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Requalification Testing
Phase 2

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2. OBJECTIVE

The objective of this test program is to validate the performance of Raychem's Nuclear Grade Cable Accessories to the requirements of Class 1E circuits for nuclear Power Stations as outlined in the relevant sections of IEEE 323-1974, IEEE 323-2003, IEEE 383-1974, and IEEE 383-2004 and to prove the equivalency of the products manufactured with the modified tubing (WCSF) and molded end caps made from the (-52) material, to the original products in fit, form and function. This test report also supplements the data included in EDR-5336.

3. SUMMARY

This qualification test program of Raychem Nuclear Compounds was driven by several factors, some of which were external but others were internal. As previously stated in EDR-5336, Tyco Electronics no longer could procure its flame retardant and needed to remove lead based raw materials from the compounds, so other equivalent material substitutions were made. Great care was taken to find as close match as possible for those endangered ingredients with appropriate ingredients which Tyco Electronics felt would have long term market viability, but, most importantly, behave almost identically both chemically and physically to the ingredients which they were replacing. Because the new ingredients used in the reformulated, or "new" recipes are chemically very similar to those they replaced in the previous or "old" recipe, Tyco Electronics fully expected that the use of products made from these reformulations would be essentially identical to that of the previous products. However, Tyco Electronics made the decision to run a complete requalification program, which also allowed the opportunity to examine the design parameters and increase the number of and the application range of the qualified configurations. This test program included several additional products, sample configurations, and objectives simultaneously. This report is limited to the sample configurations described in section 4. Samples not described in section 4 are not included in this report.

The test program objectives were:

- Establish qualification of V-Stub type splice and by inference other configurations using molded end caps and breakout boots manufactured with the new compounds.
- Verify the performance of the in-line type splice with bolted connections using a bolt pad at application range of 2.5 x.
- Establish compliance with the mandrel bend provisions in IEEE 383.
- Monitor insulation resistance of in-line WCSF splices during LOCA environmental exposure including the profile peaks.

All testing, heat aging and irradiation was done by an independent test lab (WYLE project #43854).

As can be seen in the sample description section in this report, the following types of samples were subjected to accident simulation tests:

- Virgin samples representing beginning of life.
- 40 years accelerated aged and irradiated samples.
- Extended use range samples for WCSF (2.5x the tubing recovered internal diameter vs. 2.0x originally).
- Shorter seal length for WCSF (25mm).

Samples of Raychem's Nuclear Grade Cable Accessories were type tested in applications that are common and specific to the harsh environment inside the containment structure of nuclear generation stations as outlined in the relevant sections of IEEE 323 and IEEE 383.

For each specimen type included in the test program, at least four samples were type tested. Generally, half of the samples were aged to an equivalent 40 years of service including ambient radiation. The other half was tested unaged to simulate an accident at their infancy stage. All of the samples were then exposed to accident radiation and environmental exposure to simulate a Loss Of Coolant Accident on the first day of installation and after 40 years of installation.

The test results prove the fit, form, and functional equivalency of products using the new molded end cap and breakout boot (-52) material. Additionally, the test results supplement the data in EDR-5336 to demonstrate the performance of splices made with WCSF tubing.

4. SAMPLE DESCRIPTION

4.1 Materials

All Raychem Nuclear Products were manufactured with components controlled by 10 CFR 50 Appendix B requirements. All components were taken from normal Tyco Electronics Corporation production runs. The polymeric splice materials met the requirements of Tyco Electronics Corporation internal specifications PPS 3010/7, PPS 3011/8 or PPS 3012/19. All components conformed to the applicable Raychem specifications.

4.2 Sample Preparation

The tested splice configurations represented well-defined applications and apply to the spectrum of anticipated field installations described in Raychem installation instructions. The splice configurations were specifically intended to replicate those tested in prior Raychem WCSF and molded part qualification test programs. Samples were installed on Class 1E LOCA rated wire and cable of commonly used conductor sizes and diameters. The entire program (sample preparation and tests) was performed in accordance with 10 CFR 50 Appendix B quality assurance requirements. The hardware (crimp connectors, lugs, bolts, nuts, etc.) used was appropriate and generally approved or certified for use in the respective application. All samples were mounted on mandrels (Figure 1) or on flat cable trays. Each splice was identified individually for purposes of data recording. All samples were prepared by Tyco Electronics Corporation. Appendix 1 gives the details of the different cables used to fabricate the samples. For simplicity, the cables are referenced hereafter by their number shown in Appendix 1

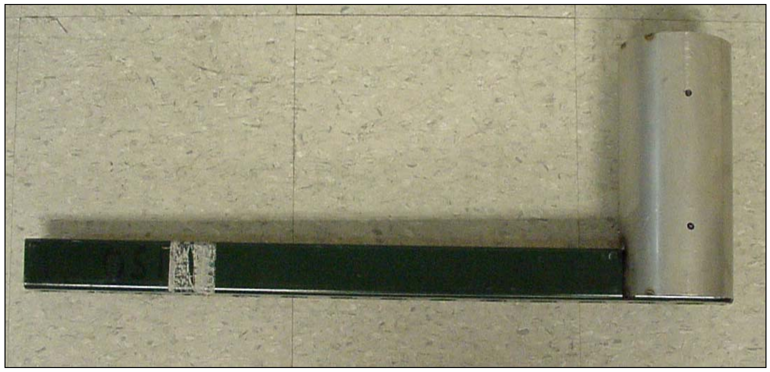
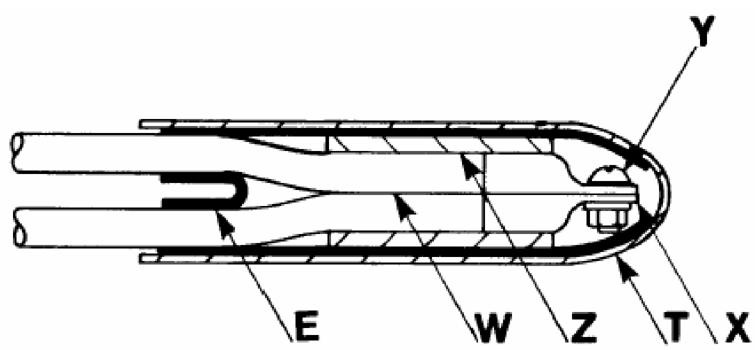


Figure 1: Side view of a typical mandrel. Mandrel diameter may vary according to the test description.

The following sections detail the configurations tested:

4.2.1 V-type Wire Splice (NPKV)

Figure 2: illustrates the general construction of the V-type wire splice with 2 wires.



Key	Component	Description
E	302A812-52-10/144-N	Conductor sealing breakout
Z	WCSF-200-18/5-1U	Breakout body shim
T	101A062-52/144-N	End cap
W	1/C #12 AWG wire	Single conductor wire
X	Ring tongue lugs	
Y	Bolt, washer and nut	#8, 1/4" long

Figure 2: V-Type Wire Splice

These samples were used to establish the qualification of the V-splice construction as well as the conductor sealing breakout boot, and outer sealing end cap in other configurations. Furthermore, the test proves the equivalency of the products made from the new compound to those made from the old compound

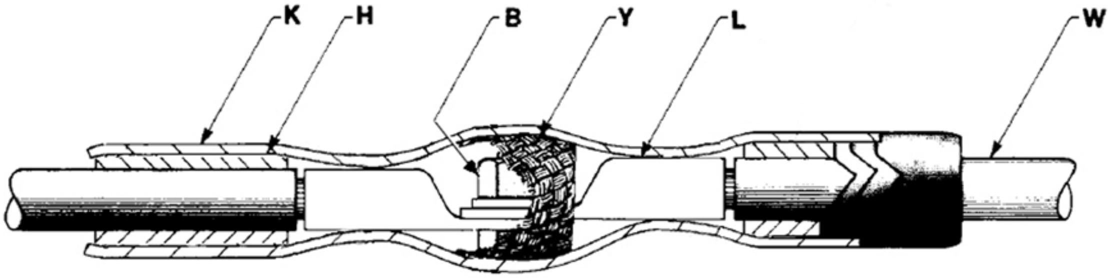
The construction (except for the compound) was identical to the existing NPKV-2-14 kit. One splice was installed on each loop. The sample construction procedure is described in Raychem Laboratory Book # 17923.

These samples were constructed using a #14 AWG cable (Cable #1) spliced together using ring tongue lugs, secured with bolts, washers and nuts with breakout body shim (WCSF-200-18/5-1U), conductor sealing breakout (302A812-52-10/144-N) with an outer sealing end cap (101A062-52/144-N). Four samples were constructed (Samples #1, #2, #7 and #8).

Two of the samples (#1 and #2) were thermally aged and irradiated to represent 40 years of service (@90°C) and two (Samples #7 and #8) were not aged. All samples were subject to full LOCA conditions.

4.2.2 In-Line Splice with Bolted Connection

Figure 3 illustrates the general construction of the In-Line Splice with Bolted Connection.



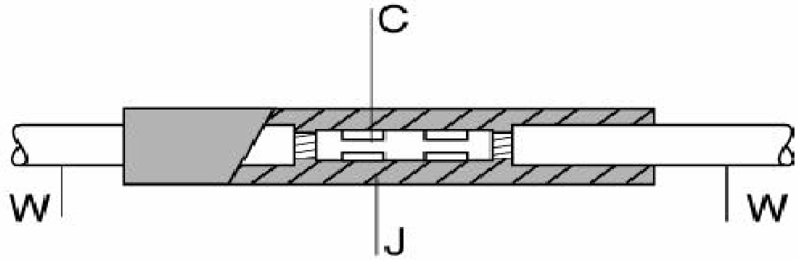
Key	Component	Description
Y	EPPA-109N-1	Bolt pad
K	WCSF-200-18/5-4N	Outer sealing sleeve
H	WCSF-070-6/2-1N	Cable shim
B	Bolt, nut and washer	#10 – 32 x 1/2"
L	1 hole lugs	1-hole lugs
W	1/C wire	1/C wire

Figure 3: In-Line splice with bolted connection

These samples were used to verify the performance of the in-line bolted splice kit using the maximum application range (hold-out) of 2.5x at the bolt location. One splice was installed on each loop and mounted on a mandrel with a diameter of 13.5". The sample construction procedure is described in Raychem Laboratory Book # 17923. Four samples were constructed using a #12 AWG cable (Cable #2). Each sample was spliced together using ring tongue lug, secured with a bolt, a washer and a nut with each side shimmed with 1" (25 mm) WCSF-070-6/2-1N and with an outer sealing sleeve WCSF-200-18/5-4N with 1" (25 mm) seal lengths. A fiber-glass bolt pad was used on these samples. This arrangement results in 1.3x use range based on cable diameter and 2.5x use range at the bolt position (including the bolt pad). Two of the samples (#9 and #10) were thermally aged and irradiated for equivalent of 40 years (@90°C), and two were not aged (Samples #11 and #12). All samples were exposed to LOCA conditions.

4.2.3 Insulation Resistance Measurement Samples

Figure 4 illustrates the general construction of the In-Line Splice with Crimp Connections used for measuring the insulation resistance.



Key	Component	Description
W	1/C, 14 AWG XLPE Wire	Wire
J	WCSF-070-6/2-5N	Splice Sealing Sleeve
C	D-094-05-10-11-02	Crimp Connector

Figure 4: In-line splice with crimp connector

These samples were used to measure the insulation resistance of the WCSF tubing during the LOCA exposure and particularly during the peaks. Four samples were constructed using equal lengths of the same wire (cable #10, 14 AWG XLPE). Two in-line splices were inserted in the middle of two samples using a Raychem crimp connector and WCSF-070-6/2-N-5 with 2″ (50 mm) seal lengths (Samples #47 and #48), while the other two samples were not spliced (Samples #49 and #50). This In-Line Splice configuration represents 2″ (50 mm) seal length and 2.0x OD parameter. The samples lead wires were long enough to facilitate passing through the LOCA chamber penetration without the need for any additional splicing inside the chamber.

Two of the samples (#47 and #49) were thermally aged and irradiated for equivalent of 40 years (90°C), and two were not aged (Samples #48 and #50). All samples were exposed to LOCA conditions.

4.2.4 Bending Sample

This sample was constructed in order to demonstrate the capability of the WCSF products to meet the mandrel bend test provisions of IEEE 383. A bare 100″ (2540 mm) long, 0.143″ (37 mm) Diameter, stranded copper conductor was rejacketed using WCSF-115-9/3-N and bent on a mandrel with a bending diameter of 30 times the jacket diameter (Sample #25It was aged and irradiated to an equivalent of 40 years of service life. A total of three sections of WCSF (40″, 40″ and 21″) were used to cover the entire length of the conductor with 1″ of sealing overlap between sections. The installed WCSF tubing had an insulation thickness of 0.88″ (2.2 mm). As described in Section 1.3 in Bending Sample LOCA profile, this sample was exposed to modified LOCA conditions. This sample was not energized or current loaded during the accident simulation.

5. TEST PROCEDURE

The type test samples were subjected to the test sequence shown in Table 1. The procedure used for each sequence is described in the applicable portion of this section.

Sequence	Test	Test report Section
1	Initial functional tests	5.2
2	Sample heat aging (where needed)	5.3.1
3	Post-Heat aging functional tests	5.2
4	Sample Irradiation	5.3.2
5	Pre-exposure functional tests	5.2
6	LOCA & MSLB environmental exposure	5.4
7	Post-exposure functional tests	5.2

Table 1: Type test sequence.

5.1 Hold Points:

In addition to the functional tests, the following hold points were enforced to track the test progress and document the samples' status during the test sequence:

1. Sample set-up. (Inspect setup of samples.)

2. After heat aging. (Visual inspection, document review and calibration.)

3. After radiation. (Visual inspection, document review and calibration)

4. After Environmental exposure. (Visual inspection, document review and calibration, Functional Tests)

5.2 Functional Tests

The following tests and methods were performed for each of the functional test sequences. Unless otherwise noted, the tests were performed with the samples mounted on either the test mandrels or cable trays, as applicable.

5.2.1 Insulation Resistance

Test samples were immersed for 24 hours in tap water at room temperature, 25±5°C. All configuration assemblies were at least 12 inches (300 mm) below water surface. The insulation resistance of all samples was measured after 24 hours of water immersion while they remained in the water. DC voltage of 500 volts was applied for 1 minute while the measurement was taken. The conductivity of the water bath was measured and documented (Ref. ASTM D257-1992). The water bath was used as the ground plane for the insulation resistance test.

5.2.2 AC Voltage Withstand

An AC voltage withstand test was performed to test samples based on the guidance of IEEE 383. Specifically, while still immersed from the insulation resistance test, the samples were energized at a potential of 80 V/mil of cable insulation thickness for 5 minutes. Applied voltage for cable sizes are listed below (Table 2).

Cable Number	Insulation material	Insulation Thickness (inches/mm)	Applied voltage
1	XLPE	0.03/0.76	2400
2	XLPE	0.03/0.76	2400
10	XLPE	0.03/0.76	2400

Table 2: Applied voltage values for the different cable types

5.3 Sample Preconditioning

The aged samples were preconditioned with exposure to heat and radiation according to the requirements of the test plan.

5.3.1 Temperature Aging

Some test samples were thermally aged to conservatively represent 40 years at an operating temperature of 90 °C. The duration of the accelerated aging was derived from an Arrhenius aging analysis performed on the tubing and the molded parts compounds as described in Tyco Electronics reports EDR 5331 and EDR 5332, respectively. The samples were thermally aged while mounted on the test mandrels or cable trays, as applicable. A short portion of the sample lead wires was routed outside the aging oven and was not exposed to thermal aging. This was intended to prevent problems when splicing sample lead wires to vessel penetration leads before the LOCA simulation.

5.3.1.1 40 Year Thermal Aging for tubing and molded parts

Samples #1, #2, #9, #10, #47, #49 were aged in an air circulating oven for 878 hours at a temperature of 150 °C. Based on EDR 5331 and EDR 5332, this accelerated thermal aging corresponds to 42 years life at 90 °C for the tubing (5% margin) and 47.5 years life at 90 °C for the molded parts (18.75% margin). Sample #25 was aged in an air circulating oven for 152.26 hours at a temperature of 180 °C. This aging temperature was selected to accommodate schedule constraints. Based on EDR 5331 and EDR 5332, this accelerated thermal aging also corresponds to 42 years life at 90 °C for the tubing (5% margin). Samples 7, #8, #11, #12, #48, and #50 were not thermally aged.

5.3.2 Radiation

The samples were exposed to a total cumulative exposure representing the radiation dose expected over the installed lifetime (0 to 40 years) plus the accident radiation dose. All radiation exposures were derived from a Co^{60} source. The radiation dosage rate did not exceed $1.0X10^6$ rads per hour and did not fall below $5.0X10^5$ rads per hour for all exposures. The samples were irradiated while mounted on the test mandrels or cable trays, as applicable.

Appendix 5 shows the irradiation logs.

5.3.2.1 Aged Samples Accumulated Dose and Design Basis Events (DBE)

The planned exposure for the samples #1, #2, #9, #10, #25, #47 and #49 was to a nominal air gamma radiation dose equivalent to $2.15X10^8$ rads. This corresponds to a 40 year accumulated dose at an ambient cumulative radiation exposure of $5.0X10^7$ rads (IEEE 383) and a design basis event exposure of $1.65X10^8$ rads ($1.50X10^8$ rads plus 10% Margin).

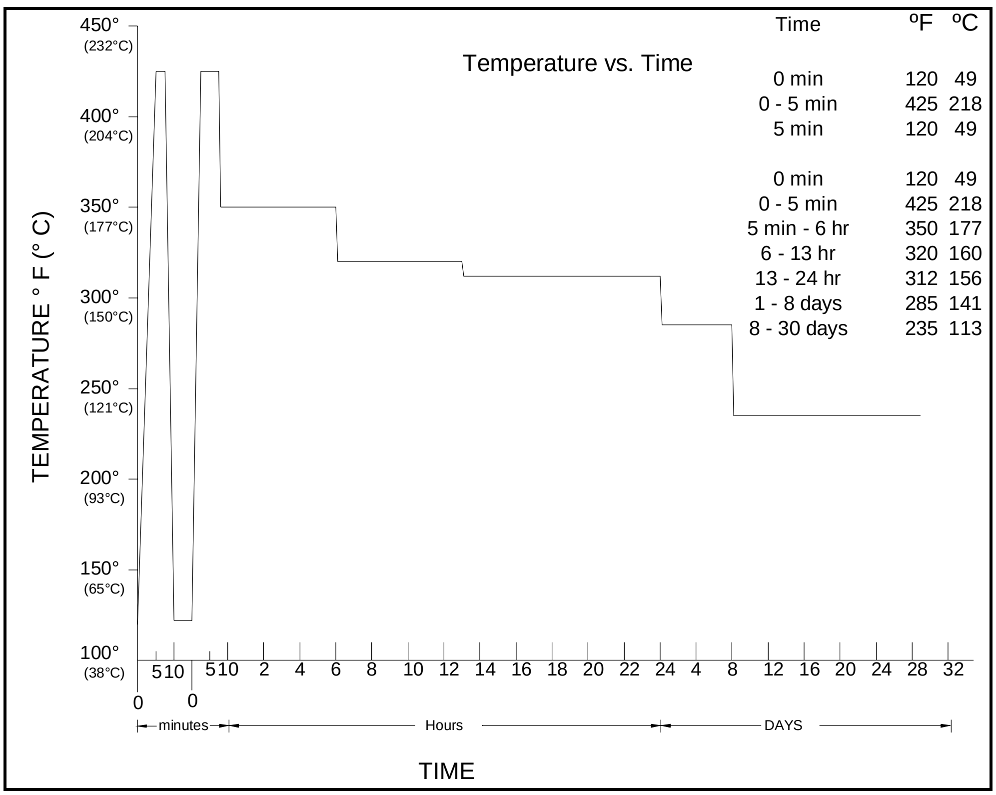
5.3.2.2 New (un-aged) Samples Design Basis Events (DBE)

The planned exposure for the un-aged samples #7, #8, #11, #12, #48 and #50 was to a design basis event nominal air gamma radiation dose equivalent to $1.65X10^{8}$ rads. ($1.50X10^{8}$ rads plus 10% Margin).

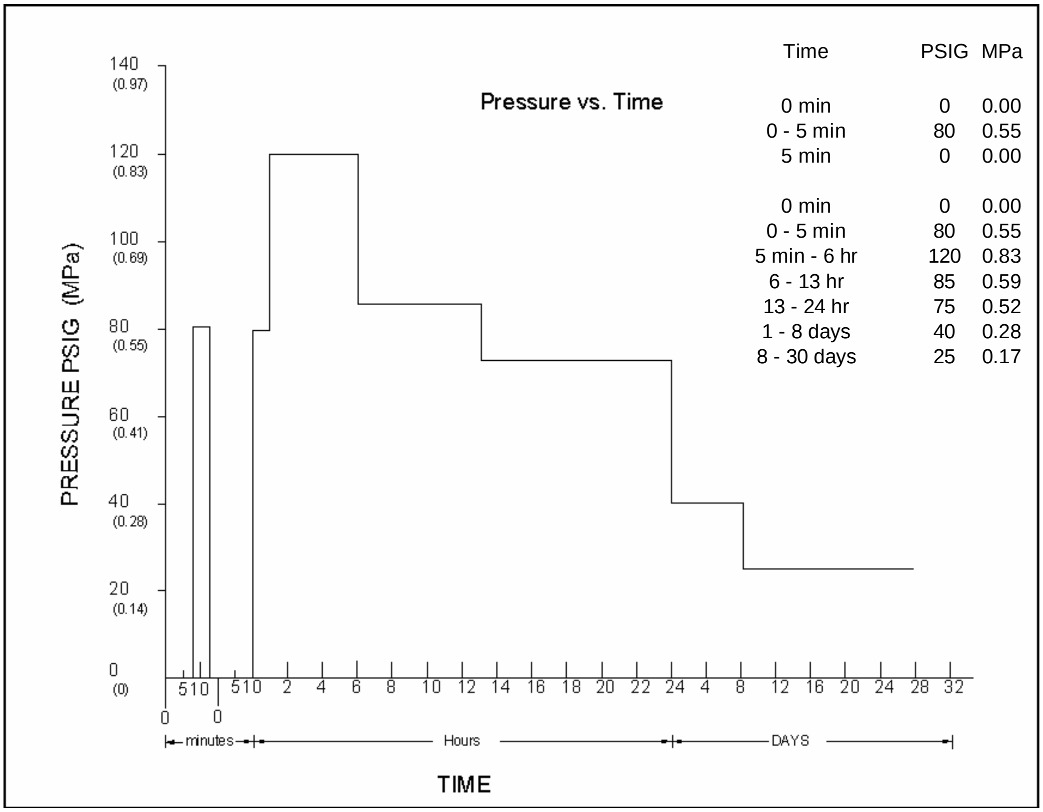
5.4 LOCA Environmental Exposure

5.4.1 Environment Conditions

The planned time/temperature/pressure profile for all type test sample configurations is shown in Figure 5. Appendix 2 shows the actual time/temperature/pressure graphs as measured during the environmental exposure.



(A) Temperature profile



(B) Pressure profile

Figure 5: LOCA profile

5.4.2 Chemical Spray

Type test samples were sprayed with chemical solution starting at the sixth hour and continuing through the end of the environmental exposure. Chemical spray solution consisted of 0.28 molar H_3BO_3 and 0.064 molar $Na_2S_2O_3$ buffered with NaOH to a pH of 10.5 at 25±5°C (IEEE 323). Chemical spray was directed vertically downward at a minimum rate of 0.15 gal/min/ft^2 (6.1 l/min/m^2) of area of the test chamber projected onto a horizontal plane. The chemical spray concentration was not adjusted during the test and was recycled throughout the environmental exposure.

5.5 Bending Sample

After preconditioning, the bending sample was straightened and then wound around a mandrel of 20 times the jacket diameter in the opposite direction. The sample was immersed under 1 foot (30 cm) of water for 24 hours and then tested for dielectric withstand to 7000 volts AC for 5 minutes as required in the IEEE-383. Additionally, the sample was then exposed to a LOCA environmental simulation then retested for dielectric withstand at 7000V for 5 minutes.

5.5.1 Mounting

Type test samples remained mounted on trays or mandrels during the environmental simulation. Test sample trays were fixed within the LOCA test vessel and located horizontally with respect to the earth. Test mandrels were mounted with axes pointing vertically. All samples had a minimum lead length of ten feet of insulated conductor inside the test chambers. All the sample trays and mandrels were solidly grounded to the mounting frame, which was electrically grounded to the test chamber.

5.5.2 Test set-up

5.5.2.1 Accessory connections and Marking

Test vessel penetrations used Teflon wires having a larger wire gauge than the test samples. The un-aged portion of the test sample lead wire was used to connect the vessel penetration wires to the test samples. Joint connections inside the chamber were crimped and insulated with un-aged Raychem WCSF splicing sleeves. All sample test leads were individually identified. Samples #47, #48, #49 and #50 were constructed with enough lead length to enable connection to the terminal strips outside of the chamber without splicing to any auxiliary wires (Teflon or otherwise) inside the test chamber. Sample #25 did not use test vessel penetrations since it was not energized or current loaded during the accident exposure.

5.5.2.2 Equipment Sources, Fusing, and Monitoring

Six sample circuits with independent voltage and current sources were utilized to energize and monitor the test samples. Each test circuit was independently fused for its applied circuit voltage and rated current. Applied voltage, circuit current and leakage current-to-ground were monitored continuously throughout the environmental exposure. The schematic diagrams of the monitoring circuits are shown in Appendix 4. Some circuits include samples that represent configurations not included in this report.

5.5.2.3 Voltage and current requirements

Applied voltage for each sample (except #47, #48, #49 and #50) circuit was 600Vac to ground according to the cable manufacturers' recommendations. Each test sample circuit carried rated current at a 25°C ambient temperature based on wire size (Appendix 3). Unless otherwise noted, voltage and current were applied continuously during the environmental simulation. Each current source was appropriately fused based on required current; all voltage sources used ½ amp fuses to interrupt excessive ground leakage current. Samples #47, #48, #49, and #50 were energized at +125Vdc with respect to ground.

5.5.2.4 Monitoring

Calibrated monitoring test equipment was used to detect changes in variables monitored against a change in time. During the LOCA test, temperature, pressure, voltage, circuit current and leakage current were monitored at one second intervals during the peaks, one minute intervals during the short plateaus and every 15 minutes otherwise.

5.6 ACCEPTANCE CRITERIA

Electrical Integrity of the test samples at room temperature after the LOCA exposure was based on:

1. Insulation resistance measurements at 500 Vdc (IR > $2.5X10^6$ Ohms).
2. Voltage withstand tests (5 minutes withstand at voltage level listed in Table 2).

Performance of the test samples during the environmental simulation was based on the ability to maintain electrical loading at rated voltage and current during the environmental simulation.

Performance of the bending sample will be determined by the ability of the sample to successfully complete a voltage withstand test at 7000 V (based on 80 V/mil of insulation thickness), after being straightened and then wound back on a 20D mandrel in the opposite direction.

5.6.1 Insulation performance

During the environment exposure, Insulation Resistance (IR) measurements were taken periodically to ensure insulation performance of the samples in the 600 Vac circuits. The IR voltage was applied for 1 minute to insure reading stability. IR measurements were performed on all monitored samples prior to transient 1, prior to transient 2, at the 4-hour point, 20-hour point, 240-hour point, the 384-hour point, and at the 720-hour point (the end of the exposure) with the samples still at temperature. Furthermore, IR measurements were performed during the peaks of transients 1 and 2 for samples #1, #9, #11, and #47 through #50. Samples #47 through #50 were connected in series and the dc leakage current was monitored continuously using the data acquisition system throughout the entire environmental exposure. Separate IR measurements for each of the Samples #47 to #50 were taken manually, generally twice every working day, throughout the exposure, except on weekends, when IR readings were taken for the whole group of samples or when the test facility experienced problems that prevented measurements..

6. RESULTS AND DISCUSSION

6.1 Deviations from test plan

6.1.1 Thermal Aging

During the thermal aging of the samples, the temperature of the aging chamber used for aging Tray 1, which contained samples #1 and #2, dropped below the required aging temperature of 302°F for approximately 1 hour and 45 minutes. The lowest temperature recorded during that time was 297°F. As a result, 1 hour and 45 minutes were added to the thermal aging time for all samples affected.

6.1.2 Radiation Exposure

Based on the objectives of the test program, the aged samples were to be subjected to a total of 215 Mrads of Gamma radiation to account for 40 years of life (50 Mrads) and a DBE of 165 Mrads (150 Mrads +10% margin) and the unaged samples were to be subjected to a DBE dose of 165 Mrads. Appendix 5 contains the radiation certifications. Table 3 shows the target and the actual radiation doses for the aged and unaged samples.

	Aged Samples Cumulative Dose	Unaged Samples Cumulative Dose
Target Dose (rads)	2.15E+08	1.65E+08
Actual Dose (rads)	2.25E+08	1.74E+08

Table 3: Target and Actual doses.

6.1.3 LOCA simulation

Transient 1:

The test chamber was filled with room-temperature tap water to completely submerge the test samples contained within. Following a 24-hour wait, an Insulation Resistance test was then performed on each sample. The test chamber was then drained and the test chamber average temperature was increased to approximately 140°F and held for approximately 30 minutes prior to the start of the first transient of the Accident Simulation. The temperature and pressure profiles shown in Figures 1 and 2 in Appendix III were used for the application of steam and pressure for the first transient.

The ramp up in temperature from 140°F to 425°F was performed on a best-effort basis. The time to reach an average chamber temperature of 425°F for the initial transient was approximately 128 seconds. The highest temperature recorded by an individual thermocouple during the first transient was 438°F. The pressure followed the general trend of the temperature profile reaching a maximum of 131.8 psi and a minimum of 108 psi during the transient, significantly higher than the target value of 80 psi. (See Appendix 2).

After completing the required duration of the peak temperature and pressure the conditions were maintained for an additional 13 minutes to enable measuring the insulation resistance of the samples identified in section 5.6.1.

When the IR measurements were concluded, the test chamber temperature was reduced to ambient temperature following the completion of the first transient. The test chamber was then filled with room-temperature tap water to completely submerge the test samples contained within. Following a 24-hour wait, an Insulation Resistance test was then performed on each sample. The test chamber was then drained and the test chamber temperature was increased to approximately 135°F and held for approximately 68 minutes prior to the start of the second transient of the Accident Simulation.

During the immersion test samples 9 and 12 had low IR values to ground. They were moved to circuit 30A(3) to minimize the possibility of blown fuses in circuits 30A(1) and 30A(2) so that other samples in these circuits would remain energized at the test voltage during transient #2. After this move circuits 30A(1), 30A(2) and 30A(3) all sustained the test voltage and were powered normally until the end of the test.

Transient 2:

The time to reach an average chamber temperature of 424°F (highest average temperature reached) for the second transient was approximately 134 seconds. The highest temperature recorded by an individual thermocouple during the second transient was 432°F. The average temperature stayed above 400°F for a total of 6 minutes. .Due to difficulties maintaining the chamber temperature, the average temperature fell below 400°F approximately 256 seconds after reaching the peak temperature. The temperature was then lowered to approximately 350°F and held for approximately 7 hours and 55 minutes. The temperature was then lowered to approximately 320°F and chemical spray was initiated. Note that each temperature plateau was extended to account for the time the samples were not energized due to Insulation Resistance testing or sample troubleshooting or the target temperature and/or pressure was not maintained. Refer to Appendix 6 Chronological Summary of Deviations from Plan for a detailed description of the deviation events.

The temperature was held at approximately 320°F for 16 hours and 11 minutes. The temperature was then lowered to approximately 312°F and held for approximately 12 hours and 30 minutes. The average temperature of the test chamber was then reduced to approximately 285°F. The 285°F plateau was held for 175 hours and 22 minutes with 1 hour and 16 minutes of that time below the specified temperature (due to equipment malfunction) for a total of 174 hours and 6 minutes at the required temperature. The average chamber temperature was then reduced to approximately 235°F. The 235°F plateau was held for 579 hours and 12 minutes with 10 minutes of that time below the specified temperature (due to equipment malfunction) for a total of 579 hours and 2 minutes at the required temperature.

The total durations of the transients were – Transient #1: 18 minutes and Transient #2: 789 hours and 44 minutes.

The full LOCA exposure profile is presented in Appendix 2

Bending Sample LOCA profile

The bending sample was exposed to a different LOCA profile due to the fact that it was mounted on tray 7 which contained other samples not described in this report. A mid test decision was made to change the LOCA profile for the other samples at which time it was too late to switch the bending sample back according to the original plan. Figure 6 shows the amended profile for the bending sample. The actual LOCA exposure profile is presented in Appendix 2. There was no chemical spray present during this simulation.

