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PROCESS AND APPARATUS FOR ANALYZING GAS

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Fig. 1.

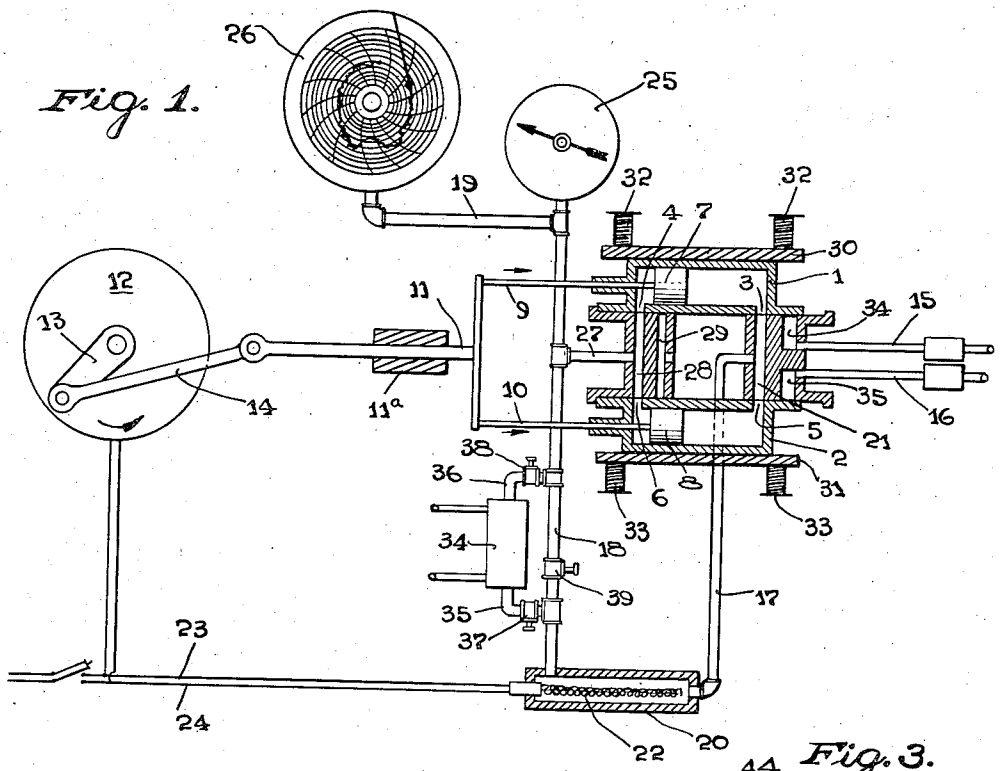


Fig. 3.

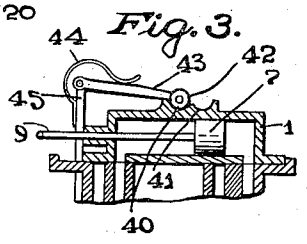
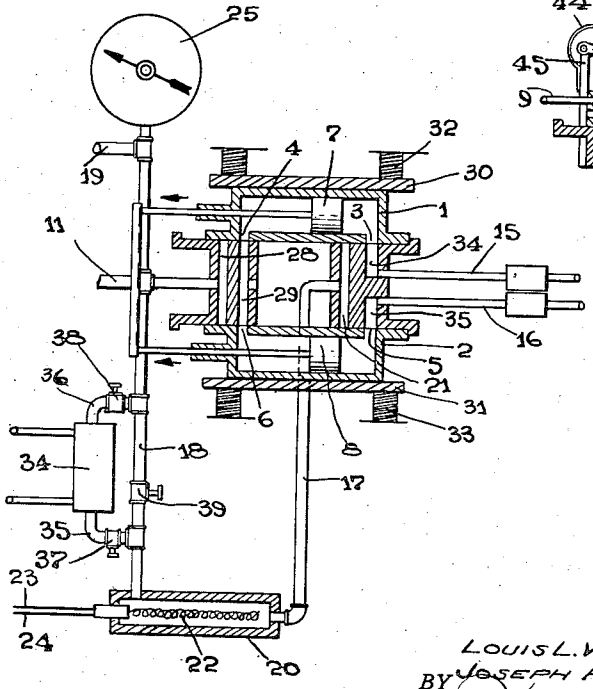


Fig. 2.



INVENTORS
LOUIS L. VAYDA AND
JOSEPH A. STEIN
BY James C. Bradley
ATTORNEY

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PROCESS AND APPARATUS FOR ANALYZING GAS

Louis L. Vayda, Aspinwall, and Joseph A. Stein, Pittsburgh, Pa.

