply of separate and separately controllable combustion air to the inlets through the said walls, whereby the combustion air is preheated within said outer chambers, and the conical walls of the combustion chamber are correspondingly cooled.

2. A stationary combustion apparatus for burning liquid fuel to produce a stream of hot clean gases at a rate of heat liberation ranging from 0.5×10^6 to 3.0×10^6 British thermal units per cubic foot per hour

per atmosphere, said apparatus comprising a liquid fuel atomiser in combination with a combustion chamber having a front wall and a coaxial rear wall, the said atomiser being mounted axially in the apex region of the front wall of said chamber and being capable of dispersing into said chamber finely divided liquid fuel in the form of a widely spread forwardly divergent whirling cone of spray of at least 45 degrees cone angle, the front wall of the chamber being correspondingly conical and correspondingly wide-spread, and the said rear wall being of corresponding conicity and size but disposed oppositely and having its apex region formed as an efflux duct, the peripheries of the said walls being secured directly to one another, at least one group of circularly disposed air inlets to said chamber being provided through the said rear wall for directing combustion air under pressure convergently towards the relatively low pressure apex region of the cone of fuel spray, whereby a steady aerodynamic pattern of turbulence and mixing is maintained within the chamber, said apparatus also having at least one group of circularly disposed air inlets through said front wall for directing separately controlled combustion air under pressure to impinge on the external surface of the fuel cone spray, and a casing around said conical walls and spaced therefrom and forming an outer chamber around each conical wall of the combustion chamber for the supply of separate and separately controllable combustion air to the inlets through the said walls, whereby the combustion air is preheated within said outer chambers, and the conical walls of the combustion chamber are correspondingly cooled.

3. Stationary combustion apparatus as claimed in claim 2 and a cylindrical bridge member of length not more than the height of one conical wall of the said chamber connecting the peripheries of the opposed front and rear cone walls of the combustion chamber.

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