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INDUSTRIAL PREPAREDNESS STUDY LACQUER FILM CAPACITORS

QUARTERLY PROGRESS REPORT NO. 15
PERIOD: August 25 to November 25, 1962

SIGNAL CORPS SUPPLY AGENCY
Philadelphia, Pennsylvania

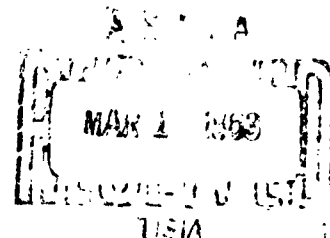


HEADQUARTERS

DEPARTMENT
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ENGINEERING

WESTERN ELECTRIC COMPANY
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WINSTON-SALEM, NORTH CAROLINA





INDUSTRIAL PREPAREDNESS STUDY

LACQUER FILM CAPACITORS

QUARTERLY PROGRESS REPORT NO. 15

FOR THE PERIOD

August 25, 1962 to November 25, 1962

**OBJECT: Establish Pilot
Line Production For
Lacquer Film Capacitors**

CONTROLLING SPECIFICATION 900-12

CONTRACT NO. DA-36-039-00-01200

ORDER NO. Y616-PP-69-01-01

Prepared by J. B. RAWLS

Approved by W. S. BANZHOF

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ABSTRACT

During the past quarter, considerable improvement was made in yields of good capacitors after the 50-hour conditioning process with regard to effective series resistance and dissipation factor.

Pilot run samples of the 0.1 uf size are now in environmental tests. Pilot run samples of the 1.0 uf size are being manufactured and will be tested during the next quarter.

Raw materials for the pilot run of 1.0 uf polycarbonate capacitors are in.

At Bell Telephone Laboratories, additional data have been obtained regarding fundamental properties of polycarbonate resins.

PURPOSE

The purpose of this contract is as follows:

1. Provide the development engineering required to establish manufacturing techniques and determine appropriate operations for the production of lacquer film capacitors.
2. Design, develop, and procure or manufacture tooling, machinery and test equipment which is required to execute point one, above.
3. Institute a quality control program to monitor and control process variables and materials during fabrication.
Prepare and submit a Quality Control Manual.
4. Prepare and submit monthly and quarterly progress reports.
5. Produce and submit for approval to the Signal Corps, pre-production samples which comply with applicable specifications.
6. Produce, on a pilot line, approved lacquer film capacitors.
7. Prepare and submit a mobilization planning report.
8. Prepare and submit a final report covering the full contract.

The intent of this quarterly report is to familiarize the Signal Corps with the advancements made on the Industrial Preparedness Contract and to indicate the amount of progress made during the period covered.

NARRATIVE AND DATA

Cellulose Acetate Lacquer Film Capacitors

General

During the past quarter, effort was directed toward stabilizing the yields of good capacitors with respect to effective series resistance and dissipation factor after 50-hour conditioning (100 V DC - 85°C), producing the pilot run of 0.1 uf and 1.0 uf capacitors and obtaining raw materials for the polycarbonate capacitors.

With regard to the yield of good capacitors after the 50-hour conditioning process, considerable improvement has been made. Analysis of lots showing high yields after 50-hour conditioning for effective series resistance were compared to lots with low yields through sectioning of the capacitors axially. The history of changes made to the manufacturing process were reanalyzed to determine if the changes affected the capacitors adversely. Correlation studies were made on existing data from lots with good and bad yields of effective series resistance and dissipation factor. Manufacturing techniques in processes directly affecting ESR and DF were reanalyzed.

The investigation revealed a number of possible contributing factors to poor ESR and DF. Sectioned capacitors used in the preproduction test program as opposed to sectioned capacitors of product out of limits on ESR and DF after 50-hour conditioning revealed several

differences. It was noticed that the glass to metal end seals in the out-of-limit product were recessed into the can approximately .020" further on each end of the can preventing the curlique lead from performing its springing action. Also noticed was the fact that the dielectric film of the preproduction samples was considerably thicker than the out-of-limit product and had less paper turns. This meant that the volume provided was not being filled to its potential. In addition, it was felt the excess paper winding of .6 mil paper might possibly be acting as a cardboard cylinder having a temperature coefficient of expansion different than the capacitor body, thereby introducing stress on the termination under elevated heat and voltage.

To allow for the decrease in case length due to recessed end seals, it was noted also in the sectioned capacitors that the solder block thickness had been reduced from .030" to .020" to pick up .020" (.010" each end) of space inside the case. Under magnification there was some evidence that the lead (.025") was pulled away from the solder block. This may have been done in sectioning the capacitor on the grinder but it was decided to return to the .030" blocks.

Some months ago the primary electrical drop-out problem was capacitance. A low frequency capacitance bridge was introduced

at the winding machine to measure unterminated capacitors. Capacitors were then wound to the correct capacitance and paper turns were added to control the diameter for the solder spray mask. When thin film (.10 to .12 mils) was used, a large number of paper turns resulted. This situation contributed to the paper cyclinder effect previously mentioned. Capacitors are now wound to capacitance with three turns of insulating paper outside. An experiment was run to determine if the thin film or the paper windings were causing the ESR troubles. This experiment is inconclusive at this time. A correlation study between failures on ESR and the number of turns required at the winding machine for a given capacitance was made. This study revealed that the lower the number of turns for a given capacitance the higher the failure rate. As a result, a lower limit on the number of turns of acetate film allowable for each code of capacitor was introduced to prevent thin film from being processed regardless of previous thickness measurements.

Several rolls of lacquered film have now been processed using thicker film (.15 mil and above) with .030" solder blocks, end seals out to the end of the capacitor can and three turns by insulating paper which has resulted in a significant improvement in ESR and DF yields after 50-hour conditioning.

The 0.1 mfd pilot run samples have been manufactured and are now on environmental tests. These capacitors have shown high yields and excellent electrical characteristics.

Raw materials for the polycarbonate pilot run have been ordered and received. As soon as conditions permit, initial runs of polycarbonate film are to be made.

Mixing and Lacquering

It would appear that casting thin films (.10 to .13 mil) on a lacquer machine would be more difficult than casting thicker films (.15 mil and above). However, this is not necessarily the case. Difficulty develops in controlling light tensions (ounces) and in drying when thicker films are cast. It is a natural tendency for any lacquer machine operator to run thinner films simply because the machine runs better. It is paramount to the production of good lacquer film that the initial thickness readings be correct and adjustments for thickness made to the machine accordingly in the initial period. Variations thereafter are not too great. This is being watched very closely.

It should be pointed out here that dielectric thicknesses up to 0.2 mils can be used in codes of capacitors up 1.0 uf without

oversize diameter difficulty. Above the 1.0 uf code and up to the 4.9 uf size, 0.15 mil dielectric film can be used quite satisfactorily. However, the 5.6 uf code of capacitor requires nominal film (0.13 mil) and much difficulty is encountered with oversize windings if thicker film is used. Therefore, parent rolls are selected before metalizing for their end use in capacitance.

Metalizing, Slitting, Stripping, Winding

Lack of control on capacitor body length (as measured without solder blocks) was evidenced during the past quarter. Only a few variables affect body length, namely: offset - capacitor plates are offset .015" to extend the metal for good solder connection, slit width - width of stripped film (metal and unmetallized margin) is determined by center to center distances of the slitting knives, and telescoping - the tendency of a capacitor body to be concave on one end and convex on the other end due to variations in tension at the winding machine.

Investigation revealed that the stripped film width varied in some cases up to .025 inches. New fixtures are being made to hold the center to center distance between slitting blades more accurately and to immobilize the ends of the blades to prevent weaving during slitting.

Termination, Canning, Impregnation

A number of experiments involving pressure changes, heat, and distances were run on the terminal block solder spray operation during the past quarter. It was found through spraying phonograph record chips that the distance from the spray pot to the capacitors may have been too close. Several chips of phonograph records used to determine definition of sprayed solder, warped and indicated hot spots. Previous thermocouple checks had indicated a temperature of around 200°F which the capacitors should withstand.

Subsequent data on capacitors sprayed with a further distance from the nozzle did not show a significant improvement in ESR. However, it was felt the less heat the better and this change remains in the process. Definition of peeled solder blocks from capacitors and peeled solder from phonograph records definitely showed an improvement.

Capacitors are now allowed to cool a minimum of twelve hours after impregnating to allow time for heat dissipation. It was felt that sealing the capacitors after a one-hour cooling period was causing stress on the capacitor body and terminal blocks due to further cooling and shrinking of the body after sealing.

Testing and Electrical Evaluation

As a normal production procedure, heretofore, capacitors which had received long periods of voltage such as the conditioning operation (100 V DC - 85°C - 50 hours) were shorted for a period of six (6) hours minimum. In many cases these capacitors would remain shorted over the week end or for days. For production insulation resistance - 85°C tests, the shorting bars were removed and the capacitors were placed in the IR - 85°C test oven for measurement. The inspector observed polarity and made his measurement accordingly. Several times polarity was not observed and low IR's at 85°C resulted.

Experiments with cellulose acetate capacitors showed that if the capacitors were charged for a short time in the opposite direction of the last significant charge, the IR - 85°C measurements could be repeated for either end of the capacitor. Since these capacitors are non-polar, it was decided that the method for measuring IR - 85°C should be changed to include charging time or that the requirement be set at the reverse polarity IR - 85°C measurement level, or that the requirement for 85°C IR specify to observe polarity. All 85°C IR measurements are now preceded by a 15-minute 50 V DC electrification time after which they are shorted for a minimum of one minute and read for insulation resistance at the end of a one-minute electrification. IR - 85°C test data now shows correlation to other parameters, that is, dielectric thickness.

Test data for the 0.1 uf and 1.0 uf pilot run samples for insulation resistance at 85°C will be taken in this manner. Effort is continuing on IR - 25°C measurement to replace the megohmmeters now being used with a sensitive DC meter to measure leakage current.

Dielectric strength from terminal to case, according to SCS -12 (Signal Corps Specification) is to be measured at a minimum of 100 V DC for a period of 15 seconds with no apparent damage to the capacitor, as evidenced by subsequent tests for capacitance, dissipation factor, and insulation resistance specified as acceptance criteria. In addition, a terminal to case insulation resistance requirement of 10,000 megohms at 50 V DC is required. A commercially available instrument was purchased to test for dielectric strength at 300 V AC. Leakage in a capacitor between terminal and case was indicated by a light on this instrument. The 50 V DC insulation resistance measurement between terminal and case is made on a megohmmeter with a readout in megohms.

During tests for lead to case insulation resistance (50 V DC - 10,000 megohms) a capacitor was found which had a 3 megohms short on one end lead to case. This capacitor had previously been checked at 300 V AC on the dielectric strength test set. A recheck was made at 300 V AC and no current leakage was evidenced (light did not burn). Investigation revealed that the 300 V AC dielectric

strength test set would not indicate a short (light on) above .6 megohms in resistance. It is planned to either replace this instrument or modify it so that it will indicate a short of 10,000 megohms at 300 V AC. Dielectric strength (L to C) will be measured on a megohmmeter at 100 V DC in the interim. This particular capacitor cleared itself during the verification testing and a short could not be found on any test set used. It was discarded.

CONCLUSION

Data for tests being performed, in accordance with SCS-12, for the pilot run samples of 0.1 uf and 1.0 uf size will be presented in the next quarterly report.

Initial runs of polycarbonate film capacitors is scheduled to take place during the next quarter.

Polycarbonate Lacquer Film Development Section

Quarterly Report to the Signal Corps

by

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ABSTRACT

During this period additional data have been obtained regarding the fundamental properties of polycarbonate resins. Special emphasis was placed on the Tennessee Eastman (BTL No. L-33) type resin which, on the basis of experimental capacitor performance, has been chosen for pilot plant production in the WECo.

Tennessee Eastman Company has recently produced six additional laboratory batches of this type of polymer. These have been characterized for average molecular weight by dilute solution viscosity and impurity content by DC conductivity of toluene solutions of the polymer. Four suitable batches have been mixed and this composite has been certified for WECo trial production. Viscosity concentration curves have been established and the data used for both BTL experimental film casting operations and as a guide for WECo pilot plant tests.

The dissipation factor of BTL No. L-33 has been measured as a function of temperature and frequency and compared to a Bisphenol A type polycarbonate (BTL No. L-24). A low temperature and a high temperature loss process have been observed in each polymer and, in addition, a Maxwell-Wagner type polarization has been observed at low frequency and high temperature for the L-24 type.

It has been established that polycarbonate stripped lacquer film capacitors made from TE resin (BTL No. L-33) will successfully withstand 100 V DC and 125°C for hundreds of hours if unimpregnated. They will meet 50 V IR, and tan delta requirements between -78°C and +125°C. Capacitance changes indicate the need for stabilization. This temperature range -78°C to +125°C greatly exceeds the IPS contract goals (25°C to 85°C).

