Oct. 28, 1947. G. W. KING 2,429,694

METHOD AND EQUIPMENT FOR INDICATING THE WATER CONTENT OF A GAS

Filed March 29, 1944 2 Sheets-Sheet 1

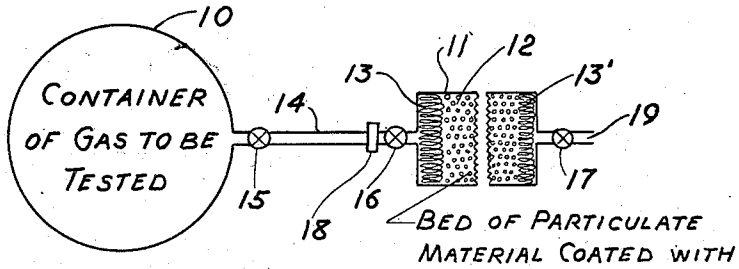


FIG. 1.

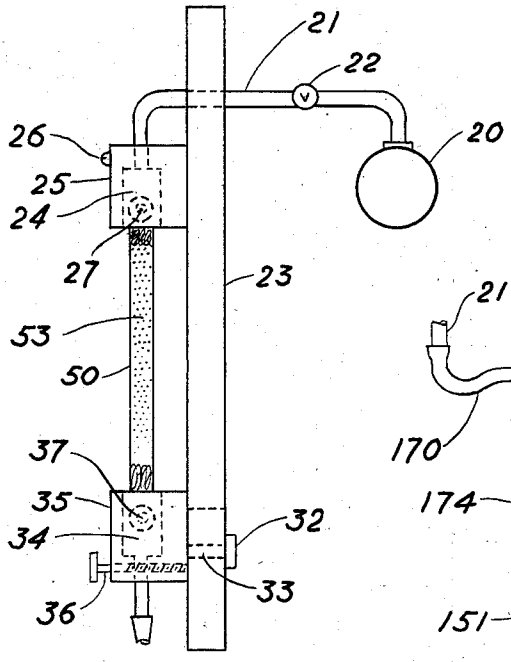


FIG. 3.

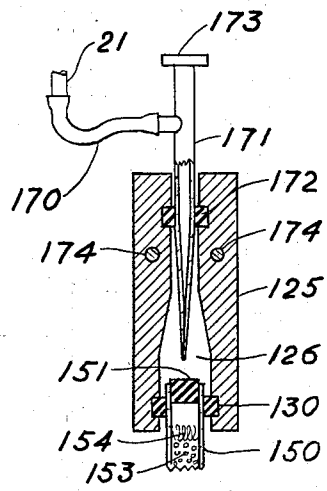


FIG. 5.

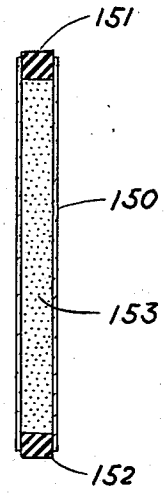


FIG. 4.

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Filed March 29, 1944 2 Sheets-Sheet 2

