APPARATUS FOR THE APPLICATION OF AN A.C. ELECTROSTATIC FIELD TO COMBUSTION FLAMES

FIG. 1

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FIG. 4
LUMINOSITY VS. FIELD STRENGTH
PROPANE DIFFUSION FLAMES

LIGHT INTENSITY - PHOTOCCELL READING

A.C. FIELD IN KILO VolTS, (RMS)

1 L/MIN. PROPANE

10 L/MIN. PROPANE

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FIG. 5

EFFECT OF FIELD STRENGTH ON PROPANE DIFFUSION FLAME

![Graph showing the effect of field strength on propane diffusion flame.](image)
FIG. 6
EFFECT OF FREQUENCY ON PROPANE DIFFUSION FLAME

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This invention relates to the application of electrostatic fields to flames. More particularly, the invention relates to a process and apparatus for improving the characteristics of flames resulting from the combustion of gases, vapors, liquids, solids and mixtures of these by means of a particular type of electrostatic field.

It has been known for over a hundred years that flames conducted by electrolysis. It has been determined that certain ionic species are responsible for this phenomenon. The most widely accepted path for the formation of ions in flames is the following:

\[ \text{CH}_3\text{O} \rightarrow \text{CHO}^+ + e^- \]
\[ \text{CHO}^+ + \text{H}_2\text{O} \rightarrow \text{CO}^+ + \text{H}_3\text{O}^+ \]

In the reaction zone of a pure hydrocarbon flame, concentrations of \(10^{12}-10^{14}\) ion pairs/cc. can be reached.

D.C. currents and D.C. electrostatic fields have been employed to bend flames and to increase the amount of heat generated by combustion. The chief disadvantages of D.C. currents and fields are flame distortion and excessive power dissipation.

The object of the present invention is to influence the movement of charged species present in flames without undulydistorting the flame. Another object of the invention is to improve flame characteristics such as flame length, flame luminosity, flame color and soot forming tendency. A major object of the invention is to provide the aforementioned objects by the application of a low power loss electrostatic field to the flame.

I have found that combustion efficiency and flame characteristics can be greatly improved by impressing an A.C. electrostatic field across a flame transverse to the flame and by insulating the flame from at least one of the electrodes.

The invention will be more fully described with reference to the attached drawings in which:

**FIGURE 1** is a schematic view of the apparatus showing one arrangement of the apparatus elements.

**FIGURES 2 and 3** are side and top views respectively of a particular electrode configuration.

**FIGURE 4** is a graphical comparison of luminosity and field strength.

**FIGURE 5** is a graph showing the effect of field strength on a propane diffusion flame.

**FIGURE 6** is a graph showing the effect of A.C. frequency on a propane diffusion flame.

**FIGURES 7 and 8** are schematic views of flames with and without the A.C. field.

**FIGURE 9** is a schematic view of an apparatus having two sets of electrodes, each set having a different frequency.

**FIGURE 10** shows the location of a pair of electrodes with respect to the flame and the burner head.

Referring to **FIGURE 1**, reference numeral 1 denotes a line carrying a fuel from any suitable source. The fuel line is oriented with a hole 2 drilled in a Teflon block 3. The block is also drilled vertically and a glass burner tube 4 is inserted in the hole. The burner tube terminates in a nozzle 5 having a diameter of .022 mm. The burner tube is surrounded by a glass chimney 6. The chimney is 4 inches in diameter and is 20 inches long. The bottom of the chimney is sealed by means of a rubber stopper 7.

Combustion air is supplied by line 8 which passes through the stopper and terminates at the bottom of a layer of lead shot 9. The purpose of the layer of lead shot is to distribute the air over the cross-sectional area of the chimney producing a smooth flow of air vertically through the chimney. A Nichrome wire electrode 10 passes from attachment point 11 in the Teflon block through the burner tube to a suitable attachment point 12 above the glass chimney. Both attachment points are insulated. A cylindrical copper electrode 13 which is 5 inches in diameter and 8 inches long surrounds the glass chimney. Thus the chimney insulates the Nichrome wire electrode 10 from the copper electrode 13 and as a result there is essentially no flow of current through the flame 14.

