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402703
VIA
CAPACITORS

**RESEARCH AND DEVELOPMENT PROGRAM
INTRINSIC RELIABILITY
SUBMINIATURE CERAMIC CAPACITORS**

THIRD QUARTERLY PROGRESS REPORT

PERIOD: 1 DECEMBER 1962 - 28 FEBRUARY 1963

TO

**U. S. ARMY SIGNAL RESEARCH & DEVELOPMENT LABORATORY
FORT MONMOUTH, NEW JERSEY**

CONTRACT NO. DA-36-039-SC-90705

D. A. PROJECT NO. 3A99-15-001

**SPRAGUE ELECTRIC COMPANY
NORTH ADAMS, MASSACHUSETTS**

NO. 1

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RESEARCH AND DEVELOPMENT PROGRAM
INTRINSIC RELIABILITY
SUBMINIATURE CERAMIC CAPACITORS

Third Quarterly Progress Report

Period: 1 December 1962 - 28 February 1963

Object of Study: To conduct investigations leading to the approaches for the attainment of high reliability in subminiature ceramic capacitors and the determination of failure rate as a function of voltage and temperature.

Contract No. DA-36-039-SC-90705
D. A. Project No. 3A99-15-001

Controlling Specifications:
Signal Corps Technical Guidelines, "Reliability Long Life
Component Studies," 1 November 1961
Signal Corps Technical Requirements No. SCL-2101N,
14 July 1961

Report Prepared by

E. E. Prokopowicz
W. A. Tatem
L. H. D. Folster

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SECTION I

PURPOSE

The purpose of this contract is to carry out research work for a period of 18 months commencing June 1, 1962, and ending November 30, 1963, involving investigations leading to approaches to the attainment of high reliability in subminiature ceramic capacitors and the determination of failure rate as a function of voltage and temperature.

In particular, this involves the following:

- (1) Establishment of Matrix I test conditions through a series of pre-matrix tests.
- (2) Development and evaluation of a short-term test to eliminate early failures effectively without shortening the time to the wearout mode of failure.
- (3) A determination of the failure rate as a function of voltage and temperature through Matrix I and Matrix II testing. From the data thus obtained, derating curves will be derived and overall failure rates for operating conditions will be estimated.
- (4) Compilation of quarterly progress reports in accordance with Signal Corps Technical Requirements No. SCL-2101N, dated 14 July 1961.
- (5) Compilation of a final report in accordance with Signal Corps Technical Requirements No. SCL-2101N, dated 14 July 1961.

SECTION 2

ABSTRACT

Current-voltage relations as functions of time and temperature are presented for C67 Case Size I Monolythic[®] capacitors. A study of possible means of predicting the capacitor life is reported. No correlation has been found between charge and discharge currents measured before life test and time-to-failure on life test. Also, no correlation has been found between AC corona starting voltage and time-to-failure. It appears the only technique now available for the elimination of potential early failures is a measurement of leakage resistance after accelerated testing. Study is continuing.

SECTION 3

PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

The Second Quarterly Progress Report, covering the period 1 September 1962 - 30 November 1962, was submitted for U. S. Army Electronics Research and Development Agency approval during this quarter. Approval was received, and the report was distributed per USAERDA instructions.

SECTION 4

FACTUAL DATA

4.1 General

During the third quarter attention was directed primarily toward examining charge and discharge currents of C67 Case Size I Monolythic capacitors. Attempts were made to correlate charge and discharge currents measured before life test and time-to-failure on life test but were unsuccessful. Likewise, no correlation was found between AC corona starting voltage and time-to-failure. It appears the only technique now available for the elimination of potential early failures is a measurement of leakage resistance after testing for a number of hours at accelerated voltage and temperature.

4.2 Charge and Discharge Currents

After the voltage is removed from a capacitor, a current flows in a direction opposite the direction in which it flows during voltage application. The charge or polarization current and the discharge or depolarization current have been measured as functions of applied voltage, temperature, and time for C67 Case Size I Monolythic capacitors. The discharge time and the magnitude of the discharge current indicate a considerable amount of charge remains trapped in the ceramic after removal of the charging field.

The C67 Case Size I Monolythic capacitor utilizes a barium titanate ceramic having a dielectric constant of 2000. The thickness of each dielectric layer is 0.0025 in. The ceramic capacitor is enclosed in a molded cylindrical case of 0.095 in. diameter and 0.250 in. length.

The circuit used for measurement of charge and discharge currents is shown in Figure 1, which, with all figures mentioned herein, is found at the end of this section. After charging the capacitor the power supply is replaced by a short circuit. The Ekco 1079C vibrating reed electrometer permits the resistor in series with the test capacitor to be changed so that

an extremely wide range of currents can be covered. The largest resistor used in series with the test capacitor was 10^{12} ohms. Most of the data were obtained using resistors of 10^8 and 10^{10} ohms.

Figure 2 presents a discharge current curve for a C67 Case Size I Monolithic capacitor near room temperature. This curve was obtained in the following manner: After 15 min of discharge, the discharge circuit was opened for 1 hr, then closed again. At this point the discharge current was greater than when the discharge circuit was first opened. Further, after an additional 13 min of discharge the discharge current reached a magnitude and time rate of change that would have been expected had the circuit not been opened. This behavior suggests that charge carrier traps of various depths exist in the material. It is theorized that during the open circuit condition some of the charges move from deep traps to traps which are more shallow. Also, it is evident the resistance of the ceramic is extremely high at discharge and open-circuit conditions.

Figure 3 presents charge current as a function of time at 150°C for C67 Case Size I Monolithic capacitors. A fresh capacitor was used for each voltage stress to avoid current complications which might result from stressing one capacitor repeatedly. After 15 min of charging the currents showed very little indication of stabilizing except at the highest voltage stress. The charge current data are replotted as a function of charge potential in Figure 4.

One interesting point is that over most of the range the charge current at any time is proportional to the charging potential. At approximately 25 VDC/mil the charging current appears proportional to some power of charging potential higher than one. When the same capacitor is used for all voltages, from the smallest to the largest, no current anomaly is found in the range, 18 VDC/mil to 36 VDC/mil, as can be seen in Figure 5. The current anomaly shown in Figure 4 cannot yet be dismissed as spurious, since the literature¹ contains examples of the use of normalizing voltages before current measurements, though not in exactly the same situation.

The data presented in Figures 4 and 5 describe transient charge currents. The current-voltage relations suggest an ohmic behavior for the capacitors, but the data do not validate such a conclusion. Steady-state conditions are necessary to determine if the current-voltage relation is

¹ Cardon, F., "Polarization and Space-Charge-Limited Currents in Rutile," *Physica*, 27:841-9 (1961).

ohmic or space-charge-limited. The work of Branwood and Tredgold² indicates the current-voltage relation for barium titanate single crystals is space-charge-limited.

Following charging the capacitors described in Figure 3 were discharged. The discharge current as a function of time for these capacitors is shown in Figure 6. The discharge current at various times as a function of applied potential for the same capacitors is presented in Figure 7. The value of discharge current after a particular discharge time is proportional to the charging voltage. It is noteworthy that no current anomaly occurs in the voltage range, 18 VDC/mil to 36 VDC/mil. This is in contrast to Figure 4. Figure 7 suggests some mechanism is limiting the discharge currents when the capacitors are initially charged at voltage stresses greater than 70 VDC/mil.

Figure 8 presents the relationship between charging current and temperature. To obtain these data, the same capacitor was used for all temperatures. Since the charge current at each temperature changes quickly with time, these data cannot be used to calculate the activation energy for conduction. The pseudo activation energy for conduction over much of the temperature range is 0.24 electron volts (ev).

An attempt was made to determine the steady-state resistance-temperature relationship for a fresh capacitor. The results are presented in Figure 9. To obtain these data, the capacitor was charged at 150°C until the charging current no longer decreased with time but achieved a steady value. The temperature was then lowered while voltage was kept on the unit, and the steady-state charging current was recorded for each temperature. The resistance-temperature relationship is complex and cannot be described by one value of activation energy for conduction. The data suggest two activation energies: 0.34 ev below 115°C and 1.7 ev above 115°C. The titanate ceramic dielectric material has a slight permittivity maximum at approximately 115°C. Above 115°C the permittivity decreases in a manner similar to the way in which barium titanate decreases above the Curie temperature.

The capacitor was charged at each temperature for which charging data are presented in Figure 8, then discharged. The discharge current curves are presented in Figure 10.

Figure 11 presents charge and discharge current curves for a capacitor which had been life tested previously at 150°C and 75 VDC/mil for 1600 hr. During the life test the resistance of the unit decreased

²Branwood, A., Tredgold, R., "The Electrical Conductivity of Barium Titanate Single Crystals," Proceedings of the Physical Society, 76:93-98 (1960).

approximately four orders of magnitude. The degraded capacitor was charged for 15 min at 100°C and 225 VDC in the same direction as during life testing, then discharged. The corresponding charge and discharge curves for this operation are labeled (+) on the figure. Following discharge the capacitor was charged in the direction opposite the charging direction during life testing, then discharged. The corresponding charge and discharge curves for this operation are labeled (-) in the figure. It will be observed that the discharge curves are approximately one order of magnitude apart. For comparison, a fresh capacitor was charged in one direction and discharged, then charged in the opposite direction and discharged. The resulting discharge curves are within 20% of one another, as can be seen in Figure 12. The data suggest that ionic migration resulting from life testing leads to charge carrier traps of different average depth in the proximity of each electrode. This hypothesis assumes that release of trapped charges is effected by thermal energy.

The magnitude of the discharge or depolarization currents observed for the C67 Monolithic capacitor raises the question of their origin. It is not known whether these currents are primarily related to the polycrystalline form of the material, with its attendant defects such as grain boundaries and closed pores, or whether they are related primarily to the bulk or surface characteristics of the crystal structure itself. It appears the polycrystalline form is of secondary importance in determining the occurrence of the discharge currents. Figures 13 and 14 present discharging currents of barium titanate single crystals prepared by the Remeika³ technique. These currents are approximately 100 times greater than the discharge currents of a C67 capacitor under comparable conditions of charging. The discharge currents are presented in Figure 15. While the chemical composition of the single crystals differs from that of the ceramic they are both essentially barium titanate, and it can be tentatively concluded that the discharge currents of the C67 material are not a consequence of its polycrystalline form.

4.3 Lifetime Indicators for C67 Case Size I Monolithic Capacitors

Recent work at Linden Laboratories, Inc.,⁴ indicates there is a correlation between discharge current and the stability of titania ceramic capacitors on life test. Experiments were conducted by Sprague in an effort to determine if a correlation exists between charge or discharge

³Remeika, J., "A Method for Growing Barium Titanate Single Crystals." J. Amer. Chem. Soc., 76:940 (1954).

⁴Linden Laboratories, Inc., "Crystal Chemistry of Ceramic Dielectrics," Report No. 15, July 15, 1962, Contract No. DA-36-039-SC-78912.

currents and time-to-failure on life test for C67 Case Size I Monolithic capacitors. Life testing was at accelerated conditions of 150°C, 190 VDC (75 VDC/mil). A capacitor was defined a failure when its resistance dropped below 100 megohms at test conditions. A resistance of 100 megohms at 150°C is a decrease of approximately three orders of magnitude from the resistance of a new unit. A resistance change of this magnitude indicates the capacitor is wearing out although, as will be seen from subsequent data, a capacitor of this type may go on for many additional hours before its resistance drops to a level which makes it unusable in many circuits.

Figure 16 presents the relationship between charging current and time-to-failure for 23 capacitors. The relationships of time-to-failure and other measurements are presented in Figures 17 and 18. No correlations exist within the rather narrow range of failure times for the 6000 μ f capacitors. Figure 19 presents the relationship between electrical resistance after 50 hr and time-to-failure on life test. While it is evident that the relative lifetimes of the capacitors can be estimated after life testing has been underway for a time, the data reveal the lifetime estimate for some capacitors could be in considerable error. Figure 20 presents the resistance as a function of time during life testing for several capacitors. In the early stages of life testing the capacitors behave similarly but later they diverge.

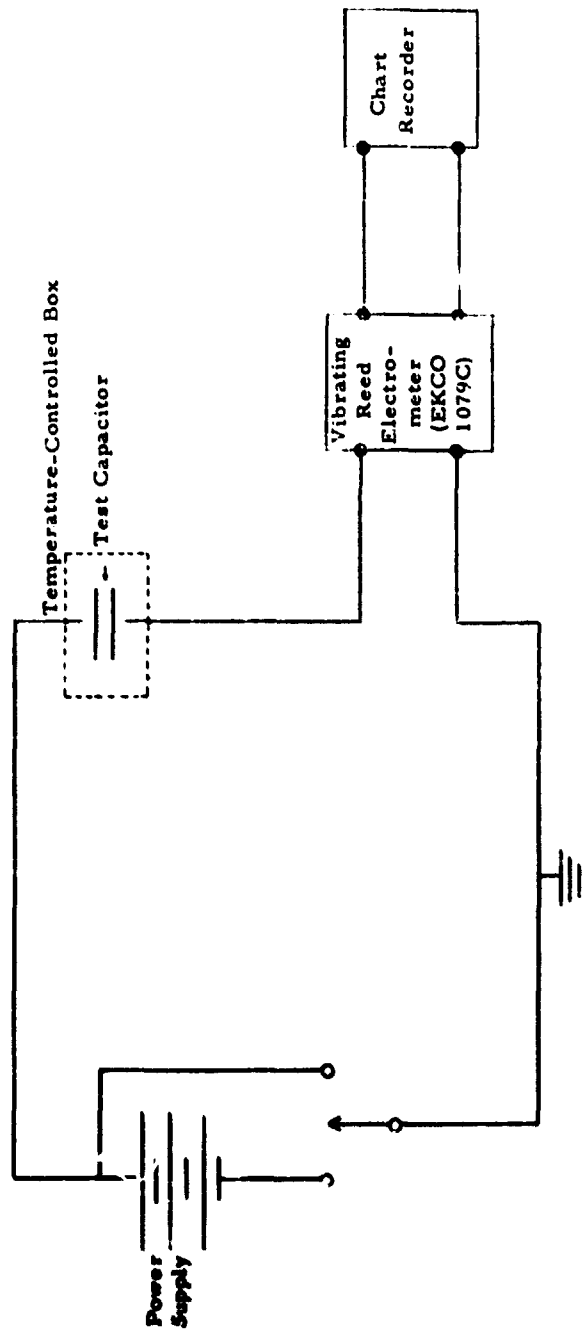
In another experiment a group of 22 capacitors was conditioned with 190 VDC at 150°C for 24 hr before the charge and discharge currents were measured. Attempts to correlate these measurements and others made before or in the early stages of life testing are presented in Figures 21 through 24. A relationship exists between the resistance after 25 hr of life testing and time-to-failure on life test, though, as was seen earlier in similar relationships, maverick capacitors occasionally occur. Figure 25 shows resistance as a function of time for several capacitors during life testing.

In another experiment a group of 24 capacitors was conditioned with 50 VDC at 150°C for 168 hr before charge and discharge currents were measured. The life testing of these units is not yet completed but enough data are available to allow the conclusion that no correlation exists between charge or discharge currents and time-to-failure. The correlation attempts are presented in Figures 26 through 28. There is apparently a relationship between the resistance after 100 hr of life testing and time-to-failure on life tests, as shown in Figure 29. Figure 30 presents the resistance as a function of time during life testing for several capacitors.