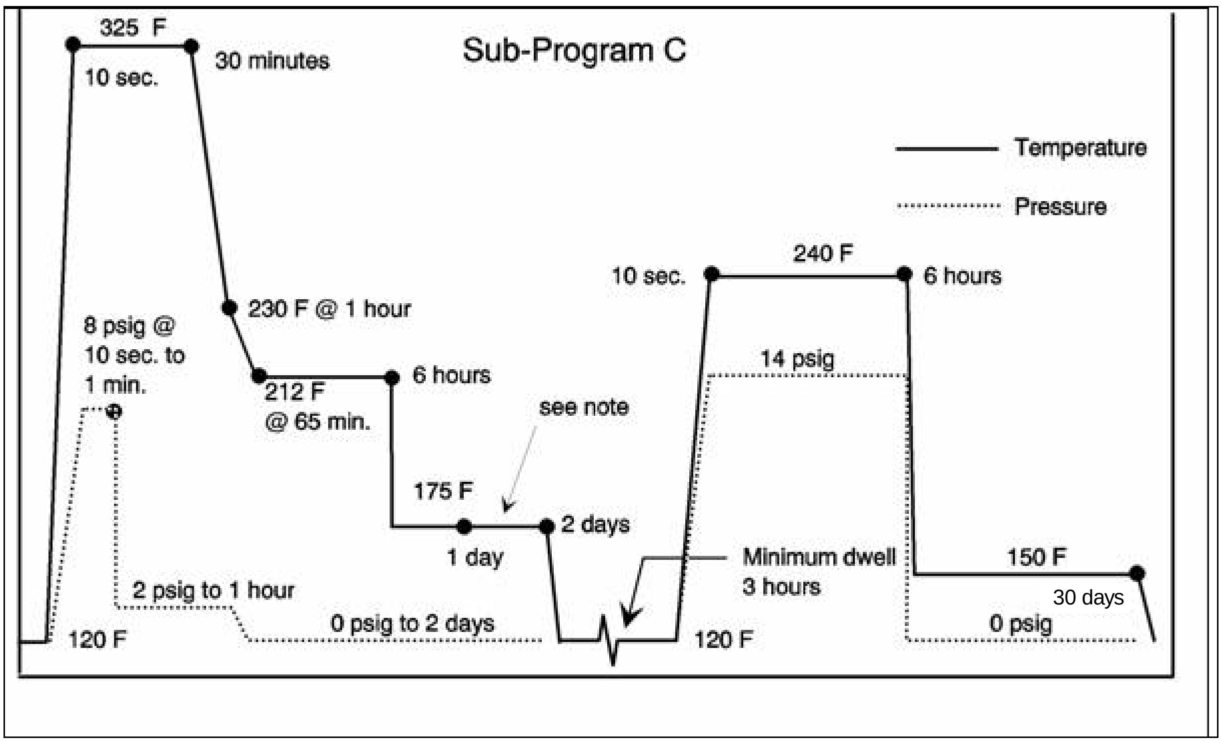
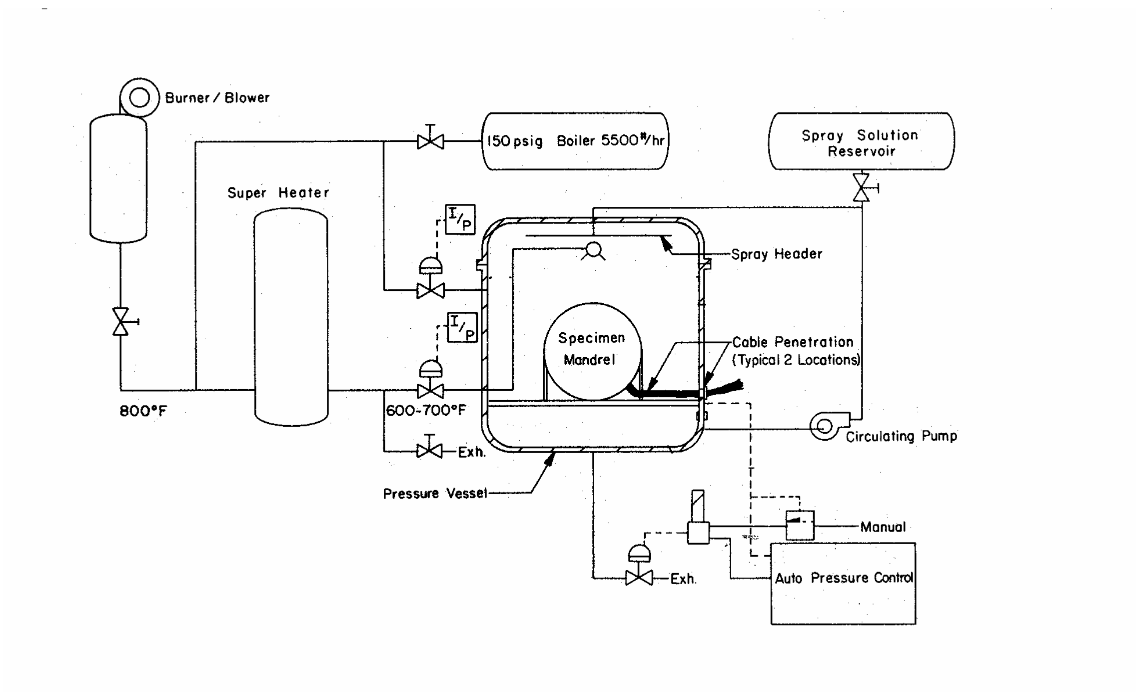


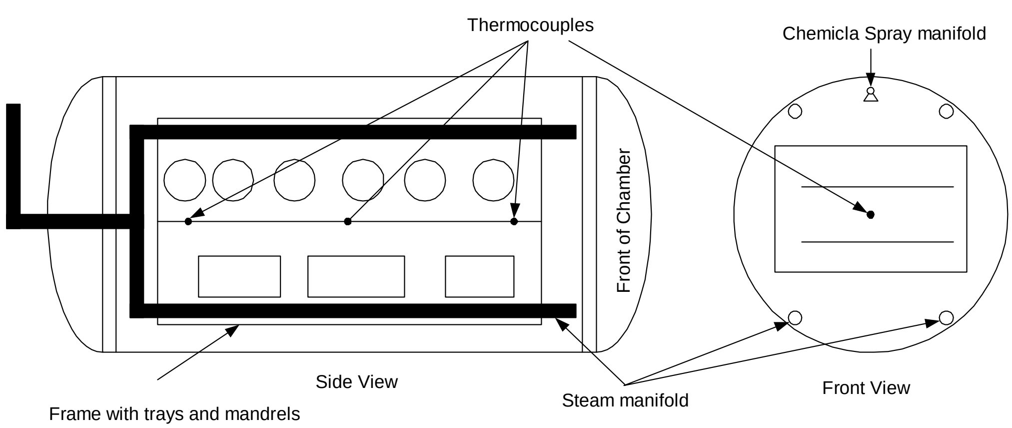
Figure 6: Target LOCA profile for the bending sample.

6.2 LOCA simulation Vessel

Figure 7 shows a schematic diagram of the LOCA test chamber.



(A)



(B)

Figure 7: LOCA pressure vessel and auxiliary equipment.

Figure 8 shows a picture of the LOCA simulation chamber after the conclusion of the test.

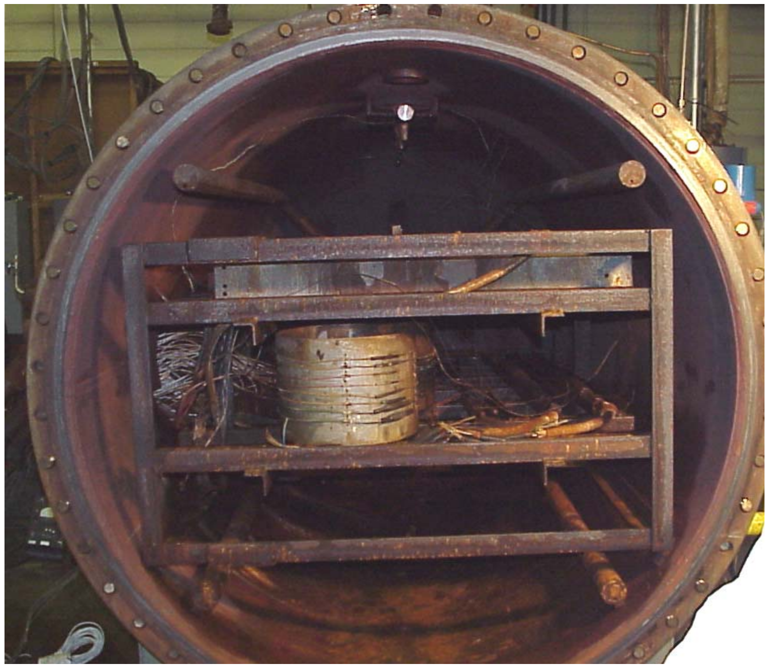


Figure 8: LOCA simulation test chamber and internal vessel support frame after the accident simulation.

6.3 Sample Analysis

6.3.1 V-type wire splice (NPKV) (Samples #1, #2, #7 and #8).

This category included 4 samples. Table 4 shows a list of the samples and a summary of the qualification test results.

SAMPLE NO.	TRAY NO.	AGING TIME & TEMP.	RADIATION DOSE (rads)	Test Circuit	Time Energized Trans1/Trans2	RESULTS
1	T1	878.17 hr @ 302°F	2.259E+08	25A(1)	18 min/789 hrs	Qualified
2	T1	878.17 hr @ 302°F	2.259E+08	25A(1)	18 min/789 hrs	Qualified
7	T2	Not Aged	1.739E+08	25A(4)	18 min/789 hrs	Qualified
8	T2	Not Aged	1.739E+08	25A(4)	18 min/789 hrs	Qualified

Table 4: V-type wire splice (NPKV) (Samples #1, #2, #7 and #8) qualification results. Radiation doses represent (accident + ambient) for aged samples or accident only for un-aged samples.

The test samples were inspected for evidence of damage and proper installation and mounting before the start of the test sequence. There was no visible evidence of damage. All samples and mounting conformed to Tyco Electronics requirements. The test samples were visually inspected and subjected to the functional tests described in Section 5.2 before thermal aging, irradiation and the environmental exposure. All samples revealed no signs of damage and passed the functional tests. These samples remained energized and current loaded throughout both accident transient simulations, except for (1) circuit 25A(4) troubleshooting and a blown fuse on 5/27 @ 15:51 (for 36 minutes) and again @ 23:39 (for 38 minutes), (2) during planned IR measurements and (3) troubleshooting associated with the facility or other samples. Appendix 8 shows the circuits' voltage and current time plots for the entire simulation. No specific cause was identified for blowing the fuse of circuits 25A(4) twice and no additional incidents occurred for the duration of the exposure. The functional tests were performed on the samples after the LOCA simulation as part of the post LOCA evaluation. The results of the functional tests are given in

Table 5. Additionally, periodic IR measurements were made before, during, and after the accident simulation and at the end of the test program. Each sample was also tested for AC dielectric breakdown to demonstrate margin. Test samples were submerged under water and

AC voltage was applied in steps of 1000V for 30 seconds until breakdown. The periodic IR and breakdown data are given in Table 6.

Sample	Initial Base Line			Post Heat Aging			Post Irradiation			Post LOCA		
	IR, Ω	W/S, V	I_{leak}, μA	IR, Ω	W/S, V	I_{leak}, μA	IR, Ω	W/S, V	I_{leak}, μA	IR, Ω	W/S, V	I_{leak}, μA
1	1.6E12	2400	440	2.2E11	2400	200	1.4E12	2400	500	4.4E11	2400	580
2	1.8E12	2400	440	2.2E11	2400	200	1.8E12	2400	480	1.7E10	2400	660
7	5.2E11	2400	440	n/a	n/a	n/a	3.0E11	2400	520	2.4E11	2400	540
8	5.9E11	2400	440	n/a	n/a	n/a	5.0E11	2400	580	9.6E10	2400	520

Table 5: Functional Tests at Program Sequence points for V-type wire splice (NPKV) (Samples #1, #2, #7 and #8).

Table 6 shows the IR measurements performed on the monitoring circuits during the LOCA exposure at 500 volts DC (unless otherwise noted).

.	Sample 1	Sample 2	Sample 7	Sample 8
Prior 1st peak	4.0E10	3.0E10	1.8E10	2.2E10
At 1st Peak 425°F	2.4E08	n/a	2.8E08	n/a
Prior to 2nd transient	3.0E10	8.2E10	1.8E10	2.8E09
At 2nd Peak 385°F	2.8E08	n/a	5.2E09	n/a
4 hour point of 2nd transient	1.4E08	2.4E08	3.8E08	2.4E08
3-hour point of the 312°F plateau	4.0E07	3.0E07	6.0E07	1.8E07
96-hour point of 235°F plateau	2.6E08	2.2E08	1.3E08	1.1E08
241-hour point of 235°F plateau	2.8E08	1.8E08	1.1E08	1.0E08
At End of 2nd transient at 238°F	3.5E08	1.5E08	9.8E07	8.8E07
At End of 2nd Transient submerged 24 hrs	8.8E09	4.0E09	2.4E10	1.4E10
Functional Test (after removal from chamber and submerged 24 hrs)	4.4E11	1.7E10	2.4E11	9.6E10
Destructive Testing Dielectric Breakdown	17,000 v breakdown at Lead wire	18,000 v breakdown at tip of endcap	7,000 v breakdown at side of endcap	8,000 v breakdown at Lead wire

Table 6: IR and Dielectric Breakdown Measurements

All samples met the acceptance criteria during the prescribed Function Tests and exhibited expected performance during the periodic IR and breakdown tests. The AC breakdown test voltages substantially exceeded the IEEE-383 specified high potential test voltage.

6.3.2 In-Line Splice with Bolted Connection (Samples #9, #10, #11, and #12)

This category included 4 samples. Table 7 lists the samples and a summary of the qualification test results.

SAMPLE NO.	Mandrel NO.	AGING TIME & TEMP.	RADIATION DOSE (rads) Actual	Test Circuit	Time Energized Trans1/Trans2	RESULTS
9	M1	878.17 hr @ 302°F	2.262E+08	30A(1)/30A(3)	18 min/789 hrs	Meets requirements
10	M1	878.17 hr @ 302°F	2.262E+08	30A(1)	18 min/789 hrs	Meets requirements
11	M2	Not Aged	1.743E+08	30A(2)/30A(3)	18 min/789 hrs	Does not meet requirements
12	M2	Not Aged	1.743E+08	30A(2)	18 min/789 hrs	Does not meet requirements

Table 7: In-Line Splice with Bolted Connection (Samples #9, #10, #11, and #12)
Note: Samples 9 and 12 were moved to circuit 30A(3) prior to transient 2.

The test samples were inspected for evidence of damage and proper installation and mounting before the start of the test sequence. There was no visible evidence of damage and all samples and mounting was conformed to Tyco Electronics requirements. The test samples were visually inspected and subjected to the functional tests described in Section 5.2 before thermal aging, irradiation and the environmental exposure. These samples remained energized and current loaded throughout both accident transient simulations, except during planned IR measurements and troubleshooting associated with the facility or other samples. Appendix 8 shows the circuits' voltage and current time plots for the entire simulation. The functional tests were performed on the samples after the LOCA simulation as part of the post LOCA evaluation. The results of the functional tests are given in Table 8. Additionally, periodic IR measurements were made before, during, and after the accident simulation and at the end of the test program. Each sample was also tested for AC dielectric breakdown to demonstrate margin. The periodic IR and breakdown data are given in Table 9.

Sample	Initial Base Line			Post Heat Aging			Post Irradiation			Post LOCA		
	IR, Ω	W/S, V	I_{leak}, μA	IR, Ω	W/S, V	I_{leak}, μA	IR, Ω	W/S, V	I_{leak}, μA	IR, Ω	W/S, V	I_{leak}, μA
9	1.1E12	2400	460	2.0E11	2400	360	1.2E12	2400	470	5.2E11	2400	640
10	1.1E12	2400	460	2.0E11	2400	360	1.1E12	2400	480	5.0E11	2400	600
11	1.1E12	2400	460	n/a	n/a	n/a	1.6E12	2400	480	5.0E05	1200	>10mA
12	1.2E12	2400	460	n/a	n/a	n/a	1.4E12	2400	500	1.8E05	600	>10mA

Table 8: Functional Tests at Program Sequence points for In-Line Splice with Bolted Connection (Samples #9, #10, #11, and #12).

Table 9 shows the IR measurements performed on the monitoring circuits during the LOCA exposure at 500 volts DC (unless otherwise noted).

	Sample 9	Sample 10	Sample 11	Sample 12
Prior 1st peak	1.8E10	3.5E10	3.5E10	4.0E10
At 1st Peak 425°F	2.4E08	n/a	3.5E08	n/a
Prior to 2nd transient	No measurement was taken (Wyle Labs error)	2.0E10	2.2E10	1.8E05 @50volts
At 2nd Peak 385°F	4.0E08	n/a	4.5E08	n/a
4 hour point of 2nd transient	3.0E08	1.3E09	1.5E09	2.8E08
3-hour point of the 312°F plateau	3.0E05 @50volts	1.1E07	2.8E07	3.0E07
96-hour point of 235°F plateau	8.0E05	1.3E08	2.0E08	2.2E07
241-hour point of 235°F plateau	1.0E06	1.4E08	3,7E07	4.0E06
At End of 2nd transient at 238°F	8.0E06	4.5E07	2.0E07	1.5E06
At End of 2nd Transient submerged 24 hrs	<5.0E04 @10volts	3.0E07	5.2E06	1.5E05 @50volts
Functional Test (after removal from chamber submerged 24 hrs)	5.2E11	5.0E11	5.0E05 @50volts	1.8E05 @50volts
Destructive Testing Dielectric Breakdown	12,000 v Failure of the splice at approx end of bolt pad	14,000 v Failure of the splice at approx end of bolt pad	1,000 v Fail on sleeve at damaged area.	400 v Fail at split in side of sleeve

Table 9: IR measurements during LOCA simulation

Table 10 contains a summary of the IR measurements anomalies observed during and after the LOCA simulation

SAMPLE	Post LOCA IR with the splice in chamber submersed	Post LOCA IR with the splice and available sample leads submersed	Results / Remarks
9	<5.0E04	5.2E11	Started giving low IR readings after the second transient. It was 4.0E08 ohms during the peak at 385ºF but then went low after 1 hour of chemical spray (about 7 hours of transient 2 at temp of 322ºF). The readings improved but remained lower than other samples during the remainder of the simulation. As the temperature dropped. The IR went low again during the in chamber submergence test but the sample passed the Functional tests at room temperature out of chamber in water. Tested to failure where it punctured a hole at the end of the bolt pad at 12,000 volts. Investigation revealed no problem in the splice. Further investigation revealed a longitudinal split of the lead wires approximately 31" away from the splice on both sides.
11	5.2E06	5.0E05	Started giving low IR only after the sample was removed from the chamber. The failure was caused by a depression on the surface of the sleeve. It appears as though a corner of the internal vessel support frame assembly that contains the mandrels and trays in the chamber (fig. 8) may have pinched into the cover sleeve. This is also where the dielectric strength test failed.
12	1.5E05	1.8E05	The sample split with an unusual fracture that curves around the general area of the end of the bolt pad.

Table 10: Insulation Resistance measurements anomalies for In-Line Splice with Bolted Connection

Results Discussion: All the samples maintained rated voltage and current during the accident simulations. However, only sample #10 also met the acceptance criteria during the prescribed Function Tests and exhibited expected performance during the periodic IR and breakdown tests. The following information is provided for the other three samples.

Sample #9 showed progressively lower IR readings during the LOCA exposure after the chemical spray. It must be mentioned that these IR readings are not necessarily an accurate indication to the performance of the tested sample because it integrates the insulation resistance of the whole tested circuit including the sample leads, the test leads and the additional connecting (sample/test lead) splices that are inside the test vessel. Initial investigation of the sample after removal from the chamber revealed no damage to the sample or the adjacent sample leads as evidenced by the high IR values, the successful voltage withstand test as well as the high breakdown voltage value at the end of the test which demonstrates the high residual margin in the insulation performance. Further investigation revealed a longitudinal split of the lead wires approximately 31″ away from the splice on both sides. Figure 9 shows the damage to the lead wires of Sample #9.

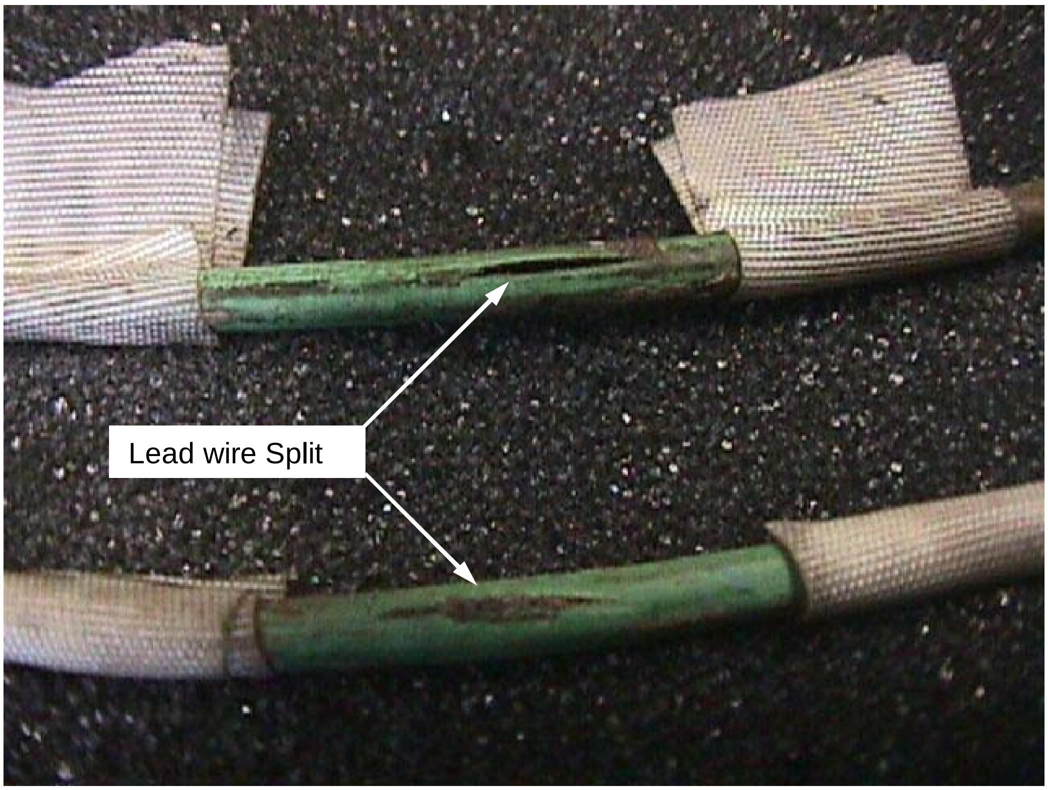


Figure 9: Damage to the lead wires of Sample #9

The damage to the lead wires may have been caused by a sharp edge of the mandrel handle. Figure 10 shows a picture of Mandrel #1 where Sample #9 has been installed. The position of the damage to the wires corresponds approximately to the end of the handle. Tyco Electronics concludes that the low IR values recorded during the accident simulation were due to these longitudinal splits.

Figure 10: Side view of Mandrel #1.

Sample #11 exhibited low insulation resistance values only after the sample was removed from the chamber. Physical examination determined that these low IR's were caused by a depression on the surface of the sleeve. It appears as though a corner of the internal vessel support frame may have pinched into the WCSF cover sleeve (see Figure 11). This is also where the dielectric strength test failed. All measurements taken prior to removal from the chamber rendered acceptable values. However, due to this damage, the sample did not meet the post-simulation Function Test acceptance criteria.

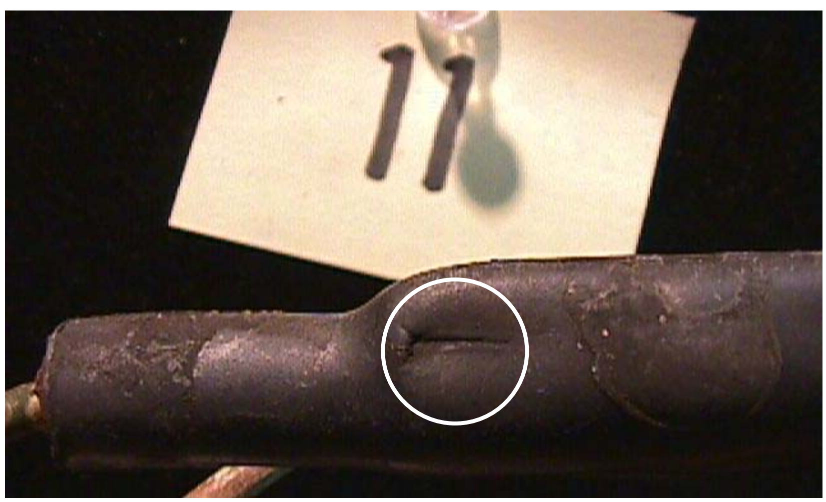


Figure 11: External damage to Sample #11

Sample #12 exhibited low IR values during the two "in vessel" immersion tests and subsequently failed the post-accident Function Tests. During the post-test visual examination the sample was found to be split with an unusual fracture that curves around the general area of the end of the bolt pad. (See Figure 12)

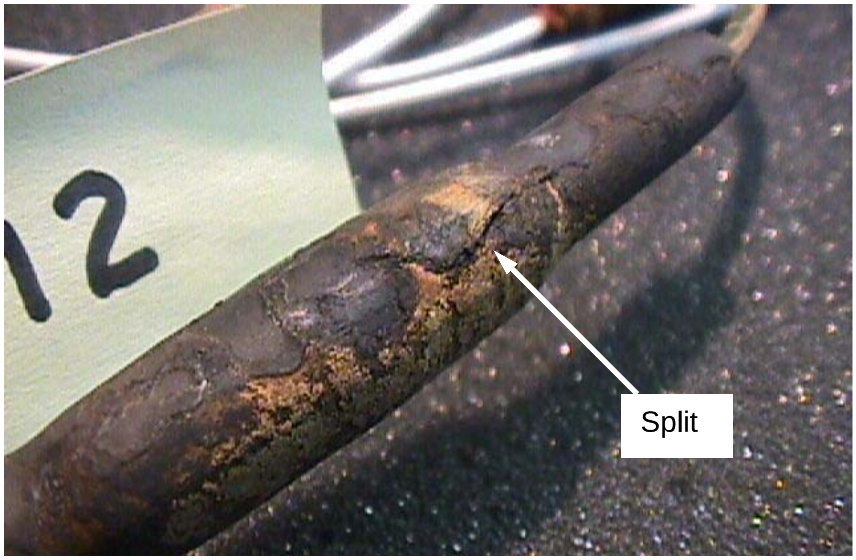


Figure 12: Fracture on sample #12

During the investigation, a definitive cause for this unusual failure was not determined. Several factors were considered to have possibly contributed to the split which likely occurred sometime during the first transient possibly as the pressure dropped. These factors include, construction at greater than the 2.5x holdout (2.6x as measured), excess free volume within the splice, a poor bolted electrical connection which resulted in excessive splice temperatures, steam injection during the accident simulation directed toward this point of the splice. Another possible factor was any of the pre-test 24 hour immersion highpots – if water got into the sample (e.g., a cable end was accidentally submerged) then water would be trapped there after splicing to the test leads), and/or an undetected flaw or damage which pre-existed the accident simulation testing. Evaluation of the sample #12 failure also considered the performance of 30 similar bolted connection splices with 2.5x holdout during qualification testing documented in EDR-5336. In EDR-5336 a total of 24 bolted splices with shim sleeves and a WCSF-200-18/5-N sealing sleeve but with no bolt pad were subjected to a qualification test sequence that was essentially identical to the sequence used for sample #12. One of the 24 splices split during the accident simulation and another failed the post-accident high potential test. Both failures were from wall thinning due to the sharp edges of connection washers (no bolt pad was used on either sample). None of the other 22 splices exhibited any tube splitting or dielectric withstand problems. The testing reported in EDR-5336 also included 4 bolted splice samples with bolt pads, shims, and a WCSF-500-38/13-N sealing sleeve. All 4 samples met the test acceptance criteria. Since the WCSF-500-38/13-N sleeve has a thicker wall than the WCSF-200-18/5-N at the same holdout, it should be less prone to splitting or dielectric failures due to wall thinning.

In summary, (1) sample #10 successfully completed the program and met the acceptance criteria, (2) the sample #11 post-accident function test anomalies appear related to splice physical damage that is not related to the WCSF product or representative of typical applications, (3) sample #9 IR problems appear to be due to splits in the test leads and not the splice, and (4) Raychem has been unable to determine the specific cause of the splitting of sample #12 although it appears related to wall thinning at the edge of the high holdout area. A total of 30 WCSF-200 sleeved samples were tested in both programs and 1 experienced this "unexplained" rupture while 4 WCSF-500 sleeved samples were tested and none ruptured. Based on the our evaluations and available test information sufficient evidence does not exist for Tyco Electronics Corporation, to conclude that In-Line Splice with Bolted Connections with a holdout of 2.5x with tubing smaller than WCSF-500-38/13-N meets the environmental qualification requirements. Similar configurations using WCSF-500-38/13-N, which has a larger wall thickness, have been qualified previously in EDR-5336 Rev.3 and their qualification is not affected by this conclusion.

6.3.3 Insulation Resistance Measurement Samples (In-Line Splice with Crimp Connector) (Samples #47, #48, #49, and #50)

This category included 4 samples, Samples #47 and #48 were constructed with splices and Samples #49 and #50 were used as references constructed only out of the same type of lead wire as used in the spliced samples. Table 11 shows a list of the samples and a summary of the test results.

SAMPLE NO.	TRAY NO.	AGING TIME & TEMP.	RADIATION DOSE (rads) Actual	Test Circuit voltage (Vdc)
47 (splice)	M1	878.17 hr @ 302°F	2.262E+08	125
48 (splice)	M2	Not Aged	1.743E+08	125
49 (wire only)	M1	878.17 hr @ 302°F	2.262E+08	125
50 (wire only)	M2	Not Aged	1.743E+08	125

Table 11: Insulation Resistance Measurement Samples (In-Line Splice- with Crimp Connector) (Samples #47, #48, #49, and #50). Radiation doses represent (accident + ambient) for aged samples or accident only for un-aged samples

The test samples were inspected for evidence of damage and proper installation and mounting before the start of the test sequence. There was no visible evidence of damage and all samples and mounting conformed to Tyco Electronics requirements. The test samples were visually inspected and subjected to the functional tests described in Section 5.2 before thermal aging, irradiation and the environmental exposure. The samples remained energized throughout both accident transient simulations, except during planned IR measurements and troubleshooting associated with the facility or other samples. Appendix 8 shows the circuits' voltage and current time plots for the entire simulation. The functional tests were performed on the samples after the LOCA simulation as part of the post LOCA evaluation. The results of the functional tests are given in Table 12. Additionally, periodic IR measurements were made before, during, and after the accident simulation and at the end of the test program. Each sample was also tested for AC dielectric breakdown to demonstrate margin. The periodic IR and breakdown data are given in Table 12.

Sample	Initial Base Line			Post Heat Aging			Post Irradiation			Post LOCA		
	IR, Ω @500 V	W/S, V	I_{leak}, μA	IR, Ω @500 V	W/S, V	I_{leak}, μA	IR, Ω @500 V	W/S, V	I_{leak}, μA	IR, Ω @500 V	W/S, V	I_{leak}, μA
47	1.6E12	2400	800	1.1E11	2400	700	4.0E11	2400	830	3.5E11	2400	940
48	1.6E12	2400	820	n/a	n/a	n/a	2.2E12	2400	840	2.2E12	2400	980
49 Wire only	5.0E11	2400	800	1.1E11	2400	780	8.6E11	2400	860	5.8E11	2400	920
50 Wire only	2.0E12	2400	870	n/a	n/a	n/a	2.8E12	2400	880	2.2E11	2400	980

Table 12: Functional Tests at Program Sequence points for Insulation Resistance Measurement Samples (In-Line Splice- with Crimp Connector) (Samples #47, #48, #49, and #50).

Table 13 shows the IR measurements performed on the monitoring circuits during the LOCA exposure at 500 volts DC.

	Sample 47	Sample 48	Sample 49	Sample 50
Prior 1st peak	5.8E10	5.2E10	5.4E10	6.0E10
At 1st Peak 425°F	9.4E07	1.5E08	3.5E08	1.8E08
Prior to 2nd transient	2.2E10	3.8E10	5.8E10	7.8E10
At 2nd Peak 385°F	3.6E08	2.2E08	5.9E08	3.5E08
4 hour point of 2nd transient	7.9E08	5.2E8	1.3E09	1.1E09
3-hour point of the 312°F plateau	2.5E07	8.0E07	2.0E09	2.2E09
96-hour point of 235°F plateau	5.6E08	8.2E08	3.0E10	6.8E10
241-hour point of 235°F plateau	6.8E08	1.5E09	2.8E10	5.0E10
At End of 2nd transient at 238°F	5.6E08	8.2E08	3.0E10	6.8E10
At End of 2nd Transient submerged 24 hrs	1.1E10	8.6E09	2.6E10	3.5E10
Functional Test (after removal from chamber submerged 24 hrs)	3.5E11	2.2E12	5.8E11	2.2E11
Destructive Testing Dielectric Breakdown	24,500 V No breakdown Limit of equipment	20,000 V breakdown at middle of splice	24,000 V breakdown at Lead wire	24,000 V breakdown at Lead wire

Table 13: Periodic IR measurements during LOCA simulation.

In an effort to quantify the performance of the splice sleeves, additional insulation resistance measurements were performed on these samples during the LOCA event. These measurements were made approximately every 12 hours during the LOCA simulation. Figure 13 shows the results of these measurements. The data is tabulated in Appendix 7.

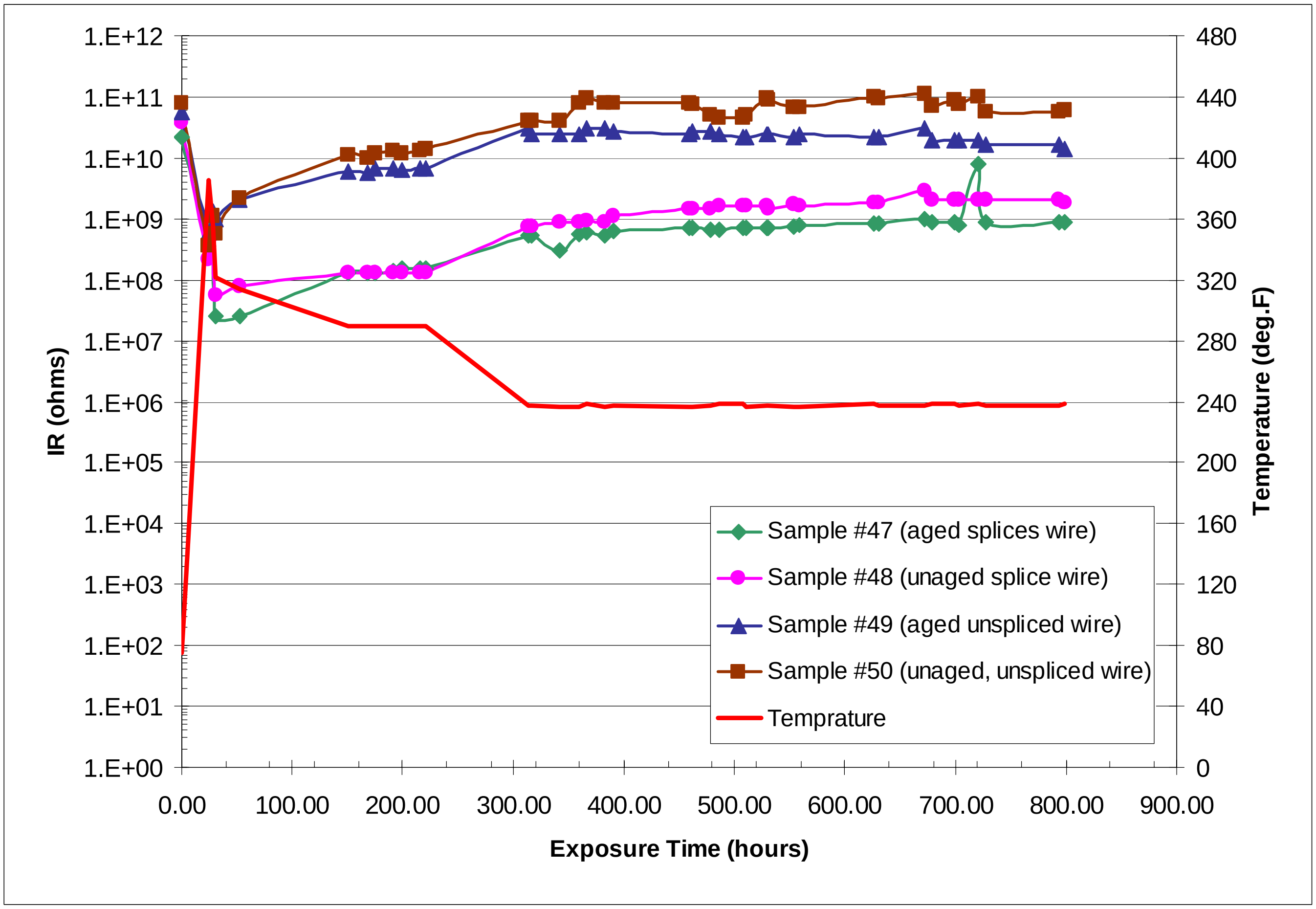


Figure 13: Chart of Insulation Resistance measurements during LOCA Transient #2.

