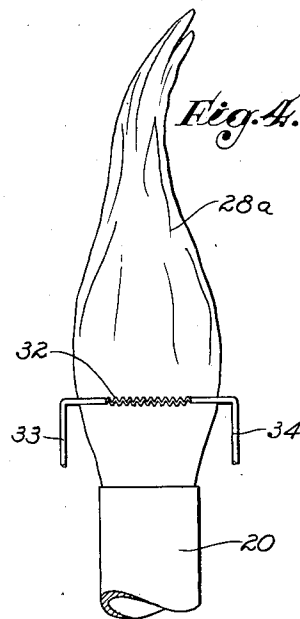
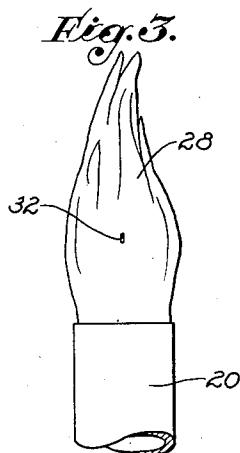
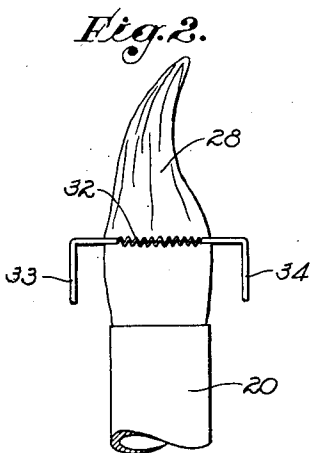
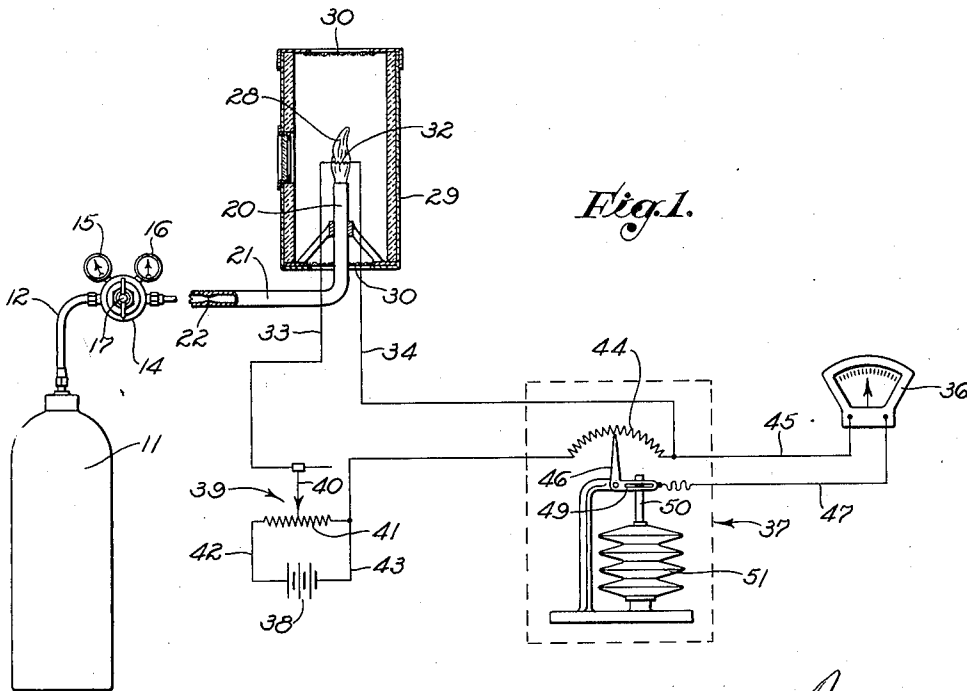


July 18, 1939.

F. R. COLLBOHM
METHOD AND APPARATUS FOR INDICATING OXYGEN
CONCENTRATION IN A GASEOUS MEDIUM
Filed Aug. 26, 1935

2,166,104

2 Sheets-Sheet 1



INVENTOR
FRANKLIN RUDOLF COLLBOHM
BY
Frederic H. Harris
ATTORNEY.

