RESISTANCE OF HIGH TENSION PORCELAIN INSULATORS

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

California Institute of Technology,
Pasadena, California, 1928.

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INTRODUCTION.

High tension insulators are generally built of several porcelain discs in series, the discs being connected by galvanized steel hardware. When alternating voltage is impressed across such a string the voltage is not distributed symmetrically because the charging current is not the same through the string. There is capacitance from each connector to the next, from each connector to the ground and to the line wire, as well as capacitance from one connector to one which is not adjacent. If the voltage impressed is direct and all the units or discs are exactly alike, then such an ~~air~~ insulator string would have across each unit the same value of voltage. A certain leakage current flows through each insulator, and the d. c. voltage across each unit will be the leakage current multiplied by the resistance of each unit.

In the transmission of high-voltage direct current, such as the Thury system[1] found in Europe, high-tension porcelain insulators can be used to insulate the line from the ground. Such insulators are exposed to changing weather

[1] Electrical World, Vol. 63, Page 583.

conditions of humidity and temperature. Also, these insulators on account of being subjected to mechanical stresses, electrical stresses, and repeated temperature cycles, depreciate in resistance, become faulty, and unless detected may interfere with the operation of the transmission system. If the resistance of the insulators forming the string, and the effect produced on the resistance by temperature, humidity, etcetera, are known then it is possible to predict to a certain degree of approximation what service the insulators can give. Besides determining the condition of such insulators, a knowledge of the resistance would give a basis for comparing different types of insulators, and likewise would furnish a means for arriving at the voltage distribution of different makes and types and the uniformity with which a given type could be expected to run.

In the investigation carried out, the results of which are tabulated below, particular attention was given to the determination of the surface and interior resistance, and the effect of change of temperature and humidity on the electrical resistance of various types and makes of high-tension porcelain insulators. The humidity effect is not an internal one, but manifests itself by changing the surface of the insulator so that a greater freedom is given to the flow of current over the surface between the cap and the pin of the insulator.

THE METHOD AND APPARATUS.

The method employed to determine the resistance of the insulators was similar to that used by Mr. F. Hamburger,[1] California Institute of Technology. Briefly, it consists in applying a known rectified alternating voltage across the insulator whose resistance is being investigated, which is connected in series with a standard condenser. The current that leaks through the insulator is allowed to accumulate on the condenser which is discharged after a known time into a voltage-calibrated ballistic galvanometer. The capacity effect of the insulator is disregarded.

A sketch of the apparatus and connections is given below in Figure 1.

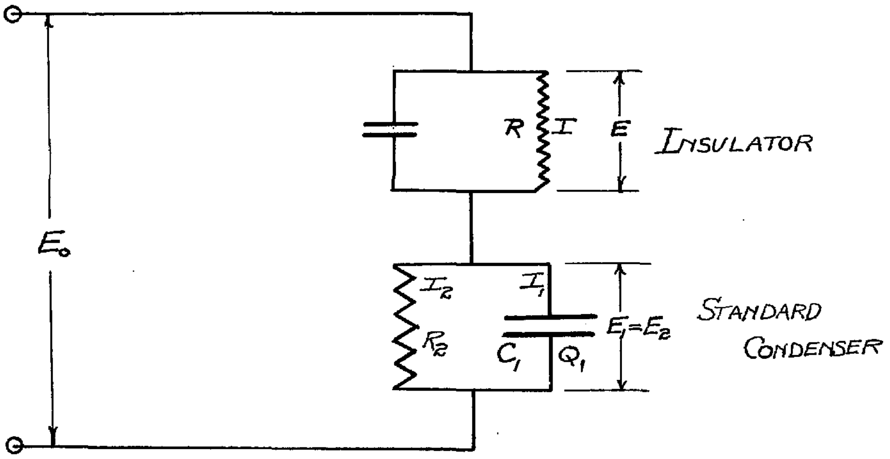

Figure 1.

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[1] A Method of Measuring Extremely High Resistances, F. Hamburger, C. I. T. Library.

R = Leakage resistance of the insulator

E_0 = Rectified a. c. voltage

E = Voltage across insulator

E_1 = E_2 = Voltage across terminals of standard condenser.

C_1 = Capacitance of standard condenser

I = Leakage current of the insulator

I_1 = Charging current of the condenser

I_2 = Leakage current from one plate of the condenser to the other.

According to the above mentioned paper the following equation expresses the relation between leakage current and quantities which enter into its computation.

$$I = \frac{Q_1}{C_1R_2} \times \frac{1}{1 - e^{-\frac{t}{c_1R_2}}} \qquad (1)$$

Since $\frac{Q_1}{C_1} = E_1 = E_2$, then the above equation becomes

$$I = \frac{E_1}{R_2} \times \frac{1}{1 - e^{-\frac{t}{c_1R_2}}} \qquad (2)$$

$$\begin{aligned} E_0 &= E + I_2R_2 \\ &= IR + I(1 - e^{-\frac{t}{c_1R_2}}) \end{aligned} \qquad (3)$$

whence

$$R = \frac{E_o - I(1 - e^{-\frac{t}{C_1R_2}})}{I} \qquad (4)$$

Hamburger has shown that the second term in the numerator of equation (4) amounts to only about ½% of E_o and therefore is negligible in comparison with E_o. Therefore equation (4) becomes

$$R = \frac{E_o}{I}\text{, approximately.}$$

In the expression $(1 - e^{-\delta})$, if δ is small, then $(1 - e^{-\delta})$ closely approximates the value δ. In this investigation $C_1 = 10^{-6}$ microfarad, $R_2 = 20 \times 10^{10}$ ohms, approximately, and t, say, equals 1800 seconds, then δ is equal to 0.009. Therefore $(1 - e^{-\frac{t}{C_1R_2}})$ can be put equal to $\frac{t}{C_1R_2}$ and since $\frac{Q_1}{C_1} = E_1 = E_2$, equation (1) results in

$$I = \frac{E_1}{R_2} \times \frac{C_1R_2}{t} = E_1 \times \frac{C_1}{t}$$

and equation (4) becomes

$$R = \frac{E_o}{I} = \frac{E_o}{E_1} \times \frac{t}{C_1}\text{, approximately.} \qquad (5)$$

Equation (5) was used throughout the calculations to determine R.

The apparatus used was the same as that employed by Hamburger, with two exceptions. For d. c. power supply a UX-281 radiotron was used as rectifier instead of a 3-element vacuum tube with grid and filament connected together. The radiotron, which was a 750-volt tube was made available for 3200 volts by boring a small hole in the base and forcing transformer oil through it into the cavity between the socket and glass ~~vacuum~~. The tube was placed in a vertical position, base downwards, in a jar containing transformer oil, so that the oil reached up about one-third of the height of the tube. The presence of the oil furnished the necessary insulation between the lead-in wires.

As with Hamburger's apparatus, the insulator and standard condenser were placed in separate compartments with an "insulating" compartment between. This insulating compartment prevented any change in the condenser due to a change of temperature and humidity in the insulator compartment. Particular care was taken that the wire connecting the insulator and condenser did not touch the box at any point and allow leakage from the wire to the box. The holes containing the bakelite bushings through which the bus bar passed were lined with copper and grounded. This prevented any leakage through the bushing from the bar getting to the condenser by way of the wood of the box.