Results Discussion: These samples and associated IR data were included in this test program for information only and were not intended to establish qualification for particular splice configurations. The IR readings represent the integrated insulation resistance of the entire test circuit, including the sample splice and sample leads. Reasonable efforts were made to use the same length sample leads and to similarly configure the samples on the test mandrels and within the test vessel. The IR data in Table 13 and Figure 13 indicates that reasonably similar IR values were measured for the spliced and unspliced samples during the pre and post-simulation ambient temperature tests. The IRs were also similar during the peak conditions although the values for the spliced samples were slightly lower than those for the unspliced samples. Subsequent measurements during transient #2 indicate the IR values for the spliced samples were substantially lower than those for the unspliced samples.

6.3.4 Bending Sample (Sample #25)

This sample was used to demonstrate margin based on the mandrel bend test provisions of IEEE 383. The test sample was visually inspected and subjected to the dielectric withstand test described in Section 5.5 after radiation exposure, after being straightened and wound on a mandrel of 20 times the diameter of the jacket in the opposite direction from the position during thermal and radiation preconditioning. The sample was then subjected to the modified LOCA profile but was not energized or electrically monitored. The dielectric withstand test was performed on the sample after the LOCA simulation as part of the post LOCA evaluation. The results of the functional tests are given in Table 12. Additionally, at the end of the test program, the sample was tested for AC dielectric breakdown to demonstrate margin. The sample failed at 24,000 Volts.

SAMPLE NO.	TRAY NO.	AGING TIME & TEMP.	RADIATION DOSE (rads) Actual	RESULTS
25	T7	152.26 hr @ 356°F	2.16E+08	Complies with IEEE-383

Table 14: Aging conditions of the bending sample. The total radiation dose given is the sum of previous radiation cumulative doses and recent additional doses. See appendix 5 for the radiation certificates related to this sample mounted on Tray 7.

Sample	Initial Base Line			Post Heat Aging			Post Irradiation			Post LOCA		
	IR, Ω @500 V	W/S, V	I_{leak}, μA	IR, Ω @500 V	W/S, V	I_{leak}, μA	IR, Ω @500 V	W/S, V	I_{leak}, μA	IR, Ω @500 V	W/S, V	I_{leak}, μA
25	N/A	N/A	N/A	N/A	N/A	N/A	6.0E11	7000	2200	N/A	7000	1600

Table 15: Functional Tests at Program Sequence points for the bending sample.

7. CONCLUSION

Samples of Raychem's Nuclear Grade Cable Accessories were type tested in applications that are common and specific to the harsh environment inside the containment structure of nuclear generation stations as outlined in the relevant sections of IEEE 323 and IEEE 383. Both aged (thermally aged and exposed to radiation aging) and unaged samples were exposed to accident radiation before they were exposed to a LOCA simulation.

The test results described in this report demonstrated:

1. The qualification of the V-type splice with a service life of 40 years (based on a DBE of 150 Mrads, plus 10% margin, and life aging of 50 Mrads for a total dose of 215 Mrads).

2. The qualification equivalency of molded end cap manufactured with modified compound to the original qualified product in fit, form and function. This equivalence extends and confirms the applicability of previously issued test reports and application guides to the products made from the new formulation including accepting their use with other substrates (e.g., EPR, silicone, resin-impregnated glass braid, or metal), submergence qualification (EDR-5011) and Beta radiation qualification.

3. The qualification of the End Cap (-52) molded part in a kit configuration for a service life of 40 years (based on a DBE of 150 Mrads, plus 10% margin, and life aging of 50 Mrads for a total dose of215 Mrads).

4. The confirmation of the qualification of the breakout boot (-52) molded parts a kit configuration for a service life of 40 years (based on a DBE of 150 Mrads, plus 10% margin, and life aging of 50 Mrads for a total dose of 215 Mrads).

5. That the WCSF tubing material exhibits adequate margin based on the mandrel bend provisions in IEEE 383.

6. That until additional information becomes available through tests or investigation, there is insufficient evidence to support the qualification of In-Line Splice with Bolted Connection configuration within an expansion holdout greater than 2.0x for kits comprised of WCSF-300-28/8-N or smaller as the splice cover. Since one of the failures of the unaged samples was due to accidental damage to the splice and the other's cause is undefined,

Tyco Electronics, consistent with its conservative nature, chooses not to claim qualification for this configuration. However, there is ample evidence in the test results reported in EDR-5336-Rev.3 to support the extension of the use range from 2.0x to 2.5x for the general use of the WCSF tubing in other qualified configurations except for the WCSF-050-3/1-N when used as a splice cover

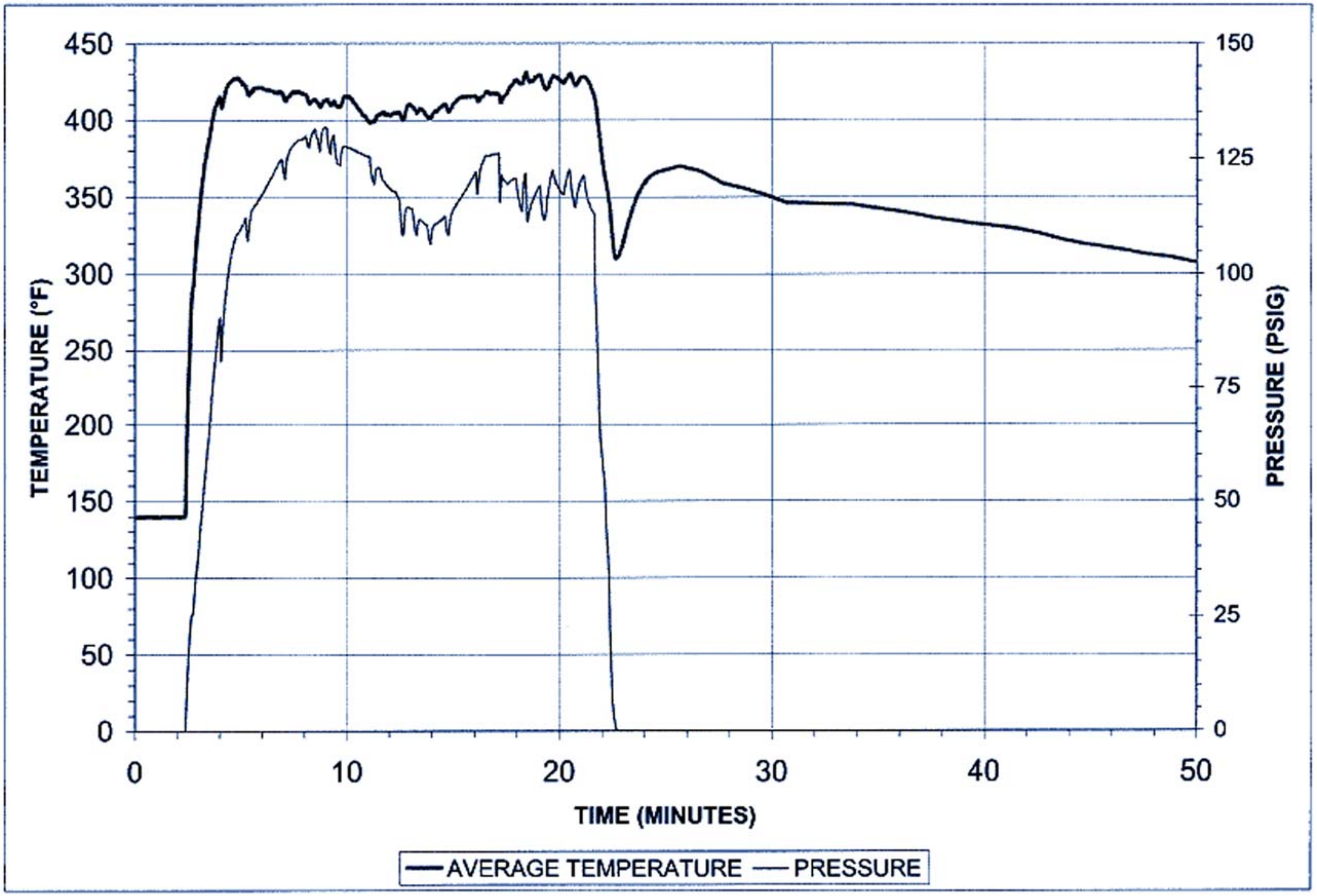
APPENDIX 1

CABLES DESCRIPTION

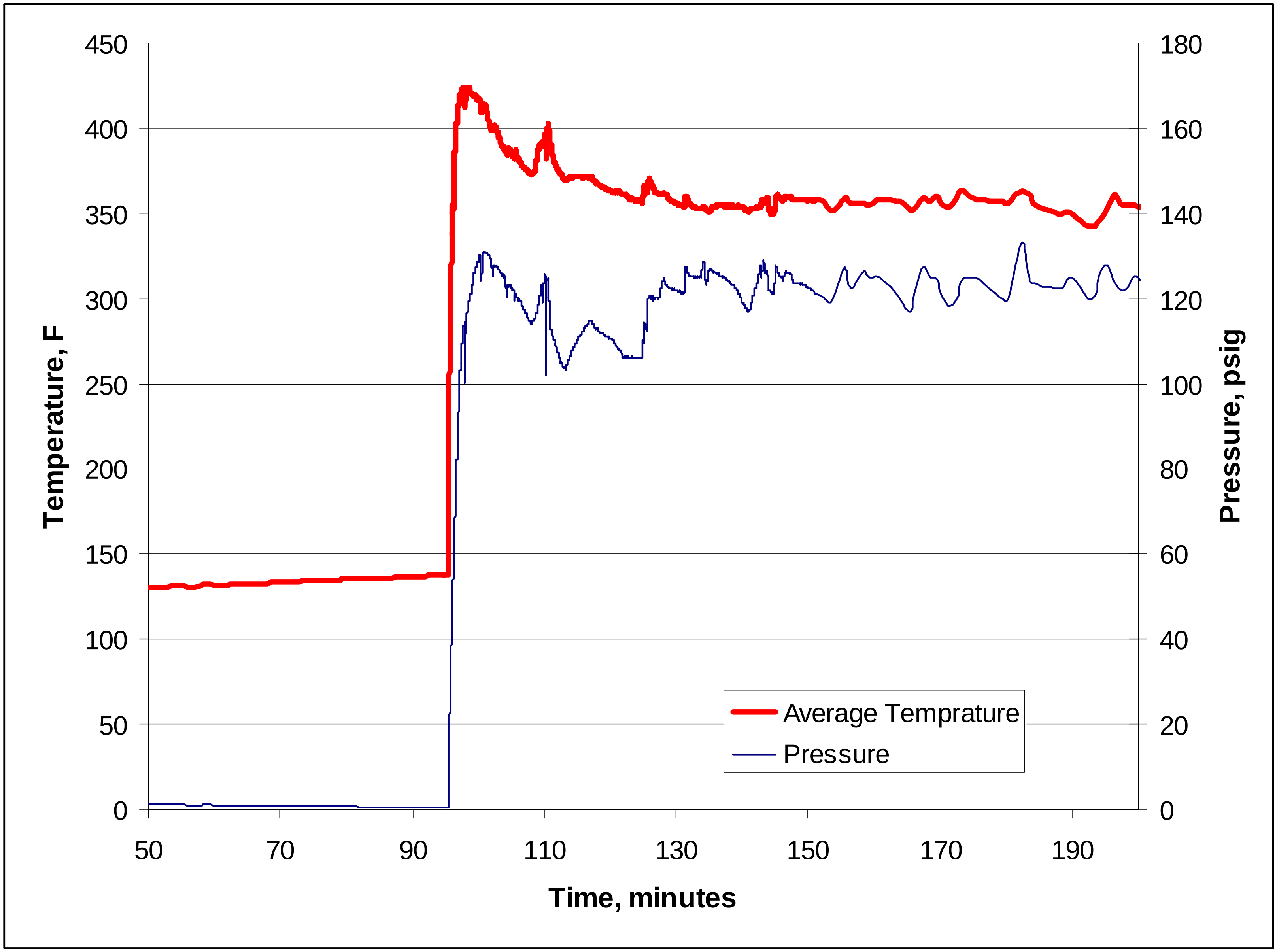
Cable Number	Related samples	Reel #	Manufacturer	Insulation material	Insulation Diameter (in) Nominal	Insulation Thickness (in) Nominal	Wire AWG	# of Cond.
1	1,2,7,8,	1Fmcc13C	Rockbestos	XLPE	0.14	0.03	14	1
2	9,10,11,12	9810294G01	Rockbestos	XLPE	0.16	0.03	12	1
10	47,48,49,50	03G0612G06	Rockbestos	XLPE	0.14	0.14	14	1

APPENDIX 2

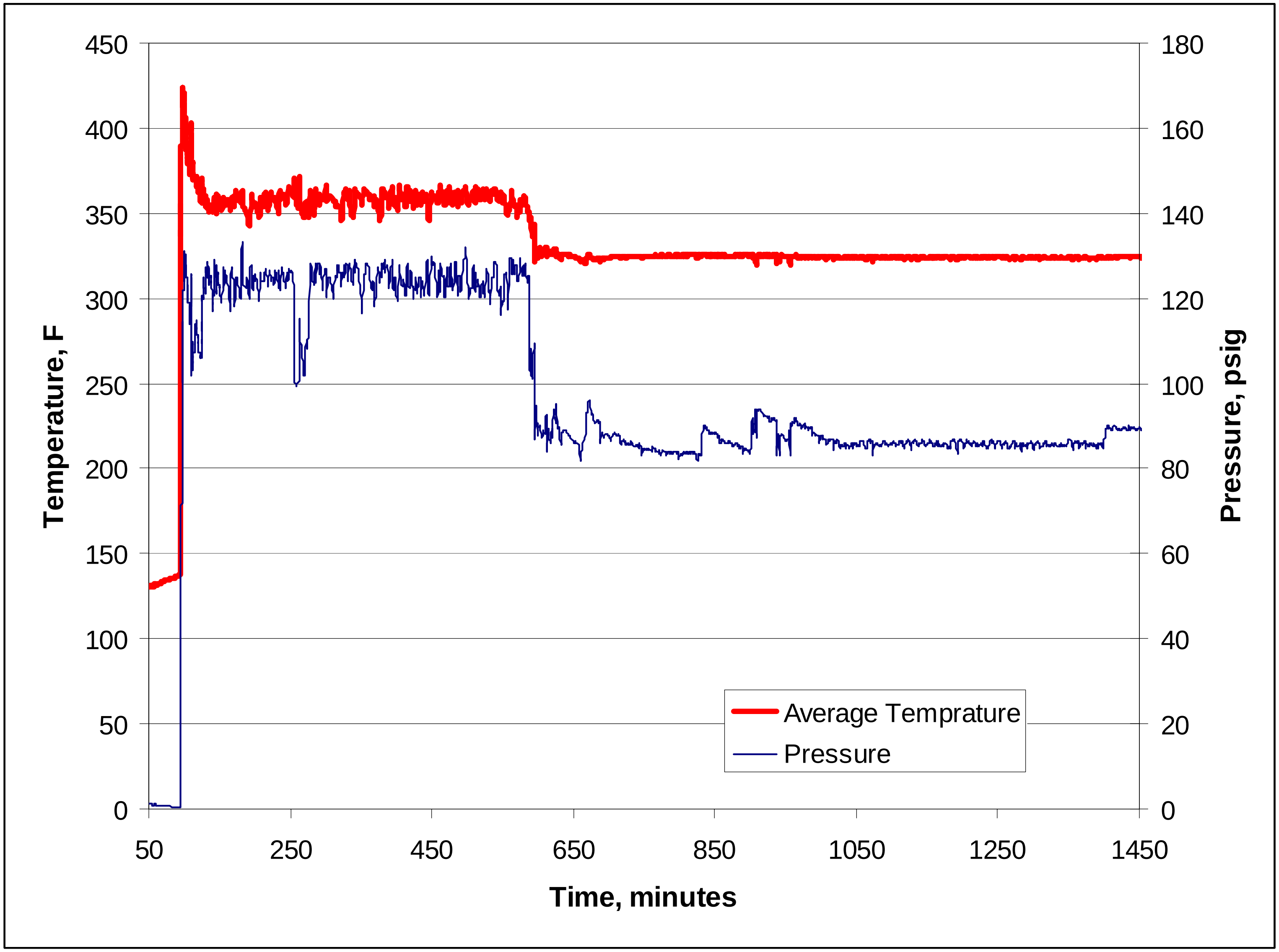
LOCA PROFILE



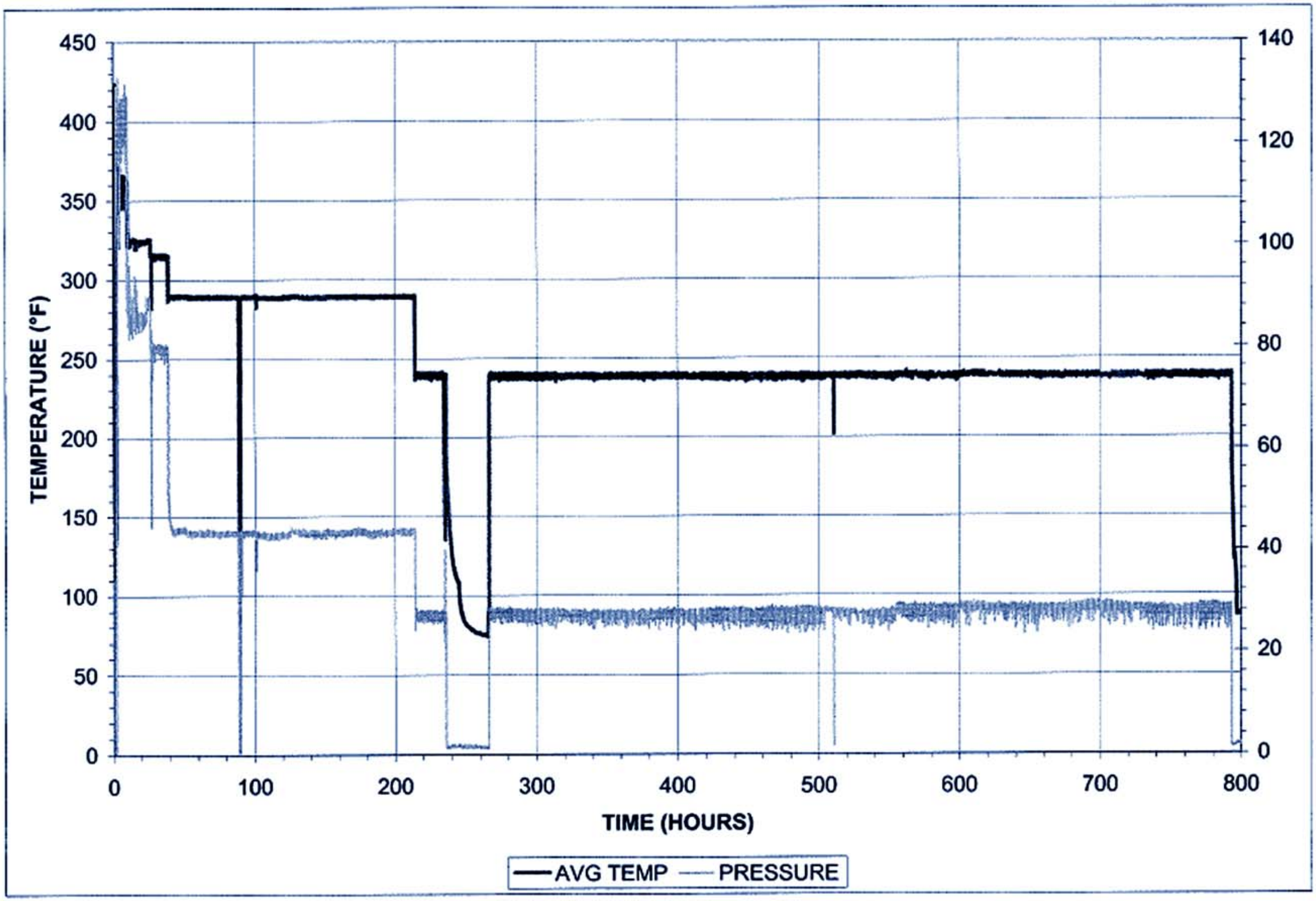
LOCA Profile (First Transient)



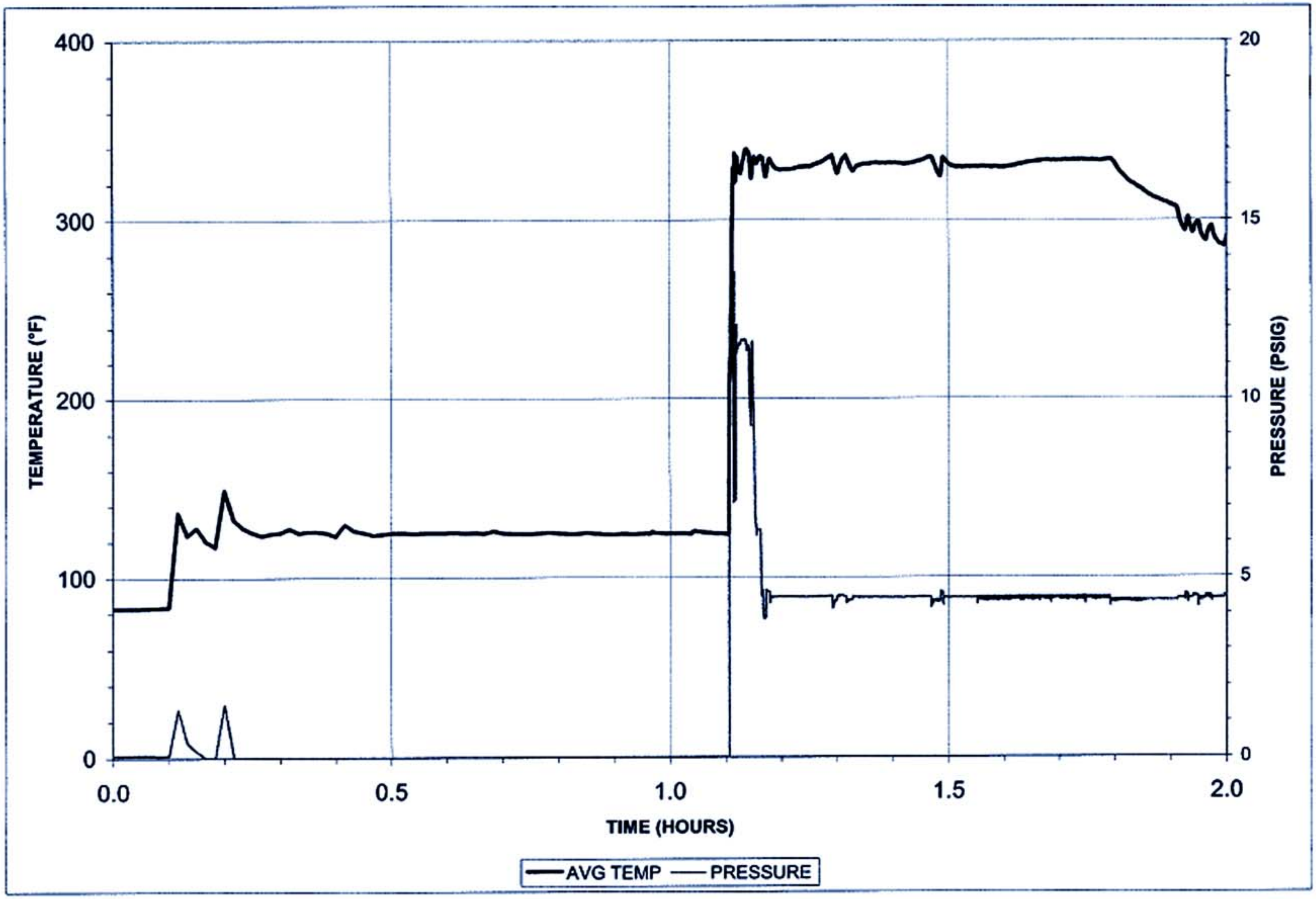
LOCA Profile (Second Transient Start)



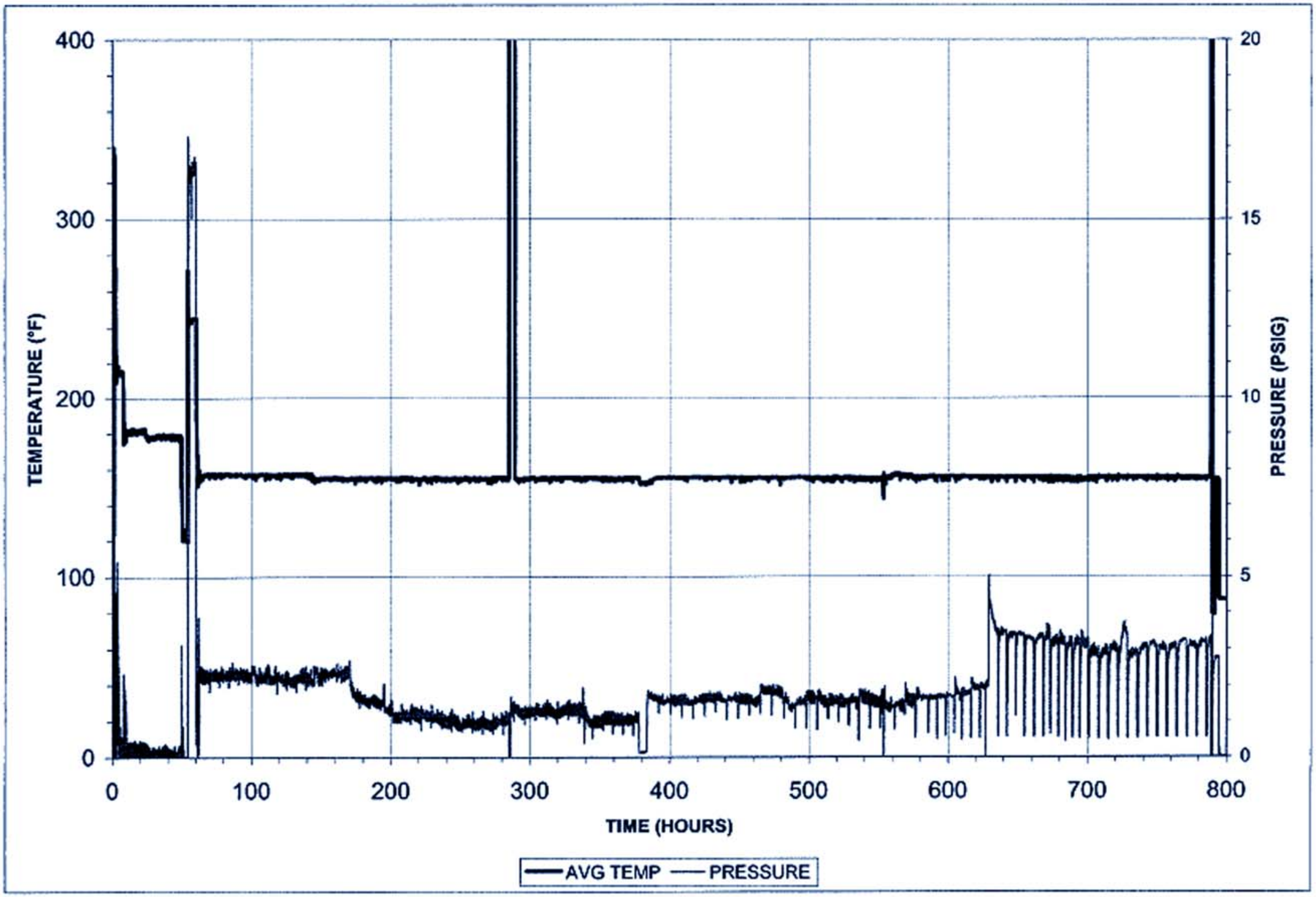
LOCA Profile (Second Transient 1st 24 hours)



LOCA Profile (Second Transient)



LOCA Profile for bending sample (First Transient)



LOCA profile for the bending sample (Second Transient)

APPENDIX 3

SAMPLE TEST CONDITIONS

Sample Type	SAMPLE NO.	Cable Number	CONNECTION WIRE (AWG)	Tray NO.	AGING TIME & TEMP.	RADIATION DOSE (rads)		APPLIED CURRENT DURING LOCA (AMPS)
						Target	Actual	
V-Type Splice	1	1	14	T1	878 hr @ 302°F	2.15E+08	2.25E+08	25
	2	1	14	T1	878 hr @ 302°F	2.15E+08	2.25E+08	25
	7	1	14	T2	N/A	1.65E+08	1.74E+08	25
	8	1	14	T2	N/A	1.65E+08	1.74E+08	25

Sample Type	SAMPLE NO.	Cable Number	CONNECTION WIRE (AWG)	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rads)		APPLIED CURRENT DURING LOCA (AMPS)
						Target	Actual	
In-Line Splice With bolted connectors	9	2	12	1	878 hr @ 302°F	2.15E+08	2.26E+08	30
	10	2	12	1	878 hr @ 302°F	2.15E+08	2.26E+08	30
	11	2	12	2	N/A	1.65E+08	1.74E+08	30
	12	2	12	2	N/A	1.65E+08	1.74E+08	30

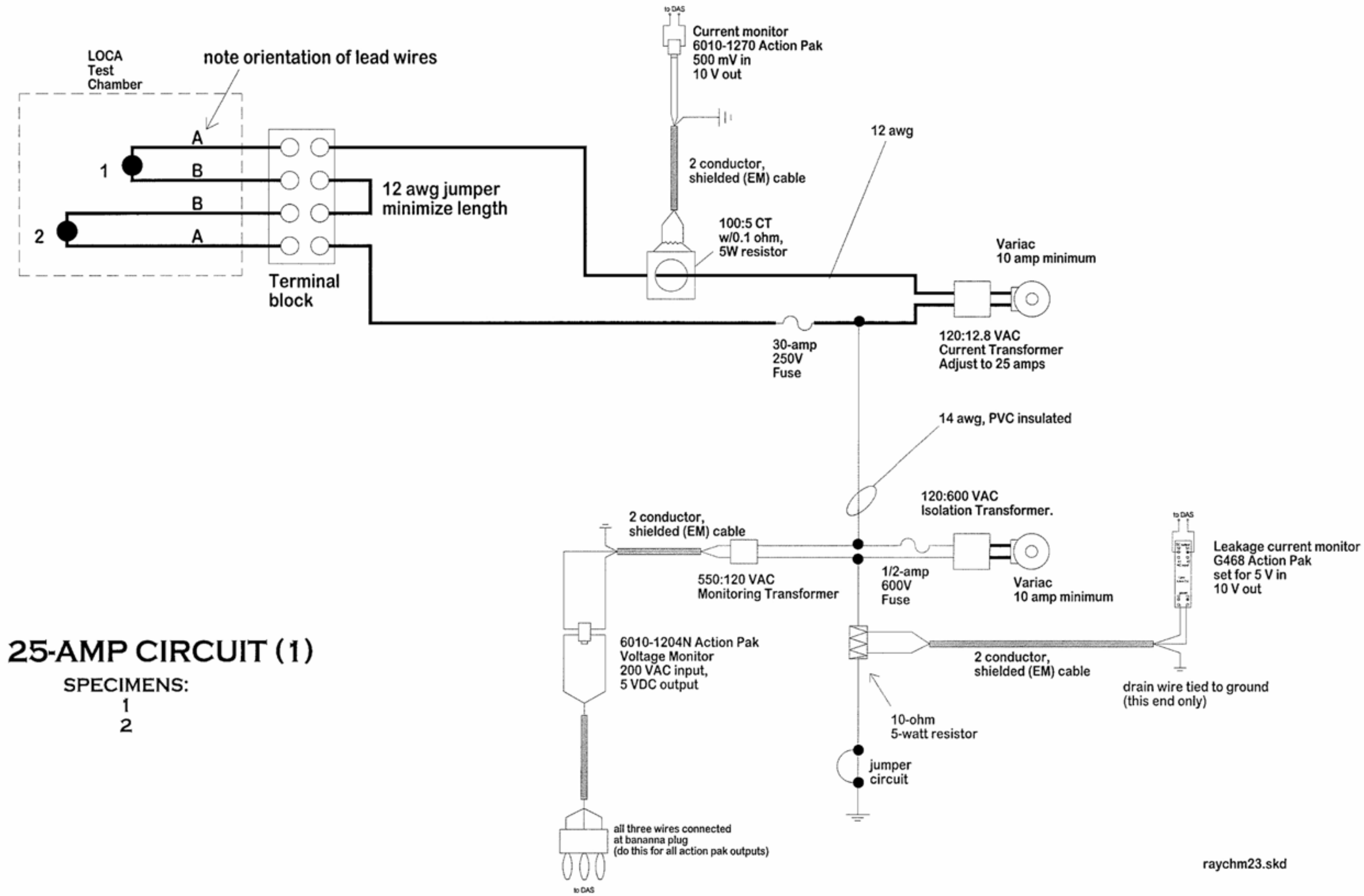
Sample Type	SAMPLE NO.	Cable Number	CONNECTION WIRE (AWG)	Tray NO.	AGING TIME & TEMP.	RADIATION DOSE (rads)		APPLIED CURRENT DURING LOCA (AMPS)
						Target	Actual	
Bending Sample	25	N/A	N/A	7	152.26 hr @ 356°F	2.15E+08	2.16E+08	N/A

