

Aug. 17, 1965

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ULTRASONIC BURNER

Filed June 4, 1962

2 Sheets-Sheet 1

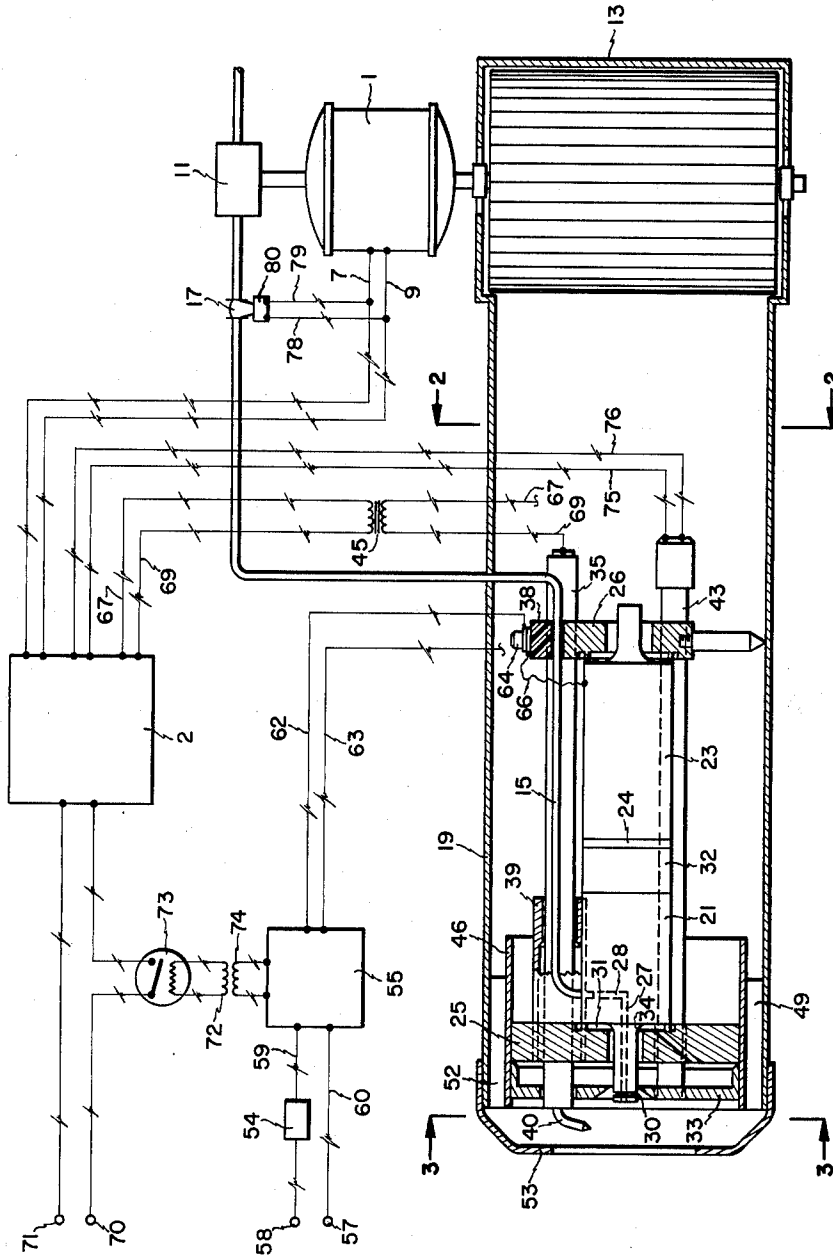


FIGURE 1

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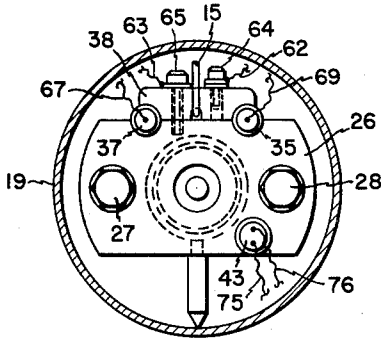