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2 Sheets-Sheet 2

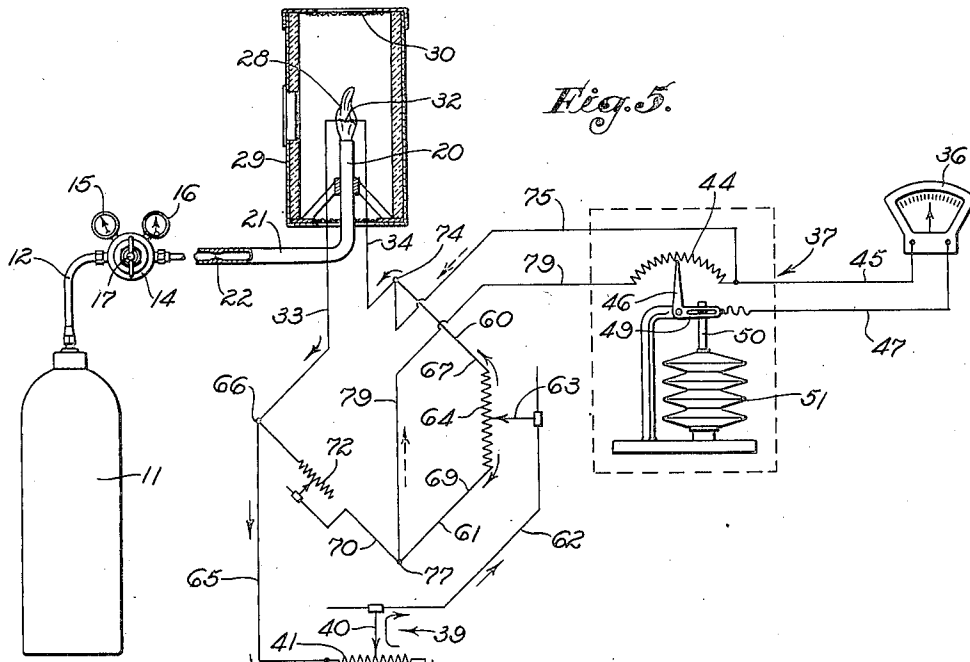


Fig. 5.

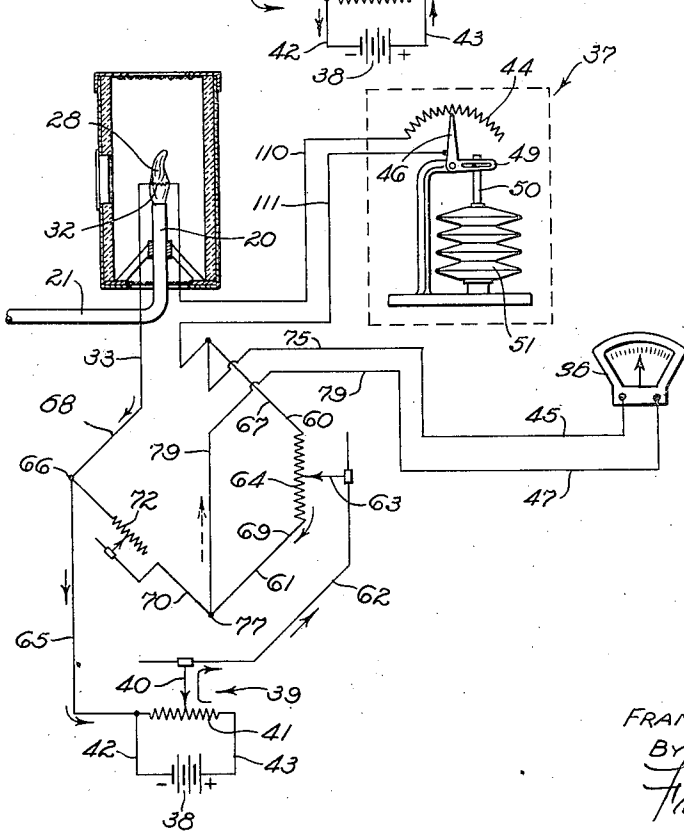


Fig. 6.

INVENTOR
FRANKLIN RUDOLF COLLBOHM

By
Ford H. Harris

ATTORNEY.

UNITED STATES PATENT OFFICE

2,166,104

METHOD AND APPARATUS FOR INDICATING
OXYGEN CONCENTRATION IN A GASEOUS
MEDIUMFranklin Rudolf Collbohm, Santa Monica, Calif.,
assignor to Douglas Aircraft Company, Inc.,
Santa Monica, Calif., a corporation of Dela-
ware

Application August 26, 1935, Serial No. 38,009

1 Claim. (Cl. 23—255)

My inventions forming the subject matter of this application relate to the art of determining or indicating the oxygen concentration of the atmosphere or other gaseous medium.

5 I believe my inventions to be broadly new, both in their entirety as well as in their several combinations of steps and elements less than the whole, and in the steps and elements which enter into the inventions as a whole or in the several sub-combinations thereof.

10 My invention is of utility in the various arts or industries wherein it is desired or necessary either to know or control the oxygen concentration of the atmosphere or other gaseous medium.

