United States Patent

[11] 3,586,468

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[21] Appl. No. 759,997
[22] Filed Sept. 16, 1968
[45] Patented June 22, 1971
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[54] **BURNER COMBUSTION CONTROL INCLUDING ULTRASONIC PRESSURE WAVES**
2 Claims, 4 Drawing Figs.

[52] U.S. Cl. 431/1, 431/75, 324/33
[51] Int. Cl. F23n 1/00
[50] Field of Search 431/2, 78, 1, 75; 324/33; 340/228, 228.1, 228.2

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ABSTRACT: An apparatus is provided for the generation and detection of an identifiable electromagnetic wave to determine the presence and characteristics of a zone of ionized fluid, the identifiable electromagnetic signal being generated by propagation of an ultrasonic pressure wave in said fluid, with a receiving means being used to detect and amplify the resultant signal.

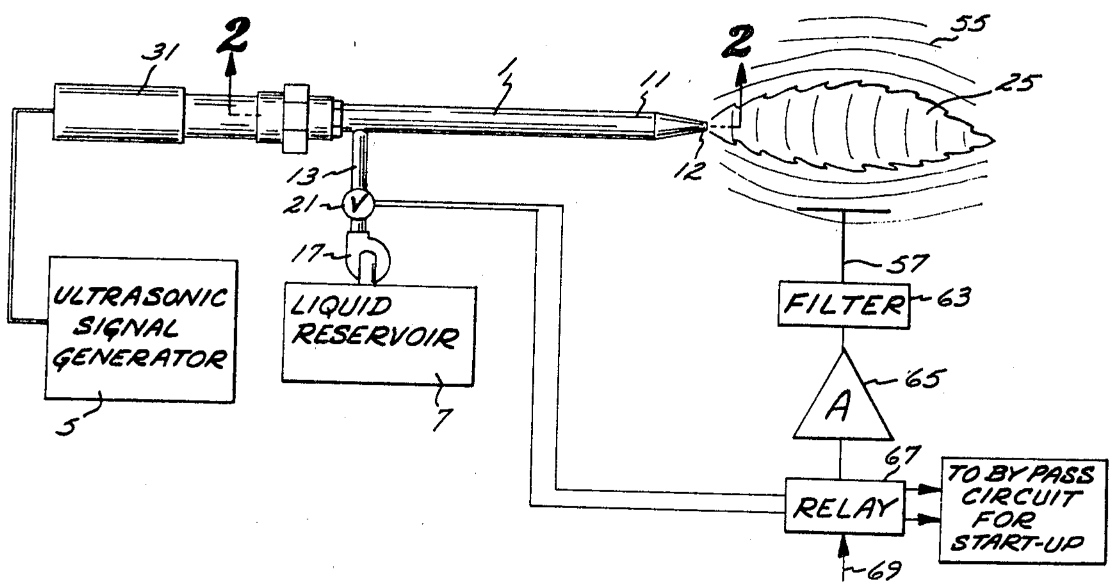


FIG. 1

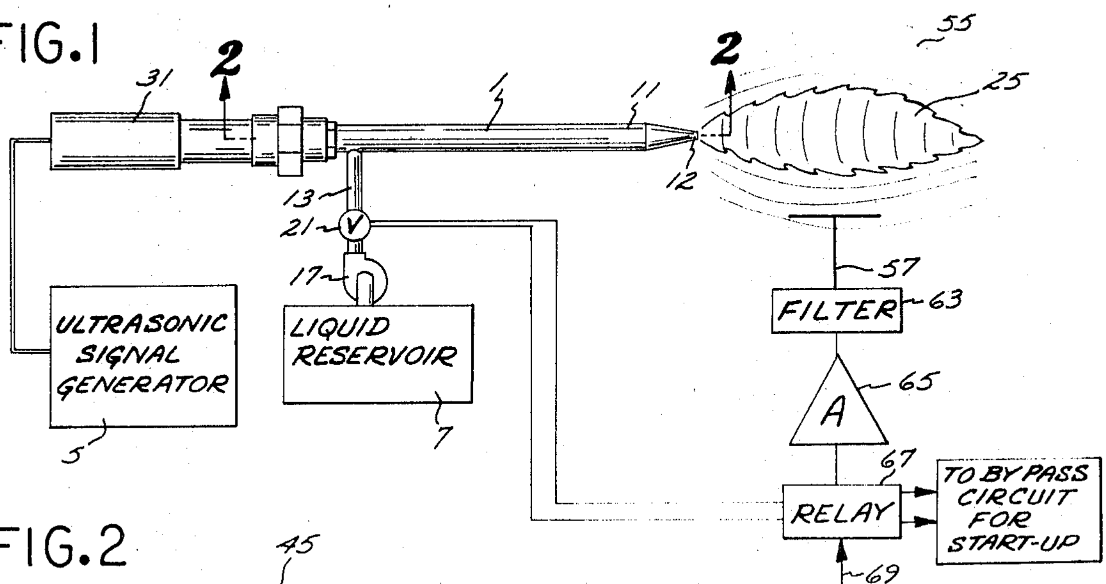


FIG. 2

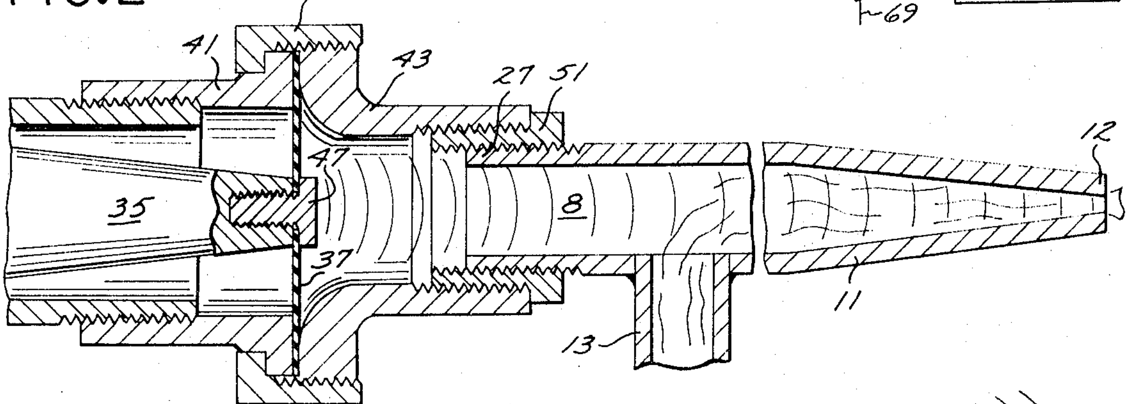


FIG. 3

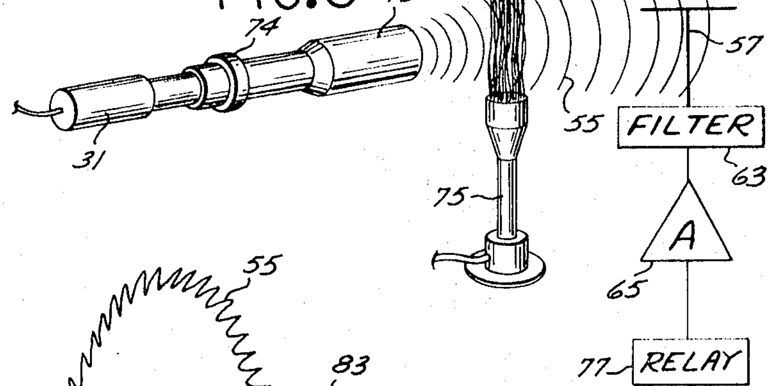
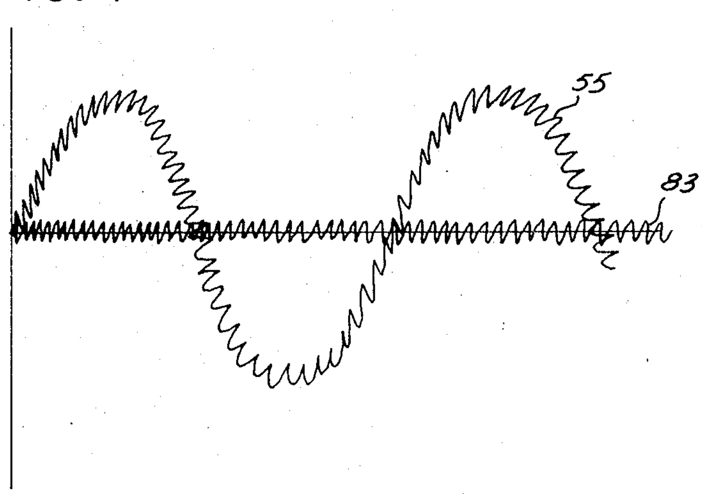