The relative humidity was determined from readings furnished by a Lambrecht Wet and Dry Aspiration Psychrometer which was placed in the enclosure containing the insulator. The thermometers projected through holes in the top of the box. The wind-wheel was driven by a shaft coming through the side of the box and connected to a small motor. A motor speed of between one and two revolutions per second gave the required velocity of air flow by the wet bulb and thus permitted the use of the "Psychrometric Tables" by C. F. Marvin (U. S. Department of Agriculture, Weather Bureau) and the Smithsonian Physical Tables, Seventh edition, Second Reprint. An increase in humidity was obtained by electrically heating a high resistance coil submerged in a small vessel of water in the enclosure. To lower the humidity the box was opened to the atmosphere.

The insulators tested in the investigation were those selected at random from a number which had been lying in a dry atmosphere for months and thus were air-dried.

Before being tested the insulators with one exception were cleaned and rubbed with alcohol in order to get an insulator surface as free as possible from dirt and moisture. (One insulator was given a test with its surface untouched.) The surface of an uncleaned insulator may be considered as covered with a poor conducting layer formed by the accumulation of dirt and moisture. Surface conditions influence to a great extent the resistance characteristic of the insulator. This is clearly demonstrated in readings below. The insulator was suspended from the bus bar, the box closed, and stable conditions of temperature and humidity attained before the voltage was applied. The voltage was applied for a known time; the charge which accumulated on the standard condenser was discharged into the ballistic galvanometer and the deflection noted. From a voltage-deflection calibration curve there was read the voltage existing on the condenser before discharge. A solution of equation (5) with inserted values as obtained gave the resistance of the insulator.

The temperature of the insulator was taken as the temperature of the enclosure holding the insulator. Enough time was given after a change of temperature or humidity was made, to allow the insulator to come to the stable conditions of the enclosure. By the manipulation of suitably arranged switches the temperature could be maintained within half a degree and the humidity kept practically constant.

In the comparison of the various types of insulators it was considered that three different temperatures for each type were sufficient to furnish a basis for comparison.

For some of the readings a one-inch copper band was placed around the insulator so as to touch the outer skirt and arranged so that good contact was made with the insulator porcelain. This copper band was connected to earth, or the bus bar, or the standard condenser, as desired. The readings thus obtained made available the resistance over the surface of the porcelain and furnished interesting information regarding the effect of the surface on the resistance of the insulator.

In recording the Resistance-Humidity values, both the absolute and relative humidities are plotted.

COMPUTATIONS.

In a single run the following readings were taken and recorded: Time, Galvanometer Deflection, Static Voltmeter Scale Reading at beginning and end of run, Temperature of Dry and Wet Bulb Thermometers, and Atmospheric Pressure.

The galvanometer deflection on the calibration curve gave the value of $E_1 = E_2$ in volts. The voltmeter scale reading gave the voltage E_0 in volts across the insulator and condenser. The atmospheric pressure was necessary for the psychrometric tables. The difference between the dry and wet bulb thermometer readings together with the dry bulb thermometer reading furnished values for the determination of the relative humidity for any particular atmospheric pressure, using the psychrometric tables mentioned above.

To change relative humidity in per cent to absolute humidity in grams per cubic meter, the Smithsonian table 259, page 235, Seventh edition, Second reprint, was used. A curve was drawn showing the relation between density in grams per cubic meter and temperature in degrees Fahrenheit for temperatures between 30° F and 140° F. From this curve the absolute humidity for any particular temperature between 30° F and 140° F could be accurately obtained. Since these values are for saturated steam then the absolute humidity can be found, using the known relation that absolute humidity = maximum humidity times relative humidity.

The capacity of the standard condenser was 1 microfarad.

When insulating material is subjected to a continuous voltage, the current at first is a capacity current which continues thereafter with decreasing intensity over periods of time which vary with the kind of material.[1] The total current at any instant after the continuous current is applied is made up of the decreasing capacity current and the steady current due to the conductivity. After a time the capacity current approaches zero and the true conductivity may be measured after the capacity current has died out. This capacity current in this piece of work was considered of no consequence because, if the ballistic galvanometer was in

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[1] Electrical World, Vol. 82, p. 1007.

the circuit when the voltage was applied, a slight deflection was registered, which in all the cases observed amounted to only about 0.1 volt. The influence of this voltage was considered negligible and no correction was made in the voltage at the end of the run.

The relation existing between the resistance and temperature of the insulator with constant humidity is represented by a logarithmic curve of the form $R = Ae^{-KT}$; where R = resistance; A = a constant; K = another constant, the slope; and T = temperature. Since the logarithmic curve drawn on semi-logarithmic paper is found to be a straight line, then there exists the following relation:

$$\frac{d(\log_e R)}{d(T)} = K$$

Then, $\log_e R = KT - K^1$

when $T = 0$, $K^1 = \log_e R$.

Therefore in the case of the Resistance-Temperature Curve 1, Curve Sheet 1, for $T = 0$, $R = 5.5 \times 10^{13}$,

then $K^1 = \log_e 5.5 \times 10^{13} = 31.64$.

Taking any value of R and T on the curve we get, for instance,

when $T = 90^\circ$ and $R = 4 \times 10^{11}$, that

$$\log_e 4 \times 10^{11} = 31.64 - K \times 90.$$

Whence $K = .0552$. Therefore the equation of the curve is

$$\log_e R = 31.64 - .0552T$$

or

$$R = 31.64\, e^{-.0552T}$$

DISCUSSION OF CURVES.

On Curve Sheet 1 are found two curves. Curve 1 shows the relation between the temperature and resistance, with constant humidity and with no copper band on the insulator. Curve 2 is for the same conditions, excepting that the copper band on the insulator was connected to ground. There is not much variation in the two curves, which shows that for a constant humidity of 52 per cent the main resistance of the insulator was an internal one. Because the curves cross each other does not mean that the resistance for the lower temperatures is smaller when the copper band is on the insulator. It is quite possible that another set of readings taken later would give curves lying practically parallel to one another and perhaps quite close. This conclusion is based on subsequent work. Curve 1 was used to determine the constants in the logarithmic law established on page 11.

Curve Sheet 2 shows the relations existing between resistance and absolute humidity with temperature constant, for various temperatures. Curve Sheet 3 shows the same relations excepting that relative humidity is substituted for absolute humidity. In both curves the resistance drops with increase in humidity. It is difficult to tell why this should be the case. It seems that for humidities up to the point where a film of moisture gathers on the insulator the resistance should remain practically constant when there is no change in temperature. In the curves on Sheet 3 the resistance drops very rapidly after a high humidity is reached, excepting for the 89° and 110° curves. The change is indicated by broken lines because the readings of resistance at high humidities are doubtful. As many as ten readings have been taken for one high humidity, but no two readings checked and there was no regular change between them as they decreased and increased and decreased again. It is quite obvious that up to a fairly high humidity the points fall well on a straight line, showing that there is a logarithmic relation between resistance and humidity. Following the same procedure as in finding the resistance-temperature equation, the following law is found for the 110° curve:

$$\log_e R = 26.61 - .024H$$

where H = relative humidity in per cent. Since the curves are not parallel this law will not hold for other temperatures; however, the laws for the various temperatures will have constants in the neighborhood of those in the equation above.