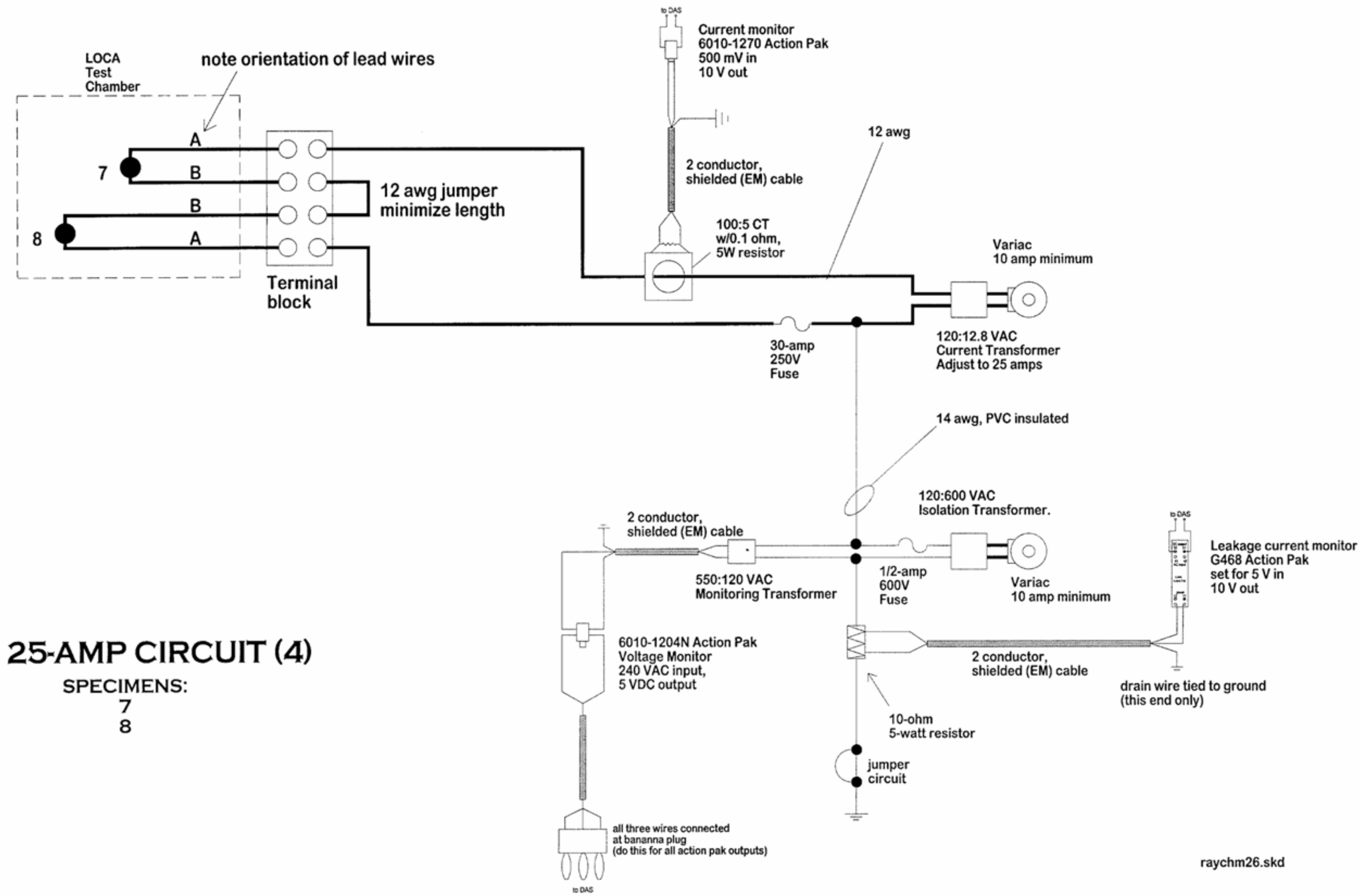
Sample Type	SAMPLE NO.	Cable Number	CONNECTION WIRE (AWG)	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rads)		APPLIED Voltage V_{DC}
						Target	Actual	
Insulation Resistance samples	47	10	14	1	878 hr @ 302°F	2.15E+08	2.26E+08	125
	48	10	14	2	N/A	1.65E+08	1.74E+08	125
	49	10	14	1	878 hr @ 302°F	2.15E+08	2.26E+08	125
	50	10	14	2	N/A	1.65E+08	1.74E+08	125

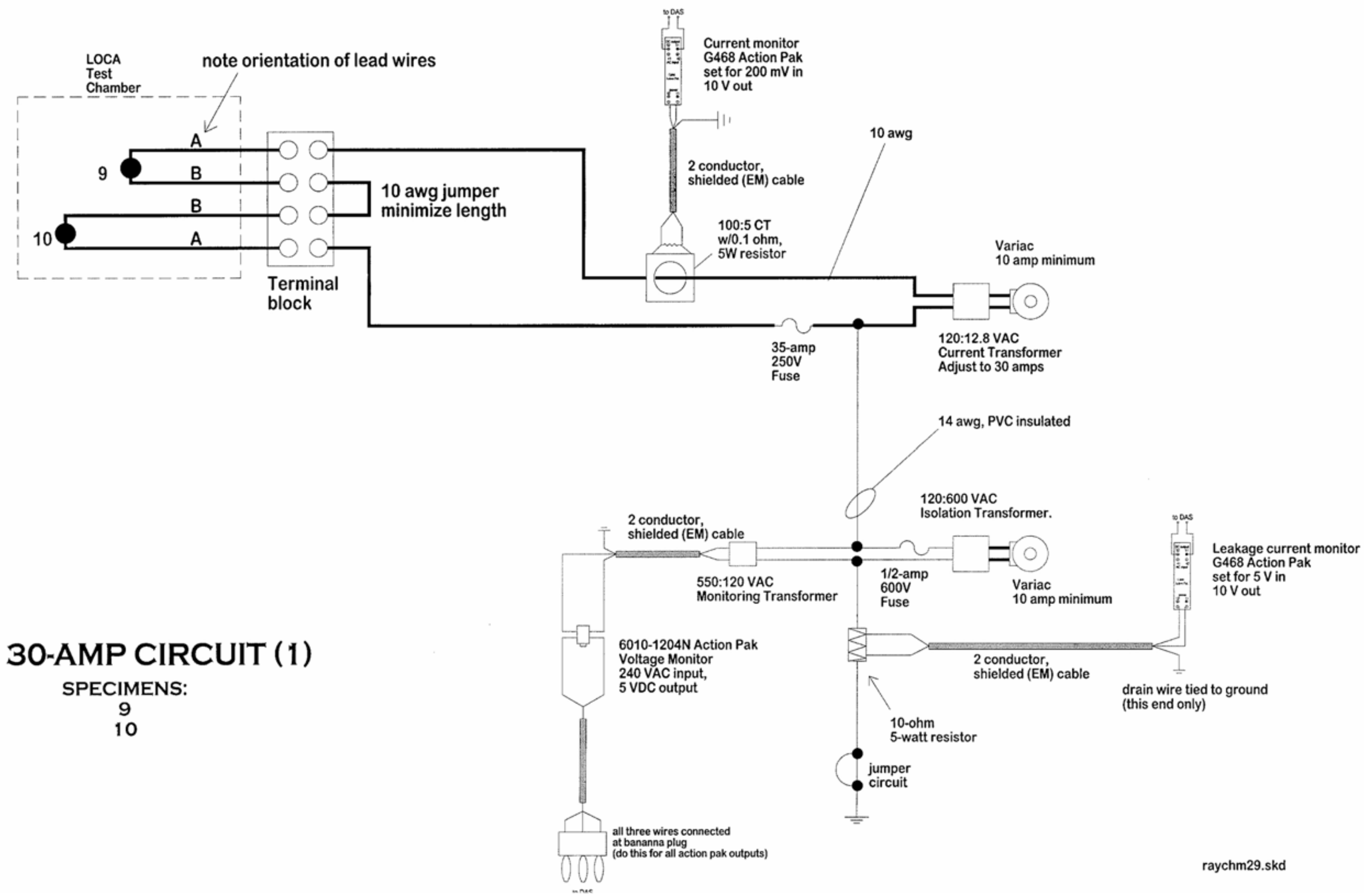
APPENDIX 4

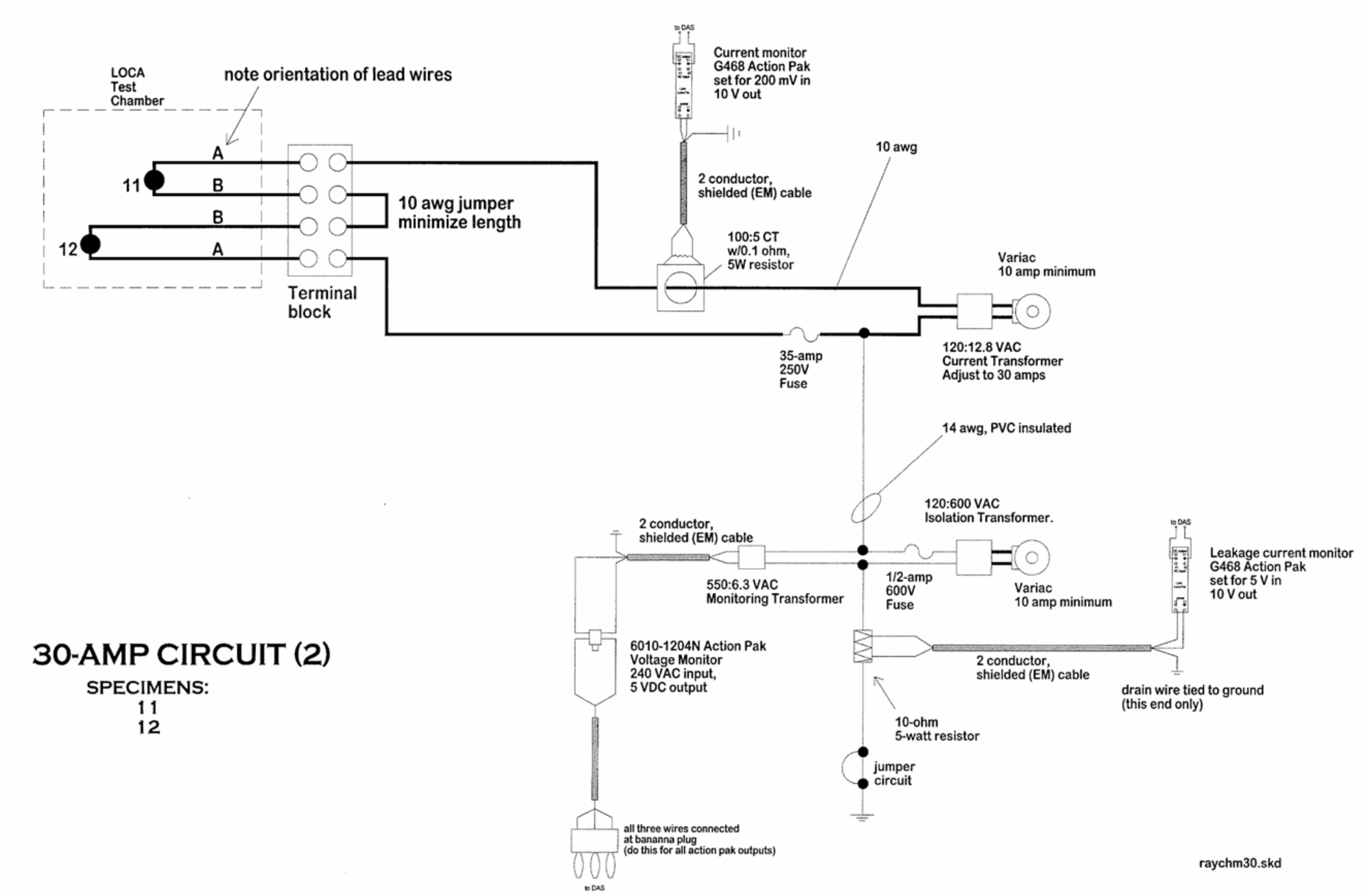
SAMPLE MONITORING CIRCUITS

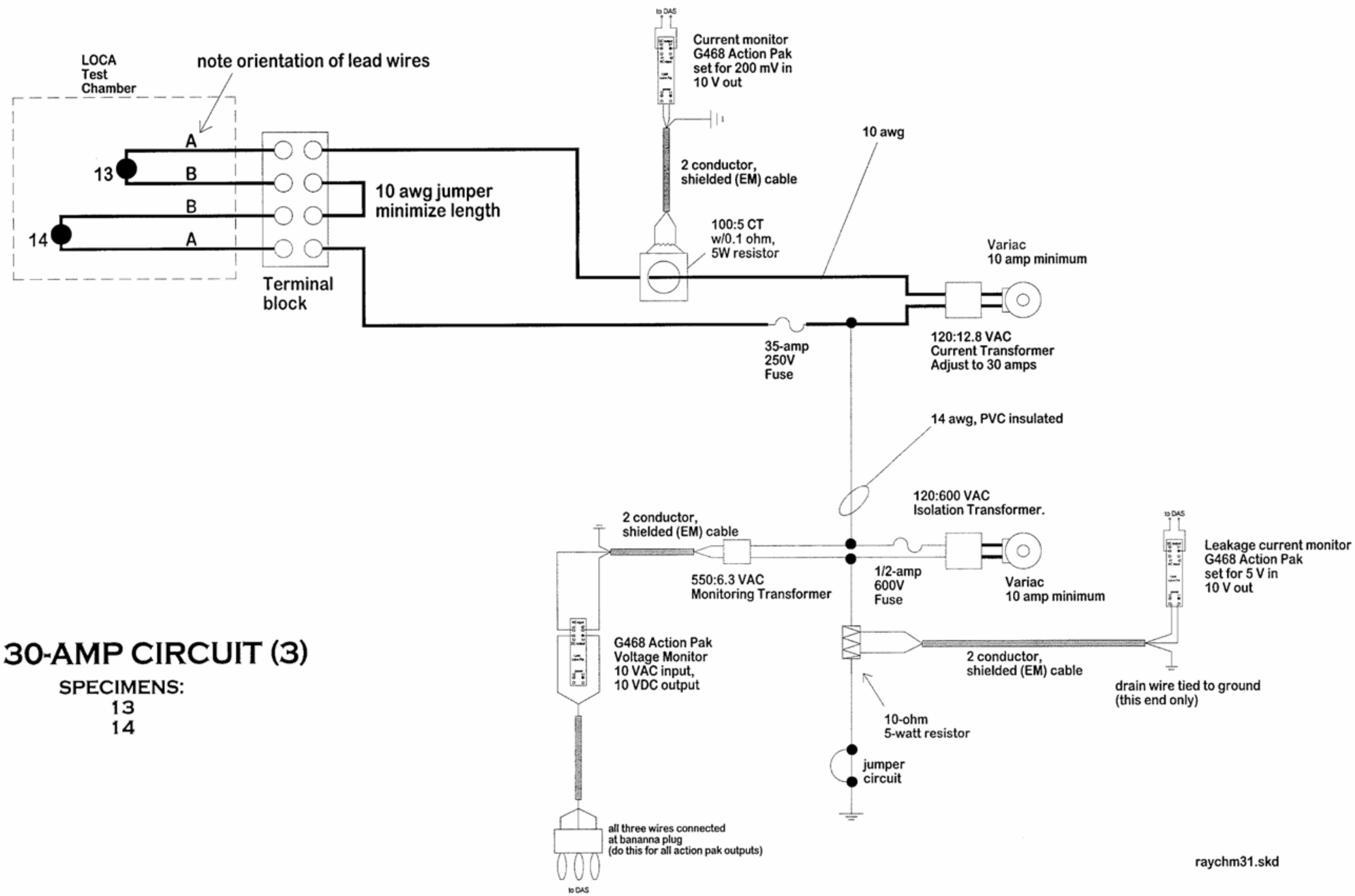
Note: Some test samples were of different construction and the results are not presented in this report.


to DAS
Current monitor
6010-1270 Action Pak
500 mV in
10 V out
LOCA
Test
Chamber
note orientation of lead wires
A
1
B
B
2
A
12 awg jumper
minimize length
Terminal
block
12 awg
2 conductor,
shielded (EM) cable
100:5 CT
w/0.1 ohm,
5W resistor
Variac
10 amp minimum
30-amp
250V
Fuse
120:12.8 VAC
Current Transformer
Adjust to 25 amps
14 awg, PVC insulated
120:600 VAC
Isolation Transformer.
2 conductor,
shielded (EM) cable
550:120 VAC
Monitoring Transformer
1/2-amp
600V
Fuse
Variac
10 amp minimum
to DAS
Leakage current monitor
G468 Action Pak
set for 5 V in
10 V out
25-AMP CIRCUIT (1)
SPECIMENS:
1
2
6010-1204N Action Pak
Voltage Monitor
200 VAC input,
5 VDC output
2 conductor,
shielded (EM) cable
drain wire tied to ground
(this end only)
10-ohm
5-watt resistor
jumper
circuit
all three wires connected
at bananna plug
(do this for all action pak outputs)
to DAS
raychm23.skd


to DAS
Current monitor
6010-1270 Action Pak
500 mV in
10 V out
LOCA
Test
Chamber
note orientation of lead wires
A
7
B
B
8
A
12 awg jumper
minimize length
Terminal
block
2 conductor,
shielded (EM) cable
12 awg
100:5 CT
w/0.1 ohm,
5W resistor
Variac
10 amp minimum
30-amp
250V
Fuse
120:12.8 VAC
Current Transformer
Adjust to 25 amps
14 awg, PVC insulated
120:600 VAC
Isolation Transformer.
2 conductor,
shielded (EM) cable
550:120 VAC
Monitoring Transformer
1/2-amp
600V
Fuse
Variac
10 amp minimum
Leakage current monitor
G468 Action Pak
set for 5 V in
10 V out
25-AMP CIRCUIT (4)
SPECIMENS:
7
8
6010-1204N Action Pak
Voltage Monitor
240 VAC input,
5 VDC output
2 conductor,
shielded (EM) cable
drain wire tied to ground
(this end only)
10-ohm
5-watt resistor
jumper
circuit
all three wires connected
at bananna plug
(do this for all action pak outputs)
to DAS
raychm26.skd


LOCA
Test
Chamber
note orientation of lead wires
A
9
B
B
10
A
10 awg jumper
minimize length
Terminal
block
Current monitor
G468 Action Pak
set for 200 mV in
10 V out
2 conductor,
shielded (EM) cable
100:5 CT
w/0.1 ohm,
5W resistor
10 awg
Variac
10 amp minimum
120:12.8 VAC
Current Transformer
Adjust to 30 amps
35-amp
250V
Fuse
14 awg, PVC insulated
120:600 VAC
Isolation Transformer.
2 conductor,
shielded (EM) cable
550:120 VAC
Monitoring Transformer
1/2-amp
600V
Fuse
Variac
10 amp minimum
Leakage current monitor
G468 Action Pak
set for 5 V in
10 V out
30-AMP CIRCUIT (1)
SPECIMENS:
9
10
6010-1204N Action Pak
Voltage Monitor
240 VAC input,
5 VDC output
2 conductor,
shielded (EM) cable
drain wire tied to ground
(this end only)
10-ohm
5-watt resistor
jumper
circuit
all three wires connected
at bananna plug
(do this for all action pak outputs)
raychm29.skd

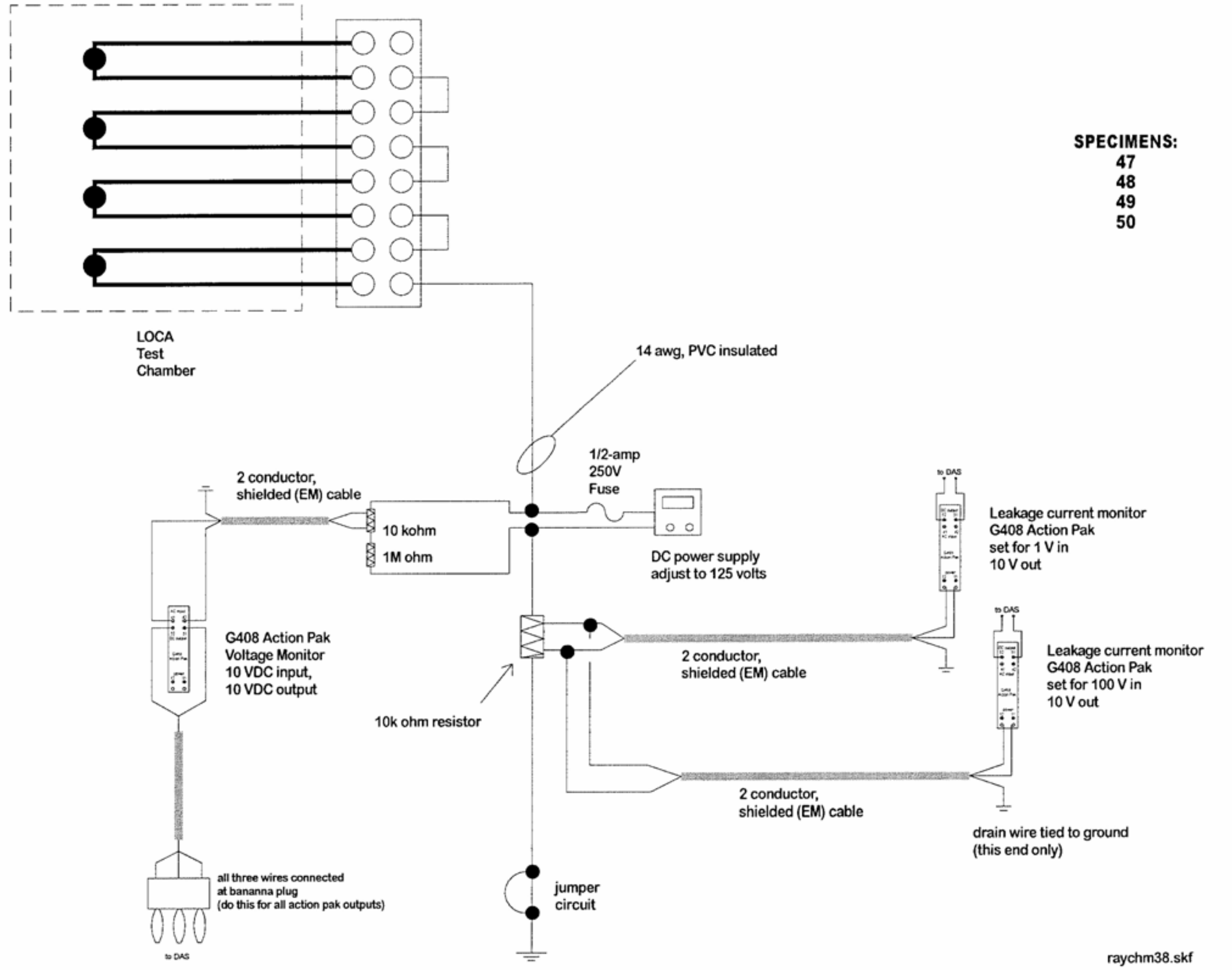

LOCA
Test
Chamber
note orientation of lead wires
A
B
B
A
11
12
Terminal
block
10 awg jumper
minimize length
Current monitor
G468 Action Pak
set for 200 mV in
10 V out
2 conductor,
shielded (EM) cable
100:5 CT
w/0.1 ohm,
5W resistor
10 awg
Variac
10 amp minimum
120:12.8 VAC
Current Transformer
Adjust to 30 amps
35-amp
250V
Fuse
14 awg, PVC insulated
120:600 VAC
Isolation Transformer.
2 conductor,
shielded (EM) cable
550:6.3 VAC
Monitoring Transformer
1/2-amp
600V
Fuse
Variac
10 amp minimum
Leakage current monitor
G468 Action Pak
set for 5 V in
10 V out
6010-1204N Action Pak
Voltage Monitor
240 VAC input,
5 VDC output
2 conductor,
shielded (EM) cable
drain wire tied to ground
(this end only)
10-ohm
5-watt resistor
jumper
circuit
all three wires connected
at bananna plug
(do this for all action pak outputs)
raychm30.skd
30-AMP CIRCUIT (2)
SPECIMENS:
11
12



30-AMP CIRCUIT (3)

SPECIMENS:
13
14

DC VOLTAGE CIRCUIT



APPENDIX 5

SAMPLES IRRADIATION LOGS

Georgia Institute of Technology
Neely Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, GA 30332-0425

Gamma Irradiation Log and Dose Rate Measurement Sheet

Client:	Wyle Labs	**NRC Reference:**	2004-02e
Reference:	HSV0030567	**Total Dose:**	1.65E8 Rads w/Unc
Items:	Mandrels 1,2,3	**Dose Rate:**	<1.0E6 Rads/hr

Start Date	Start Time	End Date	End Time	Lapsed Hours	Dose Rate Rads/hr	Total Dose Rads	Cum Dose Rads
02/17/04	13:55	02/26/04	10:49	212.90	7.792E+05	1.659E+08	1.659E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	6.392E-07	7.784E+05
2	6.395E-07	7.790E+05
3	6.402E-07	7.804E+05

Average Dose Rate (Rads/hr): 7.792E+05

Note – Mandrel 1 contains Specimens 9, 10, 47, and 49

Note – Mandrel 2 contains Specimens 11, 12, 48, and 50

Note – Mandrel 3 contains Specimens 13 through 20

*Dose Rate determined from ionization probe current using the following formula:
DR(Rads/hr)= 1.206E18 * (Amps)2 + 4.468E11 * (Amps) + 142.531

Completed: [signature] Date: 4/7/04

Reviewed: [signature] Date: 4-12-04

Georgia Institute of Technology
Neely Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, GA 30332-0425

Gamma Irradiation Log and Dose Rate Measurement Sheet

Client:	Wyle Labs	**NRC Reference:**	2004-02f
Reference:	HSV0030567	**Total Dose:**	1.65E8 Rads w/Unc
Items:	Mandrels 1,2,3	**Dose Rate:**	<1.0E6 Rads/hr

Start Date	Start Time	End Date	End Time	Lapsed Hours	Dose Rate Rads/hr	Total Dose Rads	Cum Dose Rads **
02/26/04	16:36	02/27/04	9:27	16.85	5.011E+05	8.444E+06	1.743E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	4.852E-07	5.008E+05
2	4.855E-07	5.013E+05
3	4.856E-07	5.014E+05

Average Dose Rate (Rads/hr): 5.011E+05

*Dose Rate determined from ionization probe current using the following formula:
DR(Rads/hr)= 1.206E18 * (Amps)2 + 4.468E11 * (Amps) + 142.531
** Continuation of 2004-02e

Completed: [signature] Date: 4/7/04

Reviewed: [signature] Date: 4-12-04

Georgia Institute of Technology

Neely Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, GA 30332-0425

Gamma Irradiation Log and Dose Rate Measurement Sheet

Client: Wyle Labs
Reference: HSV0030567
Items: Mandrel 1

NRC Reference: 2004-02g
Total Dose: 2.15E8 Rads w/Unc
Dose Rate: <1.0E6 Rads/hr

Start Date	Start Time	End Date	End Time	Lapsed Hours	Dose Rate Rads/hr	Total Dose Rads	Cum Dose Rads **
02/27/04	15:35	03/02/04	9:35	90.00	5.760E+05	5.184E+07	2.262E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	5.302E-07	5.760E+05

Average Dose Rate (Rads/hr): 5.760E+05

Client: Wyle Labs
Reference: HSV0030567
Items: Mandrel 3

NRC Reference: 2004-02g
Total Dose: 2.4E8 Rads w/Unc
Dose Rate: <1.0E6 Rads/hr

Start Date	Start Time	End Date	End Time	Lapsed Hours	Dose Rate Rads/hr	Total Dose Rads	Cum Dose Rads**
02/27/04	15:35	03/02/04	9:35	90.00	8.670E+05	7.803E+07	2.524E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	6.826E-07	8.670E+05

Average Dose Rate (Rads/hr): 8.670E+05

*Dose Rate determined from ionization probe current using the following formula:
DR(Rads/hr)= 1.206E18 * (Amps)2 + 4.468E11 * (Amps) + 142.531
** Continuation of 2004-02f

Completed: [signature] Date: 4/7/04

Reviewed: [signature] Date: 4-12-04

Georgia Institute of Technology
Neely Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, GA 30332-0425

Gamma Irradiation Log and Dose Rate Measurement Sheet

Client:	Wyle Labs	**NRC Reference:**	2004-02k
Reference:	HSV0030567	**Total Dose:**	1.65E8 Rads w/Unc
Items:	Tray 1, 2, 3	**Dose Rate:**	<1.0E6 Rads/hr

Start Date	Start Time	End Date	End Time	Lapsed Hours	Dose Rate Rads/hr	Total Dose Rads	Cum Dose Rads
03/19/04	12:10	03/26/04	9:01	164.85	6.274E+05	1.034E+08	1.034E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	5.591E-07	6.269E+05
2	5.592E-07	6.271E+05
3	5.597E-07	6.280E+05
4	5.596E-07	6.278E+05

Average Dose Rate (Rads/hr): 6.274E+05

Note – Tray 1 contains Specimens 1, 2, 30, 32-46, and 51-53

Note – Tray 2 contains Specimens 7, 8, and 31

Note – Tray 3 contains Specimens 3 through 6

*Dose Rate determined from ionization probe current using the following formula:
DR(Rads/hr)= 1.206E18 * (Amps)2 + 4.468E11 * (Amps) + 142.531

Completed: [signature] Date: 4/7/04

Reviewed: [signature] Date: 4-12-04

Georgia Institute of Technology
Neely Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, GA 30332-0425

Gamma Irradiation Log and Dose Rate Measurement Sheet

Client:	Wyle Labs	**NRC Reference:**	2004-02m
Reference:	HSV0030567	**Total Dose:**	2.15E8 Rads w/Unc
Items:	Tray 1	**Dose Rate:**	<1.0E6 Rads/hr

Start Date	Start Time	End Date	End Time	Lapsed Hours **	Dose Rate Rads/hr	Total Dose Rads	Cum Dose Rads ***
04/01/04	15:00	04/05/04	9:00	89.00	5.848E+05	5.205E+07	2.259E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	5.349E-07	5.841E+05
2	5.357E-07	5.855E+05

Average Dose Rate (Rads/hr): 5.848E+05

Client:	Wyle Labs	**NRC Reference:**	2004-02m
Reference:	HSV0030567	**Total Dose:**	2.4E8 Rads w/Unc
Items:	Tray 3	**Dose Rate:**	<1.0E6 Rads/hr

Start Date	Start Time	End Date	End Time	Lapsed Hours **	Dose Rate Rads/hr	Total Dose Rads	Cum Dose Rads ***
04/01/04	15:00	04/05/04	9:00	89.00	8.808E+05	7.839E+07	2.522E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	6.891E-07	8.807E+05
2	6.892E-07	8.809E+05

Average Dose Rate (Rads/hr): 8.808E+05

*Dose Rate determined from ionization probe current using the following formula:
DR(Rads/hr)= 1.206E18 * (Amps)2 + 4.468E11 * (Amps) + 142.531
** Daylight savings time change taken into account
*** Continuation of 2004-021

Completed: [signature] Date: 4/7/04

Reviewed: [signature] Date: 4-12-04

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Neely Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, GA 30332-0425

Gamma Irradiation Log and Dose Rate Measurement Sheet

Client:	Wyle Labs	**NRC Reference:**	2004-021
Reference:	HSV0030567	**Total Dose:**	1.65E8 Rads w/Unc
Items:	Tray 1, 2, 3	**Dose Rate:**	<1.0E6 Rads/hr

Start Date	Start Time	End Date	End Time	Lapsed Hours	Dose Rate Rads/hr	Total Dose Rads	Cum Dose Rads **
03/26/04	12:00	03/31/04	12:00	120.00	5.869E+05	7.043E+07	1.739E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	5.398E-07	5.927E+05
2	5.336E-07	5.819E+05
3	5.370E-07	5.878E+05
4	5.357E-07	5.855E+05

Average Dose Rate (Rads/hr): 5.869E+05

*Dose Rate determined from ionization probe current using the following formula:
DR(Rads/hr)= 1.206E18 * (Amps)2 + 4.468E11 * (Amps) + 142.531
** Continuation of 2004-02k

Completed: [signature] Date: 4/7/04

Reviewed: [signature] Date: 4-12-04

Georgia Institute of Technology
Neely Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, GA 30332-0425

Gamma Irradiation Log and Dose Rate Measurement Sheet

Client:	Wyle Labs	**NRC Reference:**	2004-02d
Reference:	HSV0030567	**Total Dose:**	1.98E7 Rads w/Unc
Items:	Tray 7	**Dose Rate:**	<1.0E6 Rads/hr

Start Date	Start Time	End Date	End Time	Lapsed Hours	Dose Rate Rads/hr	Total Dose Rads	Cum Dose Rads
02/11/04	9:35	02/12/04	9:35	24.00	8.683E+05	2.084E+07	2.084E+07

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	6.837E-07	8.693E+05
2	6.831E-07	8.681E+05
3	6.829E-07	8.676E+05

Average Dose Rate (Rads/hr): 8.683E+05

Note – Tray 7 contains Specimens 23 and 25 (phase 1 testing Nos. 142 and 143)

*Dose Rate determined from ionization probe current using the following formula:
DR(Rads/hr)= 1.206E18 * (Amps)2 + 4.468E11 * (Amps) + 142.531

Completed: [signature] Date: 4/7/04

Reviewed: [signature] Date: 4-12-04

Georgia Institute of Technology
Neely Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, GA 30332-0425

Gamma Irradiation Log and Dose Rate Measurement Sheet

Client:	Wyle Laboratories	**NRC Reference:**	00-17f
Reference:	HSV0018395	**Total Dose:**	1.952E+08
Items:	Trays 1, 2, 4, 5, 7	**Dose Rate:**	≤1.0E6 Rads/hr

Start Date	Start Time	End Date	End Time	Lapsed Hours	Dose Rate Rads/hr	Total Dose Rads	Cum Dose Rads
09/27/00	14:00	10/09/00	8:15	282.25	4.527E+05	1.278E+08	1.952E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	8.302E-07	4.511E+05
2	8.328E-07	4.527E+05
3	8.337E-07	4.533E+05
4	8.302E-07	4.511E+05
5	8.331E-07	4.529E+05
6	8.373E-07	4.555E+05

Average Dose Rate (Rads/hr): 4.527E+05

*Dose Rate determined from ionization probe current using the following formula:
DR(Rads/hr)= (1.017E17 * (Amps)2 + 5.360E11 * (Amps) - 666.526) * 0.877

Completed: [signature] Date: 6-6-02

Reviewed: [signature] Date: 6-10-02

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Neely Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, GA 30332-0425

Gamma Irradiation Log and Dose Rate Measurement Sheet

Client:	Wyle Laboratories	**NRC Reference:**	00-17e
Reference:	HSV0018395	**Total Dose:**	6.738E+07
Items:	Trays 1, 2, 4, 5, 7	**Dose Rate:**	≤1.0E6 Rads/hr

Start Date	Start Time	End Date	End Time	Lapsed Hours	Dose Rate Rads/hr	Total Dose Rads	Cum Dose Rads
09/21/00	14:50	09/27/00	11:20	140.50	4.796E+05	6.738E+07	6.738E+07

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	8.703E-07	4.760E+05
2	8.760E-07	4.796E+05
3	8.736E-07	4.781E+05
4	8.777E-07	4.807E+05
5	8.840E-07	4.846E+05
6	8.748E-07	4.788E+05

