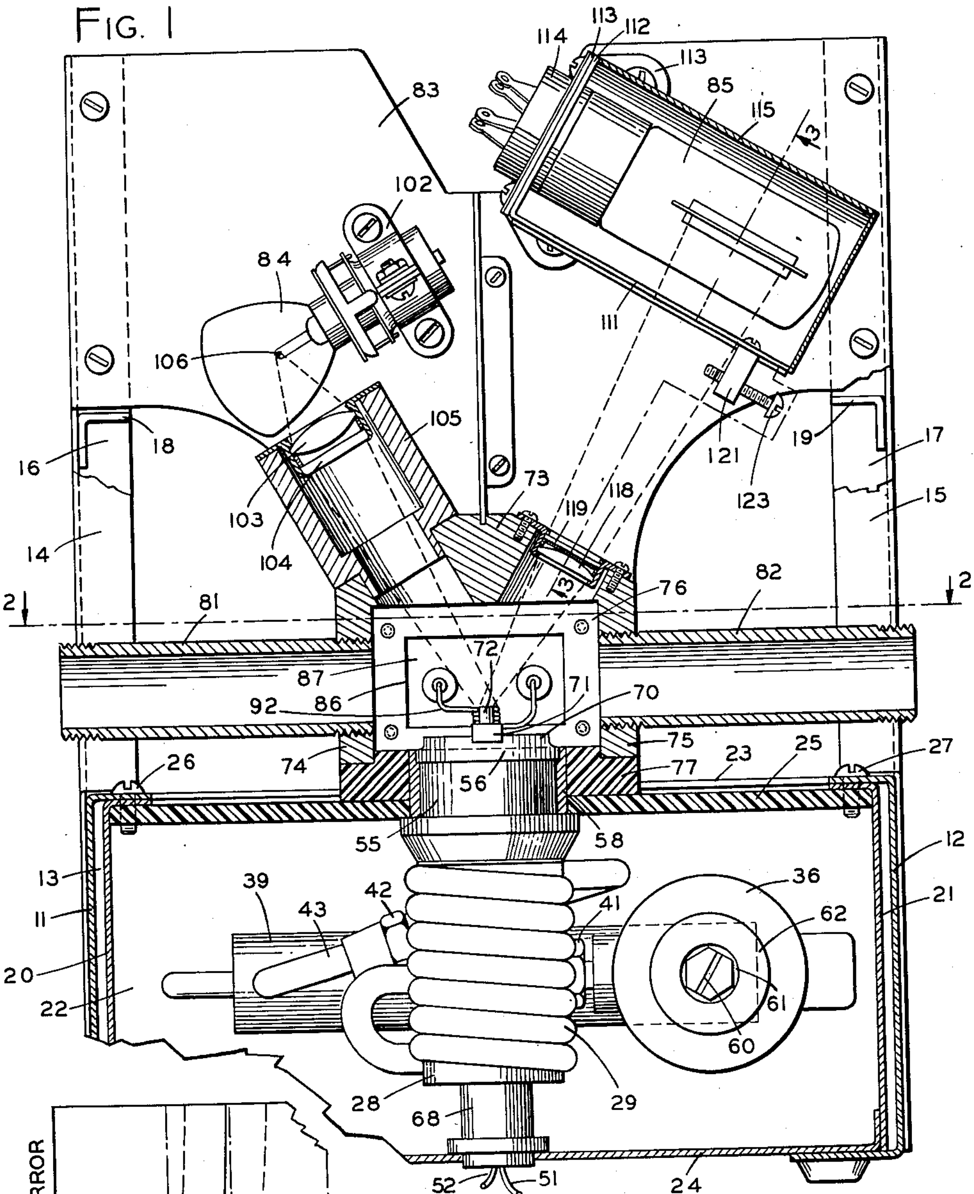
Jan. 6, 1953 DE WITT T. VAN ALEN 2,624,195

