Sept. 27, 1966 J. E. McCULLOUGH 3,275,059

NOZZLE SYSTEM AND FUEL OIL BURNER INCORPORATING IT

Filed May 10, 1965 2 Sheets-Sheet 1

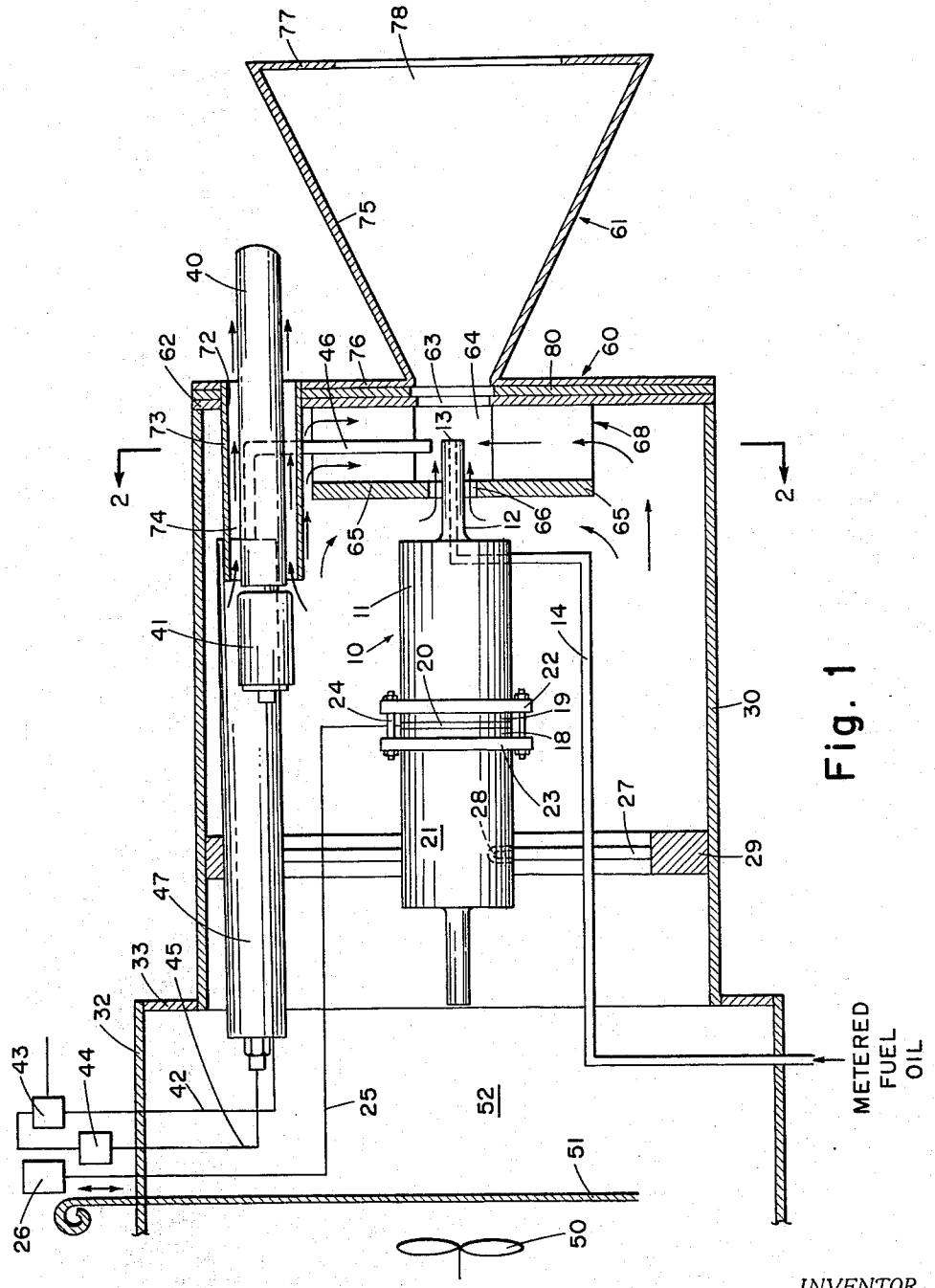


Fig. 1

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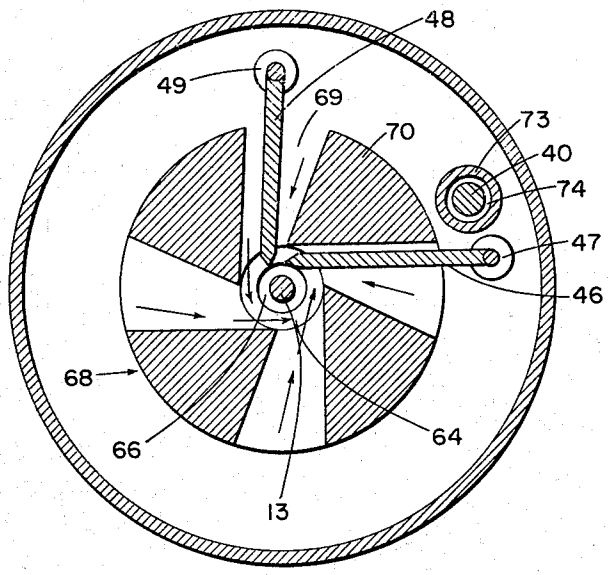


Fig. 2

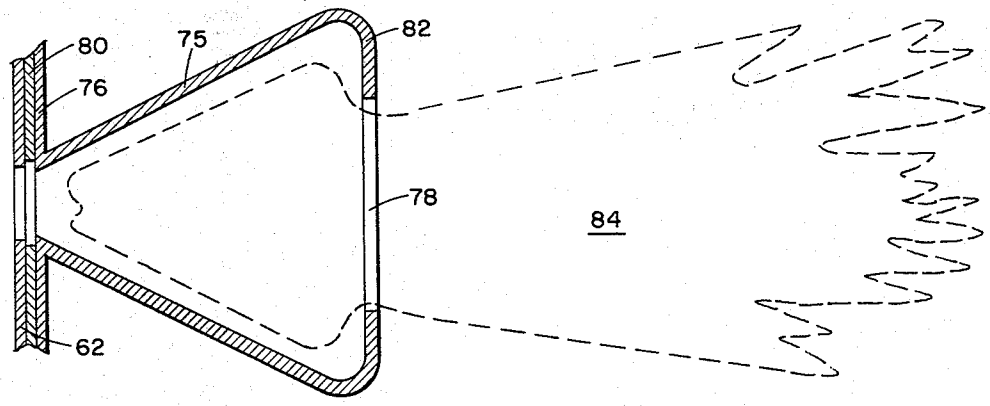


Fig. 3

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NOZZLE SYSTEM AND FUEL OIL BURNER INCORPORATING IT

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13 Claims. (Cl. 158—28)

This invention relates to nozzle systems and more particularly to nozzle systems suitable for use with ultrasonic atomizers in fuel oil burners or with atomizers which deliver to a combustion zone low-energy spray particles of relatively wide size distribution.

Recent developmental work in liquid fuel oil burners has been directed to the use of ultrasonic atomizers to replace the more conventional high-pressure spray nozzle burners. The ultrasonic atomizers have among other advantages the ability to operate on very low fuel feed rates, e.g. less than one-half gallon per hour. Thus the use of ultrasonic atomizers offers the possibility of making low firing rate oil burners for such uses as space heaters and home water heaters. Extensive experiments with these ultrasonic atomizers has shown, however, that the oil spray produced differs from that produced by a high-pressure spray nozzle in that the droplets lack significant kinetic energy. Instead of the droplets leaving the nozzle in a well-defined cone-shaped pattern, they tend to drift off the transducer horn tip and immediately descend under the influence of gravity. This action produces an asymmetric mist cloud which must be mixed with highly turbulent air before clean combustion can be attained in the small volume. Moreover, the ultrasonic atomizers tend to produce droplets having a relatively larger size distribution than a high-pressure spray nozzle for example. It would therefore be desirable to have a nozzle system which in its design and operation would be capable of burning large oil droplets and at the same time be capable of achieving thorough clean combustion even in a very small volume.

In addition to the ultrasonic atomizers used as an example in the description of the nozzle system which follows, there are also under consideration low-pressure spray nozzles which deliver low-energy, relatively large and widely sized liquid oil particles to the combustion zone. The nozzle system of this invention is applicable for use with this type of nozzle or any nozzle which delivers fuel oil droplets of the characteristics noted.

