tyco Electronics

Energy Report

EDR-5336

Nuclear Products
Requalification Testing

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REVISION RECORD

Revision	Page	Paragraph	Description	Date
1	4, 128		Added detailed information on error in irradiation dose units	8/20/02
1	16, 54, 56		Added NJRT test sample construction, results, conclusion	8/20/02
1	128		Added Appendix 6 – correspondence regarding irradiation dose units	8/20/02
2	100, 116, 134	App. 4, 5 and 7	The full set of the samples' monitoring circuits, irradiation log and the chronological account of the events during the LOCA exposure are provided in Appendices 4, 5 and 7, respectively.	3/20/03
2			Comments and data regarding qualification for 60-year aged specimens were deleted.	3/20/03
2			Test information for the NMCK test specimens was deleted	3/20/03
3	4, 5	1, 5	Deleted reference to modified S1119	5/01/03
3	4	2	Expanded description of new formulation	5/01/03
3	5	7	Deleted reference to cable performance	5/01/03
3	6	Table 1	Added note regarding S1119 manufacturing location change	5/01/03
3	All part number references		Corrected part numbers	5/01/03
3	12	2, 3	Corrected holdout data	5/01/03
3	19	2	Deleted reference to modified S1119	5/01/03
3	20	2	Added additional aging data	5/01/03

Revision	Page	Paragraph	Description	Date
3	20	5	Added additional planned aging data	5/01/03
3	24		Deleted margin information	5/01/03
3	26	Section 7	Added additional sample data regarding extended aging and irradiation	5/01/03
3	26, 27	4, 5 and table 4	Corrected irradiation data	5/01/03
3	27, 28	2-6, 1	Added data pertaining to circuits exhibiting high leakage current during the first transient	5/01/03
3	28	2	Added description of lead wires post LOCA	5/01/03
3	30-31	Table 5	Corrected sample 7-12, 19-24 transient 1 time energized, added sample data for 37-42	5/01/03
3	33	Table 6	Added data for sample 41	5/01/03
3	35	Table 7	Added data for samples 37-42	5/01/03
3	35	Table 8	Added circuit 18A (1) and (2)	5/01/03
3	36	Table 9	Corrected sample 49 transient 2 data	5/01/03
3	42, 43	Table 13	Corrected transient 1 time	5/01/03
3	44	Table 14	Deleted "Black Stripe" sample 87	5/01/03
3	44 - 47	2, 2	Added additional data and post LOCA testing on NPTS splices	5/01/03
3	53	1	Added application range note	5/01/03
3	54	Table 21	Corrected transient times	5/01/03
3	56	No. 2	Added No.2	5/01/03
3	56	No. 3	Deleted S1119	5/01/03
3	56	No. 5	Added "in a kit configuration"	5/01/03
3	57	No. 8	Added No. 8	5/01/03
3	97	Appendix 3	Added aging data	5/01/03
3	101	Appendix 4	Added Circuit 18 A(1)	5/01/03
4	25	2	Insulation Resistance comment reflects EDR-5389	7/22/05
4	41	3	Bolted splices WCSF-300 and smaller limited to 2.0x	7/22/05
4	56,57	No. 6	Bolted splices WCSF-300 and smaller limited to 2.0x	7/22/05
5	58	No. 7	Changed WCSF-115 to WCSF-200	9/06/05

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1. REVISION 5

Revision 5 was created specifically to permit the use of WCSF-200-18/5 with a 1 inch seal length. This is reflected in the conclusion no. 7 on page 58 based on the specimens described in section 7.2.2.

2. REVISION 4

Revision 4 was released as a result of information that was determined by the Phase 2 testing as reported in EDR-5389. Specifically the limitation of the increased use range for small tubing over a bolted connections as described in conclusion number 6 which now reads:

> The qualification of the increased use range (up to 2.5x) of the thick wall WCSF tubing. This increased use range does not apply to the WCSF-050 size. The use range over a bolted connection and for hardware, that may have sharp corners or edges, should be limited to 2.0x for WCSF-300 and smaller tubing. WCSF-300 and smaller should not be used above 2.0x. For WCSF-500 and larger, the use of bolt pads is recommended for situations where the hardware may have sharp corners/edges and if the use range is 2.0x – 2.5x.

This revision also added a comment related to new findings regarding insulation resistance measurements. (See page 25-26) It had been stated that measurements of spliced and un-spliced specimens would be predominately influenced by the conductor insulation. Although the insulation measurement values were acceptable, the Phase 2 testing demonstrated that this statement was not accurate.

3. REVISION 2 AND 3

These revisions provide more detailed information about the test results of the different specimens and answers the questions that some of the customers had about the previous revision of this report. The full set of the samples' monitoring circuits, the samples' irradiation log and the chronological account of the events during the LOCA exposure are provided in

Appendices 4, 5 and 7, respectively. Sixty years life qualification claims were removed from this revision and will appear in a separate report. However, the test information for 60 year aged specimens was kept. Test information for the NMCK test specimens was deleted from this report since these specimens did not use the new formulation materials and were previously qualified.

4. REVISION 1

This revision reports on the error in irradiation dose units as per the letter presented from Georgia Tech, the irradiation subcontractor, which was received by WYLE laboratories on April 11, 2002 and consequently brought to Tyco's attention on May 28, 2002 (Appendix 6).

Georgia Tech reported radiation doses in units of rads-air (absorbed dose in air), but the actual radiation dose units were Roentgens. Consequently, the actual radiation dose is only 0.877 of the reported values.

The actual radiation doses as well as the required radiation doses are reported in the appropriate sections in this revision.

This revision also reports the test results of the Jacket Repair Tape NJRT.

The following table shows the specific revision changes/additions.

Original Issue Date: 11/01/2001
Revision 1 Issue Date: 08/20/2002
Revision 2 Issue Date: 03/17/2003
Revision 3 Issue Date: 05/01/2003
Revision 4 Issue Date: 07/22/2005

5. 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 323-1983 and IEEE 383-1974 and to prove the equivalency of the products manufactured with the modified tubing (WCSF), molded parts (-52), and tape (NJRT) to the original products in fit, form and function. In addition, Raychem sought to expand certain configuration limits established by the prior test programs.

6. SUMMARY

The qualification test program of Raychem Nuclear Compounds was driven by several factors, some of which were external but others were internal. Raychem 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 Raychem 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" recipes are chemically very similar to those they replaced in the standard recipe, Raychem fully expect that the use of products made from these reformulations would be essentially identical to that of the standard products. However, Raychem made the decision to run a complete requalification program, which also allowed the opportunity to examine the design parameters and increase the qualified configurations. Furthermore, as a service to customers, it was desirable to prove some specific customers' designs.

The test program objectives were:

- Qualify products manufactured with the new compounds.
- Prove equivalency of the new compounds to the old.
- Extend qualified configurations (1″ seal, extended use range).
- Qualify specific customer configurations (i.e. Ontario Hydro).

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 specimens 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 extruded 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 323-1974 and IEEE 383-1974.

For each specimen type included in the test program, at least six 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 a LOCA simulation to simulate a Loss Of Cooling 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 manufactured with modified tubing (WCSF), modified molded parts (-52), and modified nuclear grade tape (NJRT) to the original qualified products. In addition, the testing confirms that the old and the new WCSF tubings are interchangeable and can be used in any approved combination.

The test results prove the adequacy of the increased use range (up to 2.5x for both smooth and irregular substrates) and the shorter seal length, 1″ (25mm), of the WCSF tubing.

Finally, some special utility-specific designs were included in the program and successfully qualified.

7. SAMPLE DESCRIPTION

7.1 Materials

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

Table 1 shows typical old and new product designations used for this test and referred to in this report.

	Old component	New component
Tubing	WCSF-200N	WCSF-200-18/5-N
Molded Parts	Not Used	-52N
Tape	Not Used	NJRT
Adhesive Tape	S1119-2	S1119-2N

Table 1: Designation of the products used for the test program.

Note: The change of name of the adhesive tape is related to the change of the manufacturing location.

7.2 Specimen Preparation

Splice configurations represented well-defined applications and encompassed the spectrum of anticipated field installations described in Raychem installation instructions. Except for utility-specific designs, the splice configurations were specifically intended to replicate those tested in prior Raychem WCSF, repair tape, 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. Most samples were mounted on mandrels (Figure 1), the remainder were installed on flat cable trays. Each splice was identified individually for purposes of data recording. All samples were prepared by Raychem.

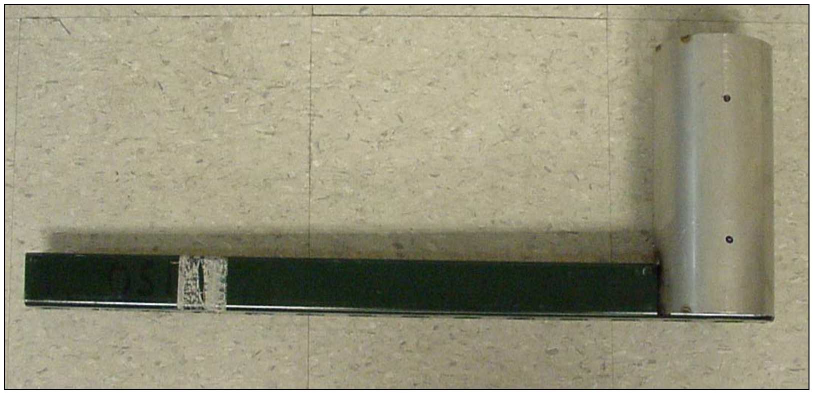


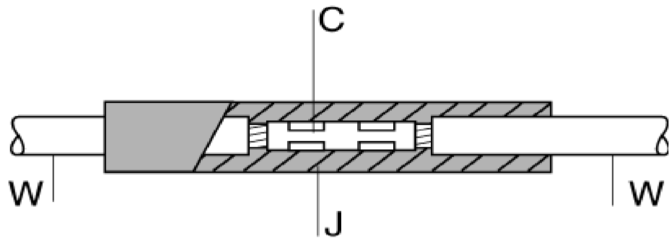
Figure 1: Side view of a typical mandrel. Mandrel diameter may vary according to the test description.