15 My invention, however, has a particularly valuable application in the aeronautical industry, and therefore, for the purpose of illustrating the features, advantages, and objects of my invention, I will describe them as they may be employed in the aeronautical industry. It should be understood, however, that I do not thereby wish to be limited to the aeronautical industry.

20 In the aeronautical industry my inventions are of utility in determining the suitability of the atmosphere within the cabin of an airplane for the maintenance of human life, and in maintaining a suitable oxygen concentration in the atmosphere.

25 The respiratory process of the human body is essentially a constant volume process; that is, the lungs inhale a constant volume of atmosphere, extract from that volume of atmosphere the amount of oxygen required by the body, and exhale the unused atmosphere and the products of combustion. The volume of atmosphere inhaled in a normal respiration is very nearly a constant, not varying, therefore, with changes in pressure due to altitude. Since the body inhales a constant volume, we must, in order to maintain ordinary life, be certain that at all times in the cabin of the airplane the number of molecules of oxygen in each unit volume of our cabin atmosphere be held above a definite lower limit.

30 Airplanes flying at high altitudes transport the occupants thereof into zones where the concentration of oxygen in the atmosphere of the cabin of the plane is insufficient or inadequate to satisfy normal breathing requirements of the occupants; or in closed cabins the occupants may use sufficient oxygen to lower the oxygen concentration of the atmosphere therein below the lowest limit satisfactory to respiration; and in either of these cases there results either dis-

comfort or, in extreme deficiencies of oxygen, injury to the occupants of the airplane.

As an example of a situation which may very readily arise, let us analyze what occurs in an atmosphere as we increase altitude. If we go to an altitude of 18,000 feet, holding our cabin temperature constant, the pressure and the density in the cabin will be one-half of what it was at sea level. The percentage of oxygen in the cabin atmosphere remains the same as it was at sea level; that is, for each cubic foot of atmosphere at this altitude we have half the number of molecules of oxygen that we had in a cubic foot at sea level, notwithstanding that the percentage of oxygen in the atmosphere remains the same as at sea level. In view of the fact that the respiratory process requires a certain amount of oxygen; that is, a certain number of molecules of oxygen, when the number of molecules per volume of oxygen drops below a certain amount, the atmosphere which is breathed by the occupants of the airplane will not contain sufficient molecules of oxygen per respiration to normally satisfy breathing requirements. Therefore, in order to provide the occupants of the cabin with a sufficient amount of oxygen, we must raise the number of molecules of oxygen per unit volume to the same concentration that we had at sea level. This at 18,000 feet altitude increases the percentage of oxygen in the cabin atmosphere from 21% to 41% by volume, although our concentration, that is, the number of molecules of oxygen per unit volume, remains the same.

It will be readily perceived from the foregoing that in airplanes, especially those flying at high altitudes, it is of great value, first, to know the oxygen concentration of the atmosphere in the cabin of the plane, and, second, to be able to maintain the oxygen concentration of the atmosphere in the cabin of the plane above a predetermined lower limit of concentration.

My present invention relates to apparatus for indicating the oxygen concentration of a gaseous medium, while my co-pending application entitled Method of and apparatus for maintaining oxygen concentration in a gaseous medium, Serial No. 56,501, filed Dec. 28, 1935, relates to a method wherein the oxygen concentration may be maintained or controlled. The value of the present invention is to indicate rather than control or maintain the oxygen concentration in a gaseous medium, and, knowing the oxygen concentration, the supplying of oxygen to the gase-

ous medium may be increased or decreased either manually or automatically by other means.

It is an object of my present invention to provide a method and apparatus for determining oxygen concentration (that is, molecules of oxygen per unit volume) of an atmosphere or gaseous mixture.

It is a further object of my invention to provide a method and apparatus of the character referred to in the foregoing paragraph in which the oxygen concentration is measured and recorded.

It is a still further object of my invention to provide a method and apparatus whereby the oxygen concentration in a gaseous medium is determined by measuring the temperature, within a flame formed in the gaseous medium to be tested, by burning fuel therein at a constant rate by weight.

In the method and apparatus of my invention a burner is provided which is designed to emit and burn a constant rate or constant weight of fuel, this rate being held constant regardless of the pressure of the supporting atmosphere or gaseous medium. The flame which is produced by the burning of the fuel and the oxygen in the gaseous medium is the volume within which the molecules of the fuel are united with the molecules of oxygen in the gaseous medium. In order to burn the fuel it is necessary that there be a certain predetermined number of molecules of oxygen to combine with the fuel. Therefore, if we have a predetermined number of molecules of fuel, such, for example, as hydrogen, to be burned, it is necessary that there be the required number of molecules of oxygen to chemically react therewith in order to produce a complete burning of the hydrogen. Where the concentration of oxygen molecules in the atmosphere or gaseous medium is reduced, all of the fuel molecules cannot be burned without encompassing a larger volume, and this is exactly what occurs, with the result that the flame produced by the burning becomes larger in volume in direct proportion to the change in oxygen concentration in the gaseous medium.

