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Hori et al.

[11] **3,796,536**

[45] **Mar. 12, 1974**

[54] **LIQUID FUEL BURNER**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **431/1,** 431/183, 239/102, 239/405, 239/DIG. 19

[51] **Int. Cl.** **F23c 3/02**

[58] **Field of Search** .... 431/183, 184; 239/102, 239/405, 406, DIG. 19, 591

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Primary Examiner—Carroll B. Dority, Jr.
Attorney, Agent, or Firm—Milton J. Wayne et al.

[57] **ABSTRACT**

A liquid fuel burner is provided which has a fuel atomizing surface or portion formed at the free end of an exponential horn whose base is securely fixed to a vibrator coupled to an ultrasonic wave generator and which is so mounted that its vibrations may not be transmitted to an outer duct or housing enclosing the horn. An inner mixing vane assembly is disposed coaxially and outwardly of the fuel atomizing surface of the horn in spaced apart relation therewith, and an outer mixing vane assembly is also disposed coaxially and outwardly of the inner mixing vane assembly. At the discharge end of the outer duct or housing is formed an end member comprising a diverging wall portion, an arcuate wall portion and a radially inwardly extending flange portion in order to control the flow of atomized fuel particles.

10 Claims, 9 Drawing Figures

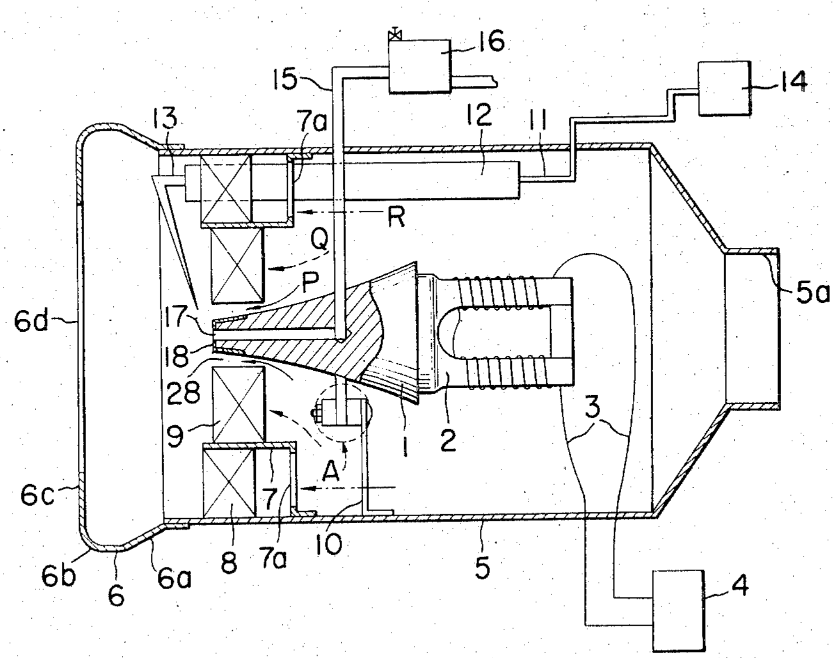
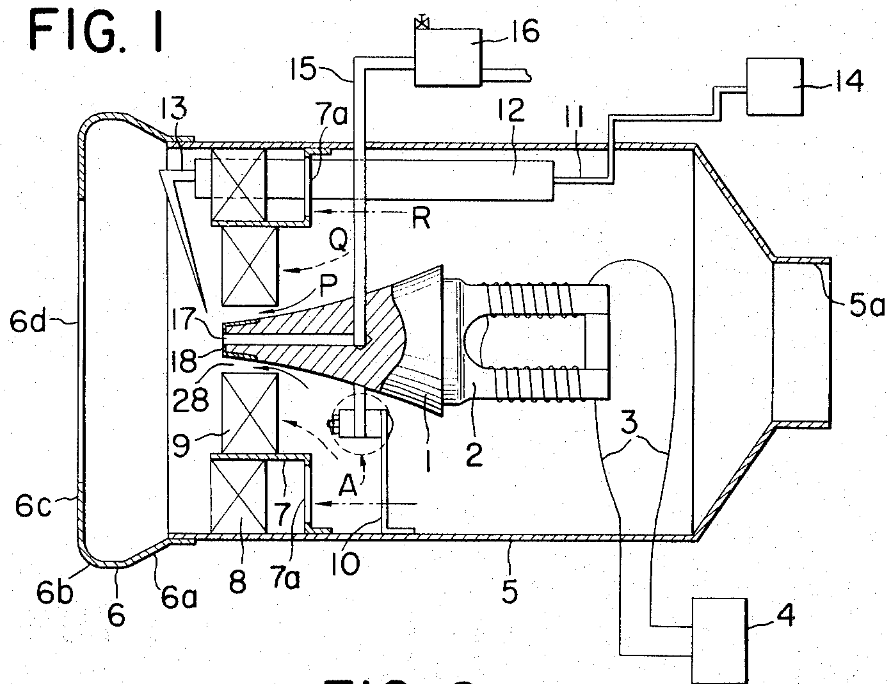