Double usual aluminum (1 ohm per square) with resultant large improvement in low loss characteristics is feasible with film from BTL No. L-33. With most other polycarbonates, the extra amount of electrode aluminum gives capacitor clearing difficulties and degradation of IR.

WECO has informally been given the information necessary for the pilot plant run including suggested machine modifications which they have tried and found successful.

Chemical and Physical Properties

After examination of the data amassed for the various polycarbonates noted in the previous quarterly reports, it was decided to concentrate on the Tennessee Eastman experimental polycarbonate (L-33 type). This decision was based mainly on the better values obtained on laboratory fabricated capacitor units. Examination of the capacitor processing as a whole led to a more critical perusal of certain phases of the operation to establish greater constancy of good values. A further hope was to raise the capacitor quality commensurate with findings on the basic properties of the polymer.

In handling of the lacquer film for metallizing, slitting, stripping and winding operations cleanliness is, of course, a major factor. For instance, it was found that if an operator washed his hands with soap and did not completely remove all residual soap it could lead to polymer degradation. An accelerated experiment was set up in which sections of thicker film (~5 mils) were contaminated with soap. Films were placed on glass dishes in an air oven at 160°C and examined periodically over a three month exposure. All six types of polycarbonate polymer as noted in previous reports were included in this experiment in order to obtain the relative resistance to degradation. The reactivity of the various types of polycarbonate was roughly in the same order as their relative rates of hydrolysis. These severe conditions would probably never be encountered in capacitors but the maintenance of clean surroundings and avoidance of direct contact with the film cannot be over-emphasized.

A second lacquering run was made using Tennessee Eastman's polymer L-33. The lacquer used was the collected overflow from an earlier run. The concentrated solution viscosity was determined on this refiltered solution and it was found to be in the correct range for lacquering. Solution samples were removed continuously during the two hour run. The viscosity remained quite constant during this time, varying only about $\pm 4.3\%$ from an average value of 4.42 poises.

Film in the range of 0.001" was cast from a benzene solution of polymer L-33 for use as capacitor overwrap. This was done to insure good electrical quality even if trace amounts of solvent remained in the film. Previous film from chloroform solution was suspect in contributing to lowered insulation resistance due to chlorinated solvent residue. However, there are many other opportunities for trace contamination in the lacquer film operations so this effect might be of second order magnitude. Capacitors made under extremely clean conditions are now under test.

Following the decision to investigate the Tennessee Eastman polycarbonate (L-33 type) in production equipment, a more intensive investigation of some of the basic properties was initiated. Additional films of this polycarbonate were cast from both chloroform and benzene and are in the process of being dried to constant weight. Plans are underway to obtain rate curves for both oxidative and hydrolytic degradation from a series in which temperature is the only parameter.

Tennessee Eastman Co. has produced six batches of this type of polycarbonate for the Western Electric Company on a laboratory basis. Each batch was of about a 35 lb yield and they were kept segregated throughout the complete processing operation. Each of these batches was characterized as to the average molecular weight by dilute solution viscosity, DC conductivity in toluene solution, and, in some cases, concentrated solution viscosity. These data appear in Tables 1 & 2. When Tennessee Eastman finished working up a batch, a three pound sample was shipped to BTL-MH for evaluation while the remainder was sent to WECO-NCW. Corresponding BTL numbers were assigned to each sample and were related to the Tennessee Eastman numbers as transmitted to WECO.

It may be noted from the data in Table 1 that samples BTL L-52, L-53, L-55 and L-56 have low DC conductivities as received. This does not preclude the use of the L-54 and L-57 batches for use in producing lacquer film but, with sufficient quantity available in the above four batches, it was decided to make a composite sample of these for use in BTL lacquering operations. It was recommended to WECO that they follow the same procedure. The composite batch was produced by dry mixing equal weights of each batch and tumbling in a clean fibre drum. The average molecular weight as noted by DSV is very close to that calculated from the individual values and, it is also close to the older sample L-33 which has been included for comparison. The DC conductivity in toluene solution is almost exactly the

same for the composite and BTL L-33. There are strong indications that conducting impurities are adsorbed and removed from solutions of these polycarbonates by cellulosic filter material. This technique could lower the initially higher conductivities observed for batches L-54 and L-57.

Table 2 shows the effect of the concentration of polymer in chloroform solution. When these data are plotted as the \log_{10} of the concentrated solution viscosity against the concentration in grams/100 ml of solvent, straight lines can be drawn through the experimental points. This has been depicted graphically in previous quarterly reports (Reports No. 12 and No. 13). One slight difference is noted in comparing these latter polycarbonates with BTL L-33, which, according to Eastman, are the same chemical composition. Our data indicate a difference in the slope of the viscosity-concentration curves in which the L-33 is slightly higher. This could be due to a slight difference in molecular weight distribution but should not affect the basic material for use as a capacitor dielectric.

Two separate lacquering runs were made with this composite sample. The first was made using original solution prepared to a concentration of 10.0 g/100 ml solvent. The second run was made by using some of the overflow from the first run mixed with a smaller portion of original solution. The measured concentrated solution viscosity showed that this mixture was slightly too dilute to produce film in the optimum thickness range. Based on the first run in which film thickness

was on the low side, more polymer was added to produce a concentration of about 10.5 g/100 ml solvent. The first run had been made with a lacquer solution of 3.60 poises equivalent to a concentration of 9.9 g/100 ml of chloroform while the second run was made using a solution of 4.28 poises or 10.4 g/100 ml of chloroform.

Each lacquer run was monitored continuously for viscosity changes. In the first run, as noted, the conditions were such that the dried lacquer film was on the thin side. Some solvent was getting back into the application trough from the drip bottles which are used to wash excess lacquer from the doctor rod. This spurious dilution obviated correlation of film thickness to viscosity of the lacquer. There were some unexplained variations in viscosity during this film casting operation. The viscosity, as measured, varied about $\pm 7.7\%$ from the average of 4.21 poises. The second run which was under better control varied only $\pm 4.7\%$ from an average viscosity of 4.51 poises.

Average film thickness on a number of lacquer capacitor films has been determined by the weight-density method as described previously. Typical results for the Tennessee Eastman L-33 polycarbonate are as follows. One run of about 1000 feet of film showed an average thickness of 0.112 mils with a total spread of +0.007 mils to -0.003 mils for the left hand portion. The right hand portion had the same average thickness with a spread of +0.006 mils to -0.004 mils. This shows not only

constancy of film thickness throughout the casting operation but also small variations across the cast film. A second run consisting of about 1500 feet of film showed an average of 0.096 mil with a minimum of 0.089 mil and a maximum thickness of 0.105 mil for the left hand portion. The right hand portion had an average of 0.104 mil with a total spread of +0.006 to -0.006 mil. This run, while quite adequate for capacitor film, was not as constant either in longitudinal or transverse thickness control as the first run noted above.

The dissipation factor has been measured as a function of temperature at four frequencies (10^2 , 10^3 , 10^4 and 10^5 cps) for L-33 and L-24 polycarbonates. These data provide a measure of the intrinsic loss of the polymers and are useful in the interpretation of measurements previously made on capacitors as well as in the prediction of capacitor properties. In addition, inferences concerning the nature of the absorption process at the molecular level may be drawn.

The L-24 polycarbonate is a Bisphenol A type supplied by the Mobay Chemical Co. The Tennessee Eastman Co. supplied a different structure of polycarbonate (L-33). A single sample of each type of polycarbonate was used for all measurements below 150°C. Samples were prepared by casting from chloroform solution. The films prepared by casting were dried to constant weight (the drying time was 2 weeks for L-24 and 3 weeks for L-33) at 110°C under vacuum. The average thickness of the L-33 sample was 9.7 mils; that of the L-24 was 7.6 mils.

Circular aluminum electrodes (2 inch diameter) were evaporated onto the films. The aluminum thickness was 3000 to 5000 angstrom units. The films were trimmed closely to the edge of the electrodes.

Measurements were made on a General Radio Co. 716-C bridge with a 1690-A dielectric sample holder. On this bridge, $\tan \delta$ is read directly. The dielectric sample holder was modified by the addition of entrance and exit ports through which pure, dry nitrogen was passed. The nitrogen was heated or cooled by external coils and served to heat or cool the sample holder as well as to protect the sample from contact with air. A thermocouple was inserted in the exit port to contact the ground electrode. The output was fed to a millivolt recorder. The temperature of the cell changed slowly as the gas was passed through. To obtain a reading, the bridge was balanced, the recorder reading noted immediately, and then the bridge readings were taken.

Results are shown in Figs. 1, 2, and 3. The direct reading of $\tan \delta$ from the setup described is plotted as a function of temperature at each frequency. The $\tan \delta$ read from the bridge differs from the true $\tan \delta$, but calculations indicated that it differed from the true value by only a few per cent. The loss of the empty holder is very low and does not change significantly in the range 25 - 140°C.

Figs. 1 and 2 show $\tan \delta$ of L-33 at four frequencies. The open circles and triangles indicate the heating portion of the cycle above 25°C and the cooling portion of the cycle below

25°C. The filled circles and triangles indicate the cooling portion of the cycle down to 25°C and the warming portion of the cycle up to 25°C. The true values probably lie somewhere in between the two sets of points. The curve drawn is intended only as an aid in following the points. Figure 3 presents similar data for L-24 polycarbonate though only two frequencies were utilized.

It is interesting to note that the L-33 polycarbonate has a minimum $\tan \delta$ at 15 - 25°C at 1 KC. The minimum for L-24 at the same frequency lies in the range 70 - 120°C. This explains the previous observation that the Q ($\equiv \frac{1}{\tan \delta}$) of capacitors made with L-33 tends to decrease with increasing temperature whereas that of L-24 was found to increase. The capacitor measurements were made at 25°, 85°, 105° and 125°C. The minimum dissipation factor observed for both types of polymers (0.0003 to 0.0006) is the same within the error of measurement, which may be quite large for the very low values of $\tan \delta$ measured.

Both materials appear to have a low temperature absorption process and a high temperature absorption process. The complete peak for the low temperature process was covered only for L-24 polycarbonate at 100 KC. The high temperature process was examined through measurements made with a small gold-plated brass and teflon sample holder. The electrodes (circular, 1 in. diameter) were completely enclosed and the cell was heated by nitrogen in the same manner as described for the

1690-A holder. A pile-up of 5 and 6 ten mil sections of each polycarbonate (prepared as described previously) was placed between the electrodes of the holder without attaching additional electrodes. This somewhat crude setup did not give good absolute values of $\tan \delta$ but a check of the temperature of maxima occurring in polyethylene terephthalate agreed well with those reported by Reddish.¹ It was then assumed that the shape of the curves obtained was correct though the magnitude of the absorptions was not. Figure 4 shows a plot of log frequency at maximum $\tan \delta$ (f_m) vs. the reciprocal of the absolute temperature for the two polycarbonates. A calculation of the energy of activation for the high temperature dielectric relaxation process gave a value of about 16 kcal/mole for each polymer. The entropy change of this process is 26 kcal/mole for L-33 and 28.5 kcal/mole for L-24. These calculations were based on reaction rate theory as applied to dielectric absorption.²

The high and low temperature absorption processes cannot be related with a high degree of certainty to molecular processes but a possible explanation of the high temperature process may be that it is a combination of carbonyl group relaxation and segmental motions of the polymer chain. It is

1. Reddish, W., Faraday Soc. Trans. 46, 459 (1950).

2. Smyth, C. P., Dielectric Behavior and Structure, McGraw-Hill Co., N. Y. (1955).

significant that the absorption begins just above the glass transition temperature of L-24 (150°C as determined by a refractive index method). The glass transition temperature has not been reported for L-33, but may be somewhat higher than 150° due to the greater stiffness of the chain. The nuclear magnetic resonance data presented in a previous report showed a sharp increase of molecular motion in the range 150 - 210°C for L-24 polycarbonate and 160 - 250°C for L-33 polycarbonate. The inflection points of the curves were approximately 185° for L-24 and 220° for L-33. These temperatures correspond approximately to the temperatures of the maxima in $\tan \delta$ found at 10^4 cps for L-24 and L-33 in the present study.

The low temperature process may result from end group polarizations, but must be studied further.

In addition to the high temperature process discussed above, a high temperature-low frequency conduction process was observed for L-24. This seems to be a Maxwell-Wagner loss resulting from ionic conduction in amorphous regions.^{2,3}

Polycarbonate Stripped Lacquer Film Capacitors

During this period, life testing was continued for capacitors made from the four most promising polycarbonate resins (BTL Nos. L-24, L-33, L-34, and L-35). However primary attention was devoted to 844E₁ capacitors made from the

3. McCall, D. W., and Anderson, E. W., J. Chem Phys., 32, 237 (1960).

Tennessee Eastman experimental resin BTL No. L-33 which was chosen (see last quarterly report) for the WECO pilot plant run. Additional 844E₁ and 844E₂ capacitors, (the latter with double usual aluminum) were prepared and tested. More film was cast from the residual BTL No. L-33 (chloroform solvent) to which additional resin was added, and the solution refiltered to remove particles larger than one micron size. This film was used to make capacitors of the 855E₁ and 855E₂ series which were used for impregnation studies.