FIG. 4



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BURNER COMBUSTION CONTROL INCLUDING ULTRASONIC PRESSURE WAVES

In all of the various combustion processes, such as in chemical synthesis by oxidation, heaters and gas fired boilers, where extinguishment of the flame can result in a rapid build up of fuel and a possible explosion, it is important to continuously sense the presence or absence of the flame in order to turn off the supply of reactants or fuel supply when the flame goes out. Many of the devices proposed herefore for flame detection rely either upon optical means or else upon the conductivity of the ionized flame zone. In the latter case a current is passed between two or more electrodes immersed in, or immediately adjacent the flame. However, after prolonged use, the flame eventually erodes the electrodes or else forms a relatively nonconductive coating on the electrode surface which seriously impairs their effectiveness. Such devices are therefore unsatisfactory where absolute reliability is required.

The combustion products from the above-described combustion processes used, for example, in heating and manufacture, as well as the exhaust fumes from internal combustion engines are being pointed at as the chief source of air pollution. In all of these combustion processes the unreacted oxygen in the flame combines with incoming atmospheric nitrogen to produce considerable quantities of the several toxic oxides of nitrogen. These oxides which are the primary constituents of photochemical smog must be either eliminated or maintained below tolerable levels if the air pollution problem is to be solved. It has been heretofore necessary in controlling the formation of these nitrogen oxides to employ combustion chambers which either affect burning in two stages, or else employ baffles or like means for obstructing the flow of inlet air to minimize turbulence in the flame zone. However, these measures in combustion chamber design result in lower combustion efficiency, and it is necessary to pay a performance penalty where air pollution is an important consideration.

It is therefore a principal object of the present invention to provide an improved and reliable device for the detection of a flame which can also be used to control the fuel supplied thereto.

Another object is to provide an improved flame detection device which can be used to measure the flame temperature without coming in direct contact with the flame zone.

Still another object is to provide a novel device which can be used to control and minimize the oxides of nitrogen formed in a combustion process.

Yet another object is to provide a device which can be used for measuring the degree of ionization in either a gaseous flame or else in an ion reaction occuring in the liquid state.

To attain the foregoing objects, it was surprisingly found that an electromagnetic signal can be generated in a body of an ionized fluid by propagating a cyclic pressure wave through the ionized fluid at a sufficiently high frequency to produce a signal which is discernible from the background electromagnetic activity of the fluid. The amplitude of the generated electromagnetic signal was found to increase with the degree of ionization and the temperature of the fluid. The temperature of a flame and its relative size can therefore be easily ascertained by measuring the amplitude of the electromagnetic signal emanating therefrom. To generate in a flame an electromagnetic signal which is clearly distinguishable from background static, it is preferred to propagate through the flame zone a cyclic pressure wave in the ultrasonic frequency range, although pressure waves in the audio frequency range can be used when the receiver incorporates a filter for screening out background noise.

In using the device of the present invention it was also unexpectedly found that the content of nitrogen oxides in the combustion products are considerably lower than ordinarily produced, even using the aforementioned combustion chamber designs. For example, when the device of the present invention was employed on a conventional gas fired boiler, it was found that the ordinary nitrogen oxide content of about 400 p.p.m. in the flue gas was reduced at least about 50 percent, and often as much as 60 percent.

Although the mechanism responsible for controlling and inhibiting the formation of these nitrogen oxides is not entirely understood, it is believed that the smooth, cyclic pressure waves propagated through a combustion zone minimizes and controls the rate at which the pressure changes at the interface between the burning fuel and air, and also the extreme pressure fluctuations within the flame. In most cases, the nitrogen oxide level can be reduced by using a smooth, cyclic pressure wave within the ultrasonic frequency range. With combustion processes fed, for example, by conventional hydrocarbon fuels, it is preferred to propagate an ultrasonic signal of from about 20 to 30 Hertz through the flame to affect the desired reduction in nitrogen oxides. Further objects and many of the attendant advantages of the present invention will be readily appreciated as the same becomes more fully understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

FIG. 1 is a schematic diagram of the electromagnetic wave generating and detecting device of the present invention, illustrating particularly the manner in which the flame can be detected and the liquid fuel supply therefore can be controlled;

FIG. 2 is a fragmentary cross-sectional view taken along lines 2–2 of FIG. 1, illustrating the manner in which a pressure wave is propagated through the liquid fuel;

