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AN IMPROVED ELECTRIC HYGROMETER

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ABSTRACT

The psychrometer and hair hygrometer are common means of determining the moisture content of air. There are, however, many circumstances to which these are not well adapted, especially in the measurement of upper-air humidities by means of the radio sonde, where marked and sudden changes of humidity are encountered. In fact, when humidity readings are to be made or recorded graphically, remote from the point of measurement, or where humidity must be determined rapidly or in confined spaces or at low temperatures, these methods are not practical.

This paper describes a type of electric hygrometer which better fulfills the above requirements. It covers improvements made in an earlier type of electric hygrometer previously described by the author. The improved unit consists of an 0.01-inch-wall aluminum tube $1\frac{11}{16}$ inches long coated with polystyrene resin and wound with a bifilar winding comprising 20 turns (of each wire) per inch of No. 38 AWG bare palladium wire. The unit is then coated with a thin film of partially hydrolyzed polyvinyl acetate with the addition of a small amount of lithium chloride, the amount depending upon the humidity range to be covered by the unit. The electric resistance of the film between the two coils is a function of humidity.

The thin-walled aluminum tube enables the unit to assume quickly the temperature of the air, as it must if measuring relative humidity. The use of palladium wire eliminated a continuous aging effect or increase in resistance caused by a film which continued to form on the surface of all other wires previously used. The polystyrene resin forms an excellent water-resistant surface of high electric resistance for the wire and water-sensitive film. This construction eliminated hysteresis effects previously experienced, caused by the adsorption of water by glass and other materials used as bases.

The polyvinyl acetate forms a porous binder for the lithium chloride, which not only gives stability and uniformity to the units but also greatly reduces polarization effects previously experienced when using the electric hygrometer in the d-c radio-sonde circuit.

Methods of construction, coating, aging, and using the units in both a-c and d-c circuits are given.

A method is provided which makes possible the measurement of relative humidity from 10 to 100 percent by using several units of different sensitivities in parallel, with resistors in series with each.

The humidity-resistance characteristics are given for individual units coated with different percentages of lithium chloride and for three- and five-element composite units.

A calibration of a three-element unit used in the radio-sonde circuit serves as an example of measurements over a temperature range from $+30°$ to $-60°$ C.

Electric-hygrometer units have been made which have not varied more than 2 or 3 percent over a period of several months.

CONTENTS

I. INTRODUCTION

The psychrometer method of measuring humidity has long been a common means of determining the moisture content of air. There are, however, many conditions for which this method is not well adapted, a particular case being the measurement of upper-air humidities by means of the radio sonde. When remote indications or recording of the humidity is required, or when measurements must be made in small confined spaces or at low temperatures, the psychrometer method is not practical. The hair-type hygrometer is now generally used, but its slow rate of response and other peculiarities have made its use undesirable in many instances. In radio meteorography the large time lag in response of the hair hygrometer introduces serious errors, since sudden humidity changes are often encountered by a rapidly ascending balloon. This lag increases with decreasing temperature, with the result that the accuracy of this type of hygrometer becomes progressively less at increasing altitude.

In a previous paper,[1] an electric type of hygrometer was described for use with the radio sonde, which, subject to certain precautions, gave some promise of satisfying the requirements for a remote humidity-indicating device without moving parts or appreciable lag. It consisted of two fine tinned copper wires spirally wound simultaneously on a thin-walled etched glass tube so as to form 20 bifilar turns per inch. After the glass tube was wound, it was coated with a dilute solution of lithium chloride in water. The lithium salt, with the moisture which it takes up from the air, formed an electrolytic conductor on the glass surface between the two wires. The resistance of this conducting film varied greatly with the moisture content of the air, so

[1] F. W. Dunmore, *An electric hygrometer and its application to radio meteorography*, J. Research NBS **20**, 723–744 (1938) RP1102.

that the resistance of the unit could be expressed in terms of percentage of relative humidity. Such a unit gave satisfactory results if certain precautions were observed in its use. These precautions were necessary because of continuous short- and long-period aging effects and a polarization error when the unit was used in d-c circuits. It was also found necessary to switch in two or more units of different sensitivities in order to cover the full humidity scale.

Recent research on this hygrometer has substantially overcome these difficulties, resulting in a unit which now appears to be definitely superior to the hair-type hygrometer, especially for radio-sonde use. It also has advantages over the psychrometer method under many other conditions of measurement. The original features of rapid rate of response and inherent variation in resistance with changes of humidity have been retained.

The present paper describes the improvements made in the original electric hygrometer, the method of construction, the operating characteristics of the new unit in a-c and d-c circuits, and some special applications.

The method of using the electric hygrometer in the radio sonde and results obtained on routine operation are given in a separate paper.[2]

II. IMPROVEMENTS OVER EARLIER DEVICE

The improvements incorporated in the new electric hygrometer may be classified under four headings: (1) Prevention of long-period aging; (2) prevention of a hysteresis effect, or short-period aging; (3) use of partially hydrolyzed polyvinyl-acetate film, (a) lithium-chloride binder, (b) homogeneous film, (c) reduction of polarization; (4) special design for covering the full humidity range without switching means.

