Nov. 23, 1943. A. P. SULLIVAN 2,335,032

ANALYSIS OF GASES

Filed Oct. 12, 1940

Fig. 1.

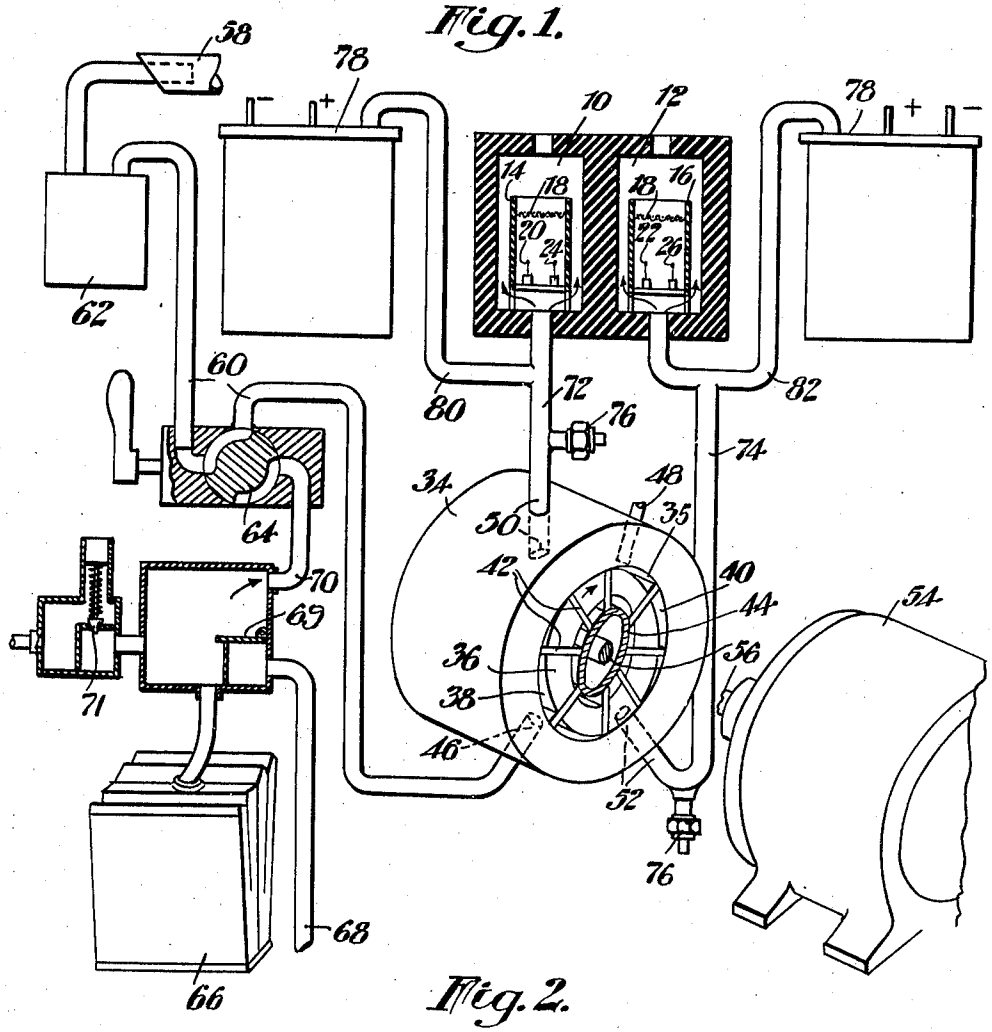
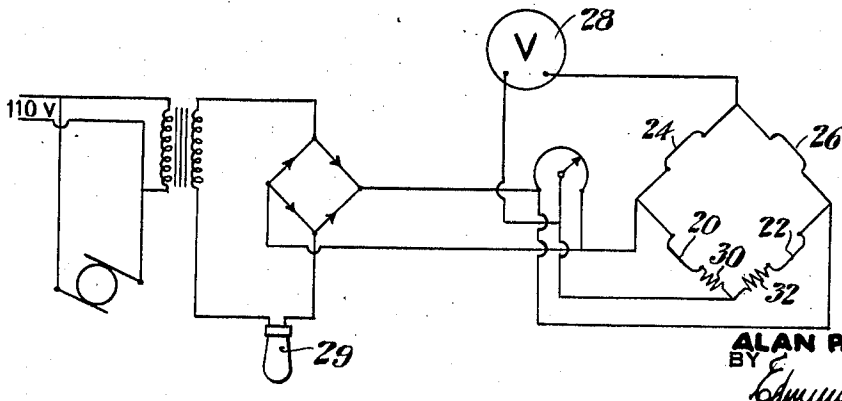


Fig. 2.