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.

The following sections detail the configurations tested:

7.2.1 In-Line Splice- with Crimp Connector

Figure 2 illustrates the general construction of the In-Line Splice with Crimp Connection. Shims may have been used to increase the cable diameter when necessary.



Key	Component	Description
W	1/C wire	Single conductor wire
J	WCSF	Splice sealing sleeve
C	D 609-07 & D 609-08	Crimp connector

Figure 2: In-Line splice with crimp connector

These specimens were used to establish qualification of in-line crimp connection single conductor splices. The in-line crimp connection single conductor splice is the most common application of the coated WCSF tubing and is used to establish the critical design parameters for the Nuclear Product line. The two major design parameters examined in this series of samples were seal length and use range. Seal length is the minimum linear dimension of contact that the tubing makes with the substrate to affect an environmental seal. Use range is the smallest and largest diameter substrate that the tubing is considered to maintain functional properties of mechanical protection, environmental seal and electrical insulation. The samples were installed on 4.5″ (115 mm) diameter mandrels (20 times the smallest splice outer diameter – Configuration #1) according to the IEEE 383-1974.

In this test, a total of 39 samples were constructed. The sample construction procedure was consistent with the guidance provided in Raychem WCSF installation instructions and is documented in Raychem Laboratory Book # 17923.

This series of splices were constructed to establish the following type test configurations:

1. Cable sample was an in-line splice using cable #9, 16 AWG PEEK (Appendix 1), a crimp connector and WCSF-070-6/2-5N with 2″ (50 mm) seal lengths. This establishes the 2″ (50 mm) seal length and minimum (1.0x) OD parameter. Six samples were constructed (Samples #1 to #3 and #13 to #15).

2. Cable sample was an in-line splice using cable #9, 16 AWG PEEK (Appendix 1), a Raychem crimp connector and WCSF-070-6/2-3N with 1″ (25 mm) seal lengths. This establishes the 1″ (25 mm) seal length and minimum (1.0x) OD parameter. Six samples were constructed (Samples #4 to #6 and #16 to #18).

3. Cable sample using cable #6, 14 AWG, XLPE (Appendix 1) spliced together using crimp connectors and WCSF-070-6/2-5N with 2″ (50 mm) seal lengths. This establishes the 2″ (50 mm) seal length and conventional maximum (2.0x) OD parameter. Six samples were constructed (Samples #7 to #9 and #19 to #21).

4. Cable sample using cable #6, 14 AWG, XLPE (Appendix 1) spliced together using one WCSF-050-3/1-1N shim, crimp connectors and WCSF-070-6/2-3N with 1″ (25 mm) seal lengths. This establishes the 1″ (25 mm) seal length and new maximum (2.5x) OD parameter. Six samples were constructed (Samples #10 to #12 and #22 to #24).

5. Six samples were constructed identical to Configuration #2 using the old adhesive formulation (T446) together with the new tubing formulation (Samples #25 to #27 and #31 to 33).

6. Cable sample was an in-line splice using cable #9, 16 AWG PEEK (Appendix 1), a Raychem crimp connector and WCSF-050-3/1-3N with 1″ (25 mm) seal lengths and a 1.4x OD parameter. This establishes the ability of WCSF-050-3/1-3N to be used as a full splice cover with 1″ (25 mm) seal length. Six samples were constructed (Samples #124 to #126 and #127 to #129).

Half of the samples within each configuration were aged (based on the new tubing formulation aging data) and irradiated to represent 40 years of service (90°C) and half were unaged.

7. Six additional samples of configuration #2 were constructed. Three were identical to configuration #2 (Samples #37 to #39) and used new formulation tubing. Three others (Samples #40 to #42) were identical to configuration #2 except they used the old formulation tubing (WCSF-070N). All the samples were aged (based on the new tubing formulation aging data) and irradiated to represent a longer service life.

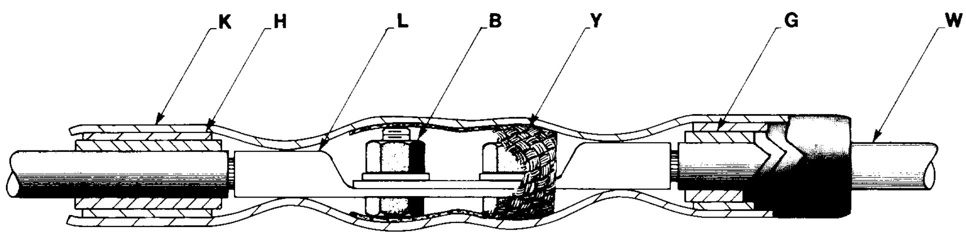
8. Finally, three identical samples to configuration #4 were constructed using the old formulation tubing (WCSF-070 and WCSF-050) to examine the applicability of the short seal length, 1" (25 mm), and the expanded use range, 2.5x, to the old tubing (Samples #130 to #132). All samples were aged and irradiated to represent 40 years of service (90°C).

All samples were exposed to the LOCA environmental conditions as described in the design basis event (Section.8.4).

7.2.2 In-Line Splice- with Bolted Connection

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

(Note: Some of the specimens used one bolt and nut with ring tongue lugs)



Key	Component	Description
Y	EPPA-109N-1	Bolt pad
K	WCSF-500-38/13-N	Outer sealing sleeve
G	WCSF-300-28/8-N	Cable shim
H	WCSF-200-18/5-N	Cable shim
B	Bolt, nut and washer	1/2″ x 1″L
L	2 hole lugs	2-hole lugs
W	1/C wire	1/C wire

Figure 3: In-Line splice with bolted connection

These specimens were used to establish qualification of bolted connection single conductor splices consisting of bolted terminal lugs, single and double shim used with an outer sealing sleeve, with and without bolt pads. Samples were installed on 13.5″ (340 mm) diameter mandrels. The sample construction procedure was consistent with the guidance provided in Raychem WCSF installation instructions and is documented in Raychem Laboratory Book # 17923.

This series of splices were constructed to establish the following type test configurations:

1. Cable sample used cable #4, 12 AWG (Appendix 1) spliced together using ring tongue lugs, secured with bolts, washers and nuts with each side shimmed with 2″ (50 mm) WCSF-070-6/2-2N with an outer sealing sleeve WCSF-200-18/5-7N with 2″ (50 mm)

seal lengths. No bolt pad was used. This arrangement results in 1.3x use range based on cable diameter and a 2.5x use range over the connection hardware. Six samples were constructed (Samples #43 to #45 and #58 to #60).

2. Cable sample used cable #4, 12 AWG (Appendix 1) spliced together using ring tongue lugs, secured with bolts, washers and nuts with each side shimmed with 1″ (25 mm) WCSF-070-6/2-1N and WCSF-115-9/3-1N with an outer sealing sleeve WCSF-200-18/5-4N with 1″ (25 mm) seal lengths. No bolt pad was used. This arrangement establishes 1″ (25 mm) of seal length and 1.9x use range, based on cable and shim diameters and a 2.5x use range over the connection hardware. Six samples were constructed (Samples #46 to #48 and #61 to #63).

3. Cable sample used cable #2, 4 AWG (Appendix 1) with one side shimmed with 2″ (50 mm) WCSF-200-18/5-2N and WCSF-300-28/8-2N and the other side shimmed with one 2″ (50 mm) WCSF-300-28/8-2N, two hole lugs secured with bolts, washers and nuts, a fiber bolt pad and an outer sealing sleeve WCSF-500-38/13-12N. This set used 2″ (50 mm) seal lengths and 1.4x maximum expansion for the tubing based on the cable and shims diameters and a 2.5x use range over the connection hardware. This configuration is shown above (Figure 3) except for the single shim side of the splice. Six samples were constructed (Samples #49 to #51 and #64 to #66).

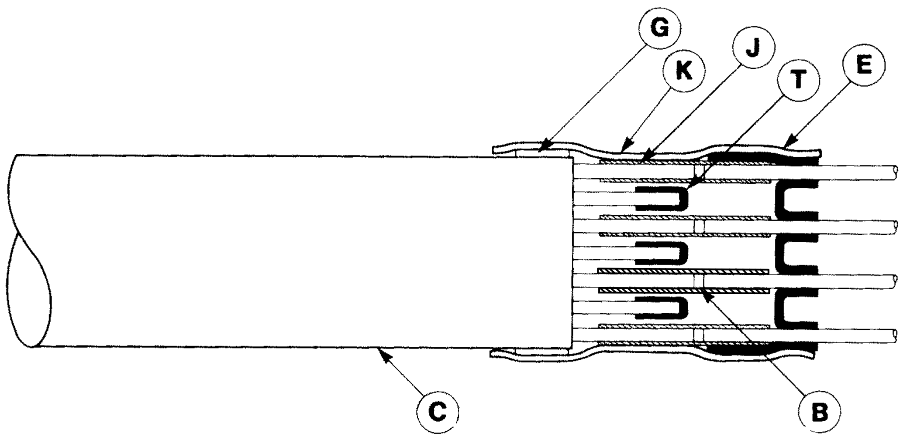
4. Cable samples identical to configuration #1 except outer sealing sleeve made out of the old formulation WCSF 200-7N with 2″ (50 mm) seal lengths. Six samples were constructed (Samples #52 to 54 and #67 to #69).