Film has been cast from Tennessee Eastman composite resin (BTL Nos. L-52, L-53, L-55 and L-56) which duplicates BTL L-33 and which represents material WECO has on hand for pilot plant runs.

WECO has informally been given the information necessary for the pilot plant runs including suggested machine modifications which are under consideration by the W.E. Co.

Without presenting in detail the voluminous test data for polycarbonate stripped lacquer film capacitors (844E₁, 844E₂, 855E₁, and 855E₂) made from Tennessee Eastman resin BTL No. L-33, certain results need comment.

50 VDC-IR

The IPS contract goal was 10,000 ohm farads minimum at 25°C and 5000 ohm farads at 25°C after life test at 85°C 100 VDC for 250 hours.

For unimpregnated capacitors, this goal has been greatly exceeded in terms of IR values, range of temperature, and life duration (see Figs. 5 and 6). For example, with unimpregnated,

desiccated 1 UF capacitors constructed with paper core and cover, the median 50 V IR exceeded 50,000 ohm farads at every measurement at room temperature throughout 1500 hours life test at 85°C, 100 VDC, plus 750 hours life at 105°C, 100 VDC, plus an additional 500 hours life at 125°C, 100 VDC (Fig. 5). Excellent values were obtained also for capacitors sealed in their cans, but not as good as for unsealed capacitors (Fig. 6). In fact, the extensive life test improved rather than degraded the IR's of both sealed and unsealed (but desiccated) capacitors. For some unknown reason other groups of capacitors did not do quite so well, but had generally fairly good IR results.

Measured at 85°C, 105°C, and 125°C, the median 50 V IR's exceeded 10,000 ohm farads, except for one value which dropped to 5240 ohm farads but recovered. They exceeded 100,000 ohm farads at -78°C (Fig. 6).

Various impregnants degraded the IR's as will be discussed later in this report.

The IPS goal of 200 for Q_{1KC} measured at 25°C was greatly exceeded as shown below. Median Q_{1KC} for unimpregnated capacitors measured at room temperature remained greater than 1000 throughout life of 1500 hours at 85°C, 100 VDC plus 500 hours at 105°C, 100 VDC (Fig. 7). For the same period, median Q_{1KC} measured at 85°C, and at 105°C remained greater than 950. Life at 125°C, 100 VDC degraded the Q_{1KC} particularly when it was measured at 125°C (Fig. 7). For some unknown reason, the Q_{1KC} degraded faster during life testing for sealed unimpregnated capacitors, but then recovered (Fig. 8).

For unimpregnated capacitors, $Q_{0.1KC}$ measured at room temperature was generally double the Q_{1KC} value and stood up excellently throughout life of 1500 hours at 85°C, 100 VDC, plus 500 to 750 hours at 105°C, 100 VDC, plus 250 to 500 hours at 125°C, 100 VDC. All Q measurements had 0.08 ohm correction for long leads where applicable, but no bridge corrections.

No attempt was made to stabilize the capacitance of the unimpregnated capacitors under discussion (844E₁, capacitor Nos. 1-6, 7-12, 13-18, and 19-24). The capacitance drifted upward 1.5 to 2% during the first 250 hours life at 85°C, 100 VDC, and had gained an additional 1.5% by the end of 1500 hours at 85°C, 100 VDC. When the temperature was raised to 105°C (100 VDC) the capacitance increased 1.5 to 3% during 750 hours at 105°C, 100 VDC. When the temperature was further raised to 125°C (100 VDC), the capacitance further increased 0.5 to 3% to a total of 6 to 10% above the initial values. This indicates the serious need for capacitance stabilization if the very low temperature coefficient of capacitance ±50 ppm/°C is to be practically utilized.

Effects of Impregnation

To test possible chemical attack of PEPB (without anthraquinone) and of a proposed high melting impregnant, Lanosterol, well dried 1 mil films from Tennessee Eastman polycarbonate resin (BTL No. L-33) were suspended in air at 130°C under 50 lb/sq in tension in each of these impregnants. The sample in PEPB (no AQ) withstood more than 6 days with no

visible deterioration within the PEPB, but edge tears began to form above the PEPB where the film exposure was to air at 130°C. The film in Lanosterol withstood 7 hours, but for each of two trials made, was found to be broken in the Lanosterol the next morning, i.e., after 22 hours indicating chemical attack. This eliminated Lanosterol from further consideration.

One group of capacitors 844E₁, Nos. 19-24, was impregnated with PEPB (no AQ) after very extensive life tests made before impregnation (Table 3). The immediate effect was to somewhat degrade IR, increase capacitance slightly, and degrade Q_{1KC} and Q_{.1KC} slightly. However, after additional life tests at 85°C, 100 VDC, for 2312 hours and 2504 hours, the IR's were greatly degraded, the capacitance continued to drift upward, i.e., was not stabilized, and the Q_{1KC} and Q_{.1KC} continued to drift downward. Measured at 85°C this degradation of IR was very pronounced.

Figures 9 & 10 show that capacitors impregnated (PEPB + AQ) before any life tests show similar poor IR's when compared with similar unimpregnated capacitors (Figs. 5 & 6). In Fig. 10 there is a further indication that IR's improve with extended life testing.

For further impregnation studies, additional polycarbonate film was cast from Tennessee Eastman resin (BTL No. L-33) and called 855E₁ (normal amount of aluminum electrode) and 855E₂ (with 2x or double usual amount of aluminum, i.e., about one ohm per square). The Hawthorne Schooping mask with V opening in resultant terminals was used to permit impregnation.

Two groups of 855E₁ capacitors were prepared, one of which was impregnated with PEPB without AQ, and one not impregnated for control measurements. The impregnated capacitors (Fig. 11) show inferior IR's at both 25°C and 85°C compared with the unimpregnated capacitors, Fig. 12, or compared with previous 844E₁ unimpregnated capacitors Figs. 5 and 6.

Having eliminated anthraquinone from the impregnating compound, another test was then made to determine whether the polybutene or the polyethylene component of PEPB previously caused low IR.

Hence four additional groups of 855E₁ and 855E₂ capacitors were prepared and used in the study of four impregnants. The impregnants were low molecular weight grade 6 AC polyethylene alone (Table 4); polybutene No. 32 alone (Table 5); a mixture of polyethylene and polybutene without anthraquinone (Table 6); and biwax (Table 7). The IR and Q of the capacitors in this experiment were measured before impregnation, after impregnation, and after additional life testing.

The capacitors were given 112 hours life at 85°C, 100 VDC except for 65°C, 100 VDC for biwax in order to stay below its softening region. However, the biwax impregnated capacitors unintentionally received 48 hours life at 85°C, 100 VDC as a part of the 112 hours. The IR's stood up better for capacitors in impregnants polyethylene and in polybutene (Tables 4 & 5), than in the mixture of polyethylene with polybutene (PEPB), or in biwax (Tables 6 & 7). The Q's stood up well for all impregnants during this short life test, but were lower in general for biwax (Table 7).

As is apparent in Tables 4-7, the double amount of aluminum did not impair IR's for L-33 resin, but significantly improved Q, and also greatly reduced Q deterioration during life tests. In all cases, the four impregnants apparently injured $Q_{.1KC}$ much more than Q_{1KC} .

Capacitors are being produced from the composite Tennessee Eastman resin (BTL Nos. L-52, L-53, L-55, and L-56) for comparing with those reported above made from similar BTL No. L-33, and with capacitors soon to be made by WECO during the pilot plant run.

Several problems need to be solved:

1. The large spread in BTL test results indicates need for better control of capacitor manufacturing details.
2. A good impregnant which does not excessively lower IR's needs to be found.
3. The capacitors (especially without impregnation) need capacitance stabilization to take full advantage of the very low temperature coefficient of capacitance inherent in the polycarbonate resin.
4. If capacitors are to be used without impregnation, then it needs to be determined if such capacitors will meet all military tests including vibration.
5. The maximum operating voltage and temperature for polycarbonate lacquer film capacitors with or without

impregnation from the composite Tennessee Eastman
resin needs to be established.

W. McMAHON

H. G. WEHE

J. H. HEISS

D. D. KASARDA

MH-2623-WMcM JHH-CK
 HGW DDK

Att.
Tables 1 through 7
Figs. 1 through 12

Copy to
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 W. McMahon - MH
 H. A. Stone - MH
 H. G. Wehe - MH

ENGINEERING TIME

The engineering hours spent on the contract from August 25, 1962, to November 25, 1962, were 336 hours by Western Electric personnel and 1,277 hours by Bell Telephone Laboratories personnel.

PERSONNEL

The engineering personnel assigned to the contract during the fifteenth quarter, and their areas of responsibility, are as follows:

J. B. Rawls

Senior Engineer - Manufacturing processes and electrical evaluation

TABLE 1

Dilute Solution Viscosity and DC Conductivity of
Tennessee Eastman Polycarbonates Type X-6192-28

<u>TE Number</u>	<u>BTL No.</u>	<u>DSV (CHCl₃)</u>	<u>DC Conductivity (5.0 g/100 ml Toluene)</u>
6440-135	L-52	1.218	$0.19 \times 10^{-6} \mu$ mhos/cm
6440-117	L-53	1.167	μ mhos/cm
6440-133	L-54	1.349	1.8 μ mhos/cm
6440-142	L-55	1.384	0.35 μ mhos/cm
6440-143	L-56	1.412	0.05 μ mhos/cm
6440-122	L-57	1.365	4.8 μ mhos/cm
Composite Sample			
6440-135	L-52	1.288	0.11
6440-117	L-53		
6440-142	L-55		
6440-143	L-56		
	L-33	1.295 (calc.)	0.20 (calc.) μ mhos/cm
	L-33	1.278	0.12 μ mhos/cm

TABLE 2

Concentrated Solution Viscosities on Tennessee Eastman
Polycarbonate Type X-6192-28 in Chloroform

<u>TE Number</u>	<u>BTL No.</u>	<u>DSV</u>	<u>Concentrated Solution Viscosity, Poises</u>		
			<u>7.5 g/100 ml</u>	<u>10.0 g/100 ml</u>	<u>15.0 g/100 ml</u>
6440-135	L-52	1.218	0.99	2.93	17.7
6440-117	L-53	1.167	0.89	2.76	14.5
<u>Composite Sample</u>					
6440-135	L-52				
6440-117	L-53	1.288	1.30	3.90	21.6
6440-142	L-55				
6440-143	L-56				
	L-33	1.278	1.14	3.18	24.6

TABLE 3

EFFECT OF IMPREGNATION AFTER LONG-LIFE TESTS (NO BRIDGE CORRECTION)

NO. 844E₁ NOS. 19-24 CAPACITORS (SELF-SUPPORTED, NCW MASK, HEADED LEADS) L-33 POLYCARBONATE

	<u>BEFORE IMPREGNATION</u>					
	<u>CAP.*** NOS.</u>	<u>50 VIR</u>	<u>C_{1KC}</u>	<u>Q_{1KC}</u>	<u>C_{0.1KC}</u>	<u>Q_{0.1KC}</u>
Measured @ 25°C						
after Σ 1500 hrs	19	72,667	.95976UF	649**	.96015	2150**
@ 85°C 100 VDC	20*	8,687	.95076	240**	.95115	1450**
plus Σ 489 hrs	21	130,000	.98184	782**	.98230	2285**
@ 105°C 100 VDC	22	75,600	1.02714	940**	1.02760	2658**
plus Σ 567 hrs	23	80,490	.98715	940**	.98760	2710**
@ 125°C 100 VDC	24*	67,990	.92366	624**	.92419	1920**
(cap. not yet sealed & not yet impregnated)						

	<u>AFTER IMPREGNATION</u>					
Measured @ 25°C						
after above life,	19	108,362	.96095	600	.96146	1948
plus impregnation	21	98,371	.98371	671	.98429	2131
with PEPB (NO AQ),	22	13,619	1.02786	729	1.02841	2153
sealing & reclearing.	23	1,807	.98854	703	.98904	2142

* No. 20 & No. 24 sealed after 1500 hrs LIFE @ 85 C, 100 VDC, plus 347 hrs LIFE @ 105 C 100 VDC, with no significant subsequent effect (not impregnated).

** Q's corrected for 0.08 ohm long leads on these unsealed capacitors.

*** Capacitors kept desiccated during life & during measurements.

TABLE 3 (cont.)

