

March 15, 1949.

J. C. ALBRIGHT

2,464,546

HUMIDITY ANALYZER

Filed June 20, 1945

3 Sheets-Sheet 1

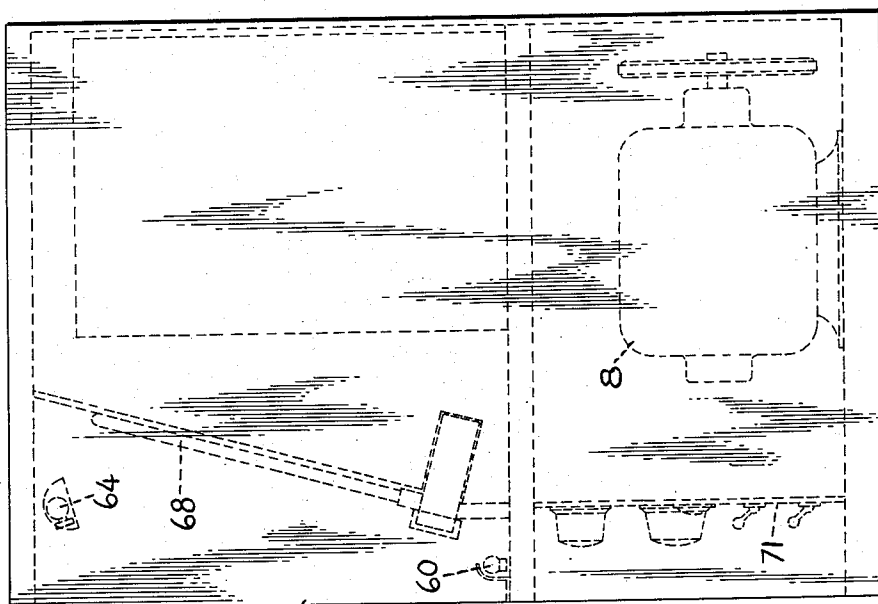


Fig. 2

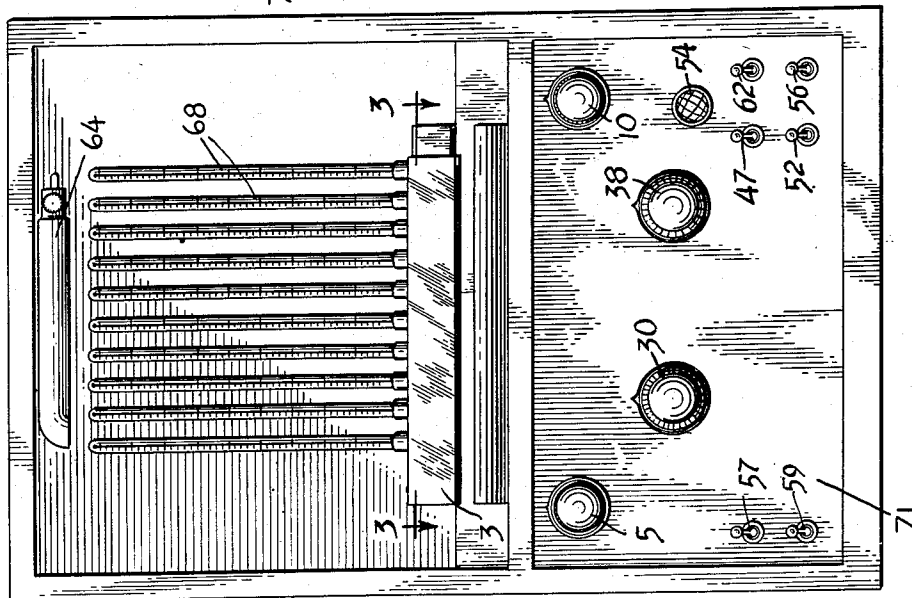


Fig. 1

Inventor
Joseph C. Albright

By *Samuel Keegan Beale & Samuel*
Attorneys

March 15, 1949.