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Patented Nov. 23, 1943

2,335,032

UNITED STATES PATENT OFFICE

2,335,032

ANALYSIS OF GASES

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Application October 12, 1940, Serial No. 360,862

5 Claims. (Cl. 23—232)

This invention relates to the analysis of gas, and is particularly concerned with the quantitative analysis of the oxygen content of gas mixtures. A primary object of the invention is to provide improved method and means for making accurate quantitative analyses of the oxygen content of gas mixtures such as furnace flue gases and Diesel engine exhaust gases.

In combustion operations such as those normally practiced in the operation of industrial furnaces and in the cylinders of Diesel engines, best practice demands the use of air or oxygen in excess of that necessary to effect complete combustion of the fuel. However, the use of too great an excess of air or oxygen must be avoided, since this entails a loss of heat in the form of sensible heat taken up and removed from the combustion zone by the excess air. Correct adjustment of the proportions of air and fuel supplied to the combustion zone can best be made from information obtained by periodic or continuous analysis of the waste gases from the combustion operation to measure the amount of excess oxygen present.

Methods of gas analysis are now known according to which hydrogen or other combustible is added to a gas under analysis for its oxygen content, after which the gas mixture is passed through a combustion cell and combustion reaction between the oxygen and the combustible is promoted by contact with a heated catalyst. The temperature increase of the catalyst which results from the combustion can then be measured electrically, as by employing a Wheatstone bridge circuit whch incorporates the catalyst and a galvanometer. Most known methods for analyzing gas quantitatively for oxygen content have proved unsatisfactory and unreliable for continuous commercial use because of difficulties encountered in maintaining the calibration of an analyzing instrument by reason of deterioration of the catalyst and variations in rate of gas flow and in gas composition.

Another object of the present invention is to provide improved method and means adapted for making accurate quantitative gas analyses independently of variations in rate of gas flow and independently of catalyst deterioration.

Another object of the present invention is to provide an instrument of simple design which can be readily operated and calibrated by an unskilled operator.

The improved gas analyzing instrument of the present invention employs duplicate combustion chambers through which balanced streams of gas to be tested and air or other comparison gas are respectively forced by duplicate gas pumping units. Duplicate amounts of hydrogen or other combustible are added to both gas streams in amount sufficient to insure complete reaction of oxygen present in the air passing through the one combustion chamber. In passing through the combustion chambers the respective gas and air streams are likewise contacted with duplicate catalyst wire filaments both preheated to a uniform temperature which is above the ignition temperature of any combustion components in the gas contacting the catalyst. Any differential temperature thereby developed at the surfaces of the two catalysts by combustion is measured by a Wheatstone bridge electric circuit which incorporates both catalyst filaments as variable legs. Calibration of the instrument is simply effected by passing balanced streams of air admixed with equal volumes of hydrogen through both combustion chambers.

With the above and other objects and features in view, the invention will be hereinafter described by reference to the accompanying drawing, in which:

Fig. 1 is a diagrammatic illustration of a preferred apparatus arrangement in which certain parts are displayed in vertical section, while the pump unit is shown in perspective with one end removed; and Fig. 2 is a wiring diagram of a Wheatstone bridge circuit suitable for use with the apparatus of Fig. 1.

In the drawing, numerals 10, 12 designate duplicate hollow tubular combustion cells each having gas inlet ports at their lower ends and gas exit ports at their upper ends. Duplicate imperforate cup-shaped baffles 14, 16 are disposed respectively in the central portion of each combustion cell in baffling relation to gas flowing therethrough. Multi-apertured screens 18 are shown as stretched across the open tops of each of the cups 14, 16 for the purpose of interfering with access of gas to the interior of the cups except by diffusion.

