tyco Electronics

Energy Report

EDR-5391

Qualification Testing of
Nuclear High Voltage Splice
(NHVS)

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Qualification Testing of Nuclear High Voltage Splice (NHVS)	
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Prepared by:		
Sherif Kamel /Jonathan Cornelius	Jonathan C. Cornelius	6/22/05
Approved by:	Signature:	Date:
Frank Drumm	F. Drumm	6/22/05
Approved by:	Signature:	Date:
Kathy Maher	Kathryn M. Maher	6/22/05
	Signature:	Date:

Raychem
Tyco Electronics-Energy
8000 Purfoy Road
Fuquay-Varina, NC 27526

REVISION RECORD

Revision	Page	Paragraph	Description	Date
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1. REVISION: 0

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2. OBJECTIVE

The objective of this test program is to qualify a new MV (5/8 kV) in-line heat shrinkable splice to the requirements of Class 1E circuits for nuclear Power Stations as outlined in the relevant sections of IEEE 323, and IEEE 383

3. SUMMARY

This qualification test program of Raychem Nuclear Medium Voltage splice (NHVS) was driven by market need for such a splice for safety related circuits in nuclear power plants outside containment. A total of 4 splices were tested in this program. Two splices were aged to an equivalent service life of more than 5 years and the others were not aged. All of the samples were then exposed to accident radiation and environmental exposure to simulate a Loss Of Cooling Accident on the first day of installation and after 5 years of installation. All the samples passed the test requirements and qualified for the conditions intended by the test. Additionally the test specimens were taken to failure under AC voltage conditions to demonstrate the additional margin after the LOCA exposure.

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

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 3010/40 or PPS 3012/19. All components conformed to the applicable Raychem specifications.

4.2 Specimen Preparation

The splice configuration represented a well-defined application and applies to the anticipated field installations. Samples were installed on Class 1E LOCA rated cable of commonly used conductor size and diameter. The entire program (sample preparation and tests) was performed in accordance with 10 CFR 50 Appendix B quality assurance requirements. The hardware (crimp connectors, copper mesh, etc.) used was appropriate and generally approved or certified for use in the respective application. All samples were mounted on trays (Figure 1). Each splice loop was identified individually for purposes of data recording. All samples were prepared by Tyco Electronics Corporation. Table 1 gives the details of the cable used to construct the samples.

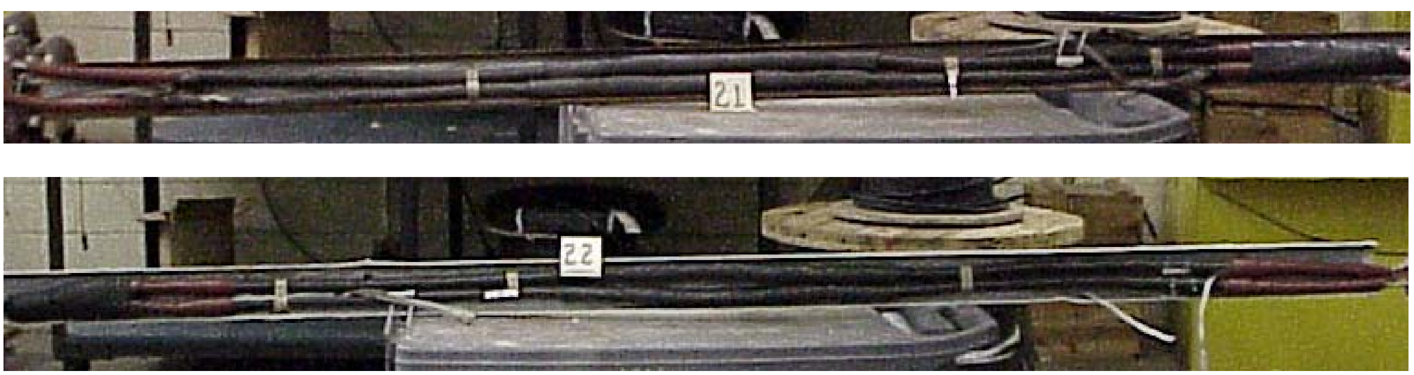


Figure 1: Specimen loops installed in trays.

Reel #	Manufact.	Insulation material	Insulation Diameter (in) Nominal	Insulation thickness (in) Nominal	Wire AWG	# of Conductors
307322-B4	Okonite	EPR	0.68	0.117	2/0	1

Table 1: Cable specifications

4.3 Sample Construction

Figure 2 illustrates the general construction of the specimen loop for each of the aged and non-aged samples. Each of the specimen loops contained two High Voltage Splices (NHVS). Each of the two High Voltage Splices were constructed on a branch of the V-type splice (NMCK8-4V-A) and connected to the external circuit via a NMCK8-1L splice and a non-shielded 8kV, 4/0 cable.

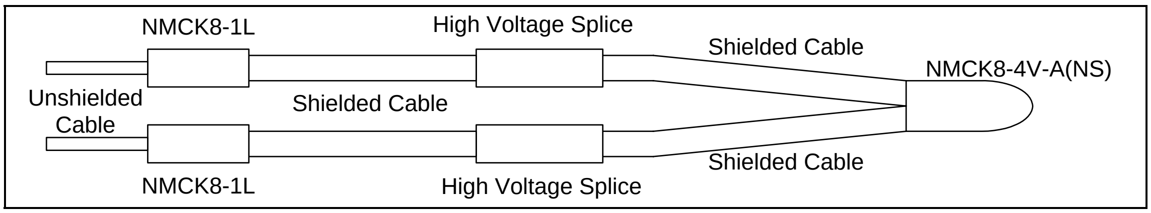


Figure 2: Schematic diagram for the specimen loop construction

The high voltage splice for the 2/0, 5/8kV shielded cable is based on an HVS-822S (See Appendix 1 for the standard HVS-822S Installation Instructions) with the following changes:

- The outer jacket is changed from MWTM 50/16 to WCSF-650-50/17-N.
- The connector's Stress Relief Mastic, S1189, is replaced with S1119.
- The semi-con cutbacks are filled with Discharge Control Compound, DCC, in place of the S1189.
- The connector is a tin plated copper crimp type (Richard's Mfg pn. 926919).
- The S1251 sealant is changed to S1119.

Two loops were constructed, each containing two splices. One loop was aged to more than 5 years equivalent life (90°C) and ambient radiation (Loop #21) and the other was not aged at all (Loop #22). All samples were subjected to accident radiation and LOCA environmental exposure conditions.

5. TEST PROCEDURE

The type test samples were subjected to the test sequence shown in Table 2. 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 2: 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. The tests were performed with the specimens mounted on the cable trays.

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 specimens were energized at a potential of 80 V/mil of cable insulation thickness for 5 minutes. The AC withstand voltage amounted to 9360 V.

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

Two samples were aged to an equivalent service life of 38.75 years for the WCSF tubing used as an outer jacket and 46 years of an equivalent service life of the molded parts used for the NMCK8-4-A at an operating temperature of 90 °C as calculated from an Arrhenius aging analysis performed on the tubing as described in Tyco Electronics reports EDR 5331 and EDR-5332. The equivalent service life of the CICM-N tubing is conservatively estimated to be more than 5 years. The specimens were thermally aged while mounted on the cable trays.

5.3.1.1 Thermal Aging for tubing

Specimen #21 was aged in a circulating air oven for 72.51 hours at a temperature of 180 °C. This accelerated thermal aging corresponds to 38.75 years life at 90 °C for the WCSF tubing, 46 years life at 90 °C for the molded parts and estimated to be at least 5 years life at 90 °C for the CICM-N tubing.

5.3.2 Radiation

The specimens 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 exposure was 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 specimens were irradiated while mounted on the test mandrels or cable trays, as applicable. Appendix 4

Irradiation Logs, shows the irradiation logs for each sample.

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

The planned exposure for the specimen #21 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) Sample Design Basis Events (DBE)

The planned exposure for the un-aged specimen #22 was to a 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 3. Appendix 2 shows the actual time/temperature/pressure graphs as measured during the environmental exposure.

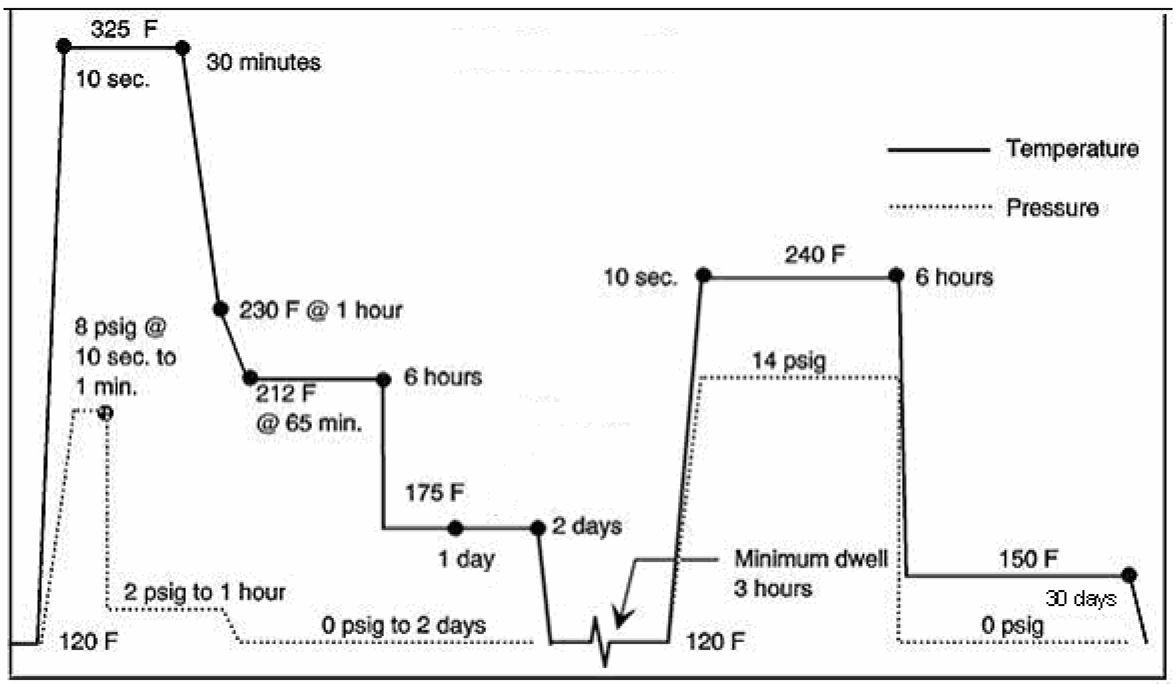


Figure 3: LOCA profile

5.4.2 Chemical Spray

No water or chemical spray was used during this accident simulation.

5.4.3 Mounting

Type test samples remained mounted on the trays during the environmental simulation. Test sample trays were fixed within the LOCA test vessel and located horizontally with respect to the earth. The sample trays were solidly grounded to the mounting frame, which was electrically grounded to the test chamber.

5.4.4 Test set-up

5.4.4.1 Accessory connections and Marking

Test vessel penetrations used 8kV, 4/0 unshielded cable connected to the terminated ends of each of the test loops using two hole lugs and suitable hardware. The connection was then insulated using NMCK8-1L kits. All sample test leads were individually identified.

5.4.4.2 Equipment Sources, Fusing, and Monitoring

Two 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 3.

5.4.4.3 Voltage and current requirements

During the LOCA simulation, the applied voltage for each sample circuit was 8000Vac to ground. Each test sample circuit carried rated current at a 25°C ambient temperature based on wire size (Table 3).

SPECIMEN NO.	CONNECTION WIRE (AWG)	Tray NO.	AGING TIME & TEMP.	RADIATION DOSE (rads)		APPLIED CURRENT DURING LOCA (AMPS)
				Target	Actual	
21	4/0	4	72.51 hr @ 356°F	2.15E+08	2.15E+08	195
22	4/0	5	N/A	1.65E+08	1.65E+08	195

Table 3: Test conditions

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.

5.4.4.4 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.

5.5 ACCEPTANCE CRITERIA

Electrical Integrity of the test specimens 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 Section 5.2.2).