If the absolute humidity is used instead of relative humidity the equation derived from the 110° curve on Curve Sheet 2 is

$$\log_e R = 26.56 - .0382H$$

where H = absolute humidity in grams per cubic meter.

The curves on Curve Sheet 2 are not parallel except in pairs, consequently the last derived equation will not show the relations existing between resistance and absolute humidity for the temperatures different from 110°. The two last equations do not vary considerably from each other, showing that the resistance-absolute humidity relation is of much the same character as the resistance-relative humidity relation.

The curves on Curve Sheets 4 and 5 show the relations between the resistance of the insulator and relative humidity and absolute humidity respectively, the insulator having no copper band attached. On account of the variation in readings of humidity for any particular temperature, it is possible that the curves give only a poor approximation of actual conditions. There is a certain similarity between the curves, but no explanation seems feasible for the peculiarity of the shape of the individual curves. No general equation will describe the curves as it does in the case of resistance-temperature relations. Since no copper band is present to conduct away any surface current the resistance as shown by the curves is the combined resistance of surface and porcelain between cap and pin.

Curves 1 and 2 on Curve Sheet 6 are of interest only in showing that for constant humidity there is little change in resistance with change in temperature whether the band is connected to the bus bar or to the pin, the insulator being suspended from the bus bar in both cases. Curve 1, Sheet 1, which is not shown here, fits closely to these curves. Curve 3 results from readings taken with the insulator cap insulated from the bus bar and the copper band connected to the bus bar. Such readings will thus give the resistance over the under surface of the insulator. Of course it is possible that some of the current leaks through the porcelain, as well as over the under surface. Curve 4 shows the relation when the insulator is suspended from the bus bar and the band is connected to the standard condenser; no connection exists between the pin and band except through the porcelain. If there is no leakage through the porcelain between cap and band, then the values shown by curve are values of surface resistance between cap and band. Since Curves 3 and 4 are not parallel apparently there is an internal change with one or both connections, or more with one than with the other. Adding these two curves gives values of total resistance; and since this sum is much larger than the resistance of the insulator porcelain between cap and pin, one is justified in concluding that the sum is the total surface resistance.

From the 100° curve on Sheet 3 for 52% relative humidity the resistance is 238,000 megohms, which is the internal resistance between cap and pin. For the same temperatures and humidity from Curves on Sheet 6, the total surface resistance is (3,360,000 + 1,170,000) = 4,530,000 megohms. The internal resistance and surface are in parallel when the insulator is in normal operation; then for the values of temperature and humidity chosen the surface resistance is so large in comparison with the internal resistance that practically all of the leakage current goes through the porcelain between pin and cap. For high humidities such a condition of affairs does not exist and the surface leakage is considerable.

With the copper band on the insulator, the insulator suspended from the bus bar, and the band connected to the standard condenser with no connection between pin and condenser, a set of readings was taken to get the relation between resistance and humidity with constant temperature. Three different temperatures were chosen. The curves of the readings thus obtained are shown on Curve Sheets 7 and 8, and show the changes in the resistance with humidity of the upper surface of the insulator. The curves on each sheet bear a certain resemblance to each other, but there seems to be no plausible explanation of why the humidity should have such a peculiar effect on the resistance. Further work will have to be carried out in order to find the reason for such an effect.

For all readings taken up to this point the same insulator had been used. The insulator at all times was clean of dust and free from moisture, except in the humidity experiments where moisture did accumulate on the surface due to the change of humidity conditions in the enclosure. At this point an insulator of the same type as the one previously used, namely, a Westinghouse Type, Number 631, was selected at random from a number that had been lying in a dry room for considerable time, at least a year, and there had gathered over its surface a film of dust and dirt. Without disturbing this film of dust and dirt, the insulator was suspended from the bus bar in the enclosure and first the resistance-temperature relation obtained, and second the resistance-humidity relation. The insulator was then cleaned of dust and moisture and the above experiments repeated. The curves on Curve Sheet 9 show the decided change when the insulator was cleaned. As would be expected there was considerable variation in readings for any particular temperature when the insulator had its film of dust. See Curve 1. For some temperature below 70° F the curves come together, which indicates that for these temperatures the surface resistance is not a factor to consider when speaking of the insulator resistance, but that the leakage current finds its way through the porcelain between the cap and pin.

The resistance-humidity relation is not given in curve form, but the readings are tabulated in Table I.

For the final test a number of insulators of various types and makes were selected at random from the Southern California Edison Company's high tension laboratory where they had been air-drying for a number of months, and compared as to change in resistance caused by a change in temperature. The insulators were cleaned of dust and dirt and rubbed with alcohol to remove the surface moisture. Three different temperatures were decided on because it was thought that a fair comparison could be made using temperatures about 30° apart. The readings obtained are included below in Table II.

Insulators of the same type in some cases vary considerably in resistance, while some insulators of different types have much the same resistance under the same conditions. With the number of insulators taken, there was no regular change between the various makes for the same change of temperature. In some, the temperature had greater effect than in others.

A single-skirt type and a four-skirt type made by the Lapp Company were compared as to change in resistance due to change in humidity and the results of the comparison are included in Table III. For the low humidity, the single-skirt type has a much higher resistance, but suffers considerable reduction in resistance for high humidity. Therefore where a moisture accumulation would be the prevalent condition the four-skirt type would offer the greater resistance. This type is known as a high strength fog type. The readings indicate that it is living up to its name.

Table IV shows the readings taken on an insulator before and after immersion in water for 96 hours for three different temperatures. For the 100° set of readings, the resistance is practically the same in both cases, showing that there was no change due to absorption of water by the porcelain.

An Ohio Brass insulator which had developed a radial crack in the porcelain from the pin to the outer edge was found to have a resistance of about 170 megohms. This crack which showed only on the lower side and extended only in one radial direction was sufficient to cause a tremendous drop in the resistance and, of course, would make the insulator of no use on a transmission line.

Many thanks are given by the author to Dr. S. S. Mackeown for his advice and help throughout the investigation.

TABLE I.

Resistance-Humidity Data.
Insulator No. 3, Westinghouse Type 631.

Temperature of Enclosure °F.	Relative Humidity Per Cent	Absolute Humidity Gms./C.M.	Resistance--Megohms	
			Insulator Unclean	Insulator Clean
70	50	9.0	1,170,000	2,040,000
70	50	9.0	1,080,000	2,340,000
70	73	13.87	4,050	471,000
70	73	13.87	4,450	445,000
90	37	12.40	586,000	865,000
90	37	12.40	636,000	854,000
90	50	16.75	113,000	563,000
90	50	16.75	140,000	664,000
90	50	16.75	114,000	718,000
90	62	20.77	12,800	437,000
90	62	20.77	15,400	523,000
90	62	20.77	16,000	470,000
90	71	23.79	2,260	120,000
90	71	23.79	1,540	108,000

TABLE II.

