May 1, 1934. F. A. HOLT 1,957,341

COMBUSTION ANALYZER

Filed Jan. 21, 1931 2 Sheets-Sheet 1

Fig. 1.

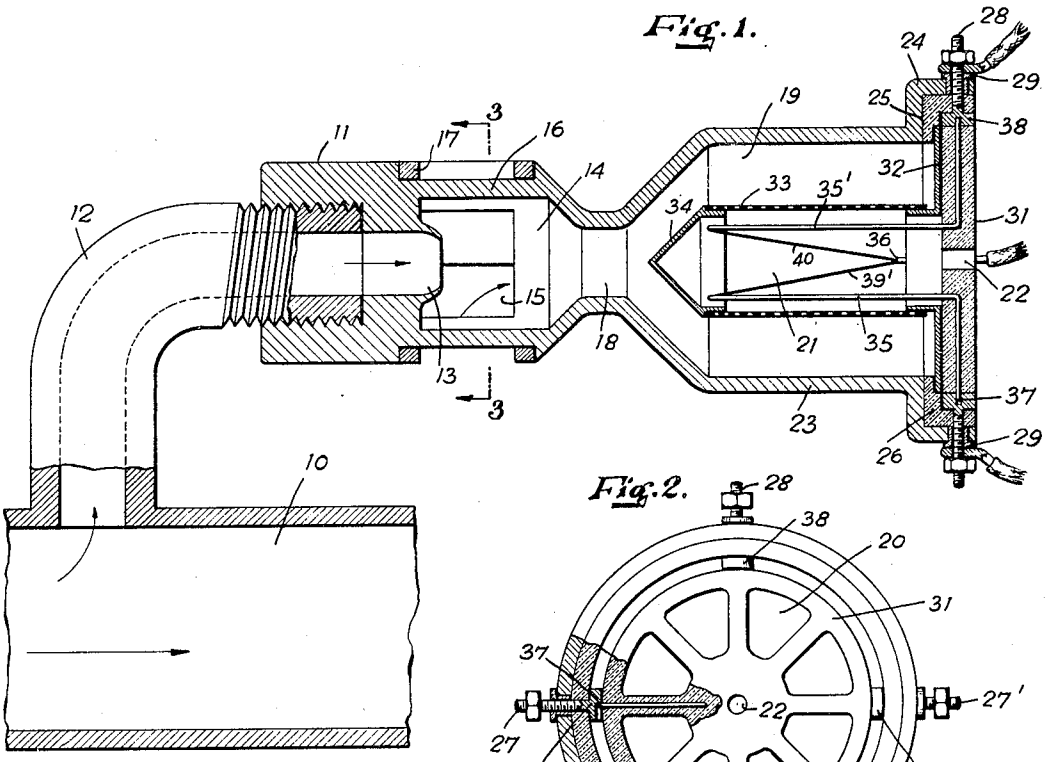

Fig. 2.

Fig. 4.

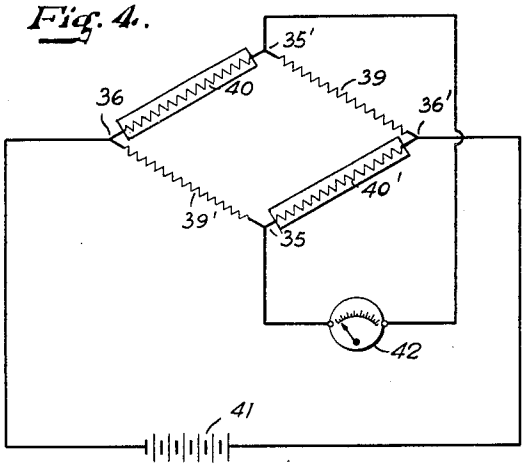

Fig. 3.

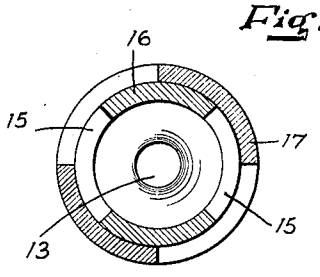

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Fig. 5.