J. C. ALBRIGHT

2,464,546

HUMIDITY ANALYZER

Filed June 20, 1945

3 Sheets-Sheet 2

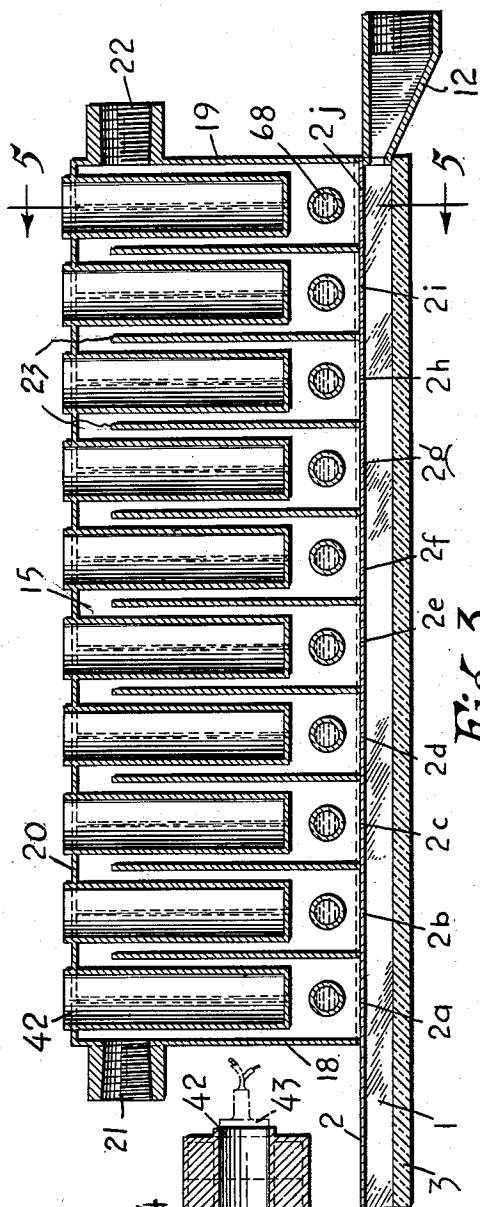


Fig. 3

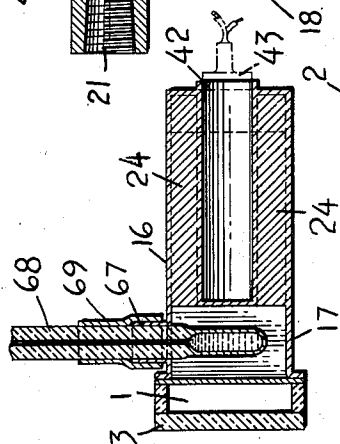


Fig. 5

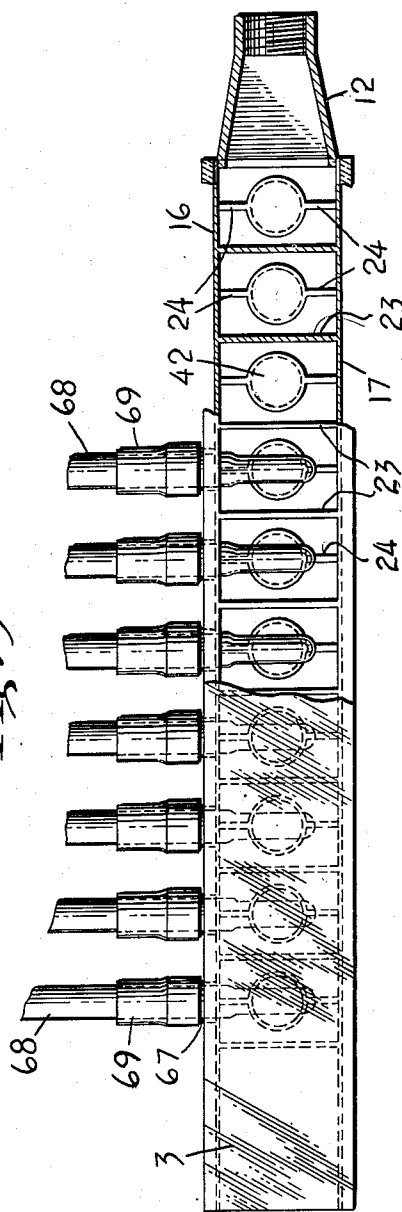


Fig. 4

Joseph C. Albright ^{Inventor}

334 Lemmes Keegan Beale & Lemmes
Attorneys

2,464,546

Filed June 20, 1945

3 Sheets-Sheet 3

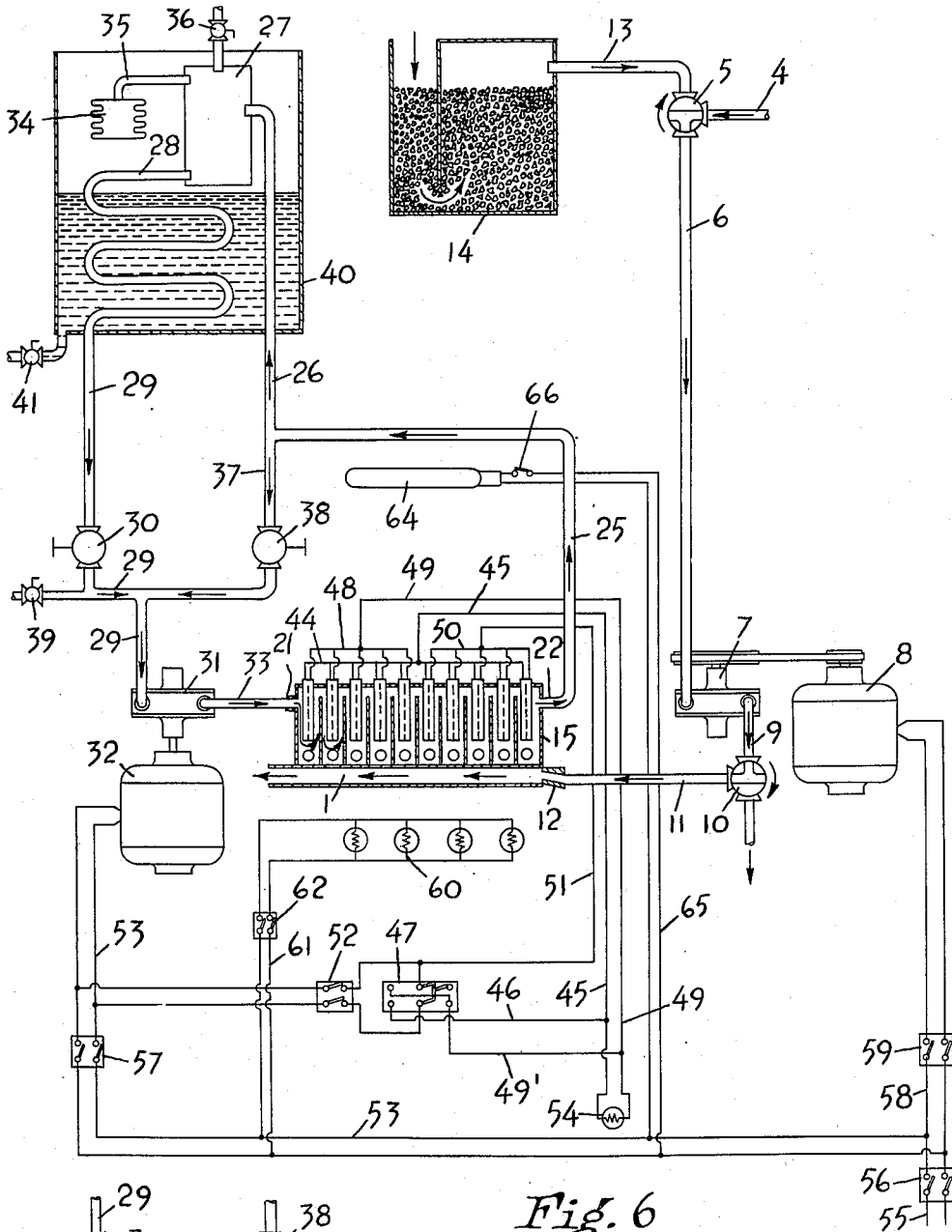


Fig. 6

Joseph C. Albright

Inventor

By Semmes Keegin Beale & Semmes
Attorneys

Attorney -

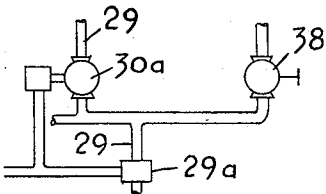


Fig. 7

UNITED STATES PATENT OFFICE

2,464,546

HUMIDITY ANALYZER

Joseph C. Albright, Bala Cynwyd, Pa., assignor
to The Davison Chemical Corporation, Balti-
more, Md.

Application June 20, 1945, Serial No. 600,500

9 Claims. (Cl. 73-17)

1

This invention relates in general to the determination of the moisture content of air and gases and more particularly has reference to a method and apparatus for measuring the dew point temperature of a gas.

It is quite often desirable to ascertain the dew point temperature of a gas in order that its moisture content can be determined. Heretofore dew point temperature determinations have been made by chilling a surface and exposing it to a vapor laden gas. This procedure has been slow and not flexible enough for wide use.

An object of this invention is to provide an apparatus for determining the dew point temperature of a moisture laden gas.

Another object of this invention is to provide an apparatus for maintaining a series of surface increments at progressively varying temperatures.

Still another object of this invention is to provide an apparatus for maintaining a series of surface increments at progressively varying temperatures and for passing a moisture laden gas over said surface increments.