1. PREVENTION OF LONG-PERIOD AGING

Early work with the bifilar-coil electric hygrometer showed that the electric resistance of the unit continued to increase from week to week, so that it was necessary to calibrate the device shortly before using. It has since been found that this increase in resistance was caused by a film which gradually formed on the surface of the wire used for the coils. After units were wound with many kinds of wire, it was found that platinum and palladium wire were the only kinds which would eliminate this aging effect. (Recent tests indicate that it may be possible to use gold or gold-plated wire.) As palladium is cheaper than platinum, the former is now used. Units wound with this wire have been found to hold a calibration to within ±3 percent for 6 months. Twenty bifilar turns per inch of No. 38 AWG gave the best results. A reduction in the number of turns per inch increases the current density at the surface of the wire, which tends to increase the polarization effect in d-c circuits and to decrease the life of the unit in a-c circuits. Fewer turns, however, make a unit which covers a greater range of humidity for a given resistance change. With amplifying means between the unit and indicating instrument, it is possible that fewer turns might be used.

[2] H. Diamond, W. S. Hinman, Jr., and F. W. Dunmore, *An improved radio sonde and its performance*; Publication pending.

2. ELIMINATION OF SHORT-PERIOD AGING

Another phenomenon termed hysteresis, or short-period aging, involving intervals of several hours before becoming apparent, made it necessary to calibrate the units shortly before using, or to store them at a fixed humidity. The cause of this effect was finally traced to the adsorption of water by the etched-glass surface upon which the bifilar coils were wound. As giving up or taking on of water by the glass required several hours, the result was a shift in the calibration curve for the unit to lower values of resistance if the unit had been exposed to a high humidity for several hours, or to higher resistance values if the unit had been exposed to a low humidity for several hours. This behavior of the units was illustrated in the previous paper.

A way of overcoming this effect was to store the units in a fixed humidity chamber until ready for use.

After many water-resistance coatings had been tried on the glass, polystyrene, a thermoplastic resin, was found which overcame this troublesome effect. A coating is applied by dipping the glass tube in a solution of polystyrene.

The construction now preferred consists of a thin-walled aluminum tube in place of the glass tube. The aluminum tubing is dipped in the polystyrene solution, heated to drive off the solvents, and it is then wound with the bifilar coil of palladium wire. The aluminum tubing should be of the commercial hard-tempered type with an outside diameter of ⅜ inch and a wall thickness of 0.01 inch. The thin wall is necessary, as the unit must attain the temperature of the air surrounding it in order to register the true relative humidity. This is especially important in radio-sonde use, where sharp temperature inversions are often encountered. Such a unit is shown in figure 1.

The polystyrene film on the aluminum tube serves as a surface of high electric resistance for the bifilar coil and the moisture-sensitive coating, without adversely influencing the functioning of the device.

In applying this film it is important that the composition of the polystyrene solution be such that the film will dry without cracking or crazing. Any such surface irregularities tend to produce a hysteresis effect, or lag in response of the device. Also, such a surface structure causes nonuniformity of the coating of the moisture-sensitive film which is applied after the unit is wound.

A satisfactory polystyrene solution for coating the aluminum tubing by dipping was found to be as follows:

100.0 g of polystyrene (Resoglaz).
18.4 g of dibutyl phthalate (plasticizer).
90.0 g of ethyl acetate.
133.0 g of butyl acetate.
90.6 g of xylene.
135.0 g of toluene.

The aluminum tubing (with ends closed) was dipped in this solution and immediately withdrawn at a steady rate of approximately 1 inch per 7 seconds. This process was repeated with a drying interval between each coat of 3 hours, until the film of styrene resin was about 0.01 inch thick. After the application of the last coat the unit was heated at 80° C for 18 hours before winding. The polystyrene surface should not be roughened, as such treatments produce units which are not reproducible when coated with the moisture-sensitive film.

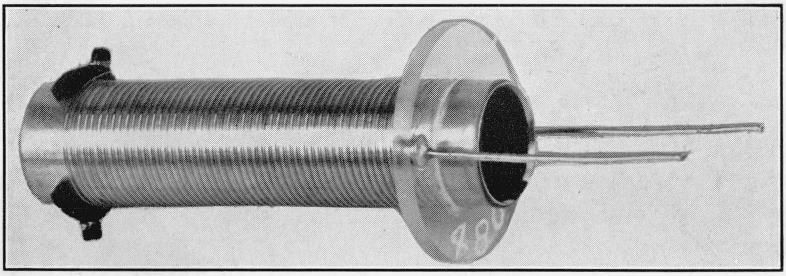

FIGURE 1.—*An electric-hygrometer unit.*

(See p. 706 for approximate dimensions.)