In another experiment, a group of 24 capacitors was subjected to

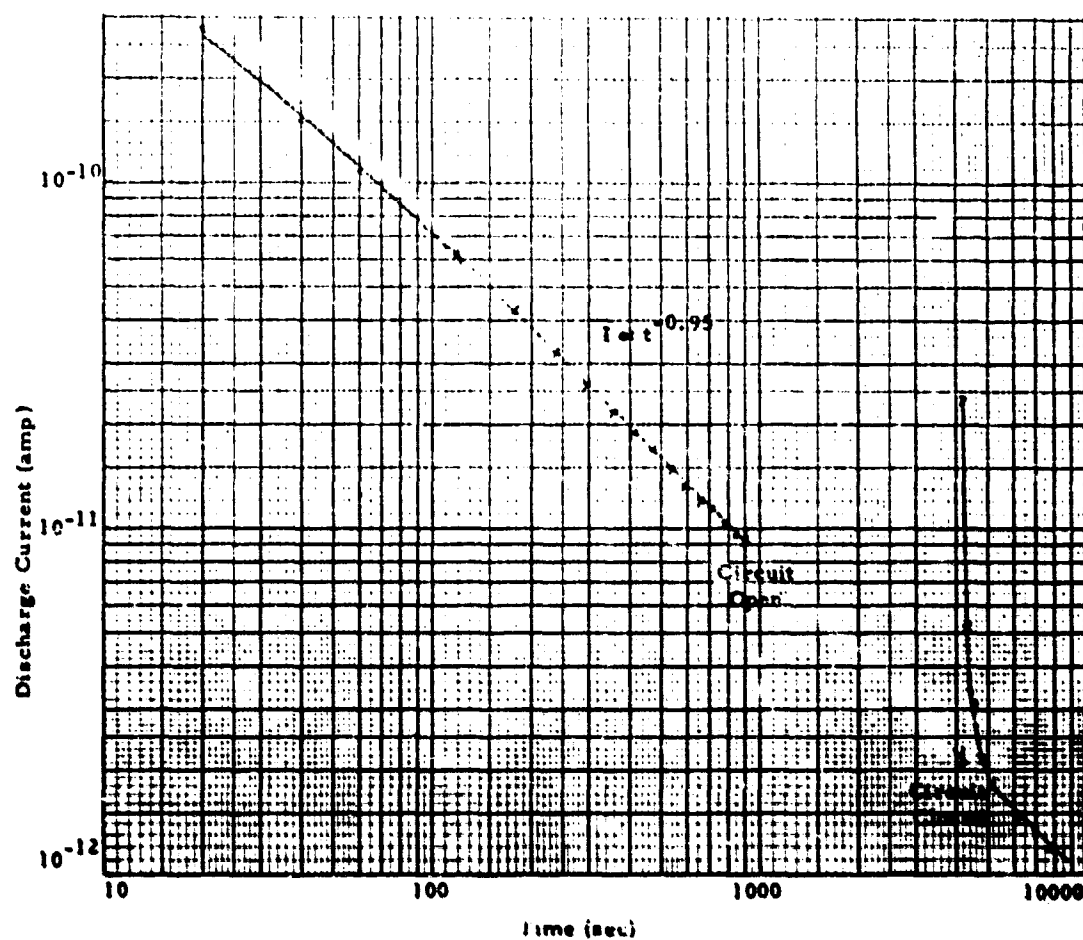
175 V rms (60 cps) at 150°C for 5 hr before charge and discharge currents were measured. The life testing of these capacitors is not yet completed, but the available data indicate no correlation exists between charge or discharge currents and time-to-failure. The correlation attempts are presented in Figures 31 to 33. There is apparently a relationship between the resistance of the capacitors after 100 hr of life testing and time-to-failure on life test, as presented in Figure 34. Figure 35 presents the resistance as a function of time during life testing for several capacitors.

An additional experiment involved an attempt to correlate 60 cps corona starting voltage and time-to-failure of the capacitors on DC life test. The location of the corona may be in voids or cracks within the dielectric material or between the electrodes and dielectric surface in certain instances. It is not known whether this can be related to capacitor life time. In determining corona starting voltage each capacitor was flashed with 30 VAC when the voltage supply was switched on. The AC voltage was then increased slowly until corona could be detected. A 0.1 in. deflection on the oscilloscope screen was equivalent to 0.4 mv. No corona was produced by the equipment below 2000 VAC. The relationship between corona starting voltage for 27 capacitors and time-to-failure is presented in Figure 36. There is apparently no correlation. The units subjected to corona start testing failed within the same time range as the control units. This indicates the corona testing did not damage the units. As noted for other capacitor groups, a relationship exists between the resistance of the capacitors after 50 hr of life testing and time-to-failure on life test. This is shown in Figure 37.



**CIRCUIT USED FOR MEASURING CHARGE AND DISCHARGE CURRENT
OF C67 CASE SIZE 1 MONOLITHIC CAPACITORS**

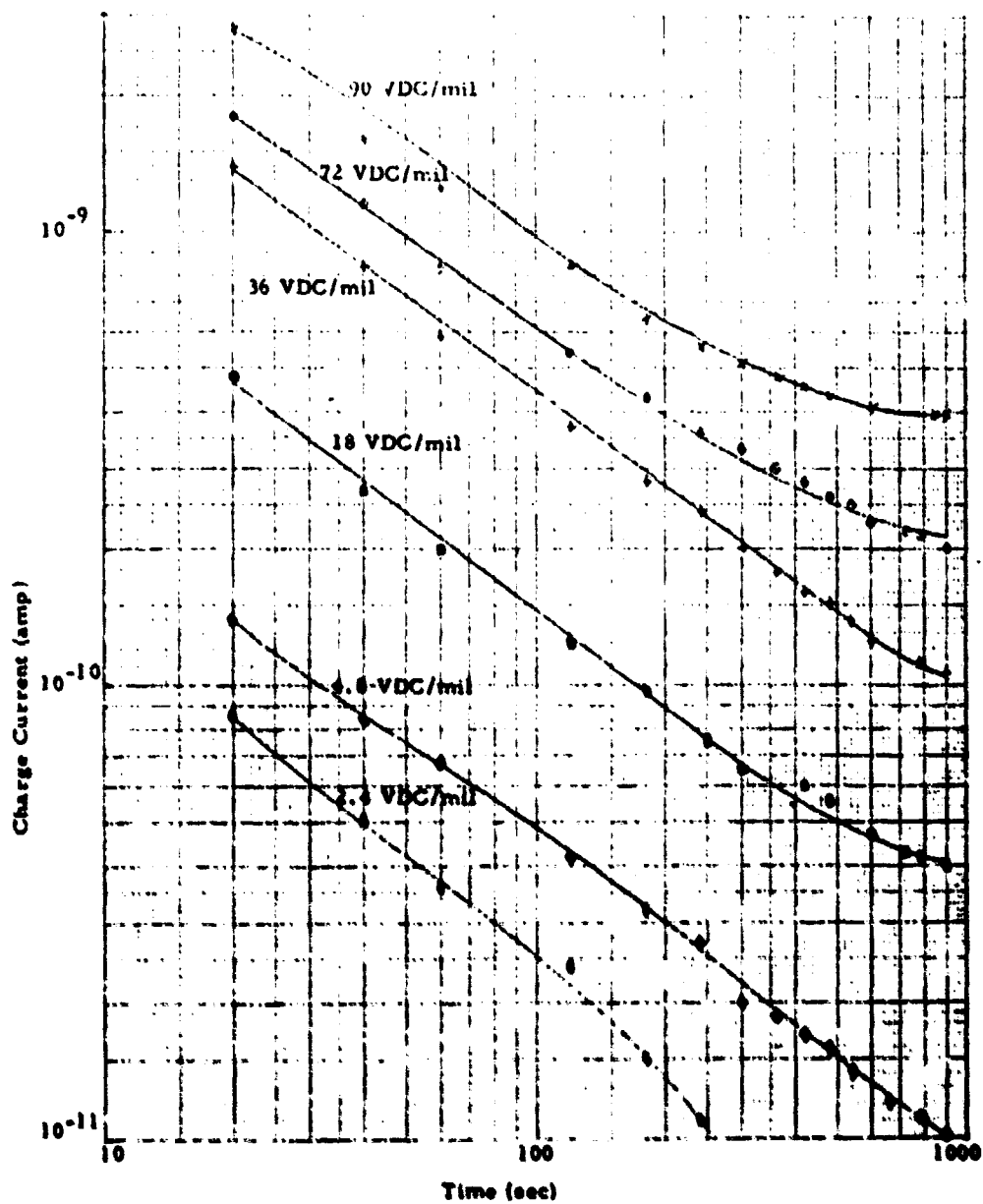
Figure 1



DISCHARGE CURRENT
FOR
A C67 CASE SIZE 1 MONOLITHIC CAPACITOR (~6000 μmF)
(Charge conditions: 225 VDC, 1 hr, 28°C)

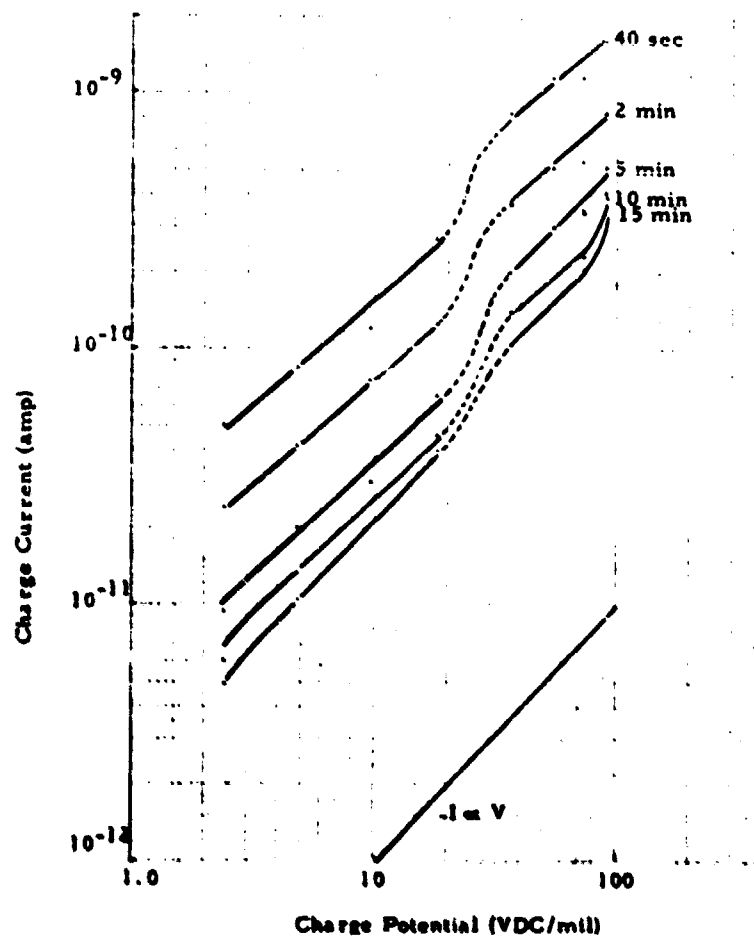
(Explanation of Graph: This graph shows discharge current vs time from initial discharge. After 15 min continuous discharge the discharge circuit was opened for one hour, after which it was closed again and the discharge continued.)

Figure 2



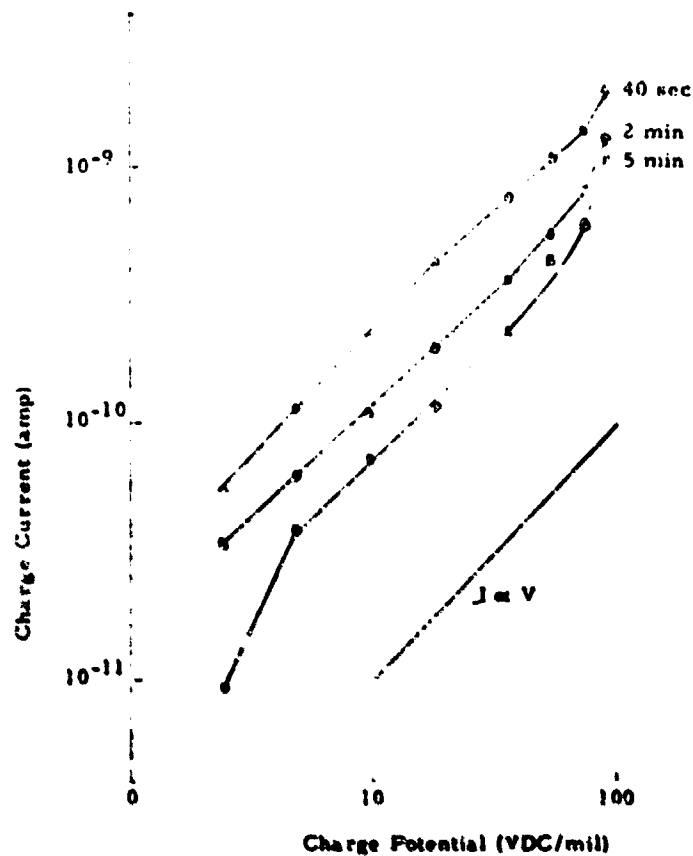
CHARGE CURRENT VS TIME
FOR C47 CASE SIZE 1 MONOLYTHIC CAPACITORS (~6000 pF)
(Charge conditions: 2.4-90 VDC/mil, 150°C)

Figure 3



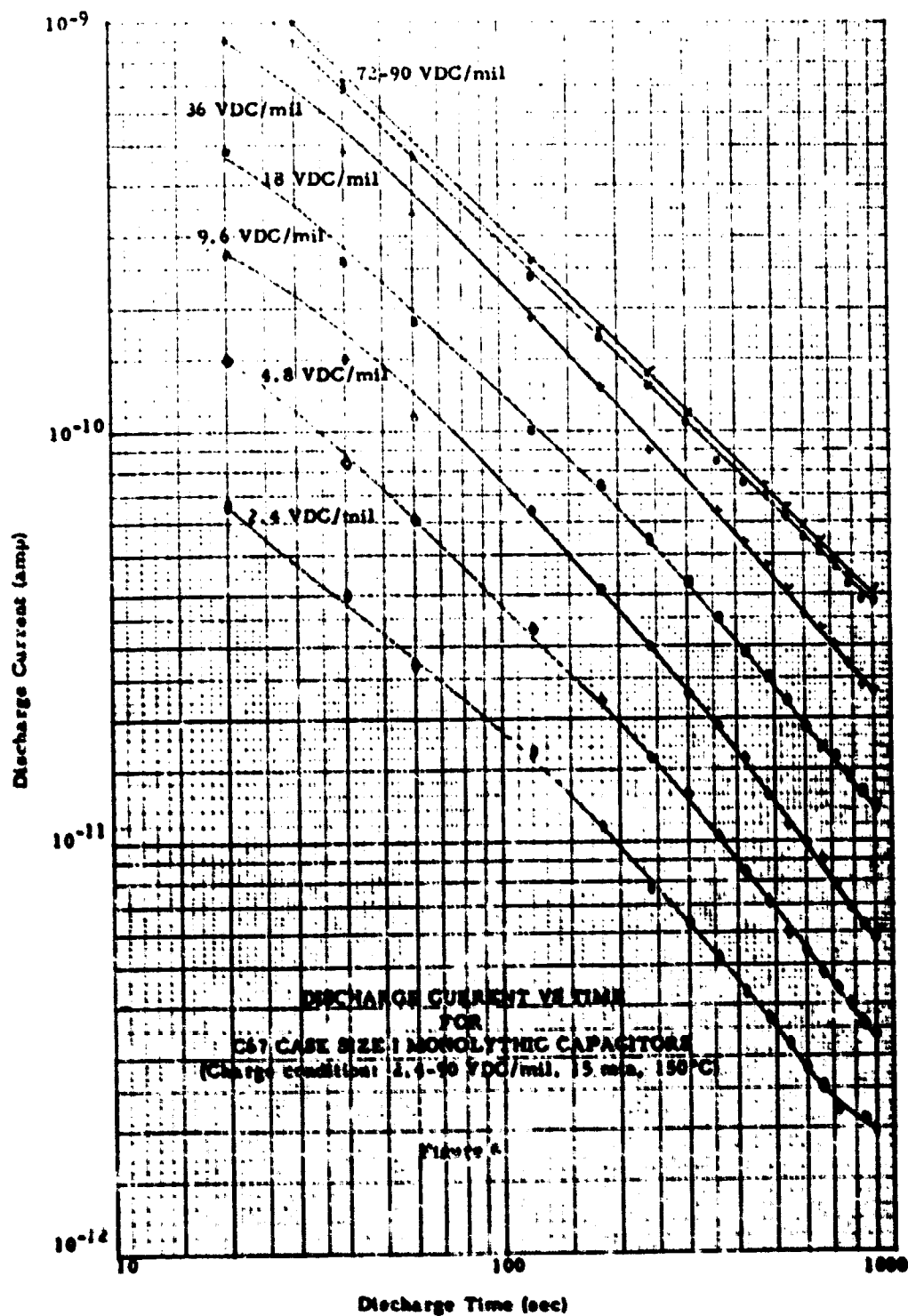
CHARGE CURRENT AT VARIOUS TIMES
VS APPLIED POTENTIAL
FOR
C67 CASE SIZE 1 MONOLITHIC CAPACITORS
(T = 150°C)

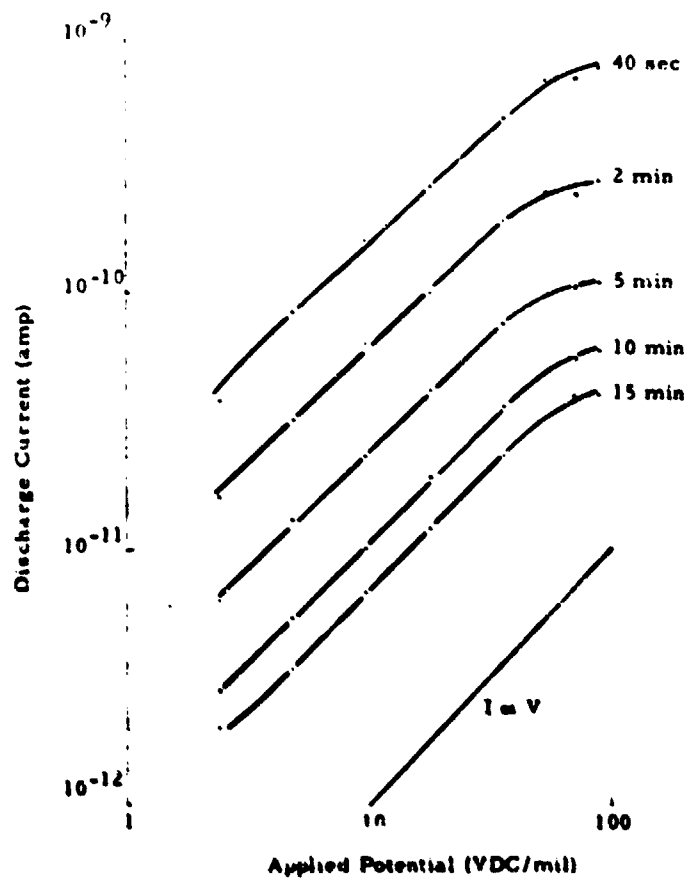
Figure 4



CHARGE CURRENT AT VARIOUS TIMES
VS APPLIED POTENTIAL
FOR
A C67 CASE SIZE I MONOLYTHIC CAPACITOR (~6000 p.p.f.)
($T = 150^{\circ}\text{C}$)