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

5.5.1 Insulation performance

During environment exposure, Insulation Resistance measurements were taken to ensure insulation performance. The voltage was applied for 1 minute to insure reading stability. IR measurements were performed on all monitored samples prior to transient 1, at the end of transient 1, at the 4-hour point, the 24-hour point, the 55-hour point (at transient 2), the 144-hour point, the 380-hour point and at the 790-hour point (the end of the exposure) with the specimens still at temperature.

6. RESULTS AND DISCUSSION

6.1 Deviations from test plan

6.1.1 Thermal Aging

The samples were aged for 72.25 hours instead of 72.51 hours at the target temperature of 356°F. However, the specimens were in the thermal aging chamber at approximately 350°F for 1 hour and 20 minutes prior to the temperature reaching 356°F.

6.1.2 Radiation Exposure

The specimens were irradiated in two stages. The first stage was carried out in the year 2000 and the samples actually received 195.2Mrads and 148.9Mrad (aged and non-aged respectively) due to a reporting error from Georgia Tech where the samples were irradiated. Subsequently, the samples were irradiated again in the year 2004 to complete the target total irradiation dose of 215Mrads and 165Mrads. Appendix 4 contains the radiation certifications. Table 4 shows the target and the actual radiation doses for the aged and unaged samples.

		Aged Samples Cumulative Dose (rads)	Unaged Samples Cumulative Dose (rads)
Target Dose		2.15E+08	1.65E+08
Actual Dose	Stage 1	1.952E+08	1.489E+08
	Stage 2	1.98E+07	1.61E+07
	Total	2.15E+08	1.65E+08

Table 4: Target and actual irradiation doses.

6.1.3 LOCA simulation

Transient 1:

The test chamber was filled with room-temperature tap water to completely submerge the test specimens contained within. Following a 24-hour wait, an Insulation Resistance test was then performed on the specimens. The test chamber was then drained and the test chamber average temperature was increased to approximately 120°F and held for approximately 57 minutes prior to the start of the Accident Simulation. The ramp up in temperature from 120°F to 325°F was performed on a best-effort basis using superheated steam. The time to reach an average chamber temperature of 325°F for the initial transient was approximately 26 seconds. The highest temperature recorded by an individual thermocouple during the first transient was 359°F. The time the average chamber temperature was above 325°F was approximately 42 minutes. The average chamber temperature was then gradually reduced to approximately 212°F. The time the average chamber temperature was above 212°F was approximately 5 hours and 47 minutes. The average chamber temperature was then reduced to approximately 175°F. The time the average chamber temperature was above 175°F was approximately 42 hours and 31 minutes.

The test chamber temperature was reduced to approximately 120°F per the environmental profile. The test chamber temperature was held at approximately 120°F for 3 hours and 31 minutes prior to the start of the second transient of the Accident Simulation.

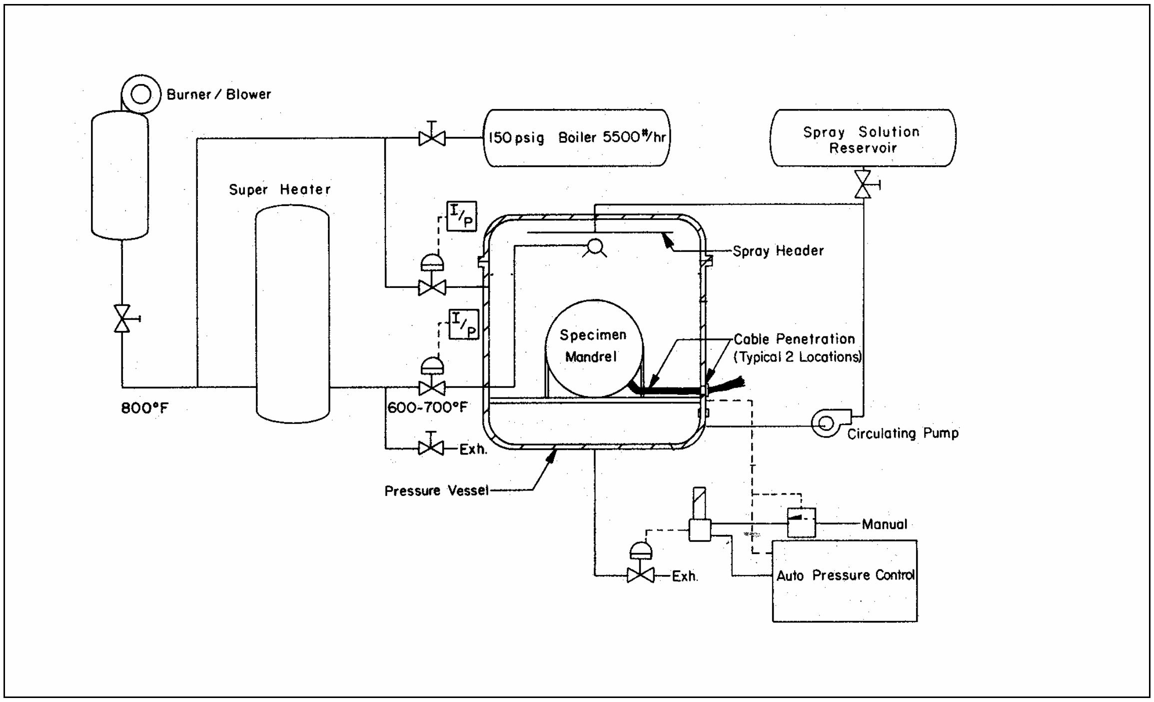
Transient 2:

The time to reach an average chamber temperature of 240°F for the second transient was approximately 11 seconds. The highest temperature recorded by an individual thermocouple during the second transient was 308°F. The time the average chamber temperature was above 240°F was approximately 6 hours and 8 minutes. The temperature was then lowered to approximately 150°F and held for approximately 734 hours and 6 minutes. Note that each temperature plateau was extended to account for the time the specimens were not energized due to Insulation Resistance testing or specimen troubleshooting.

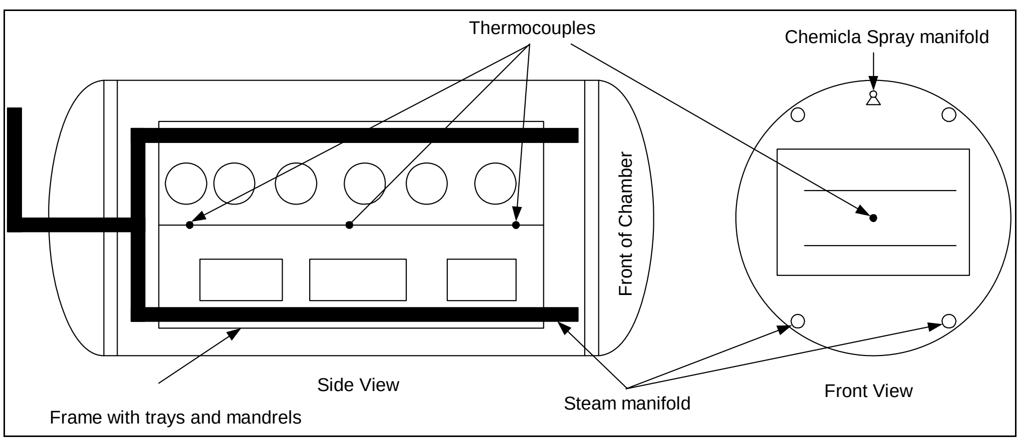
The full LOCA exposure profile is presented in Appendix 2 and a chronological account of the events during the LOCA exposure is presented in Appendix 5.

6.2 LOCA simulation Vessel

Figure 4 shows a schematic diagram of the LOCA test chamber.



(A)



(B)

Figure 4: LOCA pressure vessel and auxiliary equipment.

Figure 5 shows a picture of the LOCA simulation chamber after the conclusion of the test.

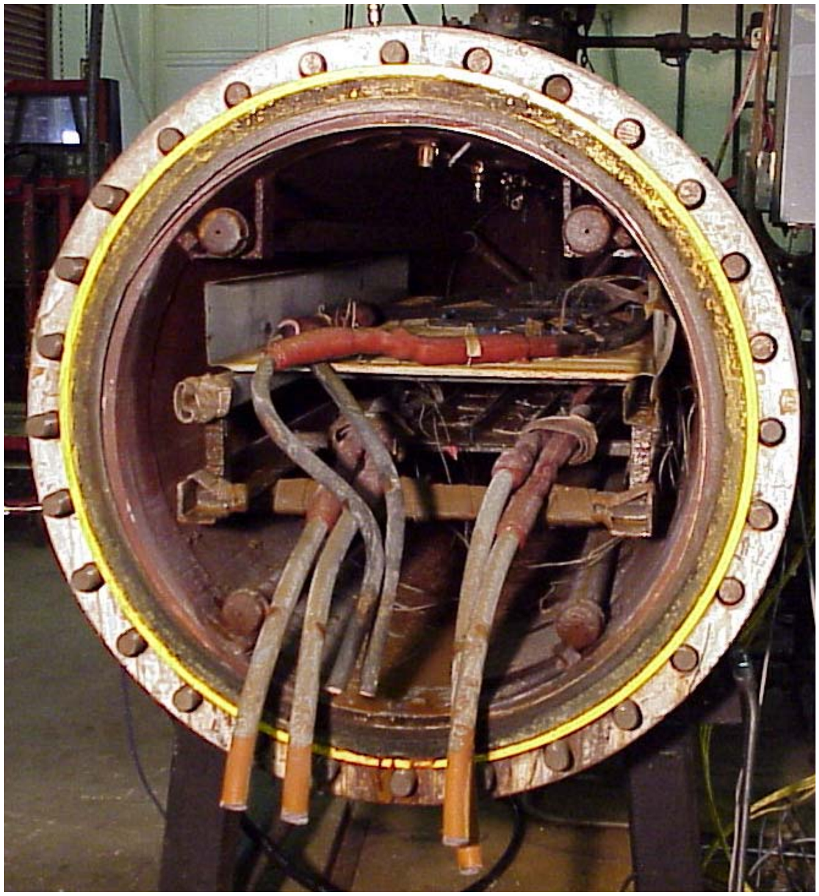


Figure 5: LOCA simulation test chamber after the test.

6.3 Sample Analysis

Table 5 shows a list of the samples and a summary of the qualification test results.

SPECIMEN NO.	TRAY NO.	AGING TIME & TEMP.	RADIATION DOSE (rads)	Test Circuit	Time Energized Trans1/Trans2	RESULTS
21	T4	72.25 hr @ 356°F	2.15E+08	195A(1)	792.5 hrs	Qualified
22	T5	Not Aged	1.65E+08	195A(2)	792.5 hrs	Qualified

Table 5: NHVS splices qualification results. Radiation doses represent (accident + ambient) for aged samples or accident only for un-aged samples.

The test specimens 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 specimens and mounting conformed to Tyco Electronics requirements. The test specimens were visually inspected and subjected to the functional tests described in Section 5.2 before thermal aging, irradiation and the environmental exposure. After thermal aging the endcap component of the NMCK-8 of specimen #21 milked off due to an improper installation. This anomaly is unrelated to the NHVS other than it was installed on the same cable/specimen loop. The specimen was then repaired and put back to complete the test sequence with no further anomalies. The functional tests were also performed on the samples after the LOCA simulation as part of the post LOCA evaluation. Additionally, at the end of the test program, each sample was tested for AC dielectric breakdown to demonstrate margin. The results of the functional tests are given in Table 6.

Sample	Initial Base Line			Post Heat Aging			Post Irradiation			Post LOCA		
	IR, Ω	W/S, V	I_{leak}, mA	IR, Ω	W/S, V	I_{leak}, mA	IR, Ω	W/S, V	I_{leak}, mA	IR, Ω	W/S, V	I_{leak}, mA
21	1.8E10	9360	6.8	2.5E10	9360	7.6	4.0E10	9400	0.72	6.4E10	9400	9.1
22	2.0E10	9360	6.6	n/a	n/a	n/a	4.0E12	9400	0.78	5.0E10	9400	8.9

Table 6: Functional tests at Program Sequence points for test specimens

Table 7 shows the IR measurements performed on the monitoring circuits during the LOCA exposure at 500 volts DC (unless otherwise noted).