With these and other objects in view, the present invention resides in the parts and combinations and steps and procedures hereinafter set forth.

In order to facilitate an understanding of the invention, reference is made to the annexed drawings in which:

Figure 1 is a front elevational view of a humidity analyzer embodying the principles of the present invention.

Figure 2 is a side elevational view of the device of Figure 1.

Figure 3 is a detailed sectional view of the view box taken on line 3-3 of Figure 1 including the conduit for the flow of the moisture laden gas and the cooling jacket in heat exchange relation thereto.

Figure 4 is a fragmentary front elevational view of the view box with parts in section.

Figure 5 is a sectional view of the view box taken on line 5-5 of Figure 3.

Figure 6 is a diagrammatic or schematic view showing gas and cooling medium flow circuits and the electrical circuits.

Figure 7 is a fragmentary view similar to Figure 6 illustrating a modified form of the invention.

The present invention is based upon the phenomena of the condensation of moisture from a moisture laden gas upon a surface cooled low enough to cause the gas in contact therewith to assume a temperature at which the moisture content thereof is sufficient to saturate the gas. Un-

2

der these conditions, the moisture will condense or deposit upon the cooled surface and the temperature at which the initial condensation takes place is termed the "dew point temperature."

Once having ascertained the dew point temperature of a given gas sample, it is a simple matter to determine the moisture content of the gas at any temperature by calculation or from available tables or charts.

As hereinbefore indicated, the present invention is directed to an apparatus and procedure for ascertaining the dew point temperature of a moisture laden gas. In accordance with the present invention, the dew point temperature of a moisture laden gas is ascertained by passing the gas through a passage having a plurality of surface increments at different temperatures, the temperatures thereof progressively decreasing in the direction of gas flow, and ascertaining the temperature of the warmest surface increment upon which moisture condenses.

An apparatus suitable for carrying out the present invention is illustrated in the accompanying drawings. As shown more particularly in Figures 3 and 6, the apparatus comprises a view box or gas conduit 1, one wall 2 of which is formed of material of high heat conductivity such as metal and at least the opposite wall 3 of which is formed of a transparent material such as glass or a transparent synthetic resin through which any condensation of moisture upon the surface of the wall 2 may be observed. Other portions of conduit 1 may be constructed of transparent, opaque, or any other kind of material. The wall 2 of the view box or gas conduit is divided into a plurality of increments 2a, 2b, etc., as illustrated in Figure 3. These increments of the wall 2 are maintained at different temperatures which decrease progressively in the direction of movement of the moisture laden gas through the conduit 1. Maintenance of a temperature gradient along the wall 2 will be described hereinafter.

A moisture laden gas, the dew point temperature of which is to be ascertained, is drawn from any desired source or location and delivered into conduit 4 which communicates with one port of the casing of a three-way valve 5. Communicating with another port of the three-way valve 5 is a conduit 6 which communicates with the intake port of a pump 7 driven by a suitable source of power such as the electric motor 8. The discharge port of the pump 7 communicates through a line 9 with one port of a three-way valve 10 which has one of its other ports connected by a

conduit 11 with the intake fitting 12 of the gas conduit or view box 1.

The third port of the three-way valve 5 is connected by means of a conduit 13 with a gas dehumidifying unit 14. This is to enable atmospheric air or some other gas to be drawn through the dehydrating material in the dehydrator 14 and then forced by the pump 7 through the view box or gas conduit 1 to clear the wall 2 and any other parts of the conduit 1 of condensed moisture.

The third port of the three-way valve 10 is provided for discharge of the air or other gas forced from the pump 7 without passing the same through the conduit 1.

Wall 2 is cooled by means of a cooling medium circulated through a cooling jacket 15 associated therewith. As illustrated, the cooling jacket comprises top and bottom walls 16 and 17 respectively, end walls 18 and 19, and a rear wall 20. The other wall of the cooling jacket is a portion of the wall 2 of the gas conduit 1 which is formed of material having a high heat conductivity. Cooling jacket 15 is provided with an inlet port 21 and a discharge port 22 so arranged that the cooling medium passed through the jacket flows in a direction generally counter-currently with respect to the flow of the moisture laden gas through the gas conduit 1.

A plurality of baffles 23 extend between the top and bottom walls 16 and 17 and laterally from the wall 2 to a region spaced from the wall 20 of the cooling jacket. It will be noted that the baffles 23 are substantially perpendicular to the heat conducting wall 2 and divide the space within the jacket 15 into a plurality of compartments, each corresponding to one of the surface increments 2a, etc. Intermediate the baffles 23 a plurality of baffles 24 is provided. Baffles 24 extend from the wall 20 to a region spaced from the wall 2 as clearly illustrated in Figures 3 to 6 of the drawings.