FIG. 3 is a perspective view of an ultrasonic horn adjacent a gasfueled burner, and a schematic diagram of a receiver for detecting the electromagnetic signal emanating from the flame; and,

FIG. 4 contrasts the background electromagnetic wave pattern in a flame with the wave pattern generated with the device of the present invention. With reference now to the drawing, a burner indicated generally at 1 comprises a fuel reservoir 7 and a burner nozzle 11 to which the fuel 8 is supplied via line 13 having therein a fuel pump 17 and a control valve 21. Beyond the tip 12 of nozzle 11, the fuel reacts with oxygen in the air to form a flame or combustion zone 25 of a highly ionized gas (FIG. 2). Connected to the rearward end 27 of nozzle 11 is an ultrasonic transducer 31 which comprises an ultrasonic or oscillatory means 35 having fixedly secured to its end a flexible metal diaphragm seal 37. The outer periphery of diaphragm 37 is held securely between flange 41 and flange 43, which are secured together by a mechanical coupling 45, with a bolt 47 extending through an aperture in the diaphragm and into threaded engagement with the end of horn 35 forming an extension of this horn. A bushing 51 intermediate, and in threaded engagement with flange 43 and the rearward end 27 of nozzle 11, provides a fluidtight seal therebetween.

An ultrasonic signal generator 5 supplies an AC current to the transducer 31, which by means of horn 35, transduces the electric signal into ultrasonic pressure waves which pass through the liquid fuel 8 in the nozzle 11, out the nozzle top 12, and into the combustion zone 25.

As described hereinbefore, it was discovered that these ultrasonic pressure waves generate in the zone of combustion an electromagnetic signal which is discernible from the background noise of the flame. Although the mechanism of the electromagnetic wave generation is not entirely understood, it is believed that the pressure waves propagated by the transducer 31 are of a sufficiently high frequency to affect movement of the free ions in the combustion zone, much as electrical charges are moved in a radio transmitter antenna. In this connection, it was also unexpectedly discovered that the strength and amplitude of the electromagnetic wave is increased as the area of the combustion zone increases, and also the temperature of the flame is increased. Thus, by measuring the strength and amplitude of the resultant electromagnetic signal emanating from a flame, the fuel and air supply thereto can be regulated in order to produce any desired flame temperature and/or optimize the combustion process for maximum heating.

In the devices shown in FIGS. 1 and 2, for example, the electromagnetic wave 55 (FIG 4) propagated from flame or combustion zone 25 is received by antenna 57, and passed through filter 63 to amplifier 65. Since the preexisting turbulence of the gases in the combustion zone create a background static such as illustrated by line 83 in FIG. 4, it is preferred to employ a filter 63 which passes only those frequencies emanating from the flame which correspond to the frequencies of the ultrasonic pressure waves being propagated through the flame. The filtered signal is then preferably amplified and the output from amplifier 65 energizes relay 67, which in turn energizes solenoid valve 21. Power is supplied via conductor 69 to the system in order to hold valve 21 open when relay 67 is energized by the signal from amplifier 65. When the electromagnetic wave, emanating from the flame, is either greatly reduced in strength or else stops entirely, the output from amplifier 65 is insufficient to energize relay 67, and as a consequence, solenoid valve 21 closes, and the supply of fuel is stopped. In place of the on-off valve 21, the fuel and air supply to the flame can be regulated by the assistance of an automatic valve means in the line 13 through which fuel is supplied to the combustion zone, the valve means being actuatable and controlled by the receiving means 67 whereby the output signal from the receiving means regulates the setting of the valve means and correspondingly controls flow of fuel to the combustion zone.

As can be seen, the system of the present invention is particularly suitable as a flame-detecting device, and can be used as such in equipment such as boilers, kilns, furnaces, or other fired equipment. The pressure waves can be transduced either directly into the fuel supply or else into the atmosphere adjacent the flame zone, as shown in FIG. 3. In this latter use, an ultrasonic high gain horn 73 connected by an ultrasonic coupler 74 to ultrasonic transducer 31 generates in the flame zone 25 from gas burner 75, a smooth, cyclic pressure wave. The resultant electromagnetic signal 55 emanating from flame zone 25 is picked up on antenna 57, passed through filter 63 into the amplifier 65, the amplified output then being used to energize relay 77 in the gas fuel line.