.	Specimen 21	Specimen 22
Prior 1st peak (submerged in chamber)	1.4E10	4.0E07
At 1st Peak 325°F (30 minutes point)	4.5E07	6.5E07
At 214°F (4-hour point of test)	2.5E08	3.5E08
At 178°F (24.5-hour point of test)	7.0E08	1.0E09
At 240°F (2 hours of 2nd peak – 55-hour point of test)	1.5E08	1.4E08
At 155°F (144.5-hour point of test)	1.7E09	1.2E09
At 152°F (382.5-hour point of test)	1.4E09	2.1E09
At 153°F (792.5-hour point of test)	1.5E09	8.4E08
Destructive Testing Dielectric Breakdown	41,000 v breakdown at tip of endcap of V-splice	36,000 v breakdown at splice

Table 7: IR measurements during LOCA simulation.

7. CONCLUSION

Samples of Raychem's Nuclear Medium Voltage splice (NHVS) were type tested in applications that are common and specific to Class 1E environment as outlined in the relevant sections of IEEE 323-1974, IEEE 323-1983 and IEEE 383-1974. 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 NHVS splice with a service life of more than 5 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 NHVS splices demonstrated a comfortable margin after passing a LOCA simulation by withstanding an AC voltage of more than 7 times the phase to ground voltage.

APPENDIX 1

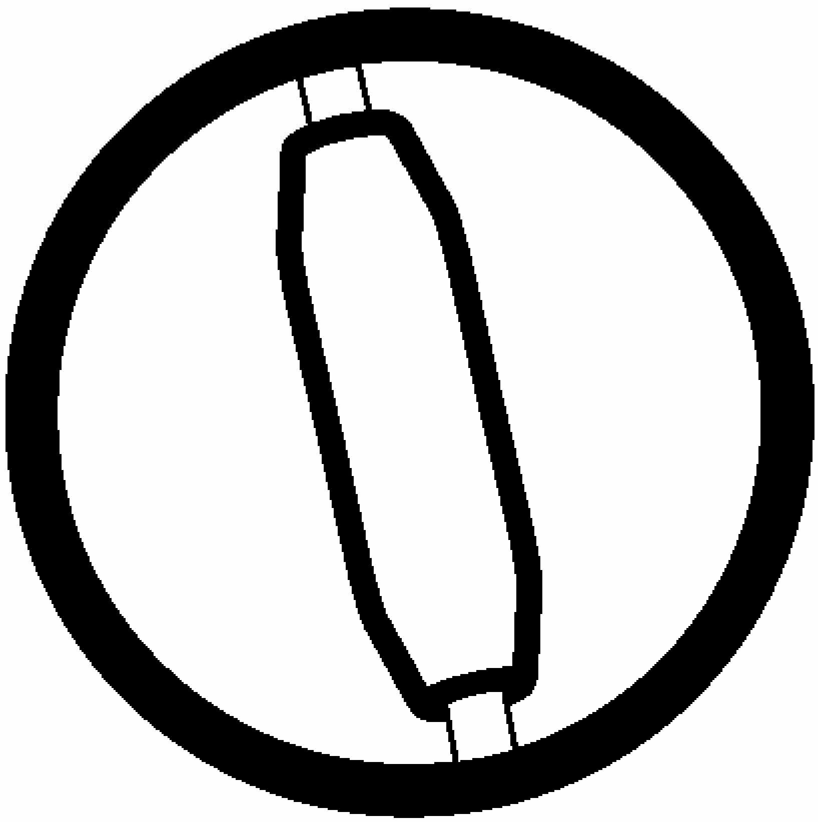
HVS-822S INSTALLATION INSTRUCTIONS

Raychem

Product Installation Instructions

HVS-820S Series
8kV Class

Splice for Extruded Dielectric (Poly/EPR) Power Cables: Metallic Tape, Wire Shield, UniShield®, LC Shield, or Lead Sheath Cables



UniShield is a registered trademark of Cablec Corporation.

Raychem Corporation
Electrical Products Division
220 Lake Drive
Newark, DE 19702

PII-53383, Rev AD
DCR C27039
PCN 492431-000
Effective Date: March 1995

General Instructions

Suggested Installation Equipment (not supplied with kit)

- Cable preparation tools
- Raychem P63 cable preparation kit or cable manufacturer approved solvent
- Clean, lint-free cloths
- Non-conducting abrasive cloth, 120 grit or finer
- Electrician's tape
- Connector(s) and installation tools
- Raychem recommended torch

Recommended Raychem Torches

Install heat-shrinkable cable accessories with a "clean burning" torch, i.e., a propane torch that does not deposit conductive contaminants on the product.

Clean burning torches include the Raychem FH-2609, FH-2629 (uses refillable propane cylinders) and FH-2616A1 (uses disposable cylinder).

Safety Instructions

Warning: When installing electrical power system accessories, failure to follow applicable personal safety requirements and written installation instructions could result in fire or explosion and serious or fatal injuries.

To avoid risk of accidental fire or explosion when using gas torches, always check all connections for leaks before igniting the torch and follow the torch manufacturer's safety instructions.

To minimize any effect of fumes produced during installation, always provide good ventilation of confined work spaces.

As Raychem has no control over field conditions which influence product installation, it is understood that the user must take this into account and apply his own experience and expertise when installing product.

Adjusting the Torch

Adjust regulator and torch as required to provide an overall 12- inch bushy flame. The FH-2629 will be all blue, the other torches will have a 3- to 4-inch yellow tip. Use the yellow tip for shrinking.

Regulator Pressure

FH-2616A1	Full pressure
FH-2609	5 psig
FH-2629	15 psig

Cleaning the Cable

Use an approved solvent, such as the one supplied in the P63 Cable Prep Kit, to clean the cable. Be sure to follow the manufacturer's instructions. Failure to follow these instructions could lead to product failure.

Some newer solvents do not evaporate quickly and need to be removed with a clean, lint-free cloth. Failure to do so could change the volume resistivity of the substrate or leave a residue on the surface.

Please follow the manufacturer's instructions carefully.

General Shrinking Instructions

- Apply outer 3- to 4-inch tip of the flame to heat-shrinkable material with a rapid brushing motion.
- Keep flame moving to avoid scorching.
- Unless otherwise instructed, start shrinking tube at center, working flame around all sides of the tube to apply uniform heat.

To determine if a tube has completely recovered, look for the following, especially on the back and underside of the tube:

1. Uniform wall thickness.
2. Conformance to substrate.
3. No flat spots or chill marks.
4. Visible sealant flow if the tube is coated.

Note: When installing multiple tubes, make sure that the surface of the last tube is still warm before positioning and shrinking the next tube. If installed tube has cooled, re-heat the entire surface.

Installation Instructions

1. Product selection.

Check kit selection with cable diameter dimensions in Table 1.

*If using 5/8kV (115 mils) cable, use 8kV selection.

2. Check ground braid.

Verify that ground braid(s) or bond wire have equivalent cross-section to cable metallic shield. Additional braid may be needed for LC shield, lead sheath cables, or if external grounding or shield interrupting is required.

Raychem HVS-EG supplies ground braid, spring clamp and suggested modifications to make an external ground or shield interrupt.

Table 1 Kit	5kV Nominal Cable Range	8kV Nominal Cable Range	Maximum Jacket Diameter	Insulation Diameter Range	Maximum Connector Dimensions Length	 Diameter
Dimensions in inches						
HVS-821S	#6-2/0 AWG*	#6-#2 AWG	0.80	0.35-0.65	3.0	0.50
HVS-822S	3/0-300 kcmil*	#1-4/0 AWG	1.15	0.55-0.90	4.25	0.75
HVS-823S	350-750 kcmil*	250-350 kcmil	1.80	0.80-1.25	6.0	1.10
HVS-824S	1000-1500 kcmil*	500-750 kcmil	2.30	1.00-1.60	8.0	1.45
HVS-825S		750-1000 kcmil	2.45	1.30-2.25	8.0	1.85
Dimensions in millimeters						
HVS-821S	*#6-2/0 AWG**	*#6-#2 AWG*	*20*	*9-17*	*76*	*13*
HVS-822S	*3/0-300 kcmil**	*#1-4/0 AWG*	*29*	*14-23*	*108*	*19*
HVS-823S	*350-750 kcmil**	*250-350 kcmil*	*46*	*20-32*	*152*	*28*
HVS-824S	*1000-1500 kcmil**	*500-750 kcmil*	*58*	*25-41*	*203*	*37*
HVS-825S		*750-1000 kcmil*	*64*	*33-57*	*203*	*47*

3. Prepare cables.

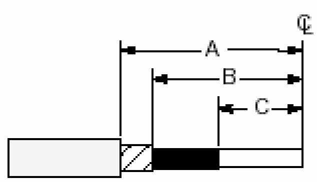
Choose the cable type (Choice 1-3) and use the dimensions shown in Table 2 to prepare the cables.

Table 2

Kit	Jacket Cutback A	Metallic Shield Cutback B	Semi-con Cutback C
HVS-821S	7-1/2" *(190mm)*	6" *(150mm)*	3-1/4" *(80mm)*
HVS-822S	8-1/2" *(215mm)*	7" *(180mm)*	4" *(100mm)*
HVS-823S	9-1/2" *(240mm)*	8" *(200mm)*	5" *(125mm)*
HVS-824S	11" *(280mm)*	9-1/2" *(240mm)*	6" *(150mm)*
HVS-825S	11-1/2" *(290mm)*	10" *(250mm)*	6" *(150mm)*

CHOICE 1

If Metallic Tape Shield, Lead Sheath, or LC Shield Cable



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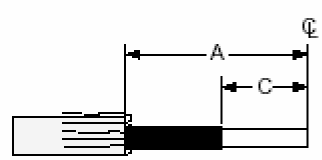
CHOICE 2

If Drain Wire Shield Cable



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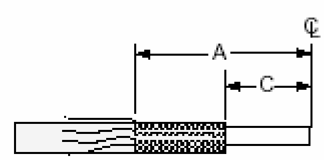
CHOICE 3

If UniShield Cable



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Installation Instructions

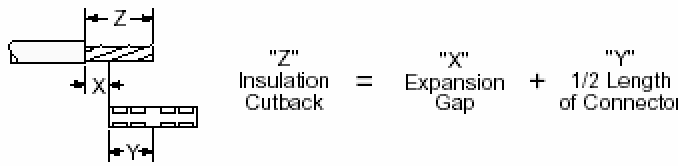
4. Remove insulation.

Refer to Table 3 and Figure 1; cutback the insulation as shown.

Table 3

Kit	Maximum Connector Dimensions Length	Diameter	Expansion Gap "X"
HVS-821S	3.0" *(76mm)*	0.50" *(13mm)*	1/4" *(5mm)*
HVS-822S	4.25" *(108mm)*	0.75" *(19mm)*	1/4" *(5mm)*
HVS-823S	6.0" *(152mm)*	1.10" *(28mm)*	1/2" *(10mm)*
HVS-824S	8.0" *(203mm)*	1.45" *(37mm)*	1/2" *(10mm)*
HVS-825S	8.0" *(203mm)*	1.85" *(47mm)*	1/2" *(10mm)*

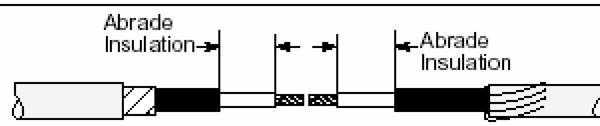
Figure 1: Insulation Cutback



400

5. Abrade insulation.

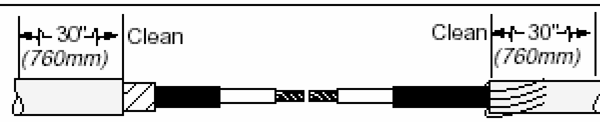
Abrade the insulation, as necessary to remove imbedded semi-con, and clean.



