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Cottell

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[54] **COMBUSTION METHOD AND APPARATUS BURNING AN INTIMATE EMULSION OF FUEL AND WATER**

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[51] **Int. Cl.** **B05b 3/14**

[58] **Field of Search** 239/422, 432, 428, 239/429, 430, 431, 416.4, 102

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[57] **ABSTRACT**

A combustion apparatus and process in which a water-in-oil emulsion of liquid fuel, such as liquid hydrocarbons, containing from 10 to 50 percent water, the emulsion being produced without any substantial emulsifying agent and preferably by sonic agitation, is burned.

4 Claims, 5 Drawing Figures

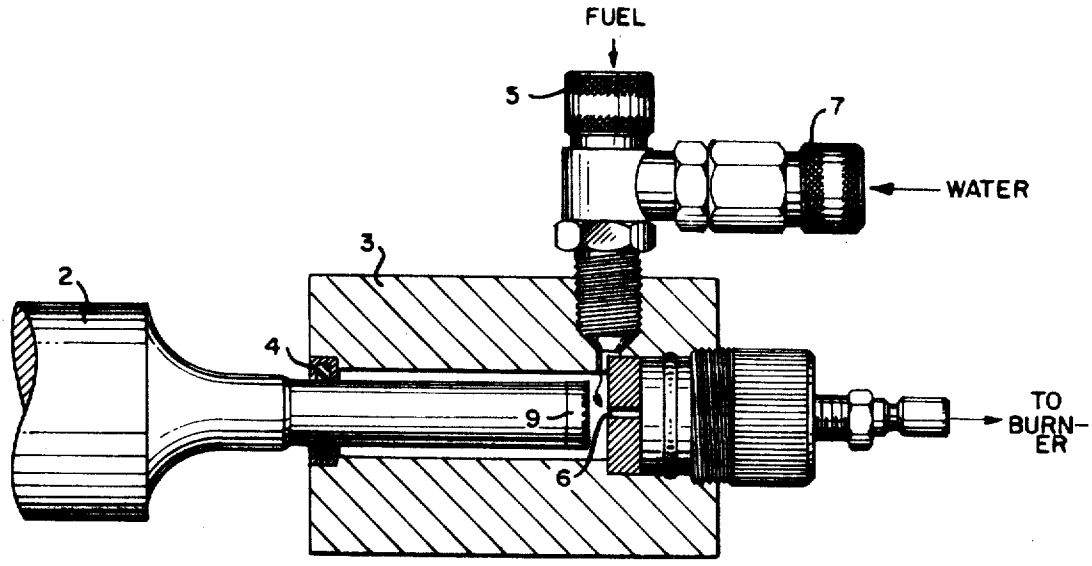


FIG. 1

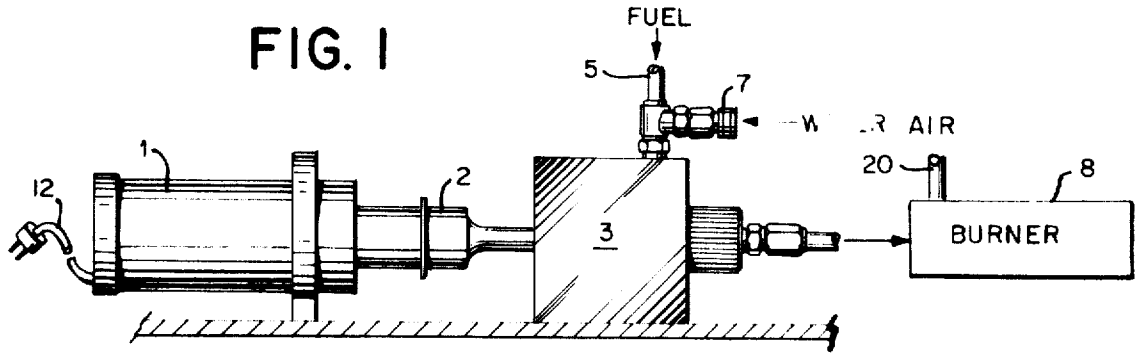
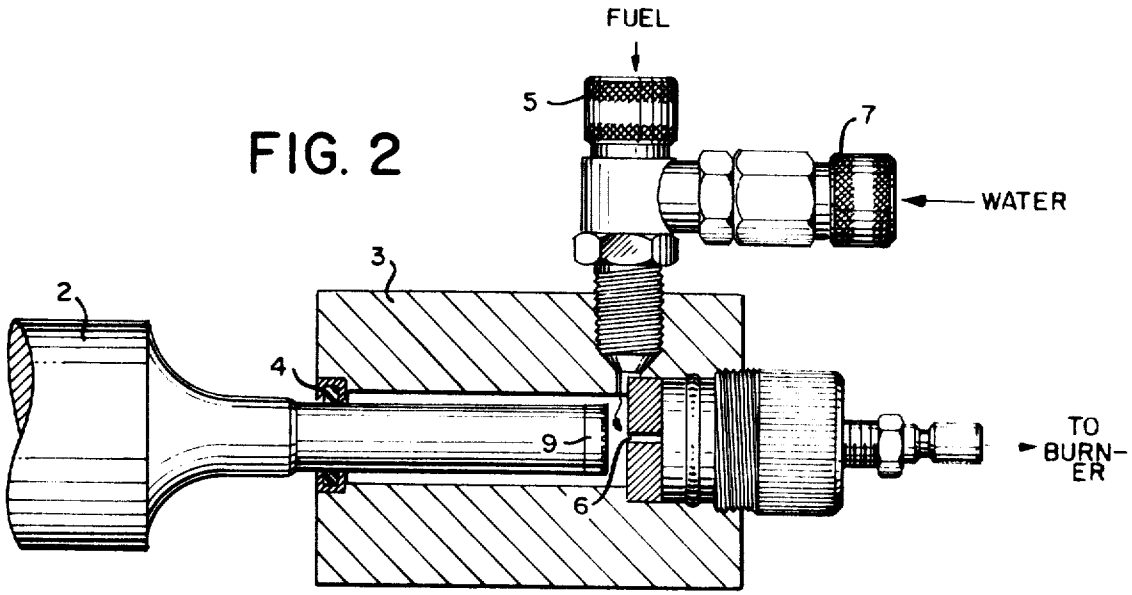