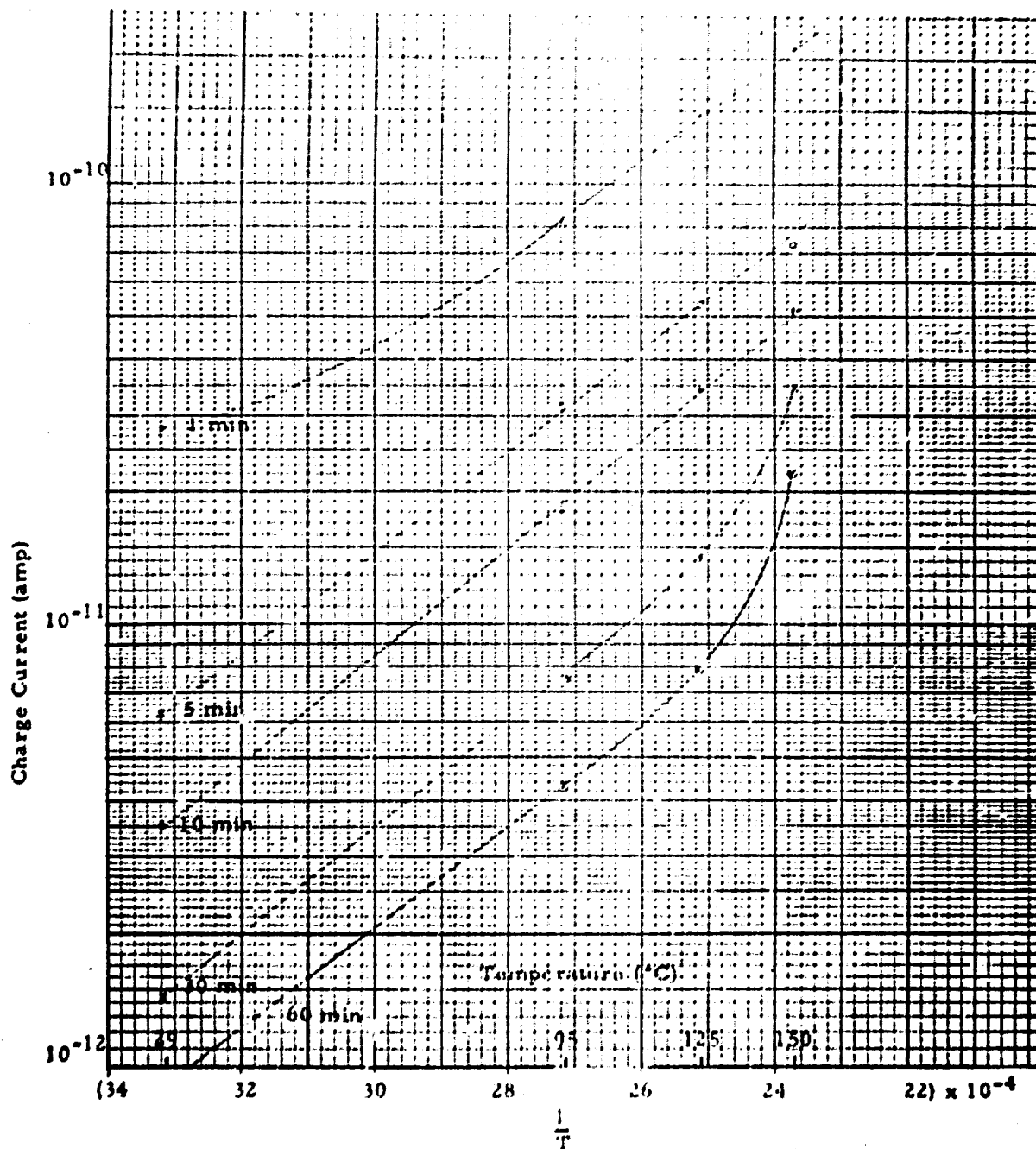
Figure 5





DISCHARGE CURRENT AT VARIOUS TIMES
VS APPLIED POTENTIAL
FOR
C67 CASE SIZE I MONOLITHIC CAPACITORS
(T = 150°C; Charge time = 15 min)

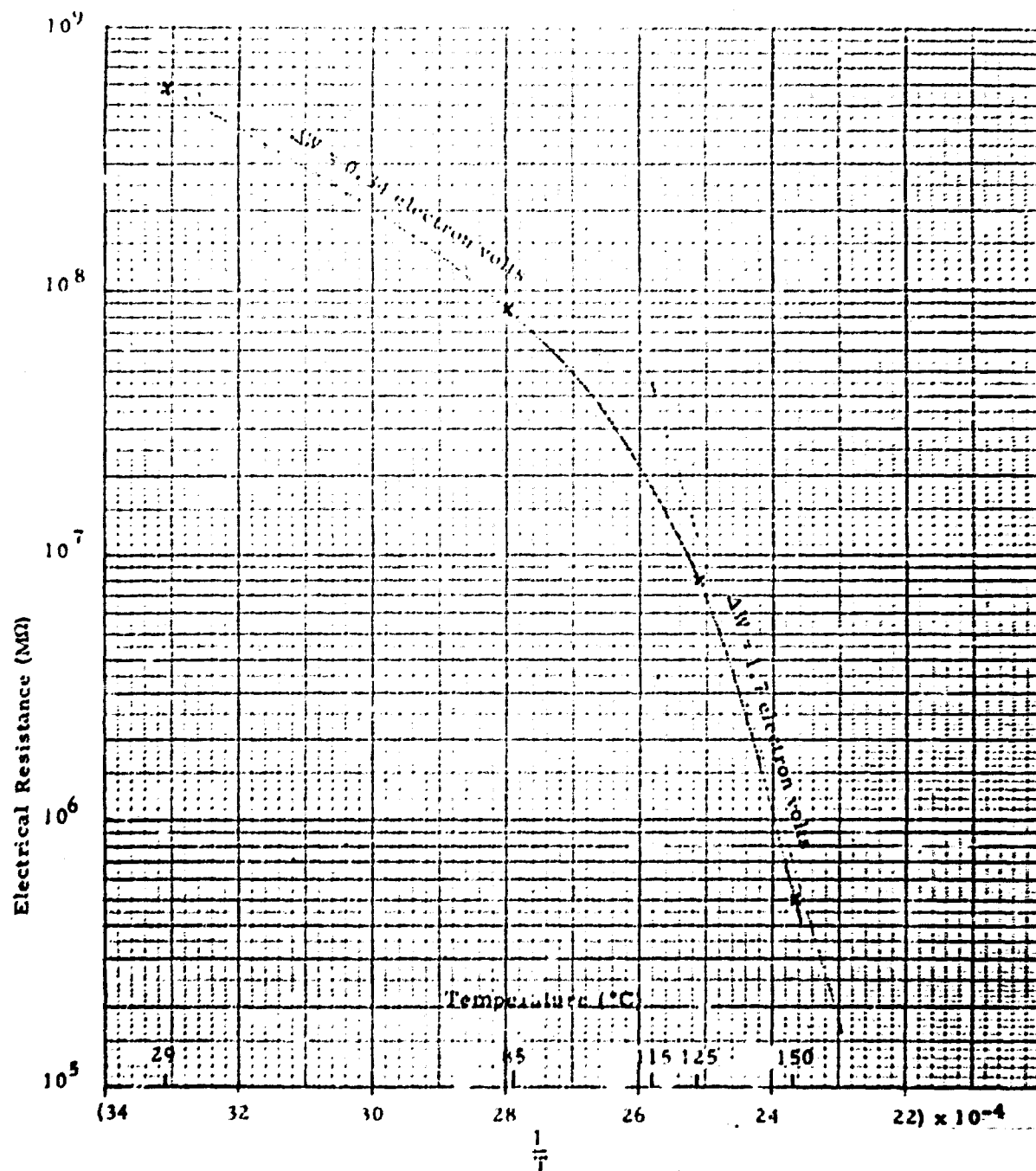
Figure 7



RELATIONSHIP OF CHARGING CURRENT
AND INVERSE ABSOLUTE TEMPERATURE
WITH TIME OF EVALUATION AS PARAMETER
FOR A C67 CASE SIZE I MONOLITHIC CAPACITOR (~6000 μF)
(Charging voltage: 45 VDC (18 V/rad))

Figure 8

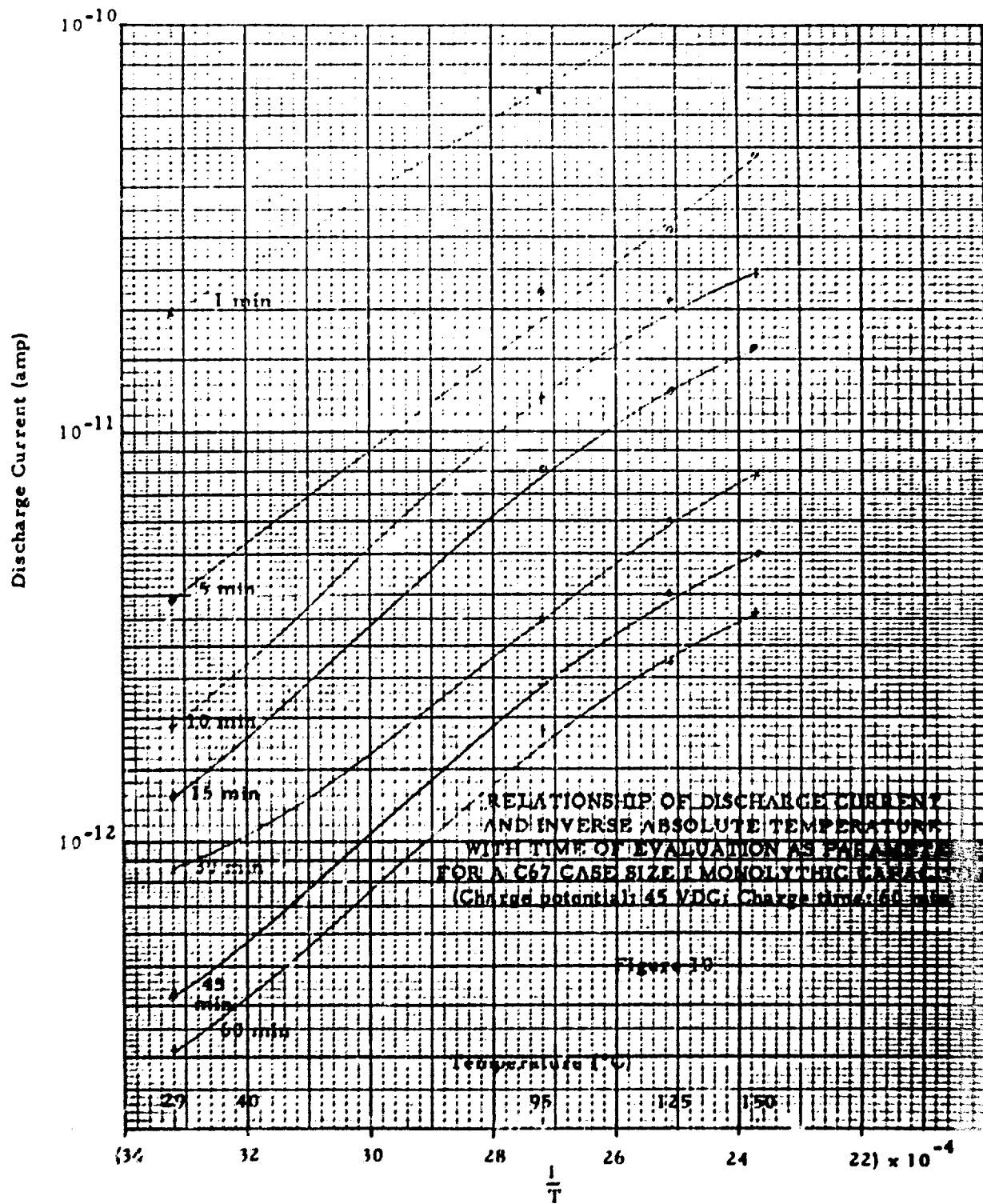
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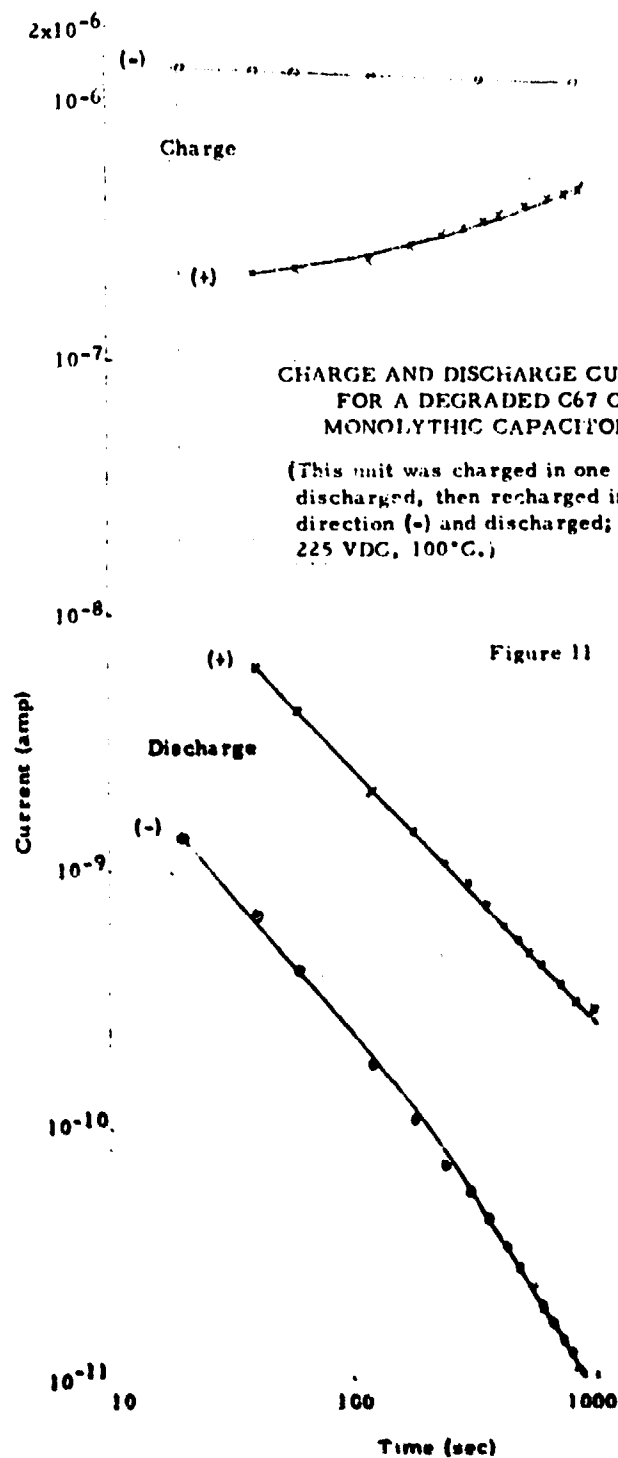


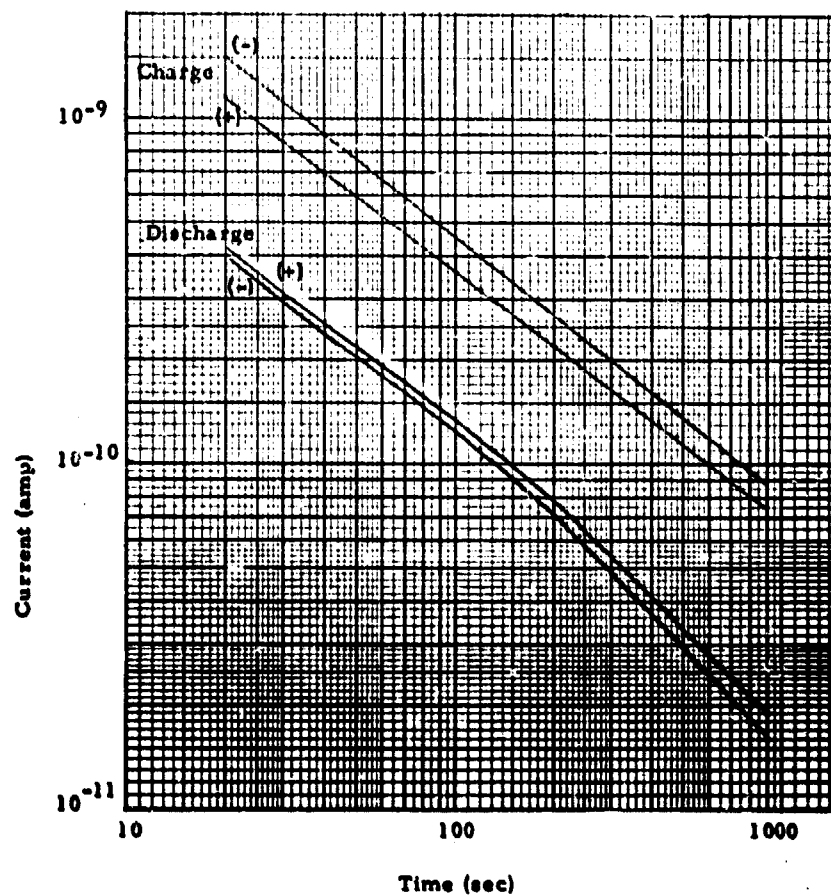
RELATIONSHIP OF RESISTANCE OF FRESH UNIT
WITH INVERSE ABSOLUTE TEMPERATURE
FOR A C67 CASE SIZE 1 MONOLITHIC CAPACITOR
(Charging voltage: 190 VDC (76 V/mil); P (MIL-cm) = 12R)