FIG. 1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14
13
7a
12
11
R
Q
P
5a
6d
17
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28
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6c
7
8
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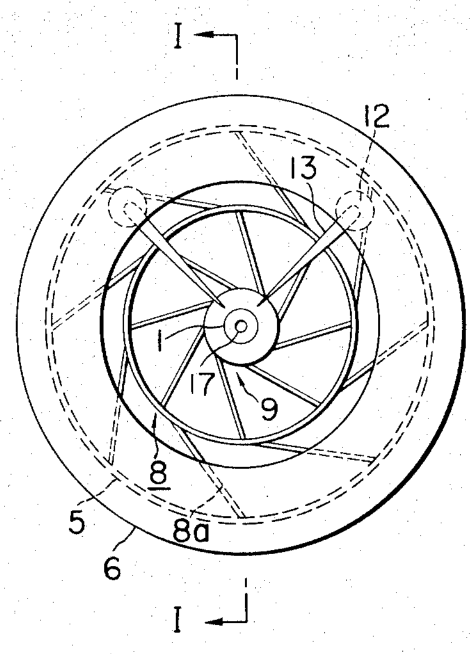
4
6b
6
6a

FIG. 2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17
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I

FIG. 4

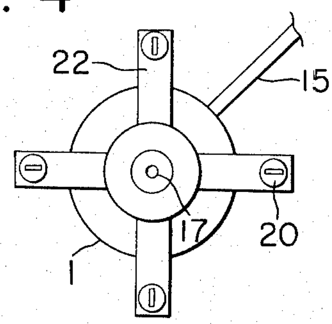


FIG. 3

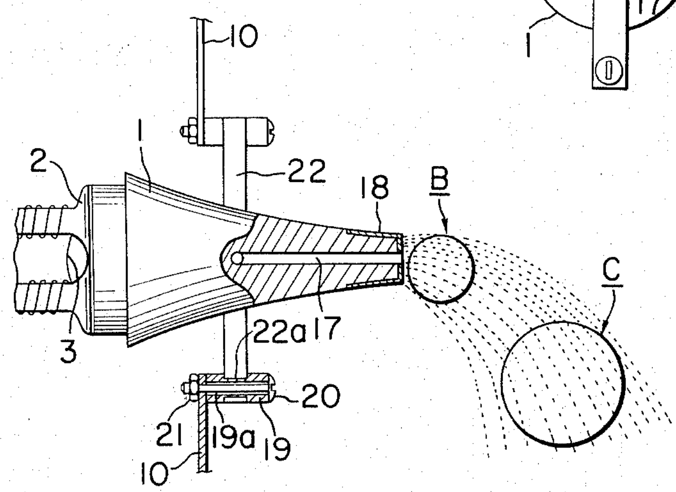


FIG. 5

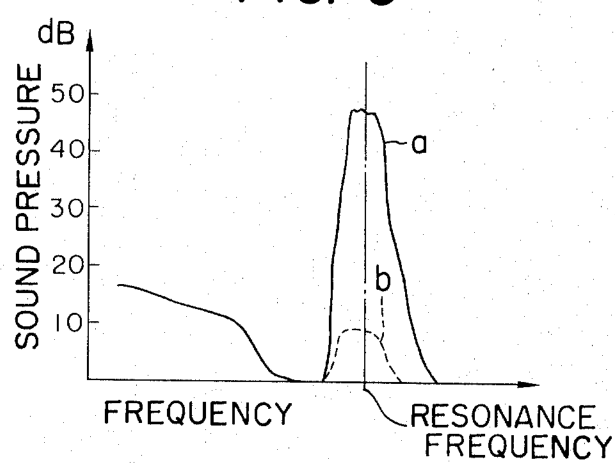


FIG. 9

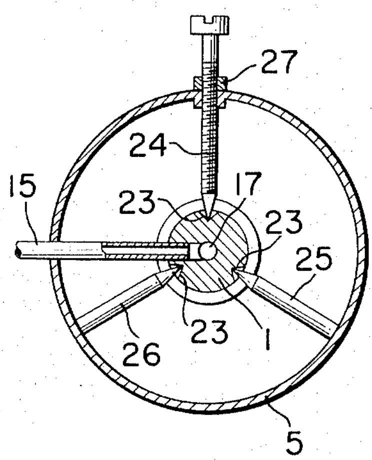


FIG. 8

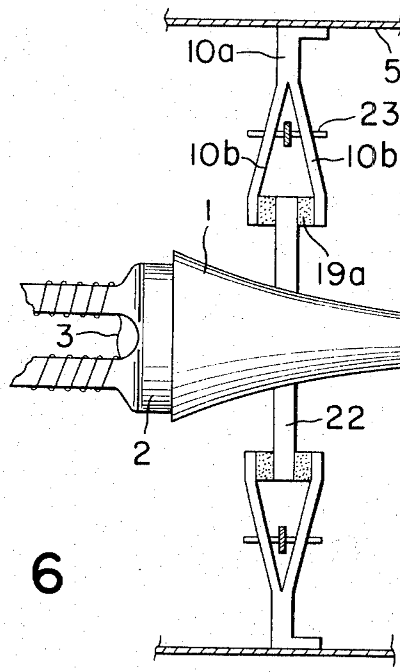


FIG 6

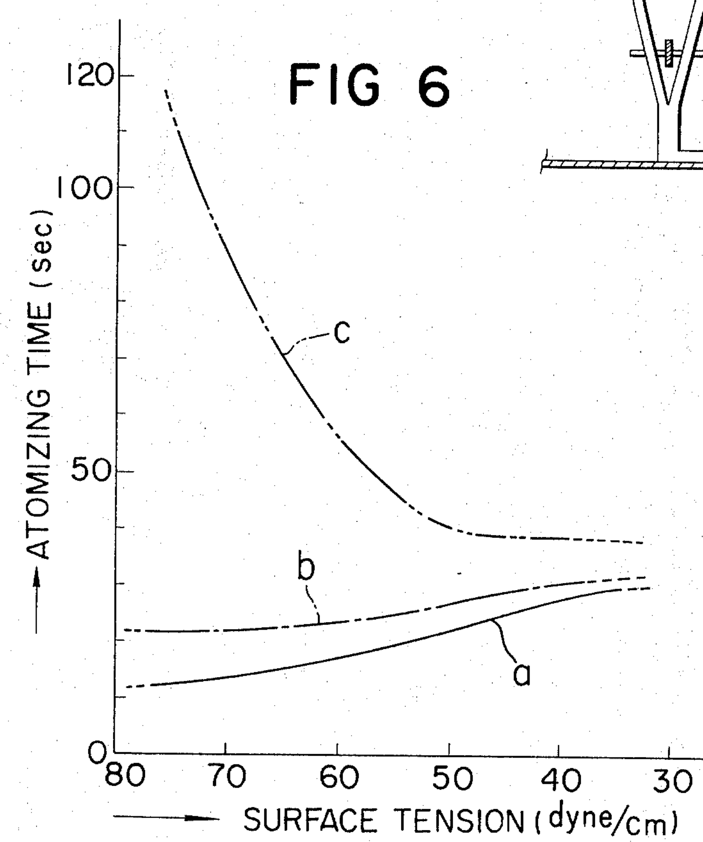