AFTER IMPREGNATION

	<u>CAP.***</u> <u>NOB.</u>	<u>50 VIR</u>	<u>C_{1KC}</u>	<u>Q_{1KC}</u>	<u>C_{0.1KC}</u>	<u>Q_{0.1KC}</u>
Measured @ 25°C 24 hrs later	19	62,101	.96081	584	.96129	2082
	21	65,160	.98356	683	.98409	2131
	22	17,021	1.02771	724	1.02823	2306
	23	1	.98835	459	.98884	120
Measured @ 25°C after Σ 312 hrs Life @ 85°C 100 VDC since impregnation	19	8,047	.97126	427	.97176	1849
	21	10,301	.99076	374	.99126	1729
	22	1,309	1.06388	526	1.03736	2172
	23		(Not placed on life because of low IR.)			
Measured @ 85°C after Σ 312 hrs Life @ 85°C 100 VDC since impregnation	19	1,470	.97081	367	.97141	1326
	21	1,457	.98995	354	.99054	1220
	22	323	1.03559	484	1.03612	1414
Measured @ 85°C after Σ 504 hrs Life @ 85°C, 100 VDC since impregnation	19	2,064	.97372	388	.97448	1224
	21	584	.99061	323	.99140	1132
	22	98	1.03599	450	1.03673	1385
Measured @ 25°C after Σ 504 hrs Life @ 85°C 100 VDC since impregnation	19	7,601	.97459	454	.97505	2041
	21	6,829	.99135	346	.99185	1730
	22	458	1.03725	477	1.03778	2102

*** Capacitors kept desiccated during life & during measurements.

TABLE 4

IMPREGNATION STUDY (IMP NO. 1 AC POLYETHYLENE GRADE 6) FOR CAPACITORS

NO. 855E₁ NOS. 37, 38, & NO. 855E₂ NOS. 1-4 (SELF-SUPPORTED, SCHOOPING 30/70,

HAWTHORNE MASK, BTL FORMED LEADS, MAKROFOL WRAP) L-33 POLYCARBONATE

	Cap. No.	50 VIR	50 VIR	50 VIR	Q _{0.1KC} *	Q _{1KC} *
		Ohm-F	(Ohm-F)	Ohm-F		
		After Clear	Reclear	24 hrs After Reclear		
Measured @ 25°C Before Impreg. (No cans)	855E ₂					
	1	12	48	439	2810	2735
	2	50,100		55,132	3710	3000
	3	7,450	24,800	47,368	3650	2865
	4	47,200		64,828	3860	2810
	855E ₁					
	37	28,800		,683	2860	975
	38	451	454	544	2335	500
	Cap. No.	50 VIR (Ohm-F) Not Reclear	50 VIR (Ohm-F) After Reclear		Q _{0.1KC} *	Q _{1KC} *
Measured @ 25°C After Impreg. (IMP No. 1 AC Polyethylene Grade 6) (No cans)	855E ₂					
	1	20	17		1685	2700
	2	272	61,533		1555	2535
	3	190	57,038		1460	2455
	4	1,746	124,185		1817	2665
	855E ₁					
	37	9,976	10,184		1240	687
	38	193	445		1035	400

* Q's corrected for 0.08 ohm long leads.

TABLE 4 (cont.)

	<u>Cap. No.</u>	<u>50 VIR</u> <u>(Ohm-F)</u>	<u>Q_{0.1KC}*</u>	<u>Q_{1KC}*</u>
Measured @ 25°C After Σ life 112 hrs at 85°C 100 VDC	855E ₂			
	1	4,046	1687	3400
	2	54,359	1540	2550
	3	8,657	1460	2310
	4	31,087	1425	2375
	855E ₁			
	37	1,228	1244	559
	38	14,840	900	314
Measured @ 85°C After Σ life 112 hrs at 85°C 100 VDC	855E ₂			
	1	874	1005	1710
	2	22,906	1000	1630
	3	4,752	886	1484
	4	5,079	1000	1615
	855E ₁			
	37	173	916	457
	38	2,412	713	254

* Q's corrected for 0.08 ohm long leads.

TABLE 5

IMPREGNATION STUDY (IMP NO. 6 POLYBUTENE NO. 32) (NO CANS)

NO. 855E₁, NOS. 39, 40, NO. 855E₂, NOS. 4-8,

SELF-SUPPORTED, SCHOOPING 30/70, HAW, MASK, BTL FORMED LEADS,

MAKROFOL WRAP, L-33 POLYCARBONATE

	<u>Cap. No.</u>	<u>50 VIR (Ohm-F) After Clear</u>	<u>50 VIR (Ohm-F) Reclear</u>	<u>50 VIR (Ohm-F) 24 hrs After Reclear</u>	<u>Q_{0.1KC}</u>	<u>Q_{1KC}</u>
	855E ₂					
Measured @ 25°C Before Impreg. (No cans)	5	86,500		64,866	4080	2550
	6	66,800		59,400	4000	2320
	7	164	265	312	3970	2620
	8	309	404	526	3910	2650
	855E ₁					
	39	44,000		52,829	2750	707
	40	3,010	3,002	3,645	2870	1060
		<u>50 VIR (Ohm-F) Not Recleared</u>	<u>50 VIR (Ohm-F) After Reclear</u>		<u>Q_{0.1KC}*</u>	<u>Q_{1KC}</u>
Measured @ 25°C After Impreg.	5	70,324	70,324		1437	2270
	6	63,070	56,763		1850	2055
	7	2	57		1855	2290
	8	19	114		1452	2350
	39	43,900			1200	332
	40	798	576		1174	439
		<u>50 VIR (Ohm-F)</u>			<u>Q_{0.1KC}*</u>	<u>Q_{1KC}*</u>
Measured @ 25°C After Σ Life 112 hrs at 85°C 100 VDC	5	33,724			1207	1882
	6	17,064			1223	1640
	7	61			1493	1870
	8	683			1227	2020
	39	10,612			908	336
	40	270			1012	401

*Q's corrected for 0.08 ohm long leads.

TABLE 5 (cont.)

- 2 -

	Cap. Nos.	50 VIR (Ohm-F)	<u>Q_{0.1KC}*</u>	<u>Q_{1KC}*</u>
Measured @ 85°C	5	6,344	887	1316
After Σ Life	6	14,486	903	1160
112 hrs at 85°C	7	61	904	1290
100 VDC	8	722	900	1377
	39	1,616	650	302
	40	56	694	351

*Q's corrected for 0.08 ohm long leads.

TABLE 6

IMPREGNATION STUDY (IMP NO. 5 PEPB NO AQ) (NO CANS)NO. 855E₂, NOS. 9-12, NO. 855E₁, NOS. 41, 42SELF-SUPPORTED, SCHOOPING 30/70, HAW. MASK, BTL FORMED LEADS,MAKROFOL WRAP, L-33 POLYCARBONATE

Cap. No.	50 VIR	50 VIR	50 VIR	Q _{0.1KC}	Q _{1KC}
	(Ohm-F)	(Ohm-F)	(Ohm-F)		
	After Clearing	Reclear	24 hrs After Reclear		
855E ₂					
9	1,265	1,328	1,398	3990	2420
10	1,865	3,598	2,518	3950	2620
11	16	1,470	18	3970	2730
12	52,500		65,555	4170	2790
855E ₁					
41	46,000		50,646	2840	957
42	5,500	5,541	5,098	2610	806
	50 VIR	50 VIR		Q _{0.1KC} *	Q _{1KC} *
	(Ohm-F)	(Ohm-F)			
	Not Recleared	After Reclear			
9	706	672		1445	2210
10	750	740		1715	2310
11	28	12		1432	2490
12	1	2,298		1965	2435
41	38,826			1137	597
42	1,874	4,181		1137	519
	50 VIR			Q _{0.1KC} *	Q _{1KC} *
	(Ohm-F)				
9	385			1217	1980
10	565			1541	2002
11	22			1465	2105
12	1,063			1610	2120
41	1,116			1169	588
42	1,216			1425	692

*Q's corrected for 0.08 ohm long leads.

TABLE 6 (cont.)

- 2 -

	<u>50 VIR</u> <u>(Ohm-F)</u>		<u>Q_{0.1KC}*</u>	<u>Q_{1KC}*</u>
Measured @ 85°C	9	92	900	1358
After Σ Life	10	246	1133	1427
112 hrs @ 85°C	11	41	1023	1325
100 VDC	12	403	1007	1385
	41	743	764	417
	42	186	765	379

*Q's corrected for 0.08 ohm long leads.

TABLE 7

IMPREGNATION STUDY (IMP NO. 3 BIWAX) CAP. IN CANS NOT SEALED NO. 855E₁, NOS. 21-26

PAPER CORE AND COVER, SCHOOPING 30/70, HAW. MASK, BTL FORGED LEADS,

L-33 WRAP, L-33 POLYCARBONATE

	855E ₁ Cap. Nos.	50 VIR	50 VIR	50 VIR	Q _{0.1KC} *	Q _{1KC} *	50 VIR	50 VIR
		(Ohm-F)	(Ohm-F)	(Ohm-F)			(Ohm-F)	
		After	Reclear	24 hrs			Flushed	4 hrs after
		Clearing		After			With Dry	Oxy. Ten
				Reclear			Oxy. Ten	Times &
							Reclear	4 hrs after
								Oxy. Flush
Measured @ 25°C	21	952	621	733	3025	1310	1,190	1,329
Before Impreg.	22	80	77	96	2950	1457	103	135
In cans,	23	55,000		55,091	2890	1575	55,091	61,212
not sealed	24	8,070	8,769	9,591	2800	1097	7,218	9,022
	25	1,065	11,760	1,201	2980	1117	1,045	1,065
	26	24	24	31	2670	1145	39	42

	855E ₁ Cap Nos.	50 VIR	50 VIR	Q _{0.1KC} *	Q _{1KC} *
		(Ohm-F)	(Ohm-F)		
		Not	After		
		Recleared	Reclear		
	21	302	37,362	1150	1350
	22	3,418	890	1396	1723
Measured @ 25°C	23	77,207		1310	1853
After Impreg.	24	4,499	3,552	1460	1460
	25	24	1,566	1338	1308
	26	1,093	937	913	240

	855E ₁ Cap. Nos.	50 VIR	Q _{0.1KC} *	Q _{1KC} *
		(Ohm-F)		
Measured @ 25°C	21	2,121	1245	1245
After Σ Life	22	767	1400	1350
112 hrs (48 hrs at	23	1,165	1315	1507
85°C 100 VDC + 64 hrs	24	1,827	1237	996
at 65°C 100 VDC)	25	661	1135	901
	26	548	618	102
Measured @ 65°C	21	1,400	1137	1034
After Σ Life	22	391	1171	1364
112 hrs (48 hrs at	23	816	1194	1373
85°C 100 VDC + 64 hrs	24	1,676	995	898
at 65°C 100 VDC)	25	377	1045	758
	26	163	735	154

*Q's corrected for 0.08 ohm long leads.

