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Report

of

Test of Loss Factor and High Frequency Flash-over of Phenolic Insulating Materials.

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APPENDICES

AUTHORIZATION FOR TEST

1. This problem was authorized by Bureau of Engineering letter, reference (a), and additional references pertinent to this problem are listed as references (b) to (k).

Reference: (a) BuEng. ltr. S67/61(2-15-W8) of 15 March 1934.
(b) Navy Specifications 17-I-14.
(c) BuEng. ltr. S62-2(V)/L5(2-1-W8) of 1 September 1934.
(d) Material Laboratory, Navy Yard, N. Y. ltr. S62-2/L5-2(V-4). of 28 May 1934.
(e) Material Laboratory, Navy Yard, N.Y. ltr. JJ17I14/L5-1(V-4). of 23 July 1934.
(f) Material Laboratory, Navy Yard, N.Y. ltr. S62-2/L5-2(V-4) of 11 September 1934.
(g) Material Laboratory, Navy Yard, N.Y. ltr. S62-2/L5-2(V-4) of 11 September 1934.
(h) Text book entitled "Dielectric Phenomena in High Voltage Engineering" by Peek.
(i) Weston Elec. Inst. Corp. ltr. to N.R.L. of 28 May 1934.
(j) N.R.L. Report R-1065 of 17 July 1934 - High Frequency Insulation Tests.
(k) Navy Specifications RE 13A 317F.

OBJECT OF TESTS

2. The object of the tests was to determine if several commercially manufactured phenolic insulating products conform to certain of the specified requirements for Type E insulating materials as stated in Navy Specifications for phenolic insulation, reference (b). These products were tested to determine compliance in the following respects:

(a) Radio frequency loss factor as stated in paragraph 5(d)(2) of these specifications.

(b) High frequency flash-over as stated in paragraph 5(d)(3) of the same specifications.

ABSTRACT OF TEST

3. The samples of phenolic insulating material were tested to determine the following:

(a) The loss factor, measured by the parallel substitution method, this test being conducted in a manner similar to that described in paragraph 6(g) of reference (b).

(b) The voltage required at a frequency of 90 kilocycles to cause a flash-over along the surface of the insulating material, this test being conducted as specified in paragraph 6(f) of this reference.

Recommendations

(a) It is recommended that paragraph 5(d)(2) of specifications, reference (b), be amended as follows:

> "The loss factor at a temperature of 20°C and at a frequency between 400 and 700 kilocycles shall not be greater than 20%, in either dry or wet condition. Loss Factor shall be defined as the product of power factor expressed in per cent and the dielectric constant of the material."

It may be noted that loss factor and power factor are expressed in per cent, and not by a decimal fraction, as was used heretofore in this paragraph of these specifications. As these quantities are expressed in per cent in nearly all literature on this subject, this change has been recommended. Attention is called to the fact that these factors are expressed in per cent in Navy specifications for ceramic and glass insulators, reference (k). As it may be somewhat inconvenient to conduct loss factor tests at a fixed frequency, a reasonable frequency latitude has been provided.

(b) It is recommended that paragraph 5(d)(3) of the specifications, reference (b), be amended as follows:

> "The high frequency flash-over for the standard test specimen shall not be lower than 10,000 volts."

(c) It is recommended that paragraph 6(f)(3) of the specifications, reference (b), be amended as follows:

> "Method of Test - The tests shall be made in air at a room temperature of approximately 20°C. A test potential of 5,000 volts (effective) shall be applied for a period of five minutes. The test voltage shall be increased in steps of 1,000 volts each, at the end of each consecutive five-minute period until breakdown occurs.
>
> "Three samples of each material shall be tested and the average of the observed flash-over voltages shall be considered that of the material."

(d) It is recommended that paragraph 6(g) of the specifications, reference (b), be amended as follows:

> "Measurements of power factor and dielectric constant shall be made on samples of sheet insulating material 6" x 6" x 1/4" whose thickness and flatness are uniform to within 3% of the thickness. The sample shall be placed between, and in contact with, two metallic plates six inches square, which shall serve as electrodes. The measurements shall be made at low impressed voltage, at a frequency between 400 and 700 kilocycles, and at a temperature of approximately 20°C.

"Three samples of each material shall be tested and the average of these three measurements of loss factor shall be considered that of the material.

"Each sample shall be first tested as received, and subsequently tested after immersion in distilled water at a temperature of approximately 20°C for a period of 24 hours. After removal from water, the specimen shall be dried with a clean cloth and tested immediately thereafter."

(e) If the Bureau of Engineering concurs with the Laboratory's recommended changes in specifications regarding flash-over, it is recommended that Products 2 and 7 receive Navy type approval for type E materials, in so far as their radio frequency characteristics are concerned.

(f) Since Products 3, 4, 5 and 6 conform neither to existing flash-over test requirements, nor to recommended requirements, and since Product 4, in addition, does not comply to existing loss factor requirements, it is recommended that Navy type approval for Type E materials be withheld from these products.

(g) It is recommended that an additional Navy type of insulation be designated to include the low loss types of organic insulators, and that specifications for this type of material be prepared.

(h) It is recommended that any material now approved for Type E insulation, but on which no flash-over tests have been conducted, be tested to determine compliance with the revised high frequency flash-over specification when issued by the Bureau.

DESCRIPTION OF MATERIAL UNDER TEST

4. Descriptions of the specimens used in the tests are furnished in the following subparagraphs:

(a) The specimens used in determining the loss factor were in the form of flat sheets having a thickness of approximately 1/4" and an area of from 25 to 36 square inches.

(b) The specimens used in the high frequency flash-over tests were in the form of flat sheets, 6-1/2" x 8" x 1/2".

5. The materials tested and the symbols used in this report to refer to these materials are shown in Table 1. Of these materials, only Products 2 to 7, inclusive, were tested to determine whether or not they should receive Navy type approval. All materials listed in Table 1 received the high frequency flash-over test, but only Products 2 to 7, inclusive, were tested for loss factor. No flash-over tests have been previously conducted by this Laboratory, and consequently, as many materials as were available were subjected to the flash-over test for comparative purposes, and to obtain more flash-over test data to serve as a basis in recommending specification revision. Product 1 was obtained from stock available at this Laboratory and was used in making preliminary tests to determine standard conditions under which a sample should be tested for flash-over. Product 2 was submitted to this Laboratory at the request of the Bureau of Engineering, reference (c). Products 3 to 7, inclusive, were furnished to this Laboratory via the Material Laboratory, Navy Yard, New York, as indicated in references (d) to (g), inclusive. The test numbers assigned by the Material Laboratory to each sample forwarded are shown in Table 1. Products 9 to 13, inclusive, were obtained from stock available at this Laboratory. Products 11 to 13, inclusive, are not phenolic materials, and these products were tested for information as to endurance of types of organic insulators when subjected to the high frequency flash-over test. Where more than one sample of a product was tested, separate samples are indicated by letters appended to the symbol.

6. During the past five years, this Laboratory has measured the loss factors of many types of organic insulating materials, and the results of these tests are useful in certain subsequent parts of this report. These materials are listed in Table 2, with information as to manufacturer, manufacturer's grade or type and trade name, date of test, and the symbols used in this report to refer to the various products.

METHOD OF TEST

7. The methods used in testing the specimens of insulating material are discussed in the following subparagraphs:

(a) The method used for determination of loss factor is commonly known as the parallel substitution method. The equipment, the procedure, the circuit analysis, and the conditions under which specimens were tested are discussed in the following subparagraphs:

(1) Plate 1 shows a wiring diagram of the equipment used for determination of radio frequency loss factor. The measuring circuit consists of a low loss inductance, a non-inductive variable calibrated radio frequency resistor, a low loss variable calibrated precision condenser, a condenser formed by two suitably sized metallic plates between which the test specimen is placed, and a switch to connect these two condensers in parallel. Radio frequency power is furnished by a 50 watt battery operated oscillator, which is loosely coupled to the measuring circuit. The circuit used for indication of resonance (between oscillator and measuring circuit) consists of a pick-up coil, a crystal detector, a radio frequency filter, and a precise d.c. microammeter. The pick-up coil is loosely coupled to the tuning inductance of the measuring circuit. The use of an external resonance indicator of this type allows a measuring circuit of much lower loss than could be obtained by use of a thermal instrument connected directly into the measuring circuit. In order to obtain accurate measurements it is necessary that the following factors remain unchanged throughout the measurement: Frequency and output of oscillator, coupling between oscillator and measuring circuit, and coupling between measuring circuit and resonance indicator.

(2) The first step in measuring the loss factor of a specimen consists in closing the switch, setting the standard resistor to zero value, setting the standard condenser to its minimum value, and adjusting the frequency of the oscillator until resonance is obtained with the measuring circuit. Resonance is indicated by the maximum deflection of the microammeter, and the reading of this instrument at resonance is noted and recorded. The second step of this test consists in disconnecting the test specimen by opening the switch, increasing the capacity of the standard condenser until resonance is again obtained, and increasing the resistance of the standard resistor until the reading of the microammeter is the same as that previously noted. The value of the capacity required to tune the circuit to resonance and the value of inserted resistance necessary to cause the same microammeter deflection are noted. The frequency at which the test is conducted is also determined.

(3) An analysis of the capacitative portion of the measuring circuit is furnished in order to indicate the means of determination of loss factors from data obtained as discussed in the preceding subparagraph. The electrical

circuit formed by the two parallel capacities in the first step of the measurement is shown in Plate 2, Figure A, where

C_a = Capacity in farads of the standard condenser when set at minimum value.

R_a = Equivalent series radio frequency resistance in ohms of the standard condenser at the frequency of test.

C_x = Capacity in farads of the test specimen.

R_x = Equivalent series radio frequency resistance in ohms of the test specimen at frequency of test.

I = Radio frequency current in amperes flowing in both branches of circuit.

I_a = Radio frequency current in amperes flowing through the standard condenser.

I_x = Radio frequency current in amperes flowing through test specimen.

The total power loss in this portion of the circuit is shown by the following formula:

$$P = I^2_a R_a + I^2_x R_x \qquad (1)$$

where P = Total power loss in watts in the capacitative portion of the measuring circuit.

The electrical circuit formed by the standard condenser and the inserted resistance in the second step of the measurement is shown in Plate 2, Figure B, where

C_b = Capacity in farads of standard condenser at resonance.