FIGURE II

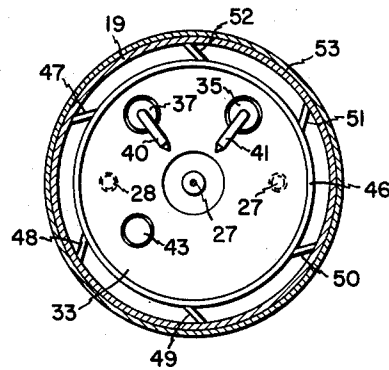


FIGURE III

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ULTRASONIC BURNER

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Filed June 4, 1962, Ser. No. 199,788

12 Claims. (Cl. 158-77)

The present invention relates to a liquid fuel burner. It relates more specifically to a burner which utilizes an ultrasonic atomizer. Units made according to this invention may be of various sizes and capacities, but the invention has particular applicability to fuel burners operating at low consumption rates.

In the prior art, numerous liquid fuel burners, particularly those operating on petroleum distillates, have been used successfully all over the world. Conventional burners which use high pressure nozzles are reliable at high oil rates. However, at rates below 0.6 gallon per hour the conventional burners are not reliable. The tiny swirl slots needed to obtain fine atomization at low rates are prone to plugging.

There is a need for a reliable burner capable of operating at low firing rates. For example, such a burner is needed for domestic hot water heaters and for homes in relatively mild climate.

It is, therefore, an object of this invention to provide a burner which is reliable at oil rates below 0.6 gallon per hour.

Other objects will be apparent as one reads the description of the invention.

The objects of this invention are achieved by utilizing a specific and particularly efficient ultrasonic atomizer in a burner system specifically designed to enhance the reliability of the atomizer.

The invention is best understood by referring to the accompanying drawings wherein:

FIGURE I is an elevational view, partly in section, depicting a preferred type of unit.

FIGURE II is a cross-sectional view taken at section 2-2 of FIGURE I.

FIGURE III is a cross-sectional view taken at section 3-3 of FIGURE I.

Referring first to FIGURE I, a controller 2 is shown. The circuitry of the controller is not shown herein as the controller is of the conventional type. For example, General Electric CR7865-A101A master controller can be used in this system. A suitable motor 1 connected to the controller 2 by leads 7 and 9 drives oil pump 11 and blower 13. The oil pump 11 transfers fuel oil from a suitable source, not shown, through line 15 to the ultrasonic atomizer to be described below. Unlike a gun burner, the ultrasonic burner does not require a high pressure oil supply. Therefore, a simple low torque pump, such as a gear pump, may be used in conjunction with a cheap shaded pole motor. If the low torque pump is used, it is necessary to employ a solenoid controlled blocking valve 17. Alternatively, a high torque pump can be used. In the alternative system, it is necessary to employ a clutch, e.g., centrifugal clutch, to engage the motor and the pump. A high torque pump acts as a blocking valve when not operating, thus valve 17 may be excluded, if the alternate system is used.

The blower or fan 13 can be of the "squirrel cage" or cylinder type, as shown, or any other suitable type. The blower supplies ambient air to the system. The air is blown through the space between the atomizer assembly and the more or less conventional blast tube 19, and is admixed with the atomized oil. Secondly, but importantly, the air serves to cool the transducer, thereby prolonging the life of the burner.

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The atomizer assembly is an integral unit comprising the ultrasonic atomizer, two ignition electrodes, a heat shield, and a flame sensing device.

The ultrasonic atomizer is essentially the device described in copending application Serial Number 122,308, filed July 6, 1961. A brief description will suffice for the purposes of this invention. The atomizer comprises two stepped horn units 21 and 23. These are placed in a base-to-base relationship with a piezoelectric crystal disc 24 between them. The disc is made of a piezoelectric ceramic, such as lead-zirconium titanate.

The stepped horns 21 and 23 are held in compression against the piezoelectric disc 24 by mechanical clamping means comprising front and rear flanges 25 and 26 and studs connecting such flanges. The studs 27 and 28 are shown in FIGURES II and III. The studs enter the rear flange 26 and are screwed into the front flange 25.