It will be noted that the arrangement of the baffles 23 and 24 provides a tortuous flow path for the cooling medium through the jacket 15 from the inlet port 21 to the discharge port 22 thereof.

Cooling jacket 15 is adapted to be filled with a cooling medium such as ethyl alcohol. Most commercial anti-freeze liquids for use in the cooling systems of internal combustion engines, etc., may be employed. It is preferable to select a liquid for this purpose that is free flowing at -100°F . when low temperature refrigeration such as afforded by solid CO_2 is employed. However, when refrigeration at temperatures of about 32°F . are employed, the cooling system liquid may be one that is free flowing at temperatures of about 32°F . or lower. The discharge port 22 of the jacket 15 has a conduit 25 communicating therewith which is connected by a T-fitting to a conduit 26 which leads to a reservoir 27. Reservoir 27 communicates through a cooling coil 28 and a conduit 29, provided with a valve 30, with the intake of a liquid pump 31 driven by an electric motor 32 or other source of power. Liquid discharging from the pump 31 is introduced into the jacket 15 by means of a conduit 33 communicating with the intake port 21 of the jacket.

Reservoir 27 is provided with a pressure relieving device 34 which communicates with the reservoir through a tube 35. This serves to prevent the generation of any undue pressure on the liquid circulating through the cooling jacket 15 and avoids damage to the unit. Any air or gas en-

trained in the liquid separates in the reservoir and may be discharged through the gas release valve 36 which communicates with the upper portion of the reservoir 27. In order to permit a portion of the liquid discharged from the cooling jacket 15 to be recirculated without passing through the cooling coil 28, a by-pass conduit 37 is provided. This conduit is fitted with a valve 38 to control the flow of liquid through said by-pass. Drainage of liquid from the cooling liquid circulating system may be effected through the drain valve 39.

Reservoir 27 and cooling coil 28 are positioned within a tank 40 which is adapted to be filled with a liquid such as ethyl alcohol or one of the commercial anti-freeze compounds to a level to cover the cooling coil 28. Refrigeration of the liquid within the tank 40 may be effected by the introduction of pieces of solid carbon dioxide therein. Of course, any other means for cooling the liquid within the tank 40 for producing a cooling effect on the circulating liquid passing through the coil 28 may be employed. For instance, a coil in which a refrigerant is evaporated may be disposed within the liquid in the tank 40. Drainage of liquid from the tank 40 may be effected through a drain valve 41.

From the foregoing description, it will be appreciated that the present invention provides for the circulation of a cooling medium through the tortuous passage provided within the cooling jacket 15. As the cooling liquid flows from the intake port 21 through the several compartments of the tortuous passage in the jacket 15 to the discharge port 22, its temperature is gradually and progressively raised.

In accordance with the present invention, it has been found that a more effective temperature gradient along the wall 2 may be obtained by providing means in the several compartments between the baffles 23 for applying heat to the cooling medium as it flows through the tortuous passage in the jacket 15. Any suitable means for applying heat to the liquids during its flow through the cooling jacket may be employed. One form of such heating means as shown in the drawings embodies electric heating elements. For positioning the electric heating elements in the several compartments between the baffles 23, tubes 42 closed at one end and open at the other end extend through the wall 20 with their closed end disposed within the compartments between the baffles 23. It has been found effective to position the tubes 40 within the baffles 24 or to form the same integrally with said baffles 24 as illustrated in the several figures of the drawings. With this construction, electric heating elements 43 may be disposed within the tubes 42 so as to be securely sealed from the liquid circulating through the jacket 15.

The electrical heating elements 43 are connected as diagrammatically illustrated in Figure 6 of the drawings. One terminal of each element is connected to a common conductor 44 which in turn is connected by the lines 45 and 46 with one pole of a double pole double throw switch 47. One group of said heating elements 43 have their other terminals connected to a common conductor 48 which is connected by lines 49 and 49' with diagonally disposed poles of the switch 47. The other group of the electric heating elements have their other terminals connected to a common conductor 50 which in turn is connected by a line 51 to one blade of the double throw double pole switch and through a control switch 52 to a power

5

line 53. The other blade of the switch is also connected through the control switch 52 to the power line 53. With this connection of the electric heating elements 43 to the power line 53, all of the heating elements may be connected in parallel with each other or the heating elements of each of the two groups may be connected in parallel, with one group connected in series with the other group. Thus, full line potential may be applied to each of the heating elements or one-half of full line potential may be applied to the heating elements. A telltale lamp 54 is connected across the conductors 45 and 49 to indicate whether the heating elements are operating on full line potential or one-half full line potential.