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7 Claims. (Cl. 23—256)

The invention relates to a process and apparatus for analyzing gas. The objects of the invention are the provision of a process and apparatus which have a very wide field of use permitting their use for practically all gases for which commercial requirement for analyzing exists. A further object is the provision of an apparatus which is dependable and accurate; which is operable without difficulty; and which is relatively cheap and simple in construction.

The process involves the use of a closed system, to which a gas mixture containing a constituent or constituents, whose percentage is to be determined, is supplied continuously, such mixture also containing a gas or gases which will react with said constituent or constituents. This reaction is caused to occur by the application of a suitable degree of heat and/or by a catalyzing agent, and a residual volume of gas is constantly evacuated from the system. If the volume of gases in the system tends to be increased or reduced by the reaction, this will be indicated by a change in pressure in the system, and it is this variation in pressure which indicates the extent of the reaction and consequently the amount of the reacting constituent. The instrument used may be easily calibrated to indicate the percentage of the constituent in the gas being tested. This will be readily understood from a consideration of the apparatus of the drawing, wherein:

Figure 1 is a diagrammatic view partly in section showing the moving parts in one position. Fig. 2 is a similar view of a part of the apparatus with the moving parts in another position. And Fig. 3 illustrates a modification.

Referring to the drawing, 1 and 2 are a pair of cylinders mounted for reciprocation, and provided with the ports 3, 4, 5 and 6; and 7 and 8 are a pair of pistons working in the cylinders and provided with piston rods 9 and 10 connected to the common cross head 11. This cross head is slidable in the block 11*a* and is driven from the electric motor 12 by means of the crank 13 and connecting rod 14. A gas to be analyzed for $CO+H_2$ content, such as flue or exhaust gases from the combustion of fuel, is supplied to the cylinder 1 through the pipe 15, while a second gas, such as air, is supplied to the cylinder 2 through the pipe 16. The two cylinders discharge to a closed system which includes the pipes 17, 18 and 19, and the furnace 20 through the passage 21 when the parts are in the position of Fig. 1 with the ports 3 and 5 in registration with such passage. The furnace 20 is heated from the coil 22 supplied with electric current from the leads 23 and 24, which also supply current for driving the motor 12. The pipes 18 and 19 are connected to the pressure indicators 25 and 26, the latter of which is of the recording type. The pipe 18 is connected by means of a pipe 27 with a passage 28 which communicates at its ends with the ports 4 and 6 when the parts are in the position of Fig. 1. 29 is an exhaust passage to the atmosphere which registers with the ports 4 and 6 when the parts are in the position of Fig. 2. The cylinders 1 and 2 are mounted for sliding movement from one extreme position, as indicated in Fig. 1, to another extreme position, as indicated in Fig. 2, and their movement from one position to the other occurs when the pistons 7 and 8 approach the ends of their strokes and engage the cylinder heads. The cylinders are pressed yieldingly against the surfaces upon which they slide by any suitable means which, in the present case, are diagrammatically shown as plates 30 and 31 engaging the outer faces of the cylinders and pressed inward by springs 32 and 33.

Starting with the parts in the position of Fig. 1, and the pistons moving to the right, the pistons are forcing into the pipe 17 the gases in the cylinders to the right thereof via the ports 3 and 5 and passage 21. At the same time, gas is being evacuated from the pipe 27 into the cylinders to the left of the pistons via the passage 28 and ports 4 and 6. This causes a circulation of the gas through the pipe 17, furnace 20, and pipe 18, giving opportunity for a reaction to occur in the furnace resulting in a change in pressure, as more fully described later.

This supply of gas to the pipe 17 and withdrawal through the pipe 27 continues until the pistons reach the right hand ends of the cylinders where they engage the cylinder heads, and move the cylinders to the position of Fig. 2. This brings the ports 3 and 5 into registration with the passages 34 and 35 respectively with which the pipes 15 and 16 communicate, and as the pistons move to the left, the cylinders are charged with gas from such pipes. With the cylinders in the position of Fig. 2, the ports 4 and 6 are in registration with the exhaust passage 29 so that, as the pistons move to the left, the contents of the cylinders to the left of the pistons is discharged to the atmosphere. This charging of the right hand ends of the cylinders and the exhausting of the left hand ends thereof continues until the pistons engage the heads at the left hand end of the cylinders, when such cylinders are shifted to the left to the position of Fig. 1. The pistons now start to the right, bring-

ing the parts back to the starting point of the cycle as above outlined.

In the above operation, the reactions in the furnace **20** transforming the CO in the flue gases to CO_2 and the hydrogen to H_2O would normally reduce the volume of the gases of reaction, as compared with the initial volume of the gases mixed. It follows that since the capacity of the system remains constant, the pressure will be reduced in proportion to the extent of the reaction, so that by proper calibration of the indicators **25** and **26**, these can be made to read in terms of the percentage of the combustible constituent supplied from the pipe **15**.

