T H E S I S

on

THE CAPACITANCE OF HIGH-VOLTAGE PIN-TYPE INSULATORS

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THE CAPACITANCE OF HIGH-VOLTAGE PIN-TYPE INSULATORS

INTRODUCTION

Section I

THE PROBLEM - A high-voltage pin-type insulator consists of a mass of electrical porcelain which serves as an insulator for a high-voltage line. These insulators are provided with a pin hole into which a pin, usually of metal, is screwed. The head of the insulator is provided with a conductor groove into which the electrical conductor of the line is placed. This conductor is held in position by a tie wire which passes both around the conductor, and around the tie wire groove in the head of the insulator.

It is evident that there exists a certain amount of capacitance between the metal pin as one electrode, and the tie wire and the conductor as the other electrode. This is further augmented by the fact that the relative permittivity or dielectric constant of the electrical porcelain is from five to seven compared with air as unity. The purpose of this investigation was: first, to devise a simple, rapid, and accurate method for measuring this capacitance; second, to measure the capacitance of a large number of insulators; third, to study the factors affecting the capacitance; and fourth, to determine the effect of the capacitance on other test characteristics of the insulators.

METHOD EMPLOYED - It is natural in pursuing this study that the course should follow closely the order in which the various phases of the problem were stated. After considerable study and some experimentation, a satisfactory method was found for making the capacitance measurements. Briefly, this consisted of setting a circuit containing inductance in the form of a wave meter coil, capacitance in the form of a variable precision condenser, and resistance consisting chiefly of a thermo-galvanometer, in resonance with a current generated by a vacuum tube oscillator. Connections were provided so that the insulator capacitance could be introduced in parallel with the variable condenser. With the frequency constant, the difference in the setting of the variable condenser to produce resonance with the insulator in the circuit, and again with it out of the circuit, is the capacitance of the insulator.

Using the method outlined the capacitance of 180 insulators which were submitted by six different manufacturers to the Electrical Engineering Department for various insulator tests was measured. These insulators were of three classes: 13-17 kilovolt; 45-55 kilovolt; and 66 kilovolt. After the experimental data had been taken, a study was made of some of the factors affecting the capacitance. This proved to be a problem of considerable magnitude, and therefore, only a few of the apparent factors were investigated. It was found that the thickness of the head and the size of the tie wire used, were, among other things, important factors in determining the magnitude of the capacitance.

A study was also made to determine any relations which might exist between the capacitance of the insulators and their other test characteristics, as determined by a group of senior students working under the direction of Associate Professor F. O. McMillan of the Electrical Engineering Department. Although it could not be shown that the capacitance influenced any of these characteristics to any marked degree, it was found that some of the test characteristics and the capacitance were to some extent related.

DIVISIONS - In preparing this thesis an attempt has been made to include under the proper headings the different phases of the investigation. In the Table of Contents the reader will find a complete tabulation of the material included under each section. In general, the divisions of the material included follow the order in which the investigation was made.

THEORETICAL CONSIDERATIONS

Section II

Before an attempt will be made to discuss in detail the method of making these measurements, and before discussing any of the results obtained, or conclusions drawn, it will prove helpful, no doubt, to consider in detail the theoretical factors involved.

THEORY OF THE CAPACITANCE MEASUREMENTS - If a circuit contains resistance "R", inductance "L", and capacitance "C", the resonant frequency of the circuit is determined by the relation of the values of L and C. If the inductance is fixed, and the capacitance variable, the various settings of the condenser will control the resonant frequency. When such a circuit is inductively coupled with a vacuum tube oscillator, the frequency of which is constant, a current of constant frequency will be induced in this resonant circuit. With the capacitance value properly adjusted, the inductive reactance 6.283fL will be equal and opposite to the capacitive reactance 1/6.283fC, and the impedance of the circuit consists only of the resistance. In the form of an equation, the above becomes

$$6.283fL = \frac{1}{6.283fC} ,$$

and if f, the resonant frequency is solved for,

$$f = \frac{1}{6.283\sqrt{L\,C}} .$$

In the above equations, f will be in cycles per second if the inductance L is in henries, and the capacitance C is in farads.

The condition of resonance for the constant frequency would result in a maximum current flow, and therefore, this condition could be detected by having an instrument such as a thermo-galvanometer in the circuit, and adjusting until a maximum deflection was obtained. If after the condition of resonance is obtained an additional value of capacitance is introduced in parallel with that already in the circuit, these two values will add directly, and the condition of resonance will be destroyed. The circuit will now be resonant to some other frequency different from the constant frequency being generated by the vacuum tube oscillator. To again produce resonance for the frequency of the oscillator, it will be necessary to reduce the setting of the variable condenser by an amount exactly equal to the capacitance which was added in parallel. Obviously, if the variable condenser is a precision condenser which has been carefully calibrated, it is possible to accurately measure very small values of capacitance by this method. The circuit would first be set for resonance; after this was done, the condenser to be measured would be connected in parallel with the standard condenser, and the circuit again adjusted for resonance. The difference between the two standard condenser settings would give the capacitance of the unknown condenser.

<u>THE EFFECT OF FREQUENCY ON CAPACITANCE</u> - It is a well known fact that a dielectric which is non-uniform will absorb a certain amount of energy if left connected to a source of potential difference after the condenser had apparently become charged. When this is true, the capacitance of the condenser would vary somewhat with the frequency;

at low frequencies, the capacitance would apparently be greater than at the higher frequencies. Dr. C. P. Steinmetz has given a very satisfactory explanation for this absorption.[1] This theory, according to Professor J. B. Whitehead,[8] was origionally due to J. Clark Maxwell. Dr. Steinmetz shows that this effect is entirely due to an adjustment of the voltage gradient in the non-uniform dielectric, which is only complete after a considerable time since charges must flow into the dielectric which has a very high resistance.

An attempt was made to find data regarding the effect of frequency on the permittivity of porcelain. However, nothing of this nature was found for porcelain, although some interesting figures were found for glass which it is believed would more closely approximate electrical porcelain than any other substance for which data were available. It was found by Hector J. MacLeod[2] that for glass the capacitance was 0.9131×10^{-9} farads at 498 cycles per second, and 0.9019×10^{-9} farads at 1,000,000 cycles per second. These figures show a slight decrease although it is so small it is practically negligible. In connection with direct current measurements, W. A.Fraser and H. W. M. Secord[3] made measurements on pin-type insulators, and using a constant voltage of 1100 volts, obtained a capacitance of 0.000088 microfarads. This measurement is not closely in accord with the values which were obtained in this investigation, and is due, no doubt to the fact as Fraser and Secord state, that their method is not accurate. The exact size and type of insulator used in their investigation is not known. The Westinghouse Electric and Manufacturing Company was the only Company able to supply data on the capacitance of their insulators. Their measurements which were made with a capacitance bridge at 200 cycles per second are of the same magnitude as were obtained at the frequency used in this study. For their insulators of the 13-17 kilovolt class, they specified a capacitance of 8 - 12 micro-microfarads. The values obtained at 500,000 cycles in this study are well within these limits. It is therefore felt that although there may be differences in permittivity with changes in frequency for some dielectrics, that this difference for electrical porcelain is so very small as to be negligible. This is probably due to the fact that the mixture is uniform, and that the resistance is very high. For this reason, the measurements made in this investigation at a frequency of 500,000 cycles per second would be practically the same as at a lower frequency of 60 cycles per second.

THE EFFECT OF VOLTAGE GRADIENT ON CAPACITANCE - Apparently very little has been done in determining the effect of the voltage gradient upon the permittivity of electrical porcelain. Many investigators have found that the capacitance of impregnated paper cables varied very much with increases in the voltage gradient. This has been attributed by C. L. Dawes, and P. L. Hoover[4] to ionization of the air spaces included within the dielectric. In the article referred to by Fraser and Secord[3] they state that at a voltage of 150 volts the measured capacitance of a pin-type insulator was 0.000092 microfarads; at 300 volts, it was 0.000104 microfarads; and that at 1100 volts it was 0.000088 microfarads. Their measurements were made at a constant (direct) voltage, and much of the variation is attributed to inaccuracy of measurement.

It is known that electrical porcelain is sometimes made in such a manner as to contain small amounts of air in spaces within the material. If Dawes and Hoover[4] are correct in their statement as to the effect of ionization in increasing the capacitance of a condenser, it is conceivable that some porcelain insulators should also show increases in capacitance with an increase in the voltage gradient. It is felt however, that electrical porcelain or in fact any similar material would not show any great increase in permittivity with an increase in the voltage gradient. It is probable therefore that an insulator which is well made, and well designed, would show no great increase in capacitance as the gradient was increased to the normal value, and that although the tests made in this investigation were with very low gradients the results obtained would be applicable to an insulator at higher gradients.

<u>THE EFFECT OF THE TIE WIRE ON CAPACITANCE OF INSULATORS</u> - The size of the tie wire used would obviously affect the capacitance of the insulator. Data were taken, as will be shown later, which indicate this effect. The various other tests made in this department were made in accordance with the specifications[5] of the American Institute of Electrical Engineers, which require that a tie wire of size not less than #8 shall be used. A #6 annealed copper wire was used in all the capacitance tests made, since a wire of this size was used in the

other tests to which the insulators were subjected.

THE EFFECT OF THE CONDUCTOR ON CAPACITANCE OF INSULATORS - The size and length of the object placed in the conductor groove also affects the capacitance. Since it was desired that the results obtained in the capacitance measurements be compared with other tests made, a conductor similar to the one employed in the puncture tests was used.

THE EFFECT OF THE PIN ON CAPACITANCE OF INSULATORS - The object used in the insulator pin hole would also affect the capacitance. Some of the insulators were provided with metal thimbles which were cemented in the insulator. In order to secure good contact and uniform results, mercury was placed in the pin hole of all insulators not provided with metal thimbles.

THE ACCURACY OF THE METHOD EMPLOYED - From the above considerations it can be seen that the method employed is accurate, and that the results obtained by this method should be reliable at normal insulator frequencies and voltages. It is possible that if accurate measurements had been made at these normal voltages and frequencies that the results would have been slightly more valuable. However, at these voltages and frequencies such measurements would be very difficult to make.

CAPACITANCE MEASUREMENTS

Section III

In the preceding section the theoretical side of the capacitance measurements has been given. This section will include a detailed description of the apparatus used and the method employed in making the measurements.

INSULATORS MEASURED - Insulators from six different manufacturers were tested. These were divided into three classes: 13-17 kilovolt; 45-55 kilovolt; and 66 kilovolt. In each class there were ten insulators from each manufacturer, thus measurements were made on a total of 180 insulators. The manufacturers of the insulators are as follows:

Westinghouse Electric & Manufacturing Co.

Locke Insulator Manufacturing Co.

Lapp Insulator Co.

R. Thomas & Sons

Porcelain Insulator Corporation

Ohio Brass Company

THE VACUUM TUBE OSCILLATOR - The wiring diagram of the oscillator is shown on Page 11 together with a list of the individual pieces of apparatus. Photographs are included on Pages 17 and 18 which give a fair idea of the arrangement of the various units. The oscillator was designed and built in such a manner that it could at a later date, with slight modifications, be used for much lower frequencies. For

LIST OF APPARATUS

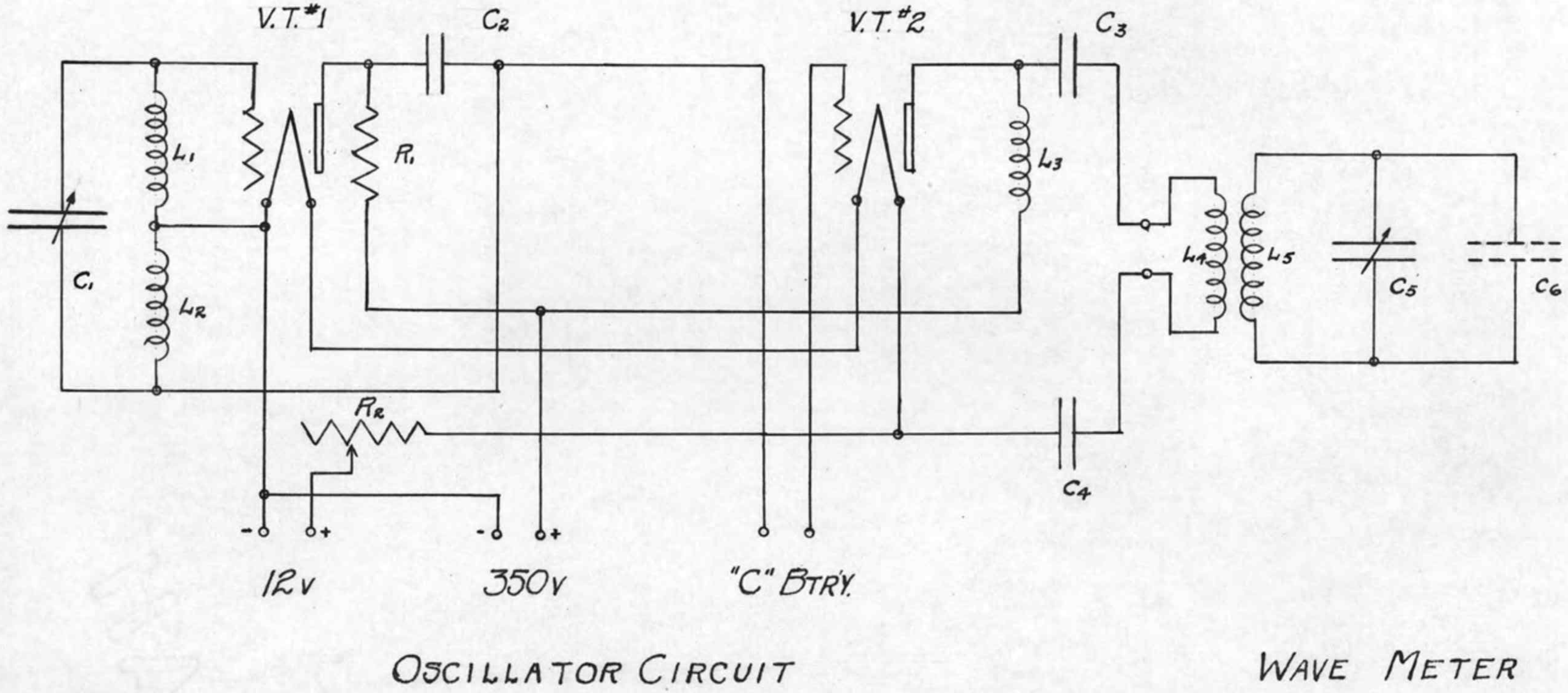
VT#1&VT#2	Radiotron 5-watt oscillator tubes. UV 202.
L_1 & L_2	Giblen-Remler inductance coils Type 35.
L_3	Ordinary telephone induction coil.
L_4	Output coil. Approx. 30 turns #18 wire.
L_5	Wave Meter coil. Coil B.
C_1	Acme Low loss variable air condenser, capacitance 0.000016-0.0005 mfd.
C_2,C_3&C_4	Dublier By-Pass condensers. 2.0 mfd. Type 659.
C_5	Wave meter precision air condenser.
C_6	Capacitance of the insulator to be measured.
R_1	Two 27,000 ohm fixed resistances, General Electric Company.
R_2	0-12 ohm filament rheostat.
Wave Meter	Precision Wave Meter, General Radio Corp. Type 224 Serial #23.
Thermo-Galv.	Not shown in diagram - Model 425 #4355.

WIRING DIAGRAM

of the

VACUUM TUBE OSCILLATOR

WIRING DIAGRAM



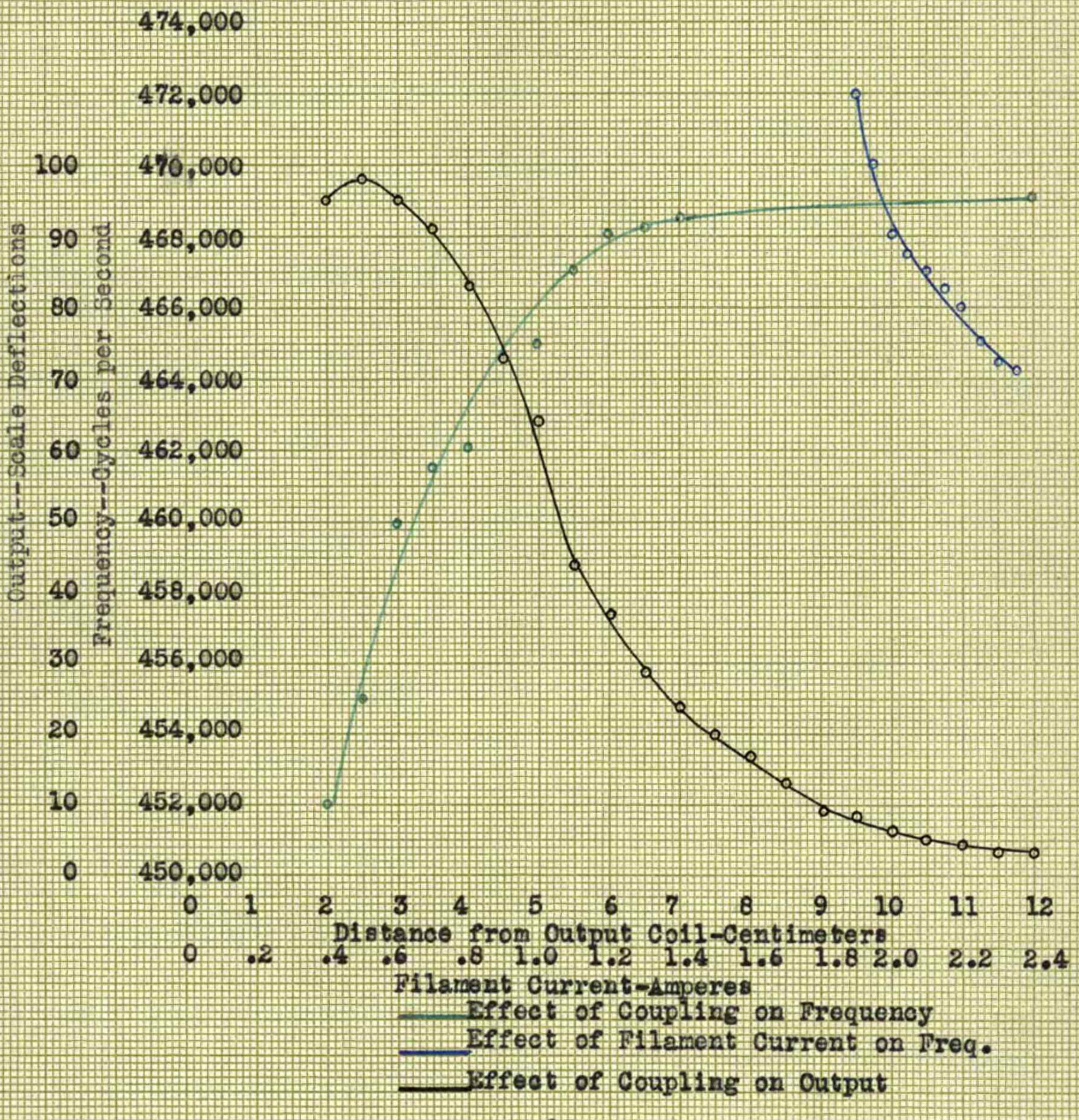
A.W.A

this reason, many of the pieces of apparatus are different from those which would have been used had only a 500,000 cycle frequency been desired. The oscillator proved entirely satisfactory, and no trouble was experienced with it. However, in order to determine its characteristics so that no errors would be introduced in the capacitance measurements due to it, a study was made of the factors which affected the frequency of the generated current.

On the following page are shown graphically the results of this study. The data from which these curves were plotted may be found on Pages 109 and 110. It can be seen that the frequency is influenced to some extent by the filament current. As a result, in making these investigations it was important that the filament current remain constant. It was also noted that the coupling, or the distance from the output coil of the oscillator to the coil of the wave meter, affected the output in two ways. First, the induced current was varied in magnitude; and second, the frequency was also greatly influenced. In view of the above facts, it was very important that no change was made in the coupling while the tests were in progress; to insure this, the oscillator output coil was securely tied to the wave meter coil. The calibration curve and data for the oscillator are included on Pages 104 and 105.

Although data were not taken, and this condition is not shown, it was found that the variations in plate voltage affected the frequency considerably. A D. C. motor generator set which was operated from a 12 volt storage battery, was first used to produce the 350 volts for the plate supply. Excessive voltage fluctuations

Characteristics of The Vacuum Tube Oscillator



causing bad frequency changes caused this set to be discarded, and the tests were completed using an A.C. motor-generator set. This set operated from 110 volts A.C., and delivered a plate voltage of 350 volts D.C. It was more satisfactory than the first set, but was far from perfect. It is recommended that no attempt be made to use a source of plate voltage of this type when making measurements of this nature. Much more satisfactory results will be obtained from large radio "B" batteries, or from storage cells.

It will be noted from the wiring diagram that provisions were made for a "C" battery. It was found that the oscillator operated satisfactorily without such a battery, and for this reason none was used, and the terminals were shorted. The filament current was obtained from the laboratory cells.

<u>THE WAVE METER</u> - The wave meter used consisted of a precision variable condenser and a thermo-galvanometer in a shielded wooden box and a coil which fastened as is shown on Pages 17 and 18 to heavy terminals on the outside of the box. The wave meter consisted then of resistance, chiefly in the thermo-galvanometer; capacitance in the form of the variable precision condenser; and inductance, chiefly in the form of the wave meter coil. It is therefore well adapted for making the measurements as outlined in Section II. The condenser of the wave meter used was very sensitive to adjustments, and thus very small differences in capacitance settings could be observed. The thermo-galvonometer was sensitive, but not to as high a degree as the condenser. This fact limited the degree of accuracy that was obtainable.

AUXILIARY APPARATUS - The photographs shown on Pages 17 and 18 show some of the other pieces of apparatus used in obtaining the capacitance of the insulators. The #10 wire shown suspended from the stand was used to make contact with the insulator pin and close one side of the circuit. A linen thread of very high resistance was used to support the wire and thus insure that the circuit capacitance was the same both with and without the insulator in place. The end was provided with an adjustable contact wire so that connections could be made to the different sizes of insulators.

The manner in which the connections were made to the other side of the circuit is evident from the photographs. A brass tube 0.5 inch in outside diameter, 0.375 inch in inside diameter, and one foot long was used in the conductor head. The photograph on Page 17 shows one of the tubes in place on the insulator, and a similar tube laying on the stand. As can be seen, connections were made from the conductor on the stand to the wave meter with another brass tube having an outside diameter of approximately the inside diameter of the tube used as the conductor.

METHOD OF MAKING CAPACITANCE MEASUREMENTS - The above discussion of the theory and description of the apparatus make the method of obtaining the capacitance obvious. The oscillator was first adjusted to the proper frequency of approximately 500,000 cycles per second. After this had been done the conductor was securely tied in the conductor groove of the insulator to be tested with a #6 annealed copper tie wire. In all cases only one turn was placed around the insulator tie wire groove. The insulator was then placed in position as shown on the following pages, and the precision condenser of the wave meter was adjusted until resonance was obtained as indicated by the maximum deflection of the thermo-galvanometer. In order to partly compensate for any errors in reading and adjusting the wave meter, and also in consideration of the fact that the thermo-galvanometer was not as accurate as the condenser, three adjustments were made for resonance, and three readings were taken for each insulator. The insulator was then removed from the circuit, and the conductor replaced as shown on Page 17. With this circuit, the point of resonance was obtained by three separate trials, and the readings recorded. Both these readings and the three readings with the insulator in the circuit were later averaged and these averages regarded as the correct value.

As was previously mentioned, precautions were taken to insure that the frequency did not vary during the tests. As an added precaution, whenever it was noted that the capacitance measured, deviated to any great extent from the values previously determined for insulators of the same type and class, check measurements were taken to insure that an error had not been made.

It may appear that replacing the conductor in the circuit when the second set of readings were taken introduced an error. It may appear that in doing this the effect of the capacitance of the insulator conductor was entirely eliminated, and that as a result all that was measured was the capacitance from the pin to the tie wire. However, careful measurements have shown that this is not true. When the insulator is removed from the circuit when the second set of

PHOTOGRAPHS OF APPARATUS

UPPER PHOTOGRAPH

This illustration presents a view of the apparatus with the insulator not in position. This was the condition when resonance was obtained without the insulator in the circuit. A tube similar to the one in place on the insulator head is shown laying on the stand.

LOWER PHOTOGRAPH

This illustration shows an insulator of the 13-17 kilovolt class in position on the stand. This was the condition of the apparatus when resonance was obtained with the insulator in the circuit.