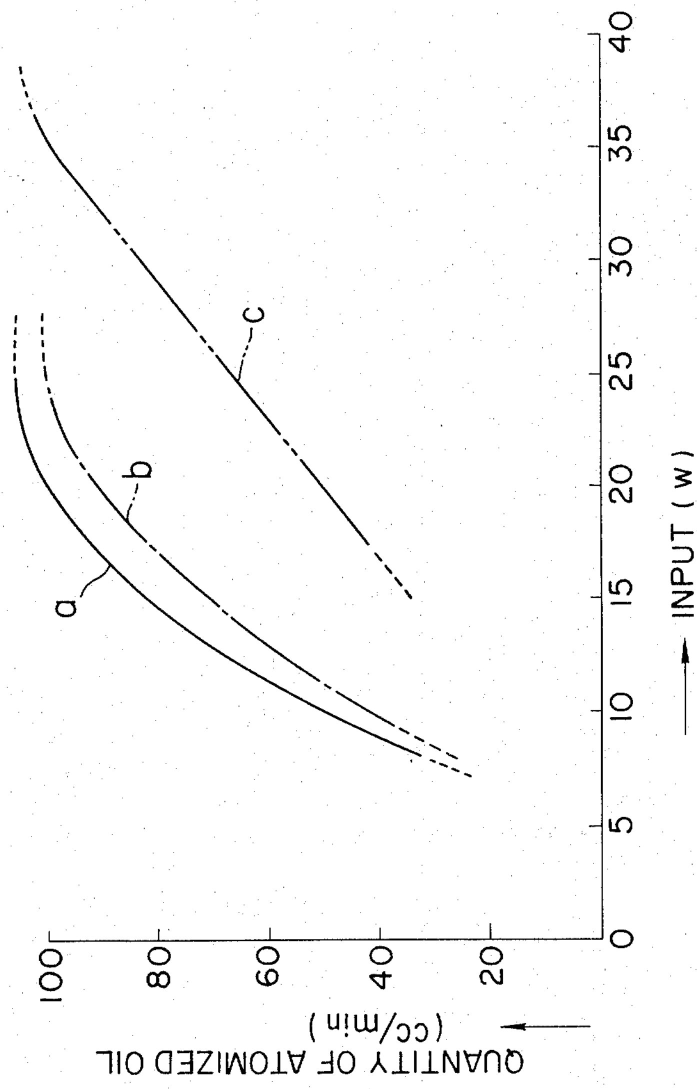


FIG. 7


a
b
c
0
5
10
15
20
25
30
35
40
INPUT (w)
20
40
60
80
100
QUANTITY OF ATOMIZED OIL
(cc/min)

LIQUID FUEL BURNER

BACKGROUND OF THE INVENTION

The present invention relates to generally a liquid fuel burner, and more particularly a liquid fuel burner utilizing an ultrasonic wave in order to atomize fuel oils.

