Jan. 7, 1958 C. H. HOLM ET AL 2,818,860

METHOD OF AND MEANS FOR MAINTAINING DESIRED PERCENTAGES OF OXYGEN IN OXYGEN TENTS OR OTHER SPACES

Filed Nov. 17, 1955 4 Sheets-Sheet 1

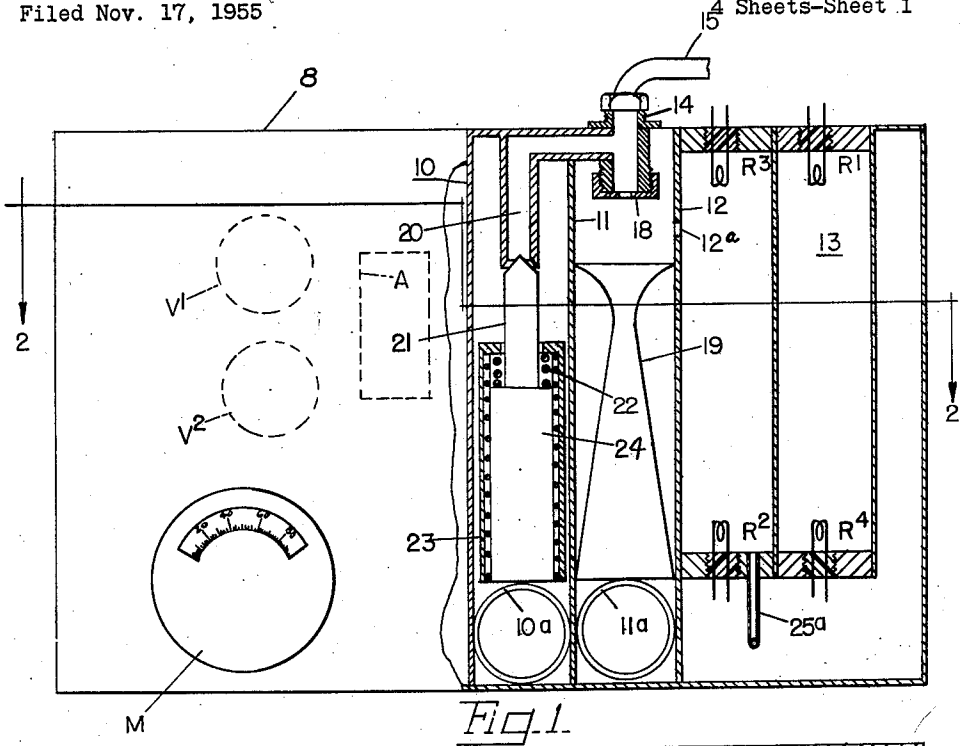


Fig. 1

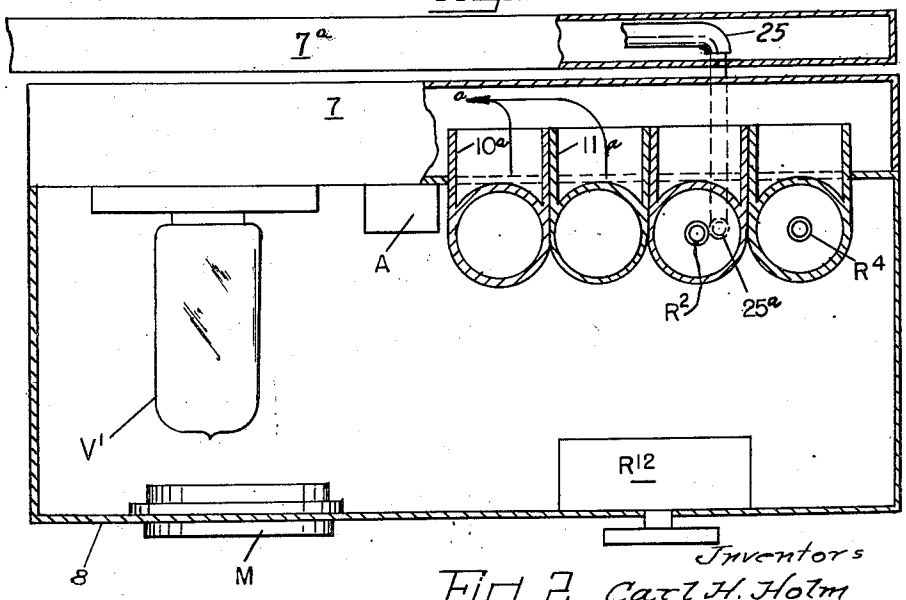


Fig. 2

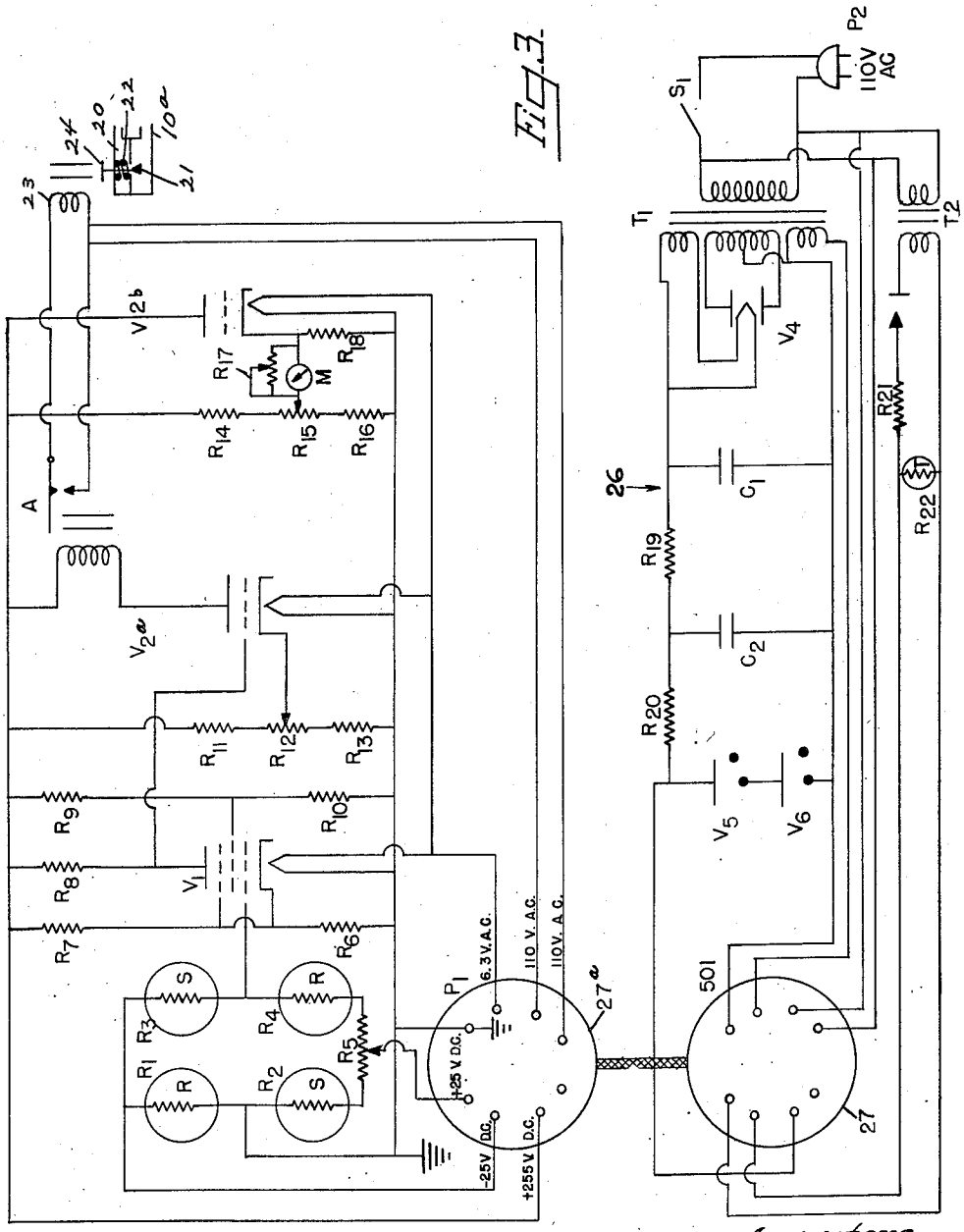
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Fig. 3