249

6. Clean cable jackets.

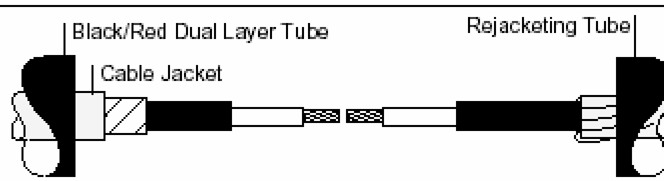
Clean cable jackets for the length of the tubes.



271

7. Place splice tubes over cable as shown.

Protect tubes from end of conductor as they are placed over cable end.

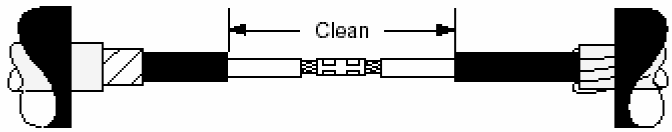


128

8. Install connector.

After installation, deburr connector.

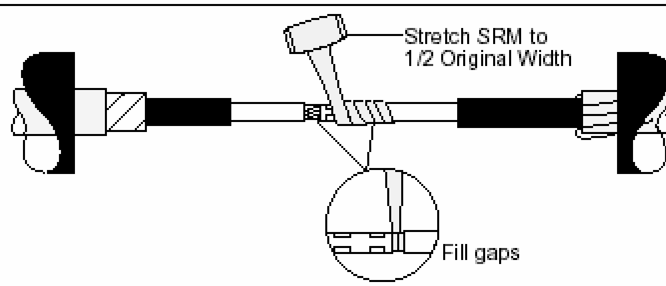
Using an oil-free solvent, clean the insulation as shown.



129

9. Apply SRM over connector.

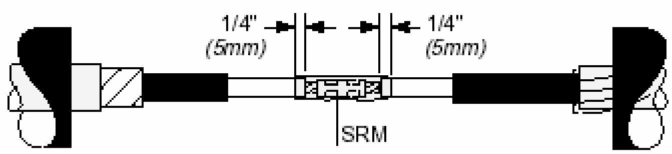
Remove backing from one side of the *long strip* of Stress Relief Material (SRM). Roll the SRM and remaining backing strip into a convenient size. Remove the remaining backing strip and tightly wrap the SRM around the connector and exposed conductor. Be sure to fill the gaps and low spots around the connector.



297

Continue to wrap SRM onto the solvent cleaned insulation as shown.

Note: If connector diameter is larger than insulation diameter, apply two half-lapped layers of SRM over the entire connector. Discard any excess SRM (long strips).

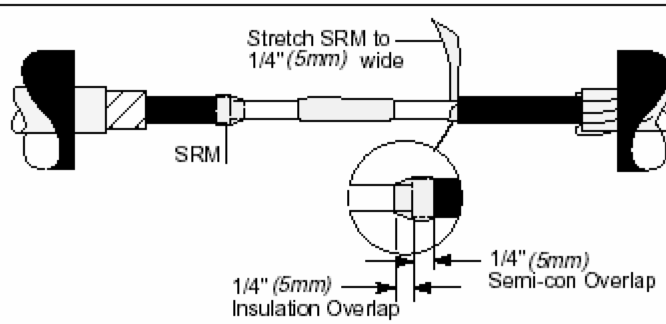


272

10. Apply SRM at semi-con cutback.

Remove backings from the *short angle-cut piece* of SRM. Place tip of SRM at semi-con cutback and tightly wrap to fill semi-con step. Overlap semi-con and insulation as shown. Taper SRM down to meet insulation.

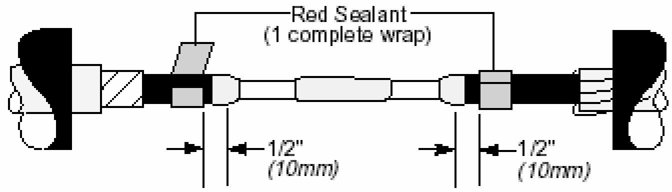
Note: If using UniShield cable, apply SRM as shown to fill conductive jacket step.



284

11. Apply red sealant.

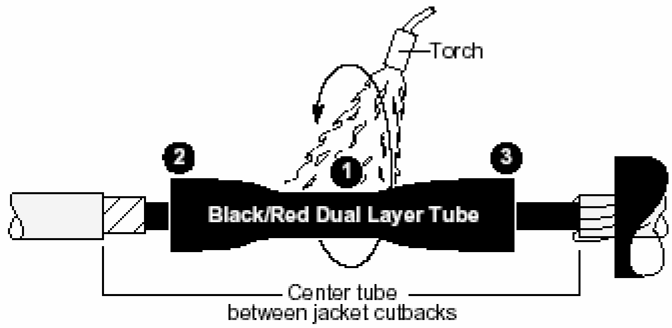
Remove the backing from the red sealant and place one complete wrap onto the cable semi-con as shown.



12. Position black/red dual layer tube; shrink in place.

Center tube over splice as shown. Begin shrinking at center of tube (1), working torch with a smooth, brushing motion around the tube. After center portion shrinks, work torch as before toward one end (2), then to the opposite end (3). Apply sufficient heat to ensure softening of the SRM, indicated by a smooth surface profile.

Note: Do not point the flame directly at the cable semi-con layer.



Note: If External Grounding or Shield Interrupting

Refer to Raychem HVS-EG, "Guide for External Grounding and Shield Interrupting of Power Cable Splices" for modifications to these instructions.

13. Install ground.

Choose the appropriate cable type (Choice 1-3) and follow the directions given.

CHOICE 1

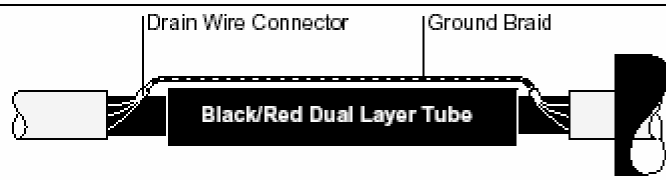
If Drain Wire or UniShield Cable

Pigtail the shield wires on each side. Crimp the ground braid onto one pigtail with the connector provided.

Lay braid across splice tubes and attach to pigtail on the other side. Cut off excess braid and trim pigtailed wires.

Discard spring clamps and foil tape.

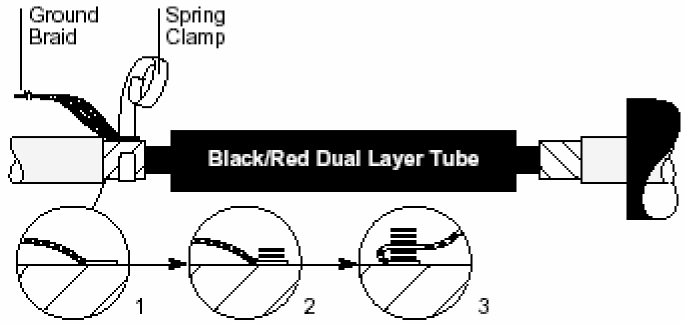
Go to Step 14, page 7.



CHOICE 2

If Metallic Tape or LC Shield Cable

(1) Flare one end of the ground braid and place it onto the metallic tape butted up to the installed splice tube. (2) Attach the braid to the shield by placing two wraps of the spring clamp over the braid. (3) Fold the braid back over the spring clamp wraps. Continue to wrap the remaining clamp over the braid. Tighten clamp by twisting it in the direction it is wrapped and secure with copper foil tape provided.

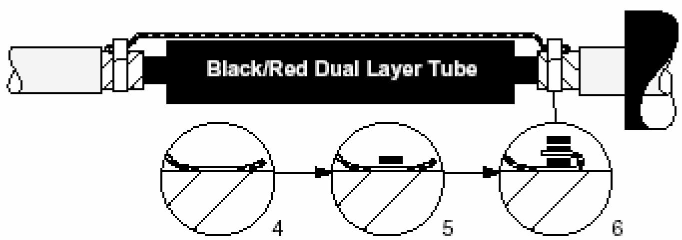


611

(4) Lay the braid across the splice tube and onto the exposed tape shield on the other side. (5) Make two wraps of the clamp over the braid. (6) Fold the braid back toward the splice and finish wrapping the clamp. Tighten and secure. Cut off excess braid.

Discard connectors.

Go to Step 14.



612

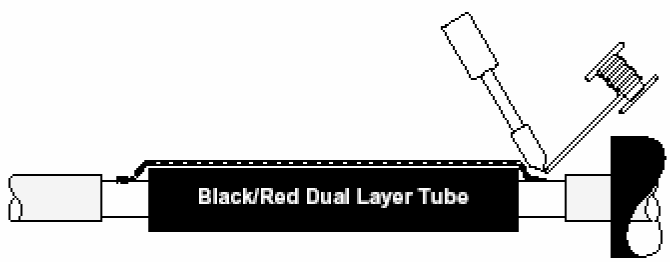
CHOICE 3

If Lead Sheath Cable

Solder ground braid(s) or bonding wire on to lead sheath. Deburr connection.

Discard spring clamps, connectors, and foil tape.

Go to Step 14.

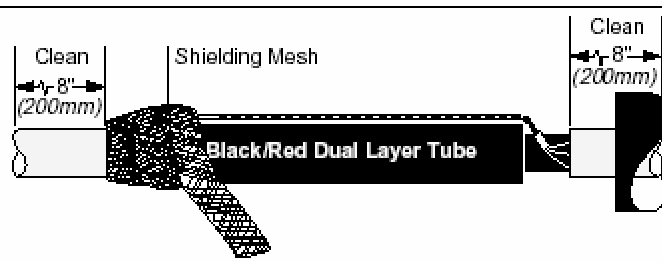


613

14. Install the shielding mesh.

Wrap a half-lapped layer of the mesh across the entire splice and tie off.

Abrade and solvent clean cable jackets as shown to provide an oil-free surface.



614

15. Position rejacketing tube.

Remove or tape over all sharp points to prevent puncture of rejacketing tube.

Center tube over splice.

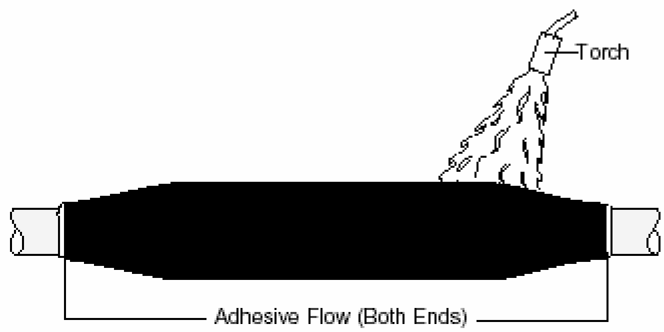
615

16. Shrink rejacketing tube.

Begin shrinking at the centerof the tube and work toward each end.

This completes the splice.