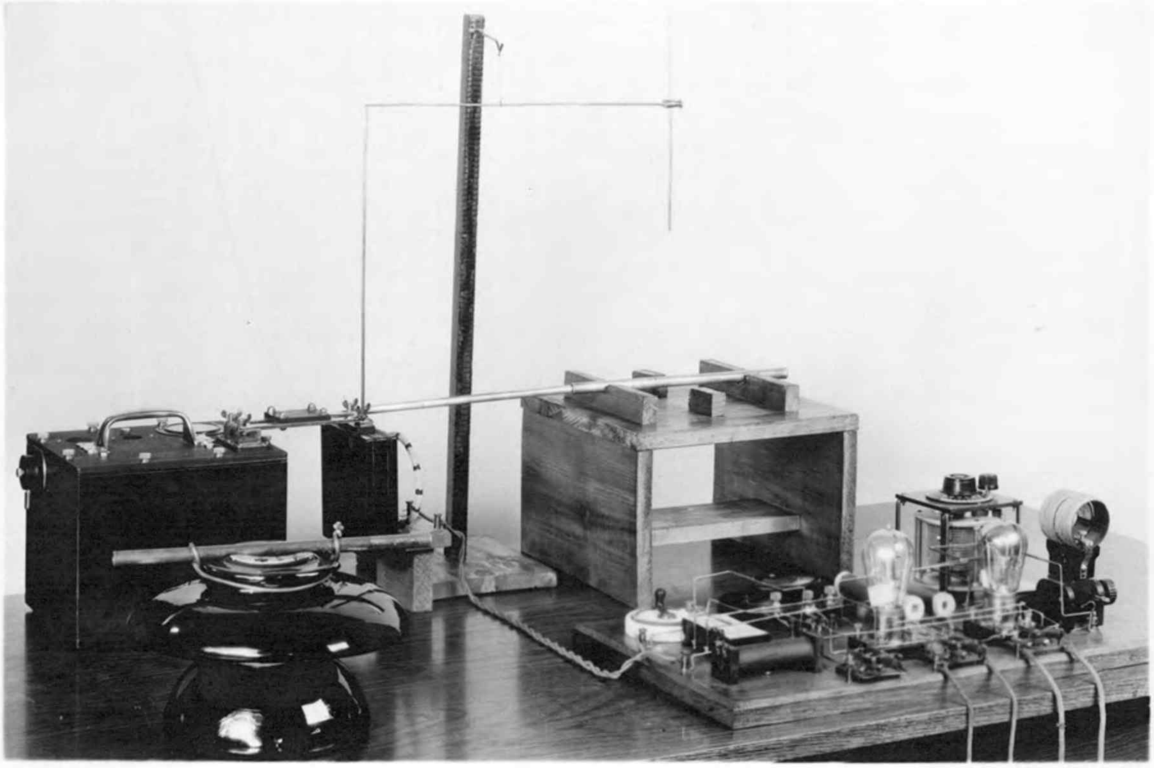
PHOTOGRAPHS OF APPARATUS

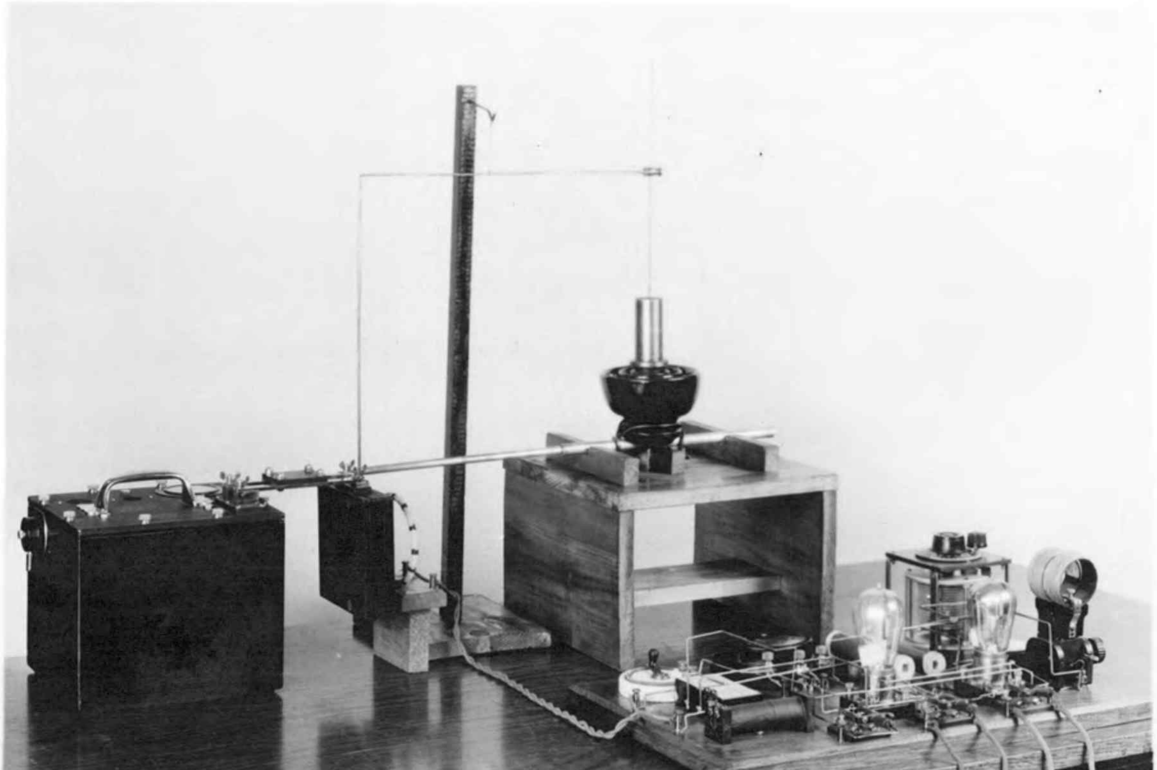
UPPER PHOTOGRAPH

This illustration shows as is evident, an insulator of the 45-55 kilovolt class in place for the adjustment for resonance with the insulator in the circuit.

LOWER PHOTOGRAPH

The insulator in position in this case is one of the 66 kilovolt class.





readings is taken, the pin is also removed, and there is little capacitance between the straight wire that formerly touched the pin and the conductor in place on the stand. Furthermore, it was mentioned that the wave meter was shielded, and it also appears that one set of plates of the condenser is connected to this shield. This then would cause one wave meter terminal to be grounded, and it was to this terminal that the tubes were connected. The above theory is advanced and would seem to explain the action of the wave meter although it was not opened to see if this were true. The non-grounded side of the meter was used for the wire which was entirely supported in air. In determining which side of the meter would be the best for the grounded side, it was found that if the side which appeared to be connected to the shield were used that the measured capacitance of the insulator would be the same both with or without the conductor in place on the table. However, it was found that if the other side were used that an error estimated at about 15% would be introduced. In making these capacitance measurements, the side which did not introduce an error in the results was used as the grounded side.

<u>COMPUTATIONS AND DATA</u> - The manner in which the readings were taken and averaged has been mentioned. These readings were in condenser settings, and it was necessary to use the calibration curve to obtain the corresponding values of capacitance. It would have been possible to have found each of these values directly from the curve, but this would prove to be a slow and tedious process. On the part of the curve used in making these tests, the curve is a straight line, and

is plotted with values of capacitance on the Y-axis, and values of condenser settings on the X-axis. By carefully determining the tangent of the angle which the curve made with the X-axis, it was possible to obtain a constant which when multiplied by the difference in condenser settings gave the insulator capacitance directly in micromicrofarads. The tangent of the angle was computed to be 0.59. A complete set of the capacitance data is found from Pages 73 to 102. In studying these data it will be remembered that A, B, C, D, E, and F refer to the various manufacturers. The insulators from 11 to 20 are of the 13-17 kilovolt class; those from 31 to 40 are of the 45-55 kilovolt class; and those from 51 to 60 are of the 66 kilovolt class.

MEASUREMENT OF DIMENSIONS

Section IV

When an attempt was made to analyze the capacitance measurements, it was found advisable to make measurements of the dimensions of the insulators to determine any affect that these dimensions might have on the other characteristics of the insulators. Accordingly, each of the 180 insulators which had been used for the capacitance measurements was measured and their dimensions recorded.

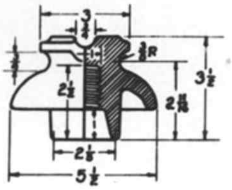
FACTORS AFFECTING INSULATOR DIMENSIONS - If a group of insulators is carefully examined, it will be found that in general there are very great deviations from the dimensions that are issued by the manufacturer. The reasons for these deviations are better understood if a brief description of the method of manufacture is given. The material presented in this discussion has been taken from a pamphlet issued by the Westinghouse Electric and Manufacturing Company.[6]

Most high voltage insulators are formed by what is known as the wet process. The ingredients are flint, feldspar, and clays. After certain mixing processes, the material which is in a moist state is ready for shaping. This is done by pressing the material into a plaster of paris mold, and giving the insulators, or the insulator parts if they are of the multi-section type, their proper shape. After shaping the insulators, or parts, they are placed in the release dryer which shrinks and hardens them to such an extent that they may be removed from the mold. After a second drying, a trimming and a glazing process, the insulators are ready for firing. In the firing process the insulators are placed in containers and fired at a high temperature for from fifty to seventy hours. During this firing a number of physical and chemical changes take place due to the high temperature. According to the pamphlet previously mentioned, the shrinkage is considered to be governed almost entirely by the percentage of the various engredients used. It would appear however, that the firing, the grade of workmanship, and perhaps other factors would enter into determining these large variations in dimensions from the catalogue values. These factors are mentioned because in some cases the data taken show very wide variations in dimensions.

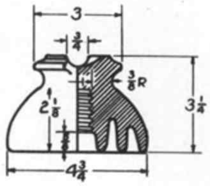
METHOD OF MAKING MEASUREMENTS OF DIMENSIONS - Practically all of the important dimensions of the 13-17 kilovolt class were measured. It was found however, that they were not all necessary. As a result, for the 45-55 kilovolt, and 66 kilovolt classes, only the thickness from the top of the pin hole to the conductor groove and the length of the tie wire groove were measured.

These measurements were made with an ordinary scale, steel tape, and calipers. Thus, the degree of accuracy is not high. To make highly accurate measurements would be very difficult, and could probably only be made by destroying the insulators. In many cases, the insulators were so irregular that only average values could be obtained. The data obtained are shown on Page 106 for the 13-17 kilovolt, on Page 107 for the 45-55 kilovolt, and on Page 108 for the 66 kilovolt class. Drawings of the insulators showing the dimensions as specified by the manufacturers are shown on Page 24 for the 13-17 kilovolt class, on Page 25 for the 45-55 kilovolt class, and on Page 26 for the 66 kilovolt class.

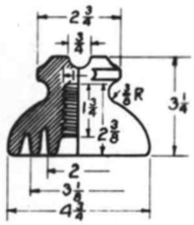
A 1-20



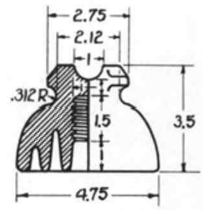
D 1-20



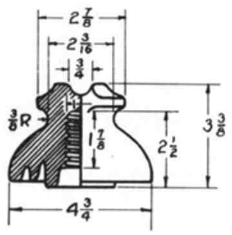
B 1-20



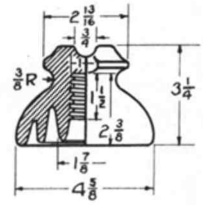
E 1-20



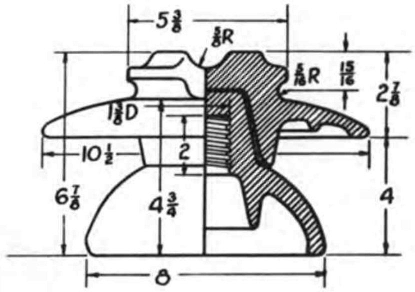
C 1-20



F 1-20



A 21-40



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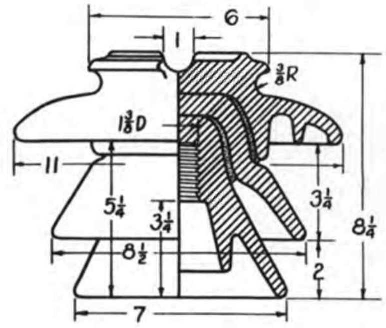

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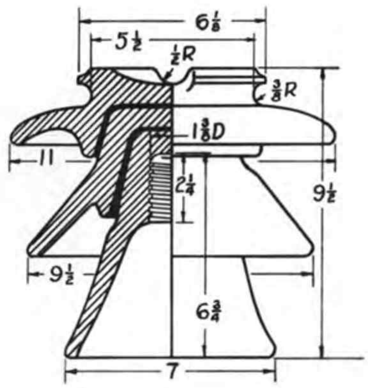

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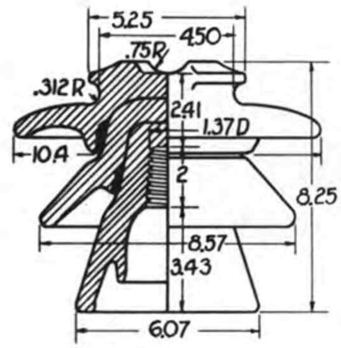

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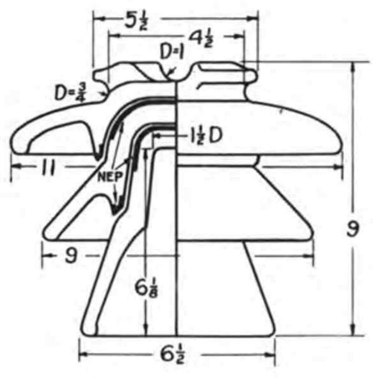
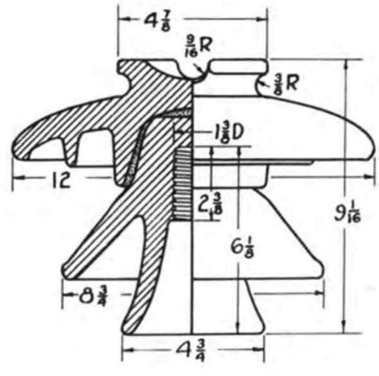
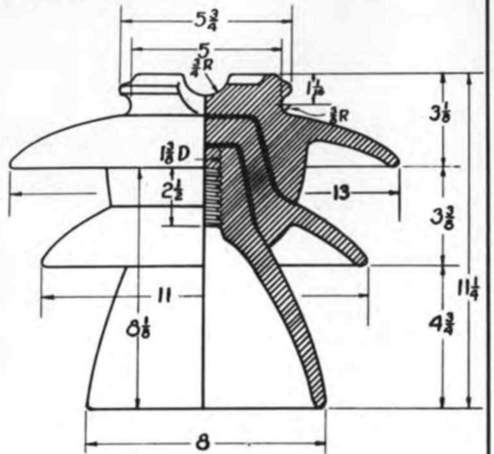


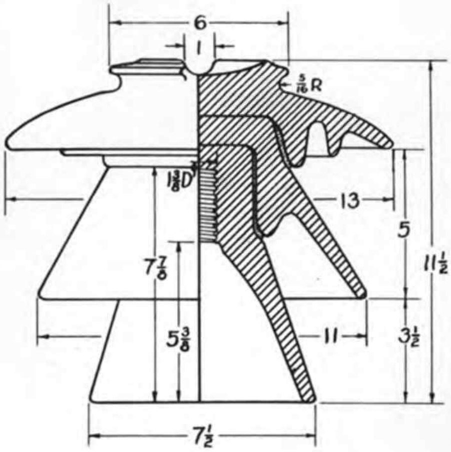
F 21-40



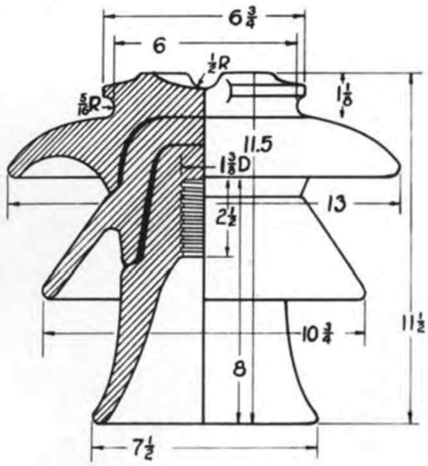
A 41-60



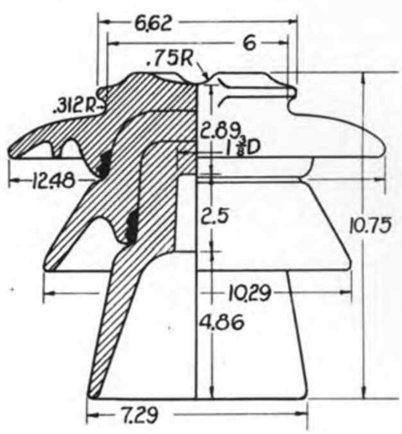
D 41-60



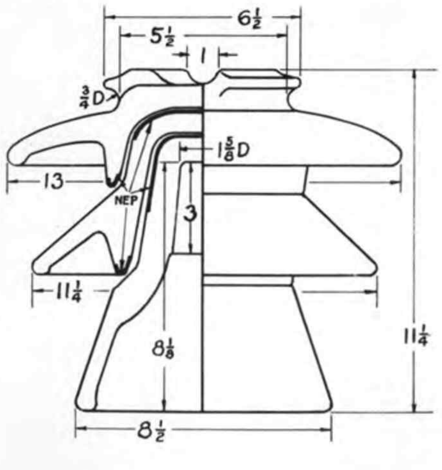
B 41-60



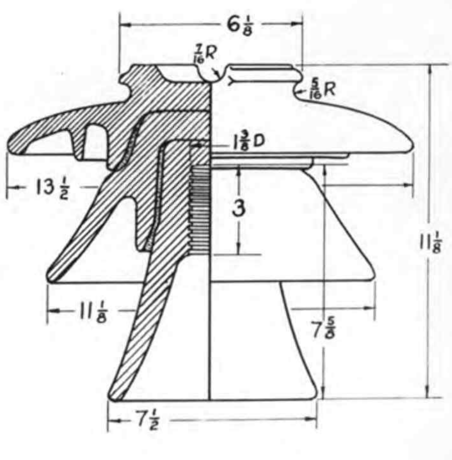
E 41-60



C 41-60



F 41-60



ANALYSIS OF EXPERIMENTAL DATA

Section V

This section will be devoted to a discussion of the data obtained, and the conclusions which have been drawn as a result of this study.

THE CAPACITANCE OF HIGH-VOLTAGE PIN-TYPE INSULATORS - The data obtained show that pin-type insulators have an appreciable amount of capacitance, and that this capacitance can be readily measured by the method outlined. The data further show that the capacitance varies for the different types of insulators of the same general class. The complete data are included from Pages 73 to 102, and on Pages 28, 29, and 30, will be found a summary of the capacitance values. To each of the six manufacturers a request was made for information regarding the capacitance of their insulators. Only one was able to supply any figures, and as was previously mentioned, these figures were closely in accord with the values obtained by these tests. It is probable that the differences were due to the tie wires and the conductors used. For the three classes of insulators tested, the capacitance obtained was as follows:

13-17 kilovolt class	8.4 - 11.8	micro-microfarads
45-55 kilovolt class	10.0 - 14.4	micro-microfarads
66 kilovolt class	10.6 - 14.5	micro-microfarads

THE EFFECT OF THE TIE WIRE ON CAPACITANCE - This effect was mentioned before, and is shown graphically on Page 32. This curve shows that

SUMMARY OF CAPACITANCE TEST DATA

13 - 17 Kilovolt Insulators

A-11 - 11.0 mmfd.	B-11 - 11.6 mmfd.	C-11 - 10.7 mmfd.
12 - 10.3 mmfd.	12 - 11.6 mmfd.	12 - 11.0 mmfd.
13 - 10.5 mmfd.	13 - 10.5 mmfd.	13 - 11.5 mmfd.
14 - 10.5 mmfd.	14 - 11.5 mmfd.	14 - 11.0 mmfd.
15 - 10.4 mmfd.	15 - 10.4 mmfd.	15 - 11.4 mmfd.
16 - 10.5 mmfd.	16 - 11.2 mmfd.	16 - 11.1 mmfd.
17 - 10.5 mmfd.	17 - 10.4 mmfd.	17 - 10.5 mmfd.
18 - 9.7 mmfd.	18 - 11.3 mmfd.	18 - 11.3 mmfd.
19 - 11.5 mmfd.	19 - 11.6 mmfd.	19 - 11.8 mmfd.
20 - 10.5 mmfd.	20 - 10.3 mmfd.	20 - 10.2 mmfd.
Average-10.54mmfd.	Average-11.08 mmfd.	Average-11.05mmfd.

D-11 - 8.4 mmfd.	E-11 - 9.4 mmfd.	F-11 - 9.5 mmfd.
12 - 9.4 mmfd.	12 - 10.4 mmfd.	12 - 10.0 mmfd.
13 - 8.5 mmfd.	13 - 9.7 mmfd.	13 - 11.0 mmfd.
14 - 9.0 mmfd.	14 - 9.6 mmfd.	14 - 11.0 mmfd.
15 - 8.8 mmfd.	15 - 9.4 mmfd.	15 - 10.9 mmfd.
16 - 9.3 mmfd.	16 - 9.9 mmfd.	16 - 9.4 mmfd.
17 - 9.7 mmfd.	17 - 9.7 mmfd.	17 - 10.9 mmfd.
18 - 9.1 mmfd.	18 - 9.1 mmfd.	18 - 10.3 mmfd.
19 - 8.8 mmfd.	19 - 9.5 mmfd.	19 - 10.4 mmfd.
20 - 9.0 mmfd.	20 - 9.8 mmfd.	20 - 10.4 mmfd.
Average-9.10 mmfd.	Average-9.65 mmfd.	Average-10.38mmfd.

Averages

A -- 10.54 mmfd.
B -- 11.08 mmfd.
C -- 11.05 mmfd.
D -- 9.10 mmfd.
E -- 9.65 mmfd.
F -- 10.38 mmfd.

SUMMARY OF CAPACITANCE TEST DATA

45 - 55 Kilovolt Insulators

A-31 - 12.6 mmfd.	B-31 - 12.4 mmfd.	C-31 - 11.6 mmfd.
32 - 13.6 mmfd.	32 - 11.7 mmfd.	32 - 11.4 mmfd.
33 - 13.3 mmfd.	33 - 11.6 mmfd.	33 - 11.3 mmfd.
34 - 12.6 mmfd.	34 - 12.9 mmfd.	34 - 11.7 mmfd.
35 - 14.4 mmfd.	35 - 12.1 mmfd.	35 - 11.6 mmfd.
36 - 13.4 mmfd.	36 - 11.8 mmfd.	36 - 12.2 mmfd.
37 - 12.6 mmfd.	37 - 11.6 mmfd.	37 - 11.7 mmfd.
38 - 12.0 mmfd.	38 - 12.0 mmfd.	38 - 12.3 mmfd.
39 - 12.9 mmfd.	39 - 12.3 mmfd.	39 - 11.9 mmfd.
40 - 13.8 mmfd.	40 - 11.6 mmfd.	40 - 11.4 mmfd.
Average-13.12 mmfd.	Average-12.00 mmfd.	Average-11.71mmfd.

D-31 - 10.4 mmfd.	E-31 - 11.1 mmfd.	F-31 - 11.2 mmfd.
32 - 11.5 mmfd.	32 - 11.1 mmfd.	32 - 11.3 mmfd.
33 - 10.9 mmfd.	33 - 10.0 mmfd.	33 - 11.1 mmfd.
34 - 11.0 mmfd.	34 - 10.0 mmfd.	34 - 11.0 mmfd.
35 - 10.9 mmfd.	35 - 11.0 mmfd.	35 - 11.1 mmfd.
36 - 10.3 mmfd.	36 - 11.0 mmfd.	36 - 11.0 mmfd.
37 - 10.5 mmfd.	37 - 10.7 mmfd.	37 - 11.3 mmfd.
38 - 10.7 mmfd.	38 - 10.4 mmfd.	38 - 11.1 mmfd.
39 - 11.3 mmfd.	39 - 10.3 mmfd.	39 - 11.0 mmfd.
40 - 11.3 mmfd.	40 - 10.7 mmfd.	40 - 10.7 mmfd.
Average-10.88 mmfd.	Average-10.60 mmfd.	Average-11.08mmfd.

Averages

A -- 13.12 mmfd.
B -- 12.00 mmfd.
C -- 11.71 mmfd.
D -- 10.88 mmfd.
E -- 10.60 mmfd.
F -- 11.08 mmfd.

SUMMARY OF CAPACITANCE TEST DATA

66 Kilovolt Insulators

A-51 - 12.3 mmfd.	B-51 - 12.7 mmfd.	C-51 - 14.2 mmfd.
52 - 12.6 mmfd.	52 - 13.0 mmfd.	52 - 13.9 mmfd.
53 - 12.6 mmfd.	53 - 12.9 mmfd.	53 - 13.7 mmfd.
54 - 12.2 mmfd.	54 - 12.7 mmfd.	54 - 14.2 mmfd.
55 - 12.0 mmfd.	55 - 12.7 mmfd.	55 - 14.5 mmfd.
56 - 12.2 mmfd.	56 - 12.7 mmfd.	56 - 14.1 mmfd.
57 - 11.9 mmfd.	57 - 13.0 mmfd.	57 - 13.9 mmfd.
58 - 12.5 mmfd.	58 - 13.0 mmfd.	58 - 14.3 mmfd.
59 - 12.3 mmfd.	59 - 12.7 mmfd.	59 - 14.4 mmfd.
60 - 12.5 mmfd.	60 - 12.8 mmfd.	60 - 14.2 mmfd.
Average-12.31 mmfd.	Average-12.82 mmfd.	Average-14.14mmfd.

D-51 - 12.6 mmfd.	E-51 - 11.4 mmfd.	F-51 - 10.7 mmfd.
52 - 11.5 mmfd.	52 - 11.8 mmfd.	52 - 10.6 mmfd.
53 - 12.3 mmfd.	53 - 12.0 mmfd.	53 - 11.0 mmfd.
54 - 11.7 mmfd.	54 - 11.7 mmfd.	54 - 10.9 mmfd.
55 - 12.1 mmfd.	55 - 11.6 mmfd.	55 - 11.0 mmfd.
56 - 11.5 mmfd.	56 - 11.4 mmfd.	56 - 10.9 mmfd.
57 - 11.7 mmfd.	57 - 11.8 mmfd.	57 - 10.9 mmfd.
58 - 12.1 mmfd.	58 - 11.7 mmfd.	58 - 11.0 mmfd.
59 - 12.0 mmfd.	59 - 11.9 mmfd.	59 - 11.2 mmfd.
60 - 12.2 mmfd.	60 - 12.0 mmfd.	60 - 10.9 mmfd.
Average-11.97 mmfd.	Average-11.73 mmfd.	Average-10.91mmfd.

Averages

A -- 12.31 mmfd.
B -- 12.82 mmfd.
C -- 14.14 mmfd.
D -- 11.97 mmfd.
E -- 11.73 mmfd.
F -- 10.91 mmfd.

the size of the wire affects the capacitance considerably. Apparently on the insulator A-35 which was used there was a point below which, and another point above which, the size of the wire did not influence the capacitance as much as it did between these points. The data from which these conclusions regarding the tie wire are drawn is on Page 33.

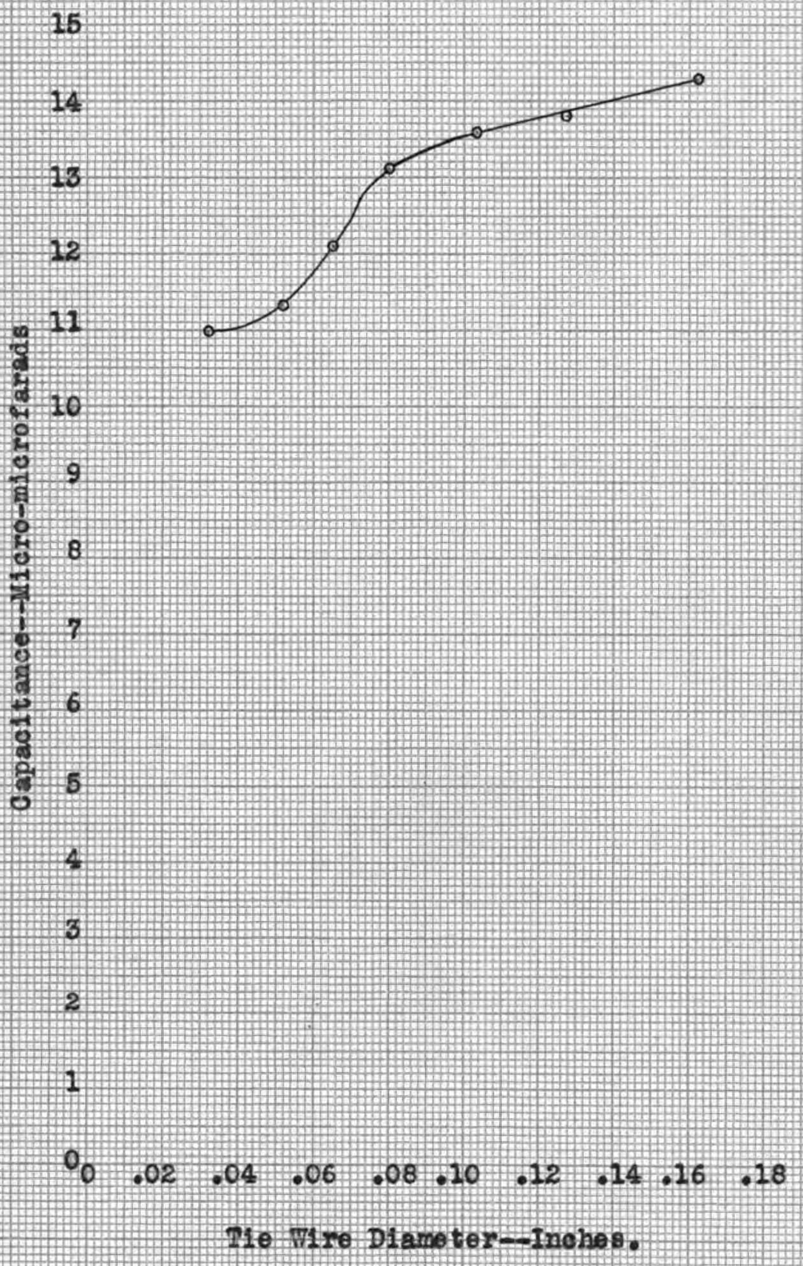
THE EFFECT OF CONDUCTOR SIZE ON CAPACITANCE - Tests were not made to show this effect; however, it can be inferred from a study of the effect of the size of tie wire, that the size of the conductor would also influence the capacitance. Also, the length of the conductor and the cross-arm (in case measurements were made to very closely approximate service conditions) would also cause the capacitance to vary.