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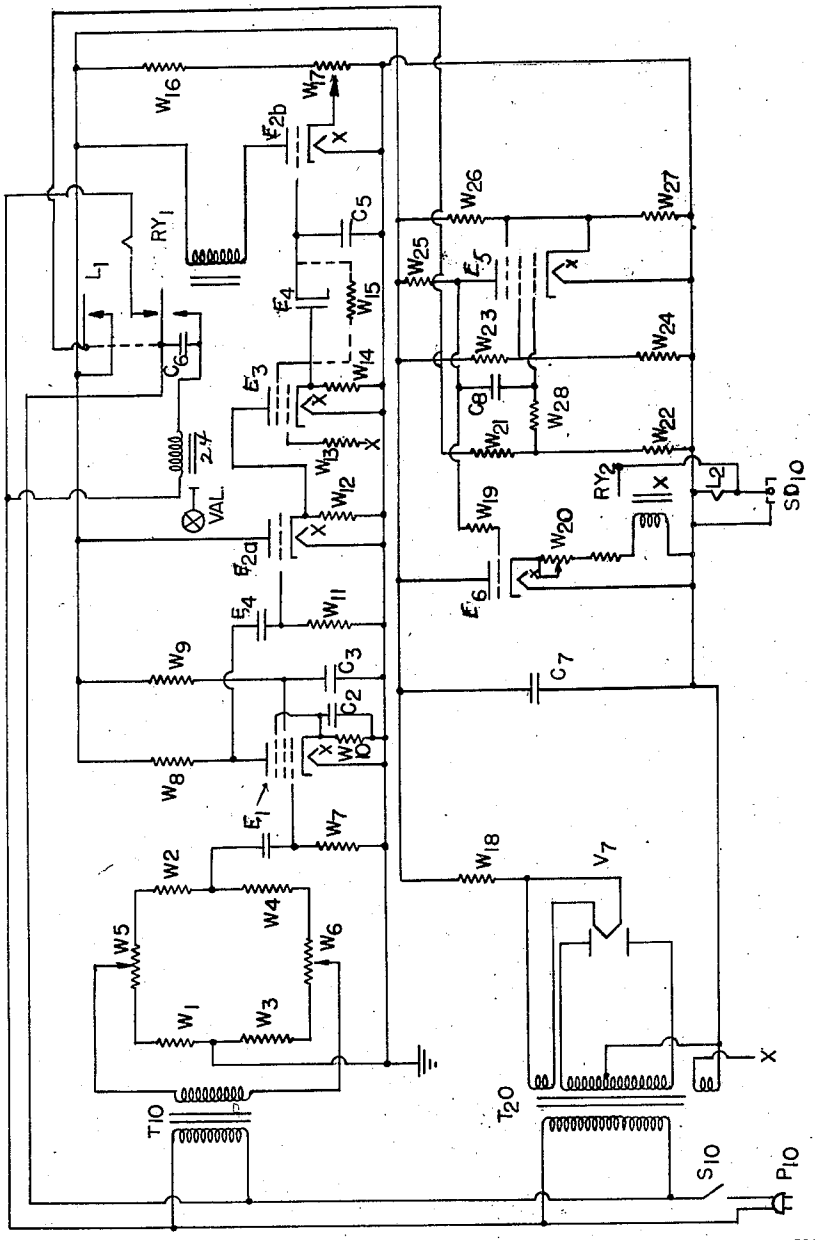


Fig. 3a.

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Filed Nov. 17, 1955 4 Sheets-Sheet 4