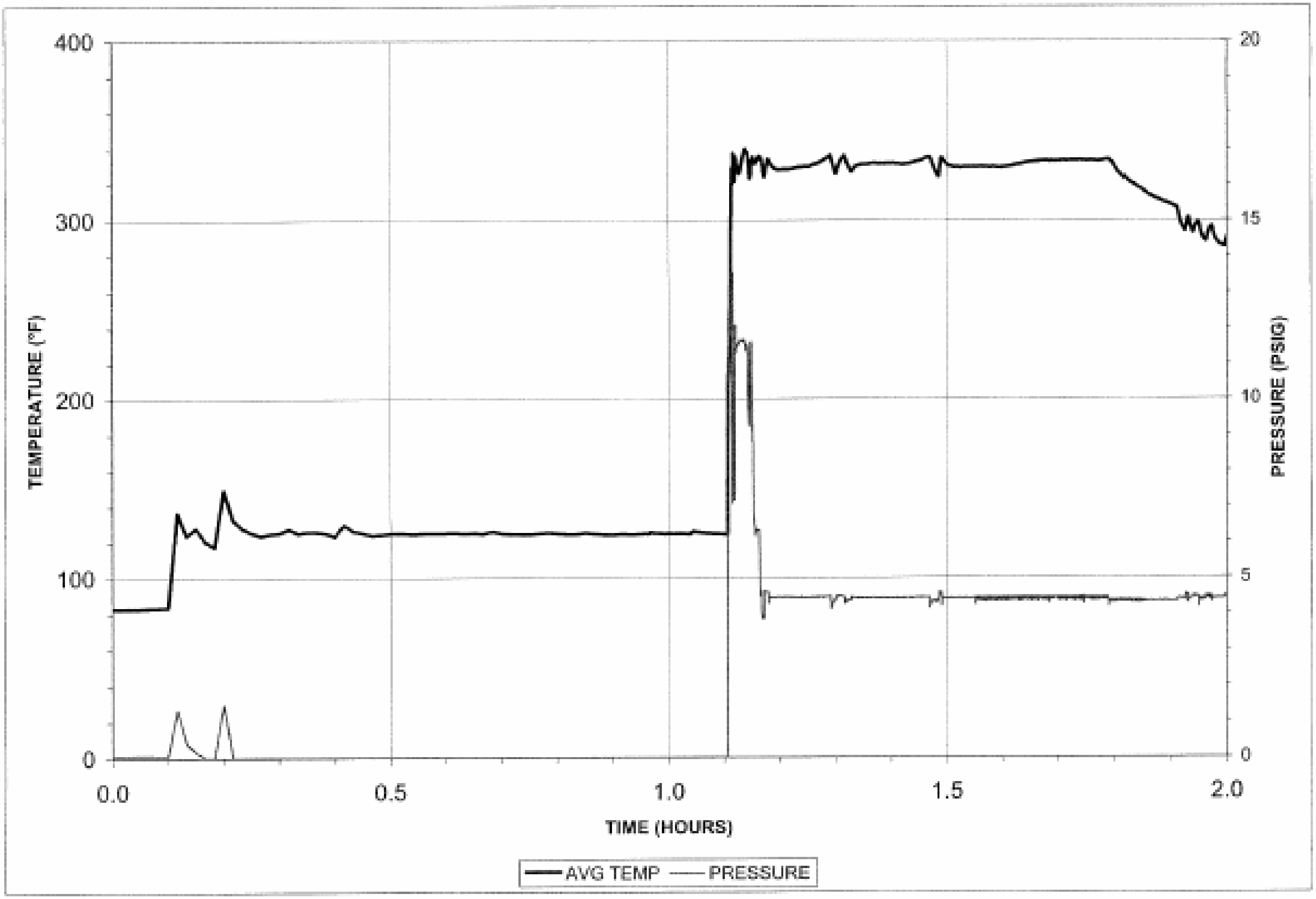
Note: Allow to cool before moving or placing in service.



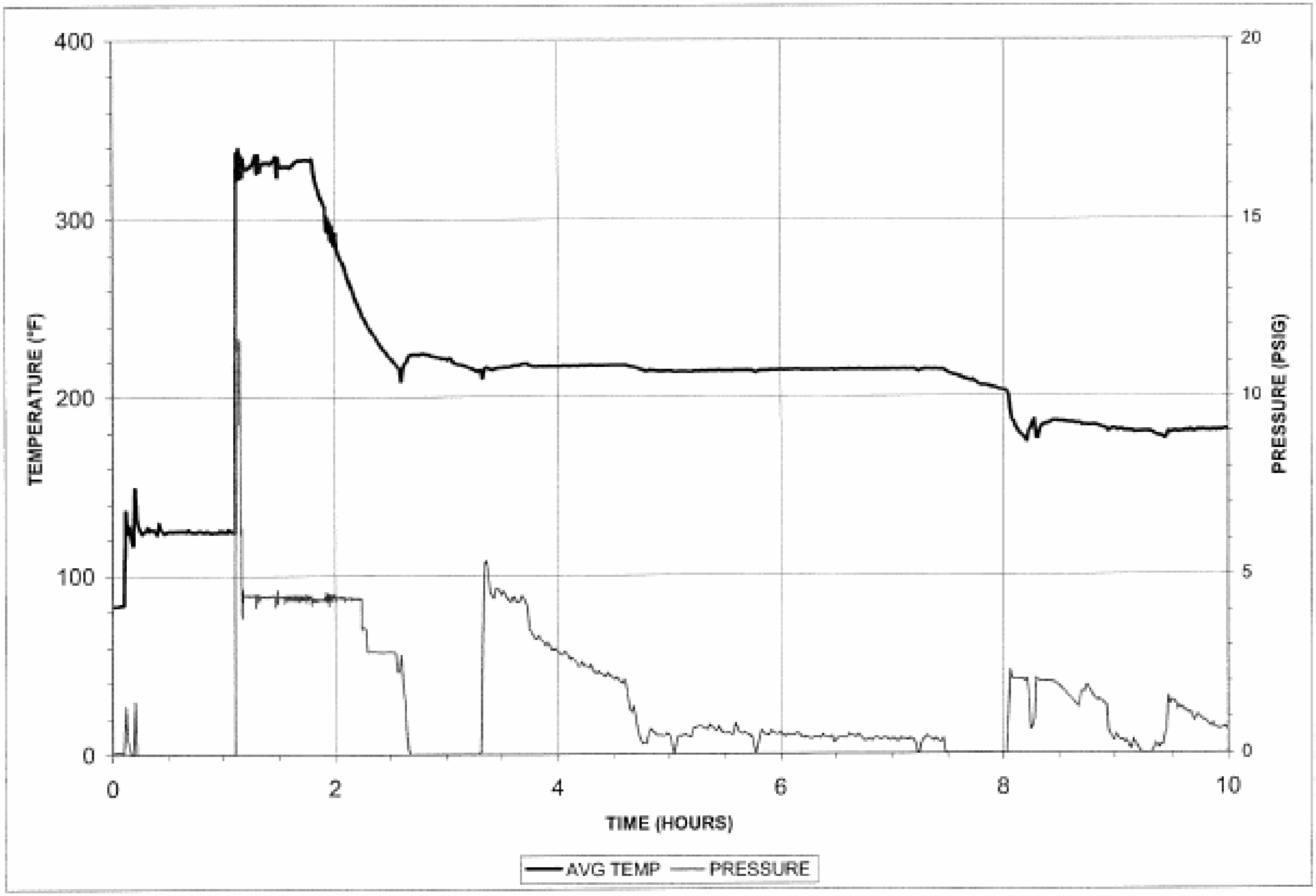
616

APPENDIX 2

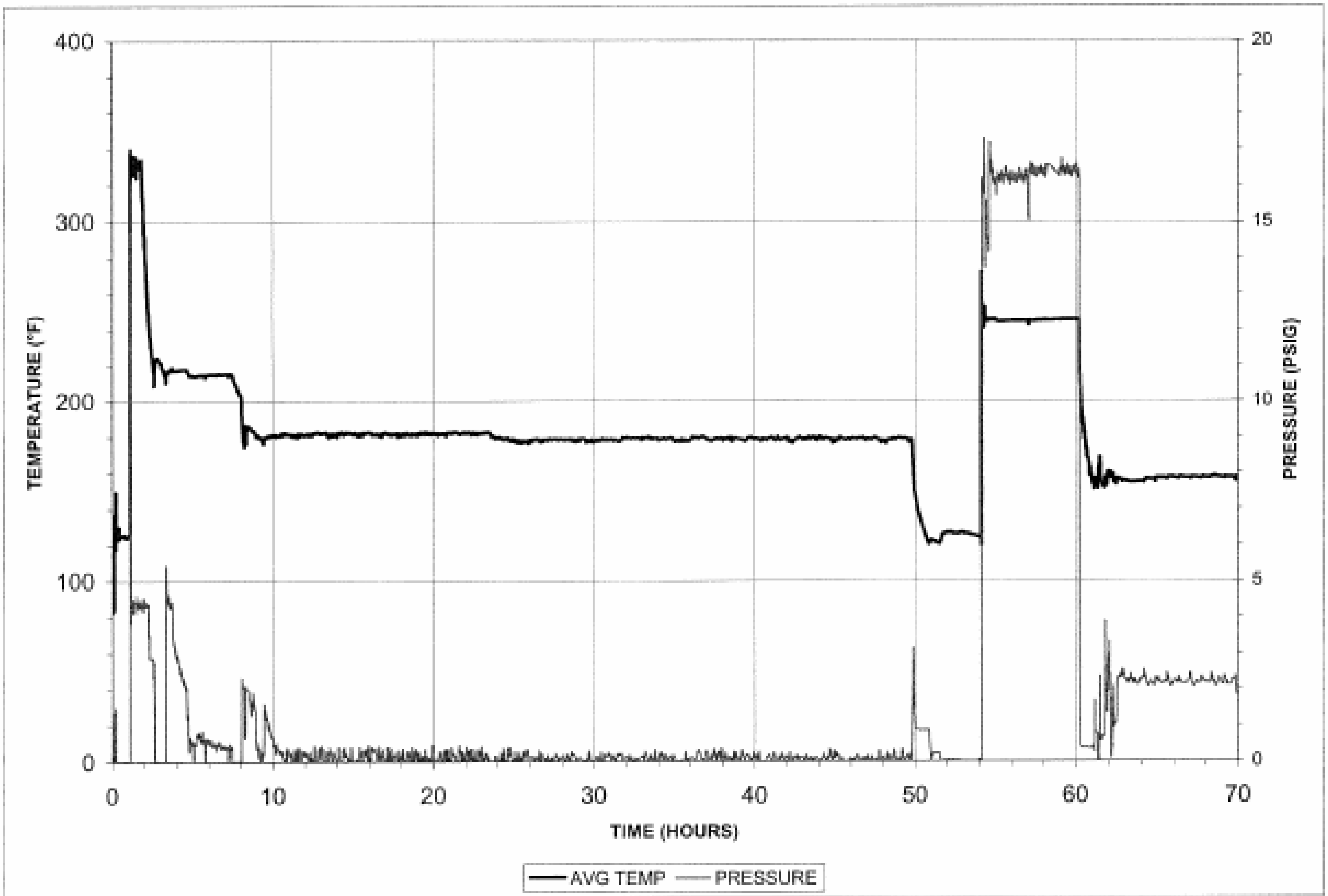
LOCA PROFILE



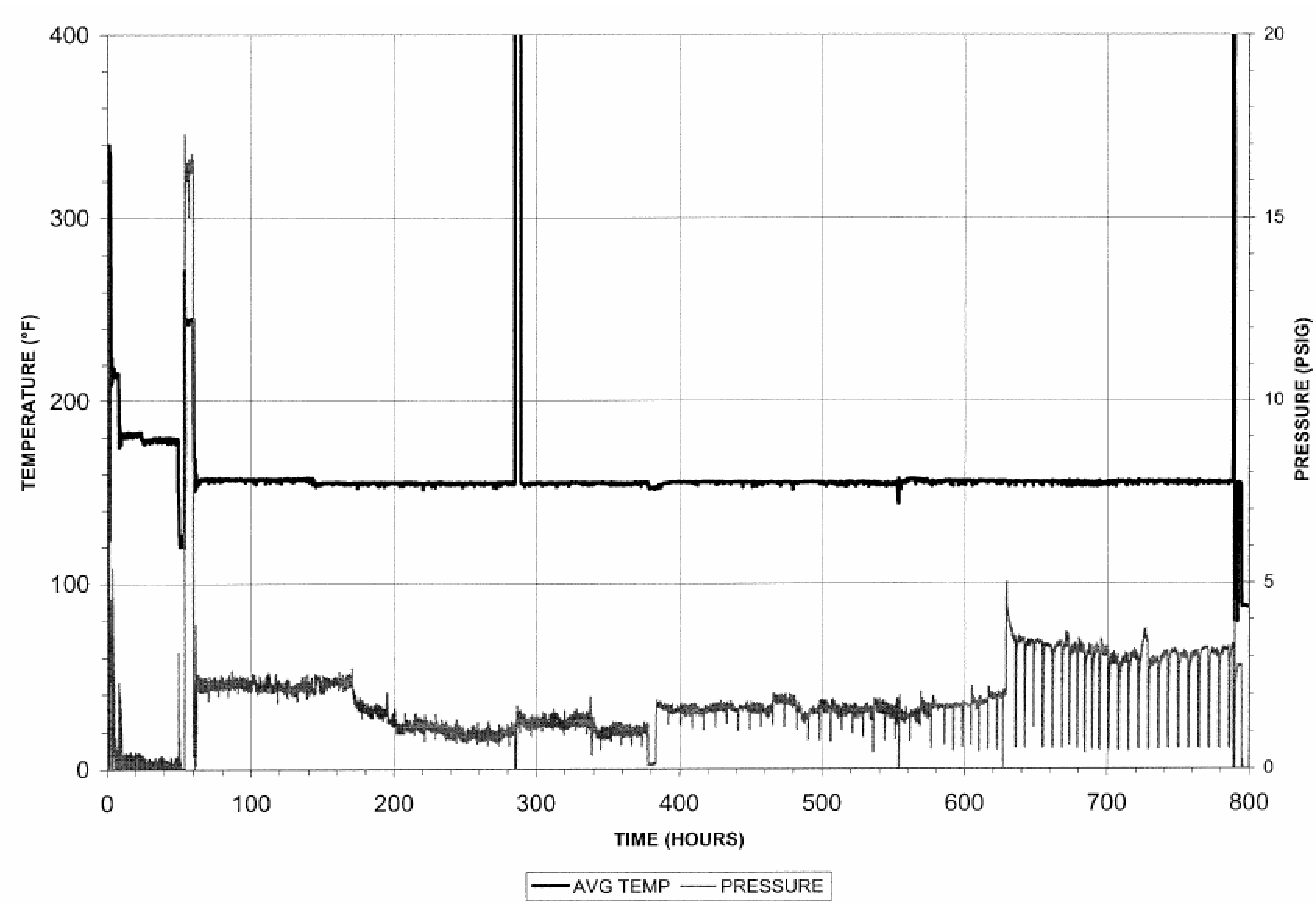
LOCA Profile (First Transient)