The reaction which occurs in the reactions above indicated is shown by the following equations:

$$2CO+O_2=2CO_2$$
$$2H_2+O_2=2H_2O$$

From which it is seen that three volumes of the reacting gases in either case give two volumes of gaseous products of reaction. This operation, in order to give accurate results, will require that the cylinders connecting passages and piping be maintained at a temperature high enough to prevent condensation of the water vapor formed by the reacting gases, which can easily be accomplished by placing the apparatus in a heated cabinet (not shown) or by submerging it in a heated liquid, such as oil, which latter expedient has the further advantage of lubricating the moving parts.

A further application of the apparatus is in the determination of the percentage of oxygen in the flue and furnace gases from boiler furnaces, industrial heating and annealing furnaces, open hearth furnaces, kilns, etc. In using the apparatus, the cylinder **1** is connected to draw in the gas to be analyzed, while the cylinder **2** is connected to draw in a gas which will unite with the oxygen, such as hydrogen. The reaction in the furace is indicated by the following equation:

$$O_2+2H_2=2H_2O$$

From which it is seen that three volumes of the reacting gases give two volumes of the gaseous products of the reaction, resulting in a change in pressure in the system as heretofore described. This use of the apparatus also requires a maintenance of the temperature of the apparatus above a given point to prevent condensation, and suitable means may be employed for this purpose as above pointed out.

The apparatus may further be used to determine the per cent of carbon monoxide and/or hydrogen in air, such as may exist in vehicular tunnels, garages, or other confined spaces subject to pollution by the exhaust gases from automotive vehicles. In this case, however, the air to be tested is drawn into the system from the pipes **15** and **16** by both pistons **7** and **8**, the oxygen in the mixture being sufficient to give the necessary reaction in the furnace **20**. The reaction is indicated in the following equation:

$$2CO+O_2=2CO_2$$
$$2H_2+O_2=2H_2O$$

It will be seen that three volumes of the reacting gases in either case gives two volumes of gaseous products of reaction. But since the percentage by volume of carbon monoxide and/or hydrogen in the air tested, will in most cases be small, the volume change due to the reaction, will be correspondingly small, perhaps too small for practical measurement of the resulting change in pressure. It is, therefore, desirable to increase the difference in pressure, and this is accomplished by bringing into play the condenser or absorber unit **34**, connected to the pipe **18** by pipes **35** and **36** provided with the valves **37** and **38**. The unit may be equipped to provide for the removal of the carbon dioxide formed, as by the use of potassium hydroxide and/or for the removal of the water vapor by the use of calcium chloride. When so used, the gases from the furnace, are caused to pass through the casing **34** by closing the valve **39** and opening the valves **37** and **38**. The volume of the reacting gases may, in this manner, be removed from the system, and the resulting change in pressure is correspondingly increased. When the use of the unit **34** is not required, it is cut off from the system by the valves **37** and **38**, at which time the valve **39** is open.

The apparatus may be similarly employed to determine the percentage of inflammable gas or vapors in air, such as for example the percentage of methane in air which has been used for the ventilation of a mine. As in the preceding example, the gas to be tested is drawn in through the pipes **15** and **16** by both pistons, and the unit **34** is utilized. In this case, the reaction is indicated by the following equation:

$$CH_4+2O_2=CO_2+2H_2O$$

It will be seen that three volumes of the reacting gases gives three volumes of the gaseous products of the reaction. There is thus no change in volume, and no change in pressure. The necessary change in pressure is secured by passing the gases through the unit **34**, which, as before, is equipped to chemically remove the carbon dioxide, as by the use of potassium hydroxide, and to remove the water vapor by the use of calcium chloride. The volume of reacting gases may thus be removed and the resulting variation in pressure in the system measured.

Fig. 3 illustrates a modified means for holding the cylinders against their seats and maintaining them yieldingly in their extremes of movement until positively moved by the pistons. The cylinder is provided on its upper side with two recesses **40** and **41** adapted to be engaged by the roller **42** on the arm **43** yieldingly pressed down by the spring **44**, the arm **43** being pivoted to the fixed bracket **45**. The cylinder is held in the position shown until the piston which is moving to the left engages the end of the cylinder and moves it to the left. The roller **42** resists this movement, but is cammed upward and then moves down and engages the recess **41** holding the cylinder in its new position until the reverse movement of the piston shifts the cylinder back to the position shown.