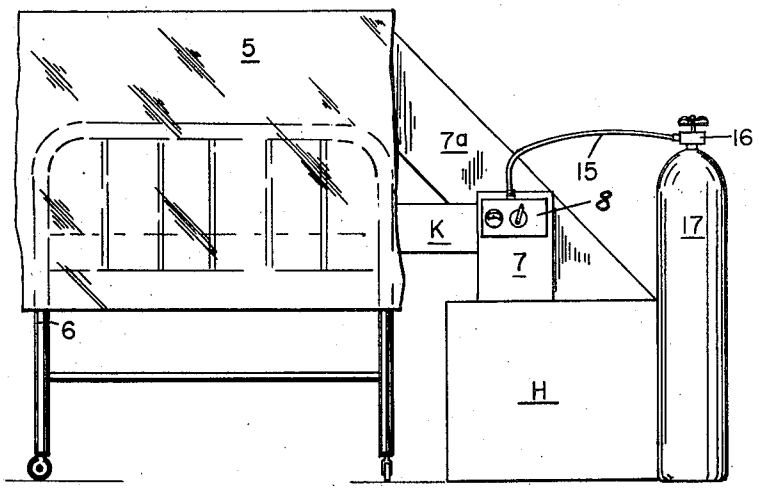


Fig. 4

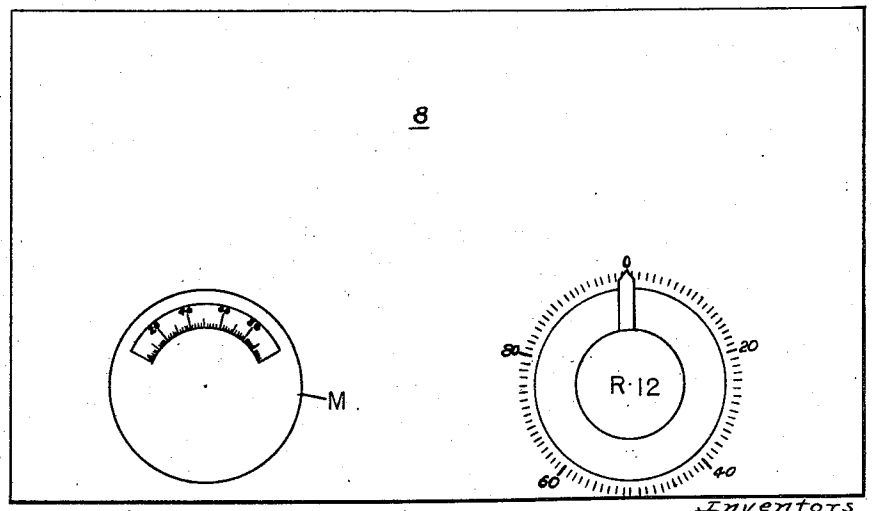


Fig. 5

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United States Patent Office 2,818,860 Patented Jan. 7, 1958

2,818,860

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Application November 17, 1955, Serial No. 547,439

16 Claims. (Cl. 128—191)

This invention relates to a method of and means for controlling the oxygen content of the breathing medium in oxygen tents.

The invention and its objects will be best understood by reference to the accompanying drawings, wherein:

Fig. 1 is a view partly in front elevation and partly in vertical section, of a casing in which the control apparatus is contained, and with the electrical wiring omitted,

Fig. 2 is a view in horizontal section upon line 2—2 of Fig. 1,

Fig. 3 is a diagrammatic view of the electrical connections and units employed in the apparatus, and Fig. 3A is a like view illustrating alternating current electrical apparatus, hereafter described.

Fig. 4 is a diagrammatic view of the oxygen tent and associated parts, and

Fig. 5 is a front elevation of the control box of the device.

Referring to Fig. 4, 5 designates an oxygen tent, arranged over a hospital bed 6. An intake duct 7 which may be of metal, canvas, rubberized cloth or otherwise has a small, boxlike casing 8 secured to its side wall. The interior of the right hand end of this casing is shown in section in Fig. 1. Here it will be seen that within casing 8 vertically disposed tubes 10, 11, 12 and 13 are disposed. A fitting 14 located at the top of tube 11 is connected by a pipe 15 (which may be a flexible hose, if desired) to the conventional outlet reducing valve 16 at the top of the tank 17, of oxygen. Thus, oxygen at say 60 lbs. per square inch, may be continuously supplied to fitting 14. Part of the oxygen is discharged forcibly through a cap 18 which has a small opening therethrough. The oxygen discharged from the cap 18 enters a venturi tube 19 which may be made of plastic or any other suitable material. The discharge of this stream of oxygen forcibly through the venturi tube induces air flow from tube 12 into tube 11 through a port 12^a and this air, together with the oxygen discharged through venturi tube 19 passes from the lower end of tube 11 through a lateral extension 11^a into the intake duct 7.