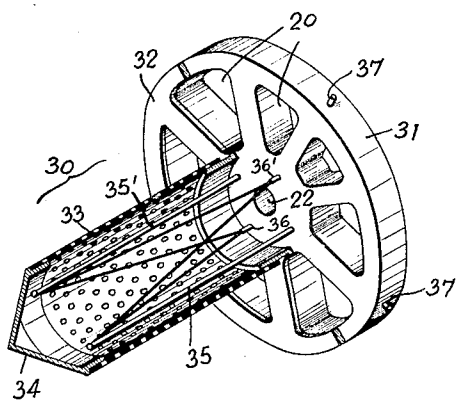


Fig. 6.

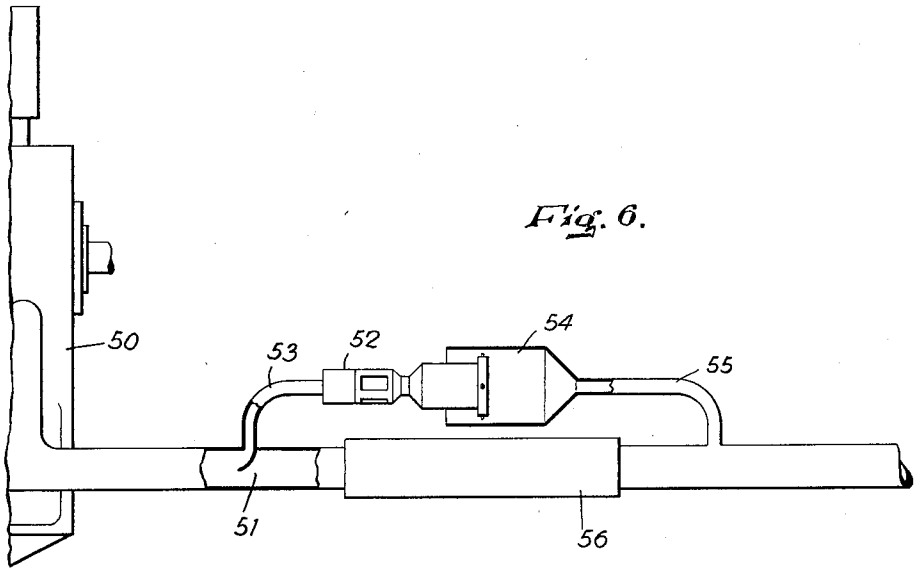
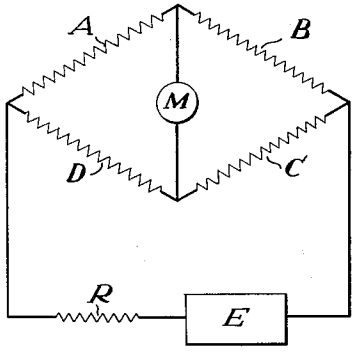


Fig. 7.



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Patented May 1, 1934 1,957,341

UNITED STATES PATENT OFFICE

1,957,341

COMBUSTION ANALYZER

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Application January 21, 1931, Serial No. 510,183

8 Claims. (Cl. 23—255)

This invention relates to apparatus for analyzing gases and more particularly to apparatus for analyzing the exhaust gases from internal combustion engines.

Unless combustion of fuel is complete, combustibles exist in the exhaust gases of internal combustion engines. By their proportion to the total volume is indicated the degree of inefficiency in the utilization of fuel and the attendant unnecessary increased cost of operation. In addition to the consideration of cost, however, incomplete combustion causes other undesirable results. Thus, in the operation of internal combustion engines and especially such as utilize gasoline and other like volatile fuel, excess fuel causes accumulation of carbon on cylinder heads; piston and spark plug insulation; the pitting of exhaust valves through lodgment of particles of carbon between valve heads and seats; the cutting of lubricating oils on cylinder walls; the dilution of lubricating oils of the engine system, all of which make it desirable that excessive fuel be avoided.

A carburetor possesses component parts, the intelligent adjustment of which will enable it to supply a proper proportion of fuel and air to provide perfect combustion under definite operating conditions, but so many variables exist in commercial operation of mobile vehicles that it is necessary manually or otherwise to adjust a carburetor to conform to the existent variable conditions.