In the liquid fuel burners utilizing an ultrasonic wave generator, the fuel oil forms a very thin film upon the vibrating surface having a certain area and vibrating at an ultrasonic frequency so that the fuel oil may be atomized into finely divided particles under the ultrasonic vibrations of the oscillating surface. However, the prior art liquid fuel burners utilizing ultrasonic wave generators have a common defect in that the kinetic energies of the atomized fuel particles are less than those of the fuel particles atomized under the pressure of air flow or the like, so that the atomized fuel particles are not uniformly distributed. That is, since the atomized fuel particles start to drop by gravity immediately after they are discharged from the vibrating surface, they form an excessively densely concentrated combustion or air-fuel mixture zone in the proximity of the vibrating surface. Therefore, not only does the ignition of such densely concentrated air-fuel mixture become difficult, but also the pulsation in combustion and jumping of flames occur because the percentage of air in the air-fuel mixture is small. As a result, the combustion efficiency is substantially reduced whereas the combustion noise is increased. Furthermore, since the atomized fuel particles have less kinetic energies they are easily susceptible to the combustion air flow, so that they tend to be spread out of the combustion zone into the poor combustion zone. Thus a considerable amount of atomized fuel particles are wasted.

Furthermore, in order to atomize a greater quantity of fuel, the input to the ultrasonic wave generator must be increased. Further, when input power greater than the rated power is used, heat dissipation is increased, thus resulting in shorter service life of the fuel burner. Moreover, in case of the liquid fuel burners utilizing the ultrasonic wave generators, the vibrations of the vibrator are transmitted to other associated component parts, so that a substantial increase in noise is produced.

SUMMARY OF THE INVENTION

One of the objects of the present invention is therefore to provide a liquid fuel burner utilizing an ultrasonic wave for atomizing fuel oils the burner being characterized by high combustion efficiency.

Another object of the present invention is to provide a liquid fuel burner which produces less combustion noise.

Another object of the present invention is to provide a liquid fuel burner which produces less mechanical vibrations due to the ultrasonic vibrations.

Another object of the present invention is to provide a liquid fuel burner with high fuel oil atomization efficiency.

In liquid fuel burners, it is imperative that the atomized fuel particles are well mixed with the air, and are uniformly distributed in the air-fuel or combustion mixture. Therefore, according to the present invention, the atomized fuel particles which are carried by the streamlined or straightened air flow are enclosed by two whirling air flows so that the atomized fuel particles which tend to spread away from the cumbustion zone may be converged toward the combustion zone. Furthermore, in order to minimize the noise due to the ultrasonic vibrations, the exponential horn and hence the atomizing portion are supported in such a manner that the transmission of the vibrations of the horn to the other component parts may be minimized. The materials for the atomizing portion are selected in order to attain the highest atomization efficiency.

The above and other objects, features and advantages of the present invention will become more apparent from the following description of the preferred embodiments thereof taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING:

FIG. **1** is a longitudinal sectional view of one preferred embodiment of the present invention taken along the line I—I OF FIG. **2**;

FIG. **2** is an end view thereof looking to the left side thereof;

FIG. **3** is a front view, partly in section, of an exponential horn thereof illustrating the detail thereof;

FIG. **4** is an end view thereof looking to the right end thereof;

FIGS. **5–7** are graphs used for explanation of the advantages of the liquid fuel burner in accordance with the present invention; and

FIGS. **8** and **9** are a side view and an end view illustrating two variations of the method for mounting the exponential horn of the fuel burner in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, an exponential horn **1** has its base fixed to a magnetostrictive vibrator **2** which in turn is electrically coupled through leads **3** to an ultrasonic wave oscillator **4**. Therefore, the horn **1** vibrates at an ultrasonic wave frequency as the magnetostrictive generator **2** oscillates. An outer cylindrical duct or housing **5** is disposed coaxially of the exponential horn **1** and has its left end fixed to an annular end member **6** having a diverging or tapered portion **6**a, an arcuate wall portion **6***b* and a radially extending flange portion **6***c*. Within the outer duct or housing **5** is disposed an annular inner duct **7** coaxially of the horn **1**, and between the outer and inner ducts **5** and **7** is disposed an outer mixing vane assembly **8** having a plurality of helical vanes **8***a*. Between the horn **1** and the outer mixing vane assembly **8** is disposed an inner mixing vane assembly **9** similar in construction to that of the outer mixing vane assembly **8.** The exponential horn **1** is securely supported in the outer duct or housing **5** by a plurality of brackets **10** as will be described in more detail hereinafter. Ignition plugs **12** which are disposed in the outer duct or housing **5** and have spark discharge electrodes **13** extend through the outer mixing vane assembly **8** and are electrically coupled to a transformer **14** through high tension lines **11.** A fuel oil regulator **16** is hydraulically communicated through a fuel line **15** with a fuel injection port **17** formed at the center of the horn **1** so that the fuel oil is supplied to an atomizing surface **18** at the left end of the horn **1** through the regulator **16**, the fuel line **15** and the fuel injection port **17.**