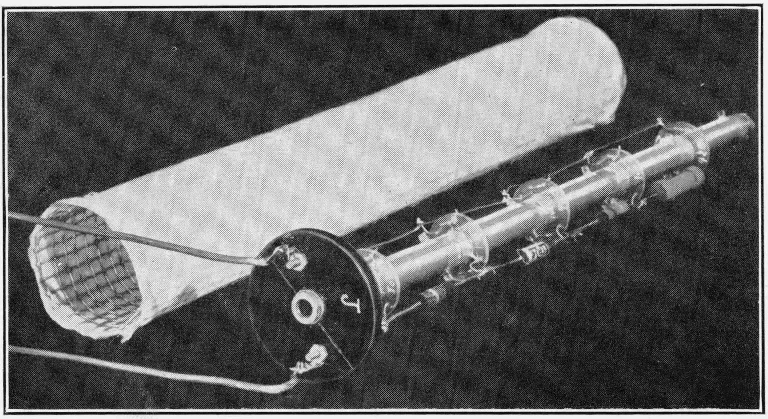

FIGURE 4.—*Five-element electric hygrometer for indicating relative humidities from 10 to 100 percent.*

The five units are connected as shown in figure 3. The cloth-covered housing protects the units from dirt but allows water vapor to reach them.

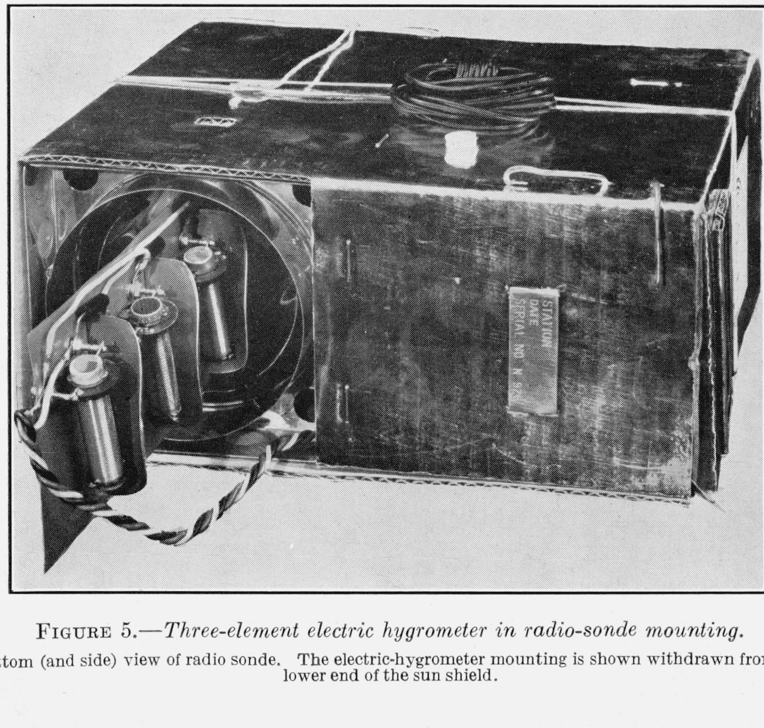

FIGURE 5.—*Three-element electric hygrometer in radio-sonde mounting.*

Bottom (and side) view of radio sonde. The electric-hygrometer mounting is shown withdrawn from the lower end of the sun shield.

3. USE OF PARTIALLY HYDROLYZED POLYVINYL-ACETATE FILM

(a) USE AS A BINDER FOR THE LITHIUM CHLORIDE

The moisture-sensitive material used on the polystyrene surface is a dilute solution of lithium chloride in water. In order to keep the lithium chloride on the smooth polystyrene surface, a suitable binder had to be found which would mix readily with the solution of lithium chloride in water and form a thin film which would readily pass water vapor without producing appreciable lag in the response of the unit.

Early in the work on the electric hygrometer, at the suggestion of T. P. Sager, of the Bureau's Chemistry Division, a partially hydrolyzed polyvinyl acetate called Hydrogel or Solvar was tried as a sensitive hygroscopic coating on shellac, spar varnish, and balata as bases. These combinations were not sufficiently sensitive. However, in later work this material mixed with lithium chloride as the sensitive element proved to be a most satisfactory combination. This partially hydrolyzed polyvinyl acetate (36 percent saponifiable) is sold by the Shawinigan Products Corporation, Empire State Building, New York City, under the name of Solvar—sample 6341 S. O. 1232, W. O. 5356–11. This was furnished in the form of a viscous alcoholic solution containing 25 percent of solid material. A satisfactory dipping mixture consists of 1 part of this solution by volume to 6 parts (by volume) of a mixture of equal parts of water and ethyl alcohol. To this solution the saturated solution of lithium chloride in water (at 21° C) is added in percentages by volume, depending upon the range in the humidity scale to be covered by the unit to be coated. In using this solution, care should be taken to prevent evaporation of the alcohol as this causes the solution to become more concentrated, giving units with a resistance below normal. The percentages of lithium chloride necessary to cover specified ranges of humidity will be discussed under section IV–2 (a).

(b) HOMOGENEOUS FILM

Another advantage in the use of the partially hydrolyzed polyvinyl-acetate–lithium-chloride solution is that it flows evenly on the smooth polystyrene-resin surface, thereby distributing the lithium chloride uniformly. Lithium chloride and water alone form small globules. With the uniform film, units may be duplicated so that about 75 percent of them will agree in their humidity indications to within ±3 percent. A satisfactory method of coating is described under section II–4 (b).