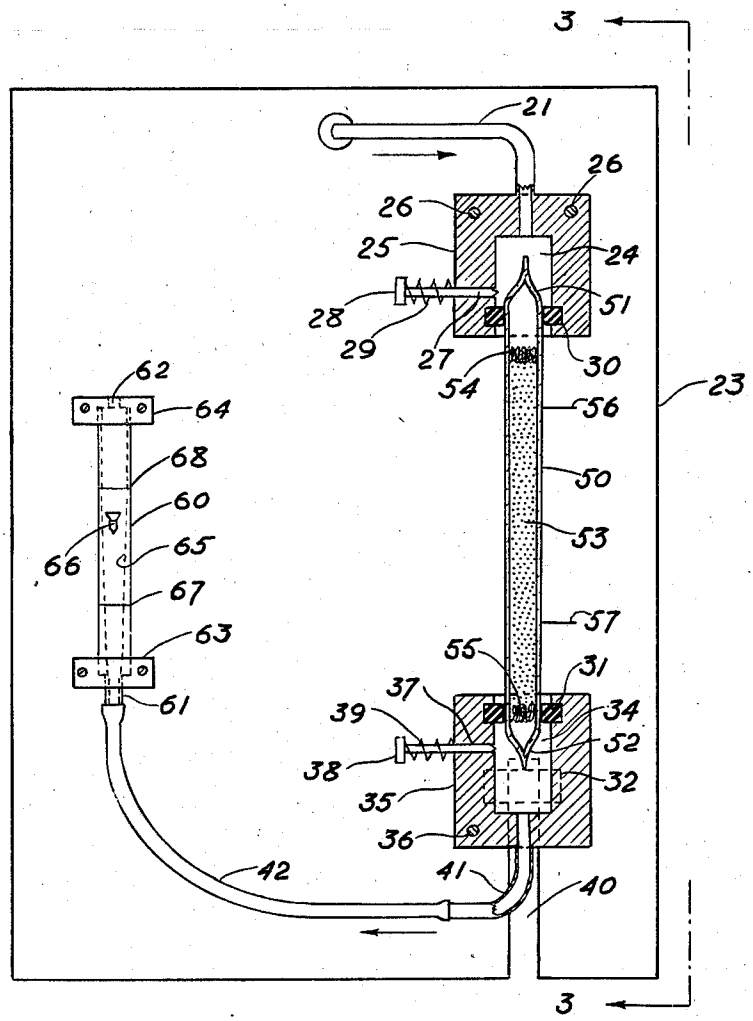


FIG. 2.

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Patented Oct. 28, 1947 2,429,694

UNITED STATES PATENT OFFICE

2,429,694

METHOD AND EQUIPMENT FOR INDICATING THE WATER CONTENT OF A GAS

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Application March 29, 1944, Serial No. 528,607

16 Claims. (Cl. 23—232)

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This invention relates to apparatus and methods for testing various gases for the presence of water (ordinarily as water vapor) in concentrations of the order of a few parts per million, and for approximate quantitative determination of the water content of such gases.

The determination of the water content of ordinary air and like gases at ordinary atmospheric or higher temperatures, and accordingly in concentrations of the order of parts per hundred, may be readily carried out by well known methods and apparatus. For some purposes, however, the determination of minute quantities of water vapor in gases is particularly desirable. One such purpose is the determination of the water-vapor content of air or air-oxygen mixtures supplied to aviators for their use when flying at high altitudes at very low temperatures,—e. g. below about —40° C. At such low temperatures, the water-vapor content of air or oxygen or mixtures thereof is exceedingly small, and is scarcely or not at all determinable with any real accuracy by any simple known method or apparatus. The determination of the presence of such small amounts of water vapor is however of paramount importance in such instances, because of the fact that water vapor, if present in such gases in more than certain minimum amounts, will solidify as ice crystals on parts of the apparatus supplying these gases to the breather, with consequent plugging of the passages and blocking of the supply of the gas. For most aviation purposes of the type just referred to, it is preferable to use air-oxygen or similar oxygen-rich gaseous mixtures having dew-points of not more than about —60° C., in order to avoid this ice-crystal formation.

It is accordingly a purpose of the present invention to provide a relatively simple apparatus and method for determining, approximately quantitatively, the presence and amount of water vapor in air and like gases having very low dew points, e. g. as low as about —60° C. Another purpose is the provision of certain chemical substances in a form particularly useful for such uses.

Other objects will appear from the following disclosure.

While this invention is concerned principally with the testing of air or oxygen or mixtures of air and oxygen, it is equally applicable to the testing of all elementary gases which are substantially fixed constituents of the atmosphere—specifically oxygen, nitrogen and the noble gases—as well as mixtures of any or all of them; and is, in fact, applicable generally to the testing

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of gases which are not harmful to the chemical reaction products used in making the test—e. g. hydrocarbons.

