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March 28, 1939. B. MILLER 2,152,439

METHOD OF AND APPARATUS FOR ANALYZING GAS

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Fig. 1.

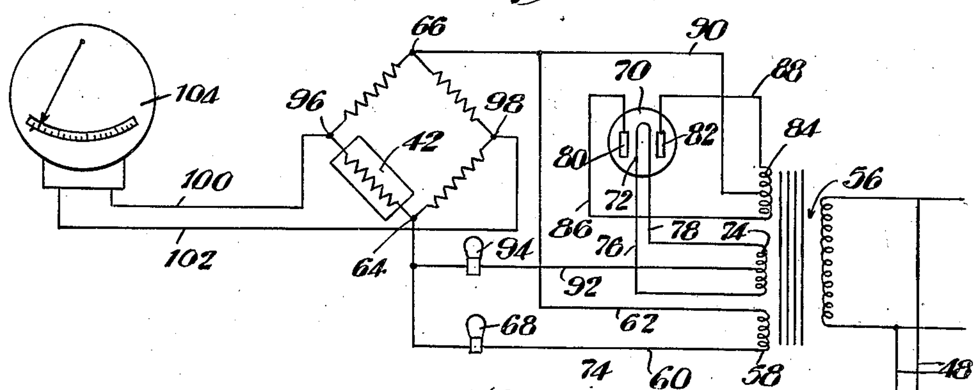


Fig. 3.

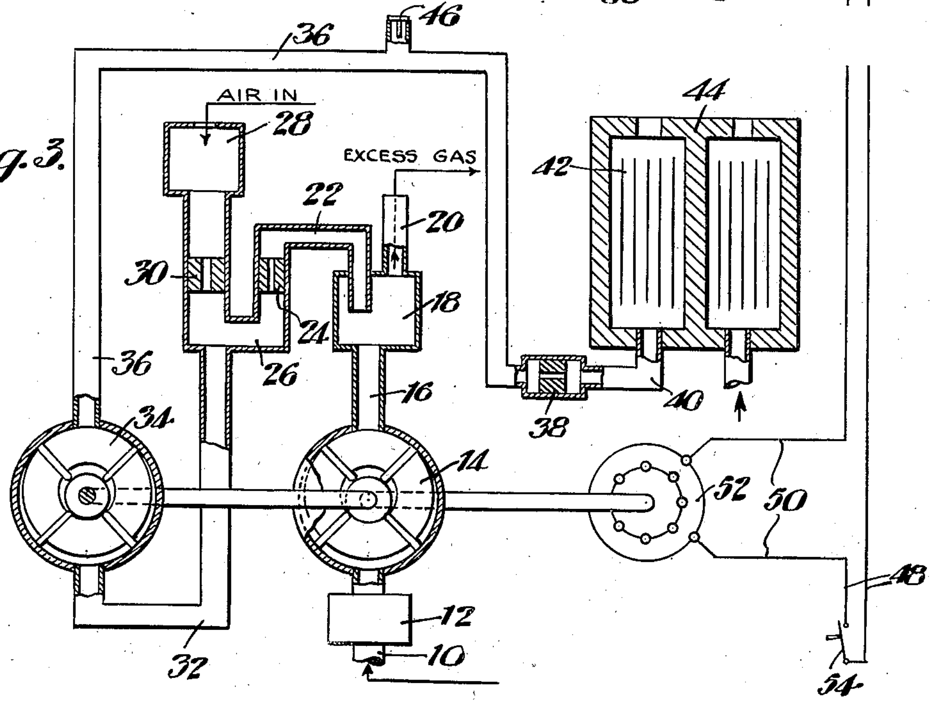
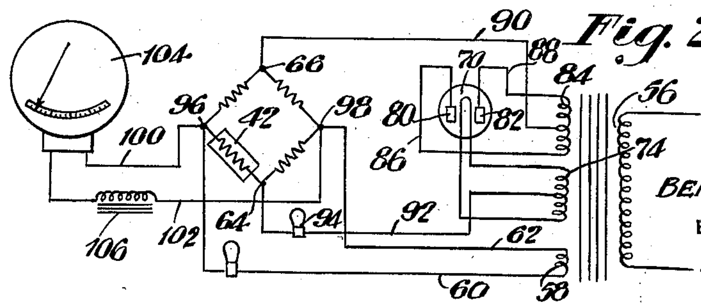


Fig. 2.



