

Oct. 28, 1930.

N. J. THOMPSON
METHOD OF TESTING THE FLAMMABLE CONDITION OF A MIXTURE
OF AIR OR OXYGEN WITH A FLAMMABLE GAS OR VAPOR
Filed Sept. 14, 1926

1,779,569

2 Sheets-Sheet 1

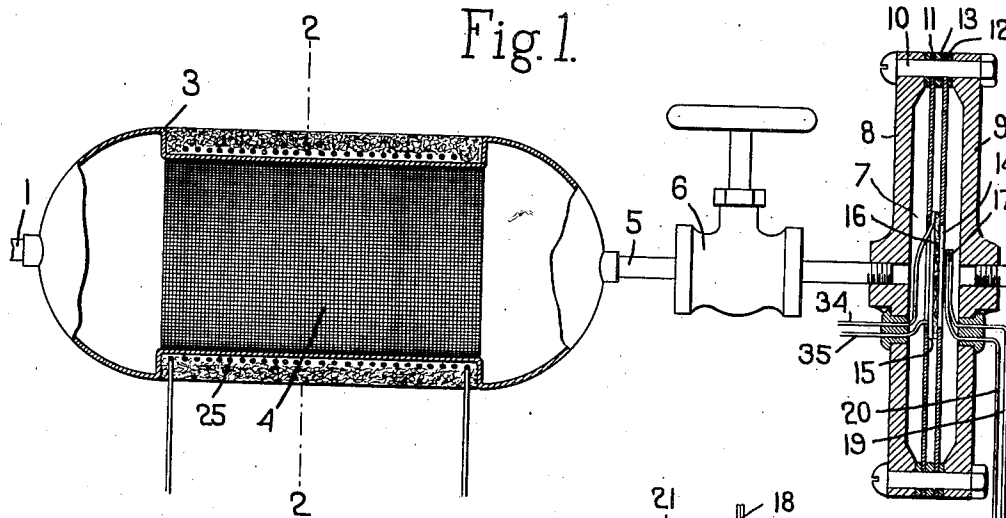


Fig. 2.

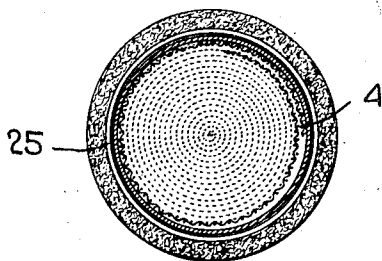
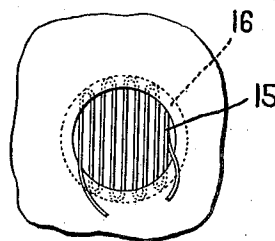


Fig. 3.



Inventor.
Norman J. Thompson
by *Heard Smith & Tennant.*
Attys.

Oct. 28, 1930.