In its broader aspects, this invention provides a testing apparatus for the purposes set forth which comprises a sealed cartridge or tubular or other suitable device containing a substance which changes color when exposed to water; this cartridge is held at each end by a clamp, or other suitable means, each such holding means including means for unsealing the ends of the cartridge so that the contents of the cartridge may be exposed, at one end, to the gas to be tested, and at the other end, to a flow-meter device for measuring the rate of flow of the gas. The unsealing may be done by breaking or crushing the sealed ends of the cartridge, or by puncturing neoprene-stoppered (or the like) ends of the cartridge by means of hollow needles, for example. The gas to be tested is held in an ordinary compressed-gas cylinder or other suitable container, at any desired pressure, preferably above atmospheric, and is fed to the cartridge at a suitable rate which may be regulated by proper valve arrangement. This rate may be initially established by inserting an open-ended empty cartridge in the clamps, opening the valves between cartridge and cylinder, and adjusting the flow of reference to the flow-meter. The empty cartridge is then removed, a filled sealed cartridge inserted, and the ends of the latter unsealed to permit flow of the gas therethrough. The use of the open-ended empty cartridge also permits the said gas to sweep out all other gases from all interior parts of the apparatus between the cylinder and the cartridge which come in contact with the gas to be tested. The unsealing of the ends of the cartridge is carried out under conditions such that the resulting openings are exposed only to the gas to be tested, and so that no possibility exists of contact between the outside air or other extraneous ambient fluid and the contents of the cartridge.

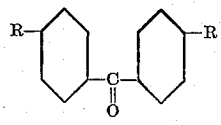
It is furthermore important that the apparatus be so constructed that none of the parts in contact with the gas to be tested in its passage from the cylinder or container to and through the cartridge shall be of a substance which absorbs or adsorbs water. In general, metals are suitable for this purpose, whereas plastics are not. Metal valve packings are also used accordingly; furthermore, any corners, crevices, pipe threads and like pockets or regions which might collect water are to be avoided.

Instead of having the gas in the containing cylinder at superatmospheric pressure, it may be at normal or sub-atmospheric pressure and the flow of the gas through the testing equipment may be effected by suction on the exit end or by other means such as a pump or blower.

A number of compounds are known which change color on exposure to water—for example, some of the salts of copper, of nickel, and of cobalt. Thus, anhydrous cupric sulfate, which is white, is converted to the pentahydrate, which is blue, on exposure to water. The brown anhydrous nickel chloride is similarly converted to the green hexahydrate. Such compounds may be used in the testing of gases containing relatively large amounts of water, by means of the apparatus and procedure herein set forth, but under most circumstances there is no particular advantage in doing so.

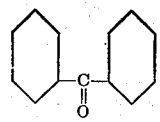
In the testing of gases containing very small amounts of water—e. g. with dew points well below 0° C., much more sensitive compounds or agents are required if the testing is to be accomplished within a reasonable length of time. It is found, in accordance with the present invention, that the compounds or reaction products of Grignard reagents with certain ketones are especially suited to this purpose. The ketones preferred for this purpose are of the benzophenone series, and may be represented by the formula:

(1)



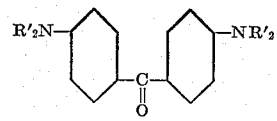
wherein R is either hydrogen, in which instance the ketone is benzophenone

(2)



or a dialkyl amino group R'_2N—, in which instance the ketone is a tetraalkyl-p,p'-diamino benzophenone

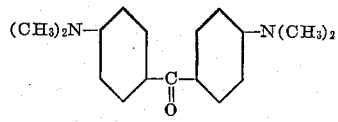
(3)



The four alkyl groups R' may be alike or different.

Particularly useful in the present invention is a member of this latter group of compounds (3) wherein each R' is a methyl group—i. e. Michler's ketone or tetramethyl-p,p'-diamino benzophenone:

(4)



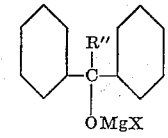
A Grignard reagent is any one of a group of organic magnesium compounds having the formula:

(5) $R''MgX$

wherein R'' is an organic radical and X is a halogen.

