Feb. 26, 1952 F. F. YANIKOSKI 2,586,899

GAS ANALYSIS APPARATUS

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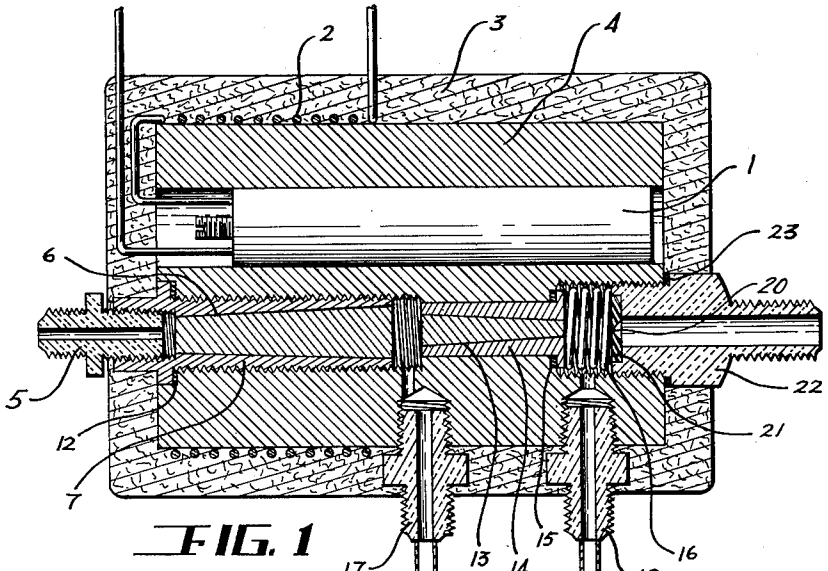


FIG. 1

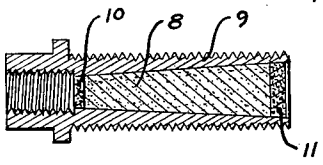


FIG. 4

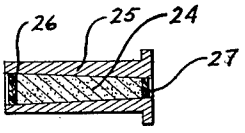


FIG. 5

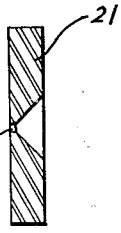


FIG. 3

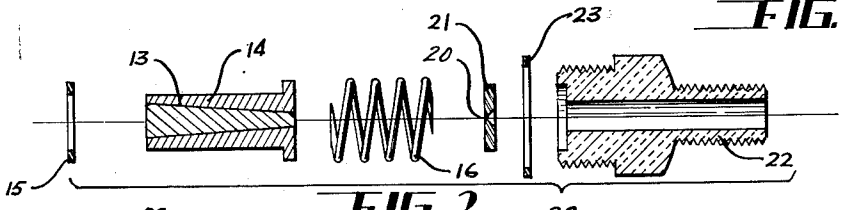


FIG. 2

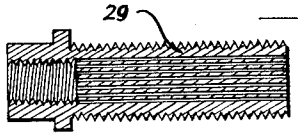


FIG. 6

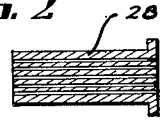


FIG. 7

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GAS ANALYSIS APPARATUS

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1 Claim. (Cl. 73—25)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

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The invention described herein may be manufactured and used by or for the Government for governmental purposes without payment to me of any royalty thereon.

This invention relates to gas analysis apparatus of the type that continuously determines the percentage of one gas in a mixture of two or more gases. One object of the invention is to provide a gas analysis apparatus capable of very high speeds in responding to a change in the composition of the sample. Another object is to provide an apparatus of simple construction which provides accurate analyses substantially independent of the temperature and pressure of the surrounding atmosphere. Still another object is to provide an apparatus capable of safely analyzing explosive mixtures of gases. Still another object is to provide a gas analysis apparatus which utilizes the fact that the relative viscosities of gases change as a function of temperature. Still another object is to provide an apparatus which utilizes the fact that the viscosity of gas apparently changes when the width of the flow path is reduced to values approaching that of the mean free molecular path.

These and other objects will be apparent to those skilled in the art from the following description and the related drawings.

In the drawings:

Fig. 1 is a sectional view of the preferred form of the invention shown connected to one type of pressure differential indicator;

Fig. 2 is an exploded view of some of the parts shown in Fig. 1;

Fig. 3 is an enlarged sectional view of the orifice plate;

Fig. 4 is a sectional view of an alternate type of heat exchanger;

Fig. 5 is a sectional view of an alternate type of restriction to flow;

Fig. 6 is a sectional view of another alternate type of heat exchanger; and

Fig. 7 is a sectional view of another alternate type of restriction.