(c) REDUCTION OF POLARIZATION

A third advantage in the use of the partially hydrolyzed polyvinyl-acetate film proved to be a reduction of the polarization, or counter-electromotive force, set up by the direct current flowing through the unit when used with the radio sonde developed by Diamond, Hinman, and Dunmore.[3] In normal use alternating current may be applied to the units when making measurements, in which case polarization errors are not present. However, it is necessary to use the same type of circuit or indicating instrument as was used in calibrating the units, as the resistance of the unit is a function of the current flowing through it. The coating on the unit behaves like an electrolyte.

[3] H. Diamond, W. S. Hinman, Jr., and F. W. Dunmore, *A method for the investigation of upper-air phenomena and its application to radio meteorography*, J. Research *NBS* **20**, 369–392 (1938) RP1082.

The reason for the reduction of polarization by the polyvinyl-acetate film is not fully understood.

4. METHOD OF MAKING THE HYGROMETER UNITS

(a) CONSTRUCTIONAL DETAILS

A typical unit, as shown in figure 1, consists of 32 inches (about 25 bifilar turns) of 38 AWG bare soft-drawn palladium wire having an ultimate tensile strength of 600 grams. This wire is wound 20 bifilar turns per inch on the polystyrene-coated aluminum tube. (See section II–2 for description of polystyrene coatings.) The tubing is about $1\frac{11}{16}$ inches long with an outside diameter of $\frac{3}{8}$ inch and a wall thickness of 0.01 inch. The insulated washer at one end serves to hold the terminal leads while the split washer at the other end serves to anchor the free ends of the bifilar coil. These washers should be made of a highly water-resistant material, such as polystyrene resin, and should be put on over the polystyrene-resin coat and anchored with a drop or two of the polystyrene solution about $\frac{1}{8}$ inch from the end of the tube. This gives a longer leakage path from the terminals to the aluminum tubing. If sufficient rigidity could be obtained with a unit moulded from polystyrene resin with a wall thickness of 0.02 inch, then the whole unit, washers and all, could be moulded in one piece without the need for the aluminum tubing. High temperatures might cause such a unit to lose shape and thereby loosen the winding. This type of construction is still under consideration.

In order to insure a tight winding, the palladium wires should be heated as they go on to the tubes so that they seat just slightly into the polystyrene-resin surface.

(b) COATING PROCEDURE

In order to obtain units with predetermined operating characteristics, it is important that a standard method of applying the polyvinyl-acetate–lithium-chloride coating be followed. A satisfactory procedure is to mount the units with their longest axis vertical. They are quickly immersed up to the terminal washer in the solution and then withdrawn by a motor-driven device at a constant rate of 1 inch in 12 minutes. The surplus liquid clinging to the lower end of the unit is absorbed with a blotter, and the units are allowed to dry in still air.

(c) AGING

After the units are coated, they must go through an aging period of at least 10 to 14 days before they are ready for use. During this time the resistance of the units continues to decrease until it settles down to a final value (for any given humidity) where it remains for 6 months, at least, which is the longest time a unit has been on test. Recent experiments on 19 units seem to indicate that this aging period may be reduced to 2 days by putting the units in a humidity chamber with air at 60-percent relative humidity and 26° C and continually circulating the air gently over the units.

Attempts to age by baking in an oven in still air at 60° C were not successful.

5. SPECIAL DESIGN FOR COVERING THE FULL HUMIDITY RANGE WITHOUT SWITCHING MEANS

If an attempt were made to cover the full humidity range with a single unit such as shown in figure 1, the variation in resistance of the unit would be so extreme that it would extend outside the normal limits of a measuring device. Furthermore, the excessive current from the measuring circuit through the unit at high humidities would be harmful to the unit.

For the radio sonde the resistance variation for a change in humidity from 5 to 100 percent from +30° to −30° C should not vary outside the limits of 3 megohms to 10,000 ohms. When used in an a-c circuit, such as with a Weston model 764 capacity meter (calibrated to read in ohms), the resistance variation for a change from 5- to 100-percent humidity should be confined within the limits from 8 megohms to 75,000 ohms.

In order to make possible this condition for radio-sonde use, a multiple-unit design with different percentages of LiCl coatings on each unit was devised. By arranging three units in parallel with 1-, 2-, and 3-percent LiCl coatings, respectively,[4] with the proper resistors in series with each, as shown in figure 2, it is possible to confine the resistance variation of the composite unit to the required limits.

For use in an a-c circuit a five-element unit as shown in figures 3 and 4 has been found necessary. In such an arrangement, unit *A*, figure 3, would have a polyvinyl-acetate coating only, *B* a coating of 0.25 percent of LiCl, *C* 0.5 percent of LiCl, *D* 1.0 percent of LiCl, *E* 2.2 percent of LiCl. R_5 is greater than R_4, R_4 than R_3, etc. At the high humidities, units *B*, *C*, *D*, and *E*, although practically shorted, are prevented from causing a short at terminals *F* by resistors R_2, R_3, R_4, and R_5, yet the resultant resistance at *F* will vary through limits below the values of the parallel circuits of R_2, R_3, R_4, and R_5, since unit *A* has resistor R_1, only, in series with it. Thus *A* is the controlling unit at high humidities. On the other hand, at low humidities *A*, *B*, *C*, and *D* are practically open-circuited, whereas R_1, R_2, R_3, R_4, and R_5 are not sufficiently high to prevent the change in resistance of unit *E* from affecting the over-all resistance at *F*. Thus *E* is the controlling unit at low humidities. In a like manner, units *B*, *C*, and *D* become the controlling units in turn at intermediate humidities. See section IV–2(a).