FIG. 2



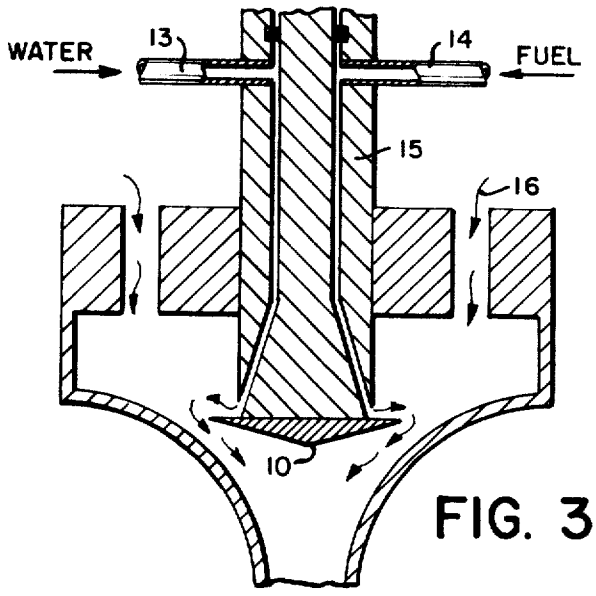


FIG. 3

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FIG. 4

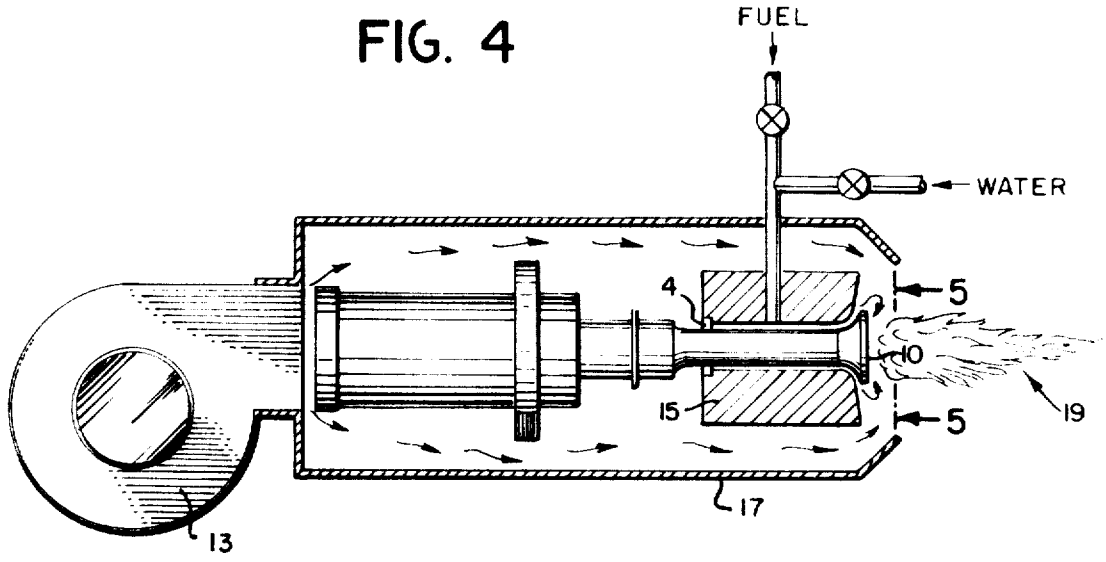
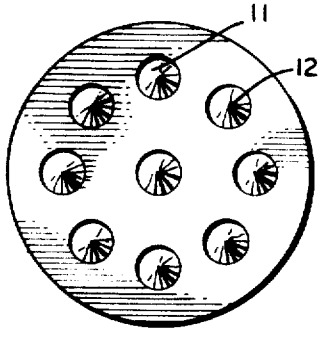


FIG. 5



COMBUSTION METHOD AND APPARATUS BURNING AN INTIMATE EMULSION OF FUEL AND WATER

BACKGROUND OF THE INVENTION

The combustion of liquid fuel, such as liquid hydrocarbons, is a standard method of power and/or heat generation. The combustion may be in a system where the heat is transferred to another medium, such as water, with or without boiling the water, or the fuel may be burned in various types of internal combustion engines, such as those operating on Otto, diesel, or other cycle. The amount of oxygen, usually air, is at least about theoretically sufficient for complete combustion of the fuel elements.

Considerable problems have arisen. If there is a very large excess of oxygen, the efficiency of the combustion process is lowered because a considerable amount of air, including inert nitrogen, has to be heated up. In the case of an internal combustion engine also operating with excessive excesses of oxygen can result in slow combustion, which can overheat and burn out exhaust valves. If the combustion is with amounts of oxygen and fuel more nearly in balance, for example with only a small excess of oxygen, problems arise with incomplete combustion. This can result in excessive amounts of carbon monoxide and/or incompletely burned fuel, which may show up as unburned hydrocarbons, soot, and the like. Incomplete combustion lowers the combustion efficiency and can also contaminate the equipment. In the case of internal combustion engines, unburned hydrocarbons, carbon monoxide, and oxides of nitrogen, generally symbolized by the formula NO_x, are serious atmospheric pollutants as they give rise to photochemical smog and the like. Contamination of nitrogen oxides from an internal combustion engine usually results when combustion temperature is high.

It has been proposed in the past to introduce streams of water into a burner or to inject water into an internal combustion engine as it operates. This has proven to reduce somewhat incompletely burned fuel deposited in the form of carbon, and in the case of internal combustion engines this can lower nitrogen oxide production and also in certain cases, such as aircraft piston engines, permit operating for short times at higher power outputs with very rich mixtures which would otherwise burn up the engine. Water injection, however, has serious drawbacks. In the first place, it is very difficult to control relative amounts of water and fuel precisely. Even if the control is maintained to a satisfactory degree, efficiency drops because the water has to be vaporized, with its extremely high latent heat, and heated up in the combustion, which takes further power because of the high specific heat of water vapor. As a result, water injection has only been practically used in unusual circumstances.