It will be understood that the apparatus is illustrated in a very simple form and is capable of various modifications. Other forms of pumps may be substituted for those shown, such as those of the rotary displacement type. In some cases, the apparatus may be made with only the one pump for use in those cases in which no additional gas need be applied to the system to promote the reaction as in the determination of CH_4 in air as heretofore described. It is also not necessary to provide for the reaction by heat as supplied in the furnace **20**. The reaction may be secured by the use of a catalyzing agent with or without heat, such as may be accomplished by the use of palladium sponge or certain metallic oxides.

What we claim is:

1. An apparatus for analyzing gas, comprising a closed reaction system provided with a pressure indicator, and means for delivering a gas mixture into the system and evacuating it therefrom comprising a piston and means for reciprocating it, a cylinder in which the piston works mounted for limited endwise movement, and adapted to be moved endwise by the piston when it reaches the end of its stroke in each direction, a port at one end of the cylinder through which the gas to be analyzed is supplied when the cylinder is in one position and the piston is retreating from the port and through which the gas is expelled into the system when the cylinder is in its other position and the piston is moving toward the port, and a second port at the other end of the cylinder through which the gas to be evacuated from the system is supplied from the system when the cylinder is in its last mentioned position and the piston is retreating from the said second port and through which gas is expelled to the atmosphere when the cylinder is in its first mentioned position and the piston is moving toward the said second port.

2. A method of analyzing gas, which consists in separately pumping into a closed gas tight system (1) a gas mixture containing a constituent the percentage of which it is desired to determine, and (2) a fixed proportion of some other gas which will react with the constituent in a definite manner so that the volume of the gaseous products of the reaction tends to vary from the initial volume of the combining gases, causing said reaction to occur, treating the products of said reaction to reduce their volume, withdrawing from the system by a pumping operation coincident with the supply of gas thereto a quantity of the gas which has been exposed to said reaction bearing a fixed relation to the quantity of gas delivered into the system, and measuring the variation of pressure in the system while gas is being supplied to the system and withdrawn therefrom.

3. An apparatus for analyzing gas, comprising a closed gas tight passage provided with an inlet and an outlet, a pressure indicator connected to the passage, two sets of pumping means each of which is connected to said inlet and outlet, one of which is adapted to supply a gas to be tested and the other of which to supply a reaction gas to said inlet, and which pumping means simultaneously withdraw a volume of gas from said outlet which is equal to the volume supplied to the inlet, ignition means in the passage past which the gas is caused to flow by the pumping means, and means for driving the pumping means continuously.

4. A method of analyzing gas, which consists in pumping continually into a closed gas tight system, a gas mixture containing a constituent whose percentage it is desired to determine, said mixture containing some other gas which will react with said constituent in a definite manner so that the volume of the gaseous products of the reaction tends to vary from the initial volume of the combining gases, causing said reaction to occur, withdrawing continually from the system coincident with the supply of gas thereto, and by a pumping operation a quantity of gas which has been exposed to said reaction bearing a fixed relation to the quantity of gas delivered into the system, and measuring the variation in pressure in the system while the operations of supplying gas to the system and withdrawing it therefrom are in progress.

5. A method of analyzing gas, which consists in pumping continually into a closed gas tight system a gas mixture containing a constituent whose percentage it is desired to determine, said mixture containing some other gas which will react with said constituent in a definite manner so that the volume of the gaseous products of the reaction tends to vary from the initial volume of the combining gases, causing said reaction to occur, withdrawing continually from the system coincident with the supply of gas thereto and by a pumping operation a quantity of gas which has been exposed to said reaction which is equal to the quantity of gas delivered into the system, and measuring the variation in pressure in the system while the operations of supplying gas to the system and withdrawing it therefrom are in progress.

6. An apparatus for analyzing gas, comprising a closed gas tight passage provided with an inlet and an outlet, a pressure indicator connected to the passage, pumping means connected to said inlet and outlet and adapted to simultaneously supply a volume of gas to be tested to said inlet and to withdraw a volume of gas from said outlet bearing a fixed relation to the first volume of gas, ignition means in the passage past which the gas is caused to flow by the pumping means, and means for driving the pumping means continuously so as to cause a continual flow of gas past the ignition means.

7. An apparatus for analyzing gas, comprising a closed gas tight passage provided with an inlet and an outlet, a pressure indicator connected to the passage, pumping means connected to said inlet and outlet and adapted to simultaneously supply a volume of gas to be tested to said inlet and to withdraw a volume of gas from said outlet bearing a fixed relation to the first volume of gas, ignition means in the passage, absorption means in the passage between the ignition means and said outlet for absorbing a part of the products of the reaction which occurs due to the ignition means, and means for driving the pumping means continuously so as to cause a continual flow of gas past the ignition and absorption means.

LOUIS L. VAYDA.
JOSEPH A. STEIN.