It is therefore a primary object of this invention to provide a nozzle system adapted for use with an atomizer which delivers relatively low-energy fuel oil particles for combustion with a combustion fluid, e.g. air. It is another primary object of this invention to provide a nozzle system to augment the performance of the ultrasonic atomizers so that clean combustion is achieved. It is another object of this invention to provide a nozzle system of the character described which makes it possible to achieve efficient and clean burning of fuel oil atomized by an ultrasonic device even though the power into the ultrasonic atomizer is not optimum. An additional object is to provide a nozzle system suitable for use with low-pressure spray nozzles. It is another object of this invention to provide such a nozzle system which is suitable for use in a burner designed to operate on very low feed rates, e.g., of the order of one-half to one gallon per hour or less. It is another object of this invention to provide an improved fuel oil burner incorporating an ultrasonic atomizer suitable for such applications as space heaters and home water heaters. Other objects of the invention will in part be obvious and will in part be apparent hereinafter.

As noted above, the nozzle system is suitable for use with atomizers delivering relatively low-energy particles for burning. For convenience in describing the nozzle system of this invention it will be discussed and illustrated in detail with reference to its use use with an ultrasonic atomizer. It is, however, to be understood that other atomizers may be used in place of the ultrasonic atomizer shown.

The invention accordingly comprises the features of construction, combination of elements and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawings in which.

FIG. 1 is a longitudinal cross-section of the nozzle system of this invention showing its relationship to an ultrasonic atomizer;

FIG. 2 is a cross-section of the nozzle system of FIG. 1 taken along line 2—2 of FIG. 1; and

FIG. 3 is a cross-section of a portion of the forward end of the nozzle system showing another corner configuration.

A number of ultrasonic atomizers, along with their attendant fuel supply and mounting means have been developed. Among these may be cited the atomizer disclosed in U.S.P. 3,162,386 and U.S. application Serial No. 356,323, filed in the name of Robert R. Perron and assigned to the same assignee as the present invention. Typically these ultrasonic atomizers comprise a transducer, which includes a stepped horn and an electromechanical means for driving it, and a power supply means which incorporate some type of feedback means to insure that the transducer is driven at its resonant frequency. In addition, means are provided to introduce the fuel oil which is to be atomized at the atomizing surface, i.e., the small diameter surface of a stepped horn, to clamp the transducer with an opposing mass stub and to mount the transducer. The ultrasonic atomizer is not a part of the present invention and is therefore illustrated in a typical form in the drawings. It is of course to be understood that any ultrasonic device capable of atomizing fuel oil at an atomizing surface, or other atomizer delivering low-energy particles, may be used in conjunction with the nozzle system of this invention.

FIG. 1 illustrates the nozzle system of this invention in a fuel oil burner using an ultrasonic atomizer. The ultrasonic atomizer illustrated in FIG. 1 is that which is disclosed in the above-identified application Serial No. 356,323. The atomizer, generally indicated by the numeral **10**, comprises a stepped horn formed of a large diameter section **11** and a small diameter section **12** joined through a fillet. The free surface **13** of the small diameter section **12** is the atomizing surface and fuel oil is delivered to it by means of a suitable fuel line **14**. The fuel oil feed line extends internally of the large diameter section **11** and runs centrally through the small diameter section **12** opening out into surface **13** as shown by the dotted lines. The transducer horn is driven by a pair of piezoelectric crystals **18** and **19** having an electrode **20** positioned therebetween. An opposing mass stub **21**, in the transducer of FIG. 1 having acoustic characteristics similar to those of the driving horn, is clamped to the driving horn by means of flanges **22** and **23**, which are integral parts of the driving horn and the opposed mass stub, and bolts **24**. Power to the electrode is brought in through suitable lead wires, here illustrated as **25**, from a power-feed back circuit shown diagrammatically at **26**. Means must be provided to mount the entire transducer

10 within the burner and this is done through the use of a supporting system comprising three pins 27 free to move radially within drilled holes 28 in the opposed mass stub. The pins in turn are mounted in a support ring 29 which in turn are affixed to the internal wall of the forward burner housing 30.

The main burner housing is comprised, in addition to the forward housing 30 of an after housing section 32 joined to the forward section 30 by means of shoulder 33. The forward housing 30 which is associated with the nozzle system is closed by the nozzle block as described subsequently.

The remaining portion of the burner, other than the nozzle system which is to be described, comprises a light pipe 40 which extends into the housing and is associated with a photocell 41. This light pipe is designed to concentrate radiation from the combustion zone to actuate the photocell which in turn is connected through suitable lead wires 42 to an electrode control mechanism shown diagrammatically at 43. This in turn is connected to an electrode power supply 44 which supplies, through lead wires 45, the necessary power to the electrode 46 which over a portion of its length is suitably insulated in a ceramic insulator 47. As will be seen in FIG. 2 a second electrode 48 contained within an insulator 49 is also provided to form with electrode 46 the required ignition spark. It is preferable to position these electrodes so that they do not fall in the plane of the atomizing surface 13. When the electrode tips are positioned slightly behind the atomizing surface 13, fuel oil droplets cannot collect on the electrodes and carbonize thereon to foul them. To complete the burner there are provided means for introducing air into the housing such as the blower shown diagrammatically as fan 50. Associated with the housing are also means for controlling the amount of air introduced into the interior 52 of the housing. One such means is illustrated as a blast gate 51. As described below the light pipe, the photocell, or other optical pickup, and the electrodes are so positioned as to be protected from heat.