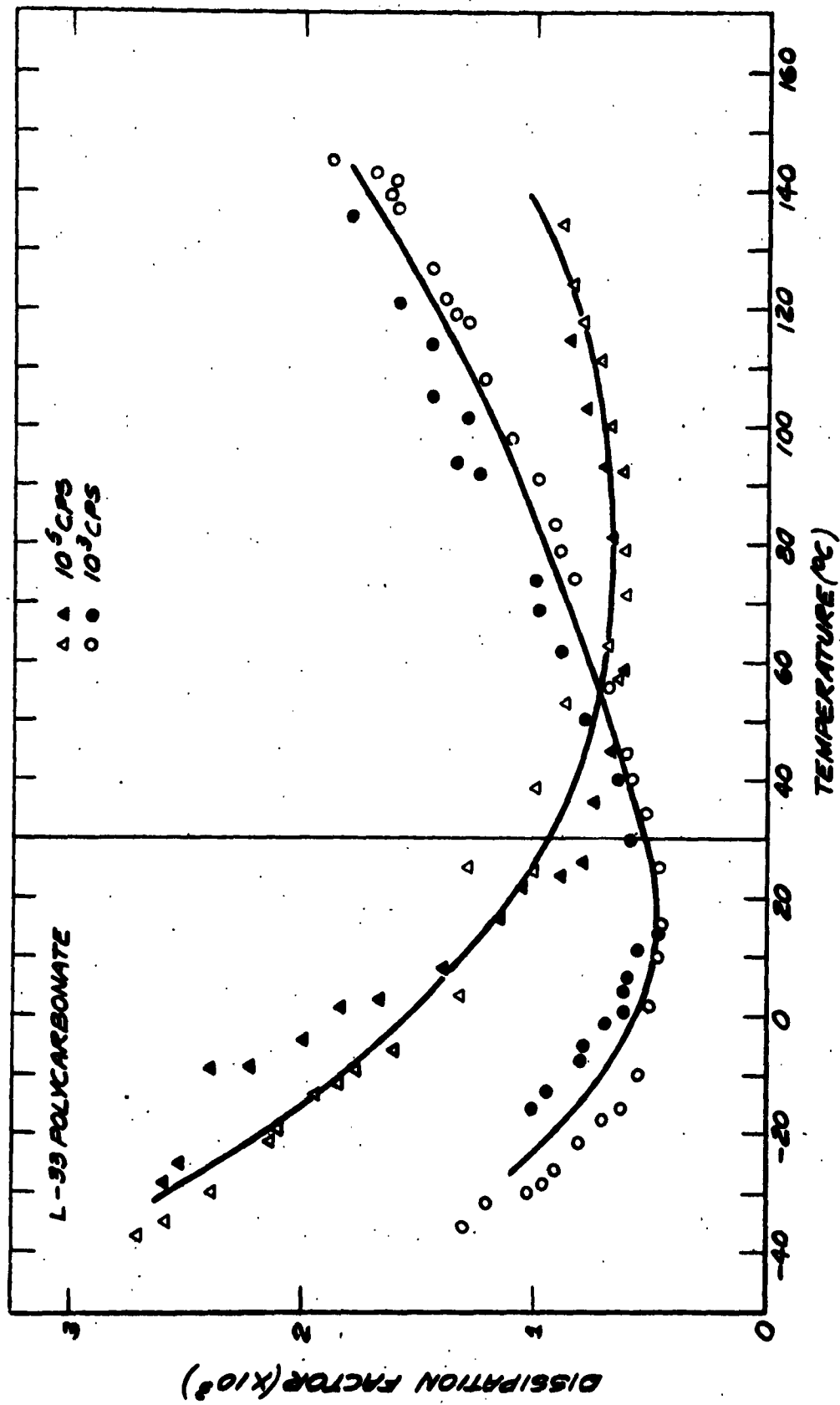


FIGURE 1. DISSIPATION FACTOR VS TEMPERATURE FOR L-33 POLYCARBONATE

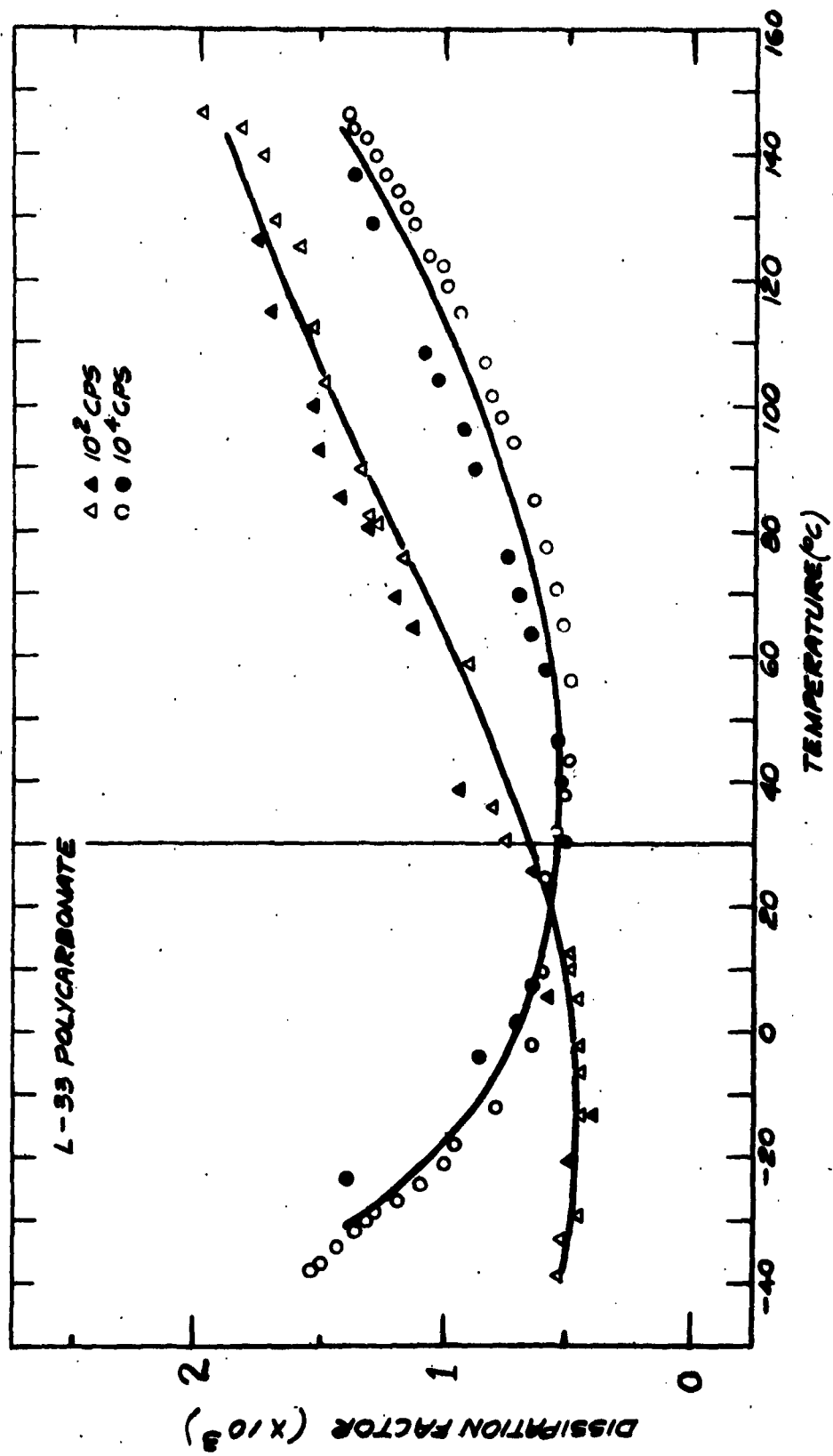


FIGURE 2. DISSIPATION FACTOR VS TEMPERATURE FOR L-33 POLYCARBONATE