SUMMARY OF THE INVENTION

The present invention burns an extremely fine emulsion of water and liquid fuel, normally hydrocarbonaceous fuel, in which the water droplets are dispersed in an extremely fine average particle size. While the present invention is not absolutely limited to the method by which the emulsion is carried out, it is preferred to emulsify by using an ultrasonic probe or other device which agitates the fuel and water to produce an extraordinarily finely dispersed emulsion, because it is the fine dispersion that produces the important new results which will be set out below; mere presence of water does not.

According to the present invention, if a very fine emulsion is burned, which may have from about 10 percent to as much as 50 percent water, extremely clean combustion results, contamination and pollution are minimized, and in a straight atmospheric burner up to 30 percent of water will give results in which the heat obtained by the combustion is substantially the same as if all hydrocarbon fuel were burned. In other words, with 70 percent fuel and 30 percent water, the emulsion will produce the same amount of heating. This surprising result has been repeatedly tested, and while I do not want to limit the present invention to any particular theory, it seems probable that the combustion of the emulsion is sufficiently more complete so that the smaller amount of fuel is completely burned and the same final heat is obtained as if there were no water present. The above statements are made with respect to a system in which the surfaces which are heated are at a sufficiently high temperature so that water vapor does not condense. In other words, no part of the new result is due to condensation of water vapor on cooler surfaces. In the case of the application to an internal combustion engine, not only are the surfaces hot but the exhaust gases leave an engine cylinder at a temperature greatly above the condensation point of water vapor.

In the internal combustion engine modification of the present invention, while the total amount of power may be as great or, under certain circumstances, even greater, the peak flame temperature is usually lower, and it seems probable that the reduced emission of nitrogen oxide results primarily from this factor. However, this is not known, and the water vapor present in larger amounts as compared to carbon dioxide may also play a part. Therefore, it is not intended to limit the invention to any particular theory, and the above statements are made because I think the factors mentioned are at least some, and conceivably the only, factors involved.

The invention is not limited to the time in the whole operation when the very fine water-in-oil emulsion is actually produced. This may be at the point where atomization takes place just prior or at the point of ignition. This, however, is not necessary, and the emulsion may be preformed and conveyed to the burner nozzle in a preformed state. Particularly with the preferred emulsions obtained by sonic agitation, the emulsion is quite stable and so it can be produced at a point remote from the actual burner itself, and such a modification is of course included. It is also possible to have the emulsion formed by flowing water and oil over the emulsifying point, preferably along the end of a sonic probe, so that the emulsion is formed at the same place, or practically at the same place, as atomization into the flame takes place. In the case of the use of sonic atomization, particularly for internal combustion engine use, it is almost always preferable to have the streams of water and fuel unite just prior to the point of atomization. It is possible, of course, to feed to the sonic atomizer an already formed emulsion, but this requires a separate step and the results are not significantly better. Therefore, particularly in the case of sonic atomization for combustion, and even more particularly in the case of internal combustion engines, it is generally

preferred to have the emulsion formed at the point and as a part of the atomization or atomizing device.

It is an important advantage of the present invention that it is not necessary to use any emulsifying agent, particularly when sonic emulsification is used. This eliminates the added step and, therefore, cost of the emulsion is reduced, although in a broader aspect the present invention does not exclude an emulsion which has been made in the presence of a small amount of an emulsifying agent, such as a small amount, usually a fraction of a percent, of a dialkyl sulfosuccinate or other well known emulsifying agent capable of facilitating the formation of water-in-oil emulsions. The invention in this aspect, which is normally not preferred, may use any known emulsifying agent.

Ordinarily more problems are presented with the burning of heavy residual fuel oil, and this frequently requires steam heating. In the case of the present invention, however, the heavy oil emulsifies more readily than light oil, and when emulsified with a considerable amount of water, the viscosity is low enough so that it can be burned without preheating. This is an additional advantage for use with heavier oils. Why the heavy oil emulsifies more readily and to a lower viscosity has not been fully determined. It is possible that the heavy fuel oil contains contaminants which aid in the emulsification which are not present in the purer lighter fuel oils. It is not intended, however, to limit the present invention to any theory of action.