This reduction in oxygen concentration may result from the occupants of the cabin of the air plane using a portion of the oxygen for breathing purposes. It may also result in the plane climbing from sea level to any altitude without introducing additional oxygen into the atmosphere. It is known that when we climb from sea level the pressure of the atmosphere decreases, and we therefore know that the number of molecules of oxygen per unit volume is less at an altitude.

In the process and the apparatus constituting the inventions of this application I am enabled to determine the oxygen concentration of a gaseous medium by determining the temperature within the flame produced by the burning of the fuel, as pointed out heretofore, for the following reasons. Since in the burning process we are completely burning a constant amount of fuel; namely, a certain number of molecules per unit time, at any altitude, the total heat developed by the flame is constant. Therefore, if the flame has a greater volume, and it must of necessity have a greater volume when the oxygen concentration in the gaseous medium is decreased, it follows that the temperature within the flame, or the temperature per unit volume or elemental volume within the flame, and not above the flame, is affected by the number of molecules of oxy-

gen per unit of volume of the gaseous medium. In other words, the temperature within the flame or the temperature of a unit volume or elemental volume of the flame is affected by the oxygen concentration in the supporting atmosphere or gaseous medium.

It is an object of my invention to provide a method and apparatus in which oxygen is supplied to a gaseous medium in response to the temperature within a flame, which flame is produced in said gaseous medium by the burning of a fuel therein.

It is another object of my invention to provide a method and apparatus of the character referred to in which changes in temperature within the flame formed in the gaseous medium are converted into a form of energy which is available for operating an indicating means.

It is a further object of my invention to provide methods and apparatus of the nature pointed out in the foregoing paragraph in which changes in temperature within the flame are used to vary a flow of electricity in a circuit, and in which said flow of electricity is used for determining the temperature within the flame.

In the atmosphere or gaseous medium in which the fuel is burned there are certain inert materials. As the density of the atmosphere or gaseous medium decreases, such as occurs when an altitude is reached, the actual weight of the inert materials; that is, the number of inert materials per unit volume, decreases. Therefore, the temperature within the flame or burning area or the temperature of a unit volume thereof tends to rise. This would result in a flame temperature which does not represent or correspond to the oxygen concentration of the gaseous medium, and would result in an indication which is less in effect than that of the normal decrease in oxygen concentration due to the decreased pressure of the atmosphere. This is by no means negligible and must be compensated for; otherwise, a true determination of the oxygen concentration cannot be obtained, or in the method and apparatus for maintaining the oxygen concentration the oxygen supply means would not be accurately operated.

It is an object of my present method and apparatus to determine the oxygen concentration of a gaseous medium, or to supply oxygen to a gaseous medium in accordance with the temperature within a flame formed in said gaseous medium, in which compensation is made for any change in density of the gaseous medium.

In the foregoing discussion of the objects, features, and advantages of my invention I have discussed those which will be informative of the general character and nature of my invention. In addition to those which I have already pointed out, there are other unique and important features of construction and operation and unique steps of my method which will be brought out in the course of the following detailed description of a certain illustrative form of my invention at such places where these advantages and features may be advantageously and more beneficially brought to the attention of the reader.

In the accompanying drawings which form a part of this application, I have diagrammatically illustrated various apparatus which are particularly designed for performing the various steps of the process of my invention and which incorporate certain unique features on which I desire patent protection.

Referring to the drawings,

Fig. 1 is a view diagrammatically illustrating a form of my invention adapted to record the oxygen concentration in a gaseous medium.

Figs. 2, 3, and 4 are views illustrating the character of flame produced in my method and apparatus, and illustrating the manner in which I record or measure the temperature within the flame. Of these three views, Figs. 2 and 4 are views looking at the side of the flame and at the side of a temperature responsive element, Fig. 2 being a normal flame and Fig. 4 being an abnormally large flame. Fig. 3 is an elevational view taken at right angles to Fig. 2.

Fig. 5 is a diagrammatic view of my invention illustrating a different means for converting the temperature within the flame into energy available for use in indicating the temperature within the flame.

Fig. 6 is a diagrammatic view illustrating the same electrical hook-up, as disclosed in Fig. 5, as utilized in a method and apparatus for automatically supplying oxygen to the gaseous medium in order to maintain a certain oxygen concentration therein.