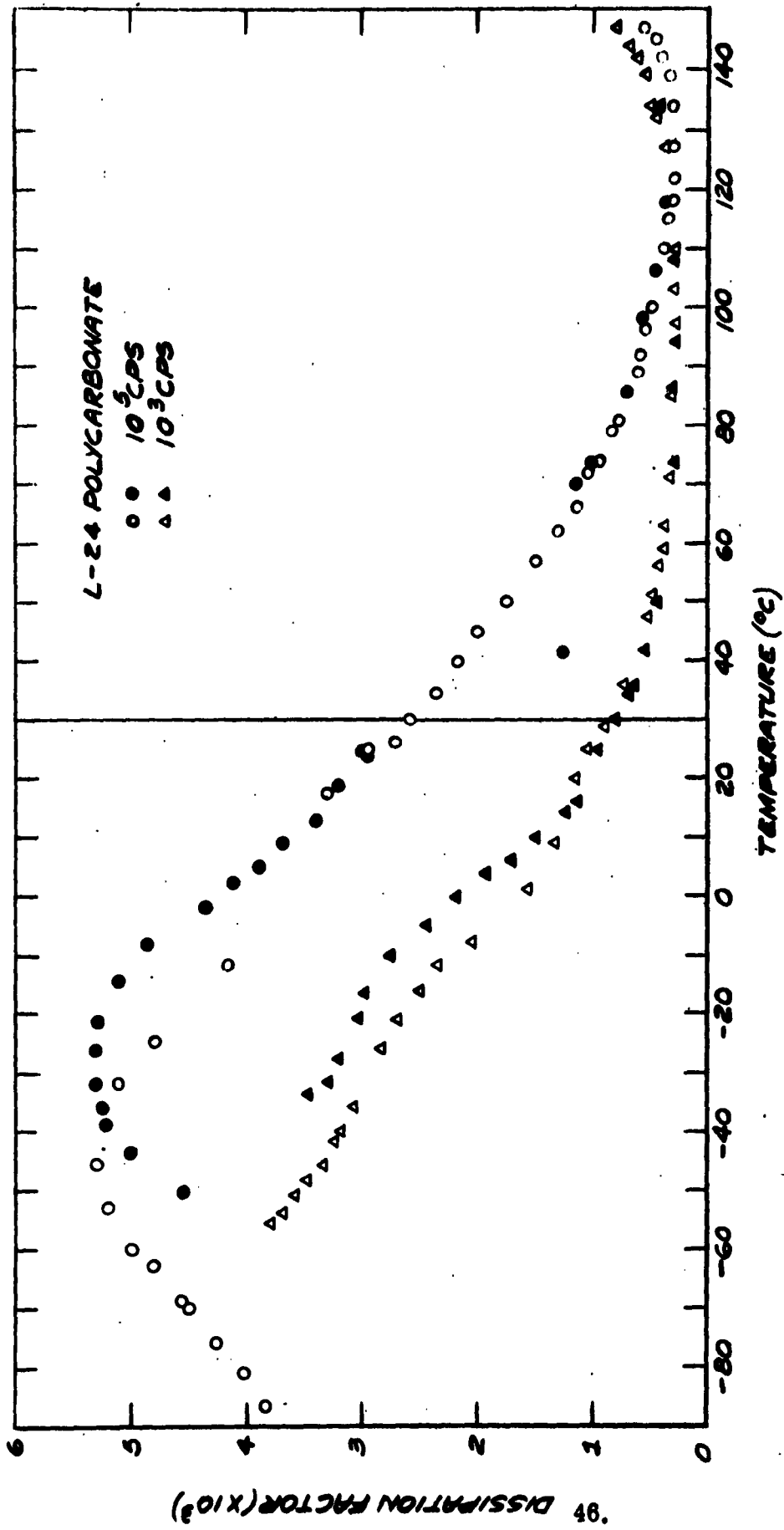


FIGURE 3. DISSIPATION FACTOR AS A FUNCTION OF TEMPERATURE
FOR L-24 POLYCARBONATE

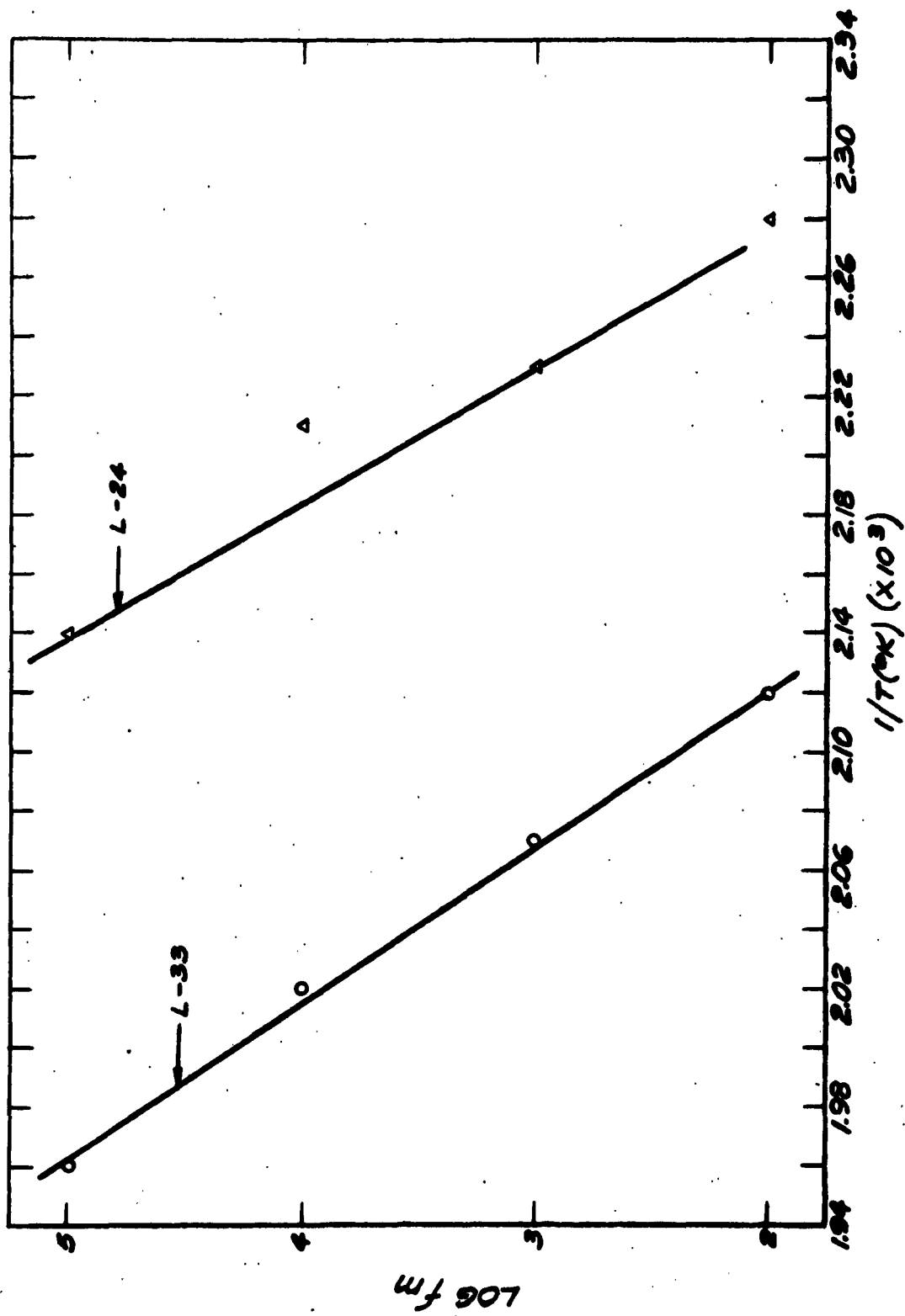
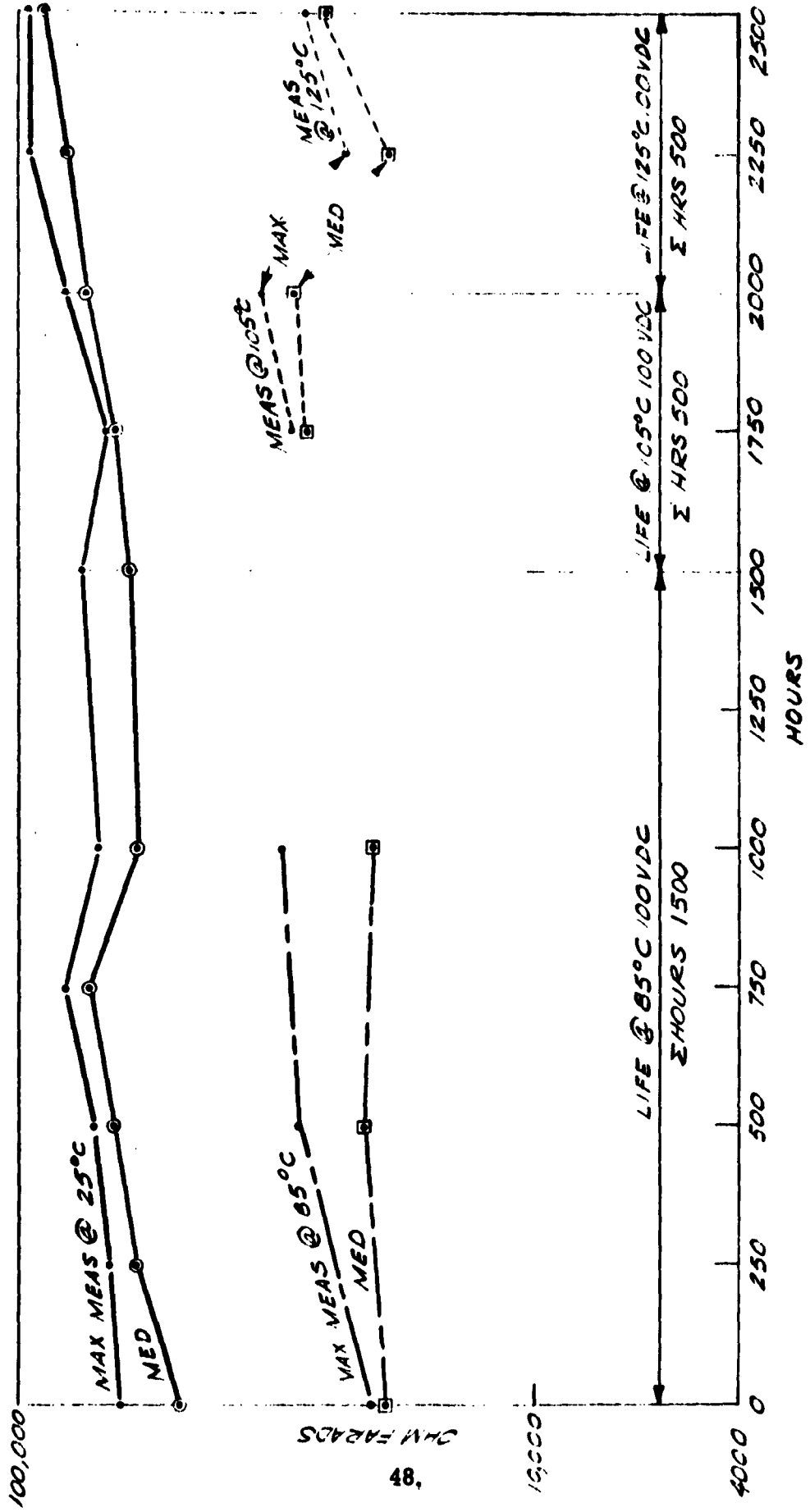