The nozzle block of this invention is designated generally by the numeral 60 and its associated combustion cone by the numeral 61. Although the nozzle block is preferably from one piece of metal, it can be thought to consist of a forward plate 62 which serves as the forward end plate of housing section 30. Within this forward plate 62 is a central opening 63 which communicates with a central channel 64 drilled in the nozzle block. An afterplate 65 having a central opening 66 defines the upstream end of the nozzle block. The stepped horn of the atomizer is positioned within the fuel oil burner so that the small diameter section 12 extends through central opening 66 into the central channel 64 of the nozzle block. The small diameter section 12 of the stepped horn in this portion defines with the back plate 65 of the nozzle block an annular channel through which air is directed as indicated by the arrows.

The nozzle block can be considered to have a central section designated by the number 68. As will be seen in FIG. 2 this central section has a series of air passage 69 drilled in it in a manner to provide for the tangential introduction of combustion air into the central channel 64. The remaining portion of the central block is made up of solid sections 70. Finally as illustrated in FIG. 1 the forward plate 62 has an opening 72 in which is mounted a protective sleeve 73 extending internally of the housing. The sleeve 73 serves as a means for supporting and protecting the light pipe 40. Between the internal wall of the sleeve 73 and the surface of light pipe 40 is an annular passage 74 through which air flows as indicated by the arrows. Thus the light pipe is air-cooled and continuously cleaned by air passing over it. It will also be seen that in this arrangement the light responsive means, typically a cadmium sulfide photocell, associated with the light pipe is protected from heat which would deteriorate it without suffering the reduced light intensity which would be experienced if the light responsive means were positioned at the end of an open sight tube.

The combustion cone 61 is seen to be formed of a conical section 75 which terminates at the burner end in a flange 76 and in a lip portion 77 at the other end. The combustion zone established within the combustion cone extends beyond the cone through a large forward opening 78. The flange 76 of the combustion cone is mounted to the external wall of the end plate 62 through an appropriately shaped, heat-resistant gasket 80. It is preferable, as illustrated in FIG. 1, to extend the cone flange 76 and the gasket 80 to cover the entire front face of the nozzle system to provide an efficient heat shield or barrier. This thermally insulates the nozzle system, as well as the remaining portion of the atomizer, from the heat of the combustion zone.

FIG. 3 is a cross-section of the forward end of the burner showing a modification in the configuration of the combustion cone. It will be seen in this modification that the conical section 75 terminates in a rounded shoulder 82. FIG. 3 also illustrates the approximate configuration and extent of the combustion zone 84. It will be seen to begin slightly forward of the plane of the flange 76 within the combustion cone and to extend external of this cone and downstream therefrom.

The nozzle block is preferably made from cast iron while the combustion cone must be of a metal which is capable of withstanding the thermal stresses set up within it by virtue of its configuration and the temperature gradients existing in the cone. As an example one suitable material for the combustion cone is Hastelloy X having a thickness of 0.040 inch.

It will be seen from FIGS. 1 and 2 that there are in fact in the nozzle system of this invention two distinct fluid flow paths, one which is axial, the other tangential. The result of this combination of flow paths is to produce a vortex around the transducer atomizing surface tip. This means that the atomizing surface 13 as well as a portion of the small diameter section 12 of the horn is surrounded by swirling air resulting from the axially introduced air mixing with the tangentially directed air. This combination of flow paths is important since the free vortex around the horn tip causes strong recirculation currents downstream of the tip thus promoting rapid, clean combustion. Then the tangentially directed air picks up the fuel oil droplets, which because of their lack of kinetic energy would normally drop downwardly, and maintains them in the combustion air. The combustion cone in turn confines the vortex so that its energy cannot be dissipated before vaporization is complete. It is, of course, the function of the combustion cone to insure clean combustion and maintain the droplets suspended in the air until they are essentially completely vaporized and at least partially burned.