Similar reference numerals indicate the same parts throughout the several views.

My invention is embodied in various combinations of apparatus which cause a sample of gas to undergo pressure changes depending on the chemical nature of the sample, and indicating or recording apparatus operated by the said pressure change. When considering a mixture of two definite gases the pressure-operated apparatus may be calibrated directly in terms of the percentage of each gas present in the sample.

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More specifically, the measured pressure drop occurs as the sample passes through restrictions which cause viscous drag, the volumetric flow rate through the said restrictions being determined by causing the sample gas to pass through an orifice at the maximum rate. The maximum rate of flow for some gases is considerably different from that of other gases, but is substantially independent of the pressure upstream of the orifice provided the absolute pressure downstream of orifice does not exceed approximately one-half the absolute pressure upstream of the orifice. Since the viscosity of gases is also substantially independent of the pressure, the viscous pressure drop developed in the restriction is substantially independent of the pressure of the sample.

Both the viscosity and the maximum flow rate of all gases are functions of temperature, therefore preferable combinations of apparatus include means to correct the temperature of the sample to within a fraction of a degree of a predetermined temperature before the sample passes through the restriction and the orifice. Assuming a constant temperature, the pressure drop developed by viscous flow through the restriction is

$$dp=Cuv \tag{1}$$

dp—pressure drop.
u—viscosity (poises).
v—volumetric flow rate.

Neglecting errors due to the assumptions of the gas law $PV=WRT$, the volumetric flow rate through the orifice is

$$v=C_1A\sqrt{gTRk\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}} \text{ ft.}^3\text{/sec.} \tag{2}$$

C, C_1, C_2, C_3—constants.
A—orifice area, ft.^{2}.
g—gravitational const.
T—degrees Rankine.
R—gas constant.
k—ratio of spec. heats.
w—molecular weight.

Writing R as 1544/molecular weight and combining all constants, (2) becomes

$$v=C_2\times\frac{1}{\sqrt{W}}\sqrt{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}} \tag{3}$$

Substituting the value of v into Equation 1, and combining constants

$$dp=C_3\frac{u}{\sqrt{W}}\sqrt{k\left(\frac{2}{k+1}\right)^{(k+1)/(k-1)}} \tag{4}$$

The long radical in Equation 4 may be replaced by approximate values tabulated below:

For inert gases (helium and argon)	.725
For diatomic gases (N_2, O_2, air, CO, HCl, NO, etc.)	.685
For complex gases (hydrocarbons, etc.)—varies	.64 to .67

Values of pressure drop relative to air are listed below for certain common gases:

Pressure drop relative to air for a certain analyzer operating at 100° F.

Hexane	.20
Ethyl ether	.26
Freon 12	.34
Methyl bromide	.42
Acetylene	.57
Carbon dioxide	.66
Bromine	.80
Air	1.00
Hydrogen	1.70
Helium	2.65

While this list is far from complete, it serves to illustrate the wide difference in pressure drops developed in some cases. The pressure drop for each of the gases listed above is sufficiently different from others that mixtures of any two could be analyzed. A complete table of gases would lead to innumerable other combinations that could be analyzed. Certain groups of gases, such as CO, N_2, and air, have substantially identical pressure drops and may be treated in any proportions as a single gas when analyzing for one other gas, such as CO_2, which has a substantially different pressure drop.

Since viscosity is a function of temperature, the relative values would be somewhat different if the operating temperature of the analyzer were changed. By choosing the proper temperature it is possible in some cases to cause two or more gases to undergo an identical pressure drop, and under these circumstances any proportions of said gases may be treated as a single gas when analyzing for still another gas. When seeking such a temperature it is only necessary to plot curves of pressure drop against temperature for the various gases concerned and choose the temperature at which the pressure curves cross or become tangent.

The pressure drop developed by viscous flow through a resistance is, in addition to the temperature, also a function of the mean free path of the gas molecules provided the cross section of the flow path is not large compared to the length of the molecular free path. By means described later in this discussion, the average cross section of the flow path may be reduced to the point where the relative pressure drops may be changed slightly to cause two or more gases to have an identical pressure drop for the purpose of determining the percentage of still another gas having a substantially different pressure drop. Furthermore, by combining the effect of changing the operating temperature and the effect of changing the cross section of the flow path, still other groups of gases may be caused to develop identical pressure drops for the purpose of analyzing for one gas in a mixture of more than two gases.

The means used to accomplish the operations described above are combinations of apparatus which will now be described.

The preferred embodiment of my invention is illustrated in Fig. 1. A thermostatic control of any type known to the art, but in this instance

represented by a thermostatic switch 1 and heater winding 2 operates to maintain all the internal parts at substantially a certain constant temperature.

