June 8, 1937. J. D. MORGAN 2,083,522

GAS ANALYZING APPARATUS

Filed Sept. 12, 1932 2 Sheets-Sheet 1

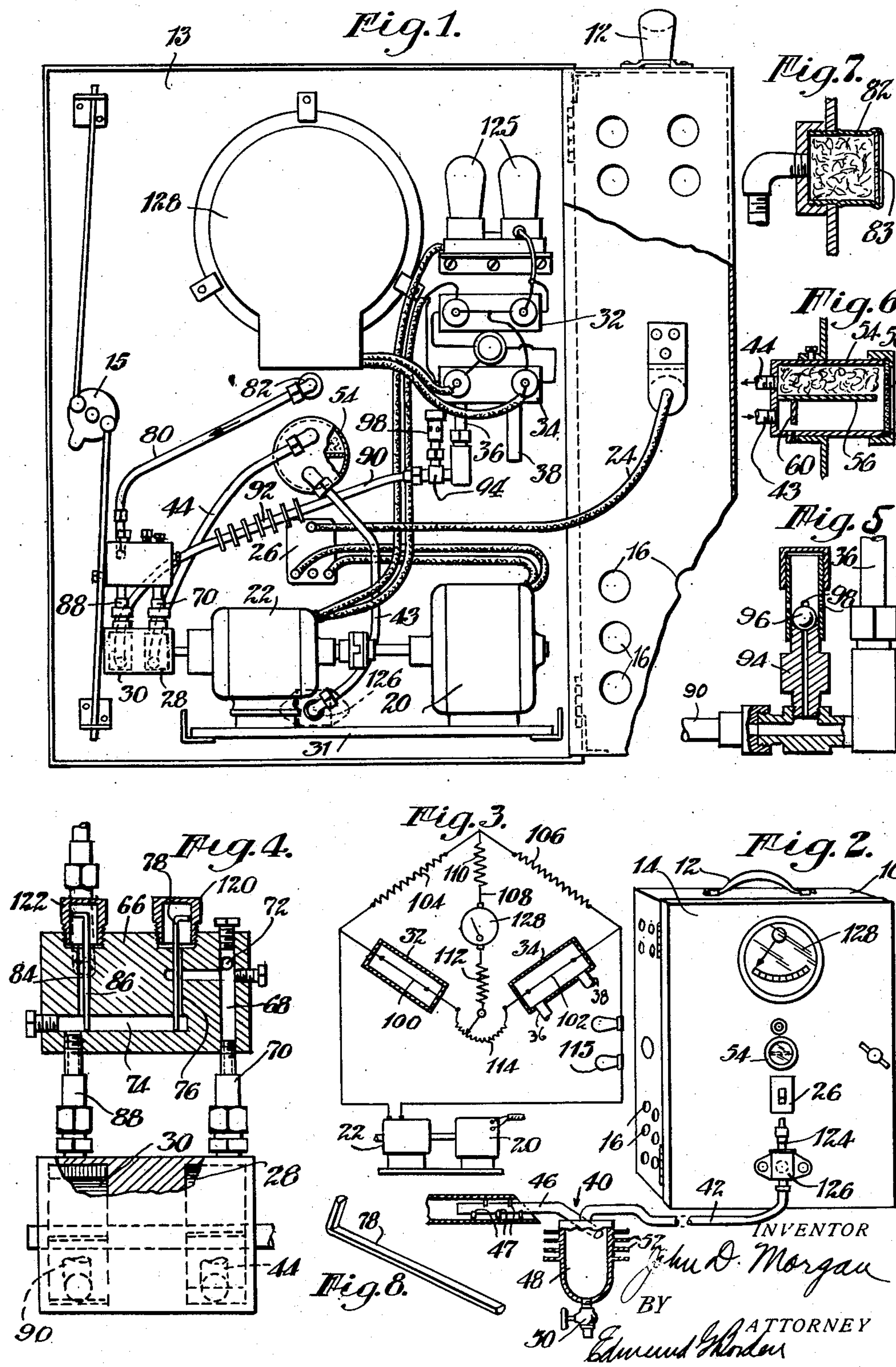

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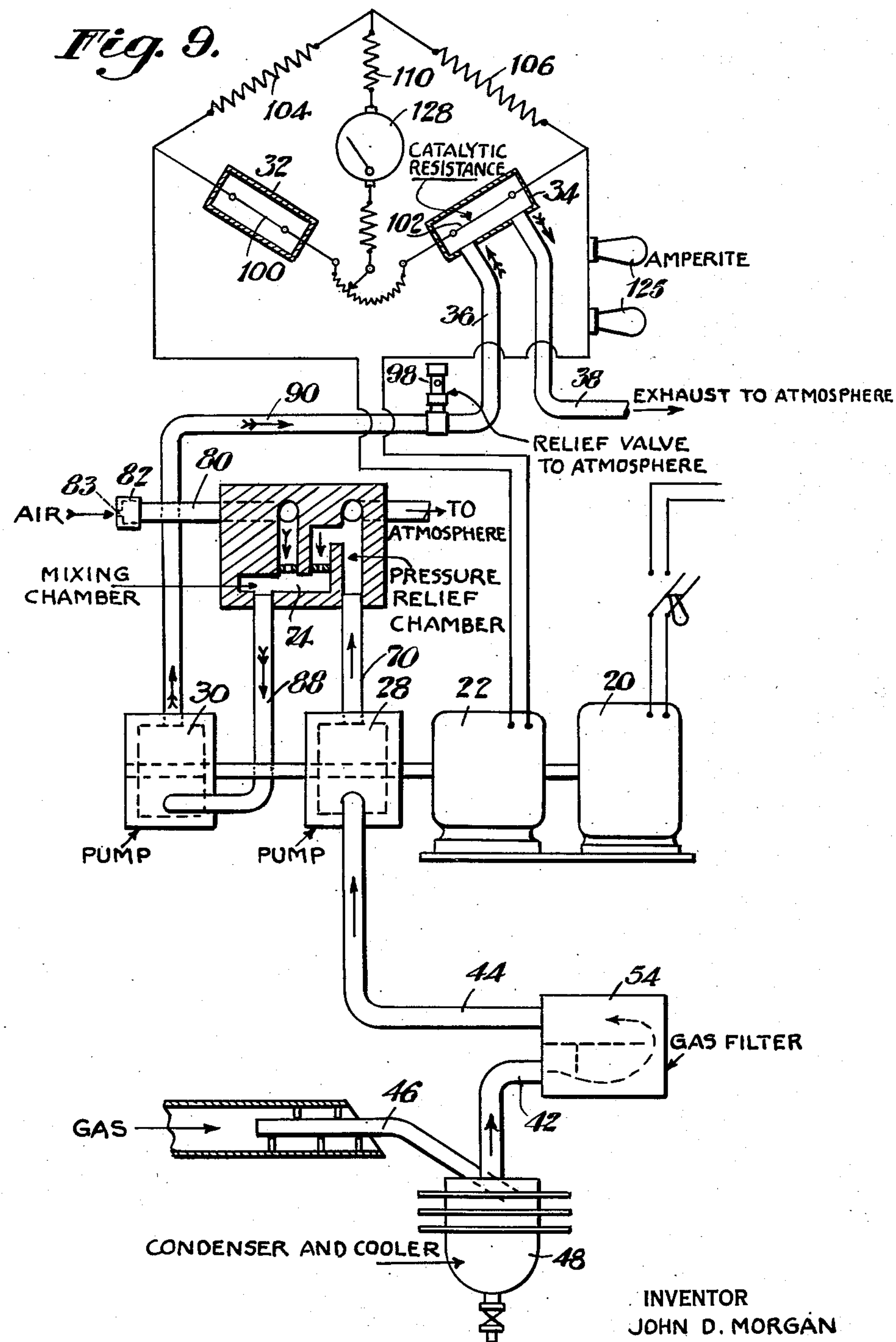
Fig. 9.



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GAS ANALYZING APPARATUS

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2 Claims. (Cl. 137—165)

This invention relates to an apparatus for quantitatively measuring the combustible components in a gaseous mixture such as those from domestic and industrial combustion operations, and it has special utility in the examination of exhaust gases from an internal combustion motor of the automotive type resulting from the combustion of hydrocarbon fuels under conditions of under-ventilation. More especially the invention concerns the quantitative measurement of combustibles by the controlled catalytic combustion of such gases with or without prior admixture therewith of additional combustion-supporting fluid, employing catalytic elements disposed in the usual Wheatstone bridge circuit or its equivalent utilizing a galvanometer.