DEW POINT HYGROMETER

Filed Oct. 25, 1946 3 Sheets-Sheet 1

FIG. 1



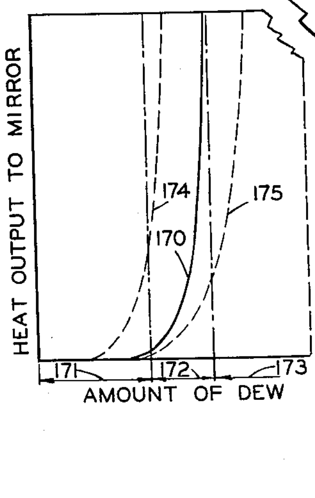


FIG. 7

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FIG. 2

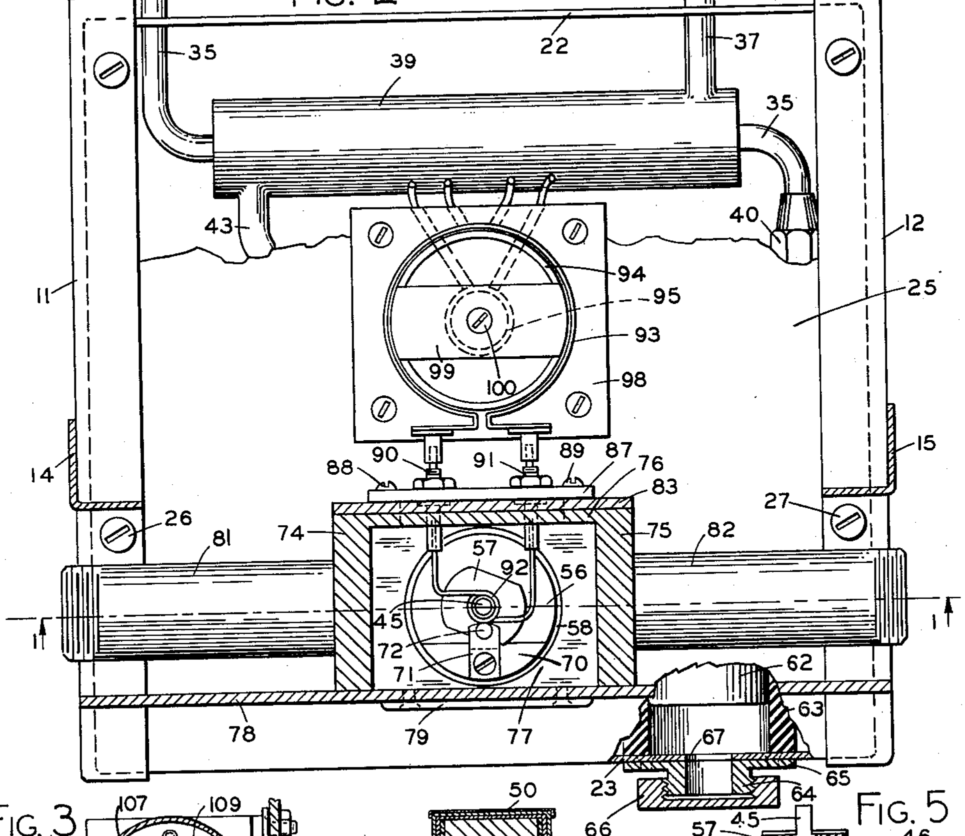


FIG. 3

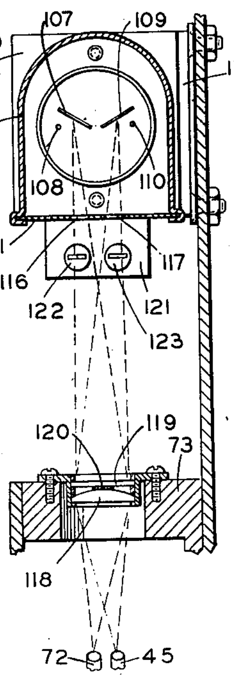


FIG 4

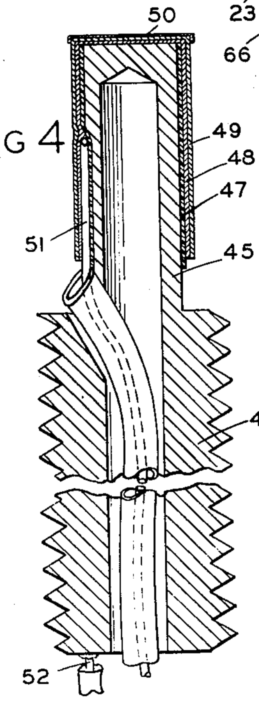
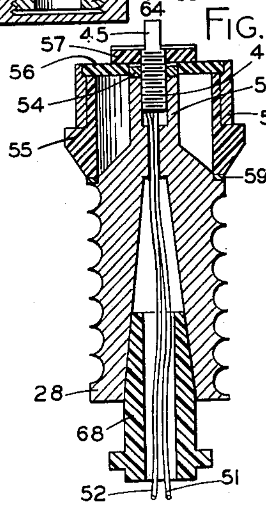


FIG. 5



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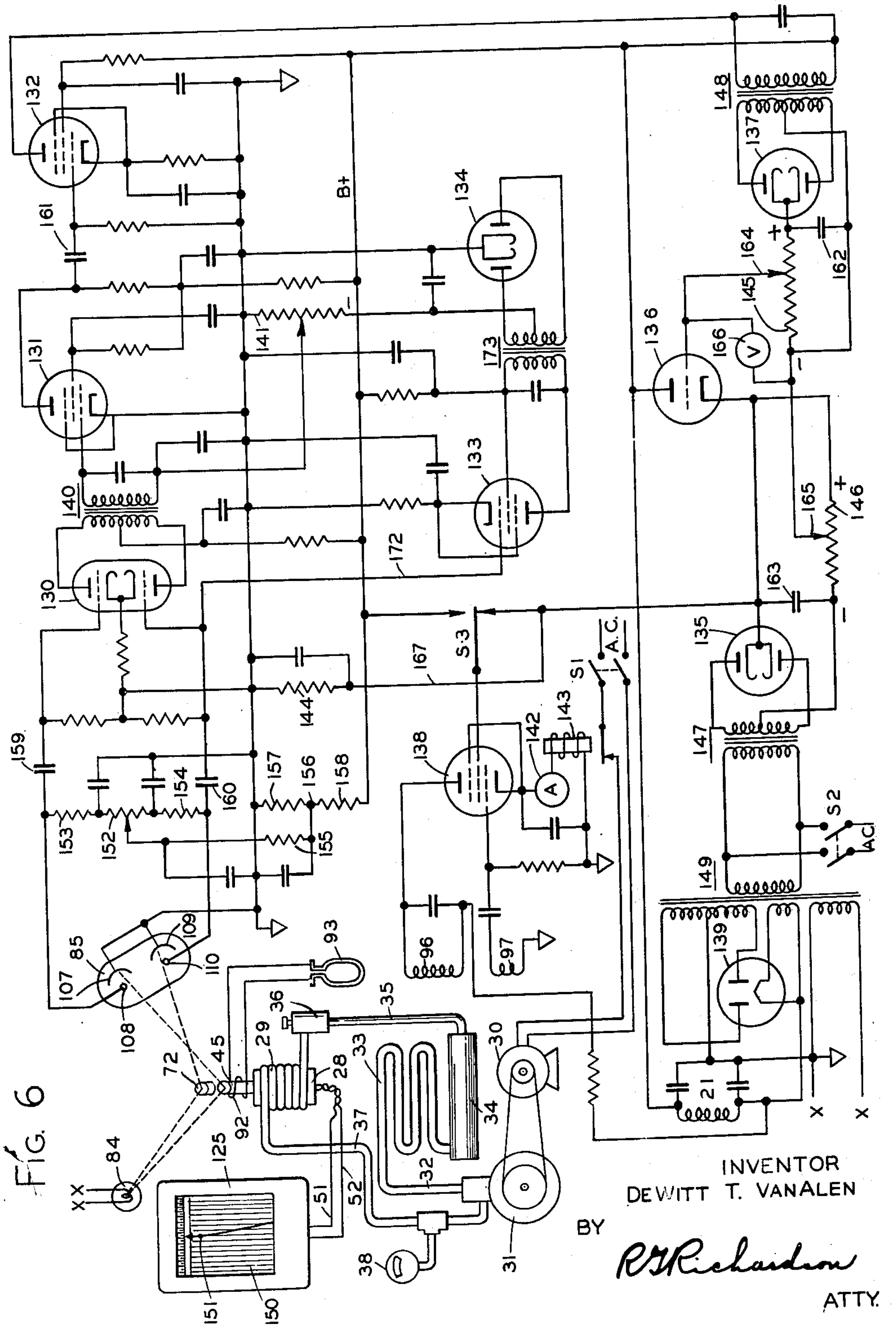

FIG. 6

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Patented Jan. 6, 1953 2,624,195

UNITED STATES PATENT OFFICE

2,624,195

DEW POINT HYGROMETER

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Application October 25, 1946, Serial No. 705,689

22 Claims. (Cl. 73—17)

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The present invention relates in general to dew point hygrometers, and the object of the invention is a new and improved instrument of this character.

The invention may be considered as an improvement on the invention disclosed in the application of Brissman et al., Ser. No. 584,022, filed March 21, 1945.

A feature of the invention is a new and improved mirror for a dew point hygrometer.

Another feature is a new and improved optical system employing two mirrors, and a circuit arrangement controlled thereby, whereby the operation of the instrument is made independent of variations in the intensity of the light source, or of variations in the amount of light reaching the mirrors due to other causes.

A further feature is a circuit arrangement which utilizes the pulsating output of photocells in an optical system in which the light source is energized by alternating current.

The foregoing and other features of the invention will be described more fully hereinafter, reference being made to the accompanying drawings, in which—

Fig. 1 is a vertical section through the mirror chamber and cold box on the line 1—1, Fig. 2, showing the optical system and a part of the refrigerator;

Fig. 2 is a horizontal section on the line 2—2, Fig. 1;

Fig. 3 is a partial section on the line 3—3, Fig. 1;

Fig. 4 is a sectional view of the dew mirror, on an enlarged scale;

Fig. 5 is a view of the cold rod, in section;

Fig. 6 is a diagrammatic circuit drawing of the complete dew point hygrometer; and

Fig. 7 is a graph showing by means of curves the relation between the amount of dew deposited on the dew mirror and the amount of heat supplied thereto.

Referring to the drawings, the instrument has a deep rectangular sheet metal base comprising the sides 11 and 12 and the rear end 13. The base is open at the front to give access to the cold box. Extending above the base there is a frame comprising the vertical angle members 14 and 15 in front and the corresponding angle members 16 and 17 at the rear. These angle members may be spot welded to the side members 11 and 12 of the base and are connected by the horizontal members 18 and 19.