Figure 9

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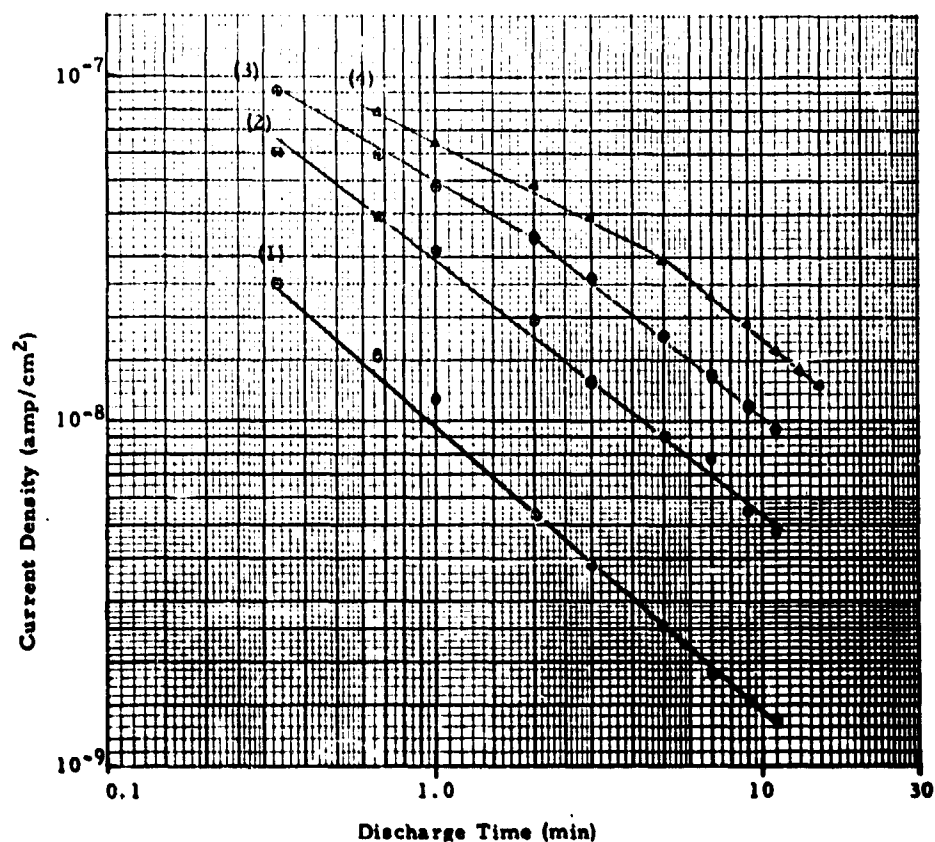




**CHARGE AND DISCHARGE CURRENT CURVES
FOR
A FRESH C67 CASE SIZE I MONOLYTHIC CAPACITOR (~6000 μf)**

(This unit was charged in one direction (+) and discharged, then recharged in the reverse direction (-) and discharged; charge conditions: 225 VDC, 100°C)

Figure 12

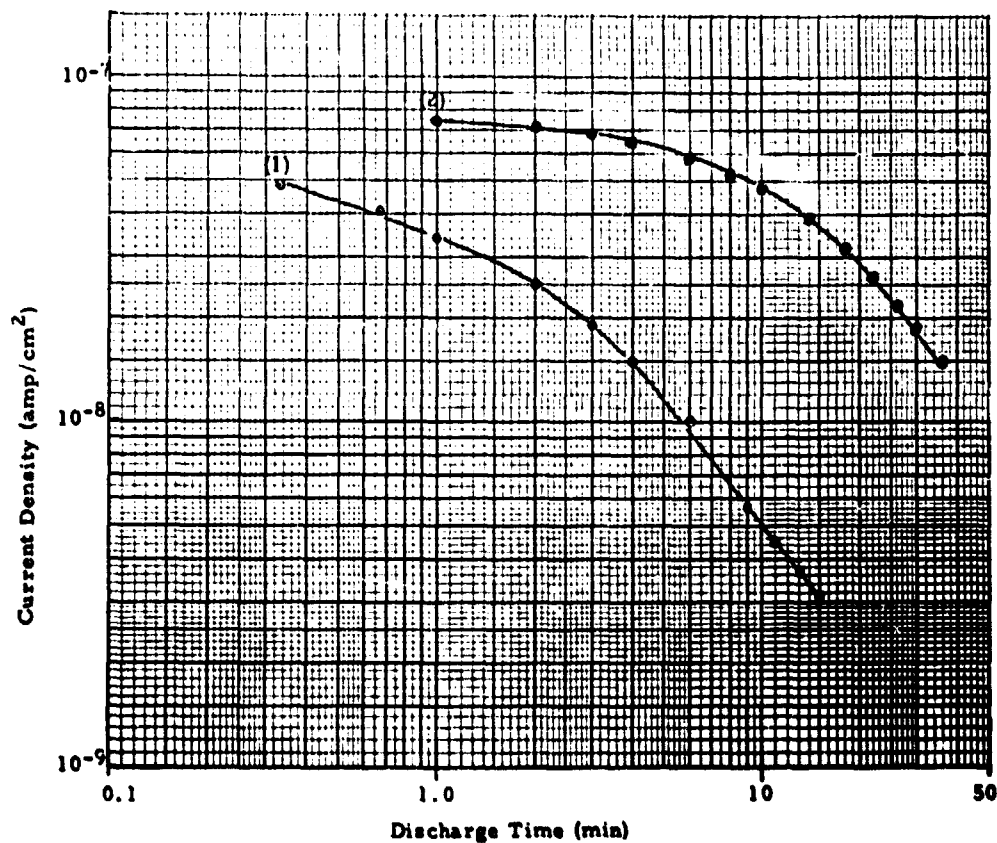


Sequence of Operations

- (1) Crystal charged at 6 V for 0.67 min, then discharged
- (2) Crystal charged at 6 V for 3 min, then discharged
- (3) Crystal charged at 6 V for 6 min, then discharged
- (4) Crystal charged at 6 V for 15 min, then discharged

DISCHARGE CURRENT AT 150°C
FOR A BaTiO₃ SINGLE CRYSTAL
(Silver-palladium alloy electrodes: area - 0.10 cm², thickness - 0.027 cm)

Figure 13

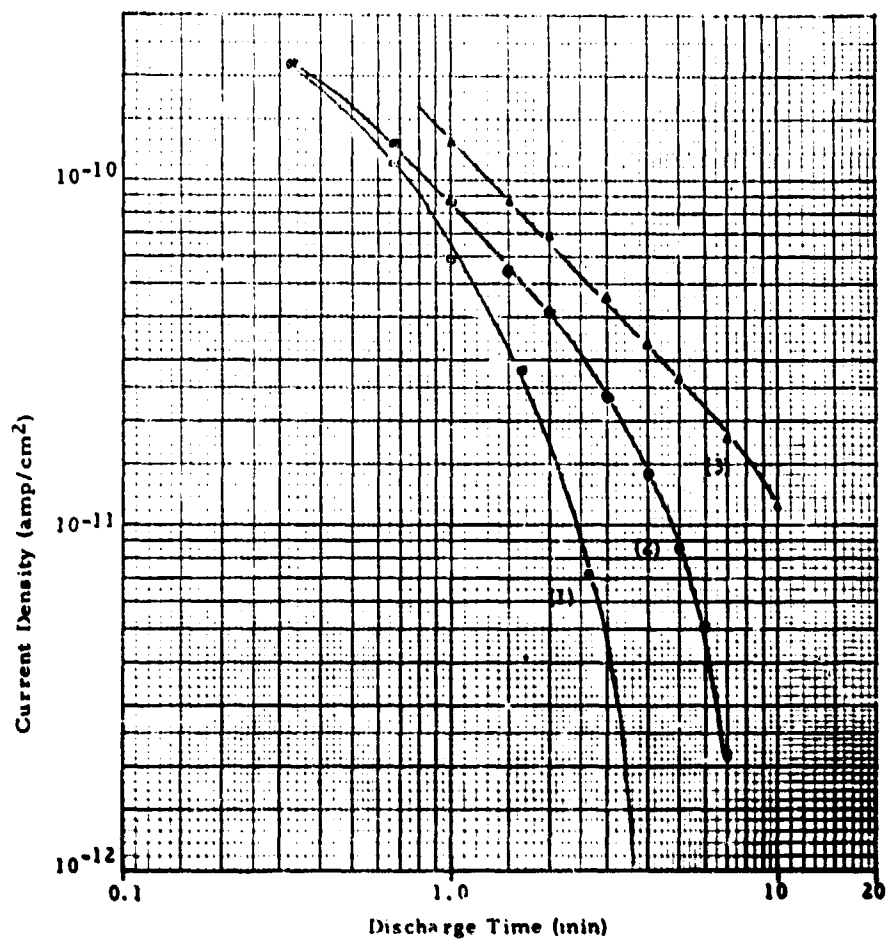


Sequence of Operations

- (1) Crystal charged at 6 V for 1.3 min, then discharged
- (2) Crystal charged at 6 V for 15 min, then discharged

DISCHARGE CURRENT AT 150°C
FOR A BaTiO₃ SINGLE CRYSTAL
(Silver electrodes: area - 0.12 cm², thickness - 0.035 cm)

Figure 14

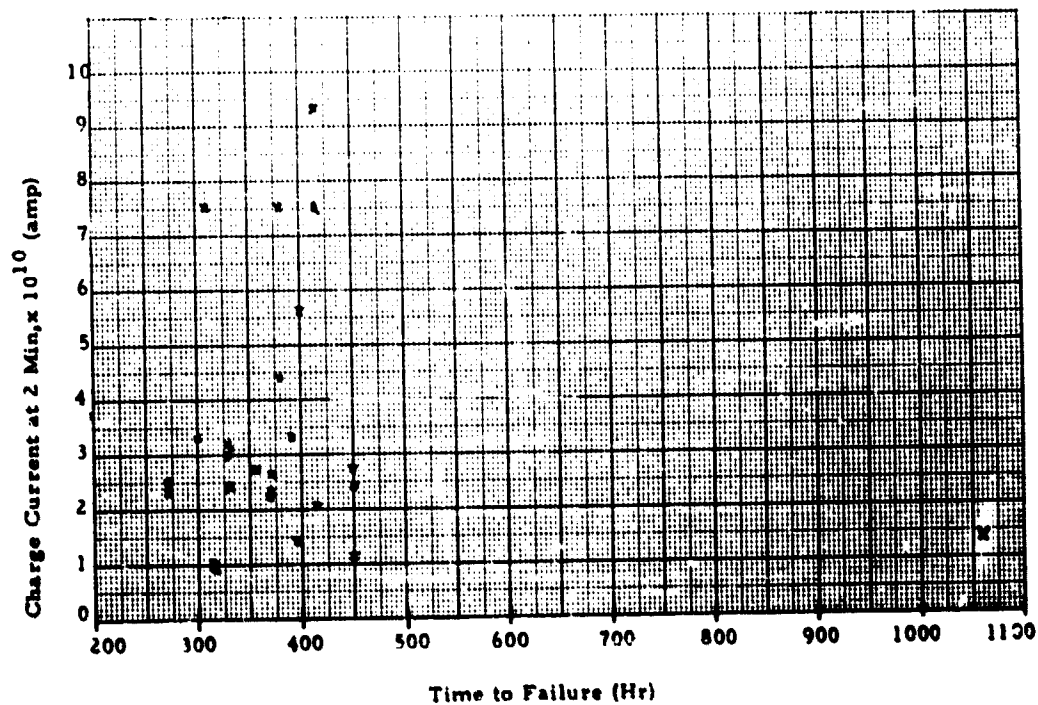


Sequence of Operations

- (1) Capacitor charged at 6 V for 1 min, then discharged
- (2) Capacitor charged at 6 V for 5 min, then discharged
- (3) Capacitor charged at 6 V for 30 min, then discharged

DISCHARGE CURRENT AT 150°C
 FOR A C67 CASE SIZE I MONOLYTHIC CAPACITOR
 (Dielectric area: 0.51 cm²; dielectric thickness: 0.0064 cm)

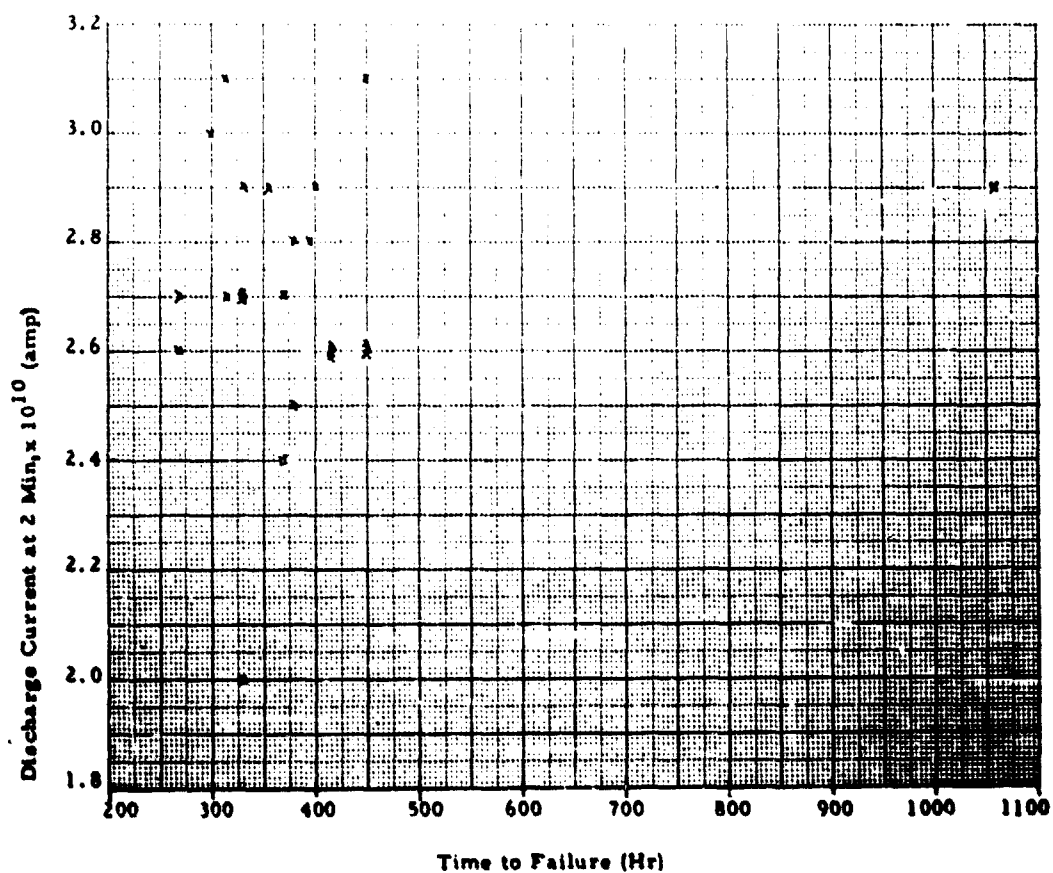
Figure 15



RELATIONSHIP BETWEEN CHARGE CURRENT AT 2 MIN
AND TIME TO FAILURE
FOR
C67 CASE SIZE 1 MONOLITHIC CAPACITORS (~6000 μ F)
(Charge conditions: 150°C, 225 VDC)

(Definition of Failure: electrical resistance < 100 M Ω
at life test conditions of 150°C, 190 VDC)