While, as has been stated, the invention is not limited to any particular method of forming the fine water-in-oil emulsion, sonic emulsification is greatly preferred. It produces emulsions of maximum fineness at very low costs, and so in one further aspect of the invention there is included the combination of forming ultrasonically a fine water-in-oil emulsion and then introducing this into a burner.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows, in diagrammatic form, a sonic emulsifier and a burner;

FIG. **2** is a detail on a somewhat enlarged scale, partly in section, of the emulsifier;

FIG. **3** is a semi-diagrammatic illustration of a combined sonic atomizer and emulsifier, especially useful with internal combustion engines;

FIG. **4** is an illustration of a unitary emulsifier and furnace burner, particularly for larger units, and

FIG. **5** is a horizontal elevation detail of the expanded plate at the end of the probe.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. **1** a sonic generator **1** is shown powering a sonic probe **2** in the form of an acoustic transformer, the end **9** of which extends into a chamber **3** through a flexible seal **4** located substantially at a nodal point of the sonic probe. A stream of fuel, such as house heating fuel oil, is introduced through a conduit **5** and a stream of water joins it through a conduit **7** with a fail safe valve **18** opened by fuel pressure. These two streams strike the vibrating end **9** of the sonic probe, as can best be seen in FIG. **2** where a portion of the chamber **3** is shown in section. The violent sonic agitation emulsifies the two streams, which then leave axially through an outlet conduit **6** in a plate **10** which is located closely adjacent to the vibrating end **9** of the sonic probe. From the outlet conduit **6** the emulsion passes into a conventional burner **8** in a combustion chamber, (not shown). Air is introduced at **20** and a flame results. While the proportions of fuel and water can vary over a wide range, for example from about 10 percent water to about 50 percent water, a very suitable mixture is about 70 percent fuel and 30 percent water.

The sonic probe **2** is of conventional design with a stack of piezoelectric plates, (not shown), which are energized through the cable **12** by a suitable high frequency oscillator, (not shown), which may operate, for example, at a frequency of approximately 20,000 HZ. The plate **9** at the end of the sonic probe **2** may be a flat plate or it may also be provided with a suitable baffle, for example a spiral baffle, to extend the period of residence in the violent sonic agitation field. The sonic generator illustrated diagrammatically is of a common commerical type sold by the Branson Instruments under their trade name "Sonifier." The particular design of the sonic emulsifier has nothing to do with the present invention and the illustration shows merely a typical one.

FIGS. **4** and **5** illustrate a unitary emulsifier and burner for furnace use. The same elements are given the same reference numerals as in FIGS. **1** to **3**. The end of the Sonifier tip is of the general shape shown in FIG. **3**, which will be described further below, and the parts bear the same reference numerals there as in FIG. **3**. It will be seen that in FIG. **4** there is an overall housing through which a blast of air passes from the blower **13**. This air flows over the ultrasonic generator, thus cooling it, which is desirable in a large sized burner, and finally passes over the end of the housing **15**. The fuel and water streams flow into an annular space between the housing **15** and the Sonifier probe. The latter is provided with an end plate **10** which has a series of small annular depressions **11** with a central projection **12** forming the inside of the annulus. This can be seen in FIG. **5**. The clearance between the end of the housing and the plate **10** is quite narrow and is shown somewhat exaggerated in FIG. **4** for the sake of clarity. A film of the fuel and water flows over the plate, where it is emulsified and atomized and thrown some distance to the right, forming a flame, which is diagrammatically shown at **19**.