Average Dose Rate (Rads/hr): 4.796E+05

*Tray 7 contains sample 143

* This text added by Tyco Electronics

*Dose Rate determined from ionization probe current using the following formula:
DR(Rads/hr)= (1.017E17 * (Amps)2 + 5.360E11 * (Amps) - 666.526) * 0.877

Completed: [signature] Date: 6-6-02

Reviewed: [signature] Date: 6-10-02

APPENDIX 6

CHRONOLOGICAL SUMMARY OF DEVIATIONS FROM PLAN

Date	Time	Circuits/Samples	Action
5/25/04	17:06-17:25	All circuits	Powered interrupted for IR measurements during the first transient.
5/25/04	17:38	All circuits	Power interrupted. Transient 1 completed
5/27/04	9:56-10:03	All circuits	Power interrupted for IR
5/27/04	14:20-15:30	All circuits	Power interrupted for IR
5/27/04	15:51-16:27	25(4)	Troubleshooting samples #7, #8
5/27/04	19:10-19:20	All circuits	Power interrupted for IR
5/27/04	22:35-22:57	All circuits	Power interrupted for troubleshooting
5/27/04	23:39-	25A(4)	Power interrupted for blown fuse
5/28/04	00:17	25A(4)	Power restored
5/28/04	00:17-00:38	All circuits	Power interrupted for troubleshooting
5/28/04	13:00-14:20	All circuits	Power interrupted for IR
5/29/04	13:22-13:31	All circuits	Power interrupted
5/30/04	14:25-14:35	All circuits	Power interrupted
5/31/04	00:59-02:15	Chamber	Pressure and Temperature below target values
5/31/04	02:05-02:35	All Circuits	Power interrupted
5/31/04	10:03-10:11	All Circuits	Power interrupted
6/1/04	6:13-6:19	25(2) (not included in report)	Power interrupted
6/1/04	6:19-6:19	25(1)	Power interrupted

6/6/04	04:01-	Chamber	Temperature and pressure drop due to boiler problems
6/6/04	13:00	All circuits	Power Interrupted
6/7/04	09:33	All circuits	Power restored
6/7/04	10:41	Chamber	Temperature and pressure restored
6/9/04	6:29-7:34	All Circuits	Power interrupted for IR
6/15/04	7:32-8:42	All Circuits	Power interrupted for IR
6/29/04	06:17-07:12	All Circuits	Power interrupted for IR

APPENDIX 7

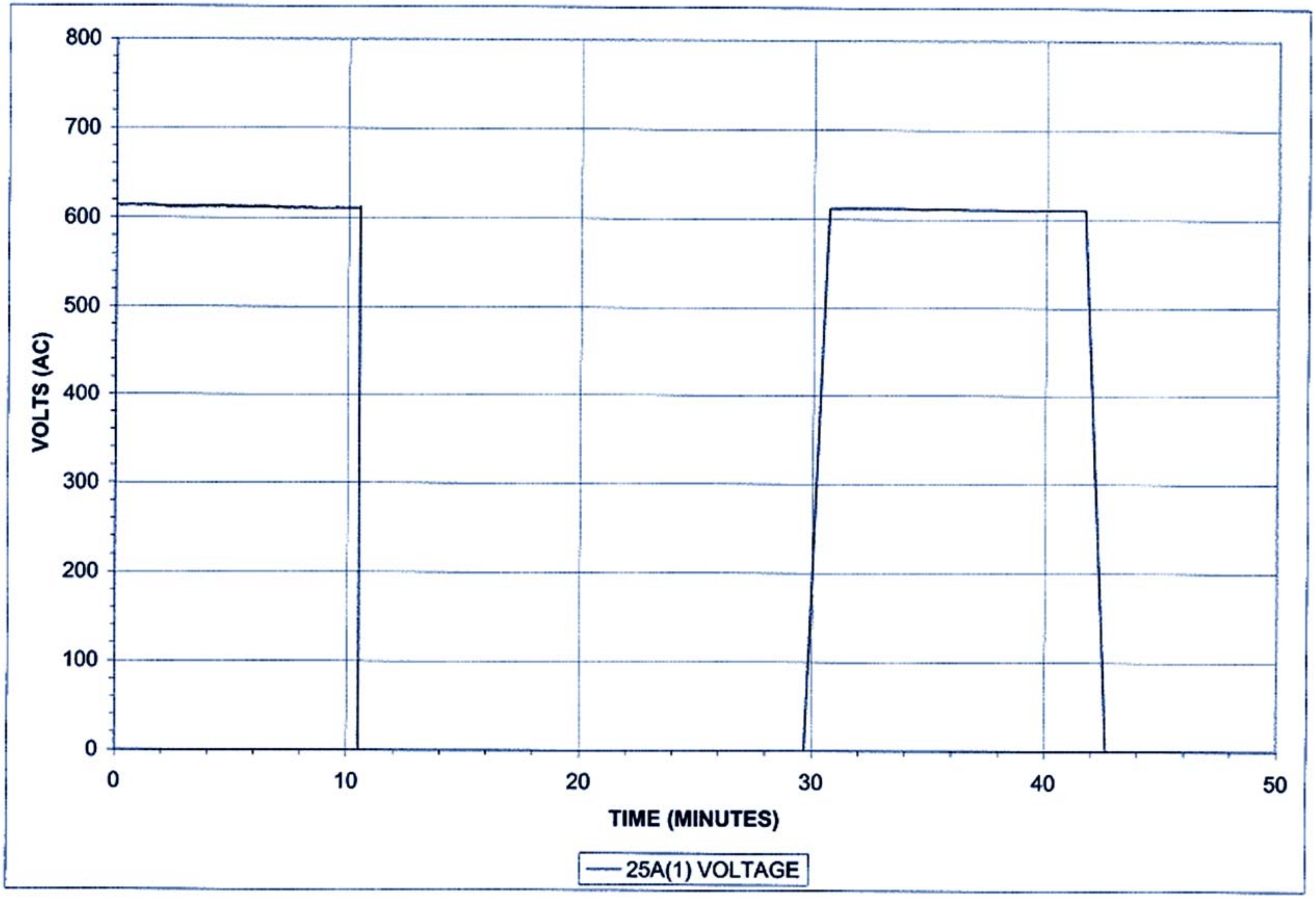
IR MEASUREMENTS FOR THE INSULATION RESISTANCE SAMPLES

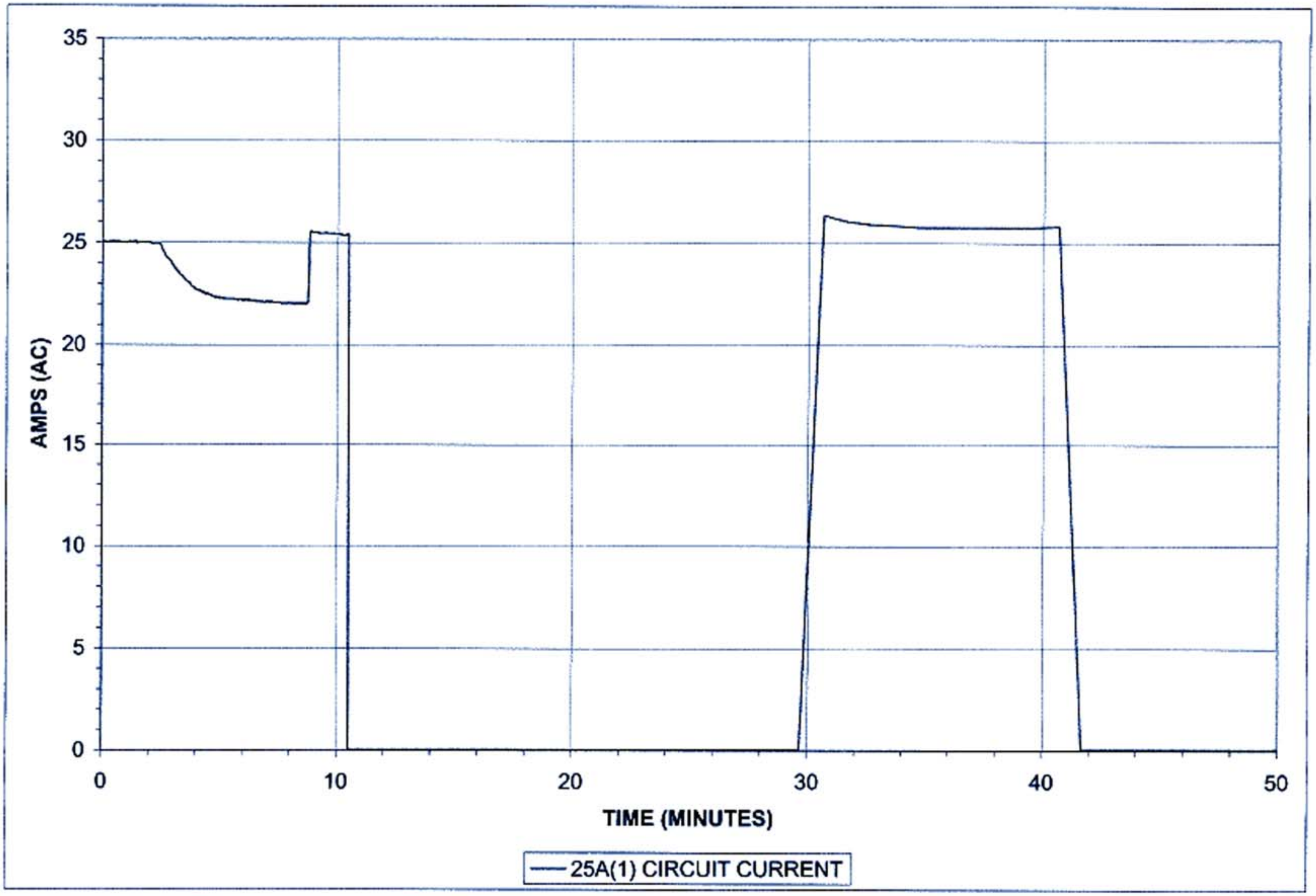
Date	Day number	Sample 47	Sample 48	Sample 49	Sample 50	Chamber Temperature °F
5/27/04	Day 1	IR measurements taken for all samples				
5/28/04	Day 2	IR measurements taken for all samples				
5/29/04	Day 3	Weekend				
5/30/04	Day 4	Weekend				
5/31/04	Day 5	No data available – facility problems				
6/1/04	Day 6 a.m.	1.2E08	1.4E08	6.4E09	1.1E10	288
6/1/04	Day 6 p.m.	1.3E08	1.3E08	6.0E09	1.1E10	289
6/2/04	Day 7 a.m.	1.3E08	1.3E08	5.8E09	1.0E10	289
6/2/04	Day 7 p.m.	1.3E08	1.3E08	6.6E09	1.2E10	289
6/3/04	Day 8 a.m.	1.4E08	1.3E08	6.6E09	1.3E10	289
6/3/04	Day 8 p.m.	1.5E08	1.3E08	6.2E09	1.2E10	289
6/4/04	Day 9 a.m.	1.5E08	1.3E08	6.8E09	1.3E10	289
6/4/04	Day 9p.m.	1.5E08	1.3E08	6.8E09	1.4E10	289
6/5/04	Day 10	Weekend				
6/6/04	Day 11	Weekend				
6/7/04	Day 12	No data available – facility problems				
6/8/04	Day 13 a.m.	5.4E08	7.6E08	3.0E10	4.0E10	238
6/8/04	Day 13 p.m.	5.4E08	7.6E08	2.5E10	4.0E10	238
6/9/04	Day 14 p.m.	3.0E08	8.6E08	2.5E10	4.0E10	237
6/10/04	Day 15 a.m.	5.6E08	9.0E08	2.5E10	7.8E10	237
6/10/04	Day 15 p.m.	5.8E08	9.2E08	3.0E10	9.2E10	239
6/11/04	Day 16 a.m.	5.4E08	8.8E08	3.0E10	8.0E10	237
6/11/04	Day 16p.m.	6.4E08	1.1E09	2.8E10	8.0E10	238
6/12/04	Day 17	Weekend				
6/13/04	Day 18	Weekend				
6/14/04	Day 19 a.m.	7.2E08	1.5E09	2.5E10	7.8E10	237
6/14/04	Day 19 p.m.	7.2E08	1.5E09	2.8E10	7.4E10	237
6/15/04	Day 20 a.m.	6.8E08	1.5E09	2.8E10	5.0E10	238
6/15/04	Day 20 p.m.	6.8E08	1.6E09	2.5E10	4.5E10	239
6/16/04	Day 21 a.m.	7.2E08	1.6E09	2.2E10	4.5E10	239

6/16/04	Day 21 p.m.	7.2E08	1.6E09	2.2E10	5.0E10	237
6/17/04	Day 22 a.m.	7.0E08	1.6E09	2.5E10	9.2E10	238
6/17/04	Day 22 p.m.	7.0E08	1.5E09	2.5E10	9.0E10	238
6/18/04	Day 23 a.m.	7.4E08	1.7E09	2.2E10	6.8E10	237
6/18/04	Day 23 p.m.	7.8E08	1.6E09	2.5E10	6.8E10	237
6/19/04	Day 24	Weekend				
6/20/04	Day 25	Weekend				
6/21/04	Day 26 a.m.	8.2E08	1.8E09	2.2E10	1.0E11	239
6/21/04	Day 26 p.m.	8.2E08	1.8E09	2.2E10	9.2E10	238
6/22/04	Day 27	No data available				
6/23/04	Day 28 a.m.	1.0E09	2.8E09	3.0E10	1.1E11	238
6/23/04	Day 28 p.m.	8.6E08	2.0E09	2.0E10	7.0E10	239
6/24/04	Day 29 a.m.	8.8E08	2.0E09	2.0E10	9.0E10	239
6/24/04	Day 29 p.m.	7.8E08	2.0E09	2.0E10	7.4E10	238
6/25/04	Day 30 a.m.	8.0E09	2.0E09	2.0E10	1.0E11	239
6/25/04	Day 30 p.m.	9.0E08	2.0E09	1.6E10	5.8E10	238
6/26/04	Day 31	Weekend				
6/27/04	Day 32	Weekend				
6/28/04	Day 33 a.m.	9.0E08	2.0E09	1.6E10	5.8E10	238
6/28/04	Day 33 p.m.	9.0E08	1.8E09	1.4E10	6.0E10	239

APPENDIX 8

CIRCUIT VOLTAGE AND CURRENT PLOTS


800
700
600
500
400
300
200
100
0
VOLTS (AC)
0
10
20
30
40
50
TIME (MINUTES)
25A(1) VOLTAGE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30
25
20
15
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5
0
AMPS (AC)
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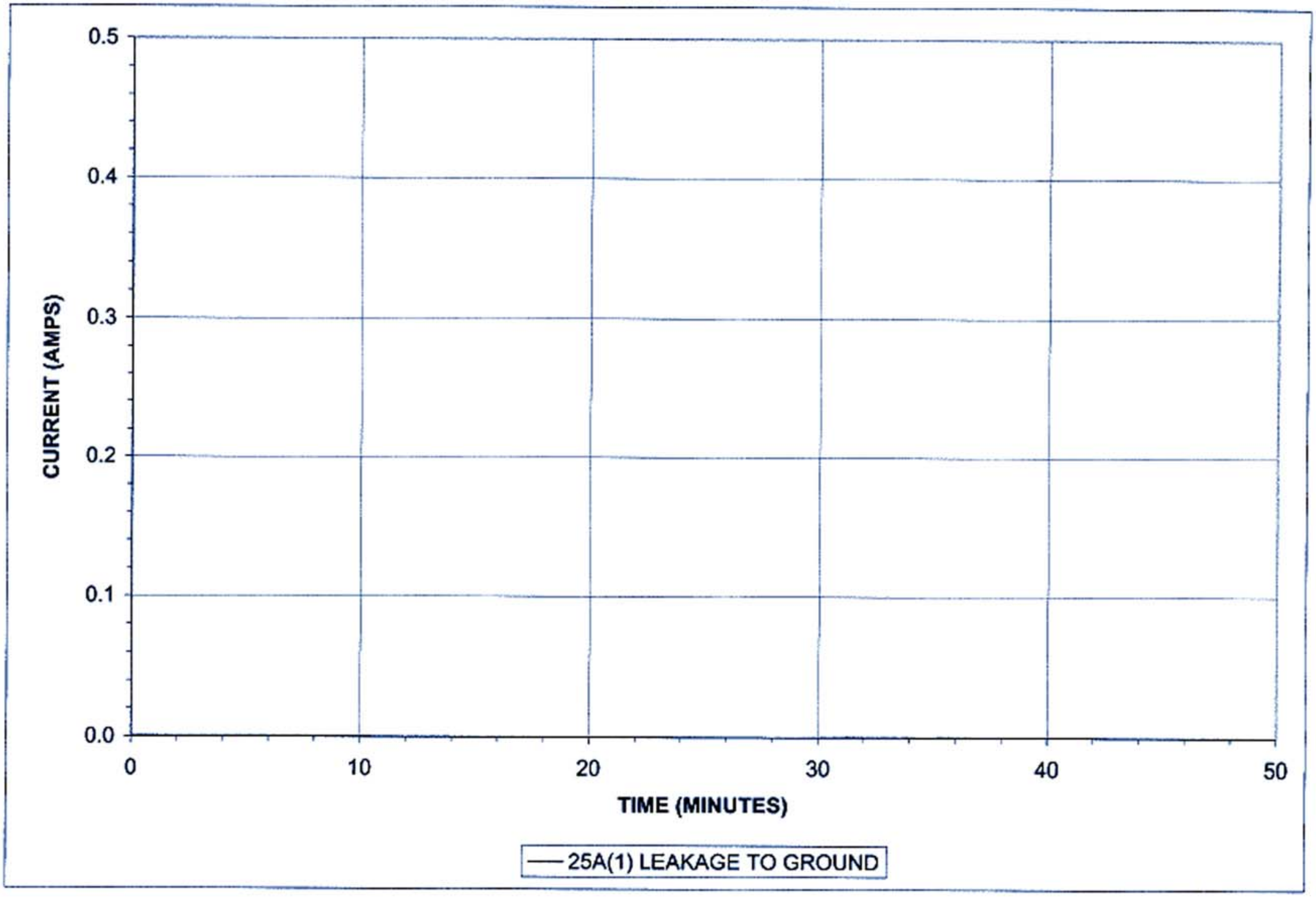
10
20
30
40
50
TIME (MINUTES)
25A(1) CIRCUIT CURRENT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0.4
0.3
0.2
0.1
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CURRENT (AMPS)
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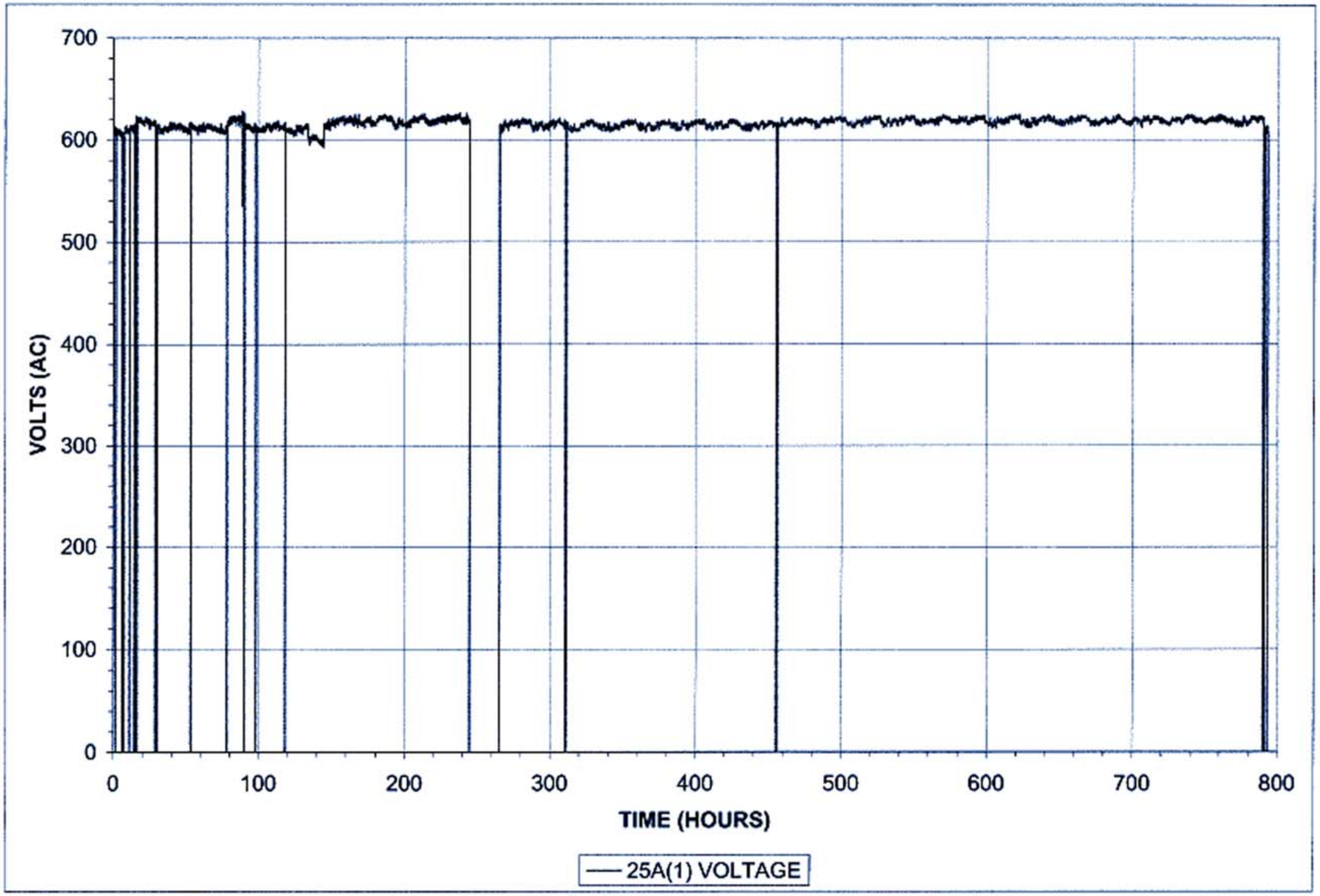
10
20
30
40
50
TIME (MINUTES)
25A(1) LEAKAGE TO GROUND


700
600
500
400
300
200
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VOLTS (AC)
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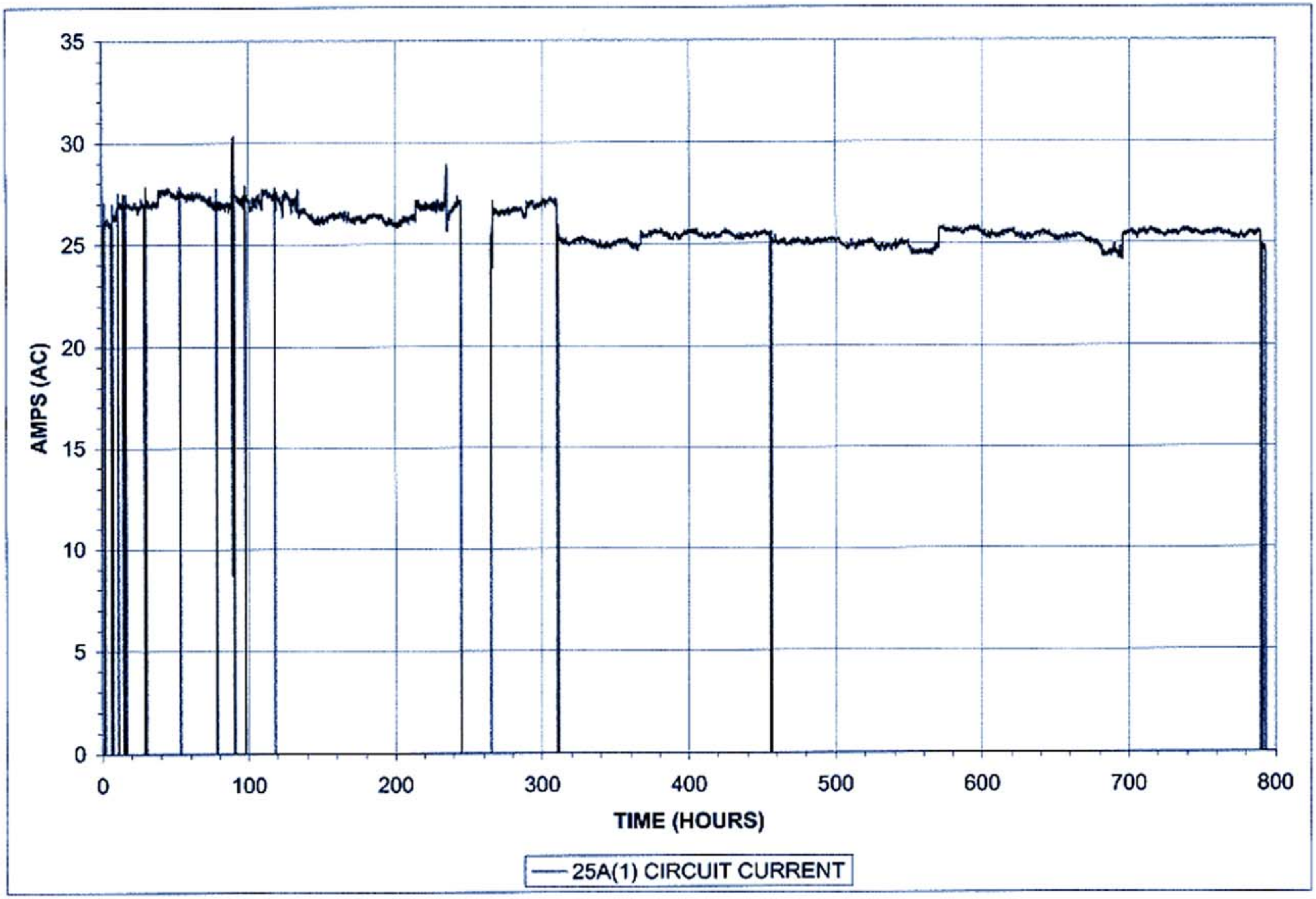
100
200
300
400
500
600
700
800
TIME (HOURS)
25A(1) VOLTAGE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5
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AMPS (AC)
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200
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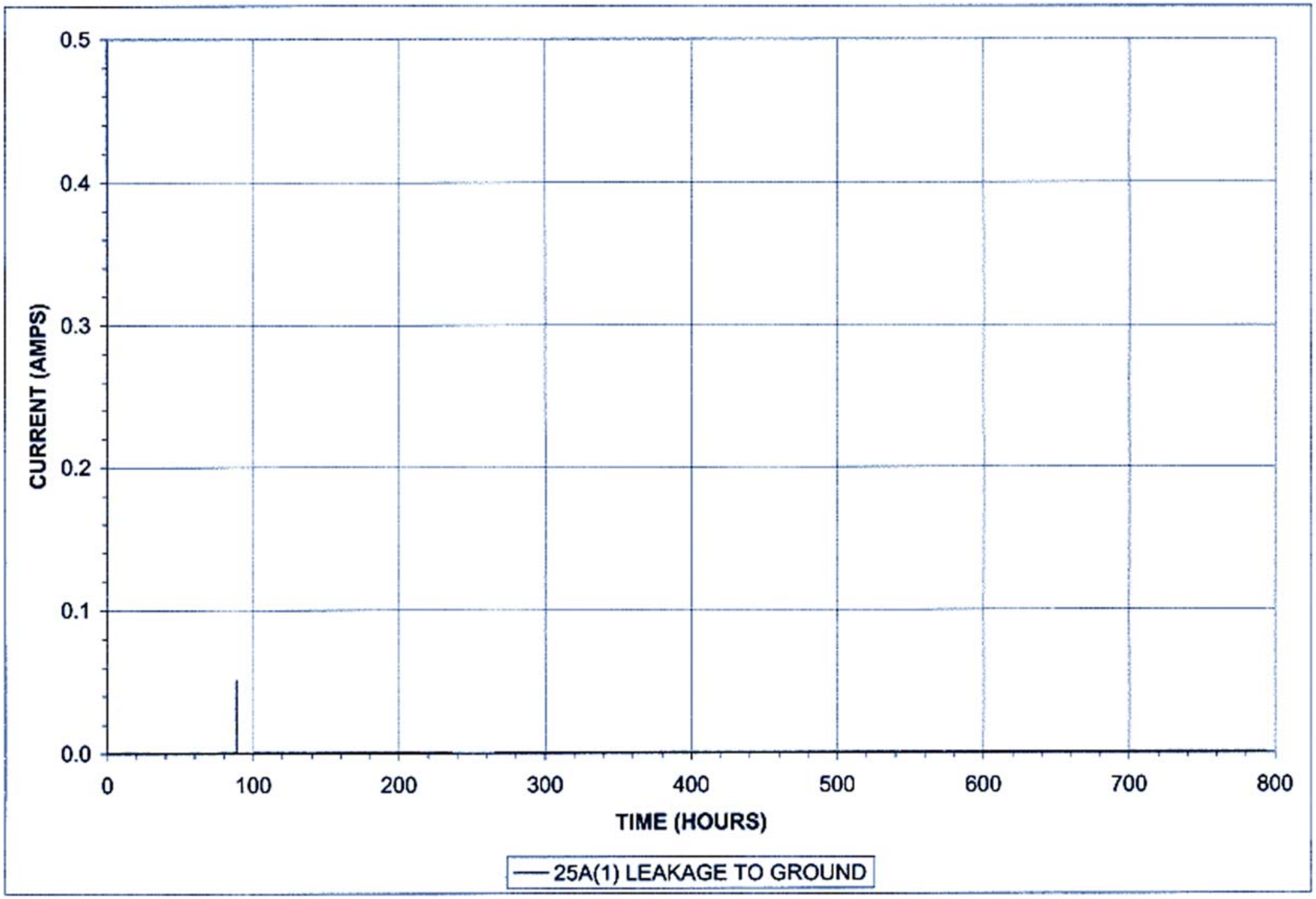
400
500
600
700
800
TIME (HOURS)
25A(1) CIRCUIT CURRENT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0.4
0.3
0.2
0.1
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CURRENT (AMPS)
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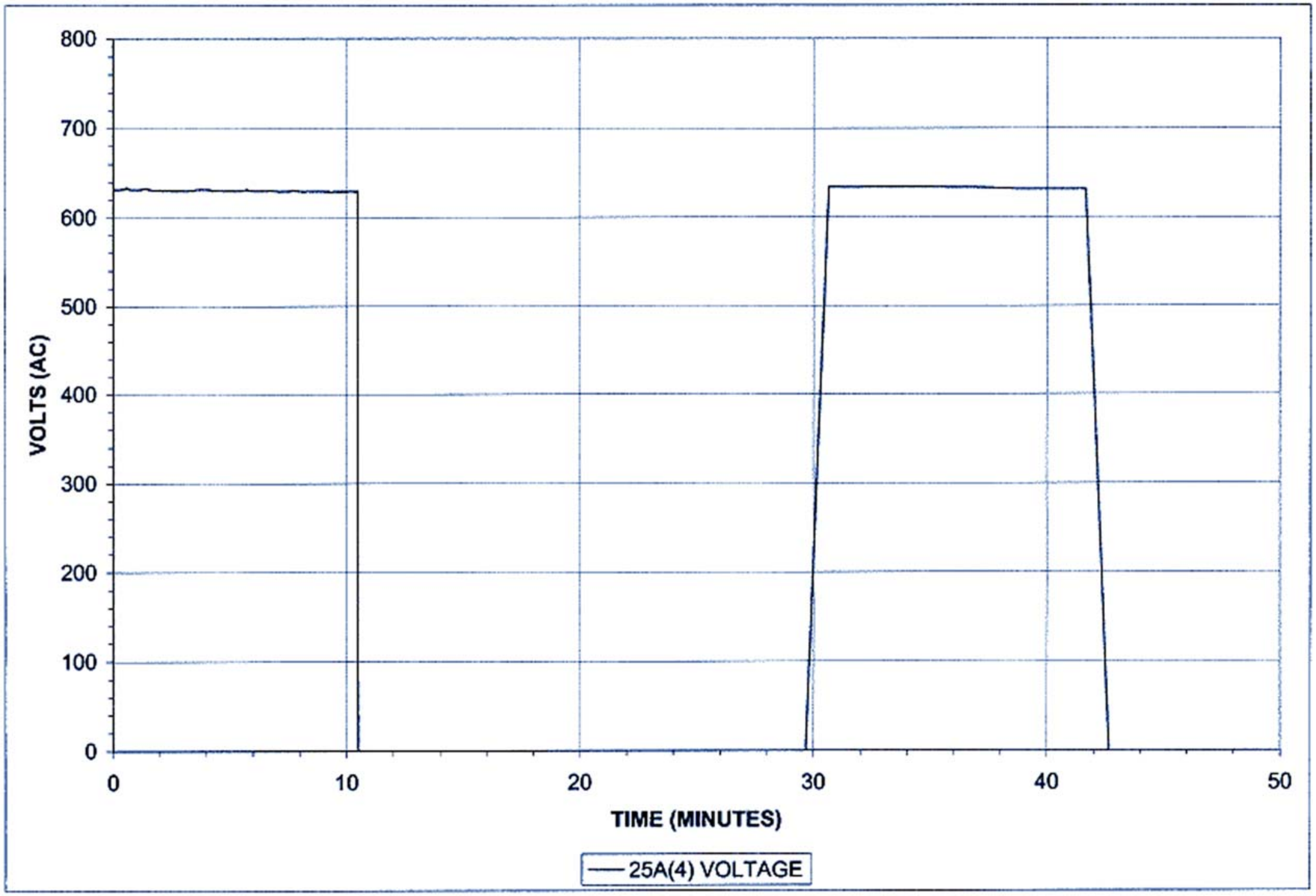
100
200
300
400
500
600
700
800
TIME (HOURS)
25A(1) LEAKAGE TO GROUND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0
VOLTS (AC)
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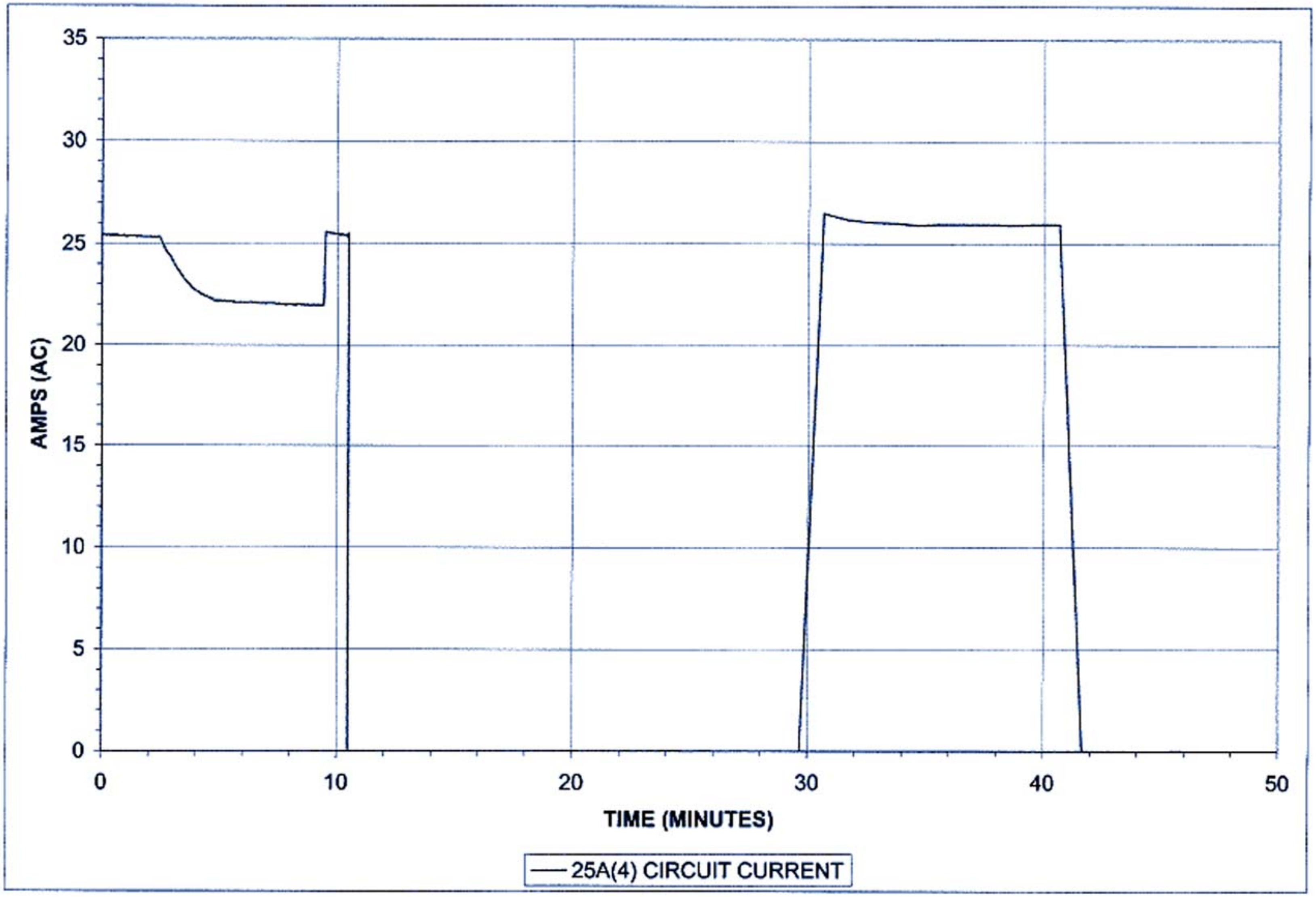
20
30
40
50
TIME (MINUTES)
25A(4) VOLTAGE