For example, when a well designed and constructed carburetor is adjusted under (*a*) a definite air barometric pressure and humidity and (*b*) a definite fuel, excellent fuel economy can be attained, but when one of these conditions change, intelligent readjustment of the carburetor is immediately necessary and with no indication of the existing fuel-to-air ratio, it is impossible properly to adjust the carburetor.

An object of the invention is to indicate automatically the combustible contents present in the exhaust gases of internal combustion engines.

Another object of the invention is to mix air automatically with the exhaust gases to produce a combustible mixture with any of the combustible components present in the exhaust gases.

Still another object of the invention is to prevent sudden changes in the temperature of the active heated wires, by convection resulting from changes in the velocity of the gases passing these wires.

Other objects of the invention will be in part obvious and will in part appear hereinafter.

A feature of the invention resides in a device which utilizes a portion of the gas from an exhaust manifold of an internal combustion engine and permits the thorough mixing of air therewith to produce a combustible mixture with any of the combustible components present in the exhaust gases. Within the instrument is a compartment having a wall of fine wire mesh or gauze through which the combustible mixture may be diffused independently of the velocity of the gases passing along the outside threof. Within this compartment is a catalytic and a non-catalytic element, the former having the property of stimulating combustion along its surface when in contact with a combustible mixture, whereas the latter has no such effect upon a combustible mixture. Furthermore, the amount of combustion taking place along the surface of the catalyst is proportional to the quantity of combustibles present in the mixture. Thus, by comparing the effects produced upon the catalytic and non-catalytic elements an indication of the amount of unconsumed combustibles present in the exhaust of an engine is obtained.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts, which will be exemplified in the construction hereinafter set forth and the scope of the application of which will be indicated in the claims.

A better understanding of the invention may be had from the following description together with the accompanying drawings wherein

Fig. 1 shows a longitudinal sectional view of the apparatus attached to the exhaust of an internal combustion engine.

Fig. 2 is an end view partially in section, of the apparatus.

Fig. 3 is an elevational cross section through the airport on line 3—3 of Fig. 1.

Fig. 4 is a circuit diagram illustrating the principle on which the instrument operates and the manner in which it is connected to the source of current and the indicating instrument.

Fig. 5 is a view in perspective of one part of the instrument.

Fig. 6 is a view showing another method of associating the instrument with the exhaust manifold of an engine, and

Fig. 7 is a diagram illustrating another form of circuit which may be used with a combustion indicator.

Referring now to the figures, wherein like numbers refer to corresponding parts, the number 10 represents the exhaust manifold of an internal combustion engine with the combustion

analyzer 11 connected thereto by means of an elbow 12. The gases from the exhaust pass, under pressure, through the nozzle or jet 13 into the mixing chamber 14 where they are brought into contact with a regulated quantity of a substance capable of chemically reacting with constituents of the exhaust gases, such as air, aspirated through the ports 15 in the walls 16 of the chamber 14 and the walls of the cylindrical collar 17. The amount of the substance aspirated may be regulated by turning the collar 17 to adjust the size of the ports 15 as shown most clearly in Fig. 3.

The combined gases pass through the constriction 18 where they are intimately mixed and into the annular chamber 19 which communicates with the atmosphere through the ports 20 shown in Fig. 2 and also with the combustion chamber 21 which in turn communicates with the atmosphere through the ports 22.

The wall 23 of the chamber 19 terminates in an enlarged section 24 which provides a seat at 25. Abutting against the seat 25 is a collar 26 of insulating material such as bakelite. Passing through this collar and the upper wall 24 are four studs 27, 27', 28 and 28', which provide binding posts for electrical connections for a purpose which will be hereafter described. These studs are insulated from the casing by insulating bushings 29.

Fitting within the end of the casing is the analyzer unit 30 shown in Fig. 1 and designated in Fig. 5 consisting of a top plate 31 of insulating material which may also be bakelite. Secured to the inner face of this plate is another plate 32 to which is secured a cylindrical screen or gauze element 33. The other end of the cylindrical screen is closed by means of an imperforate shield or cone 34 which serves to prevent gases entering the combustion chamber 21, except through the screen 33.

Projecting within the combustion chamber 21 are two long rods 35 and 35' and two short rods 36 and 36'. A portion of these rods is embedded in the cover plate 31 with studs projecting as at 37, which are adapted to fit into slots 38 in the enlarged ends of the studs 27, 27', 28 and 28' making electrical connection therewith. The analyzing unit is thus readily removable merely by turning it a small distance in a counter-clockwise direction and withdrawing it from the shell.