As is seen in FIGURE I, the front flange contacts the first stepped horn 21 at the periphery of the shoulder of the stepped horn in order to minimize damping of the ultrasonic atomizer. As is explained in copending application Serial Number 122,308, the atomizer is designed so that planes of essentially zero displacement exist at the shoulders of the stepped horns. The rear flange contacts the second stepped horn 23 at the periphery of the shoulder of said horn. In the particular design shown, it is necessary that a suitable insulating material, for example, mylar, be placed between the rear flange and the second stepped horn.

An axial hole 27 is drilled in the tip of the first stepped horn 21. The axial hole extends back to a radial hole 28 located essentially at a vibrational node in the horn. The radial hole is located near a nodal point so that the oil feed line 15 can be attached to the side of the horn without damping the atomizer.

The stepped horns are made of a suitable material, for example, aluminum. For the purposes of this invention the first stepped horn is modified in at least three respects. The tip of the stepped horn is preferably filleted at 34 in order to reinforce the tip so that it can withstand a high degree of stress. A groove 30 is formed around the tip of the first stepped horn. This prevents oil from creeping back along the horn. If the oil were not prevented from creeping back along the horn, it would accumulate in the space 31 between the shoulder of the horn and the front flange 25. This could damp the atomizer and thus render it less effective or even inoperable.

Another modification of the first stepped horn is also desirable. The disc of piezoelectric material 24 must be kept at relatively low temperatures in order to ensure the reliability of the system. If the disc is subjected to relatively high temperatures, for example, temperatures above 150° F., for prolonged periods, it will be depolarized. As mentioned before, the atomizer is cooled by the combustion air supplied by the blower 13. However, at low oil rates, the flow rate of air is greatly diminished.

In order to protect the piezoelectric material from heat, a portion of the aluminum stepped horn 21 is replaced by a disc of stainless steel 32. Stainless steel has a thermal conductivity of about one-tenth that of aluminum. Moreover, it has sonic properties approaching those of aluminum.

To further protect the atomizer, a heat shield 33 is attached to the front flange in order to reduce the amount of radiant heat input to the atomizer.

Ignition of the fuel-air admixture is accomplished by an arc formed between two electrodes. The positions of the electrodes 35 and 37 are best observed in FIGURES II and III. The electrodes are fastened to the rear flange 26 by means of a fiber clamp 38. As shown in FIGURE I, electrode 35 is inserted through the heat shield 33 and is

fitted into an electrode guide 39 which is drive fitted into the front flange 25. Electrode 37, not shown in FIGURE I, is mounted in like manner. The electrodes are insulated with a suitable material, for example, porcelain. Ignition is accomplished by an arc formed across the electrode tips 40 and 41, shown in FIGURE III.

The atomizer assembly is also equipped with a flame detector 43 which is mounted through the rear flange and extends through the front flange and heat shield. A flame detector, such as the one described in copending application Serial Number 128,846, now abandoned, can be used in this system. The flame detector upon "seeing" the flame sends a signal to the controller which breaks the circuit to the ignition transformer 45. If no flame is established, the controller 2 will shut down the burner, repeat the cycle and then lock the system out.

The atomizer unit is fitted into a turbulator tube 46 which has vanes 47, 48, 49, 50, 51 and 52, shown in FIGURE III, around its periphery. These vanes are tacked to the blast tube 19. Attached to the end of the blast tube is an end cone 53 which serves to channel the combustion air to ensure efficient combustion. The atomizer unit need not be attached to the turbulator tube. In fact, it is preferred that it merely fit snugly in said tube. This allows the convenient removal of the atomizer unit for maintenance. The vanes of the turbulator tube serve to impart a centrifugal force to the combustion air. In the prior art devices vanes have been employed. However, there is usually a large central space through which the air can pass. Thus, only a small portion of the air comes under the influence of the vanes. For the purposes of this invention, it is highly desirable that the front flange 25 blocks off the air flow so that all the combustion air is forced to flow in the annular space between the turbulator tube and the blast tube. Thus, all the combustion air comes under the influence of the vanes and a greater centrifugal force is imparted thereto. This results in a greater combustion efficiency and it also results in moving the flame away from the burner tip. These functions are especially important at low oil rates and correspondingly low combustion air flow rates.

