

HIGH FREQUENCY CONDUCTANCE OF PYREX GLASS IN THE
PRESENCE OF VAPORS

by

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TABLE OF CONTENTS

I Introduction

a. Previous Investigations	page 4
b. Purpose of Present Research	5

II Experimental Method

a. Theory of Method and Experimental Procedure	6
1. Justification of Approximations	12
2. Experimental Verification of Method	14
b. Description of Apparatus	
1. Test Element	15
Figure	16
2. Vapor System (figure)	17
Description.	18
3. Test Circuit	19
4. Oscillator	21
Diagram	22
c. Calibration of Apparatus	
1. Method of Frequency Determinations	24
2. Method of Obtaining C_L	25
3. Coil Calibration Curves	29
4. New Wavemeter Calibrations	43
5. Meter Calibration Curves	45

TABLE OF CONTENTS (continued)

III	Data and Results	
	a. Table of Symbols	47
	b. Table of Established Values	49
	c. Alcohol Vapor at 79° C	50
	d. Alcohol Vapor at 107° C	58
	e. Alcohol Vapor at 65° C	61
	f. Alcohol Vapor at 51° C	66
	g. Water Vapor at 50° C	71
IV	Discussion of Data and Results	78
	a. Discontinuities in Curves of Conductance vs Frequency	79
	b. Capacitance of Surface Film	82
	c. Variation of R_t with Current	83
	d. Variation of Surface Leakage with Frequency	86
	e. Variation of Surface Leakage with Temperature	88
	f. Variation of Volume Conductance With Temperature	89
	g. Resonance Effect with Surface Films	92
	h. Surface Conductivity	
	1. In the Presence of Alcohol Vapor	97
	2. In the Presence of Water Vapor	99
V	Summary and Conclusions	101

INTRODUCTION

H. L. Knowles¹ in some measurements of the dielectric constants of ethyl alcohol vapor showed that certain anomalies in his results could be explained by inordinately high electrical leakage across the insulators of his test condenser. However, when he measured the direct current leakage it was far too low to account for the discrepancies. He, of course, assumed that the high frequency leakage was of the same order of magnitude as the direct current leakage. Later investigations have shown such assumptions to be far from the facts.

Yager and Morgan² and others have shown that the electrical conductivity of pyrex glass increases rapidly with the frequency of the applied e. m. f. They also investigated the effect of water vapor on the surface leakage and found that the leakage increased very rapidly with the percent of saturation of the vapor.

Experiments at high pressures by T. C. Poulter³ have shown that ethyl alcohol behaves much the same as water in its tendency to penetrate the surface layers of glass.

(1) H. L. Knowles--Doctor's Thesis and "Dielectric Constants of Ethyl Alcohol Vapor and Possible Effect of Conductivity" (Jour. of Phys. Chem., Vol. 36, p. 2554, Oct. 1932)

(2) W. A. Yager and S. O. Morgan--"Surface Leakage of Pyrex Glass" Jour. Phys. Chem., 35 2026 (1931)

(3) T. C. Poulter and R. O. Wilson--Phys. Rev., Vol. 40, p. 877, June 1, 1932.

Hence, it seemed probable that in the presence of alcohol vapor and at high frequencies the resistivity of pyrex might be very different than its known d. c. values when dry.

It therefore seemed worth while to investigate the problem thoroughly and to chart the manner in which the volume and surface conductivities vary with frequency in the presence of ethyl alcohol vapor. To accomplish this purpose the present research was instituted.

EXPERIMENTAL METHOD

The standard procedure in all resistance measurements is to use some form of "bridge". However, high frequency bridges are quite complicated arrangements and, due to the transformers which must be incorporated in their design, they will not cover a very wide range of frequencies. In the present problem a wide range was more to be desired than high accuracy. Results with less than 5% of error were considered good enough for this purpose. Therefore, another form of circuit was employed. The method finally decided upon was one suggested by J. D. Stranathan and one which preliminary experiments showed to be both reliable and simple.

The wiring arrangement is shown in figure 1.

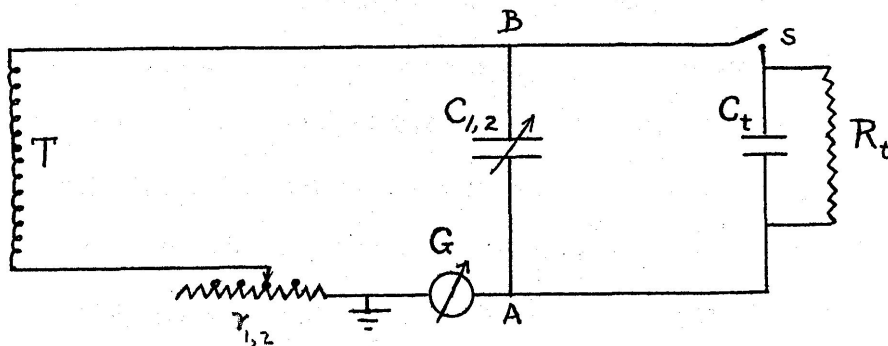


Figure 1

By means of the coil T the circuit was very loosely coupled to the oscillator. C_t is the test element having a leakage resistance R_t . $C_{0,2}$ was a standard variable capacity and $r_{0,2}$ was a standard decade resistance box.

With switch S closed and $r_{0,2}$ set at some small value r_1 (generally zero) $C_{0,2}$ was varied until the thermogalvanometer G indicated that the circuit was tuned to resonance. This setting of the condenser was designated as C_1 . The switch S was then opened and the circuit retuned and $r_{0,2}$ varied so that when tuning was accomplished there was exactly the same current in G as before. In retuning, the capacity of the condenser $C_{0,2}$ was increased to a value C_2 and $r_{0,2}$ was increased to a value r_2 .

Under the second conditions (S open) the total capacity and equivalent resistance in the circuit were the same as under the first conditions (S closed) since the circuit was tuned to the same frequency in both cases and since the current was exactly the same in both cases (the coupling and the inductance of course remaining constant).

The circuit as shown in figure 1 is not exactly that which pertained in actual practice. In reality there was a small leakage between A and B across the insulators both inside the condenser $C_{0,2}$ and across the hard rubber blocks used to mount the leads to the test element. There was also a small capacity between the leads and distributed in coil T. Since such capacities are, for the most part,

in parallel they could be taken care of by the capacity C_L in figure 2. The leakage in this part of the circuit is shown in figure 2 as R_2 .

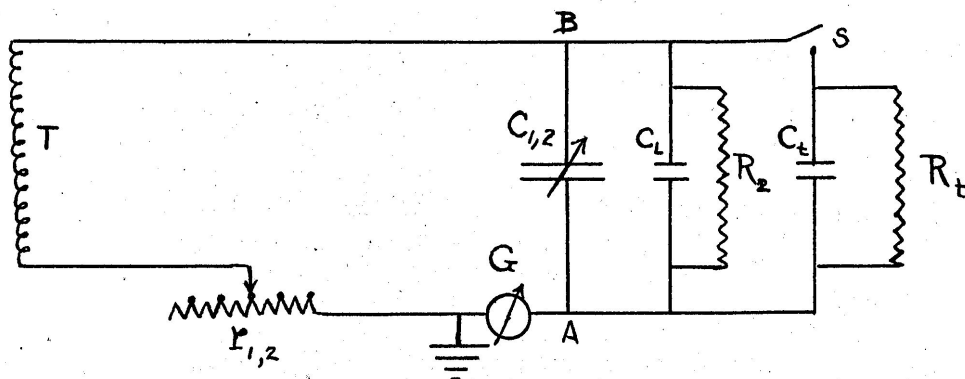


Figure 2

As shown by Morecroft,⁴ any leakage resistance R may be considered as an equivalent series resistance r where the energy dissipated by the total current in r is the same as that dissipated by the leakage current in R . Thus, in the procedure described above, the change in resistance $r_{1,2}$ was equivalent to the leakage resistance R_t .

To develop the actual relationship between r and R_t :-

Let x_2 = reactance of $C_2 + C_L$

x_t = reactance of C_t

and x_1 = reactance of $C_1 + C_L$ where C_1 is the

(4) Morecroft-- Experimental Radio Engineering p. 100

capacity of $C_{1,2}$ when the circuit is tuned with S closed and C_2 is the capacity when the circuit is tuned with S open. Also let Z_1 be the impedance of the circuit from A to B when tuned with S closed and Z_2 the impedance when tuned with S open. Then in complex algebra we may write

$$\frac{1}{Z_2} = \frac{1}{R_2} + \frac{1}{-jX_2}$$

or
$$Z_2 = \frac{-jR_2X_2}{-jX_2 + R_2} \cdot \frac{jX_2 + R_2}{jX_2 + R_2} = \frac{R_2X_2 - jR_2X_2}{X_2^2 + R_2^2} \quad (1)$$

Now for all frequencies used $R_2 \gg x_2$; x_2 was never larger than 5×10^3 while rough measurements showed R_2 to be greater than 10^6 ohms. Therefore equation (1) may be written

$$Z_2 = \frac{X_2^2}{R_2} - jX_2 \equiv r_2' - jX \quad (1a)$$

The real part of (1a) $r_2' \equiv \frac{X_2^2}{R_2}$ is the equivalent series resistance between A and B in the "second" case and x_2 is the equivalent reactance.

In a similar manner we may write

$$\frac{1}{Z_1} = \frac{1}{R_2} + \frac{1}{R_t} + \frac{1}{-jX_1} + \frac{1}{-jX_t}$$

To simplify this expression let

$$\frac{1}{D} = \frac{1}{R_2} + \frac{1}{R_t} \quad \text{and} \quad \frac{1}{-jS} = \frac{1}{-jX_1} + \frac{1}{-jX_t}$$

Thus
$$D = \frac{R_2 R_t}{R_2 + R_t} \quad \text{and} \quad S = \frac{X_1 X_t}{X_1 + X_t}$$

Then since $\frac{1}{Z_1} = \frac{1}{D} + \frac{1}{-jS} = \frac{-jS + D}{-jSD}$

$$Z_1 = \frac{-jSD}{-jS + D} \cdot \frac{D + jS}{D + jS} = \frac{S^2 D - jSD^2}{D^2 + S^2} \quad (2)$$

The real part $\frac{S^2 D}{D^2 + S^2}$ must be the equivalent series resistance.

And from Equation (1) the real part of Z_2 is $\frac{X_2^2 R_2}{R_2^2 + X_2^2}$ (not making the approximation).

$$\text{Therefore } \frac{S^2 D}{D^2 + S^2} - \frac{X_2^2 R_2}{R_2^2 + X_2^2} = r_2 - r_1 = r. \quad (3)$$

To further simplify let $\rho = r + \frac{X_2^2 R_2}{R_2^2 + X_2^2}$.

Then from (3) $\frac{S^2 D}{\rho} = D^2 + S^2$

or $D^2 - \frac{S^2}{\rho} D + S^2 = 0$

$2\rho D = S^2 \pm (S^4 - 4S^2\rho^2)^{1/2} = S^2 \pm S^2 \left(1 - \frac{4\rho^2}{S^2}\right)^{1/2}$ from which

Expanding the parenthesis by the binomial theorem we have

$$2\rho D = S^2 \pm S^2 \left(1 - \frac{1}{2} \frac{4\rho^2}{S^2} + \frac{\frac{1}{2}(-\frac{1}{2})}{2} \frac{16\rho^4}{S^4} - \frac{\frac{1}{2}(-\frac{1}{2})(\frac{3}{2})}{2 \cdot 3 \cdot S^6} 64\rho^6 + \dots\right)$$

$$2\rho D = S^2 \pm S^2 \left(1 - \frac{2\rho^2}{S^2} - \frac{2\rho^4}{S^4} - \frac{4}{3} \frac{\rho^6}{S^6} + \dots\right) \quad (4)$$

ρ is of the order of a few ohms while s is of the order of a thousand ohms. Therefore we may neglect terms containing ρ/s in higher powers than the second. If we take the negative sign before the parenthesis we have

$$2\rho D = 2\rho^2 \quad \text{or} \quad D = \rho.$$

That is, since $D \equiv \frac{R_2 R_t}{R_2 + R_t}$, $R_t R_2 = \rho R_t + \rho R_2$

from which $R_t(R_2 - \rho) = \rho R_2$

$$\text{or } R_t = \frac{R_2 \rho}{R_2 - \rho} = \frac{\rho}{1 - \rho/R_2}$$

and since

ρ is of the order of a few ohms while R_2 is of the order of a megohm

$$R_t = \text{approximately } \rho. \quad (5)$$

However, when resistances of 10,000 ohms or less were placed in parallel with R_t the current in G dropped to zero. Therefore, in the present circumstances R_t was not the small value that is mathematically possible.

Going back to Equation (4) and taking the positive sign before the parenthesis $2\rho D = 2S^2 - 2\rho^2$ (neglecting terms containing higher powers of ρ/S than the second)

Thus $D = \frac{S^2}{\rho} - \rho$ and for the same reason given above we may neglect $-\rho$ in comparison with $\frac{S^2}{\rho}$ which leaves

$$D = \frac{S^2}{\rho}. \quad (6)$$

Remembering that $D = \frac{R_t R_2}{R_t + R_2}$ from (6)

$$R_t R_2 = \frac{S^2}{\rho} (R_t + R_2)$$

or solving for R_t we have

$$R_t (R_2 - \frac{S^2}{\rho}) = \frac{R_2 S^2}{\rho}$$

$$\text{or } R_t = \frac{R_2 \frac{S^2}{\rho}}{R_2 - \frac{S^2}{\rho}} = \frac{R_2}{\frac{R_2 \rho}{S^2} - 1} = \frac{R_2 S^2}{R_2 \rho - S^2}.$$

Further transforming:

$$R_t = \frac{S^2}{\frac{R_2 \rho}{S^2} - 1} = \frac{1}{\frac{\rho}{S^2} - \frac{1}{R_2}}$$

$$\text{From which } \frac{1}{R_t} = \frac{\rho}{S^2} - \frac{1}{R_2} \quad (7)$$

Since $S = \frac{X_t X_t'}{X_t + X_t'}$ and since $\rho = r + \frac{X_2^2 R_2}{R_2^2 + X_2^2} r + r_2'$

we may replace ρ and S^2 by their values and obtain

$$\frac{1}{R_t} = \frac{(r + r_2')(X_t + X_t')^2}{X_t^2 X_t'^2} - \frac{1}{R_2} = (r + r_2') \left(\frac{1}{X_t} + \frac{1}{X_t'} \right)^2 - \frac{1}{R_2}.$$

But $\frac{1}{X_t} = C_t \omega$ and $\frac{1}{X_t'} = (C_t + C_l) \omega$ where $\omega = 2\pi$ times the frequency.

$$\text{Therefore } \frac{1}{R_t} = (r + r_2') (C_t + C_l + C_l)^2 \omega^2 - \frac{1}{R_2}.$$

But from Equation (1a) $r_2' = \frac{X_2^2}{R_2}$ or $\frac{1}{R_2} = \frac{r_2'}{X_2^2}$

or $\frac{1}{R_2} = r_2' (C_2 + C_L)^2 \omega^2$.

Therefore $\frac{1}{R_t} = \omega^2 \left\{ r(C_t + C_i + C_L)^2 + r_2' [(C_t + C_i + C_L)^2 - (C_2 + C_L)^2] \right\}$.

It will be shown in the next section that $C_i + C_t = C_2$

Hence $\frac{1}{R_t} = \omega^2 \left\{ r(C_2 + C_L)^2 + r_2' [(C_2 + C_L)^2 - (C_2 + C_L)^2] \right\}$.

And therefore $\frac{1}{R_t} = r \omega^2 (C_2 + C_L)^2$ (8)

In other words

$$R_t = \frac{X_2^2}{r} \quad (8a)$$

where r is the difference in the settings of $r_{1,2}$ for the two cases (switch s closed and open).

TO SHOW THAT THE APPROXIMATIONS ARE JUSTIFIED:

If R_t and R_2 were infinite then $D = \infty$ and the capacitative reactance of the circuit in the second case was $X_2 = \frac{1}{C_2 \omega + C_L \omega}$. Also in the first case the reactance would be the imaginary part of Equation (2) which is $\frac{sD^2}{D^2 + S^2}$ and since $D = \infty$ this expression becomes just s . Since the inductance of the circuit remained unchanged for the two cases and since the frequency was constant then the two capacitative reactances were equal. Thus

$$S = X_2 \quad \text{but} \quad S = \frac{X_i X_t}{X_i + X_t}$$

Hence $X_2 = \frac{X_i X_t}{X_i + X_t}$ or $\frac{1}{X_2} = \frac{X_i}{X_i X_t} + \frac{X_t}{X_i X_t}$

and therefore $\frac{1}{X_2} = \frac{1}{X_t} + \frac{1}{X_1}$. But $X_t = \frac{1}{C_t \omega}$

and $X_1 = \frac{1}{(C_1 + C_L) \omega}$ Putting in these values and dividing out ω we have $C_2 + C_L = C_t + C_1 + C_L$.

Whence $C_2 = C_t + C_1$.

But since D is not infinite the capacitative reactance in the first case is not exactly S but is $\frac{S}{1 + \frac{S^2}{D^2}}$

To obtain an approximate value of S when it is at its maximum value take the values of C_1 , C_2 and the approximate C_t from the table of data on page 54 for the 223 K. C. frequency and calculate x_1 and x_t . x_1 is found to be approximately 1.8×10^3 while $x_t = 2.5 \times 10^3$. Then $S = \frac{X_t X_1}{X_t + X_1} = 10^3$ ohms.

As was stated before when 10,000 ohms or less were shunted across the test element the current in G dropped to a value too small to read. This meant that the resistance D was very large in comparison to 10,000 ohms. However, let us use 10,000 ohms for the value of D as an approximation. Thus the capacitative reactance in the first case is $\frac{S}{1 + \frac{10^6}{10^8}} = .99S$.

Thus if we should calculate D from the real part of Equation (2) as

$$D = \frac{S^2}{R_2'} \quad \text{the error in D would be approximately 2\%.}$$

However, the lowest value of D calculated in all the experiments was greater than 1.5×10^5 . Putting this value back in the value for the reactance we find the capacitative reactance to be $\frac{S}{1 + \frac{10^6}{2 \times 10^{10}}} = .9998S$.

Thus it is seen that for the values used in this series of experiments the parallel resistance did not change appreciably the equivalent capacity.

EXPERIMENTAL VERIFICATION OF METHOD

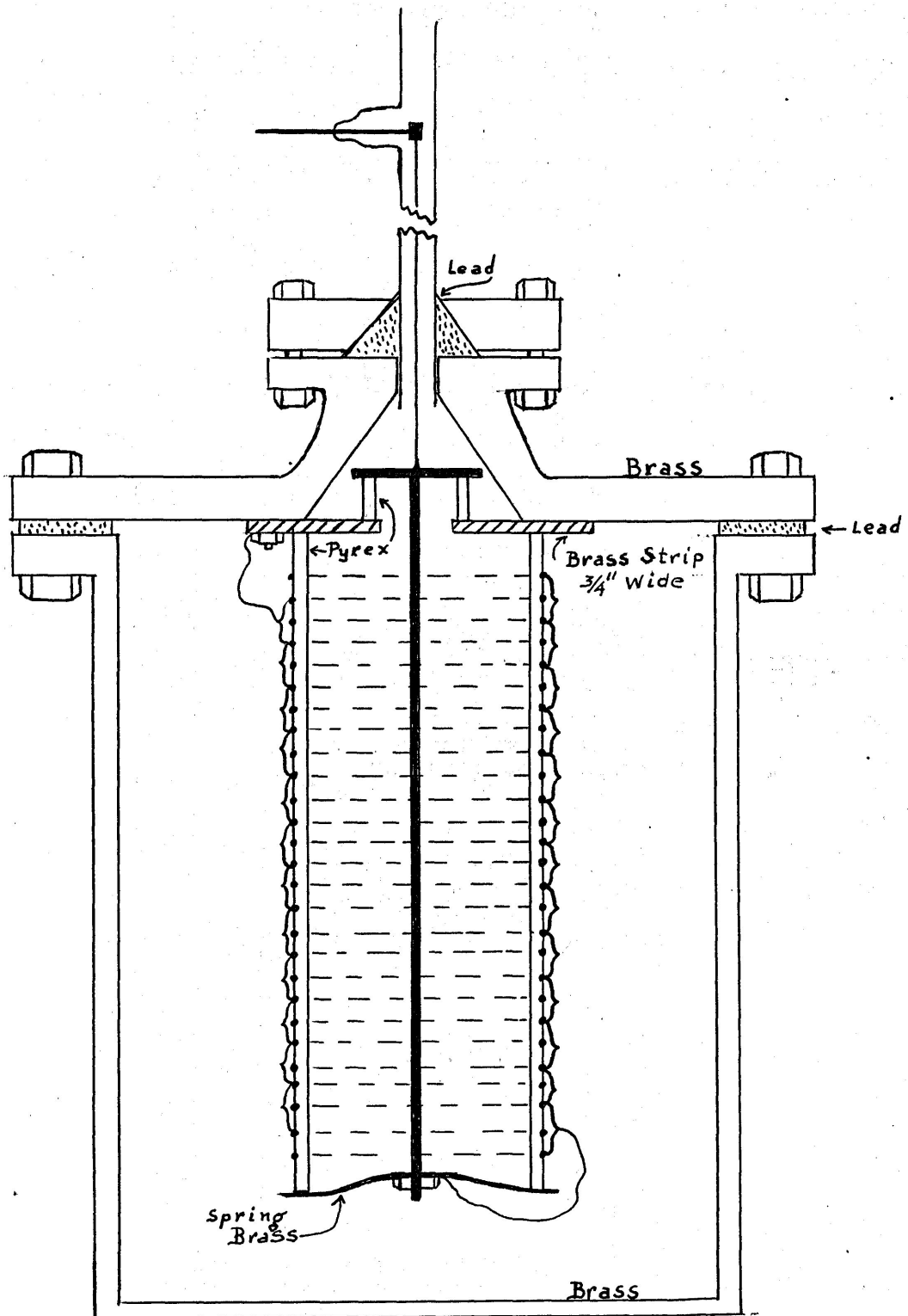
A number of preliminary experiments were run measuring resistances of known values at various frequencies. All the results checked the known values to within 2%.