The cold box, which is substantially square, is contained in the front part of the base. Above the

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cold box there is the mirror chamber and the optical system, also the R. F. heating apparatus, as shown clearly in Figs. 1 and 2. The rear portion of the base serves for the mounting of certain items of electronic equipment, the remainder of which is mounted on a removable chassis adapted to be supported on the horizontal members 18 and 19. This chassis and the rear part of the base are not shown, since the arrangement of the electronic equipment is in accordance with known practice in the radio and allied arts.

The cold box is entirely closed and comprises the sides 20 and 21, the back 22, front 23, bottom 24, and top 25. These parts may be of sheet metal except for the top 25 which is preferably made of some good heat insulating material such as Bakelite. The cold box is supported inside the base by means of screws such as 26 and 27.

The cold rod 28 is located inside the cold box, also the means for extracting heat from the cold rod, said means comprising the evaporator coils 29 and associated parts which are included in the refrigerator.

The refrigerator may be of any suitable type and as shown diagrammatically in Fig. 6 comprises the motor 30, the compressor 31, pipe 32, condenser 33, liquid reservoir 34, pipe 35, expansion valve 36, evaporator coils 29, and pipe 37 leading back to the compressor. There may also be a vacuum pressure gauge 38 which is connected to the low pressure line 37 by means of a T connector.

The pipe 35 enters the cold box through the rear wall 22, as seen in Fig. 2, and is preferably coiled up inside the heat exchanging cylinder 39, emerging at the other end of the cylinder, where it is connected to a short pipe leading to the expansion valve 36 by the coupling 40. The heat exchange cylinder 39 is not shown in Fig. 6. The circulating system can be further traced by reference to Fig. 1 from which it can be seen that the outlet from the expansion valve 36 is connected to the evaporator coils 29 by means of a coupling 41, the evaporator coils being connected by means of another coupling 42 to a short pipe 43 extending to the heat exchanging cylinder 39. From the other end of the cylinder the pipe 37, Fig. 2, extends through the rear wall 22 of the cold box, and leads back to the compressor.

The expansion valve 36 is adjusted by means of a slotted nut 60, Fig. 1, which is ordinarily covered by a cap 62 to prevent the circulation of air around the nut from which frost could form. In order to make this nut accessible from the outside of the cold box an opening 61 is made in the cap

62, and an aligned opening 67, Fig. 2, is made in the front wall 23 of the cold box. A short piece of rubber tubing 63 is fitted over the cap 62 and extends forward to the front wall 23. The opening 67 is normally closed by means of a removable cap 66 which is threaded on to a hollow thimble 64 having a flange 65 by means of which it is secured to wall 23 in alignment with opening 67. With this arrangement the valve may be adjusted by means of a screw driver, after removal of the cap 66.

Although omitted from the drawing to avoid concealing the parts shown, it may be stated that the interior of the cold box should be filled with some suitable fibrous or granular heat insulating material in order to prevent so far as possible the conduction of heat to the evaporator coils and cold rod from the walls of the cold box. Comminuted cork can be used for this purpose.

Details of the construction of the dew mirror and the cold rod are shown in Figs. 4 and 5.

Referring to Fig. 4, the mirror comprises a hollow rod 45 made preferably of the alloy known as "constantan" and has an integrally formed extension 46 of larger diameter which is threaded for connection to the cold rod. The rod 45 has a groove on one side for reception of the copper wire 51, which is bonded to a layer 48 of copper deposited on the rod by electro-plating. In the manufacture of the mirror the cylindrical surface of the rod 45 is given a coating 47 of insulating varnish, after which the insulated wire 51 is passed up through the inside of the extension 46 and out through an opening which is in angular alignment with the afore mentioned groove. The bare end of the wire is then secured in the groove by tying it with thread near the point where it protrudes from the insulation. It will be understood that the bare end of wire 51 is insulated from the constantan rod 45 by the layer of varnish 47. The rod 45 is then dipped in a colloidal suspension of graphite in alcohol, thinned out by the addition of carbon tetrachloride, whereby a very thin conductive film is formed on the end of the rod and on the layer of varnish 47 which covers its cylindrical surface. This film also covers the bare wire 51. An electrical connection is then made to the extension 46 and to the copper wire 51 and the layer 48 of copper is deposited by electro-plating in known manner.

The end of rod 45 and the layer of copper deposited thereon constitute the hot junction of a thermo-couple. The leads from the thermocouple are the wire 51 and a constantan wire 52 which is soldered to the extension 46.

The mirror is finished by plating on a layer of nickel 49 and a very thin layer of rhodium 50 to form a reflecting surface. This surface is preferably buffed and polished. The layer of nickel performs two functions. It facilitates the formation of the reflecting surface of rhodium, which can be deposited more readily on nickel than on copper, and it increases the efficiency of the radio frequency inductive heating apparatus. In further explanation of the increased heating efficiency it may be pointed out that the induced currents which heat the mirror are largely confined to the outer layer and nickel is a better material for this layer than copper because of its higher resistance.

It should be explained also that prior to the plating on of the nickel layer 49 the portion of the copper layer 48 which is on the end of rod 45 is made extremely thin by lapping and buffing operations. The nickel layer on the end of the rod is also lapped and buffed before deposition of the rhodium layer and should be no thicker than necessary to cover the copper layer. All these layers together are very thin, which brings the thermocouple very close to the reflecting surface of the mirror.

Referring now to Fig. 5, the cold rod 28 is preferably made of copper, which is a good heat conductor, and has a helical groove in which the coils 29 of the evaporator are wound. These coils are preferably made of copper tubing and are sweated to the cold rod by solder. The cold rod 28 is hollow and has a hollow extension 53 at the top which is tapped for reception of the threaded extension 46 of the mirror 45. A lock nut 54 aids in securing the mirror rigidly to the cold rod. The conductors 51 and 52 from the thermo-couple extend down through the hollow cold rod and are brought to the outside of the cold box through a flanged tubular member 68 which is fitted into an opening in the bottom 24. The member 68 is made of some heat insulating material such as Bakelite. The arrangement described makes it possible to remove the mirror 45 without disturbing the cold rod or other parts in the cold box, which are packed with heat insulating material as previously mentioned.

The upper end of the cold rod projects above the top 25 of the cold box and is insulated by means of the flanged cylindrical member 55 and the washer 56, which define an annular space around the extension 53 of the cold rod. The member 55 and the washer 56 are made of insulating material such as Bakelite or polystyrene and the space around the extension 53 is filled with insulating material. The cylindrical member 55 is surrounded by a metal sleeve 58 for mechanical protection and its lower flanged end rests on a cork gasket 59 which is seated on the cold rod 28. The washer 56 rests on the top of member 55 and its periphery extends into an annular recess formed in the metal sleeve 58. These parts are clamped together by means of a polystyrene nut 57 which is threaded on to the extension 46 of the mirror 45. The Bakelite top 25 of the cold box has an opening through which sleeve 58 projects and the top engages the flange on the cylindrical member 55, as shown in Fig. 1.

The washer 56 has a slotted raised sector 70, to which there is secured a small block 71 of thermal insulating material. This block supports the dummy mirror 72, which may be a short piece of brass rod plated with rhodium on the end to form a reflecting surface similar to the reflecting surface on the mirror 45.