The device of the present invention can be used in a chemical synthesis to measure the quantity of certain of the reactants, the rate of reaction, and/or the temperature of the reaction. It has been surprisingly found, in this connection, that the amplitude of the signal generated in a reaction mass is proportional to the degree of ionization and the temperature of the mass. By propagating an ultrasonic pressure wave through a reaction mass, the amplitude of the generated electromagnetic signal can be used in determining the temperature or rate of reaction. For example, in the manufacture of acetylene, by partial oxidation, an ultrasonic pressure wave can be passed through the reaction mass and the amplitude of the generated signal measured to determine the temperature and the ratio of the hydrocarbon feed rate to the oxygen feed rate.

The device of the present invention is particularly advantageous in measuring elevated temperatures without the necessity of subjecting a temperature sensor, such as a thermocouple, directly to the zone of high temperatures, and also in a moving solid-gas reactions where mixing of the solid reaction mass causes erosion of a temperature sensor and severely reduces the longevity thereof.

During the operation of a rotary kiln in the manufacture, for example, of coke or cement, accurate temperature measurement of the reaction mass is extremely difficult to obtain because of the uneven temperature distribution throughout the mass of hot solids, and the wear of a thermocouple in such a moving bed. Previous tests with optical pyrometers have proven unsatisfactory because of the clouds of particulate matter interfere with the transmission of light used in the measurement of temperature. With the aid of the device of the present invention, an ultrasonic horn attached to either the fuel or air supply can be used to generate an electromagnetic signal which emanates from the high temperature mass. By comparing the amplitude of the resultant signal with the amplitude of signals generated under similar conditions at known temperatures, it is thus possible to continuously monitor the bulk temperatures within the kiln.

The device of the present invention can be used to monitor the operation of a jet engine which may experience either a partial or total flame-out while in flight. It is imperative to detect any disruption of the normal combustion within the combustion chamber or chambers of the engine in order to make appropriate corrections before complete and total flame-out occurs. By propagating an ultrasonic pressure wave through the gases in the combustion chamber, there is generated an electromagnetic signal whose amplitude and frequency characterize the operation of the engine. The transducer tip of an ultrasonic horn as described above can form part of the wall of the combustion chamber and the antenna pickup can be located, if desired, external to the engine. It is preferred in most instances to employ a plurality of directional antennas positioned adjacent the engine combustion chamber in order to more accurately pinpoint the source of trouble within the engine.

In still another aspect of the invention, an ultrasonic pressure wave can be propagated through the fuel-air mixture in the cylinder of an internal combustion engine in order to effect ignition of the fuel-air mixture and control extreme pressure perturbations within the burning mixture. The ultrasonic pressure wave is produced in the fuel-air mixture by oscillatory means or vibratory transducer located in and forming a part of the cylinder head. Although the energy required to cause ignition of the fuel-air mixture will vary with the type of fuel and compression ratio of the engine, the exact amount of energy required in any given case to effect ignition can be routinely determined by merely increasing the magnitude of the vibratory energy while turning over the engine until ignition of fuel occurs. Effecting ignition in this manner controls extreme pressure perturbations within the burning fuel-air mixture and inhibits the formation of nitrogen oxides as well as effecting the more complete combustion of the hydrocarbon fuel.

From the foregoing description, it can be readily seen that the present invention provides a simple, practical, and reliable device for detecting a flame as well as measuring its temperature or degree of ionization. The present device thus eliminates the possibility of false operation due to erosion or oxidation of electrodes in a flame zone and facilitates detection of a flame without the need for any mechanical device being in direct contact with the flame.

From the foregoing description, one skilled in the art can easily ascertain the essential characteristics of this invention, and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various usages and conditions. Consequently, such changes and modifications are properly, equitably, and intended to be, within the full range of equivalence of the following claims.

We claim:

1. An apparatus for monitoring the presence and rate of reaction and flame temperature in a combustion zone and adapted to regulate the flow of fuel to a burner supplying fuel to the combustion zone, which comprises: a burner, automatic valve means in the line supplying fuel to said burner, an ultrasonic horn adapted to transduce on ultrasonic pressure wave into the ionized fluid which is being oxidized in the combustion zone and thereby generating a discernible electromagnetic signal whose amplitude varies with the degree of ionization and temperature of said fluid, and receiving means to detect said signal and resultant amplitude and to provide an output signal to regulate the setting of said valve means and correspondingly control the flow of fuel to the combustion zone.

2. The apparatus of claim 1, wherein the ultrasonic pressure wave is impressed into unreacted fuel to be oxidized in the combustion zone.