Secured within the cells 10, 12 respectively are corresponding ignition elements in the form of wire filaments 20, 22 of a heat refractory metal which is catalytic. Such wire filaments may be constructed of platinum or platinum alloy, or preferably of cerium oxide coated platinum. Other non-catalytic filaments or wires 24, 26 (preferably of gold plated platinum) are also mounted respectively in cells 10, 12. As shown in Fig. 2, these catalyst and non-catalyst wire filaments are electrically connected as the varia-

ble and fixed resistance legs, respectively, of a Wheatstone bridge circuit which also includes a millivoltmeter 28 and a source of heating current which has been illustrated as comprising an A. C.-D. C. transformer-rectifier assembly which incorporates an amperite 29 for insuring substantially constant current supply. A pair of compensating resistances 30, 32 are shown as mounted in series respectively with the catalyst wire filaments 20, 22 in the variable legs of the bridge.

A pump unit 34 is provided to develop flow of gas mixture to be analyzed through cell 10 and a corresponding flow of air through comparison cell 12. Pump unit 34 has a housing with an elliptical bore 35 within which is mounted a cylindrical rotor 36. The major longitudnal axis of rotor 36 coincides with that of bore 35, and the outside surface of rotor 36 is dimensioned to form a tight journal fit within the bore 35 along the minor axis of the ellipse. With rotor 36 so mounted, two non-communicating pump compartments 38 and 40 of equal displacement are formed in the bore on opposite sides of the rotor. Rotor slots are formed at uniformly spaced distances around the periphery of the rotor, and blades 42 are mounted to reciprocate in these slots; such blades having their outer ends always held in wiping contact with the walls of the bore by an elliptical shaped blade guide 44. Blade guide 44 is shown as centered within the bore and as shaped to conform thereto, with its major and minor axes coinciding with those of the bore. For clearer illustration, the pump has been shown in perspective without its near end plate in place. Guide 44 would normally be attached to such end plate.

Two suction ports 46, 48 for the respective pump compartments 38 and 40 are located in the housing at the corresponding intake ends of the said compartments. The rotor of the pump is shown as rotating in a clockwise direction with the suction ports located respectively at opposite ends of one diameter of the rotor and at points equidistant from and adjacent to the minor axis of the elliptical bore. Discharge or exit ports 50 and 52 respectively open out of the discharge ends of compartments 38 and 40 at points equidistant from the minor axis of the bore and equidistant from the suction ports. Rotor 36 is driven from an electric motor 54 by means of a shaft 56. Suction port 46 of pump chamber 38 is connected to a source 58 of gas to be analyzed by means of a conduit 60 which incorporates a filter 62 and a double throw valve 64. The discharge port 50 of pump chamber 38 is connected by a conduit 72 to the bottom intake port of cell 10. Where a continuous supply of gas is available to be analyzed the supply is connected with the inlet 58. Provision, however, is made by which an isolated sample may be collected to be analyzed. To accomplish this a bellows pump 66 (Figure 1) is connected with an inlet pipe 68 through a check valve 69. When the bellows is opened a sample of gas will be drawn in through the inlet 68 and stored in the bellows by the check valve 69. At the same time the pressure of the gas sample in the bellows will be controlled by a relief valve 71 to maintain any desired pressure. For example a sample of the human breath may be drawn in through the inlet pipe 68 and stored in the bellows. When it is desired to analyze this sample the double-throw valve 64 is rotated to connect the bellows pump with the inlet pipe 60 of the pump 38. The pump will then draw a sample from the bellows for making the analysis.

Suction port 48 of pump chamber 40 communicates with the outside atmosphere and is designed to function as an air intake port. Discharge port 52 of chamber 40 is connected to the lower part of cell 12 by a conduit 74. Conduits 72 and 74 should be of identical cross-section and are preferably each equipped with relief valves 76 for the purpose of insuring balanced pressures in the two conduits. Two identical hydrogen cells 78 are shown as connected respectively to conduits 72 and 74 by hydrogen supply pipes 80 and 82.