R_b = Equivalent series resistance in ohms of standard condenser at frequency of test.

R = Inserted resistance in ohms.

Since in both steps of the measurement, the same microammeter deflection is obtained and the applied frequency and impressed radio frequency voltage are unchanged, it is obvious that the radio frequency current through the circuit is the same in both cases. Therefore, the following equation expresses the power loss in the standard condenser and inserted resistor in the second step of the measurement:

$$P_b = I^2(R + R_b) \qquad (2)$$

where P_b = Total power loss in watts in the standard condenser and inserted resistance.

Now since the circuit formed by the standard condenser and inserted resistance in the second step of the measurement is the equivalent of that formed by the two parallel capacities (including losses) in the first step of the measurement, and since the same current flows through the circuit in both cases, it is obvious that the power loss is also the same in both cases ($P = P_b$). Therefore, the following relationship is true:

$$I^2{}_aR_a + I^2{}_xR_x = I^2(R + R_b) \qquad (3)$$

The following equations express the relationships between capacity, frequency, voltage, and current in the various parts of capacitative portion of the circuit:

$$I = 2\pi\ f\ C_bE \qquad (4)$$

$$I_a = 2\pi\ f\ C_aE \qquad (5)$$

$$I_x = 2\pi\ f\ C_xE \qquad (6)$$

where E = Impressed radio frequency voltage.
f = Frequency in cycles per second.

Substituting in equation (3) the values of current shown in equations (4), (5) and (6), the following equation results:

$$(2\pi fC_a)^2R_a + (2\pi fC_x)^2R_x = (2\pi fC_b)^2\ (R + R_b) \qquad (7)$$

If the common assumption be made that the product of series resistance, angular velocity, and the square of the capacity is a constant, then the power loss in a high grade condenser is independent of capacity setting, if the impressed voltage and applied frequency are held constant. It has been definitely established that the standard condenser used in these tests is of such grade. Therefore, the terms which are proportional to the power loss in the standard condenser in each step of the measurement may be assumed equal, and therefore:

$$(2\pi fC_b)^2R_b = (2\pi fC_a)^2\ R_a \qquad (8)$$

Substituting for the term $(2\pi fCa)^2R_a$ of equation (7) its equal in equation (8), the following equation is obtained:

$$R_x = R(C_b/C_x)^2 \qquad (9)$$

The capacity of the test specimen is expressed by the following equation:

$$C_x = C_b - C_a \qquad (10)$$

This equation may be rearranged as follows:

$$C_b = C_x + C_a \qquad (11)$$

Substituting in equation (9) the value of C_b shown in equation (11), then equation (9) becomes:

$$R_x = R(1 + C_a/C_x)^2 \qquad (12)$$

From equation (12) the equivalent series radio frequency resistance of the material may be computed since all other terms of the equation are known quantities. The capacity of the test specimen may be computed from equation (10) as the other terms of this equation are known quantities. The power factor of the material may be found from the following equation:

$$P.F. = R_x(2\pi fC_x) \qquad (13)$$

where P.F. = The power factor.

The dielectric constant of the test specimen is obtained from the ratio of the capacity of the test specimen (C_x) to the calculated capacity which the applied electrodes would have if the test specimen were removed and the electrode spacing unchanged. The loss factor is by definition the product of the dielectric constant and the power factor.

(4) Each sample was tested first as received, and again tested after immersion in distilled water at room temperature for 24 hours, in order to determine the effects of moisture absorption upon loss factor. After the sample was removed from water, it was dried with a clean cloth before testing.

(b) In conducting the high frequency flash-over tests, the placing of electrodes in the test specimen, the electrode termination, the power supply, the voltage measuring equipment, the procedure, and the conditions under which samples were tested, are discussed in the following subparagraphs.

(1) Holes were placed in the test specimen to admit electrodes across which the high frequency potential was impressed. Plates 3 shows the location, size, and spacing of these holes, and the accuracy to which the spacing was kept. A template was used to place these holes in order to insure accuracy and uniformity of spacing in the various samples. After drilling, these holes were reamed to a diameter of 0.499". Plate 4 shows a view of one of the brass electrodes used in these tests. These electrodes are pressed into the holes in the test specimen as shown in Plate 5. The electrodes were tapered on one end to assist in pressing them into the specimen. Since the hole in the specimens is somewhat smaller than the diameter of the central portion of the electrode, a close fit is assured. Now it is possible that the side across which the flash-over will occur is dependent upon the direction of insertion of the drill, reamer and electrode. To eliminate the uncertainty of these factors, the drill and reamer were started from one side of the test specimen which is hereafter designated as side B. The opposite side is designated as side A. The electrodes were also inserted from side B. Plate 5 shows the direction of insertion of the drill, reamer, and electrode, as well as the side designation.

(2) If the test potential were applied to the electrodes as shown in Plate 5, it is possible that either corona or a spark-over would result at the ends of the electrodes before a voltage sufficiently great to cause a flash-over across the test specimen could be applied. Consequently, these cylindrical electrodes must be terminated in such a manner as to prevent corona and spark-over. A metallic sphere attached to the ends of the cylindrical electrodes (as shown in Plate 6) is the best type of electrode termination. The diameter of these spheres must be so chosen that the voltage required to cause a spark-over between them will be as great as possible. The laws governing the relationship between spacing, radius, and the electric field of spherical electrodes are discussed in reference (h), page 30. Therein it is shown that the electric field between spherical electrodes is non-uniform, and that the field intensity is greatest along a line between the centers at the surface of the spheres. The intensity of the electric field at the highest point is dependent upon the applied voltage, the radius of the spheres, and the distance between the nearest spherical surfaces. From the discussion in this textbook it may be shown that if the distance between the centers

This equation may be rearranged as follows:

$$X = 3.81 - 2r \qquad (16)$$

Substituting in equation (14) the value of X shown in equation (16) the following equation results:

$$g = \frac{e}{3.81 - 2r} \phi \qquad (17)$$

On the assumption that a unit potential exists between the spheres, equation (17) becomes:

$$g = \frac{\phi}{3.81 - 2r} \qquad (18)$$

By assuming various values of r, determining ϕ from the curve shown in Plate 7, and then substituting these quantities in equation (18), a curve may be drawn showing the relationship between g and any selected value of r. Such a curve is shown in Plate 8. It is shown by this curve that a sphere radius of 1.05 cm. (diameter 0.828") results in the lowest value of field intensity at the point of greatest field intensity, and consequently, this radius would withstand more applied voltage before a spark-over would occur than would any other selected radius. The curve shown in Plate 8 also indicates that the optimum sphere radius is not highly critical, as a sphere radius of from 0.95 cm. to 1.2 cm. would be nearly as satisfactory. As a result of this analysis, the cylindrical electrodes were terminated by brass spheres having a radius of 0.828" as shown in Plate 6. In order to apply an electric field as uniform as possible to each side of the test specimen, spheres were attached to both ends of the electrodes. Plugs were placed on two of the spheres to facilitate connection to the applied potential.

(3) Plate 9 shows a schematic diagram of the equipment used in conducting the high frequency flash-over tests. Radio frequency power is obtained from a type SE 38107, 20 kilowatt power amplifier which is controlled by a type SE 38151, 1 kilowatt master oscillator. As the output frequencies of the master oscillator and power amplifier are both 90 kilocycles, neutralization is required to insure stability. The output circuit of this power amplifier is loosely coupled through a short transmission line to a multiple tuned radio frequency step-up transformer. A guard ring condenser and thermal milliammeter are connected to the output terminals of the radio frequency transformer. The function of this condenser and milliammeter will be fully discussed subsequently. The test specimen is connected to the

output terminals of the transformer, in parallel with the series circuit formed by the guard ring condenser and thermal instrument. Variation in the radio frequency voltage applied to the test specimen is obtained by variation of the power amplifier plate voltage. Plate power for this amplifier is furnished by a rectifier whose output voltage is controlled by an induction regulator. By means of a sensitive absorption wavemeter, it was determined that the output of the radio frequency transformer was very nearly free of harmonics, and consequently, the wave form of the potential applied to the test specimen was approximately sinusoidal.

(4) The value of radio frequency voltage applied to the test specimen was measured with a radio frequency voltmeter composed of a thermal milliammeter and a capacitative multiplier. This multiplier consists of the guard ring section of a specially constructed condenser composed of two coaxial brass cylinders. Plate 10 shows a view of this condenser, with dimensions of parts, and connections to the instrument and other parts of the circuit. The position of this guard ring condenser in the circuit is shown by C_3 of Plate 9. It is obvious that the current through the guard ring section only passes through the instrument. The capacity of the guard ring section may be calculated from its dimensions by a formula used for calculation of capacity between two concentric cylinders. In the calculation of this capacity, no correction for "edge effects" is required, as no fringing of flux occurs at the ends of the guard ring section. From the capacity of the guard ring section and the current through this portion, the voltage across this condenser may be calculated. A curve is furnished in Plate 11 showing relationship between radio frequency voltage across the condenser and current through the guard ring section. The means of connection of the test specimen to the guard ring condenser is shown in Plate 12.

(5) In testing a specimen, a potential of 5,000 volts (effective) was applied to the electrodes for a period of five minutes, and then, the voltage was increased in 1,000 volt steps at the end of each consecutive five-minute period until flash-over occurred. After flash-over, the test potential was removed as quickly as possible, usually within a few seconds. The voltage required to produce flash-over, and its effects upon the test specimen were noted. This test was repeated until the specimen had deteriorated to such an extent as to make additional tests impossible.