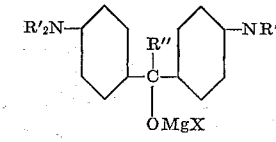
The exact mechanism of the reaction between the ketone and the Grignard reagent, and of the change from colorless to colored form induced by the presence of water, is not known, but the knowledge thereof is not necessary to an understanding of the present invention. Apparently, however, these two compounds react to form the reaction product:

(6)



when benzophenone is the ketone, or

(7)



when the ketone is a tetraalkyl-p,p'-diamino benzophenone; and each of these products rearranges itself in the presence of traces of water to form a product of different color. A related group of compounds which is also useful in carrying out the present invention is that obtained by reacting a metal alkyl with a benzophenone of the type represented by Formula 1. An example is the reaction product of Michler's ketone and diphenyl magnesium.

An example of the preparation of the reaction product, using methyl magnesium iodide as the Grignard reagent and Michler's ketone as the ketone, is as follows:

2 grams of Michler's ketone, which had been dried to constant weight at 110° C., was dissolved in 100 cc. of benzene distilled in sodium (to remove all traces of water). To this was added slowly methyl magnesium iodide (CH_3MgI) solution, made by reacting 14.7 g. of magnesium turnings with 54.6 g. of methyl iodide in the presence of 200 cc. of dibutyl ether in accordance with known methods, and under strictly anhydrous conditions. An orange precipitate appeared on addition of the first few cc. of methyl magnesium iodide solution; this precipitate dissolved on further addition, and the final product was a clear, pale yellow solution. This was stored in darkness and out of contact with the atmosphere and any other sources of water vapor.

The same procedure is followed when using other Grignard reagents and other ketones of the class described—allowance of course being made for their differences in molecular weights.

The reaction product prepared in accordance with the foregoing example changes from pale yellow (or nearly colorless) to blue, on exposure to water. That prepared similarly but with ethyl magnesium bromide instead of methyl magnesium iodide as the Grignard reagent turns from colorless to green on exposure to water, while when phenyl magnesium iodide is the Grignard reagent, the reaction product changes from yellow to dark blue-green. When the ketone is benzophenone and the Grignard reagent is phenyl magnesium iodide the change is from colorless to reddish brown.

These reaction products differ sufficiently in water-sensitivity and other properties to permit selection of a particular one of them for a particular set of conditions. For example, the reaction product based on ethyl magnesium bromide is more water-sensitive than that based on methyl magnesium iodide, and still more water-sensitive than the two referred to above based on phenyl magnesium iodide with either ketone.

It will be noted that the relative amounts of the ketone and the Grignard reagent given in the foregoing example are not mol for mol, but are

higher in Grignard reagent. This is considered desirable in order to cause the reaction to go sufficiently to completion in forming the reaction product.

A volume of 0.05 cc. of a solution of the reaction product of Michler's ketone and methyl magnesium iodide (CH_3MgI) prepared in accordance with the foregoing example—and having a concentration of 1% with respect to the Michler's ketone—when spread on #60 mesh sand, turns blue with 0.06 milligram of water, when testing ordinary cylinder oxygen at ordinary temperatures. This sensitivity varies with variation in conditions. For example, since the color reaction occurs on the surface of the solution, only a very small amount of the solution need be used if it is spread out as a very thin film, e. g. on the #60 mesh sand, as indicated above. The appearance of color also depends to some extent upon the concentration of water in the gas being tested—higher than ordinary concentrations resulting in somewhat lower sensitivity and lower concentrations in higher sensitivity. The sensitivity also increases somewhat with decreased concentration of the solution of the reaction compound and with decreased rate of flow. It is also significantly increased by dispersion of the reaction compound over an extensive surface, as described in detail hereinafter.

These reaction products of Grignard reagents and the ketones of Formula 1 are stable and effective within a fairly wide range of conditions of temperature and keeping time. For example, the reaction product of Michler's ketone and CH_3MgI retains effective sensitivity to water after heating to 110° C., and after cooling to —78° C., and after keeping for over six weeks at 65° C. When this reaction product is used, the color change reaction has a fairly large temperature coefficient—thus, it takes twice as long to develop the same amount of color at 0° C. as at 25° C., and half as long at 50° C. as at 25° C.—corresponding to a 6° C. change in dew point. These facts introduce no practical difficulties, however, inasmuch as the length of the test time and other factors can be adjusted within a wide range to balance them.