In the operation of the analyzer, the Wheatstone bridge is first balanced by passing uniform streams of air admixed with hydrogen through both cells 10 and 12. During this calibration, the source of gas 58 would be disconnected from the conduit 60 to allow air only to be drawn through this conduit into the pump chamber 38. The supplies of hydrogen from generators 78 are adjusted to deliver balanced streams of hydrogen to both cells in amount sufficient to insure complete combustion of the 21% of oxygen present in the air streams passing through both cells. After the calibration has been completed, conduit 60 is connected with the source 58 of gas to be analyzed, and a stream of gas to be analyzed is then passed through cell 10 in admixture with the hydrogen supplied from one hydrogen cell, while continuing the delivery of air admixed with hydrogen at a uniform rate through cell 12 from pump chamber 40. The amount of oxygen in the gas under analysis will normally be less than the oxygen content of the air passing through cell 12, with the result that the temperature of the catalyst wire 20 will be lower than the temperature of the catalyst wire 22. This will develop an unbalance of the Wheatstone bridge, and the amount of the unbalance, as measured by the millivoltmeter 28, will indicate the relative amount of oxygen in the gas sample passing through cell 10 with respect to the known amount of oxygen in the air sample passing through cell 12.

Having thus described the invention in its preferred form, what is claimed as new is:

1. In analyzing a mixture of gas quantitatively for oxygen content, the steps comprising passing a stream of the gas mixture at a uniform rate through one combustion cell and simultaneously passing a stream of air of known oxygen content at a corresponding rate through a second like combustion cell, adding a combustible gas in equal amount to the gas and air streams before they enter the respective combustion cells, the amount of combustible gas added being sufficient to insure complete combustion of the maximum oxygen content in either of the gas and air streams, contacting the gas and air streams in each cell with like combustion catalyst filaments while electrically heating said filaments to a temperature above the ignition temperature of the oxygen and combustible gas constituents, and measuring any temperature differential developed between the catalyst filaments as a result of combustion of the respective oxygen constituents in the two streams.

2. Apparatus for analyzing gas quantitatively for its oxygen content comprising a pair of duplicate combustion cells, a Wheatstone bridge electric circuit having a pair of active catalyst legs and a pair of inactive legs, an active and an inactive leg of said bridge being mounted in each

cell, duplicate pumping means with connections mounted for passing a stream of gas to be analyzed for its oxygen content at a uniform rate through one combustion cell and for simultaneously passing a stream of air of known oxygen content at a corresponding rate through the second combustion cell, means having conduits for introducing hydrogen at uniform rates into the connections for the gas and air streams entering the respective cells, and a millivoltmeter shunted across the bridge for measuring bridge unbalance in terms of oxygen content of the gas under analysis.

3. Apparatus as defined in claim 2 together with imperforate cup baffles disposed within each combustion cell in the path of gas and air streams flowing therethrough, said cells having the catalyst filaments mounted within said cups, and apertured shielding elements mounted over the open end of each cup whereby to shield the catalyst wires against direct flow contact with the gas stream while permitting the constituents of the stream to contact the filaments by diffusion and convection.

4. The apparatus as defined in claim 2 in which a variable volume bellows-like pump of relatively large storage capacity has a valved connection with the gas inlet of the duplicate pumping means for delivering gas to the pumping means, said bellows pump having a check valve inlet and a pressure relief valve.

5. A method of analyzing a gas to determine its oxygen content, the steps which comprise passing a stream of the gas to be analyzed at a uniform rate through a combustion cell, simultaneously passing a stream of air at a corresponding rate through a combustion cell of substantially the same shape and arrangement as the first-mentioned combustion cell, generating hydrogen in separate cells in substantially the same volume and adding hydrogen from one cell to the stream of air and from the other cell to the stream of gas to be tested, the amount of hydrogen being added in each case being sufficient to completely burn any oxygen in the air or gas sample, contacting the gas and air streams in each cell with combustion catalysts of substantially the same properties and arrangement, said combustion catalysts being heated in each cell to substantially the same temperature which is above the ignition temperature of the oxygen and hydrogen constituents in the streams passing through the cells, and measuring any temperature differential developed between the catalyst filaments as the result of combustion of the oxygen contents of the gases in the respective streams.

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