INVENTOR
BENJAMIN MILLER
BY
ATTORNEY

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METHOD OF AND APPARATUS FOR ANALYZING GAS

Benjamin Miller, Richmond Hill, N. Y., assignor to Power Patents Company, Hillside, N. J., a corporation of Maine

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7 Claims. (Cl. 23—232)

This invention relates to a method of and apparatus for analyzing gases containing combustible constituents to quantitatively determine the calorific value of the gases. The apparatus of the present invention finds its special utility as an apparatus for analyzing the exhaust gases of automotive engines to determine the percentage of combustible constituents in the gas and thus indicate the combustion efficiency of the engine in which the gases have been burned.

The invention finds more special application in that type of gas analyzers in which the gas to be analyzed is mixed with air and passed into contact with a catalyst wire positioned as one arm of a Wheatstone bridge wherein the catalyst wire acts to assist in burning the combustible of the gas and at the same time the catalyst wire is used to measure the temperature rise due to combustion of combustibles in the gas that come into contact with the catalyst wire. The rise in temperature of the catalyst wire due to combustion acts to change the resistance of the wire to current flow. The catalyst wire is mounted in a galvanometer circuit so that the change of resistance to the flow of current through the wire due to its temperature rise provides a voltage in the galvanometer circuit to measure the temperature rise.

A large number of experiments have shown that in the use of a gas analyzer of the type outlined above it is important that the temperature of the catalyst wire in the active cell of the Wheatstone bridge be comparatively high in order to obtain accurate results. If the temperature is low the results do not seem to be consistent and the calibration of the instrument is soon destroyed. Working with gases having a comparatively wide range of combustible constituents, that is from .5% to 20%, temperatures of the catalyst wire should be from 1350° F. to 950° F. The various constituents usually found in gas have different burning characteristics. Experiments have shown that in order to obtain effective combustion of a gas in contact with a catalyst wire regardless of its composition or different kinds of constituents requires a high temperature operation in the range of 950°–1350° F. It has also been found that when low temperatures are used for combustion of the gases, secondary reactions in the oxidation of the gases take place to form intermediate products and these products tend to form carbon, and other constituents that interfere with the accurate measurement of the temperature rise.

A satisfactory catalyst wire for the present invention must be catalytically active at high temperatures in order to promote combustion of the gases having a small amount of combustible therein. The catalyst wire should also have a high specific electrical resistance in order that it may be rapidly heated with a comparatively low electrical current. The catalyst wire should further have a high temperature coefficient of resistance, that is the resistance of the wire should change rapidly as the temperature changes in order that the change of resistance of the wire may be used for measuring the temperature rise of the wire due to the combustion of gas in contact therewith. These requirements have restricted the choice of catalysts to platinum or platinum alloys containing a small percentage of an alloying metal such as iridium. Although the platinum-iridium wire has a satisfactory temperature coefficient of resistance when operating at the high temperatures mentioned, this alloy has a comparatively low specific electrical resistance so that fairly large current flows must be used to maintain the high temperatures desired in the range of 950°–1350° F. Also since the current required for heating increases with the wire diameter a catalyst wire of the finest gauge that will provide the required mechanical strength is used. Experiments have shown that the finest gauge platinum-iridium alloy wire usable in a commercial analyzer requires a current of about one ampere in order to maintain a temperature of 950°–1350° F.

With a D. C. Wheatstone bridge type analyzer, such as referred to above, it is practicable to develop an unbalanced voltage of 50 millivolts when burning a gas containing 20 percent of carbon monoxid and hydrogen in the active cell. Furthermore for direct current measurements sensitive galvanometers may be used which will give a full scale deflection with an unbalanced voltage of 10 millivolts. Such instruments have a high degree of accuracy and are capable of being operated with comparatively small temperature changes in the catalyst wire.