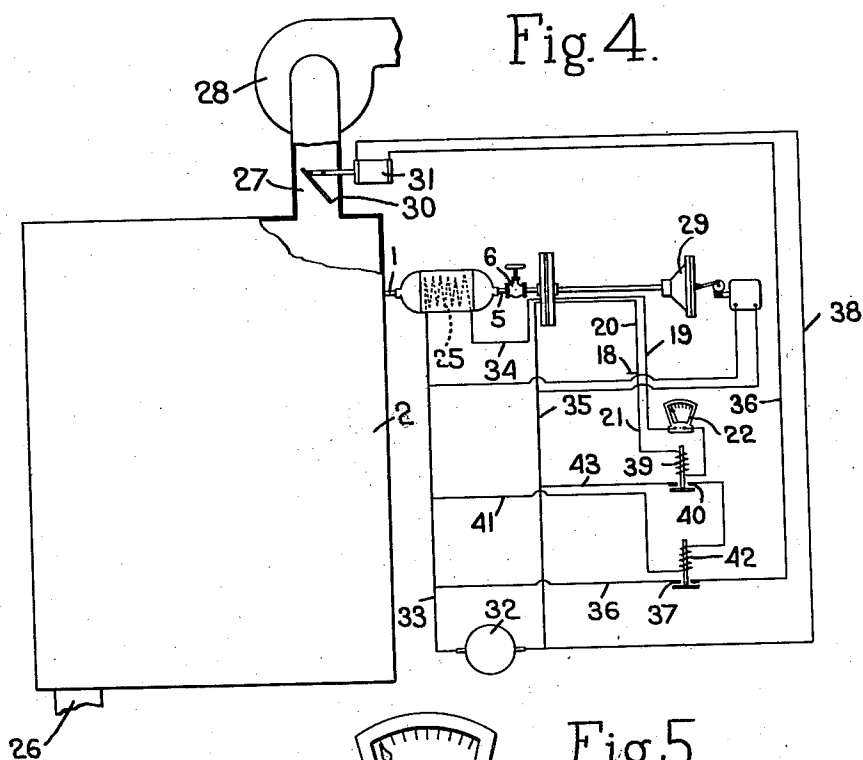
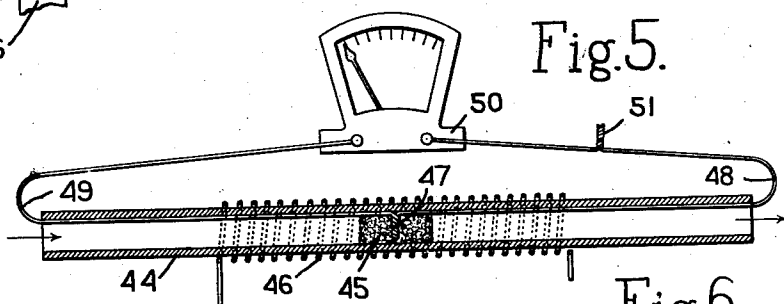
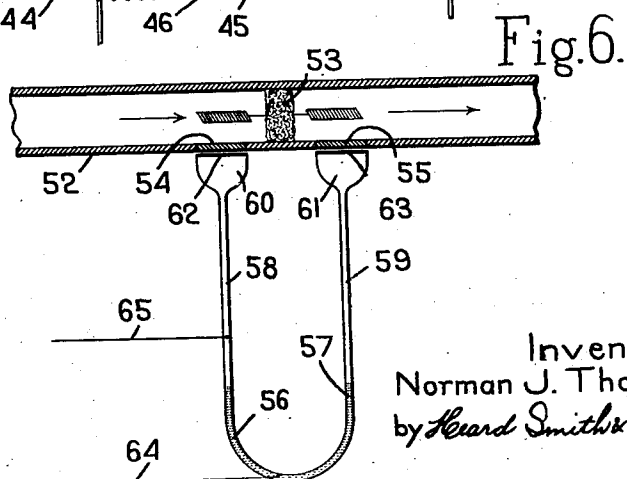
N. J. THOMPSON

1,779,569

METHOD OF TESTING THE FLAMMABLE CONDITION OF A MIXTURE
OF AIR OR OXYGEN WITH A FLAMMABLE GAS OR VAPOR

Filed Sept. 14, 1926

2 Sheets-Sheet 2



Inventor.
Norman J. Thompson
by *Heard Smith & Tennant.*
Attys.

UNITED STATES PATENT OFFICE

NORMAN J. THOMPSON, OF WELLESLEY HILLS, MASSACHUSETTS

METHOD OF TESTING THE FLAMMABLE CONDITION OF A MIXTURE OF AIR OR OXYGEN WITH A FLAMMABLE GAS OR VAPOR

Application filed September 14, 1926. Serial No. 135,322.

This invention relates to methods for continuously determining the flammable condition of a mixture of air and flammable gases, such as are widely employed commercially in various arts in which flammable, volatile solvents are used, in order that suitable steps may be taken to prevent the mixture from reaching or dangerously approaching the lower explosive limit.

The terms "gas" and "gases" are used herein to include not only such materials as are true gases at ordinary temperatures, but also vapors of materials which are normally liquid at ordinary temperatures.

