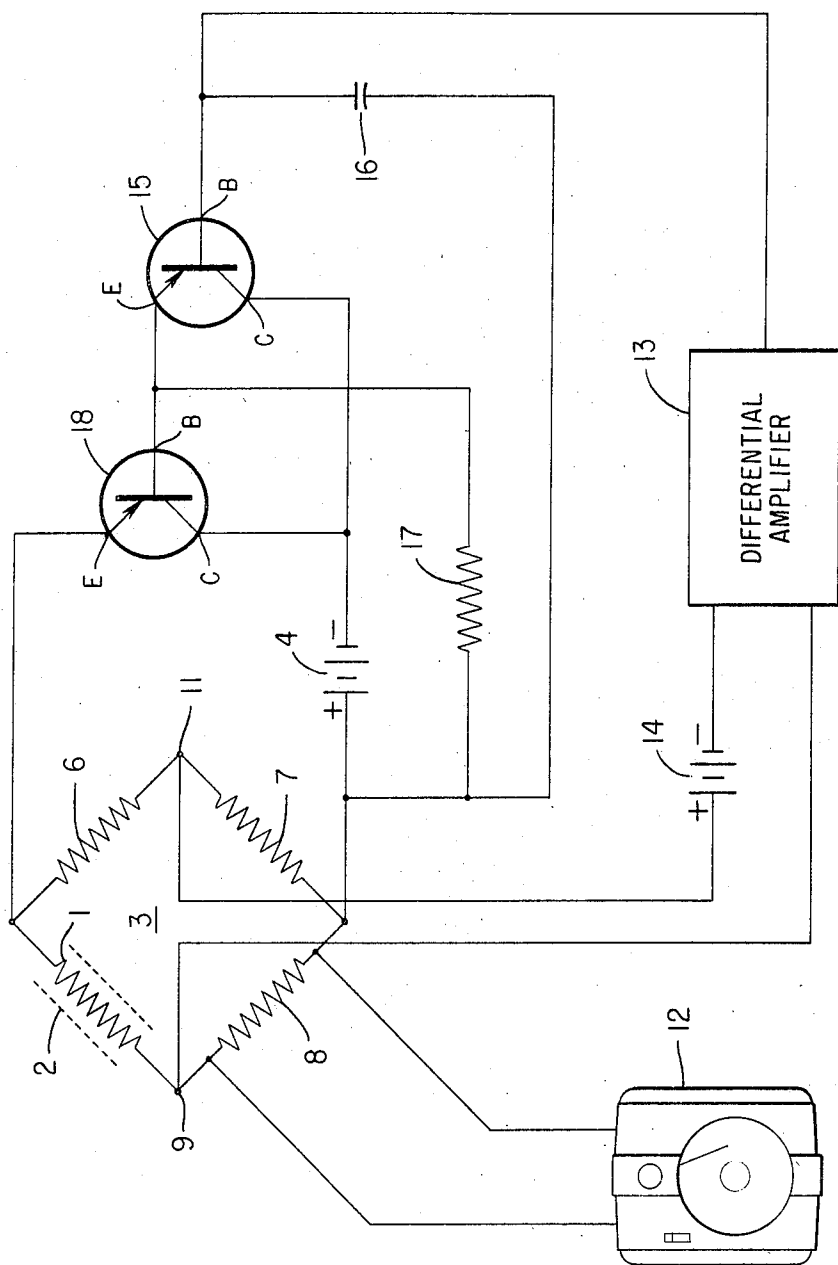


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GAS ANALYSIS METHOD FOR DETERMINING THE OXYGEN CONTENT
OF A GAS CONTAINING CARBON DIOXIDE
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GAS ANALYSIS METHOD FOR DETERMINING THE OXYGEN CONTENT OF A GAS CONTAINING CARBON DIOXIDE

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5 Claims

ABSTRACT OF THE DISCLOSURE

A method for determining the oxygen content of a gas containing carbon dioxide (CO₂) by maintaining a heated filament at a constant temperature between 700° F. and 800° F. to minimize the effect of the endothermic H₂+CO₂=CO+H₂O reaction, the CO₂ and H₂O thermal conductivity effect and the specific heat effect.