When the A.C. field is to be applied to the flame, switch 15 is closed activating transformer 16. The A.C. circuit is completed by line 16 connected to Nichrome wire electrode 10 and line 17 connected to cylindrical copper electrode 13. The transformer can be of the variable type capable of supplying a field strength of 1—500 kv. A voltmeter 18 is connected across lines 16 and 17 and line 17 contains an ammeter 19.

The apparatus described above was used to alter the flame characteristics of a propane flame. Propane was passed by line 1 at selected rates ranging from .05 to 15 liters per minute to the nozzle 5. The flow of fuel and air was adjusted to provide flames having a length of 4 to 40 inches. Both laminar and turbulent flames were subjected to the A.C. field. With a turbulent diffusive flame burning 5 liters of propane per minute, the temperature of the Nichrome wire 10 is measured by an optical pyrometer was found to have been raised from 1700° F. to 1800° F. by the application of a field of 500 v/cm. with a power dissipation of .03 watts.

The A.C. field of the invention can be applied to gases such as natural gas, stack gases, propane, butane, producer gas and in general to any other type of combustible gas having sufficient ionic species which are affected by an electrode field. The concept can also be applied to vapor or liquid fuels having an initial boiling point range of 80° F. to 700° F., preferably 80° F. to 400° F. such as naptha, fuel oil, gasoline, kerosene, coal oil, petroleum residuum, petroleum crude oil and the like. The liquid fuels are usually vaporized by heat or atomized by passing them through an atomizing nozzle into a combustion zone in the form of vapor or fine droplets, mist or fog. The fuels can be premixed with air, oxygen or other oxidizing gas prior to exit from the burner nozzle and equivalent results will be obtained when the field is applied. Solid fuels such as coal and coke can also be used to provide the flame.

**FIGURE 2** discloses an embodiment in which the flame 59 from burner 51 is centrally located in an A.C. electrostatic field. The electrodes 52 and 53 are curved to partially encircle the flame and they are approximately the same length as the flame. Line 54 connects one electrode with transformer 55. Line 56 connects the other electrode with the transformer. The electrodes are held in the desired position relative to the flame by any suitable type of mounting bracket, not shown.

**FIGURE 3** has been included to show that electrode 52 is coated or covered with an electrical insulation material 57. Electrode 53 is also covered or coated with an insulating material 58. Suitable insulating materials include non-combustible materials such as ceramics, Alumnum, etc.

**FIGURE 4** is a plot of luminosity versus field strength. The data points were obtained using an apparatus like that shown in **FIGURE 1**, a photocell was oriented toward the flame. The voltage was varied from 0 to 10 kv. The luminosity of a flame is the amount of light it gives off. In terms of flame quality, a yellow flame is a low...
quality flame and a blue flame is an efficient high quality flame. The curves plotted in FIGURE 4 show that with propane diffusion flames derived from burning 1 liter of propane per minute and 10 liters of propane per minute the luminosity decreases as the A.C. field intensity is increased.

FIGURE 5 discloses another method of showing the effect of field strength on the flame. An apparatus like that shown in FIGURE 1 is modified to supply nitrogen to the burner. When the propane-air ratio is fixed to produce a luminous (yellow) flame, the flame can be made nonluminous by the addition of nitrogen to the fuel. This is because the addition of nitrogen to the propane leads to increased turbulence of the flame which leads to more effective mixing of the fuel with air. The plot shows that without the field over 1.7 liters per minute of nitrogen must be added to the propane to achieve a nonluminous flame. As the A.C. field strength is increased, much less nitrogen is required. At a field strength of about 8 kV/cm, the nitrogen requirement levels out at about 1 liter per minute to achieve nonluminous combustion. The A.C. field was also applied to the flame derived from premixing 6.5 liter per minute of air with 2 liters per minute of propane and controlling the secondary air at 2 liters per minute. When the field was increased over a range of 0 to 10K volts at 60 cycles per second the nitrogen requirement decreased. Thus, field assisted combustion provided improved results with diffusion flames and premixed flames.

FIGURE 6 discloses the effect of frequency variation on nitrogen requirement. As explained previously with respect to FIGURE 5, the smaller nitrogen requirement indicates improved combustion. The plot indicates that A.C. frequencies above 60 cycles per second provided improved combustion. Frequencies of 1 to 2000 cycles per second are satisfactory to provide the fields of the invention and frequencies of 60 to 500 cycles per second are preferred.