(6) It is possible that the voltage required to cause flash-over will be affected by factors such as atmospheric humidity, impurities on the surface of the test specimen, moisture within the sample, etc. In order to remove surface impurities, the surfaces of all specimens were thoroughly cleansed with acetone. In order to determine the effects of humidity and moisture absorption, several preliminary tests were made under special conditions to compare the results with those obtained from samples tested without special treatment. These preliminary tests were made on seven specimens (Products 1a to 1g, inclusive) which were obtained from one sheet of material. Products 1a and 1b were tested without special treatment. Products 1c to 1g, inclusive, received special treatment, as will be discussed subsequently, and after receiving such treatment were tested immediately thereafter. The holes for electrodes were placed in each of the specimens before they received special treatment. Product 1c was thoroughly dehydrated in a desiccator. Product 1d was immersed in distilled water at room temperature for one hour, and when removed was dried with a clean cloth before testing. Product 1e was immersed in a 5% solution of sodium chloride at room temperature for one hour, and after removal was washed in distilled water and dried with a clean cloth. Product 1f was boiled in distilled water for one hour, allowed to cool and remain in the water for 24 hours, and then removed and dried with a cloth. Product 1g was placed in a chamber having controlled temperature and humidity, and subjected to a temperature of 50°C and a relative humidity of 75% for a period of 24 hours. By comparison of the results obtained from samples receiving treatment with those obtained from specimens tested without special treatment, it may be determined whether or not humidity, moisture absorption, etc., are factors affecting the flash-over tests. This comparison will also indicate whether or not the samples submitted for approval should be tested under controlled conditions. All other specimens were tested without special treatment.

DATA RECORDED DURING TEST

8. The observed data are recorded in Tables 3 to 10, inclusive, and the following discussion is furnished to assist in the interpretation of these data:

(a) Loss factor test data are shown in Table 3. Power factors and loss factors are expressed in decimal

(b) Errors in measurement of applied voltage in the high frequency flash-over test result from inaccuracies of the thermal instrument, and from error in determination of capacity of the guard ring section of the condenser. This instrument was carefully checked at a frequency of 60 cycles with a precise thermal instrument (Weston Model 412), and the results indicated that the thermal milliammeter used in voltage measurements was in first class condition. As the scale of a thermal instrument is non-uniform, the accuracy to which it may be read depends upon its deflection. By comparison with the precision instrument, it was determined that readings accurate to within 3% could be obtained at and above deflections corresponding to 10,000 volts. No appreciable frequency error occurs in the instrument used in the voltage measurement, as the manufacturer states in a letter, reference (i), that this type of instrument requires no frequency correction at any frequency below 5,000 kilocycles. Since the accuracy of the computation of the capacity of the guard ring section of the condenser depends only upon correctness of measurement of certain dimensions, it is probable that the calculated value of this capacity is accurate to within 1%. As the frequency impressed on the condenser is relatively low, no change in characteristics of the condenser with change in frequency may be expected. It is estimated that flash-over voltage measurements are accurate to within 5% for applied voltages of 10,000 volts or greater. As paragraph 5(d)(3) of the specifications, reference (b), requires that the material withstand a voltage of not less than 12,000 before flash-over, this degree of accuracy is sufficient.

RESULTS OF TEST

10. The results of tests conducted are discussed in the following subparagraphs:

(a) The results of tests to determine dielectric constants, power factors, and loss factors indicate that moisture absorption has a slight effect on dielectric properties, although in many of the products, the resulting changes are within experimental error. It may be noted that all tests were not conducted at the same frequency, and the question naturally arises as to whether or not the test frequencies must be considered in comparing the test data of two materials tested at different frequencies. Tests have been conducted by this Laboratory on one material at various frequencies between 200 and 800 kilocycles, and no frequency change in dielectric properties was found which could not be attributed to experimental error. It may be noted that all materials tested, with the exception of Product 4, have much smaller loss factors than the maximum allowed by paragraph 5(d)(2) of the specifications, reference (b), which states that loss factors shall not exceed 0.24. Product 4 has a loss factor much greater than that allowed, and even if this product was given the benefit of experimental error (as discussed in paragraph 9(a) of this report), it would not then conform to specifications regarding loss factor.

(b) The most important part of the data shown in Tables 4 to 9, inclusive, are the values of high frequency flash-over voltage, as their values are required in order to determine compliance with specifications. The other data are furnished merely as a description of other effects of these tests. These tables show information regarding period of time required for flash-over to result after the applied voltage had been increased to the value which ultimately resulted in flash-over (not the total time the specimen was under test), the side across which the flash-over occurred, the effects of the electric field on the material as indicated by blistering and carbonization, and other observed data. Plate 13 is furnished to illustrate the various sizes of blisters listed in Tables 4 to 9, inclusive. The degree of carbonization resulting is expressed in relative terms. It may be noted that the size of blisters and degree of carbonization usually increase with the number of tests. Flash-over usually resulted on the side which had previously blistered, and never occurred on both sides simultaneously. During all tests the temperature of the portion of the test specimen between the electrodes increased as the applied voltage was increased. This temperature rise was caused by radio frequency losses in the test specimen. Also the temperature of the high potential electrode increased with increase in applied voltage, although that of the low potential one did not change perceptibly. The voltage required for flash-over in the first two tests is nearly the same, although that required in subsequent tests is usually less. Eventually the result of successive tests produces a carbonized path between the electrodes, and then flash-over will result immediately upon application of voltage. In the test of a few of the specimens, the second flash-over occurred on the side opposite that of the first flash-over. It may be noted that, in a few instances, a greater voltage was required to produce the second flash-over than that required in the first test. The direction of insertion of the drill, reamer, and electrode may have some effect upon the side of flash-over, as the results of 77 flash-overs show that 29%

occurred on Side A and 71% on Side B. Referring to paragraph 7(b)(6) of this report, certain of the specimens (Products 1c to 1g, inclusive) were tested after special treatment in order to compare their results with those of other specimens (Products 1a and 1b) tested without special treatment, and thereby determine if moisture content or humidity were factors affecting the results of the flash-over tests. From the results, it is obvious that no marked difference in results is obtained from these materials with the exception of Product 1e, and this specimen was boiled and soaked in water before testing. Therefore, humidity or ordinary moisture absorption are not factors affecting these tests. Consequently, no discrepancy will occur in the tests of materials submitted for type approval (products 2 to 7, inclusive) because of difference in humidity at time of test, or because of a slightly different moisture content. In order for moisture content to appreciably affect these tests, its degree must be quite high, probably near saturation. A slight degree of moisture content produces no appreciable effect, probably because the temperature of the specimen before flash-over increases to a value sufficiently to drive out most of the moisture. The values of flash-over voltage shown in Tables 4 to 9, inclusive, are repeated in Table 10, in order to more easily compare the results of the successive tests. Paragraph 6(f)(3) of the specifications, reference (b), requires that each specimen be tested ten times, and that the average of these flash-over voltages be considered the dielectric strength of the material. However, the results of the tests on the phenolic materials indicated no material would withstand more than six tests before flash-over immediately upon application of 5,000 volts. It is probable that no phenolic material would comply with this part of the specifications, because, as the number of tests progressed, the degree of carbonization would increase until a short-circuited path between electrodes resulted before that number of tests could be conducted. Consequently, it appears that the number of required tests must be reduced in order to allow any phenolic material to comply. From the data in Table 10, it is shown that one test is probably sufficient, as no important information is disclosed in subsequent tests. If the specifications required a voltage as great as 12,000 for flash-over in the first test, only 40% of the total products tested and only 17% of the products tested for type approval would comply. If the flash-over voltage requirement was reduced to 10,000 volts, then 60% of the total number of products tested and 33% of the products tested for type approval would conform. Since phenolic insulators are now used much less frequently in high power circuits than previously, a reduction in the flash-over voltage requirement could probably be effected without percentage of materials included in the several classifications at various loss factor tolerances is shown in this table. The information shown in Table 13 is based on the tests of 17 products. It may be noted that as loss factor tolerance is reduced, the number of satisfactory materials decreases rapidly. If existing specifications are modified in such a manner as to reduce loss factor tolerance considerably, the number of satisfactory products obtainable is correspondingly reduced, and competition is likewise decreased, and the increased cost of insulating material would offset any slight benefits obtained. If the loss factor tolerance were reduced to 0.20, instead of 0.24 which is the present requirement, approximately one-half of the tested materials would be satisfactory, and this value of loss factor tolerance appears reasonable.

14. The loss factor test data of non-phenolic types of organic insulation shown in Table 12 are furnished for information to serve as a basis for loss factor tolerance in a recommended additional Navy type of insulation. If the purchase of any of the materials shown on Table 12 were necessary, no specifications are in effect at the present time for obtaining such materials, and as many Naval applications require materials of this type, it would be highly desirable to issue a suitable specification. The mechanical properties of these materials are somewhat inferior to phenolic insulators, and consequently, in any new specifications, such factors must be considered. It seems that a loss factor tolerance of 0.07 would appear reasonable for any new grade, and that a high frequency power test similar to that described in reference (j) would be desirable. However, it would be necessary to conduct some actual power tests to obtain information to serve as a basis in specifying requirements in this respect. The power effects upon these types of materials could be very easily conducted in connection with the test of ceramic insulators, Bureau of Engineering Problem M1-4, as similar equipment and procedure would be utilized.

15. The high frequency power test, described in the preceding paragraph in connection with qualification tests for the suggested new type of materials, may also be useful in testing phenolic materials, with the object of superseding the 90 kilocycle flash-over test with a power test at a higher frequency. Although phenolic materials are now used less frequently as insulators than previously, such a test would possibly indicate defects which would not be shown by tests at 90 kilocycles. Such tests could also be conveniently conducted in connection with the ceramic insulation investigation.

CONCLUSIONS

16. Products 2 and 7 are considered suitable for use in the Naval Service in so far as radio frequency characteristics are involved, although they do not conform to existing flash-over test requirements. Products 3, 4, 5 and 6 are not considered satisfactory for use in the Naval Service.

17. Recent improvements in commercial manufacture makes possible a reduction in the maximum allowable loss factor.

18. As no known phenolic material conforms to existing flash-over test requirements, the flash-over voltage requirements should be reduced to a reasonable value. Suitable flash-over test requirements have been stated in Recommendations (b) and (c).

Table 1

Key to Symbols

Materials Tested for this Report

NRL Symbol	Manufacturer	Trade Name	Manufacturer's Grade or Type	Mat.Lab. N.Y.Navy Yard Test No.
Product				
1	Spaulding Fibre Co.	Spauldite	-	-
2*	Mica Insulator Co.	Lamicoid	6022	-
3	General Electric Co.	-	2008	2820
4	General Electric Co.	Textolite	1841A	2901
5	Taylor and Company	-	X	2919
6	Taylor and Company	-	XX	2919
7	Richardson Company	Insurok	-	2958
8	Synthane Corp'n	Synthane	XX	-
9	Synthane Corp'n	Synthane	A	-
10*	Mica Insulator Co.	Micanite	6022	-
11	Dielectric Products Co.	Victron	E	-
12	American Hard Rubber Company	Hard Rubber	-	-
13	Dielectric Products Company	Victron	AA	-

* These products are probably the same, although they have different trade names. The manufacturer and manufacturer's grade are identical.