Combustion results in a boiler were measured in relative times to bring the water in the boiler jacket from a particular temperature to a temperature just below its boiling point. The test accurately measures the relative heating efficiencies and is shown in the following table, which illustrates the results of eight tests, tests 1 to 5 being with straight No. 2 domestic heating oil and tests 6, 7 and 8 with a mixture of 70 percent oil and 30 percent water

	Temperature (1)	Temperature (2)	Time (min)	Material
1.	150°	192°		Oil
2.	150°	194°	4-13	"
3.	150°	194°	4-14	"
4.	146°	192°	4-6	"
5.	144°	194°	3-40	"
6.	146°	194°	3 30	600 oil 325 water
7.	144°	192°	4-20	850 oil 200 water
8.	144°	196°	4-16	800 oil 250 water

Boiler surfaces were carefully examined in the tests and were clean. A flame was produced which was whiter; there was no visible smoke from the chimney, and stack gas analysis showed a more complete and perfect combustion.

FIG. 3 illustrates a modification particularly useful for internal combustion engines. The Sonifier with its probe carry the same reference numerals as in FIGS. 1 and 2, but, as in FIGS. 4 and 5, the shape of the end of the probe is a little different, being expanded out into a plate 10. The plate is flat instead of provided with annular depressions as in FIG. 4. Gasoline was introduced through the conduit 14 into an annular space between the probe and a housing 15, and water was introduced through conduit 13. The two liquids flow down until they come to the edge of the expanded plate 10, where they proceed to flow along the top of the plate and are atomized and emulsified at the same time. Air is introduced adjacent the atomized emulsion through an air conduit 16 and the resulting mixture is fed into the manifold of an internal combustion engine, (not shown).

The plate 10 projects beyond the housing, the clearance between housing and Sonifier being exaggerated as in FIG. 4, and the violent sonic agitation of the plate throws a finely divided emulsion up from the upper surfaces of its projection. As FIG. 3 is designed to connect with a manifold of an internal combustion engine, there will usually be a certain amount of vacuum, and this causes the emulsion to be pulled around the edge of the plate, as is shown by the arrows. Thorough mixing of the air takes place, but it is not necessary that the emulsion be thrown by sonic vibration into the manifold, whereas in FIG. 4 with the horizontal burner this is necessary so that the fine emulsion atomized in the blast of air moves horizontally to form the burner flame. It is for this reason that the actual contact of the plate with the film of fuel and water flowing over it is on its forward face so that it will be thrown in the direction to form the burner flame, for of course in an ordinary burner there is not the vacuum which exists in an internal combustion engine manifold.

FIGS. 3 and 4 and 5 illustrate different forms of Sonifier and emulsion forming plate, but the invention is not limited to the exact shapes shown, nor for that matter to the flat tip face as shown in FIG. 2. These are simply illustrations of typical configurations, but the invention is not limited to the details thereof.

The internal combustion engine fed with a gasoline and water emulsion atomized into the air ran with the same power as on straight gasoline, and pollutants were reduced, unburned hydrocarbons practically zero, carbon monoxide greatly reduced, and nitrogen oxides still more reduced. The figures illustrate the pollutant concentrations, the engine running at about 5,000 rpm under load. It will be noted that the pollutant concentrations are far below present emission standards and even meet more rigid standards proposed for later years. Carbon monoxide 0.94 percent, unburned hydrocarbons 0.0, nitrogen oxide 11.35 ppm.

I claim:

1. A combustion device comprising an ultrasonic probe, a housing surrounding said probe and defining therewith a narrow annular zone, said housing being open at the end of the probe, a plate on the end of the probe of larger cross-section than the probe extending at least to the edge of the housing, the end of the annular zone communicating with the back of the plate, means for introducing two liquids into said annular zone, means for energizing said probe at sonic frequency to vibrate in a longitudinal mode, whereby liquids introduced into the annular space are emulsified and are atomized from the end of the plate on the probe.

2. A combustion device according to claim 1 in which the probe and its housing are surrounded by a second housing, an opening in said second housing opposite the front of the plate on the probe, and means for blowing a stream of gas through the surrounding housing and out through the opening therein, whereby emulsified liquids are atomized by said plate into said stream of gas.

3. A combustion device according to claim 2 in which the plate on the end of the probe has a flat face and an exponentially curved portion projecting into the housing around the probe.

4. A combustion device according to claim 2 in which the plate on the end of the probe has a flat face and an exponentially curved portion projecting into the housing around the probe.

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