THE EFFECT OF THE PIN ON CAPACITANCE - Although no data were taken, it is obvious that the size of the pin used, and the distance the pin was screwed into the insulator would also affect the capacitance. To insure uniform results, in making measurements some substance such as mercury should be used in the pin hole to insure a good contact with the porcelain. This would not be necessary with insulators provided with metal thimbles.

THE EFFECT OF THE PERMITTIVITY ON CAPACITANCE - The permittivity, or the dielectric constant of the porcelain would probably be one of the controlling factors in determining the capacitance of the insulators. No measurements were made to determine this effect, or to determine

The Effect of Tie Wires on Capacitance

Insulator A-35



Data Showing the Effect of Tie Wire
On
Insulator No. A*-35

No. 6 Tie Wire

Ins. Out	1184.2	
	1184.0	
	1185.0	
Ave.		1184.4
Ins. In	1160.6	
	1159.6	
	1160.5	
Ave.		1160.0
	Diff.	24.4

Capacitance 14.4 mmfd.

No.12 Tie Wire

Ins. Out	1191.0	
	1190.8	
	1191.3	
Ave.		1191.0
Ins. In	1168.0	
	1169.5	
	1169.0	
Ave.		1168.8
	Diff.	22.2

Capacitance 13.1 mmfd.

No.14 Tie Wire

Ins. Out	1191.5	
	1191.4	
	1192.5	
Ave.		1191.8
Ins. In	1171.1	
	1171.9	
	1170.9	
Ave.		1171.3
	Diff.	20.5

Capacitance 12.1 mmfd.

No. 8 Tie Wire

Ins. Out	1193.0	
	1192.5	
	1193.2	
Ave.		1192.9
Ins. In	1169.0	
	1169.7	
	1169.8	
Ave.		1169.5
	Diff.	23.4

Capacitance 13.8 mmfd.

No.16 Tie Wire

Ins. Out	1190.8	
	1191.1	
	1191.0	
Ave.		1191.0
Ins. In	1172.3	
	1171.5	
	1171.0	
Ave.		1171.6
	Diff.	19.4

Capacitance 11.4 mmfd.

No.10 Tie Wire

Ins. Out	1191.7	
	1190.5	
	1191.5	
Ave.		1191.2
Ins. In	1168.0	
	1167.5	
	1168.7	
Ave.		1168.1
	Diff.	23.1

Capacitance 13.6 mmfd.

No. 20 Tie Wire

Ins. Out	1191.5	
	1191.2	
	1191.7	
Ave.		1191.5
	1173.2	
	1173.5	
	1172.0	
Ave.		1172.9
	Diff.	18.6

Capacitance 11.0 mmfd.

*Insulator with metal thimble.

this constant. The value given by those of the manufacturers who had the information available was approximately from five to seven. An accurate knowledge of the permittivity of the different insulators would probably do much to explain the capacitance variations.

<u>THE EFFECT OF FREQUENCY ON CAPACITANCE</u> - The data included on Page 35 show that within the frequency range investigated there was no apparent change in the capacitance of the insulators. It is further believed that accurate measurements taken with either a low-frequency or direct current would show practically the same capacitance values as were here obtained with a frequency of approximately 500,000 cycles per second. Other investigators[7] have obtained practically constant values of capacitance over wide frequency ranges for materials which are similar to electrical porcelain.

<u>THE EFFECT OF INSULATOR DESIGN ON CAPACITANCE</u> - With the exception of the several studies which will be outlined in the following paragraphs, no study of the effects of insulator design on the capacitance were made. However, it is probable that the amount of porcelain and the form in which it is molded will cause variations in capacitance.

<u>THE RELATION BETWEEN WEIGHT AND CAPACITANCE</u> - Since the weight is a rough indication of the amount of porcelain present, and since the porcelain has a permittivity of about 5 to 7 compared to air, a comparison was made of the weight and the capacitance for one of the classes. A certain relation did exist, but this was the same as the

Data Showing the Effect
of
Frequency on the Capacitance of
Ins. No. A-35*

Frequency 452,000 cycles per second.

Ins. Out 1234.1
1234.8
1235.0
Ave. 1234.6
Ins. In 1212.5
1212.3
1212.1
Ave. 1212.3
Diff. 22.3
Capacitance 13.1

Frequency 577,000 cycles per second.

Ins. Out 760.2
760.6
769.8
Ave. 760.2
Ins. In 738.4
737.7
738.2
Ave. 738.1
Diff. 22.2
Capacitance 13.1 mmfd.

Note-The apparent capacitance should decrease with an increase in frequency. However, the increase in capacitance is not great enough to be observable. The changes noted are due to errors in readings.

Frequency 932,000 cycles per second

Ins. Out 300.5
300.5
300.5
Ave. 300.5
Ins. In 278.5
278.0
277.8
Ave. 278.1
Diff. 22.4
Capacitance 13.2 mmfd.

*Insulator with metal thimble.

relation between the thickness from the pin to the conductor groove and the thickness from the pin to the tie wire groove. In considering the effect of the weight, or of the amount of porcelain in any case it must be remembered that an increase might actually decrease the capacitance due to the fact that the distance between the electrodes would also be increased.

THE THICKNESS FROM PIN TO THE TIE WIRE GROOVE AND CAPACITANCE - This study was only made for the 13-17 kilovolt insulators. As can be seen, from the diagrams issued by the manufacturers on Pages 24, 25, and 26, in the case of the 45-55 kilovolt, and the 66 kilovolt insulators the tie wire was not opposite, but considerably above the pin, and therefore, this distance was not computed. However, in the case of the 13-17 kilovolt insulators the thickness from the pin to the tie wire groove was very important in determining the point at which the insulator punctured.

If a detailed study is made of the curves for the insulators of the 13-17 kilovolt class shown on Pages 49 to 54, it will be found that no consistent relation exists between the capacitance and the thickness of porcelain from the pin to the tie wire groove. However, in considering the curves for the average values of each type of this class on Page 55 it will be seen that in general as the thickness of porcelain from pin to the tie wire groove increased that the capacitance decreased. The close relation between the thickness from the pin to tie wire groove, and from pin to conductor groove is also interesting.

THE LENGTH OF THE TIE WIRE GROOVE AND CAPACITANCE - The insulators with the longer tie wires would be expected to have a greater capacitance than those with a shorter one. An investigation was therefore made to determine if a relation existed between the length of tie wire groove and the capacitance. This study was made for all of the insulators, but the data are only included for the 45-55 kilovolt, and the 66 kilovolt classes. For the 13-17 kilovolt class, the thickness from pin to tie wire groove proved more interesting.

On Page 57, the curves for the type A insulators of the 45-55 kilovolt class show a slight rise in length of tie wire groove with a decrease in capacitance. The curves for the type B insulators on Page 58 show no consistent relation. This is also true for the type C insulators on Page 59, and the type D on Page 60. However, on Page 61 the curves for the type E insulators indicate that as the length of the tie wire decreases, the capacitance decreases also. On Page 62, the curves for the type F insulators show no consistent relation. The averages of these values have been plotted for each type on Page 63. These curves indicate that there is no consistent relationship for this class of insulators between the capacitance and the length of the tie wire groove.

The curves for the 66 kilovolt class are still more erratic with regard to consistent variations between capacitance and the length of the tie wire groove. An examination of the curves from Page 65 to 70 will show that no consistent variation takes place. This is also the case for the averages of these values shown on Page 71.

THE THICKNESS FROM PIN TO CONDUCTOR GROOVE AND CAPACITANCE - The curve on Page 49 for the 13-17 kilovolt insulators of type A do not show as consistent a relation between the thickness of head and capacitance as would be expected. The curves for the type B insulators on Page 50 and for the type C insulators on Page 51 also show no consistent variations. However, for the type D insulators on Page 52 the trend of the thickness of head curve is upward with a decrease in the capacitance curve. It should be noticed that for these insulators both the thickness of the wall and the thickness of the head are greater than for any of the other insulators of this class. Attention is also called to the fact that this type of insulators had the lowest capacitance of any of the insulators of this class. The curves for the type E insulators, and for the type F insulators shown on Page 53, and 54, respectively, both show a tendency for thickness of head to be associated with decrease in capacitance.

Although for individual insulators of a given class the variations in thickness from conductor groove to pin hole may not in all cases be associated with consistent variations in capacitance, the curves for the averages of each type on Page 55 show clearly that a relation does exist. In general, a thick head will mean a lower capacitance than a thin one.

Since the design of the 45-55 kilovolt class was different from the 13-17 kilovolt class, the former class being of the multisection type, and as a whole, much more uniform in dimensions, it is best to consider these separately. The curves for the type A insulators of the 45-55 kilovolt class shown on Page 57 show a tendency for the capacitance and the thickness from pin to the conductor groove to vary directly. For the type B curves on Page 58 it can be seen that there is no consistent relation. The curves for the type C insulators on Page 59 also show a tendency for the capacitance and the thickness to vary directly. The curves for the type D; the curves for the type E; and the curves for the type F insulators on Pages 60, 61, and 62 show no consistent relations.

The averages for the 45-55 kilovolt class are plotted on Page 63. The effect of the thickness from the pin to the conductor is less marked than in the case of the 13-17 kilovolt insulators. However, for this 45-55 kilovolt class there is a relationship existing; in general, an insulator which has a thick head will also have a lower capacitance than an insulator of the same class having a thin head.

The insulators of the 66 kilovolt class were found to be much more uniform than either of the other classes examined, in general this was true of both the dimensions and the capacitance. If an examination is made of the curves for the type A insulators of this class on Page 65, it will be found that there is no relation between the capacitance and the thickness from the pin to the conductor groove. The curves for the type B insulators on Page 66 indicate a lowering in capacitance with an increase in the thickness of the insulator head. For the type C insulators this is also the tendency. An examination of the curves for the type D insulators on Page 68; for the type E insulators on Page 69; and the type F insulators on Page 70 will show no apparent relationships existing. The close agreement in the uniformity of dimensions and the uniformity of the capacitance values for the type F insulators is interesting.

The curves for the averages of these 66 kilovolt insulators are on Page 71. Here it will be found that the relation between the thickness of the porcelain from the pin hole to the conductor groove is even less than for either of the other classes. Nevertheless, it is evident that there is still a relationship existing, and that in general a thick head will mean low capacitance, and a thin head a relatively higher value.

THE RELATION BETWEEN CORONA AND CAPACITANCE - To determine if there were a relation between these factors, corona formation voltage values for the different insulators of the 45-55 kilovolt class were plotted and compared with the capacitance values. It was found that the corona voltage values decreased to some extent with decreasing capacitance. However, the relation was not very consistent, and the curves have not been included. These corona formation voltages were obtained from the data gathered by Professor McMillan and the students who worked with him.

THE RELATION BETWEEN PUNCTURE AND CAPACITANCE - The exact nature of dielectric losses due to an alternating field is not definitely known, and there is at present a great amount of study being carried on to determine if possible the exact nature of these losses. An article by Professor J. B. Whitehead[8] gives a very good summary of past and present views on the subject. There are those who advocate that alternating losses are due entirely to absorption losses, and those who hold that there is a loss due to the changing flux which has been termed dielectric hysteresis. Although Whitehead[8] states that alternating losses in solid dielectrics are due almost entirely to absorption, it is hard to make this a general statement which will fit all cases, all frequencies, and all dielectrics. In an article considering the design of porcelain antenna insulators, W. W. Brown[9] brings out the point that dielectric losses are proportional nearly to the square of the flux density. Although Whitehead and many others probably would not agree with the idea, it is not impossible that when the exact nature of dielectric losses is well known that it will be found that there are changes within the atom which account for much loss with a rapidly alternating dielectric field.

If there is a loss in the insulators which is proportional to the dielectric flux in the porcelain, this loss would also depend on the capacitance of the insulator. Since it is well known that a dielectric will puncture at a much lower voltage when at a high temperature than at a low temperature, it was expected that a relation would be found between the capacitance and the puncture voltage value of the insulators. In fact, it was this phase of the subject that first lead to the study of the capacitance of the insulators.

One of the many tests made by Professor McMillan and the group of students under his supervision was a determination of the puncture voltage of the insulators. These tests were made in accordance with the specifications of the American Institute of Electrical

Engineers[5] as was previously mentioned. Very briefly, the method consisted of immersing the insulator in an inverted position in a metal tank containing oil. The head of the insulator was provided with a conductor in the groove consisting of two 0.5 inch brass tubes one foot long which were fastened together at their centers and which were held in place with a #6 tie wire. These conductors were in contact with the bottom of the tank from which connections were made through ground to one side of the high voltage transformer. The pin, in place in the insulator, was connected to the other side of the transformer. After the connections were made the voltage was raised at a uniform rate to about 80% of the puncture value to determine with the sphere gap the transformer ratio. The voltage was then removed to permit the sphere gap to be opened so that it would not flash, and then the voltage was again raised at a uniform rate until puncture of the insulator occurred.

Curves showing graphically the relation found between the puncture voltage value and the capacitance are included for the 13-17 kilovolt class. Data were not available for the other classes as the tests have not been completed. The curves for the type A insulators on Page 49 show that in general where the capacitance is low the puncture voltage is also low. The curves for the type B insulators on Page 50, and for the type C insulators on Page 51 also show this to be true. The curves for the type D insulators on Page 52 show no consistent variations. The curves for the type E and type F insulators on Pages 53 and 54 each show in general a decreasing voltage with decreasing capacitance. This is not what would be expected if the alternating flux, the magnitude of which depended on the capacitance, had any predominating influence on the temperature rise in the insulators, and therefore the puncture voltage value. However, the averages of the different types plotted on Page 55 show that in general, the insulators having high capacitance have also a low puncture value, and that those having a low capacitance have a high puncture voltage. However, a further investigation showed that this was not due to the effect of the capacitance.

On Page 44 data are found for these puncture voltage values together with the point at which the insulators punctured. A summary is also shown on Page 45. These figures show that for the type A insulators, 100% of the individual insulators punctured from the conductor groove to the pin hole. An examination of the curves on Page 55 show why this was true. The thickness of porcelain was much less at this point than at any other. These same curves show that for the type B insulators the difference in the thicknesses are not so marked. The puncture data show that as a result of this, that 50% punctured through to the tie wire and 40% to the conductor groove. The curves for the type C insulators show that there is a wider deviation between the two thicknesses than in the case of the type B insulators. As a result, 70% punctured from the conductor groove, and only ten per cent to the tie wire groove. For the type D insulators, the thickness of the porcelain is less to the tie wire groove, and the greatest to the conductor groove. It is shown that as a result 80% of the insulators of this type punctured to the tie wire groove, and only 20% to the conductor groove. The dimensions of the type E

PUNCTURE VOLTAGE DATA

15 - 17 Kilovolt

Insulator Number	Location of Puncture	Puncture Voltage	Insulator Number	Location of Puncture	Puncture Voltage
A-11	X	76.4 Kv.	B-11	Y	96.3 Kv.
12	X	76.5	12	X	101.2
13	X	102.3	13	Y	101.8
14	X	81.6	14	Y	100.2
15	X	83.2	15	X	96.4
16	X	83.6	16	Z	94.8
17	X	96.2	17	X	95.6
18	X	90.0	18	X	102.2
19	X	91.3	19	Y	100.1
20	X	89.8	20	Y	81.6
	Average	87.1		Average	97.0
C-11	X	95.0 Kv.	D-11	Y	100.8 Kv.
12	X	82.4	12	Y	105.6
13	X	107.8	13	Y	102.3
14	Z	98.5	14	Y	116.3
15	Y	98.8	15	Y	103.7
16	X	100.4	16	X	108.0
17	X	94.2	17	X	101.3
18	X	99.0	18	Y	99.7
19	X	100.0	19	Y	107.6
20	Z	81.0	20	Y	107.7
	Average	95.7		Average	105.3
E-11	Y	81.5	F-11	Y	73.0
12	Y	92.3	12	Z	99.2
13	Y	99.6	13	X	102.0
14	X	88.8	14	X	88.4
15	X	99.0	15	X	102.8
16	Y	100.8	16	Y	94.0
17	Y	105.3	17	X	86.1
18	X	93.7	18	Y	97.2
19	Y	97.2	19	X	95.6
20	Y	87.2	20	X	84.3
	Average	94.5		Average	92.7

X -- Punctured from Conductor Groove to Pin Hole
Y -- Punctured from Tie Wire Groove to Pin Hole
Z -- Punctured from Top of Head to Pin Hole

LOCATION OF PUNCTURES

15 - 17 Kilovolt

Type A	Conductor Groove to Pin Hole	100%
Type B	Conductor Groove to Pin Hole	40%
	Tie Wire Groove to Pin Hole	50%
	Top of Insulator to Pin Hole	10%
Type C	Conductor Groove to Pin Hole	70%
	Tie Wire Groove to Pin Hole	10%
	Top of Insulator to Pin Hole	20%
Type D	Tie Wire Groove to Pin Hole	80%
	Conductor Groove to Pin Hole	20%
Type E	Tie Wire Groove to Pin Hole	70%
	Conductor Groove to Pin Hole	30%
Type F	Conductor Groove to Pin Hole	60%
	Tie Wire Groove to Pin Hole	30%
	Top of Insulator to Pin Hole	10%

insulators are more nearly the same than the type D insulators, and as a result 70% punctured to the tie wire groove and 30% through the head. The values for the type F insulators indicate that these should puncture from pin to conductor groove more often than from the pin to the tie wire groove. Such was the case, 60% puncturing to the conductor groove, and 30% to the tie wire groove. Therefore, if the dimensions are known, it is possible in general to predict the point at which the insulator will fail.

From the above considerations it may be concluded that there is a relation between the capacitance and the puncture voltage, but that this relation is determined by the thickness of porcelain which also generally determines the point at which the insulators puncture. At 60 cycles it would appear that the capacitance of the insulator would not determine the puncture voltage value although it might influence this value. However, if the discussion by W. W. Brown[9] is true, at radio frequencies the capacitance might be the factor which largely determined the puncture value. Mr. Brown's statement is as follows:

"We must not loose sight of the fact that flux densities which are permissible in insulators for 60 cycles can seldom be used in insulators subjected to radio frequency continuous waves because of the high dielectric loss."

CONCLUSIONS

Section VI

The major conclusions to be drawn from this study are as follows:

(1) High-voltage pin-type insulators have an appreciable amount of capacitance which was found to vary from about 8 to 15 micro-micro-farads.

(2) The tie wire influences the capacitance to some extent. Within certain limits, an insulator with a large tie wire will show an increase in capacitance over the same insulator with a small tie wire.

(3) The frequency at which the measurements are made does not influence, to any great extent, the capacitance of the insulators.

(4) Various factors of design such as weight, thickness from pin to tie wire groove, and thickness from pin to conductor groove affect the capacitance, although the general laws are difficult to determine.

(5) There seems to be no consistent relation between corona and the capacitance of insulators.

(6) A relationship exists between the puncture voltage and capacitance which is entirely due to the thickness of the porcelain which determines both the puncture voltage and capacitance.

(7) From a knowledge of the thickness of porcelain it is possible to predict at what point the insulator will fail.

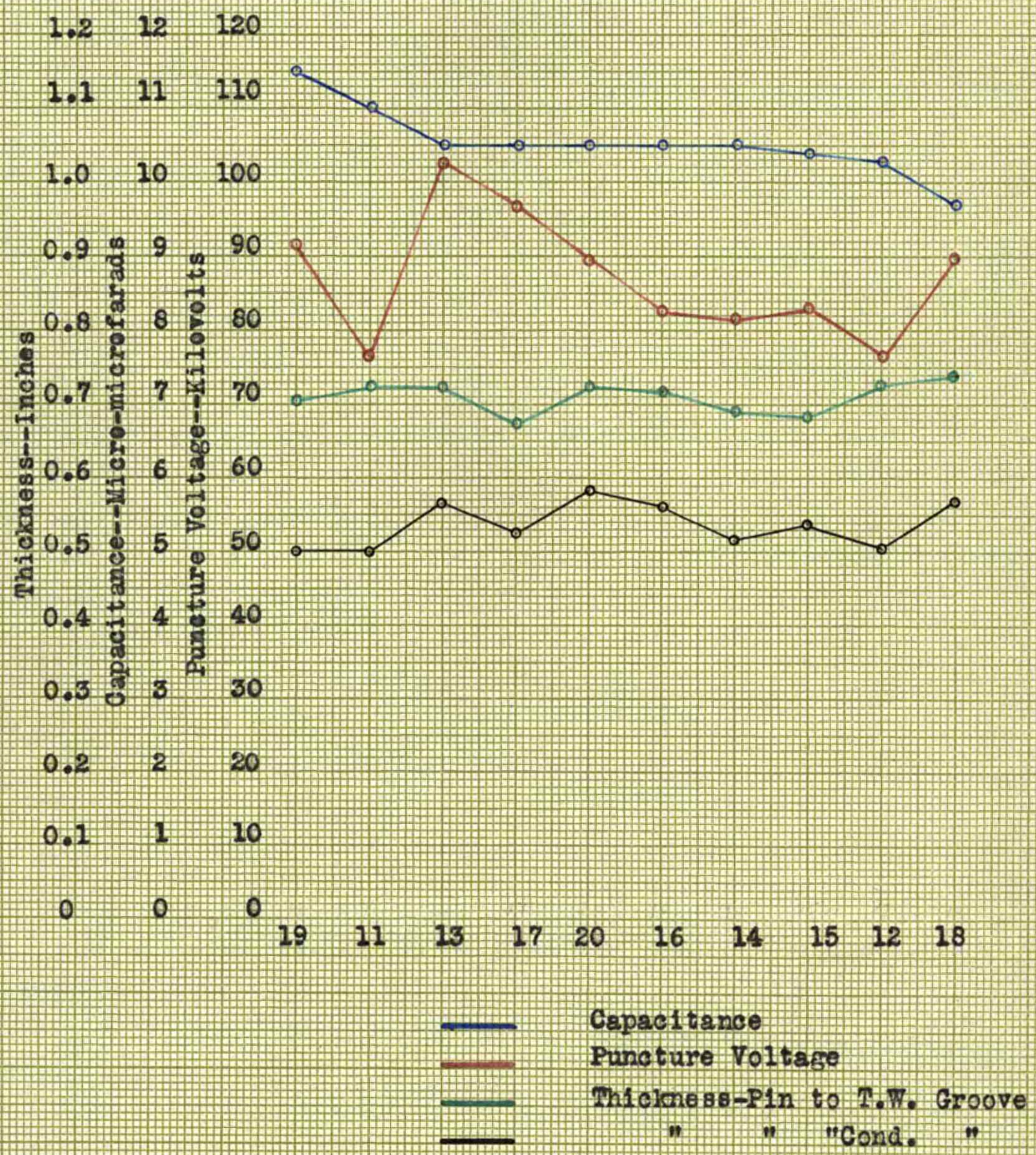
(8) Although at 60 cycles the capacitance does not determine the puncture voltage, at radio frequencies it might be the determining factor.