LOCA Profile (First Transient)



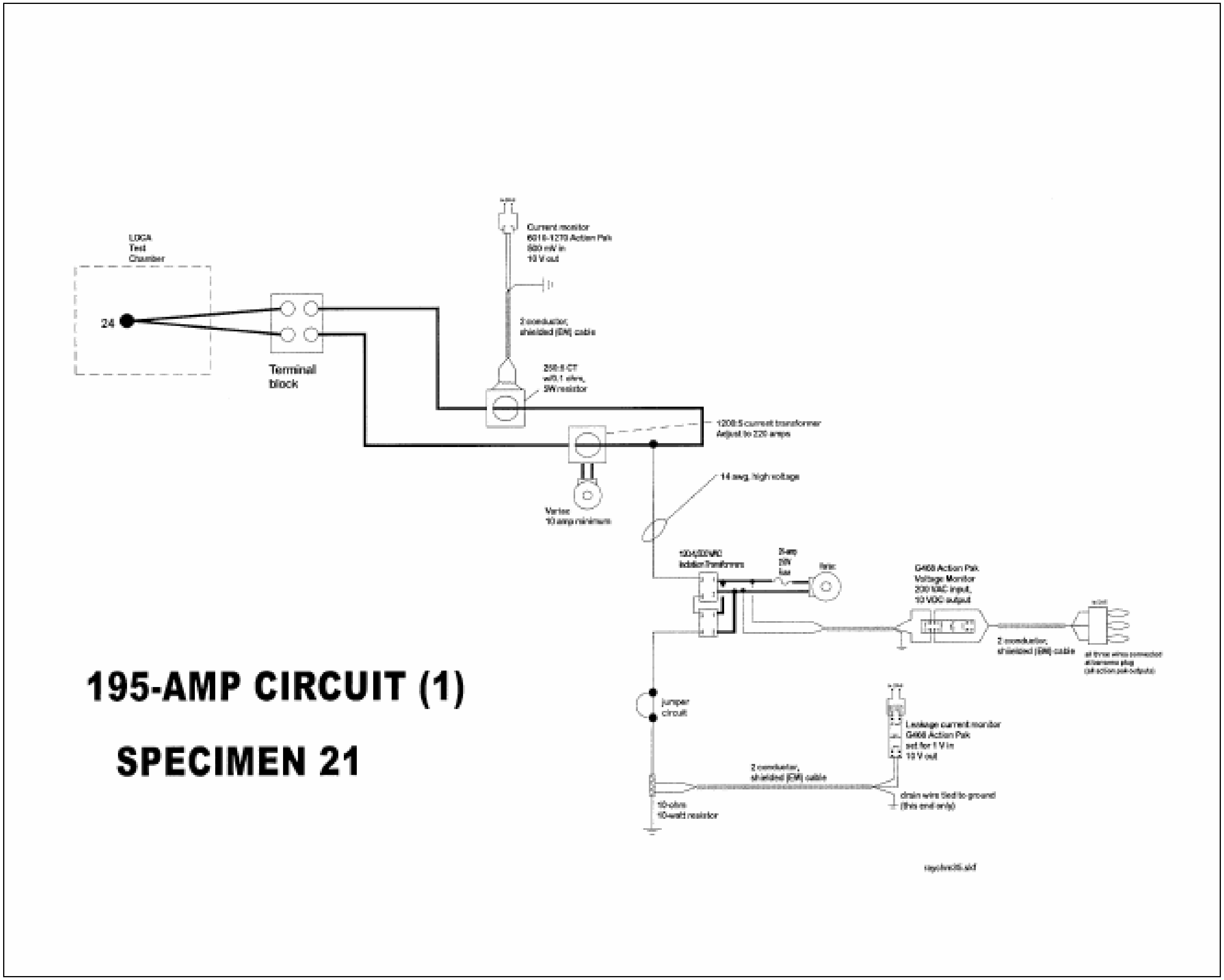
LOCA Profile (First Transient)

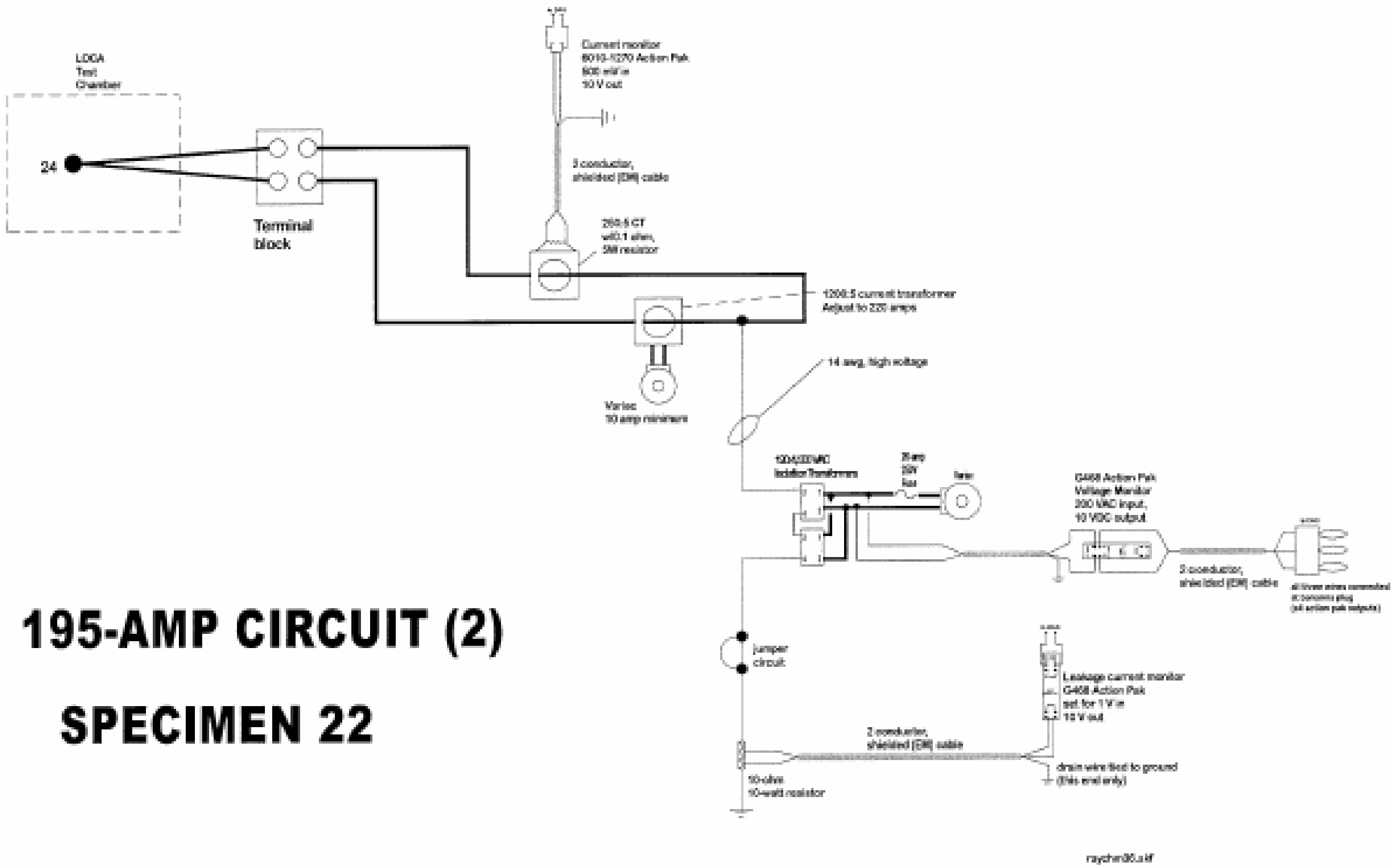


LOCA profile for the bending sample (Second Transient)

APPENDIX 3

MONITORING CIRCUITS


LOCA
Test
Chamber
24
Terminal
block
Current monitor
10 V out
2 conductor,
shielded (EM) cable
1200:5 current transformer
Adjust to 220 amps
14 awg. high voltage
Variac
10 amp minimum
G468 Action Pak
Voltage Monitor
10 VDC output
2 conductor,
shielded (EM) cable
jumper
circuit
Leakage current monitor
G468 Action Pak
set for 1 V in
10 V out
2 conductor,
shielded (EM) cable
drain wire tied to ground
(this end only)
10-ohm
10-watt resistor
195-AMP CIRCUIT (1)
SPECIMEN 21



195-AMP CIRCUIT (2)

SPECIMEN 22

APPENDIX 4

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 Laboratories	**NRC Reference:**	00-17c
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

*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

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

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:**	2004-02j
Reference:	HSV0030567	**Total Dose:**	1.98E7 Rads w/Unc
Items:	Tray 4	**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
03/17/04	17:00	03/19/04	11:10	42.16	5.012E+05	2.113E+07	2.113E+07

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	4.865E-07	5.029E+05
2	4.856E-07	5.014E+05
3	4.847E-07	5.000E+05
4	4.854E-07	5.011E+05
5	4.852E-07	5.008E+05

Average Dose Rate (Rads/hr): 5.012E+05

Note – Tray 4 contains Specimen 21 (phase 1 testing No. 139)

*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:**	00-17d
Reference:	HSV0018395	**Total Dose:**	1.489E+08
Items:	Trays 3 and 6	**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
08/29/00	13:15	09/11/00	8:15	307.00	4.849E+05	1.489E+08	1.489E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	8.871E-07	4.866E+05
2	8.835E-07	4.843E+05
3	8.829E-07	4.839E+05

Average Dose Rate (Rads/hr): 4.849E+05

*Dose Rate determined from ionization probe current using the following formula:
DR(Rads/hr)= (1.017E17 * (Amps)2 + 5.360E11 * (Amps) - 686.526) * 0.877

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

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

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:**	2004-02h
Reference:	HSV0030567	**Total Dose:**	1.61E7 Rads w/Unc
Items:	Tray 5	**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
03/02/04	10:30	03/03/04	10:30	24.00	7.067E+05	1.696E+07	1.696E+07

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	6.020E-07	7.061E+05
2	6.028E-07	7.076E+05
3	6.022E-07	7.065E+05

Average Dose Rate (Rads/hr): 7.067E+05

Note – Tray 5 contains Specimen 22 (phase 1 testing No. 140)