This invention further relates to methods which may be utilized to determine the proportion of the flammable constituents of a mixture of flammable gases with air or oxygen irrespective of the particular gas or gases which may constitute the flammable constituents thereof.

The invention further comprises a method of automatically regulating the proportions of air or oxygen and flammable gases in a chamber in such a manner as to avoid with certainty the production of explosive mixtures therein.

Other objects and features of the invention will more fully appear from the following description and the accompanying drawings and will be particularly pointed out in the claims.

The present method and apparatus which may be employed in the performance thereof are particularly valuable in commercial arts in which volatile solvents are employed which are subsequently vaporized and the vapors thereof mixed with air as in japanning, enamelling, and various branches of the rubber industry and other industries.

Inasmuch as the volatile solvents used in commercial industries are largely hydrocarbons, the present method and apparatus will be more particularly described with reference thereto, although it will be understood, as will hereinafter more fully appear, that the invention is also applicable to the testing of the flammable condition of mixtures of air or oxygen with other flammable

vapors and gases, such for example, as hydrogen, carbon monoxide, etc.

The term "hydrocarbon" is employed herein in a broad sense to define any vapor or gaseous compounds of carbon and hydrogen, or of carbon, hydrogen and oxygen, or any mixture of such vapors or hydrocarbons either alone or combined with oxygen. Usually commercial hydrocarbons, such as gasoline, naphtha, benzol, and the like, comprise mixtures of various compounds containing hydrogen and carbon and are all included, together with various other hydrogen, carbon and oxygen-containing mixtures, within the above definition of "hydrocarbon". Such hydrocarbons, when mixed with air in proper proportions, form an explosive mixture and the present invention provides means for determining with exactness the proportion of flammable vapors in the mixture of such hydrocarbons with air so that the approach of the content of flammable gases or vapors in a mixture with air to the lower explosive limit may be determined and indicated in commercial apparatus and sufficient additional air or oxygen supplied to prevent explosion under the heat conditions existing.

In drying and baking chambers, such as are employed in enamelling or japanning the surfaces of metals, and in the rubber industry, the hydrocarbons which are used as solvents are rapidly volatilized so after the coated materials are placed in the oven and if the air introduced is insufficient in quantity an explosive mixture is quickly formed. The introduction of air into such ovens is usually maintained at a substantially constant rate and in numerous instances serious explosions have occurred by the overcharging of the ovens, or by the failure to introduce a sufficient amount of air to maintain the mixture in the oven below the lower explosive limit.

In continuous conveyor ovens and in other apparatus such as that used for coating fabrics with rubber the mixture of hydrocarbon and air in different portions of the chamber vary widely. By reason of the present method and apparatus the condition of the oven, or other chamber, at various points may be continuously tested so that the operator may be

advised of the exact conditions in the various parts of the chamber and, therefore, will be able to take suitable steps to avoid explosion.

In usual methods of testing the flammable condition of mixtures of vapor and hydrocarbon a sample of vapor is taken from the oven, or other chamber, and is thereafter subjected to an analytical or other test to determine the proportion of hydrocarbon contained therein. Such tests are subject to considerable error by reason of the condensation of the hydrocarbon vapors.

The present invention contemplates the testing of the mixture at a temperature in excess of that which will permit condensation.

I have found that the minimum temperature necessary to prevent condensation below explosive strength mixture of the hydrogen and carbon-containing vapors, which are commercially employed at the present time, is usually not over 212° F. The present invention, therefore, contemplates, where necessary, the maintenance of the mixture at a temperature in excess of 212° F. or at such other temperature as is necessary to prevent condensation below flammable strength.