Moving the flame away from the burner tip protects the tip from the destructive combustion. Moreover, it reduces the amount of heat transferred to the atomizer, thus lowering the temperature in the area of the piezoelectric material. Thus, it is seen that using a design herein suggested results in increased combustion efficiency, protects the tip of the atomizing transducer and prolongs the life of the piezoelectric material.

The atomizer is supplied with power by an electronic driver or oscillator 55 which is connected with electric mains 57 and 58 by leads 59 and 60. The driver is connected to the atomizer with leads 62 and 63. The input lead 62 is connected with a post 64 which is imbedded in the fiber clamp 38. It is necessary that the post 64 does not extend through the fiber clamp and make contact with the rear flange 26. The post 64 is connected with the second stepped horn 23 by lead 66. As shown in FIGURE II, return lead 63 is connected with post 65 which extends through the fiber clamp and is screwed into the rear flange.

The driver 55 is essentially the one described in copending application Serial Number 59,335, filed September 29, 1960 now Patent No. 3,121,534 issued February 18, 1964. The driver supplies power at a frequency which corresponds with the natural resonance of the atomizer or one of the major harmonics thereof. The frequency will depend upon the particular design of the sonic atomizer, but will usually be within the range of from 20,000 to 230,000 cycles per second. It is preferred that the atomizer be designed to have a resonant frequency within the range of from 50,000 to 100,000 cycles per second.

The sonic atomizer converts the electrical energy into mechanical energy due to the cyclic expansion and con-

traction of the piezoelectric material. As described in copending application Serial Number 122,308, the transducer is designed so that a displacement antinode exists at the tip of the stepped horn. Thus, the vibrations of the horn atomizes the oil emerging from the horn into particles having a mass median particle diameter of 125 microns or less.

The ignition electrodes 35 and 37 are connected to the ignition transformer with leads 67 and 69. Lead 69 is connected with electrode 35, as shown in FIGURE I, and lead 67 is connected with electrode 37, as shown in FIGURE II.

The ignition transformer steps up the line voltage of 115 volts to a voltage, e.g., 15,000 volts, sufficient to cause an arc across electrode tips 40 and 41.

In order to integrate the driver 55 into the rest of the control circuit and to ensure that oil cannot be injected into the atomizer before the driver and transducer are operating suitably, a simple but unique delay means is employed. A coil 72 is inductively coupled with the plate inductance 74 of the driver. The coil is connected to the heater resistance of a thermal delay switch 73, and the switch is connected across the thermostat terminals of the conventional controller 2.

In operating this burner, thermostat 54 upon receiving the desired stimulus completes the circuit which is supplied with 115 volt alternating current by electric mains 57 and 58. The electronic driver 55 transmits power to the atomizer via leads 62 and 63 at the resonant frequency of the atomizer.

As the driver "warms up," current is transmitted to the normally open thermal delay switch 73. The switch closes completing the circuit supplied with 115 volt alternating current by electric mains 70 and 71 to activate the controller.

The controller supplies the ignition transformer with voltage via leads 67 and 69. The transformer steps up the voltage to an amount sufficient to cause an arc to form across the electrode tips 40 and 41. Current is supplied to the solenoid 80 via leads 78 and 79. The solenoid then opens valve 17 to permit the passage of oil. The motor 1 is connected to the controller by leads 7 and 9. The motor drives the oil pump 11 and oil is pumped through feed line 15 at a rate of from 0.2 to 1.0 gallon per hour and higher.

The motor also drives the fan or blower 13 which supplies air at a rate of from 6 to 30 cubic feet per minute and higher, depending upon the oil rate. The flow of air is adjusted by a manual control valve, not shown. The oil passes into the radial hole 28, through the axial hole 27, is atomized by the vibration of the stepped horn, and emerges from the tip of the first stepped horn 21 to be admixed with the combustion air which has flowed past the atomizer and between the turbulator tube 46 and the blast tube 19. The air-oil admixture is ignited by the arc formed across the electrode tips 40 and 41.

The flame sensing device or photocell 43 "sees" the flame and sends a signal to the controller 2 which breaks the circuit to the transformer and turns off the arc.