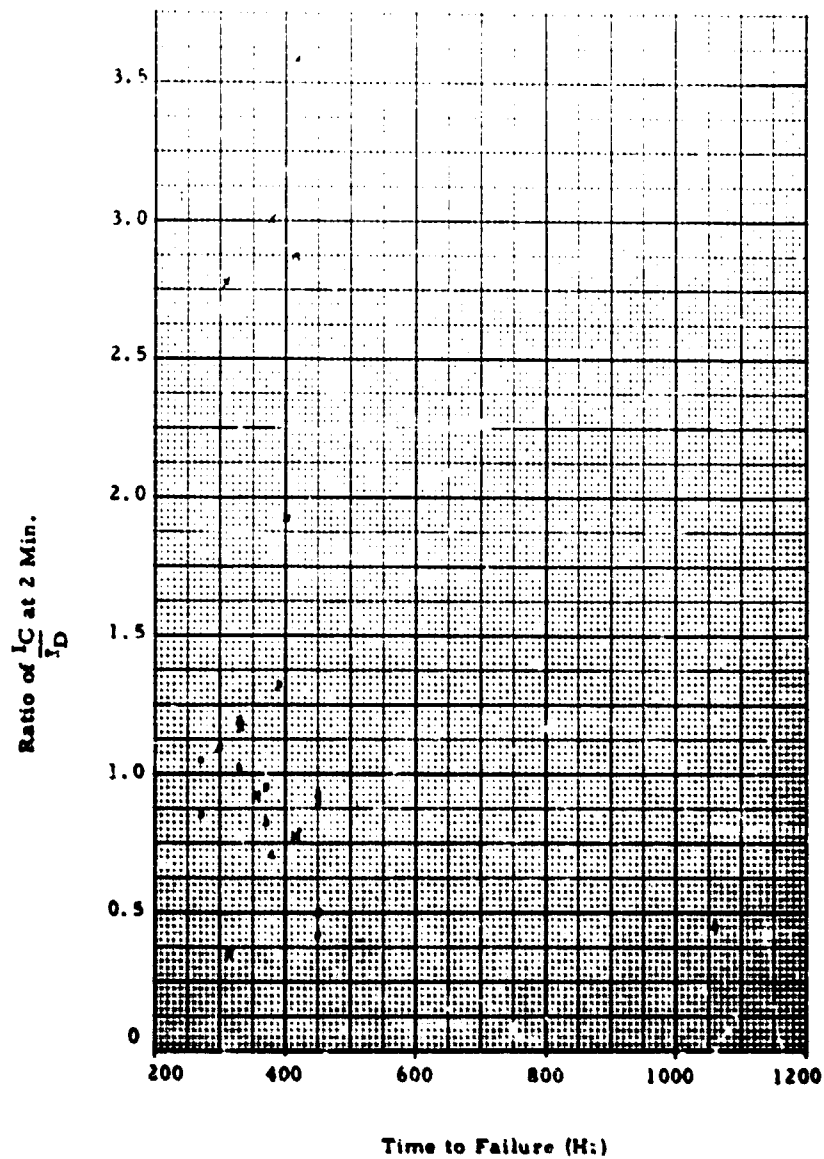
Figure 16



RELATIONSHIP BETWEEN DISCHARGE CURRENT AT 2 MIN
AND TIME TO FAILURE
FOR
C67 CASE SIZE 1 MONOLYTHIC CAPACITORS (~6000 μf)
(Charge conditions: 150°C, 225 VDC, 15 min)

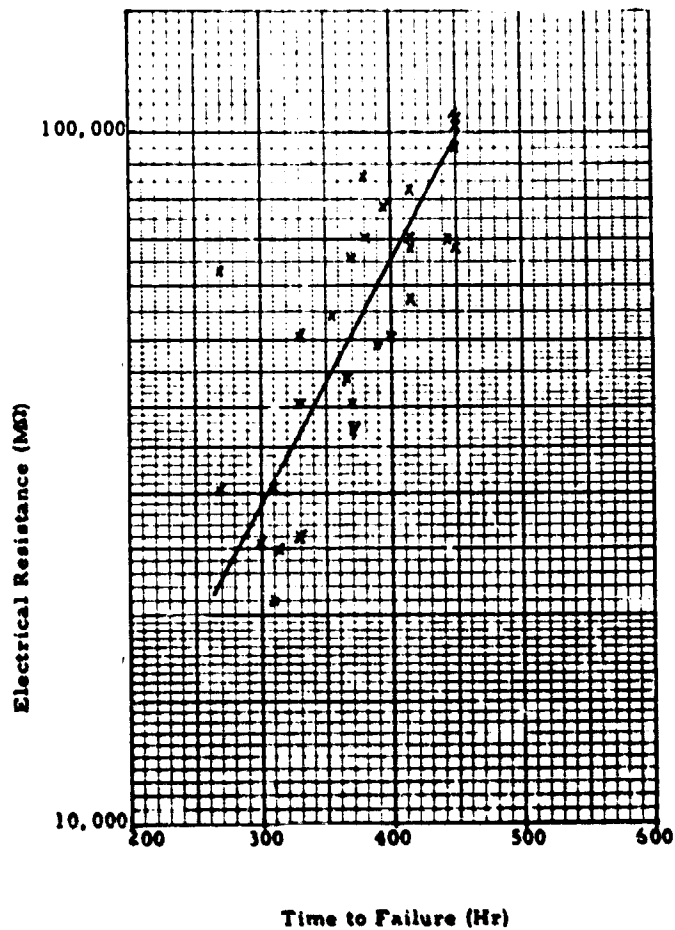
(Definition of Failure: electrical resistance < 100 M Ω
at life test conditions of 150°C, 190 VDC)

Figure 17



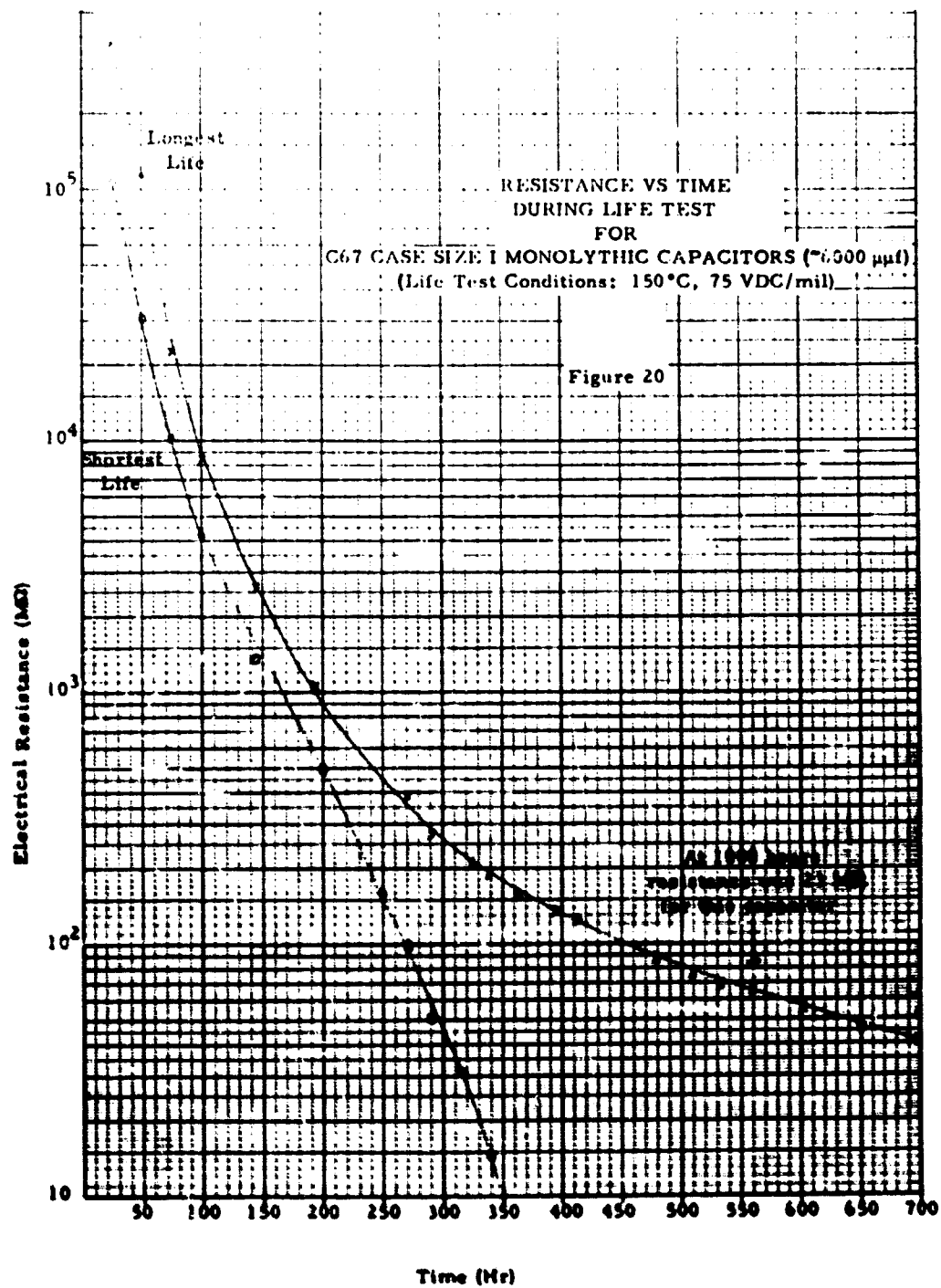
RELATIONSHIP BETWEEN RATIO OF CHARGE CURRENT AT 2 MIN
TO DISCHARGE CURRENT AT 2 MIN
AND TIME TO FAILURE
FOR
C67 CASE SIZE I MONOLYTHIC CAPACITORS (~6000 μf)
(Charge conditions: 150°C, 225 VDC, 15 min)

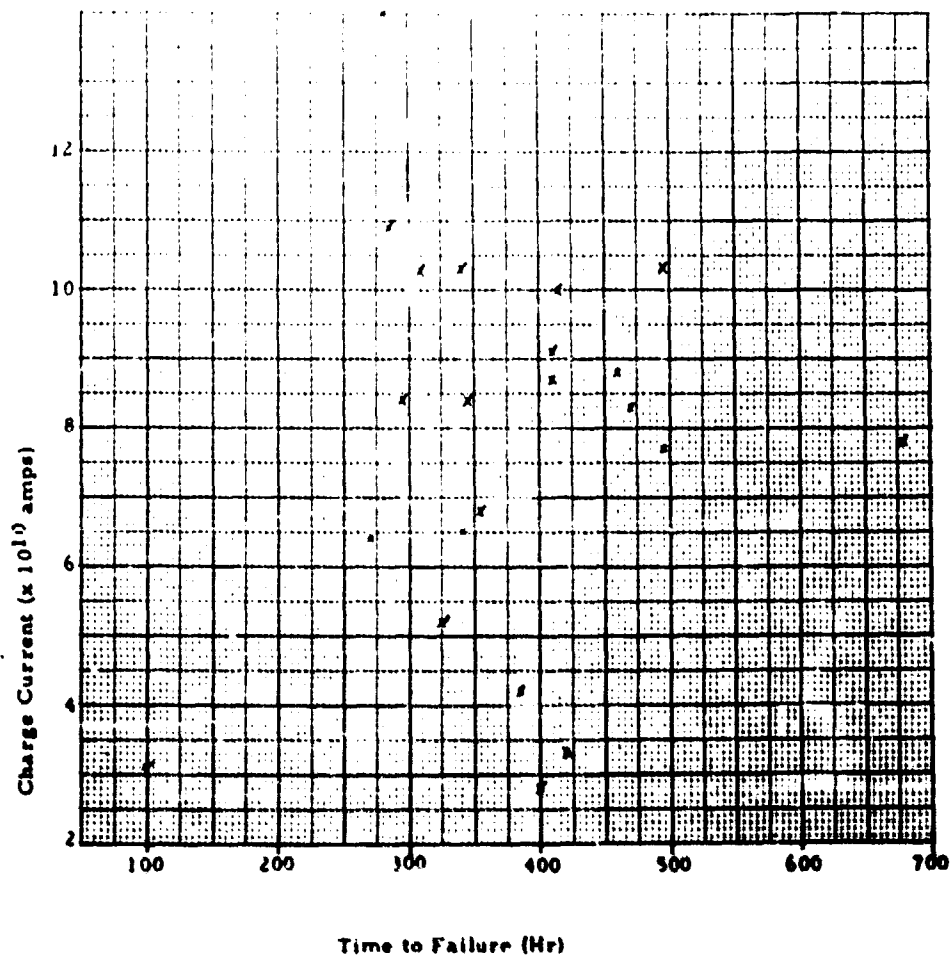
Figure 18



RELATIONSHIP BETWEEN ELECTRICAL RESISTANCE
AFTER 50 HR OF LIFE TESTING
AND
TIME TO FAILURE ON LIFE TEST
FOR
C67 CASE SIZE 1 MONOLYTHIC CAPACITORS (~6000 μF)
(Definition of Failure: electrical resistance <100 MΩ)

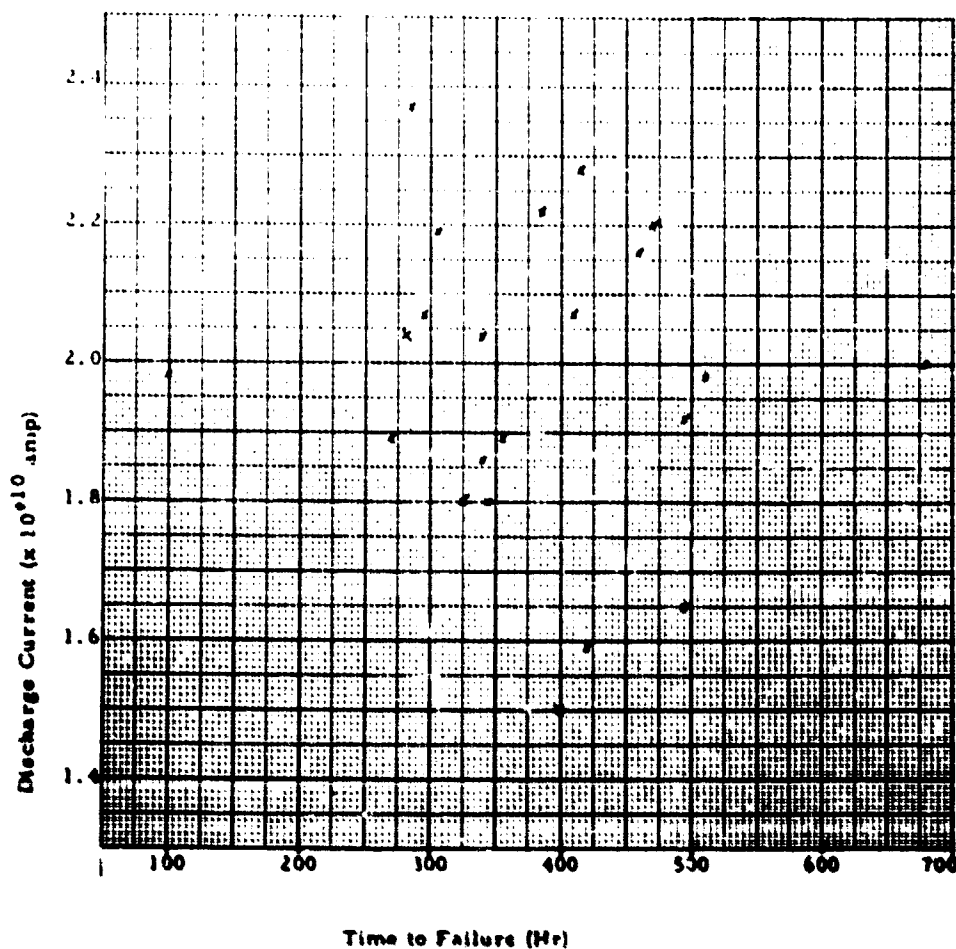
Figure 19





RELATIONSHIP BETWEEN CHARGE CURRENT AT 2 MIN
AND TIME TO FAILURE
FOR
C67 CASE SIZE 1 MONOLITHIC CAPACITORS ($\sim 6000 \mu\text{f}$)
(Charge Conditions: 225 VDC, 150°C ;
Burn-in Conditions: 75 VDC/ml, 24 hr, 150°C)
Definition of Failure: electrical resistance $< 100 \text{ M}\Omega$