The mirror chamber is formed in part by the bottom member 77 which rests on the top 25 of the cold box and has an opening for receiving the sleeve 58. Supported on the bottom 77 there is a one piece casting comprising the top 73, bored out to receive parts of the optical system, the ends 74 and 75, and the rear wall 76. The front of the mirror chamber is closed by the front panel 78, which has a window 79 through which the mirrors may be inspected during operation of the machine. This window also gives access to the mirrors when they have to be cleaned.

The pipes 81 and 82 are threaded into the end walls 74 and 75, respectively, of the mirror chamber. These pipes are included in the system for circulating the air or other gas, the dew point of which is to be determined, through the mirror chamber. In case the dew point of the outside air is to be determined, for example, the circulating system may include a blower (not shown) having an intake pipe extending outside the building in which the instrument is located and an exhaust pipe connected to the pipe 82, whereby a stream of air may be directed through the mirror chamber. No connection is made to pipe 81, unless the dew point of some gas other than atmospheric air is to be determined, in which case it may be necessary to provide a closed circulating system.

The plate 83 on which the lamp 84 and photocell 85 are mounted is fastened to the vertical members 14 and 15 of the frame by means of screws, as seen in Fig. 1, and is also secured to the rear wall 76 of the mirror chamber. There is an opening 86 in this wall and a corresponding opening in plate 83 which are covered by a plate 87 of insulating material. The screws 88 and 89, Fig. 2, pass through plate 89 and plate 83 and are threaded into wall 76.

The terminals 90 and 91 are mounted on the insulating plate 87 and extend into the mirror chamber where they support the radio frequency heating coil 92. This coil, consisting of about 4 or 5 turns, surrounds the dew mirror 45. Outside the mirror chamber the terminals 90 and 91 are connected to and support the one turn secondary winding 93 of an air core transformer. The primary winding 96 of this transformer, shown in Fig. 6, is wound on an insulating tube 94. The grid coil 97 is wound on a tube 95 of smaller diameter and both tubes are clamped to a plate 98 of insulating material by means of the cross member 99 and the brass screw 100. The plate 98 may be secured to the top 25 of the cold box by screws and has channels for the conductors leading to the coils 96 and 97.

The light source 84 may be an automobile headlight lamp of the prefocused type having a socket which is secured to the plate 83 by a clamp 102. The lamp socket should be so oriented that the axis of the lamp filament 106 is perpendicular to the plate 83. The reference character 103 indicates a condenser lens. This lens is carried by a conventional lens mount 105 the lower end of which is fitted to one of the bores in the top 73 of the mirror chamber. The focus of the lens is some distance beyond the mirrors 45 and 72 so that the reflecting surfaces of both mirrors are covered by the light projected from lamp 84.

The reference character 104 indicates an infra red filter which is provided to prevent heat rays from reaching the mirrors.

The photocell 85 may be a Cetron type CE–21–D gas filled twin phototube and has cathodes 107 and 109 and anodes 108 and 110, as seen in Fig. 3. The tube is enclosed in a suitable casing of which the bottom and one end are formed by an L-shaped piece 111—112 which is attached to the bracket 113 by means of two screws which also serve to fasten the socket 114 in the opening provided for it. The bracket 113 is attached to the plate 83 by screws as shown. The casing is completed by a cover 115 of U-shaped cross section which slides on to the bottom 111.

The light beams reflected from the mirrors 45 and 72 are projected on to the cathodes 107 and 109, respectively, by the lens 118 through the openings 116 and 117 in the bottom 111 of the casing which encloses the phototube 85. The lens 118 is a plano convex lens and is supported in a bore in the top 73 of the mirror chamber in conventional manner. The reference character 119 indicates a light spreading disc. Between the lens 118 and disc 119 there is a mask 120, which may be formed by a strip of opaque tape or other material. This mask insures that the light reaching each cathode is confined to that which is reflected by the associated mirror, and prevents cathode 107, for example, from receiving any light which is reflected from the mirror 72.

Secured to the bottom 111 of the casing for the phototube there is a block 121 which is drilled and tapped for the two screws 122 and 123. These screws are located in front of the openings 116 and 117 and may be turned in or out to block these openings more or less against the passage of light. The purpose of this arrangement will be explained presently.

Referring now to Fig. 6, the conductors 51 and 52 from the thermo-couple in the mirror 45 extend to a graphic recorder 125, which may be of any suitable type, such as the "Micromax" recording potentiometer manufactured by Leeds and Northrup Company, for example. This instrument includes a temperature compensated cold junction and may be calibrated in micro-volts or in degrees Fahrenheit or centigrade as desired. If the instrument is calibrated in micro-volts the dew point temperature corresponding to any reading is found by reference to a table showing the temperaures which correspond to various voltages.

The optical system comprising the light source 84, the mirrors 45 and 72 and the phototube 85 is shown diagrammatically to the right of the recorder 125.

The circuits which include the phototube 85, the tube 130 and the balancing transformer 140 are designed to balance out variations in the intensity of the light source 84 and to derive an output which is proportionate to the amount of dew on the mirror 45. The tube 130 may be a type 6SN7 twin triode.

The tubes 131 and 132 and associated circuits constitute a two stage amplifier for amplifying the output of the transformer 140. The tube 131 may be a type 6SK7 variable mμ pentode, while tube 132 is preferably a type 6V6 beam power amplifier.

The tubes 133, which may be a type 6SH7 pentode, and 134, a type 6H6 diode rectifier, are included in an automatic volume control circuit the purpose of which will be explained. The circuit includes the potentiometer 141 from which a negative grid bias is supplied to tube 131 and by means of which the amount of grid bias can be adjusted.

The radio frequency oscillator includes the primary winding or tank coil 96, the grid coil 97 and the tube 138, which may be a type 6L6 beam power tube. An ammeter is indicated at 142. The ammeter and a relay 143 are in the cathode plate circuit of the oscillator tube and the relay is arranged to shut down the refrigerator when the oscillator output reaches a predetermined value. The frequency of the oscillator may be on the order of 500,000 cycles per second.

The output of the oscillator is controlled by the voltage developed across the resistor 144 which is included in the cathode plate circuit of tube 136. This voltage is applied to the screen grid of tube 138 through contacts of the defrost switch S3. This switch makes it possible to apply the full +B potential to the screen of the tube 138 to increase its output to the maximum value and is employed when it is desired to defrost or clear the dew from the mirror 45.

The tube 136 may be a type 6F5 Hi $m\mu$ triode. The current flow in this tube determines the amount of voltage developed across the resistor 144 and is dependent upon the difference between the voltages developed across the potentiometers 145 and 146, which are connected in the cathode grid circuit of the tube in series opposition. The voltage across potentiometer 146 is developed by a current produced by rectification of commercial alternating current through the medium of the transformer 147 and the diode rectifier tube 135, while the voltage across the potentiometer 145 is developed by current produced by rectification of the signal output of tube 132 by means of transformer 148 and the diode rectifier tube 137. The potentiometer 146 is used to adjust the "threshold" of control, that is, to fix the lower limit of the range of dew values used for control purposes. Potentiometer 145 is used to adjust the sensitivity or rapidity of the response to a change in dew value. All this will be more fully explained in the course of the explanation of the operation of the hygrometer.

Direct current for the plate circuits of the various tubes is supplied by a well known type of full wave rectifier which includes the rectifier tube 139 and transformer 149. The conductors marked x—x supply current at low voltage to the heater circuits of the tubes (not shown) and also supply current to the lamp 84.