35
30
25
20
15
10
5
0
AMPS (AC)
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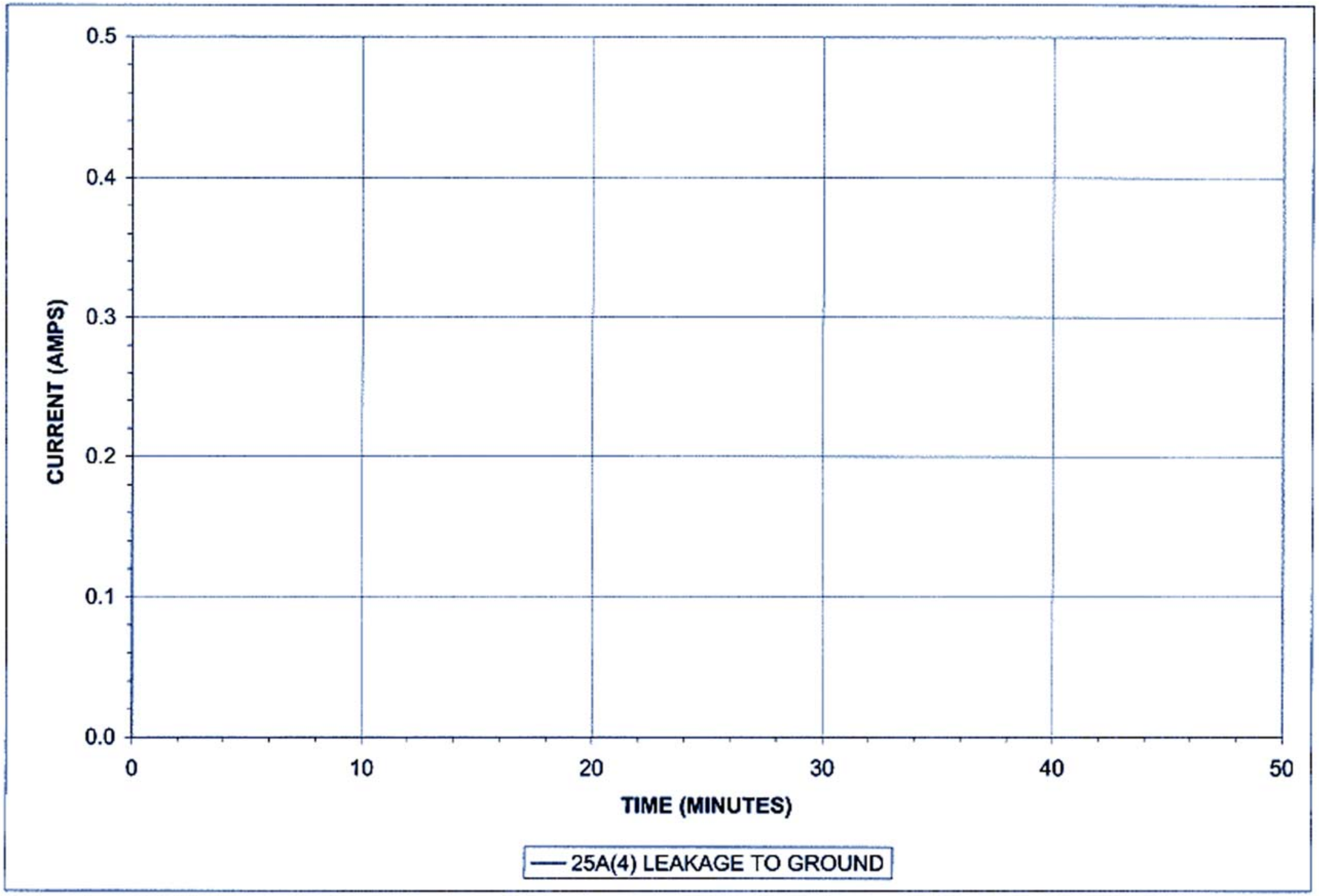
10
20
30
40
50
TIME (MINUTES)
25A(4) CIRCUIT CURRENT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0.4
0.3
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0.0
CURRENT (AMPS)
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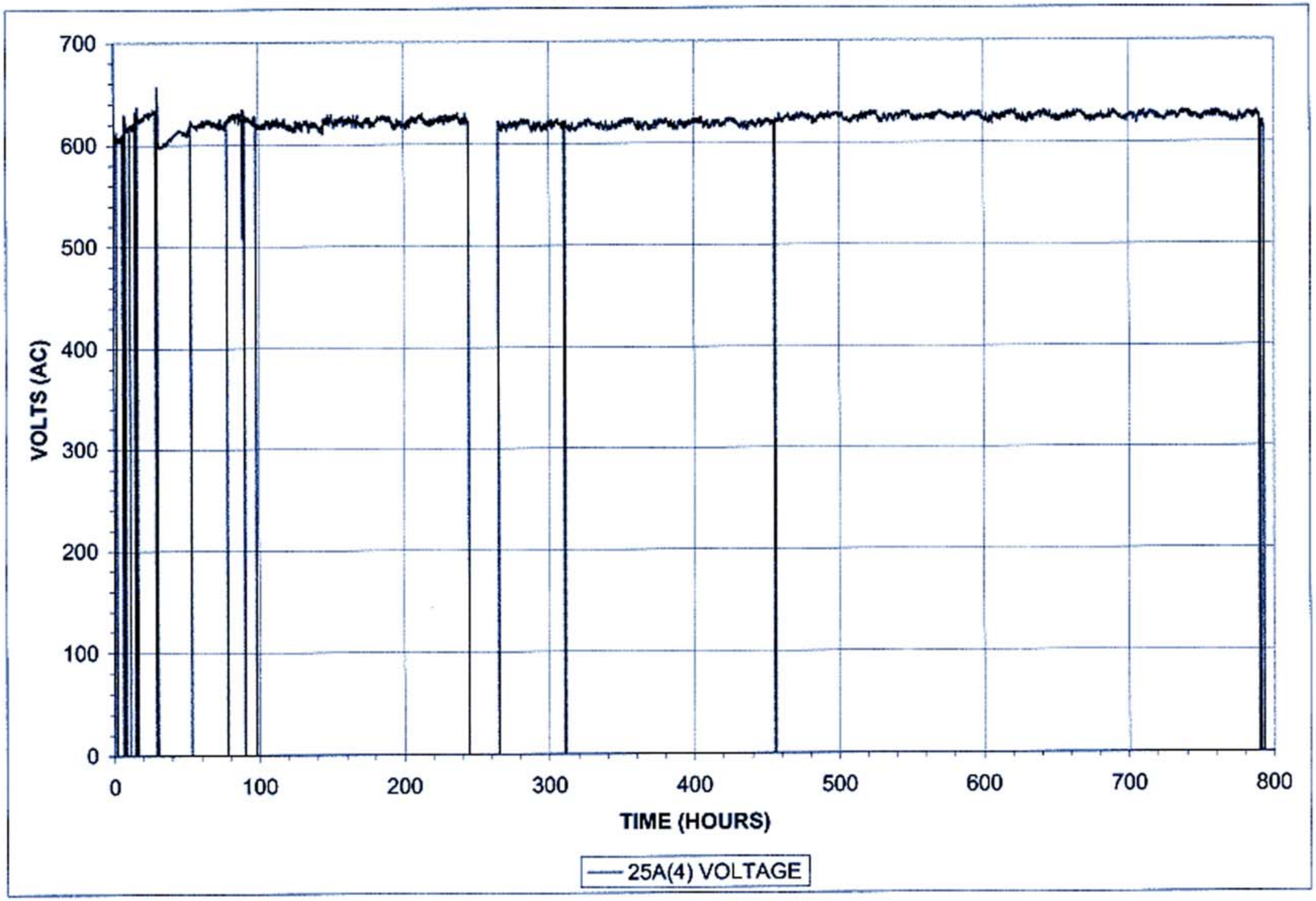
10
20
30
40
50
TIME (MINUTES)
25A(4) LEAKAGE TO GROUND


700
600
500
400
300
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100
0
VOLTS (AC)
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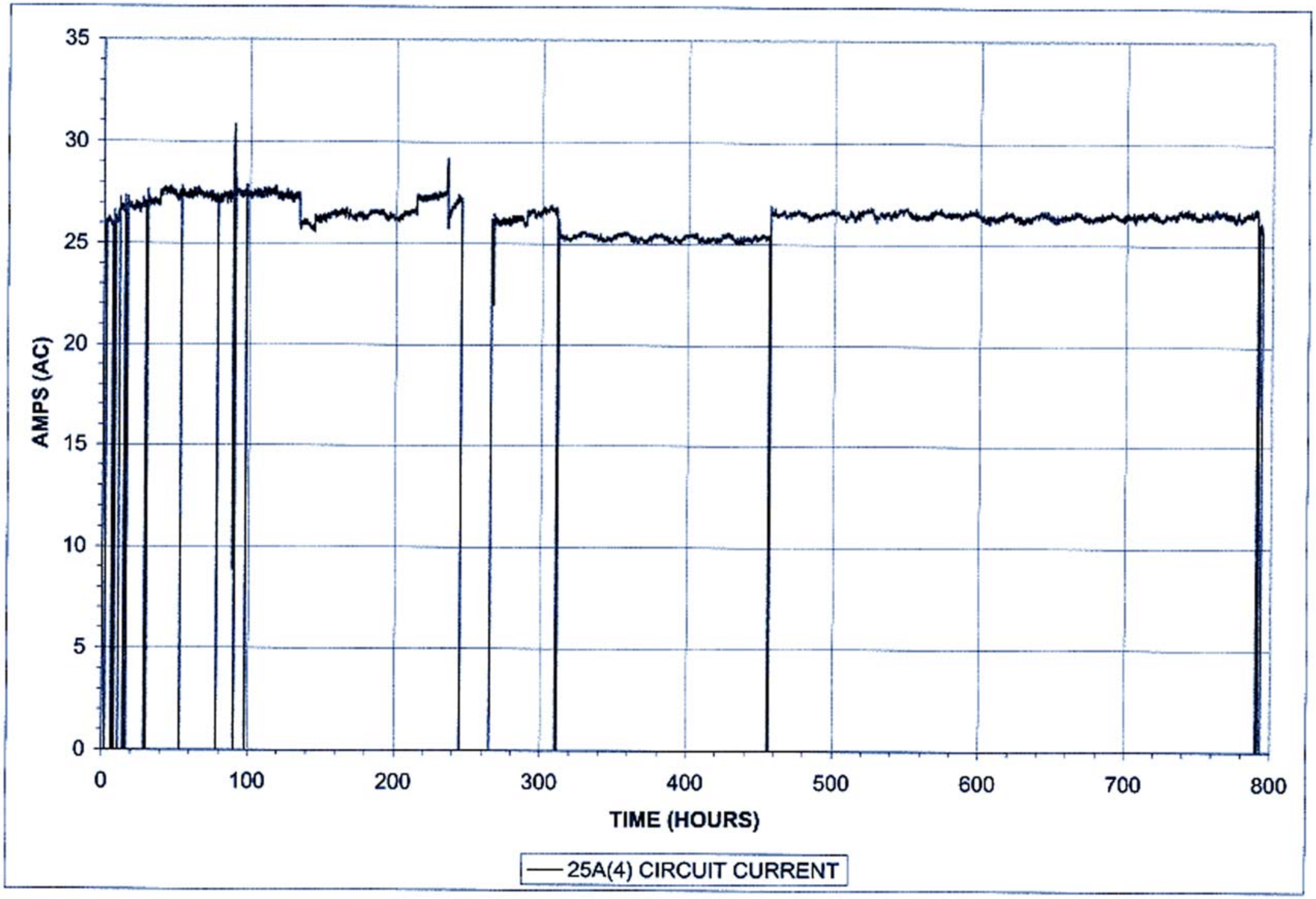
100
200
300
400
500
600
700
800
TIME (HOURS)
25A(4) VOLTAGE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30
25
20
15
10
5
0
AMPS (AC)
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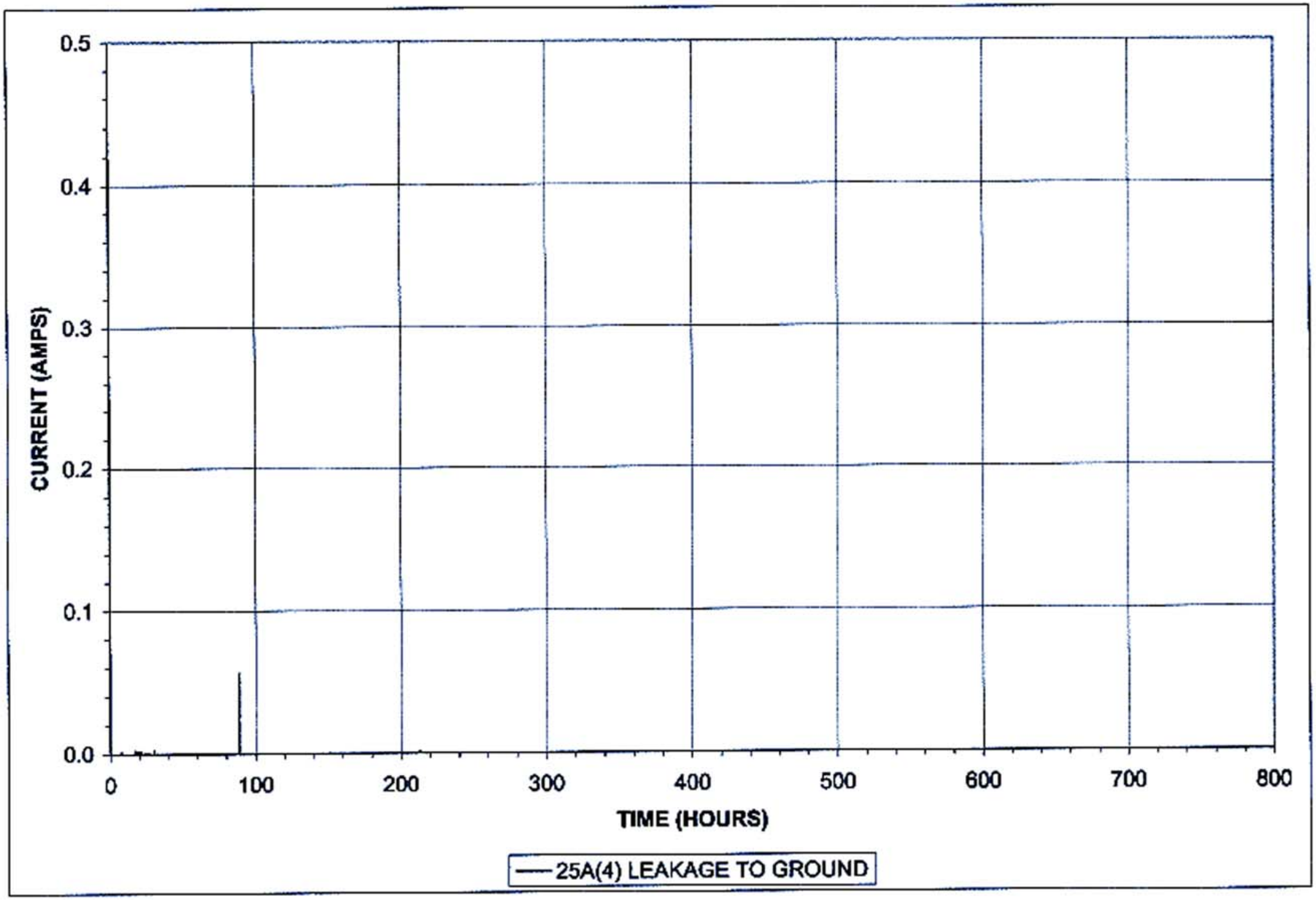
100
200
300
400
500
600
700
800
TIME (HOURS)
25A(4) CIRCUIT CURRENT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0.4
0.3
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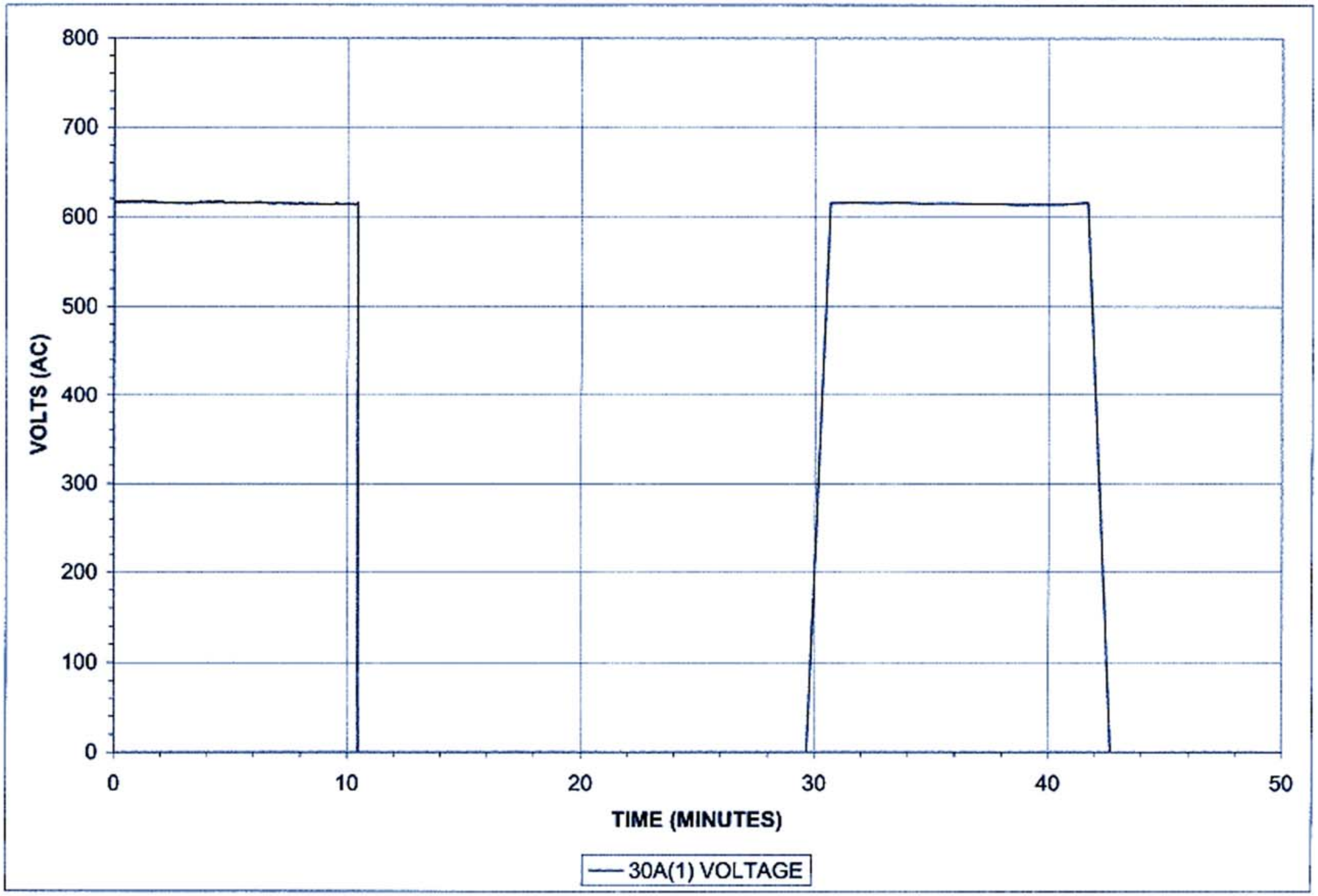
100
200
300
400
500
600
700
800
TIME (HOURS)
25A(4) LEAKAGE TO GROUND


800
700
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500
400
300
200
100
0
VOLTS (AC)
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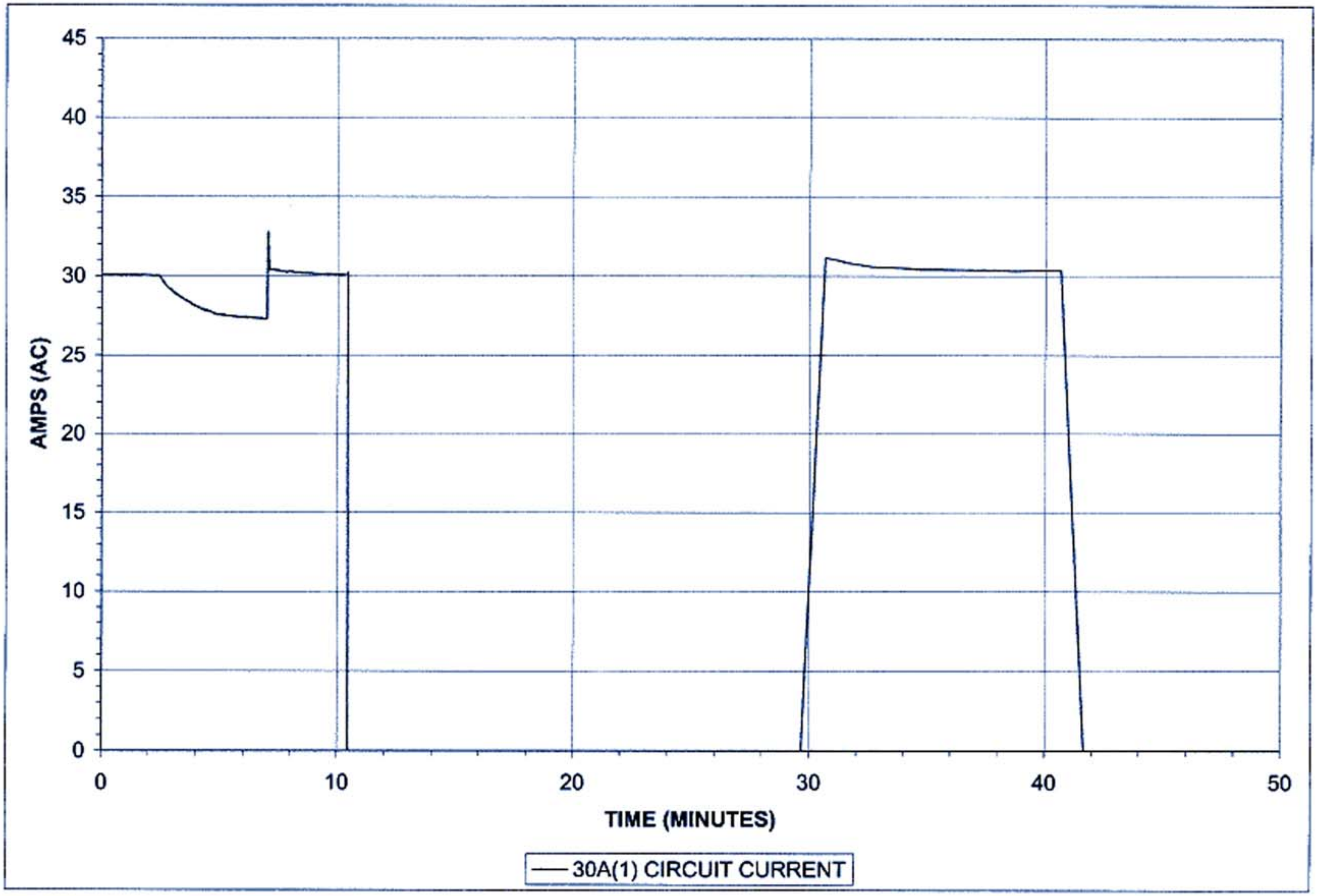
10
20
30
40
50
TIME (MINUTES)
30A(1) VOLTAGE


45
40
35
30
25
20
15
10
5
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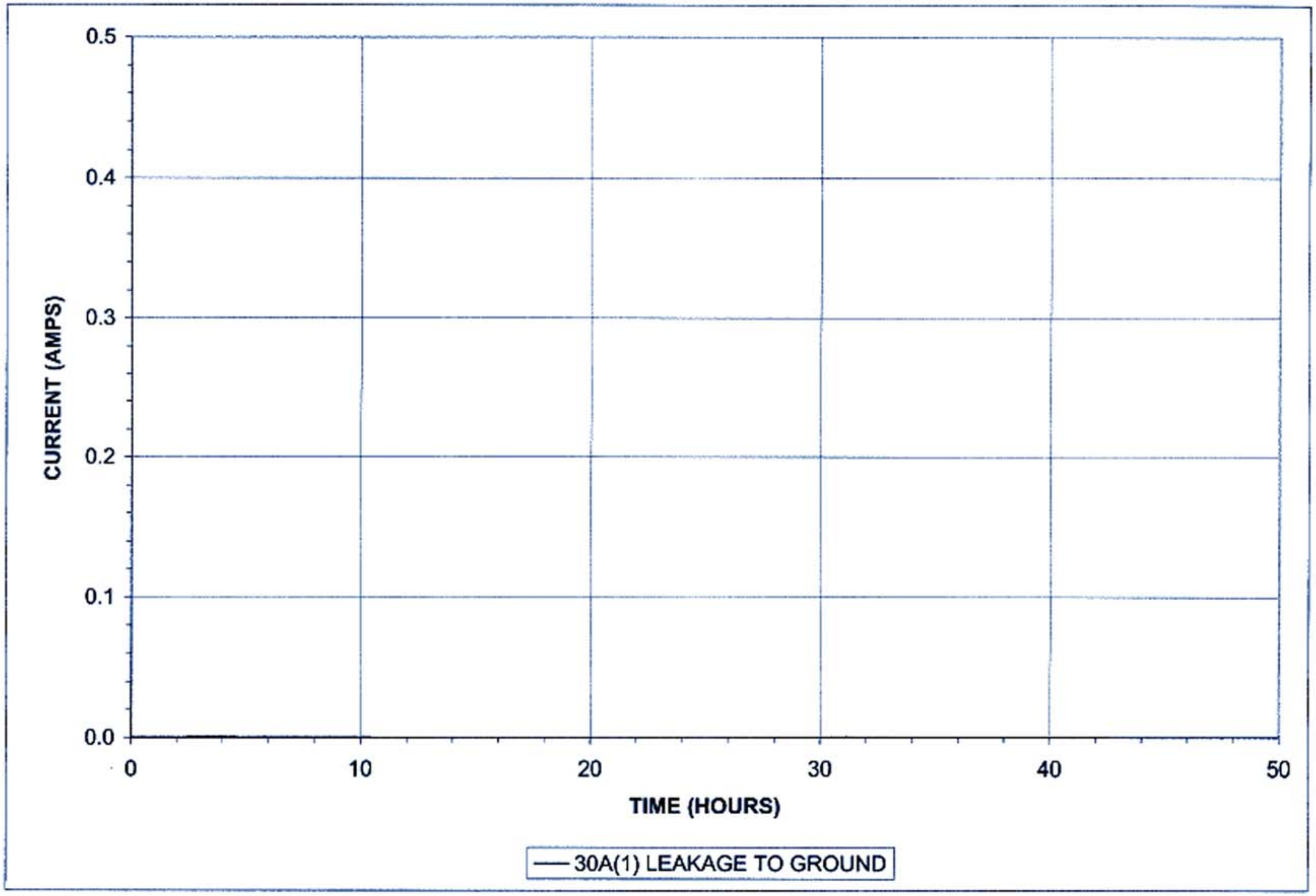
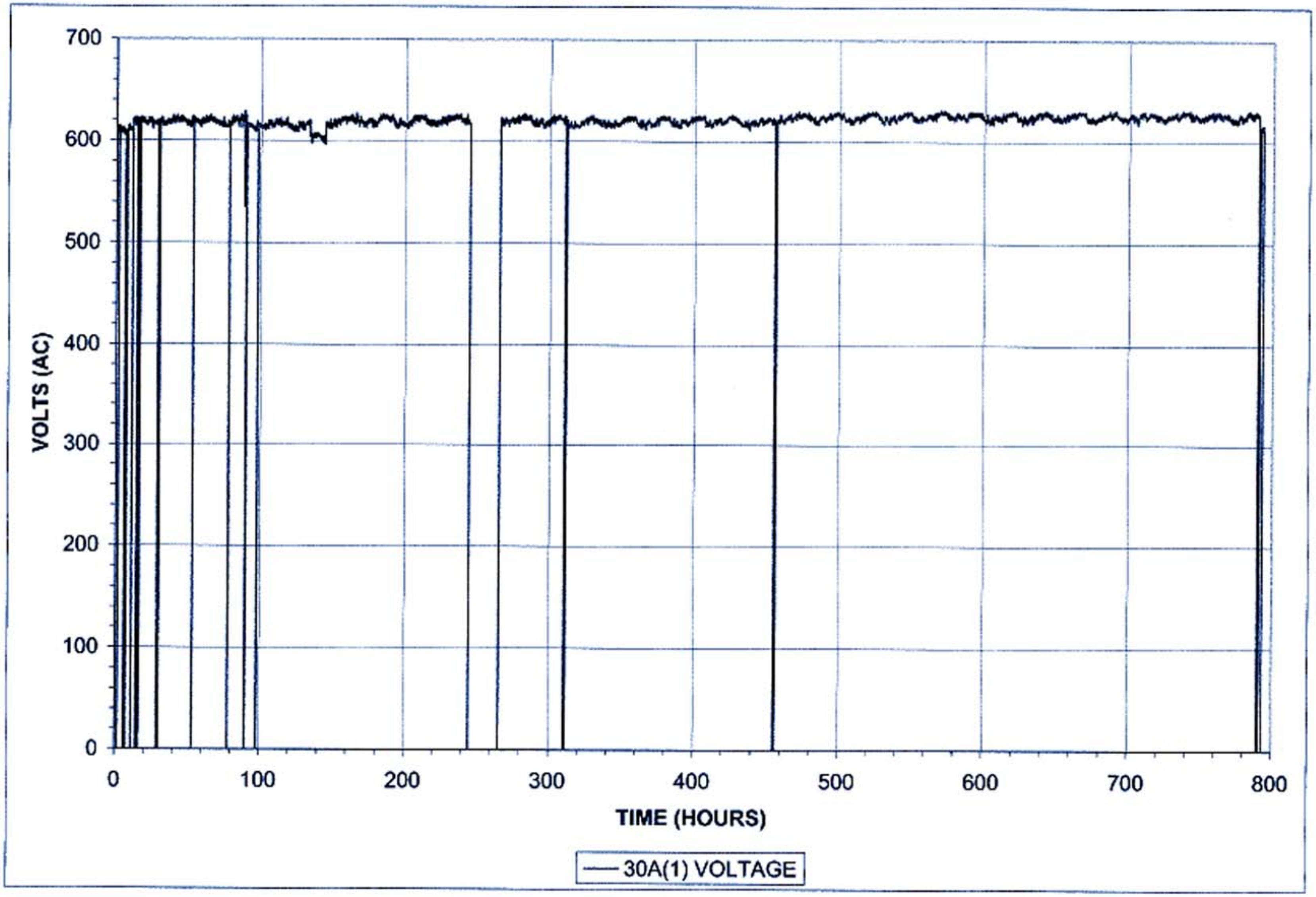
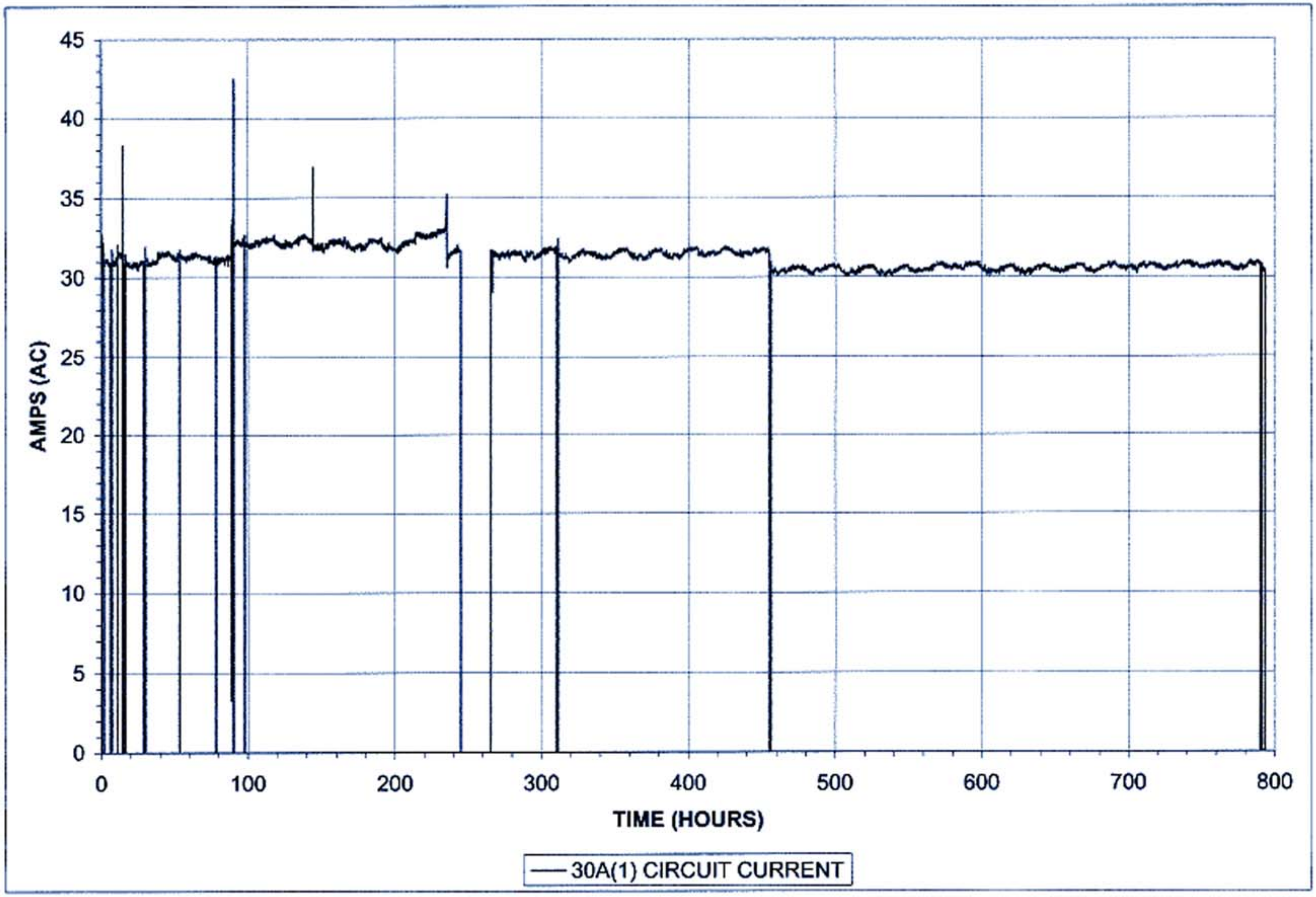
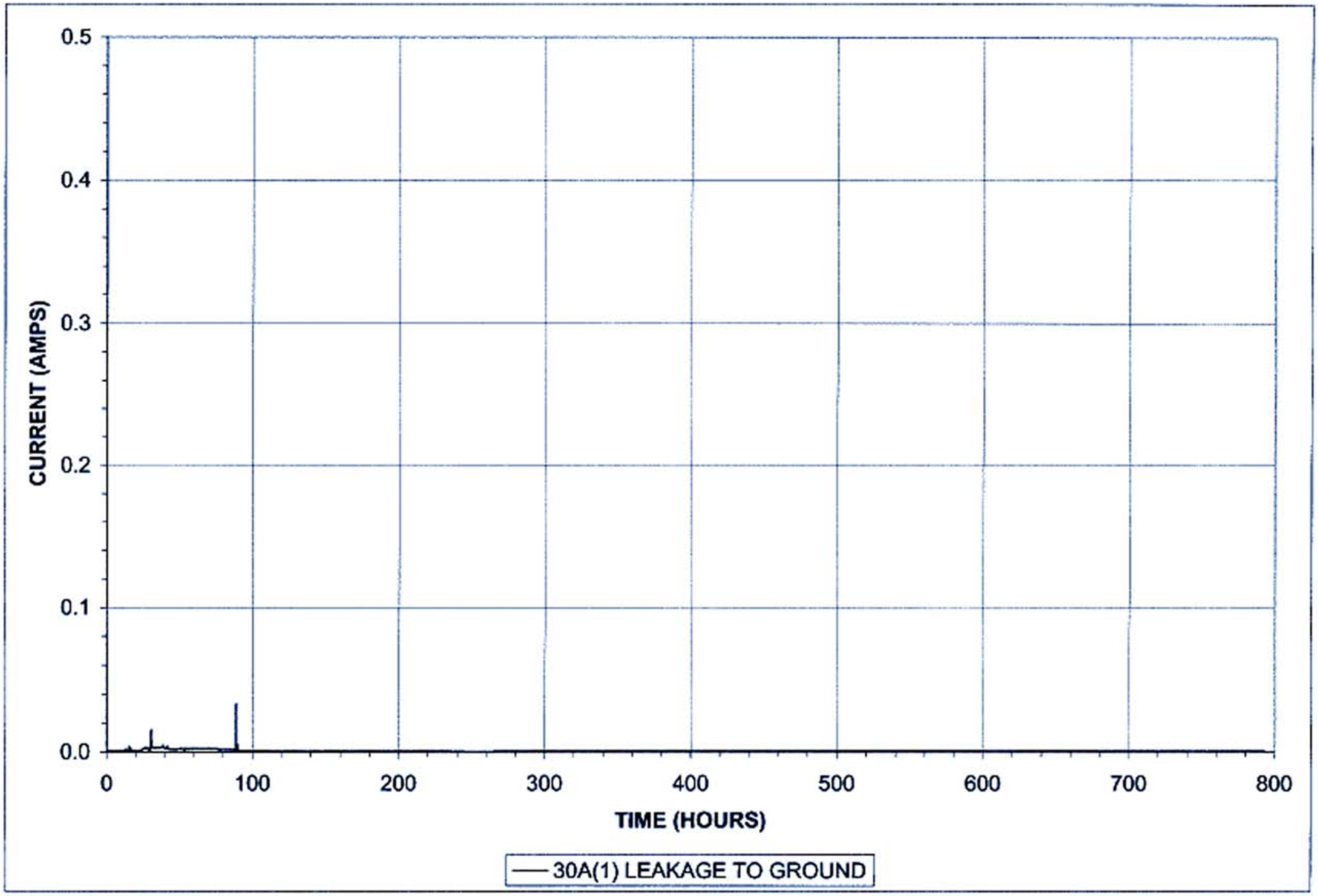
AMPS (AC)
0
10
20
30
40
50
TIME (MINUTES)
30A(1) CIRCUIT CURRENT