DESCRIPTION OF APPARATUS

1. The Test Element. The test element was built quite similar to that used by Yager and Morgan⁵. Several pieces were built exactly according to their design but various difficulties caused the design to be simplified somewhat. Among the difficulties encountered were the loosening of the ribbon, injury to the surface due to sand blasting and high resistance of ribbons that were finally obtained. In its final form the test element consisted of a $5\frac{1}{2}$ inch length of rather thick wall pyrex tubing $2\frac{1}{8}$ inches in outside diameter. Into this tube was cut 39 transverse grooves. These grooves were approximately .5 m. m. wide and about .3 m. m. deep and were spaced about 2.0 m. m. apart. In each groove was wrapped tightly one turn of No. 30 copper wire. Every other turn was connected to make one set and the other turns in another set. Copper was then electroplated on the wires until the grooves were completely filled. The conductors were then nearly a millimeter in diameter. This element was mounted rigidly to the top of the vapor chamber as shown in figure 3.

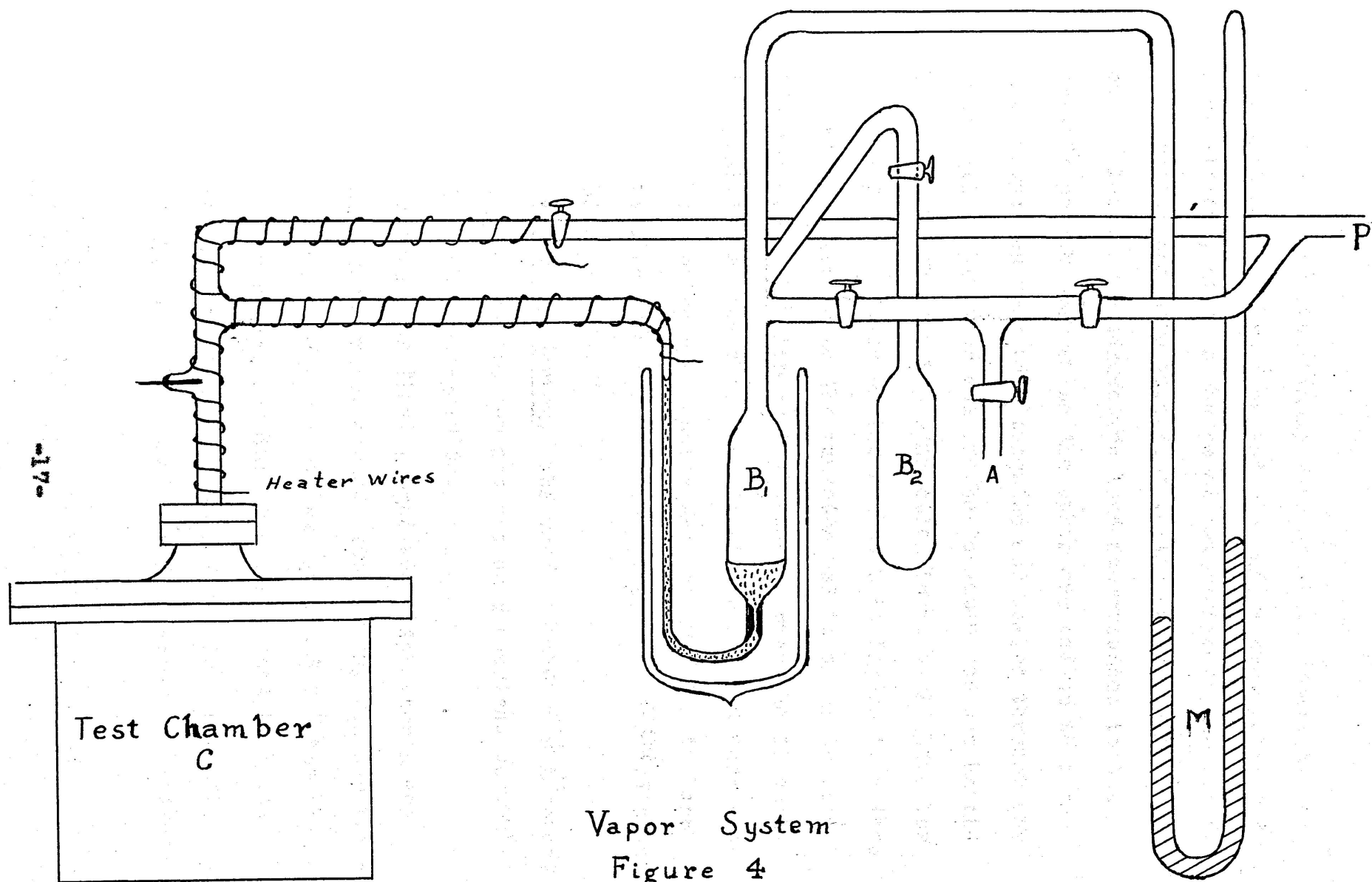
The test element was cleaned with chromic acid, washed with a pure soap solution, then rinsed several times with

(5) Loc. Cit.



TEST CHAMBER AND ELEMENT

Figure 3



Vapor System
Figure 4

distilled water and finally with alcohol. The whole vapor system was taken down and cleaned, along with the test element, at each change of temperature. Air tight lead seals were made according to the design described by Knowles⁶. One conducting lead was grounded to the brass vapor chamber while the other was led up through the exhaustion tube to a tungsten rod sealed through the tube wall. The outer end of the tungsten rod was heavily brazed so that a clip connection to it would have low resistance. In place of the switch S in figure 1. a lead was merely clipped to the tungsten rod in order to close the circuit. The clip was released to open the circuit. The position of the clip (and lead) was changed very little in the closing and opening process in order to keep the distributed capacity of the system as nearly constant as possible.

2. The Vapor System. The vapor chamber was immersed in an oil bath and its temperature held constant to $.02^{\circ} \text{C}$ by an Aminco Thermo Regulator.

The chamber was first pumped to a high vacuum and then dried alcohol vapor was admitted to any desired pressure by means of the vapor system diagramed on page 17 figure 4. The system is similar to that used by Miles⁷ and Knowles⁸. Referring to figure 4: C is the vapor chamber, P the exhaustion port and M a mercury manometer

(6) Loc. Cit.

(7) J. B. Miles: Phys. Rev. 34 964 (1929)

(8) Loc. Cit.

with a vacuum in the right hand tube. Carefully dried and purified alcohol was kept in the tube B_2 . And as it was needed alcohol was evaporated from B_2 and collected in the cold chamber B_1 . B_1 was kept at approximately -80°C by using solid CO_2 in a mixture of carbon tetrachloride and chloroform.

The vapor was introduced into the vapor chamber in the following manner: Air which had been dried by passing through calcium chloride and over phosphorus pentoxide is admitted at A. The increase in pressure forces the alcohol in tube B_1 up in b as far as the heating wires. Here it evaporates and passes into the chamber C until the pressure in the chamber equals that in B_1 . In calculating the pressure in the chamber the difference in height of the alcohol surfaces in b and B_1 and the capillary rise in b are taken into account.

3. The Electrical Receiving Circuit or Test Circuit.

The electrical circuit has been shown in figures 1 and 2 and partially described with the test element. The variable condenser $C_{1,2}$ was a General Radio precision condenser of $1,500\mu\mu\text{f.}$ capacity which had been calibrated by Stranathan and Knowles to an accuracy of $.06\mu\mu\text{f.}$ The resistance r was a General Radio standard decade box whose lowest setting was .1 ohm and whose calibration was good to .1 of 1% up to 10^6 cycles.

It will be noted from Equation (8a) $\left(R_t = \frac{x_2^2}{r}\right)$ that for the same R_t , r is proportional to x_2^2 . Since x

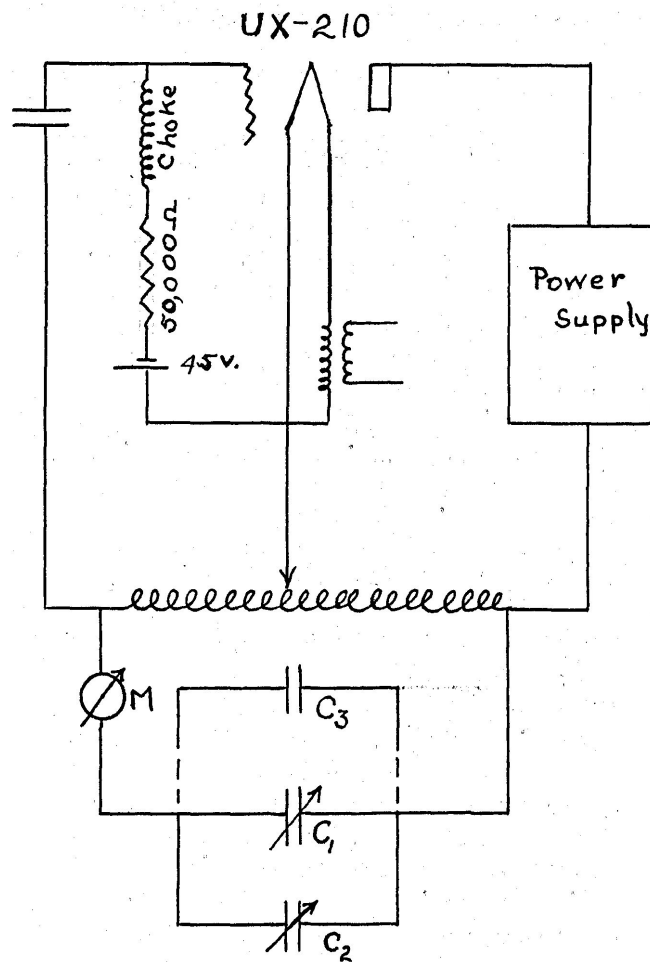
is inversely proportional to the capacity in the circuit then the tuning coils should be of such an inductance that C would tune at a small value. Such conditions make r as large as possible and therefore, make for greater accuracy. For this reason it was best to design a separate coil for each frequency. Therefore, for T, a number of coils were wound on a wood frame one foot square. The number of turns in the coils ranged from 5 for No. 1 coil to 75 for No. 6 coil. Each contained only a single layer and in the smaller coils the turns were well spaced. The whole frame was then mounted in a fixed position and each coil connected into the circuit as it was needed. However, it was found that at the higher frequencies the larger coils absorbed considerable energy even though they were not connected. They thus affected the distributed capacity of the circuit. Therefore, this large frame of coils was used for the low frequencies only while separate new coils were wound for frequencies above 100 k. c. These new coils were designated as (1), (2) and (3). Later when other frequencies were desired coils 7 and 8 were added. This method of replacing the tuning coils for each frequency had the disadvantage that it was a little difficult to set the coil in exactly the same position each time. However, markings were made on the table which made it possible to remove a coil and replace it without changing the tuning of the circuit by as much as $\frac{1}{2}$ division on the precision condenser. A variation of two

divisions did not affect the accuracy of the reading by as much as 1%.

At first a thermo-galvanometer (Weston Model 425) was used for G. However, when it was found that the magnitude of the current was affecting the results this instrument was replaced by a Western Electric thermo-couple and a Leeds and Northrup type R galvanometer. This latter arrangement proved very slow in tuning. Therefore, a more sensitive thermo-couple (W. E. Type 20 A D) with a Weston micro-ammeter (Model 301) was substituted. This combination proved very satisfactory although it was still much slower than the thermo-galvanometer.

4. The Oscillator. The oscillator was a modified Hartley design as shown in figure 5. C_1 and C_2 were each variable air condensers of $1,800 \mu\mu\text{f.}$ capacity. C_3 which was connected in the circuit only when the 38.5 k.c. frequency was desired was a $5,000 \mu\mu\text{f.}$ fixed capacity mica condenser. Two interchangeable sets of tuning coils were used at the ends of flexible leads so that the coupling to the receiving circuit could be easily changed. The tube was a #210. The 50,000 ohm grid leak drew a grid current of about 8 m. a. when the tube was in operation. The plate of the tube was supplied 35 m. a. at 600 volts by a well filtered power supply.

The oscillator was quite stable and after it had been in operation a few minutes the frequency drift was imperceptible for nearly an hour.



THE OSCILLATOR

Figure 5

The oscillator coupling coils were never closer than $4\frac{1}{2}$ feet from the receiving circuit and in most instances they were turned at an angle of more than 80° to the receiving circuit coils. To test the coupling between the two circuits the oscillator current was watched closely while the current in the test circuit was changed from a maximum to zero and back to a maximum. No change whatever could be noted in the oscillator current.

CALIBRATION OF APPARATUS

The principal calibration necessary was the determination of the frequencies used and the evaluating of C_L for each of the coils used in the test circuit.

A wavemeter was available which covered the desired range of frequencies but anomalous results soon caused the accuracy of this instrument to be suspected. A standard wavemeter whose calibration had been checked within the past four months was available for frequencies down to 425 k. c.

For the lower frequencies a temporary wavemeter was made up from the coils of the old wavemeter and a precision condenser. This meter was then calibrated and afterwards designated as the "New Wavemeter". The calibration was made in the following manner: A radio receiving set was set up in the same room with the oscillator and tuned to some broadcasting station whose frequency was known. The oscillator was then tuned to some frequency which was known approximately. Then a slight variation of this tuning would cause one of the upper harmonics of the oscillator to beat with the frequency of the broadcast station. This beating was easily heard in the receiving set.

With the oscillator tuned to zero beat the wavemeter reading was taken. Then by lowering the frequency of the oscillator the next higher harmonic began to beat with the broadcast frequency. This procedure was repeated with

several consecutive harmonics and with two different broadcast stations whose frequencies differed widely. then when $1/f^2$ was plotted against the capacity of the wavemeter condenser a straight line was obtained. If the numbers of the harmonics were not guessed correctly, the points taken from one station did not lie on the same line with those taken from another station nor were the lines strictly straight. However, after a few trials the right numbers of the harmonics were found and thus the frequencies known accurately.

From the slope of the line thus obtained along with its intercept on the capacity axis (which gives the distributed capacity in the wavemeter circuit) the calibration equation may be written $1/f^2 = S(C+A)$ where S is the slope of the line and A the intercept.

From this equation
$$f = \frac{1}{\sqrt{S(C+A)}} = \frac{\sqrt{1/S}}{\sqrt{C+A}}$$

Such calibration curves are shown on pages 43 and 45

It is seen that the test circuit with the switch S open is the same as a wavemeter circuit. Also since the distributed capacity for each coil had to be measured the test circuit itself was calibrated (for each of the larger coils) in the manner described above. Thus there was less likelihood of errors being introduced than if a wavemeter had been calibrated and C_L measured from the wavemeter readings.

It is also seen from Equation (8a)
$$R_t = \frac{X_2^2}{r}$$

that the value of R_t depends upon the capacity of the condenser C_2 , and upon the frequency. With a given coil in the test circuit the condenser will tune at the same setting for the same frequency. And since, as mentioned above, the coils could be removed and replaced without changing the tuning, once the capacity setting C_2 is accurately determined for a given frequency then that frequency could be obtained at any time by varying the oscillator frequency until the test circuit again tuned with the capacity C_2 .

The frequency was determined accurately not only once but several times to make sure the calibration of the test circuit had not changed. After all other data were taken "check points" were made on each of the coil calibrations. All of these "check points" were found to lie very closely on the curves originally determined. Thus the frequencies were determined and set each time with an error of less than 1%. The reason for the odd values of frequencies was that even values on the old wavemeter turned out to be at error and since some valuable data had been taken it was thought best to go on using the same frequencies although they were odd.

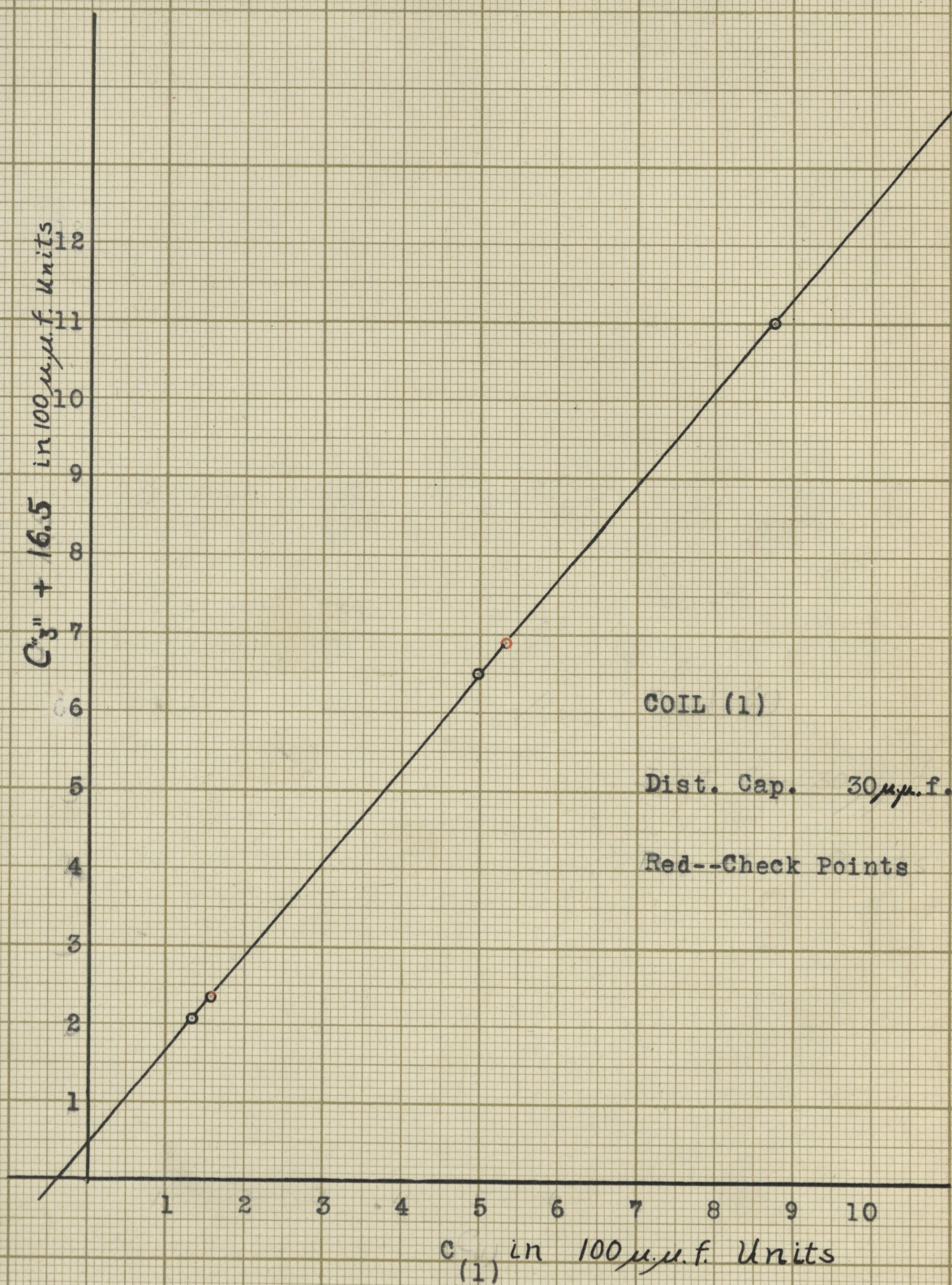
The distributed capacity for each coil was measured in a manner similar to that described for the wavemeter. With the desired coil in the test circuit the condenser $C_{1,2}$ was varied until the circuit was tuned to the frequency of the oscillator. The value of $C_{1,2}$ which tuned

the circuit was recorded along with the frequency to which it was tuned. If the standard wavemeter was used to determine the frequency $\frac{1}{f^2} = k(C_s + A_s)$ where k is the calibration constant for the wavemeter, C_s is the capacity in the wavemeter condenser and A_s is the distributed capacity in the wavemeter circuit. The values of $C_{1,2}$ were then plotted as abscissae against $\frac{1}{f^2}$ or, when the wavemeter was used to determine f , the values of $C_{1,2}$ were plotted against $C_s + A_s$. These curves were straight lines having negative intercepts on the $C_{1,2}$ axis. If one of these intercepts had a value A_x , then the total capacity in the circuit was $C_x + A_x$ where C_x is the capacity in $C_{1,2}$. That is, A_x is the distributed capacity in the circuit when coil "x" was in the circuit.