The rods 35, 35' and 36, 36' serve as conjugate connections for a Wheatstone bridge circuit which includes one pair of wires as 39, 39' of a material such as platinum which is a catalyst of combustion and another pair 40, 40' of nickel or of platinum protected from contact with the gases as by a thin coating of glass or other refractory material.

A circuit diagram of the instrument is shown in Fig. 4. It may be the well known Wheatstone bridge arrangement wherein the conjugate terminals 36 and 36' are connected through suitable wires to a source of current 41 which may be the storage battery used for starting and ignition of the internal combustion engine. The other conjugate terminals 35, 35' may also be connected through suitable leads to a galvanometer or millimeter 42 which is positioned in view of the engine operator.

The operation of the device depends upon the well known principle that combustible gases in the presence of oxygen will unite along the surface of a catalyst of combustion and when this catalyst is in the form of a wire, its temperature is increased and consequently its resistance. Platinum is such a catalyst and when it contacts with the exhaust gases of an internal combustion engine will cause combustion at a temperature of about 300° and 350° C. The Wheatstone bridge circuit is adjusted so that the current through the arms of the bridge circuit is sufficient to heat the catalytic wires to the proper temperature for surface combustion with exhaust gases. The mixture of the exhaust gases and air from the chamber 19 will diffuse through the screen 33 into the presence of the catalytic and non-catalytic wires. The mixture has no effect upon the nickel or the protected platinum wires 40 and 40', but combustion will be promoted along the surface of the catalytic wires 39 and 39', thus increasing their temperature, which is accompanied by a corresponding increase in their resistance. This produces an unbalance in the Wheatstone bridge circuit which registers in well known manner on the indicator 42. The amount of unbalance is proportional to the quantity of combustibles in the exhaust gases so that by properly calibrating the instrument the efficiency of combustion is indicated, at a glance, to the operator.

It will be noted that the mixed exhaust gases and air through the restriction 18 and the chamber 19 are prevented from direct contact with the wires 39, 39' and 40, 40' by the cone 34 so that these gases can come into contact with the wires only by diffusion through the screen 33. This arrangement prevents loss of heat from the wires by convection currents since without this arrangement, that is, with the wires exposed directly to the gas stream, changes in the velocity of the gases produce changes in the heat loss from the wires by convection, thus resulting in false indications of the meter 42. The screen 10 surrounding the wires also tends to store heat and prevents sudden changes in the temperature of the wires 39, 39', 40 and 40'.

The wire screen also serves as a safety device acting on the well known Davy lamp principle, by preventing ignition of the exhaust gases in the outer compartment should the concentration of combustibles within the combustion chamber 21 be sufficiently great to cause an explosion therein.

The composition of the gases within the screen 33 quickly follows changes in the composition of the gases in the chamber 19 not only by ordinary diffusion, but because of the change of volume of the gases within the combustion chamber 21 due to surface combustion. Thus representing the combustible component of the exhaust gases as carbon monoxide, this unites with the oxygen from the air drawn into the mixing chamber 14 by a reaction which may be represented volumetrically:

$$2CO+O_2=2CO_2$$

2 volumes+1 volume=2 volumes

which shows that two volumes of carbon monoxide unite with one volume of oxygen to form two volumes of carbon dioxide.

Another method of installing the combustion analyzer is illustrated in Fig. 6. Herein the internal combustion engine 50 has an exhaust manifold 51 which is connected to the combustion indicator 52 by means of an elbow 53. The combustion indicator is identical in every respect to that heretofore described, but instead of permitting the gases leaving the combustion analyzer to escape directly into the atmosphere, a hood

54 is provided which returns the analyzed gases back to the exhaust through a connection 55 preferably beyond the exhaust end of the muffler 56. This is particularly desirable when the internal combustion engine is used in a confined space as for instance in the engine room of a motor boat.

As a further modification, the tube 55 may communicate directly with the outside atmosphere without again returning to the exhaust manifold.