I have discovered that at any given temperature and at the lower limit of explosive strength of mixtures of hydrocarbon vapors or gases with air, the heat of complete combustion of a definite volume of the mixture is approximately the same regardless of the particular hydrocarbon or hydrocarbons in question. It, therefore, follows that at any definite fraction of the lower explosive limit strength different mixtures will give identical heat units of combustion. Different hydrocarbons in mixture with air vary in the percentage of vapor required to produce complete combustion at the lower explosive or flammable limit, for example, the lower explosive limit percentage of gasoline is approximately 1.3%; of benzol 1.4%; of acetylene 2.5%; and of methane 5.5%. The heat of complete combustion per 100 cubic centimeters of vapor and air mixture at, for example, 20-degrees C. and 760-mm. barometric pressure, for all of these, as well as of other hydrocarbon compounds, is the same, being approximately fifty calories in each case.

The present invention is based upon the above discoveries.

I have also found that an instrument for performing the process herein described when calibrated for a particular hydrocarbon may be employed to determine the proportion of flammable vapor or gases of any other hydrocarbon.

Furthermore, I have found that the process and the apparatus for performing the same is not limited to hydrocarbons so that the same instrument may, by suitable calibration, be employed for any other flammable

gas or gases, such as hydrogen or carbon monoxide.

The novel method of testing flammable or or explosive condition of a mixture of flammable gases and air may, in its broad sense, be defined as consisting in maintaining a continuously flowing sample of the mixture at a temperature sufficient to prevent condensation, causing combustion of the flammable gases of said sample, and measuring the increase in temperature produced thereby and in determining from such increase in temperature the proportion of flammable vapors in the mixture.

In performing the method a current of hydrocarbon-containing air is caused to flow through a conduit in which it is maintained at a temperature in excess of the temperature of condensation of an explosive mixture of the flammable material and is subjected, while in the conduit, to means, preferably a catalyst, heated or not, or a heated inert material, which will cause combustion of the flammable content of the mixture. The increase in temperature caused by such combustion is measured by suitable means and the proportion of flammable material, which is proportional to the increase in temperature caused by such combustion, is determined therefrom. A thermocouple, located in contact with the catalyst or inert material, or in the field of combustion in proximity thereto, provides a convenient means for determining the proportion of the flammable material in the mixture as the rise in voltage in the thermocouple is proportional to the increase in temperature produced by such combustion and consequently to the proportion of flammable material contained in the mixture.

It will, however, be understood that various other means may be employed for determining the increase in temperature caused by such combustion and that the present method contemplates the utilization of any means for accomplishing this purpose.

Different types of apparatus are disclosed in the accompanying drawings which are adapted to perform the method herein described, and it will be understood, therefore, that the method in its broad sense contemplates the employment of any apparatus or means for producing the various steps of the method herein described.

In the drawings:

Fig. 1 is a view, partly in section, of a preferred form of apparatus for testing the flammable condition of a mixture of air or oxygen with a flammable gas or vapor in accordance with the method herein described;

Fig. 2 is a detail sectional view on line 2—2 Fig. 1 of the "flashback" preventer;

Fig. 3 is a detail elevation showing the heating unit for raising the temperature of the mixture to a temperature sufficient to cause

combustion of the hydrocarbon or other flammable material contained in the mixture, illustrating also the catalyst or inert material in contact with or in proximity thereto;

Fig. 4 is a diagrammatic view showing apparatus for performing the present invention applied to a drying chamber, together with means for automatically regulating the supply of air to the chamber for the purpose of maintaining a sufficient amount in the chamber to avoid the production of an explosive mixture therein;

Fig. 5 is a view, partly in section, showing a different form of apparatus adapted to perform the method above described; and,

Fig. 6 is a view, partly in section, illustrating another form of apparatus for the same purpose.

The apparatus illustrated in Figs. 1 to 4 inclusive comprises a conduit adapted to receive a continuously flowing sample of the mixture of air with a flammable gas or gases, with means for maintaining the mixture at a higher temperature than the temperature of condensation of the flammable material, with means in the path of the flowing current of mixture to cause combustion, and means for measuring the increase in temperature caused by such combustion.

