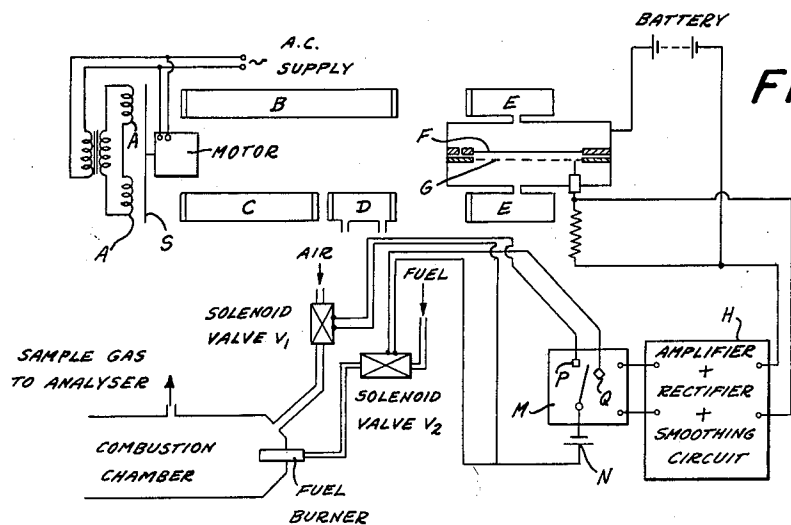
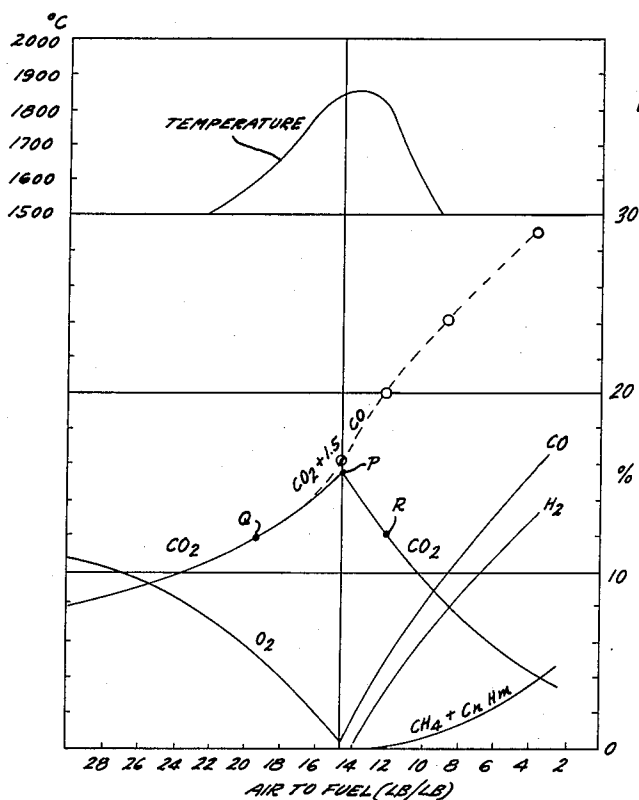


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MEANS FOR ANALYSING COMBUSTION PRODUCTS
AND VARYING AIR FUEL RATIO
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MEANS FOR ANALYSING COMBUSTION PRODUCTS AND VARYING AIR-FUEL RATIO
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1 Claim. (Cl. 236-15)

It is well known that when any carbonaceous fuel is being burnt in a furnace or other equipment for producing heat or power, optimum performance is obtained by careful adjustment of the air/fuel ratio. If the air supply is limited complete oxidation of the combustible material is not attained and, on the other hand, if excess air is employed combustion is complete but the products of combustion are diluted and heat is wasted in heating the excess air.
Given a reliable CO₂ meter, conditions can be varied until maximum CO₂ is obtained in the exhaust gas and this will correspond approximately to optimum working conditions.

An alternative is to determine CO, for which purpose an infra red gas analyser is convenient, and then one operates close to zero CO. Yet another method is to measure the temperature of the burning gas, but this is difficult since the temperature is generally very high and the value will only be useful if the rate of fuel consumption is kept constant.

All of these methods suffer from the disadvantage that the optimum working point tends to correspond to either a maximum (CO₂ and temperature) or zero (CO). Thus there is no continuous indication throughout a useful air-fuel range on both sides of the optimum value. If for example the CO₂ meter indicates 12% CO₂, one may be operating on either side of the optimum value and as the percent CO₂ falls on both sides of the optimum value it is not obvious whether the air or the fuel supply should be increased. Consequently it is not normally possible to use automatic control of air/fuel ratio to maintain optimum combustion efficiency.

The object of the present invention is to provide means whereby this difficulty may be overcome and a continuous indication obtained.