Meter Calibrations

While it was not necessary to know the actual value of the current in standard units to calculate R_t it was desirable to know approximately what currents were being used. Therefore, the calibration curves of the various thermo-couple devices are given on pages

<u>Coil (1)</u> <u>Cond. Set.</u>	<u>Cap.</u>	<u>St.Coil #3</u> <u>Cond. Set.</u>	<u>Cap.</u>	<u>C₃ + 16.5</u>
2.45	138 <i>μμ.f.</i>	3.55	187 <i>μμ.f.</i>	203 <i>μμ.f.</i>
9.12	540	11.52	667	684
14.79	883	18.35	1078	1095
19.70	1183	24.25	1435	1452



<u>Coil (2)</u> <u>Cond. Set.</u>	<u>Cap.</u>	<u>St. Coils #3</u> <u>Cond. Set.</u>	<u>Cap.</u>	<u>C₃ + 16.5</u>
2.31	130 <i>μμf.</i>	13.66	796 <i>μμf.</i>	219 <i>μμf.</i>
0.59	56.2	7.20	407	424
2.98	168.7	16.95	994	1011
3.87	222.7	21.35	1261	1278
4.47	259	24.33	1440	1457

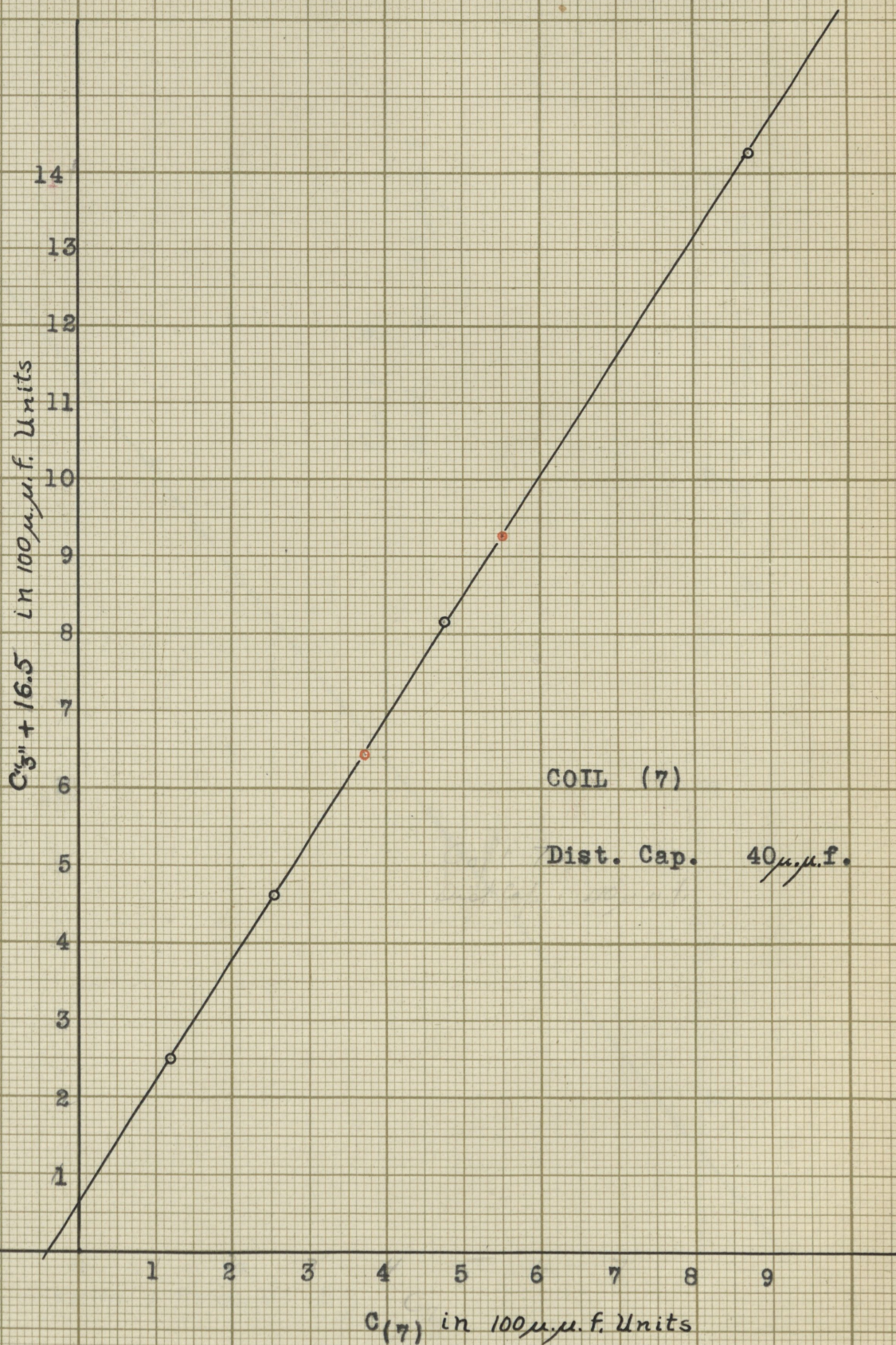
$C_3'' + 16.5$ in 100 μ f. Units

COLL (2)

Dist. Cap. 30 μ f.

Red--Check Points

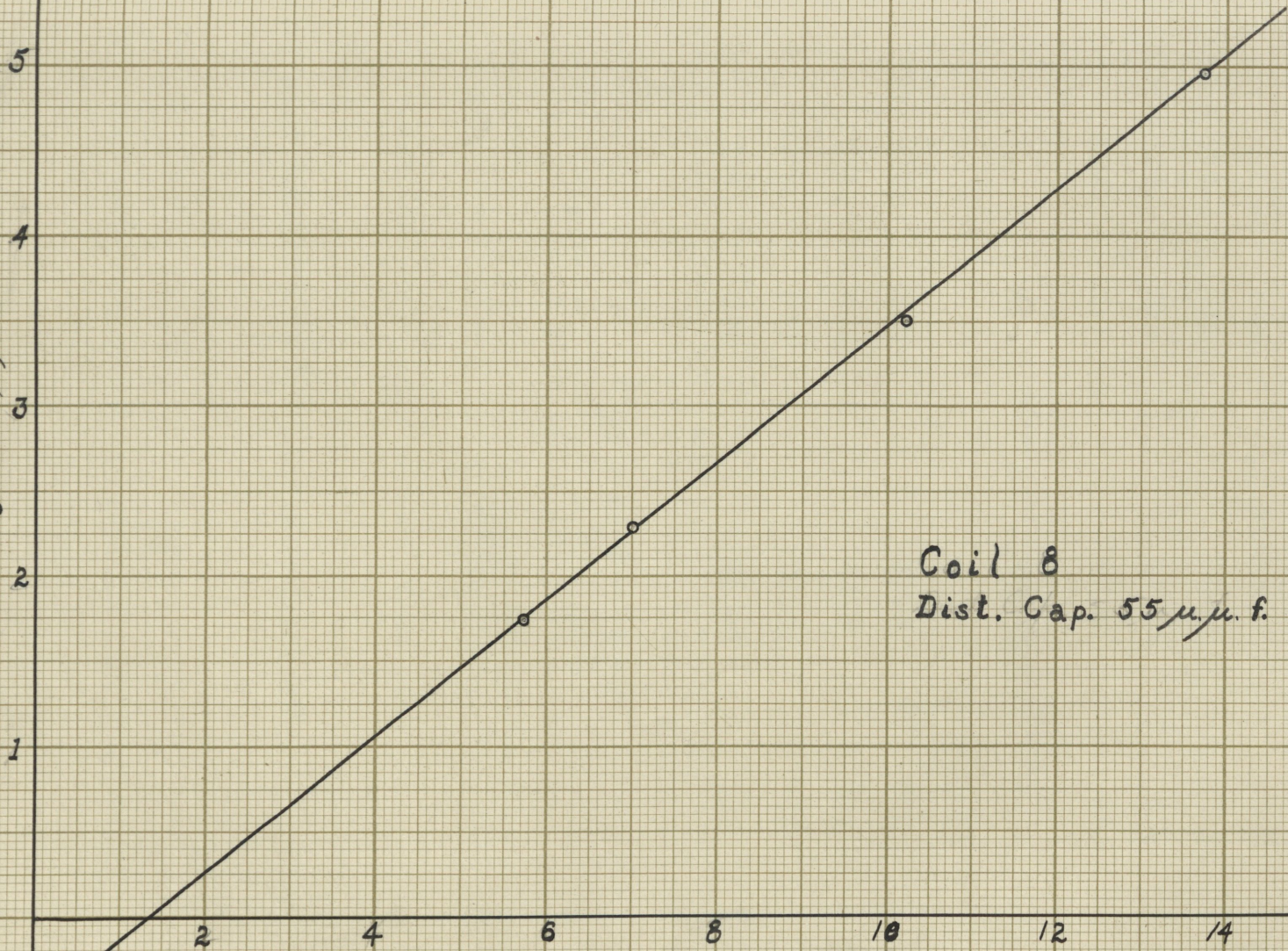
$C_{(2)}$ in 100 μ f. Units



-35-
 C_8 in 100 $\mu\mu.f.$ Units

Coil 8
Dist. Cap. 55 $\mu\mu.f.$

$C_3^{m.} + 16.5$ in 100 $\mu\mu.f.$ Units



NEW WAVEMETER

Coil "C"

<u>Cond. Set.</u>	<u>Cap.</u>	<u>Set. of Receiving Condenser</u>	<u>Cap. R.C.</u>	<u>$\frac{1}{f^2}$</u>
19.00	1119 $\mu\mu.f$	21.56	1310 $\mu\mu.f$	1.255×10^{-10}
9.00	516	10.44	620	.621
3.00	155	3.71	213	.242

Beating with Station WDAF
610 k.c.

<u>Harmonic</u>	<u>Freq. in K.C.</u>			
3rd	203	3.72	213	$.242 \times 10^{-10}$
4th	153	7.95	415	.430
5th	122	11.33	674	.672
6th	102	16.55	990	.962

$$\text{Slope} = 9.27 \times 10^{-8}$$

$$\frac{1}{f^2} = (C_3 + 50) 9.27 \times 10^{-8}$$

$$f = \frac{3284}{\sqrt{C_3 + 50}}$$

$$\text{Frequency "2.4"} = \frac{3284}{\sqrt{238}} = 223 \text{ k.c.}$$

$$\text{Frequency "1.5"} = \frac{3284}{\sqrt{509}} = 145.6 \text{ k.c.}$$

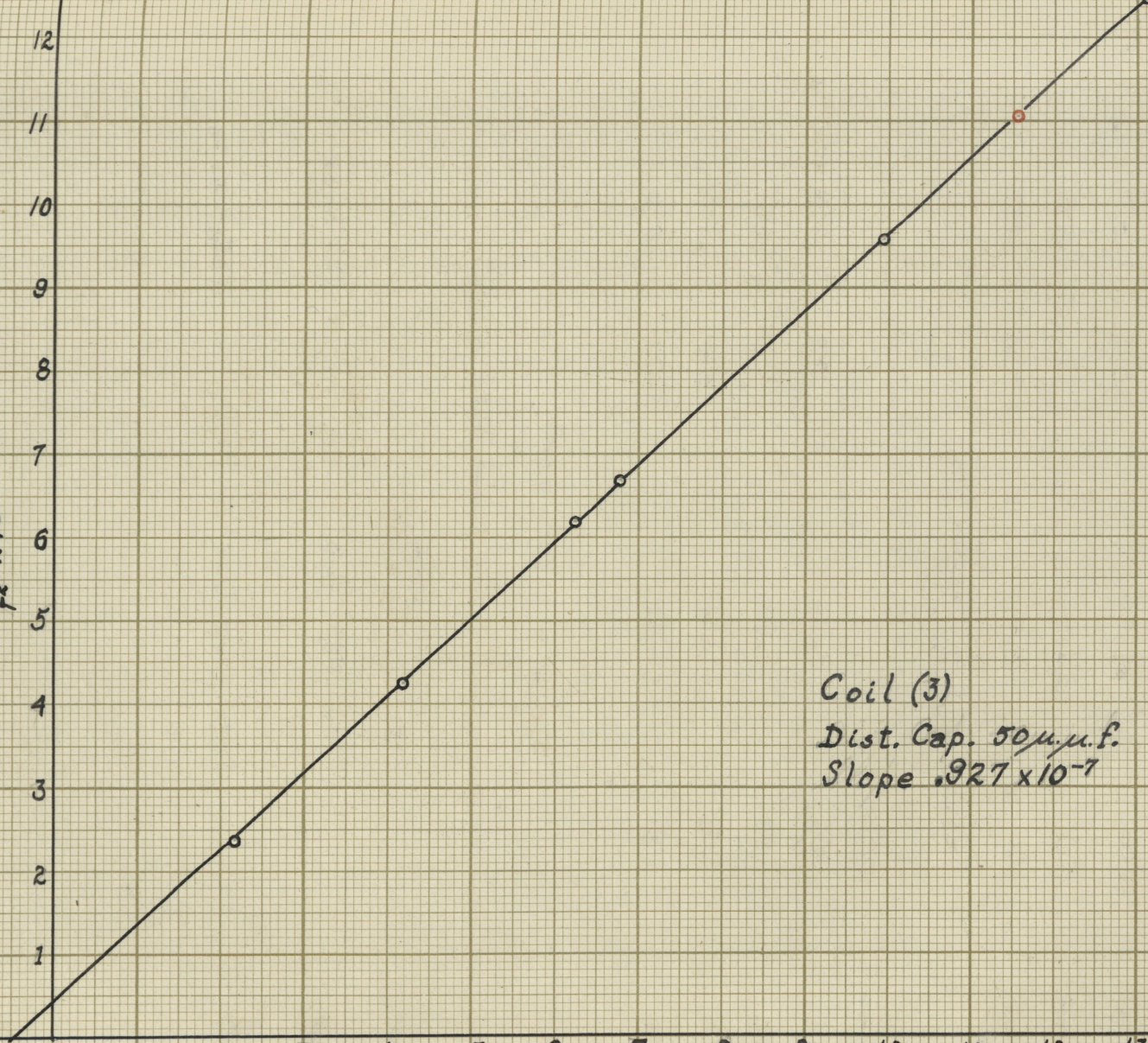
$\frac{1}{f^2} \times 10^{11}$

12
11
10
9
8
7
6
5
4
3
2
1

1 2 3 4 5 6 7 8 9 10 11 12 13

$C_{(3)}$ in 100 $\mu\mu\text{f.}$ Units

Coil (3)
Dist. Cap. 50 $\mu\mu\text{f.}$
Slope $.927 \times 10^{-7}$



<u>Coils 1-5</u> <u>Cond. Set.</u>	<u>Cap.</u>	<u>New W-M</u> <u>Coil "C"</u>	<u>Cap.</u>	<u>C₀ + 75</u>
1.48	85.1 $\mu\mu.f.$	4.00	214 $\mu\mu.f.$	289
6.62	389.0	15.85	928	1003
10.15	602.	24.00	1423	1498

[Coil C of New Wave meter]

$C_{1-5} + 75$
in $100\mu\mu.f.$ Units

14
13
12
11
10
9
8
7
6
5
4
3
2
1

1 2 3 4 5

C_{1-5} in $100\mu\mu.f.$ Units

COILS 1-5

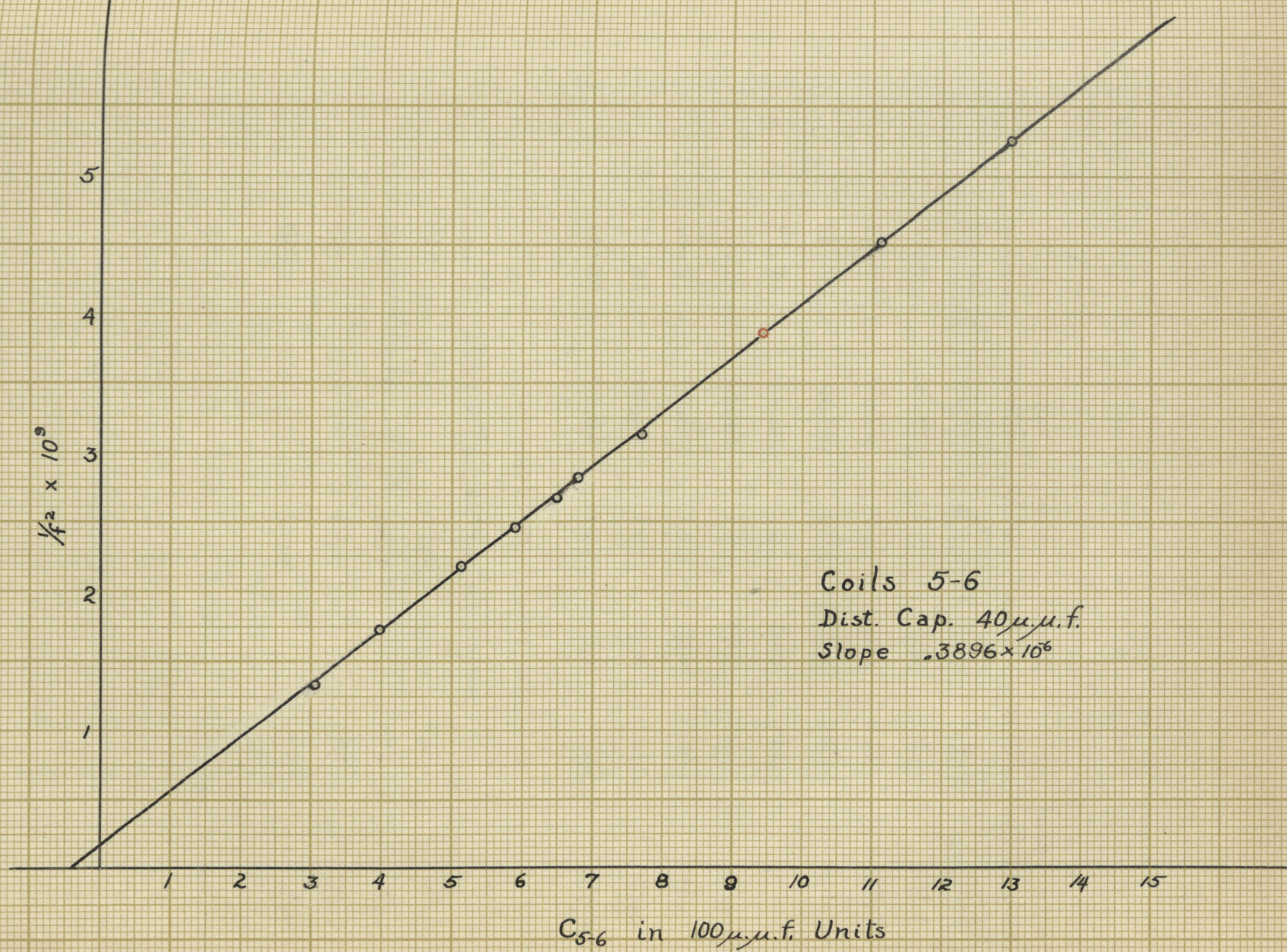
Dist. Cap. $35\mu\mu.f.$

Recheck Point

<u>Coils (5-6)</u> <u>Cond. Set.</u>	<u>Cap.</u>	<u>Sta.</u> <u>freq.</u>	<u>Har-</u> <u>monic</u>	<u>Osc.</u> <u>freq.</u>	<u>$\frac{1}{f^2} \times 10^9$</u>
5.10	307 $\mu\mu.f.$	610 k.c.	7	87.14 k.c.	1.32
6.79	399	610	8	76.25	1.72
8.71	515	610	9	67.78	2.17
10.05	596	950	15	63.33	2.49
10.87	654	610	10	61.00	2.69
11.50	684	950	16	59.38	2.83
13.04	777	950	17	55.88	3.20
18.67	1119	610	13	46.92	4.54
21.66	1304	610	14	43.57	5.26

To Check New Wavemeter

	<u>N.W. Coil "D"</u>	<u>Cap.</u>	<u>$C_D + 92$</u>
8.24	487	2.94	151 $\mu\mu.f.$ 243
11.36	675	4.36	236 328
14.23	850	5.78	322 414
23.05	1389	9.90	571 663



<u>Coils 1-6</u> <u>Cond. Set.</u>	<u>Cap.</u>	<u>Sta.</u> <u>freq.</u>	<u>Har-</u> <u>monic</u>	<u>Osc.</u> <u>freq.</u>	<u>$\frac{1}{f^2} \times 10^4$</u>
2.12	104 $\mu\mu.f$	950	9	106	.897
5.06	294	950	13	73.1	1.87
7.50	442	610	10	61.0	2.69
7.95	469	950	16	59.4	2.84
9.04	535	950	17	55.9	3.20
11.43	680	950	19	50.0	4.00
13.06	778	610	13	46.9	4.55
20.02	1203	610	16	38.1	6.89

To Check New Wavemeter

	<u>Cond. Set.</u> <u>Coil "D"</u>	<u>Cap.</u>	<u>$C_D + 85$</u>
7.27	428	4.00	214 $\mu\mu.f$ 300
11.36	675	6.66	375 460
16.38	980	10.00	576 668
19.68	1182	12.22	709 794