5. Cable samples identical to configuration #1 except each side shimmed with 2″ (50 mm) of the old WCSF 070-2N. Six samples were constructed (Samples #55 to #57 and #70 to #72).

Half of the samples were aged and irradiated for an equivalent of 40 years (90°C) and half were unaged. All samples were exposed to LOCA conditions.

7.2.3 Nuclear Plant Transition Splices

Figure 4 illustrates the general construction of the Nuclear Plant Transition Splice.



Key	Component	Description
E	502A812-52/144-N	Conductor sealing breakout
G	WCSF-300-28/8-1N	Cable jacket shim
T	101A021-52/144N	End cap
C	7/C #14 AWG wire	Seven conductor wire
B	Crimp connector	3/4″ long
J	WCSF-070-6/2-3N	Conductor sealing tubing
K	WCSF-500-38/13-12N	Rejacketing tubing

Figure 4: Nuclear plant transition splice.

This type test verifies the performance of the transition and multi-conductor splice configuration (Figure 4). In this configuration, a 7 conductor #14 cable (Cable #7 - Appendix 1) was prepared by stripping the overall jacket to expose the core conductors. Three of the seven core conductors were capped off with molded end caps and four conductors were spliced to 1/C #14 wires using WCSF tubing with a 1″ seal length and a 2.0x use range. These 1/C wires passed through a 4-leg cable breakout. The splice area was covered with a rejacketing tube that spanned from cable jacket shim over the jacket of the multi-conductor cable (2″ overlap) to the body of the breakout (2″ overlap). Samples were installed on a flat tray. The sample construction procedure was consistent with the guidance provided in Raychem installation instructions and is documented in

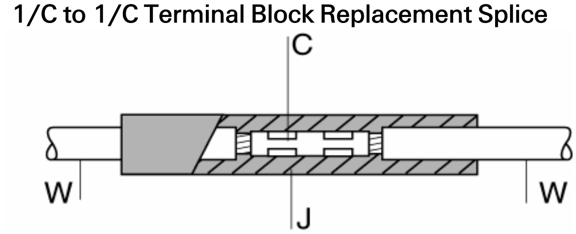
Raychem Laboratory Book #17923. The end caps facilitated configuration of the test specimens but were not being qualified by these test samples.

Eight samples of this splice were tested; seven samples were aged to 40-year (90°C) equivalent life and ambient radiation (Samples #80 to #82 and #84 to #87) and one was unaged (Sample #83). All samples were subjected to LOCA conditions.

7.2.4 Terminal Block Replacement Kit

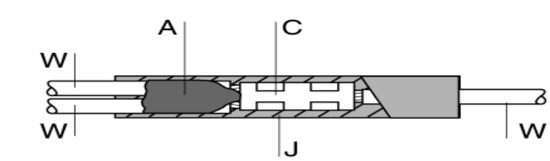
Figure 5 illustrates the general construction of the three different configurations of the terminal block replacement splice.

1/C to 1/C Terminal Block Replacement Splice

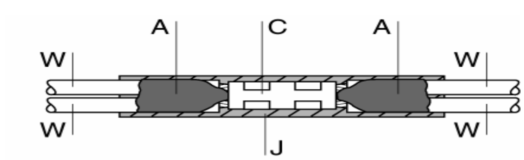


Key	Component	Description
W	1/C #16 AWG wire	Single core wire
C	D-609-07	Crimp sleeve
J	WCSF-115-9/3-3N	Splice sealing tube

2/C to 1/C Term. Block Replacement Splice



2/C to 2/C Term. Block Replacement Splice



Key	Component	Description
W	1/C #16 AWG wire	Single core wire
C	D-609-08	Crimp sleeve
J	WCSF-115-9/3-3N	Splice sealing tube
A	S1119-2N	Nuclear adhesive

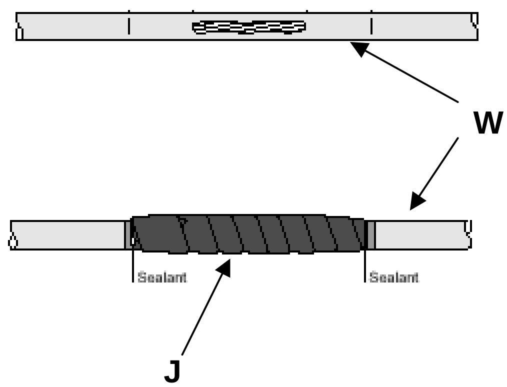
Figure 5: Terminal block replacement kit.

These specimens were used to establish qualification of WCSF-115-9/3-N tubing as a terminal block replacement system for three specific conductor combinations, a 1/C to 1/C crimp connection, a 1/C to 2/C crimp connection and a 2/C to 2/C crimp (Figure 5). In all configurations, a #16 cable (Cable #5 - Appendix 1) was used to construct the samples. For each 2/C crimp connection, a strip of S1119-2N was used to seal the crotch area in lieu of a cable breakout boot, which is the conventional multi-conductor sealing technique. The seal length was 1″ (25 mm) with an application range of 2.0x on the 2/C side (based on cable OD and the volume of S1119-2N) and 1.0x on the 1/C side. All the specimens were installed on a mandrel with an overall diameter of 13.5″. The sample construction procedure was consistent with the guidance provided in Raychem WCSF installation instructions and is documented in Raychem Laboratory Book # 17923.

For each of the three configurations six splices were constructed (total of 18 splices); half were aged and irradiated for equivalent of 40 years of life (90°C) and half were unaged. The sample designations (aged and then unaged) are as follows: 1/C to 1/C (Samples #88 to #90 and #91 to #93), 2/C to 1/C (Samples #94 to #96 and #97 to #99), 2/C to 2/C (Samples #100 to #102 and #103 to #105). All samples were exposed to the LOCA conditions.

7.2.5 Nuclear Grade NJRT Jacket Repair Sealing Tape

Figure 6 illustrates the general construction of the jacket repair sealing tape.



Key	Component	Description
W	Cable	1/C Wire
J	WBTF	Nuclear Jacket Repair Tape

Figure 6: Jacket repair sealing tape.

These specimens used to establish qualification of WBTF tape used in the NJRT heat shrinkable tape kits used as splice insulating materials over damaged cable insulation.

Six samples of NJRT were installed on #4 AWG XLPE insulated, Hypalon jacketed cable (Cable #2 - Appendix 1) with the jacket and insulation removed to expose the conductor over a distance of 0.25 inch. The jacket was further removed to provide a minimum of 2" (50 mm) seal length to the XLPE insulation on each side of the defect (Samples #109 to #111 and #115 to #117).

The samples were installed on a 13.5" diameter mandrel.

The sample construction procedure was consistent with the guidance provided in Raychem installation instructions and is documented in Raychem Laboratory Book # 17923. Five of the samples (Samples #109, #110, #111, #116 and #117) were aged to the equivalent of a 40-year life (90°C) and ambient radiation dose and the one (Sample #115) was unaged. All samples were subjected to the LOCA conditions.

8. 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	8.2
2	Sample preconditioning (where needed)	8.3
3	Pre-exposure functional tests	8.2
4	LOCA & MSLB environmental exposure	8.4
5	Post-exposure functional tests	8.2

Table 2: Type test sequence.

8.1 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. The samples were visually inspected by Raychem for proper installation and mounting.
2. After heat aging. The samples were visually inspected by Wyle.
3. After radiation. The samples were visually inspected by Wyle.
4. After LOCA exposure. The samples were visually inspected by Raychem and Wyle.

No visual damage was observed during any of inspection at any of the hold points except as discussed in the results section regarding the after LOCA conditions.

8.2 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 specimens mounted on either the test mandrels or cable trays, as applicable.

8.2.1 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. Post-LOCA, the lead wire condition for some samples did not allow testing as outlined above. In these cases the test method depended on proximity of the lead wire damage to the Raychem test sample. If the wire damage location permitted immersion of the Raychem test sample, IR measurements were carried out as outlined above except only the Raychem test sample and a short length of lead wire were underwater. If the damage precluded immersion of the Raychem test sample, IR measurements were carried out by wrapping the splice with a soaked paper towel to act as the ground plane and 500 volts was applied for 1 minute while the measurement was taken.

8.2.2 AC Voltage Withstand

An AC voltage withstand test was performed to test samples based on the guidance of IEEE 383-1974. 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. Applied voltage for cable sizes are listed below (Table 3). Consistent with prior Raychem qualification test practices, the cable thickness was used to define the test voltage. Thin wall PEEK insulation resulted in a relatively low voltage (800 Vac), however the tubing used for splicing such a cable (WCSF-070-6/2-N) was also tested with other cables (e.g., cable #6) at higher voltages.

Cable Number	Insulation material	Insulation Thickness (in)	Applied voltage (Vac)
2	XLPE	0.045	3600
4	XLPE	0.03	2400
5	XLPE	0.03	2400
6	XLPE	0.03	2400
7	XLPE	0.03	2400
9	PEEK	0.01	800

Table 3: Applied voltage values for the different types of cables used.

The water bath was used as the ground plane for the AC voltage withstand tests. Post-LOCA, the lead wire condition of some samples did not allow testing as outlined above. In these cases the test method depended on proximity of the lead wire damage to the Raychem test sample. If the wire damage location permitted immersion of the Raychem test sample, the withstand test was carried out as outlined above except only the Raychem test sample and a short length of lead wire were underwater. If the damage precluded immersion of the Raychem test sample, the tests were carried out by wrapping the splice with a soaked paper towel to act as the ground plane while the voltage was applied for 5 minutes to the conductor.

