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D. R. BLUMER

2,848,306

HUMIDITY DETERMINATION

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FIG. 1

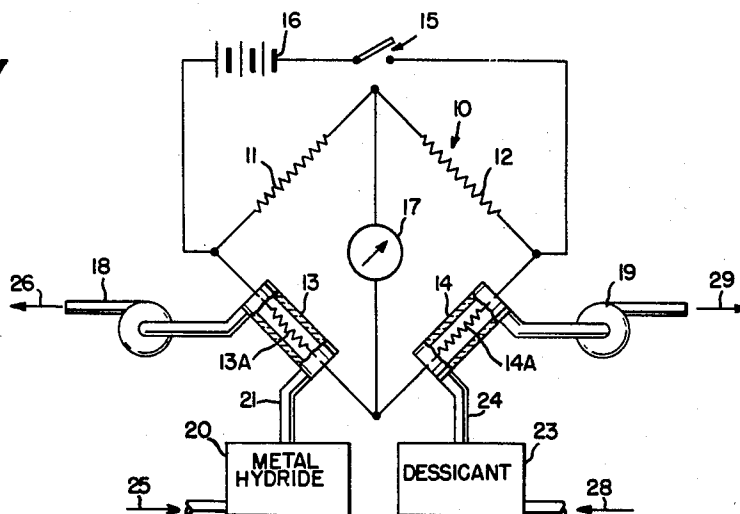


FIG. 2

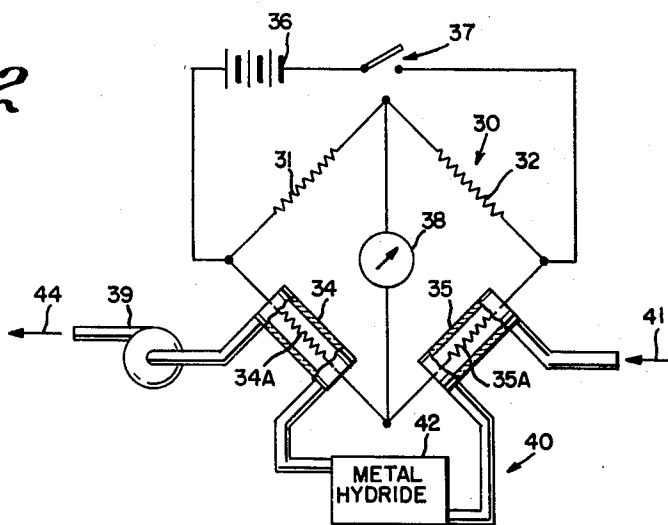
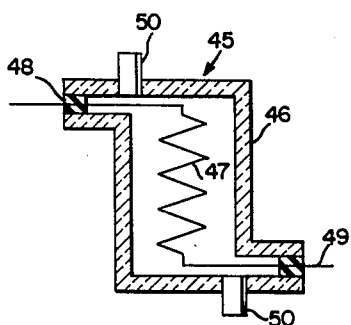


FIG. 3

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2,848,306

HUMIDITY DETERMINATION

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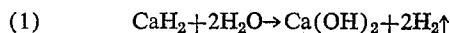
2 Claims. (Cl. 23-232)

The present invention relates generally to the determination of humidity or water vapor in gaseous mixtures. More specifically, the invention relates to the determination of humidity in a gaseous mixture by means of comparing the thermal conductivity of a reference gas with that of an unknown gas wherein the water vapor in the unknown gas has previously been converted to hydrogen. Previously, attempts have been made to measure the water vapor content of air by means of comparing the thermal conductivity of an unknown sample with that of a sample of either desiccated or saturated air; however, these systems have not been entirely satisfactory because of the lack of sensitivity of this type of device. It is noted, in this connection, that the thermal conductivity of air at 32° is 0.0140 B. t. u./hr. sq. ft. F.° ft. while the same thermal conductivity for water vapor at that temperature is about 0.0110. On the other hand, with my apparatus, the water vapor is converted to hydrogen which has a thermal conductivity coefficient of 0.100. It is seen, therefore, that the thermal conductivity of hydrogen is substantially one order of magnitude greater than that of either air or water vapor, and hence the sensitivity of my apparatus is very high.