All materials used for mounting and wiring the units for the parallel arrangements must be highly water-resistant.

III. OPERATING CHARACTERISTICS IN D-C RADIO-SONDE CIRCUITS

As the radio-sonde circuits pass pulsating direct current through the electric hygrometer, the characteristics of the unit in such a circuit differ somewhat from those obtained when it is used in a-c circuits. Some polarization exists in d-c circuits, but it is a fixed factor in a given type of circuit and does not change the calibration of the unit appreciably during the period of a flight. The unit appears to have a higher resistance at a given humidity than if measured with alternating current flowing through it, as described under section IV–1.

[4] In this paper 1-, 2-, and 3-percent LiCl units refer to those coated with solutions in the proportion of 1.01, 2.02, and 3.03 ml, respectively, of a saturated solution of LiCl in water at 21° C; to 100 ml of the polyvinyl-acetate–alcohol-water (Solvar) solution. Similarly for other percentages.

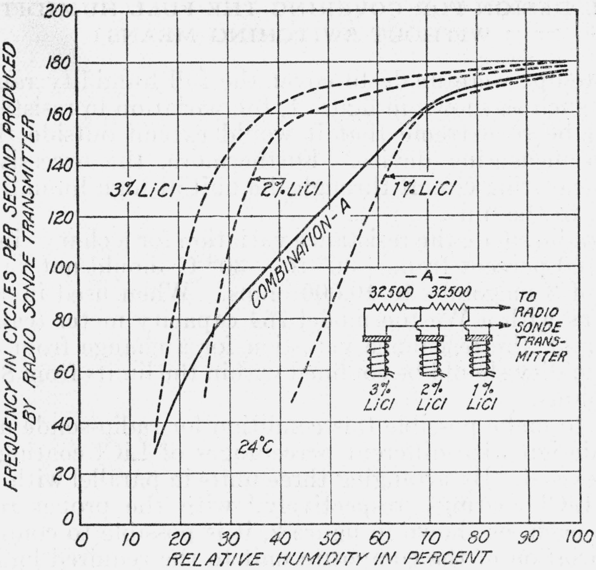

FIGURE 2.—*Circuit arrangement and frequency-humidity characteristics for a three-element electric hygrometer as used in radio sonde.*

Dotted lines show characteristics for individual units. Full line shows characteristic for units connected as shown at *A*.

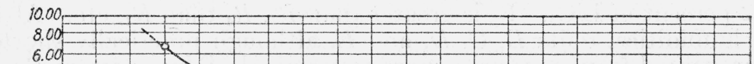

FIGURE 3.—*Five-element electric-hygrometer circuit arrangement with humidity-resistance characteristics (24° C).*

1. THREE-ELEMENT UNIT

For use in the radio-sonde circuit developed for the Navy Department,[5] a three-element unit has been found satisfactory. It consists of three units constructed as outlined under section II–5. Figure 2

[5] See footnote 2, page 703.

shows this circuit arrangement, while figure 5 shows the units mounted on a panel which slides into the sun shield of the radio sonde. The units are coated with a 1-, 2-, and 3-percent lithium-chloride-poly-vinyl-acetate solution respectively. The three units are connected in parallel with 32,500 ohms in series with the 2- and 3-percent units.

2. FREQUENCY-HUMIDITY CHARACTERISTIC

In the radio-sonde circuit the variation in resistance of the electric hygrometer alters the audio frequency generated by a special audio oscillator which in turn modulates the carrier-frequency oscillator.

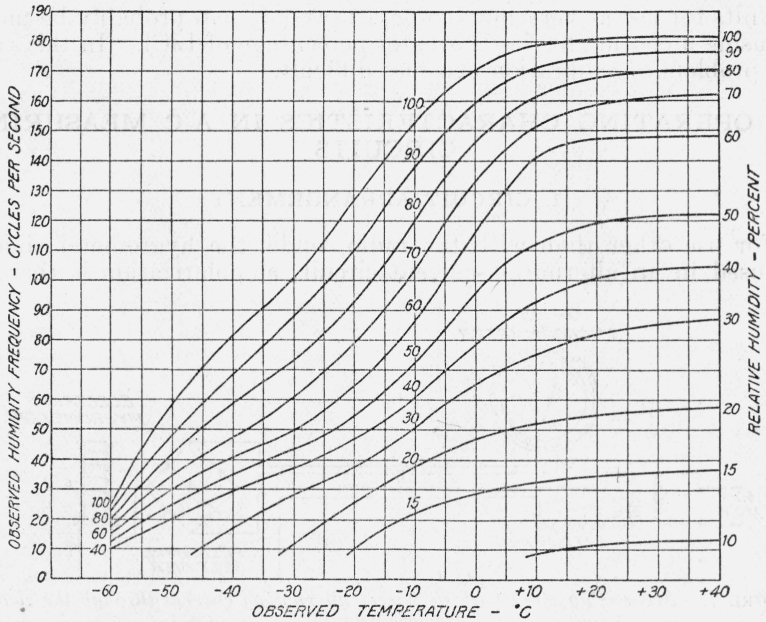

FIGURE 6.—*Graphs for evaluating true humidity from observed humidity (frequency) and temperature.*