8.3 Sample Preconditioning

8.3.1 Temperature Aging

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 is described in Raychem reports EDR 5331 and EDR 5332, respectively. The specimens were thermally aged while mounted on the test mandrels or cable trays, as applicable. A short portion of the specimen lead wires was routed outside the aging oven and was not exposed to thermal aging. This was intended to prevent problems when splicing specimen lead wires to vessel penetration leads before the LOCA simulation.

8.3.1.1 40 Year Thermal Aging for tubing and molded parts

Each set of samples, which was tested for an equivalent of 40 years of life, was thermally 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).

Furthermore, six samples of the In-Line Splice configuration have been aged for an extended period of 1379 hours at 150°C.

8.3.2 Radiation

The specimens were exposed to a total cumulative exposure representing the radiation dose expected over the installed lifetime (0 or 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 5 shows the irradiation logs and Appendix 6 contains information on errors in these irradiation logs. Section 9.1 discusses these deviations from the planned exposure.

8.3.2.1 Aged Specimens Accumulated Dose and Design Basis Events (DBE)

The planned exposure for the forty year equivalent thermally aged samples 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 383-1974) and a design basis event exposure of $1.65X10^8$ rads ($1.50X10^8$ rads plus 10% Margin).

Six samples were to be subjected to a planned irradiation dose of $2.40X10^8$ rads.

8.3.2.2 New Samples Design Basis Events (DBE)

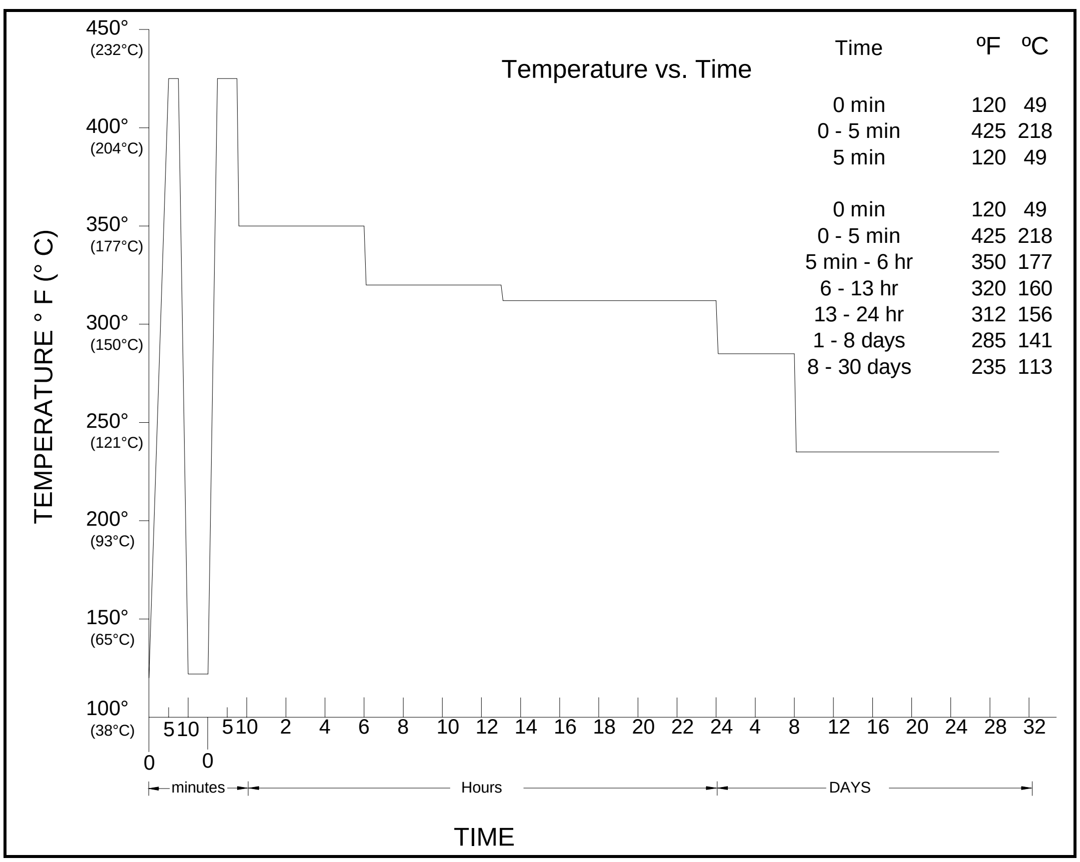
The planned exposure for the un-aged samples of each test configurations was to a nominal air gamma radiation dose equivalent to $1.65X10^8$ rads.

8.4 LOCA Environmental Exposure

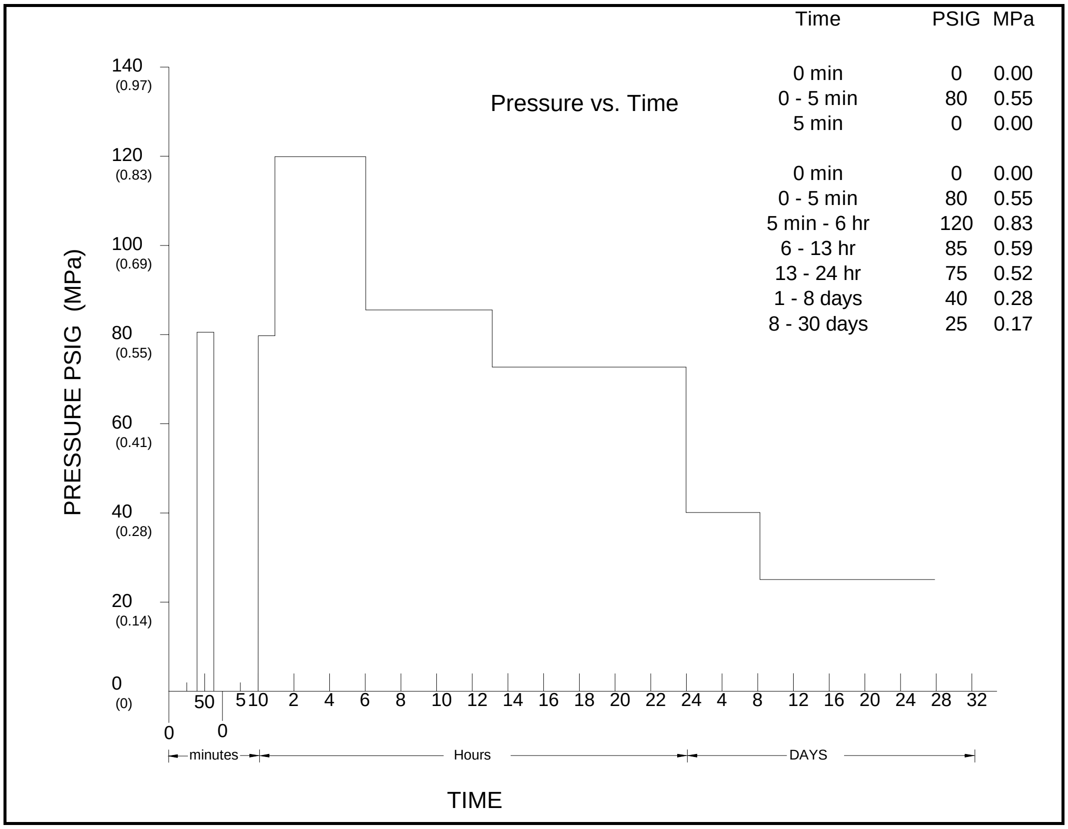
8.4.1 Environment Conditions

The planned time/temperature/pressure profile for all type test sample configurations is shown in Figure 7. Appendix 2 shows the actual time/temperature/pressure graphs as measured during the environmental exposure.

The first ramp was performed using superheated steam. The duration was only 8 minutes. Superheated steam was used for the first 8 minutes of the second ramp. At the 8-minute point, the test requirements were 350°F and 120 psig, which is saturated. Saturated steam was used from the 8-minute point until the end of the test.



(A) Temperature profile



(B) Pressure profile

Figure 7: LOCA profile

8.4.2 Chemical Spray

Type test samples were sprayed with chemical solution after reaching the 320ºF plateau (at approximately 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 323-74 Table A1). 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.

8.5 Sample Mounting, Connection, and Monitoring

8.5.1 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. (IEEE 383-1974 2.3.3.1). All the sample trays and mandrels were solidly grounded to the mounting frame, which was in turn grounded to the test chamber.

8.5.2 Test set-up

8.5.2.1 Accessory connections and Marking

Test vessel penetrations used Teflon wires having a larger wire gauge than the test specimens. 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 using Raychem Shrinkmarks.

8.5.2.2 Equipment Sources, Fusing, and Monitoring

Fifteen 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 show samples that represent configurations not included in this report.

8.5.2.3 Voltage and current requirements

Applied voltage for each sample 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.

8.5.2.4 Monitoring

Calibrated monitoring test equipment was used to detect changes in variables monitored against a change in time. (Refer to IEEE 323-1974 section 6.3.1.4). 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.

8.6 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 Table 3).

Performance of the test specimens during the environmental simulation was based on:

1. The ability to maintain electrical loading at rated voltage and current during the environmental simulation.

8.6.1 Insulation performance

During environment exposure, Insulation Resistance (IR) measurements were taken to evaluate insulation performance. IR measurements were performed prior to transient 1, prior to transient 2, at the 213-hour point, the 386-hour point, and at the 720-hour point (the end of the exposure) with the specimens still at temperature. Measurements were carried out on the test circuits and not on the individual samples (except for those carried out prior to transient 1).

