MULTINOZZLE SYSTEM FOR VORTEX BURNERS

ABSTRACT: A nozzle to be positioned around a fuel atomizer between a rotary air chamber and a coaxial combustion chamber. The nozzle consists of a 45° conical frustum surrounding the atomizer but spaced therefrom, and at least one frustoconical baffle with the same cone angle, located between the outer frustum and the atomizer. Thus are defined two concentric, converging annular passageways through which rotating air passes from the air chamber into the combustion chamber around the atomizer.
FIG. 6.
DISTRIBUTION OF TANGENTIAL VELOCITY COMPONENTS ALONG THE RADIUS

FIG. 7.
DISTRIBUTION OF AXIAL VELOCITY COMPONENTS ALONG THE RADIUS.
MULTINOZZLE SYSTEM FOR VORTEX BURNERS

This invention relates generally to oil burners, and has to do particularly with an oil burner assembly in which combustion air first enters an air chamber, wherein the air is rotated, and then passes through a nozzle around a fuel atomizer into a combustion chamber. This invention specifically concerns the construction of the nozzle through which combustion air passes from the air chamber into the combustion chamber.

As will be explained in greater detail below with reference to the drawings, conventional oil burner assemblies of the same general kind have a tendency to develop "backflow" type deposits of carbon on the fuel atomizer, primarily due to the reverse flow characteristics in the region of the central axis of the combustion chamber.

Accordingly, it is one object of the present invention to provide an oil burner assembly in which backflow-type deposits of carbon on the fuel atomizer are substantially eliminated.

Although it is of advantage to eliminate the carbon deposits on the fuel atomizer, it is not desirable to reduce the recirculation characteristics of the gases in the combustion chamber, which is a contributing factor to the carbon buildup. Furthermore, it is of advantage to atomize the fuel to as fine a particle size as possible for good combustion characteristics, but unfortunately, fine particle size is also a contributing factor to the carbon buildup on the fuel atomizer.

Accordingly, it is a further object of this invention to provide an oil burner assembly in which carbon deposits on the fuel atomizer are substantially eliminated, without sacrificing either the fineness of particle size or the recirculating characteristics of the combustion gases in the combustion chamber.

Essentially, the above objects are accomplished by this invention through the provision of a multiple-nozzle assembly in which concentric cones, converging in the downstream direction, define at least two parallel converging passageways for the whirling air in the air chamber to pass around the fuel atomizer into the combustion chamber.

More specifically, this invention provides, in an oil burner assembly, a nozzle for positioning around a fuel atomizer between an air chamber and a combustion chamber, said nozzle comprising: means defining around the fuel atomizer an annular passage through which air passes from the air chamber to the combustion chamber, said means including adjacent the combustion chamber a frustoconical portion whose apex is downstream of its base, and a frustoconical baffle supported between the fuel atomizer and said frustoconical portion, thereby to define two substantially concentric annular air passageways each converging toward the combustion chamber, one of said passageways being outwardly adjacent said baffle, the other of said passageways being inwardly adjacent said baffle.

Two embodiments of this invention are shown in the accompanying drawings, in which like numerals denote like parts throughout the several views, and in which:

FIG. 1 is an axial sectional view of a prior art oil burner assembly of the general kind to which this invention relates;

FIG. 2 is a sectional view taken at the line 2--2 in FIG. 1;

FIG. 3 is a broken-away axial sectional view, to a larger scale than FIG. 1, of the fuel atomizer and nozzle portion of the assembly of FIG. 1;

FIG. 4 is an axial sectional view of a nozzle assembly constructed in accordance with the first embodiment of this invention;

FIG. 5 is an axial sectional view of a nozzle assembly and combustion chamber constructed in accordance with the second embodiment of this invention;

FIG. 6 is a graph showing tangential air velocity distribution along the radius at the downstream end of the prior art nozzle and the nozzles of the first and second embodiment of this invention; and

FIG. 7 is a graph showing the axial air velocity distribution along the radius at the downstream end of the same three nozzles as FIG. 6.

For the efficient combustion of oil fuels, a high rate of evaporation is desirable. This rate can be substantially increased by the recirculation of hot combustion gases from the exit section of the combustion chamber to the vicinity of the burner discharge. Many conventional oil burners are designed to promote such recirculation, and an example of a conventional recirculating burner of the vortex type is shown in FIGS. 1, 2 and 3.

PRIOR ART

The prior art recirculating vortex burner shown in FIGS. 1, 2 and 3 is seen to include a vortex air chamber 10, a tangential inlet 12, a combustion chamber 14 defined by cylindrical walls 15 and an end wall 16, and a frustoconical discharge nozzle 18 in the end wall 16. An elongated fuel atomizer 20 is provided to extend concentrically through the vortex air chamber 10, and terminate in the vicinity of the discharge nozzle 18.