It is important in the operation of the Wheatstone bridge type of combustion analyzer to maintain a substantially constant current flow for heating the catalyst wire. A storage battery has been found satisfactory for this purpose but a satisfactory storage battery is not convenient for a portable analyzing machine. It is very desirable to use the usual 110 volt A. C. current for operating the analyzer. The use of an A. C. current necessitates the provision of supplying a direct current of a constant value for heating the catalyst wire. The means employed comprise conversion equipment, such as a motor generator set or a transformer rectifier assembly and with these forms of current supply ballast lamps, such as iron filament in hydrogen lamps, were required to maintin a constant current flow with the frequent fluctuations in voltage of the supply current. The apparatus required for rectifying and maintaining a uniform direct current from alternating current for operating the Wheatstone bridge requires constant checking and calibration of the instrument. Therefore attempts have been made to use alternating current for operating the Wheatstone bridge. An alternating current is quite satisfactory for heating the catalyst wire for combustion but an alternating current meter introduces complications as a means of measuring the temperature rise due to heating the catalyst wire by combustion. All alternating current meters have relatively high energy consumption so that the alternating current analyzer was not practicable until a rectifier type of alternating current meter had been perfected. The lowest voltage which could be used to give full scale deflection with an alternating current meter of the rectifier type was 500 millivolts so that it was necessary to increase the length of the active catalyst wire in the Wheatstone bridge circuit at least ten times that required for direct current measurement. The rectifier type of alternating current meter does not produce an accuracy better than five percent on full scale deflection. For precision instruments this accuracy is not always satisfactory.

The primary object of the present invention is to use separate electric currents for operating a Wheatstone bridge analyzer whereby one current will act for heating the catalyst analyzer and another current will be used for measuring the temperature rise of the catalyst due to combustion of gas in contact therewith.

Another object of the invention is to utilize the ordinary 110 volt alternating current circuit which is commonly available for operating a Wheatstone bridge analyzer.

A further object of the invention is to use alternating current for heating the catalyst analyzing wire and a direct current for operating the instrument for measuring the temperature rise due to the combustion of the gas in contact with the analyzer wire.

With this object in view one feature of the invention contemplates the use of an alternating current usually a 110 volt commercial current through means of a transformer to impress upon the Wheatstone bridge an alternating current of an amperage of .8 to 1.1 amperes for heating the catalyst wire in the active cell. The 110 volt alternating current is also utilized through a transformer for operating a small vacuum rectifying tube to produce a current having a value of .1 to .2 ampere which may be superimposed upon the alternating heating circuit of the Wheatstone bridge for operating the galvanometer in measuring the temperature rise of the catalyst by combustion of gas in contact therewith.

With these and other objects and features in view the invention consists in the method of and apparatus for analyzing gases hereinafter described and more particularly defined in the claims.

In the drawing Figure 1 is a diagrammatic view illustrating the electric circuit to be used in a Wheatstone bridge analyzer in accordance with the present invention;

Figure 2 is a diagrammatic view illustrating a modified form of the electric wiring circuit for operating a Wheatstone bridge analyzer; and

Fig. 3 is a diagrammatic view, partly in section, illustrating a gas analyzing cell and the flow circuit for measuring mixing, and supplying the gas to be analyzed to the analyzer.

Referring to Figure 3, the gas to be analyzed enters the apparatus through a conduit 10 and flows through a filter 12 to a pump 14. The gas flows from the pump 14 through a line 16 to a pressure equalizing chamber 18 where a uniform pressure on the gas is maintained, the excess gas introduced into the chamber passing out through an outlet 20. The sample to be analyzed flows through a line 22 in which is located an orifice measuring block 24. The gas passing through the orifice in the block enters a mixing chamber 26 where it is mixed with air entering through a filter 28 and orifice block 30.

Since the pressure analyzing chamber 18 is open to the atmosphere and the air filtering chamber 28 is open to the atmosphere the air and gas enter the mixing chamber 26 at the same pressure. From the mixing chamber 26 the gas flows through a line 32 to a pump 34. The pump 34 forces the gas air mixture through a line 36 and through an orifice measuring block 38. In the orifice block a predetermined volume of gas is measured and admitted through a line 40 to the active catalyst cell 42 of an analyzer 44. A pressure regulating valve 46 is mounted in the line 36 by which a predetermined pressure may be maintained on the orifice in the block 38 in order to supply a uniform measured quantity of gas to the analyzer. Any excess gas introduced into the line 36 by the pump 34 exhausts to the atmosphere through the valve 46. The details of construction of this type of analyzer are illustrated and described in the patent of Morgan and Sullivan No. 2,057,246 issued October 13, 1936.

The Wheatstone bridge wiring arrangement of the analyzer is illustrated in Figs. 1 and 2. The active arm of the Wheatstone bridge which is located within the cell 42 is indicated in Figs. 1 and 2 as 42.