Due to the large number of specimens, it was not possible to take IR measurements during the transient peak conditions. It is Raychem's position that the IR values of qualified test specimens and test circuits are not adversely affected by the Raychem splices. Given the form, fit and function similarity of these test specimens and compound materials to previously tested specimens using the old formulations, Raychem concludes that the IR values measured in these previous programs are representative for components using the new formulations. Subsequent testing as reported in EDR -5389 indicates that there is a measurable reduction in insulation resistance caused by the application of the splice. The exact cause has not been determined due to the limited number of various specimen configurations tested.

9. RESULTS AND DISCUSSION

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 and all specimens and mounting conformed to Raychem requirements. The test specimens were visually inspected and subjected to the functional tests described in Section 8.2 before thermal aging, irradiation and the environmental exposure. All specimens did not show any signs of damage and passed the functional tests. The functional tests were also carried out on the samples after the LOCA simulation as part of the post LOCA evaluation.

Many of the test samples completed the whole test program and passed the test requirements successfully. However, some test circuits exhibited anomalies during the LOCA exposure and were de-energized for sometime during the test. A thorough investigation was carried out at the end of the LOCA exposure to determine the reasons for these anomalies. Each sample was individually examined to determine the cause of the problem.

The following sections discuss the final results.

9.1 Radiation deviations from planned exposure

As mentioned in Section 4, due to an error in reporting the irradiation dose, the actual dosages the samples received were less than the target values (Appendix 6).

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 150 Mrads +10% margin. Given the actual doses applied to the samples (minimum of 196.4 Mrads), and maintaining a DBE of 150 Mrads, the samples were subjected to a minimum of 46.4 Mrads of aging irradiation (equivalent to 37.12 years of life instead of 40 years).

If the DBE dose is to be reduced to 140 Mrads, the total amount of radiation will represent the 40 years of simulated life plus the DBE with 4.6% of margin, respectively. Table 4 explains how to interpret these doses.

Target dose (rad)	Minimum actual dose (rad)	DBE (rad)	Normal life dose (rad)	Equivalent life (years)	Margin %
2.15E+08	1.964E+08	1.50E+08	4.64E+07	37.12	-
2.15E+08	1.964E+08	1.40E+08	5.00E+07	40	4.6

Table 4: Normal life and DBE doses based on actual irradiation values.

Six additional samples were intended to be subjected to a total dose of 240 Mrads. The actual exposure dose was 218 Mrads.

9.2 LOCA simulation deviations from planned profile

Transient 1: During the performance of the first transient (including preheating), circuits 18-amp (5), 25-amp (1), 25-amp (2), 25-amp (3) and 25-amp (5) experienced high leakage currents that resulted in blown leakage-current fuses. The following comments pertain to these circuits:

Circuit 18A (5): The voltage was normal during pre-heat and the transient. Circuit current was on and normal during the transient. However, the circuit current dropped and returned during pre-heat. From the looks of the plot, it may have been operator error in the adjustment. No measurable leakage current was recorded.

Circuit 25A (1): The fuse in the voltage circuit opened during pre-heat. Voltage was restored prior to the ramp and maintained throughout transient 1. Circuit current was sporadic during pre-heat but mostly stable during the transient. Leakage current was mostly stable at approximately 130mA during the transient.

Circuit 25A (2): The voltage circuit fuse opened during pre-heat but was restored prior to the ramp and maintained throughout transient 1. Circuit current was stable during pre-heat and the transient.

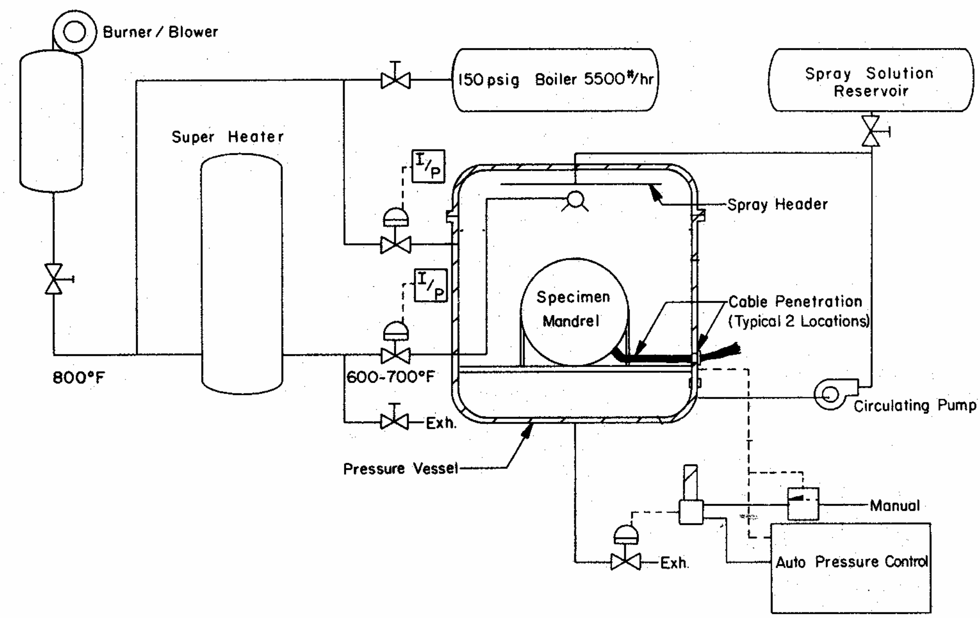
Circuit 25A (3): The voltage circuit fuse opened during pre-heat. The voltage was restored prior to the ramp and maintained throughout transient 1. Circuit current was very unstable during pre-heat and the transient but was maintained throughout the transient.

Circuit 25A (5): The voltage was normal during pre-heat and transient 1. Circuit current actually went up to approximately 35 amps during the transient. The cause is unknown but was most probably a technician error in adjustment. The Leakage current was somewhat stable at approximately 140mA during the transient.

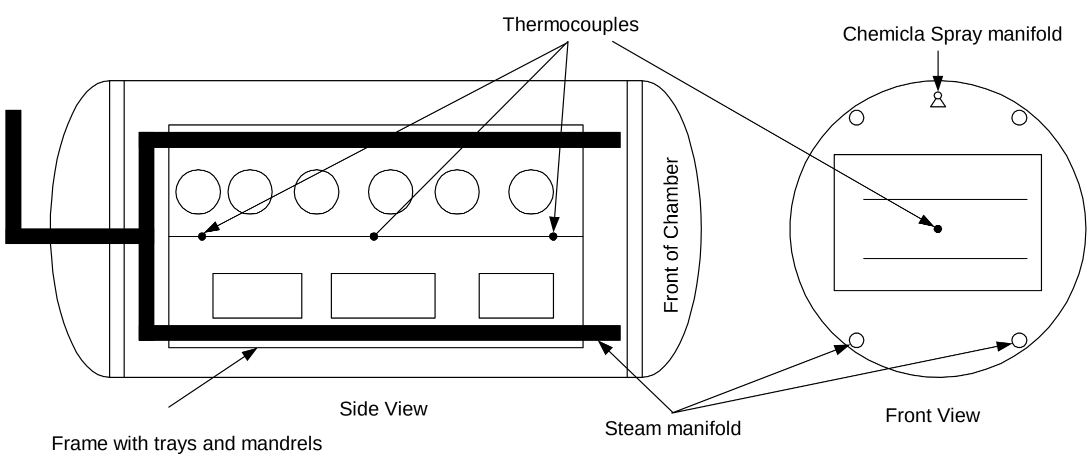
Following the completion of the first transient, and during its cool down, it was discovered that the wiring, external to the test chamber, had overheated and the insulation had melted, thus allowing the wires to come into contact with each other and ground. The overheating was caused by bundling of the wires (which were rated at 105° C) and retained the heat generated by the current flowing through them. The wires that were connected directly to the specimens and exited the chamber were Teflon insulated and were rated for 200°C. Those wires exited the potted penetrations and were approximately 12″ to 24″ long outside the chamber. The PVC-insulated wires were spliced (outside the chamber) to the Teflon-insulated wires and routed to the powering circuits. The PVC-insulated wires were bundled for neatness but once the problem was found, the damaged external wiring was replaced with Teflon insulated wire (between transients 1 and 2) and the wires were not re-bundled. Additionally, before the second transient was performed, an inspection was performed on the Teflon-insulated wires that exited the potting. No problems were identified with those wires. The test chamber was not opened between transients. Following the completion of the LOCA test, when the chamber was opened, the Teflon-insulated wires inside the chamber (connected to the specimens) were inspected and found to be in excellent condition. However, no inspection was carried out on the wire imbedded in the potting material in the chamber penetration conduits.

Transient 2: The temperature profile during the LOCA simulation dropped below the designed value at four occasions due to malfunction of the control equipment. The deviation took place in three occasions during the 285°F plateau (totaling 5 hours and 15 minutes) and one time during the 235°F plateau (lasting for 11 hours and 30 minutes). In both cases, the duration of the LOCA simulation time at the respective temperature was extended by an equal length to compensate for time under the required temperature. A chronological account of the events during the LOCA simulation is provided in Appendix 7

Figure 8 shows a schematic diagram of the LOCA test chamber.



(A)



(B)

Figure 8: LOCA pressure vessel and auxiliary equipment.

Figure 9 shows a picture of the LOCA simulation chamber after the conclusion of the test.