It is common practice to condition air supplied to oxygen tents by passing the same through conventional humidifying, temperature controlling and/or CO_2 removing apparatus and the casing of such an apparatus is indicated at H. The duct 7 constitutes the intake duct for the apparatus H while the outlet duct 7^a leads from H to the oxygen tent and delivers to said tent the breathing medium which has been oxygen controlled by the bridge senser herein described. The practice has sometimes been followed, where no accurate oxygen control has been employed, of flooding the system with oxygen and thereby sweeping out of the tent undesirable quantities of CO_2. In apparatus such as ours, where excess of oxygen is avoided it may be desirable to provide means for getting rid of the CO_2. For that purpose a duct K may be employed to carry air from the tent to conventional apparatus in casing H which removes the CO_2. Another part of the oxygen delivered to the fitting 14 passes through

pipe 20 to a normally open oxygen valve 21. This valve is biased to open position by spring 22 and is closed, against the action of said spring, when the coil of a solenoid magnet 23, is energized, the core 24 of said magnet carrying the valve element 21. When the valve is in its normally open position the oxygen flowing through said valve passes downwardly into the lower portion of tube 10 and thence rearwardly through a lateral extension 10^a of said tube into intake duct 7. A sample of the breathing medium or air from within the tent is drawn by the induced air flow through tube 12, into said tube 12 through a sampling tube 25, This tube leads through outlet duct 7^a, or otherwise from the interior of the tent, at a point selected by the physician, to the lower portion of the tube 12, as indicated at 25^a, from which point the air must travel substantially the full length of the tube 12 to reach its point of escape at port 12^a. In this travel it contacts the thermally sensitive resistors R2, R3, hereinafter described.

Referring now to Fig. 3, 26 designates a power pack from the conventional elements of which potentials of the kind indicated are delivered to a plug 27—27^a.

The oxygen sensing circuit is shown in Fig. 3. It consists of a bridge, of the Wheatstone type, composed of the thermally sensitive resistors R1, R2, R3, R4, together with bridge balancing adjustment R5. In operation a sufficiently great current is made to flow through the bridge to cause appreciable heating of these four thermally sensitive elements. Resistors R2 and R3 are placed (as for example in tube 12) in an atmosphere of the gas whose composition is to be monitored and controlled while resistors R1 and R4 are placed (as for example in tube 13) in a reference atmosphere. The bridge is initially adjusted by means of R5 so that there is no potential difference between the point of junction of R1 and R2 and the point of junction of R3 and R4. Should the composition of the gas being sampled and its consequent thermal conductivity vary, a new equilibrium temperature for R2 and R3 will be established. This change in temperature will make itself manifest by the resulting change in value of these resistors with a consequent bridge unbalance which in turn results in the appearance of a potential from the point of junction of R1 and R2 to the point of junction of R3 and R4. The use of four thermally sensitive elements in the bridge results in a greater unbalance potential than would be the case should only two thermally sensitive elements and two fixed resistors be employed. The potential appearing across the aforementioned junction points is of the order of half a volt when the bridge is first balanced on air and then oxygen being admitted to the chamber that houses the resistors R2 and R3; resistors R1 and R4 remaining in an air atmosphere during this time. The unbalance signal appearing across the bridge is amplified by a D. C. pentode amplifier stage V1 that has an approximate voltage gain of 50. The output of this amplifier is fed simultaneously into two triode stages $V2^a$ and $V2^b$. The first of these $V2^a$ is made to operate a relay A which closes at a signal level that is governed by the setting of potentiometer R12. Relay A controls the solenoid operated oxygen supply valve 21. The control R12 is used to adjust the oxygen level in the tent to the desired value. In setting the device to maintain a given percentage of oxygen in the tent the physician or attendant sets the potentiometer dial at the desired point. Whether the oxygen control valve is open or not is controlled by two factors; the first is the level of the signal applied to the grid of $V2^a$ from the output of V1 and the other factor is the setting of potentiometer 12. Thus the oxygen control valve can be made to close at any desired level by the proper adjustment of R12. The second triode stage $V2^b$ is a cathode follower that actuates

a milliometer M to give visual presentation of the oxygen level existing in the tent. Resistor R15 is adjusted so that the milliometer zero corresponds with 0% oxygen in the sample chamber. Resistor R17 adjusts the sensitivity or span of the milliometer and is adjusted so as make full scale meter deflection coincide with the presence of 100% oxygen in the sample chamber.

The high voltage power supply is rather conventional providing regulated 255 volts D. C. Also included in the power supply is a source of unfiltered 25 volts D. C. regulated by means of thermistor R22 and fixed resistor R21. This latter supply does not have any common connections with the high voltage supply including the ground and thus it can be considered to be "floating."