Therefore, it is an object of the present invention to provide a method and apparatus for determining the water vapor content of a gaseous mixture by means of a thermal conductivity bridge wherein the water vapor in the unknown sample has previously been converted to hydrogen.

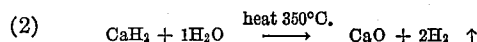
It is a further object of the present invention to provide an improved method and apparatus for determining water vapor content of gaseous mixtures with a particularly high degree of sensitivity. It is still a further object of the present invention to provide an improved method and device for determining the water vapor content of air by means of thermal conductivity comparisons utilizing a sample of air which has had its water vapor content converted to molecular hydrogen prior to the thermal conductivity comparisons.

In accordance with the present invention, therefore, there is provided, for example, a Wheatstone bridge type of device in which two opposite legs are provided with chambers for passing gas samples therethrough and wherein the relative ratios of thermal conductivities between the gases being passed through the two chambers may be determined. In order to convert the water vapor contained in the gas sample undergoing determination to molecular hydrogen, there is provided in the line upstream from the thermal conductivity chamber, a container which has available an active metal hydride which reacts quantitatively with the water vapor to release hydrogen. For example, calcium hydride has been found satisfactory in this connection, and the reaction is carried on as illustrated in the following formula:



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or, preferably



If desired for extra sensitivity, the other thermal conductivity sensing leg of the bridge, which uses a standard or reference gas, may be provided with a desiccating chamber or the like in order to remove the water vapor from the reference gas, thereby providing a consistent standard or reference sample. If, on the other hand, this particularly high degree of sensitivity is not necessarily required, the two chambers may be connected in series, with the metal hydride chamber positioned between the two cells. Of course, a source of electrical energy is required for the device as well as an indicating meter, such as a galvanometer or the like connected across opposite legs of the bridge network. The gas may be moved through the system by means of a suitable power source such as an impeller or the like.

My invention may be more easily and fully comprehended with reference to the accompanying drawings in which:

Figure 1 is a schematic view showing a preferred modification of the present invention;

Figure 2 is also a schematic view of a slightly modified form of the present invention; and

Figure 3 is a detailed view, on a slightly enlarged scale and partially in section showing a thermal conductivity cell which may be utilized in connection with the bridge networks as shown.

In accordance with the preferred modification of the present invention, there is shown in Figure 1 a Wheatstone bridge system generally designated 10 which includes a pair of standard resistance members 11 and 12 and a pair of thermal conductivity resistance chambers 13 and 14. There is also provided in this system a source of potential 16 controlled by the switch 15, and an indicator 17 for indicating the degree of electrical unbalance present in the system. The source 16 is shown as a unidirectional power source such as the battery supply 16. In order to provide for air travel through the thermal conductivity measuring chambers 13 and 14, there are provided impellers or fans 18 and 19 respectively operated from any suitable source of power, not shown. A chamber 20 containing a metal hydride is situated in the feed line 21 which leads to the thermal conductivity chamber 13. Likewise, on the other leg of the bridge, wherein chamber 14 is situated, a desiccant medium 23 is placed in the line 24 which feeds the reference gas, in this case, dry air, to the thermal conductivity chamber 14. Flow regulators should be provided for the impellers 18 and 19 in order that substantially equal quantities of gas will flow through each of the systems.