In this apparatus the conduit 1 which, as illustrated in Fig. 4, communicates with the interior of a drying or other chamber 2 containing a mixture of air and inflammable vapor and/or gases, leads to a flashback preventer 3 in the form of a cylindrical chamber containing a closely wound spiral coil of wire mesh 4 through which the flowing sample of air passes, thence through a continuation 5 of the conduit 1 provided with a regulating valve 6 to the chamber 7 of the testing device. The particular form of testing device illustrated in Figs. 1 to 4 inclusive comprises duplicate casing members 8 and 9, preferably of circular form, having peripheral inwardly-extending flanges which are clamped together by a series of bolts 10. A pair of insulating disks 11 and 12, preferably of mica, which are separated from each other and from the flanges of the casing by asbestos packing 13, are clamped between the peripheries of the casing members 8 and 9. The mica disks 11 and 12 are provided with central apertures 14 through which the mixture is caused to flow. A heating unit 15, which may be in the form of a grid of nichrome wire, is located transversely of this aperture and preferably in contact with a suitable catalyst 16, such as platinized asbestos.

The presence of a heating unit may not be necessary if a suitable catalyst is employed. Furthermore, a suitable inert material may be used in place of the catalyst where a heating unit is employed for raising the temperature of the mixture to or above the flammable

temperature of the hydrocarbon thereof.

Any suitable means may be employed for measuring the rise in temperature caused by the combustion of the hydrocarbon content of the mixture. As illustrated in Fig. 1 the thermocouple 17 is located in contact with the catalyst or inert material, or in such close proximity thereto as to be in the field of combustion and suitable means are provided for measuring the increase in voltage caused by such combustion.

Preferably the temperature-measuring device comprises a hot and a cold thermocouple arranged in series with a millivoltmeter in circuit operable by the differential in voltage produced by the hot and cold thermocouples. As illustrated in Figs. 1 to 4 of the drawings the hot thermocouple 17 is located in contact with, or in close proximity to, the catalyst within the chamber 7 of the testing device, while the cold thermocouple 18 is exposed to the temperature of the atmosphere.

Any suitable materials may be employed to form the elements of the thermocouple. Very satisfactory materials for forming the thermocouples in practical apparatus of this kind comprise a wire 19 of constantin and a wire 20 of chromel connected together to form the hot thermocouple 17, the wire 20 being also connected to a wire of chromel 21 to form the cold thermocouple 18 with a millivoltmeter 22 in the portion of the circuit comprising the chromel wires 19 and 21. By this construction the hot and cold thermocouples 17 and 18 tend to produce currents in opposite directions and when the thermocouples are subjected to equal temperatures no voltage is produced which will effect the reading of the voltmeter. When, however, the hot thermocouple 17 is subjected to the increase in temperature caused by the combustion of the flammable content of the mixture being tested, an increase in voltage is produced in the thermocouple 17 which throws the thermocouple system out of balance and causes the millivoltmeter to indicate by the movement of its hand 23 the change in voltage due to the differential of the voltages produced by the hot and cold thermocouples. This change in voltage has been found to be in proportion to the content of flammable material in the mixture so that the scale 24, over which the hand of the voltmeter passes, may be graduated to indicate the proportions of hydrocarbon or other flammable gases in the mixture as well as the change in voltage in the differential of the currents produced by the thermocouples. The scale may, if desired, be graduated to indicate arbitrary factors, such as, explosive limit, danger, etc.

Any suitable means may be employed for producing the desired continuous flow of the hydrocarbon-containing mixture through the apparatus above described. Desirably, how-

ever, suitable means for producing a suction to draw the mixture through the conduit is employed as such means will enable the intake end of the conduit to be connected to the wall of the chamber containing the mixture.

Any suitable means may be used for maintaining the flowing current of mixture at a temperature above the condensation temperature of the flammable gas. A preferred mechanism, which is illustrated in the present construction, comprises a combined heater and flashback preventer. The flashback preventer 3, has heretofore been described as comprising a closely coiled body of wire mesh 4 located within the enlarged cylindrical chamber forming part of the conduit through which a sample of the mixture is caused to flow. The means for heating the mixture illustrated herein comprises a heating coil 25 surrounding the cylindrical conduit containing the wire mesh coil and preferably enclosed by a suitable layer of insulating material, such as asbestos composition. The section of conduit 5, containing the regulating valve 6 and leading from this chamber, desirably is as short as may be in order to prevent condensation of the flammable content of the mixture before the mixture comes in contact with the catalyst or other means for causing combustion thereof. By suitable manipulation of the regulating valve 6 any desired rate of flow of the mixture through the chamber 7 containing the catalyst may be attained.