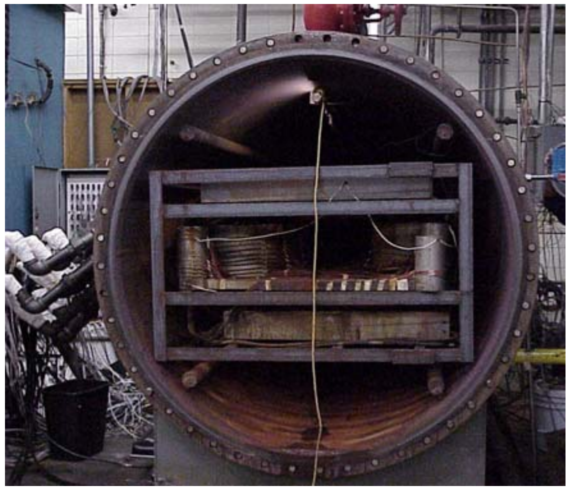


Figure 9: LOCA simulation test chamber after the test.

9.3 In-Line Splice with Crimp Connector

This category included a total of 39 samples. Table 5 shows a list of samples and a summary of the qualification test results.

SPECIMEN NO.	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rad) Actual	Test Circuit	Time Energized Trans1/Trans2	RESULTS
1*	1	878 hr @ 302°F	1.964E+08	18A(8)	8 min/24.7 hrs	Qualified
2	1	878 hr @ 302°F	1.964E+08	18A(8)	8 min/655.9 hrs	Qualified
3	1	878 hr @ 302°F	1.964E+08	18A(8)	8 min/655.9 hrs	Qualified
4	1	878 hr @ 302°F	1.964E+08	18A(8)	8 min/655.9 hrs	Qualified
5*	1	878 hr @ 302°F	1.964E+08	18A(8)	8 min/24.7 hrs	Qualified
6*	1	878 hr @ 302°F	1.964E+08	18A(8)	8 min/24.7 hrs	Qualified
7	1	878 hr @ 302°F	1.964E+08	25A(3)	8 min/728.3 hrs	Qualified
8	1	878 hr @ 302°F	1.964E+08	25A(3)	8 min/728.3 hrs	Qualified
9	1	878 hr @ 302°F	1.964E+08	25A(3)	8 min/728.3 hrs	Qualified
10	1	878 hr @ 302°F	1.964E+08	25A(3)	8 min/728.3 hrs	Qualified
11	1	878 hr @ 302°F	1.964E+08	25A(3)	8 min/728.3 hrs	Qualified
12	1	878 hr @ 302°F	1.964E+08	25A(3)	8 min/728.3 hrs	Qualified

Table 5: In-Line Splice with Crimp Connector qualification results. Radiation dose represent (accident + ambient) for aged samples or accident only for unaged samples.

SPECIMEN NO.	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rad) Actual	Test Circuit	Time Energized Trans1/Trans2	RESULTS
13	2	N/A	1.487E+08	18A(8)	8 min/655.9 hrs	Qualified
14*	2	N/A	1.487E+08	18A(8)	8 min/435.9 hrs	Qualified
15	2	N/A	1.487E+08	18A(8)	8 min/655.9 hrs	Qualified
16	2	N/A	1.487E+08	18A(8)	8 min/655.9 hrs	Qualified
17	2	N/A	1.487E+08	18A(8)	8 min/655.9 hrs	Qualified
18*	2	N/A	1.487E+08	18A(8)	8 min/82.7 hrs	Qualified
19	2	N/A	1.487E+08	25A(2)	8 min/728.3 hrs	Qualified
20	2	N/A	1.487E+08	25A(2)	8 min/728.3 hrs	Qualified
21	2	N/A	1.487E+08	25A(2)	8 min/728.3 hrs	Qualified
22	2	N/A	1.487E+08	25A(2)	8 min/728.3 hrs	Qualified
23	2	N/A	1.487E+08	25A(2)	8 min/728.3 hrs	Qualified
24	2	N/A	1.487E+08	25A(2)	8 min/728.3 hrs	Qualified
25*	3	878 hr @ 302°F	1.964E+08	18A(8)	8 min/95.7 hrs	Qualified
26	3	878 hr @ 302°F	1.964E+08	18A(8)	8 min/655.9 hrs	Qualified
27*	3	878 hr @ 302°F	1.964E+08	18A(8)	8 min/24.7 hrs	Qualified
31	4	N/A	1.487E+08	18A(8)	8 min/655.9 hrs	Qualified
32*	4	N/A	1.487E+08	18A(8)	8 min/94.4 hrs	Qualified
33	4	N/A	1.487E+08	18A(8)	8 min/655.9 hrs	Qualified
37	5	1379 hr @ 302°F	2.184E+08	18A(1)	8 min/727.3 hrs	Qualified
38	5	1379 hr @ 302°F	2.184E+08	18A(1)	8 min/727.3 hrs	Qualified
39	5	1379 hr @ 302°F	2.184E+08	18A(1)	8 min/727.3 hrs	Qualified
40	5	1379 hr @ 302°F	2.184E+08	18A(1)	8 min/727.3 hrs	Qualified
41*	5	1379 hr @ 302°F	2.184E+08	18A(2)	8 min/216.5 hrs	Qualified
42	5	1379 hr @ 302°F	2.184E+08	18A(2)	8 min/727.3 hrs	Qualified
124	3	878 hr @ 302°F	1.964E+08	18A(8)	8 min/655.9 hrs	Qualified
125	3	878 hr @ 302°F	1.964E+08	18A(8)	8 min/655.9 hrs	Qualified
126	3	878 hr @ 302°F	1.964E+08	18A(8)	8 min/655.9 hrs	Qualified
127	4	N/A	1.487E+08	18A(8)	8 min/655.9 hrs	Qualified
128*	4	N/A	1.487E+08	18A(8)	8 min/95.7 hrs	Qualified
129*	4	N/A	1.487E+08	18A(8)	8 min/95.7 hrs	Qualified
130	3	878 hr @ 302°F	1.964E+08	25A(1)	0 min/728.3 hrs	Qualified
131	3	878 hr @ 302°F	1.964E+08	25A(1)	0 min/728.3 hrs	Qualified
132	3	878 hr @ 302°F	1.964E+08	25A(1)	0 min/728.3 hrs	Qualified

Table 5: In-Line Splice with Crimp Connector qualification results (cont.). Radiation doses represent (accident + ambient) for aged samples or accident only for unaged samples. The samples identified by Asterisks were not energized throughout the entire LOCA exposure.

The total durations of the transients were – Transient #1: 8 minutes and Transient #2: 728.3 hours. Some specimens were not energized for the entire duration because they were in circuits that experienced performance problems with other specimens. These specimens are considered to meet the criteria of being energized throughout the entire LOCA simulation. The samples identified by Asterisks (Table 5) were not energized throughout the entire LOCA exposure. These samples were removed at different times after the leakage current fuses of their respective circuits had blown and their sample loops were identified as problematic during troubleshooting. Full investigation of these samples could not be done until the end of the test. After depressurization and cool down from the LOCA simulation, the test vessel was opened and the test specimens carefully removed by cutting the test leads inside the chamber. The asterisk marked specimens and test leads were removed from the mandrel or tray and carefully examined to identify damage. These specimens were then subjected to immersion IR testing to identify any obvious degradation or damage. Table 6 summarizes the results of these examinations and IR tests. Upon careful investigation, the splices were found to be intact. For 10 of the 11 specimens, no reason for anomalous behavior during the LOCA was found on the specimens or the removed portion of the leads. On one specimen, a nick was found on the attached Wyle test lead.

Subsequently, all the specimens were subjected to and passed the specified post-LOCA functional tests. During this test, the nicked portion of the Wyle test lead on specimen 14 was not submerged. All the function test results are presented in Table 7.

SPECIMEN	IR with the splice only submersed	IR with the splice and available sample leads submersed	Results / Remarks
1	1.5E12	1.2E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
5	2.0E12	1.0E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
6	1.5E12	1.0E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
14	3.0E11	Short	Wyle test lead was nicked.
18	2.0E12	1.5E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
25	2.0E12	1.5E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
27	3.0E12	1.4E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
32	1.6E12	1.3E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
41	4.0E12	2.0E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
128	1.5E12	1.0E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
129	2.0E12	1.0E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber

Table 6: Results of examination of the asterisk marked samples in Table 5.

These 11 samples are considered to be qualified based on successful completion of the post-LOCA examinations and tests and the fact that similarly constructed specimens passed the entire test program, the functional tests, and satisfied the acceptance criteria. Further, it is noted that approximately one-half of the 11 asterisk marked specimens were unaged and one-half were aged. This indicates that the problems encountered during the LOCA simulation were not related to the samples or their aging.

Table 7 shows the functional test results of the samples at the different test stages.