*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

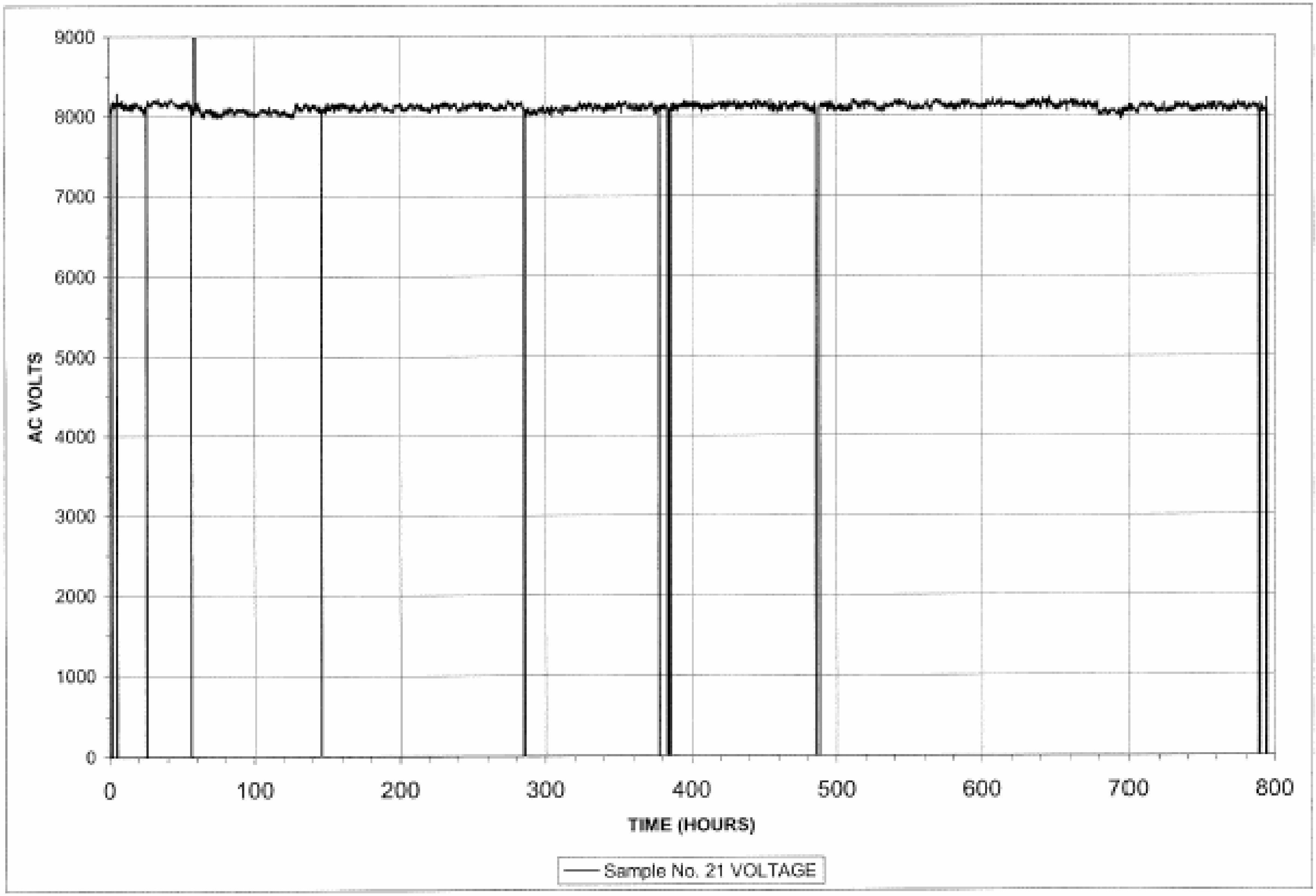
APPENDIX 5

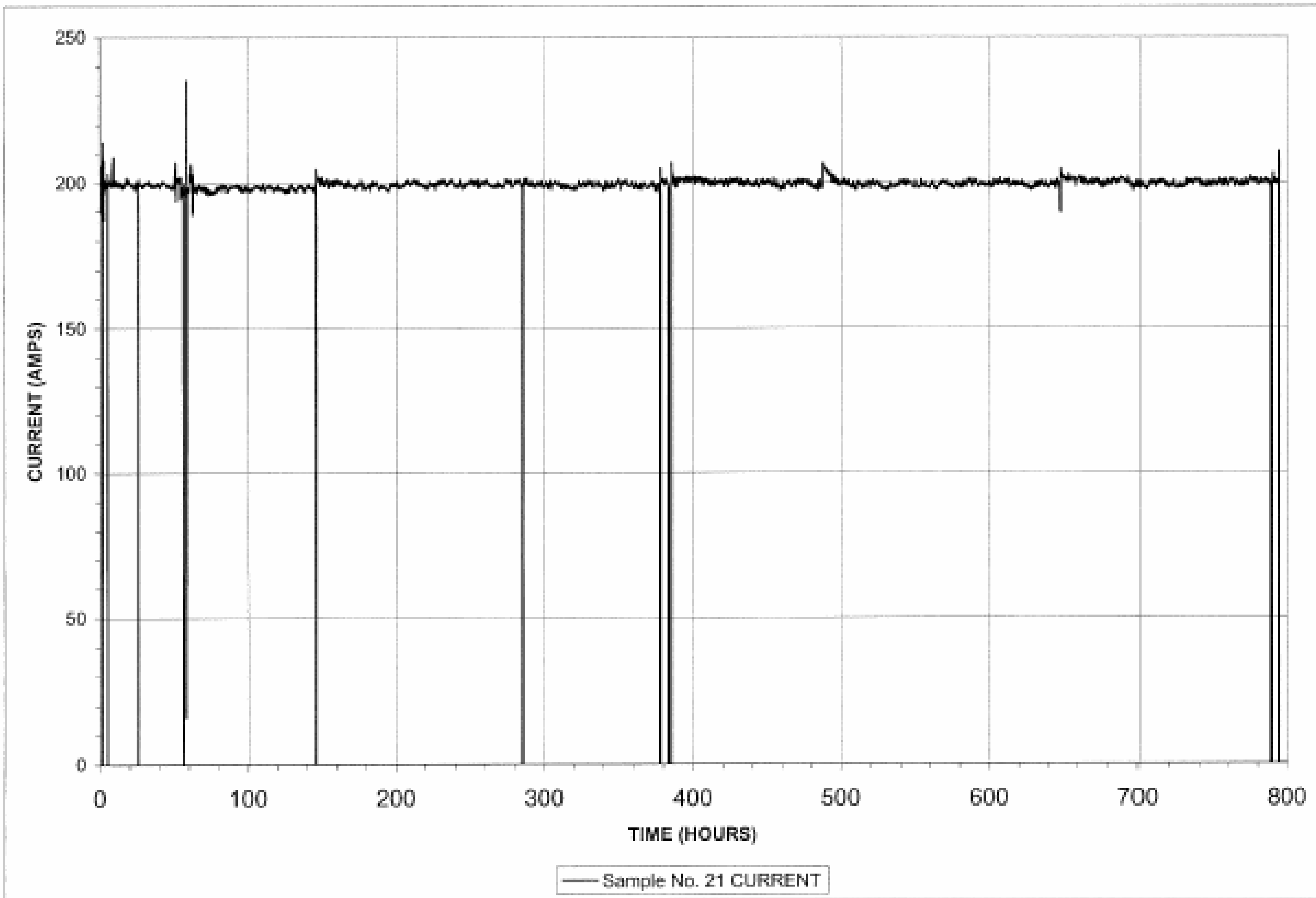
CHRONOLOGICAL SUMMARY OF DEVIATIONS FROM PLAN

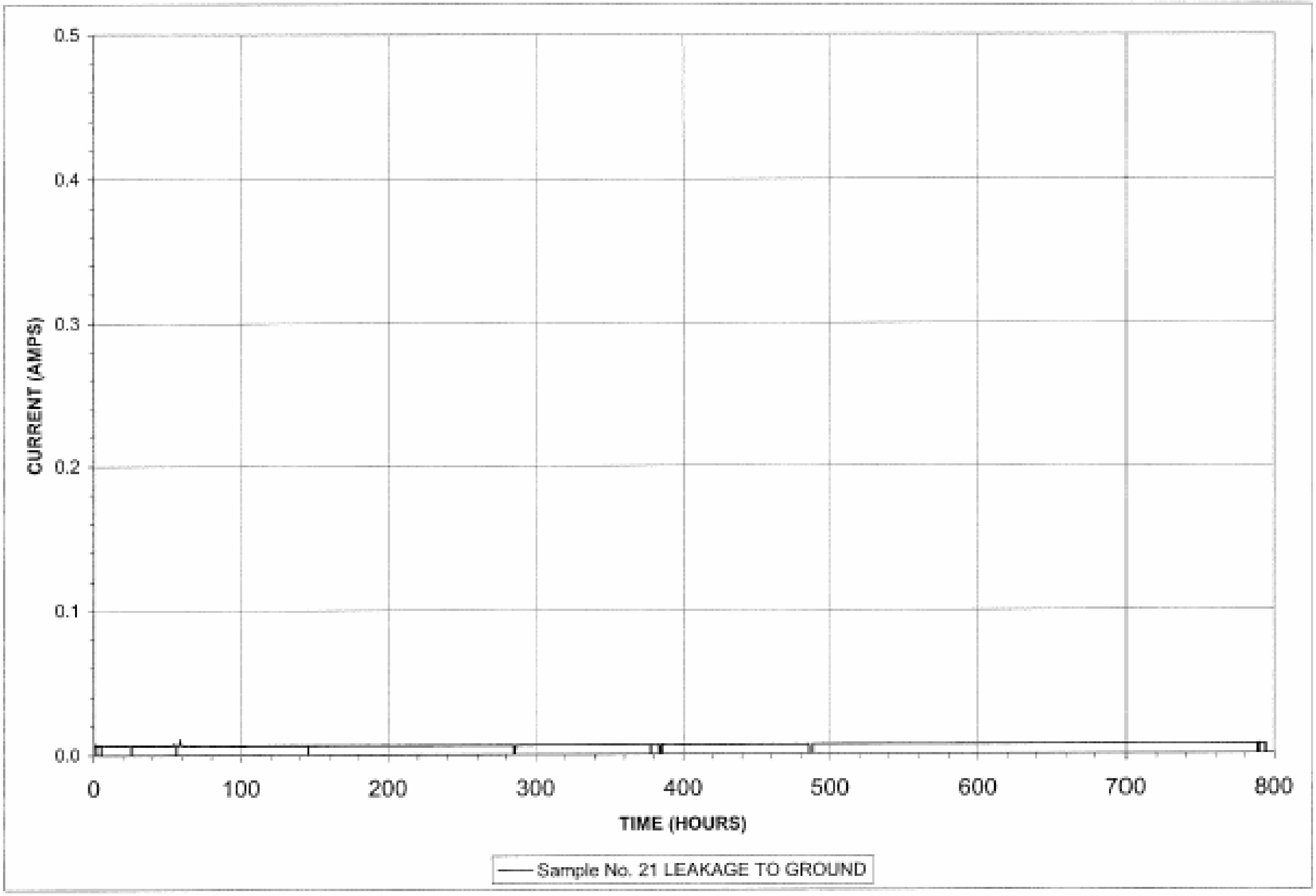
Date	Time	Circuits/Specimens	Action
6/23/04	09:39-09:48	All circuits	Loading interrupted for IR measurements during the 325°F transient.
6/23/04	13:09-13:17	All circuits	Loading interrupted for IR measurements at 212°F plateau
6/24/04	09:38-09:43	All circuits	Loading interrupted for IR measurements at 178°F plateau
6/25/04	16:13-16:18	All circuits	Loading interrupted for IR measurements at 240°F transient
6/25/04	18:19-19:00	All circuits	Data acquisition glitch
6/29/04	09:29-09:34	All circuits	Loading interrupted for IR measurements at 150°F plateau
7/05/04	04:53-09:11	All circuits	Power out and data acquisition computer malfunction
7/08/04	21:27	Circuit 195A(2)	Loading interrupted
7/09/04	07:32-9:34	All Circuits	IR measurements at 150°F plateau
7/13/04	13:32-16:07	All Circuits	Problems with the HV transformers – circuit currents were not interrupted
7/26/04	04:52-05:46	All Circuits	Power interrupted
7/26/04	09:48-09:53	All Circuits	Loading interrupted for IR