The use of the invention for continuously testing the condition of a mixture of air with flammable gases or vapors, and for automatically maintaining the proportion of vapor in the mixture well below the lower explosive limit, is illustrated in Fig. 4 of the drawings in which a chamber 2, such as a drying chamber, is illustrated as being provided with an inlet 26 for the air and an outlet 27 through which the mixture is drawn by a suitable suction device, such as a fan or pump 28. Any suitable means may be provided for drawing a sample of the mixture of air and hydrocarbon from the drying chamber through the testing device, such, for example, as an electrically driven pump 29 having its intake pipe connected to the outlet of the testing device.

Means are provided for automatically regulating the rate at which the mixture is drawn from the chamber under the control of the testing and indicating device heretofore described. In the illustrative embodiment of the invention shown in the drawings the outlet pipe 27 is provided with a damper 30 which is controlled by a solenoid 31 the energization of which is regulated by the testing mechanism. In the construction illustrated a suitable source of electric power, such as a generator 32, may be employed to furnish the current for the testing appara-

tus and also for actuating the solenoid. As illustrated herein a conductor 33 leads from the generator to the heating coil 25 of the flashback preventer and from such coil through a conductor 34 to the heating unit 15 of the testing device. From the heating unit a return conductor 35 leads to the other pole of the generator. Another circuit leads from the generator through the conductors 33 and 36 through a switch 37 to the solenoid 31 from which a return conductor 38 extends to the generator 32. The switch 37 normally is maintained in open condition, but is adapted to be closed through suitable relays by the action of a testing device when the flammable vapors or gases in the mixture reach or exceed a predetermined proportion. Inasmuch as a very small current is generated by the thermocouples it is usually necessary to provide one or more relays for actuating the switch 37. As illustrated in the accompanying drawings the circuit of the current produced by the thermocouples through the elements 19, 20 and 21 thereof, includes a solenoid 39 adapted to control a switch 40 in a shunt circuit for operating the switch 37. This shunt circuit as illustrated herein comprises a conductor 41 leading from the conductor 33 to the solenoid 42 of the switch 37 and therefrom to the relay switch 40 which normally is maintained in open condition. A return conductor 43 leads to the return conductor 35 of the circuit which includes the heating units of the testing device.

In the normal operation of the device illustrated the damper 30 is set to provide for the passage of a certain current of air through the drying chamber sufficiently to maintain a predetermined low proportion of flammable vapors or gases in the mixture produced in the oven by the vaporization of liquid solvent from the surface of the article placed in the oven. If the vapor content of the mixture in the oven increases above the predetermined amount the increase in temperature in the chamber 7 of the combustion device, which is caused by the combustion of the increased amount of vapor or gas, will produce an increase in voltage in the thermocouple circuit, thereby both indicating such increase upon the millivoltmeter, and also actuating the solenoid 39 to close the shunt circuit through the conductors 41, the switch 40, and return conductors 43 and 35. The current thereupon flowing through this shunt circuit will close the switch 37 thereby completing the circuit from the generator through the solenoid. The actuation of the solenoid 31 will produce an opening movement of the damper 30 thereby enabling the fan to draw the mixture from the oven at an increased rate so that the additional amount of air which enters the oven will promptly increase the proportion of air relatively to

that of flammable vapors or gases contained in the mixture. When the additional air thus introduced into the oven has reduced the proportion of flammable gases or vapors to or below the predetermined amount the reduction of the combustion in the testing device will correspondingly reduce the current produced by the thermocouples and will permit the springs of the relays and switches to break the shunt and solenoid-actuating circuits respectively so that the damper, which desirably is spring actuated, will be returned to its normal position.