Table 2

Key to Symbols

Materials tested during past few years.

NRL Symbol	Manufacturer	Trade Name	Manufacturer's Grade or Type	Date of Test
Product				
14	Spaulding Fibre Co.	Spauldite	-	3-6-29
15	General Electric Co.	-	-	4-30-29
16	Spaulding Fibre Co.	Fibre	-	10-20-30
17	Spaulding Fibre Co.	Spauldite	-	4-24-31
18	Spaulding Fibre Co.	Fibre	-	4-24-31
19	Synthane Corp'n	Synthane	A	4-25-31
20	Mica Insulator Co.	Micanite	6022	5-1-31
21	Spaulding Fibre Co.	Fibre	-	5-19-32
22	National Vulcanized Fibre Company	Fibre (natural)	XP-209	10-6-32
23	National Vulcanized Fibre Company	Fibre (black)	-	10-7-32
24	Panelyte Corp'n	Panelyte	-	12-1-32
25	Dielectric ProductsCo.	Victron	178-D	1-2-31
26	American Hard Rubber Company	Hard rubber	1113	1-26-31
27	Dielectric Products Co.	Victron	E	8-16-32
28	Manhattan Rubber Manufacturing Co.	Parock	-	10-11-32
29	Dielectric Products Co.	Victron	A	1-10-34
30	Dielectric Products Co.	Victron	AA	2-13-34
31	American Hard Rubber Co.	Hard rubber	1119	10-26-34
32	Carbide and Carbon Chemical Corp'n	Vinylite	-	7-16-34

Table 3

Loss Factor Test Data

Material	Loss Factor Dry	Loss Factor Wet	Dielectric Constant Dry	Dielectric Constant Wet	Power Factor Dry	Power Factor Wet	Test Frequency Kcs
Product 2a	0.12	0.129	4.46	4.26	0.0268	0.0302	450
2b	0.109	0.110	4.23	4.12	0.0258	0.0266	460
3a	0.133	0.159	4.98	5.10	0.0266	0.0311	485
3b	0.124	0.144	4.94	5.00	0.0251	0.0288	485
4a	1.59	*	8.9	*	0.179	*	560
4b	1.77	*	9.3	*	0.190	*	550
5a	0.153	0.155	5.36	5.36	0.0285	0.0289	465
5b	0.161	0.158	5.39	5.39	0.0298	0.0293	465
6a	0.152	0.156	5.34	5.33	0.0284	0.0292	475
6b	0.142	0.155	5.24	5.35	0.0271	0.0289	475
7a	0.165	0.189	5.36	5.54	0.0307	0.0342	475
7b	0.155	0.170	5.36	5.45	0.0288	0.0313	475

Power factors and loss factors are expressed in decimal fractions and not in percent.

* The "dry" test indicated that this material was so inferior that no "wet" test was conducted.

Table 4
High Frequency Flashover Test Data
First Test

Material	Flashover Voltage	Time in Minutes	Side of Flashover	Blister Size	Degree of Carbonization	Remarks
Product 1a	13,000	4-1/2	B	medium	slight	Blister formed 1/2 minute before flashover.
1b	13,000	3-1/2	B	small	slight	Blister formed 1/2 minute before flashover.
1c*	14,000	3	A	small	slight	Blister formed 1 minute before flashover. Yellow gas expelled as if under pressure from portion of test specimen near low potential electrode 1/2 minute before flashover.
1d*	12,000	1-1/2	B	small	slight	Blister formed 1/2 minute before flashover.
1e*	13,000	2-1/2	A	small	none	Blister formed 1-1/2 minutes before flashover.
1f*	8,000	1/2	A	large	none	Blister formed 1/4 minute before flashover.
1g*	13,000	3	B	small	slight	Blister formed 1/2 minute before flashover.
2a	11,000	4-1/2	B	medium	none	Blisters formed on both sides A and B, 1 and 1-1/2 minutes respectively, before flashover. Flashover occurred on side B only.
2b	11,000	4	B	medium	slight	Blisters formed on both sides A and B, 1 and 1-1/2 minutes respectively, before flashover. Flashover occurred on side B only. A liquid having a phenolic odor was expelled from specimen near high potential electrode on side B shortly before flashover.

Table 4 continued

Material	Flash-over Voltage	Time in Minutes	Side of Flash-over	Blister Size	Degree of Carbonization	Remarks
Product						
3a	8,000	4-1/2	B	small	large	Blister formed on Side A, 1-1/2 minutes before flash-over; however, the flash-over occurred on opposite side. No sign of a blister on Side B.
3b	8,000	4-1/2	B	small	large	Blister formed on Side A, 1-1/2 minutes before flash-over; however, the flash-over occurred on opposite side. No sign of a blister on Side B.
4a	5,000	3	-	medium	-	Blister formed on both sides simultaneously 1 minute before flash-over. An internal breakdown occurred near Side B.
4b	5,000	3	-	small	-	Blister formed on Side A 1-1/2 minutes before flash-over. A liquid having a phenolic odor was expelled from the test specimen near low potential electrode on Side A shortly before flash-over. An internal breakdown occurred near Side A.
5a	8,000	4-1/2	A	medium	large	Blister formed on Side A 1 minute before flash-over. This blister exploded a few seconds before flash-over. Specimen ignited by flash-over and flame was extinguished shortly thereafter.
5b	8,000	4	B	small	moderate	Blister formed 1/2 minute before flash-over.
6a	9,000	3	B	small	large	Blister formed 1/2 minute before flash-over.
6b	9,000	1-1/2	B	small	large	Blister formed 1/2 minute before flash-over.
7a	13,000	1-1/2	B	none	slight	No blister formed.
7b	12,000	2-1/2	A	small	slight	Blister formed 1/2 minute before flash-over.
8a	14,000	2	B	very small	large	Blister formed 1/4 minute before flash-over.

Table 4 continued

Material	Flash-over Voltage	Time in Minutes	Side of Flash-over	Blister Size	Degree of Carbonization	Remarks
Product 8b	13,000	3-1/4	B	very small	large	Blister formed 1/4 minute before flash-over.
9a	9,000	1	A	large	moderate	Blister formed 1/2 minute before flash-over.
9b	9,000	1	A	large	large	Blister formed 1/2 minute before flash-over.
10	19,000	1	B	small	large	Blister formed 1/2 minute before flash-over.
11	-	-	-	-	-	Deformation of the material occurred in the portion of the specimen between the electrodes when the applied voltage was increased to 13,000. The degree of deformation increased with increase in voltage. No flash-over was produced when the applied voltage was increased to 25,000. No additional tests were conducted on this product.
12	-	-	-	-	-	When the applied voltage was increased to 25,000, neither flash-over nor indications of deterioration resulted. The temperature of the portion of the specimen between the electrodes increased slightly. No additional tests were conducted on this product.
13	-	-	-	-	-	When the applied voltage was increased to 25,000, neither flash-over nor indications of deterioration resulted. No increase in temperature of the portion of the specimen between the electrodes was observed. No additional tests were conducted on this product.

* Specimens so marked tested after special treatment. See paragraph 7(b)(6).

Table 5
High Frequency Flash-over Test Data
Second Test

Material	Flash-over Voltage	Time in Minutes	Side of Flash-over	Blister Size	Degree of Carbonization	Remarks
Product						
1a	13,000	2	B	medium	moderate	Blister exploded and expelled with considerable force a piece of ignited material shortly before flash-over, although the specimen did not become ignited.
1b	12,000	3	A	medium	moderate	Blister formed on Side A 1/2 minute before flash-over. Flash-over occurred on side opposite that in first test. Yellow gas expelled on both sides of test specimen near high potential electrode shortly before flash-over. A liquid having a phenolic odor appeared on the specimen surface around the high potential electrode about one minute before flash-over.
1c*	12,000	1-1/2	A	medium	slight	A red glow along a narrow carbonized path appeared about one minute before flash-over, and the intensity of this glow increased until flash-over occurred.
1d*	13,000	2-1/2	B	medium	moderate	A small blister formed on Side A about 1/2 minute before the flash-over occurred on the opposite side. An odorless liquid (probably water) was expelled from the specimen around the low potential electrode shortly before flash-over.
1e*	14,000	3-1/2	B	small	none	Blister formed on Side B about 1/2 minute before flash-over. Flash-over occurred on side opposite that in first test.

Table 5 continued

Material	Flash-over Voltage	Time in Minutes	Side of Flash-over	Blister Size	Degree of Carbonization	Remarks
Product						
1f*	9,000	3	B	large	none	Blister formed on Side B about 1/4 minute before flash-over. Flash-over occurred on side opposite that in first test. A liquid having a phenolic odor was expelled around the high potential electrode shortly before flash-over.
1g*	12,000	2-1/2	B	medium	moderate	A yellow gas expelled from specimen, near high potential electrode on Side B during 1-1/2 minute period before flash-over.
2a	12,000	3-1/2	B	large	large	A yellow gas was expelled from the portion of the specimen around the high potential electrode. A liquid having a phenolic odor was expelled on Side B near the high potential electrode.
2b	13,000	2	B	large	large	Arcing along a carbonized path occurred shortly before and persisted until flash-over.
3a	5,000	0	B	medium	large	Flash-over occurred instantaneously with application of voltage. No additional tests conducted on this product.
3b	5,000	0	B	medium	large	Flash-over occurred instantaneously with application of voltage. No additional tests conducted on this product.
4a	5,000	2-1/2	-	medium	-	Blister sizes increased. Internal breakdown again occurred near Side B.
4b	5,000	1	-	medium	-	Blister size increased on Side A. Internal breakdown occurred near Side A. An odorless liquid appeared on the specimen near low potential electrode shortly before breakdown.