The electric power for operating the Wheatstone bridge is preferably 110 volt alternating current. This current is derived from mains 48. These mains are preferably connected with the mains 50 of an electric motor 52 that is used for operating the pumps 14 and 34. When a switch 54 in the main 48 is closed to operate the pump the power will be placed upon the primary of a transformer 56 to supply a heating current for heating the catalyst wire in the Wheatstone bridge. A secondary coil 58 of the transformer 56 is used to supply the heating current for the bridge. Terminals 60 and 62 connected with the secondary of the transformer are in turn connected with points 64 and 66 of the Wheatstone bridge. A ballast tube, such as an amperite tube 68, is mounted in series in the line 60 in order to deliver a uniform current to the Wheatstone bridge. This current may be in the range of .8 to 1.1 amperes, in providing a temperature of from 950° to 1350° F.

The direct current which is used for operating the galvanometer of the Wheatstone bridge circuit is derived from a vacuum tube 70. This tube has a filament 72 which is heated by means of alternating current derived from a secondary winding 74 of the transformer 56. The secondary winding 74 is connected to the filament by means of lead wires 76 and 78. Plates 80 and 82 in the

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vacuum tube 70 have alternating current impressed thereon from a secondary winding 84 of the transformer 56. The plates 80 and 82 are connected by the secondary winding 84 by lead wires 86 and 88. When the alternating current is impressed upon the plates 80 and 82 with the filament 72 heated a direct current then flows from a mid point of the secondary winding 84 through a line 90 to the point 66 on the Wheatstone bridge, then through the arms of the bridge to the point 64 and returns through a line 92 connected to the mid portion of the secondary winding 74 of the transformer. A uniform current flow from the vacuum tube through the lines 90 and back through 92 is maintained by a ballast lamp 94 which is mounted in the line 92. Points 96 and 98 of the Wheatstone bridge are connected by lines 100 and 102 to a galvanometer 104. Part of the direct current which is impressed on the Wheatstone bridge from the vacuum tube flows through the lines 100, 102 to the galvanometer when there is any unbalancing of the current flow through the various arms of the Wheatstone bridge. If the Wheatstone bridge becomes unbalanced due to the special heating of the active arm of the bridge 42, then a current will flow through the galvanometer to indicate the temperature rise.

With the connections of the galvanometer with the Wheatstone bridge as illustrated in Fig. 1 there is substantially no difference in potential of the alternating current at the points 96 and 98 and therefore there is no tendency for alternating current to flow through the lines 100 and 102 of the galvanometer circuit. However, the change of resistance of the catalyst wire in the active arm 42 of the bridge will tend to produce the direct current potential across the Wheatstone bridge and this direct current voltage will be measured by the deflection of the galvanometer needle.

In the modified wiring diagram illustrated in Figure 2 the connections of the vacuum tube 70 with the transformer 56 are the same as in Figure 1. The secondary filament transformer 74 is connected to the tube in the same way and the plate secondary transformer 84 is connected to the tube in the same way. The connections of the lines 90 and 92 with the mid portions of the secondary transformers 84 and 74 with the Wheatstone bridge are the same. On the other hand the secondary winding 58 of the transformer is connected with the points 96 and 98 through the lines 60 and 62. With these connections the full voltage of the alternating current transformer is impressed upon the galvanometer circuit. It may be desirable therefore in the operation of the galvanometer with these connections to provide a choke coil 106 so that the alternating heating current will not interfere with the operation of the galvanometer by the direct current superimposed on the alternating heating current in the Wheatstone bridge.

With this invention it will be seen that the functions of the catalyst wire of the Wheatstone bridge, that is of promoting burning of the gas and of indicating, by its change of resistance, the temperature rise, are operated by separate currents that are separately controlled and therefore any desired heating current may be used with any desired galvanometer operating current. Furthermore since these two circuits are independently controlled and since the direct current may be superimposed upon the alternating current without being affected by the alternating heating current it will be seen that almost any desired type of galvanometer may be used to give full scale deflection for measuring small amounts or large amounts of combustible in gas. If the gases to be measured have a high calorific value then a galvanometer requiring a comparatively large voltage for full scale deflection would be used. On the other hand if very small amounts of combustible are to be measured then a very sensitive galvanometer which will give a full scale deflection with a small millivolt across it may be used. Furthermore the vacuum tube which is used as a rectifier to give the direct current for operating the galvanometer is cheap and available at most any place and may be easily removed and inserted in the circuit.