Next referring to FIGS.3 and 4, the mounting of the horn 1 will be described in detail hereinafter. In FIG. 3 the portion marked by A in FIG.1 is shown in detail. The horn 1 which is vibrated by the magnetostrictive vibrator 2 has the nodes along its axis at which the amplitudes are zero so that the fuel line 15 is so located as to extend radially into the horn 1 at the nodal position to communicate with the fuel injection port 17. The horn 1 is also supported at the nodal position. That is, a plurality of arms 22 having holes 22*a* at the free ends are equiangularly extended from the nodal position of the horn 1 as best shown in FIG.4, and are joined to the brackets 10 through vibration isolators 19 with bolts 20 and nuts 21 as best shown in FIG.3. More particularly, the vibration isolator 19 is fitted into the hole 22*a* at the free end of the arm 22, and the bolt 20 is inserted into the hole 19*a* of the isolator 19. Therefore, the brackets 10 and the arms 22 are spaced apart from each other by the vibration isolators 19. The bases of the brackets 10 may be securely fixed to the inner wall of the outer duct or housing 5 for example by welding. Since the arms 22 have a mass, the vibrations of the horn 1 are transmitted to the arms, but since the vibration isolators 19 are interposed between the arms 22 and brackets 10, the transmission of vibrations from the horn 1 to the outer duct or housing 5 can be substantially reduced as shown in FIG.5. In FIG.5 the solid line curve *a* illustrates the relation between the sound pressure and the frequency when no vibration isolators are used, whereas the dashed curve *b*, the relation when the vibration isolators 19 are used. It will be seen that according to the present invention the sound pressure can be reduced almost about one fourth as compared with the burners using no vibration isolators.

Referring back to FIG.1, the fuel oil supplied to the atomizing surface 18 through the regulator 16, the fuel line 15 and the fuel injection port 17 spreads over the atomizing surface 18 to form a thin fuel oil film and then is finely atomized. That is, the air is induced into the burner by a fan (not shown) disposed on the left side of the burner in FIG.1, through an inlet 5a of the outer duct or housing 5. The induced air flows in the directions indicated by the arrows P, Q and R. That is, the air flows along the peripheral surface of the horn 1 and through the horn 1 and the inner mixing vane assembly 9 as indicated by the arrow P; and the air also flows through the inner mixing vane assembly 9 as indicated by the arrow Q and through openings 7*a* of the inner duct 7 and the outer mixing vane assembly 8 as indicated by the arrow R. Thus the induced air mixes with the fuel oil atomized at the atomizing surface 18, and the air-fuel mixture or combustion mixture is ignited by the spark produced between the electrodes 13 so that the flame and the combustion products are discharged through an opening 6*d* of the end member 6 into a combustion chamber (not shown).

In conventional burners utilizing the ultrasonic wave generators for atomizing fuel oils, the kinetic energies of the atomized particles are generally very small so that the uniform distribution of the atomized particles may not be attained. This will be explained hereinafter in detail with reference to FIG.3. The atomized fuel particles discharged from the atomizing surface 18 of the horn start to fall as indicated by B in FIG.3, and the atomized fuel of relatively large particle sizes tends to spread far away from the extension of the axis of the horn 1. In some cases, the atomized fuel particles of large sizes spread out of the combustion fuel zone as indicated by C in FIG.3. Thus the fuel particles atomized and discharged from the horn 1 will not be uniformly distributed about the extension of the axis of the horn 1,so that the desired combustion mixture zone may not be formed. As a result, the combustion efficiency is substantially reduced. Furthermore, the atomized fuel particles have rather slow speeds so that they are easily susceptible to the air flow. As a result, the combustion tends to pulsate, and the flames tend to leap, resulting in increased noise to the detriment of the environment.