The power line 53 is a branch of a main line 55 controlled by main switch 56 and is equipped with a control switch 57 so positioned that when said switch 57 is closed, power is supplied from the main line 55 to the electric motor 32 and also to the heating elements 43. With this arrangement, whenever the heating elements are energized the motor 32 for circulating the cooling medium will also be energized to provide for circulation of said medium and thereby avoid overheating of said elements 43.

Another branch line 58 equipped with a control switch 59 is provided for energizing the motor 8 which drives the pump 7. Lamps 60 positioned to illuminate the view box or gas conduit 1 are in a circuit 61 controlled by switch 62 and connected to the power line 53. Another lamp 64 is connected in a circuit 65 provided with a control switch 66 and connected across the power line 53. The purpose of lamp 64 will be referred to hereinafter.

The top wall 16 of the cooling jacket 15 is provided with a series of openings surrounded by upstanding tubes 67 providing access to each of the compartments within the cooling jacket 15 between the baffles 23. Extending through each of the tubes 67 is a thermometer 68 or other temperature indicating device for indicating the temperature of the cooling medium within the several compartments formed between the baffles 23. A sealing device 69 which as shown comprises a short section of rubber tubing, provides an effective seal between the upstanding portion of the tube 67 and the thermometer 68.

To facilitate reading of the temperatures indicated by the thermometers 68, the light bulb 64 is positioned as illustrated in Figures 1 and 2 of the drawing, a suitable reflector or shield being provided if desired. It will also be noted that the bulbs 60 for illuminating the view box 1 are suitably positioned and provided with a shield or reflector.

The entire apparatus including piping and wiring is assembled within a cabinet 70 as illustrated in Figures 1 and 2 of the drawings. It will be noted that a panel 71 is provided on which the several switches and valve operating knobs are mounted.

With the structure herein described, it will be appreciated that in using the apparatus the surface of the wall 2 within the gas conduit 1 will have a deposit of moisture formed thereon. Before reusing the apparatus for determining the dew point temperature of another sample of gas, the valve 5 is positioned so that the gas drawn into the pump 7 will flow through the dehydrator 14. Dehydrated gas is thus forced through the gas conduit 1 and removes all condensation on the walls of said conduit.

The apparatus is then ready for analysis of a

6

new sample of gas which with the valve 5 in the proper position is drawn through conduits 4 and 6 into the pump 7 and then passed through the gas conduit 1. As the moisture laden gas, the dew point temperature of which is to be ascertained, flows through the conduit 1, a deposit of moisture will take place on the inner surface of the wall 2. The temperature of the warmest portion of the wall 2 on which condensation takes place is then noted and this will be the dew point temperature for the gas flowing through the conduit 1. It has been found that by providing a highly polished surface on the wall 2 of the conduit 1, the observation of the condensation of moisture thereon is facilitated.

By controlling the valves 30 and 38 and the position of the blades of the switch 47, the temperature of the several increments of the wall 2 may be maintained as desired. In some instances, it may be found preferable to replace valve 30 by a thermostatically actuated valve 30a (see Figure 7), in which instance a temperature responsive element 29a would be positioned in the line 29 just before the intake to the pump 31 to insure that the temperature of the liquid supplied to the pump would be substantially constant. It is also within the concept of the present invention to replace valve 38 or both valves 30 and 38 with thermostatically controlled valves, the principal feature of the valves being to insure the supply of liquid at a substantially constant selected temperature to the intake port 21 of the cooling jacket 15.

To ascertain the dew point temperature of a moisture laden gas in accordance with the present invention, solid carbon dioxide is added to the liquid in tank 40 and the pump 31 is placed in operation by closing the switch 57. By proper adjustment of the valves 30 and 38, the temperature of the liquid entering the jacket 15 is brought to the desired level and then switches 52 and 47 are closed to obtain the desired heating effect from the heating elements 43. By readjusting the valves 30 and 38 as required, the temperature of the liquid entering the jacket 15 may be adjusted to any desired value between the limits of -60° F. and $+110^{\circ}$ F. Variation of the position of valve 38 will change the gradient of temperature from the inlet 21 to the outlet 22 of the jacket 15. It is desirable but not necessary to have the heating capacity of all of the heating elements 43 uniform which will result in a uniform gradient in temperature throughout the jacket 15.