The accuracy of the above type of measuring instrument is dependent in considerable degree upon the careful control of the rate of flow over the catalytic element of the gases to be analyzed, and the careful and constant regulation of the proportion of gas and air in the said mixture flowing to the combustion cell.

It is well known that exhaust gases from an internal combustion motor flow from the exhaust pipe under a wide range of pressures and temperatures depending upon the speed at which the motor is being operated and the adjustment of the carbureter and ignition system. Various instrumentalities have already been employed for the purpose of insuring a uniform flow of gas and air under all conditions to the gas analyzer cell. Among such may be mentioned orificed gas sampling devices and fluid flow-inducing means generally connected with the outlet of the analyzer cell. Such devices have generally been open to the objection that the gas line leading from the motor exhaust pipe gradually may be choked up by carbon present in the exhaust gases, in which case the flow-inducing mechanism generally fails to maintain the rate of flow for which the device has been calibrated, and this, often permits of wide variations in the proportions of gas and air flowing to the analyzer.

Among the more important objects of the present invention are to provide in an improved manner for controlling by a pressure-feed type of device the flow of the gas or gas-air mixture to the analyzer cell under conditions preventing unregulated pressure variations occurring in the line connecting the pressure- and flow-inducing means and the analyzer cell; to provide for a novel portable gas analzer of the combustion or the thermal conductivity type embodying a compact Wheatstone bridge assembly; to provide in such a novel gas analyzing method and apparatus for the automatic flow of gases to the analyzer cell under uniform positive regulated pressure regardless of substantial variations in the operation of the flow-inducing means; to provide in novel manner for the uniform regulated proportioning of gas to air flowing to the analyzer cell regardless of variations in the resistance encountered in the lines conducting the gas to the mixing chamber; to provide a gas analyzer of either the combustion or thermal-conductivity type in which the accuracy of the measuring instrument is not affected by substantial changes in the power operating the flow-inducing means; to provide in novel manner, in such a process and apparatus, for the automatic reactivation of the catalytic element in the analyzer cell prior to each analysis; to provide in novel manner for the rapid and convenient cleaning of the orifice members when desired; and further to provide in such method and apparatus for quickly cleaning out the gas line leading to the gas analyzer from the motor exhaust pipe without in any manner interfering with the adjustments of the various elements of the gas analyzer.

In its broadest scope the invention involves a gas analyzer of the thermal conductivity or of the combustion type which is fully automatic and contains no adjustable valves for air and gas control, and requiring adjustment during an analysis. Important parts of the machine include a motor and generator, a multi-stage pump or its equivalent, dry filters for the gas and for the air when used, a pair of gas analyzer cells disposed in a Wheatstone bridge circuit or its equivalent, a galvanometer or similar device, and certain fluid pressure and electric current regulating means hereinafter described.

The invention will hereinafter be described more specifically in connection with the accompanying drawings which illustrates one practical embodiment of the apparatus in its preferred form.

In the drawings, Fig. 1 is a rear elevation of an instrument panel showing an apparatus assembly mounted in a portable unit;

Fig. 2 is a perspective view of the portable unit showing the front of the instrument panel of Fig. 1;

Fig. 3 shows the wiring diagram utilized in the construction illustrated in Figs. 1 and 2.

Fig. 4 is an elevation, partly in section, of the gas and air mixing and regulating apparatus and associated parts; and

Figs. 5 to 8 illustrate various apparatus elements;

Fig. 9 is a diagrammatic sketch in the nature of a flow sheet illustrating the flow of air, gas and air-gas mixture through the apparatus.

Referring to the drawings, 10 designates a portable container or box preferably of sheet metal, which may be provided with a handle 12 for convenience in transporting the same. The box has a hinged front member 13, the outer face 14 of which serves as an instrument panel. The box has a locking device 15; and the sides of the box have apertures 16 therein for ventilation purposes.

In the modification shown, the gas analyzing apparatus is mounted upon the front member 13 for convenience of assembly in producing a small portable unit. Other arrangements of parts, however, are within the purview of the invention.