Comparison of Resistance of Different Types of Insulators
Resistance-Temperature Data.
Constant Relative Humidity: 51%

Laboratory No. of Insulator	Type of Insulator	Temperature of Enclosure °F.	Resistance Megohms
3	Westinghouse, No. 631	71	2,140,000
		71	2,060,000
		100	483,000
		100	510,000
		130	86,000
		130	88,000
4	Westinghouse, No. 631	74	1,830,000
		74	1,770,000
		100	425,000
		100	450,000
		130	54,000
		130	58,600
		130	58,500
5	Westinghouse, No. 631	72	1,920,000
		72	2,130,000
		100	448,000
		100	460,000
		130	69,000
		130	79,000
		130	79,000
6	Locke, Old Type No. 2335	76	1,540,000
		76	1,720,000
		100	482,000
		100	476,000
		130	90,000
		130	110,000
7	Lapp, Single Skirt No. 2300	72	3,580,000
		72	3,860,000
		100	1,000,000
		100	963,000
		130	130,000
		130	210,000
		130	192,000

TABLE II (Continued)

Laboratory No. of Insulator	Type of Insulator	Temperature of Enclosure °F	Resistance Megohms
8	Jeffrey-DeWitt, Type A 259	74	1,720,000
		74	1,840,000
		100	258,000
		100	304,000
		100	260,000
		100	240,000
		130	89,500
		130	92,100
		130	89,500
9	Jeffrey-DeWitt, Type A259	75	2,050,000
		75	2,220,000
		100	378,000
		100	360,000
		130	62,300
		130	65,500
		130	66,000
11	Pinco	73	1,050,000
		73	1,030,000
		100	296,000
		100	289,000
		130	53,800
		130	54,600
		130	59,000
		130	58,200
12	Locke, New Type	74	2,220,000
		74	2,320,000
		100	560,000
		100	591,000
		130	125,000
		130	118,000
		130	111,000
15	Thomas	71	1,160,000
		71	1,210,000
		100	298,000
		100	290,000
		130	44,500
		130	58,500
		130	52,000

TABLE II (Continued)

Laboratory No. of Insulator	Type of Insulator	Temperature of Enclosure °F.	Resistance Megohms
16	Locke	71	1,240,000
		71	1,520,000
		71	1,660,000
		100	368,000
		100	400,000
		100	420,000
		130	49,500
		130	56,000
		130	53,000
17	Lapp, Four-Skirt High Strength Fog Type.	71	1,270,000
		71	1,550,000
		71	1,350,000
		71	1,600,000
		100	350,000
		100	360,000
		130	46,000
		130	47,300
		130	51,400
		130	46,500
18	Blue Core	71	1,420,000
		71	1,630,000
		71	1,550,000
		100	405,000
		100	415,000
		130	73,500
		130	72,500
		130	74,000
		130	71,500
19	Ohio Brass	71	554,000
		71	592,000
		100	160,000
		100	161,000
		130	30,400
		130	32,000
		130	29,400

TABLE III.

Comparison of Two Types of Lapp Insulators:
Single and Four-Skirt Type.
Constant Temperature of Enclosure: 80°F.

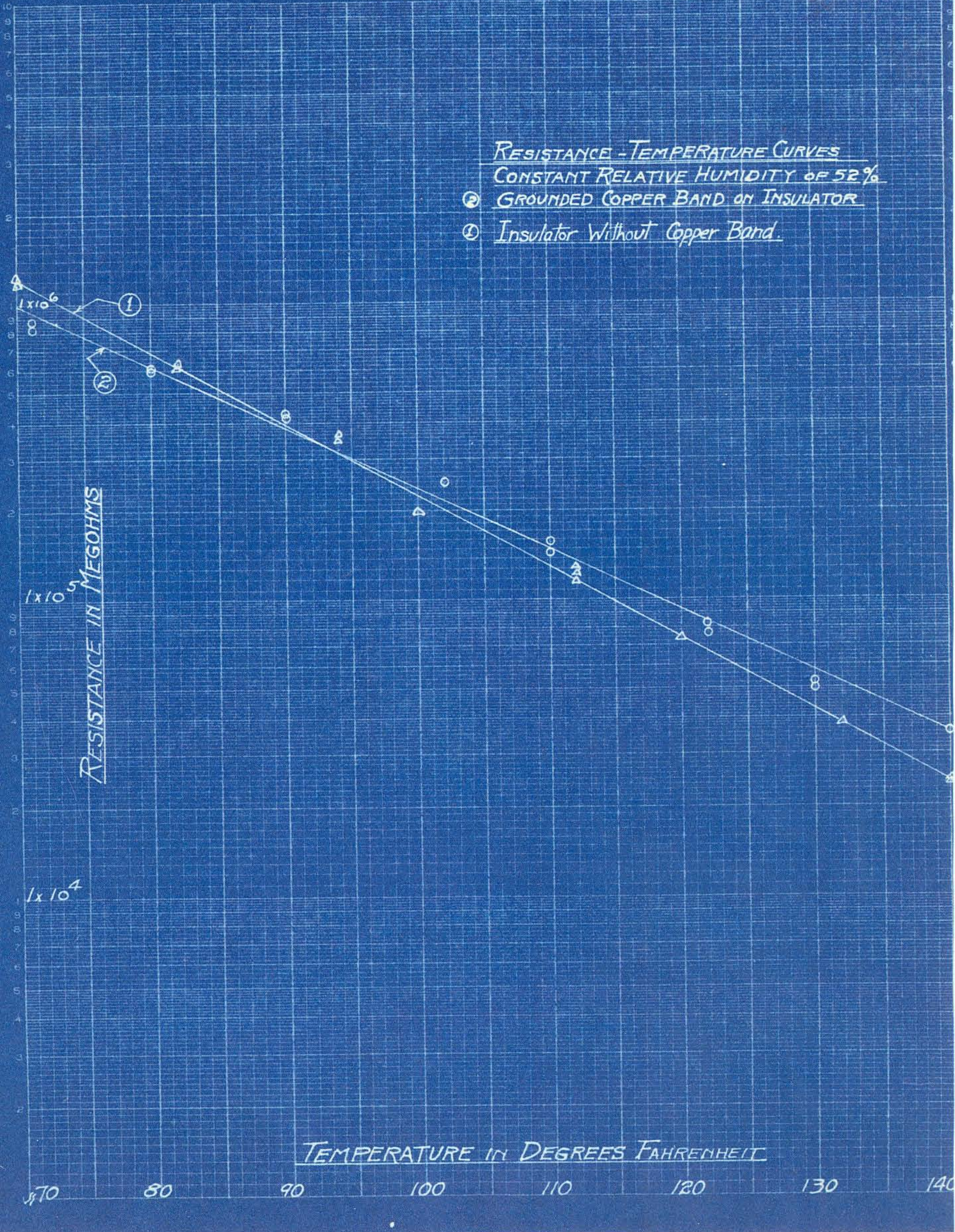
Relative Humidity Per Cent	Absolute Humidity Grams per C. M.	Resistance--Megohms Single-Skirt Lab. No. 7	Resistance--Megohms Four-Skirt Lab. No. 17
47	11.75	1,910,000	825,000
47	11.75	1,950,000	955,000
57	14.25	1,350,000	770,000
57	14.25	1,470,000	710,000
64	16.00	1,350,000	684,000
64	16.00	1,380,000	705,000
72	18.00	444,000	621,000
72	18.00	465,000	652,000
83	20.75	6,940	166,000
83	20.75	7,100	158,000
87	21.75	----	65,000
87	21.75	----	52,300

TABLE IV.