Referring to Fig. 1, the numeral 11 represents a source of fuel or fuel supply. The type of fuel may vary to meet requirements or demands, but I find it satisfactory to use hydrogen as the fuel since it is gaseous in form and is readily available for use and for control. The fuel supply 11 is connected by means of a conduit 12 to a pressure regulating means 14 which is designed to reduce the pressure to a usable pressure and at the same time to deliver a constant weight of fuel at all times. This regulating means may be of any standard form which is obtainable on the market today and may have a gauge 15 for indicating the pressure in the fuel supply 11, a gauge 16 for indicating the pressure of the fuel delivered to the burner, and an adjustment means 17 for adjusting the pressure of the fuel delivered to the burner. The burner is indicated by the numeral 20 and consists of an upwardly extending pipe or tube which is connected to a pipe or tube 21 which extends to and is connected to the pressure control means 14. In the pipe 21 there is shown a jet 22 which I have found to be desirable. I have found that it is highly desirable that this jet be kept relatively far from the mouth of the burner so that the gaseous fuel will be flowing uniformly with a low velocity by the time it reaches the point at which it burns.

The pressure regulating means 14 holds the pressure drop through the jet 22 a constant. Changes in outside pressure change only the average pressure in the jet, not the absolute change in pressure through the jet. The change in outside pressure, therefore, changes the density of the fuel passing through the jet. However, since the friction of molecules of fuel through the jet is unaffected by changes in density for all practical purposes, and since we have a constant accelerating force in the jet (due to pressure drop through the jet), it follows that the actual number of molecules passing through the jet will be constant regardless of the average density in the jet, and therefore will be independent of outside pressure. Since one molecule of a given substance always weighs the same, regardless of the condition under which it exists, we are therefore enabled to obtain a constant weight of fuel passing through the jet for each unit of time regardless of the pressure of the gaseous medium which prevails on the outside.

It will therefore be seen that in the apparatus which has been described there is supplied to the burner 20 a constant weight of fuel for each unit of time regardless of the pressure of the gaseous medium into which the fuel is introduced. The flame formed by the burning of the fuel is represented by the numeral 28.

Applicant's invention, as stated heretofore, has a particular utility in measuring or determining oxygen concentration of air and may be used for the measurement of oxygen concentration in various gaseous mediums which contain oxygen, and which, under ordinary temperatures, is a non-combustible gaseous medium. By the term "non-combustible gaseous medium" is meant one in which there are no combustible gases present or one in which combustible gas is present to a negligible extent or in such small quantities as will not interfere with the performance of the invention. It is essential in the performance of the process to completely burn all of the fuel or to burn a uniform amount of fuel, and therefore the oxygen content of the gaseous medium must be more than adequate to burn all of the fuel supplied by the burner 20.

The burner 20 is enclosed in a chimney 29 to prevent drafts from making the flame change in position, size, or shape. This will prevent the possibility of rapid fluctuations in temperature within the flame, such as would result if the flame were allowed to dance around in drafts. This chimney is preferably thermally insulated from the outside so that drafts will not cause spontaneous changes in chimney wall temperatures, which in turn would cause convection currents to be set up within the chimney and which would have the same effect on the flame as a draft. At each end of the chimney there may be provided fine mesh screens 30 which serve the dual purpose of keeping the air within the chamber quiet and acting as safety screen insuring that the flame cannot get outside the combustion chamber formed within the chimney 29.

For the purpose of measuring or determining the temperature within the flame 28, or for determining the temperature per unit volume within the flame 28, I provide a filament 32 which is a temperature responsive resistance element and in the form of my invention disclosed herein may be a fine platinum wire. This filament 32 is connected at its ends to supporting wires 33 and 34 which not only serve to support the filament 32, but also serve as a part of an electrical circuit which is employed in the forms of my invention illustrated herein. The filament 32, as illustrated best in Figs. 2 and 3, is so supported that it is at all times situated within the flame 28. It is preferably situated a short distance above the upper end of the burner 20 so that about one-half of the flame 28 will be above the filament 32. However, the position of this filament may be varied so long as it is kept within the limit of the flame 28 or, expressing the thought in a different manner, so long as the filament 32 is situated in such a position that it will be affected or influenced by the temperature within the flame or the temperature of an elemental volume within the flame as distinguished from the entire heat produced by the entire flame.

The wires or conductors 33 and 34 constitute a part of wires forming an electrical circuit, which circuit also includes an indicator or measuring device 36, a density compensator 37, a source of energy in the form of a battery 38, and a poten-

tiometer 39 for varying the flow of current through the circuit.

In the simple form of the device illustrated herein corrections for changes in temperature within the flame which result from a change in density of the gaseous medium may be compensated for in calibrating the indicator 36 or, as illustrated in Fig. 1, a compensating device may be provided.