This audio note is received on the ground, where it is recorded on a graphical frequency recorder. This record may be interpreted in terms of humidity. In figure 2 are shown in dotted lines the humidity-frequency calibration graphs at 24° C for the individual 1-, 2-, and 3-percent LiCl units when used separately in the radio-sonde circuit. The full-line graph in this figure is for the composite arrangement of the three units at 24° C connected as shown at *A*.

3. TEMPERATURE CORRECTION

The electric hygrometer functions like an electrolyte in that its resistance increases with a decrease in temperature. In radio-sonde use where temperature variations of 100° C are encountered, it is of course necessary to apply a correction to obtain the true humidity. It has not been found possible, even with a composite three-element unit, to cover the full 10- to 100-percent humidity scale, over this extreme temperature range; but it has been feasible, with the composite unit shown in figures 2 and 5 to cover a considerable portion of this range. The family of graphs determined empirically for different temperatures, shown in Figure 6, constitute the standard. These are based on the average of many composite units taken at various low temperatures and having individual units with characteristics at 24° C., as shown in figure 2. Knowing the temperature (as is the case with a radio sonde), the humidity is obtained from the frequency-humidity graph for that temperature.

If the method previously outlined for making and coating the units is carefully followed, it is possible to obtain about 75 percent of the units which will fall within ±3 percent of the standard graph.

For use at varying temperatures other than with the radio sonde, a multiscale indicating instrument may be used—see section V-3.

Units for use at very low temperatures only can probably be made by using a coating having a greater percentage of LiCl. In this case the problem of calibration becomes difficult.

IV. OPERATING CHARACTERISTICS IN A-C MEASURING CIRCUITS

1. CIRCUIT ARRANGEMENT

For use other than with the radio sonde, the hygrometer should be used in an alternating-current circuit, as polarization is thereby

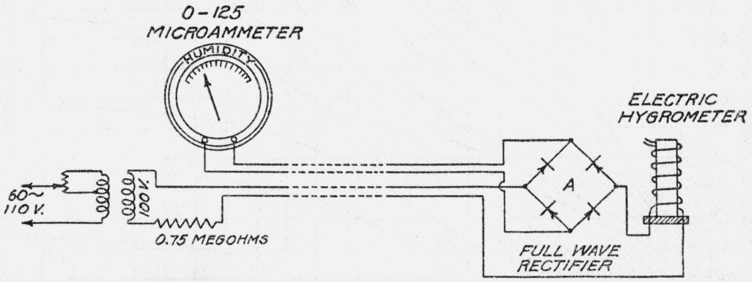

FIGURE 7.—*Measuring circuit which passes alternating current through the electric hygrometer.*

eliminated. For the radio sonde this is not a serious factor, as it does not alter the operation of the hygrometer sufficiently to change the calibration during the period of time (1 hour maximum) in which the unit is used. An a-c circuit arrangement is shown in figure 7. Here the unit is put across about a 100-volt 60-cycle alternating current with 0.75 megohm and the input of a full-wave copper-oxide rectifier in series with it. The d-c output of the rectifier is connected to a microammeter having a scale division of 0 to 125. The microammeter scale may be calibrated in terms of percentage of relative humidity. The voltage impressed on this circuit arrangement should, of course, be kept at 100. The above circuit arrangement is that obtained when using the $C/1,000$ scale of a Weston model 764 capacity meter, the electric hygrometer taking the place of the condenser to be measured. This capacity meter may be used as an ohmmeter in this fashion, since it is measuring only ohmic resistance in a nonreactive circuit. This circuit arrangement was adopted because it passes alternating current through the unit, and this current is never greater than 200 microamperes. The current must be kept under this value, as heavy currents would alter the calibration. Information as to the constancy of calibration of a unit if the current is allowed to flow through it continuously is not yet available, although a current of 100 microamperes flowing through a unit steadily for several days seemed to have little effect. It is safer, until further data are available, to read humidity by allowing current to flow through the unit only for the time necessary to take a reading, or for control purposes a timing switch could connect the unit into circuit only for a time long enough to affect the control mechanism. If this is not feasible, the hygrometer unit could be left in the control circuit continually by placing it in the input circuit of a suitable electron-tube amplifier with the indicating or control device in the output circuit. In such a circuit the current through the unit would be kept within safe limits.