As combustion air enters the vortex air chamber 10 through the tangential inlet 12, a swirling motion is imparted to it in the direction indicated by the arrow 21 in FIG. 2. After passing through the discharge nozzle 18 into the combustion chamber 14, the combustion air is mixed with atomized fuel particles from the atomizer 20 and is ignited, resulting in a vortex of hot combustion gases swirling in the combustion chamber 14.

In the vortex created in the combustion chamber 14, the pressure is higher on the periphery than it is in the center, and provided that the components of the burner are correctly proportioned, a reverse current is set up along the core or axis of the combustion chamber 14, thereby providing the desired recirculation of hot combustion gases.

The most critical section of the design is the exit plane of the discharge nozzle 18. Here, the bulk of the fuel is still in liquid state, and if the reverse current is allowed to penetrate within the nozzle 18 or air chamber 10, some of the carbon components of the fuel are deposited on exposed surfaces, particularly the atomizer 20. The stronger the recirculating current, and the finer the particle size, the greater is the tendency to form backflow-type deposits. This is so because larger particles tend to maintain their original direction, while a fine particle is easily entrained even in a weak backflow current. Although both high recirculation and fine particle size are desirable for good combustion, these backflow-type deposits cannot be tolerated, and therefore in the conventional device some sort of undesirable compromise is unavoidable.

PARTICULAR DESCRIPTION OF THE INVENTION

Essentially, this invention arises from the observation that, if a vortex of air is discharged into the combustion chamber through a plurality of essentially concentric nozzles, then separate vortices will be formed in each annulus, causing the pressure and velocity distribution in the discharge plane to become more uniform. It has furthermore been found that if a cylindrical collar is attached to the inlet side of these nozzles, it will strengthen the effect. Discharged into a common chamber, the vortices merge again into a single vortex.

The most important characteristic of this system, however, is that the penetration of the reverse flow to and beyond the discharge plane of the nozzle can be prevented, and thus the possibility of forming backflow-type deposits can be eliminated. At the same time, a significant reverse flow can be generated in the combustion chamber, and thus a very high proportion of combustion gases can still be recirculated.

FIG. 4 shows the first embodiment of this invention, in which the end wall 23 of a combustion chamber similar to that shown in FIG. 1 communicates with a nozzle 24 having a frustoconical portion 25 opening through the wall 23. The frustoconical portion 23 is similar in all important respects to the nozzle 18 shown in FIG. 1. An elongated fuel atomizer 26 is aligned concentrically with the nozzle 24, and supported between the fuel atomizer 26 and the frustoconical portion 25.
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is a frustoconical baffle 28, which defines two substantially concentric annular air passageways 29 and 30, each converging toward the combustion chamber located to the right of the end wall 23. Passageway 29 is outwardly adjacent the baffle 28, while passageway 30 is inwardly adjacent the baffle 28. The numeral 31 refers to the wall of the air chamber from which air enters the nozzle 24.

In the embodiment shown in FIG. 4, both the frustoconical portion 25 and the frustoconical baffle 28 converge in the downstream direction, and have cone angles of substantially 45°. While it is considered essential that the baffle 28 and portion 25 both converge in the downstream direction, their conical shape and their cone angle of 45° are not considered essential. The latter characteristics are preferred, however, for reasons of manufacturing simplicity and because tests made on the embodiment shown in FIG. 4 have conclusively shown air velocity characteristics superior to those obtained with the conventional nozzle. Nonetheless, it is entirely possible that different cone angles or even different and possibly curved axial profiles would prove to be no less advantageous, and possibly more so, than the embodiment shown in FIG. 4.