Any suitable insulation 3 minimizes heat exchange between the ambient air and the internal parts of the analyzer. A main body 4, hereafter known as the heat reservoir, provides a heat capacity sufficiently large to prevent sudden fluctuations in temperature. A further function of the heat reservoir is to conduct heat to all the internal parts. Still another function of the heat reservoir is to provide a convenient body to which other parts are secured.

An inlet fitting 5 insulates the internal parts from externally connected parts such as a filter, drier, saturator, chemical absorber or other preparatory apparatus well known in the art while conducting the gas sample from the said preparatory apparatus to a heat exchanger 6. The heat exchanger, preferably formed of porous metal, but which can alternatively be formed of porous ceramic, glass or other material, efficiently heats the gas passing through its numerous channels. A heat exchanger so constructed is highly preferred to others because of its ability to change the temperature of a sample as much as 200° F. in a fraction of a second and yield a terminal temperature within a fraction of a degree of the desired temperature. Accuracy combined with speed in temperature control provides response not obtainable with heat exchangers commonly used. The retainer 7, made of any heat conducting material, has a preferably tapered hole into which the porous material is fitted. An alternate type of heat exchanger illustrated in Fig. 4, consists of individual pieces of material 8 packed into a retainer 9 and held in place by end plugs 10 and 11 which have passages to pass gas but to retain solids. The material 8 may be beads, chips, strands, or other small shapes of any material, but preferably good heat conductors. Still another heat exchanger which may be used but which is not preferred is illustrated in Fig. 6. This heat exchanger 29 consists of any heat conducting material through which is formed one or more holes to conduct the sample. Gasket 12 serves as a pressure seal and as a means of exerting force on the threads of parts 4 and 7 to insure efficient heat transfer.

A restriction 13 to flow is made of porous material having numerous flow paths of small cross section. For many purposes porous metal is superior, but alternately porous ceramic, glass or other materials may be used. A retainer 14 held tightly against a gasket 15 by a spring 16, preferably fits freely in the heat reservoir 4 so that it may be easily interchanged with other retainers. Such construction permits quick changes in the operating characteristics of the analyzer if retainers containing various types of restrictive material are made available. In addition to the type of restriction made of molded porous materials, other restrictions shown in Fig. 5 and Fig. 7 may be used. The restriction in Fig. 5 is structurally similar to that of the heat exchanger in Fig. 4, consisting of particles of material 24, retainer 25, and end plugs 26 and 27. The restriction 28 shown in Fig. 7 represents many possible arrangements of one or more capillary channels, but in this case consists of a metal plug through which holes of small diameter are formed.

Fittings 17 and 18 provide means to connect any suitable device for measuring pressure drops developed in the restriction 13. A manometer 19 is representative of numerous indicators, re-

corders, or controllers known to the art which operate on a pressure differential. For example, a diaphragm operated by the differential pressure at fittings 17 and 18 could control valves in such a manner that the analyzer apparatus tends to maintain a mixture of definite proportions downstream of the said valves.

An orifice 20 in an orifice plate 21 passes a volume of gas substantially independent of the pressure of the gas provided the absolute pressure downstream of the orifice does not exceed approximately one-half the absolute pressure upstream of the orifice. An outlet fitting 22 serves as a mounting for the orifice plate, as a thermal insulator, and as a means to connect to any suitable evacuating pump (not shown). No evacuating pump is required if the gas sample enters the analyzer at a pressure high enough above atmospheric pressure to satisfy the conditions for critical flow. A gasket 23 prevents leakage of gas around the threads of fitting 22.

It is understood that the details of construction are not necessarily limited to those described above in the preferred embodiment of my invention. The invention consists in certain improvements and combinations of parts set forth in the following claim.

What I claim as my invention:

A gas analysis apparatus comprising an insulated heat reservoir through which is formed a passage for the flow of gas to be analyzed, a heater winding adjacent to the said heat reservoir, a thermostatic switch operating in a manner to close and open a circuit including the said heater winding, an elongated porous mass heat exchanger removably mounted in the said gas passage, a retainer for the said heat exchanger removably mounted in the said passage, an elongated porous restriction removably mounted in the said gas passage, a retainer for the said elongated restriction removably mounted in the said passage, insulating fittings mounted in the said heat reservoir in such a manner that their internal openings connect to the said passage at opposite ends of the said elongated porous restriction, an insulating gas connector at the outlet end of the said passage, and a restrictive orifice plate mounted in the said connector between the orifice plate and outlet, and means to maintain on opposite sides of the said orifice plate a pressure drop sufficient to cause maximum flow.

FLORIAN F. YANIKOSKI.

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