Figure 21



**RELATIONSHIP BETWEEN DISCHARGE CURRENT AT 2 MIN
AND TIME TO FAILURE
FOR**

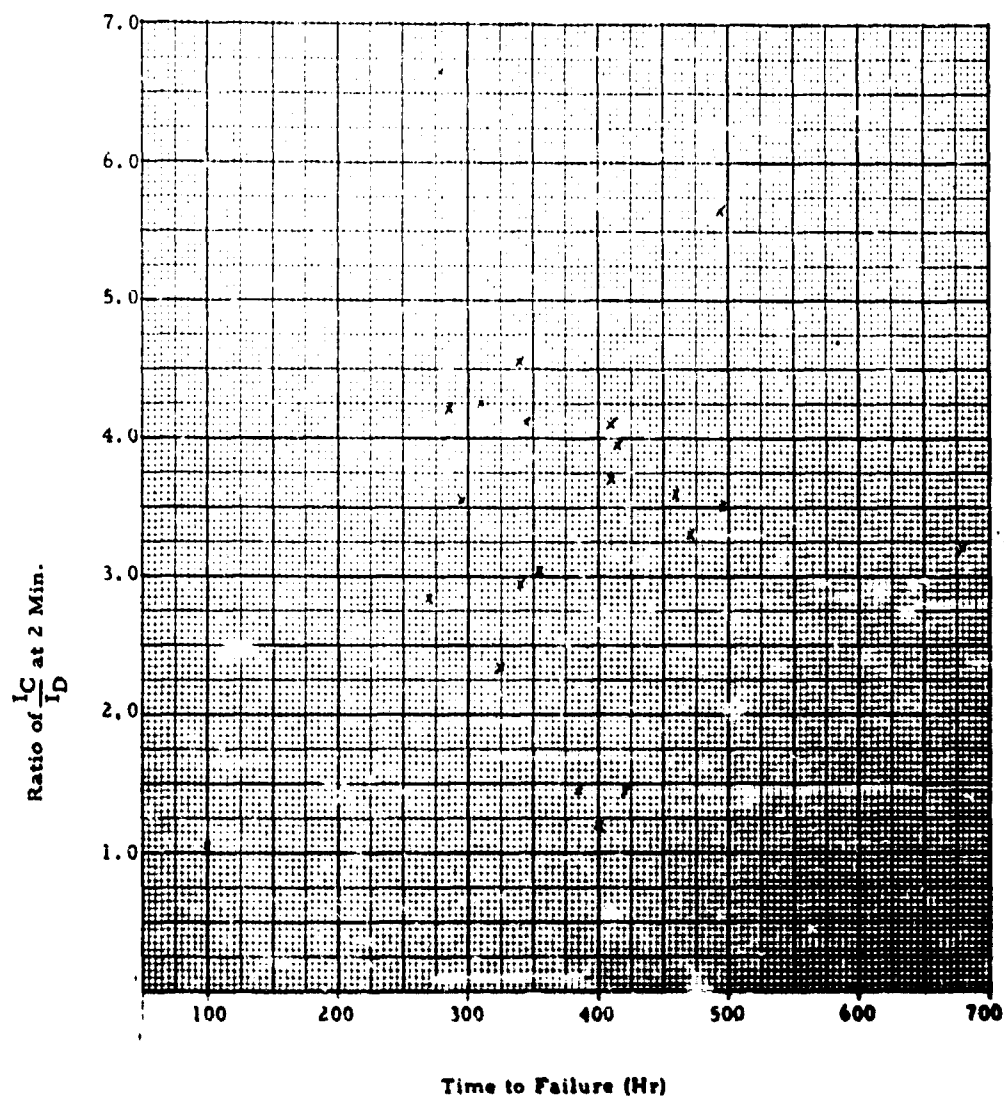
C67 CASE SIZE 1 MONOLITHIC CAPACITORS (~6000 μ fd)

(Charge Conditions: 225 VDC, 15 min, 150°C;

Burn-in Conditions: 75 VDC/mil, 24 hr, 150°C)

(Definition of Failure: electrical resistance <100 M Ω)

Figure 22



RELATIONSHIP BETWEEN RATIO OF CHARGE CURRENT AT 2 MIN
TO DISCHARGE CURRENT AT 2 MIN
AND TIME TO FAILURE
FOR

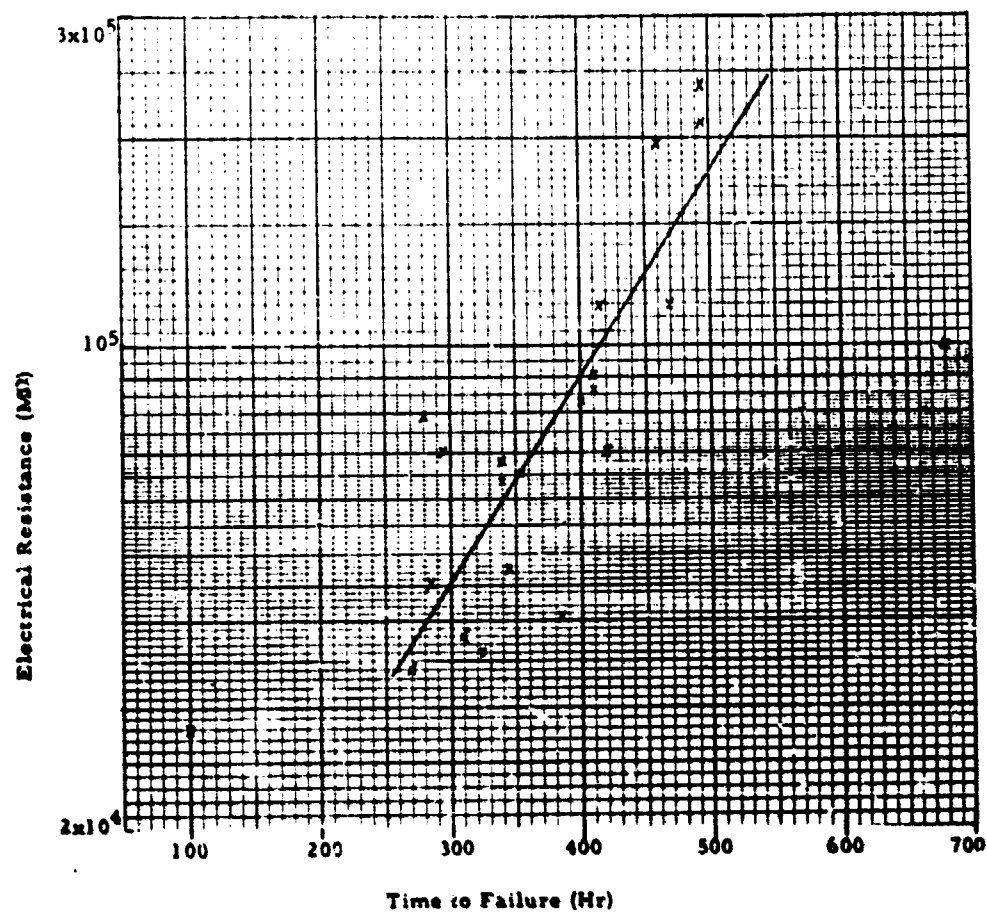
C67 CASE SIZE I MONOLYTHIC CAPACITORS (~6000 μmf)

(Charge Conditions: 225 VDC, 15 min, 150°C)

Burn-in Conditions: 75 VDC/ml, 24 hr, 150°C)

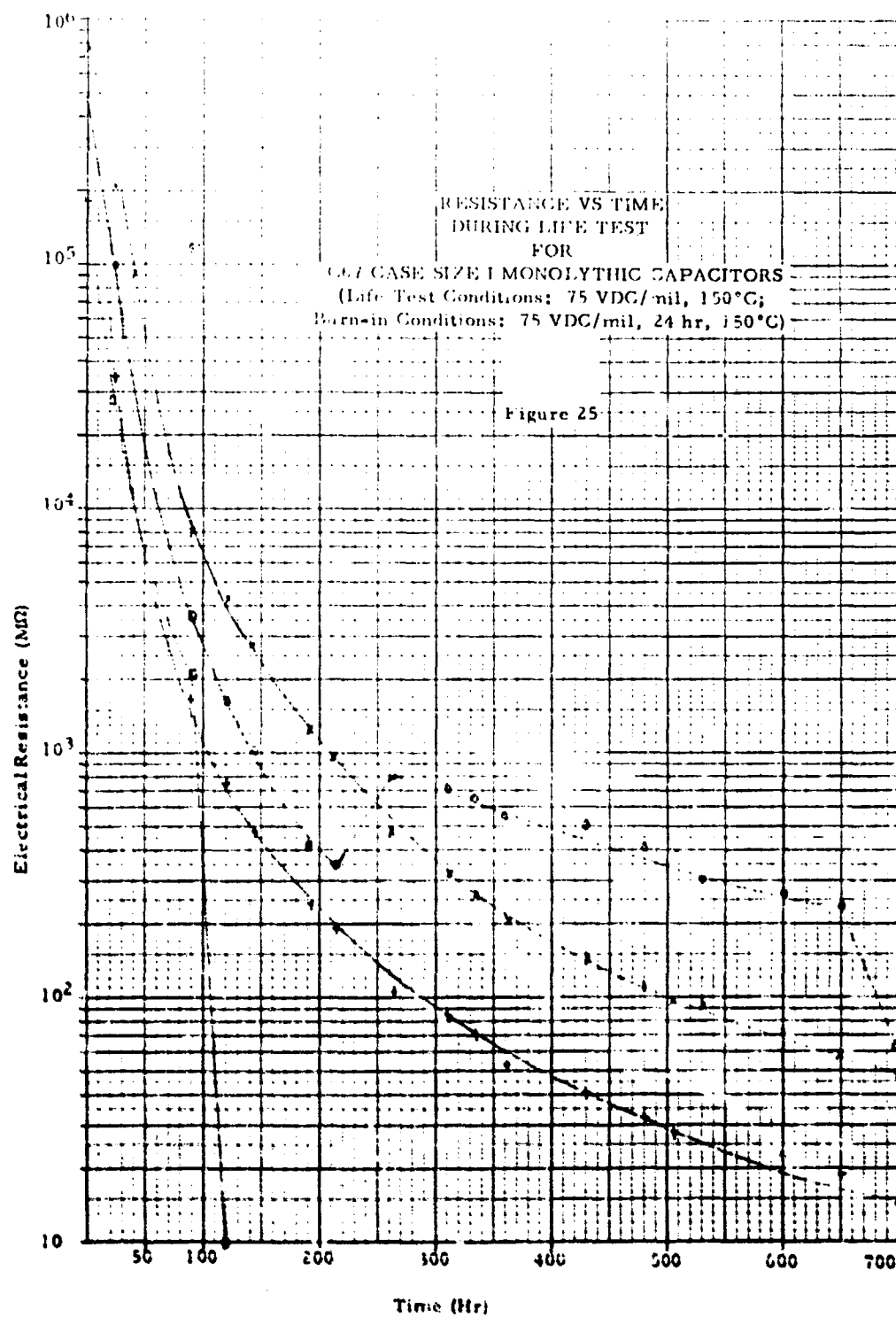
(Definition of Failure: electrical resistance <100 M Ω)

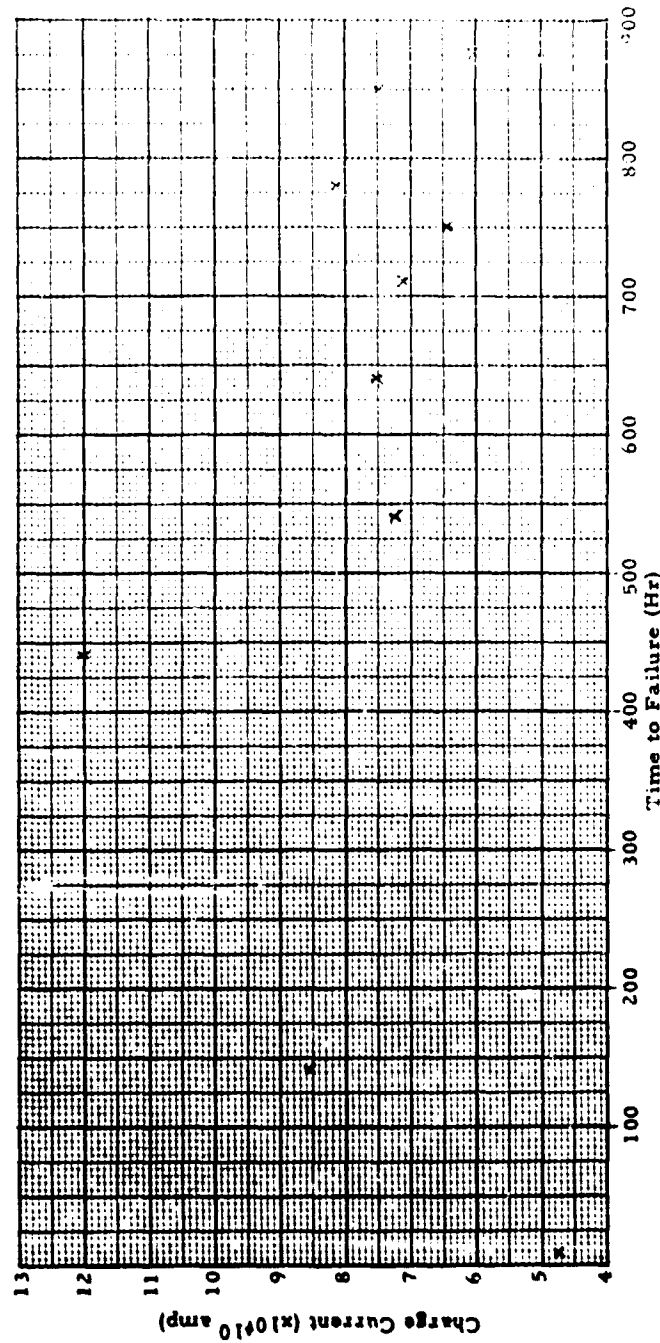
Figure 43



RELATIONSHIP BETWEEN
ELECTRICAL RESISTANCE AFTER 25 HR OF LIFE TEST
AND TIME TO FAILURE ON LIFE TEST
FOR
C67 CASE SIZE I MONOLYTHIC CAPACITORS (~6000 μf)
(Burn-in Conditions: 75 VDC/ml, 24 hr, 150°C)
(Definition of Failure: electrical resistance <100 MΩ)

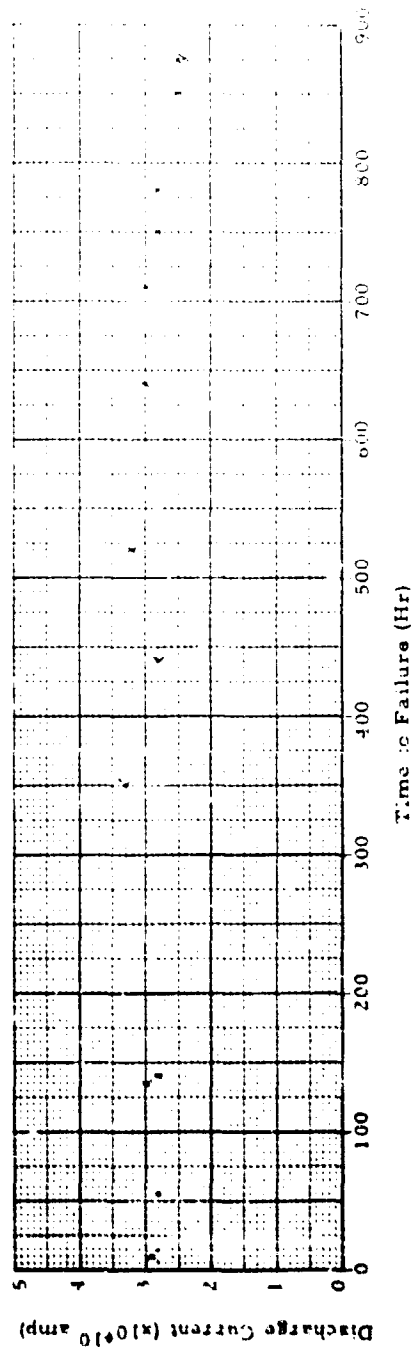
Figure 24





RELATIONSHIP BETWEEN
CHARGE CURRENT AT 2 MIN FOLLOWING DC BURN-IN
AND TIME TO FAILURE
FOR C67 CASE SIZE I MONOLITHIC CAPACITORS ($\sim 6000 \mu\text{f}$)
(Burn-in conditions: 168 hr, 50 VDC, 150°C ;
charge conditions: 15 min, 225 VDC, 150°C ;
test conditions: 185 VDC, 150°C)