0.5
0.4
0.3
0.2
0.1
0.0
CURRENT (AMPS)
0
10
20
30
40
50
TIME (HOURS)
30A(1) LEAKAGE TO GROUND


700
600
500
400
300
200
100
0
VOLTS (AC)
0
100
200
300
400
500
600
700
800
TIME (HOURS)
30A(1) VOLTAGE


45
40
35
30
25
20
15
10
5
0
AMPS (AC)
0
100
200
300
400
500
600
700
800
TIME (HOURS)
30A(1) CIRCUIT CURRENT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0.4
0.3
0.2
0.1
0.0
CURRENT (AMPS)
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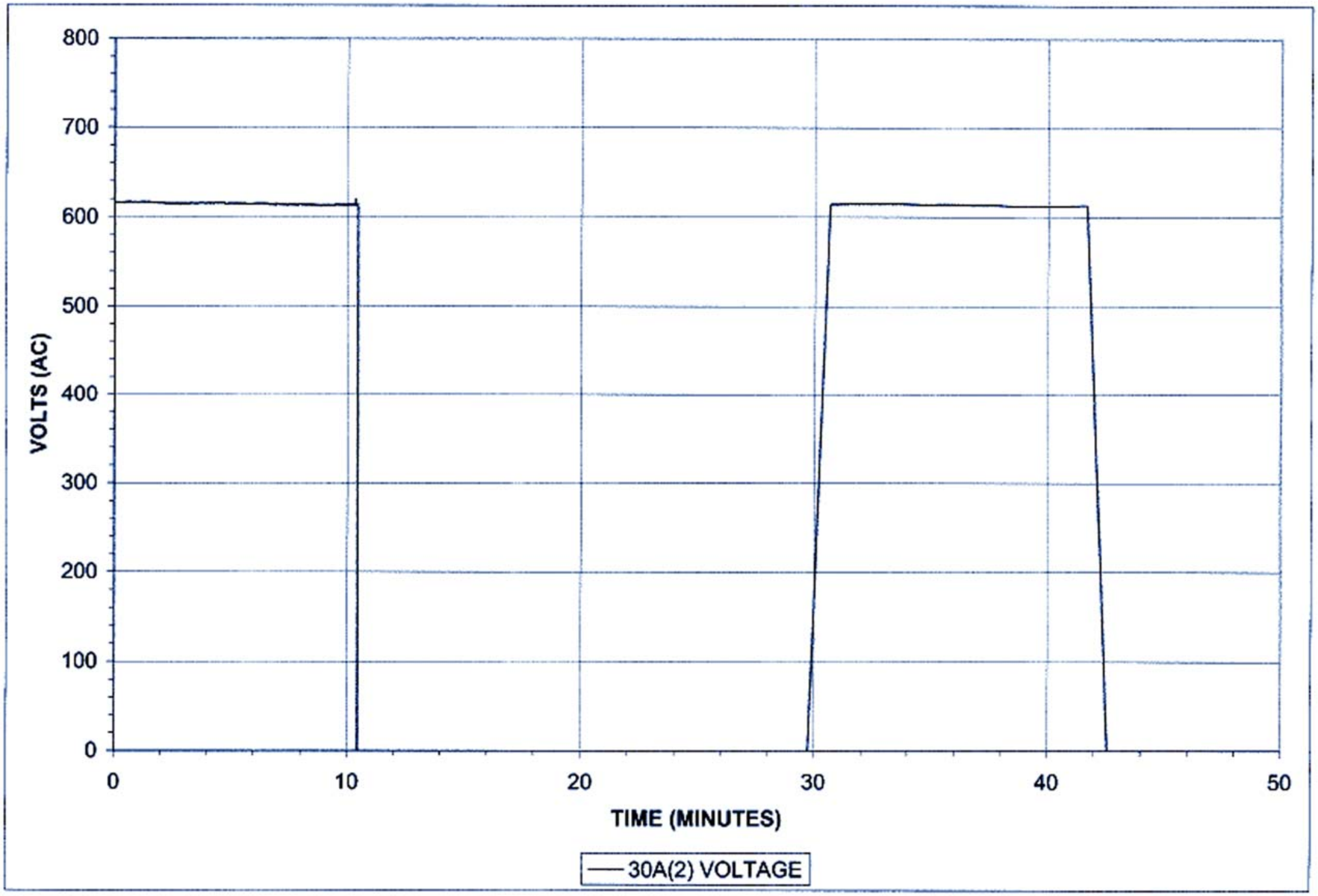
100
200
300
400
500
600
700
800
TIME (HOURS)
30A(1) LEAKAGE TO GROUND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700
600
500
400
300
200
100
0
VOLTS (AC)
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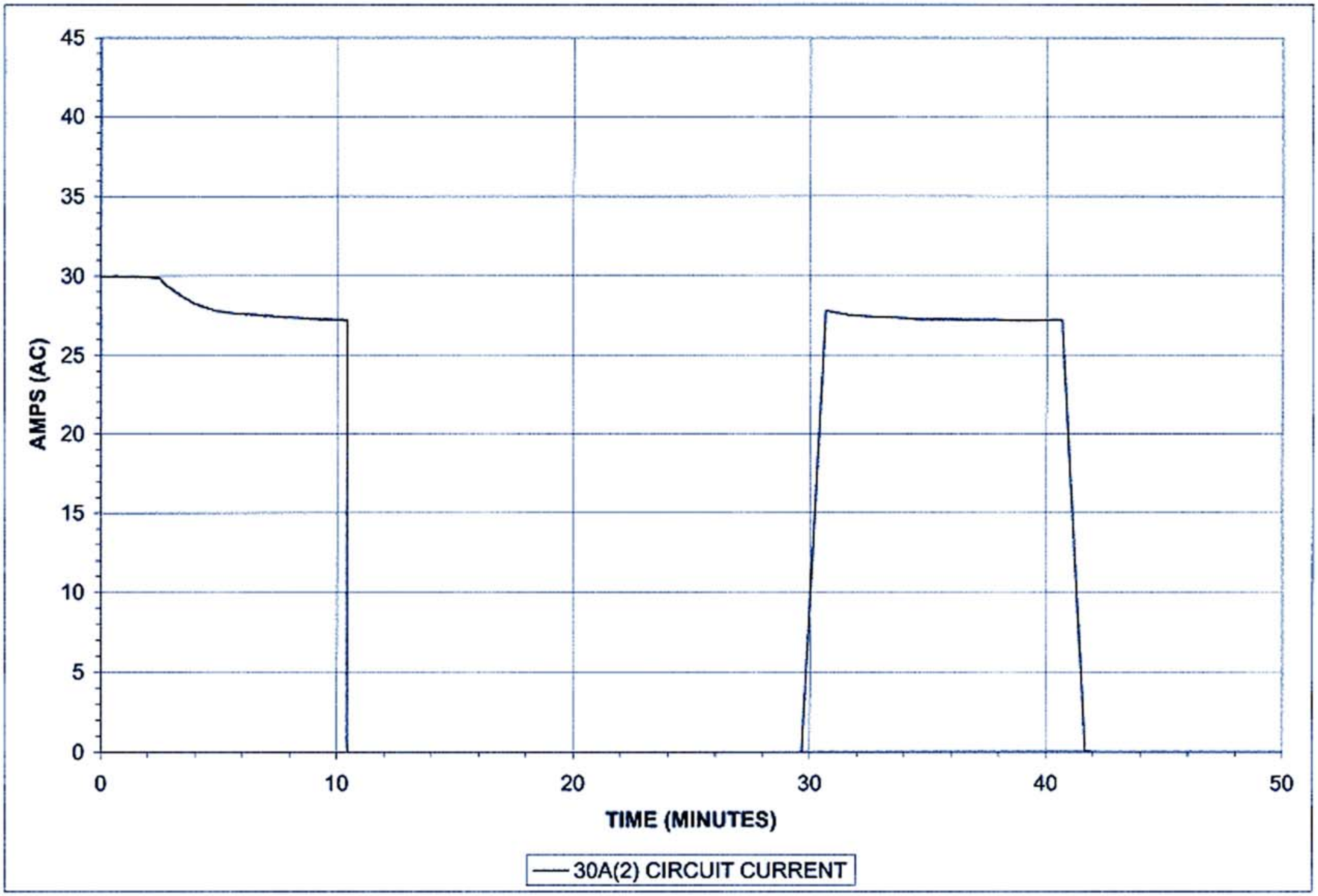
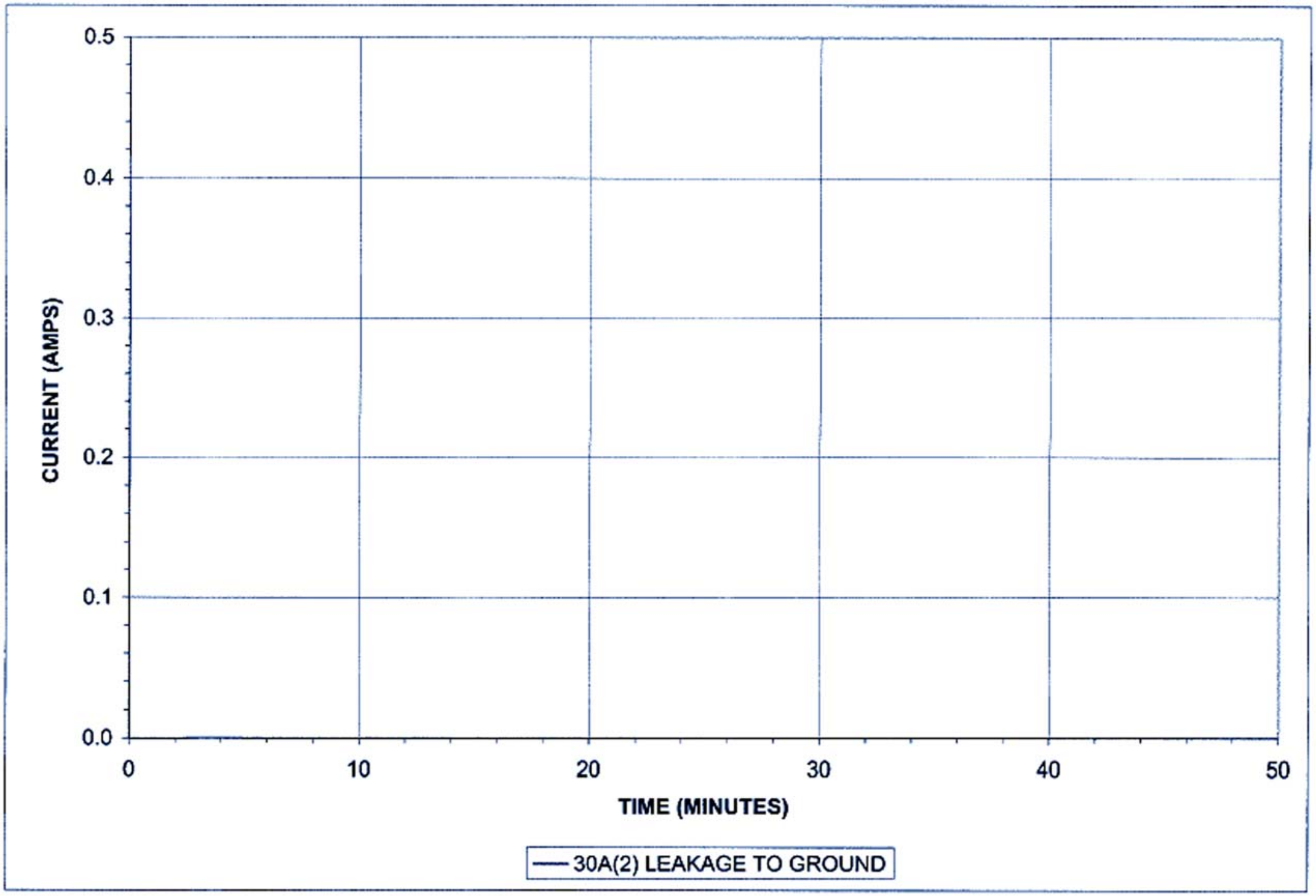
10
20
30
40
50
TIME (MINUTES)
30A(2) VOLTAGE


45
40
35
30
25
20
15
10
5
0
AMPS (AC)
0
10
20
30
40
50
TIME (MINUTES)
30A(2) CIRCUIT CURRENT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0.4
0.3
0.2
0.1
0.0
CURRENT (AMPS)
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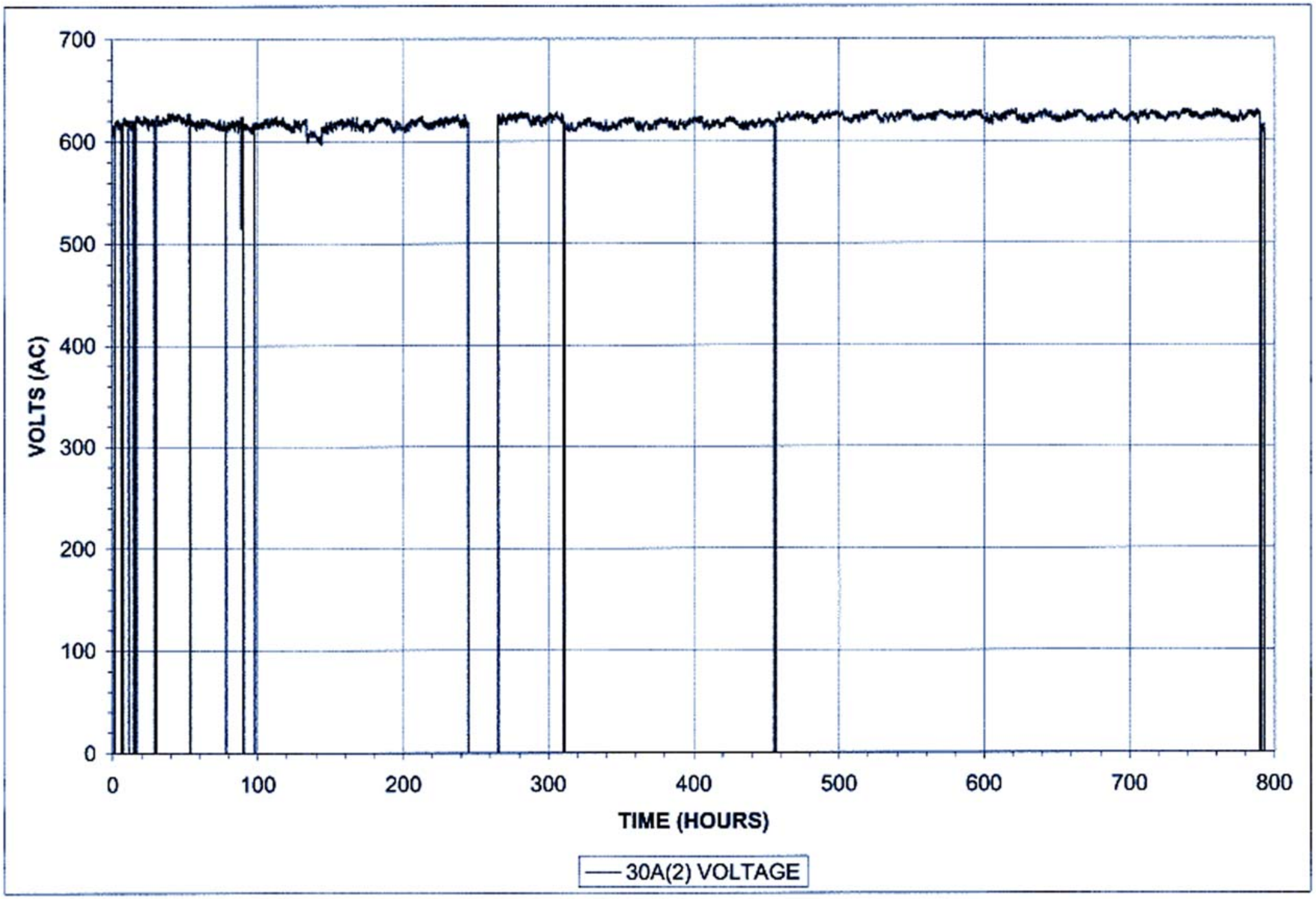
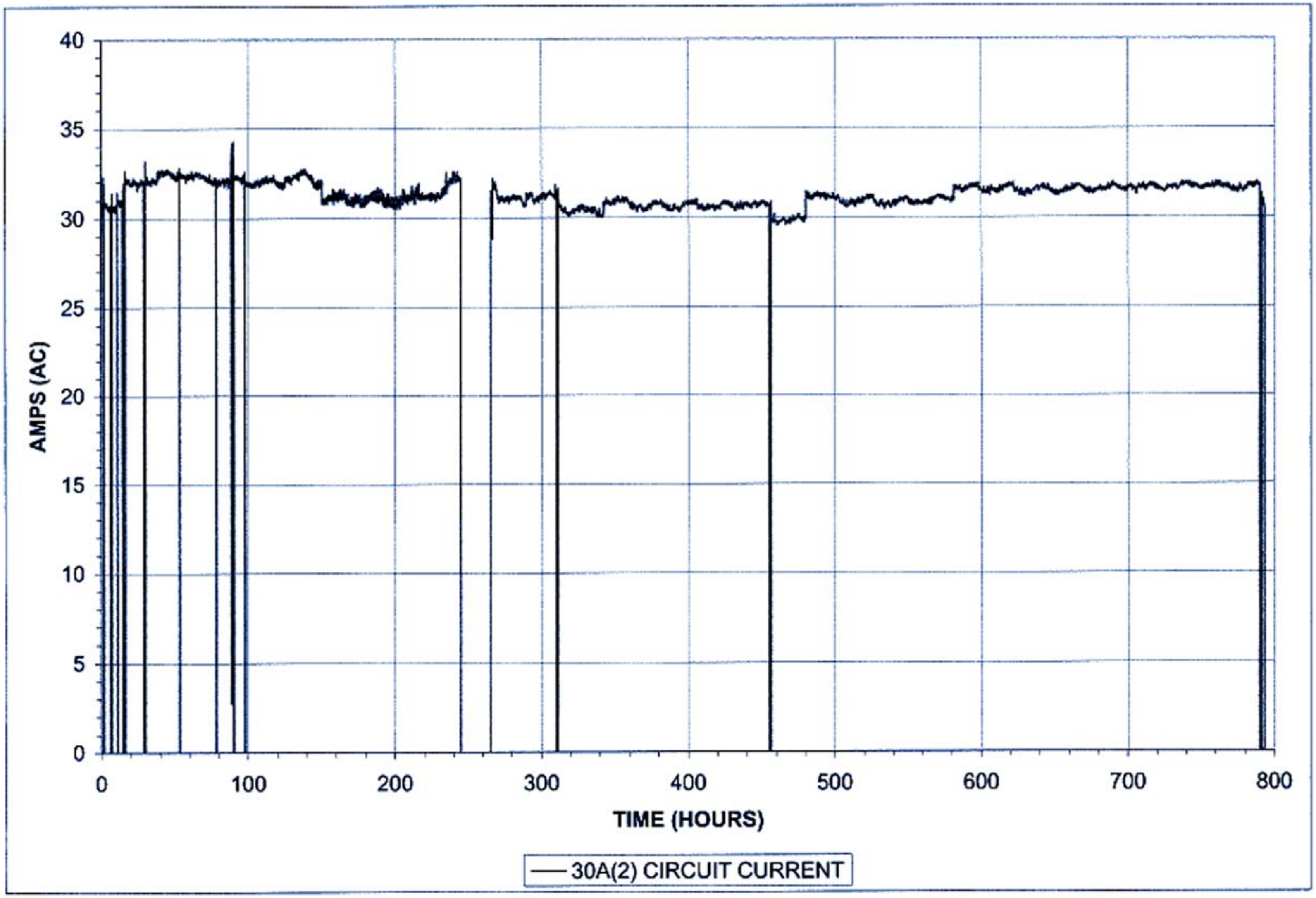
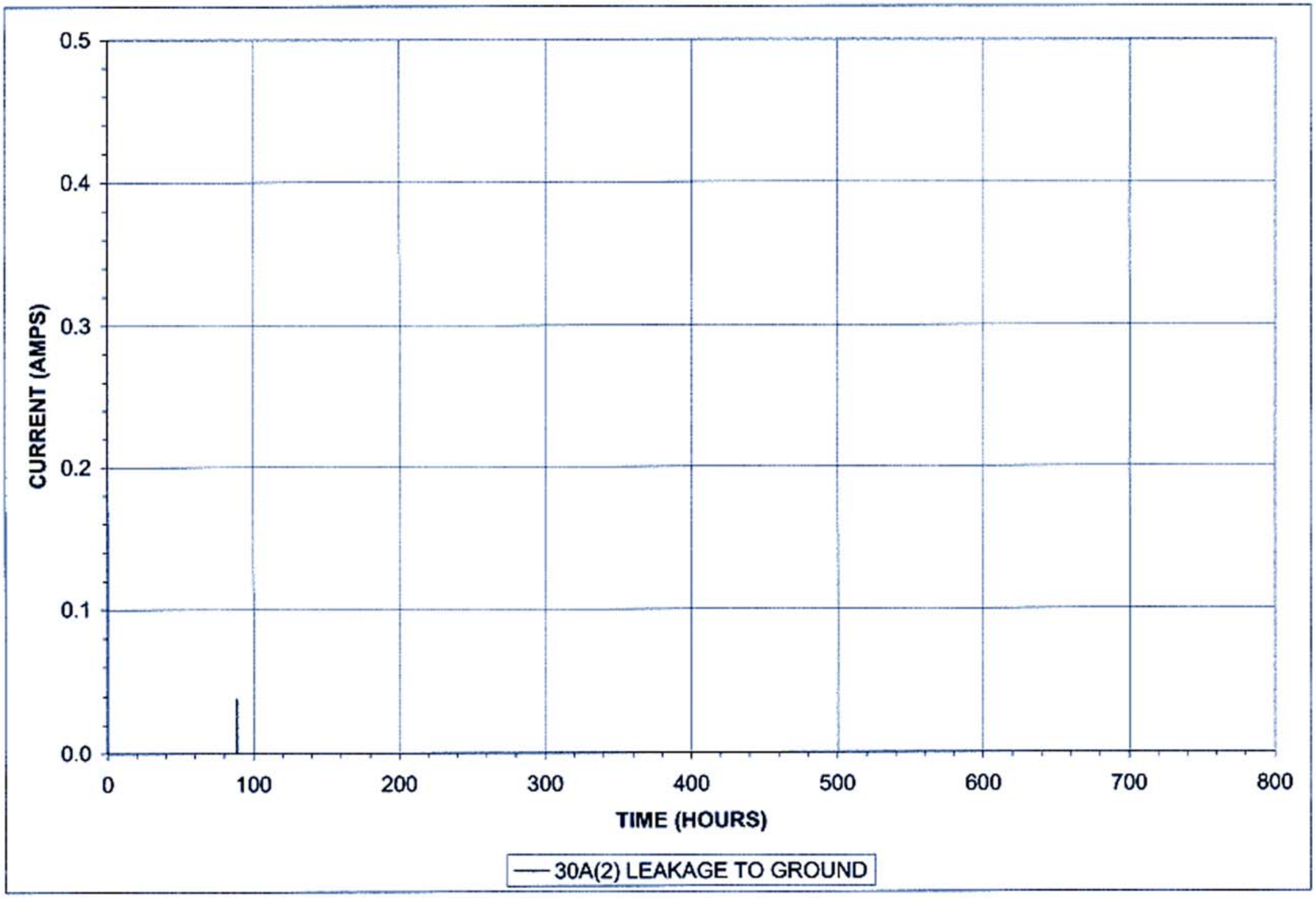
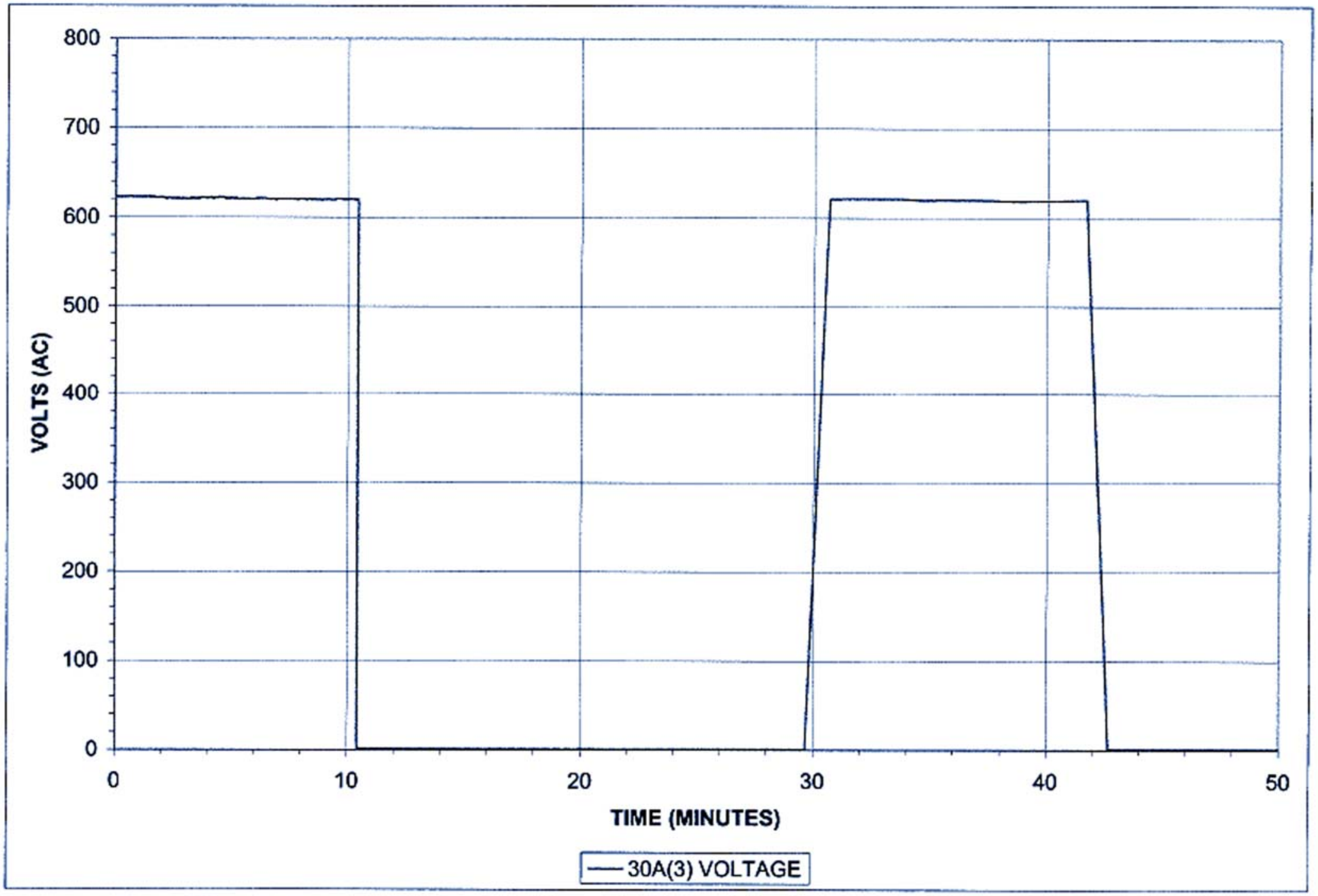
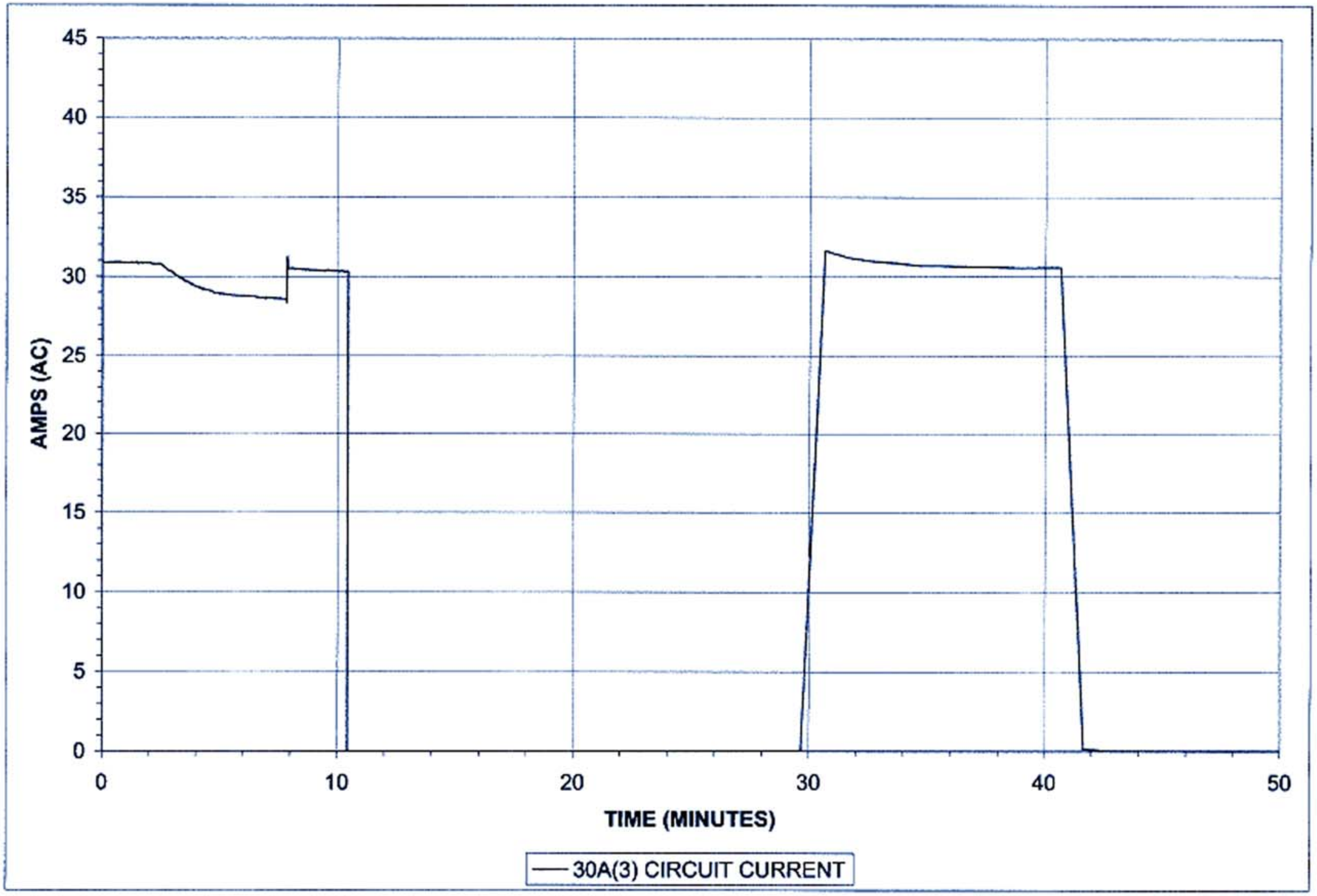
10
20
30
40
50
TIME (MINUTES)
30A(2) LEAKAGE TO GROUND