$\frac{1}{f^2} \times 10^4$

7

6

5

4

3

2

1

1

2

3

4

5

6

7

8

9

10

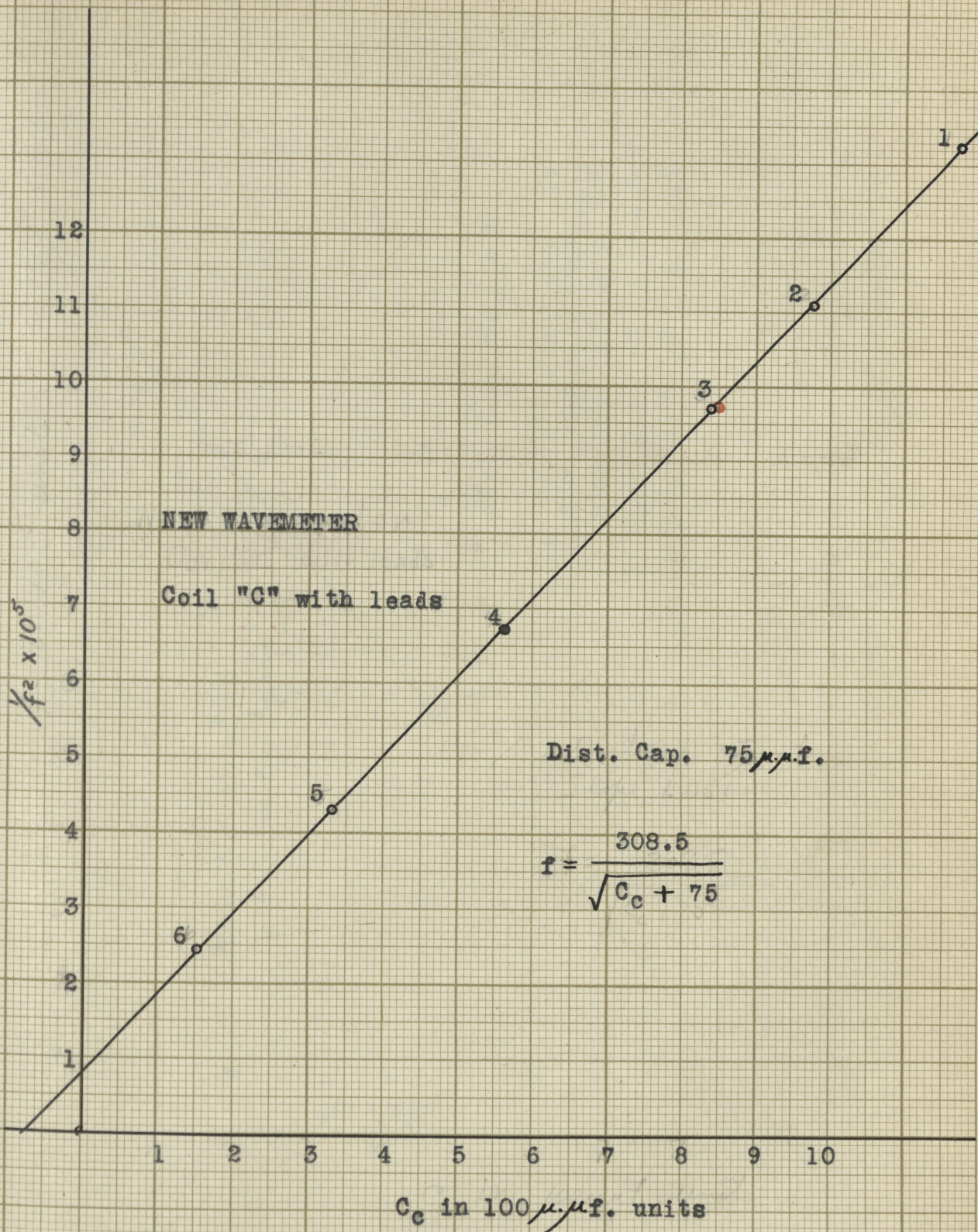
11

C_{1-6} in 100 $\mu\mu\text{f.}$ units

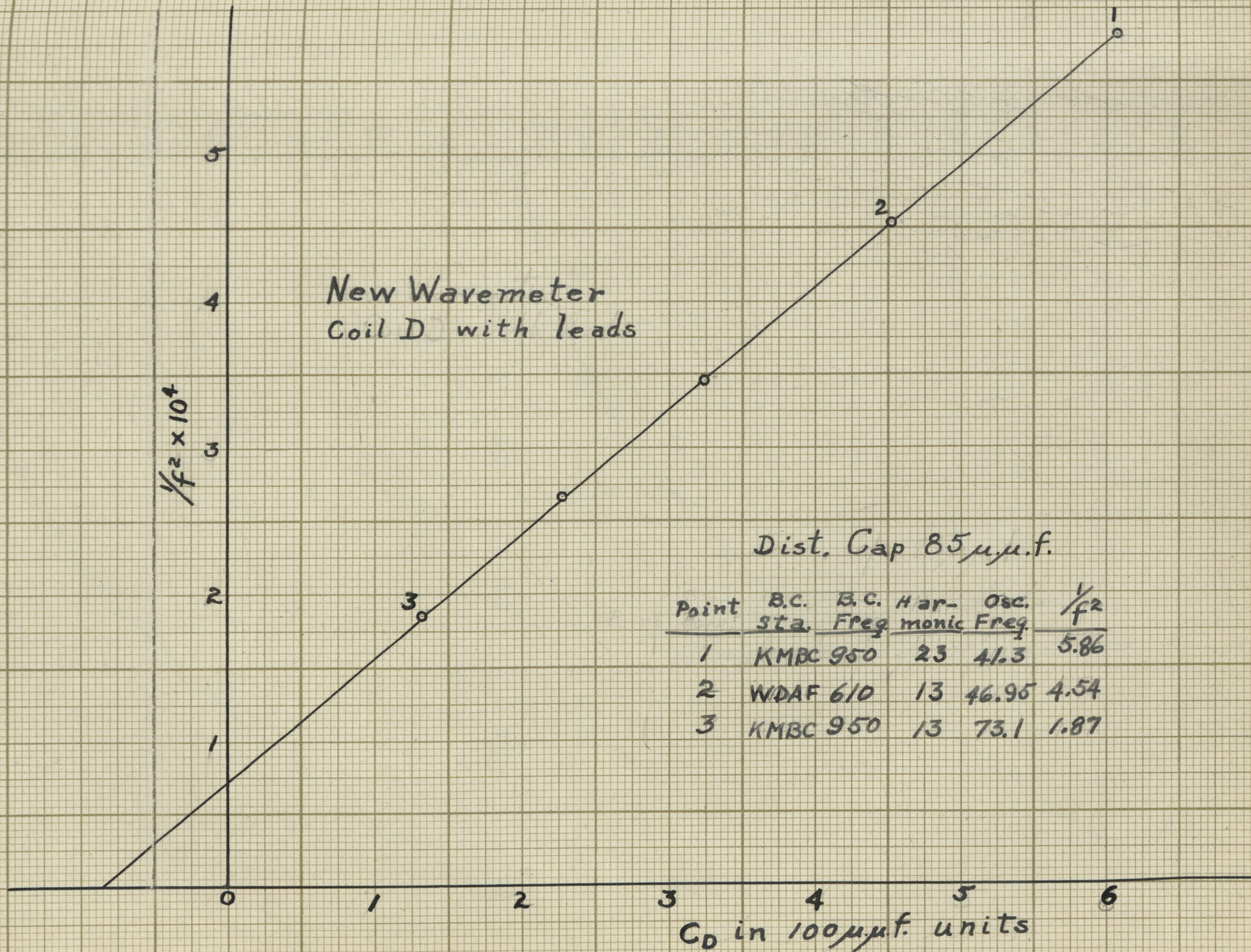
Coils 1-6

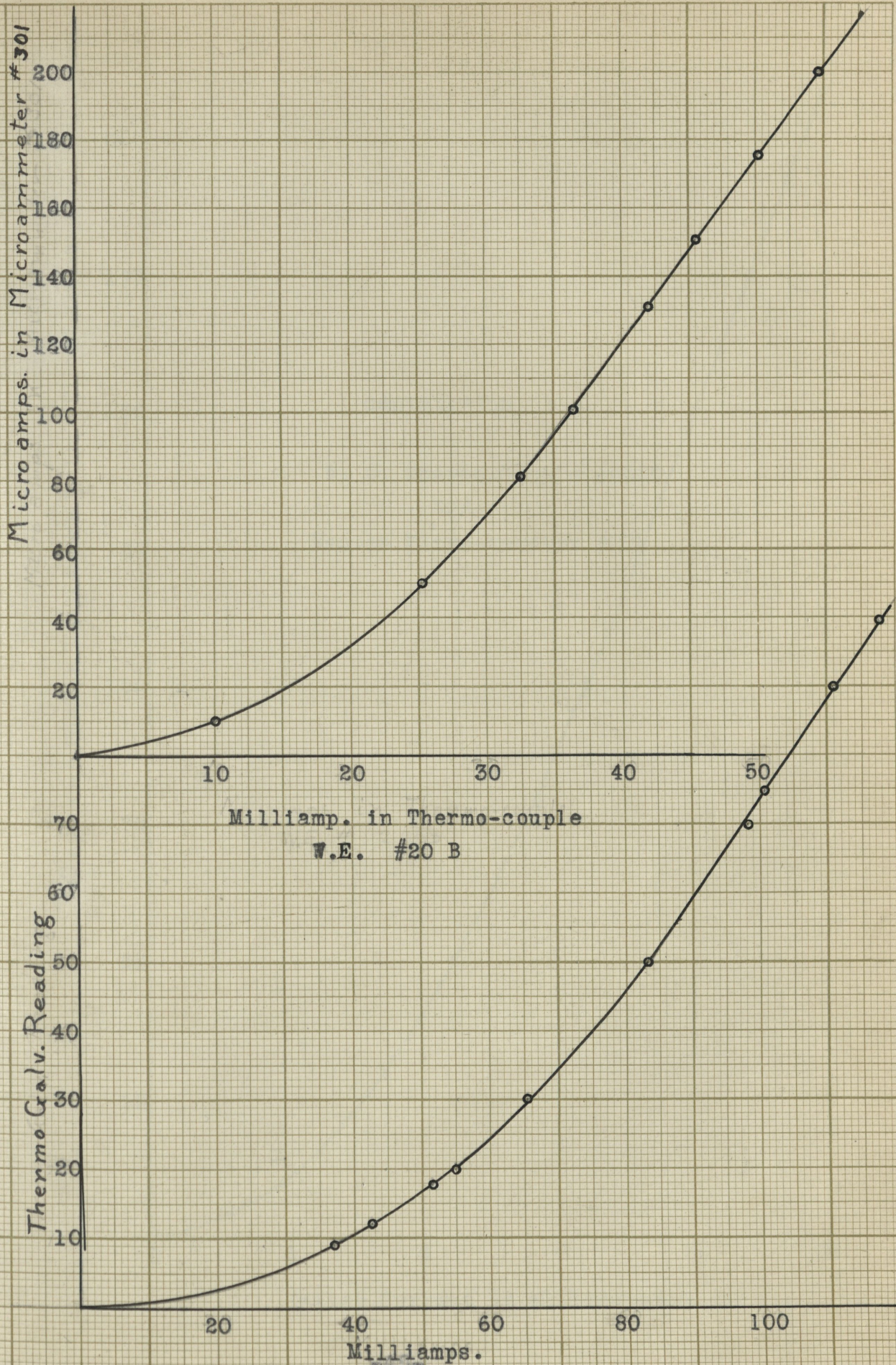
Dist. Cap. 45 $\mu\mu\text{f.}$

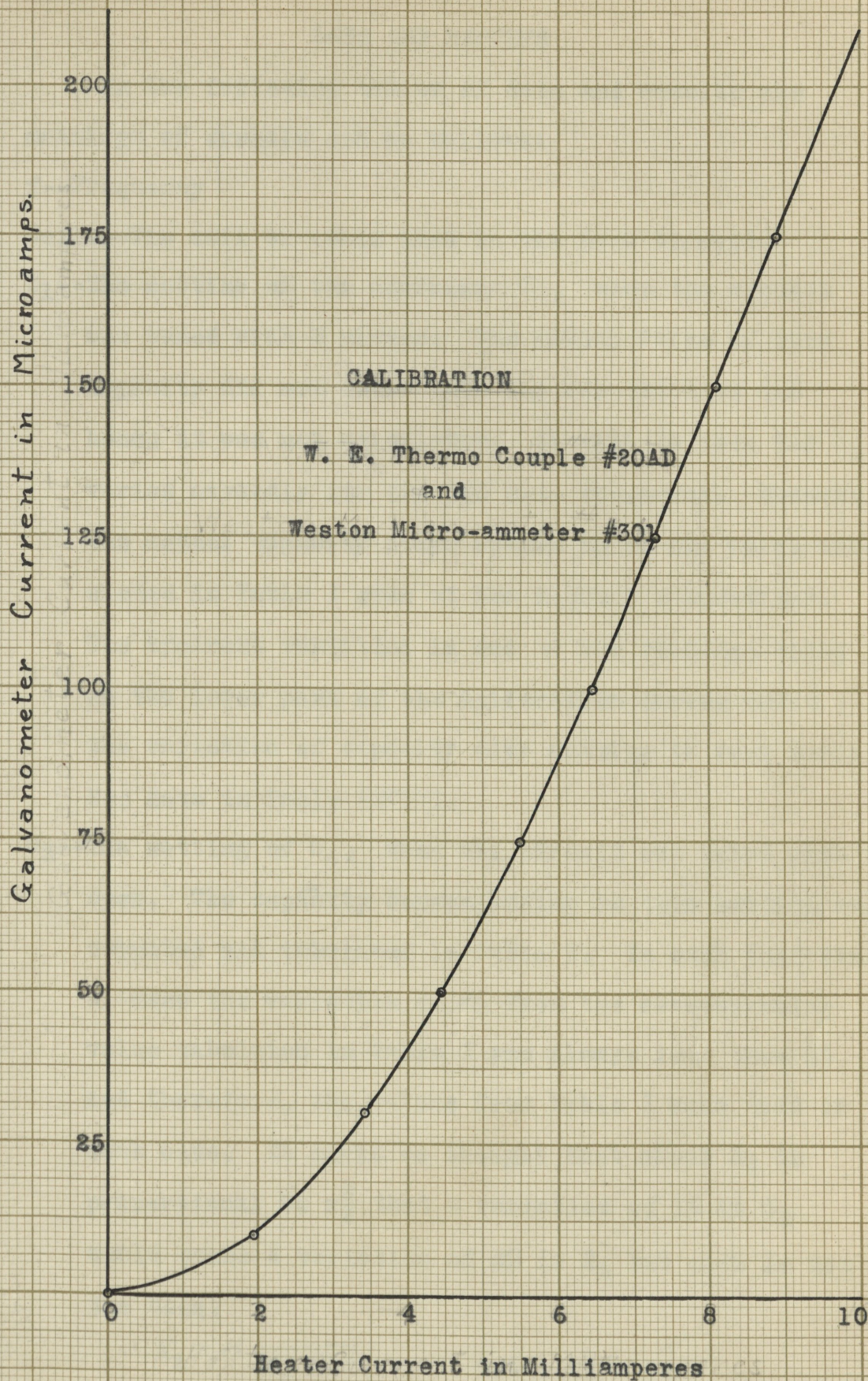
<u>Point</u>	<u>Harmonic</u>	<u>Sta. freq.</u>	<u>Osc. freq.</u>
1	7	610 k.c.	87.1×10^3
2	10	950	95.0
3	6	610	102.00
4	5	610	122.0
5	4	610	153.0
6	3	610	203.0



-44-







DATA AND RESULTS

In the following tables of data and results the meanings of symbols are as follows:

f --Frequency

Coils--The coil or coils used in the test circuit.

C_1 --The setting of the condenser $C_{1,2}$ when the circuit was tuned with S closed. The actual value of this capacity did not enter into the computations and hence it was not calculated. It will be seen the C_1 varies markedly for the 223 k.c. frequency. However, the actual capacity stays within 2% of the value tabulated in Table I even at the highest saturations. The apparent variation is due to the readings being on the lower part of the calibration curves where the variation of capacity with setting is very small. See data in Table XXVIII.

C_2 --The setting of $C_{1,2}$ when the circuit was tuned with S open. The capacity corresponding to this setting was computed and tabulated in Table I. In each individual case the variation of C_2 from the corresponding value tabulated in Table I was always less than 1% and therefore, the values from Table I were used in each case. It might be thought that since R_t is proportional to x_2^2 that a variation of 1% in C_2 would cause a variation of 2% in R_t but such is not the case.

$$X_2 = K \frac{1}{C_2 \cdot 2\pi \cdot f} \quad \text{and} \quad f = \frac{K'}{\sqrt{C_2}}$$

$$\text{Therefore } X_2 = \kappa'' \frac{1}{C_2 \sqrt{C_2}} = \frac{\kappa''}{\sqrt{C_2}}$$

$$\text{and } X_2^2 = \frac{\kappa'''}{C_2}$$

i₁--The galvanometer readings when the Type R galvanometer was used with Western Electric Thermo-couple # 20 B and with 1,000 ohms in series with the galvanometer.

i₂--The micro-ammeter readings when it was used with Western Electric Thermo-couple # 20 A D in place of G.

r--The difference in settings of r_{1,2} expressed in ohms.

x₂--The capacitative reactance of the test circuit when it is tuned with S open. The values in the column x₂² should be multiplied by 10⁶ to obtain the values in ohms.

R_t--The leakage resistance of the test element. The values in this column should be multiplied by 10⁶ to obtain their values in ohms.

$\frac{1}{R_t}$ --The conductance of the test element. The values must be multiplied by 10⁻⁶ to obtain their values in mhos.

TABLE I

<u>f</u>	<u>Coils</u>	<u>C₂</u>	<u>Capacity in <i>μ</i>.f.</u>	<u>Dist. Cap. C_L</u>	<u>x₂²</u>
987 K.C.	(1)	351	201	30	.488
899	7	309	177	40	.666
763	7	440	255	40	.500
689	8	306	207	55	1.018
644	7	640	375	40	.355
621	8	402	232	55	.805
587	7	780	460	40	.294
519	(2)	292	166	30	.245
515	8	600	350	55	.580
485	(2)	343	196.4	30	2.111
417	(2)	472	274	30	1.58
223	(3)	296	168.2	50	10.73
146	(3)	777	459.0	50	4.59
96.5	1-5	660	387.5	35	15.23
69.8	5-6	823	485.9	40	18.76
38.5	1-6	1962	1178	45	12.33

TABLE II

Alcohol	Temperature	Pressure	Saturation				
	79° C	00.0 Cm Hg	0.0%				
Pumped for 14 hours							
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₁</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 Kc	(1)	156	351	55.9	2.2	.222	4.51
899	7	099	309	16.0	3.2	.208	4.81
763	7	251	440	14.1	2.0	.250	4.00
644	7	450	640	13.0	1.3	.273	3.66
587	7	590	780	14.0	.85?	.346	2.89
519	(2)	052	292	15.5	16.2	.395	2.53
485	(2)	147	343	11.85	5.1	.414	2.42
223	(3)	066	295	8.6	14.3	.750	1.33
146	(3)	588	777	9.1	4.3	1.067	.937
96.5	1-5	470	660	8.2	9.05	1.692	.591
69.8	5-6	631	823	6.8	8.8	2.132	.469
38.5	1-6	1764	1954	12.5	3.2	3.85	.260

TABLE III

Alcohol		Temperature 79° C		Pressure 12.7 cm Hg		Saturation 16.4%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₁</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 K.C. (1)		158	353	11.8	2.4	.203	4.93
485 (2)		149	344	11.1	5.35	.395	2.53
223 (3)		071?	296	10.6	14.14	.760	1.32
146 (3)		596	777	13.5	4.4	1.043	.959
96.5 1-5		469	659	10.6	9.13	1.673	.598
69.8 5-6		626	816	11.7	9.25	2.028	.493
38.5 1-6		11769	1957	13.4	3.4	3.626	.276

TABLE IV

Alcohol		Temperature 79° C		Pressure 37.6 cm Hg		Saturation 48.5%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₁</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 K.C. (1)		158	353	10.7	2.45	.199	5.03
485 (2)		147	344	8.9	5.23	.406	2.46
223 (3)		072	269	11.1	14.23	.750	1.33
146 (3)		602	777	8.3	4.3	1.067	.937
96.5 1-5		470	661	10.4	9.4	1.620	.617
69.8 5-6		633	825	8.25	9.4	1.996	.501
38.5 1-6		1775	1965	8.6	3.5	3.523	.284

TABLE V

Alcohol		Temperature 79° C		Pressure 66.4 cm Hg		Saturation 85.7%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 κ c. (1)		154	351	91	2.5	.195	5.13
689	8	098	306	98	4.0	.255	3.93
621	8	210	402	140	3.1	.260	3.85
515	8	410	600	176	1.65	.352	2.84
485	(2)	146	342	110	5.3	.398	2.51
223	(3)	056	294	114	16.0	.671	1.49
146	(3)	587	779	181	4.7	.977	1.02
96.5	1-5	469	659	94	9.2	1.66	.604
69.8	5-6	629	820	112	10.0	1.88	.533
38.5	1-6	1772	1962	119	3.7	3.33	.300

TABLE VI

Alcohol		Temperature 79° C		Pressure 71.8 cm Hg		Saturation 92.6 %	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₁</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 κ c. (1)		155	350	7.45	2.7	.181	5.53
485	(2)	147	345	9.1	6.0	.352	2.84
223	(3)	070	296	5.73	18.0	.596	1.68
146	(3)	585	776	10.2	5.5	.835	1.20
96.5	1-5	469	660	10.0	12.2	1.248	.801
69.8	5-6	630	823	5.9	12.2	1.538	.650
38.5	1-6	1767	1958	11.4	5.0	2.47	.406

TABLE VII

Alcohol		Temperature 79° C		Pressure 74.9 cm Hg		Saturation 96.6%	
F	Coils	C ₁	C ₂	i ₁	r	R _t	1/R _t
987 K.C.	(1)	154	352	6.2	2.7	.181	5.53
763	7	248	440	11.6	2.4	.208	4.81
485	(2)	146	342	11.6	8.2	.257	3.89?
A Repeat Run							
485	(2)	146	343	196.0	6.5	.325	3.08
417	(2)	280	472	12.5	4.2	1.376	2.66
223	(3)	056	294	7.6	20.0	10.537	1.862
146	(3)	586	778	11.0	6.0	.765	1.31
96.5	1-5	470	660	5.8	14.3	1.065	.940
69.8	5-6	630	822	6.85	15.3	1.23	.816
38.5	1-6	1760	1952	7.00	6.2	1.99	.503