The second embodiment of the invention is shown in FIG. 5, to which attention is now directed. A fuel atomizer 32 is located concentrically with a vortex air chamber 33 of which only the right-hand portion has been shown. A combustion chamber 34 is provided and is coaxial with the vortex air chamber 33. The combustion chamber 35 includes a cylindrical sidewall 38, and an end wall 40. A nozzle 42 is provided between the vortex air chamber 33 and the combustion chamber 35, and is adapted to pass combustion air from the former to the latter. As in the first embodiment, the nozzle 42 includes a portion 43 which is frustoconical in shape, and which is in fact merely a frustoconical opening through the end wall 40 of the combustion chamber 35. The preferred cone angle for the frustoconical portion 43 is 45°, but again neither the conicalness nor the cone angle of 45° is considered essential to to this invention. Two frustoconical baffles 45a and 45b are disposed between the frustoconical portion 43 and the fuel atomizer 32, and the frustoconical baffles 45a and 45b have coaxial cylindrical projections 48a and 48b extending upstream from their bases. The frustoconical baffles 45a and 45b together with their cylindrical projections 48a and 48b define three substantially concentric annular air passageways 49, 50 and 51, the air passageway 49 being between the baffles 45a and 45b, the air passageway 50 being outwardly adjacent the baffle 45a, and the air passageway 51 being inwardly adjacent the baffle 45b. In addition to the cylindrical projections 48a and 48b, the frustoconical baffles 45a and 45b have frustoconical projections 52a and 52b extending forwardly from the frustoconical baffles 45a and 45b into the combustion chamber 35. The frustoconical projections 52a and 52b have a slightly smaller cone angle than the frustoconical baffles 45a and 45b.

The dotted lines with arrowheads in FIG. 5 represent the approximate axial airflow pattern for the combustion air passing through the nozzle 42, and for the combustion gases in the combustion chamber 35. Tangential motion is present, but is not represented in FIG. 5. It will be noted that essentially two toroidal vortices are created in the combustion chamber 35, these being indicated by the letters A and B. The toroidal vortex denoted B is rather elongated in the axial direction and thus, strictly speaking, there is no central hoop or loop about which the toroidal vortex rotates. Hence, the location of the letter B has no positional significance. The solid arrows around the letters A and B within the combustion chamber 35 indicate the general direction of rotation of the two toroidal vortices. It will be noted that the toroidal vortices rotate in opposite directions. In FIG. 5, it will be noted that the dotted arrow path 54 and the dotted arrow path 56 both cause a recirculation of the hot combustion gases back to the vicinity of fuel atomization.

Test Results

The effect of the two embodiments of this invention on the flow of combustion air through the nozzle, as compared to a conventional nozzle, was determined through a series of cold tests. By “cold tests” is meant that no firing or combustion took place. The results of these tests are shown in FIGS. 6 and 7.

Three different assemblies were tested:

a. Assembly 1 was a conventional single-nozzle arrangement, schematically shown at the upper left of FIG. 6, and labeled as prior art.

b. Assembly 2 was the first embodiment of this invention, and was constructed from assembly 1 by adding to the latter a frustoconical baffle. Assembly 2 is schematically shown below assembly 1 in FIG. 6.

c. Assembly 3 represents the second embodiment of this invention, and assembly 3 was constructed from assembly 2 by adding a cylindrical collar to the frustoconical baffle of assembly 2. Assembly 3 is schematically drawn beneath assembly 2 in FIG. 6.

Both the nozzle and the baffle were frustoconical in shape, with a cone angle of 45°. A Pitot tube was used to measure the velocity and the direction of the airflow in the discharge plane and from this data the axial and tangential velocity components were subsequently calculated. To determine the effect of the addition and the combination of baffles and cylindrical projection on the friction losses, all tests were run with the identical blower setting, and the delivery of the blower was held constant.

FIG. 6 shows the tangential velocity distribution in the discharge plane of the nozzle, which is the same as the plane containing the downstream end of the nozzle. As indicated at the upper left in FIG. 6, the values for the prior art assembly, without a baffle, are plotted as a short-dash broken line, the values for the first embodiment of this invention are plotted as a long-dash broken line, and the values for the second embodiment of this invention are plotted as a continuous line. The same types of lines are used in FIG. 7.

Directing attention first to FIG. 7, the plot of the axial velocity components for the three assemblies reveals that:

1. With the prior art assembly (assembly 1) there is an annulus of high velocity air around the periphery. The velocity, however, drops rapidly toward the center where a core of reverse flow with significant dimensions and velocities exists. Thus, it is seen that a core with a radius of approximately 1 inch is moving in the reverse or upstream direction in the plane defining the downstream end of the nozzle of the prior art assembly. It is this reverse flow core which entrains the fine atomized fuel particles and deposits them on surfaces upstream of the plane considered here.

2. The axial velocity distribution pattern for the first embodiment of this invention is different from that for the prior art in that the velocity drop in the vicinity of the baffle discharge is markedly reduced, and the domain of reverse flow is distinctly smaller and less intense.

3. With the second embodiment of this invention, a more pronounced change is noticeable. There is a prominent second velocity peak in the vicinity of the discharge from the baffle, and there is no reverse flow in the discharge plane.

Integration of the axial velocity components for the discharge area yields the same value for all three assemblies, indicating identical flow rates. This face was confirmed by the independent flow measurement at the blower discharge.