In order to operate the device, switch 15 is closed in order to apply a potential across the opposite legs of the bridge system, and the indicating meter, such as the galvanometer 17, is adjusted to a suitable zero position with the same gas passing through the separate cells. Upon satisfactory adjustment of the zero point, impellers 18 and 19 are set into motion, thereby drawing respective samples of gas across the heated filaments 13A and 14A which are situated in the interior of the thermal conductivity chambers 13 and 14 respectively. These filaments are preferably constructed of any type of resistor material which has a relatively high coefficient of change with temperature, such as platinum, nickel, or any suitable thermistor material. The gas sample which enters line 21 in the direction of the arrow 25 passes over a bed of metal hydride in the chamber 20 and up through conduit 21 to the thermal conductivity chamber 13, passing in contact with the resistor or thermistor 13A, and finally being exhausted through the impeller

18 in the direction of arrow 26. On the other leg of the bridge, a standard or reference gas, which may, for convenience, be the same air which is undergoing analysis in the opposite leg of the bridge is introduced into the line 24 in the direction of the arrow 28. This gas then preferably passes over a desiccant bed, which may be for example magnesium perchlorate, silica gel, phosphorous pentoxide, or the like, and then moves up the conduit 24 and through the thermal conductivity chamber 14, moving over and across the resistor element or thermistor 14A and finally to the impeller 19 and out of the system as is indicated by the arrow 29. Assuming the air undergoing test is moist, when the samples pass through the chambers 13 and 14, the resistor 13A is cooled to a greater extent than is the resistor 14A due to the higher thermal conductivity of hydrogen. The conversion of the water vapor to hydrogen is substantially quantitative, and therefore the greater the proportion of water vapor present in the gas being sampled, the greater will be the hydrogen content of the gas passing through the conductivity cells. In this connection, the greater the proportion of hydrogen in the gas passing through the cell, the greater will be the cooling effect of the gas on the resistor included in the cell. This cooling effect, of course, may be read off the indicating means in terms of a degree of unbalance in the bridge. Due to the temperature sensitivity of resistance of the respective resistance elements, an unbalance is then obtained across opposite legs of the bridge network and the magnitude of this unbalance is indicated by the galvanometer 17. For convenience, it will of course, be possible to calibrate the meter or galvanometer 17 directly in percent of absolute humidity present in the gas system undergoing test.

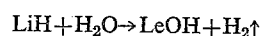
Attention is now directed to Figure 2 wherein there is shown another modification of the present invention. In this connection, there is provided a bridge system generally designated 30 which includes a pair of standard resistor members 31 and 32, a pair of thermal conductivity measuring chambers 34 and 35 which house temperature responsive resistor members 34A and 35A respectively. There is also provided a source of potential 36 which is controlled by the switch 37, and a suitable meter 38 for measuring unbalance of the system. An impeller or fan 39 is provided for drawing gas through the sampling system, and is driven by any suitable source of power, not shown. A conduit system 40 is provided for moving the gas samples through the system. There is further provided a metal hydride chamber 42 which contains a suitable metal hydride, which will quantitatively convert water vapor in the sample to molecular hydrogen. Therefore, in a given sample moving through the system, the thermal conductivity of the raw air is measured in the chamber 35 and is thence converted to a mixture of dry air and hydrogen by the metal hydride chamber 42, and this converted sample is then passed through the thermal conductivity measuring cell 34 and finally is exhausted from the system by means of the impeller 39 in the direction of the arrow 44.

The operation of the modification as illustrated in Figure 2 is substantially the same as that of the device illustrated in Figure 1. The only distinction in the two systems is that the reference sample in the device of Figure 1 represents a more standard material, such as dry air as opposed to wet air which is utilized in the device illustrated in Figure 2.

Attention is now directed to Figure 3 wherein there is shown on a slightly enlarged scale a thermal conductivity measuring cell generally designated 45 and which includes a housing 46 of suitable thermal conductivity material, such as brass, stainless steel or the like. These cells are preferably formed in a single block and thus a substantially constant temperature is maintained. The cell 45 is provided with an electrical resistance element 47 which is sensitive in its resistance characteristics to

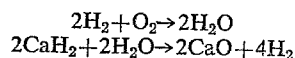
changes in ambient temperature. The resistor 47 is sealed into the chamber 45 by the plugs 48 and 49 which are electrical resistors and preferably moisture repellant. In order to pass a gas sample through this chamber, there are provided ports 50 situated on opposite sides of the chamber. Thus, in operation, a gas sample passes over a substantial portion of the resistor member 47 included in the cell 45 and the influence of the thermal conductivity of the gas passing over the resistor 47 may be read from a suitable indicating member as previously shown included within a bridge arrangement.