Of the variable resistors R12 is the only one that is to be readily accessible for adjustment, the other potentiometers, being of the screwdriver adjusting type, are set initially and only periodically checked.

The present invention is of especial value in connection with oxygen tents used to insure proper oxygen supply to new born infants and throughout the first days of a child's life. Recent developments in the medical field have shown that an improper supply of oxygen to new born babies may and frequently does result in blindness of the baby.

In determining how to insure the proper amount of oxygen to such new born babies it is necessary to take into consideration the fact that an excess of oxygen in the air supply is as objectionable as too little. Further, a new born baby in an oxygen tent is usually so very weak that it cannot cope with material pressure differences. These considerations apply also in the case of adults who are critically ill but they apply especially in the case of babies.

It has therefore been a primary object in the development of this oxygen tent senser to provide a structure in which any flow of gases necessary to carry out the sensing of the same shall be wholly independent of the breathing action of the child and in which the patient is at all times, under nature's normal atmospheric pressure. Among the reasons why the senser has its greatest utility at approximately atmospheric pressures is that experiments have shown that in the presence of materially increased pressures in the tubes 12 and 13 the thermal changes necessary to satisfactory operation do not take place because of the lowering of the filament temperatures which results from the large increase in the convective cooling effect of the ambient gases in the presence of such increased pressures.

The element H, as before stated, is a conventional air conditioner adapted to condition the air flow as to humidity, temperature and CO_2 removal and including the usual fan for setting up air circulation to and from the tent. While the senser casing 8 has been shown as attached to the intake duct 7, it could be mounted on the outlet duct 7^a or at any other place as long as the oxygen from the oxygen valve is delivered into the air stream. However, it is preferred to mount this casing as shown. Oxygen as delivered from a commercial oxygen tank or flask, such as 17, is sometimes too dry, and one of the functions of apparatus H is to supply the desired degree of humidity to the air stream.

While the tent, unit H with its fan (not shown) and ducts 7, 7^a constitute a closed circuit, the movement of the air therethrough is preferably under the influence of mechanical power (a fan); the breathing effort or inhalation and exhalation of the patient being wholly independent of this fan created or natural air circulation. Thus this device differs from closed circuit devices wherein a limited volume of air is moved under the lung action of a human being, to be treated for oxygen control and CO_2 removal and repeatedly rebreathed.

The thermally sensitive elements R1, R2, R3, R4 may be of the nature of small incandescent coils such as are found in small light bulbs but which coils are open to contact with the gases by which they are surrounded. However, the invention includes within its purview the use, in the tubes 12 and 13 of any material or substance which has its nature varied in response to the varying compositions of the gases which contact them and which as a result bring about such imbalance in the bridge as to produce a potential in the manner described.

An important feature of the invention resides in the provision of the alternating circuit parts assembly illustrated in Fig. 3A and which includes the feature of introducing alarm or warning elements, either warning lights, bells or otherwise, into the assembly and actuating these warning elements (lights for example) and the oxygen control valve.

In Fig. 3A P_{10} indicates a plug to be plugged into an alternating current and from which current is delivered to the transformers T_{10} and T_{20}. S_{10} indicates a main control switch.

In Fig. 3A the thermal conductivity bridge comprises resistors W_1, W_2, W_3, W_4, W_5, W_6, of which W_5 and W_6 are employed for changing the null-point of the bridge, W_5 being a semi-adjustable potentiometer used to compensate for individual differences in resistors W_1, W_2, W_3, W_4. Resistor W_6 is a manually varible potentiometer which is used to determine the oxygen level that it is desired for the senser and controller to maintain during the operation of the unit. Resistors W_1, W_2, W_3, W_4 are tungsten lamp filaments which function as temperature dependent resistors.