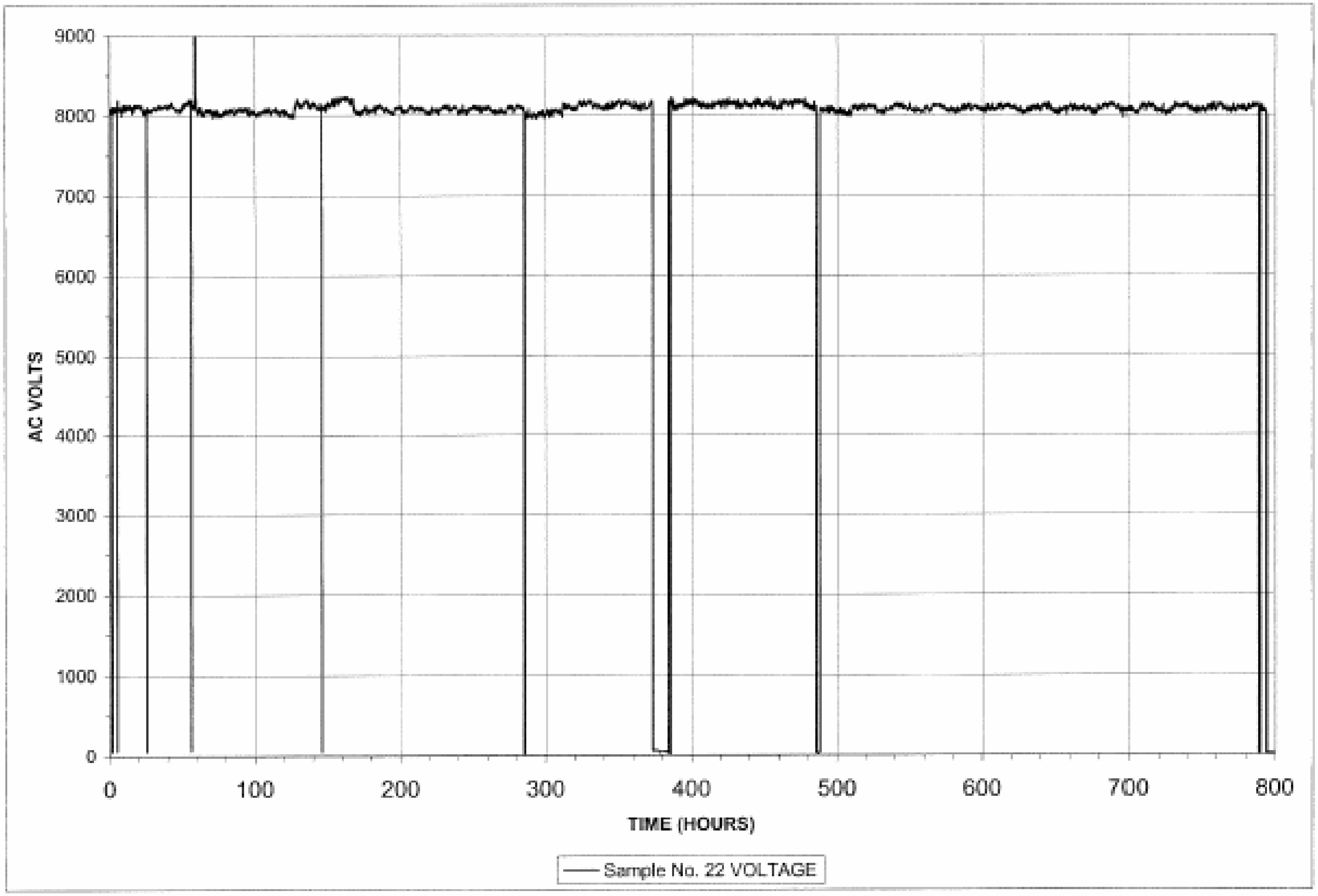
APPENDIX 6

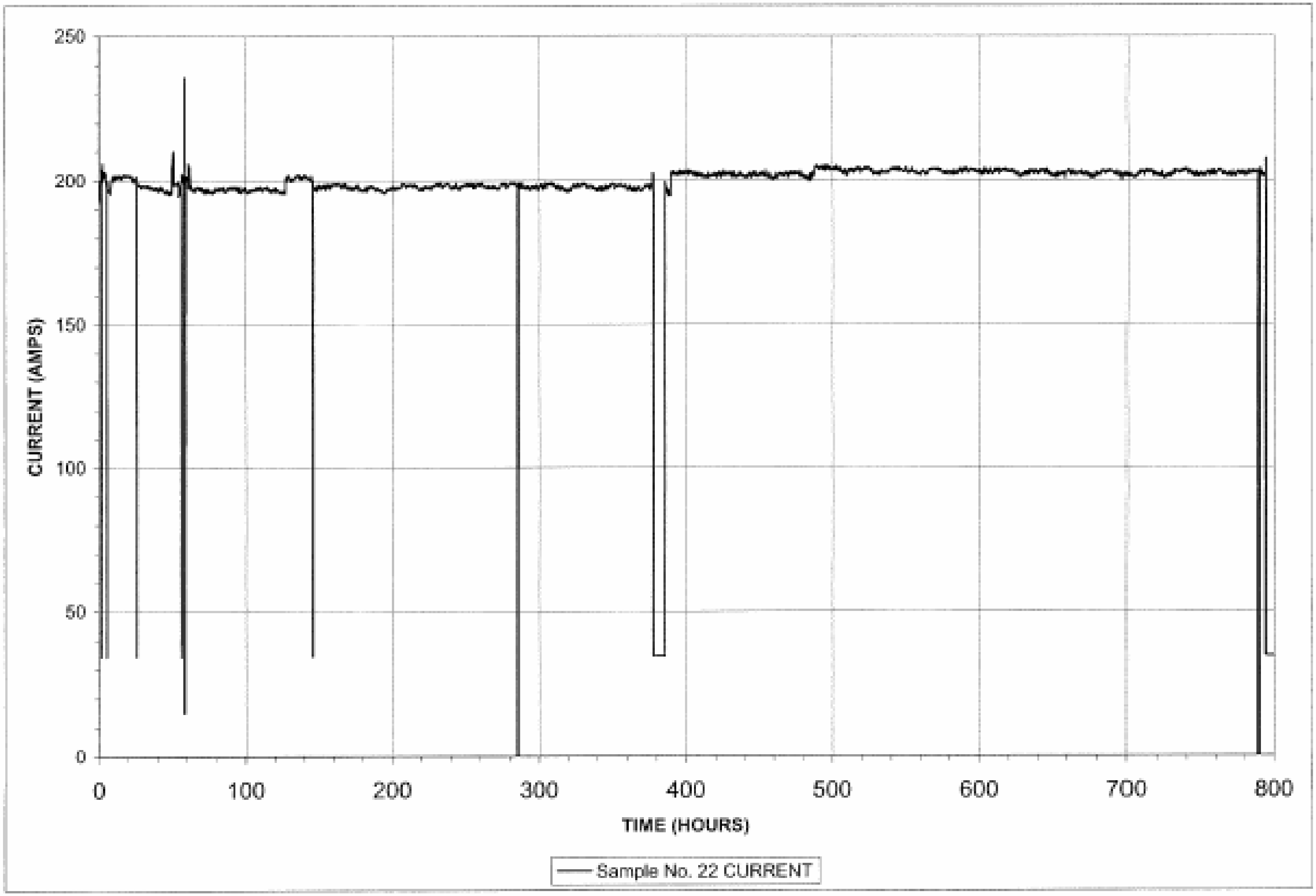
CIRCUIT VOLTAGE AND CURRENT PLOTS

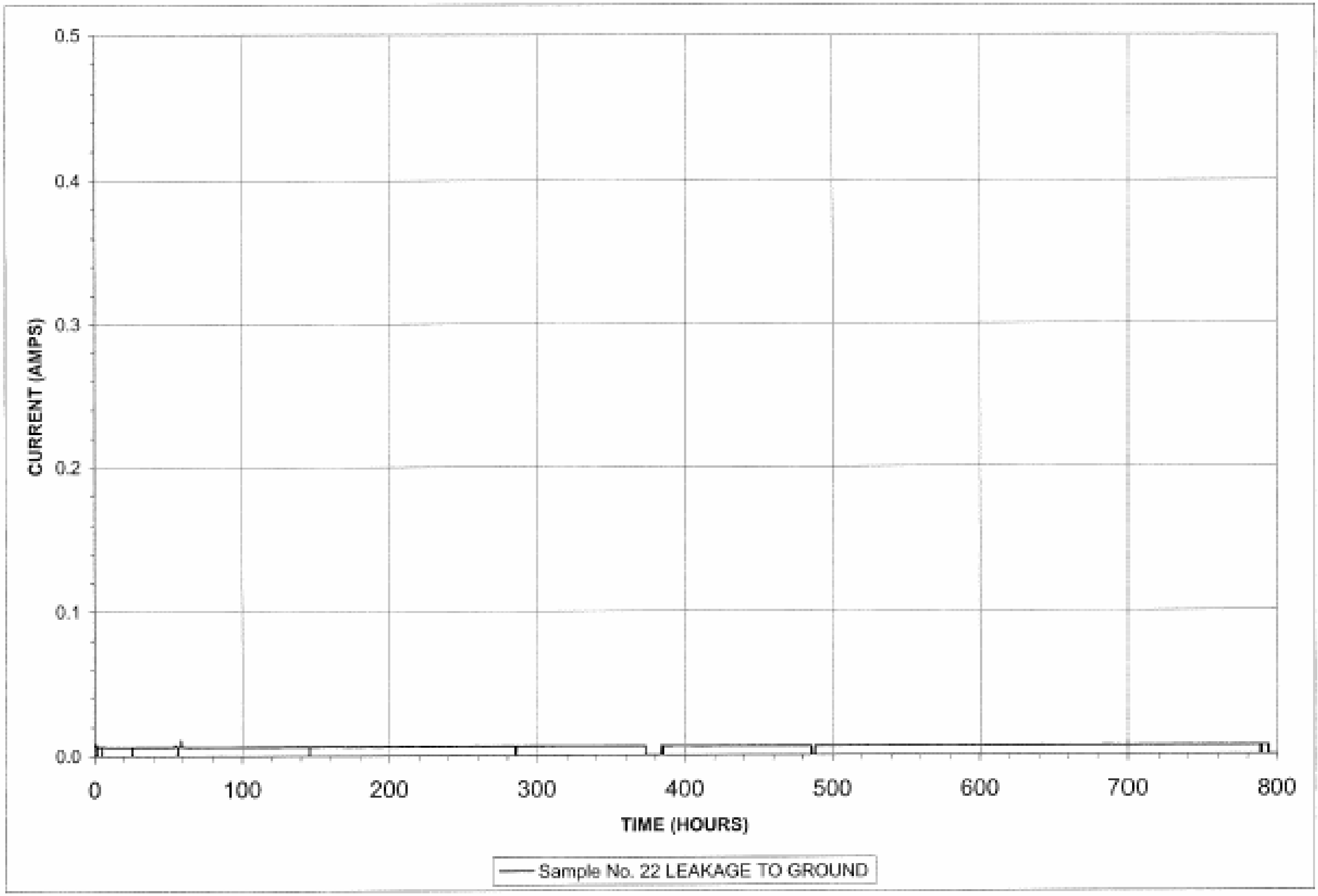

9000
8000
7000
6000
5000
4000
3000
2000
1000
0
AC VOLTS
0
100
200
300
400
500
600
700
800
TIME (HOURS)
Sample No. 21 VOLTAGE


250
200
150
100
50
0
CURRENT (AMPS)
0
100
200
300
400
500
600
700
800
TIME (HOURS)
Sample No. 21 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)
Sample No. 21 LEAKAGE TO GROUND


AC VOLTS
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
500
600
700
800
TIME (HOURS)
Sample No. 22 VOLTAGE


250
200
150
100
50
0
CURRENT (AMPS)
0
100
200
300
400
500
600
700
800
TIME (HOURS)
Sample No. 22 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)
Sample No. 22 LEAKAGE TO GROUND