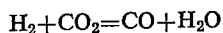
This invention relates to improvements in the detection and measurement of the oxygen content of a gas. In particular this invention relates to the method of measuring the oxygen content of a gas and eliminating the effect of the endothermic reactions, thermal conductivity effects and effects of specific heat.

It has long been recognized that the presence of carbon dioxide (CO₂) introduces an error when measuring the oxygen content of a gas by means of catalytic combustion around a heated platinum filament. In the past this error was simply ignored on the basis that it was small and insignificant. Now, however, with the need for greater accuracies in the measurement of oxygen content, this error cannot be ignored.

One of the most common and widely accepted methods of gas constituent measurement in use today is by means of catalytic combustion around a heated filament. Usually the filament is made of platinum and connected as one leg of a Wheatstone bridge circuit. The bridge current heats the platinum filament to the level necessary for catalytic combustion of the gas. Combustion of the gas raises the filament temperature and consequently its resistance. The amount of heat generated by the gas burning is directly related to its oxygen content. Thus, the filament resistance varies as the oxygen content of the gas being measured. With the filament as one leg of a Wheatstone bridge the change of filament resistance causes the bridge to be unbalanced; the magnitude of the unbalance is a measure of oxygen content.

The catalytic combustion method for analysis of oxygen in a gaseous mixture employs the combining of a gas sample with a standardized fuel, such as hydrogen. The fuel and oxygen bearing gas are exposed to the heated filament where it burns and raises the filament temperature. This method works very well and is accurate unless carbon dioxide (CO₂) is present, then an error is introduced. Formerly, it was believed this error was due only to the thermal conductivity of the CO₂.

Now, however, it has been proven that the CO₂ error is due to the combined effect of the specific heat and thermal conductivity of the CO₂, the endothermic



reaction, and the thermal conductivity of H₂O. Thermal conductivity of CO₂ tends to increase the catalyst temperature as does the thermal conductivity of H₂O; the endo-

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thermic H₂+CO₂=CO+H₂O reaction and the specific heat tend to lower the catalyst temperature. When there is an excessive amount of hydrogen available the reaction CO₂+4H₂=CH₄+2H₂O also introduces an error due to the presence of methane.

It is an object of my invention to provide a method for eliminating the CO₂ effect when measuring the oxygen content of a gas.

Another object of my invention is to provide a method for measuring the oxygen content of a gas wherein I maintain the filament at a constant temperature to eliminate the effect of the endothermic H₂+CO₂=CO+H₂O reaction, the CO₂ and H₂O thermal conductivity effect and the specific heat effects.

Still another object of my invention is to provide a method for determining the oxygen content of a gas by measuring the change in current required to maintain the filament at a constant temperature.

Another object of my invention is to provide a method for determining the oxygen content of a gas by maintaining a heated platinum filament at a constant temperature between 700° F. and 800° F. to minimize the effect of the endothermic H₂+CO₂=CO+H₂O reaction, the CO₂ and H₂O thermal conductivity effect and the specific heat effect.

These and various other objects of my invention will be particularly pointed out in the appended claims and will be apparent from the following description taken in conjunction with the drawing.

Referring to the drawing, I show schematically a Wheatstone bridge measuring circuit including a heated filament and a control circuit for maintaining said filament at a constant temperature.

In particular, I show a platinum measuring filament 1 enclosed within a chamber 2, shown schematically, through which the oxygen bearing gas and fuel are passed at a constant rate of flow. For a description of the general operation of analyzers of this design, reference is made to United States Patent No. 2,420,430 issued to C. Johnson. The measuring filament 1 comprises one leg of a Wheatstone bridge 3 supplied by a direct current source 4, shown as a battery. Current flowing from the source 4 through the measuring filament 1 raises its temperature to a point where exposing the filament to an oxygen-fuel mixture causes said mixture to burn.