Table 5 continued

Material Product	Flash-over Voltage	Time in Minutes	Side of Flash-over	Blister Size	Degree of Carbonization	Remarks
5a	9,000	2	A	large	large	None.
5b	5,000	0	B	small	moderate	Flash-over occurred instantaneously with application of voltage. No additional tests conducted on this material.
6a	7,000	1	B	medium	large	None.
6b	8,000	4-1/2	B	medium	large	Arcing along carbonized path between electrodes occurred shortly before and persisted until flash-over. Specimen was ignited by flash-over and flame was extinguished shortly thereafter.
7a	11,000	1/2	B	none	moderate	Arcing along carbonized path between electrodes occurred approximately 5 minutes before and persisted until flash-over.
7b	13,000	1	A	large	moderate	None.
8a	13,000	4-1/2	B	medium	large	Arcing along carbonized path between electrodes occurred approximately 5 minutes before and persisted until flash-over. When flash-over occurred, blister exploded and expelled a small piece of test specimen.
8b	9,000	1	B	medium	large	Arcing along carbonized path between electrodes occurred approximately 5 minutes before and persisted until flash-over.
9a	7,000	3	B	medium	moderate	Intense arcing occurred on surface on Side B near high potential electrode during the 1/2 minute period before flash-over.

Table 5 continued

Material	Flash-over Voltage	Time in Minutes	Side of Flash-over	Blister Size	Degree of Carbonization	Remarks
Product 9b	5,000	0	A	large	large	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.
10	13,000	3	B	small	large	Intermittent arcing along wide carbonized path occurred during 10 minute period before flash-over.

* Specimens so marked tested after special treatment. See paragraph 7(b)(6).

Table 6
High Frequency Flash-over Test Data
Third Test

Material Product	Flash-over Voltage	Time in Minutes	Side of Flash-over	Blister Size	Degree of Carbonization	Remarks
1a	7,000	3	B	medium	large	During 10-minute period before flash-over, arcing occurred on Side B, the intensity of which increased until flash-over.
1b	15,000	1/2	B	medium	moderate	None.
1c*	5,000	0	A	medium	moderate	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.
1d*	5,000	0	B	medium	large	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.
1e*	14,000	3	A	medium	slight	None.
1f*	12,000	1-1/2	A	large	none	None.
1g*	13,000	2	B	medium	large	During 10-minute period before flash-over, arcing occurred on Side B, the intensity of which increased until flash-over.
2a	11,000	1/2	B	large	intense	Blister exploded on Side B by flash-over. A liquid having a phenolic odor appeared on specimen near high potential electrode.
2b	7,000	4-1/2	B	large	intense	Arcing along wide carbonized path occurred during two-minute period before flash-over.

Table 6 continued

Material Product	Flash-over Voltage	Time in Minutes	Side of Flash-over	Blister Size	Degree of Carbonization	Remarks
4a	5,000	1-1/2	-	medium	-	Internal breakdown again occurred near Side B.
4b	5,000	1	-	medium	-	Internal breakdown again occurred near Side A.
5a	5,000	0	A	large	large	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.
6a	5,000	0	B	medium	large	Flash-over occurred immediately on application of voltage. Blister exploded by flash-over. No additional tests conducted on this product.
6b	5,000	0	B	medium	large	Flash-over occurred immediately on application of voltage. Blister exploded by flash-over. No additional tests conducted on this product.
7a	5,000	0	B	none	large	Flash-over occured immediately on application of voltage. No additional tests conducted on this product.
7b	13,000	3	B	small	moderate	None.
8a	7,000	1	B	medium	large	Arcing along wide carbonized path during five-minute period before flash-over.
8b	5,000	0	B	medium	large	Flash-over occurred immediately on application of voltage. No additional tests were conducted on this product.
9a	9,000	4	B	large	large	Arcing along wide carbonized path during seven-minute period before flash-over. Blister exploded by flash-over.

Table 7
High Frequency Flash-over Test Data
Fourth Test

Material Product	Flash-over Voltage	Time in Minutes	Side of Flash-over	Blister Size	Degree of Carbonization	Remarks
1a	5,000	0	B	medium	large	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.
1b	15,000	1/2	B	large	large	Arcing along narrow carbonized path during nine-minute period before flash-over.
1e*	14,000	2-1/2	A	large	large	None.
1f*	9,000	1	A	large	slight	Blister exploded by flash-over.
1g*	5,000	0	B	medium	large	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.
2a	5,000	0	B	large	intense	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.
2b	5,000	0	B	large	intense	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.
4a	5,000	0	-	medium	-	Breakdown occurred immediately on application of voltage. No additional tests conducted on this product.
4b	5,000	0	-	medium	-	Breakdown occurred immediately on application of voltage. No additional tests conducted on this product.

Table 7 continued

Material	Flash-over Voltage	Time in Minutes	Side of Flash-over	Blister Size	Degree of Carbonization	Remarks
Product						
7b	12,000	2	B	small	large	None.
8a	5,000	0	B	medium	large	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.
9a	5,000	0	B	large	large	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.

* Specimens so marked tested after special treatment. See paragraph 7(b)(6).

Table 8
High Frequency Flash-over Test Data
Fifth Test

Material	Flash-over Voltage	Time in Minutes	Side of Flash-over	Blister Size	Degree of Carbonization	Remarks
Product 1b	5,000	0	B	large	large	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.
1e*	9,000	1/2	A	large	large	Arcing occurred in portions of carbonized path near low potential electrode **during** five-minute period before flash-over.
1f*	5,000	0	A	large	moderate	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.
7b	5,000	0	B	small	large	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.

Table 9
High Frequency Flash-over Test Data
Sixth Test

1e*	5,000	0	A	large	large	Flash-over occurred immediately on application of voltage. No additional tests conducted on this product.

* Specimens so marked tested after special treatment. See paragraph 7(b)(6).

Table 10
Flashover Test Data
Flashover Voltage in Successive Tests

Material Product	1st Test Voltage	2nd Test Voltage	3rd Test Voltage	4th Test Voltage	5th Test Voltage	6th Test Voltage
1a	13,000	13,000	7,000	5,000	**	-
1b	13,000	12,000	15,000	15,000	5,000	**
1c*	14,000	12,000	5,000	**	-	-
1d*	12,000	13,000	5,000	**	-	-
1e*	13,000	14,000	14,000	14,000	9,000	5,000**
1f*	8,000	9,000	12,000	9,000	5,000	**
1g*	13,000	12,000	13,000	5,000	**	-
2a	11,000	12,000	11,000	5,000	**	-
2b	11,000	13,000	7,000	5,000	**	-
3a	8,000	5,000	**	-	-	-
3b	8,000	5,000	**	-	-	-
4a	5,000	5,000	5,000	5,000	**	-
4b	5,000	5,000	5,000	5,000	**	-
5a	8,000	9,000	5,000	**	-	-
5b	8,000	5,000	**	-	-	-
6a	9,000	7,000	5,000	**	-	-
6b	9,000	8,000	5,000	**	-	-
7a	13,000	11,000	5,000	**	-	-
7b	12,000	13,000	13,000	12,000	5,000	**
8a	14,000	13,000	7,000	5,000	**	-
8b	13,000	9,000	5,000	**	-	-
9a	9,000	7,000	9,000	5,000	**	**
9b	9,000	5,000	**	-	-	-
10	19,000	13,000	5,000	**	-	-
11	#					
12	#					
13	#					

* Products so marked tested after special treatment. See Par.7(b)(6).

** No additional tests conducted because of deterioration of specimen.

See "Remarks" concerning these products in Table 4.

Table 11
Loss Factor Test Data
Phenolics tested during past few years

Material	Loss Factor		Dielectric Constant		Power Factor		Frequency Kilocycles
	Dry	Wet	Dry	Wet	Dry	Wet	
Product 14	0.170	0.185	5.17	5.25	0.0330	0.0350	560
15	0.168	0.255	5.26	5.54	0.0320	0.0460	475
16	0.360	0.660	5.99	6.76	0.0610	0.0990	550
17	0.186	0.213	5.10	5.18	0.0365	0.0410	760
18	0.265	0.336	5.40	5.64	0.0491	0.0596	755
19	0.200	0.206	5.33	5.29	0.0375	0.0389	755
20	0.162	0.189	4.81	5.00	0.0336	0.0376	785
21	0.193	*	4.91	*	0.0393	*	475
22	0.097	*	3.81	*	0.0255	*	420
23	0.156	*	5.12	*	0.0305	*	425
24	0.156	0.199	4.26	4.30	0.0367	0.0463	405

Power factors and loss factors are expressed in decimal fractions, and not in per cent.

* No "wet" tests conducted on these materials.
Loss Factor accuracy 10%.

Table 12
Loss Factor Test Data
Non-phenolics tested during past few years

Material	Loss Factor		Dielectric Constant		Power Factor		Frequency Kilocycles
	Dry	Wet	Dry	Wet	Dry	Wet	
Product							
25	0.0182	*	2.99	*	0.0061	*	480
26	0.0228	0.0231	3.40	3.44	0.0067	0.0067	465
27	0.0554	*	3.16	*	0.0174	*	505
28	0.0193	0.065	4.33	4.41	0.0045	0.0147	340
29	0.0475	*	2.67	*	0.0178	*	460
30	0.00141	0.0084	2.48	2.47	0.00057	0.00339	485
31	0.0136	*	3.10	*	0.00437	*	500
32	0.0363	*	2.97	*	0.0123	*	620