It will be obvious, therefore, that by virtue of the present invention the mixture of flammable vapors or gases in the oven will be prevented from attaining such proportions as to approach an explosive mixture. It will, of course, be understood that the particular form of apparatus diagrammatically shown in Fig. 4 of the drawings is of an illustrative character and that various other mechanisms may be employed to accomplish the same purpose. For example, instead of providing means for regulating the damper in the outlet pipe from the chamber, suitable well known means may be employed for regulating the speed of an exhaust fan and other well known mechanisms and expedients may also be employed for the same purpose.

It will also be understood that the testing device may be arranged to communicate with any portion of the chamber and also that the device is equally applicable to the testing and regulation of the mixture contained in any part of a continuous conveyer oven or passage through which mixtures containing the flammable material flow.

It will also be understood that other forms of testing devices may be employed. In Fig. 5 a simplified form of testing device is illustrated which comprises a conduit 44 through which the mixture of air or oxygen with flammable gases is caused to flow with a suitable catalyst 45 located within the conduit. The conduit may be surrounded by an electric heating unit 46, or subjected to other means for raising the temperature of the mixture sufficiently to cause ignition of the flammable gases. A hot thermocouple 47 is located preferably within the material of the catalyst, with the conductors 48 and 49 leading from said thermocouple to the millivoltmeter 50. In this device, as in the one previously described, it is desirable that a cold thermocouple 51 may be employed in series in the circuit so that the voltmeter will be actuated by the differential of the currents produced by the respective thermocouples.

Another embodiment of the invention is illustrated in Fig. 6 which shows a conduit or tube 52 through which the mixture of air or oxygen and flammable gases or vapors is caused to flow continuously with a catalyst

53 located in the tube. In this construction the tube is provided with preferably quartz glass windows 54 and 55 located upon opposite sides of the catalyst 53, with plates preferably provided with smooth heat radiating surfaces superposed over the respective windows. These windows permit the heat radiating from the mixture before and after its contact with the catalyst to pass through them respectively. The indicating device comprises a U-shaped capillary tube 56 containing a liquid 57 in the looped portions thereof. The legs 58 and 59 terminate in enlarged closed chambers 60 and 61 located in proximity to the respective windows 54 and 55 in the conduit 52. The upper walls 62 and 63 of the chambers 60 and 61 respectively are coated with platinum black, or other heat absorbing material. When the temperature of the vapor upon both sides of the catalyst 53 is the same as when no combustion takes place in the tube, and the liquid 57 in the legs of the tube will remain at the same level in both legs 58 and 59. If, however, any proportion of flammable gas is present in the air flowing through the conduit 52 the combustion caused by its contact with the catalyst 53 will cause an increase in the heat to which the heat-absorbing top 63 of the chamber 61 is subjected, thereby causing a greater expansion of the gaseous content of this chamber than that of the chamber 60, so that the level of the liquid 57 in the tube 59 will be lowered, while the level of the liquid in the conduit 58 will be correspondingly raised. By providing an electric conductor 64 terminating in the liquid 57 in the tube and another electric conductor 65 leading into the leg 58 of the tube at a suitable distance above the normal level of the liquid 57 the device may be utilized as a regulating means since the conductors 64 and 65 may be connected in the circuit of a suitable regulating device such as that above described. In such case the capillary tube will constitute a switch since when the liquid in the tube is out of contact with the terminal of the conductor 65 no current could flow through these conductors, whereas a predetermined increase in temperature caused by the combustion of the vapor content would cause the liquid 57 to rise in the tube 58 until such liquid would complete the circuit through the conductors 64 and 65 and thereupon the mechanism for controlling the amount of air supplied to the mixture will be actuated.

It will be readily understood that the method and apparatus herein described may be employed not only for determining the proportions of flammable gases in the mixture with air or oxygen where such proportions are below the theoretical chemical combining proportions, but may be employed to determine higher proportions by the dilu-

tion of a sample of the mixture with a known amount of air or oxygen.