At —40° C. the color change in the reaction product of Michler's ketone and CH_3MgI is generally too slow for practical use. When testing is done at such low temperatures, it is therefore advisable to use a more sensitive compound, such as the reaction product of Michler's ketone and ethyl magnesium bromide, which shows the color change at —50° C. or even lower.

These various reaction products are rather sensitive to light, and should accordingly be kept in the dark except during the actual preparation and testing procedures.

As already indicated, the reaction product is much more effective for detecting the presence of water when said product is spread out as a film instead of being employed as a body of liquid. In carrying out the present invention, it has accordingly been found especially advantageous to spread the reaction product as a thin coating over a mass of clean water-free particulate material which is either transparent or of a color (e. g. white) which does not interfere with detection of the color change of the reaction product. Sand, glass beads or particles, quartz beads, silica gel, and glass wool or flakes, in clean, thoroughly water-free condition, are suitable for use as such particulate material to receive the coating of the reaction product.

In order that the color change may be readily seen, as well as to permit convenient sealing and opening, the container for the reaction product is made of glass or like transparent material, conveniently in the form of a tube. For most purposes this container may be of about 5 mm. inside diameter and about 8–10 cm. long. It may be made from a clean glass tube of suitable inside diameter, which is then sealed at one end, filled with the particulate material, and thoroughly dried. A measured quantity of the solution of the reaction product is then introduced, as by means of a hypodermic syringe; the other end of the tube is then sealed. Absolutely anhydrous conditions are maintained throughout this filling and sealing procedure.

Alternatively, and generally more conveniently, the ketone and the Grignard reagent may be kept in the form of separate solutions prior to charging the particle-filled tube, and then mixed and reacted within the tube. By introducing the Grignard reagent first, any possible traces of moisture within the tube are removed by hydrolysis of this reagent into harmless products.

The sealing may be carried out in any way such that extraneous water or other deleterious material is excluded and that the seals may be sufficiently readily broken or punctured. For example, the seals may be formed by melting the ends of the glass tube, or by plugging them with stoppers of neoprene or other composition which has no tendency to absorb or adsorb H_2O.

This invention will now be described in greater detail with reference to the accompanying drawings, wherein:

Fig. 1 represents, largely diagrammatically, the arrangement of the fundamental parts of the apparatus;

Fig. 2 represents a front view, partly in section, of a particular embodiment of this invention;

Fig. 3 represents a side view of the type of embodiment shown in Fig. 2, looking in the direction of arrows **3**, **3** in Fig. 2, and showing in particular the positioning of the means for holding the cartridge or container for the water-sensitive compound;

Fig. 4 represents a modification of the cartridge or container for the water-sensitive compound; and

Fig. 5 represents a holder and unsealing means for cartridges or containers of the type shown in Fig. 4.

Referring to Fig. 1, **10** represents a container for the gas to be tested, and **11** represents a container for the bed **12** of particulate material coated with a substance which is color-sensitive to water. Communicating between the two containers is line **14**. The ends of container **11** are provided with sealing means **16**, **17**, which are kept closed until the testing is to take place, thereby excluding all extraneous moisture from bed **12**. Bed **12** is conveniently segregated from sealing means **16**, **17** by wads or packings **13**, **13'**, which may be made of glass wool. For operation, container **11** is attached to line **14** by coupling **18**, valve **15** is opened and sealing means **16**, **17** are unsealed, whereupon gas flows from container **10** through the apparatus to outlet **19**. Line **14** should be cleared of all extraneous moisture prior to such operation. Rate of change in color of the material in bed **12** indicates the water content of the gas being tested. Suitable marks may be placed at intervals along the walls of container **11** to note the rate of advance of the leading edge of

the color change in units of distance per unit of time. Alternatively, in this and other embodiments, it is possible to omit sealing means 17 and opening 19, thus having a container 11 with only one opening, at 16. In such cases, the gas is forced under pressure into container 11, but the latter must be sufficiently strong to withstand such pressure as there is no outlet for the gas.