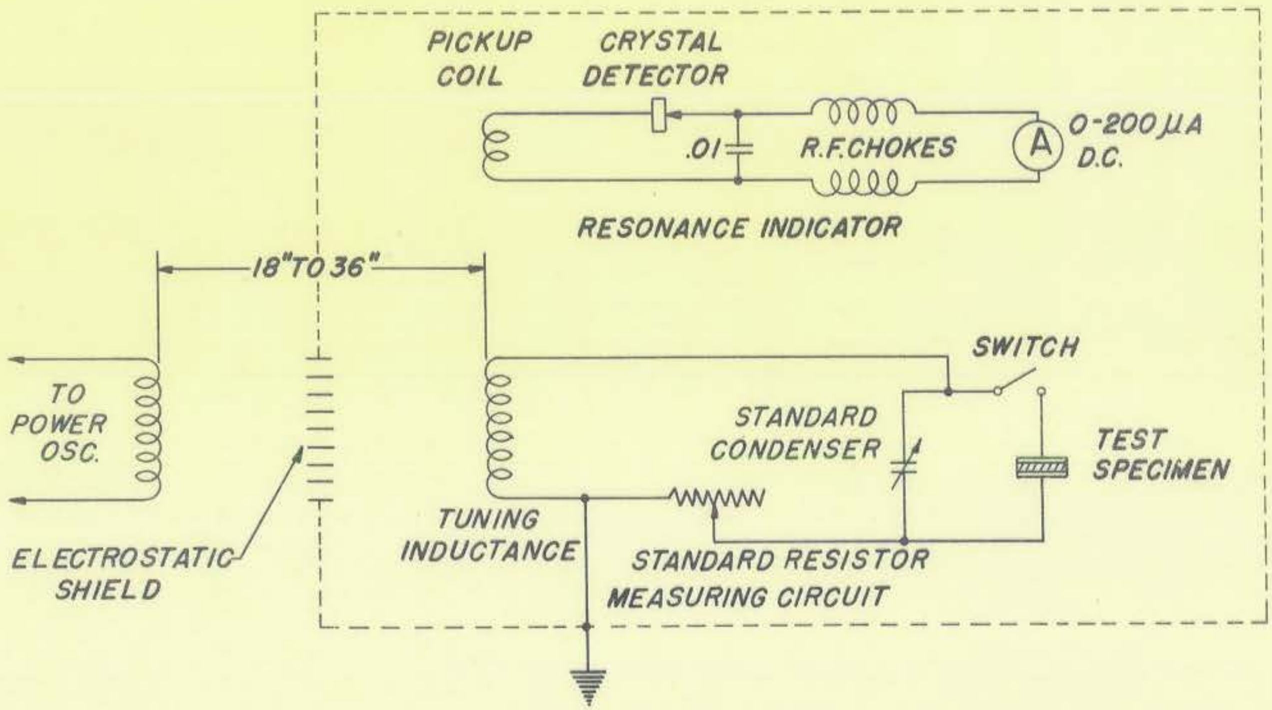
Power factors and loss factors are expressed in decimal fractions, and not in per cent.

* No "wet" tests conducted on these materials.
Loss Factor accuracy 10%.

Table 13

Classification of Phenolic Materials at Various Maximum Loss Factor Tolerances.

Maximum Loss Factor **Tolerance**	Materials Acceptable either **"Wet"** or "Dry"	Materials Acceptable "Dry" **but** Non-acceptable "Wet"	Materials Non-acceptable either "Wet" or "Dry"	Materials Appearing Acceptable from "Dry" Test, but no "Wet" Tests Conducted.
0.30	65%	-	17.5%	17.5%
0.24	59%	6%	17.5%	17.5%
0.22	59%	6%	17.5%	17.5%
0.20	47%	17.5%	17.5%	17.5%
0.18	30%	23.5%	35.5%	12%
0.16	24%	12%	53%	12%



CIRCUIT USED IN LOSS FACTOR MEASUREMENTS

PLATE I

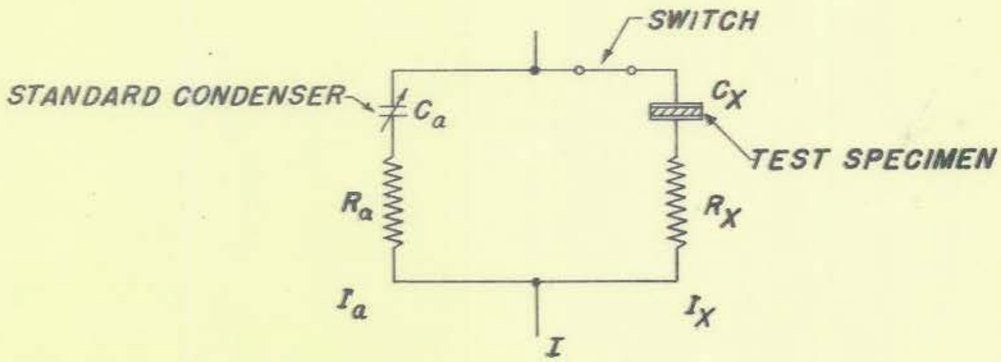


FIG. A

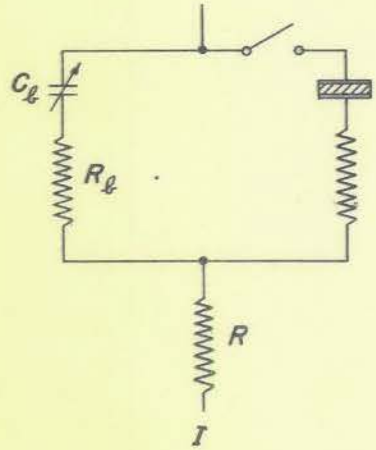
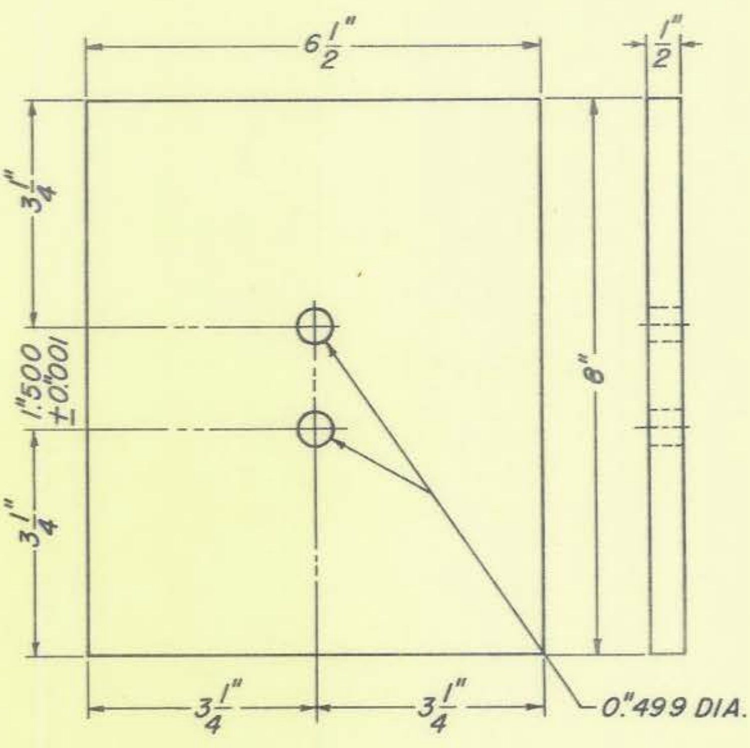


FIG. B

EQUIVALENT CIRCUITS OF STANDARD CONDENSER AND TEST SPECIMEN

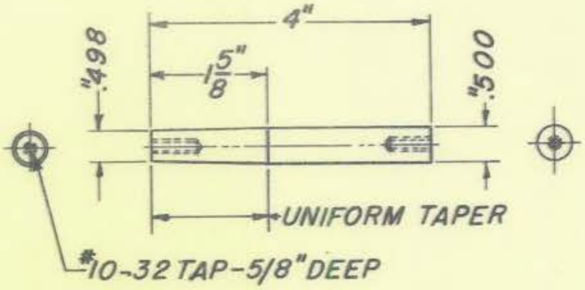
PLATE 2



LOCATION OF HOLES IN TEST SPECIMEN

SCALE-6"=1FT.

PLATE 3



BRASS ELECTRODE

SCALE-6"=1FT.

PLATE 4

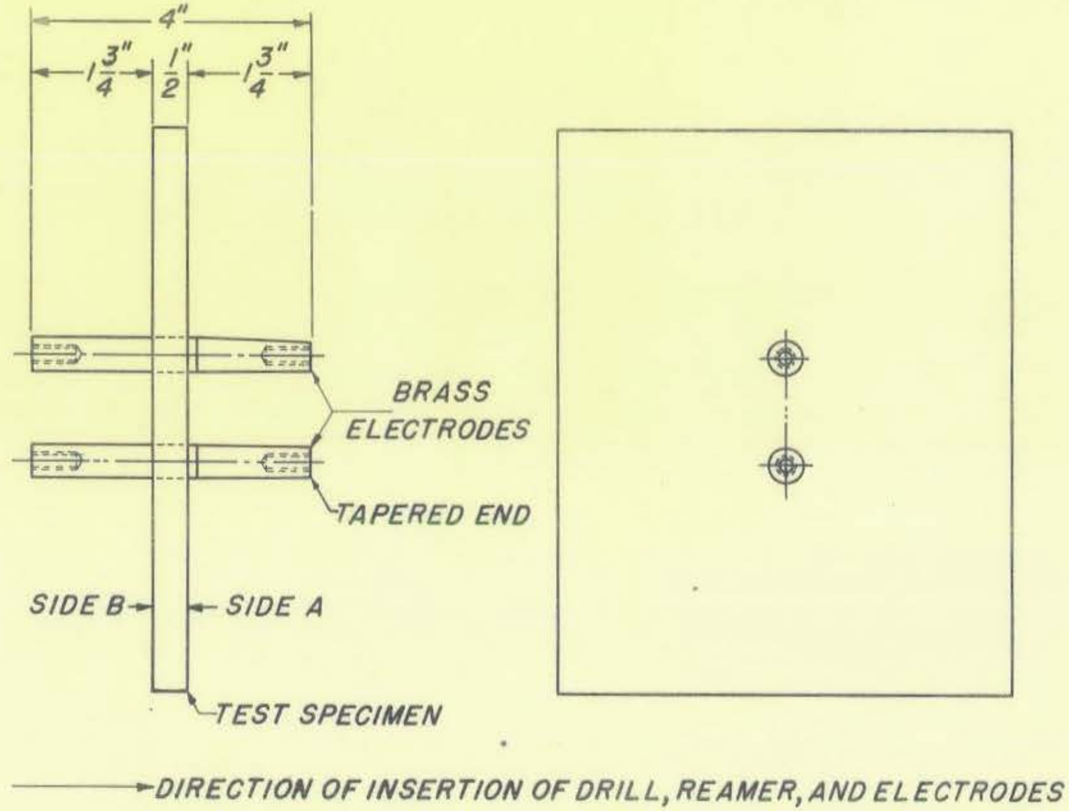
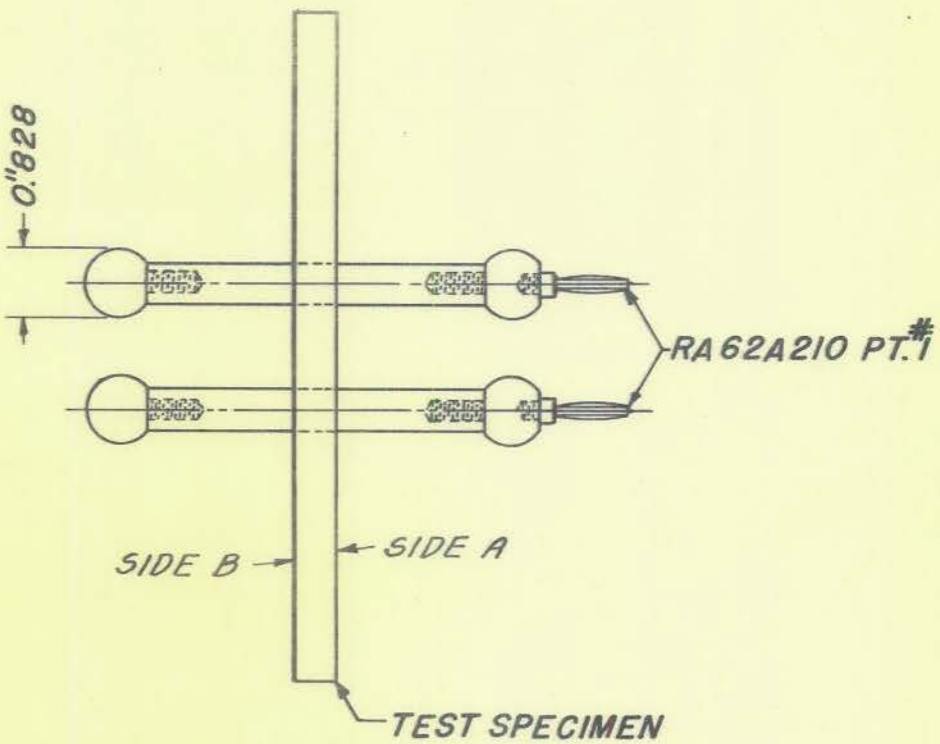