The burner described herein was fired with #2 heating oil at rates between 0.2 and 0.7 gallon per hour. Clean combustion at high stack gas CO₂ levels above 10% was obtained throughout this range.

The durability of the ultrasonic burner was tested under a variety of conditions. A life test of 0.5 gallon per hour and a CO₂ level of 10% was voluntarily concluded after a successful 5,000 hours of firing.

At the time of filing, a burner fired at a rate of 0.25 gallon per hour had been successfully operating for 1,000 hours.

The invention has been described with a certain degree of particularity. It will be obvious that other modifications may be made consistent with the invention by those skilled in the art. It is intended by the following claims to cover such modifications and variations as are properly

a part of this invention so far as permitted by the prior art.

What is claimed is:

1. In a burner for liquid fuels, the combination which comprises:

an ultrasonic fuel atomizer comprising a vibratory horn element having a substantially non-vibratory nodal point, an inlet for fuel adjacent said nodal point; a pump for supplying fuel to said atomizer and a blower for supplying combustion air in admixture with atomized fuel emerging from said atomizer; electronic drive means for said atomizer;

valve means for controlling the flow of fuel from said pump to the atomizer, and control means associated with said electronic drive means for preventing the flow of fuel from the pump to the atomizer when power is not being supplied to said drive means.

2. A burner according to claim 1 wherein a heat shield is placed between the burning atomized fuel and the ultrasonic fuel atomizer.

3. A burner in accordance with claim 1 wherein said ultrasonic atomizer comprises a stepped-horn resonator with an atomizing tip of reduced diameter, a disc of piezoelectric material and means formed in said atomizing tip for preventing liquid fuel from creeping back along the external surface of said tip.

4. A burner according to claim 3 wherein a metal disc is placed between said resonator and said disc of piezoelectric material; said metal disc having sonic properties approaching those of the resonator and a thermal conductivity substantially less than that of the resonator.

5. A burner according to claim 3 wherein said stepped-horn resonator is made of aluminum and a disc of stainless steel is placed between said resonator and said disc of piezoelectric material.

6. A burner unit capable of operating at liquid rates below 0.6 gallon per hour comprising in combination:

an ultrasonic fuel atomizer having a fuel atomizing end part, said atomizer also having a substantially non-vibratory nodal point remote from said part; means for supplying liquid fuel to said atomizer adjacent said nodal point;

a blower for supplying combustion air to the burner unit, including means for channeling such combustion air so that said air is admixed with the atomized fuel; electronic drive means for said atomizer;

turbulating means surrounding the atomizer and annularly spaced therefrom for swirling the combustion air prior to its admixture with the atomized fuel and means for directing the flow of said air so that essentially all of the combustion air comes under the influence of said turbulating means; and

igniting means for initiating combustion of the fuel-air admixture.

7. A burner unit according to claim 6 wherein combustion detector means responsive to visible flame are provided to prevent operation of said igniting means when visible flame persists.

8. A combination according to claim 6 which includes: a conventional controller for coordinating igniting means, blower, and means for supplying liquid fuel; and

control means for integrating said electronic drive means with said controller so that said controller is not activated until power is supplied to said drive means.

9. A burner unit according to claim 8 wherein said control means comprises a delay switch connecting said electronic drive means with said controller.

10. For use in a liquid fuel burner, a high frequency transducer atomizer comprising a stepped horn resonator with an atomizing vibrating tip of reduced diameter and having a relatively non-vibrating nodal point behind said tip, means for introducing fuel into said resonator near said nodal point, means comprising a disc of piezoelectric material attached to said resonator for transmitting vibratory energy thereto, means for forcing liquid fuel from said nodal point to said tip, and means formed in said resonator for preventing liquid fuel from creeping back along the external surface of said tip towards said nodal point.

11. A transducer atomizer according to claim 10 wherein a metal disc is placed between said resonator and said disc of piezoelectric material; said metal disc having sonic properties approaching those of the resonator and a thermal conductivity substantially less than the resonator.

12. A transducer atomizer according to claim 11 wherein said stepped horn resonator is made of aluminum and said disc is composed of stainless steel.

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