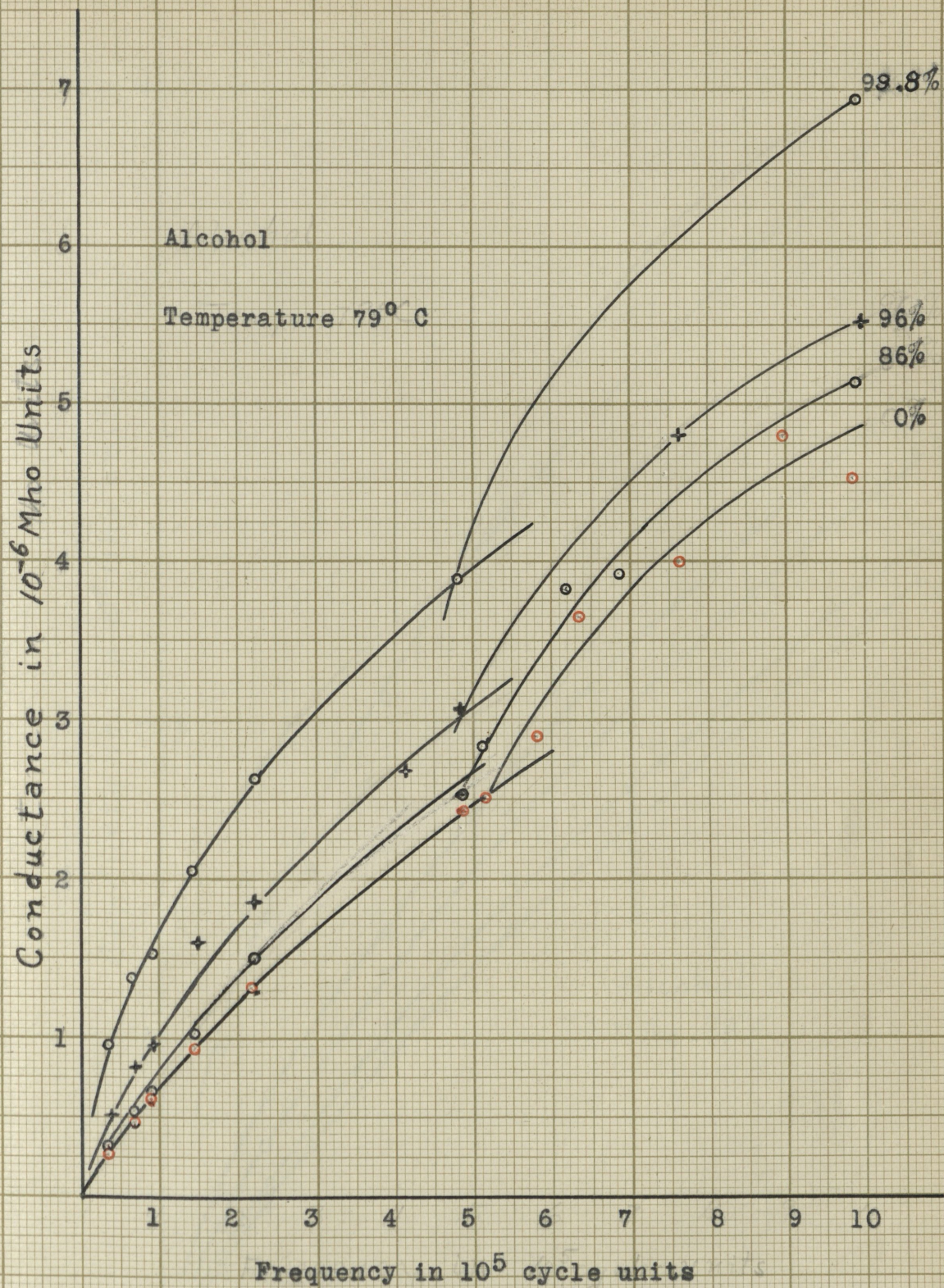
TABLE VIII

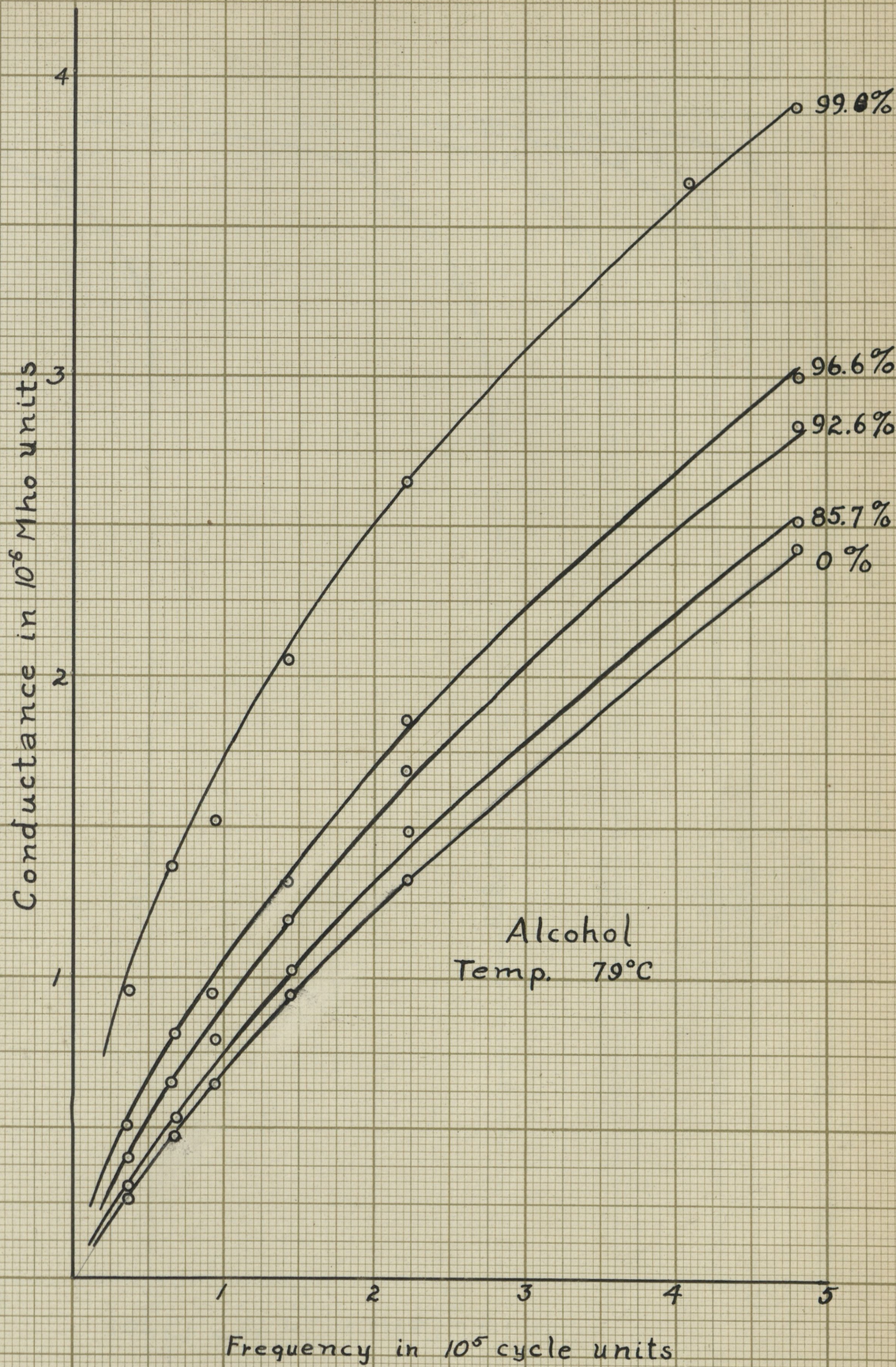
Alcohol		Temperature 79° C		Pressure 71.8 cm Hg		Saturation 92.6%	
f	Coils	C ₁	C ₂	i ₁	r	R _t	1/R _t
987 K.C.	(1)	154	349	7.3	3.48	.141	7.09
485	(2)	147	344	7.0	8.1	.261	3.83
223	(3)	064	296	6.7	26.7	.402	2.49
96.5	1-5	470	662	7.7	21.2	.718	1.39
69.8	5-6	633	826	7.3	23.6	.795	1.26
38.5	1-6	1771	1962	8.0	10.4	1.185	.844

These results are doubtful

TABLE IX

Alcohol	Temperature 79° C		Pressure 77.2 cm Hg		Saturation 99.8%		
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₁</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 K.C.	(1)	154	351	8.6	3.4	.144	6.94
485	(2)	146	342	11.6	8.2	.257	3.89
223	(3)	045	294	7.7	28.2	.380	2.63
146	(3)	584	776	7.7	9.4	.488	2.05
96.5	1-5	470	662	6.0	23.0	.662	1.51
69.8	5-6	630	823	5.8	25.9	.724	1.381
38.5	1-6	1769	1960	7.2	11.8	1.045	.957





-57-

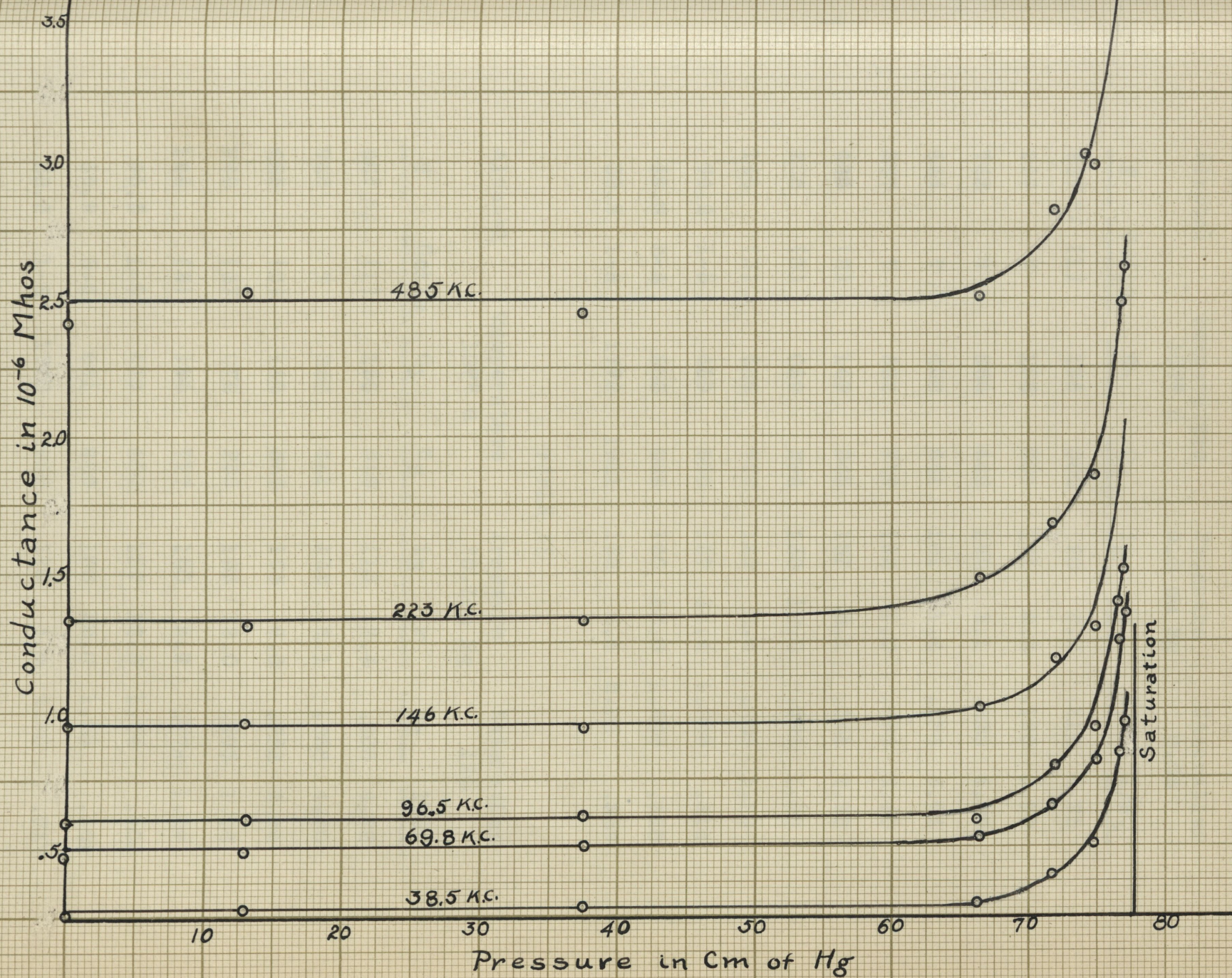


TABLE X

Alcohol		Temperature 107° C		Pressure 9.0 cm Hg		Saturation 0.0%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 KC.	(1)	156	350	98	2.3	.212	4.72
899	7	102	309	121	3.4	.196	5.10
763	7	254	442	126	2.1	.238	4.20
644	7	452	641	161	1.4	.254	3.94
587	7	592	779	162	1.0	.294	3.40
485	(2)	149	345	135	6.1	.346	2.89
223	(3)	069	296	130	18.0	.596	1.68
146	(3)	588	777	163	5.4	.850	1.18
96.5	1-5	469	660	157	12.4	1.228	.814
69.8	5-6	633	825	150	12.0	1.563	.640
38.5	1-6	1772	1961	152	4.4	2.80	.357

TABLE XI

Alcohol		Temperature 107° C		Pressure 26.3cm Hg		Saturation 12%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 KC.	(1)	156	349	113	2.4	.203	4.92
763	7	253	441	142	2.1	.238	4.20
485	(2)	150	345	173	6.0	.352	2.84
223	(3)*	072	295	139	18.0	.596	1.68
146	(3)	186	777	150	5.9	.778	1.29
96.5	1-5	469	660	157	12.3	1.24	.806
69.8	5-6	631	823	150	12.0	1.56	.640
38.5	1-6	1770	1960	175	4.4	2.80	.357

TABLE XII

Alcohol		Temperature 107° C		Pressure 58 cm Hg		Saturation 26%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987kc.	((1))	156	352	120	2.3	.212	4.72
763	7	255	443	117	2.2	.227	4.41
485	((2))	148	345	151	6.0	.352	2.84
223	(3)	070	295	108	19.0	.564	1.77
146	(3)	584	776	118	5.6	.820	1.21
96.5	1-5	471	661	149	12.0	1.271	.787
69.8	5-6	630	822	175	12.2	1.54	.649
38.5	1-6	1768	1952	119	4.5	2.74	.365

TABLE XIII

Alcohol		Temperature 107° C		Pressure 73.1 cm Hg		Saturation 33%	
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Data were taken at only four frequencies at this pressure. Since they checked so closely with the foregoing tables it was deemed unnecessary to take readings for all the frequencies.

<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
69.8kc	5-6	630	822	174	12.2	1.54	.649
146	(3)	583	775	171	5.6	.820	1.21
485	(2)	150	345	126	6.0	.352	2.84
987	(1)	153	350	120	2.3	.212	4.72

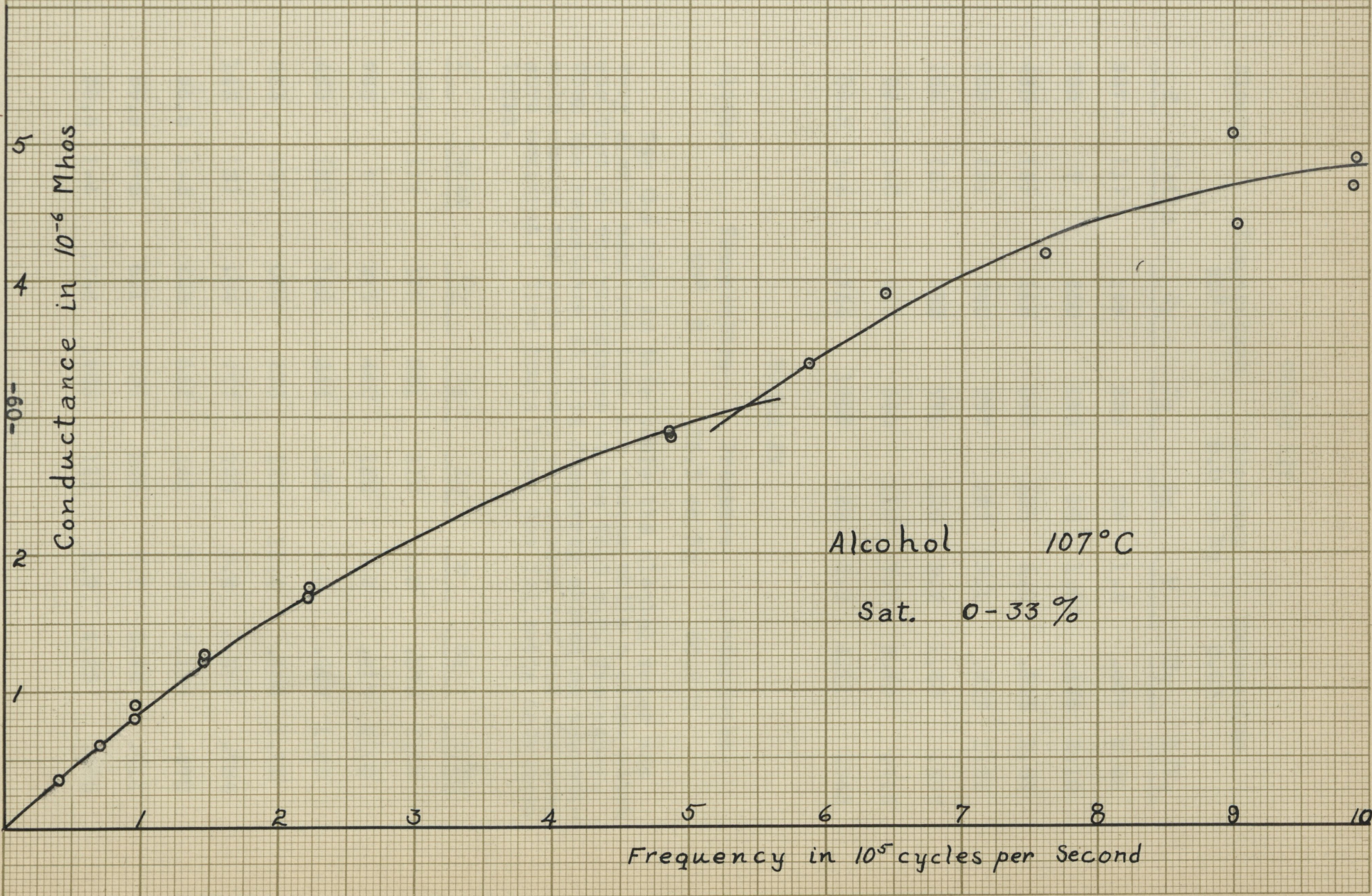


TABLE XIV

Alcohol		Temperature 65° C	Pressure 0.0 cm Hg		Saturation 0.0%		
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 K.C.	(1)	156	353	123	1.2	.407	2.46
763	7	250	440	94	1.05	.476	2.10
485	(2)	145	343	132	4.0	.528	1.89
223	(3)	060	297	122	13.1	.819	1.22
146	(3)	583	776	100	3.2	1.43	.697
96.5	1-5	467	660	110	7.0	2.35	.426
38.5	1-6	1764	1955	160	3.0	4.11	.243

TABLE XV

Alcohol		Temperature 65° C	Pressure 36.3 cm Hg		Saturation 80.8 %		
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For the data in this table the alcohol vapor was very slowly admitted into the vacuum while a close watch was kept on the resistance at the 96.5 k.c. frequency. When the resistance at this frequency showed an appreciable change the test chamber was closed off and the pressure measured. Five hours later the following data were taken.