The Wheatstone bridge 3 also consists of two calibrating resistors 6 and 7 and a dropping resistor 8. Through proper selection of the calibrating resistors 6 and 7 the bridge output voltage between terminals 9 and 11 will be zero when the measuring filament 1 is at the desired operating temperature. Connected across the dropping resistor 8 and responsive to the voltage drop developed across said resistor is a circular chart recorder 12. Various circular chart or strip chart recorders can be used to record the voltage drop across the resistor 8, the operation of these recorders is well known and no description is deemed necessary. Certain adjustment circuits would be required in the recorder to calibrate the full scale deflection of the recording pen to coincide with the range of voltages developed across the resistor 8 as the oxygen content of the gas varied from zero percent to maximum.

Exposing the measuring filament 1 to an oxygen bearing gas causes catalytic combustion to take place thereby raising the filament temperature and its resistance. As a result, the Wheatstone bridge 3 is unbalanced and a voltage difference exists between terminals 9 and 11. Connected to

the bridge terminal 9 is one input of a differential amplifier 13; connected to the bridge terminal 11, through a bias supply 14, shown as a battery, is the second input of the differential amplifier 13. Operationally, the differential amplifier 13 is well understood, in my circuit it amplifies the voltage difference between the bridge terminals 9 and 11 and generates, at its output terminal, a voltage inversely proportional thereto.

To maintain the temperature of the measuring filament 1 at the desired predetermined level, in accordance with the objects of my invention, I connect the first stage of a two-stage emitter-follower amplifier to the output of the differential amplifier 13 and the second stage in series with the power supply 4. The first emitter-follower stage consists of a transistor 15 having a base electrode B connected to the output of the differential amplifier 13 and a collector electrode C connected to the negative side of the power supply 4. Also connected to the base electrode B of the first stage transistor 15 is a capacitor 16. A bias resistor 17 interconnects the emitter electrode E of the first stage transistor 15 and the base electrode B of the second stage transistor 18 to the positive terminal of the power supply 4. The second stage transistor 18 controls current flow from the power supply 4 through the Wheatstone bridge 3. Connected to the negative side of the power supply 4 is the collector electrode C of the second stage transistor 18, the emitter electrode E of this transistor connects to the junction of the filament 1 and the calibrating resistor 6.

It should be obvious to those skilled in the art that the system heretofore described is only one of many that can be used to carry out the objects of my invention. As I have emphasized, the important feature of my invention is to maintain the filament temperature at a constant value to eliminate the errors produced by various reactions and CO_2 and H_2O thermal conductivity effects. To minimize the various endothermic reactions, thermal conductivity effects and specific heat effects, the measuring filament 1 must be operated at a temperature between 700°F . and 800°F . The system I have shown and described maintains a correct temperature by controlling the current flow through the collector-emitter junction of the second stage transistor 18.

In operation of the circuit, initially the Wheatstone bridge 3 must be balanced using a gas having zero percent oxygen content (a calibrating procedure). The calibrating resistors 6 and 7 are adjusted until the temperature of the filament is between 700°F . and 800°F . and the bridge output is zero. Exposing the measuring filament 1 to an oxygen bearing gas by passing the gas through the chamber 2 causes said gas to burn thereby increasing the filament temperature and changing its resistance. The ratios of the bridge arms are no longer equal and a voltage difference develops between the bridge terminals 9 and 11. A signal inversely proportional to the bridge unbalance between terminals 9 and 11 will be generated at the output of the differential amplifier 13 thus lowering the base drive voltage connected to the first stage transistor 15. With the base electrode B of the second stage transistor 18 connected to the emitter electrode E of transistor 15 the second stage transistor base drive voltage will likewise be lowered. Reducing the base drive voltage to the second stage transistor 18 reduces its collector-emitter current flow thus lowering the current flow through the measuring filament 1. Reducing the current flow through the filament 1 lowers its temperature and its resistance value. This operation continues until the bridge ratios are again equal and the voltage difference between terminals 9 and 11 is zero.

Since the current flow through the filament 1 and the dropping resistor 8 varies inversely with the oxygen content of the gas, the voltage drop across the resistor 8 is a measure of oxygen content. The recorder 12 responds to the voltage drop across the resistor 8 thus indicating and recording the oxygen content of the gas.