Readings Before and After 96 Hour Immersion of Insulator No. 3, Westinghouse Type 631.
Relative Humidity: 51%

Temperature of Enclosure Degrees Fahrenheit.	Resistance--Megohms	
	Before Immersion	After Immersion
71	2,140,000	--------
71	2,060,000	--------
75	---------	1,310,000
75	---------	1,370,000
100	483,000	484,000
100	510,000	462,000
130	86,000	125,000
130	88,000	123,000

CURVE SHEET #1



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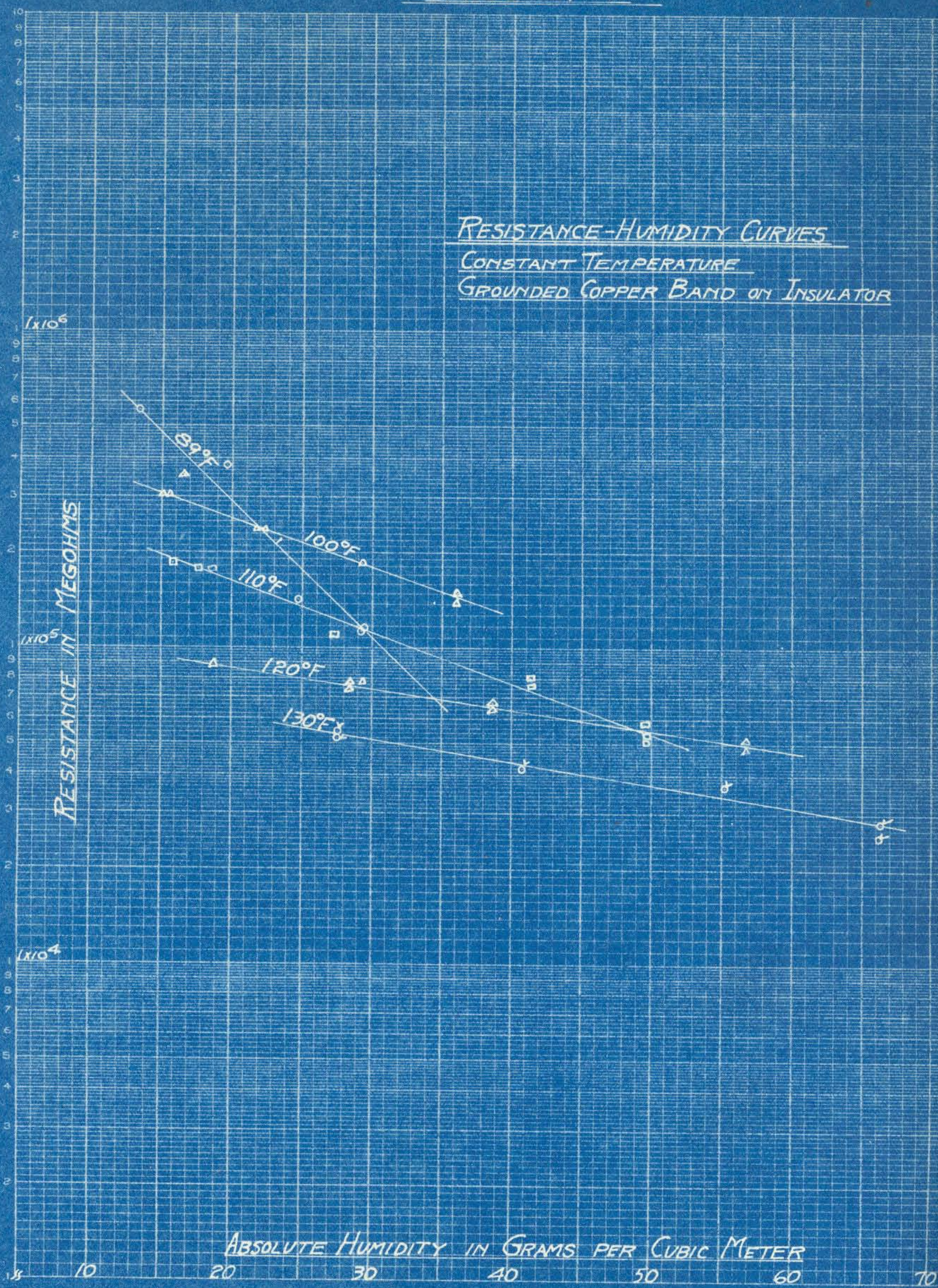
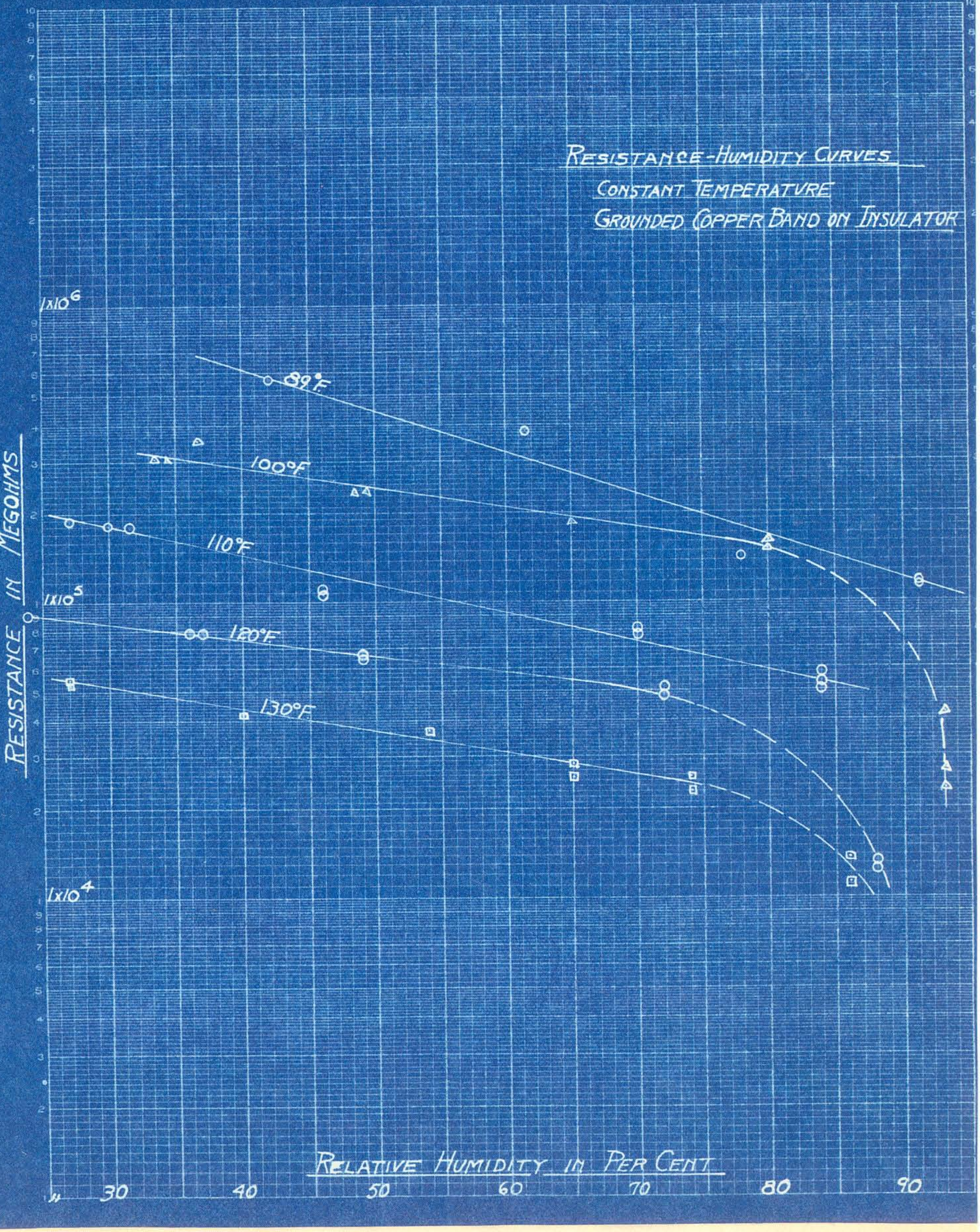