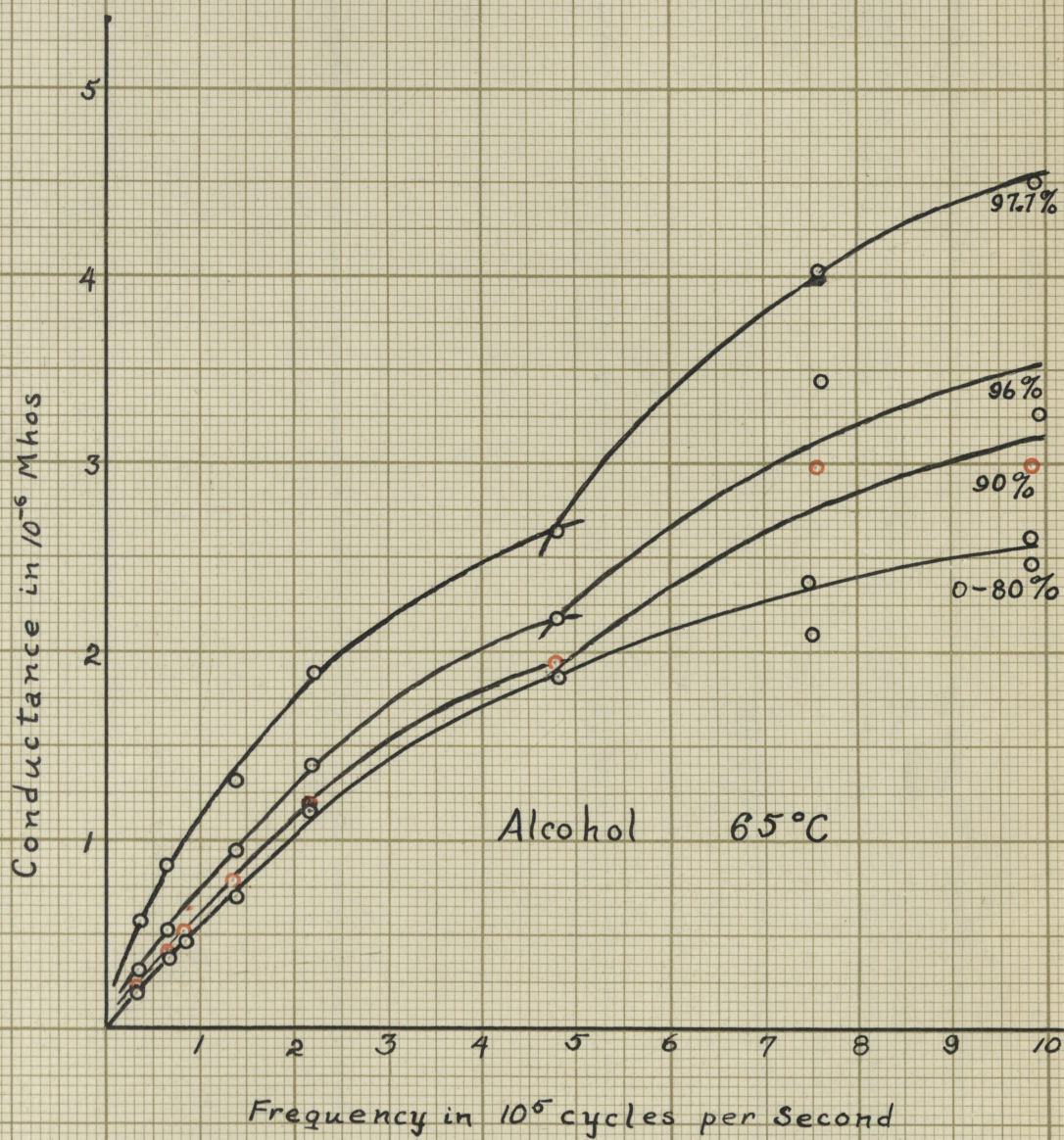
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 K.C.	(1)	152	351	110	1.3	.375	2.67
763	7	249	440	130	1.2	.417	2.40
485	(2)	146	344	150	4.0	.528	1.89
223	(3)	050	296	120	12.4	.865	1.16
146	(3)	584	777	120	3.6	1.275	.784
96.5	1-5	468	662	140	7.4	2.126	.470
69.8	5-6	631	824	130	7.7	2.44	.411
38.5	1-6	1766	1958	111	2.9	4.25	.235

TABLE XVI

Alcohol		Temperature 65° C		Pressure 40.4 cm Hg		Saturation 90%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 K.C.	(1)	150	350	100	1.45	.337	2.97
763	7	246	440	110	1.5	.333	3.00
485	(2)	145	345	145	4.15	.509	1.96
223	(3)	067	297	160	12.8	.838	1.19
146	(3)	584	777	155	3.9	1.18	.850
96.5	1-5	467	661	125	8.2	1.86	.539
69.8	5-6	628	823	130	7.9	2.38	.421
38.5	1-6	11771	1960	145	3.0	4.11	.243

TABLE XVII

Alcohol		Temperature 65° C		Pressure 43.1 cm Hg		Saturation 96%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 K.C.	(1)	150	350	120	1.6	.305	3.28
763	7	243	438	135	1.7	.294	3.40
485	(2)	142	343	130	4.6	.459	2.18
223	(3)	052	295	145	15.0	.715	1.40
146	(3)	583	776	170	4.4	1.04	.96
96.5	1-5	467	661	135	9.7	1.57	.637
69.8	5-6	629	823	95	10.2	1.84	.544
38.5	1-6	1768	1961	110	3.92	3.16	.316



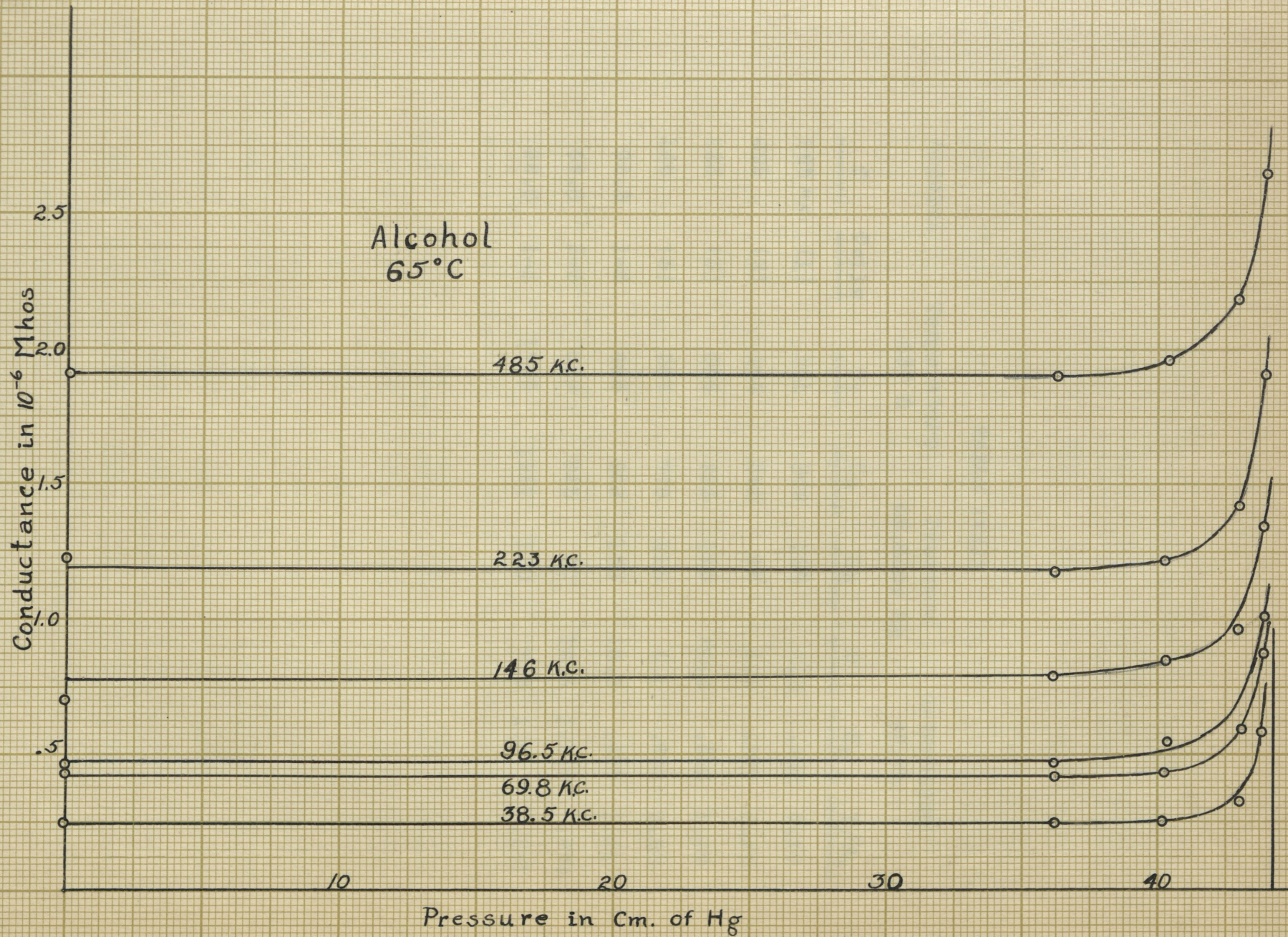


TABLE XVIII

Alcohol		Temperature 65° C	Pressure 43.85cm Hg			Saturation 97.7%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 K.C.	(1)	151	349	135	2.2	.222	4.50
485	(2)	142	343	95	5.6	.377	2.65
223	(3)	056	296	125	20.4	.526	1.90
146	(3)	587	779	115	6.1	.752	1.33
96.5	1-5	465	662	128	15.4	.989	1.01
69.8	5-6	629	823	90	16.4	1.144	.874
38.5	1-6	1769	1959	100	7.3	1.69	.592

TABLE XIX

Alcohol		Temperature 51° C		Pressure 0.0 cm Hg		Saturation 0.0%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 Kc.	(1)	148	350	95	1.1	.444	2.25
763	7	247	439	131	1.2	.417	2.40
485	(2)	145	344	138	3.8	.555	1.80
223	(3)	645	296	155	11.4	.941	1.06
146	(3)	584	777	130	3.3	1.39	.719
96.5	1-5	466	660	147	6.7	2.27	.440
69.8	5-6	628	823	112	6.7	2.84	.352
38.5	1-6	1764	1957	107	2.5	4.93	.203

TABLE XX

Alcohol		Temperature 51° C		Pressure 21.0cm Hg		Saturation 90.5%	
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As described for Table XV the vapor was admitted slowly while the resistance of the element as 69.8 k.c. was closely watched. When a noticable change occurred the test chamber was closed off and the pressure measured. The following data were taken immediately.

<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 Kc.	(1)	149	351	127	1.1	.444	2.40
485	(2)	143	344	161	3.6?	.586	1.71
223	(3)	056	296	145	11.3	.950	1.05
146	(3)	584	776	165	3.5	1.31	.763
96.5	1-5	468	661	140	7.0	2.18	.459
69.8	5-6	628	823	117	6.7	2.80	.357
38.5	1-6	1765	1960	131	2.5	4.93	.203

After four hours the following data were taken at the same pressure.

TABLE XX (continued)

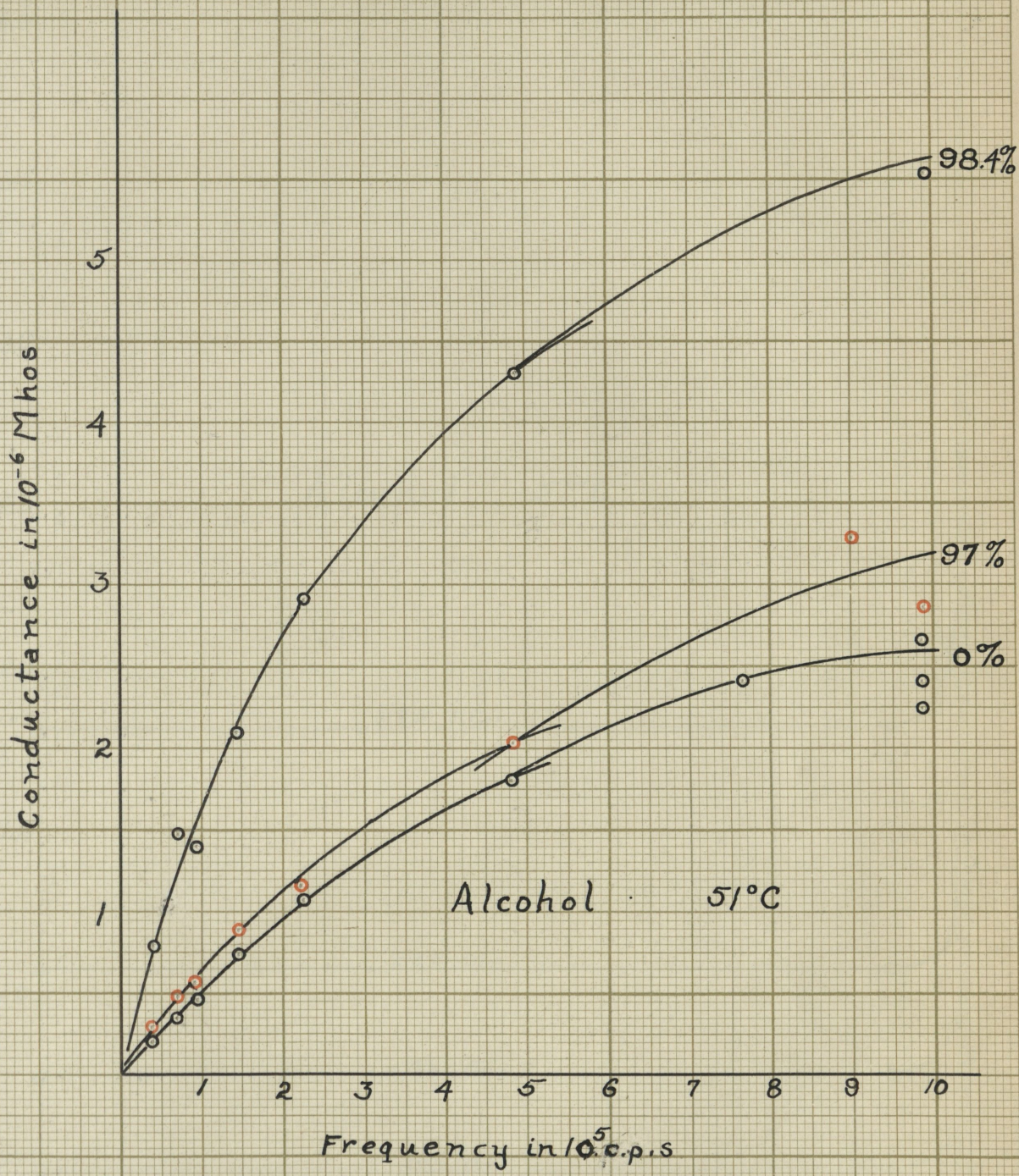
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 KC.	(1)	150	352	107	1.3	.375	2.67
485	(2)	143	344	120	3.8	.556	1.80
223	(3)	059	296	93	11.4	.941	1.06
146	(3)	584	776	1140	3.4	1.350	.741
96.5	1-5	468	663	167	6.83	2.22	.450

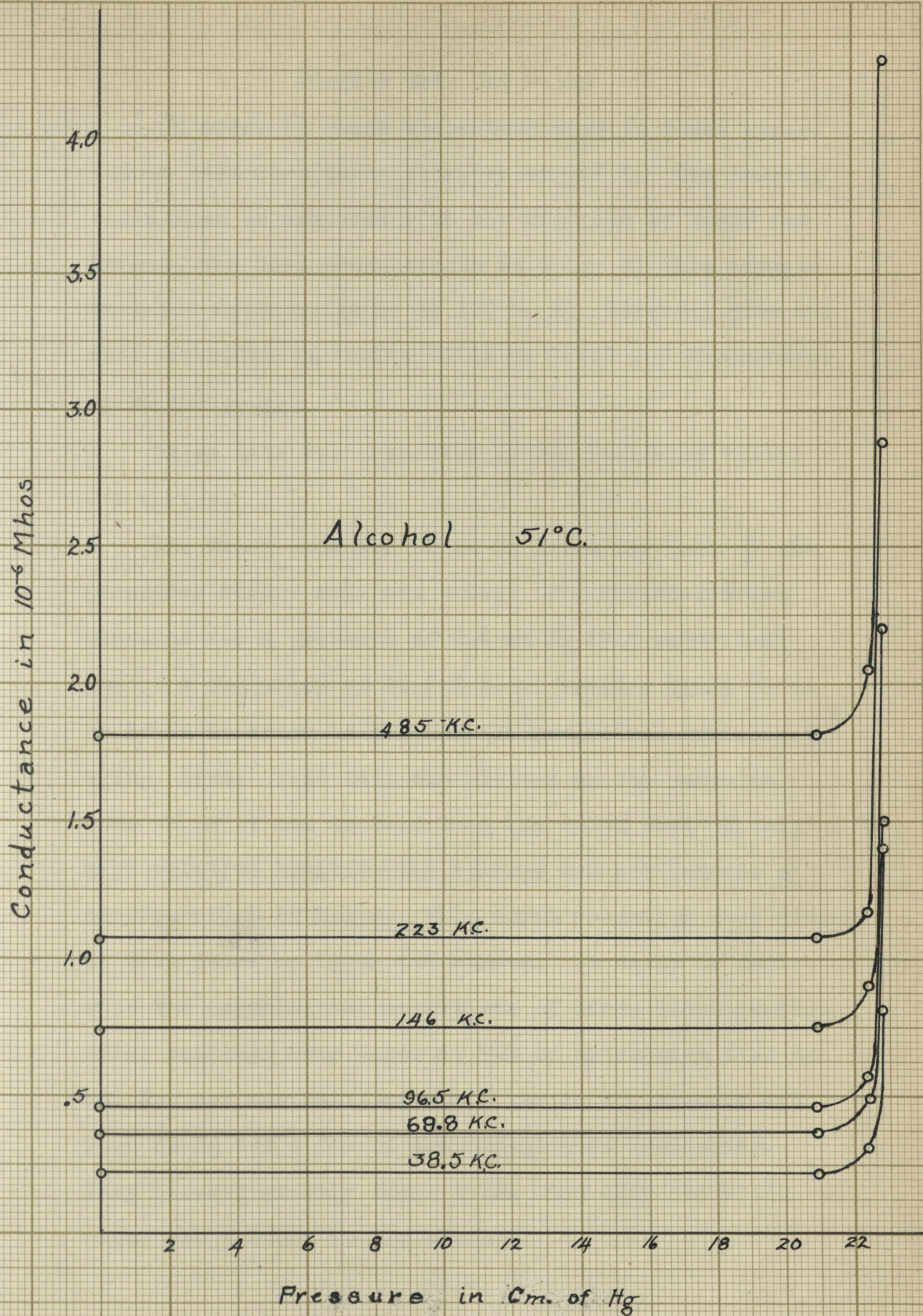
TABLE XXI

Alcohol	Temperature	Pressure	Saturation				
	51° C	22.5 cm Hg	97%				
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 KC.	(1)	149	350	113	1.4	.349	2.87
485	(2)	143	344	170	4.3	.490	2.04
223	(3)	045	297	111	12.4	.865	1.16
146	(3)	683	778	121	4.1	1.12	.893
96.5	1-5	466	660	104	8.4	1.81	.552
69.8	5-6	627	821	111	9.0	2.08	.480
38.5	1-6	1762	1955	129	3.6	3.43	.292

TABLE XXII

Alcohol		Temperature	Pressure			Saturation	
		51° C	22.84 cm Hg			98.4%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 K.C.	(1)	151	353	86	2.7	.181	5.52
485	(2)	142	343	125	9.0	.234	4.27
223	(3)	045	296	145	31.0?	.346	2.89
146	(3)	583	778	92	10.0	.459	2.18
96.5	11-5	466	660	111	21.2	.718	1.39
69.8	5-6	626	824	100	28.0	.670	1.49
38.5	1-6	1763	1961	130	10.0	1.23	.811





Similar Data For Water

In order to check the method used in these experiments data were taken on water at 50° C. The results could then be compared with the findings of Yager and Morgan, who took measurements on water at this temperature for frequencies up to 100 k. c. However, data are also presented in tables XXIII to XXVII for frequencies up to 10^6 cycles.

These data are presented in the following tables and curves.

The vapor aged for 20 to 25 hours for each of the pressures before data was taken. The resistance was measured for a pressure of 8.4 cm Hg (91% saturated) and at a frequency of 69.8 k.c. at various times up to 25 hours in order to see how the resistance varied with aging time. This data was plotted in the curve on page 72. It can be seen from the curve that at this high relative humidity the leakage had not reached a maximum after 25 hours. This curve resembles very closely that found by Yager and Morgan. In order to duplicate the experimental conditions of these investigators, after readings were taken at 79% of saturation (7.3 cm Hg) dry air was admitted until the total pressure was 73.4 cm Hg and a few of the resistances remeasured. They checked exactly those taken when only the water vapor was present in the chamber.

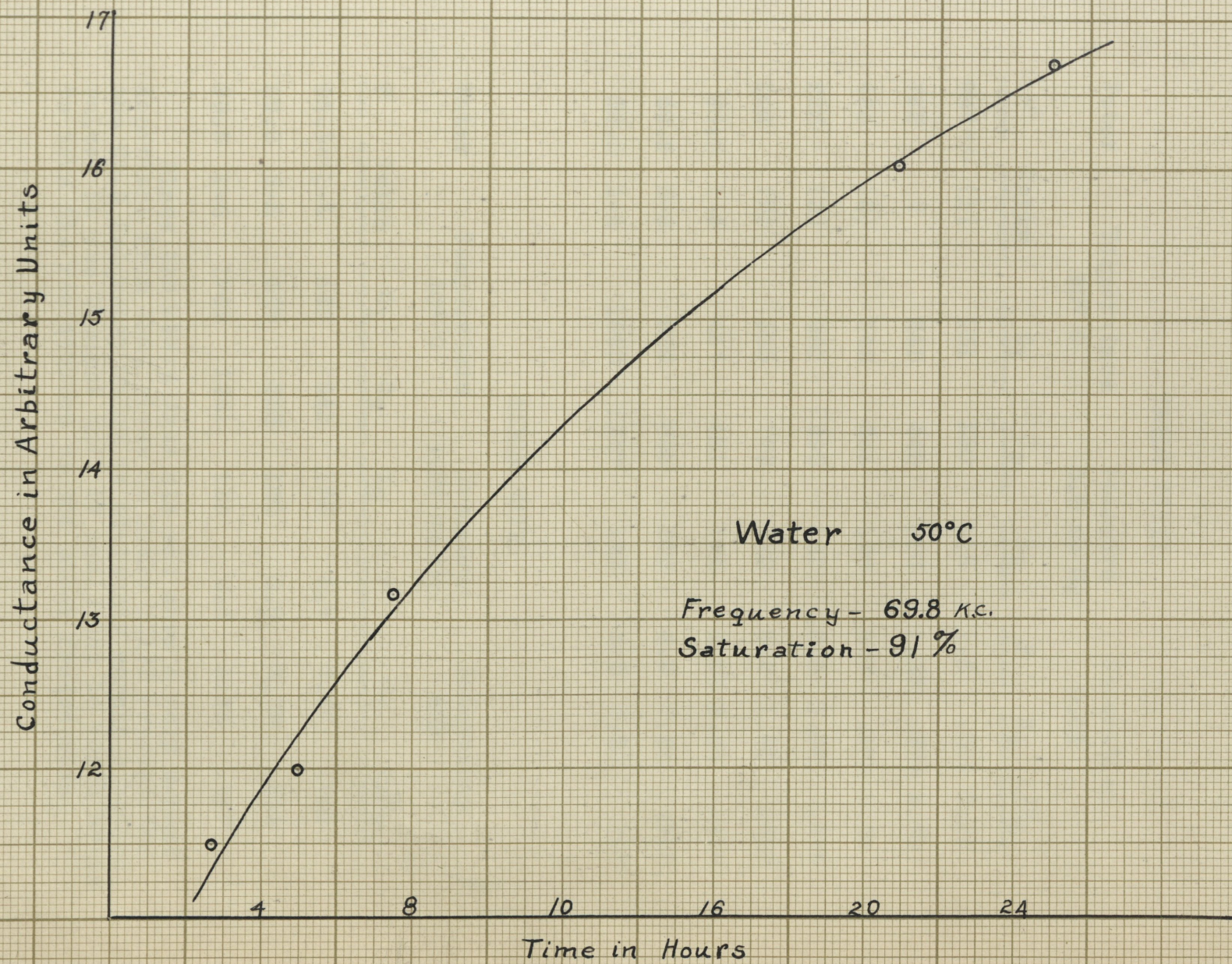


TABLE XXIII

Water		Temperature 50° C		Pressure 0.0 cm Hg		Saturation 0.0%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>F</u>	<u>R_t</u>	<u>1/R_t</u>
987 Kc.	(1)	151	350	115	1.6	.305	3.28
763	7	243	440	150	1.35	.370	2.70
485	(2)	142	344	158	3.7	.571	1.75
223	(3)	051	295	165	10.5	1.02	.978
146	(3)	585	778	140	3.2	1.43	.697
96.5	1-5	467	661	144	6.37	2.42	.414
69.8	5-6	629	823	160	6.6	2.84	.352
38.5	1-6	1665	1957	145	2.3	5.36	.187

TABLE XXIV

Water		Temperature 50° C		Pressure 4.55 cm Hg		Saturation 49%	
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
96.5 Kc.	1-5	466	661	175	6.7	2.27	.440
69.8	5-6	628	823	100	6.8	2.75	.364
38.5	1-6	1768	1961	115	2.3	5.36	.187

Since the above data did not show a very marked departure from that given in Table XXIII (except for the 96.5 frequency which is obviously merely a better value) it was thought that it would not be worth while to take the resistances at the other frequencies.