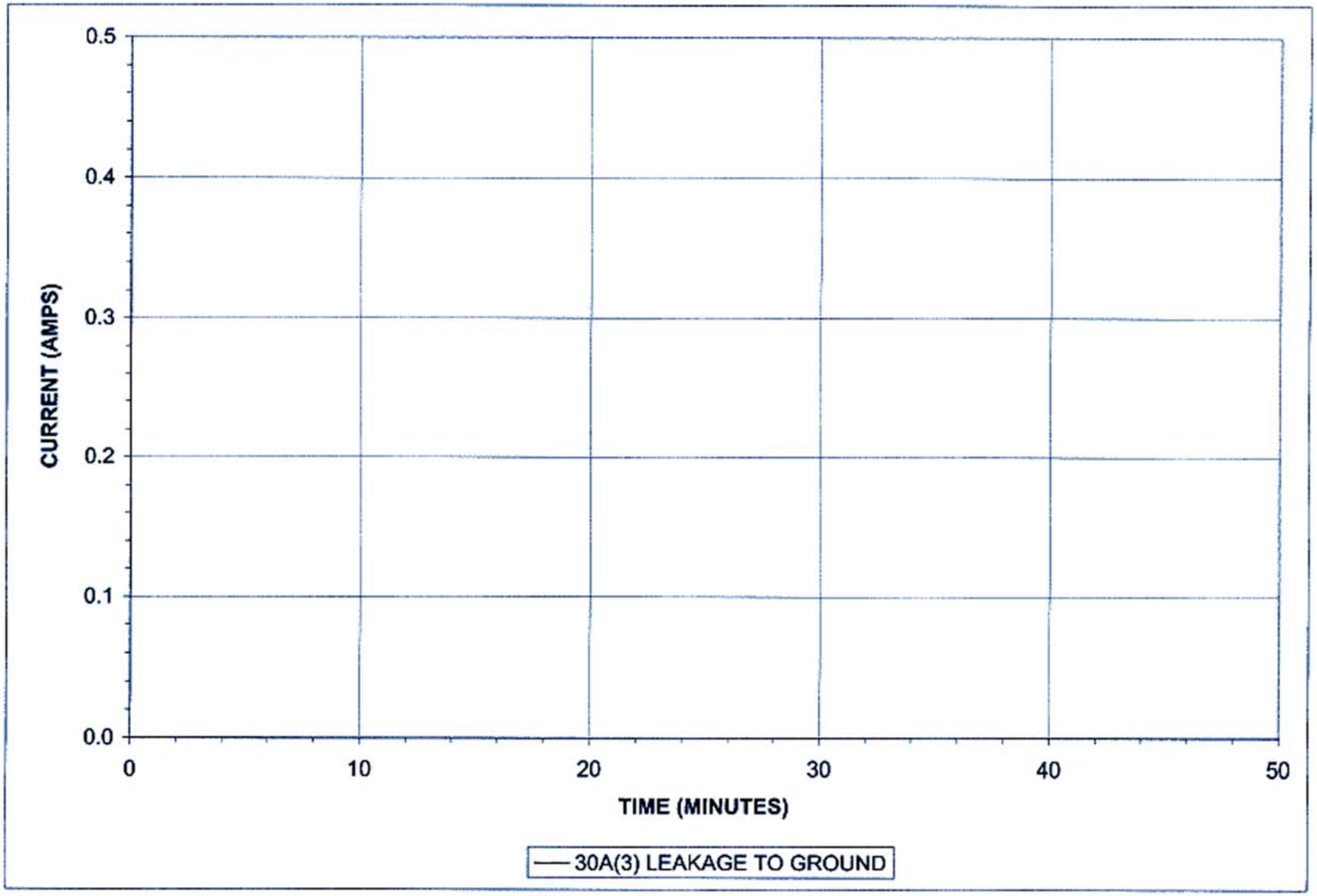

700
600
500
400
300
200
100
0
VOLTS (AC)
0
100
200
300
400
500
600
700
800
TIME (HOURS)
30A(2) VOLTAGE

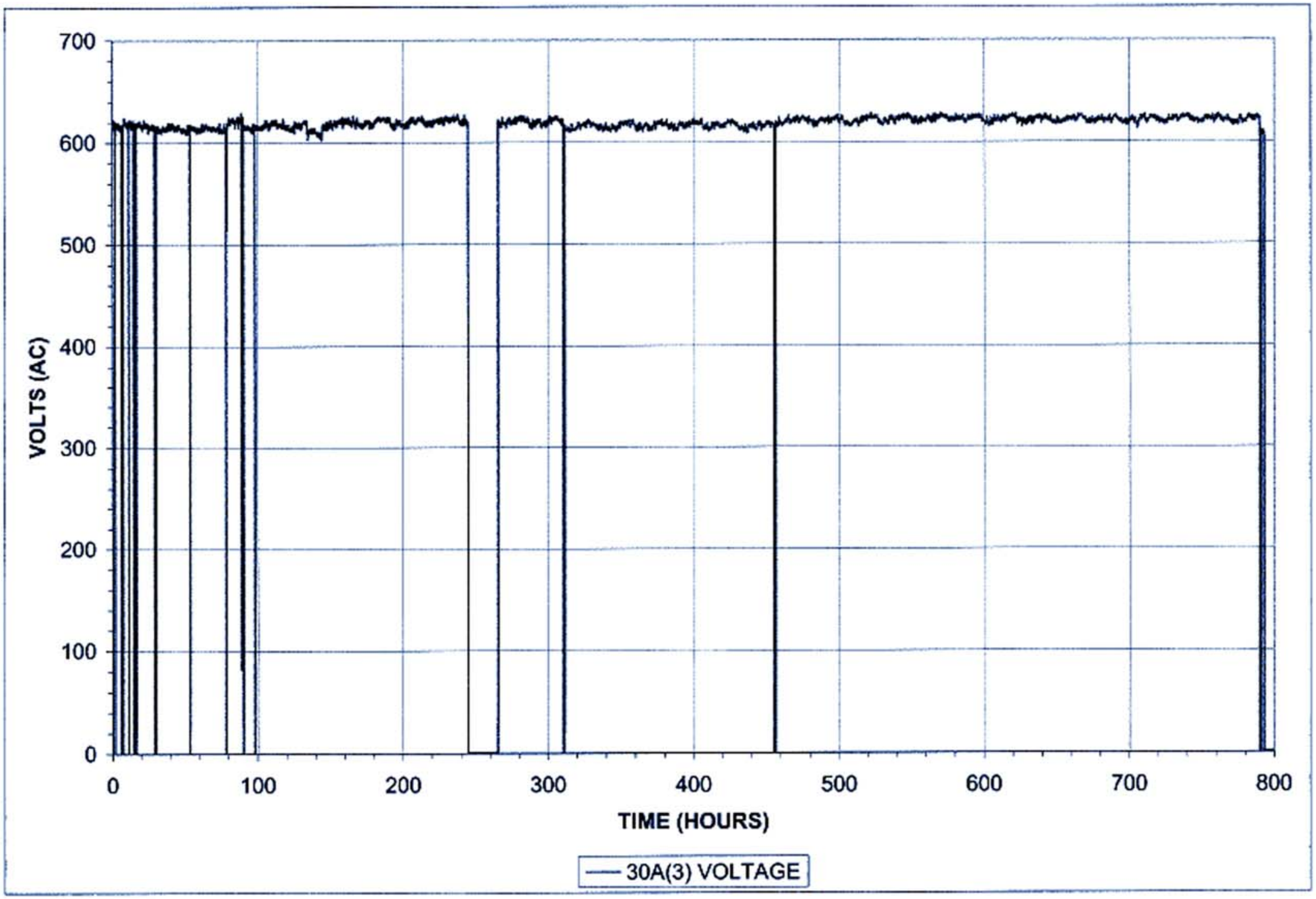

40
35
30
25
20
15
10
5
0
AMPS (AC)
0
100
200
300
400
500
600
700
800
TIME (HOURS)
30A(2) CIRCUIT CURRENT

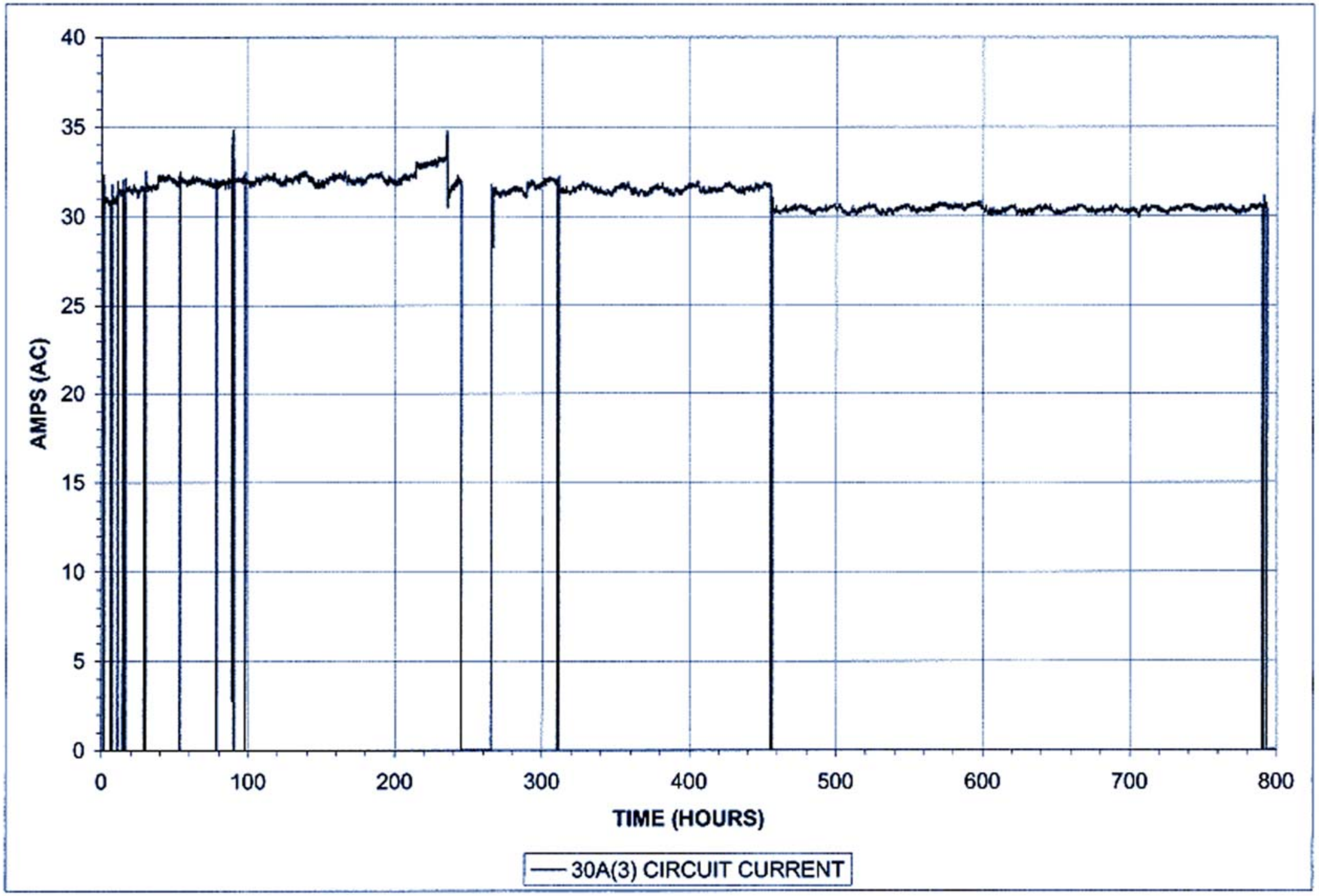

0.5
0.4
0.3
0.2
0.1
0.0
CURRENT (AMPS)
0
100
200
300
400
500
600
700
800
TIME (HOURS)
30A(2) LEAKAGE TO GROUND

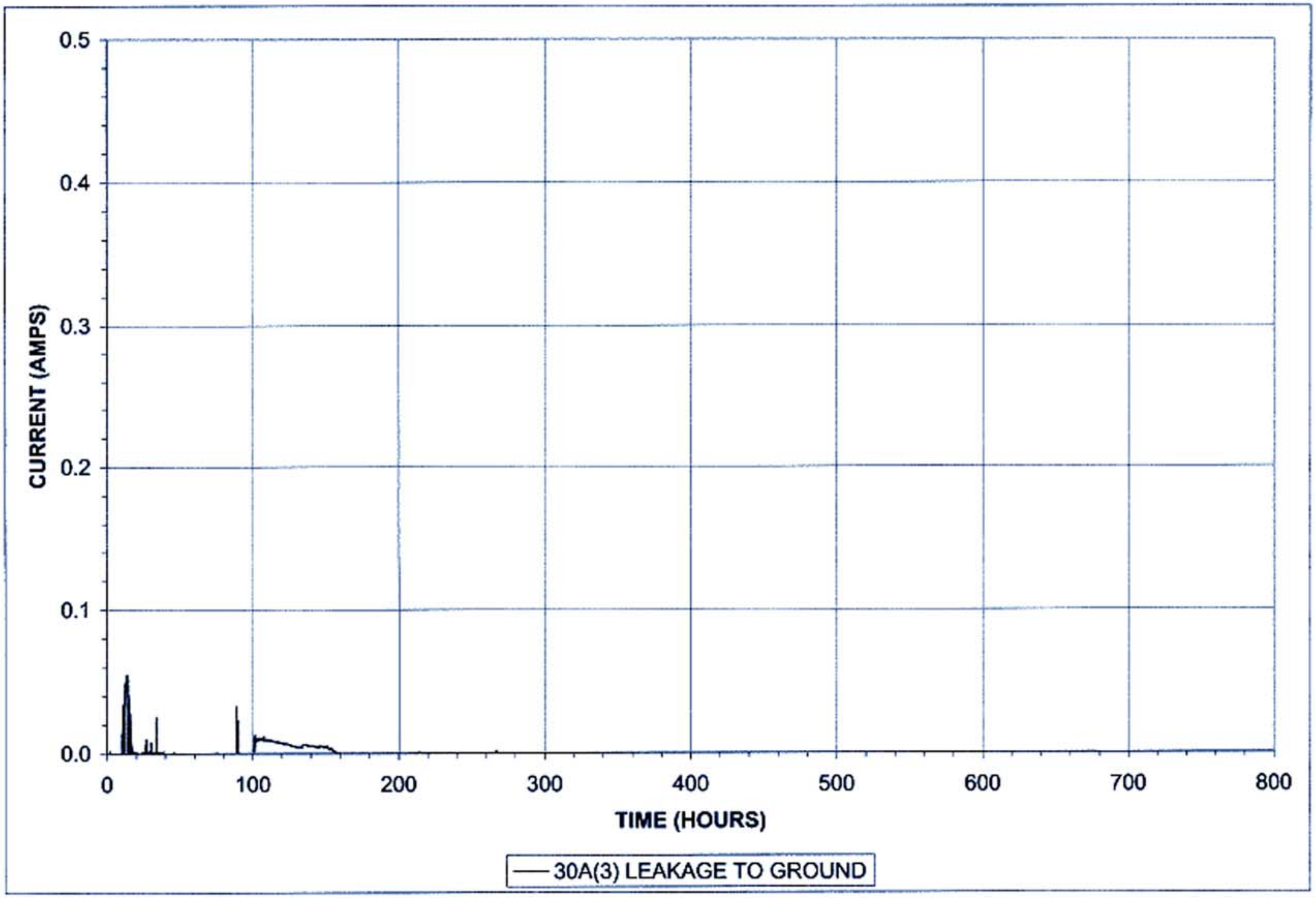

800
700
600
500
400
300
200
100
0
VOLTS (AC)
0
10
20
30
40
50
TIME (MINUTES)
30A(3) VOLTAGE

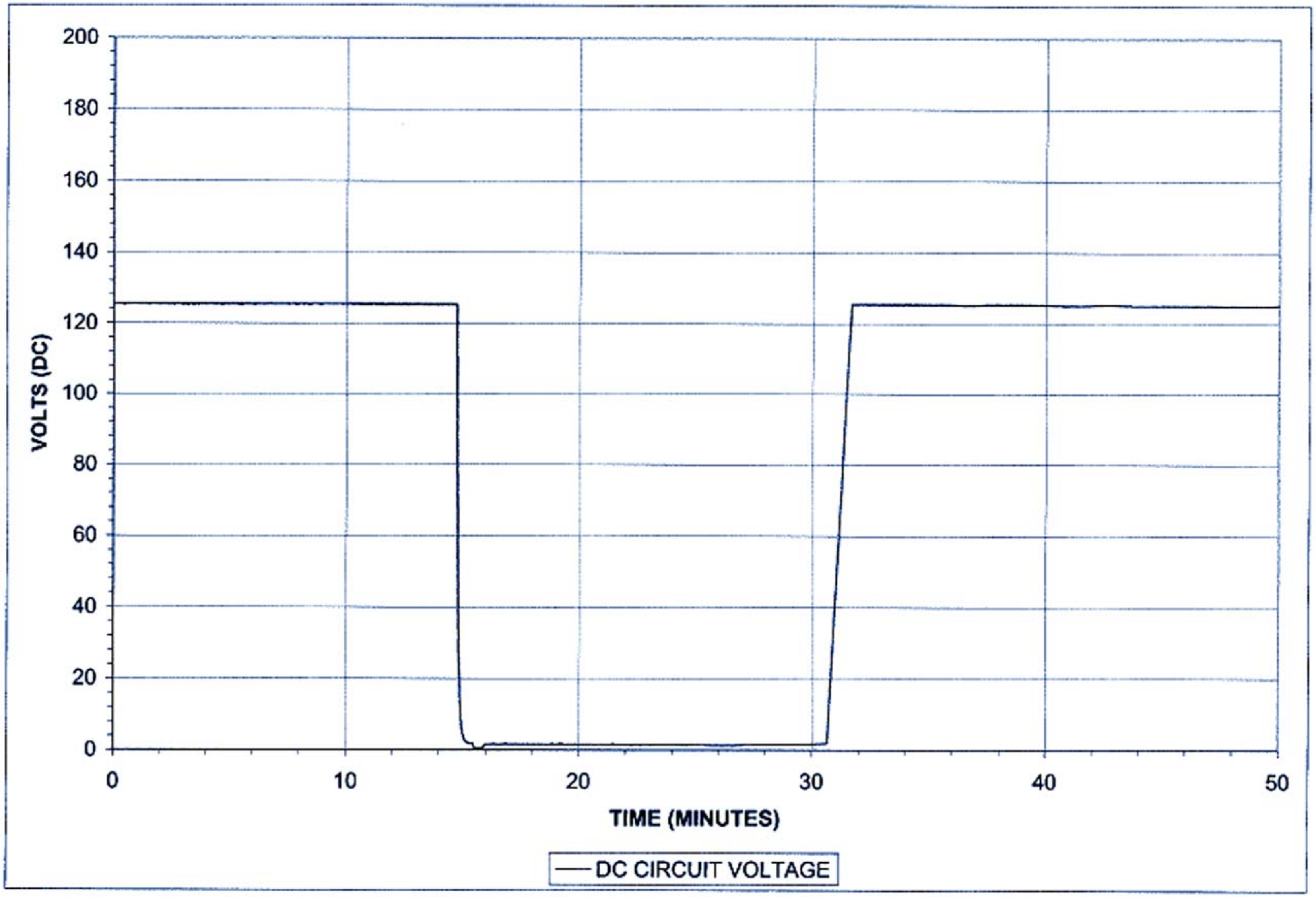

45
40
35
30
25
20
15
10
5
0
AMPS (AC)
0
10
20
30
40
50
TIME (MINUTES)
30A(3) CIRCUIT CURRENT


0.5
0.4
0.3
0.2
0.1
0.0
CURRENT (AMPS)
0
10
20
30
40
50
TIME (MINUTES)
30A(3) LEAKAGE TO GROUND


700
600
500
400
300
200
100
0
VOLTS (AC)
0
100
200
300
400
500
600
700
800
TIME (HOURS)
30A(3) VOLTAGE


40
35
30
25
20
15
10
5
0
AMPS (AC)
0
100
200
300
400
500
600
700
800
TIME (HOURS)
30A(3) CIRCUIT CURRENT


0.5
0.4
0.3
0.2
0.1
0.0
CURRENT (AMPS)
0
100
200
300
400
500
600
700
800
TIME (HOURS)
30A(3) LEAKAGE TO GROUND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180
160
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80
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40
20
0
VOLTS (DC)
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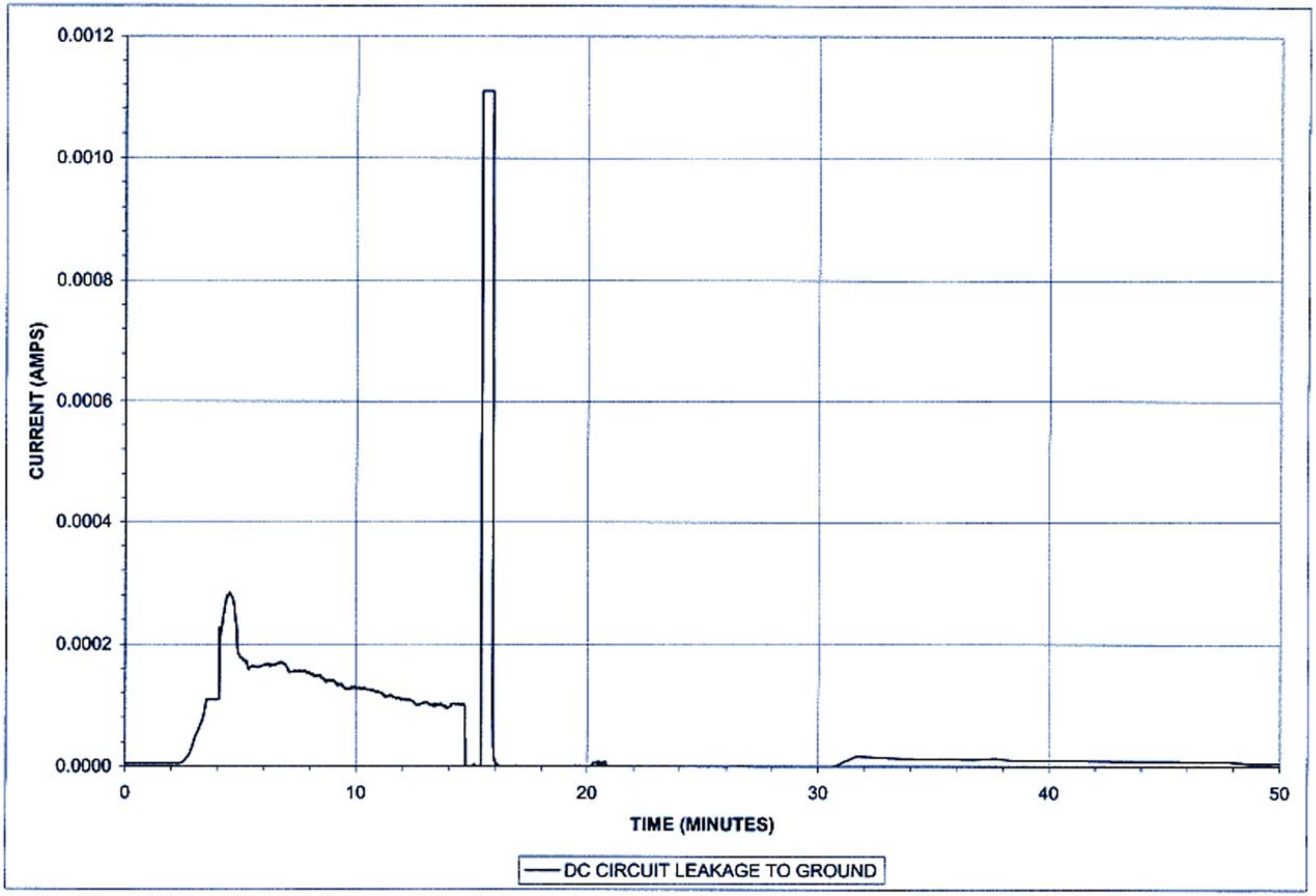
10
20
30
40
50
TIME (MINUTES)
DC CIRCUIT VOLTAGE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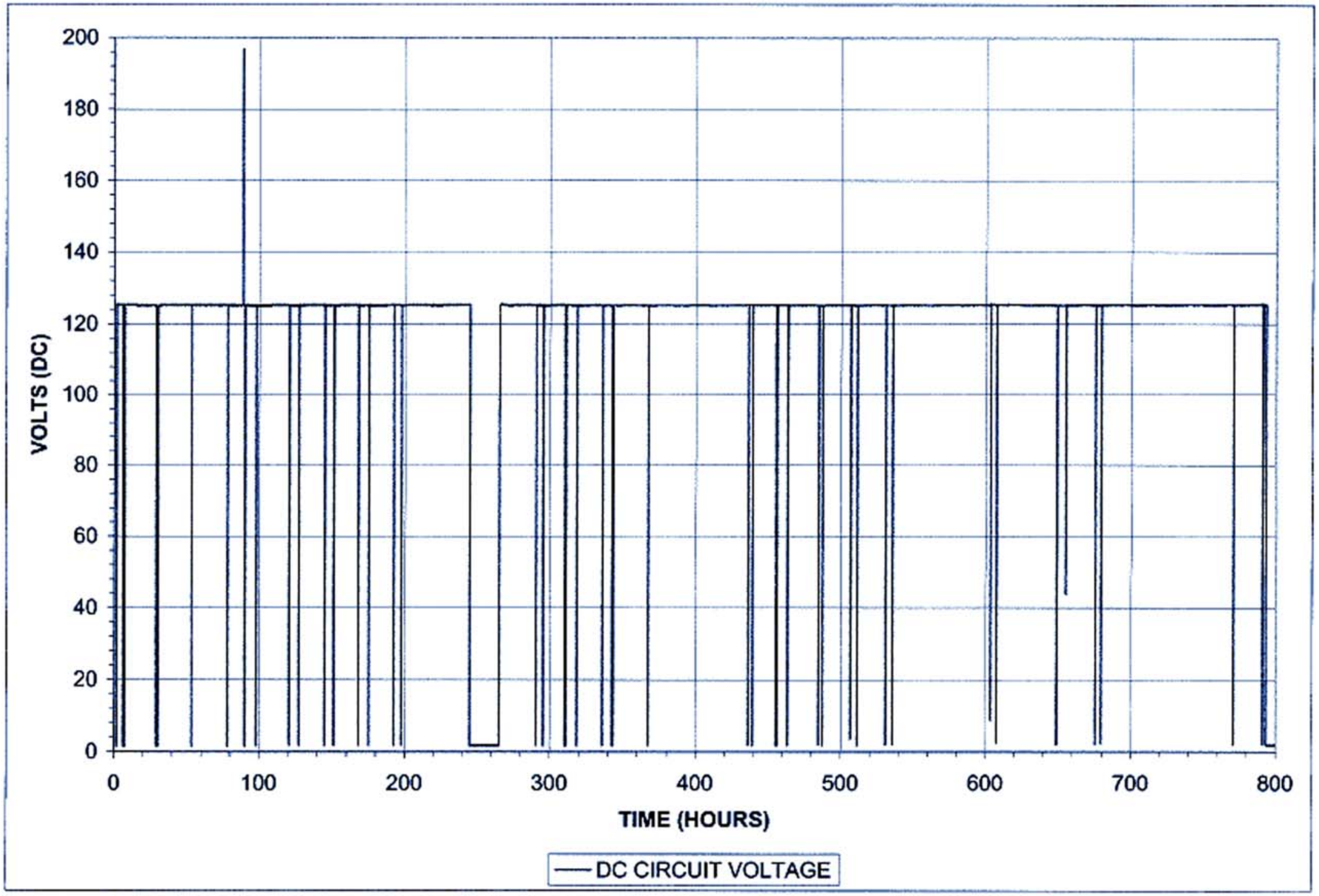
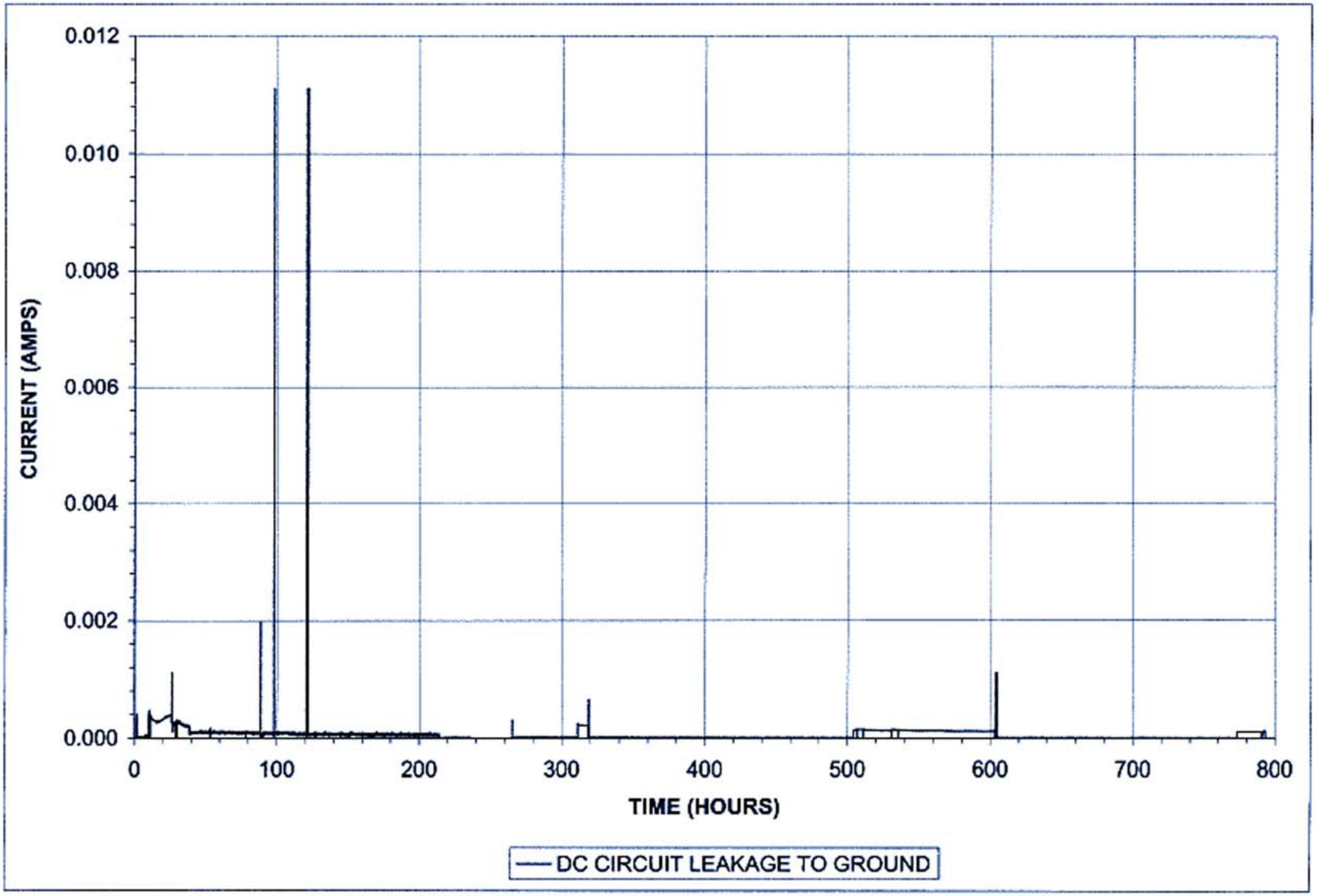
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
CURRENT (AMPS)
0
10
20
30
40
50
TIME (MINUTES)
DC CIRCUIT LEAKAGE TO GROUND


200
180
160
140
120
100
80
60
40
20
0
VOLTS (DC)
0
100
200
300
400
500
600
700
800
TIME (HOURS)
DC CIRCUIT VOLTAGE


0.012
0.010
0.008
0.006
0.004
0.002
0.000
CURRENT (AMPS)
0
100
200
300
400
500
600
700
800
TIME (HOURS)
DC CIRCUIT LEAKAGE TO GROUND