In the combustion control of the present invention the concentration of CO and CO₂ in the products of combustion are added in certain proportions such that the summation increases as the air/fuel ratio decreases, said air/fuel ratio being varied automatically in accordance with variation in the value of said summation.

The invention provides combustion control means comprising an infra-red gas analyser through which the products of combustion are passed, the analyser being made sensitive to carbon monoxide and carbon dioxide and relatively insensitive to the other gases present, the output signal of the analyser being made proportional to a value (CO₂)+k(CO) where (CO₂) and (CO) represent the concentrations of those gases in the combustion products and k is a constant appropriate to the combustion equipment in use, the value of k being chosen so that (CO₂)+k(CO) increases as the air/fuel ratio decreases, the arrangement being that variation of the analyser output because of variation of the value (CO₂)+k(CO) from a predetermined value is used to vary the air/fuel ratio until such time as the original value is restored.

Referring to FIGURE 1 the curves shown are representative of those obtained when burning heavy fuel oil in a combustion chamber.

It will be seen that the optimum working point P tends to correspond to either maximum CO₂ and maximum

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temperature, or minimum CO. Thus, if, for example, it were found by means of a CO₂ meter that there is 12% CO₂ present one may be operating at either point Q or point R and it is not obvious whether the air or the fuel should be increased.

The present invention overcomes this difficulty by arranging for the output of an infra-red gas analyser for analysing the products of combustion, to be made proportion to a value (CO₂)+k(CO) where (CO₂) and (CO) represent the concentration of those gases and k is a constant appropriate to the particular combustion equipment in use.

By way of example values from FIGURE 1 will be considered and a value of (CO₂)+k(CO) determined in each case using a value for k of 1.5.

Air to fuel, lb./lb.-----	28	19	14.5	12	8.5	3.5
CO ₂ (percent)-----	8	12	15.5	12	8	4
CO (percent)-----	0	0	0.5	5.5	10.5	16.5
CO ₂ +1.5 CO-----	8	12	16.25	20	24	29

By arranging for the gas analyser to be 1.5 times as sensitive to CO as to CO₂, the instrument indication is proportional to (CO₂)+1.5(CO) as shown in the bottom row of figures. This quantity increases regularly as the air/fuel ratio is decreased over the whole range and can therefore be used for maintaining automatically fixed combustion conditions. For example, if the optimum CO₂ production is desired, CO₂+1.5CO is set to 16.25 and the automatic control gear will maintain

(CO₂)+1.5(CO)

at this value and (CO₂) at 15.5%. If (CO₂)+1.5(CO) drops below 16.25, air/fuel is automatically reduced while if (CO₂)+1.5(CO) rises above this value air/fuel is increased.

A preferred form of apparatus for carrying out the invention is described with reference to FIGURE 2, in which infra-red radiations from heaters A, A pass through absorption tubes, B, C, D, into receiving chambers E, E, said tubes and chambers being provided with windows suitable for the transmission of desired radiations. The chambers E, E communicate with a central compartment divided into two parts by an electrode of thin metal foil F and adjacent to F is a perforated insulated electrode G so arranged that a small deformation of the metal foil electrode gives rise to a change of capacitance between F and G. The chambers E, E and central compartment contain a mixture of CO₂ and CO so that wavelengths close to 4.25 and 4.7μ are absorbed from the incident radiations by these gases respectively. Assume at first that tubes B, C and D contain no absorbing gas so that the maximum amount of energy is absorbed by the CO/CO₂ mixture in chambers E, E.

A rotating shutter S allows radiation to pass intermittently but simultaneously through tubes B and C, finally to enter chambers E, E so that each time the shutter opens energy is absorbed by the gas in E, E and the pressure increases steadily so long as radiation is passing through the gas, falling away again when the radiation is shut off and the gas cools. Since, however, the pressure variations operate simultaneously on opposite sides of the flexible diaphragm, provided that by means of an adjustable shutter the pressure variations are made equal, the forces on opposite sides of the diaphragm will balance and no deformation of the diaphragm will occur.

If now, however, a sample gas from the combustion chamber is passed into tube D any CO or CO₂ present will absorb energy and therefore diminish the quantity entering the corresponding chamber E. Every time shutter S opens a pressure pulse will therefore deform

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the diaphragm F which will consequently vibrate at the frequency of interruption of the shutter with an amplitude dependent on the energy absorbed in tube D, and the resulting variation in capacitance is caused by known means to produce a small alternating voltage which is amplified by a conventional amplifier H. The rectified and smoothed signal from H is measured with a meter M which is provided with two contacts P and Q placed respectively a little below and a little above the desired operating point.

A minute gas leak is provided across diaphragm F between chambers E, E, so that although the leak is too small to cause any appreciable reduction in sensitivity of the detector, long term pressure differences to temperature effects or unequal gas adsorption are equalised and do not deform the diaphragm.