TABLE XXV

Water	Temperature 50° C	Pressure 4.9 cm Hg	Saturation 53%				
Aged for 7 hours							
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 Kc.	(1)	151	352	115	1.6	.305	3.3
763	7	243	440	130	1.5	.333	3.0
485	(2)	144	345	115	4.0	.528	1.89
223	(3)	048	295	105	11.4	.941	1.06
146	(3)	583	777	130	3.4	1.35	.741
96.5	1-5	462	658	153	6.8	2.24	.447
69.8	5-6	628	824	160	6.95	2.70	.371
38.5	1-6	1763	1958	135	2.43	5.14	.195

TABLE XXVI

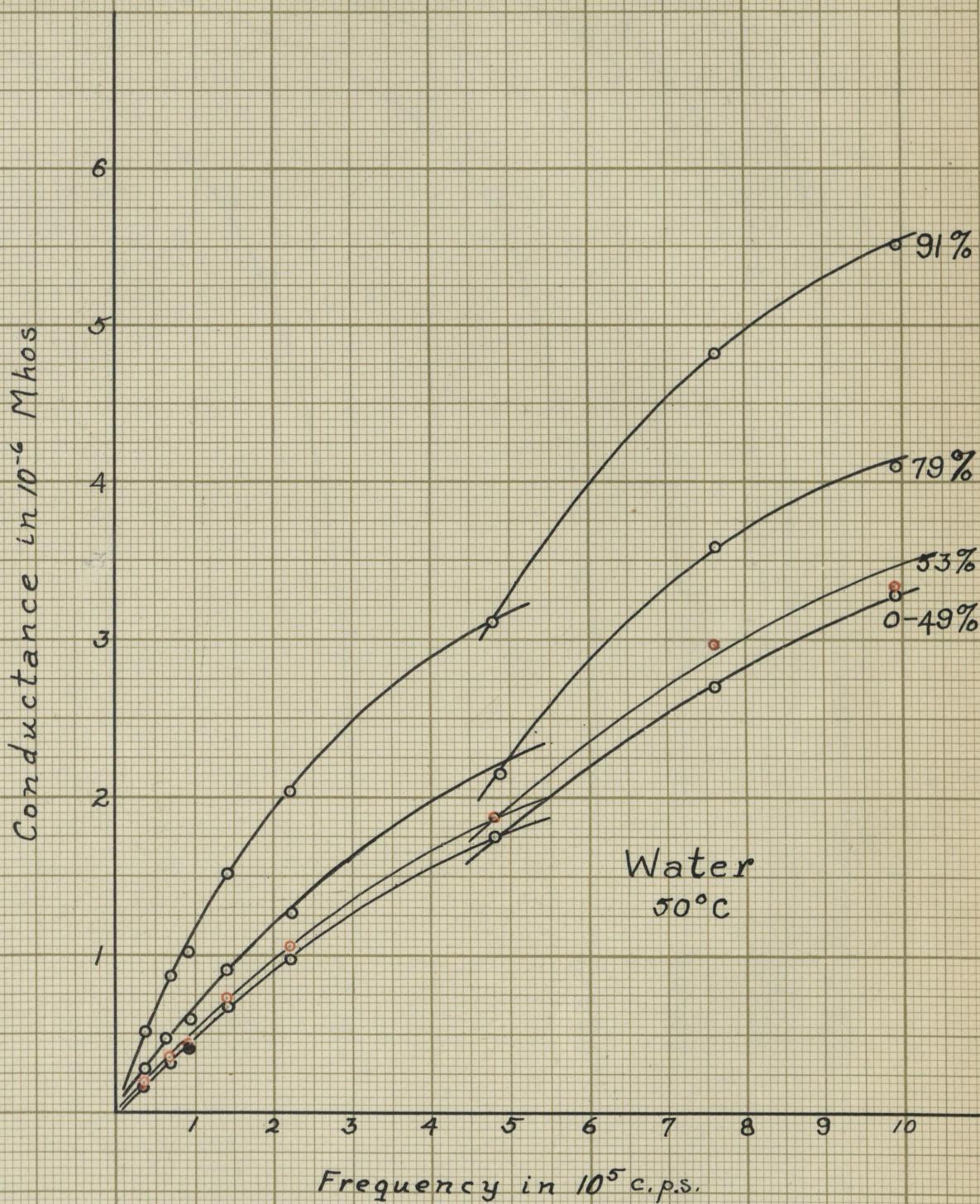
Water	Temperature	Pressure		Saturation			
	50°	7.3 cm Hg		79%			
<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 Kc. (1)		151	352	100	2.0	.244	4.1
763	7	246	440	155	1.8	.278	3.6
485	(2)	142	343	130	4.5	.469	2.13
223	(3)	047	295	130	13.7	.783	1.28
146	(3)	584	778	130	4.2	1.09	.922
96.5	1-5	465	661	115	9.0	1.69	.591
69.8	5-6	628	824	110	9.2	2.04	.490
38.5	1-6	1768	1959	125	3.7	3.33	.300

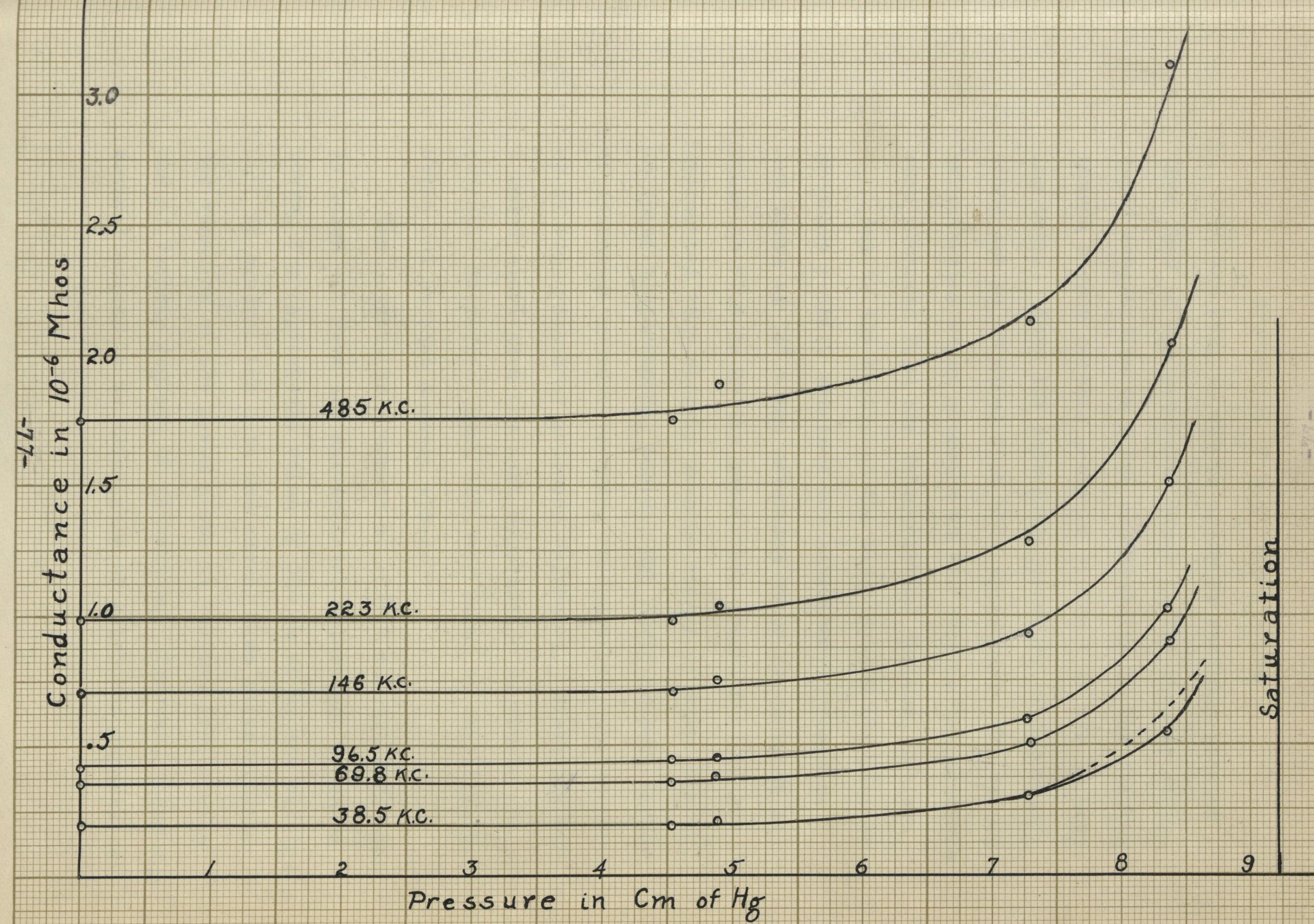
TABLE XXVII

Water	Temperature	Pressure	Saturation
	10 50° C	8.4 cm Hg	91%

Aged 25 hours. Longer times were not taken due to the difficulty of holding the pressure constant. The ice melted in the cooler after about 25 hours and in recharging it the temperature would change slightly and allow the pressure to change.

<u>f</u>	<u>Coils</u>	<u>C₁</u>	<u>C₂</u>	<u>i₂</u>	<u>r</u>	<u>R_t</u>	<u>1/R_t</u>
987 K.C.	(1)	146	349	120	2.7	.181	5.52
763	7	246	441	160	2.4	.208	4.81
485	(2)	142	345	135	6.6	.320	3.13
223	(3)	050	297	110	22.0	.488	2.05
146	(3)	583	778	155	6.9	.665	1.50
96.5	1-5	462	661	105	15.6	.976	1.03
69.8	5-6	627	823	175	15.7	1.120	.890
38.5	1-6	1765	1959	105	6.6	1.87	.535





DISCUSSION OF DATA AND RESULTS

It was easy to obtain pressure readings greater than that of the saturated vapor in the chamber since rapid evaporation in b and condensation in the chamber caused a considerable pressure gradient in the connecting tubes. Thus the saturation pressure of the vapor could not be obtained from this apparatus. The values of saturated vapor pressure at the various temperatures were obtained from the International Critical Tables.

Due to the design of the vapor system the maximum pressure readily obtained was atmospheric pressure. And since at 79°C the saturated vapor pressure of alcohol is 77.5 cm Hg the saturation pressure could be approached very closely without danger of exceeding it. At lower temperatures, besides the ~~ye~~ever present danger of excessive pressure causing condensation, the accuracy of measurement of pressure decreased. Hence the 79°C temperature gave the best opportunity to attain accuracy. Therefore, much data was taken at this temperature and checked several times.

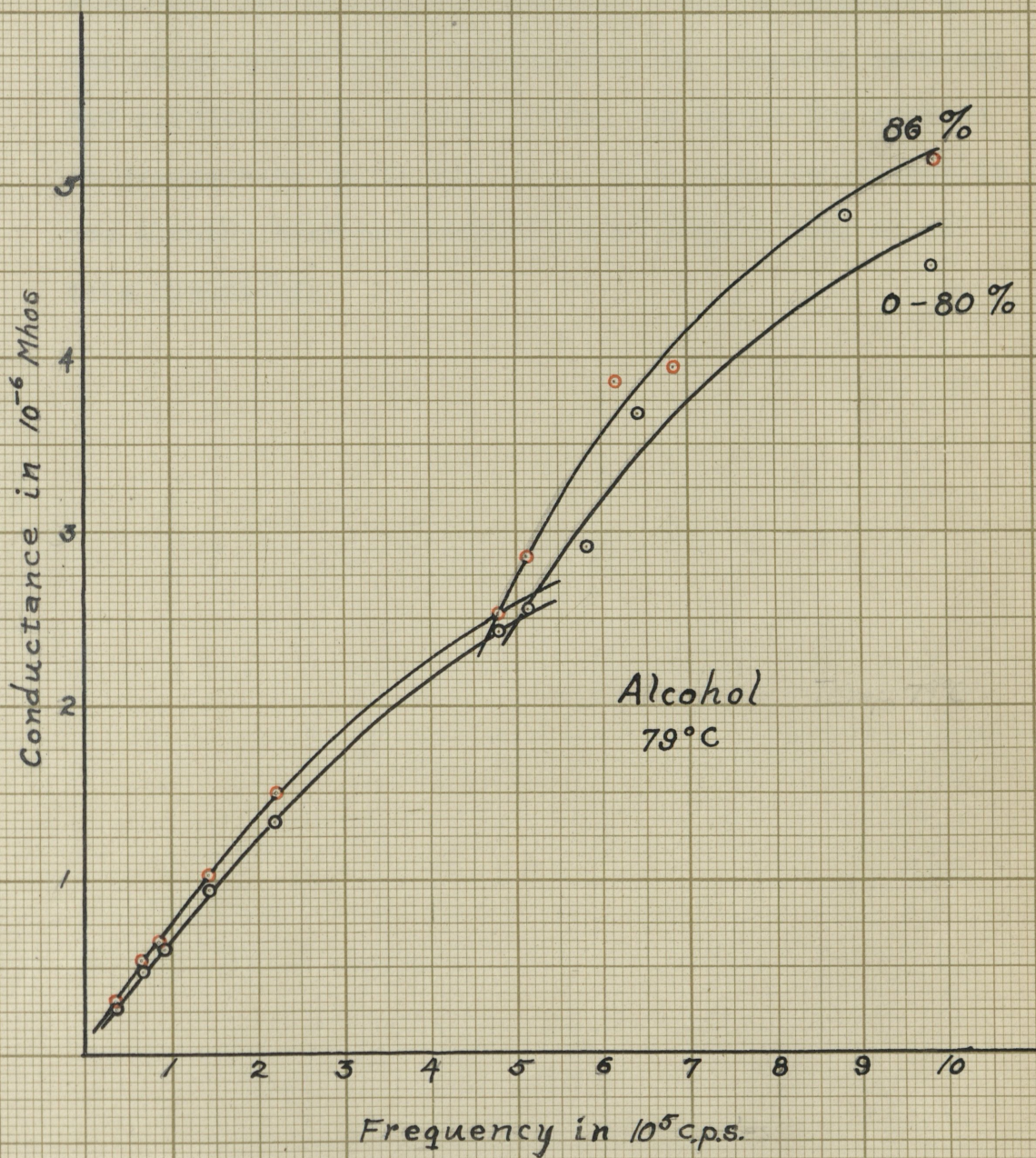
The saturation pressure at 107°C was not definitely known but from the extrapolated saturation pressure curves the approximate value of 225 cm of Hg was obtained.

In general the data and curves show quite clearly the behavior of the pyrex glass at various frequencies and at various degrees of saturation. However, there are several points to be noted, some of which are surprising.

The first of these is the apparent discontinuity in the relation of conductance to frequency at low frequencies and the same relation at high frequencies. This point occurred at about 500 k.c. whether the glass was dry or in the presence of alcohol. It apparently did not vary with the temperature. An attempt was made to find some resonant circuit about the apparatus which could cause the effect. However, none could be found. Several other frequencies were used in the neighborhood of 500 k.c., different coils were substituted in the test circuit and in the oscillator, but the discontinuity persisted.

Data taken from Tables II and V are plotted on the following page and show that there is really a discontinuity present.

If all the foregoing curves are examined closely, it will be seen that there is perhaps another such discontinuity at about 100 k.c. However, the evidence is so slight that a single smooth curve was always drawn through this region. At first, the curves were drawn continuous through the 500 k.c. region since the probable error for the higher frequencies in some instances amounted to 12%. But the point at 485 k.c. was persistently low and after much data had been taken it was seen that the points at lower frequencies and those at



higher frequencies lay on two different curves.

As mentioned above a thorough search failed to reveal any characteristics in the apparatus which would cause such break in the relationship. However, to make sure that the effect was actually a characteristic of the glass would have necessitated the complete redesign and rebuilding of the apparatus, and since the results at frequencies up to 500 k. c. were quite consistent it was thought best to vouchsafe the results only up to this frequency.

The Capacitance of the Surface Film

While C_t varied with the degree of saturation and frequency these variations were small as can be seen from the following table.

TABLE XXVIII
(Data taken from Table II)

Alcohol Temperature Saturation
 79° C 0.0%

<u>f</u>	<u>C₂</u>	<u>C₁</u>	<u>C_t</u>
987	201.2	89.2	112.0
458	196.4	84.6	111.8
223	167.6	57.0	110.6
146	459.0	343.9	115.1
96.5	387.5	272.7	114.8
69.8	485.9	369.9	116.0
38.5	1173.1	1056.7	116.4

(Taken from Table IX)
(99.8% Sat.)

<u>f</u>	<u>C₂</u>	<u>C₁</u>	<u>C_t</u>
987	201.2	88.2	113.0
485	195.8	84.1	111.7
223	167.1	54.1	113.0
146	457.5	341.5	116.0
96.5	388.6	272.8	115.8
69.8	485.9	369.3	116.6
38.5	1176.8	1059.8	117.0

It can be seen that although C_t increases with saturation and decreases with the frequency these variations are so small that nothing definite can be said concerning them.

VARIATION OF R_t WITH CURRENT

In the original set-up of the apparatus a thermogalvanometer (range 0-115 milliamps) was used for G in figure 1. However, it was found that under certain circumstances R_t varied markedly with the current. In one instance the value of R_t changed by 30% as the current in G varied from 40 to 110 milamps, R_t approached the vacuum value as i increased. Therefore, it was thought advisable to use a more sensitive current measuring device. A western Electric thermo-junction was used with a Leeds and Northrup type K galvanometer and with 1,000 ohms in series with the galvanometer. Although this was quite slow to tune, currents of the order of 6 to 12 millamperes were sufficient to give good readings. (See calibration curves on Page 45)

However, it was discovered that such wide variations of R_t with current could be avoided by thorough pumping before the vapor was admitted and by letting the vapor "age" in the chamber several hours before readings taken. Therefore, in the following tables the vacuum readings were taken after 8 to 16 hours of pumping. And the readings taken with vapor present were made after the vapor had aged from 16 to 25 hours. The aging time is noted in the table.

Some typical results taken after the above procedure was followed were as follows:

Alcohol	Temperature	Pressure	Saturation
	65° C	43.9 cm Hg	97 %

<u>f</u>	<u>Current in M.a.</u>	<u>r</u>
(Taken immediately after pumping)		
485 K.c.	6.1	5.6
	44	5.0
	94	5.0
	6.2	5.0

The last reading shows that the high currents have had a cumulative effect since, after they were used, the resistance does not return to the "low current value".

The pressure and temperature were left constant for three hours and then the following readings were taken.

485 K.c.	6.8	5.6
	40	5.5
	55	5.5
	112	5.5

About the same percentage of decrease is shown with the high currents even after long aging. Consider the following data taken after aging 22 hours.

Alcohol	Temperature	Pressure	Saturation
	79° C	66.4 cm Hg	85.7%

<u>f</u>	<u>Current in m.a.</u>	<u>r</u>
69.8 K.c.	6.4	10.0
	51	10.0
	85	9.9
	112	9.75

If small currents were used, aging did not seem to have as great an effect on the leakage conductance in the presence of alcohol vapor as it does in the case of water vapor.

Another precaution that had to be observed while admitting the vapor was that if it was allowed to rush in too rapidly so that some liquid condensed on the test piece or if at the higher pressures the saturation point was exceeded, then the R_t decreased enormously. Nor could the condition be rectified by slightly decreasing the pressure again. The only remedy was to pump out the chamber very thoroughly once more. Perhaps if one waited long enough after decreasing the pressure slightly the resistance would finally become the value it had before the saturating, but tests have shown that the time required would be more than a few hours. This effect is probably what caused Knowles' discrepancies as Stranathan has shown in a paper as yet unpublished.