Turning now to FIG. 6, the plots of tangential velocity components for the three assemblies indicate that the swirl is markedly higher with assembly than with assembly 1. Since all tests were run with identical blower setting, it follows that the friction of the additional baffle and collar was more than compensated for by the more uniform airflow density across the nozzle face.
The test data illustrated in FIGS. 6 and 7 indicate that the nozzle assembly of this invention can accomplish the following three desirable results:

1. Backflow-type deposits can be substantially reduced with the first embodiment of this invention and virtually eliminated with the second, owing to the reduction or elimination of reverse flow at the discharge plane.

2. Better combustion is attained at any given load (i.e. airflow rate), since the tangential velocities are higher and thus the shear between the swirling air mass and the fuel particles is greater. The rate of recirculation is also higher, and this arises as a result of the higher tangential velocities. Since these results are obtained with no increase in blower work, it follows that the assembly is more efficient.

3. Higher turndown ratios can be obtained, since at low loads the tangential velocity of the conventional nozzle is not adequate to sustain an acceptable combustion, that of the present multiple-nozzle assembly is still sufficient.

The data presented above corresponds to approximately 50% burner load, because with the available instrumentation, this range gave the most consistent readings. Other tests have indicated that the advantages are appreciably higher at full load, and slightly less significant at idling.

Further tests have indicated that the uniformity of the axial velocity distribution improves with an increase in the number of concentric baffles in the nozzle assembly, provided increased frictional forces are ignored. Naturally, the addition of more concentric baffles will reach a point where the improvement in combustion characteristics becomes only marginally significant if it is noticeable at all, and where the increase in air pressure losses with additional baffles is undesirable. With significantly large units, however, it is considered that the number of useful baffles that can be included in the assembly will be higher than with small units.

For testing purposes, two different vortex burners were developed with multicone assemblies in accordance with this invention. The atomizers utilized in these burners incorporated the invention which is the subject of U.S. Pat. application Ser. No. 650,342, entitled "Two-Stage Sonic Atomizing Device", filed June 30, 1967 now abandoned.

The first of these vortex burners was originally equipped with a conventional single discharge nozzle, and delivered 2.5x10^6 B.T.U. per hour at maximum load. Originally, the burner had a 4.6:1 turndown ratio. After the burner was equipped with a multicone assembly in accordance with the second embodiment of this invention, the maximum load increased to 4.25x10^6 B.T.U. per hour, and achieved a turndown ratio of 20:1. The increase in the load was accomplished with reduced air pressures, and thus the work of the combustion air blower did not increase.

The second burner had a 20x10^6 B.T.U. per hour rating, and was developed from the beginning with a multinozzle assembly. This unit also demonstrated an exceptionally high turndown ratio, 25:1. It performed well over 2 months of continuous operation in a boiler.

While preferred embodiments of this invention have been disclosed herein, those skilled in the air will appreciate that changes and modifications may be made therein without departing from the spirit and scope of this invention as defined in the appended claims.

We claim:

1. An oil burner assembly, comprising:
   an air chamber of circular cross section having an air inlet and means for causing admitted air to rotate within the air chamber,
   a combustion chamber of circular cross section coaxial with said air chamber,
   a nozzle coaxially communicating the air chamber with the combustion chamber, whereby air can pass from the former to the latter,
   a fuel atomizer extending coaxially from the air chamber into the nozzle and terminated substantially at the downstream end of the nozzle, said nozzle having adjacent the combustion chamber a substantially frustoconical portion whose apex is downstream of its base, said nozzle further having a substantially frustoconical baffle supported between the fuel atomizer and said substantially frustoconical portion, thereby to define two substantially concentric annular passageways each converging toward the combustion chamber and each communicating the air chamber with the combustion chamber, one of said passageways being outwardly adjacent said baffle, the other of said passageways being inwardly adjacent said baffle, said substantially frustoconical baffle having a cylindrical projection extending upstream from its base, thereby to increase the length of both said air passageways.

2. An oil burner as claimed in claim 1, which has a plurality of concentric baffles, of which one is the said substantially frustoconical baffle.

3. The invention claimed in claim 1, in which the cone angle of said portion and of said baffle is substantially 45°.

4. An oil burner as claimed in claim 1, in which said combustion chamber is cylindrical.

5. An oil burner assembly as claimed in claim 1, in which said means for causing admitted air to rotate within the air chamber comprises directing said air inlet substantially tangentially of the air chamber.

6. An oil burner as claimed in claim 1, in which the combustion chamber is cylindrical, and in which the cone angle of said portion and of said baffle is substantially 45°.