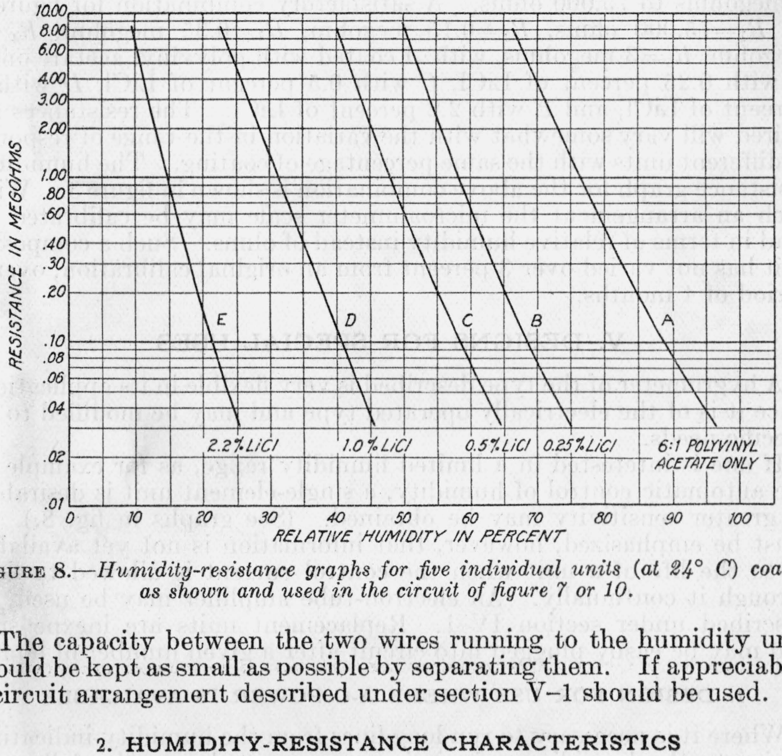

FIGURE 8.—*Humidity-resistance graphs for five individual units (at 24° C) coated as shown and used in the circuit of figure 7 or 10.*

The capacity between the two wires running to the humidity unit should be kept as small as possible by separating them. If appreciable, a circuit arrangement described under section V–1 should be used.

2. HUMIDITY-RESISTANCE CHARACTERISTICS

(a) SINGLE-UNIT CHARACTERISTICS

Using such a circuit arrangement with the capacity meter calibrated to read in ohms instead of microfarads, the humidity-resistance characteristics shown in figure 8 were obtained. Here graphs *B* to *E* are for standard units with a 0.25-, 0.5-, 1-, and 2.2-percent LiCl coating, respectively. Graph *A* is that obtained with the polyvinylacetate film alone, without LiCl.

The coatings on these units were so chosen that each unit covers a different range of humidity when varying over the same resistance. Thus, considering a resistance variation from 8 megohms to 75,000 ohms, unit *E* covers from 10 to 22 percent, unit *D* 22 to 42 percent, unit *C* 40 to 60 percent, unit *B* 50 to 70 percent, unit *A* 66 to 91 percent. A percentage of LiCl for *B* to give less overlap might be 0.10 percent. In this case *A* might be coated with a somewhat diluted polyvinyl-acetate solution, which should cause the unit to register up to 100 percent.

(b) COMPOSITE-UNIT ARRANGEMENT

While individual units as described above should find some applications (see section V, Design for Special Uses), it is evident from figure 8 that no one unit will cover the full humidity scale. However, by putting the units *A* to *E* (fig. 8) in parallel each with its proper series resistor, as shown in figure 3, it is possible to obtain in effect a single unit which covers the humidity range from 10 to 100 percent at room temperatures, with resistance variation confined within the limits of 8 megohms to 75,000 ohms. A satisfactory combination for figure 3 is: R_1=75,000 ohms, R_2=0.15 megohm, R_3=0.35 megohm, R_4=1 megohm, R_5=3 megohms, with *A* coated with polyvinyl acetate only, *B* with 0.25 percent of LiCl, *C* with 0.5 percent of LiCl, *D* with 1 percent of LiCl, and *E* with 2.2 percent of LiCl. The resistances required will vary somewhat with the variation in the range of response of different units with the same percentage of coating. The humidity-resistance graph for the above combination is shown in figure 3. With such an arrangement the microammeter scale may be calibrated to read in terms of relative humidity instead of ohms. Such a composite unit has not varied over 3 percent from an original calibration, over a period of 4 months.

V. DESIGNS FOR SPECIAL USES

A hygrometer of the type described is very flexible in its application, since it is of the electrically operated type and may be modified to fit specific needs.

If one is interested in a limited humidity range, as for example in the automatic control of humidity, a single-element unit is desirable, as greater sensitivity may be obtained. (See graphs in fig. 8.) It must be emphasized, however, that information is not yet available as to the life of a unit when the control current is allowed to flow through it continually. An electron-tube amplifier may be used, as described under section IV–1. Replacement units are inexpensive and may be easily plugged into circuit after a given number of hours.

1. DESIGN FOR USE WHERE A-C POWER IS AVAILABLE

Where it is necessary to run long lines from the humidity-indicating device to the humidity unit, it is necessary to locate the full-wave oxide rectifier, *A*, as shown in figure 7, at the location of the humidity unit and run the d-c output of the rectifier back to the location where the humidity is to be registered. This method is necessary, as the alternating current flowing across the capacity of a long line to the humidity unit would register on the indicating meter.