FIGURE 4. PLOT OF LOG f_m VS $1/T$ FOR THE HIGH TEMPERATURE ABSORPTION PROCESS IN POLYCARBONATES

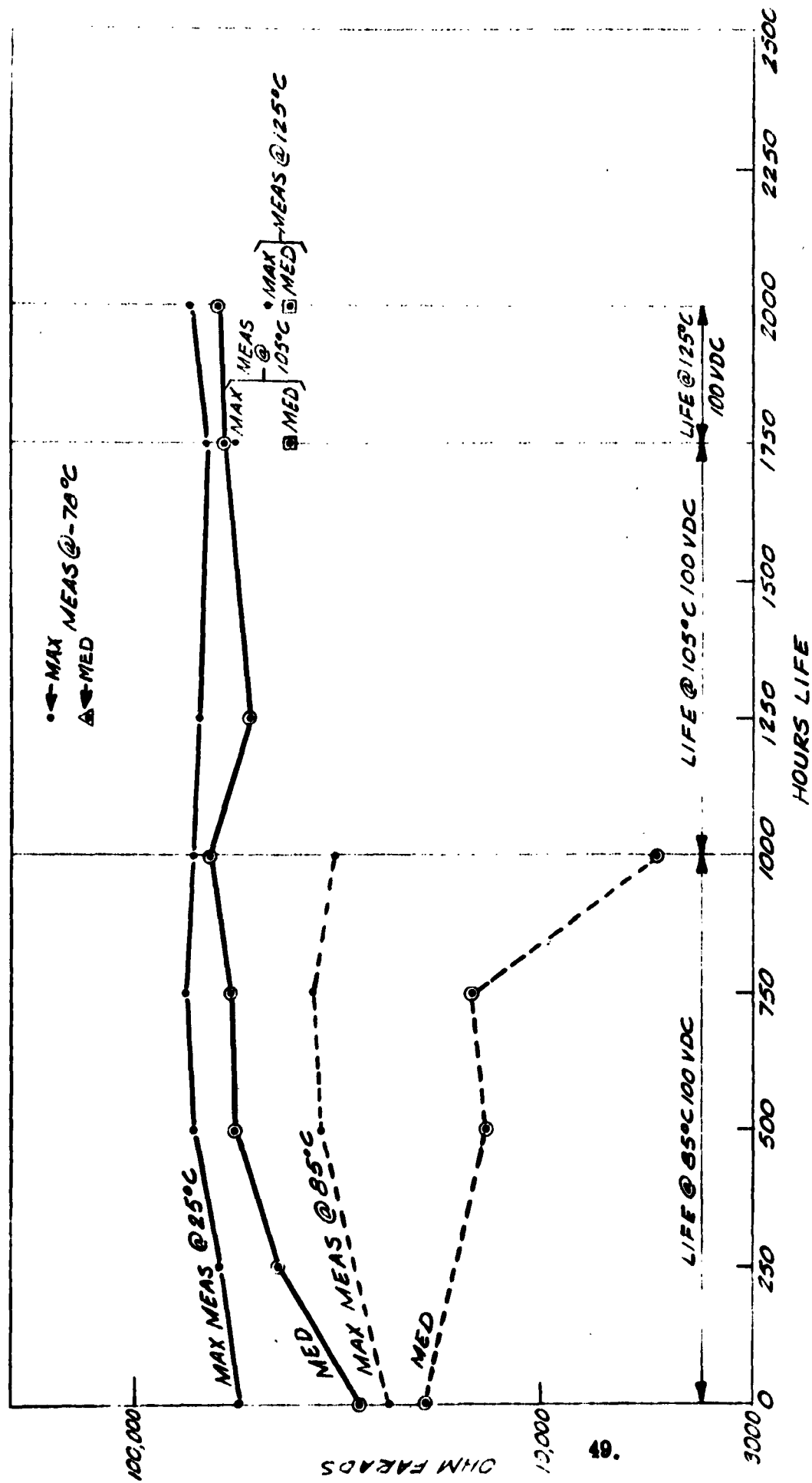


HOURS

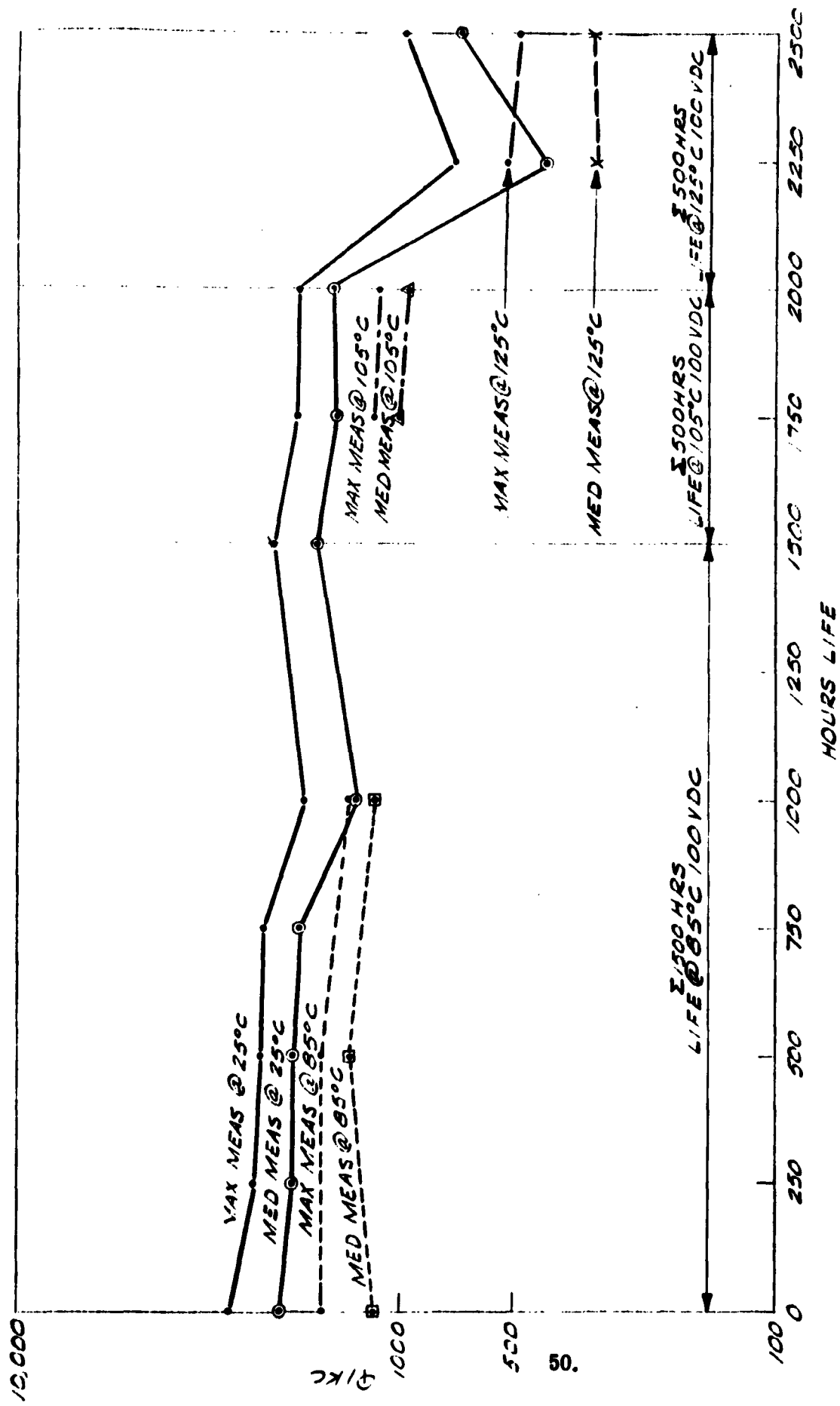
50 VIR

NC. 844E, NO. 7-12, L-33, PAPER CORE AND COVER, NOT IMPREGNATED, NOT SEALED, NCW MASK, HEADED LEADS

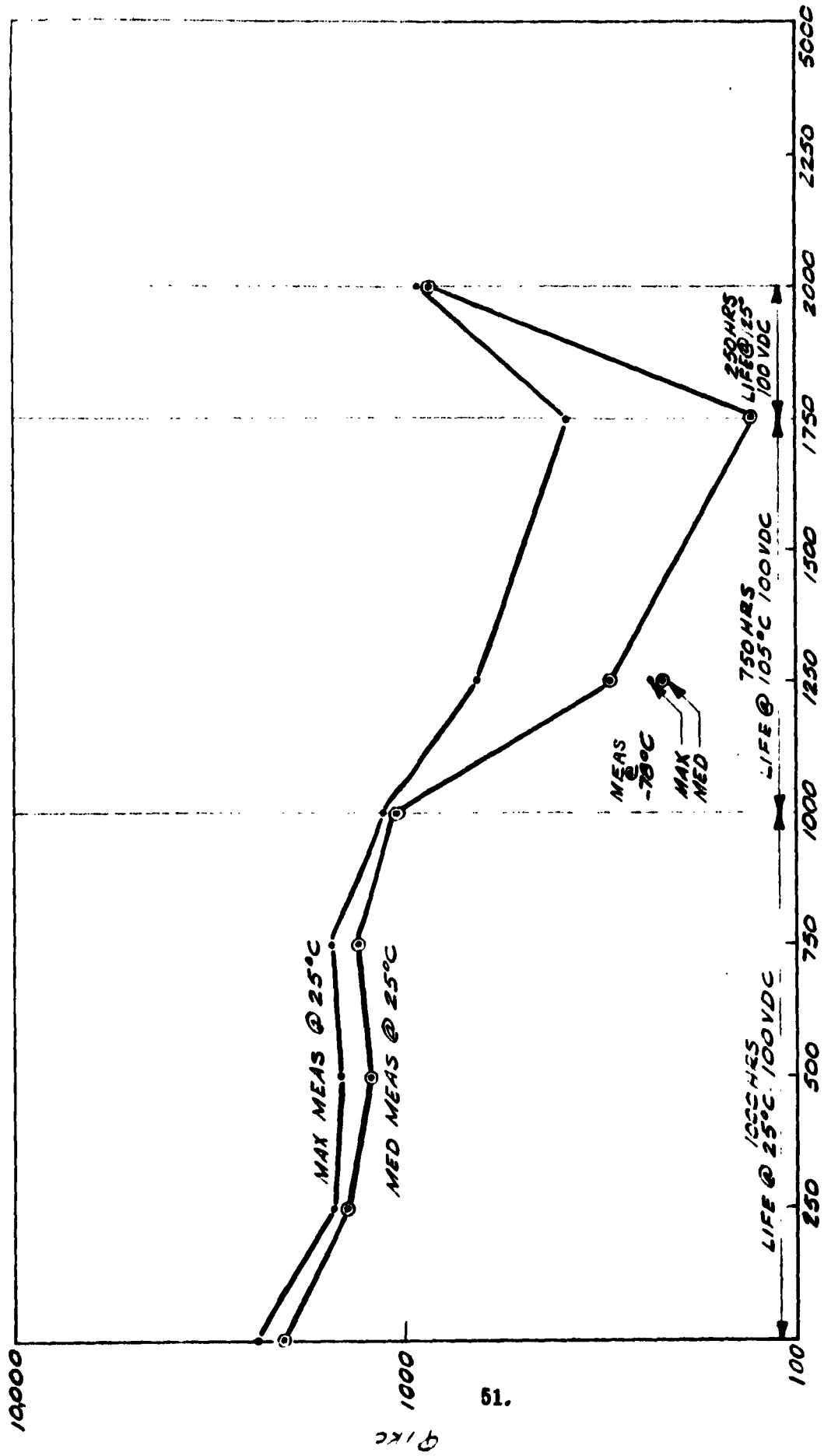
FIG. 5



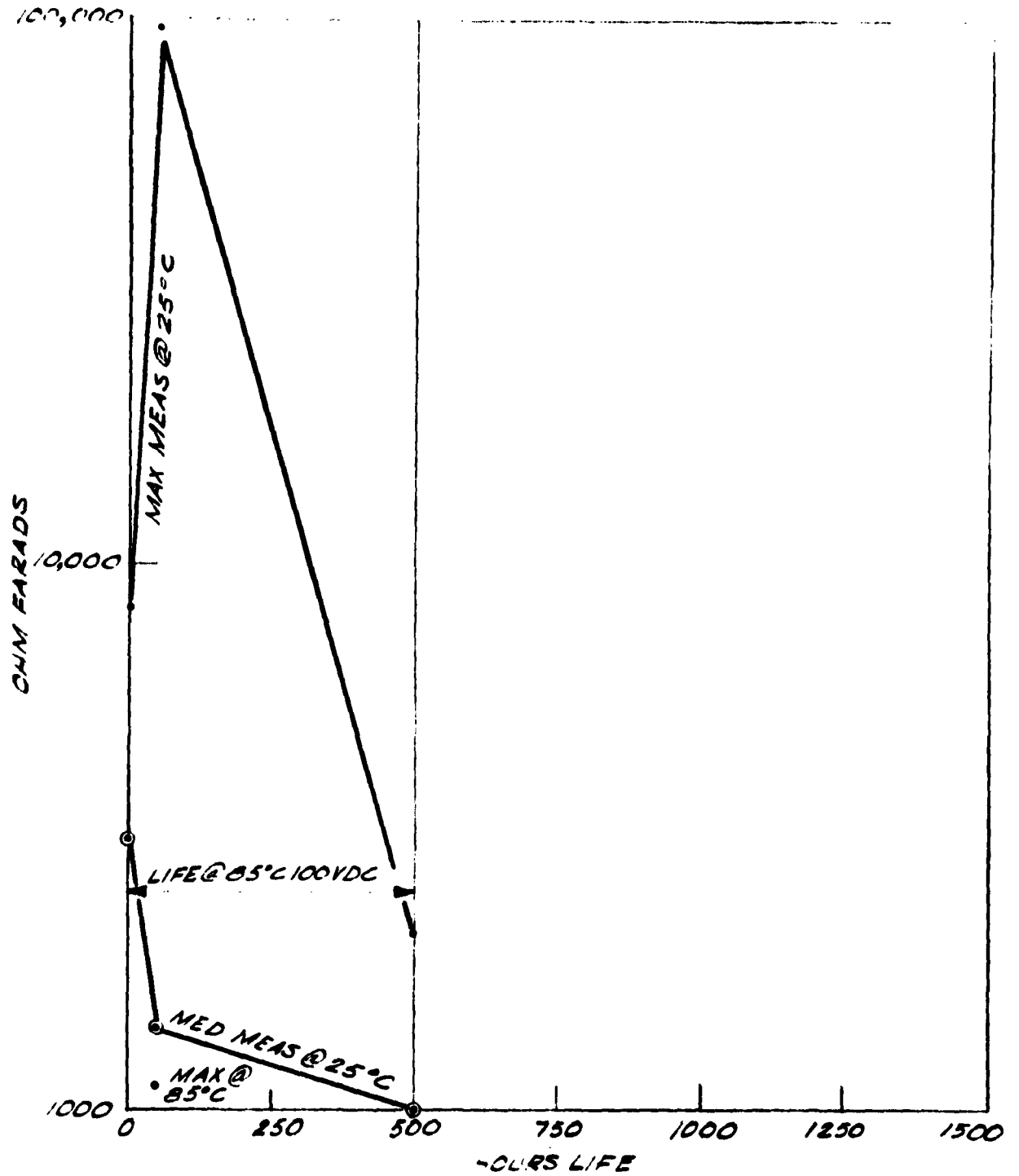
50 VIR
 NO. 844E, NO. 13-18 L-33 SELF SUPPORTED, NOT
 IMPREGNATED, SEALED, NCW MASK, HEADED LEADS
 FIG. 6