13-17 KILOVOLT INSULATOR CURVES

Section VII

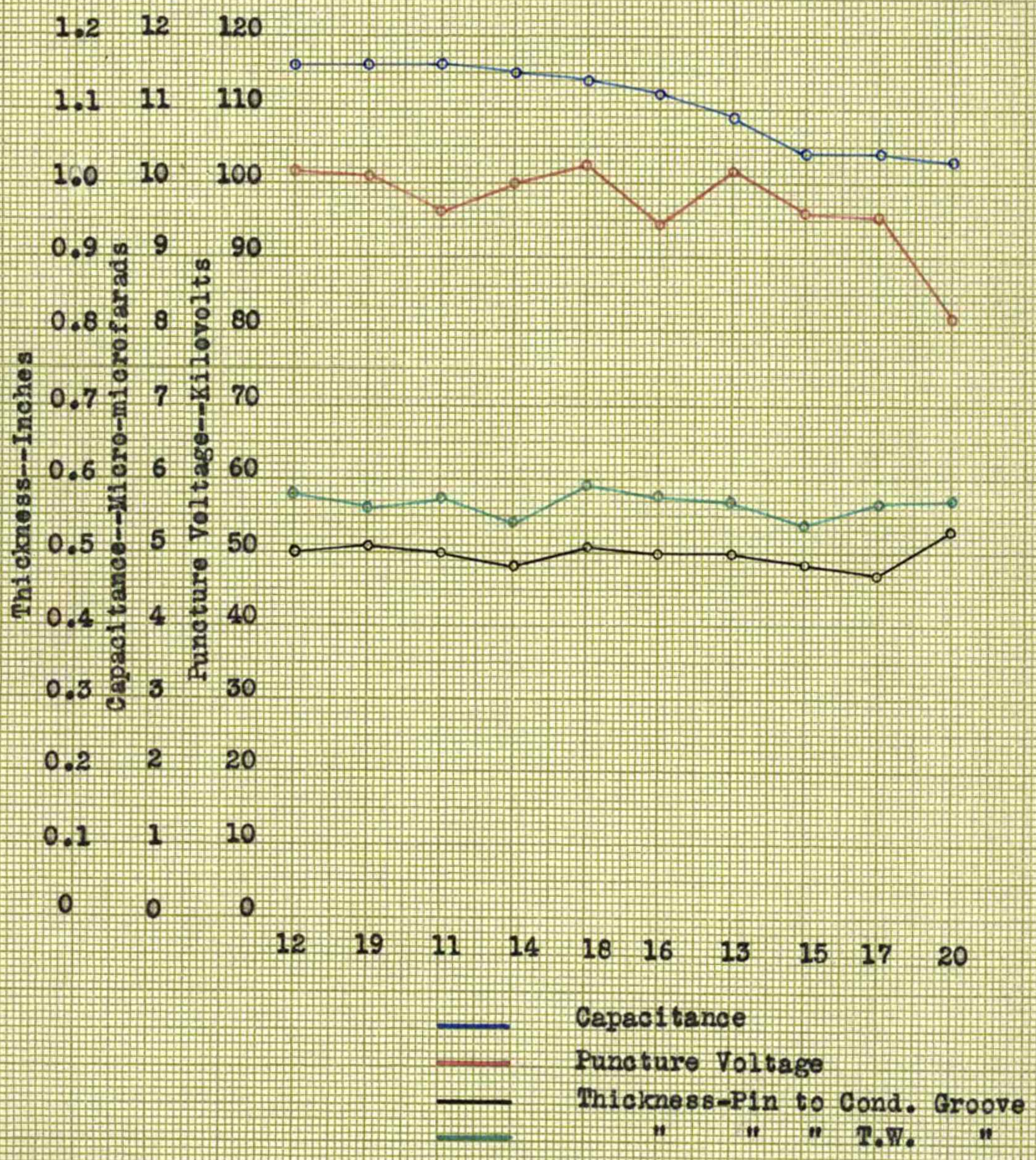
CURVES FOR TYPE "A" INSULATORS

13-17 Kilovolt Class



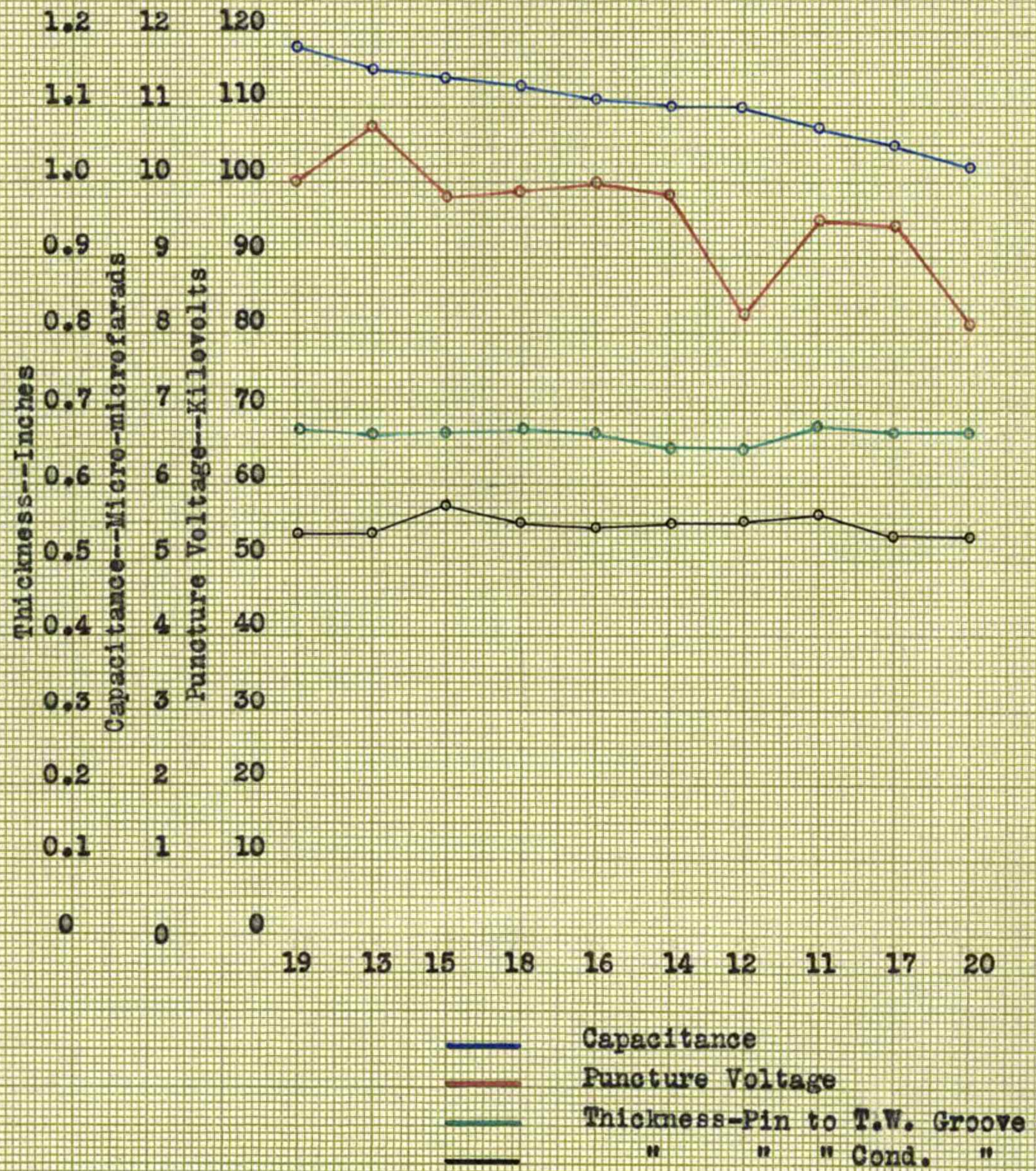
CURVES FOR TYPE "B" INSULATORS

13-17 Kilovolt Class



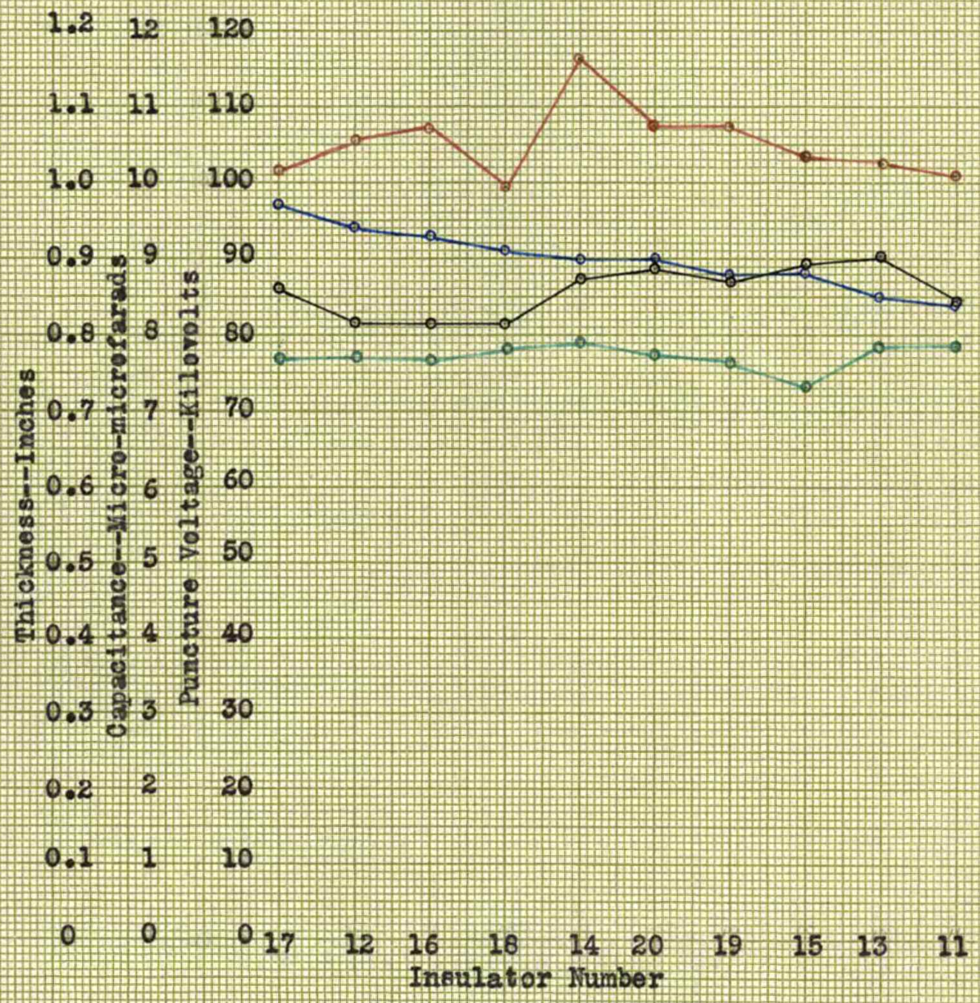
CURVES FOR TYPE "C" INSULATORS

13-17 Kilovolt Class



CURVES FOR TYPE "D" INSULATORS

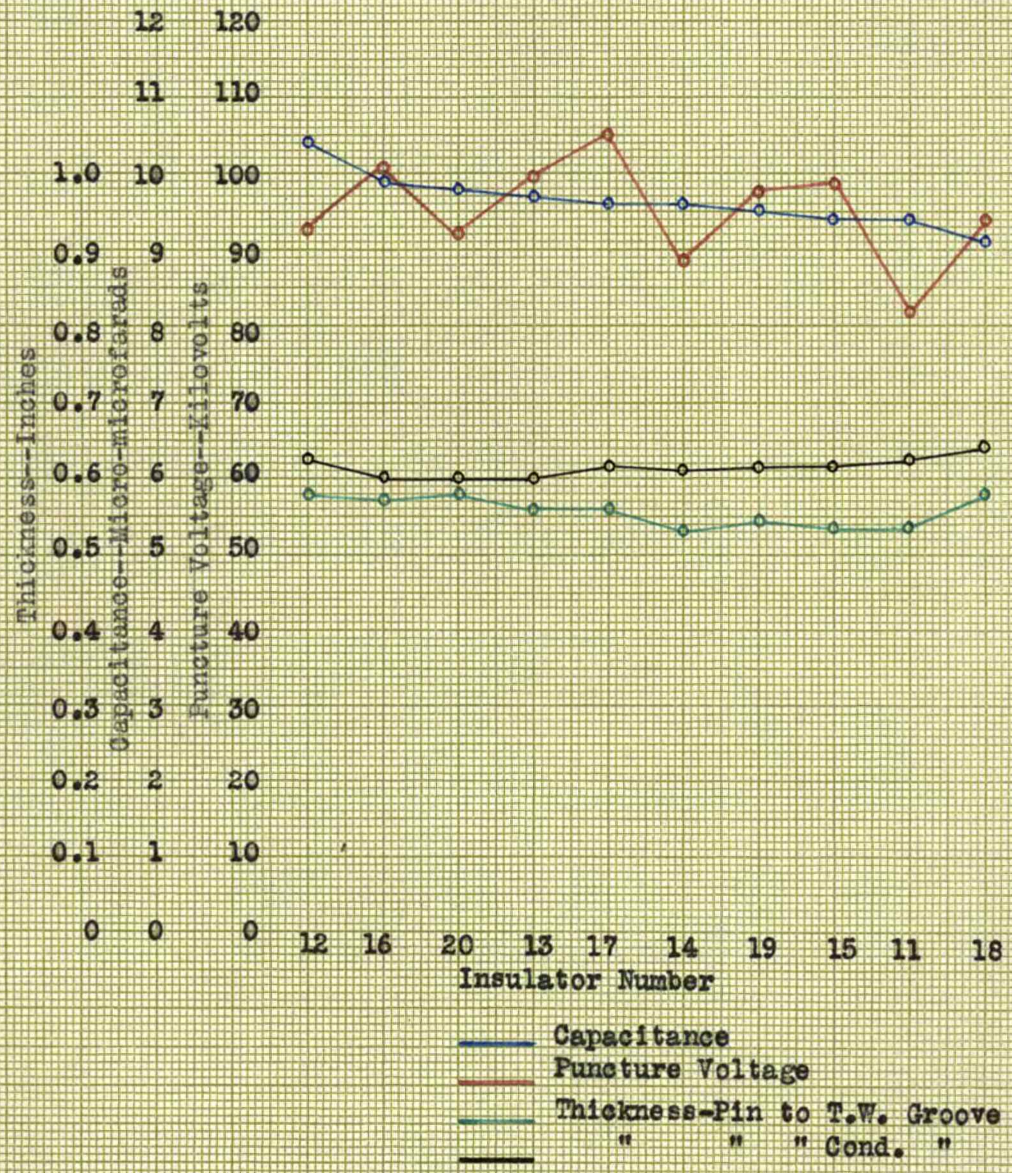
13-17 Kilovolt Class



Capacitance
Puncture Voltage
Thickness-Pin to T. W. Groove
" " " Cond. "