By the use of the alternating current for heating the arms of the Wheatstone bridge and the small direct current for operating the temperature measurement galvanometer a platinum wire or a platinum-iridium wire which is comparatively short and small in surface area may be used. Furthermore this arrangement permits the use of a platinum wire which has a gauge although small yet sufficiently large to give rigidity and stability to the analyzer so that it will stand continuous service and rough usage. The greater the wire diameter the higher is the current required for heating it and although the heating current may be increased in order to use larger size wire it is not important that a larger direct current be used for operating the galvanometer to make the temperature measurements. Accordingly a sufficiently large platinum catalyzing surface may be used with a comparatively short wire in the active cell and still get the desired resistance for operating the galvanometer.

The preferred form of the invention having been thus described what is claimed as new is:

1. In a process for analyzing a gas in which a sample of gas is burned with air in contact with a heated catalyst wire mounted in a Wheatstone bridge circuit and the temperature rise of the catalytic wire resulting from the combustion is measured by a galvanometer, the method of operating a Wheatstone bridge circuit which comprises impressing upon the bridge wires an alternating current of sufficient amperage to maintain the temperature of the wire sufficiently high to burn the gas irrespective of its composition, burning the gas in contact with the wire and impressing a small amperage direct current on the bridge circuit and on the galvanometer circuit to provide a definite operation of the galvanometer by the direct current when the bridge wire is unbalanced by change in temperature resulting from the combustion of the gas.

2. In a process for analyzing a gas in which a sample of gas is burned with air in contact with a heated catalyst wire mounted in a Wheatstone bridge circuit and the temperature rise of the catalytic wire resulting from the combustion is measured by a galvanometer, the method of operating a Wheatstone bridge circuit which comprises impressing on the bridge wires an alternating current of sufficient uniform amperage to raise and maintain the temperature of the wire such as to effectively burn the gas irrespective of its composition, burning the gas in contact with the wire and impressing a small uniform amperage direct current on the alternating current of the bridge circuit and the galvanometer circuit to provide a definite operation of the galvanometer when the bridge wire is unbalanced

by the change of temperature resulting from the combustion of the gas.

3. In a process for analyzing a gas in which a sample of gas is burned with air in contact with a heated catalyst wire mounted in a Wheatstone bridge circuit and the temperature rise of the catalytic wire resulting from the combustion is measured by a galvanometer, the method of operating a Wheatstone bridge circuit which comprises impressing upon the bridge wires an alternating current of sufficient amperage to maintain the temperature of the wire at a fixed temperature in the range of 950° F. to 1350° F., burning the gas in contact with the bridge wire and impressing a direct current of from .1 to .2 ampere on the alternating current circuit of the bridge and the galvanometer circuit to provide a definite operation of the galvanometer when the bridge wire is unbalanced by the change of temperature of the combustion of the gas.

4. In a process for analyzing a gas in which a sample of gas is burned with air in contact with a heated catalyst wire mounted in a Wheatstone bridge circuit and the temperature rise of the catalytic wire resulting from the combustion is measured by a galvanometer, the method of operating a Wheatstone bridge circuit which comprises utilizing a source of alternating current on the bridge wire to maintain the temperature of the bridge sufficiently high to burn the gas irrespective of its composition, burning the gas in contact with the bridge wire and utilizing a source of alternating current through a transformer and vacuum tube rectifier to impress a small amperage direct current on the alternating current of the bridge circuit and the galvanometer circuit to provide a definite operation of the galvanometer when the bridge wire is unbalanced by the change in temperature due to the combustion of the gas.

5. In a gas analyzer in which a sample of gas is burned with air in contact with a heated catalytic wire mounted in a Wheatstone bridge circuit and the temperature rise of the catalytic wire resulting from such combustion is measured by a galvanometer, the combination of an alternating current transformer having a secondary winding arranged to deliver a current of substantially one ampere to the Wheatstone bridge connections between the secondary winding of the transformer and the Wheatstone bridge, a second secondary winding of said transformer having connections with a vacuum tube rectifier, said transformer and rectifying tube being constructed and arranged to generate a direct current of substantially .1 to .2 ampere, connections between the rectifying tube and the Wheatstone bridge circuit and connections between the Wheatstone bridge and the galvanometer by which the direct current generated by the vacuum tube is impressed on the bridge and galvanometer circuits.

6. The gas analyzer defined in claim 5 wherein means are provided to control the alternating and direct currents flowing through the Wheatstone bridge circuit to hold the current flows uniform.

7. The gas analyzer defined in claim 5 wherein a choke is provided in the galvanometer circuit to confine the operation of the galvanometer to the direct current supplied to the Wheatstone bridge and galvanometer circuits by the vacuum tube.

BENJAMIN MILLER.