It may also be stated that where the proportion of hydrocarbon in the air is known the method may be employed to determine, from the temperature produced by combustion in the testing device, the character of the gaseous hydrocarbon contained in the mixture, as the combustion of such gases at the same predetermined proportions produces different amounts of heat units as has heretofore been pointed out.

Having thus described the invention, what is claimed as new, and desired to be secured by Letters Patent, is:

1. A universal method of testing the flammable conditions of a mixture of any of the flammable hydrocarbon gases with oxygen containing gases which comprises continuously drawing from the mixture a sample thereof, causing continuous combustion of the said sample of the mixture, and causing the increase in temperature produced by such combustion continuously to indicate the fractional proportion of the amount of heat produced by such combustion relatively to the constant amount of heat produced by continuous combustion of any hydrocarbon gases at the lower limit of explosive strength of any of the said hydrocarbon gases with air.

2. A universal method of testing the flammable conditions of a mixture of any of the flammable hydrocarbon gases with oxygen containing gases which comprises continuously drawing from the mixture a sample thereof, supplying additional heat to said sample to maintain it above condensing temperature, causing continuous combustion of the said sample of the mixture, and causing the increase in temperature produced by such combustion continuously to indicate the fractional proportion of the amount of heat produced by such combustion relatively to the constant amount of heat produced by continuous combustion of any hydrocarbon gases at the lower limit of explosive strength of any of the said hydrocarbon gases with air.

3. A universal method of testing the flammable conditions of a mixture of any of the flammable hydrocarbon gases with oxygen containing gases which comprises continuously drawing from the mixture a sample thereof, causing continuous combustion of the said sample of the mixture and causing the increase in temperature produced by such combustion continuously to produce an electric current having a voltage proportional to the increase in temperature caused by such combustion and causing the electric current so produced to indicate the fractional proportion of the amount of heat produced by such combustion relatively to the

constant amount of heat produced by continuous combustion of any hydrocarbon gases at the lower limit of explosive strength of any of the said hydrocarbon gases with air.

4. A universal method of testing the flammable conditions of a mixture of any of the flammable hydrocarbon gases with oxygen containing gases which comprises continuously drawing from the mixture a sample thereof, causing continuous combustion of the said sample of the mixture and causing the increase in temperature produced by such combustion continuously to produce an electric current having a voltage proportional to the increase in temperature caused by such combustion and causing the electric current so produced to vary the proportion of flammable gases in said mixture.

5. The method of testing the condition of a mixture of hydrocarbon gases with air contained in a chamber which comprises subjecting a continuously flowing sample of the mixture taken from said chamber to artificial heat to maintain the same at a temperature sufficiently high to prevent condensation, causing combustion of said heated mixture in the presence of a catalyst, electrically measuring the increase in temperature caused by said combustion, and causing the increase in such temperature to indicate the proportion of flammable vapors in the mixture relative to the lower limit of explosive strength thereof.

6. The method of testing the condition of a mixture of hydrocarbon gases with air contained in a chamber which comprises subjecting a continuously flowing sample of the mixture taken from said chamber to artificial heat to maintain the same at a temperature sufficiently high to prevent condensation, causing combustion of said heated mixture in the presence of a catalyst, preventing flashback into the chamber, electrically measuring the increase in temperature caused by said combustion, and causing the increase in such temperature to indicate the proportion of flammable vapors in the mixture relative to the lower limit of explosive strength thereof.

7. The method of testing the condition of a mixture of hydrocarbon gases with air contained in a chamber which comprises subjecting a continuously flowing sample of the mixture taken from said chamber to artificial heat to maintain the same at a temperature sufficiently high to prevent condensation, causing combustion of said heated mixture in the presence of a catalyst, causing the increase in temperature produced by such combustion to produce an electric current having a voltage proportional to the increase in temperature caused by such combustion, and causing the variations in the

electric current so to vary the supply of air to the chamber as to maintain a mixture in said chamber well below the lower limit of explosive strength thereof.

5 In testimony whereof, I have signed my name to this specification.

NORMAN J. THOMPSON.

10

15

20

25

30

35

40

45

50

55

60

65