Referring to Figs. 2 and 3—container 20, which holds the gas to be tested, is connected by line 21 with the testing apparatus which is mounted on instrument panel 23. Suitable valves and control mechanism 22 are positioned in line 21 to provide and regulate flow of gas from container 20 to the testing apparatus. Line 21 communicates with chamber 24 within upper holding block 25, which block is attached to panel 23 by bolts 26. Projecting through a wall of block 25 and into chamber 24 is a crusher pin 27, having head 28 and spring 29. This pin 27 fits tightly enough into a like-shaped hole in block 25 to prevent any significant passage of air from outside into chamber 24, while spring 29 operates to hold pin 27 sufficiently far withdrawn out of chamber 24 except when the pin is used to crush the upper end of cartridge 50.

Spaced apart from, and directly below, block 25 is lower holding block 35, which is slidably mounted in slot 40 so as to be movable towards and away from block 25. Block 35 is clamped in position by cooperation between set screw 36 and cross bar 32 which is firmly fixed to block 35 by bar 33. Pin 37, having head 38 and spring 39, is positioned and operates in block 35 in the same manner as does pin 27 in block 25.

Chamber 34 communicates with outlet line 41, which in turn communicates with inlet opening 61 of rotameter 60 by means of the flexible neoprene tube 42. Rotameter 60 is provided with outlet 62 which, together with inlet 61, permits passage of gases through it. Mountings 63 and 64 hold the rotameter 60 to the panel 23. The rotameter is provided with a sloping (inverted conical) inner wall 65 and a float 66, in the usual manner for such flow metering devices, and also with marks 67, 68 to indicate predetermined rates of flow of gas through the rotameter 60 when float 66 is opposite either of such marks.

Cartridge 50 is a frangible transparent tube, preferably of glass, and having sealed ends 51 and 52. Within cartridge 50 is the bed 53 of particulate material coated with a substance which is color-sensitive to water. This particulate material, if a pourable substance such as sand or glass beads, is spaced from ends 51 and 52 by glass wool wads 54 and 55 respectively. Such wads are generally unnecessary if the particulate material is fibrous—e. g. glass wool. The ends of cartridge 50 are held in position in chambers 24 and 34 by neoprene washers 30 and 31, respectively, which fit tightly around the ends of the cartridge and hence serve not only to hold it in position but also to exclude all outside air or gas from chambers 24 and 34. Marks 56 and 57 on panel 23 are used for measuring the rapidity of movement of the leading edge of the color change in bed 53 as the gas from container 20 passes through it.

Fig. 4 shows another modification of the cartridge 50 of Figs. 2 and 3. In Fig. 4, the cartridge is designated by the numeral 150, and is conveniently made of transparent material. It contains bed 153 of particulate material coated with a substance which is color sensitive to water, and is provided with end plugs 151 and 152 which seal the bed 153 from contact with the outside atmosphere. The means for holding and unsealing this cartridge 150 and cartridges of like type are shown in Fig. 5, wherein is shown the upper end of a cartridge 150 positioned within chamber 126 in upper holding block 125 (corresponding respectively to chamber 26 and upper holding block 25 in Figs. 2 and 3). Line 21, leading from container 20 (not shown) of gas to be tested, is attached through flexible neoprene tube 170 to the hollow needle 171, which is slidably held by air-tight neoprene washer 172 and has head 173 whereby it may conveniently be pushed downwardly to strike and penetrate through end plug or seal 151 and thereby admit gas from container 20 into the interior of cartridge 150. Washer 130 performs the same functions as does washer 30 of Figs. 2 and 3. The bed 153 of particulate material is shown held away from plug or seal 151 by wad 154, of glass wool or other suitable material, although if desired the bed 153 may extend clear to the plug 151 as shown in Fig. 4. Bolts 174 are provided to attach the block 125 to a suitable panel or backing, such as panel 23.

A holding and unsealing arrangement similar to that in Fig. 5 may conveniently be used as the lower holding block for cartridges of the type shown in Fig. 4.