The wire or conductor 33 is connected to a movable contact 40 which cooperates with the resistance 41 of the potentiometer 39. The resistance 41 is connected at one end to the battery 38 by a conductor 42 at its other end to the opposite side of the battery by a conductor 43.

This conductor 43 is connected to one side of a resistance 44 of the compensator 37. The wire 36 is connected to the other side of the resistance 44. Connected to the wire 34 at a point immediately adjacent the resistance 44 is a wire 45 which is connected to the indicator 36. Cooperating with the resistance 44 is a movable contact 46 which, in conjunction with the resistance, constitutes a potentiometer. The movable contact 46 has a wire 47 connected to it and this wire 47 is in turn connected to the indicator 36 and forms a means for connecting this indicator in circuit with the potentiometer. Connected to the contact 46 by means of links 48 and 50 is an evacuated bellows 51 which is subjected to the pressure of the gaseous medium in which the flame 28 is produced, it being understood that all of the apparatus is diagrammatically illustrated as being positioned within the chamber in which the oxygen concentration of the gaseous medium is to be controlled. The point at which the movable contact 46 engages the resistance 44 is determined by the pressure in the gaseous medium. As the pressure decreases, the contact 46 is moved in anti-clockwise direction so as to remove resistance from the circuit provided by the wires 45 and 47, and in this manner the increase in temperature within the flame 28 and the increase in resistance in the filament 32 which results therefrom, which is produced by a decrease in density in the gaseous medium, is compensated. It will therefore be seen that this device automatically compensates in the current flowing through the circuits of the device for any change in temperature within the flame which is occasioned by a change in density, by reason of the fact that it inserts or removes resistance due to the operation of the potentiometer and which in turn controls the supply of current to the indicator 36.

The method of my invention is performed and the apparatus of my invention, as disclosed in Fig. 1, operates as follows:

The pressure regulating means or fuel supply means 14 is regulated in order to supply the desired rate of flow of fuel to the burner 20 and it performs its function as pointed out heretofore. The fuel passing from the burner 20 is ignited in the chimney which constitutes a combustion chamber, and the flame 28 is thus formed. This flame 28 heats the filament 32 to substantially the temperature of an elemental volume within the flame 28 and thus gives to the filament 32 a certain resistance depending upon the temperature within the flame.

The potentiometer 39 is then adjusted so that the pointer of the indicator 36 properly indicates the oxygen concentration in the gaseous mixture or atmosphere. This may be readily accom-

plished in using the invention in the aeronautical industry by adjusting the parts at sea level.

It is desirable to have an adjustment on the current flow delivered to the circuit by the battery 38 so that any differences in resistance in the different replacement filaments 32 may be compensated for. By making the adjustment at sea level it is possible to move the contact 40 until the pointer 36 points to a position at which it indicates the concentration of oxygen in the atmosphere at sea level. When this adjustment has been made, then the apparatus will accurately indicate the oxygen concentration in the gaseous medium, since the indicator 36 has been properly calibrated. If desired, the indicator 36 may indicate other factors than oxygen concentration. For example, instead of indicating oxygen concentration, it might indicate altitude.

I will now describe what occurs when the oxygen concentration in the gaseous medium is reduced below normal or below concentration at sea level which, in the present example, has been chosen as the normal oxygen concentration. It will be understood, however, that other concentrations may be selected as normal. For example, it is found that the atmosphere at an altitude of 8000 feet is adequate to support normal breathing requirements, and therefore the concentration of oxygen in the atmosphere at an 8000 foot altitude might be selected as normal or zero position of the indicator 36.

I have already pointed out the manner in which the flame 28 will increase in size when the oxygen concentration of the surrounding gaseous medium decreases. This phenomena may be explained in another way. If we take a very small volume within the flame, we see that the temperature of the gases in this volume will depend upon the number of molecules of fuel uniting with the molecules of oxygen within this small volume. If the oxygen concentration is lowered, there will be fewer molecules of fuel uniting with the molecules of oxygen within this small volume. Therefore, the temperature within this small volume will decrease with any decrease in the oxygen concentration thereof.

In Fig. 4 I have illustrated a flame 28a which is produced in a gaseous medium in which the oxygen concentration is less than in the gaseous medium in which the flame 28 of Figs. 2 and 3 is produced.

As pointed out heretofore, the fuel supply means is supplying a constant number of molecules of fuel per unit of time regardless of the pressure in the gaseous medium or the oxygen concentration thereof. As previously pointed out, in order to completely burn all of these molecules of fuel it is necessary that the flame be of larger volume when the oxygen concentration is less. Furthermore, as already pointed out, since the burning of the fuel produces the same total heat it is quite obvious that the heat within the flame or the heat per unit volume or elemental volume is less where the flame is larger in volume. It will therefore be seen that under conditions which exist in Fig. 4 the temperature to which the filament 32 is heated will be less than the temperature to which the filament is heated under conditions illustrated in Fig. 2, and that this difference is in direct proportion to the relative volume of the flames 28a and 28.