RESISTANCE-HUMIDITY CURVES

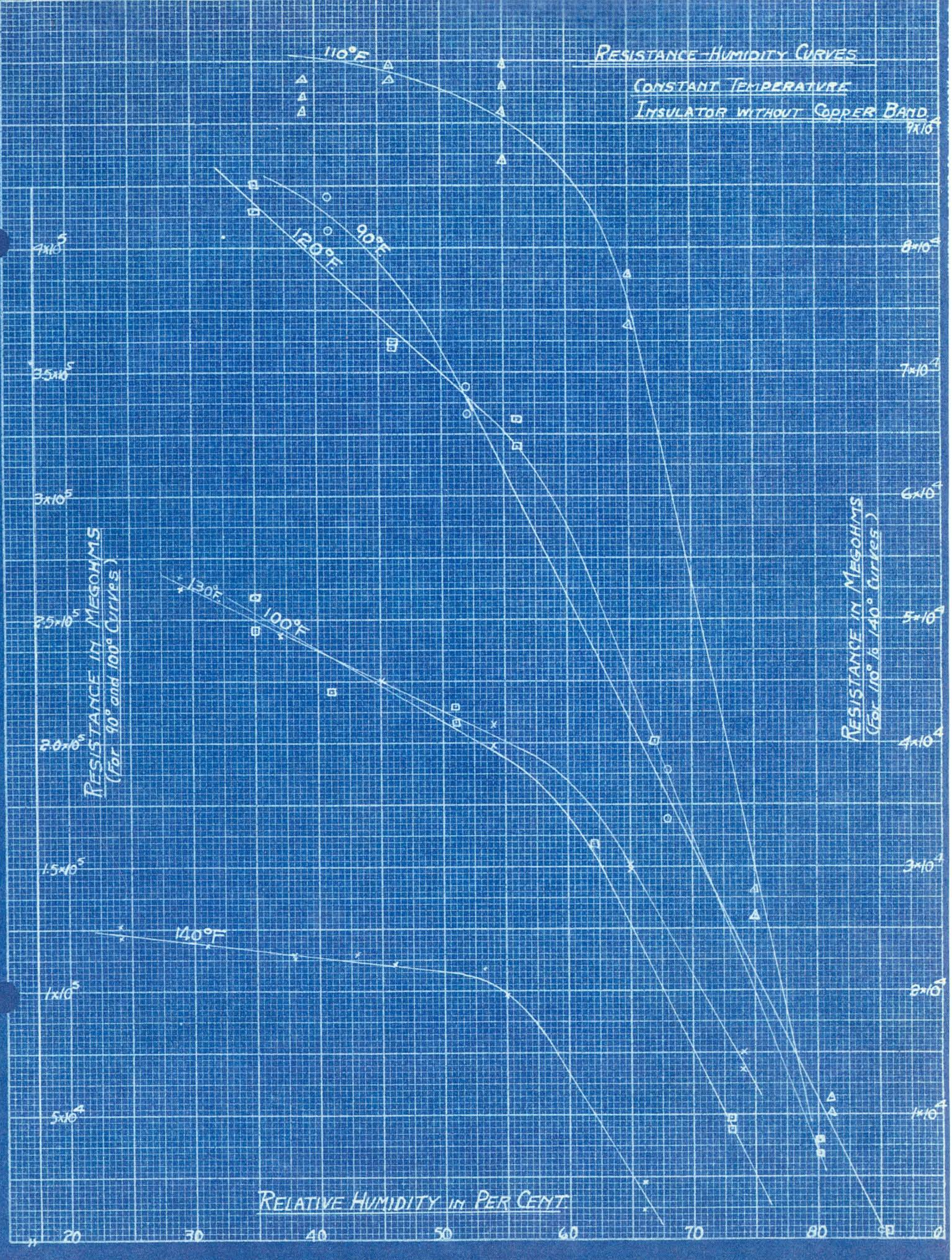
CONSTANT TEMPERATURE

GROUNDED COPPER BAND ON INSULATOR

CURVE SHEET #3



RESISTANCE-HUMIDITY CURVES
CONSTANT TEMPERATURE
GROUNDED COPPER BAND ON INSULATOR

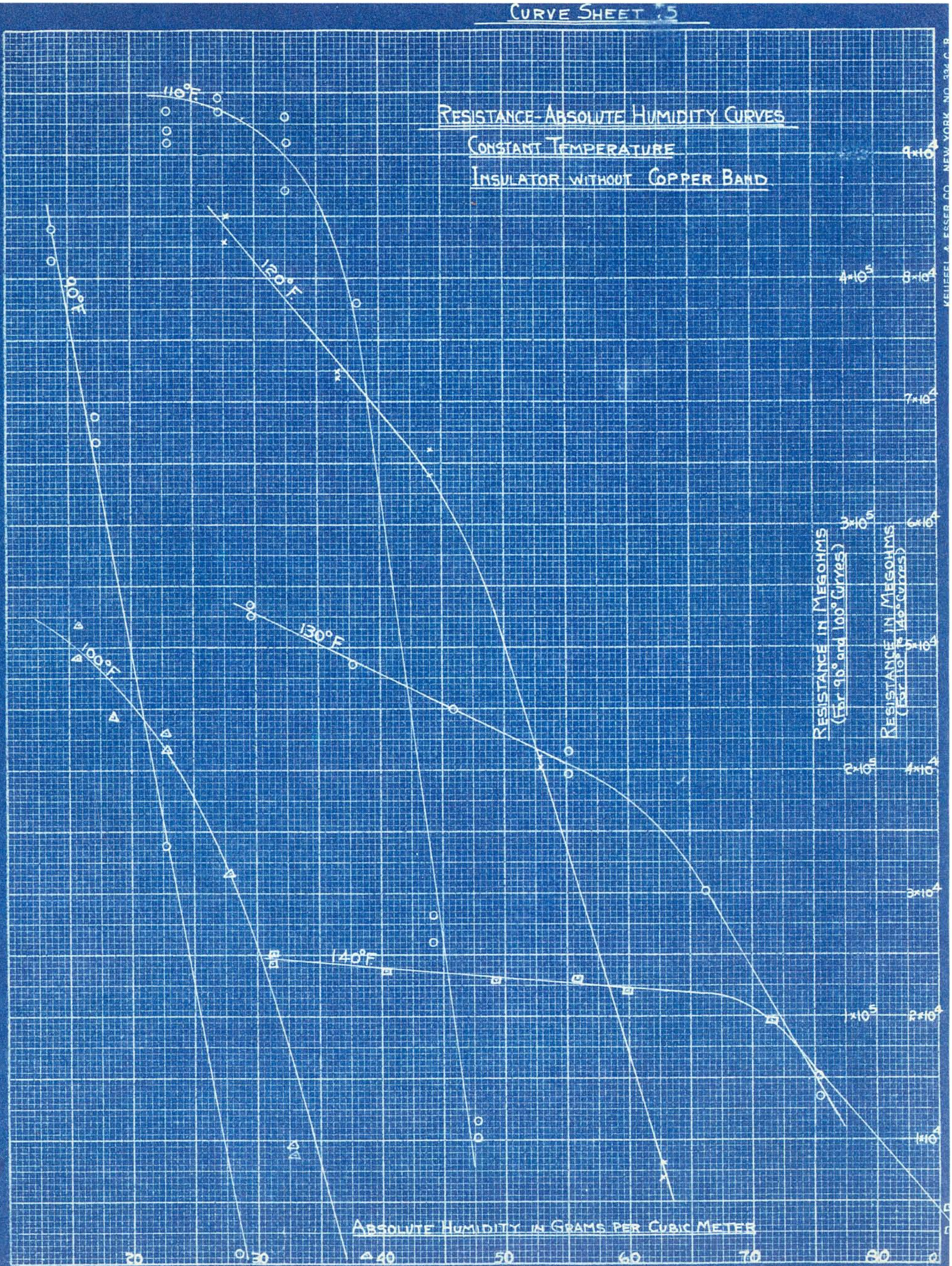


RESISTANCE-HUMIDITY CURVES

CONSTANT TEMPERATURE

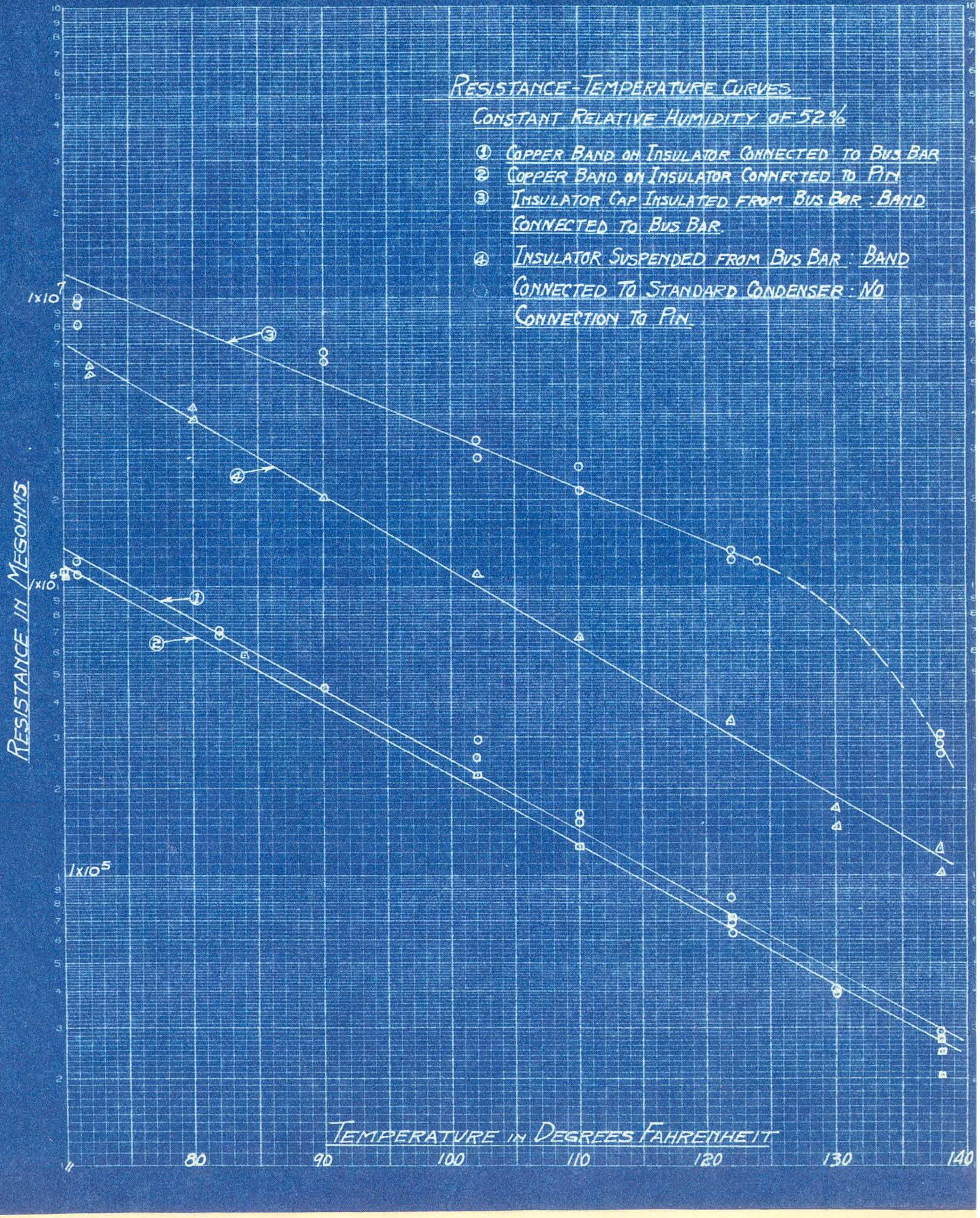
INSULATOR WITHOUT COPPER BAND