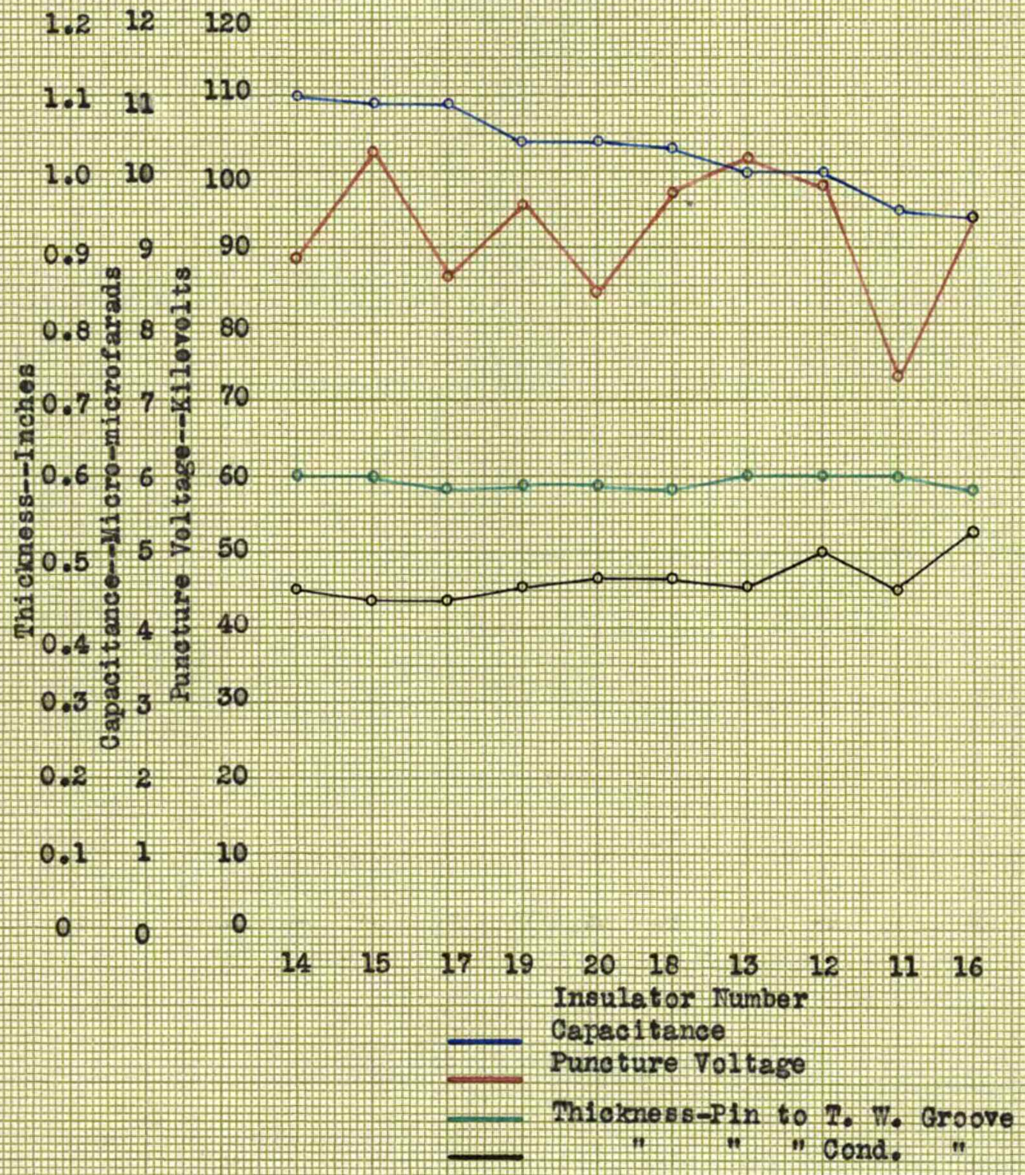
CURVES FOR TYPE "E" INSULATORS

13-17 Kilovolt Class



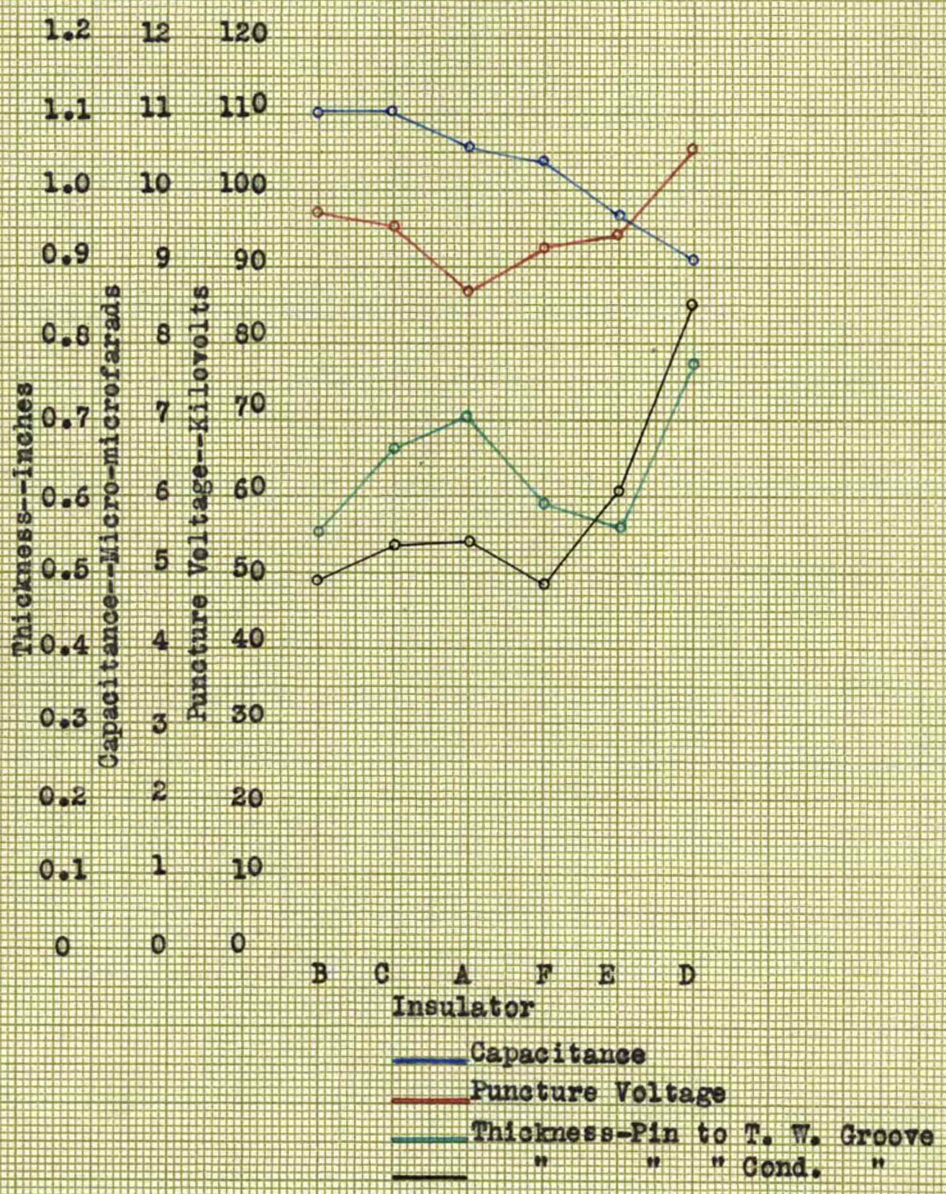
CURVES FOR TYPE "F" INSULATORS

13-17 Kilovolt Class



CURVES OF AVERAGE VALUES

13-17 Kilovolt Class

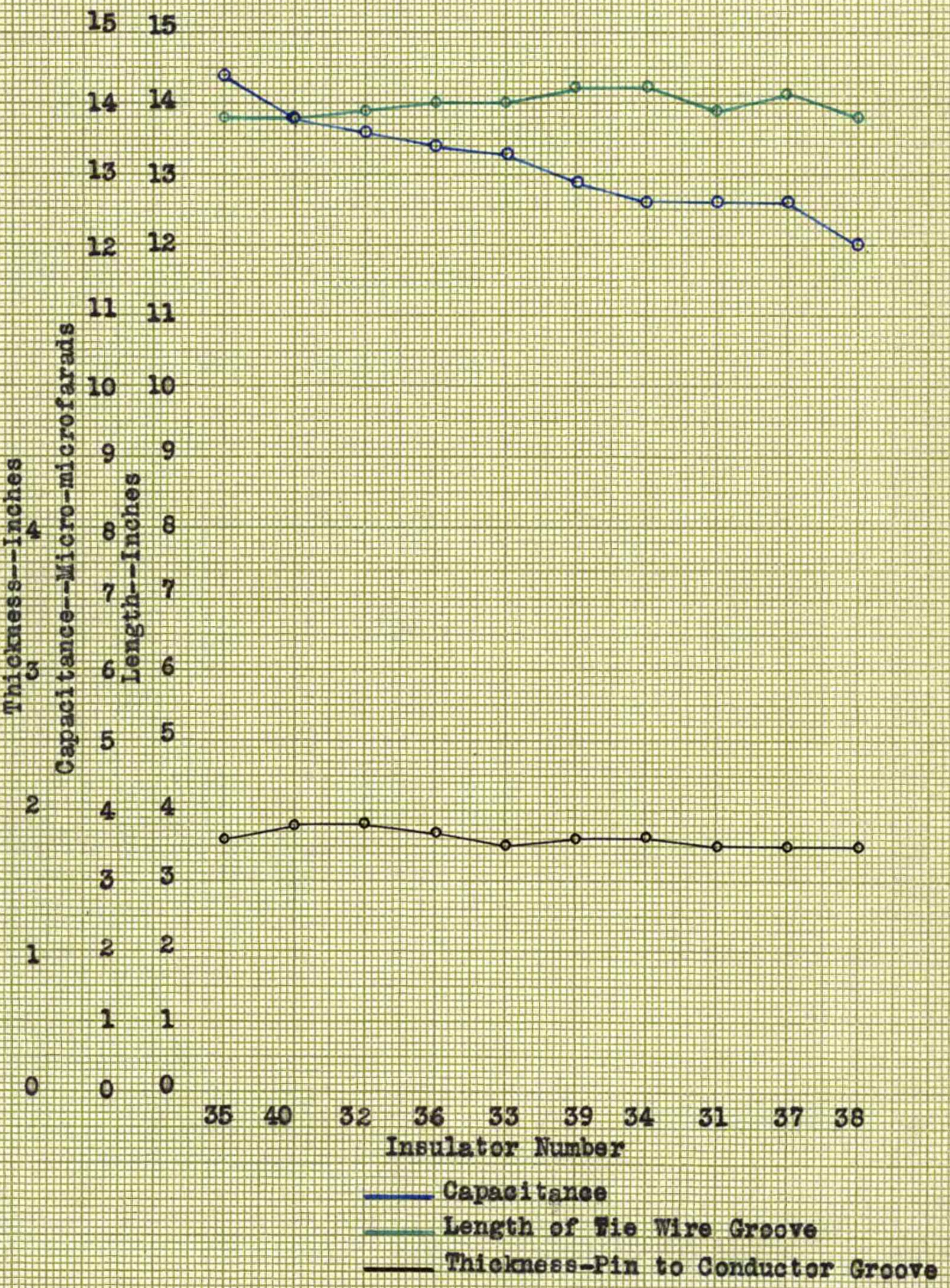


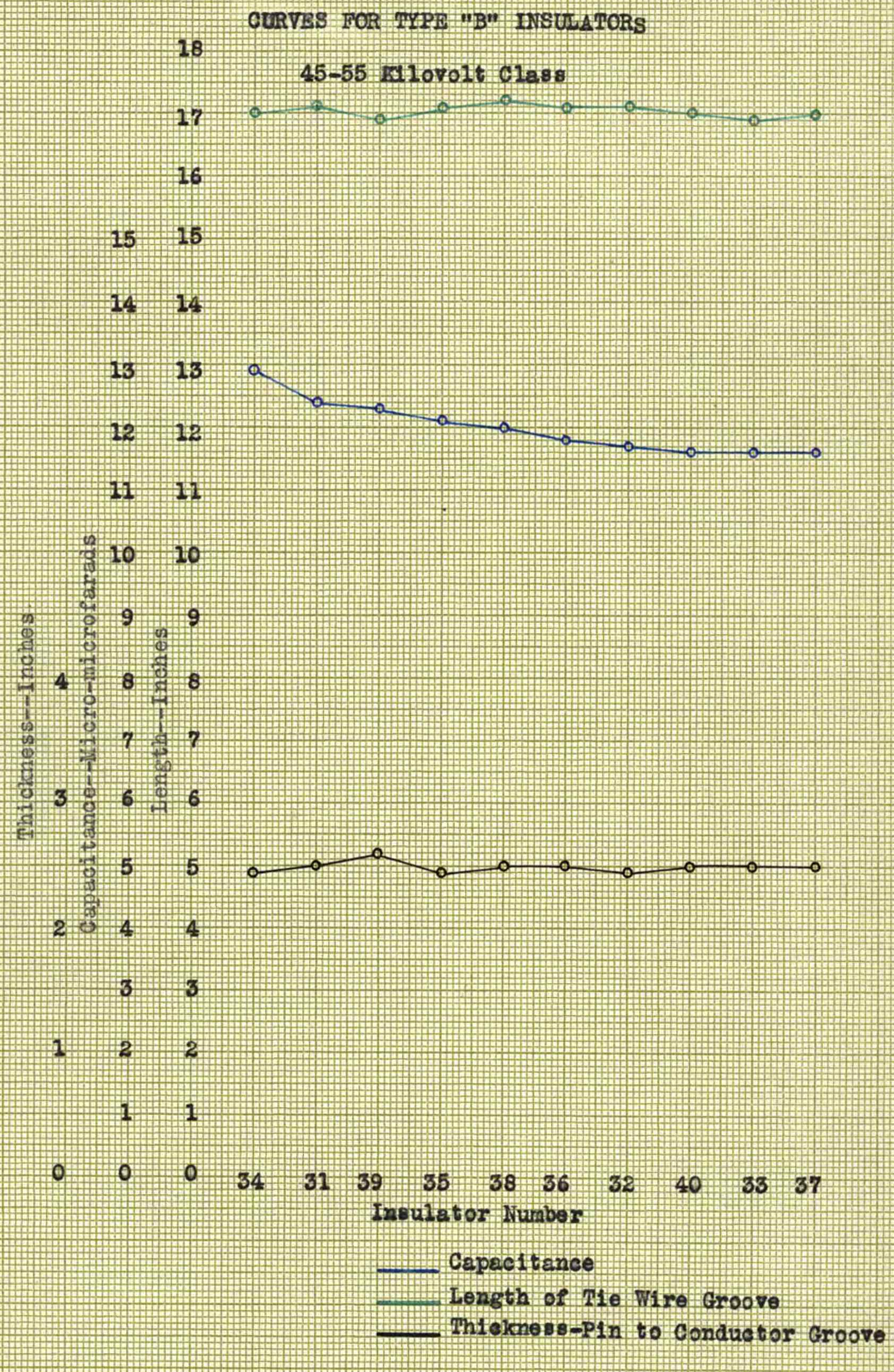
45-55 KILOVOLT INSULATOR CURVES

Section VIII

CURVES FOR TYPE "A" INSULATORS

45-55 Kilovolt Class

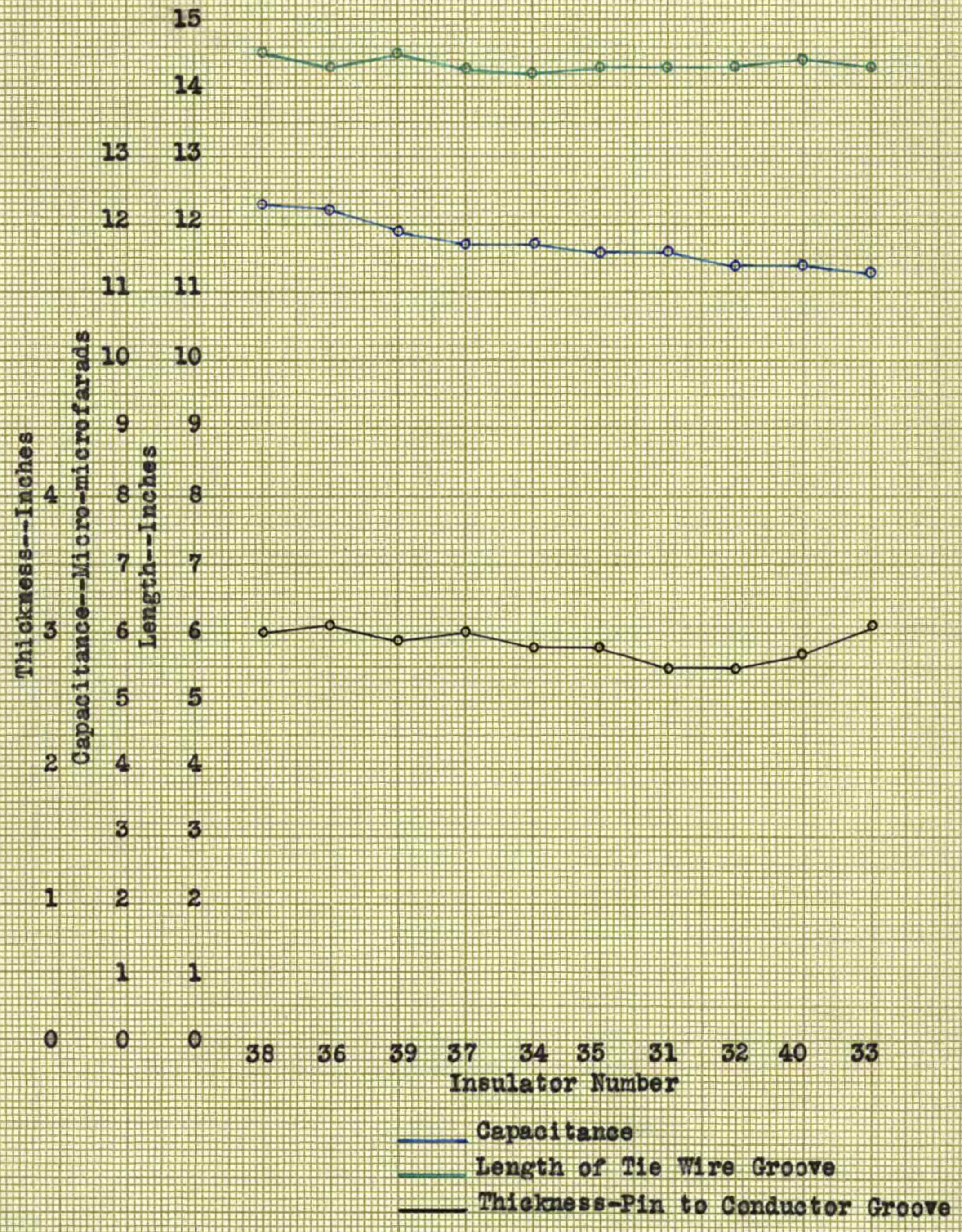


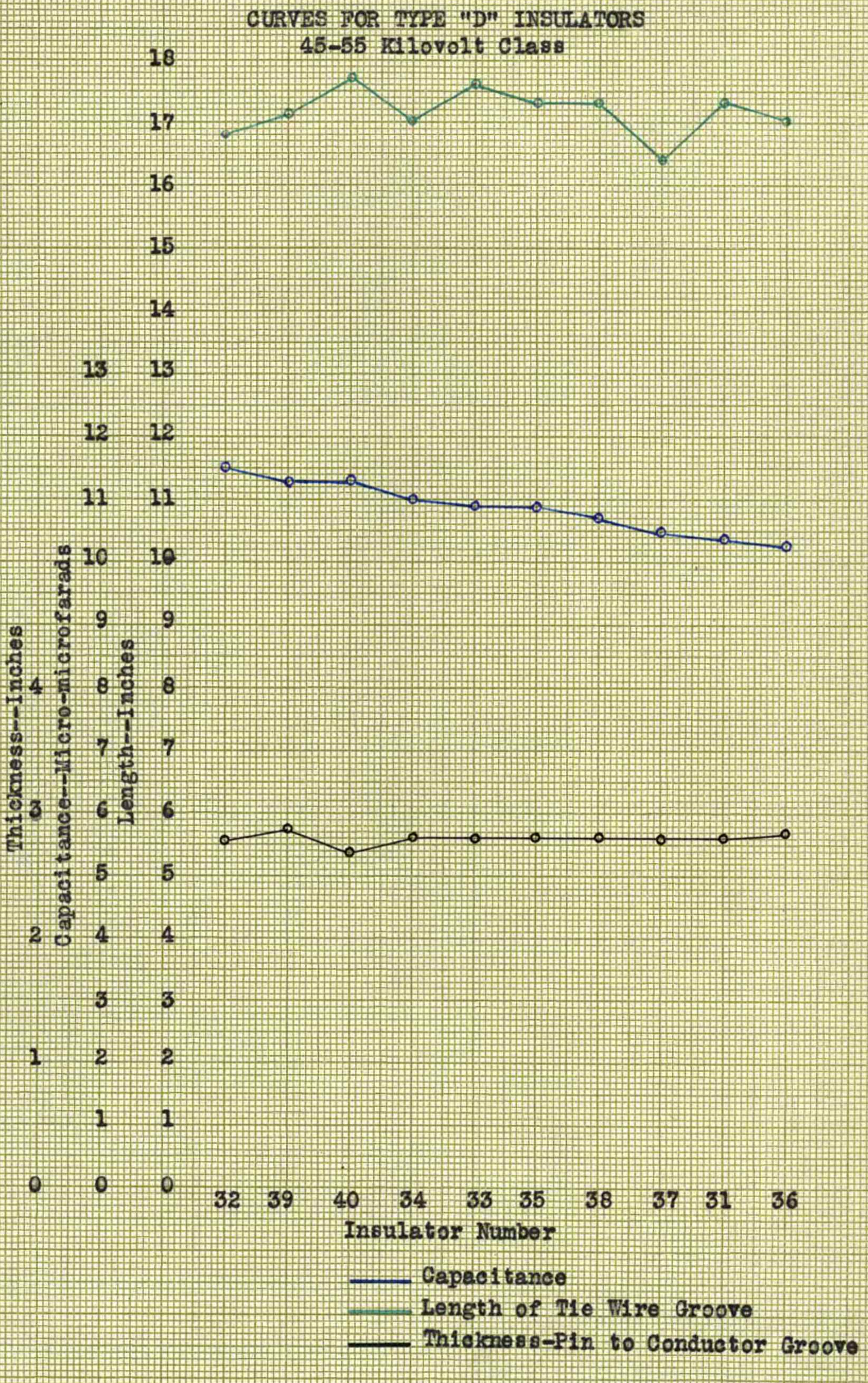


CURVES FOR TYPE "B" INSULATORS
45-55 Kilovolt Class
Thickness--Inches
Capacitance--Micro-microfarads
Length--Inches
34 31 39 35 38 36 32 40 33 37
Insulator Number
Capacitance
Length of Tie Wire Groove
Thickness-Pin to Conductor Groove

CURVES FOR TYPE "C" INSULATORS

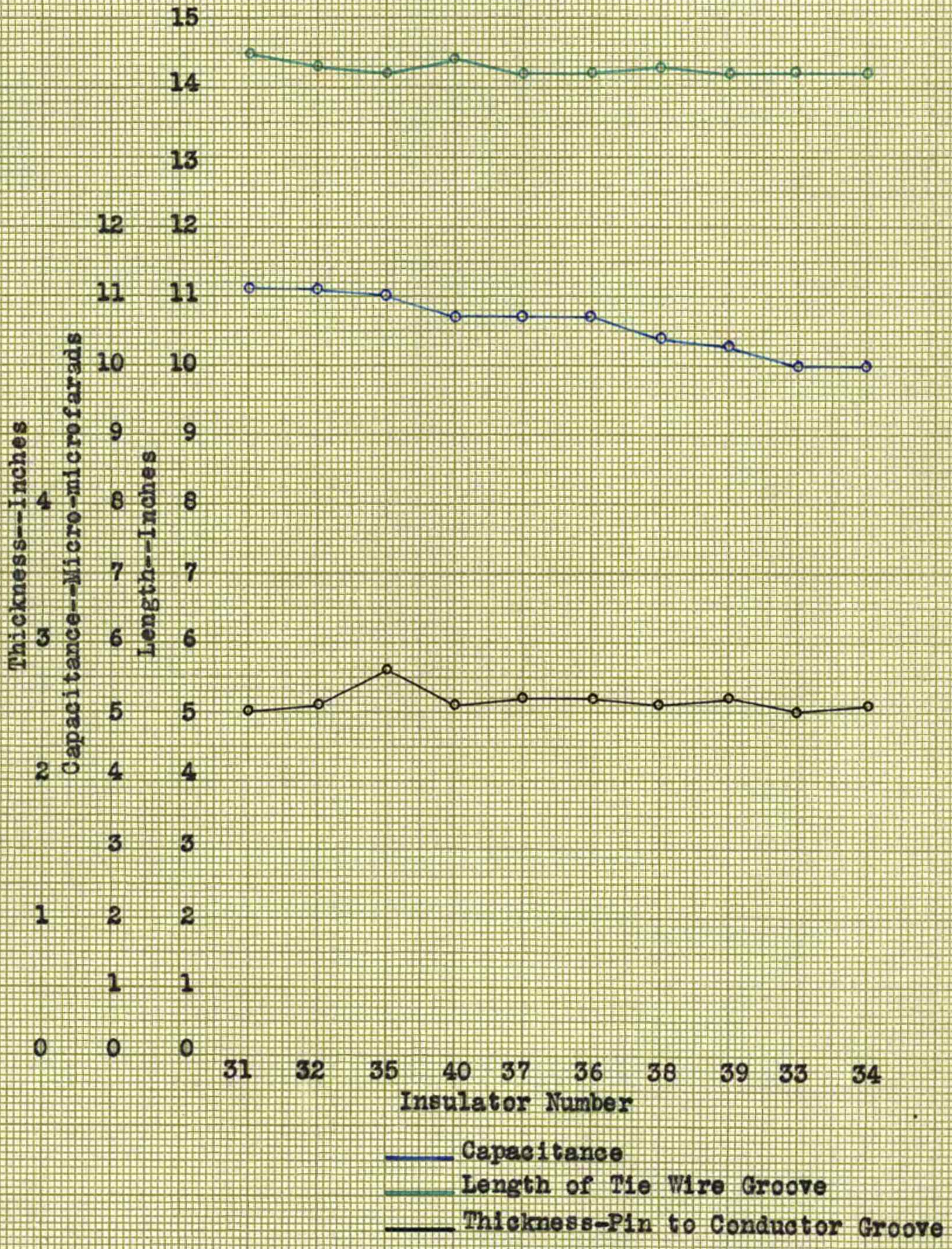
45-55 Kilovolt Class




CURVES FOR TYPE "D" INSULATORS
45-55 Kilovolt Class
Thickness--Inches
Capacitance--Micro-microfarads
Length--Inches
32 39 40 34 33 35 38 37 31 36
Insulator Number
Capacitance
Length of Tie Wire Groove
Thickness-Pin to Conductor Groove

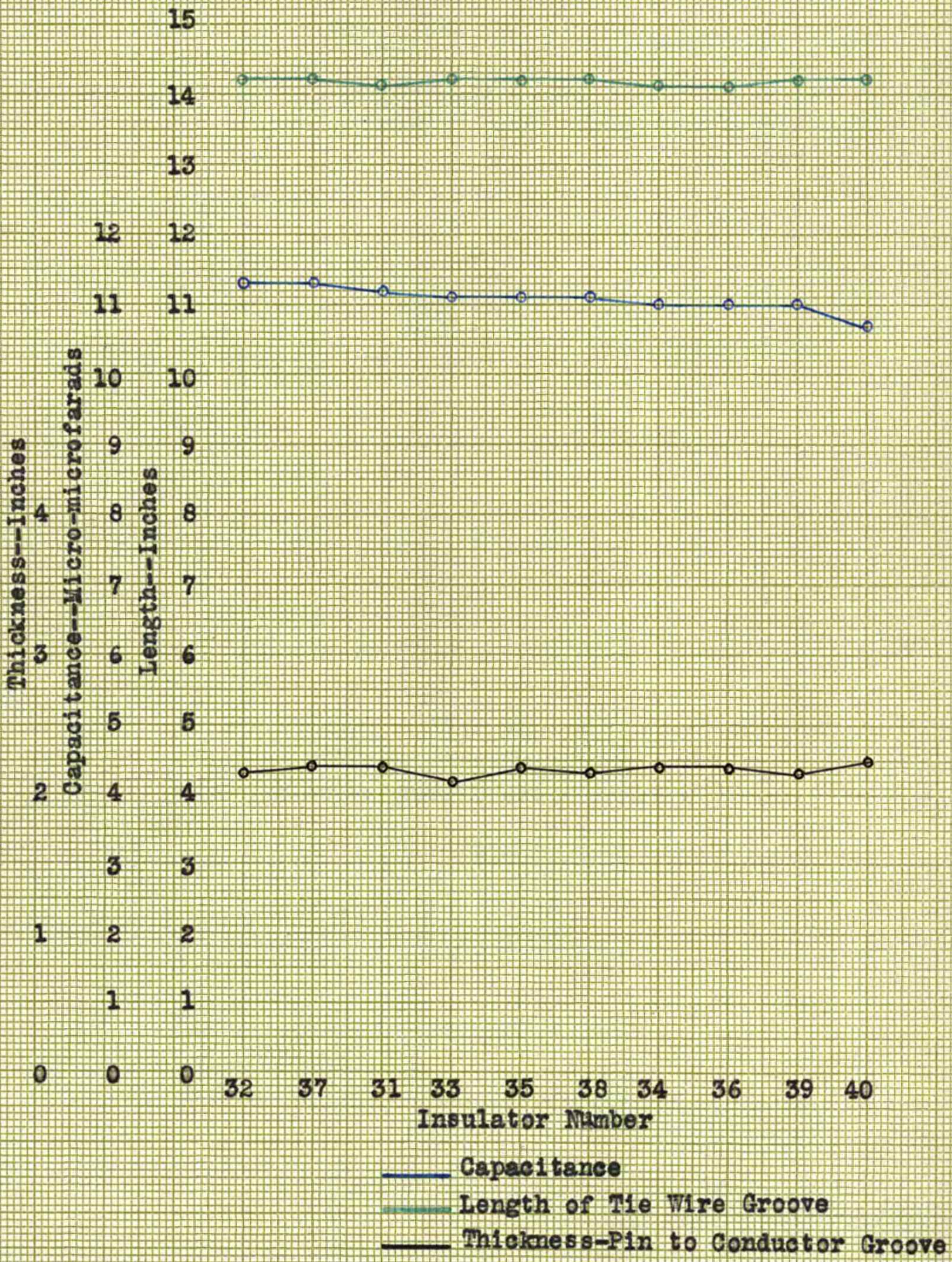
CURVES FOR TYPE "E" INSULATORS

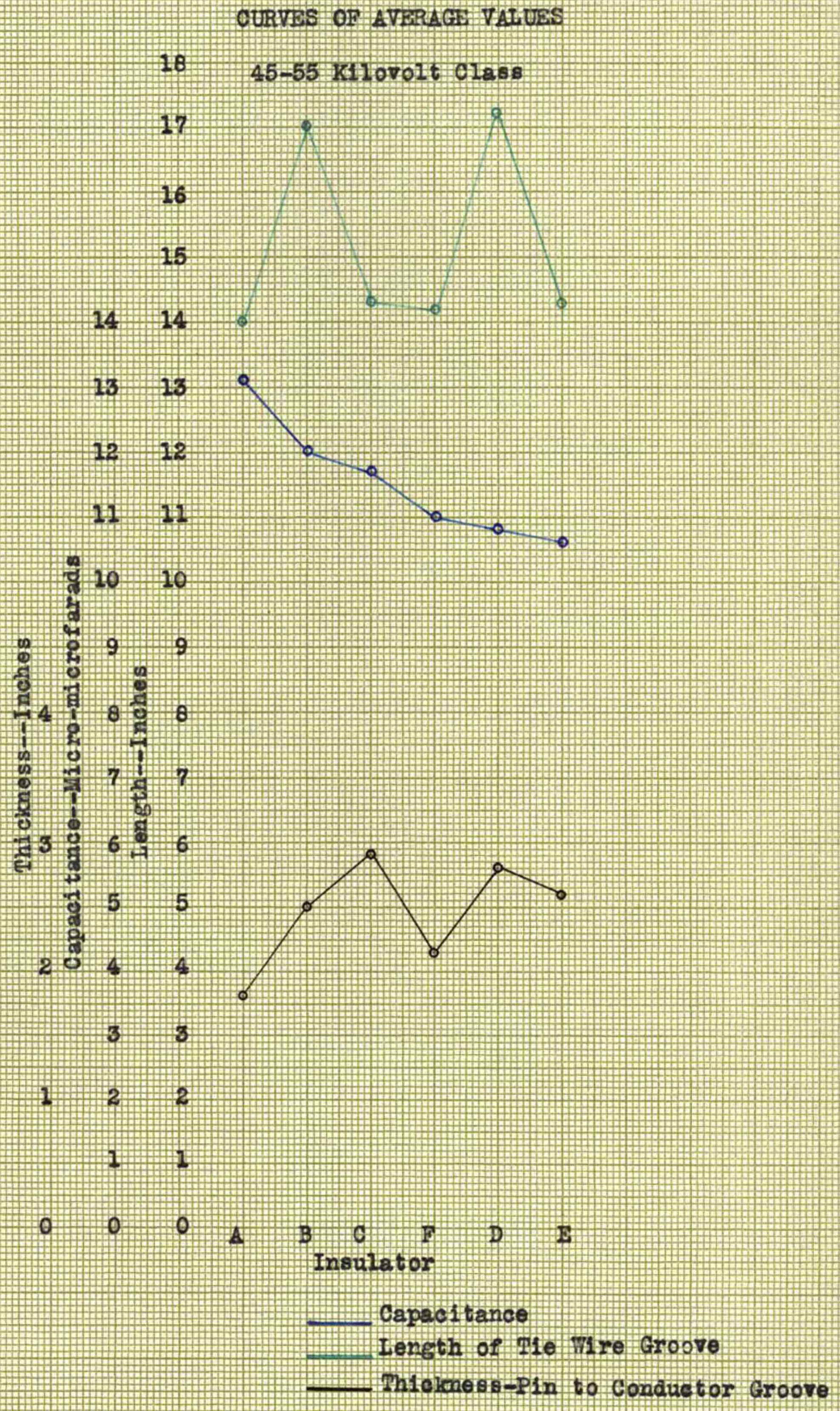
45-55 Kilovolt Class



CURVES FOR TYPE "F" INSULATORS

45-55 Kilovolt Class



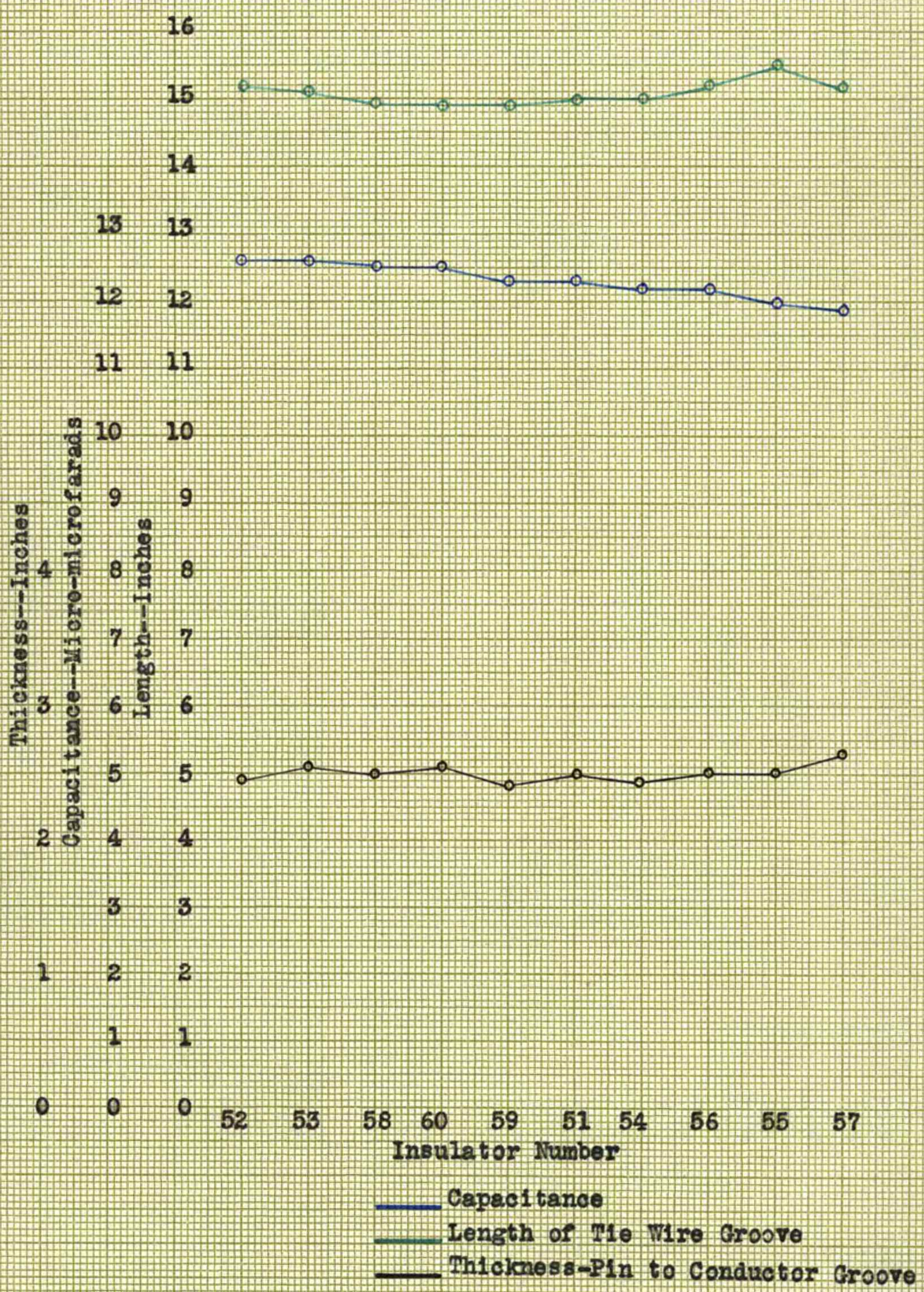

CURVES OF AVERAGE VALUES
45-55 Kilovolt Class
Thickness--Inches
Capacitance--Micro-microfarads
Length--Inches
0 1 2 3 4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
A B C F D E
Insulator
Capacitance
Length of Tie Wire Groove
Thickness-Pin to Conductor Groove