VARIATION OF SURFACE LEAKAGE WITH FREQUENCY

The surface leakage is the difference between the conductance in vacuo and the conductance at a given saturation. Data taken from the curves on page 57 give the variation in surface leakage with frequency at 79° C as follows:

TABLE XXIX

<u>f in k.c.</u>	<u>Total Cond. in 10^{-6} mhos</u>	<u>Cond. in vacuo</u>	<u>Surface Leakage</u>
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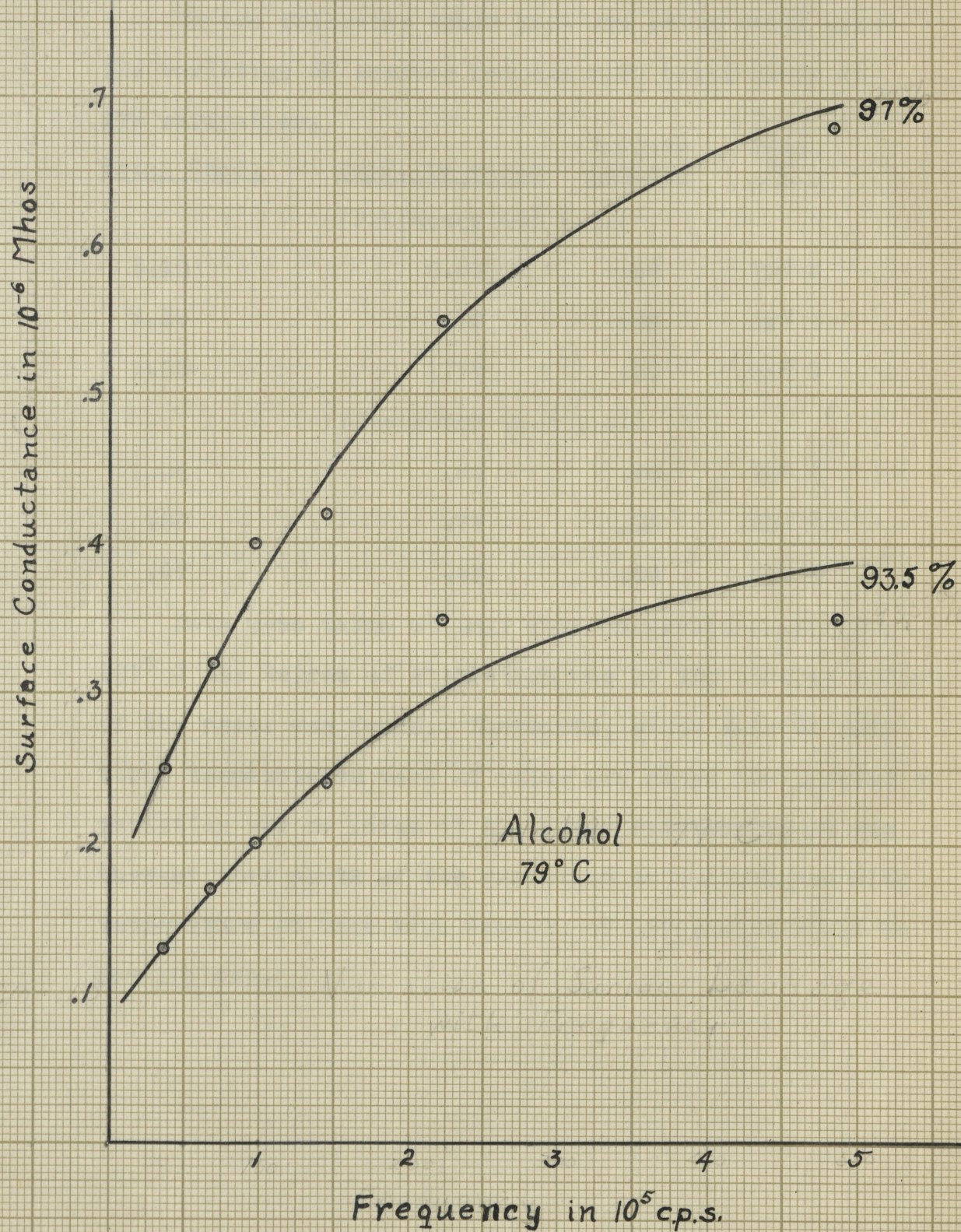
(Alcohol 96.8% Saturated)

485	3.18	2.50	.68
223	1.88	1.33	.55
146	1.38	.96	.42
96.5	1.02	.62	.40
69.8	.82	.50	.32
38.5	.53	.28	.25

(Alcohol 93.5% Saturated)

485	2.85	2.50	.35
223	1.68	1.33	.35
146	1.20	.96	.24
96.5	.82	.62	.20
69.8	.67	.50	.17
38.5	.41	.28	.13

These results are plotted in the curves on the following page.



VARIATION OF SURFACE LEAKAGE WITH TEMPERATURE

In the following table data are given which show the variation of surface leakage with temperature at 97% saturation.

<u>Total Cond.</u>	<u>Cond. in vacuo</u>	<u>Surface Leakage</u>	<u>Temp. °C</u>
(Frequency 485 k.c.)			
3.18	2.50	.68	79° C
2.55	1.90	.45	65° C
1.85	1.79	.06	51° C
(Frequency 96.5 k.c.)			
1.02	.62	.40	79° C
.80	.77	.03	65° C
.47	.45	.02	51° C

Data were taken at only four temperatures. And for 107° C the degree of saturation was so low that no effect of the vapor was found. Therefore, since data at only three temperatures were of value and since the percent of variation was so large at the lower frequencies it was thought that plots of the variation of conductance with temperature at even high degrees of saturation would be meaningless.

VARIATION OF VOLUME CONDUCTANCE WITH TEMPERATURE

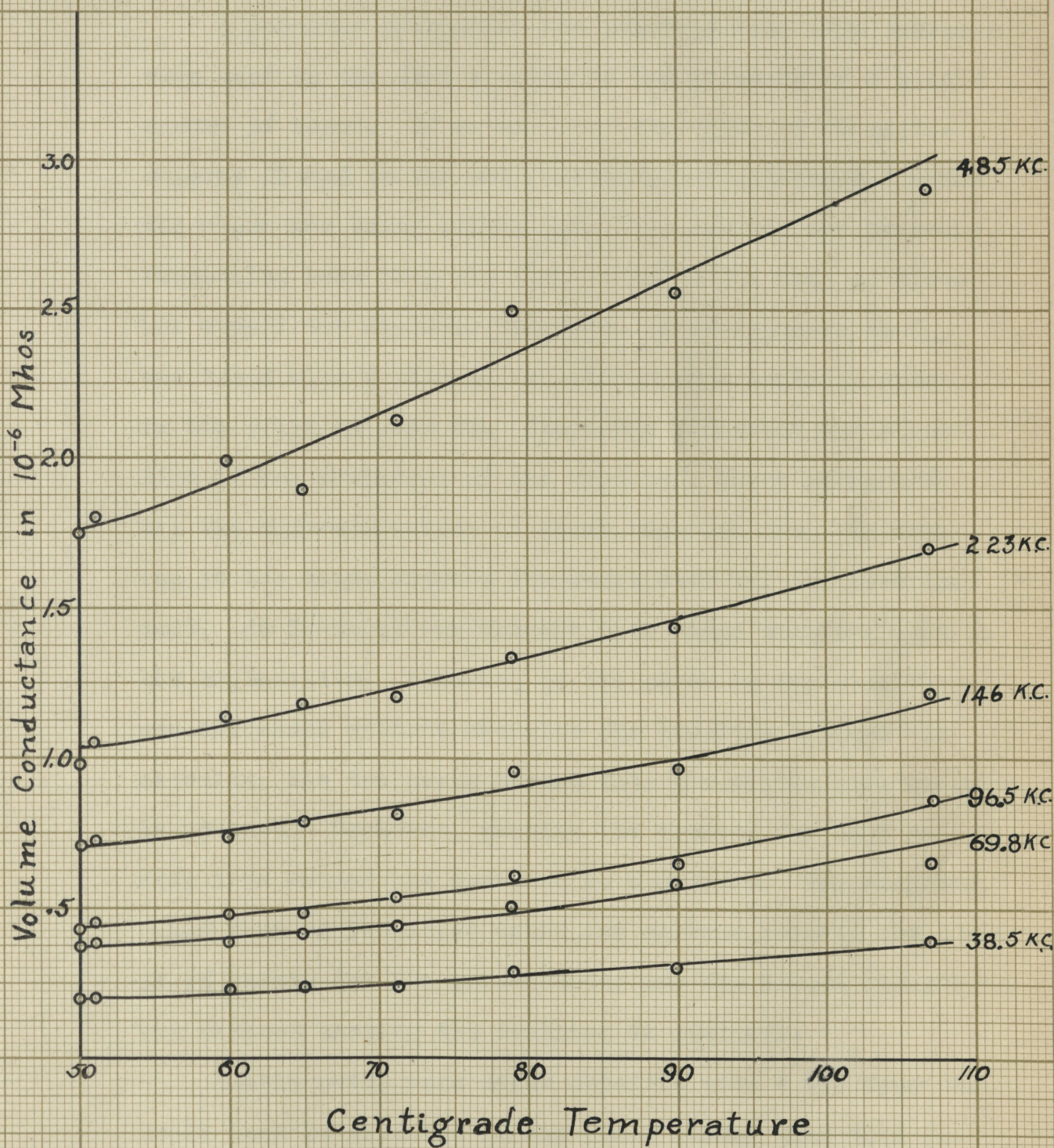
The volume conductance of the glass was the conductance in vacuo. In the main part of the experiment data was obtained for the resistance of the test piece at various frequencies and at five different temperatures. Resistance measurements were also made at three other intermediate frequencies with the test element in vacuo. The data taken at these other temperatures are listed in Table XXXI.

The currents i_g in this table are the readings of the thermo-galvanometer. This instrument was used since it could be tuned so rapidly and since the "in vacuo" value of R_t did not change with currents of this magnitude.

These data are plotted for frequencies up to 500 k.c. in the curves on page 91. There was so much variation in the data for frequencies above 500 k.c. that no curves were plotted for the higher frequencies.

TABLE XXXI

Temperature 90.0° C		Vacuum					
f	Coils	C ₁	C ₂	i ₃	r	R _t	1/R _t
485 K.C. (2)		144	343	34	5.4	.391	2.56
223 (3)		50	295	40	15.3	.701	1.43
146 (3)		584	778	60	4.4	1.04	.961
96.5 1-5		467	660	76	9.7	1.57	.637
69.8 5-6		630	823	40	9.7	1.93	.518
38.5 1-6		1770	1962	70	3.65	3.38	.296
Temperature 71.3° C							
485 K.C. (2)		145	344	55	4.5	.469	2.13
223 (3)		048	294	58	13.0	.825	1.21
146 (3)		585	777	62	3.6	1.28	.781
96.5 1-5		467	660	84	8.1	1.88	.532
69.8 5-6		631	824	57	8.0	2.35	.426
38.5 1-6		1771	1962	60	2.8	4.40	.227
Temperature 60.0° C							
485 K.C. (2)		144	343	50	4.2	.503	1.99
223 (3)		052	295	52	12.2	.980	1.14
146 (3)		583	776	56	3.35	1.37	.730
96.5 1-5		468	661	56	7.3	2.09	.478
69.8 5-6		629	823	50	7.2-	2.61	.383
38.5 1-6		1771	1963	76	2.7	4.57	.219



RESONANCE EFFECT WITH SURFACE FILMS

A peculiar phenomenon was observed when high currents were used in the test element in the presence of a slight amount of vapor. If currents of the order of 75 milliamperes flowed in the main circuit, i.e., through G, while the vapor was being pumped out, at a certain low pressure, (something less than one m.m. of Hg in the case of alcohol vapor) two distinct resonance peaks appeared as $C_{1,2}$ was tuned with S closed. A pair of such peaks is shown in the graph on page 93. The arrow indicates the direction of the variation of the capacity. These peaks had all the characteristics of those observed when the coupling is too close between the oscillator and the test circuit. At first it was thought that close coupling must be the explanation. However, if the power in the oscillator was decreased without changing the coupling between the circuits, the two peaks merged into the single peak normally present. Moreover, pumping the chamber for half an hour also caused the doubling to disappear. The coupling could then be increased until the current reached the limit of safety for the galvanometer and the decade resistance box without causing the doubling to reappear.

Double peaks were never observed when S was open nor could they be produced in any other manner than that described above. When a good vacuum had been attained in



the test chamber an artificial leak of approximately the same value as that caused by the surface film was placed across the test element without producing the double peaks. Artificial leaks of greater and of less conductance were tried without success. Finally in place of the test chamber and element a condenser of the same capacity and leakage was substituted, but still only one sharp resonance peak was observed.

Measurement of R_t with currents just below those required to produce the doubling were little, if any, different than the value of R_t in a vacuum.

The problem was then attacked from another standpoint. With the test element in the "double resonant" condition shunts of 2 to 10 megohms placed across it only lowered the current in G and did not otherwise modify the effect.

When vapor was admitted to a pressure of about 2 cm. of Hg the peaks merged into the single normal peak.

As has been remarked the coupling between the circuits was very loose. With the oscillator radiating ten watts the test circuit never absorbed more than .25 watt. However, while the double peaks were appearing if the power in the oscillator were decreased the peaks united into the normal peak.

The effect could be produced at almost any frequency although it appeared more readily at 70 and 100 k.c.

This was probably due to the fact that the coils used were of just the right inductance to produce the correct current distribution when $C_{1,2}$ was tuned. To illustrate: When the effect was observed at 100 k.c. the coils 1-5 were in the circuit while 6 was nearby. When 6 was shorted the effect disappeared. However, the circuit then tuned with a capacity about *22 μ f.* different from the value when 6 was left open. Since the oscillator was working at maximum power the only way to increase the power in the test circuit was to increase the coupling. When this was done very slightly, the doubling reappeared.

However, this caused suspicion to fall on the bank of coils and particularly on the No.6. Therefore, the whole bank was removed and an inductance built up of three entirely different coils which had approximately the same value as the coils 1-5. With these new coils in the circuit and a frequency of about 123 k.c. the double peaks were again produced. Therefore, it/seemed quite definite that the doubling of the peak depended upon the current actually in the test element.

A sensitive thermo-couple along with a sensitive micro-ammeter was placed in the circuit right beside the test element to measure the current in it while the total current was observed in G. The resistance of the thermo-couple was 35 ohms so that its presence somewhat modified

the circuit. However, the double peak could be produced in the usual manner. The current built up simultaneously in both the thermo-couple and in G as the condenser tuned the circuit. As the peak was passed both currents "broke" together to some lower value. Such experiments indicated that the C_t part of the circuit was not resonating independently of C_1 .

The same doubling of the resonance peak appeared when water vapor was present the same as with alcohol vapor. The peaks seemed a little more pronounced in the case of water and they appeared at a much higher pressure (around one cm of Hg).

Due to the lack of time this problem was not studied further, but enough was learned to make it an interesting subject for a more thorough research in the future.

SURFACE CONDUCTIVITY

Surface conductivity might be defined as the conductance of a square centimeter of surface. That is $G = \gamma L/W$ where G is the surface conductance of a strip W cm. wide and L cm. long and γ is the surface conductivity. In the present problem $L = 38 \times \pi \times 4.5 = 537$ and W (the distance between electrodes) was .2 cm. The value of W varied somewhat, but .2 is an average value. In the calculation of L there were 38 glass spaces and the circumference of the test element was $\pi \times 4.5$.

$$\text{Therefore, } G = \gamma 537 / .2 = 2680 \gamma$$

$$\text{Thus } \gamma = G / 2680 = 3.73 G \times 10^{-4} \text{ mhos / cm. square.}$$

From the curves of conductances the above relationship yields the following surface conductivities.

Alcohol	Temperature 79° C		90.0% Saturated	
f	$1/R_t$ 90	$1/R_t$ 0	G	γ
485 K.C.	2.64	2.50	$.14 \times 10^{-6}$	52.2×10^{-12}
223	1.57	1.34	.13	48.5
146	1.08	.96	.12	44.8
96.5	.70	.60	.10	37.3
69.8	.59	.50	.09	33.6
38.5	.35	.28	.07	26.1

Alcohol	Temperature 79° C 94.2% Saturated			
<u>f</u>	<u>1/R_t 94.2</u>	<u>1/R_t 0</u>	<u>G</u>	<u>γ</u>
485 K.C.	2.90x10 ⁻⁶	2.50x10 ⁻⁶	.40x10 ⁻⁶	149.2x10 ⁻¹²
223	1.73	1.34	.39	145.5
146	1.20	.96	.24	89.5
96.5	.83	.60	.23	85.8
69.8	.70	.50	.20	74.6
38.5	.43	.28	.15	56.0

Alcohol	Temperature 79° C 98.7% Saturated			
485 K.C.	3.65x10 ⁻⁶	2.50x10 ⁻⁶	1.15x10 ⁻⁶	429x10 ⁻¹²
223	2.35	1.34	1.01	377
146	1.75	.96	.79	295
96.5	1.35	.60	.65	242
69.8	1.10	.50	.60	224
38.5	.78	.28	.50	187

Water		Temperature 50° C			90.3% Saturated
<u>f</u>	<u>1/R_t 90.3</u>	<u>1/R_t 0</u>	<u>G</u>	<u>γ</u>	
485 k.c.	3.03x10 ⁻⁶	1.75x10 ⁻⁶	1.28x10 ⁻⁶	477x10 ⁻¹²	
223	1.98	.98	1.00	373	
146	1.45	.70	.75	280	
96.5	1.00	.43	.57	213 (206)*	
69.8	.86	.35	.51	190 (188)*	
38.5	.54	.18	.36	134 (161) *	

Water		Temperature 50° C			80% Saturated
<u>f</u>	<u>1/R_t 80</u>	<u>1/R_t 0</u>	<u>G</u>	<u>γ</u>	
485 k.c.	2.20x10 ⁻⁶	1.75x10 ⁻⁶	.45x10 ⁻⁶	167.9x10 ⁻¹²	
223	1.33	.98	.35	130.6	
146	.96	.70	.26	97.0	
96.5	.62	.43	.19	70.9 (71.3)*	
69.8	.52	.35	.17	63.4 (63.3)*	
38.5	.32	.18	.14	52.2 (50.8)*	

* The values in parentheses are those of Yager and Morgan.

It is seen that of the six points which may be checked with the work of Yager and Morgan in only one (38.5 k.c. at 90% saturation) is the value herein obtained seriously different from theirs. However, criticism of the curves of conductance vs pressure for water at 50° C indicate that the value obtained in the present research is probably erroneously low. The shape of the 38.5 k.c. curve at the higher pres-

tures is different than the other curves due to the position of one point. Therefore, it is likely that the curve should follow the dotted line rather than the solid. If this were the case the value of γ at 38.5 k.c. and 90.3% saturation would fall very close to the value found by Yager and Morgan.

Since the data on water was taken more to check the method and apparatus than to obtain new data, fewer points were taken than would have otherwise been observed. Therefore, the failure of one point to check the work of the other observers is not considered a serious discrepancy.

It might be added that the agreement with Yager and Morgan's work is better than the experimental error would warrant. The values of γ given for water are accurate to about 5%. The values for alcohol may be slightly better than that.

SUMMARY AND CONCLUSIONS

1. A method was developed for measuring resistances of .1 megohm to 10 megohms at frequencies up to 10^6 cycles. The actual apparatus used was capable of measuring resistances with an error of less than 5% up to 500 k.c. and an error less than 12% at 1,000 k.c. However, there is no reason why this accuracy could not be exceeded with carefully designed apparatus.

2. The manner of variation of the volume conductance of pyrex glass for frequencies between 35 k.c. and 10^3 k.c. was determined for eight different temperatures between 50° C and 107° C.

3. Each of the curves of conductance vs frequency have distinct discontinuities at about 500 k. c. So far such breaks are unexplained.

4. The surface leakage was measured for the test piece in an atmosphere of alcohol vapor. The variation of this leakage with degree of saturation was determined at four temperatures and data obtained for saturations up to 30% at a fifth temperature. Surface conductivity was computed for three degrees of saturation at 79° C and at six frequencies between 35 k.c. and 500 k.c.

5. Surface leakage was measured when the test piece was in an atmosphere of water vapor. The variation of this leakage with the degree of saturation was obtained at 50° C. Sur-

face conductivity at this temperature was computed for 80% and for 90.3% saturation at six frequencies between 35 k.c. and 500 k.c. These values check very closely with those obtained by Yager and Morgan.

6. The relationship between surface leakage and frequency was obtained for saturations of 93.5% and 96.8% of alcohol vapor.

7. Saturations of alcohol up to 85% do not appreciably effect the conductance of pyrex. Saturations of water below 50% have no appreciable effect on the conductance.

8. Under certain conditions the surface conductance decreases as the current increases.

9. The capacitance of the adsorbed alcohol film increases with saturation and decreases with the frequency.

10. An unexplained resonance (?) phenomenon was discovered at low vapor pressures of alcohol and of water. The test circuit tunes at two distinct settings of the condenser. The chief characteristics of this effect are:

- (a) It appears as the vapor is being pumped out.
- (b) The two peaks resemble very closely those obtained when two circuits are too closely coupled.
- (c) The effect disappears when a certain minimum power in the test circuit is reached
- (d) The effect disappears at high vacuum or at a few centimeters of mercury pressure of vapor.
- (e) The effect is apparently independent of frequency so long as the required minimum power is supplied the test circuit.

(f) The effect could not be produced by any artificial arrangement of capacity and resistances.

11. Aging does not change the leakage in alcohol vapor to as marked degree as in the case of water.

In conclusion the author wishes to thank Dr. J. D. Strathan who suggested the problem and method of attack.