In accordance with the patent statutes, I have described my invention in terms of a preferred embodiment. The invention may be practiced otherwise than as described and still be within the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A method of determining the oxygen content of a gas containing carbon dioxide (CO_2), comprising: mixing the gas to be analyzed with hydrogen to produce a combustible mixture; exposing a heated catalytic measuring means in one leg of a Wheatstone bridge to said combustible mixture; burning said combustible mixture in the presence of said measuring means; measuring the unbalance voltage across said Wheatstone bridge caused by the catalytic combustion of said combustible mixture; and maintaining said measuring means at a constant temperature between 700°F . and 800°F . to minimize the effect of the reaction $\text{CO}_2 + 4\text{H}_2 = \text{CH}_4 + 2\text{H}_2\text{O}$, the H_2O thermal conductivity effect and the CO_2 thermal conductivity and specific heat effects.

2. A method for determining the oxygen content of a gas-fuel mixture containing carbon dioxide (CO_2), said method minimizing the effect of the endothermic $\text{H}_2 + \text{CO}_2 = \text{CO} + \text{H}_2\text{O}$ reaction, the H_2O thermal conductivity and CO_2 thermal conductivity and specific heat effects comprising:

mixing the gas to be analyzed with hydrogen to produce a combustible mixture; exposing a heated catalytic measuring filament in one leg of a Wheatstone bridge to the gas-hydrogen mixture thereby causing catalytic combustion of said mixture; measuring the unbalance voltage across said Wheatstone bridge caused by the catalytic combustion of said gas-fuel mixture; and adjusting the power source supplying said Wheatstone bridge in response to said unbalance voltage to maintain the measuring filament temperature between 700°F . and 800°F . thereby minimizing the effect of the $\text{H}_2 + \text{CO}_2 = \text{CO} + \text{H}_2\text{O}$ endothermic reaction, the H_2O thermal conductivity and CO_2 thermal conductivity and specific heat effects.

3. A method for determining the oxygen content of a gas-fuel mixture containing carbon dioxide (CO_2), said method minimizing the effect of the endothermic $\text{H}_2 + \text{CO}_2 = \text{CO} + \text{H}_2\text{O}$ reaction, the H_2O thermal conductivity and the CO_2 thermal conductivity and specific heat effects, comprising:

mixing the gas to be analyzed with hydrogen to produce a combustible mixture; passing the gas-hydrogen mixture over a heated catalytic measuring filament at a constant rate of flow, said filament comprising one leg of a Wheatstone bridge; burning the gas-hydrogen mixture in the presence of said filament thereby generating a voltage across said bridge; and adjusting the power source supplying said Wheatstone bridge in response to said bridge output to maintain the measuring filament temperature between 700°F . and 800°F . thereby minimizing the effect of the endothermic $\text{H}_2 + \text{CO}_2 = \text{CO} + \text{H}_2\text{O}$ reaction, the H_2O thermal conductivity and the CO_2 thermal conductivity and specific heat effects.

4. The method of claim 3 including measuring the current flow through said filament to determine the oxygen content of the gas-fuel mixture containing carbon dioxide.

5. A method for determining the oxygen content of a gas-fuel mixture containing carbon dioxide (CO_2), said method minimizing the effect of the endothermic $\text{H}_2 + \text{CO}_2 = \text{CO} + \text{H}_2\text{O}$ reaction, the H_2O thermal con-

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ductivity and CO₂ thermal conductivity and specific heat effects, comprising:

- mixing the gas to be analyzed with hydrogen to produce a combustible mixture;
- exposing a heated catalytic measuring filament in one leg of a Wheatstone bridge to the gas-hydrogen mixture being analyzed thereby causing catalytic combustion of said mixture;
- measuring the unbalance voltage across said Wheatstone bridge caused by the catalytic combustion of said gas-fuel mixture;
- generating a control signal proportional to the magnitude of said unbalance signal; and
- controlling the current flow through said measuring filament as a function of the magnitude and polarity of said control signal to maintain its temperature

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between 700° F. and 800° F. thereby minimizing the effect of the endothermic reaction and the thermal conductivity and specific heat effects.

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JOSEPH SCOVRONEK, Primary Examiner

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