In operation transformer T_{10} supplies an alternating operating current to the bridge that is sufficient to result in the appreciable heating of resistors W_1, W_2, W_3, W_4. This current is limited by the maximum temperature at which the filaments may be operated without undergoing destructive oxidation. Resistors W_1 and W_4 are placed in a reference atmosphere of air while resistors W_2 and W_3 are placed in an atmosphere of the gas whose oxygen level is being monitored and controlled as previously described. Should the monitored gas be of the desired composition (determined by the setting of W_6) the bridge will be balanced and no potential will appear between the punction of W_1 and W_3 and the junction of W_2 and W_4. Should the gas deviate in composition however, from this value the bridge will become unbalanced since the thermal conductivity of the undesired mixture will differ from that of the desired mixture and this change will result in a variation of the operating temperature of resistors W_2 and W_3, with a consequent change in their resistances. The unbalance causes an alternating potential to appear between the junction of W_1 and W_3 and the junction of W_2 and W_4. The unbalance potential is amplified by a conventional pentode audio amplifier stage E_1, followed by a triode cathode follower circuit E_{2a}. The output of the cathode follower is applied to the plate of a thyratron, E_3 phase discriminator. The purpose of this latter circuit element is to determine the sense of the bridge unbalance. Thus an alternating signal present at the output of the cathode follower indicates an unbalance of the bridge but only a consideration of the phase of this error signal with respect to the bridge supply current will yield information as to which side of null the bridge has been unbalanced. The thyratron functions to permit the passage of an error signal only in the event of a bridge unbalance in the direction indicating over-abundance of oxygen. Thus an oxygen deficiency, while resulting in a bridge unbalance and consequent error signal output from the cathode follower, will not cause the subsequent portion of the circuit to operate and close the normally open oxygen control valve, VAL. The output of the thyratron is rectified by means of a germanium diode E_4, filtered, and applied to the grid of a triode amplifier stage E_{26} that operates a double pole, double throw relay, RY_1 one section of which in turn operates both an indicator lamp, L_1, preferably green, giving visual evidence of oxygen flow to the

tent, and the normally open oxygen control valve. The other section of this relay is used to generate an input signal for the delay circuit composed of E_5 which is essentially a conventional Miller integrating circuit and E_6 which operates the relay RY_2 that controls the alarm indicator L_2, preferably a red light. If the normally open oxygen control valve, VAL, is open for periods of a greater duration than that of a preset value determined by the adjustment of W_{20}, this latter relay will operate and lamp L_2 will function as will any external alarm which may be plugged into socket SO_{10}. This condition indicates that the desired atmosphere has not been had in the tent for this predetermined period, and will occur with cylinder exhaustion, badly leaking tent etc.

The A. C. bridge tent senser is more stable and maintains its calibration better than does the D. C. senser since the problem of inherent D. C. amplifier drift does not have to be contended with in the former case. The A. C. system however, suffers from an ambiguity of signal that is not present in the D. C. system. This ambiguity can be resolved without too much difficulty by several means of phase comparison one of which is the above described thyratron phase discriminator.

What is claimed is:

1. In combination, an oxygen tent, power means for setting up a flow of breaking medium to and through said tent, a source of oxygen supply, an electrically operated control valve for the oxygen supply, a Wheatstone bridge circuit and source of E. M. F. thereto, from which bridge a potential is delivered upon imbalancing of the bridge, two sets of resistance elements disposed in the legs of the bridge, a first closed chamber in which one set of the resistance elements of the bridge is disposed in a reference atmosphere, a second closed chamber in which the other set of resistance elements is disposed, and means for setting up a flow of sampling breathing medium through the second closed chamber, from the interior of the tent and means for electrically actuating the oxygen control valve by the imbalancing of the said bridge.

2. A structure as recited in claim 1 comprising means for inducing such flow of the sampling breathing medium under the influence of flow from the oxygen supply.

3. In a device for maintaining a desired concentration of oxygen in the breathing atmosphere within an oxygen tent, the combination with such tent of a duct, power means for inducing flow of the breathing medium through said duct, a source of oxygen under pressure and a senser comprising four tubular chambers, a Wheatstone bridge circuit and electric circuits and power supply for supplying electric current thereto, a set of resistance elements located in one of said tubular chambers and in a reference gas in said chamber, a second set of resistors located in the second of said tubular chambers, a venturi tube located in the third of said tubular chambers, an electrically actuated oxygen control valve located in the fourth of said tubular chambers, discharge conduits leading from the third and fourth of said chambers to the duct, a port connecting the second and third tubular chambers, a sampling tube connecting the interior of the tent to the second tubular chamber, a connection from the source of oxygen supply through which oxygen is delivered under pressure into the venturi tube to thereby induce a flow of sampling breathing medium through said second chamber and through said port into the third tubular chamber, and a connection through which oxygen from the supply source is delivered to the oxygen control valve, the oxygen which passes the oxygen control valve and the oxygen which induces flow through the venturi tube passing to the duct through said discharge conduits of the third and fourth chambers, and electrical means actuated by potential created by imbalance of the bridge for actuating the oxygen control valve.