However, according to the present invention, the atomized fuel particles may be distributed so that higher combustion efficiency may be attained. That is, the atomized fuel particles discharged from the atomizing surface 18 of the horn 1 are carried away by the straightened air flow passing through the space 28 between the horn 1 and the inner mixing vane assembly 9. Thereafter, the fuel particles are whirled by and mixed with the whirling air flow emerging out of the inner mixing vane assembly 9. Thus, the optimum air-fuel mixture may be formed, so that the combustion efficiency may be much enhanced and the pulsation in combustion and the leaping of flames may be prevented, thus resulting in the minimization of combustion noise. Furthermore, in order to prevent the fuel particle of larger particles sizes from moving away from the combustion mixture zone and from being wasted, the present invention provides the outer mixing vane assembly 8 coaxially and outwardly of the inner mixing vane assembly 9 so that the combustion mixture formed mainly by the straightened air flow passing through the space 28 and the whirling air flow passing through the inner vane assembly 9 may be surrounded by the whirling air flow passing from the outer mixing vane assembly 8. Therefore, the fuel particles which have been spread away from the vortex of the air-fuel mixture may be returned to the air-fuel mixture zone. More particularly, the whirling air flow emerging from the outer mixing vane assembly 8 flows along the inner surface of the end member 6 and then converges toward the axis of the burner by the radially extending flange portion 6*c* so that the fuel particles which have been spread out of the combustion mixture zone may be returned to and concentrated in the mixture zone. The diverging wall portion 6*a* of the end member 6 is provided so that the velocity of the whirling air flow emerging out of the outer mixing vane assembly 9 may be so suitably adjusted that the vortex of the combustion mixture may not be unnecessarily expanded by the whirling air flow emerging from the outer mixing vane assembly 8 and so that the noise due to the whirling air flow from the outer mixing vane assembly may be minimized.

In general, the burners utilizing the ultrasonic wave generators for atomizing the fuel oils are not adapted to be used with all of liquid fuels, and the atomization of liquid fuels is dependent upon the properties of liquid fuels used and of the material forming the atomizing surface 18 of the horn 1. More particularly, the atomization is especially influenced by the surface tensions of the fuel oils and the properties of the material of the atomizing surface 18. Therefore the inventor made extensive studies of the effects of the surface tensions of liquid fuels upon the atomization time. For example, the surface tension of kerosene whose inherent surface tension is 26 dynes per centimeter was varied by adding a mixture consisting of water and isopropyl alcohol, and the atomization time of kerosene with various surface tensions was measured. In the experiments, care was taken so that kerosene would not flow, while being atomized. The experimental results are shown in FIG. 6. Furthermore, the experiments showed that when the atomizing surface 18 is made of aluminum, the atomization is much enhanced than when the surface is made of other materials. The characteristic curve *a* shows the atomization time when the aluminum atomizing surface 18 was used; the curve *b*, when the atomizing surface was made of aluminum-plated soft steel; and the curve *c*, when the soft steel atomizing surface was used. From FIG.6 it is seen that the atomization by the aluminum atomizing surface is much improved and is almost independent of the surface tension of fuels used. In case of the soft steel atomizing surface, the atomization time becomes longer and is considerably influenced by the surface tension of liquid fuels.

In FIG.7 is illustrated the relation between the electrical input power (plotted along the abscissa) and the atomization speed, that is the volume of fuel atomized per minute (plotted along the ordinate). It is seen that when the aluminum atomizing surface or aluminum-plated atomizing surface is used, the volume of fuel atomized per unit of electrical input power is much increased. This means that the heat dissipation from the vibrations of the ultrasonic wave generator are less, so that the service life of the burner may be increased and the noise may be minimized. In summary, it is very important that the atomizing surface 18 must be made of or plated with a material whose properties may facilitate the atomization of liquid fuels.