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	5.0E10	800	210	3.5E09	800	200	5.0E11	800	215	1.5E12	800	75
2	4.0E10	800	190	1.0E10	800	200	6.0E11	800	210	2.0E12	800	200
3	5.0E10	800	200	2.2E09	800	200	3.0E11	800	200	3.0E12	800	220
4	5.0E10	800	200	2.6E09	800	210	5.0E11	800	200	5.0E12	800	230
5	5.1E10	800	210	8.2E09	800	210	6.2E11	800	200	2.0E12	800	65
6	5.3E10	800	200	6.0E09	800	200	5.0E11	800	200	1.5E12	800	65
7	5.0E10	2400	380	5.0E09	2400	360	1.2E11	2400	340	1.4E12	2400	207
8	5.0E10	2400	380	1.4E10	2400	360	1.3E11	2400	340	2.2E12	2400	215
9	5.8E10	2400	380	6.4E09	2400	340	1.2E11	2400	325	2.0E12	2400	225
10	5.0E10	2400	400	3.5E10	2400	340	1.2E11	2400	325	2.2E12	2400	225
11	6.2E10	2400	400	3.5E10	2400	340	1.4E11	2400	325	4.0E12	2400	440
12	5.8E10	2400	380	6.2E09	2400	340	1.4E11	2400	350	8.0E12	2400	235
13	2.6E12	800	185	N/A	N/A	N/A	4.0E11	800	190	5.0E12	800	225
14	8.0E10	800	210	N/A	N/A	N/A	5.0E11	800	190	3.0E11	800	65
15	6.2E10	800	200	N/A	N/A	N/A	3.5E11	800	200	1.4E13	800	215
16	1.0E12	800	205	N/A	N/A	N/A	3.0E11	800	200	6.0E12	800	230
17	6.4E10	800	210	N/A	N/A	N/A	2.6E11	800	190	5.0E12	800	230
18	6.6E10	800	200	N/A	N/A	N/A	5.0E11	800	190	2.0E12	800	75
19	6.0E10	2400	380	N/A	N/A	N/A	5.0E11	2400	360	3.0E12	2400	460
20	6.2E10	2400	370	N/A	N/A	N/A	4.0E11	2400	340	5.0E12	2400	450
21	6.4E10	2400	390	N/A	N/A	N/A	5.8E11	2400	340	1.5E11	2400	420
22	7.0E10	2400	390	N/A	N/A	N/A	6.4E11	2400	340	2.0E12	2400	220
23	6.8E10	2400	390	N/A	N/A	N/A	6.4E11	2400	340	3.0E10	2400	240
24	7.0E10	2400	380	N/A	N/A	N/A	6.0E11	2400	350	2.5E12	2400	450
25	1.0E12	800	205	1.2E10	800	180	7.0E11	800	200	2.0E12	800	260
26	1.2E12	800	200	1.1E10	800	200	7.0E11	800	200	5.0E12	800	550
27	1.4E12	800	200	2.8E10	800	180	6.4E11	800	220	3.0E12	800	75
31	6.0E09	800	200	N/A	N/A	N/A	5.1E11	800	200	8.0E12	800	500
32	2.4E12	800	200	N/A	N/A	N/A	5.0E11	800	190	1.6E12	800	65
33	1.6E10	800	200	N/A	N/A	N/A	8.4E11	800	190	8.0E12	800	500

Table 7: Functional test results of the In-Line Splice with Crimp Connector.

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
37	7.0E11	800	215	7.6E10	800	160	4.0E11	800	190	5.0E12	800	240
38	7.0E11	800	195	7.6E10	800	160	4.5E11	800	190	4.5E12	800	260
39	6.0E11	800	210	1.0E11	800	160	9.0E11	800	200	3.5E12	800	240
40	6.4E11	800	220	1.2E11	800	160	5.0E11	800	200	3.0E12	800	230
41	6.0E11	800	225	1.0E11	800	160	5.0E11	800	190	4.0E12	800	65
42	6.0E11	800	225	1.2E11	800	160	5.0E11	800	190	2.8E12	800	230
124	1.1E11	800	275	7.2E10	800	200	5.2E11	800	220	6.0E12	800	550
125	1.0E11	800	210	1.0E11	800	200	5.0E11	800	210	1.4E12	800	600
126	1.0E11	800	220	8.0E10	800	180	5.0E11	800	220	5.0E12	800	250
127	4.0E10	800	185	N/A	N/A	N/A	4.5E11	800	190	6.4E12	800	500
128	5.0E10	800	200	N/A	N/A	N/A	4.5E11	800	200	1.5E12	800	65
129	6.4E10	800	185	N/A	N/A	N/A	4.5E11	800	190	2.0E12	800	270
130	1.1E11	2400	380	1.4E11	2400	370	1.3E11	2400	360	4.5E12	2400	600
131	1.2E11	2400	400	1.3E11	2400	380	1.2E11	2400	380	6.0E12	2400	230
132	1.0E11	2400	380	1.3E11	2400	380	1.3E11	2400	360	7.0E12	2400	550

Table 7: Functional test results of the In-Line Splice with Crimp Connector (Cont.)

Table 8 shows the IR measurements carried on the monitoring circuits during the LOCA exposure.

Circuit	Pre 1st peak	Pre 2nd peak	213 hr point	386 hr point	720 hr point
18A(1)	4.0E10 @500 VDC	6.4E10 @500 VDC	1.5E6 @500 VDC	1.1E6 @10 VDC	2.0E5 @10 VDC
18A(2)	1.2E11 @500 VDC	1.2E11 @500 VDC	7.6E7 @500 VDC	3.5E6 @500 VDC	3.5E6 @500 VDC
18 A (8)	2.2E10 @500 VDC	1.5 E10 @500 VDC	6.4E06 @500 VDC	7.0E06 @500 VDC	4.0E06 @500 VDC
25 A (1)	2.6E10 @500 VDC	1.2E09 @500 VDC	1.0E08 @500 VDC	4.0E07 @500 VDC	1.3E07 @500 VDC
25 A (2)	4.0E10 @500 VDC	1.1E11 @500 VDC	3.0E08 @500 VDC	3.0E06 @500 VDC	4.0E06 @500 VDC
25 A (3)	2.6E10 @500 VDC	6.8E10 @500 VDC	4.0E06 @500 VDC	1.4E06 @500 VDC	5.4E05 @100 VDC

Table 8: IR measurements during LOCA simulation.

The results demonstrate the qualification of in-line splices with 1″ (25 mm) seal length. These results can be extended to other WCSF configurations (e.g., bolted connections) when the 1″ (25 mm) seal length is applied over qualified cable substrates. The results also demonstrate the qualification of in-line splices with a 2.5x cable substrate OD. However, the 2.5x results cannot be directly applied to configurations using the thin-wall WCSF-050 as a splice sealing sleeve. The results demonstrate the qualification of this tubing as an in-line splice sealing with a 1″ (25 mm) seal length and a maximum 1.4x cable substrate OD.

9.4 In-Line Splice with Bolted Connection

This category included a total of 30 samples. Table 9 shows the list of samples and summarizes the qualification test results.

SPECIMEN NO.	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rad) Actual	Test Circuit	Time Energized Trans1/Trans2	QUALIFICATION TEST RESULTS
43	6	878 hr @ 302°F	1.964E+08	30A (2)	8 min/724 hrs	Qualified
44	6	878 hr @ 302°F	1.964E+08	30A (2)	8 min/724 hrs	Qualified
45*	6	878 hr @ 302°F	1.964E+08	30A (2)	8 min/724 hrs	Failed
46	6	878 hr @ 302°F	1.964E+08	30A (2)	8 min/724 hrs	Qualified
47	6	878 hr @ 302°F	1.964E+08	30A (2)	8 min/724 hrs	Qualified
48	6	878 hr @ 302°F	1.964E+08	30A (2)	8 min/724 hrs	Qualified
49	Tray 2	878 hr @ 302°F	1.951E+08	95A	8 min/655.5 hrs	Qualified
50*	Tray 2	878 hr @ 302°F	1.951E+08	95A	8 min/6 hrs	Qualified
51	Tray 2	878 hr @ 302°F	1.951E+08	95A	8 min/655.5 hrs	Qualified
52	6	878 hr @ 302°F	1.964E+08	30A (1)	8 min/662 hrs	Qualified
53	6	878 hr @ 302°F	1.964E+08	30A (1)	8 min/662 hrs	Qualified
54	6	878 hr @ 302°F	1.964E+08	30A (1)	8 min/662 hrs	Qualified
55	6	878 hr @ 302°F	1.964E+08	30A (1)	8 min/662 hrs	Qualified
56	6	878 hr @ 302°F	1.964E+08	30A (1)	8 min/662 hrs	Qualified
57*	6	878 hr @ 302°F	1.964E+08	30A (1)	8 min/662 hrs	Failed
58	8	N/A	1.487E+08	30A (1)	8 min/662 hrs	Qualified
59	8	N/A	1.487E+08	30A (1)	8 min/662 hrs	Qualified
60	8	N/A	1.487E+08	30A (1)	8 min/662 hrs	Qualified
61*	8	N/A	1.487E+08	30A (1)	8 min/166.5 hrs	Qualified
62*	8	N/A	1.487E+08	30A (1)	8 min/121.75 hrs	Qualified
63	8	N/A	1.487E+08	30A (1)	8 min/662 hrs	Qualified
64	Tray 3	N/A	1.488E+08	95A	8 min/655.5 hrs	Qualified
65	Tray 3	N/A	1.488E+08	95A	8 min/655.5 hrs	Qualified
66	Tray 3	N/A	1.488E+08	95A	8 min/655.5 hrs	Qualified

Table 9: In-Line Splice with Bolted Connection qualification results. Radiation doses represent (accident + ambient) for aged samples or accident only for unaged samples. The samples identified by asterisks were not energized throughout the entire LOCA exposure.

SPECIMEN NO.	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rad) Actual	Test Circuit	Time Energized Trans1/Trans2	QUALIFICATION TEST RESULTS
67	8	N/A	1.487E+08	30A (1)	8 min/655.5 hrs	Qualified
68*	8	N/A	1.487E+08	30A (1)	8 min/75.5 hrs	Qualified
69	8	N/A	1.487E+08	30A (1)	8 min/662 hrs	Qualified
70	8	N/A	1.487E+08	30A (1)	8 min/662 hrs	Qualified
71*	8	N/A	1.487E+08	30A (1)	8 min/removed	Qualified
72*	8	N/A	1.487E+08	30A (1)	8 min/112.75 hrs	Qualified

Table 9: In-Line Splice with Bolted Connection qualification results (Cont.). Radiation doses represent (accident + ambient) for aged samples or accident only for unaged samples. The samples identified by asterisks were not energized throughout the entire LOCA exposure.