A modification of the Wheatstone bridge arrangement used in connection with the combustion indicator is shown in Fig. 7. In this figure the opposite arms of the circuit are shown as A and C and B and D. One pair of conjugate points is connected through an indicating meter M and the other pair to a source of voltage E through a resistance R. When a proper value is assigned to the resistance R detrimental effects on the sensitivity of the indicator, such as will take place from changes in the internal resistance of the source of voltage E, may be eliminated. It may be shown mathematically that any change in the internal resistance of the voltage source E will have a material effect upon the value of the current flowing through the indicating meter M. The normal internal resistance of the conventional storage battery is very low (less than 100th of an ohm) but its value is changed considerably by changes in temperature and conditions of charge. The effects of changes in the internal resistance of the voltage source may be eliminated by so proportioning the initial resistance of the arms A, B, C and D that a resistance R having a valve large as compared with the internal resistance of the battery E may be inserted in the circuit.

Thus, assuming the resistance R to have a value of one ohm and that the internal resistance of the battery E changes from 0.01 ohm to 0.02 ohms, the overall change in resistance in that portion of the circuit external of the actual bridge is from 1.01 ohm to 1.02 ohms which is a negligible amount. Without the resistance R the overall change in the external circuit of battery resistance is 100% for the conditions mentioned.

Since certain changes may be made in the above construction and different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:—

1. A device for determining the presence of combustibles in a gaseous mixture comprising a casing comprising a chamber, a jet adapted to project a stream of gas within said chamber, an air inlet for said chamber, a constricted passageway providing for the passage of said air and gas mixture, a catalytic element, means for passing said mixture in an annular path, diffusion means between said annular path and said catalytic element, whereby said catalytic element is exposed to a diffused portion of said mixture, and an indicator controlled by said catalytic element.

2. A device for determining the presence of combustibles in a gaseous mixture comprising a casing comprising a chamber, a jet adapted to project a stream of gas within said chamber, an air inlet for said chamber, a constricted passageway providing for the passage of said air and gas mixture, a cone in said passageway having its apex toward said jet for deflecting said mixture, a catalytic element exposed to a part of said deflected mixture, and an indicator controlled by said catalytic element.

3. A device for determining the pressure of combustibles in a gaseous mixture comprising a casing comprising a chamber, a jet adapted to project a stream of gas within said chamber, an air inlet for said chamber, a passageway providing for the passage of said air and gas mixture and having a constriction and an enlargement therebeyond, a diffusion partition larger than said constriction and smaller than said enlargement, a catalytic element exposed to the diffused mixture, and an indicator controlled by said catalytic element.

4. In a combustion indicator, a casing comprising end portions with a constriction therebetween, one end portion comprising a mixing chamber having air and gas inlets, a catalytic element in the other end portion, a diffusion screen about said catalytic element, said other end portion having outlets outside of said screen, and means for directing the greater part of the mixture from said constriction about said screen to said outlets.

5. A combustion analyzer comprising an elongated casing having a constriction intermediate its ends, a nozzle aligned with said constriction, a mixing chamber between said nozzle and said constriction, means for supplying exhaust gases to said nozzle, means for admitting air to said mixing chamber, a gauze screen aligned with said constriction, said casing comprising a chamber surrounding said gauze screen, and an imperforate conical end on said gauze screen for directing the greater part of the mixture from said constriction away from said gauze screen into the chamber therearound.

6. A readily removable unit for gas analyzing apparatus, comprising an insulating base with catalytic and non-catalytic wires forming a Wheatstone bridge, supports for said wires carried by said base, and electrical contacts on said base connected to said wires.

7. A device for determining the presence of combustibles in a gaseous mixture, comprising a casing having an outlet, a constriction in said casing, a jet nozzle in said casing aligned with said constriction and adapted to project a stream of gas thereinto, said casing having an air inlet to the exterior of said nozzle, whereby air is drawn through said constriction along with gas from said nozzle and mixed therewith, a catalytic element in said casing, a screen surrounding said element, and a shield at the end of said screen to direct the mixture of air and gases around said screen.

8. A device for analyzing a gaseous mixture comprising a casing, a nozzle for projecting a stream of gas into said casing, said casing having an air inlet adjacent said nozzle, a detachable cover for said casing, a catalytic element and a non-catalytic element supported on said detachable cover, and an indicator electrically connected to said elements for indicating the effects of said gaseous mixture thereon.

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