In addition to calcium hydride, lithium hydride may be satisfactorily utilized in connection with the present invention particularly in the presence of inert gases. It will be noted, however, that with lithium hydride one molecule of hydrogen is liberated for each molecule of water contacted. This material reacts according to the following equation:



Of course, it will be appreciated that various other hydride material which exchange hydrogen for water quantitatively may be satisfactorily utilized in connection with the present device such, for example, as barium hydride and similar commercially available hydrides. In specific cases some of the more active hydrides such as lithium aluminum hydride and the like may be used such as with inert gases such as nitrogen, argon, or the like, since in the presence of air they are likely to heat up sufficiently to catch fire by reaction with the oxygen of the air.

In addition to the two cell bridge system illustrated in Figures 1 and 2, multicell systems may be used, particularly a four cell system in which opposite arms of the bridge are exposed to the two gases of the same composition for each pair, thereby increasing the electrical sensitivity of the bridge. Similarly, an eight cell bridge which is appropriately connected to the non-hydrogen and hydrogen bearing gas streams may be used to increase the sensitivity still further. One may amplify the quantity of hydrogen present in the sample passing through the cells if greater sensitivity is desired. In this connection, the gas after passing over the hydride bed is passed over or through a platinized or palladized silica gel or asbestos layer or similar catalyst at a suitable temperature wherein the hydrogen present combines with oxygen from the air to form water vapor. This gas is then passed through or over a second hydride bed and hydrogen is formed according to the equations



Therefore, the quantity of hydrogen available to the cells is doubled. Of course, this procedure may be repeated to double the hydrogen available at each stage. The thermal effect is actually more than doubled since a portion of the low thermal conductivity oxygen is removed from the system each time the gas is passed through the catalyst bed after passing over the hydride bed.

Although various specific embodiments of the invention herein have been disclosed, it will be understood that there is no invention to limit the scope of the present invention to these specific embodiments alone, since they are used for purposes of illustration only. Many details of composition and procedure may be varied without departing from the principles of this invention. It is therefore not my purpose to limit the patent granted on this application otherwise than necessitated by the scope of the appended claims.

I claim as my invention:

1. The method of determining the water vapor content of a gaseous mixture which includes passing a standard reference gas through a first chamber wherein its relative thermal conductivity may be measured, pass-

ing a sample of a gas of unknown composition through a metal hydride bed wherein the water vapor is converted to molecular hydrogen, and thence passing said converted gas through a second thermal conductivity chamber wherein its thermal conductivity may be measured and compared with that of the reference gas. 5

2. The method of determining the water vapor content of a gaseous mixture which includes passing said mixture through a zone wherein water vapor is converted to molecular hydrogen, then to combining the hydrogen thus liberated with oxygen to form water vapor, then passing said gas through a second zone wherein the water vapor present is converted to hydrogen, and finally passing said converted gas through a zone wherein its hydrogen content is determined relative to a reference gas. 10 15

References Cited in the file of this patent

UNITED STATES PATENTS

1,855,774 Schneider ----- Apr. 26, 1932

OTHER REFERENCES

Harris et al.: Analytical Chemistry, vol. 23, No. 5, May 1951, pages 736-9.

Daynes: "Gas Analysis by Measurements of Thermal Conductivity," Cambridge University Press, London (1933), pp. 182, 183.

Technologic Papers of the Bureau of Standards, No. 249, Thermal Conductivity Method in the Analysis of Gases, January 7, 1924, page 49.

Chemical Abstract, vol. 34, column 3624 (1940).