The apparatus comprises a motor generator set consisting of a motor 20 and interconnected generator 22, the former being driven by power flowing thereto through circuit 24 controlled by the panel-mounted switch 26. Carried upon an end of the generator and generator shaft, and driven by the motor 20, are a pair of constant speed pumps 28, 30, which may be in the form of a multi-stage pump. The respective pumps may be of the same or of different capacities. The motor generator set and pump assembly shown are cushioned upon rubber and carried by supports 31 secured to the front member or panel of the box.

Mounted upon the rear face of the member 13 is a pair of catalytic combustion cells 32, 34 of well known construction, such as described in my copending application Serial No. 482,283, filed September 16, 1930. The cell 32 is sealed and contains air or other standard gas. Cell 34 has an inlet 36 and outlet 38 for conveying the gas mixture to be analyzed.

For conducting the gas to be examined to the pump 28 in undiluted form, while concurrently removing a large portion of the condensible vapors and solid impurities therein, a novel sampling device 40 is connected with the pump through the lines 42, 43, 44. The sampling device 40 comprises an open-ended hollow metal tube 46 having spaced semi-circular flanges 47 along its external surface as shown, for supporting the tube in spaced relation to the walls of a motor exhaust pipe and for forming baffles for free passage of excess gases around the said tube. The tube 46 may be very short without danger of dilution of the exhaust gases by outer air entering the exhaust pipe. The outlet end of the tube 46 discharges tangentially downward into a small collecting chamber 48, with the upper end of which the pipe 42 connects. A valved outlet 50 permits drainage of condensate from the chamber 48. The outer walls of the chamber 48 may be provided with heat radiating fins 52 or the like as shown.

Connected with the line 43 is a gas filter and separator 54 having a horizontal baffle 56 therein and a removable transparent front cover 58. A depending baffle 60 is mounted below baffle 56 adjacent the gas inlet line 43. The space above the baffle 56 is preferably filled with a dry filtering medium such as cotton, glass wool, or the like. A removable plug in the base of the separator 54 permits removal therefrom of any collected moisture. A gas outlet pipe 44 connects the filter 54 with the inlet of pump 28.

The outlet of pump 28 is connected through line 70 with the gas inlet chamber 68 of a flow-regulating and mixing device 66. The chamber 68 is permanently open to the atmosphere through a relatively large aperture 72 therein; and it is also in controlled communication with a gas and air mixing chamber 74 through a flow measuring orifice conduit 76 having therein a rotatable longitudinally-grooved flow-regulating member 78 fitting in but movable longitudinally of said orifice conduit and having an end thereof curved for convenience in moving it. The mixing chamber 74 also is in regulated communication with the air in front of the instrument panel through a line 80, one end of which is connected with a dry filter 82 containing cotton or the like and having an aperture 83 therein, the said filter being countersunk in the front of the panel or member 13. The opposite end of line 80 is connected with a flow-regulating orifice inlet conduit 84 and regulating member 86, respectively similar to the parts 76, 78 described above.

The inlet end of the pump 30 is in permanent communication with the mixing chamber 74 through line 88. The outlet of pump 30 connects with analyzer inlet line 36 through line 90, the latter of which may, if desired, be provided with heat radiation fins or the like 92. Interposed in the line 90 is a pressure-regulating device 94 for controlling the pressure and flow rate of the gas-air mixture flowing to the cell 34. In the form shown this regulating device comprises a dead weight valve having a valve seat normally closed by a ball 96 so selected that its weight is equivalent to the pressure at which it is desired to analyze the gas mixture. When such gas pressure is exceeded, the excess gases force the ball from its seat and flow to the atmosphere through apertures 98. Preferably in present practice the ball is so selected that it is lifted from its seat when for any reason a pressure greater than that corresponding to four inches of water exists in the line 90, due, for instance, to variations in the speed of the motor operating the pump.

The analyzer cells 32, 34 have the usual catalytic wires 100, 102 therein, the same being disposed in a Wheatstone bridge circuit containing fixed resistances 104; 106; and the balancing or galvanometer line 108 has therein a pair of fixed resistances 110, 112, and a variable resistance or rheostat 114. For purposes of compactness, the fixed resistances preferably are in the form of short non-magnetic coils mounted closely adjacent the cells 32 and 34,—and the rheostat is positioned midway between the cells, as shown in Fig. 1.