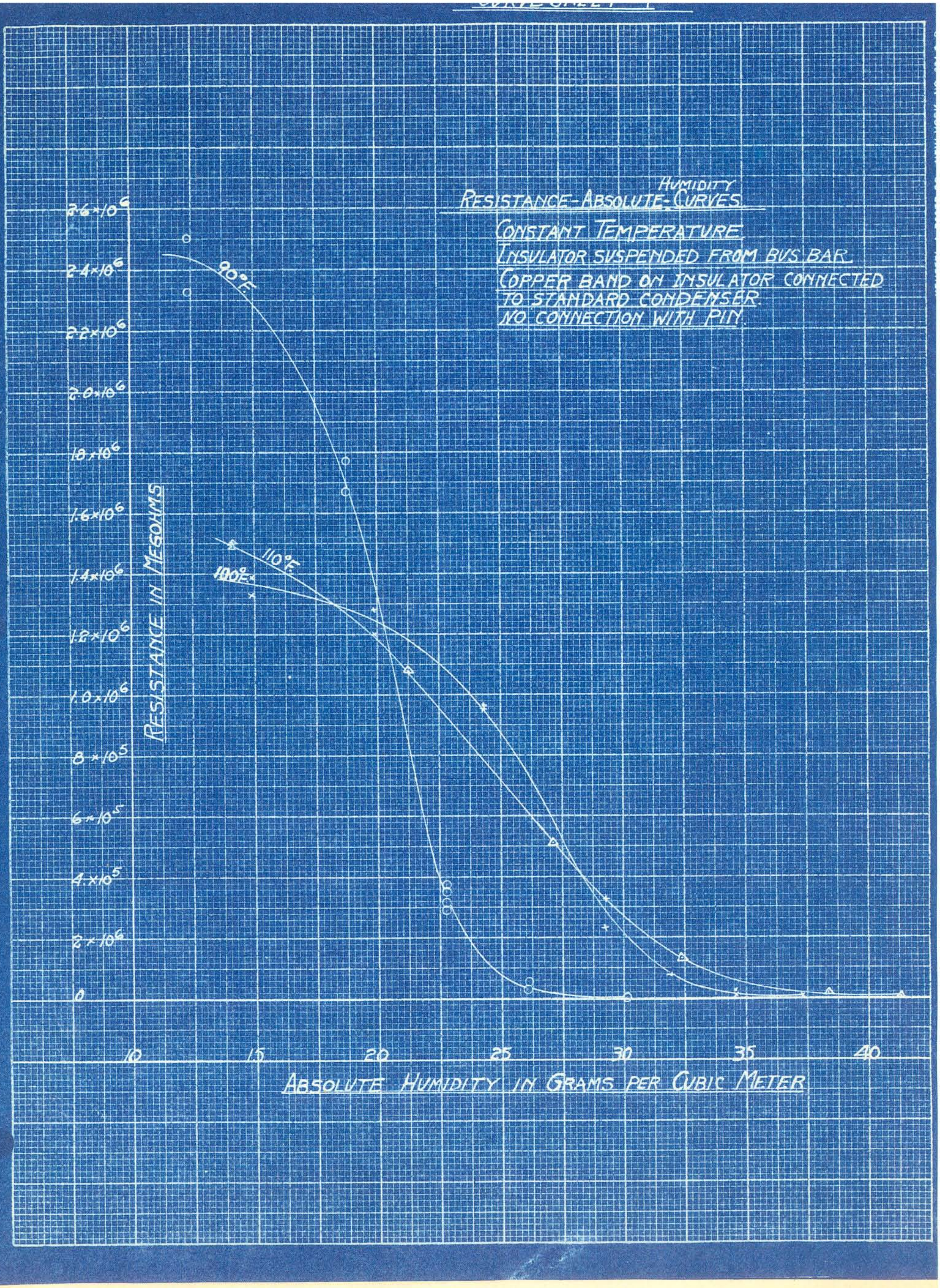
CURVE SHEET No. 5



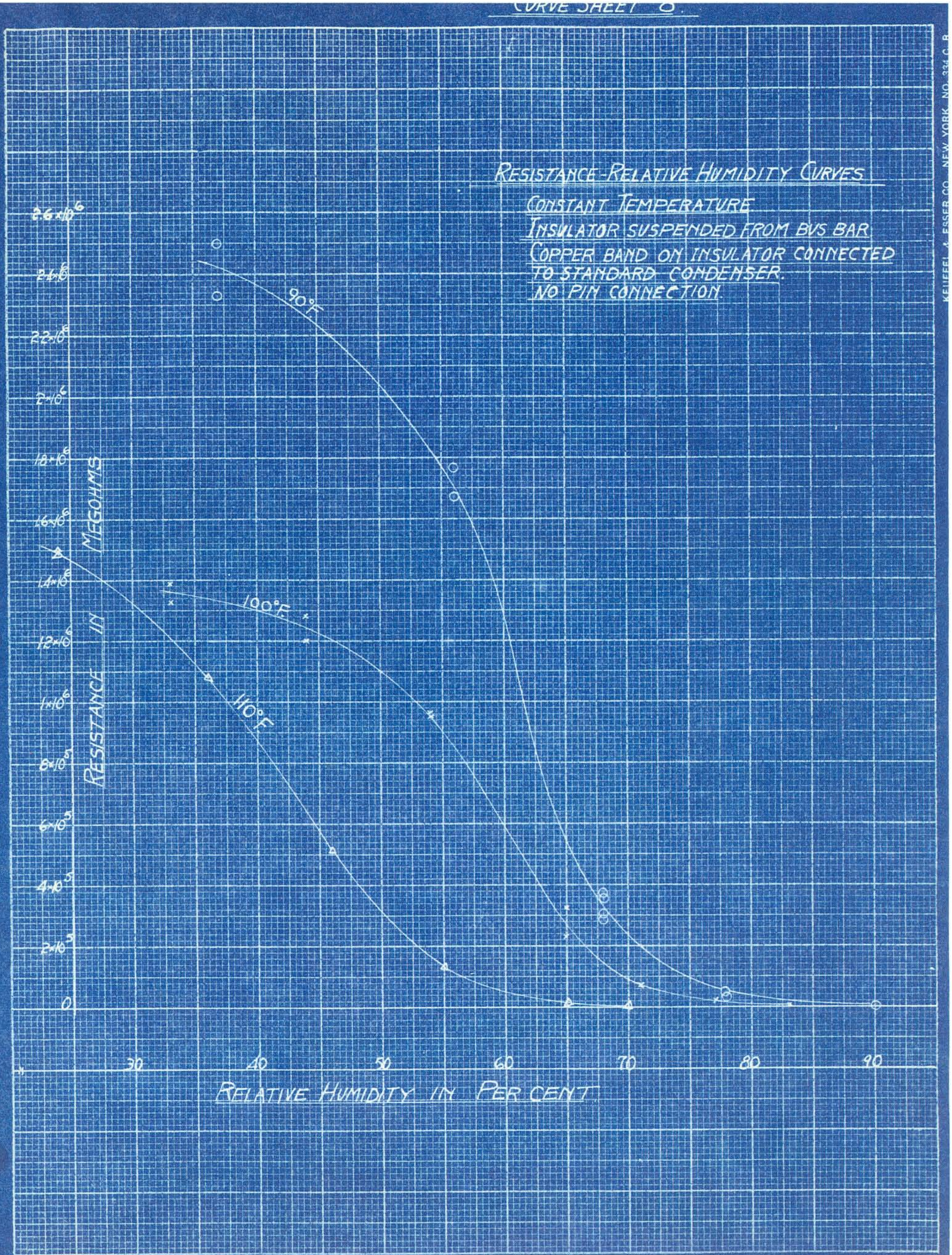
RESISTANCE-ABSOLUTE HUMIDITY CURVES
CONSTANT TEMPERATURE
INSULATOR WITHOUT COPPER BAND

CURVE SHEET #6




Resistance-Absolute-Humidity-Curves
Constant Temperature
Insulator suspended from bus bar
Copper band on insulator connected to standard condenser
No connection with pin
2.6×10⁶
2.4×10⁶
2.2×10⁶
2.0×10⁶
1.8×10⁶
1.6×10⁶
1.4×10⁶
1.2×10⁶
1.0×10⁶
8×10⁵
6×10⁵
4×10⁵
2×10⁶
0
Resistance in Megohms
90°F.
110°F.
100°F.
10
15
20
25
30
35
40
Absolute Humidity in Grams per Cubic Meter

CURVE SHEET 8.



RESISTANCE-RELATIVE HUMIDITY CURVES

CONSTANT TEMPERATURE
INSULATOR SUSPENDED FROM BUS BAR
COPPER BAND ON INSULATOR CONNECTED
TO STANDARD CONDENSER.
NO PIN CONNECTION.

CURVE SHEET #9