The switch S2 is the main switch through which commercial alternating current is supplied to transformers 147 and 149. The switch S1 supplies current to the motor 30 which drives the compressor 31 and makes it possible to start or stop the refrigerator independently.

The operation of the dew point hygrometer may now be explained. It will be assumed for the purpose of the explanation that the hygrometer is to be used for determining and recording the dew point temperature of the air at some location where the information is required, such as a station of the Weather Bureau, for example. A blower and hose connection will therefore be arranged to supply a stream of air from outside the building to the pipe 81 or 82 of the hygrometer, as previously mentioned.

The hygrometer is started by closing the switches S1 and S2. The cord (not shown) for supplying operating current to the recorder 125 should also be connected to some convenient outlet. The chart 150 will now begin to move downward and the stylus 151 will begin to draw a line thereon indicative of the temperature of the mirror 45. The temperature at the start will of course be the ambient temperature of the air supplied to the mirror chamber.

The closure of switch S1 starts the motor 30 and the compressor 31. In a short time refrigerant will be supplied to the evaporator coils 29 and the extraction of heat from the cold rod 28 and mirror 45 will begin. The temperature of the mirror will accordingly start to go down.

The closure of switch S2 starts the rectifier and the various tubes in the control circuit are rendered operative. The lamp 84 is also energized. The light from the lamp 84 is projected on to the mirrors 45 and 72 whence it is reflected to the photocell 85, the light beam from mirror 45 impinging on cathode 107 and the beam from mirror 72 impinging on the cathode 109.

A flow of current is accordingly established in a circuit which may be traced from ground by way of cathode 107, anode 108, resistor 153, upper half of potentiometer 152 and resistor 155 to the junction point 156 on the voltage divider 157—158, which is provided because the phototube requires a somewhat lower anode potential than the other tubes. Current flow is also established in a similar circuit which includes the cathode 109, anode 110, resistor 154, and the lower half of potentiometer 152.

The voltages which appear on the anodes 108 and 110 due to current flow in the above described circuits have small 120 cycle pulsating components which are caused by fluctuations in the amount of light emitted by the lamp 84. The lamp is energized by 60 cycle alternating current and although the light emitted may appear steady to the eye it nevertheless diminishes slightly each time the energizing current falls to zero, or at each half cycle. The frequency of the light fluctuations is therefore double the frequency of the energizing current.

The pulsating voltages produced at anodes 108 and 110 as above explained are applied by way of condensers 159 and 160 to the grids of the tube 130 where they produce amplified current fluctuations in the plate circuits of the tube. These circuits include, respectively, the upper and lower sections of the primary winding of the balancing transformer 140, and since the currents flow in opposite directions in these sections they oppose each other. If the currents are equal and in phase the result is zero output from the secondary winding.

The currents will be in phase or substantially so but they will not ordinarily be equal unless the instrument has previously been adjusted. It will be assumed, therefore, that a condition of unbalance exists, producing 120 cycle alternating voltages at the secondary winding of the transformer 140 which are applied to the control grid of the tube 131. This tube operates as an amplifier and amplified voltages are transmitted by way of condenser 161 to the control grid of tube 132, where they are further amplified. The plate circuit of the tube 132 includes the primary winding of the transformer 148, and the fluctuating currents in the plate circuit accordingly generate alternating voltages across the secondary winding of the transformer. Current flow is thus established alternately in two circuits which include, respectively, the upper and lower sections of the double diode rectifier tube 137 and the upper and lower sections of the secondary winding of the transformer. The current flow in the potentiometer 145, which is common to both circuits, is unidirectional and produces a unidirectional voltage across the potentiometer. The voltage peaks are smoothed out by the condenser 162, so that a fairly constant potential is produced the value of which depends on the degree of unbalance at the transformer 140.

It may be noted now that alternating current is supplied to the primary winding of the transformer 147 through the switch S2, producing alternating voltages across the secondary winding, whereby a unidirectional current flow is established in the potentiometer 146 by means of the double diode rectifier tube 135 and the circuit hook-up shown. The voltage thus developed across the potentiometer is made fairly constant by the condenser 163.

The oscillator control tube 136 has a cathode grid circuit which may be traced from the cathode by way of part of the winding of potentiometer 146, the slider 165, part of the winding of the potentiometer 145, and the slider 164 to the grid. The voltage developed across the potentiometer winding 146 has such a polarity (indicated in the drawing) that it tends to produce a negative bias on the grid while the voltage developed across the potentiometer 145 has the opposite polarity and tends to produce a positive bias on the grid. The effective grid potential with respect to the cathode is therefore equal to the difference between these two potentials.

The adjustment of the potentiometers 145 and 146 will be discussed later. However, it may be stated at this point that the potentiometer 146 should be so adjusted that with no voltage across potentiometer 145 the tube 136 is biased below cut off and passes no current. The voltage across the part of the potentiometer 146 which is in the grid circuit may be about 35 volts, for example.

It may be assumed that the amount of unbalance at transformer 140 is considerable, with the result that sufficient potential is developed across the potentiometer 145, or rather that part of it which is included in the grid circuit of tube 136, to reduce the negative potential on the grid far enough so that current can flow in the cathode plate circuit of the tube. The positive voltage, which is in opposition to the negative voltage derived from potentiometer 146, is indicated on the voltmeter 166 and may be 25 volts or more. The cathode plate circuit of the tube 136 includes the resistor 144. Current flow in the circuit causes a positive voltage to be developed on conductor 167 which is applied to the screen grid of the oscillator tube 138 by way of the normally closed contacts of the defrost switch S3. The resistor 144 may have a value of about 100,000 ohms, for example, which is sufficient to give a good range of voltages on conductor 167 responsive to changes in the current flow through the control tube 136.

At times when the tube 136 is not passing current, that is, when it is biased below cut off, the conductor 167 and the screen grid of the oscillator tube 138 are at ground potential and the oscillator is inoperative. When a positive potential appears on the screen grid, due to current flow through the control tube 136, the oscillator becomes operative and high frequency currents are generated in a circuit which includes the secondary winding or loop 93 and the heating coil 92. High frequency currents are accordingly induced in the mirror 45 which because of the skin effect are confined mainly to the nickel layer 49. Nickel is a material which is readily heated by induction, and since the underlying layer of copper 48 is a good heat conductor the heating arrangement is relatively efficient.

The reading of the ammeter 142 is indicative of the rate at which heat is supplied to the mirror. The actual temperature of the mirror is indicated by the recorder 125. If there should be danger of overheating, due to an excessive degree of unbalance at transformer 140, the rate can be reduced quickly by adjustment of the potentiometer 145.

The foregoing describes the conditions which prevail immediately after the hygrometer is started up. Reviewing the situation briefly, the refrigerator has been started and is working to extract heat from the cold rod 28. The optical system is in operation, but due to unequal outputs from the two sections of the phototube, a condition of unbalance exists at the transformer 140, producing enough signal output from the transformer to start the radio frequency oscillator. Heat is accordingly being supplied to the mirror, and its temperature is indicated on the recorder 125.

The unbalanced condition may be due to one or more of several causes. For example, the two mirrors 45 and 72 may not have exactly the same reflecting power, or the two sections of the phototube 85 may not give equal outputs for equal amounts of light received, or the two sections of tube 130 may not have the same gain. These and other causes can be expected to be present at the start in greater or lesser degree and the instrument will ordinarily be out of balance, therefore, as has been assumed to be the case.