FIGURES 7 and 8 disclose a comparison of the effect of the field on a propane diffusion flame. The flame was derived from the combustion of propane fuel flowing at the rate of 6 liters per minute through a glass burner tube. Air was supplied at the rate of 240 liters per minute through a bed of lead shot. The apparatus was essentially the same as the apparatus shown in FIGURE 1 except that the copper electrode encircled only half of the glass insulating chimney. This configuration was used to permit visual observation and to photograph the flame. FIGURE 7 depicts the flame without the electrostatic field. The flame cone extends about 12 inches above the glass chimney which is 20 inches long. The flame consists of a white zone about an inch in height, a blue zone about 6 inches in height and a yellow zone about 24 inches in height. A yellow flame connotes incomplete combustion and carbon formation and thus the flame of FIGURE 7 is very inefficient as shown by the long yellow zone. FIGURE 8 shows the effect of a 10.8 kV, 60 cycle per second insulated A.C. field on the same propane-air combustion mixture. When the field is applied, the yellow zone is eliminated which indicates that combustion is greatly improved. The flame cone also shrinks to an overall length of about 16 inches. The white zone of FIGURE 8 is higher above the tip of the burner. This is due at least in part to the fact that the propane and air are mixing for a longer period of time prior to ignition. The foregoing comparison of FIGURES 7 and 8 clearly demonstrates the improved combustion made possible by the application of an insulated A.C. field. The power dissipation across a field like that shown in FIGURE 8 is less than about one watt; thus the cost of the field is negligible in terms of power consumption.

FIGURES 9 and 10 disclose an embodiment of the invention in which two separate insulated A.C. electrostatic fields are applied across a flame at different frequencies. FIGURE 9 is a top view showing the location of the groups of electrodes with respect to each other. Transformer 101 provides a 60 cycle alternating frequency of the desired voltage to provide a field between one group of electrodes connected in parallel and shown generally by reference numeral 102 and another group of electrodes also connected in parallel and shown generally by reference numeral 103. A second transformer 104 provides a 120 cycle alternating frequency of the desired voltage to provide another field between a group of electrodes connected in parallel and shown generally by reference numeral 105 and another group of electrodes connected in parallel and shown generally by reference numeral 106. Both sets of electrodes are located on opposite sides of the flame issuing vertically from burner 107. FIGURE 10 is included to show the placement of two electrodes 108 and 109 having the same current source with respect to flame 110 and burner 111. Suitable brackets, not shown, are employed for holding the electrodes in place.

All the electrodes are coated with insulation. The frequency of the two sets of electrodes can be in phase or out of phase. For example, if one set of electrodes has a frequency of 60 cycles, the other set can have a frequency of 120 cycles or 100, 160, 300 or more cycles. Any desired number and placement of sets of electrodes in a horizontal or vertical plane can be used to provide one or more electrostatic fields having lines of force cutting across the flame at any desired angle.

From the foregoing description it will be observed that when an insulated A.C. electrostatic field is impressed upon a flame containing ion species, the intensity of the combustion process is greatly enhanced. Furthermore, it has been demonstrated that this is entirely a field effect and that the power dissipation is negligible.

There are a great many applications for the invention in areas where a more intense, less smoky, shorter flame is desirable but where costs must be minimal to obtain improved combustion. Most types of domestic and industrial furnaces which use gas burners or oil burners will provide better service when the insulated A.C. field of the invention is applied to the flame area.

1. Apparatus for improving the combustion of a fuel-air mixture formed into a flame having a lengthwise axis, comprising:
dielectric wall means disposed around said flame and being generally parallel to said axis, for means for supplying a fuel-air mixture to the interior of said wall means, first electrode means extending from said fuel-air supply means substantially along said axis of said flame, second electrode means positioned exteriorly of said wall means for establishing an electrostatic field transversely across the lengthwise axis of said flame in cooperation with said first electrode, and means for alternately charging said electrodes to opposite polarities at a predetermined frequency, whereby said electrostatic field enhances said combustion without the dissipation of any substantial quantity of electrical power across said electrodes.

2. Apparatus according to claim 1 in which the frequency is at least 60 cycles per second.

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