Q/KC
 NO. 844E, NO. 7-12, L-33, PAPER CORE AND COVER, NOT
 IMPREGNATED, NOT SEALED, NEW MASK, HEADED LEADS
 FIG. 7

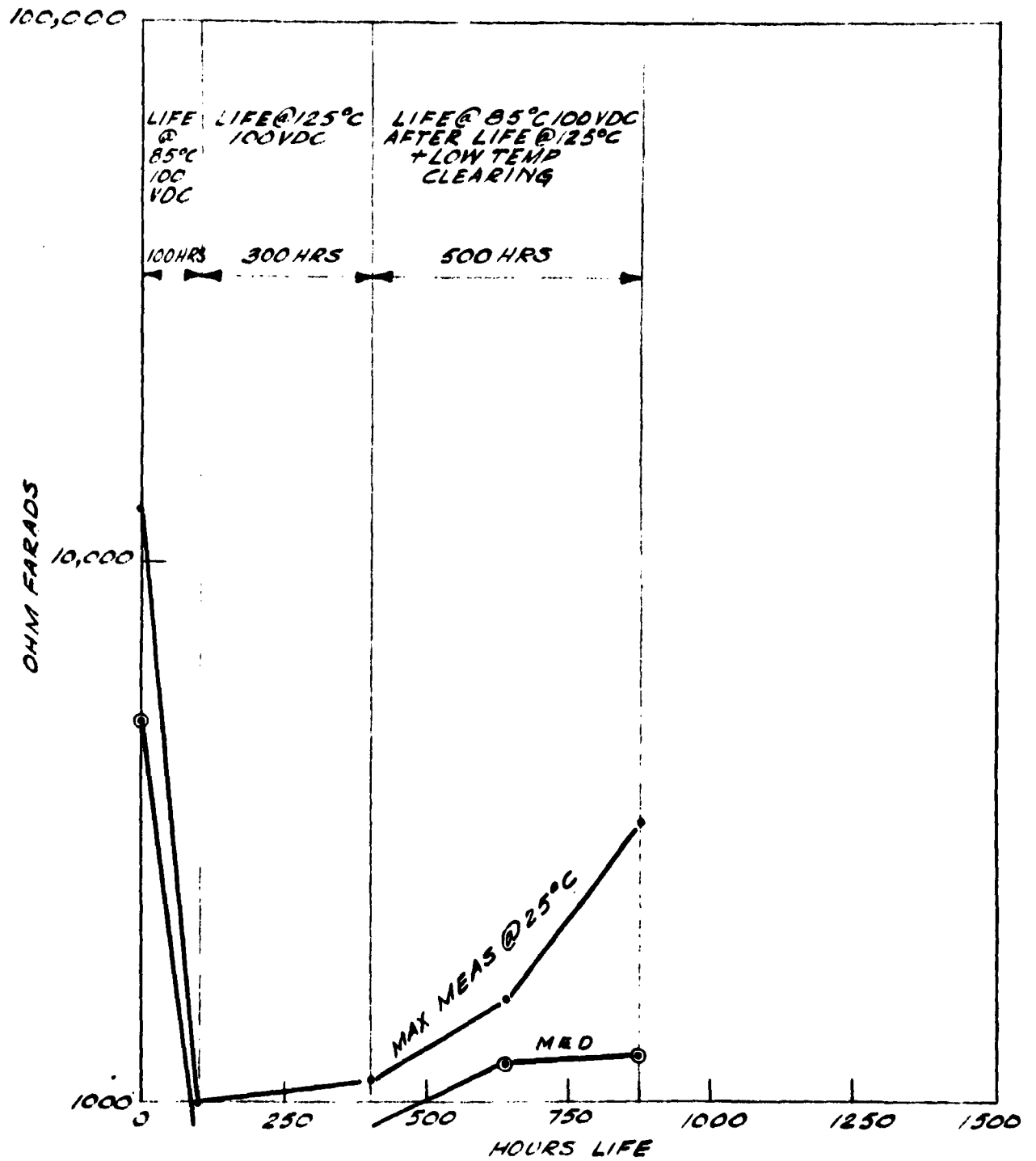


Q/KC
 NO. 8445, NO. 13-18, L-33, SELF SUPPORTED, NOT
 IMPREGNATED, SEALED, NCW MASK - HEADED LEADS
 FIG. 8

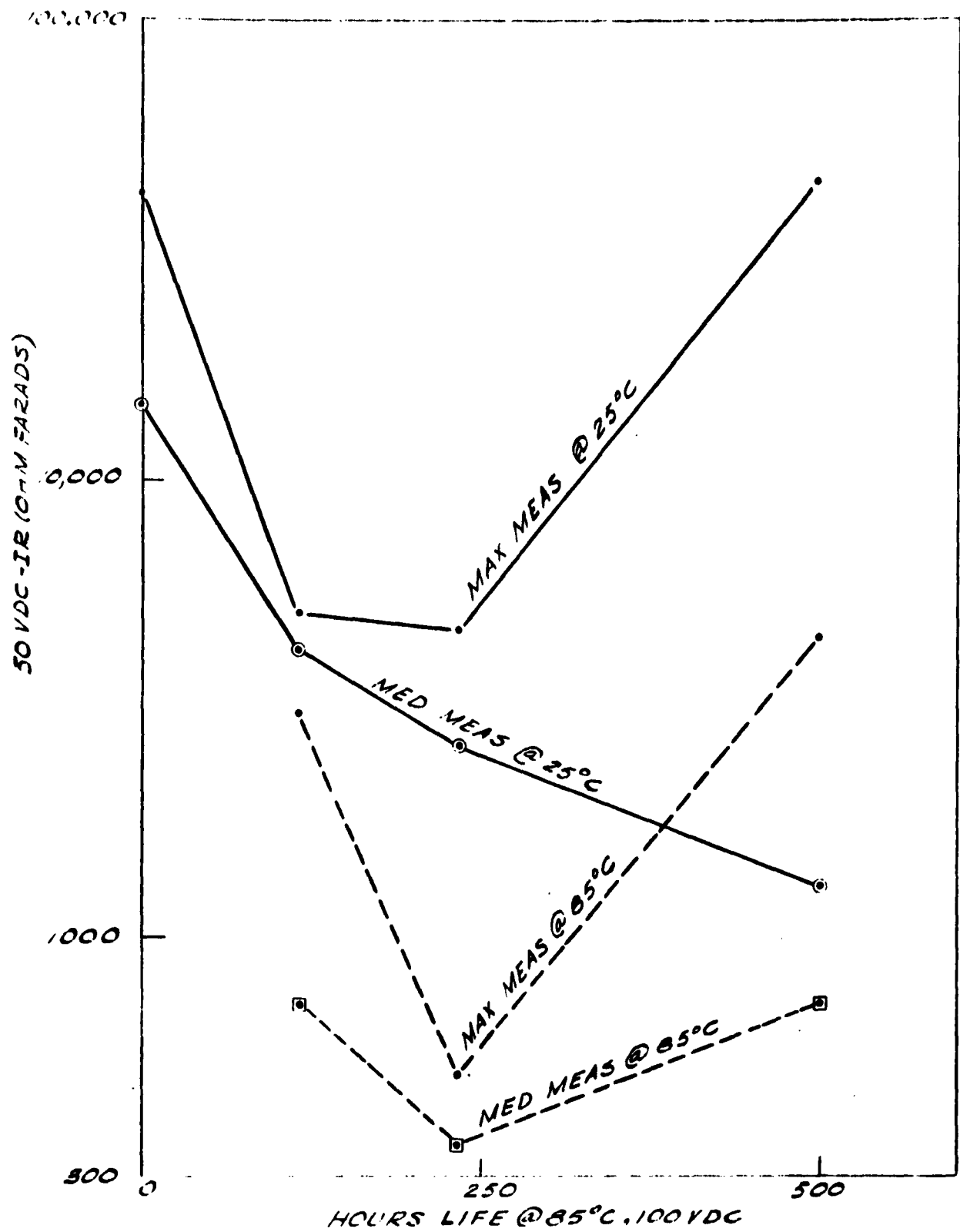


50 VIR
 MEASURED @ 25°C AND 85°C, NO. 844E, NO. 43-48, L-33, PAPER
 CORE AND COVER, IMPREGNATED PEPB + AQ, SEALED, HAW.
 MASK, BTL LEADS

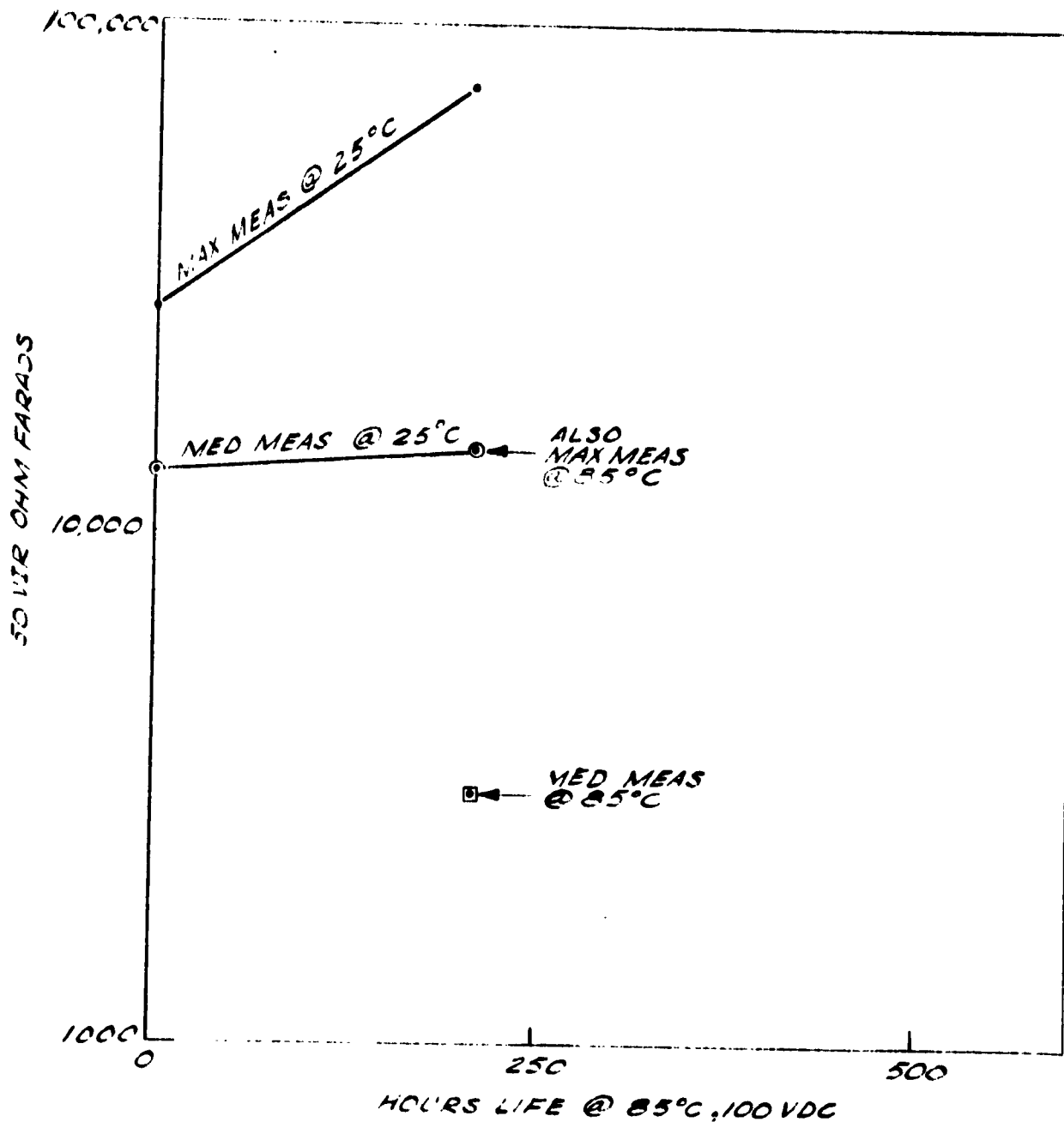
FIG. 9



50 VIR
 MEASURED @ 25°C, NO. 844E, NO. 61-66, L-33, SELF-SUPPORTED, IMPREGNATED PEPB+AQ, SEALED, HAW. MASK, BTL LEADS
 FIG. 10

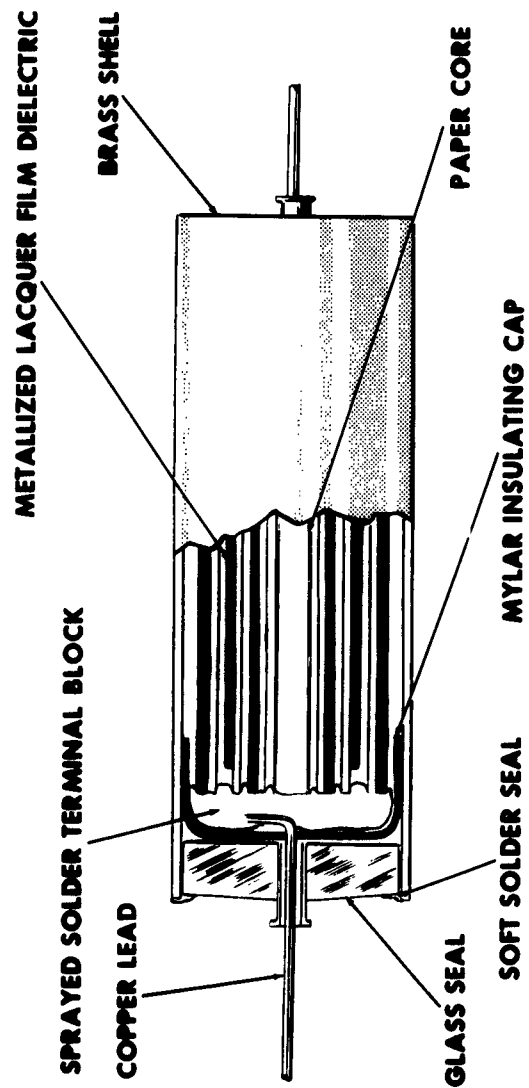


50 VIR
 NO. 855E, NO. 1-6, L-35. PEPB-NO AG, HAW. VASK,
 BTL LEADS, SEALED (SELF-SUPPORTED)
 FIG. 11



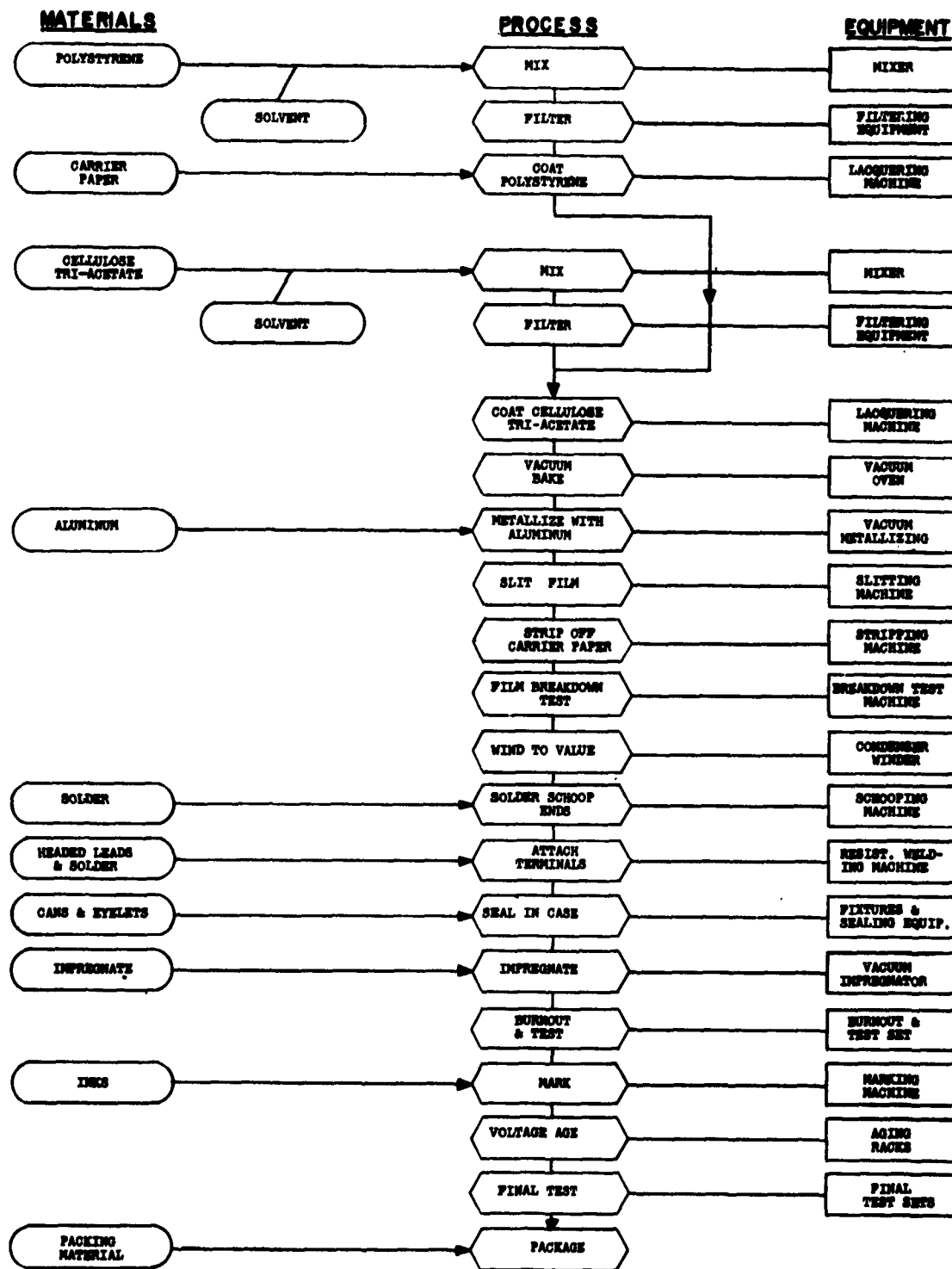
50 VIR
 NO. 654 E, NO. 13, 14, 19, 20 L-33, PAPER CORE AND COVER,
 HAW MASK-BTL LEADS, SEALED, NOT IMPREGNATED
 (NO. 15-18 USED FOR EXHIBITS)

FIG. 12



LACQUER-FILM CAPACITORS

PROCESS FLOW



LACQUER FILM CAPACITOR

PROCESS FLOW MANUFACTURING DEVELOPMENT