After the temperatures of the various portions of the cooling jacket are adjusted to the desired levels, the air pump 7 is placed in operation by closing switch 59. With the valves 5 and 10 in the position shown in Figure 6, a sample of air taken in through the tube 4 will be passed through the view slot or conduit 1 in a direction counter-currently to the direction of flow of the liquid through the jacket 15. As the air sample passes through the conduit 1 over the plate 2, it gradually comes in contact with colder and colder portions of said plate until it contacts a portion which is colder than the dew point of the air. At this temperature, the moisture will condense upon this portion of the plate and the colder portions thereof. The dew point temperature is the temperature shown by the thermometer or temperature indicating device directly behind the warmest portion of the plate 2 upon which the moisture condenses. It has been found that the temperature of the view plate 2 is for all prac-

tical purposes identical with that of the liquid flowing in contact therewith. Since the thermometers 68 indicate the temperature of the liquid surrounding the same, the reading of the thermometer directly behind the warmest portion of the plate 2 upon which moisture condenses will be the dew point temperature of the sample of air or other gas passing through the conduit 1.

In normal operation of the device shown in the drawings, it is desirable to purge the apparatus for a considerable period of time to bring the hygroscopic moisture load of the apparatus from the point of pick-up of the sample to the intake fitting 12 in equilibrium with the gas to be analyzed passing through the apparatus. For this purpose, the gas used to purge the system may be discharged to waste directly from the third port of the valve 10. After the purging operation, the sample gas to be analyzed may then be passed through the conduit 1 over the heat exchange surface 2.

After determining the dew point temperature of one gas sample, the valve 5 may be shifted to pass a dehydrated gas through the view slot or conduit 1 to remove any condensed moisture from the surfaces thereof, thereby placing the apparatus in condition for analysis of the next sample.

The amount of refrigerating effect introduced through the valve 30 must exactly balance thermodynamically the accumulating heating effect of the electric heating elements 43 taking into account any heat losses or gains through radiation or conduction to surrounding materials or atmospheres to any portion of the liquid circulating system. The variable nature of the heat losses or gains makes it desirable to employ the automatic temperature control of the valves 30 and/or 35 to maintain a proper condition of stability.

While reference has been made to the humidity analysis of air it will be appreciated that the present invention may be employed for ascertaining the dew point of any gas laden with any condensable liquid.

From the foregoing description, it will be appreciated that the present invention provides a highly effective apparatus and procedure for ascertaining the dew point temperature of a moisture laden gas.

The comparison between the clear and fogged surfaces is very sharp and distinct which enables the operator to determine with greatest accuracy the dew point temperature.

One valuable feature of the present invention is the holding of adjacent surfaces of the view plate 2 at different temperatures. This greatly facilitates the observation by the operator of the fogging of portions of the plate since the condensate will form on one portion while an adjacent portion at a slightly higher temperature will be free of condensate, affording the observer a clear surface with which he can compare the fogged surface. The presence of an adjacent clear surface will enable the observer to easily detect the slightest fogging of the surface upon which condensate forms.

I claim:

1. An apparatus for determining the dew point temperature of a moisture laden gas comprising an elongated wall of heat conductive material, means for passing a moisture laden gas along one side of the wall, means forming a cooling jacket on the other side of said wall, a plurality of baffles

extending from said other side of the wall dividing said jacket into a series of compartments extending longitudinally of the wall, means for passing a cooling medium serially through said compartments in a direction generally counter-currently to said moisture laden gas, means in each compartment for heating said cooling medium and means for determining the temperature of the cooling medium in said compartments.

2. An apparatus for determining the dew point temperature of a moisture laden gas comprising an elongated wall of heat conductive material, means for passing a moisture laden gas along one side of the wall, means forming a cooling jacket on the other side of said wall, a plurality of baffles extending from said other side of the wall dividing said jacket into a series of compartments extending longitudinally of the wall, a plurality of baffles extending from the opposite wall of said jacket intermediate said first mentioned baffles creating a zigzag tortuous passage through said jacket, heating means disposed at intervals throughout said tortuous passage, means for passing a cooling medium through said tortuous passage in a direction generally counter-currently to said moisture laden gas and means for determining the temperature of the cooling medium in said compartments.

3. An apparatus for determining the dew point temperature of a moisture laden gas comprising an elongated wall of heat conductive material, means for passing a moisture laden gas along one side of the wall, means forming a cooling jacket on the other side of said wall, a plurality of baffles extending from said other side of the wall dividing said jacket into a series of compartments extending longitudinally of the wall, a plurality of baffles extending from the opposite wall of said jacket intermediate said first mentioned baffles creating a zigzag tortuous passage through said jacket, heating means mounted in association with said second mentioned baffles, means for passing a cooling medium through said tortuous passage in a direction generally counter-currently to said moisture laden gas and means for determining the temperature of the cooling medium in said compartments.