In order to adjust the instrument to a balanced condition, the operator will first make sure that the slider of the potentiometer 152 is adjusted to mid-position and will see to it that the adjusting screws 122 and 123 are backed off far enough so that they are entirely out of the paths of the light beams with which they are associated. The operator will then turn in one of the adjusting screws, screw 122 for example, far enough to cause the end of the screw to enter the path of the associated light beam, and will note the effect on the voltmeter 166. If the voltmeter shows an increased reading the operator will be advised thereby that the circuit is unbalanced to a greater extent than it was before and he will restore screw 122 to its original position. Screw 123 is now turned in until it begins to intercept the associated light beam, with the result that the voltmeter 166 will show a decreased reading, indicating that the unbalanced condition has been improved. The adjustment is then continued until the voltmeter reads zero, or as near to zero as possible. There may be a slight phase displacement between the currents in the two sections of the primary winding of transformer 140 which will make it impossible to obtain an absolute balance, but an approximate balance can easily be obtained.

It will be understood that while the adjustment described in the foregoing is being made the temperature of mirror 45 is above the dew point and both mirrors are clear of dew.

The phototube circuits having been balanced, the output of transformer 140 is reduced to zero, or substantially zero, and the voltage developed across the potentiometer 145 is zero, or substantially zero. The voltage developed across the potentiometer 146 is now unopposed and effectively biases the tube to cut off. Current flow through the tube ceases, the potential on the screen grid of the radio frequency oscillator is reduced to ground potential and the oscillator stops oscillating, with the result that the supply of heat to the mirror is shut off.

As the refrigerator continues to operate the temperature of the mirror 45 will fall and will eventually reach the dew point of the air circulating through the mirror chamber. Dew now begins to form on mirror 45, which diminishes its reflecting power. The temperature of mirror 72 remains substantially the same as that of the circulating air, since it is insulated from the cold rod, no dew forms on this mirror, and its reflecting power remains unimpaired. As dew forms on mirror 45, therefore, the output of the 107—108 section of phototube 85 decreases, while the output of the other section remains the same, thereby again creating a condition of unbalance at the transformer 140.

There will now be an appreciable voltage generated in the secondary winding of the transformer 140, which is amplified and rectified as described and produces a potential across the potentiometer 145. This potential increases as the amount of dew increases, that is, the potential across the potentiometer is proportionate to the amount of dew on mirror 45, and very soon becomes large enough to cause the control tube 136 to again become conductive. The potential on conductor 167 accordingly again rises above ground potential, likewise the potential on the screen grid of the oscillator tube 133, and the oscillator again begins to function to supply heat to the mirror 45.

The oscillator output at this stage is low and only enough heat is supplied to the mirror 45 to compensate for the heat withdrawn by the cold rod and maintain the temperature of the mirror constant, or very nearly so. The control circuits are extremely sensitive, however, and very slight changes in the amount of dew deposited on the mirror are capable of enormously increasing the oscillator output. Thus as the temperature of the cold rod goes down, heat will be extracted from the mirror at a higher rate, its temperature will fall very slightly and the amount of dew on the mirror will be minutely increased, thereby increasing the output of the oscillator enough to make up for the higher rate of heat loss. The temperature of the cold rod will eventually reach the limit imposed by the nature of the refrigerant being used, as low as −60° F., for example, and the amount of heat supplied to the mirror will become stabilized, except for changes in the dew point. If the dew point is fairly high, +50° F., for example, a considerable amount of heat will have to be supplied to maintain the mirror at this temperature. The amount of dew on the mirror, however, has increased by only a very small amount.

The line drawn on the chart at the recorder now shows the dew point temperature and will continue to do so, except when the mirror is defrosted during occasional balance tests, as will be mentioned hereinafter.

The relation between the amount of dew on mirror 45 and the heat output to the mirror may be explained with reference to Fig. 7, where it is depicted by the curve 170. Three ranges of dew are taken into consideration, an invisible range 171, in which the dew on the mirror is not visible to the eye, a so called "useful range" 172, in which the dew is visible and is used for the purpose of control, and an indefinite range 173 in which the dew is heavier and is not used for control purposes. The temperature change over the whole range of dew values shown is quite small. Over the useful range it is only a small fraction of a degree.

The curve 170 is very steep and indicates that the heat output to the mirror increases very rapidly with an increase in the amount of dew within the useful range. This range of dew values is sufficient to control the oscillator over its whole working range extending from substantially zero output to maximum output.

The location of the curve 170 within the useful range of dew values is determined by the adjustment of the potentiometer 146, which determines the amount of negative bias on the grid of the control tube 136. The phototube 85 is extremely sensitive and can detect the formation of dew before it becomes visible and it is possible therefore to use a range of dew values which is partly or wholly within the invisible range for the control of the hygrometer. Curve 174 illustrates this operating condition. The dew point, however, is by accepted definition the temperature at which a visible deposit of dew is formed and it follows that if the hygrometer were to be operated in accordance with curve 174 it would indicate too low a temperature for the dew point. It is necessary, therefore, to utilize for control purposes a range of dew point values over which the dew on the mirror is visible. This range may be selected at a time when the oscillator output is very low, as indicated by the ammeter 142, by observing the mirror 45 and adjusting the potentiometer 146 until the deposit of dew on the mirror can just barely be seen with the eye.

The slope of the curve 170 is determined by the sensitivity of the control circuits, or the rapidity of the response to slight changes in the amount of dew, and may be adjusted by means of the potentiometer 145. The sensitivity should not be too low, a condition illustrated by the curve 175 which extends outside the useful range of dew values. On the other hand it is possible to make the sensitivity too high, in which case the instrument is apt to manifest a tendency to hunt. A condition of hunting is indicated by the periodic appearance and disappearance of the dew, also by a periodic change in the reading of the ammeter 142 and the voltmeter 166. In practice the sensitivity is adjusted to be as high as possible while maintaining a continuous deposit of dew on the mirror.

The double mirror system tends to compensate for changes in the intensity of the light source 84, such as may be due to changes in line voltage. When the machine is in operation there is a certain amount of dew on the mirror 45, which is being maintained by the simultaneous flow of heat to the cold rod and the supply of heat by the oscillator. Now equal amounts of light reach the two mirrors and if the line voltage falls the decrease in the amount of light reaching mirror 45, which would otherwise be interpreted as an increase in the amount of dew, is compensated for by an equal decrease in the amount of light reaching mirror 72.

As regards the reflected light the situation is different since the instrument operates in accordance with the difference between the amount of light reflected by mirror 45 and the amount of light reflected by mirror 72 and this difference changes percentagewise with changes in voltage which affect the intensity of light source 81. If the voltage should fall, therefore, the output of transformer 140 will fall even though the amount of dew on mirror 45 remains constant. This reduces the sensitivity of the control circuit, which is also reduced at other points, due to change in the gain of the amplifiers, for example.

The automatic volume control circuit is employed in order to maintain the sensitivity of the control circuit at a high level notwithstanding such factors as a drop in line voltage and accumulation of dust in the optical system which tend to reduce it. Explaining this further, it will be noted that the pulsating voltages produced at the anode 110 of the phototube are not only impressed on the grid at one section of tube 130 but are also impressed on the grid of tube 133, these grids being connected by a conductor 172. The output of tube 133 is rectified by the arrangement including transformer 173 and the diode rectifier tube 134 to cause a flow of direct current in a circuit which includes the winding of the potentiometer 141, thereby providing a negative grid bias for the amplifier tube 131. A potentiometer is used rather than a fixed resistor so that the best value of negative bias can be selected depending on the gain of tube 133, the sensitivity of the phototube and other factors.