Since CO_2 absorbs more intensely than CO it is necessary to reduce the sensitivity of the instrument to CO_2 relative to CO so that the desired sensitivity ratio can be obtained. This result can be achieved in various ways but a convenient method is to fill or partially fill tube C with CO_2 and seal it off so that the subsequent absorption by CO_2 in the sample gas is reduced to the required level.

It is preferable also partially to fill tube B with CO_2 to counter-balance the absorption in tube C, since the stability of the instrument is thereby improved.

Supposing now that $(\text{CO}_2) + k(\text{CO})$ (where $k=1.5$) increases above the correct operating value, the output as shown by meter M will rise and contact with Q will be made, so completing the circuit from a battery through a solenoid-operated valve V_1 , which is arranged to increase the flow of air into the combustion chamber and so reduce $(\text{CO}_2) + k(\text{CO})$. Conversely, if

$$(\text{CO}_2) + k(\text{CO})$$

falls below the correct operating value, contact P will be made and a solenoid-operated valve V_2 will effect an increase in the flow of fuel.

This particular mode of operation is only given by way of example and other methods, e.g. those involving self-balancing gas analysers and/or proportional controllers can be employed.

The essential feature of the form of invention described and illustrated in FIGURE 2 is the utilisation of a gas analyser sensitive to the presence of CO and CO_2 , but insensitive to all other gases present, and with provision for the ratio of sensitivities to CO and CO_2 to be adjusted to the value necessary for the control of a particular piece of combustion equipment, a convenient means of providing said adjustment being through the inclusion in the optical path containing the sample gas of a filter tube containing a fixed quantity of CO_2 .

While the use of an infra-red gas analyser sensitive to CO_2 and CO obviously has attractive features, it is quite possible to use two separate infra-red gas analysers, one for each gas and electrically to combine the two outputs in the desired proportions, or even to use quite other forms of gas analyser.

An alternative form of infra-red gas analyser might depend on the radiations emitted from CO_2 and CO in the flame resulting from the combustion process, since it is well known that gases when heated emit radiations at wavelengths close to those capable of being absorbed at normal temperatures. To detect these high temperature radiations a detecting condenser of the type already de-

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scribed and filled with CO_2 , CO or a mixture of the two gases, can be employed, while another possibility is to employ optical filters which can now be produced by known means to isolate narrow spectral regions appropriate to the gas to be determined, e.g. 4.25μ for CO_2 and 4.7μ for CO, and then to utilise a non-selective or partially selective detector such as a thermocouple, bolometer, semiconductive cell, photoelectric cell or magnetophotocell to measure finally the radiations falling on said detector.

A similar arrangement can be employed as an absorptiometer wherein radiations emitted by an infra-red source at, say, 700°C . are passed through an isolating filter, absorption cell containing the gas to be analysed and are then made to impinge, preferably after optical condensation, on to the detector. In place of an infra-red filter, it may be possible in certain cases to substitute known radiation dispersive systems employing prisms, diffraction gratings, or a combination of the two, to isolate a desired spectral region.

I claim:

In combustion control means for the analysis of combustion products and varying the air/fuel ratio in response to variation of the carbon monoxide and carbon dioxide content thereof, an infra-red gas analyser for the measurement of the carbon monoxide and carbon dioxide content, the output signal of said analyser being proportional to a value $(\text{CO}_2) + k(\text{CO})$ where (CO_2) and (CO) represent concentration of those gases in the combustion products and k is a constant appropriate to the combustion equipment in use, the value of k being chosen so that $(\text{CO}_2) + k(\text{CO})$ increases the air/fuel ratio decreases, the arrangement being that variation of the value $(\text{CO}_2) + k(\text{CO})$ from a predetermined value is used to vary the air/fuel ratio until such time as the original value is restored, in which the gas analyser comprises an infra-red gas analyser having two beam paths one containing the sample to be analysed and the other a comparison substance the beams of radiation leaving each path falling on a detecting unit having a detection chamber in each path containing a mixture of carbon monoxide and carbon dioxide, the two detecting chambers being separated by a thin metal diaphragm adjacent an electrode such that any difference in pressure between the chambers produces an electric signal, a sealed tube being introduced into the sample path containing a predetermined quantity of carbon dioxide to reduce the absorption of carbon dioxide in the sample path to a level such that the output signal from the detecting unit is proportional to a value

$$(\text{CO}_2) + k(\text{CO})$$

References Cited in the file of this patent

UNITED STATES PATENTS

1,591,444	Stein	July 6, 1926
1,645,350	Reineke	Oct. 11, 1927
1,770,489	Löffler	July 15, 1930
2,269,674	Liddel et al.	Jan. 13, 1942

FOREIGN PATENTS

496,436	Germany	Apr. 23, 1930
500,700	Germany	June 24, 1930
645,576	Great Britain	Nov. 1, 1950
698,023	Great Britain	Oct. 7, 1953