66 KILOVOLT INSULATOR CURVES

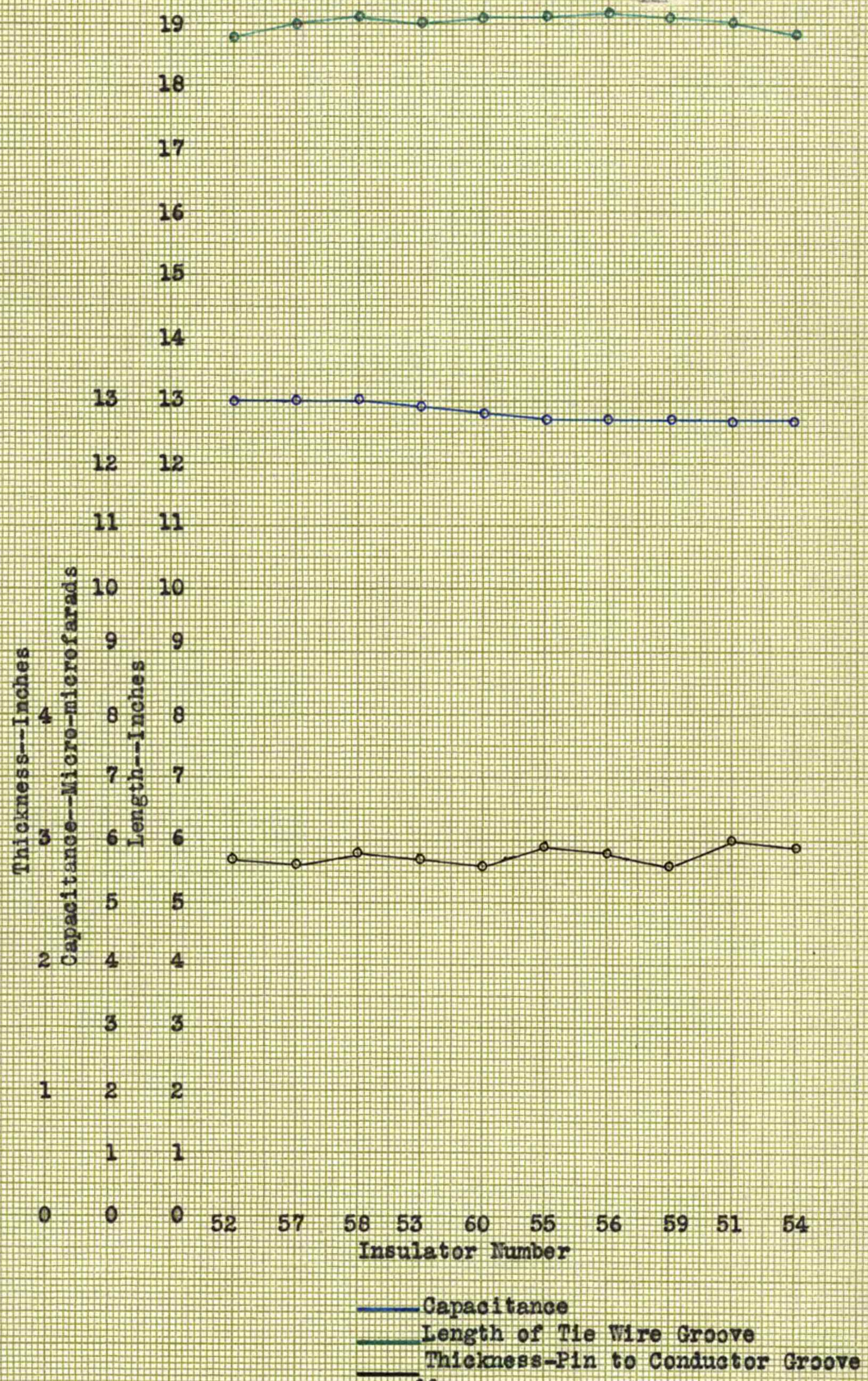
Section IX

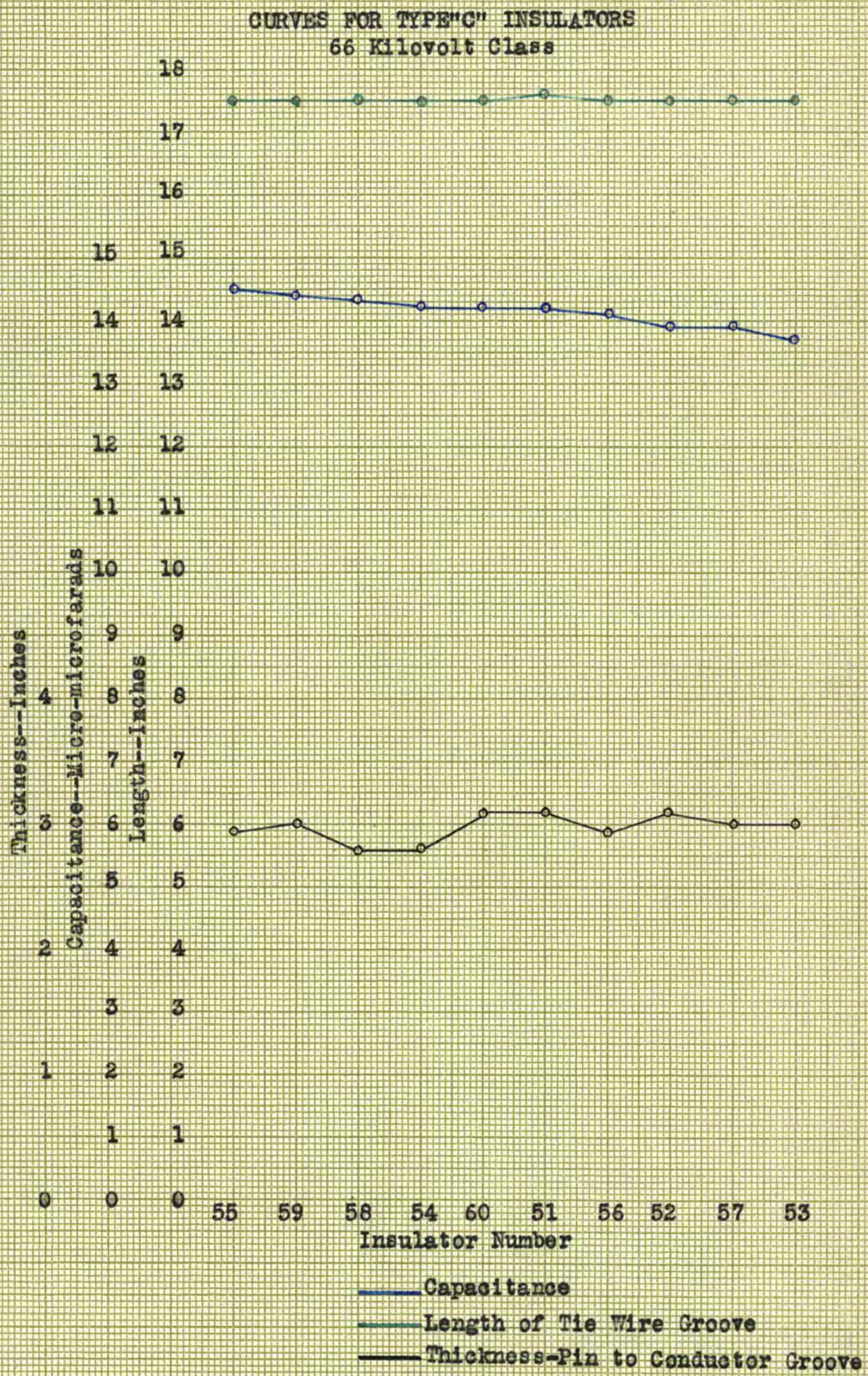
CURVES FOR TYPE "A" INSULATORS

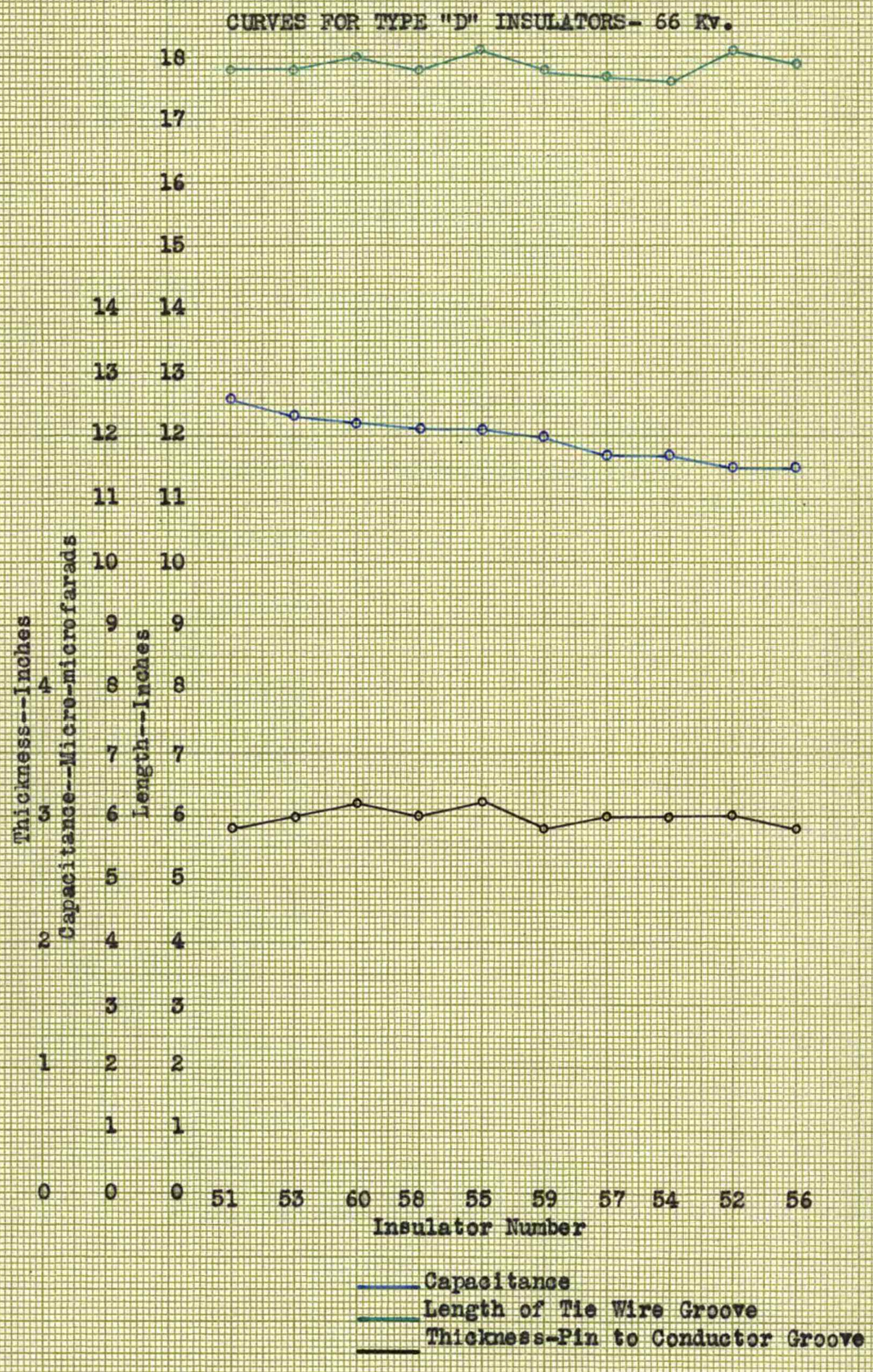
66 Kilovolt Class



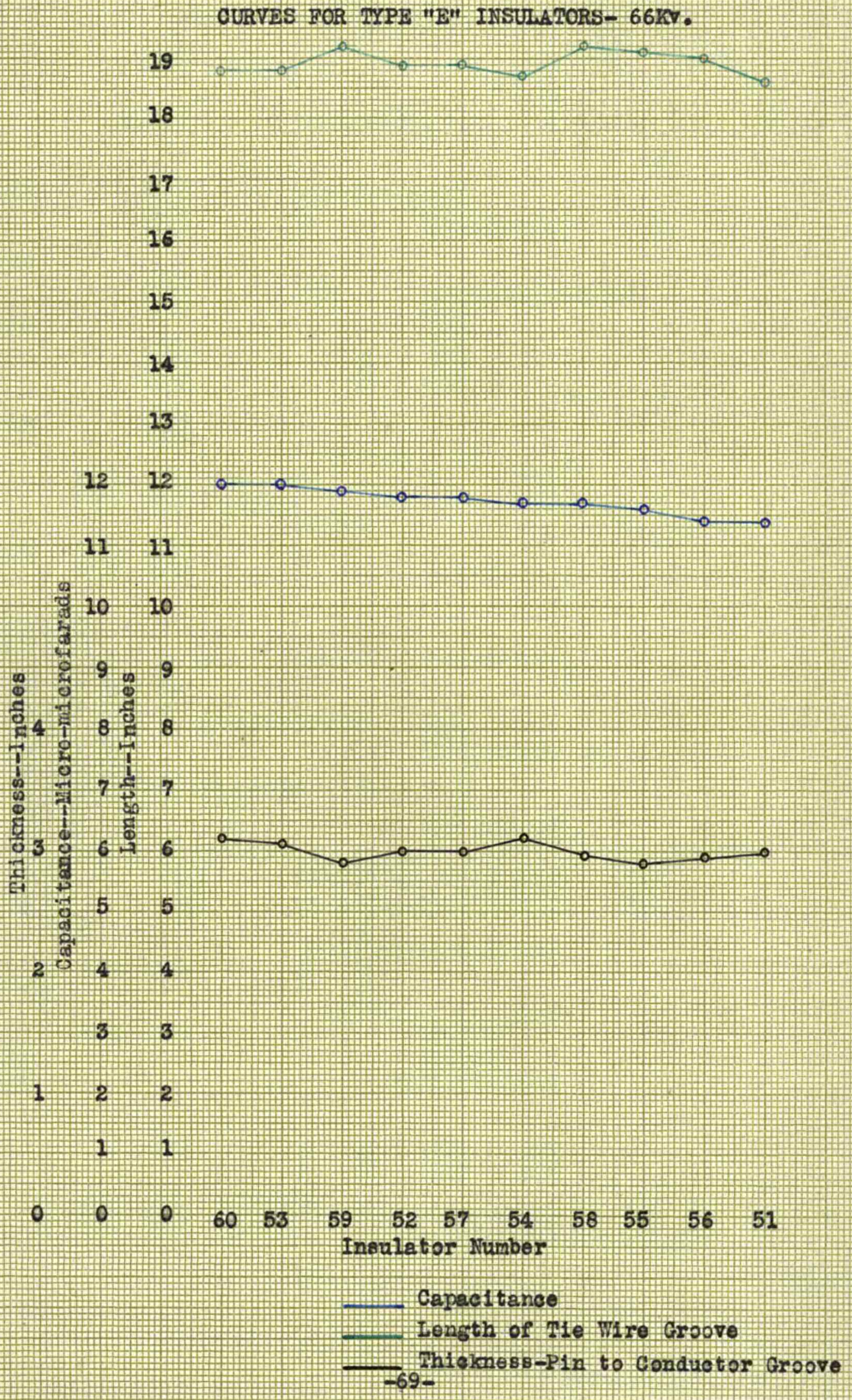
CURVES FOR TYPE "B" INSULATORS - 66 Kv.



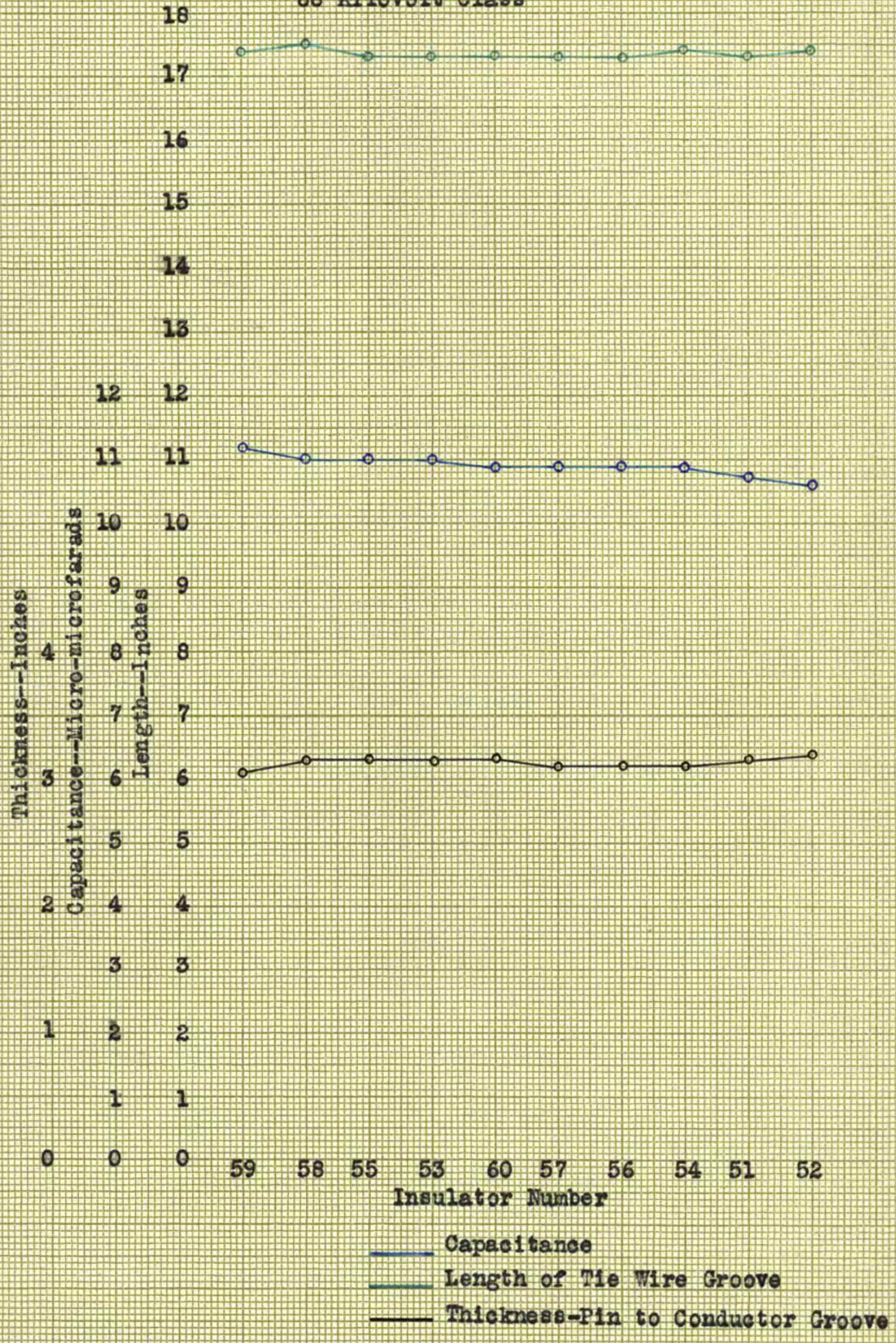

CURVES FOR TYPE"C" INSULATORS
66 Kilovolt Class
Thickness--Inches
Capacitance--Micro-microfarads
Length--Inches
Insulator Number
55 59 58 54 60 51 56 52 57 53
Capacitance
Length of Tie Wire Groove
Thickness-Pin to Conductor Groove

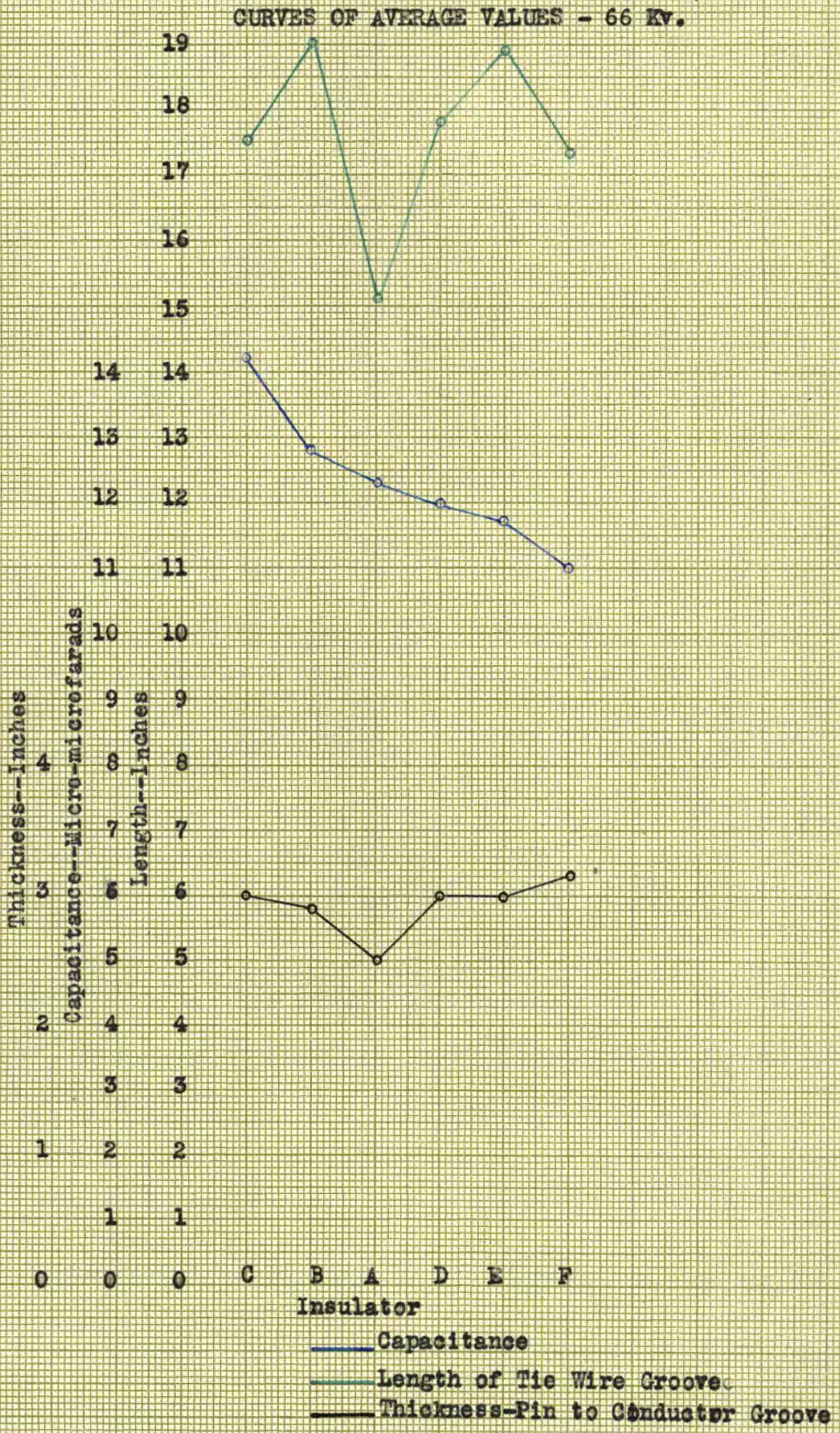


CURVES FOR TYPE "D" INSULATORS- 66 Kv.
Thickness--Inches
Capacitance--Micro-microfarads
Length--Inches
0 1 2 3 4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
51 53 60 58 55 59 57 54 52 56
Insulator Number
Capacitance
Length of Tie Wire Groove
Thickness-Pin to Conductor Groove


CURVES FOR TYPE "E" INSULATORS- 66Kv.
Thickness--Inches
Capacitance--Micro-microfarads
Length--Inches
60 53 59 52 57 54 58 55 56 51
Insulator Number
Capacitance
Length of Tie Wire Groove
Thickness-Pin to Conductor Groove

CURVES FOR TYPE "F" INSULATORS
66 Kilovolt Class




CURVES OF AVERAGE VALUES - 66 Kv.
Thickness--Inches
Capacitance--Micro-microfarads
Length--Inches
0 1 2 3 4
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
C B A D E F
Insulator
Capacitance
Length of Tie Wire Groove
Thickness-Pin to Conductor Groove

CAPACITANCE TEST DATA

Section X

Capacitance Test Data

Ins. No. A-11*

```
Ins. Out 1166.8
         1166.4
         1167.0
   Ave.       1166.7
Ins. In  1148.2
         1147.8
         1147.9
   Ave.       1148.0
      Diff.     18.7
Capacitance 11.0 mmfd.
```

Ins. No. A- 12

```
Ins. Out 1165.0
         1165.2
         1165.0
   Ave.       1165.1
Ins. In  1147.2
         1147.7
         1147.8
   Ave.       1165.1
      Diff.     17.5
Capacitance 10.3 mmfd.
```

Ins. No. A-13

```
Ins. Out 1164.7
         1165.0
         1164.6
   Ave.       1164.8
Ins. In  1147.3
         1146.8
         1146.8
   Ave.       1147.0
      Diff.     17.8
Capacitance 10.5 mmfd.
```

Ins. No. A-14

```
Ins. Out 1164.7
         1164.7
         1164.7
   Ave.       1164.7
Ins. In  1147.0
         1146.5
         1147.2
   Ave.       1146.9
      Diff.     17.8
Capacitance 10.5 mmfd.
```

Ins. No. A-15

```
Ins. Out 1165.0
         1165.1
         1165.4
   Ave.       1165.2
Ins. In  1147.4
         1147.4
         1147.7
   Ave.       1147.7
      Diff.     17.7
Capacitance 10.4 mmfd
```

Ins. No. A-16

```
Ins. Out 1165.3
         1164.8
         1165.2
   Ave.       1165.1
Ins. In  1147.5
         1147.0
         1147.0
   Ave.       1147.2
      Diff.     17.9
Capacitance 10.5 mmfd.
```

*Insulator checked to determine if error had been made in measuring the capacitance

Capacitance Test Data

Ins. No. A-17

Ins. Out	1164.5	
	1165.0	
	1165.2	
Ave.		1164.9
Ins. In	1146.5	
	1146.3	
	1146.7	
Ave.		1147.1
Diff.		17.8

Capacitance 10.5 mmfd.

Ins. No. A-18*

Ins. Out	1163.0	
	1162.8	
	1163.0	
Ave.		1162.9
Ins. In	1146.5	
	1146.3	
	1146.7	
Ave.		1146.5
Diff.		16.4

Capacitance 9.7 mmfd.

Ins. No. A-19*

Ins. Out	1164.5	
	1164.0	
	1163.8	
Ave.		1164.1
Ins. In	1144.5	
	1144.8	
	1144.7	
Ave.		1144.7
Diff.		19.4

Capacitance 11.5 mmfd.

Ins. No. A-20

Ins. Out	1163.5	
	1164.2	
	1164.0	
Ave.		1163.9
Ins. In	1146.0	
	1146.0	
	1146.3	
Ave.		1146.1
Diff.		17.8

Capacitance 10.5 mmfd

Ins. No. B-11

Ins. Out	1165.0	
	1164.5	
	1164.8	
Ave.		1164.8
Ins. In	1144.9	
	1145.1	
	1145.6	
Ave.		1145.2
Diff.		19.6

Capacitance 11.6 mmfd.

Ins. No. B-12

Ins. Out	1164.9	
	1164.9	
	1164.0	
Ave.		1164.6
Ins. In	1145.0	
	1144.9	
	1144.9	
Ave.		1144.9
Diff.		19.7

Capacitance 11.6 mmfd.

*Insulator checked to determine if error had been made in measuring the capacitance

Capacitance Test Data

Ins. No. B-13

Ins. Out 1163.5
1163.9
1164.0
Ave. 1163.8
Ins. In 1145.3
1145.2
1145.5
Ave. 1145.3
Diff. 18.5
Capacitance 10.9 mmfd.

Ins. No. B-14

Ins. Out 1164.7
1164.5
1165.0
Ave. 1164.7
Ins. In 1145.3
1145.2
1145.0
Ave. 1145.2
Diff. 19.5
Capacitance 11.5 mmfd.

Ins. No. B-15*

Ins. Out 1165.6
1165.0
1165.5
Ave. 1165.4
Ins. In 1147.7
1147.5
1148.0
Ave. 1147.7
Diff. 17.7
Capacitance 10.4 mmfd.

Ins. No. B-16

Ins. Out 1161.5
1162.0
1161.5
Ave. 1161.6
Ins. In 1142.6
1142.7
1142.5
Ave. 1142.6
Diff. 19.0
Capacitance 11.2 mmfd.

Ins. No. B-17*

Ins. Out 1164.5
1164.2
1164.4
Ave. 1164.4
Ins. In 1147.4
1146.5
1146.6
Ave. 1146.8
Diff. 17.6
Capacitance 10.4 mmfd.

Ins. No. B-18

Ins. Out 1165.3
1165.3
1164.5
Ave. 1164.0
Ins. In 1145.2
1145.0
1144.5
Ave. 1144.9
Diff. 18.7
Capacitance 11.3 mmfd.

*Insulator checked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. B-19

Ins. Out	1159.9	
	1160.5	
	1160.2	
Ave.		1160.2
Ins. In	1144.2	
	1138.8	
	1138.7	
Ave.		1140.6
	Diff.	19.6

Capacitance 11.6 mmfd.

Ins. No. B-20*

Ins. Out	1161.4	
	1161.3	
	1161.2	
Ave.		1161.3
Ins. In	1143.9	
	1143.9	
	1143.6	
Ave.		1143.8
	Diff.	17.5

Capacitance 10.3 mmfd.

Ins. No. C-11

Ins. Out	1160.3	
	1160.5	
	1161.2	
Ave.		1160.7
Ins. In	1142.4	
	1142.5	
	1143.0	
Ave.		1142.6
	Diff.	18.1

Capacitance 10.7 mmfd.

Ins. No. C-12*

Ins. Out	1168.3	
	1168.5	
	1168.0	
Ave.		1168.3
Ins. In	1149.9	
	1149.4	
	1149.5	
Ave.		1149.6
	Diff.	18.7

Capacitance 11.0 mmfd.

Ins. No. C-13*

Ins. Out	1167.6	
	1168.5	
	1168.5	
Ave.		1168.2
Ins. In	1148.6	
	1148.8	
	1148.7	
Ave.		1148.7
	Diff.	19.5

Capacitance 11.5 mmfd.

Ins. No. C-14

Ins. Out	1162.7	
	1162.5	
	1162.5	
Ave.		1162.6
Ins. In	1144.2	
	1143.9	
	1143.7	
Ave.		1143.9
	Diff.	18.7

Capacitance 11.0 mmfd.

*Insulator checked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. C-15

Ins. Out	1164.1	
	1164.5	
	1164.7	
Ave.		1164.4
Ins. In	1144.5	
	1145.2	
	1145.3	
Ave.		1145.0
	Diff.	19.4

Capacitance 11.4 mmfd.

Ins. No. C-16

Ins. Out	1151.7	
	1151.5	
	1151.1	
Ave.		1151.4
Ins. In	1132.4	
	1132.4	
	1132.7	
Ave.		1132.5
	Diff.	18.9

Capacitance 11.1 mmfd.