If we assume now that the hygrometer is operating with the control circuit in a desired condition of sensitivity, as determined by the adjustment of the potentiometer 145, a fall in line voltage will reduce the amount of light reflected from mirror 72, thereby reducing the output of tube 133 and reducing the negative grid bias at tube 131. The gain of tube 131 is thus increased and the sensitivity is maintained at its former level. It will be seen therefore that the potentiometer 145, having once been adjusted, will require a minimum of attention, since the volume control circuit automatically takes care of changes which would ordinarily require changes in the adjustment of the potentiometer.

If the air circulating through the mirror chamber is not entirely clean there will be a certain amount of dirt or dust deposited on the reflecting surfaces of the mirrors which gradually impairs their reflecting powers. It also tends to unbalance the phototube circuits since the mirror 45, being wet with dew, tends to accumulate dirt faster than the mirror 72. The instrument can be tested occasionally for an unbalanced condition by operating the defrost switch S3. When this switch is operated the full +B voltage is impressed on the screen grid of the oscillator tube 138 and the oscillator output is increased to the maximum, supplying heat enough to the mirror so that the dew or frost will quickly disappear. The operator will then note if the reading of the voltmeter 166 has dropped to zero, or substantially zero, and if it has not he will correct the unbalanced condition by adjusting the potentiometer 152. The provision of the potentiometer avoids the necessity of cleaning the mirrors too frequently. Under ordinary conditions this need not be done oftener than about once every twenty-four hours.

The relay 143 is included in the cathode plate circuit of the oscillator tube 138 and is adjusted to operate when the current flow reaches a predetermined value. The function of the relay is to shut down the refrigerator periodically at times when its continuous operation is not required, thereby effecting a reduction in the amount of power required to run the refrigerator and a similar reduction in the amount of power expended at the oscillator. Continuous operation of the refrigerator is unnecessary at times when the dew point is relatively high, 40° F. or higher, for example, since at such high dew point temperatures it is unnecessary to maintain the cold rod at an extremely low temperature and to do so involves a waste of power both at the refrigerator and the oscillator.

Describing the operation briefly, it may be assumed that the dew point has been low and has just gone up high enough so that the power consumed at the oscillator is sufficient to operate relay 143. When the relay energizes, it opens the circuit of motor 30, thus stopping the motor and the compressor 31. The temperature of the cold rod 28 now rises gradually, heat is extracted from the mirror at a progressively decreasing rate, and the power consumption at the oscillator decreases in corresponding manner. After a time the current in the cathode plate circuit of oscillator tube 138 will have decreased enough to permit the relay 143 to fall back and again close the circuit of the motor 30. The refrigerator is thus started up again and when the temperature of the cold rod has been reduced to its former value the relay 143 again energizes to repeat the cycle, assuming that the dew point has remained at a high enough temperature.

The invention having been described, that which is believed to be new and for which the protection of Letters Patent is desired will be pointed out in the appended claims.

I claim:

1. In a mirror for a dew point hygrometer, a metallic body one end of which is adapted to be connected to a cold source, a cup shaped inner metal shell enclosing the other end of said body and joined to the body at the end surface thereof to form the hot junction of a thermo-couple, an outer metallic shell enclosing said inner shell and joined to the outer surface thereof, and a mirror surface formed on the end of said outer shell.

2. In a mirror for a dew point hygrometer, a metallic rod forming one element of a thermocouple, a thin coating of a different metal deposited on said rod and forming the other element of said thermo-couple, said coating being insulated from the side wall of said rod and in conductive contact with said rod at the end thereof, and means comprising another metallic coating deposited on the end of said rod outside said first mentioned coating to form a reflecting surface.

3. In a mirror for a dew point hygrometer, a metallic rod forming one element of a thermocouple, a thin coating of a different metal deposited on said rod and forming the other element of said thermo-couple, said coating being insulated from the side wall of said rod and in conductive contact with said rod at the end thereof, a second coating coextensive with said first coating and in conductive contact therewith, said second coating being formed of a metal having a higher resistance than the metal of said first coating, and a third coating deposited on said second coating and forming a reflecting surface at the end of the rod.

4. In a mirror for a dew point hygrometer, a rigid metallic body forming one element of a thermo-couple and adapted to function as a heat conductor, a metallic layer having a limited area thereof in conductive contact with said body and forming the other element of said thermo-couple, means forming a reflecting surface on said layer over an area which is coextensive with the area in contact with said body, and a second metallic layer in conductive contact with an area of said first layer outside said reflecting surface, said second layer being made of a metal adapted to be heated efficiently by high frequency induction.

5. In a dew point hygrometer, a passage for the flow of gas, first and second mirrors located close together in said passage, means for projecting a beam of light impinging on both said mirrors, means for cooling the first mirror to the dew point of said gas, whereby the reflecting power of the first mirror is reduced by dew deposited thereon, means for heating said first mirror, and means for regulating said heating means in accordance with the difference in the amount of light reflected by said mirrors to maintain said first mirror at the dew point.

6. In a dew point hygrometer, an element having a light reflecting surface, means for cooling said surface to the dew point in the presence of a gas the dew point of which is to be deter-

mined, whereby the reflecting power of said surface is reduced by the deposit of dew thereon, a second element adjacent said first element having a light reflecting surface insulated from said cooling means, means for projecting light in the form of a single beam impinging on both said surfaces, means independent of the temperature of said gas for generating heat in said first element to counteract the effect of said cooling means, and means sensitive to the difference between the amounts of light reflected by said surfaces to maintain the reflecting surface of said first element at the dew point by regulation of said heating means.

7. In a dew point hygrometer, a mirror on which dew is deposited at the dew point temperature, means for uniformly cooling the reflecting surface of said mirror, means for heating said mirror, a second mirror maintained above the dew point temperature, two photocells, an optical system including a source of light and said mirrors for projecting two light beams to said photocells, respectively, before the deposit of dew on said first mirror begins, a control circuit for regulating said heating means, means including an amplifier for producing a voltage in said control circuit having a value which depends on the difference between the outputs of said photocells after dew has been deposited on said first mirror, and means for maintaining a constant ratio between said voltage and the amount of dew on said first mirror notwithstanding changes in the voltage of the power supply to said amplifier, said last means comprising an automatic volume control circuit in which a negative potential is developed proportionate to the output of one of said photocells, and a connection over which a portion of said negative potential is applied to said amplifier to regulate the output thereof.

8. In a dew point hygrometer, a mirror on which dew is deposited at the dew point temperature, a source of light, means for projecting a beam of light from said source to said mirror, a second mirror maintained above said temperature and located adjacent said first mirror, to intercept a part of said beam, two photocells to which light beams are reflected by said mirrors, respectively, and means for throttling either of said last mentioned light beams at will to equalize the output of said photocells at a time when there is no dew on said first mirror.

9. In a dew point hygrometer, a dew mirror and a dummy mirror, two photocells, an optical system including a source of light and said mirrors for forming two light beams and projecting them on to said photocells, respectively, means for amplifying the outputs of said photocells comprising two space discharge devices having their control grids connected to the anodes of said photocells, respectively, a transformer, and plate circuits for said devices including, respectively, two opposed sections of the primary winding of said transformer, whereby the current in the secondary winding of said transformer is proportionate to the difference between the outputs of said photocells.