4. A structure as recited in claim 3 wherein the said valve is a normally open one, actuation of the same acting to move it toward closed position.

5. A structure as recited in claim 3, wherein the resistors of the bridge are thermally sensitive resistors and wherein the electric circuits comprise means for heating the same, the thermal conductivity of said resistors varying with variations in the percentage of oxygen in the stream of sampling breathing medium.

6. A structure as recited in claim 3 wherein the resistors of the bridge are thermally sensitive resistors and wherein the electric circuits comprise means for heating the same, the temperature of said resistors varying with variations in the percentage of oxygen in the stream of sampling breathing medium and means for manually varying the heating current to said resistors.

7. A structure as recited in claim 3 wherein the resistors of the bridge are thermally sensitive resistors and wherein the electric circuits comprise means for heating the same, the temperature of said resistors varying with variations in the percentage of oxygen in the stream of sampling breathing medium and means for visually indicating the percentage of oxygen in the sampling stream, in comparison with that of the reference atmosphere.

8. A structure as recited in claim 3 wherein the resistors of the bridge are thermally sensitive resistors and wherein the electric circuits comprise means for heating the same, the temperature of said resistors varying with variations in the percentage of oxygen in the stream of sampling breathing medium, means for manually varying the heating current of said resistors and means for visually indicating the extent of such manual variations.

9. A system and apparatus for automatically controlling the supply of oxygen to an enclosed space and for indicating the percentage of oxygen content in said space which system comprises a Wheatstone bridge, electric circuits within which the elements of said bridge are included, means for supplying alternating current to said circuits, an oxygen control valve in said circuit, an electrical alarm in said circuit, a thyratron included in said circuit and receiving potential set up by unbalance of said bridge and means for energizing said alarm and oxygen control valve under control of phase discrimination in the output of the said thyratron.

10. Apparatus as recited in claim 1 including a thyratron included in any output potential from said bridge upon imbalancing of the same, signaling means and means for controlling said signaling means under control of and in accordance with thyratron phase differences.

11. Apparatus for signaling the oxygen content of the breathing medium in a confined space comprising an electric circuit, means for setting up A. C. potential in said circuit as a function of the oxygen content of said breathing medium, a phase discriminator included in said circuit and subject to said potentials, a plurality of signals and means for energizing said signals in accordance with the action of the phase discriminator.

12. In means for maintaining a determined oxygen content in the breathing medium within a confined space, a source of oxygen, a normally open electrically operated oxygen control valve disposed to control a supply of oxygen to the said breathing medium, a senser comprising a Wheatstone bridge having two sets of thermally sensitive resistors therein, one set of which is exposed to a reference sample of some of the breathed medium and the other set of which is exposed to oxygen, means for supplying current to the bridge, an electric circuit receiving any potential set up as a result of imbalancing of the bridge and a phase discriminator included in said circuit and in turn controlling the oxygen valve to cut off the oxygen supply when the imbalancing is the result of an excess of oxygen in the breathing medium.

13. A structure as recited in claim 12 in combination with an electric warning signal operable when the oxygen control valve remains open more than a predetermined time to indicate that a deficiency of oxygen is present.

14. Apparatus for signaling the oxygen content of the breathing medium in a confined space comprising an

electric circuit, means for setting up A. C. potential in said circuit as a function of the oxygen content of said breathing medium, a phase discriminator included in said circuit and subject to said potentials, a signal and means for energizing said signal in accordance with the action of the phase discriminator.

15. In means for maintaining a determined oxygen content of the breathing medium in a confined space, a source of oxygen, an electrically operated control valve controlling the flow of oxygen from said source, an electric circuit in which said valve is included, a sener operable under variations of oxygen content in the breathing medium to effect current flow in said circuit, and a phase discriminator in said circuit.

16. In means for maintaining a determined oxygen content in the breathing medium within a confined space, a source of oxygen, a normally open electrically operated oxygen control valve disposed to control a supply of oxygen to the said breathing medium, an electrical circuit in which said valve is included, an oxygen sensitive senser disposed in said circuit operable to effect current flow in said circuit in accordance with the oxygen content of the breathing medium and a phase discriminator in said circuit.

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