Operation of the device shown in Figs. 2 and 3 is as follows: Lower holding block 35 is slid downwardly far enough to admit a cartridge, and any pieces of broken cartridge ends remaining in chambers 24 and 34 from previous test runs are removed. A blank cartridge (or a spent cartridge) with ends already open is then mounted in the upper and lower holding blocks 25 and 35, the latter block being raised sufficiently to insure firm air-tight holding of the cartridge ends by washers 30 and 31, the lower block 35 being then clamped in position by set screw 36. The valve means 22 is then opened, establishing a flow of gas from the container 20 through the entire apparatus and out through upper outlet 62 of the rotameter 60. Valve means 22 is so adjusted that the float 66 rises to a designated mark, e. g. mark 68, thereby establishing a predetermined rate of gas flow through the apparatus. The lower holding block 35 is then lowered by releasing set screw 36, the blank cartridge is removed, and a fresh, filled and sealed cartridge 50 is inserted firmly through ring 31 into chamber 34 of block 35. Block 35 is then raised sufficiently so that cartridge 50 fits loosely into ring 30 of chamber 24, and the gas entering chamber 24 from container 20 is allowed to flush the chamber and the surface of end 51 of cartridge 50 for about a minute, in order to remove any extraneous moisture. Valve 22 is then closed and upper end 51 of cartridge 50 is firmly seated in ring 30, lower holding block 35 being raised sufficiently to permit this. Upper end 51 of cartridge 50 is then broken by pressing head 28 thereby impelling the pin 27 into said end; lower end 52 then is similarly broken by pressing head 38. Valve 22 is then reopened to the same degree as previously determined with the blank cartridge, and the float 66 should accordingly rise to mark 68; if it does not, the valve 22 should be adjusted until it does—in order to insure flow of gas through the apparatus at the predetermined rate. The time of starting the flow of gas is noted, and also the time at which the leading edge of the changed color of bed 53 passes mark 57. If the elapsed time is less than a predetermined amount, the gas in container 20 is too high in content of H_2O. Alternatively it may be pref-

erable to determine the time elapsed between passage of the leading edge of the changed color from mark **56** to mark **57**.

It should be emphasized that water and ice must not be allowed to condense upon or within the testing device. Obviously, the presence of any such extraneous H_2O within the testing space and channels leading thereto will spoil any determinations which are attempted.

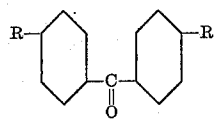
The devices shown in Figs. 4 and 5 are operated in the same general manner as already outlined, except that instead of crushing the ends of the cartridge, these ends are punctured by the hollow top needle **171** and a similar hollow bottom needle. Thus, after the preliminary valve setting using a blank cartridge, the fresh cartridge **150** is inserted after proper flushing, as described with reference to Figs. 2 and 3; pressure is then applied to head **173** to force hollow needle **171** through plug **151**, and the plug at the other end of the same cartridge is then similarly pierced and the flow of gas is established by opening valve means **22**.

The terms "water" and "H_2O" referred to herein and in the appended claims mean water in any of its several physical forms, unless otherwise specified.

What is claimed is:

1. The method of testing a gas to determine the amount of water therein, which consists in passing said gas through a water-free bed of solid, water-free particulate material coated with the reaction product of Michler's ketone and a Grignard reagent, said particles being inert toward said reaction product, and maintaining said gas, during its passage to and through said bed, completely out of contact with water other than that contained in said gas.

2. The method of testing a gas to determine the amount of water therein, which consists in passing said gas through a water-free bed of solid, water-free particulate material coated with the reaction product of a Grignard reagent and a benzophenone of the formula:



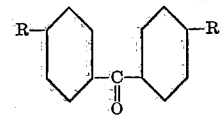
wherein R is a member of the group consisting of hydrogen and dialkyl amino, said particles being inert toward said reaction product, and maintaining said gas, during its passage to and through said bed, completely out of contact with water other than that contained in said gas.

3. The method of ascertaining the presence of small amounts of water in an elementary atmospheric gas, which comprises passing said gas, in out-of-contact relationship with ambient fluid, through a bed of clean dry particles of solid material having a surface coating of the reaction product of Michler's ketone and a Grignard reagent.