Ins. No. C-17*

Ins. Out	1151.2	
	1151.2	
	1150.2	
Ave.		1150.9
Ins. In	1133.4	
	1133.0	
	1132.8	
Ave.		1133.1
	Diff.	17.8

Capacitance 10.5 mmfd.

Ins. No. C-18*

Ins. Out	1156.7	
	1156.7	
	1156.3	
Ave.		1156.6
Ins. In	1137.2	
	1137.8	
	1137.5	
Ave.		1137.5
	Diff.	19.1

Capacitance 11.3 mmfd.

Ins. No.C- 19*

Ins. Out	1165.4	
	1165.0	
	1165.2	
Ave.		1165.2
Ins. In	1145.4	
	1145.2	
	1145.0	
Ave.		1145.2
	Diff.	20.0

Capacitance 11.8 mmfd.

Ins. No. C-20*

Ins. Out	1161.8	
	1162.0	
	1162.5	
Ave.		1162.1
Ins. In	1145.0	
	1144.8	
	1144.5	
Ave.		1144.8
	Diff.	17.3

Capacitance 10.2 mmfd.

*Insulators checked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. D-11*

Ins. Out.	1155.0	
	1155.4	
	1155.2	
Ave.		1153.9
Ins. In	1140.2	
	1139.2	
	1139.5	
Ave.		1139.6
	Diff.	14.3

Capacitance 8.4 mmdf.

Ins. No. D-12

Ins. Out	1155.5	
	1155.6	
	1155.7	
Ave.		1155.6
Ins. In	1139.4	
	1140.3	
	1139.5	
Ave.		1139.7
	Diff.	15.9

Capacitance 9.4 mmfd.

Ins. No. D-13*

Ins. Out	1154.9	
	1155.0	
	1155.2	
Ave.		1155.0
Ins. In	1140.5	
	1140.8	
	1140.5	
Ave.		1140.6
	Diff.	14.4

Capacitance 8.5 mmfd.

Ins. No. D-14

Ins. Out	1158.0	
	1157.3	
	1157.3	
Ave.		1157.5
Ins. In	1142.5	
	1142.0	
	1142.0	
Ave.		1142.2
	Diff.	15.2

Capacitance 9.0 mmfd.

Ins. No. D-15

Ins. Out	1161.5	
	1160.8	
	1160.8	
Ave.		1161.0
Ins. In	1146.0	
	1146.3	
	1146.0	
Ave.		1146.1
	Diff.	14.9

Capacitance 8.8 mmfd.

Ins. No. D-16

Ins. Out	1157.2	
	1157.5	
	1157.6	
Ave.		1157.4
Ins. In	1142.0	
	1142.5	
	1141.7	
Ave.		1141.7
	Diff.	15.7

Capacitance 9.3 mmfd.

*Insulators checked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. D-17

Ins. Out	1169.5	
	1169.4	
	1169.8	
Ave.		1169.6
Ins. In	1154.5	
	1153.8	
	1154.5	
Ave.		1154.3
	Diff.	16.4
Capacitance	9.7 mmfd.	

Ins. No. D-18*

Ins. Out	1171.3	
	1172.0	
	1171.6	
Ave.		1171.6
Ins. In	1156.9	
	1156.3	
	1155.5	
Ave.		1156.2
	Diff.	15.4
Capacitance	9.1 mmfd.	

Ins. No. D-19

Ins. Out	1172.0	
	1172.8	
	1172.4	
Ave.		1172.4
Ins. In	1157.6	
	1157.5	
	1157.0	
Ave.		1157.4
	Diff.	15.0
Capacitance	8.8 mmfd.	

Ins. No. D-20

Ins. Out	1170.7	
	1170.5	
	1170.2	
Ave.		1170.5
Ins. In.	1155.2	
	1155.1	
	1155.2	
Ave.		1155.2
	Diff.	15.3
Capacitance	9.0 mmfd.	

Ins. No. E-11

Ins. Out	1172.2	
	1172.1	
	1172.4	
Ave.		1172.2
Ins. In	1156.2	
	1156.1	
	1156.5	
Ave.		1156.3
	Diff.	15.9
Capacitance	9.4 mmfd.	

Ins. No. E-12*

Ins. Out	1170.8	
	1170.7	
	1171.3	
Ave.		1171.9
Ins. In	1154.0	
	1154.8	
	1154.2	
Ave.		1154.3
	Diff.	17.6
Capacitance	10.4 mmfd.	

*Insulator checked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. E-13

Ins. Out 1168.2
1168.7
1167.8
Ave. 1168.2
Ins. In 1151.3
1152.0
1152.0
Ave. 1151.8
Diff. 16.4
Capacitance 9.7 mmfd.

Ins. No. E-14

Ins. Out 1172.1
1172.8
1172.6
Ave. 1172.5
Ins. In 1156.5
1156.5
1156.0
Ave. 1156.3
Diff 16.3
Capacitance 9.6 mmfd.

Ins. No. E-15

Ins. Out 1172.4
1172.4
1172.7
Ave. 1172.5
Ins. In 1156.2
1156.8
1156.8
Ave. 1156.6
Diff. 15.9
Capacitance 9.4 mmfd.

Ins. No. E-16*

Ins. Out 1173.6
1172.9
1173.4
Ave. 1173.3
Ins. In 1156.5
1157.0
1156.0
Ave. 1156.5
Diff. 16.8
Capacitance 9.9 mmfd.

Ins. No. E-17

Ins. Out 1170.5
1171.5
1171.5
Ave. 1171.2
Ins. In 1155.1
1154.5
1154.5
Ave. 1154.7
Capacitance 9.7 mmfd.
Diff. 16.5

Ins. No. E-18*

Ins. Out 1172.7
1173.0
1172.5
Ave. 1172.7
Ins. In, 1157.7
1157.4
1156.8
Ave. 1157.3
Diff 15.4
Capacitance 9.1 mmfd.

*Insulators checked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. E-19

Ins. Out 1169.7
1170.0
1170.3
Ave. 1170.0
Ins. In 1154.0
1153.8
1154.0
Ave. 1153.9
Diff. 16.1
Capacitance 9.5 mmfd.

Ins. No. E-20

Ins. Out 1173.9
1173.2
1173.2
Ave. 1173.4
Ins. In 1156.5
1156.8
1157.2
Ave. 1156.8
Diff. 16.6
Capacitance 9.8 mmfd.

Ins. No. F-11

Ins. Out 1172.4
1172.4
1172.1
Ave. 1172.3
Ins. In 1156.5
1155.8
1156.2
Ave. 1156.2
Diff. 16.1
Capacitance 9.5 mmfd.

Ins. No. F-12

Ins. Out 1169.9
1169.4
1169.5
Ave. 1169.6
Ins. In 1152.5
1152.7
1153.0
Ave. 1152.7
Diff. 16.9
Capacitance 10.0 mmfd.

Ins. No. F-13

Ins. Out 1171.3
1171.3
1171.6
Ave. 1171.4
Ins. In 1154.5
1154.3
1154.5
Ave. 1154.4
Diff. 17.0
Capacitance 10.0 mmfd.

Ins. No. F-14*

Ins. Out 1172.3
1171.8
1171.7
Ave. 1171.9
Ins. In 1153.2
1153.6
1153.0
Ave. 1153.3
Diff. 18.6
Capacitance 11.0 mmfd.

*Insulators checked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. F-15

Ins. Out 1171.8
1171.5
1171.2
Ave. 1171.5
Ins. In 1153.2
1153.0
1153.2
Ave. 1153.1
Diff. 18.4
Capacitance 10.9 mmfd.

Ins. No. F-16*

Ins. Out 1170.7
1170.5
1170.5
Ave. 1170.6
Ins. In 1155.0
1154.5
1154.3
Ave. 1154.6
Diff. 16.0
Capacitance 9.4 mmfd.

Ins. No. F-17

Ins. Out 1172.0
1172.0
1172.5
Ave. 1172.2
Ins. In 1154.0
1153.5
1154.0
Ave. 1153.8
Diff. 18.4
Capacitance 10.9 mmfd.

Ins. No. F-18

Ins. Out 1172.0
1171.6
1171.5
Ave. 1171.1
Ins. In 1154.0
1154.5
1154.2
Ave. 1154.2
Diff. 17.5
Capacitance 10.3 mmfd.

Ins. No. F-19

Ins. Out 1171.3
1172.0
1171.8
Ave. 1171.7
Ins. In 1154.2
1154.3
1153.6
Ave. 1154.0
Diff. 17.7
Capacitance 10.4 mmfd.

Ins. No. F-20

Ins. Out 1171.2
1172.0
1172.5
Ave. 1151.9
Ins. In 1154.5
1154.0
1154.0
Ave. 1154.2
Diff. 17.7
Capacitance 10.4 mmfd

*Insulators checked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. A-31 M

Ins. Out	1172.6	
	1172.4	
	1172.5	
Ave.		1172.5
Ins. In	1150.5	
	1151.5	
	1151.2	
Ave.		1151.1
Diff.		21.4

Capacitance 12.6 mmfd.

Ins. No. A-32 M

Ins. Out	1178.7	
	1178.3	
	1178.8	
Ave.		1178.6
Ins. In	1156.0	
	1155.3	
	1155.5	
Ave.		1155.6
Diff.		23.0

Capacitance 13.6 mmfd.

Ins. No. A-33 M

Ins. Out	1175.5	
	1176.0	
	1175.5	
Ave.		1175.7
Ins. In	1153.1	
	1152.8	
	1153.5	
Ave.		1153.1
Diff.		22.6

Capacitance 13.3 mmfd.

Ins. No. A-34 M

Ins. Out	1177.2	
	1177.8	
	1177.0	
Ave.		1177.3
Ins. In	1156.2	
	1155.8	
	1156.0	
Ave.		1156.0
Diff.		21.3

Capacitance 12.6 mmfd.

Ins. No. A-35 M

Ins. Out	1183.0	
	1183.0	
	1183.2	
Ave.		1183.2
Ins. In	1158.7	
	1159.0	
	1158.8	
Ave.		1158.8
Diff.		24.4

Capacitance 14.4 mmfd.

Ins. No. A-36 M

Ins. Out	1180.5	
	1180.5	
	1179.7	
Ave.		1180.2
Ins. In	1157.3	
	1157.6	
	1157.5	
Ave.		1157.5
Diff.		22.7

Capacitance 13.4 mmfd.

M - Insulator with metal thimble.

Capacitance Test Data

Ins. No. A-37 M

Ins. Out 1174.5
1174.0
1173.1
Ave. 1173.9
Ins. In 1152.7
1152.9
1152.0
Ave. 1152.5
Diff. 21.4
Capacitance 12.6 mmfd.

Ins. No. A-38 M

Ins. Out 1177.0
1177.6
1177.5
Ave. 1177.4
Ins. In 1157.5
1157.0
1156.5
Ave. 1157.0
Diff. 20.4
Capacitance 12.0 mmfd.

Ins. No. A-39 M

Ins. Out 1217.7
1218.2
1217.5
Ave. 1217.8
Ins. In 1195.4
1196.2
1196.0
Ave. 1195.9
Diff. 21.9
Capacitance 12.9 mmfd.

Ins. No. A-40 M

Ins. Out 1181.4
1182.0
1181.5
Ave. 1181.6
Ins. In 1158.0
1158.7
1157.8
Ave. 1158.2
Diff. 23.4
Capacitance 13.8 mmfd.

Ins. No. B-31

Ins. Out 1177.3
1177.7
1177.0
Ave. 1177.3
Ins. In 1157.5
1157.0
1157.0
Ave. 1157.2
Diff. 21.1
Capacitance 12.4 mmfd.

Ins. No. B-32

Ins. Out 1175.5
1175.8
1175.9
Ave. 1175.7
Ins. In. 1155.5
1156.0
1156.2
Ave. 1155.9
Diff. 19.8
Capacitance 11.7 mmfd.

M - Insulator with metal thimble.

Capacitance Test Data

Ins. No. B-33

Ins. Out	1220.1	
	1219.9	
	1219.6	
Ave.		1219.9
Ins. In	1200.7	
	1200.0	
	1200.0	
Ave.		1200.2
	Diff.	19.7

Capacitance 11.6 mmfd.

Ins. No. B34*

Ins. Out	1170.0	
	1169.5	
	1170.0	
Ave.		1170.8
Ins. In	1149.0	
	1149.0	
	1148.9	
Ave.		1149.0
	Diff.	21.8

Capacitance 12.9 mmfd.

Ins. No. B-35

Ins. Out	1159.1	
	1160.8	
Ins	1160.0	
Ave.		1159.9
Ins. In	1140.0	
	1138.4	
	1139.8	
Ave.		1139.4
	Diff.	20.5

Capacitance 12.1 mmfd.

Ins. No. B-36

Ins. Out	1172.8	
	1172.0	
	1172.5	
Ave.		1172.4
Ins. In	1152.5	
	1152.7	
	1152.0	
Ave.		1152.4
	Diff.	20.0

Capacitance 11.8 mmfd.

Ins. No. B-37

Ins. Out	1268.2	
	1268.8	
	1267.5	
Ave.		1268.2
Ins. In	1248.4	
	1248.5	
	1248.5	
Ave.		1248.5
	Diff.	19.7

Capacitance 11.6 mmfd.

Ins. No. B-38

Ins. Out	1160.3	
	1161.2	
	1161.1	
Ave.		1160.9
Ins. In	1140.8	
	1140.7	
	1140.2	
Ave.		1140.6
	Diff.	20.3

Capacitance 12.0 mmfd.

* Insulator checked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. B-39

Ins. Out	1161.0	
	1161.0	
	1161.2	
Ave.		1161.1
Ins. In	1140.5	
	1140.1	
	1140.2	
Ave.		1140.3
	Diff.	20.8

Capacitance 12.3 mmfd.

Ins. No. B-40

Ins. Out	1160.8	
	1159.8	
	1161.1	
Ave.		1160.6
Ins. In	1141.0	
	1140.8	
	1141.2	
Ave.		1141.0
	Diff.	19.6

Capacitance 11.6 mmfd.

Ins. No. C-31

Ins. Out	1175.5	
	1174.8	
	1175.5	
Ave.		1175.3
Ins. In	1155.4	
	1155.8	
	1155.5	
Ave.		1155.6
	Diff.	19.7

Capacitance 11.6 mmfd.

Ins. C-32 M

Ins. Out	1173.0	
	1172.0	
	1172.2	
Ave.		1172.4
Ins. In	1152.8	
	1153.0	
	1153.3	
Ave.		1153.0
	Diff.	19.4

Capacitance 11.4 mmfd.

Ins. No. C-33 M

Ins. Out	1173.5	
	1173.8	
	1173.9	
Ave.		1173.7
Ins. In	1154.2	
	1155.4	
	1154.2	
Ave.		1154.6
	Diff.	19.1

Capacitance 11.3 mmfd.

Ins. No. C-34 M

Ins. Out	1177.9	
	1178.2	
	1179.0	
Ave.		1178.4
Ins. In	1159.0	
	1158.5	
	1158.2	
Ave.		1158.6
	Diff.	19.8

Capacitance 11.7 mmfd.

M Insulator with metal thimble

Capacitance Test Data

Ins. No. C-35 M

Ins. Out	1178.2	
	1177.0	
	1176.7	
Ave.		1177.3
Ins. In	1157.5	
	1157.5	
	1158.2	
Ave.		1157.7
	Diff.	19.6

Capacitance 11.6 mmfd.

Ins. No. C-36* M

Ins. Out	1178.9	
	1177.5	
	1177.0	
Ave.		1177.8
Ins. In	1158.2	
	1156.5	
	1156.5	
Ave.		1157.1
	Diff.	20.7

Capacitance 12.2 mmfd.

Ins. No. C-37 M

Ins. Out	1178.1	
	1178.0	
	1177.8	
Ave.		1178.0
Ins. In	1157.9	
	1157.7	
	1159.0	
Ave.		1158.2
	Diff.	19.8

Capacitance 11.7 mmfd.

Ins. No. C-38 M

Ins. Out	1178.5	
	1178.0	
	1176.5	
Ave.		1177.7
Ins. In	1157.0	
	1156.8	
	1157.1	
Ave.		1156.9
	Diff.	20.8

Capacitance 12.3 mmfd.

Ins. No. C-39 M

Ins. Out	1178.3	
	1178.4	
	1178.5	
Ave.		1178.4
Ins. In	1159.0	
	1157.5	
	1158.0	
Ave.		1158.2
	Diff.	20.2

Capacitance 11.9 mmfd.

Ins. No. C-40 M

Ins. Out	1178.5	
	1177.5	
	1178.0	
Ave.		1178.0
Ins. In	1159.4	
	1158.0	
	1158.5	
Ave.		1158.6
	Diff.	19.4

Capacitance 11.4 mmfd.

*Insulator checked to determine if error had been made in measuring the capacitance.

M - Insulator with metal thimble.

Capacitance Test Data

Ins. No. D-31

Ins. Out	1166.2	
	1166.4	
	1166.8	
Ave.		1166.5
Ins. In	1148.5	
	1149.0	
	1149.2	
Ave.		1148.9
	Diff.	17.6

Capacitance 10.4 mmfd.

Ins. No. D-32

Ins. Out	1247.8	
	1248.3	
	1248.5	
Ave.		1248.2
Ins. In	1230.3	
	1230.0	
	1230.8	
Ave.		1230.4
	Diff.	17.8

Capacitance 11.5 mmfd.

Ins. No. D-33

Ins. Out	1163.8	
	1164.1	
	1163.7	
Ave.		1163.9
Ins. In	1145.7	
	1145.7	
	1145.2	
Ave.		1145.5
	Diff.	18.4

Capacitance 10.9 mmfd.

Ins. No.D-34

Ins. Out	1161.5	
	1161.2	
	1161.5	
Ave.		1161.4
Ins. In	1142.5	
	1143.2	
	1142.3	
Ave.		1142.7
	Diff.	18.7

Capacitance 11.0 mmfd.

Ins. No. D-35

Ins. Out	1160.5	
	1161.1	
	1161.3	
Ave.		1161.0
Ins. In	1142.3	
	1143.0	
	1142.5	
Ave.		1142.6
	Diff.	18.4

Capacitance 10.9 mmfd.

Ins. No. D-36*

Ins. Out	1156.5	
	1157.2	
	1157.1	
Ave.		1156.9
Ins. In	1139.6	
	1139.5	
	1139.5	
Ave.		1139.5
	Diff.	17.4

Capacitance 10.3 mmfd.

*Insulator checked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. D-37

Ins. Out 1156.9
1156.5
1156.5
Ave. 1156.6
Ins. In 1138.7
1138.3
1139.5
Ave. 1138.8
Diff. 17.8
Capacitance 10.5 mmfd.

Ins. No. D-38*

Ins. Out 1165.2
1165.8
1165.2
Ave. 1165.4
Ins. In 1147.2
1147.5
1147.0
Ave. 1147.2
Diff. 18.2
Capacitance 10.7 mmfd.

Ins. No. D-39*

Ins. Out 1166.0
1166.0
1165.9
Ave. 1166.0
Ins. In. 1146.8
1147.5
1146.4
Ave. 1146.9
Diff. 19.1
Capacitance 11.3 mmfd.

Ins. No. D-40*

Ins. Out 1165.5
1165.4
1165.7
Ave. 1165.5
Ins. In 1146.2
1146.8
1146.3
Ave. 1146.4
Diff. 19.1
Capacitance 11.3 mmfd.

Ins. No. E-31 M

Ins. Out 1182.7
1182.7
1182.5
Ave. 1182.6
Ins. In 1164.0
1163.8
1163.4
Ave. 1163.7
Diff. 18.9
Capacitance 11.1 mmfd.

Ins. No. D-32* M

Ins. Out 1181.8
1180.5
1181.2
Ave. 1181.2
Ins. In 1162.7
1162.1
1162.0
Ave. 1162.3
Diff., 18.9
Capacitance 11.1 mmfd.

*Insulator checked to determine if error had been made in measuring the capacitance.

M Insulator with metal thimble.

Capacitance Test Data

Ins. No. E-33

Ins. Out	1169.5	
	1169.5	
	1170.2	
Ave.		1169.7
Ins. In	1152.0	
	1153.4	
	1152.6	
Ave.		1152.7
	Diff.	17.0

Capacitance 10.0 mmfd.

Ins. No. E-34

Ins. Out	1168.1	
	1167.5	
	1167.5	
Ave.		1167.7
Ins. In	1150.9	
	1150.5	
	1151.0	
Ave.		1150.8
		16.9

Capacitance 10.0 mmfd.

Ins. No. E-35 M

Ins. Out	1182.9	
	1184.0	
	1182.9	
Ave.		1183.3
Ins. In	1164.2	
	1165.0	
	1164.5	
Ave.		1164.6
	Diff.	18.7

Capacitance 11.0 mmfd.

Ins. No. E-36*

Ins. Out	1171.8	
	1171.2	
	1170.5	
Ave.		1171.2
Ins. In	1153.0	
	1153.5	
	1152.7	
Ave.		1153.1
	Diff.	18.1

Capacitance 10.7 mmfd.

Ins. No. E-37 M

Ins. Out	1182.2	
	1181.7	
	1182.7	
Ave.		1182.2
Ins. In	1163.8	
	1164.5	
	1164.0	
Ave.		1164.1
	Diff.	18.1

Capacitance 10.7 mmfd.

Ins. No. E-38* M

Ins. Out	1177.5	
	1178.2	
	1178.5	
Ave.		1178.1
Ins. In	1160.5	
	1160.7	
	1160.0	
Ave.		1160.4
	Diff.	17.7

Capacitance 10.4 mmfd.

*Insulator checked to determine if error had been made in measuring the capacitance.

M Insulators with metal thimble.

Capacitance Test Data

Ins. No. E-39 M

Ins. Out	1176.3	
	1175.9	
	1176.0	
Ave.		1176.1
Ins. In	1158.7	
	1158.5	
	1158.6	
Ave.		1158.6
Diff.		17.5

Capacitance 10.3 mmfd.

Ins. No. E-40 M

Ins. Out	1172.5	
	1171.0	
	1171.0	
Ave.		1171.5
Ins. In	1153.4	
	1153.0	
	1153.8	
Ave.		1153.4
Diff.		18.1

Capacitance 10.7 mmfd.

Ins. No. F-31

Ins. Out	1164.5	
	1165.0	
	1164.5	
Ave.		1164.7
Ins. In	1145.7	
	1146.0	
	1145.4	
Ave.		1145.7
Diff.		19.0

Capacitance 11.2 mmfd.

Ins. No. F-32

Ins. Out	1165.6	
	1165.2	
	1165.3	
Ave.		1165.4
Ins. In	1146.5	
	1146.0	
	1146.0	
Ave.		1146.2
Diff.		19.2

Capacitance 11.3 mmfd.

Ins. No. F-33

Ins. Out	1163.8	
	1163.5	
	1163.5	
Ave.		1163.6
Ins. In	1144.5	
	1145.5	
	1144.5	
Ave.		1144.8
Diff.		18.8

Capacitance 11.1 mmfd.

Ins. No. F-34

Ins. Out	1163.7	
	1164.0	
	1163.3	
Ave.		1163.7
Ins. In	1145.2	
	1145.2	
	1145.0	
Ave.		1145.1
Diff.		18.6

Capacitance 11.0 mmfd.

M - Insulators with metal thimble.

Capacitance Test Data

Ins. No. F-35

Ins. Out	1162.1	
	1163.0	
	1162.8	
Ave.		1162.6
Ins. In	1143.5	
	1144.0	
	1143.5	
Ave.		1143.7
Diff.		18.9

Capacitance 11.1 mmfd.

Ins. No. F-36

Ins. Out	1162.1	
	1162.0	
	1161.8	
Ave.		1162.0
Ins. In	1143.0	
	1143.5	
	1143.5	
Ave.		1143.3
Diff.		18.7

Capacitance 11.0 mmfd.

Ins. No. F-37

Ins. Out	1162.2	
	1162.4	
	1162.7	
Ave.		1162.4
Ins. In	1143.5	
	1143.2	
	1143.1	
Ave.		1143.3
Diff.		19.1

Capacitance 11.3 mmfd.

Ins. No. F-38

Ins. Out.	1159.0	
	1159.0	
	1158.5	
Ave.		1158.8
Ins. In	1140.5	
	1139.9	
	1139.6	
Ave.		1130.0
Diff.		18.8

Capacitance 11.1 mmfd.

Ins. No. F-39

Ins. Out	1156.3	
	1156.8	
	1157.7	
Ave.		1156.9
Ins. In	1138.0	
	1138.2	
	1138.5	
Ave.		1138.2
Diff.		18.7

Capacitance 11.0 mmfd.

Ins. No. F-40

Ins. Out	1165.2	
	1166.2	
	1164.2	
Ave.		1165.2
Ins. In	1146.2	
	1147.8	
	1146.8	
Ave.		1146.9
Diff.		18.3

Capacitance 10.7 mmfd.

Capacitance Test Data

Ins. No. A-51

- Ins. Out: 1169.3, 1168.3, 1169.0
- Ave.: 1168.8
- Ins. In: 1148.2, 1147.9, 1147.5
- Ave.: 1147.9
- Diff.: 20.9
- Capacitance 12.3 mmfd.

Ins. No. A-52

- Ins. Out: 1168.5, 1167.9, 1168.0
- Ave.: 1168.1
- Ins. In: 1146.5, 1147.0, 1146.9
- Ave.: 1146.8
- Diff.: 21.3
- Capacitance 12.6 mmfd.

Ins. No. A-53

- Ins. Out: 1259.5, 1260.5, 1259.2
- Ave.: 1259.7
- Ins. In: 1238.7, 1237.4, 1239.0
- Ave.: 1238.4
- Diff.: 21.3
- Capacitance 12.6 mmfd.

Ins. No. A-54

- Ins. Out: 1161.3, 1161.7, 1162.5
- Ave.: 1161.8
- Ins. In: 1141.6, 1141.3, 1140.5
- Ave.: ,1141.1
- Diff.: 20.7
- Capacitance 12.2 mmfd.

Ins. No. A-55

- Ins. Out: 1162.0, 1161.3, 1161.7
- Ave.: 1161.7
- Ins. In: 1141.4, 1141.7, 1141.0
- Ave.: 1141.3
- Diff.: 20.4
- Capacitance 12.0 mmfd.

Ins. No. A-56

- Ins. Out: 1163.5, 1161.5, 1162.0
- Ave.: 1162.3
- Ins. In: 1141.7, 1141.5, 1141.5
- Ave.: 1141.6
- Diff.: 20.7
- Capacitance 12.2 mmfd.

Capacitance Test Data

Ins. No. A-57*

Ins. Out 1160.8
1160.3
1160.8
Ave. 1160.6
Ins. In 1140.3
1140.1
1140.8
Ave. 1140.4
Diff. 20.2
Capacitance 11.9 mmfd.

Ins. No. A-58

Ins. Out 1166.3
1167.0
1167.2
Ave. 1166.8
Ins. In 1146.0
1144.9
1145.8
Ave. 1145.6
Diff. 21.2
Capacitance 12.5 mmfd.

Ins. No. A-59

Ins. Out 1161.5
1161.5
1161.5
Ave. 1161.5
Ins. In 1140.4
1140.6
1140.9
Ave. 1140.6
Diff. 20.9
Capacitance 12.3 mmfd.

Ins. No. A-60

Ins. Out 1166.5
1166.7
1166.3
Ave. 1166.5
Ins. In 1145.7
1145.3
1145.0
Ave. 1145.3
Diff. 21.2
Capacitance 12.5 mmfd.