The generator 22 is adjusted to produce an electric current substantially greater than that normally selected for use in the galvanometer circuit. For the purpose of maintaining a constant voltage in the galvanometer circuit irrespective of variations in the voltage driving the motor, one or more resistances in the form of carbon filament lamps or amperites 115 are arranged in series in the electric circuit connecting the generator with the Wheatstone bridge circuit, as shown. Preferably the generator is so regulated that a line voltage to the motor of 110 volts and a motor speed of 1700 R. P. M. will produce a current of 10 volts and 1.1 amperes when the catalytic wire in the circuit is at normal operating temperatures,—but will produce a current of 10 volts and 1.4 amperes for a few minutes,—at least 1 or 2 minutes,—when starting up. The amperites are then so selected as to reduce the voltage under normal operating conditions from 10 volts to 6 volts.

The orifice conduits 76, 84, and cooperating flow-regulating members 78, 86, preferably are adjusted to permit the induced flow of equal parts of air and gas to the mixing chamber 74 and thence to the pump 30 under suction from the latter. Other proportioning of air to gas is readily accomplished by replacing the flow-regulating members 78, 86 with other similar members having a larger or smaller portion of its longitudinal surface beveled or cut away in the manner shown in Fig. 8. These regulating members are readily replaceable, or removable for cleaning when necessary by unscrewing the hollow caps 120, 122, housing them and then simply sliding the said members longitudinally from their respective conduits. Thus the removal and replacement of the regulating members requires but a moment. The described dilution of the exhaust gases with air has been found to render innocuous any traces of products formed by the decomposition of antiknock substances, such as tetraethyl lead, present in the fuel used,—and to prevent injury to the catalyst by these decomposition products.

When the instrument is to be employed without the admixture of supplemental air for facilitating combustion in the analyzer cell, it will be obvious to those skilled in the art that the air filtering and regulating means and associated parts may be eliminated.

The arrangement as herein described is such that the gas-air mixture (or the gas alone when no secondary air is employed) flows to the distributing pump 30 in preselected regulated proportions under approximately atmospheric pressure regardless of the pressure existing in the line leading from the motor exhaust pipe to the inlet of the sampler pump 28.

For cleaning out the gas sampling line 42 and the sampling device 40 periodically when required, there is provided on the front 14 of the instrument panel a well known type of valve 124 such as widely used on pneumatic automobile tires. The valve is directly connected with the lines 42 and 43 through a metal fitting 126 carried on the instrument panel. Pressures as high as 50 lbs. per sq. in. may safely be imposed upon the line 42 through the valve 124 for the purpose specified, without danger of back pressure through the line 43 and associated parts injuring in any manner the delicate adjustment of the gas analyzer electric circuit or other parts of the apparatus. The galvanometer 128 disposed in the Wheatstone bridge circuit, as shown in Figs. 1 and 3, preferably is calibrated in terms of the combustion efficiency of the source from which the exhaust gases or waste gases being examined are drawn, this combustion efficiency being based upon the percentage and composition of combustibles present in the gas flowing to the analyzer.

The instrument, as here shown, is in the form of a very compact small portable unit which may readily be transported from place to place and may be employed for checking the calibration of other non-portable gas analyzers located at various places over a wide territory. Its construction here described insures uniform operation and accurate readings even under conditions where, due to irregularities in the current available for driving the motor 20, the amount of gas sample being drawn by the pump 28 substantially varies. Likewise the current flowing through the galvanometer circuit is maintained at a constant voltage which is at all times lower than that being generated by the generator 22, independently of substantial variations in the generator output due to irregularities in motor operation.