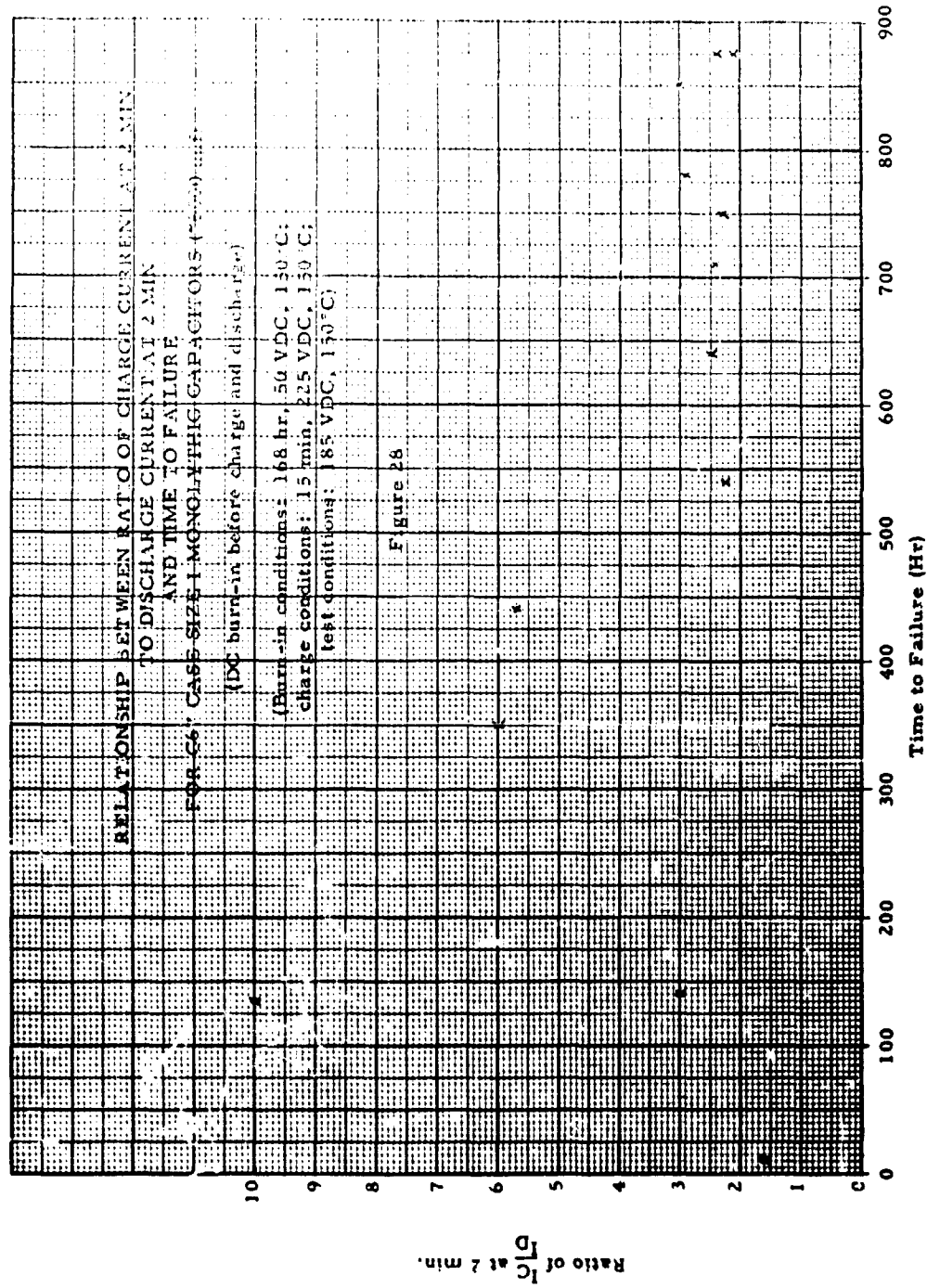
Figure 26

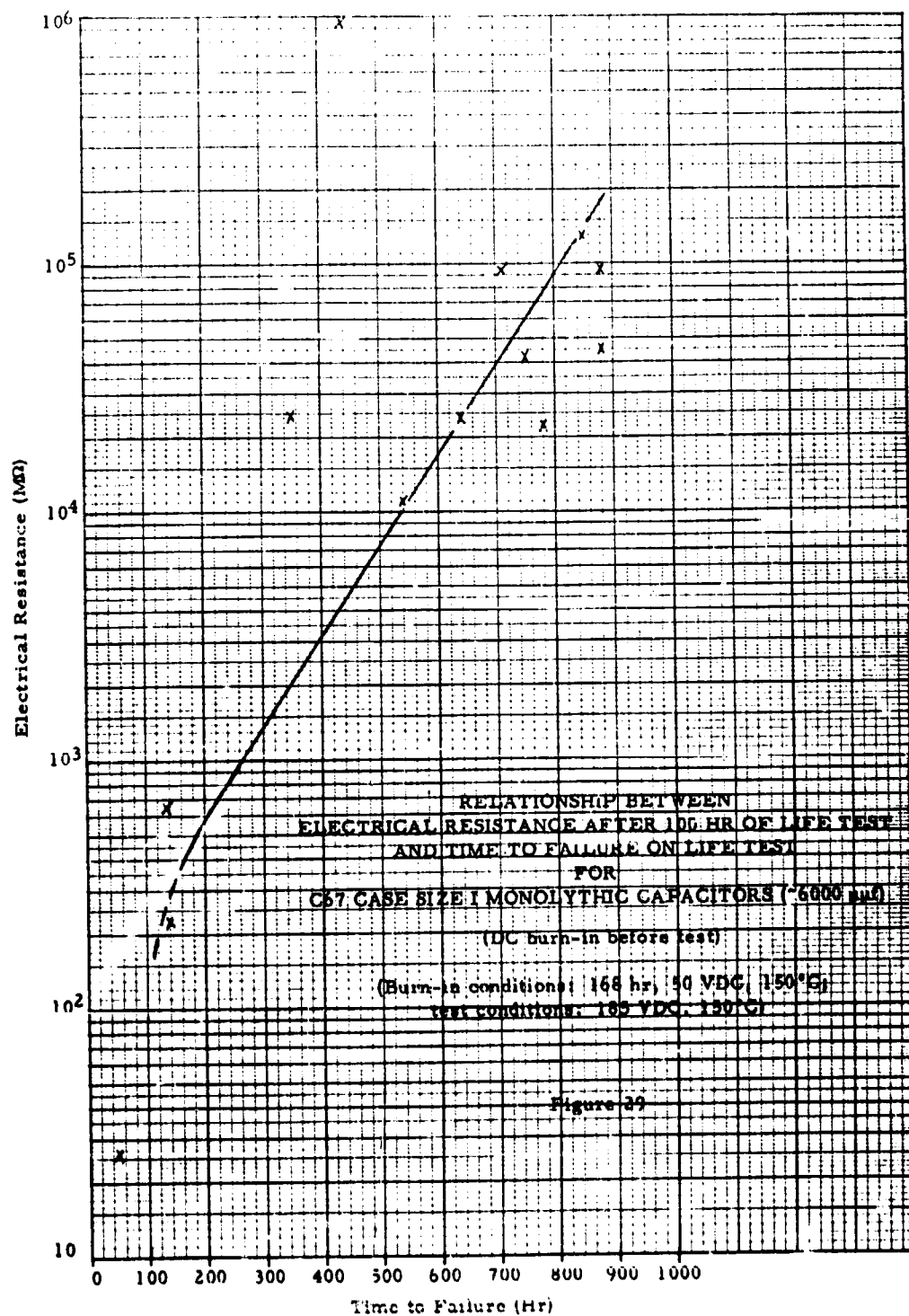


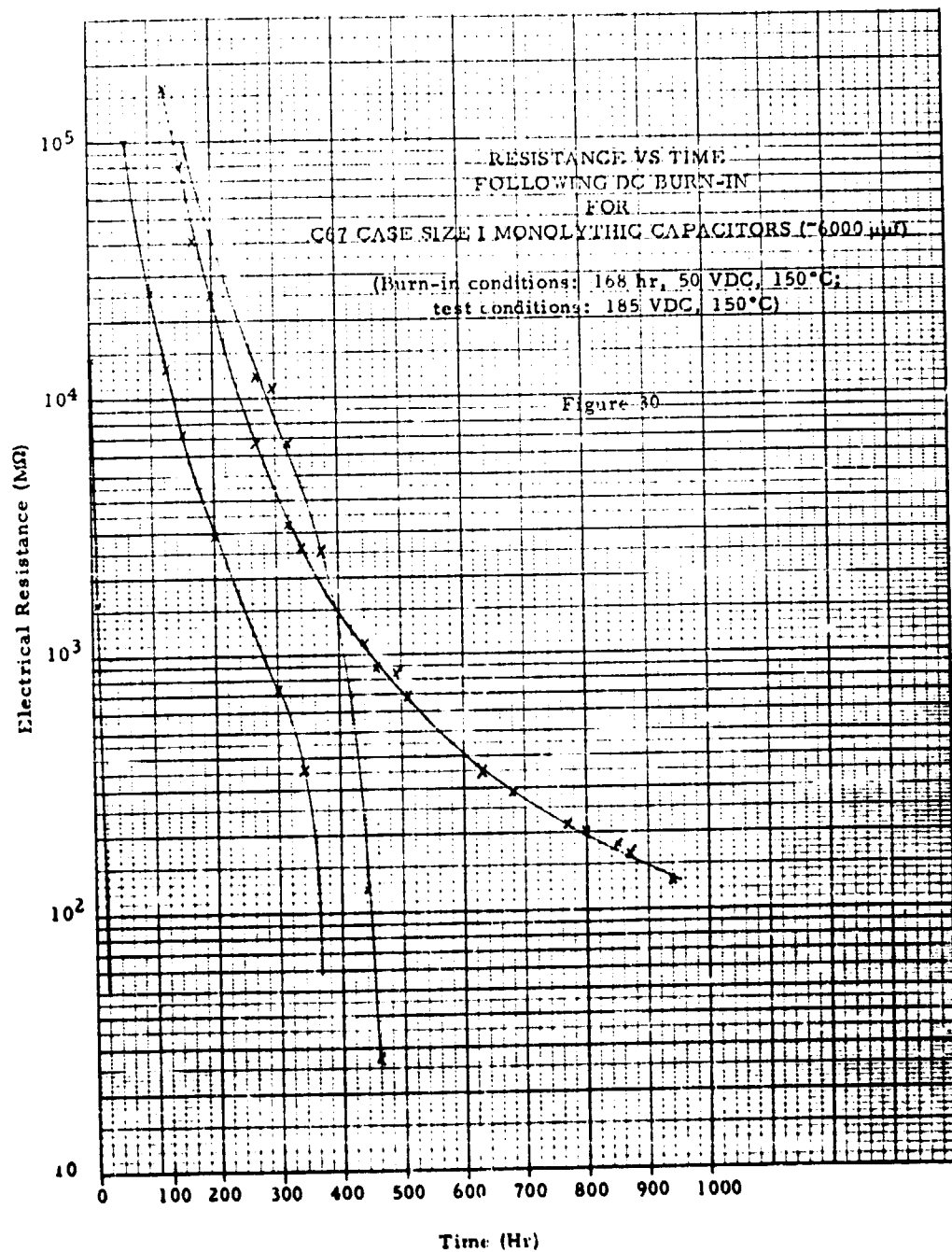
RELATIONSHIP BETWEEN
DISCHARGE CURRENT AT 2 MIN FOLLOWING DC BURN-IN
AND TIME TO FAILURE
FOR C67 CASE SIZE I MONOLITHIC CAPACITORS (~6000 μ mf)

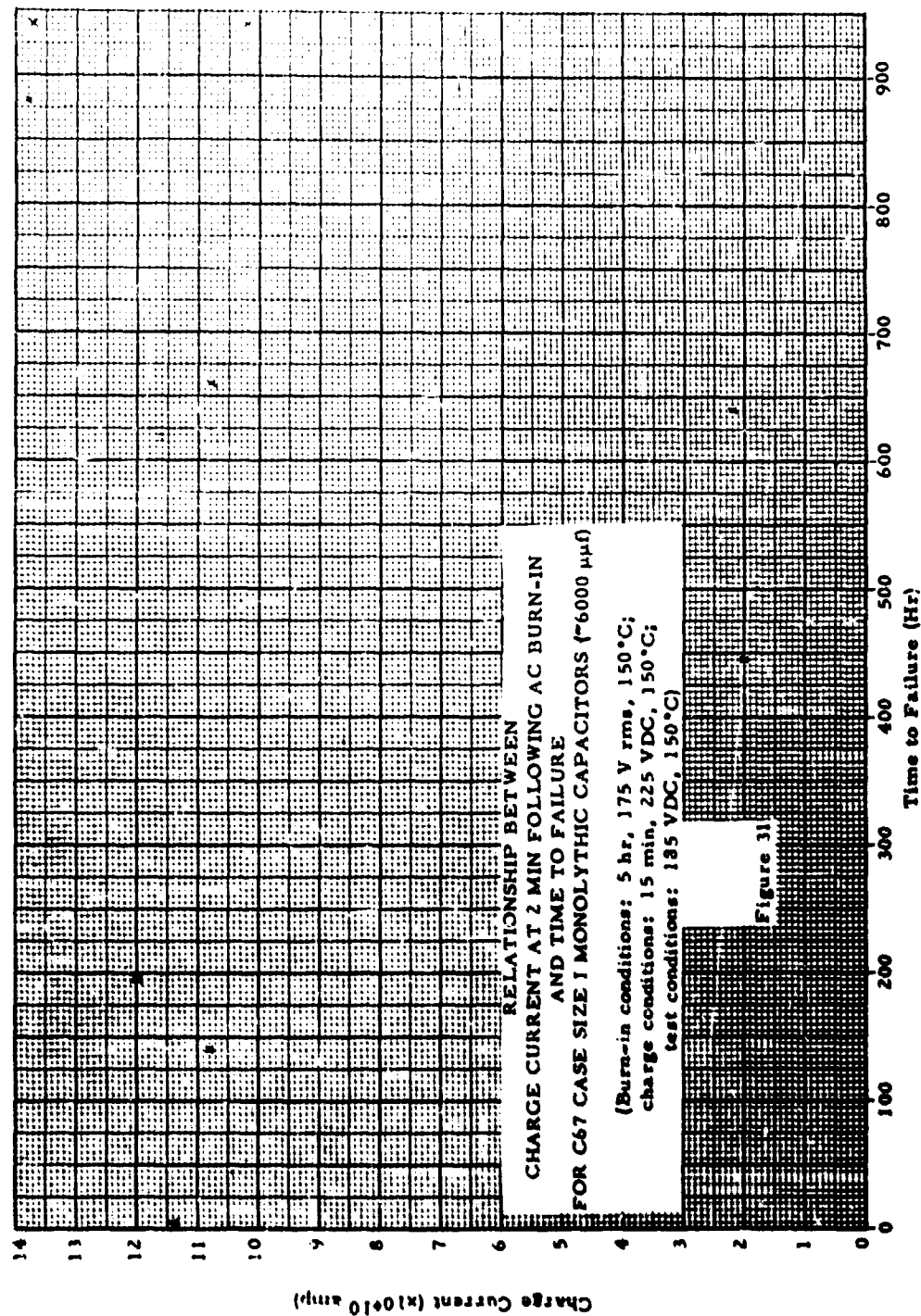
(Burn-in conditions: 168 hr, 50 VDC, 150°C;
charge conditions: 15 min, 225 VDC, 150°C;
test conditions: 185 VDC, 150°C)