A further factor which produces a decrease in the temperature in the filament 32 where the flame has increased in volume as indicated by the numeral 28a results from the fact that the tem-

perature of the unit volume or the elemental volume in which the filament 32 is located is not only affected by the heat produced as a result of the burning action occurring in such volume, but is also affected by the heat which is developed below the filament 32. It will therefore be seen that as the flame increases in size the amount of heat developed below the filament 32 naturally decreases and therefore there will be a decrease in temperature as a result of this fact, and such decrease in temperature may be utilized to assist in obtaining desired results.

The resistance of the filament 32 is changed when the temperature to which the filament is heated changes, with the result that there is a change of flow of current through the circuit including the indicator 36, and therefore the pointer of this indicator 36 will change in position in direct proportion to the change in resistance in the filament 32 which is in turn changed in proportion to the temperature within the flame or the temperature of a unit volume or elemental volume within the flame.

It will therefore be seen that as the flame changes in size, either enlarging or decreasing, there is a change in current flow and consequently a change in position of the pointer of the indicator 36 and in this way the indication of the oxygen concentration is given.

As pointed out heretofore, the density of the gaseous medium or the presence of elements other than oxygen affects the temperature within the flame and it is therefore desirable to compensate for this. The compensator means 37 operates as pointed out heretofore and compensates in the flow of current for any change in heat within the flame 28 which results from a change in density of the gaseous medium.

In the form of my invention which I have just described I have pointed out one embodiment of the process of my invention and one embodiment of the apparatus of my invention which may be employed for indicating the oxygen concentration in a gaseous medium. It will be seen that my inventions as described in detail are of use in the various industries in which it is desirable or necessary to know the oxygen concentration in a gaseous medium. My invention, however, may be embodied in other forms which may be advantageously employed in the various industries, and in Fig. 5 I have illustrated my invention incorporated in an apparatus using a balanced or bridged type of circuit means which is controlled by the temperature which exists within the flame 28. I will now refer to Fig. 5 and describe the form of my invention illustrated therein and the process which is performed thereby.

All of the parts, with the exception of the circuit balancing means, are the same as disclosed in Fig. 1 and the same numerals will therefore be applied to corresponding parts. I provide what resembles a Wheatstone bridge circuit which has an upper side 60 and a lower side 61. The adjustable contact 40 of the potentiometer 39 is connected by a wire 62 to an adjustable contact 63 which is adapted to have electrical engagement with a resistance 64. As will be seen, a part of this resistance 64 is a part of the side 60 and the other part is a part of the side 61. The resistance 41 on the left side of the battery 38 is connected by a wire 65 to the two sides 60 and 61 where they meet at a point 66. The sides 60 and 61 are divided into sections or legs 67, 68, 69, and 70. The resistance 64 is so divided by the adjustable contact 63 that a part thereof forms

a resistance in the legs 67 and 69. The wires 33 and 34 which are connected to the filament 32 are connected in series in the leg 68, and therefore the filament 32 constitutes a resistance in the leg 68. In the form of my invention disclosed I prefer to provide an adjustable resistance or rheostat 72 in the leg 70. Connected to the side 60 between the legs 67 and 68 at a point 74 is a wire 75, and connected to the side 61 at a point 77 between the legs 69 and 70 is a wire 79. The wires 75 and 79 are connected to the density compensator 37 in the same manner as the wires 34 and 43 in the form of my invention disclosed in Fig. 1.

In setting the device for operation, the adjustable contact 63 and the rheostat 72 are so positioned that the resistances of the sides 60 and 61 are equal so that the current flowing through the wires 75 and 79 and the parts connected therewith will be zero value; or if the apparatus were designed so that there is a current flow required to cause the indicator 36 to indicate normal concentration of oxygen, this may be readily obtained by properly proportioning the resistances in the sides 60 and 61.