Next the first variation of the method for mounting the horn 1 will be described with reference to FIG.8. The brackets 10 are bifurcated, and the arms 22 of the horn 1 are held between the arms of the brackets 10 through the vibration isolators 19*a*. Since the bifurcated arms of the brackets 10 may be firmly tightened by means of adjusting screws 23, the arms 22 of the horn 1 may be firmly held in position.

Next referring to FIG.9, the second variation of the method for mounting the horn 1 will be described. Along the circle of the horn 1 which corresponds to the node are formed equiangularly a plurality of blind holes 23, and the pointed ends of brackets 24, 25 and 26 are fitted into these holes 23 to support and firmly hold in position the horn 1. In order to facilitate the mounting and removal of the horn 1, one of the brackets may be a screw 24 which is screwed into an internally threaded member 27 fixed to or formed in the outer duct or housing 5 so that when the screw 24 is tightened or loosened, it may be moved toward or away from the horn 1 in order to fit into or release out of the hole 23 the pointed end of the screw 24. The second variation described above has an advantage that since the horn 1 is supported and held in position at the nodal position by the brackets or the like, the vibrations are almost not transmitted to the outer duct or housing 5 even when no vibration isolators are used.

What is claimed is:

1. A liquid fuel burner comprising
an ultrasonic wave generator,
a horn whose one end is fixed to a vibrator coupled to said ultrasonic wave generator and the other end is provided with a liquid fuel atomizing surface,
an outer duct enclosing said vibrator and said horn coaxially thereof,
means for supporting said horn within said outer duct,
means for supplying fuel oil to said atomizing surface of said horn,
an inner duct positioned between said outer duct and horn,
an outer mixing vane assembly disposed between the outer and inner ducts,
an inner mixing vane assembly disposed between said horn and said inner duct and spaced therefrom, whereby the air flows axially and in parallel through the space between the peripheral surface of said horn and said mixing vane assembly, and
means for reducing the whirling velocities of said atomized fuel particules whirled by said mixing vane assemblies, said velocity reducing means being mounted to the end of said outer duct.

2. A liquid fuel burner as set forth in claim 1 wherein said outer and inner mixing vane assemblies each have a plurality of equiangularly disposed helical vanes for whirling the flow of said atomized fuel particles.

3. A liquid fuel burner as set forth in claim 1 wherein said horn is supported and held in position at the nodal position by said supporting means.

4. A liquid fuel burner as set forth in claim 1 wherein said atomizing surface of said horn is made of material whose adhesivity to fuel oils is low.

5. A liquid fuel burner as set forth in claim 1 wherein said atomizing surface of said horn is coated with a material with a low adhesivity to fuel oils.

6. A liquid fuel burner as set forth in claim 3 wherein said supporting means include vibration isolators so that the transmission of vibrations from one of said supporting means to another may be reduced.

7. A liquid fuel burner as set forth in claim 3 wherein said supporting means comprise a plurality of blind holes formed at the nodal position and a plurality of supports whose leading ends are pointed to make substantially point contact with said horn in said blind holes thereof.

8. A liquid fuel burner as set forth in claim 4 wherein said material of said atomizing surface is aluminum.

9. A liquid fuel burner as set forth in claim 5 wherein said material for coating said atomizing surface is aluminum.

10. A liquid fuel burner as set forth in claim 1, further comprising an end member fixed to the discharge end of said cylindrical outer duct, said end member comprising a diverging wall portion adjacent said discharge end, an intermediate arcuate wall portion, and a radially, inwardly extending flange portion to reduce the vortex of air flows whirled by said mixing vane assemblies, to enhance the axial flow, and to provide a mixing space for mixing atomized fuel and air.

* * * * *