PLATE 5

PLACING OF ELECTRODES IN TEST SPECIMEN

SCALE-6"=1FT.



SPHERICAL TERMINATION OF ELECTRODES

SCALE-6″=1FT.

PLATE 6

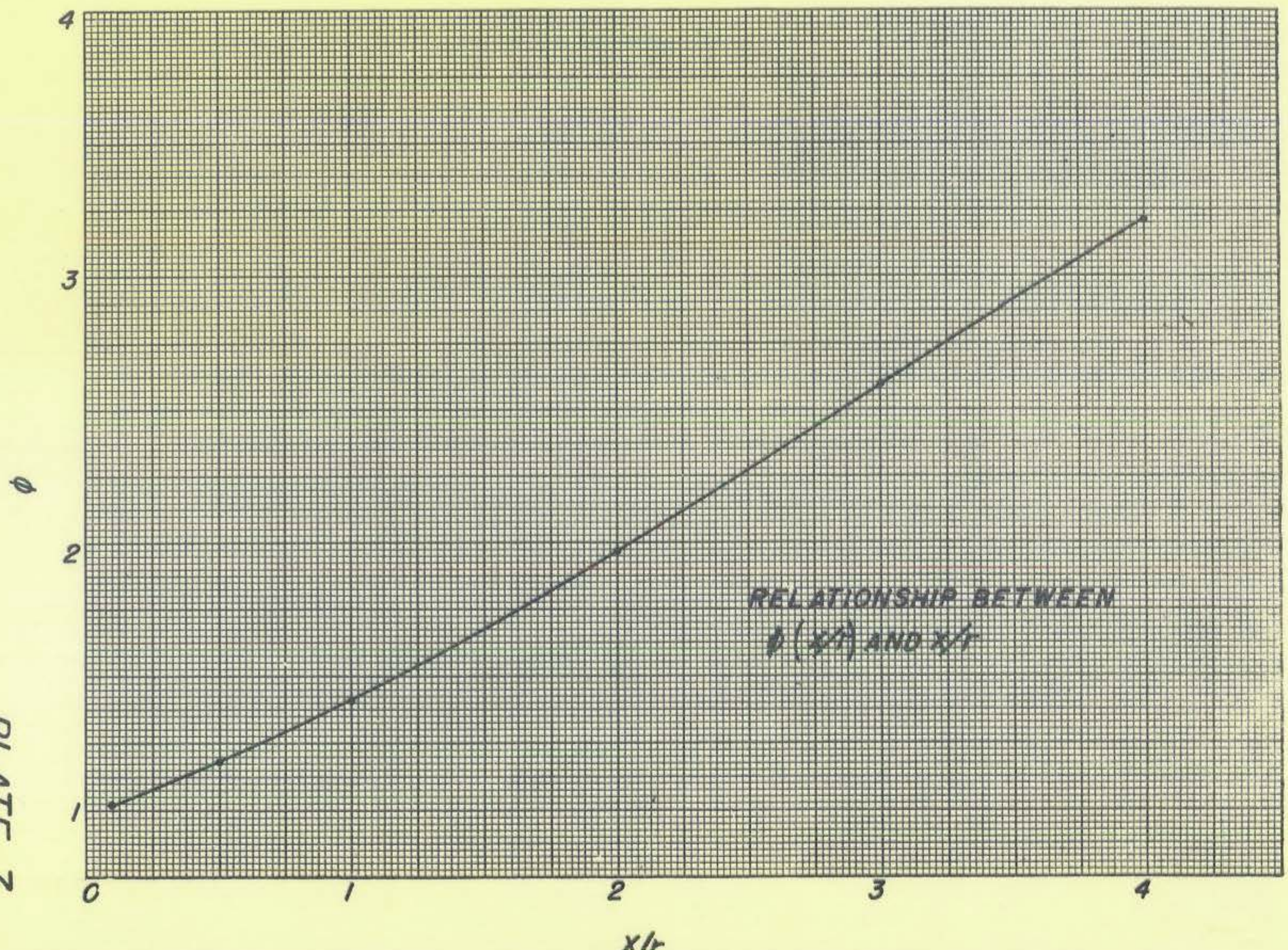


PLATE 7

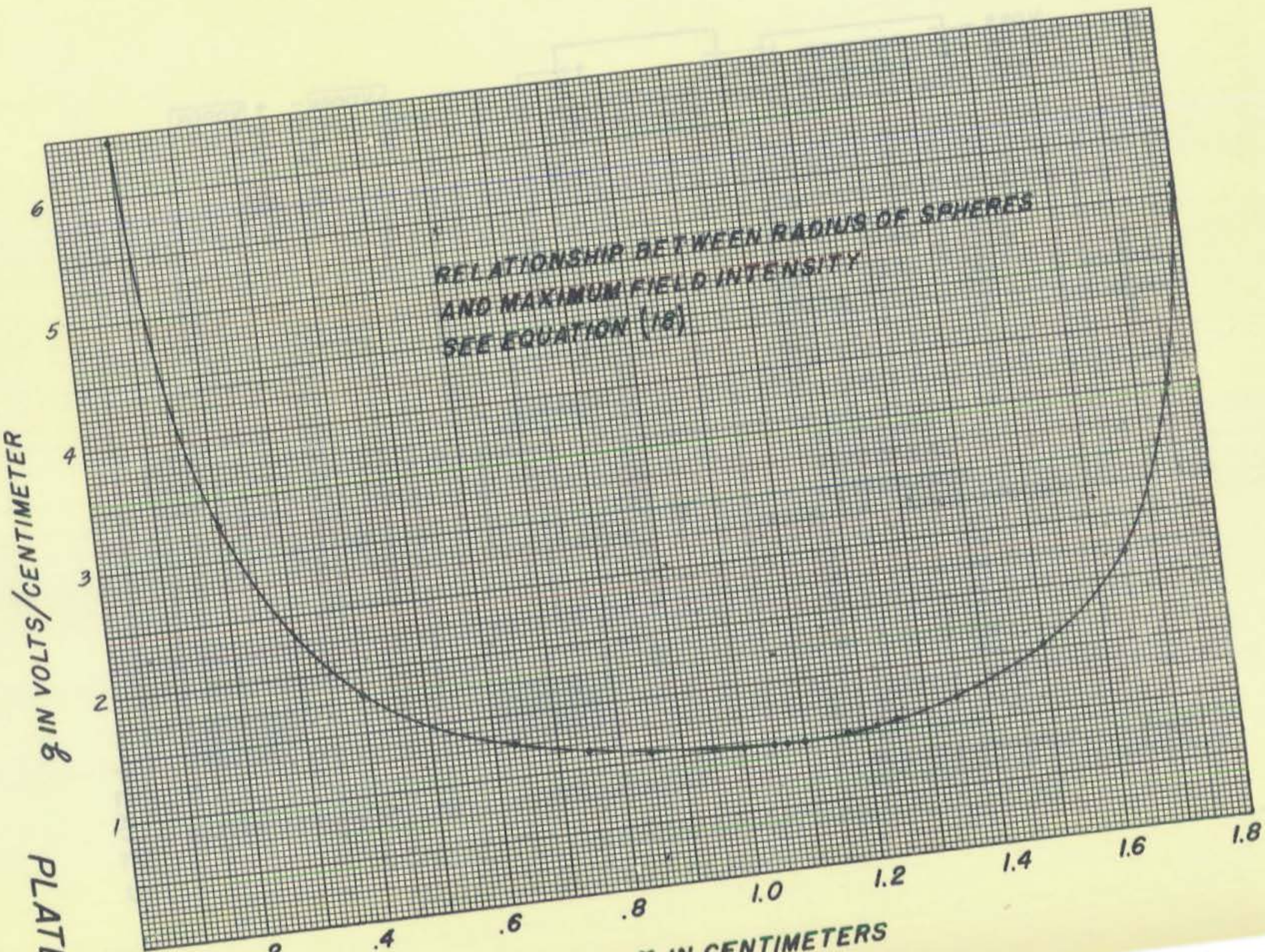
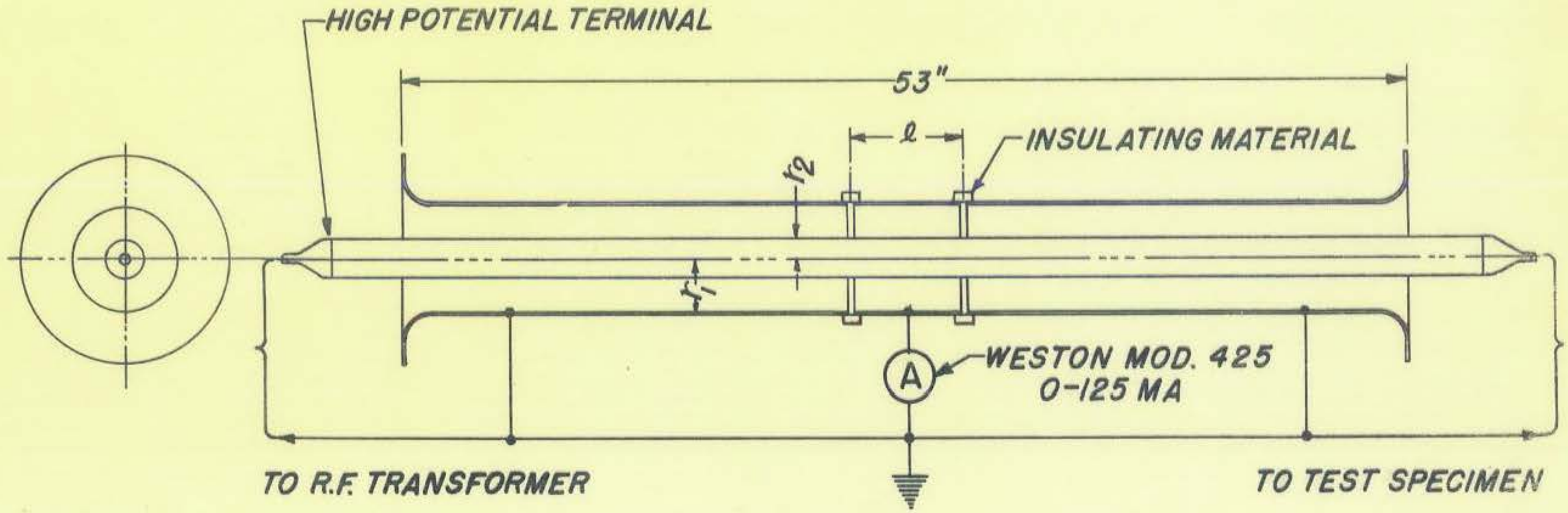