4. An apparatus for determining the dew point temperature of a moisture laden gas comprising an elongated wall of heat conductive material, means for passing a moisture laden gas along one side of the wall, means forming a cooling jacket on the other side of said wall, a plurality of baffles extending from said other side of the wall dividing said jacket into a series of compartments extending longitudinally of the wall, a plurality of baffles extending from the opposite wall of said jacket intermediate said first mentioned baffles creating a zigzag tortuous passage through said jacket, tubes extending through said second mentioned wall of the jacket in association with the second mentioned baffles and between adjacent ones of said first mentioned baffles, heating means within said tubes, means for passing a cooling medium through said tortuous passage in a direction generally counter-currently to said moisture laden gas and means for determining the temperature of the cooling medium in said compartments.

5. An apparatus for determining the dew point temperature of a moisture laden gas comprising an elongated wall of heat conductive material, means for passing a moisture laden gas along one side of the wall, means forming a cooling jacket on the other side of said wall, a plurality of baffles

extending from said other side of the wall dividing said jacket into a series of compartments extending longitudinally of the wall, means for passing a cooling medium serially through said compartments in a direction generally countercurrently to said moisture laden gas, means in each compartment for heating said cooling medium, and means having a temperature sensing device extending into each compartment adjacent said elongated wall for indicating the temperature of the cooling medium.

6. An apparatus for determining the dew point temperature of a moisture laden gas comprising an elongated wall of heat conductive material, means for passing a moisture laden gas along one side of the wall, means forming a cooling jacket on the other side of said wall, a plurality of baffles extending from said other side of the wall dividing said jacket into a series of compartments extending longitudinally of the wall, means for passing a cooling medium serially through said compartments in a direction generally countercurrently to said moisture laden gas, means in each compartment for heating said cooling medium, said jacket having a plurality of openings providing access to the compartments adjacent said elongated wall, temperature indicating devices extending through said opening, and means for sealing said temperature indicating devices in said openings.

7. An apparatus for determining the dew point temperature of a moisture laden gas comprising a gas conduit having a heat conducting wall and a transparent wall to provide visibility of the surface of the heat conducting wall within said conduit, a gas pump having an intake and a discharge, a gas dehydrator, a sample tube, means for selectively connecting said pump intake to said dehydrator or sample tube, means for selectively connecting the discharge of the pump to one end of said gas conduit and to the atmosphere, a cooling jacket including said heat conducting wall as a part thereof, a cooling device, a pump for circulating a cooling medium through said cooling device and jacket in a direction generally countercurrently to said gas, means in said jacket for heating said cooling medium during its flow through said jacket, and means for determining the temperature of said heat conducting wall along its length.

8. An apparatus for determining the dew point temperature of a moisture laden gas comprising a gas conduit having a heat conducting wall and

a transparent wall to provide visibility of the surface of the heat conducting wall within said conduit, a gas pump having an intake and a discharge, a gas dehydrator, a sample tube, means for selectively connecting said pump intake to said dehydrator or sample tube, means for selectively connecting the discharge of the pump to one end of said gas conduit and to the atmosphere, a cooling jacket including said heat conducting wall as a part thereof, a cooling device, a pump for circulating a cooling medium through said cooling device and jacket in a direction generally countercurrently to said gas, means in said jacket for heating said cooling medium during its flow through said jacket, a by-pass about said cooling device, means for controlling the flow of cooling medium through said cooling device and through said by-pass, and means for determining the temperature of said heat conducting wall along its length.

9. An apparatus for the determination of the dew point temperature of a moisture laden gas comprising a gas conduit having a heat conducting wall and a transparent wall, a cabinet supporting said conduit for observation, means for circulating a cooling medium in heat exchange relation with said heat conducting wall, means for heating said cooling medium while circulating in heat exchange relation to said heat conducting wall, means for indicating the temperature of said cooling medium while circulating in heat exchange relation with said heat conducting wall and positioned for observation, means for passing a gas through said gas conduit, and means for controlling the temperature of the cooling medium and the flow of gas through said conduit, all of said means being mounted in said cabinet.

JOSEPH C. ALBRIGHT.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,026,079	White et al.	Dec. 31, 1935
2,316,624	Romanelli	Apr. 13, 1943
2,336,238	Fordyce et al.	Dec. 7, 1943

FOREIGN PATENTS

Number	Country	Date
551,989	Great Britain	Mar. 18, 1943
632,680	Germany	July 11, 1936