10. In a dew point hygrometer, an element having a light reflecting surface, a refrigerating system for cooling said element, means including a high frequency oscillator for generating heat in said element by induction, said oscillator including a space discharge device, means for controlling the output of said oscillator to maintain the temperature of said element at the dew point, and means including a relay sensitive to current flow in the anode circuit of said device for stopping said refrigerating system responsive to the oscillator output reaching a predetermined value and for starting it responsive to said output reaching a predetermined lower value.

11. In a dew point hygrometer, an element having a light reflecting surface, means for cooling said element to cause the deposit of dew on said surface, a second element adjacent said first element and having a light reflecting surface, means for projecting a light beam on to said surfaces, two photocells to which light beams are reflected by said surfaces, respectively, at times when the first surface is free of dew, the deposit of dew on said first surface being effective to diminish the intensity of the beam reflected from such surface to the associated photocell, circuits for said photocells including a source of current, means responsive to current flow in said circuits for generating an alternating current which is proportional to the difference between the intensities of the beams reflected by said surfaces, means for rectifying said alternating current, a circuit including a source of direct current, means for deriving a control voltage which is proportionate to the difference between the rectified alternating current and the current in said circuit, and means for heating said element regulated by said control voltage to maintain the said first reflecting surface at the dew point.

12. In a dew point hygrometer, an element having a light reflecting surface, means for cooling said element to cause dew to be deposited on said surface, means including an oscillator for heating said surface, said oscillator including a space discharge device having a screen grid, a second space discharge device constituting a control tube, a source of anode current for said devices, a resistor connected between the cathode of said control tube and the negative terminal of said source, a conductor extending from said screen grid to the junction of said resistor and said cathode, whereby said oscillator is rendered inoperative by the negative potential at said junction when no anode current is flowing in said control tube, means responsive to a reduction in the light reflected from said surface by deposit of dew thereon for causing anode current to flow in said control tube to thereby raise the potential at said junction and start said oscillator.

13. A dew point hygrometer as claimed in claim 12, wherein a switch is provided in said conductor to disconnect the said screen grid from said junction and connect it to the negative terminal of said source, to thereby stop said oscillator when the current is flowing in said control tube.

14. In a dew point hygrometer, a cold rod made of good heat conducting material, a metallic member secured in a recess at one end of said cold rod and constituting one element of a thermocouple, said member having supported thereon in superimposed relation a metallic layer constituting the other element of said thermocouple and a coextensive metallic layer having a reflecting surface, a channel extending through said cold rod and said metallic member, a conductor extending through said channel and having a connection to said first metallic layer, and a second conductor connected to said metallic member and extending through that portion of said channel which is in said cold rod.

15. In a dew point hygrometer, a cold rod of good heat conducting material and having a longitudinal channel extending therethrough, an extension of said cold rod secured thereto at one end, said extension having a channel therein communicating with the channel in said cold rod and being closed at the other end, a thin layer of metal covering the end of said extension, said layer and said extension being made of different metals and constituting the hot junction of a thermocouple, a metallic layer covering said first layer and having a reflecting surface, an opening in the side of said extension communicating with the channel therein, and two conductors extending through the channel in said cold rod, one of said conductors being connected to said extension and the other conductor extending through the said channel and opening in said extension and having a connection to said first layer.

16. In a dew point hygrometer, an element having a light reflecting surface the reflecting power of which is diminished by deposit of dew thereon, means for uniformly cooling said surface to the dew point to start the deposit of dew thereon, means for uniformly heating said surface, a second element having a light reflecting surface, means for projecting light on to said surfaces, two photocells to which light beams are reflected by said surfaces, respectively, before the deposit of dew begins, and means responsive to the deposit of dew on said first surface and the resulting excess in the amount of light reaching the second photocell from the second surface for starting the operation of said heating means.

17. In a dew point hygrometer, a mirror on which dew is deposited at the dew point temperature, means for cooling said mirror, a second mirror adjacent to said first mirror but insulated from said cooling means, a source of light, means including said source and a lens for projecting a beam of light impinging on both said mirrors, two photocells in close proximity to each other, means including another lens for projecting the beams reflected from said mirrors to said photocells, respectively, and means for adjusting the cross section of at least one reflected beam to equalize the amounts of light reaching said photocells at a time when said first mirror is free of dew.

18. In a dew point hygrometer, a mirror, means for cooling said mirror to dew point temperature, a second mirror maintained substantially at ambient temperature, a periodically varying light source arranged to project light on to said mirrors, two photocells to which said mirrors reflect light beams, respectively, two circuits for said photocells, respectively, in which pulsating voltages are generated in response to periodic variations in the intensity of said light beams, two amplifiers, condensers coupling said photocell circuits to said amplifiers, respectively, whereby said pulsating voltages are transmitted to the amplifiers and are amplified thereby, means for comparing the outputs of said amplifiers, means supplying heat to said first mirror, and means for regulating said heat supplying means in accordance with the difference between said amplifier outputs to maintain said first mirror at the dew point.

19. In a dew point hygrometer, a dew mirror and a dummy mirror, two photocells, a periodically varying light source, means including said source and said mirrors for forming two light

beams and for projecting them on to said photocells, respectively, circuits for said photocells including a source of direct current and in which potentials are developed at one terminal of each of said photocells in response to the impingement of said light beams thereon, said potentials each having a pulsating component produced by the variations in the intensity of said light beams, means for equalizing said pulsating components when said dew mirror is free of dew, two amplifiers arranged to amplify said pulsating components, respectively, and means for comparing the outputs of said amplifiers and for deriving an alternating current proportionate to the difference between said components when said dew mirror has dew thereon.

20. A dew point hygrometer as claimed in claim 19, wherein the comparing means comprises a transformer having two primary windings energized by the outputs of said amplifiers, respectively, and a secondary winding in which the said alternating current is generated.

21. In a dew point hygrometer, a mirror on which dew is deposited at the dew point temperature, means for cooling said mirror, means for heating said mirror, a circuit including the resistance element of a potentiometer, means responsive to the deposit of dew on said mirror for producing direct current flow in said circuit proportionate to the amount of dew, a second circuit including a source of direct current and the resistance element of a second potentiometer, means for regulating said heating means in accordance with the current flow in said first circuit, said regulating means including a space discharge device, and a cathode grid circuit for said device including the sliders of said potentiometers and portions of the resistance elements thereof all connected in series, the slider of the first potentiometer being connected to the grid of said device, and the direction of current flow in said circuits being such that the voltages across the included portions of the resistance elements of the said potentiometers are in opposition and produce a positive potential at the grid of said device only if the voltage across the included portion of the resistance element of the first potentiometer is the greater of the two voltages.

22. In a dew point hygrometer, a mirror on which dew is deposited at the dew point temperature, means for cooling said mirror, means including an oscillator for heating said mirror by induction, a photocell to which a beam of light is reflected by said mirror when no dew is deposited thereon, means including said photocell for generating an alternating current the value of which is inversely proportionate to the amount of light in said beam, an amplifier and means for transmitting said alternating current thereto, means for rectifying the output of said amplifier to produce a control voltage, means responsive to said control voltage for starting said oscillator, means for generating a voltage in opposition to said control voltage, and means for adjusting said opposing voltage to a value which reduces the control voltage sufficiently to prevent the starting of said oscillator until a predetermined amount of dew has been deposited on said mirror.

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