Ins. No. B-51

Ins. Out 1161.5
1161.3
1161.7
Ave. 1161.5
Ins. In 1139.9
1139.8
1139.9
Ave. 1139.9
Diff. 21.6
Capacitance 12.7 mmfd.

Ins. No. B-52

Ins. Out 1161.7
1160.9
1161.2
Ave. 1161.3
Ins. In 1139.0
1139.0
1139.9
Ave. 1139.3
Diff. 22.0
Capacitance 13.0 mmfd.

*Insulator ckecked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. B-53

Ins. Out	1163.1	
	1163.1	
	1163.5	
Ave.		1163.2
Ins. In	1141.5	
	1141.5	
	1141.0	
Ave.		1141.3
Diff.		21.9

Capacitance 12.9 mmfd.

Ins. No. B-54

Ins. Out	1162.5	
	1162.5	
	1162.7	
Ave.		1162.6
Ins. In	1140.8	
	1141.2	
	1141.0	
Ave.		1141.0
Diff.		21.6

Capacitance 12.7 mmfd.

Ins. No. B-55

Ins. Out	1163.2	
	1162.8	
	1163.2	
Ave.		1163.1
Ins. In	1141.2	
	1141.7	
	1141.6	
Ave.		1141.5
Diff.		21.6

Capacitance 12.7 mmfd.

Ins. No. B-56

Ins. Out	1162.8	
	1163.5	
	1163.2	
Ave.		1163.1
Ins. In	1141.2	
	1142.0	
	1141.3	
Ave.		1141.5
Diff.		21.6

Capacitance 12.7 mmfd.

Ins. No. B-57

Ins. Out	1161.2	
	1160.8	
	1161.5	
Ave.		1161.2
Ins. In	1139.5	
	1139.0	
	1139.2	
Ave.		1139.2
Diff.		22.0

Capacitance 13.0 mmfd.

Ins. No. B-58

Ins. Out	1164.8	
	1165.0	
	1163.8	
Ave.		1164.5
Ins. In	1142.2	
	1142.5	
	1142.4	
Ave.		1142.4
Diff.		22.1

Capacitance 13.0 mmfd.

Capacitance Test Data

Ins. No. B-59

	Reading	Ave.
Ins. Out	1161.0	
	1160.5	
	1160.6	
Ave.		1160.7
Ins. In	1139.1	
	1139.3	
	1138.9	
Ave.		1139.1
Diff.		21.4

Capacitance 12.7 mmfd.

Ins. No. B-60

	Reading	Ave.
Ins. Out	1160.0	
	1161.0	
	1160.0	
Ave.		1160.3
Ins. In	1138.0	
	1139.0	
	1138.8	
Ave.		1138.6
Diff.		21.7

Capacitance 12.8 mmfd.

Ins. No. C-51 M

	Reading	Ave.
Ins. Out	1175.0	
	1175.5	
	1173.5	
Ave.		1174.7
Ins. In	1151.0	
	1151.0	
	1150.0	
Ave.		1150.7
Diff.		24.0

Capacitance 14.2 mmfd.

Ins. No. C-52 M

	Reading	Ave.
Ins. Out	1178.2	
	1178.5	
	1178.4	
Ave.		1178.4
Ins. In	1155.0	
	1154.5	
	1155.0	
Ave.		1154.8
Diff.		23.6

Capacitance 13.9 mmfd.

Ins. No. C-53 M

	Reading	Ave.
Ins. Out	1177.2	
	1175.2	
	1176.0	
Ave.		1176.1
Ins. In	1153.5	
	1152.5	
	1152.6	
Ave.		1152.9
Diff.		23.2

Capacitance 13.7 mmfd.

Ins. No. C-54 M

	Reading	Ave.
Ins. Out	1177.2	
	1177.0	
	1175.5	
Ave.		1176.6
Ins. In	1152.6	
	1153.1	
	1152.2	
Ave.		1152.6
Diff.		24.0

Capacitance 14.2 mmfd.

M - Insulator with metal thimble.

Capacitance Test Data

Ins. No. C-55 M

Ins. Out 1177.0
1178.0
1177.0
Ave. 1177.3
Ins. In 1153.5
1152.0
1153.0
Ave. 1152.8
Diff. 24.5
Capacitance 14.5 mmfd.

Ins. No. C-56 M

Ins. Out 1176.2
1176.0
1175.0
Ave. 1175.9
Ins. In 1152.5
1151.0
1152.6
Ave. 1152.0
Diff. 23.9
Capacitance 14.1 mmfd.

Ins. No. C-57 M

Ins. Out 1156.5
1157.4
1156.7
Ave. 1156.9
Ins. In 1153.2
1153.5
1153.5
Ave. 1153.4
Diff. 23.5
Capacitance 13.9 mmfd.

Ins. No. C-58 M

Ins. Out 1177.0
1177.0
1177.3
Ave. 1177.1
Ins. In 1153.5
1152.3
1152.5
Ave. 1152.8
Diff. 24.3
Capacitance 14.3 mmfd.

Ins. No. C-59 M

Ins. Out 1178.1
1176.5
1176.2
Ave. 1176.9
Ins. In 1153.2
1152.5
1151.8
Ave. 1152.5
Diff. 24.4
Capacitance 14.4 mmfd.

Ins. No. C-60 M

Ins. Out 1177.8
1179.0
1178.0
Ave. 1178.3
Ins. In 1154.5
1154.0
1154.5
Ave. 1154.3
Diff. 24.0
Capacitance 14.2 mmfd.

M - Insulators with metal thimble.

Capacitance Test Data

Ins. No. D-51*

Ins. Out 1165.5
1165.5
1165.3
Ave. 1165.4
Ins. In 1144.0
1144.2
1143.8
Ave. 1144.0
Diff. 21.4
Capacitance 12.6 mmfd.

Ins. No. D-54

Ins. Out 1157.6
1158.2
1158.5
Ave. 1158.1
Ins. In 1138.5
1138.2
1138.2
Ave. 1138.3
Diff. 19.8
Capacitance 11.7 mmfd.

Ins. No. D-52

Ins. Out 1157.5
1157.2
1157.3
Ave. 1157.3
Ins. In 1137.6
1138.2
1137.5
Ave. 1137.8
Diff. 19.5
Capacitance 11.5 mmfd.

Ins. No. D-55

Ins. Out 1160.5
1160.7
1160.5
Ave. 1160.6
Ins. In 1139.9
1140.1
1140.2
Ave. 1140.1
Diff. 20.5
Capacitance 12.1 mmfd.

Ins. No. D-53*

Ins. Out 1159.5
1158.0
1158.0
Ave. 1158.2
Ins. In 1137.5
1137.2
1137.6
Ave. 1137.4
Diff. 20.8
Capacitance 12.3 mmfd.

Ins. No. D-56

Ins. Out 1158.7
1158.9
1158.6
Ave. 1158.7
Ins. In 1139.0
1139.5
1139.0
Ave. 1139.2
Diff. 19.5
Capacitance 11.5 mmfd.

*Insulator checked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. D-57

Ins. Out	1159.0	
	1159.2	
	1159.3	
Ave.		1159.2
Ins. In	1139.5	
	1139.6	
	1139.0	
Ave.		1139.4
Diff.		19.8

Capacitance 11.7 mmfd.

Ins. No. D-58

Ins. Out.	1159.1	
	1158.2	
	1158.6	
Ave.		1158.6
Ins. In	1138.0	
	1138.3	
	1137.8	
Ave.		1138.0
Diff.		20.6

Capacitance 12.1 mmfd.

Ins. No. D-59

Ins. Out	1162.5	
	1161.2	
	1161.8	
Ave.		1161.8
Ins. In	1141.5	
	1141.6	
	1141.2	
Ave.		1141.4
Diff.		20.4

Capacitance 12.0 mmfd.

Ins. No. D-60

Ins. Out	1160.5	
	1161.0	
	1160.2	
Ave.		1160.6
Ins. In	1139.7	
	1140.0	
	1140.0	
Ave.		1139.9
Diff.		20.7

Capacitance 12.2 mmfd.

Ins. No. E-51

Ins. Out	1163.9	
	1163.9	
	1163.9	
Ave.		1163.9
Ins. In	1144.6	
	1144.7	
	1144.3	
m Ave.		1144.5
Diff.		19.4

Capacitance 11.4 mmfd.

Ins. No. E-52

Ins. Out	1158.5	
	1158.6	
	1158.0	
Ave.		1158.4
Ins. In	1138.5	
	1138.0	
	1138.7	
Ave.		1158.4
Diff.		20.0

Capacitance 11.8 mmfd.

Capacitance Test Data

Ins. No. E-53

Ins. Out 1160.9
1161.0
1161.0
Ave. 1161.0
Ins. In 1141.0
1140.4
1140.5
Ave. 1140.6
Diff. 20.4
Capacitance 12.0 mmfd.

Ins. No. E-54

Ins. Out 1159.9
1160.2
1160.5
Ave. 1160.2
Ins. In 1140.8
1140.2
1140.0
Ave. 1140.3
Diff. 19.9
Capacitance 11.7 mmfd.

Ins. No. E-55*

Ins. Out 1159.2
1158.8
1159.5
Ave. 1159.2
Ins. In 1139.7
1139.0
1139.9
Ave. 1139.5
Diff. 19.7
Capacitance 11.6 mmfd.

Ins. No. E-56

Ins. Out 1158.9
1158.9
1158.9
Ave. 1138.9
Ins. In 1139.9
1139.8
1139.3
Ave. 1139.6
Diff. 19.3
Capacitance 11.4 mmfd.

Ins. No. E-57

Ins. Out 1159.5
1159.2
1159.7
Ave. 1159.5
Ins. In 1139.9
1139.1
1139.5
Ave. 1139.5
Diff. 20.0
Capacitance 11.8 mmfd.

Ins. No. E-58

Ins. Out 1160.0
1159.6
1160.0
Ave. 1159.9
Ins. In 1140.2
1140.0
1140.0
Ave. 1140.1
Diff. 19.8
Capacitance 11.7 mmfd.

*Insulator checked to determine if error had been made in measuring the capacitance.

Capacitance Test Data

Ins. No. E-59

Ins. Out	1161.0	
	1160.0	
	1160.4	
Ave.		1160.5
Ins. In	1140.5	
	1141.0	
	1139.5	
Ave.		1140.3
Diff.		20.2

Capacitance 11.9 mmfd.

Ins. No. E-60

Ins. Out	1159.2	
	1159.5	
	1157.5	
Ave.		1158.7
Ins. In	1138.2	
	1137.8	
	1139.0	
Ave.		1138.3
Diff.		20.4

Capacitance 12.0 mmfd.

Ins. No. F-51

Ins. Out	1157.8	
	1158.5	
	1158.2	
Ave.		1158.2
Ins. In	1139.7	
	1140.1	
	1140.3	
Ave.		1140.0
Diff.		18.2

Capacitance 10.7 mmfd.

Ins. No. F-52

Ins. Out	1156.0	
	1156.7	
	1157.5	
Ave.		1156.7
Ins. In	1138.9	
	1138.8	
	1139.0	
Ave.		1138.9
Diff.		17.9

Capacitance 10.6 mmfd.

Ins. No. F-53

Ins. Out	1137.2	
	1137.2	
	1137.6	
Ave.		1137.3
Ins. In	1138.5	
	1138.7	
	1138.8	
Ave.		1138.7
Diff.		18.6

Capacitance 11.0 mmfd.

Ins. No. F-54

Ins. Out	1158.5	
	1158.3	
	1158.5	
Ave.		1158.4
Ins. In	1140.0	
	1139.4	
	1140.4	
Ave.		1139.9
Diff.		18.5

Capacitance 10.9 mmfd.

Capacitance Test Data

Ins. No. F-55

Ins. Out	1157.6	
	1157.8	
	1158.3	
Ave.		1157.9
Ins. In	1139.0	
	1139.0	
	1138.9	
Ave.		1139.3
Diff.		18.6

Capacitance 11.0 mmfd.

Ins. No.F-56

Ins. Out	1158.6	
	1157.9	
	1158.6	
Ave.		1158.4
Ins. In	1139.5	
	1139.7	
	1140.5	
Ave.		1139.9
Diff.		18.5

Capacitance 10.9 mmfd.

Ins. No. F-57

Ins. Out	1156.4	
	1156.6	
	1157.3	
Ave.		1156.8
Ins. In	1138.8	
	1138.0	
	1138.2	
Ave.		1138.3
Diff.		18.5

Capacitance 10.9 mmfd.

m**Ins. No.** F-58

Ins. Out	1137.4	
	1136.0	
	1136.5	
Ave.		1136.6
Ins. In	1138.3	
	1137.8	
	1137.8	
Ave.		1138.0
Diff.		18.6

Capacitance 11.0 mmfd.

Ins. No. F-59

Ins. Out	1158.5	
	1158.5	
	1158.5	
Ave.		1158.5
Ins. In	1139.7	
	1139.3	
	1139.6	
Ave.		1139.5
Diff.		19.0

Capacitance 11.2 mmfd.

Ins. No. F-60

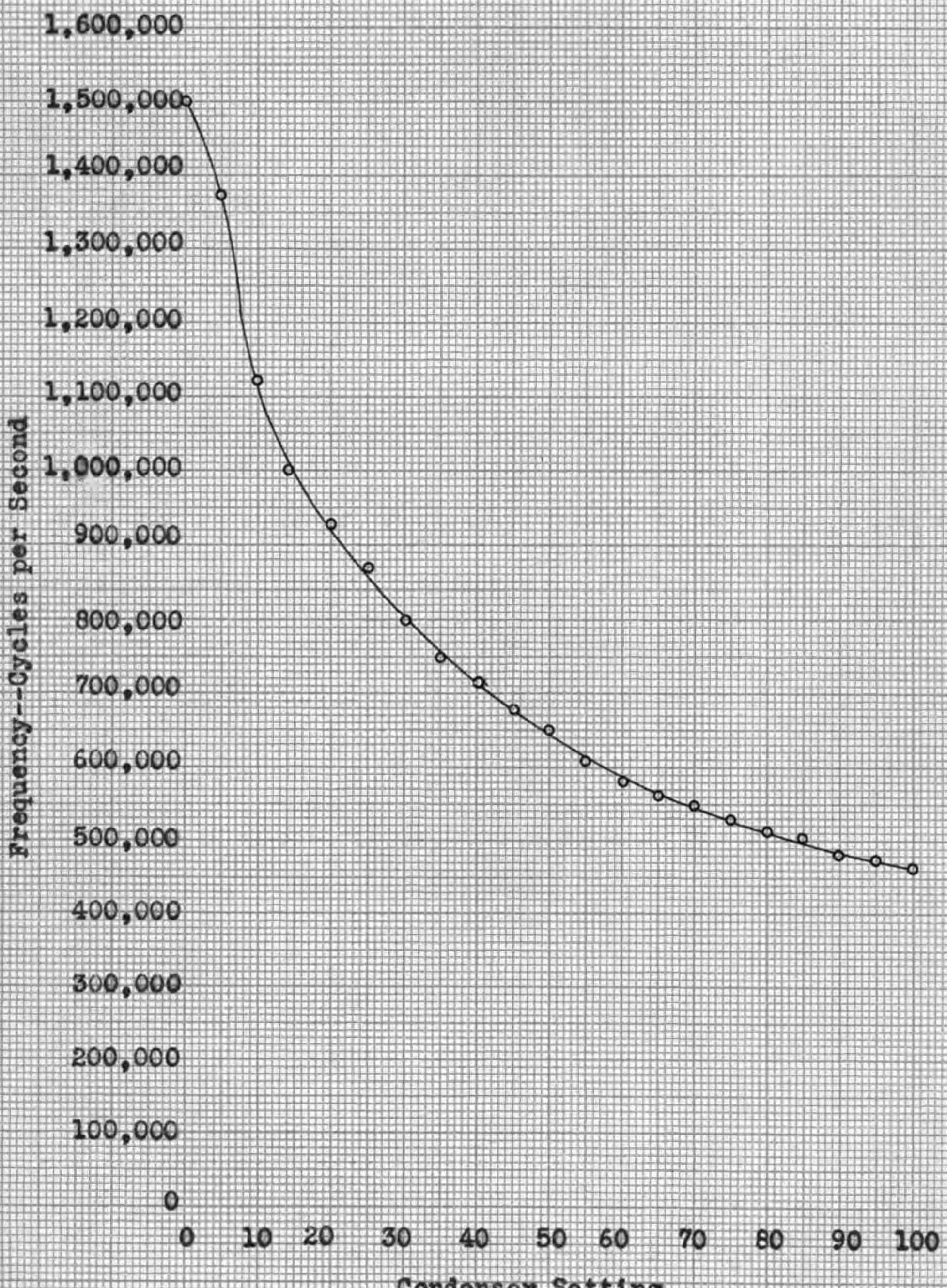
Ins. Out	1159.8	
	1159.5	
	1159.0	
Ave.		1159.4
Ins. In	1140.8	
	1140.8	
	1141.2	
Ave.		1140.9
Diff.		18.5

Capacitance 10.9 mmfd.

MISCELLANEOUS

Section XI

Calibration Curve for Vacuum Tube Oscillator



Calibration Data For Oscillator*

Oscillator Condenser Setting	Wave Meter Condenser Setting	Galvanometer Needle Deflection	Wave Length (Meters)	Frequency (Cycles per Second)
100	1166.0	97	650	462,000
95	1117.5	93	630	476,000
90	1066.5	89	620	484,000
85	1009.0	83	600	500,000
80	949.5	77	582	515,000
75	896.0	75	565	532,000
70	835.0	62	547	548,000
65	782.0	55	530	567,000
60	726.0	47	510	588,000
55	670.0	38	490	612,000
50	611.5	30	460	652,000
45	557.5	24	440	682,000
40	504.0	19	420	715,000
35	450.0	15	400	750,000
30	400.0	10	373	804,000
25	347.0	8	345	870,000
20	300.0	5	320	938,000
15	254.0	3	290	1,035,000
10	208.0	2	265	1,113,000
5	164.0	2	220	1,365,000
0	151.0	2	200	1,500,000

*Exciting Coil $1\frac{1}{2}$ inches away from the coil on the wave meter, and so placed that the axes coincide. Filament current 2.05 amperes.

DIMENSIONS OF INSULATORS

13 - 17 Kilovolt

Number	T_1	T_2
A-11	0.500	0.725
12	0.500	0.728
13	0.562	0.720
14	0.515	0.688
15	0.547	0.685
16	0.563	0.720
17	0.530	0.675
18	0.570	0.740
19	0.500	0.705
20	0.590	0.727
Average	0.537	0.711
C-11	0.564	0.676
12	0.550	0.650
13	0.532	0.670
14	0.550	0.650
15	0.575	0.670
16	0.547	0.670
17	0.532	0.670
18	0.500	0.675
19	0.532	0.675
20	0.532	0.670
Average	0.541	0.667
E-11	0.625	0.535
12	0.625	0.578
13	0.600	0.555
14	0.610	0.530
15	0.618	0.532
16	0.600	0.522
17	0.615	0.560
18	0.641	0.580
19	0.615	0.544
20	0.600	0.580
Average	0.614	0.552

Number	T_1	T_2
B-11	0.500	0.575
12	0.500	0.580
13	0.500	0.570
14	0.485	0.540
15	0.485	0.540
16	0.500	0.585
17	0.470	0.565
18	0.510	0.590
19	0.510	0.560
20	0.530	0.570
Average	0.499	0.567
D-11	0.845	0.785
12	0.815	0.770
13	0.902	0.787
14	0.871	0.790
15	0.890	0.730
16	0.815	0.765
17	0.860	0.769
18	0.815	0.780
19	0.870	0.765
20	0.885	0.772
Average	0.855	0.768
F-11	0.450	0.600
12	0.500	0.600
13	0.455	0.600
14	0.450	0.585
15	0.435	0.600
16	0.525	0.585
17	0.535	0.585
18	0.465	0.585
19	0.455	0.590
20	0.465	0.590
Average	0.474	0.592

T_1 Thickness in inches from Pin to Conductor Groove
T_2 Thickness in inches from Pin to Tie Wire Groove

DIMENSIONS OF INSULATORS

45 - 55 Kilovolt

Number	T_1	T_2	Number	T_1	T_2
A-31	1.75	13.90	B-31	2.50	17.10
32	1.90	13.90	32	2.45	17.10
33	1.75	14.00	33	2.50	16.85
34	1.80	14.22	34	2.45	17.00
35	1.80	13.80	35	2.45	17.10
36	1.85	14.00	36	2.50	17.10
37	1.75	14.10	37	2.50	17.00
38	1.75	13.80	38	2.50	17.20
39	1.80	14.20	39	2.60	16.90
40	1.90	13.75	40	2.50	17.00
Average	1.80	13.98	Average	2.50	17.03
C-31	2.75	14.30	D-31	2.80	17.30
32	2.75	14.30	32	2.80	16.80
33	3.05	14.30	33	2.80	17.60
34	2.90	14.20	34	2.80	17.00
35	2.90	14.30	35	2.80	17.30
36	3.05	14.30	36	2.85	17.00
37	3.00	14.28	37	2.80	16.40
38	3.00	14.50	38	2.80	17.30
39	2.95	14.50	39	2.87	17.10
40	2.85	14.40	40	2.70	17.20
Average	2.92	14.33	Average	2.80	17.20
E-31	2.50	14.50	F-31	2.20	14.20
32	2.55	14.30	32	2.15	14.10
33	2.50	14.20	33	2.10	14.10
34	2.55	14.20	34	2.20	14.10
35	2.80	14.20	35	2.20	14.10
36	2.60	14.20	36	2.20	14.10
37	2.60	14.20	37	2.20	14.20
38	2.55	14.30	38	2.15	14.20
39	2.60	14.20	39	2.15	14.20
40	2.55	14.40	40	2.25	14.20
Average	2.58	14.30	Average	2.18	14.15

T_1 Thickness in inches from Pin to Conductor Groove
T_2 Length in inches of Tie Wire Groove

DIMENSIONS OF INSULATORS

66 Kilovolt

Number	T_1	T_2	Number	T_1	T_2
A-51	2.50	15.0	B-51	3.00	19.0
52	2.45	15.2	52	2.85	18.8
53	2.55	15.1	53	2.85	19.0
54	2.45	15.0	54	2.95	18.8
55	2.50	15.5	55	2.95	19.1
56	2.50	15.2	56	2.90	19.2
57	2.65	15.2	57	2.80	19.0
58	2.50	14.9	58	2.90	19.1
59	2.40	14.9	59	2.90	19.1
60	2.55	14.9	60	2.80	19.1
Average	2.50	15.09	Average	2.89	19.02
C-51	3.10	17.6	D-51	2.90	17.8
52	3.10	17.5	52	3.00	18.1
53	3.00	17.5	53	3.00	17.8
54	2.80	17.5	54	3.00	17.6
55	2.95	17.5	55	3.10	18.1
56	2.95	17.5	56	2.90	17.9
57	3.00	17.5	57	3.00	17.7
58	2.80	17.5	58	3.00	17.8
59	3.00	17.5	59	2.90	17.8
60	3.10	17.5	60	3.10	18.0
Average	2.98	17.50	Average	2.99	17.86
E-51	3.00	18.8	F-51	3.15	17.3
52	3.00	18.9	52	3.20	17.4
53	3.05	18.8	53	3.15	17.3
54	3.10	18.7	54	3.10	17.4
55	2.90	19.1	55	3.15	17.3
56	2.95	19.0	56	3.10	17.3
57	3.00	18.9	57	3.10	17.3
58	2.95	19.2	58	3.15	17.5
59	2.90	19.2	59	3.05	17.4
60	3.10	18.8	60	3.15	17.3
Average	2.99	18.92	Average	3.13	17.31

T_1 Thickness in inches from Pin to Conductor Groove
T_2 Length in inches of Tie Wire Groove

Data Showing the Effect of Filament Current
On
The Frequency*

Filament Current	Galvanometer Deflection	Wave Meter Condenser	Wave Length	Frequency
1.90(Amps.)	0.5	1132.0	636 (Meters)	472,000
1.95	1.5	1136.5	638	470,000
2.00	10.0	1143.0	640	468,000
2.05	20.0	1145.0	641	467,500
2.10	40.0	1148.0	642	467,000
2.15	69.0	1151.0	643	466,500
2.20	84.0	1155.0	644	466,000
2.25	93.0	1156.5	645	465,000
2.30	97.0	1157.1	646	464,500

*Exciting coil $1\frac{1}{2}$ inches from the coil on the wave meter, and so placed that the axes coincided.

Oscillator condenser setting-- 100

Data Showing the Effect of Variable Coupling
Between
Oscillator and Wave Meter. *

Wave-Meter Condenser Setting	Distance Between Coils	Deflection Galvanometer Needle	Wave Length (Meters)	Frequency Cycles per Second
1234.5	2.0cm.	95.0	665	452,000
1207.0	2.5	98.0	660	455,000
1186.2	3.0	95.0	652	460,000
1179.2	3.5	91.0	650	461,500
1166.0	4.0	83.0	648	462,500
1160.0	4.5	73.0	646	464,000
1156.2	5.0	64.0	644	465,000
1150.0	5.5	44.0	642	467,000
1146.5	6.0	37.0	641	468,000
1146.0	6.5	29.0	641	468,000
1145.0	7.0	24.0	640.5	468,200
1143.5	7.5	20.0	640.0	468,500
1143.0	8.0	16.0		
1142.2	8.5	13.0	Calibration Curve	
1142.1	9.0	9 .0	for Wave Meter	
1141.5	9.5	8.0	Plotted to too	
1140.5	10.0	6.5	Small a Scale	
1140.0	10.5	5.0	639.5	468,900
1139.3	11.0	4.0		
1138.0	11.5	3.5	Same as Above.	
1138.0	12.0	3.0	639.0	469,000

*Exciting coil moved away form the coil on the wave meter in such a manner that the axes of the coils always coincided.

REFERENCES

A list of the articles referred to will here be given. This is not, however, to be taken as a complete list of material regarding this subject. For such a list, see reference #8.

(1) Cable Charge and Discharge - C. P. Steinmetz, Journal of the American Institute of Electrical Engineers, June, 1924

(2) The Variations With Frequency of Power Loss in Dielectrics - Hector J. MacLeod. Physical Review, January, 1923.

(3) Measuring Current Flow in Porcelain Insulators - W. A. Fraser and H. W. M. Secord, Electrical World, Feb. 9, 1924.

(4) Ionization Studies in Paper Insulated Cables - C. L. Dawes and P. L. Hoover, Paper presented at convention in New York Feb. 8-11, 1926. American Institute of Electrical Engrs.

(5) Report on Insulator Test Specification Standards. Journal of The American Institute of Electrical Engineers, Mar. 1925

(6) High Voltage Porcelain Insulators - Westinghouse Elec. & Mfg. Co.

(7) Electrical Constants of Dielectrics for Radio Frequency Currents by R. V. Gutherie Jr. Proc. Inst. of Radio Engrs. Dec. 1924.

(8) Dielectric Absorption and Theories of Dielectric Behavior - J. B. Whitehead. Reference same as (4)

(9) Radio Frequency Tests on Antenna Insulators - W. W. Brown. Proc. Institute of Radio Engineers. October,1925