Each of the two air passages has associated with it a cross-sectional area; and the sizing of these air passages is important since the smaller the total cross-sectional flow area, the greater the pressure required. Not only is it desirable to be able to adjust flow area and pressure, but it is also desirable to maintain the pressure requirement at a relatively low level to make possible the use of inexpensive blower systems. However, excessive nozzle areas, with attendant low pressures, lead to poor combustion efficiency because of low air velocity and low turbulence. It is therefore preferable that nozzle pressures be maintained between 0.50 and 0.75 inch of water column.

Another parameter of the nozzle system of this invention is the ratio of tangential nozzle area (i.e., the total cross-sectional area of the tangential passages 69 of FIG. 2) to the cross-sectional area of the axial passage (the annular channel defined between the end plate 65 and the smaller diameter section 12 of the stepped horn). If the axial flow is very large compared to the tangential flow,

the flame will tend to blow off. If on the other hand the tangential flow is excessively large compared to the axial flow, the high swirl velocity created by the air entering tangentially through passages **69** will "centrifuge" the oil droplets from the air and cause them to impinge on the internal walls of the combustion cone **75**, and then to collect in the cone.

Generally the ratio of cross-sectional area of the tangential passages to the cross-sectional area of the axial passage will range between about 2.5 and 3.5. As an example, a burner designed to consume about one-half gallon of fuel oil per hour has been found to have an optimum ratio at 3.3; while for a burner designed to consume about one-quarter gallon per hour the ratio is preferably 2.8. Under these circumstances the minimum acceptable nozzle pressure for the first consumption rate is about 0.7 inch water column; while for the lower consumption rate the minimum nozzle pressure is about 0.5 inch water column.

It will of course be understood that for each burner design and fuel oil consumption rate the ratio of the cross-sectional area of the two types of air passages will vary and can be readily determined experimentally. This is also true in determining an optimum nozzle pressure. In general, the cross-sectional areas of the tangential passages and of the axial passage must be balanced to maintain a stable flame within the combustion zone and to support the fuel droplets until burned within the combustion zone without causing any appreciable quantity to impinge on the wall of the combustion cone.

In the operation of the fuel oil burner illustrated in FIG. 1 as an example, metered fuel oil is provided at the atomizing surface **13** which is oscillated at an ultrasonic frequency by means of the transducer which includes the two crystals and the electrode with its attendant power and feedback circuit generally indicated at **26**. In operation a solenoid control switch attached to a thermostat, in accordance with known practice, actuates the power feed to the electrodes **46** and **48** when ignition is desired. Subsequent to the ignition of the fuel oil and air the power to the electrodes is cut off by virtue of the actuation of the control mechanism **43** which receives a signal from photocell **41** which in turn is actuated by light transmitted thereto through light pipe **40**. The light pipe **40** is so positioned that it is able to "see" reflected light from the combustion zone. With the establishment of a stable combustion zone ignition is no longer required.

Air entering the interior **52** of the burner housing is swept along past the transducer mechanism keeping it cool, and enters the combustion zone through the two paths described. The combustion air by the time it reaches the actual combustion zone has swept over the transducer, or other atomizing means, and the electrodes. In doing so it has maintained these elements at a relatively cool and constant temperature. In addition the location of the electrodes within the tangential air passages **69** permits a continuous flow of air over the length of the electrodes and thus provides for their continuous cleaning. This in turn reduces maintenance of the electrodes and of their attendant mechanisms to a minimum and insures reliable performance at all times.

The flow of air and fuel oil droplets entrained therein is such as to establish a combustion zone essentially as shown in FIG. 3. Radiation from this combustion zone tends to heat the combustion air and partially vaporize the fuel prior to its entrance into the combustion zone. Vaporization is completed within the combustion zone.

Extensive experimental experience with the system has shown that a burner using an ultrasonic atomizer with the nozzle system of this invention is practical, even for small, low flow rate fuel oil burners. Combustion efficiency is high as evidenced by flue gas analyses which showed 12 to 13% CO_2 at 0–1 smoke. Finally, no measurable quantity of unburned fuel oil has been collected in the combustion cone, illustrating the effectiveness of the nozzle system in maintaining the fuel oil droplets in the combustion air until vaporization and combustion is accomplished.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

I claim:

1. A burner adapted to burn atomized fuel oil in the form of low-velocity particles in a continuously supplied stream of an oxygen-containing combustion fluid, comprising in combination

(a) delivery means for providing at an atomizing surface low-velocity fuel oil droplets which lack significant kinetic energy;

(b) means forming a central passage in which said delivery means is located;

(c) means for axially directing a first portion of an oxygen-containing combustion fluid around said delivery means into said central passage;

(d) means for tangentially directing a second portion of said combustion fluid into said central passage for mixing with said first portion to form a fluid vortex around said fuel oil particles at the point of their delivery, said vortex being capable of suspending said fuel oil particles; and

(e) imperforate cone means, having an inwardly extending lipped edge at its larger discharge end, in fluid communication with said central passage and defining a portion of a combustion zone whereby the fuel oil is substantially all vaporized and partially burned prior to its discharge from said cone means.