RELATIONSHIP BETWEEN RADIUS OF SPHERES
AND MAXIMUM FIELD INTENSITY
SEE EQUATION (18)
ℰ IN VOLTS/CENTIMETER
r IN CENTIMETERS
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
1
2
3
4
5
6

PLATE 8



r_1 = 6.81 CENTIMETERS

r_2 = 2.54 CENTIMETERS

ℓ = 15.24 CENTIMETERS

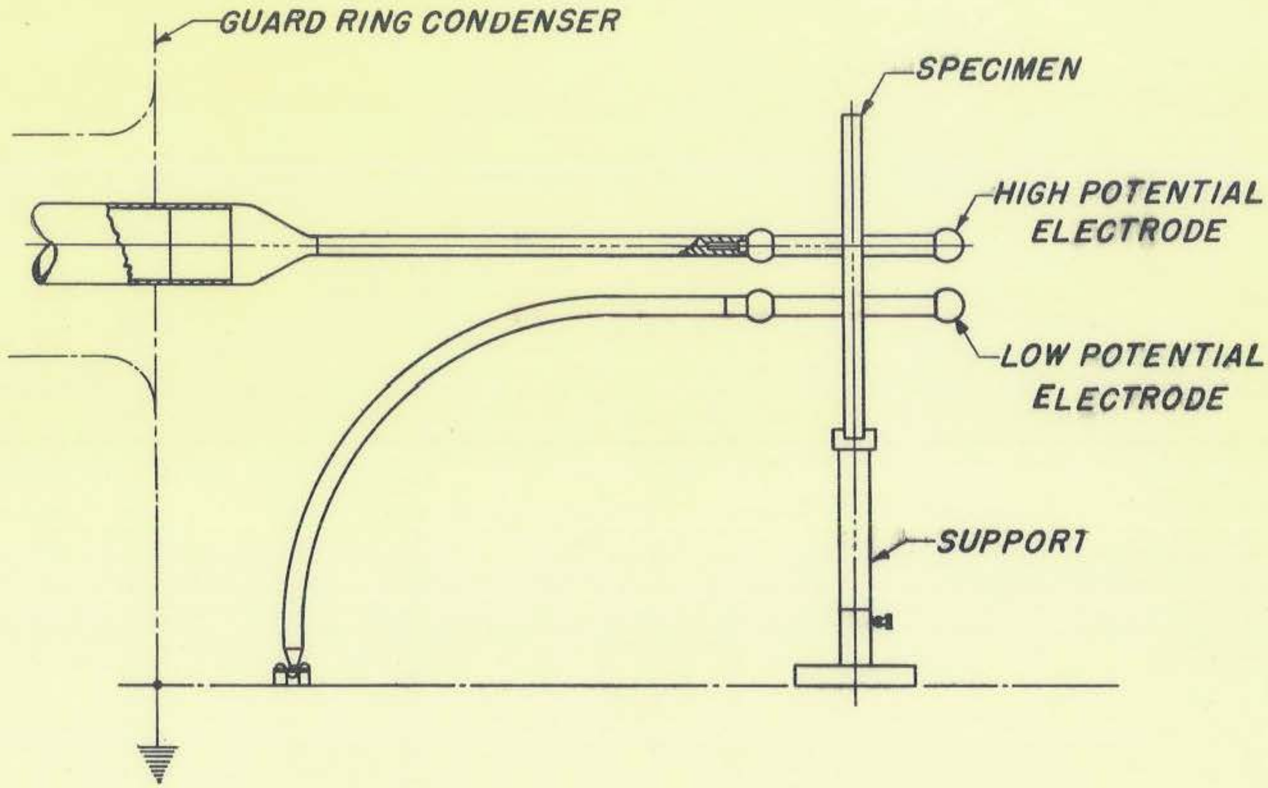
CAPACITY OF GUARD RING SECTION $= \dfrac{0.2416\,\ell}{\log 10 \dfrac{r_1}{r_2}} = 8.6\,\mu\mu f$

X_C AT 90 KCS = 205500 Ω

GUARD RING CONDENSER

SCALE – $1\frac{1}{2}$" = 1 FT.

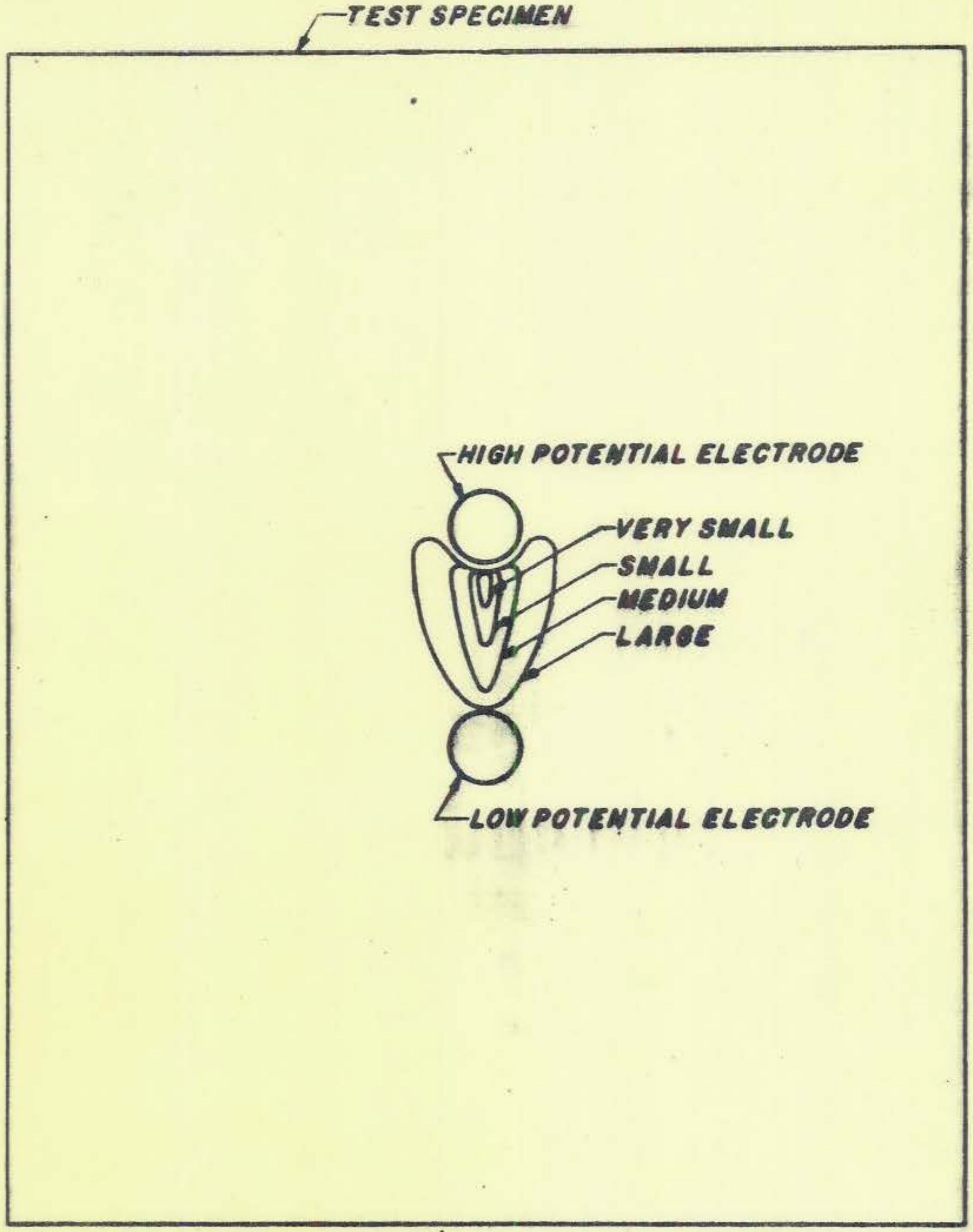
PLATE 10



CONNECTIONS BETWEEN GUARD RING CONDENSER AND TEST SPECIMEN

SCALE-3"=1FT.

PLATE 12



SIZE OF BLISTERS

PLATE 13