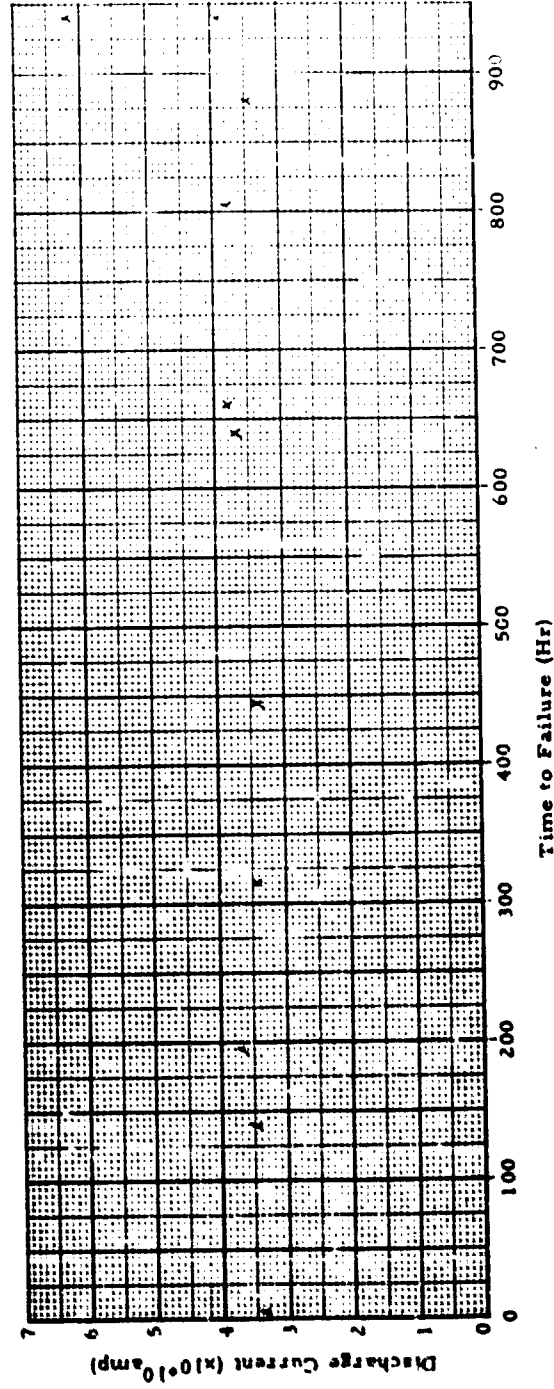
Figure 27





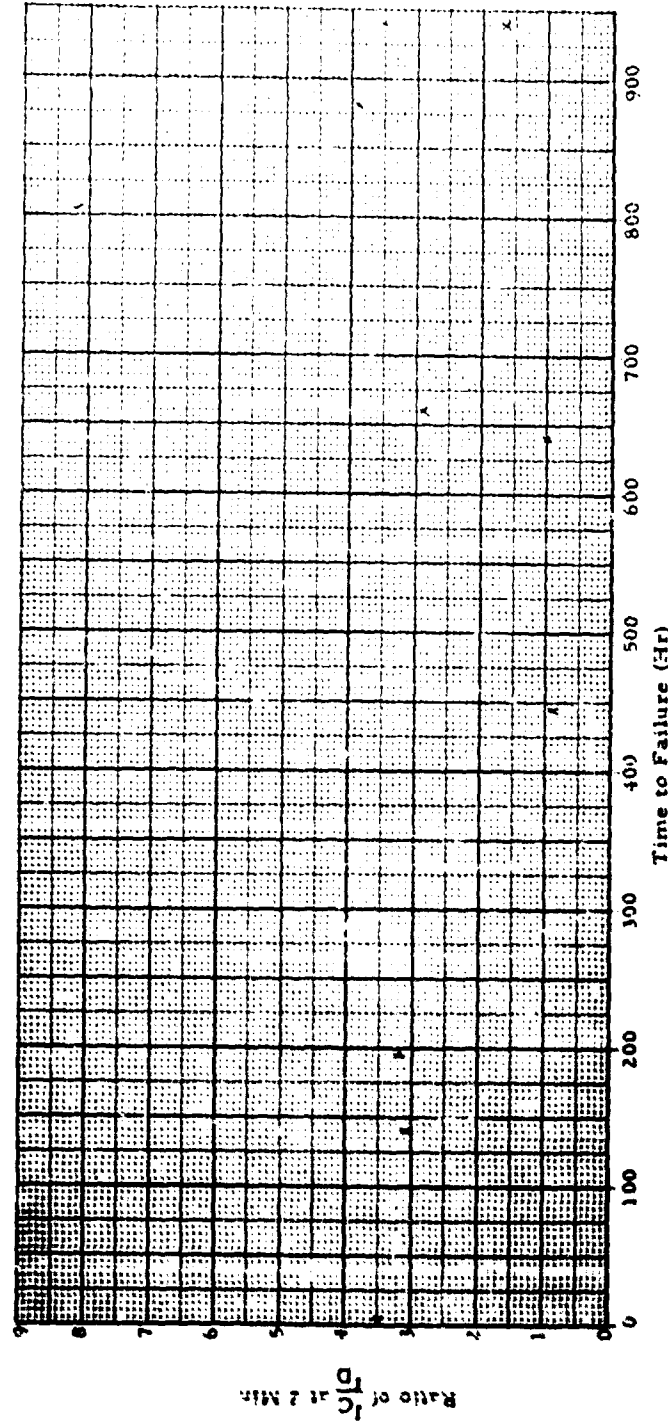






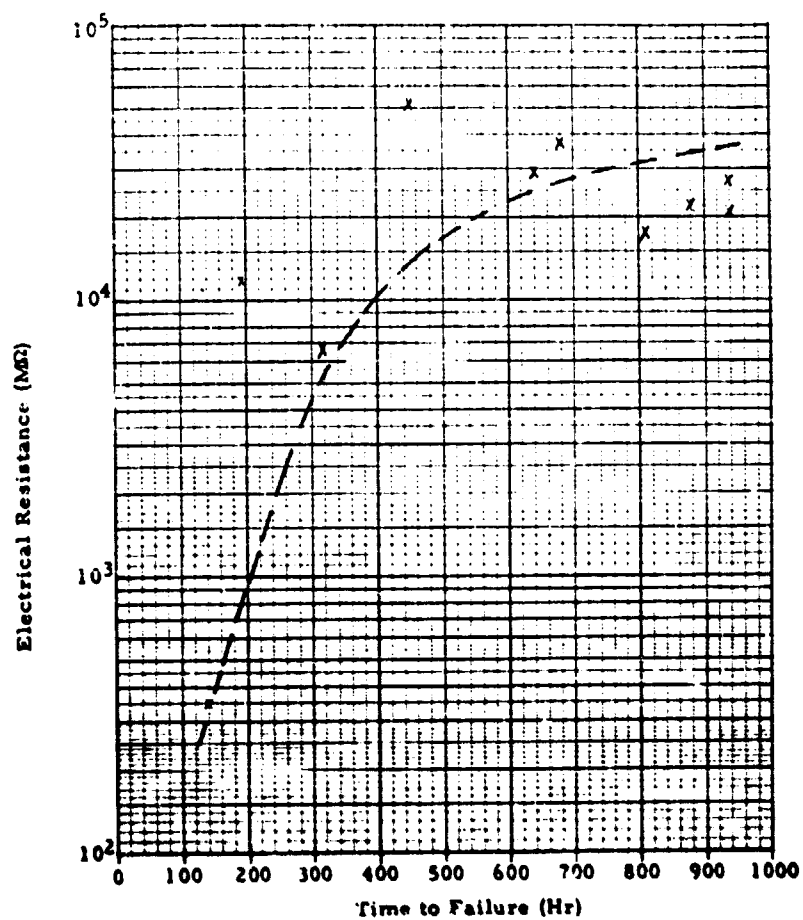
RELATIONSHIP BETWEEN
DISCHARGE CURRENT AT 2 MIN FOLLOWING AC BURN-IN
AND TIME TO FAILURE
FOR C67 CASE SIZE I MONOLITHIC CAPACITORS ($70,000 \mu\text{f}$)

(Burn-in conditions: 5 hr, 175 V rms, 150°C ;
charge conditions: 15 min, 225 VDC, 150°C ;
test conditions: 185 VDC, 150°C)



RELATIONSHIP BETWEEN RATIO OF CHARGE CURRENT AT 2 MIN
TO DISCHARGE CURRENT AT 2 MIN
AND TIME TO FAILURE
FOR C67 CASE SIZE 1 MONOLITHIC CAPACITORS (~6000 μ fd)
(AC burn-in before charge and discharge)
(Burn-in conditions: 5 hr, 175 V rms, 150°C;
charge conditions: 15 min, 225 VDC, 150°C;
test conditions: 185 VDC, 150°C)

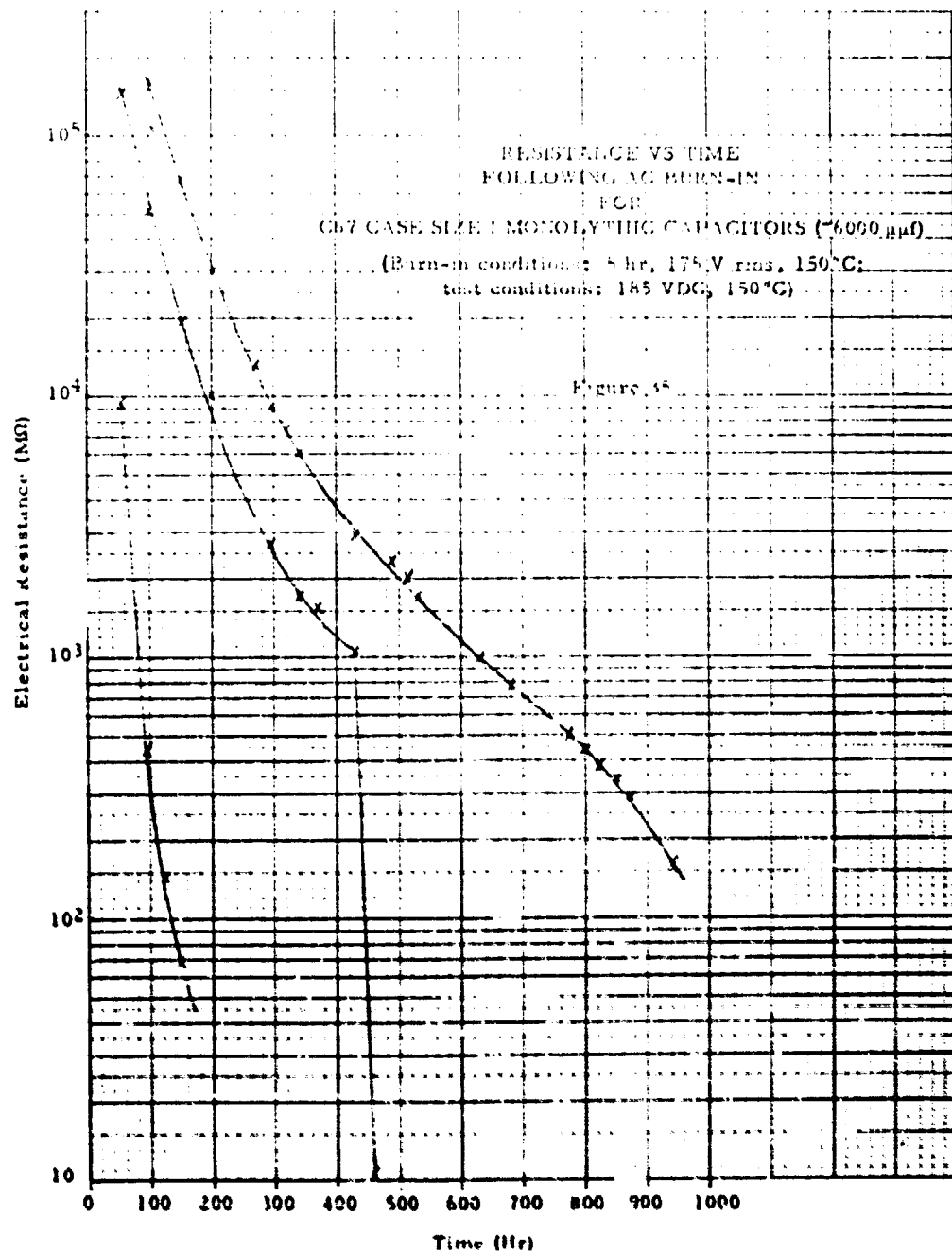
Figure 33

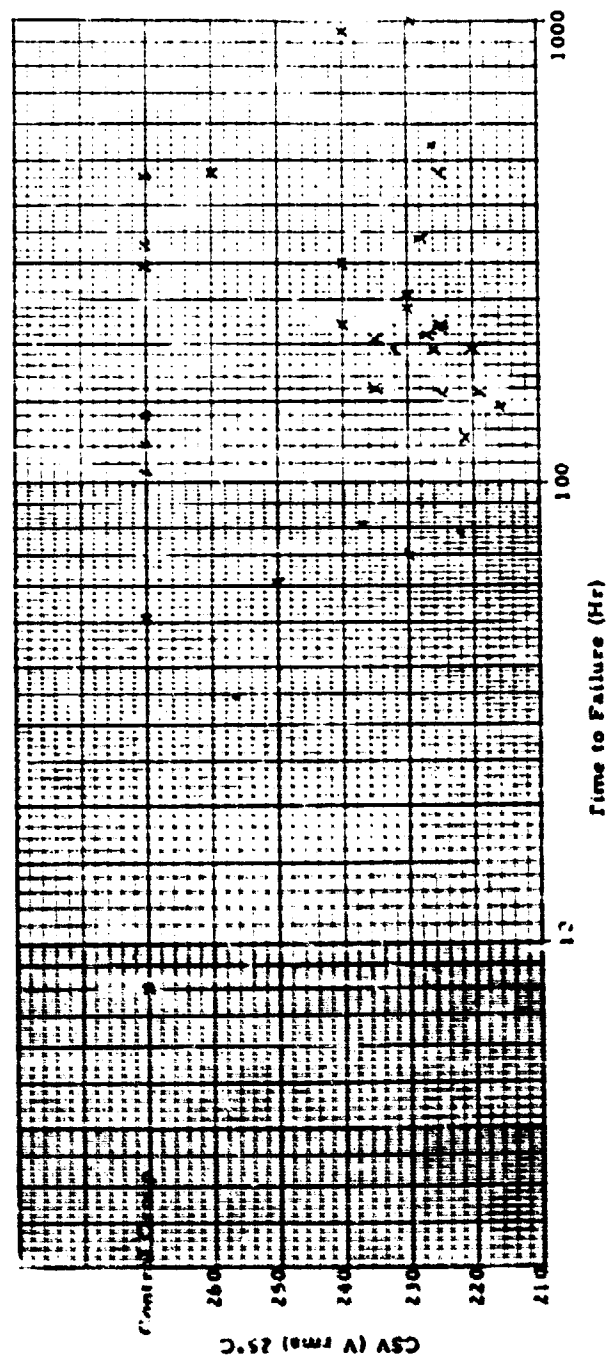


RELATIONSHIP BETWEEN
ELECTRICAL RESISTANCE AFTER 100 HR OF LIFE TEST
AND TIME TO FAILURE ON LIFE TEST
FOR
C67 CASE SIZE I MONOLYTHIC CAPACITORS (~6000 μ F)
(AC burn-in before life test)

(Burn-in conditions: 5 hr, 175 V rms, 150°C;
life test conditions: 185 VDC, 150°C)

Figure 34





RELATIONSHIP BETWEEN
CORONA START VOLTAGE (CSV)
AND TIME TO FAILURE

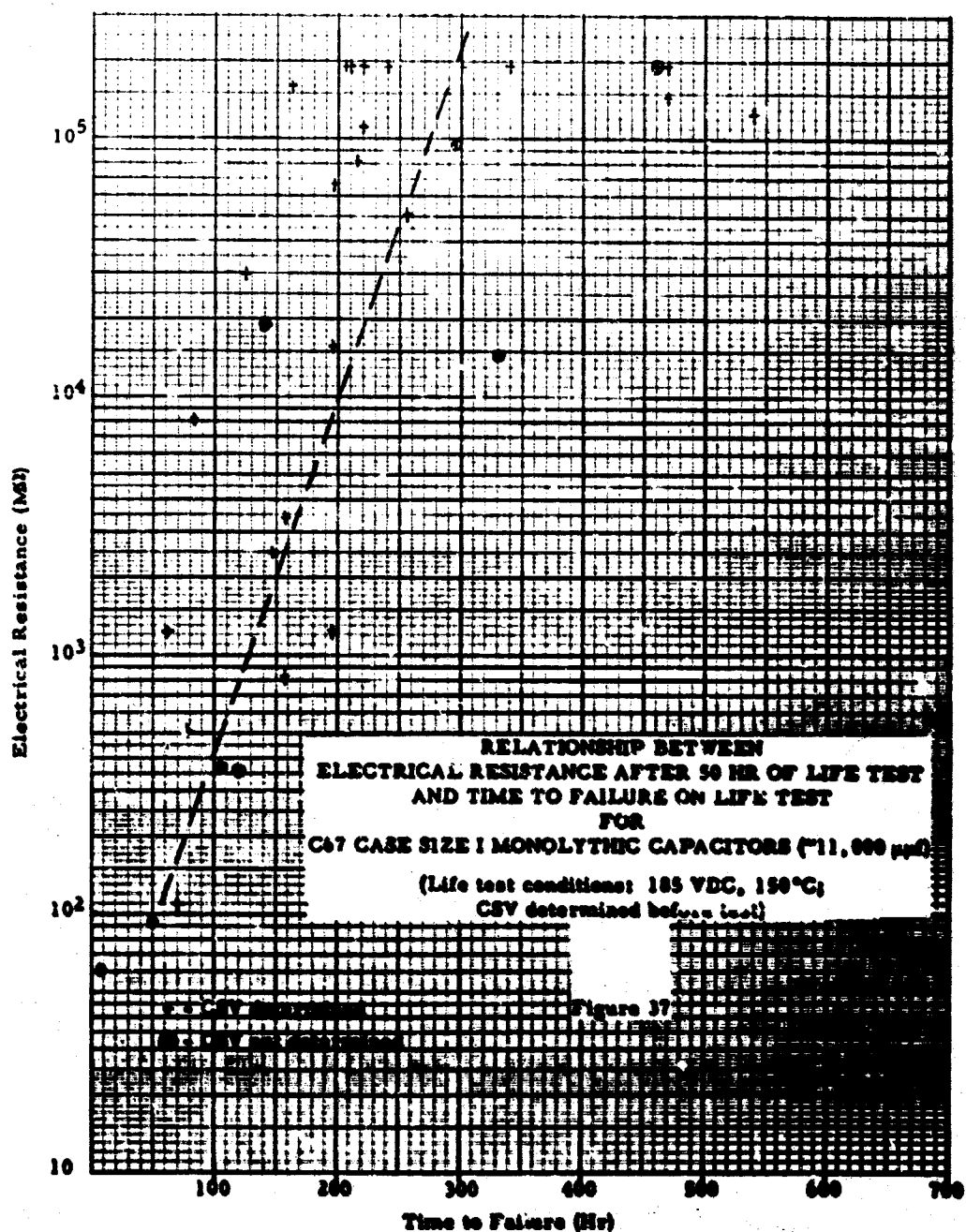
FOR

C57 CASE SIZE I MONOLITHIC CAPACITORS (11,000 μ f)

Life test conditions: 75 VDC/mil, 150°C

(Definition of Failure: electrical resistance <100 M Ω at life test conditions)

Figure 36



SECTION 5

CONCLUSIONS

- (1) No correlation was found between charge or discharge currents, measured before life test, and time-to-failure on life test for C67 Case Size I Monolythic capacitors.
- (2) No correlation was found for C67 Case Size I Monolythic capacitors which received either an AC or DC conditioning before the measurement of charge and discharge currents.
- (3) No correlation was found between AC corona starting voltage and time-to-failure for C67 Case Size I Monolythic capacitors.
- (4) It appears the only technique now available for the detection of potential early failures is a measurement of leakage resistance after a number of hours of testing at accelerated voltage and temperature conditions.

SECTION 6

PROGRAM FOR NEXT QUARTER

- (1) The technique of detecting potential early failures by DC voltage application before accelerated life testing for a number of hours will be examined using large sample sizes.
- (2) Further examination will be made of the electrical conductivity of new and degraded capacitors.

SECTION 7

IDENTIFICATION OF PERSONNEL

<u>Personnel</u>	<u>Hours</u>
J. Dziok	0.5
W. Estes	38.5
J. Fabricius	10.0
E. Jamros	377.5
E. Jones	3.0
M. Malanga	6.0
G. Olsen	0.5
T. Prokopowicz	70.5
F. Schoenfeld	7.0
W. Tatem	344.0
R. Trotter	66.0
K. Whitney	10.0
J. Willey	<u>61.0</u>
Total	994.5

SECTION 8

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