2. A burner in accordance with claim **1** wherein said means for tangentially directing said second portion of combustion fluid into said central passage comprises multiple tangential fluid passages into said central passage.

3. A burner in accordance with claim **1** further characterized by having ignition electrodes extending through said means for tangentially directing said second portion of said fluid, the tips of said electrodes being positioned just upstream from the plane of said atomizing surface located in said central passage whereby said electrodes are continuously cooled and maintained essentially free from the accumulation of fuel oil thereon.

4. A burner in accordance with claim **1** wherein said means for providing said fuel oil droplets comprises a low-pressure spray nozzle.

5. A burner in accordance with claim **1** wherein said means for providing said fuel oil droplets comprises an ultrasonic atomizer, the atomizing surface of which extends into said atomizing zone.

6. A burner adapted to burn atomized fuel oil in the form of low-velocity particles in a continuously supplied stream of air, comprising in combination

(a) means for atomizing said fuel oil to provide it in the form of low-velocity particles;

(b) housing means surrounding said atomizing means;

(c) means for delivering combustion air under pressure into said housing means;

(d) a nozzle system adapted to mix the atomized fuel oil and air and to define at least a portion of a combustion zone wherein substantially all of the atomized fuel is vaporized and partially burned, said nozzle system comprising in combination

(1) a nozzle block which defines the forward end of said housing,

(2) means forming a central zone within said nozzle block into which said fuel particles are delivered,

(3) means for axially directing a first portion of said combustion air around said atomizing means said central zone,

(4) means forming tangential passages within said nozzle block and adapted to tangentially direct a second portion of said combustion air into said central zone whereby said first and second portions of said combustion air mix to form a vortex capable of suspending said fuel oil particles,

(5) imperforate cone means, having an inwardly extending lipped edge at its larger discharge end, in fluid communication with said central zone and defining a portion of a combustion zone whereby the fuel oil is substantially all vaporized and partially burned prior to its discharge from said cone means; and

(e) electrode ignition means extending into said central zone through said tangential passages and positioned just upstream from the point of delivery of said atomized fuel.

7. A burner in accordance with claim **6** wherein said atomizing means is an ultrasonic atomizer, the atomizing surface of which extends into said central zone.

8. A burner in accordance with claim **7** further characterized in that said means for axially directing said combustion air into said central zone comprises an annular passage surrounding the portion of said ultrasonic atomizer extending into said central zone.

9. A burner in accordance with claim **6** further characterized by having

(a) light pipe means, formed of a light transmitting heat-resistant material, located to absorb and transmit radiation from said combustion zone and positioned within a sleeve extending into said housing whereby a small portion of said combustion air in passing through said sleeve cools said light pipe means; and

(b) light responsive means associated with said light pipe means and adapted to effect control of said electrode ignition means by responding to radiation from said combustion zone transmitted by said light pipe.

10. Burner in accordance with claim **6** further characterized in that said cone means is affixed to said forward end of said housing through a flange coextensive with said forward end.

11. A burner in accordance with claim **6** further characterized by having an insulating gasket disposed between said flange and said forward end of said housing.

12. A burner in accordance with claim **6** wherein said cone means terminates at its downstream end in a rounded configuration.

13. A burner in accordance with claim **6** wherein the ratio of the cross-sectional area of said tangential air passages to the cross-sectional area of said axial passage ranges between about 2.5 and 3.5, said cross-sectional areas being taken normal to the axis of said atomizing means and at the entrance to said central zone.

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JAMES W. WESTHAVER, *Primary Examiner.*

Dedication

3,275,059.—*John E. McCullough*, Carlisle, Mass. NOZZLE SYSTEM AND FUEL OIL BURNER INCORPORATING IT. Patent dated Sept. 27, 1966. Dedication filed Oct. 20, 1969, by the assignee, *American Petroleum Institute.*

Hereby dedicates to the Public the entire remaining term of said patent. [*Official Gazette January 20, 1970.*]