In the practice of the invention for analyzing motor exhaust gases, the end of the sampling device 40 is thrust into the exhaust pipe leading from the motor, the combustion efficiency of which is to be measured. The switch 26 on the instrument panel is closed, thus causing the motor generator set to function and both the pumps 28 and 30 to begin operation. Flow of gases from the exhaust pipe to the pump 28 is produced in part by the suction of the pump 28, and under some conditions in part by pressure developed in the exhaust pipe from the motor. The exhaust gases flow tangentially into the chamber 48 of the sampling device where they are substantially cooled and where a considerable portion of their moisture and solid suspended matter is deposited. The gases then flow through lines 42 and 43 to and through the separator and filter 54, and thence to the inlet of pump 28. The filtered gas is forced by the pump 28 into the chamber 68 where substantially atmospheric pressure exists due to the continuous free escape of excess gases therefrom through the aperture 72. A small regulated amount of the gas is drawn through the mixing chamber 74 under the action of the pump 30, the latter of which concurrently draws air through the filter 82, line 80, and regulating orifice chamber 84 to the mixing chamber 74. The gases then flow through the pump under a pressure continuously maintained higher than that at which they are to be analyzed in the cell 34. This gas mixture then flows to the cell past the pressure-reducing valve whereby pressure above that selected for the examination is released.

Preferably in the examination of motor exhaust gases employing the combustion type of gas analyzer, a pressure equivalent to 4 inches of water is maintained upon the gases flowing through the combustion cell 34. The use of heat-radiating fins upon the line leading from the pump to the analyzer cell facilitates introduction of the gases to the latter at an approximately uniform temperature at all times. Any small variations in gas temperature are such as do not measurably affect the accuracy of the instrument readings.

When the test is begun by closing the switch 26, the catalytic wires 100, 102, are at low temperatures, and the generator produces a 10 volt current which is then reduced to a 6 volt current of a relatively high amperage,—in the neighborhood of 1.4 amperes,—and which flows through the catalytic wires for a short period of 1 or 2 minutes. This heats the catalytic elements to temperatures generally within the range of from 1600° to 1925° F.,—following which the increased resistance of the highly heated catalytic elements reduces the current flowing in the Wheatstone bridge circuits to the normal selected operating current, preferably of 1.1 amperes, at a constant voltage of 6 volts, which is then maintained irrespective of ordinary variations in voltage of the current driving the motor. The operating temperatures of the catalytic elements preferably are then maintained around 1120° to 1380° F. The reduction of the current generated to one of constant voltage in the Wheatstone bridge circuit irrespective of variations in the generator output,—is effected by the amperites 115.

If desired, when beginning the test, the gas sampling tube may be exposed to air, so that air only is pumped over the catalytic wire 102 during the high temperature reactivation.

It will be obvious to those skilled in the art that it is not essential to the practice of the invention to employ the specific arrangement of parts herein described, including the gas sampling device, and the specific form of pressure-release valve and flow-regulating orifice members described; nor is it essential that the specific arrangement of parts in the Wheatstone bridge circuit described be employed. Furthermore the specific voltages and amperages specified in the above-mentioned specific embodiment of the invention may be materially departed from. The invention set out in the accompanying claims is susceptible of modification within the scope of the latter.

I claim:

1. In gas analyzing apparatus, flow regulating means comprising an orifice block, a pressure relief chamber within said block having an outlet leading to the atmosphere and having an inlet to which gas to be analyzed is supplied under pressure, a mixing chamber within said block, a pump having a suction conduit leading to said mixing chamber and having a discharge conduit provided with two outlets, one of which leads to the atmosphere, an orifice inlet conduit from the atmosphere leading into said mixing chamber, a flow-measuring orifice conduit communicably connecting the pressure relief chamber and the mixing chamber, and a pair of freely rotatable longitudinally slidable flow-regulating members respectively disposed longitudinally within the flow-measuring orifice conduit and the orifice inlet conduit from atmosphere and dimensioned to limit to a calibrated amount the flow capacity of each of said orifices.

2. In gas analyzing apparatus, a flow-regulating device comprising an orifice block, a pressure relief chamber within said block having an outlet leading to atmosphere and having an inlet to which gas to be analyzed is supplied under pressure, a mixing chamber within said block having an outlet from which gas is removed under suction, an orifice conduit communicably connecting said pressure relief chamber and said mixing chamber, an aperture extension of said orifice conduit ported out through a wall of said block, a freely rotatable longitudinally slidable flow-regulating member disposed longitudinally of said orifice conduit and dimensioned to limit to a calibrated amount the flow-capacity of said conduit, and a removable plug closure for the aperture whereby to afford access for the rapid removal and replacement of said flow regulating member.

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