2. BATTERY-OPERATED UNIT

For portable use and in places remote from a 60-cycle a-c supply a measuring circuit may be used in which the alternating current for operating the unit is obtained from an electron-tube oscillator operating at 60 cycles. It may be powered from small dry cells such as are used in portable radio sets.

3. MULTISCALE UNIT FOR CONDITIONS OF WIDE TEMPERATURE VARIATIONS

For registering humidity under a condition of wide variation in temperature, a multiscale indicator such as shown in figure 9 might be used. Knowing the temperature, the humidity scale for that temperature is used.

A second type of multiscale arrangement for use at room temperatures is shown in figure 10. Here individual units with different sensitivities are connected to the measuring instrument (Weston

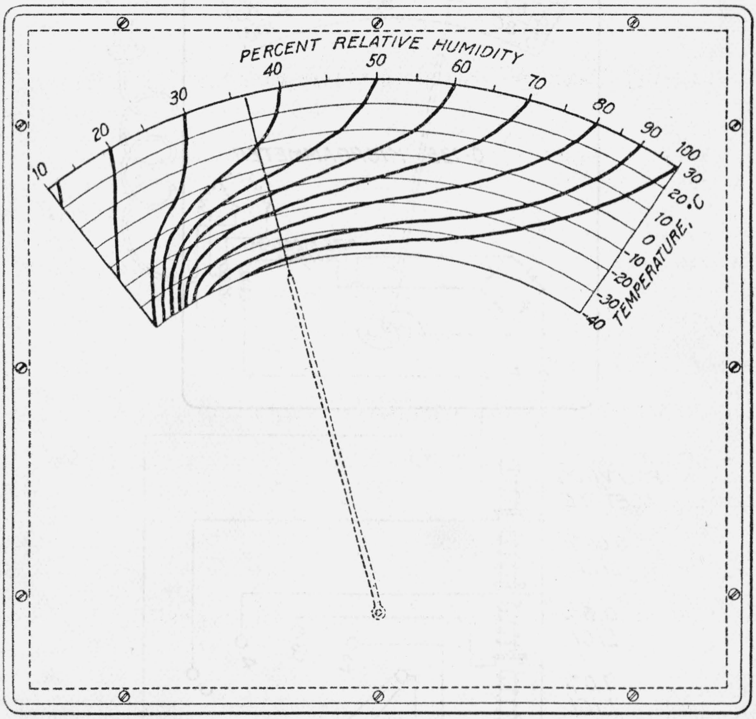

FIGURE 9.—*Proposed scale arrangement for temperature correction.*

model 764 capacity meter set at minimum capacity setting) by means of a five-point switch. Depending upon the humidity, the particular unit may be selected which brings the meter reading within the scale. Thus if the humidity is between 10 and 20 percent, switch contact 1 and scale 1 will be used. This arrangement has the advantage of very open scale, allowing greater precision in humidity readings.

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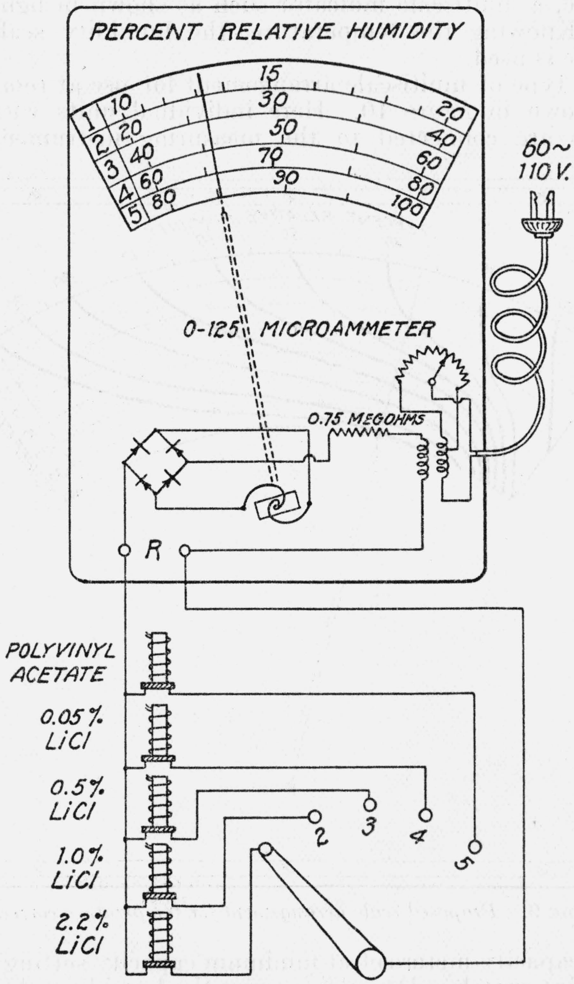

FIGURE 10.—*Multiscale arrangement for use at room temperatures, using five electric-hygrometer units each covering a different humidity range.*

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