In the set-up as shown, the flow of current from the battery is indicated by arrows. The current flows through the wire 43, a part of the resistance 41, the adjustable contact 40, the wire 62, to the adjustable contact 63. The current then divides and a part of it flows through the upper side 60 and a part through the lower side 61. The current flow then meets at the point 66 and flows through the wires 65 and 43 to the battery 38. If the resistances in the two sides 60 and 61 are the same, there will be no flow through the circuit including the wires 75 and 79 which are connected to the two sides 60 and 61 at the points 74 and 77. Upon lighting the fuel and forming the flame 28 the resistances in the two sides 60 and 61 may be regulated by moving the adjustable contact 63 or by operating the adjustable rheostat 72. These resistances are adjusted in value so that the pointer of the indicator 36 will point to the desired indication to properly indicate the oxygen concentration of the gaseous medium which must be known at the time the adjustment is made. For example, if the adjustment is made at sea level under normal atmospheric conditions, then the indicator must indicate sea-level oxygen concentration, and it may be made to do this either by adjusting the resistances so that there is no flow through the circuit to the indicator or so that there is whatever flow is necessary to get the proper indication.

The operation of this form of the invention is substantially the same as in Fig. 1 except that in the set-up in Fig. 5 a change in the volume of the flame 28 which results in a change of temperature within the flame produces a change in resistance in the filament 32 which produces an unbalanced condition of resistance in the two sides 60 and 61 and therefore either causes a flow of current through the circuit to the indicator or increases or decreases whatever flow of current may have existed at the instantaneous period immediately preceding the change in resistance of the filament 32. All of the other parts of the apparatus operate the same, and it is therefore not necessary to redescribe either their construction or their operation.

In Fig. 6 I have illustrated a form of my invention in which the density compensator 37 is of the resistance type rather than the potentiometer type and is connected by conductor

110 which connects to the resistance 44, and conductor 111 which connects to the contact 46, to the wire 34 which forms a part of the leg 68 of the Wheatstone bridge hook-up. In view of this change in position of the density compensator the wires 75 and 79 are connected directly to the wires 45 and 47 which form the circuit to the indicator 36.

In this arrangement of my invention, the increase in temperature and the resultant increase in resistance in the filament 32 and leg 68 of the bridge circuit, which is caused by the decrease in density of the gaseous medium, is compensated for in the leg 68. In this way direct compensation is obtained and the net resistance of the leg 68 of the bridge is exactly the same as though the inert material in the gaseous medium had remained a constant. The density compensator is included in the leg 68 by separating the conductor 34 and connecting one end 110 to the resistance 44 and another end 111 to the adjustable contact 46. The contact 46, as in Figs. 1 and 5, is operated by an evacuated bellows 51 through the connections 49 and 50, and upon a decrease in density resistance is removed from the leg 68 (by movement of the contact in an anti-clockwise direction) to compensate for the increase in resistance resulting from the decrease in density of the gaseous medium.

In other respects the construction and operation of this form of my invention and the method practiced thereby are identical to that shown in Fig. 5.

In the foregoing detailed description I have referred to three different forms of my invention incorporating different features thereof, and I have attempted to illustrate wherein the electrical parts and mechanical parts are chosen because of their efficiency in performing their work in my invention, yet at the same time I wish it to be clearly understood that I do not want to be limited to the precise electrical or mechanical means which I have provided because other mechanical or electrical equivalents may be substituted. As clearly illustrated in comparing Figs. 1, 5 and 6, the means for converting the differences in temperature within the flame 28 may be substituted one for the other. In fact, it is possible to work

out other electrical circuits and furthermore to employ mechanical means for utilizing this change in temperature within the flame 28 to operate an indicator.

It should furthermore be understood that the density compensator which I have disclosed is only one of many which may be used. For example, it would be possible to use a compensator of the resistance type rather than of the potentiometer type, or the same results might be accomplished by photronic or pilotronic means. It is furthermore obvious that other indicator means may be employed. The indicator means which I have shown at 36 is not intended to give a permanent record, but, if desired, a device having a graph and stylus may be employed so that a permanent record will be obtained.

I furthermore do not wish to be limited to the exact chimney or burner construction or to the exact means for supplying fuel to the burner. It may be desired to use other fuel than hydrogen and other fuel than one which is in gaseous form. For example, it may be desired to provide a fuel container having a liquid fuel such as alcohol and to provide a vaporizing means for producing alcohol vapor which may be delivered to the burner.

Likewise, other alterations may be made without departing from the spirit and scope of my invention. As stated heretofore, I believe my invention to be broadly new, and I therefore wish it to be construed in accordance with the appended claim.

I claim as my invention:

Method for determining the oxygen content of gaseous mixtures of the class consisting of air, and mixtures of oxygen with non-combustible gases, comprising forming a flame by supplying fuel to an orifice at a constant rate, passing a sample of the gaseous mixture as a surrounding envelope about the fuel stream to supply the oxygen required for the formation of the flame, the fuel being supplied at such constant rate as to be insufficient to burn all the oxygen in the sample, measuring the temperature within the flame structure in an area of the flame fixed and predetermined with relation to the fuel orifice.

FRANKLIN RUDOLF COLLEBOHM.