4. The method of ascertaining the presence of small amounts of water in an elementary atmospheric gas, which comprises passing said gas into contact with the reaction product of Michler's ketone and a Grignard reagent, in out-of-contact relationship with all extraneous water, said reaction product being distributed as a surface coating upon clean, dry, particulate solid material inert toward said reaction product and of a color which contrasts with the color imparted to said reaction product by water.

5. The method of determining small amounts of water in a gas, which comprises passing said gas into contact with an agent which is color-sensitive to small amounts of water, said agent being distributed as an anhydrous surface coating upon clean, dry, particulate solid material inert toward said agent and of a color which contrasts with the color imparted to said agent by water, and maintaining said gas, during its passage to and through said agent and said solid material, in completely out-of-contact relationship with extraneous water or other ambient fluid, said agent being the reaction product of a Grignard reagent and a benzophenone.

6. The method in accordance with claim 5, wherein said agent is the reaction product of a Grignard reagent and a benzophenone of the formula:

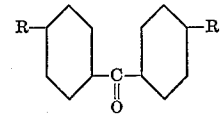


wherein R is a member of the group consisting of hydrogen and dialkyl amino.

7. The method in accordance with claim 5, wherein said agent is the reaction product of a Grignard reagent and a tetra-alkyl-p,p'-diamino benzophenone.

8. A testing device for use in indicating the water content of a gas, said device comprising an elongated gas-tight tube sealed at its ends, clean particulate solid material substantially filling said tube, and a surface coating of the reaction product of a Grignard reagent and a benzophenone upon said particulate solid material, the interior of said tube and the contents thereof being free from water, said coated particulate solid material being of a color readily distinguishable from that imparted to said reaction product by water, said tube being adapted to have said sealed ends fractured whereby the said gas may be passed therethrough for testing, said tube being transparent to permit viewing from the outside the progress of color change induced in said coating on said particulate solid material by water in said gas.

9. A device in accordance with claim 8, wherein said benzophenone has the formula:



wherein R is a member of the group consisting of hydrogen and dialkyl amino.

10. A device in accordance with claim 8, wherein said benzophenone is a tetra-alkyl-p,p'-diamino benzophenone.

11. A device in accordance with claim 8, wherein said benzophenone is Michler's ketone.

12. A device in accordance with claim 8, wherein said coated particulate solid material is spaced from each of the fracturable sealed ends of said tube by a wad of inert, gas-transmitting packing adapted to hold said particulate solid material in position.

13. Apparatus of the character described for determining the water content of a gas, which comprises first and second holding means relatively movable toward and away from each other, each of said holding means being provided with a chamber having an opening, said two openings facing each other and each being adapted to receive and hold one end of a testing cartridge in gas-tight relationship with respect to the out-

side air, seal-breaking means in each of said holding means adapted to break the seal at each end of the testing cartridge, means for introducing the gas to be tested into the chamber in said first holding means, means for conducting tested gas out of the chamber in said second holding means, said apparatus being arranged to provide completely out-of-contact relationship between said gas and the ambient fluid during passage of said gas through said apparatus.

14. Apparatus according to claim 13 wherein a pump is present in the system to effect said passage of gas through the apparatus.

15. Apparatus of the character described for determining the water content of a gas, which comprises first and second holding means spaced apart from and relatively movable toward and away from each other, each of said holding means being provided with a chamber having an opening, said two openings facing each other and each being adapted to receive and hold one end of a sealed tubular testing cartridge in gas-tight relationship with respect to the outside air, seal-breaking means in each of said holding means adapted to break the seal at each end of the testing cartridge, gas-flow-measuring means, first conduit means for leading gas to be tested into the chamber in said first holding means, second

conduit means for leading tested gas out of the chamber in said second holding means and to said gas-flow-measuring means, and means for causing the flow of said gas through said apparatus, said apparatus being arranged to provide completely out-of-contact relationship between said gas and the ambient fluid during passage of said gas through said apparatus.

16. Apparatus according to claim 15 further characterized by containing means for regulating the flow of said gas at a predetermined rate.

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