All the samples in this category passed the three acceptance criteria of Section 8.6, except those marked with asterisks. The total durations of the transients were – Transient #1: 8 minutes and Transient #2: 728.3 hours. Some specimens were not energized for the entire duration because they were in circuits that experienced performance problems with other specimens. These specimens are considered to meet the criteria of being energized throughout the entire LOCA simulation based on the fact that they were found intact with no evidence of failure and that similar samples have completed the requirements and passed the final tests. The samples identified by asterisks were not energized throughout the entire LOCA exposure. These samples were removed at different times after the leakage current fuses of their respective circuits had blown and their sample loops were identified as problematic during troubleshooting. Consequently, they could not be monitored or energized during the entire LOCA exposure. Full investigation of these samples could not be done until the end of the test. Specimens #45 and #57 were energized throughout the LOCA but failed during the post-LOCA immersion testing.

After depressurization and cool down from the LOCA simulation, the test vessel was opened and the test specimens carefully removed by cutting the test leads inside the chamber. The asterisk marked specimens and test leads were removed from the mandrel or tray and carefully examined to identify damage. These specimens were then subjected to immersion IR testing to identify any obvious degradation or damage. Table 10 summarizes the results of these examinations and IR tests. During the visual examination, it was observed that specimen #45 was split.

Upon careful investigation, all test splices were found to be intact except for specimen #45. Specimens #49 and #50 had lead wire damage and specimen #62 had a small split in the test lead connection splice. For specimens #61, #68, #71, and #72, no reason for anomalous behavior during the LOCA was found either on the specimens or the removed portion of the leads.

SPECIMEN	IR with the splice only submersed	IR with the splice and available sample leads submersed	Results / Remarks
45	Short	N/A	Longitudinal Split at the center of the splice
49	N/A	Short	Lead wires cracked and very brittle. Unable to submerge splice only without lead wires. Splice was wrapped in towel and soaked with tap water. IR = 9.0E11 Ω
50	N/A	Short	Lead wires cracked and very brittle. Unable to submerge splice only without lead wires. Splice was wrapped in towel and soaked with tap water. IR = 1.0E12 Ω
57	1.0E8	N/A	The specimen punctured during the AC withstand test.
61	1.0E12	5.0E11	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
62	1.5E12	Short	Small split found in the splice connecting the test leads to the sample leads.
68	4.0E12	1.0E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
71	N/A	1.5E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
72	1.5E12	1.0E12	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber

Table 10: Results of examination of the asterisk marked samples in Table 9.

Subsequently, all the specimens were subjected to the specified post-LOCA functional tests. Specimen #45 failed due to the longitudinal split. Specimens #49 and #50 could not be fully submerged due to the proximity of the lead wire cracks to the splice. These specimens were tested with the splice wrapped in a paper towel and soaked with water. All the function test results are presented in Table 11.

It can be seen that the anomalies leading to the high leakage currents and blown fuses during the LOCA simulation were not related to the test specimens, except for Samples # 45 and #57. The anomalous specimens were tested after the LOCA simulation and were found to satisfy the acceptance criteria with the exception of Samples #45 and #57. The anomalous samples, except for Samples #45 and #57, are considered to be qualified based on successful completion of the post-LOCA examinations and tests and the fact that similarly constructed specimens passed the entire test program, the functional tests, and satisfied the acceptance criteria (Section 8.6).

Sample #45, constructed without a bolt pad, was found to have suffered a longitudinal split at the center of the splice that corresponded to the position of a sharp edge of the washer used for the connection. Measurements showed that the WCSF tube was expanded to 2.5x at this position (the upper end of the new use range). Figure 10 shows the internal construction of Sample #45.

Figure 10: Sample #45 – Post LOCA.

Sample #57, also built without a bolt pad, punctured while performing the AC voltage withstand test. Again, the puncture corresponded to the position of a sharp edge of the washer used for the connection and measurements showed that the WCSF tube was expanded to 2.5x at this position (the upper end of the new use range).

Eighteen test samples (those using cable #4) had the WCSF tube expanded to 2.5x over the bolted connection hardware.

Table 11 shows the functional test results of the samples at the different test stages.

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
43	5.8E11	2400	440	1.1E11	2400	580	6.8E10	2400	575	9.2E12	2400	590
44	5.2E11	2400	460	1.4E11	2400	580	6.4E10	2400	580	4.5E12	2400	610
45	4.0E11	2400	440	1.3E11	2400	600	6.4E10	2400	560	Short	2400	>10k
46	3.5E11	2400	480	1.1E11	2400	580	5.4E10	2400	560	5.2E12	2400	270
47	4.0E11	2400	480	1.4E11	2400	580	5.4E10	2400	560	8.2E12	2400	610
48	5.6E11	2400	480	1.2E11	2400	580	5.6E10	2400	560	7.0E12	2400	620
49	2.0E10	3600	1000	5.0E11	3600	3000	5.0E10	3600	1100	9.0E11	3600	430
50	2.2E10	3600	1000	4.5E11	3600	3500	4.0E10	3600	1100	1.0E12	3600	460
51	2.4E10	3600	1000	4.0E11	3600	3500	3.5E10	3600	1100	7.8E11	3600	260
52	6.2E11	2400	460	1.3E11	2400	560	8.1E10	2400	520	1.0E13	2400	590
53	6.8E11	2400	460	1.4E11	2400	580	8.2E10	2400	540	1.1E13	2400	580
54	4.0E11	2400	460	1.6E11	2400	580	8.0E10	2400	520	5.4E12	2400	580
55	4.0E11	2400	460	1.2E11	2400	580	6.6E10	2400	540	6.2E12	2400	590
56	3.5E11	2400	440	1.5E11	2400	560	7.0E10	2400	520	6.2E12	2400	560
57	5.8E11	2400	460	1.1E11	2400	580	7.6E10	2400	520	1.5E8	2400	>10k
58	2.8E10	2400	420	N/A	N/A	N/A	2.6E11	2400	450	2.0E13	2400	540
59	2.4E10	2400	420	N/A	N/A	N/A	2.8E11	2400	440	1.2E13	2400	580
60	1.9E10	2400	420	N/A	N/A	N/A	2.6E11	2400	440	2.0E13	2400	560
61	1.9E10	2400	440	N/A	N/A	N/A	3.0E11	2400	440	1.0E12	2400	235
62	2.0E10	2400	420	N/A	N/A	N/A	3.0E11	2400	430	1.5E12	2400	240
63	1.8E10	2400	440	N/A	N/A	N/A	2.0E11	2400	440	1.1E13	2400	580
64	2.4E10	3600	1000	N/A	N/A	N/A	5.0E10	3600	920	1.0E11	3600	1150
65	3.0E10	3600	1200	N/A	N/A	N/A	4.5E10	3600	910	1.5E12	3600	1200
66	3.0E10	3600	1200	N/A	N/A	N/A	4.5E10	3600	900	1.4E12	3600	1100
67	2.0E10	2400	440	N/A	N/A	N/A	3.0E11	2400	430	1.1E13	2400	570
68	1.5E10	2400	420	N/A	N/A	N/A	3.5E11	2400	430	4.0E12	2400	245
69	1.7E10	2400	440	N/A	N/A	N/A	3.5E11	2400	440	1.2E13	2400	560
70	2.0E10	2400	440	N/A	N/A	N/A	2.8E11	2400	440	1.5E13	2400	560
71	1.6E10	2400	440	N/A	N/A	N/A	3.0E11	2400	440	1.5E12	2400	260
72	2.4E10	2400	420	N/A	N/A	N/A	3.0E11	2400	430	1.5E12	2400	260

Table 11: Functional test results of the In-Line Splice with Bolted Connector.

Table 12 shows the IR measurements carried on the monitoring circuits during the LOCA exposure.

Circuit	Pre 1st peak	Pre 2nd peak	213 hr point	386 hr point	720 hr point
30 A (1)	4.2E10 @500 VDC	4.5 E6 @500 VDC	3.5E06 @500 VDC	1.3E06 @100 VDC	1.4E05 @10 VDC
30 A (2)	1.0E11 @500 VDC	2.4E08 @500 VDC	5.8E05 @500 VDC	1.5E06@500 VDC	1.5E06@500 VDC
95 A	1.2E10 @500 VDC	2.0E10 @500 VDC	1.1E06 @500 VDC	2.0E05 @10 VDC	3.0E05 @10 VDC

Table 12: IR measurements during LOCA simulation.

The results confirm the equivalency of the tubing made from the new compound to that made from the old compound in Form, Fit and Function and the intermixability of the old and new tubing. The results also confirm the qualification of the tested configurations, including the 1" seal length and the expansion of the application range to 2.5x over both the bolted connection hardware and the cable substrates.

The anomalies of samples #45 and #57 suggest the use of bolt pads for all situations where the hardware may have sharp corners/edges or cause tube thinning. However, subsequent testing as reported in EDR-5389 did not provide enough evidence to support the use of WCSF -300 and smaller tubing over bolted splices above the 2.0 use range.

It must be noticed that during this testing it was necessary to stress, through accelerated aging and LOCA simulation, the WCSF compounds to demonstrate their integrity in an aged state. A natural result was that the cables, used as the substrates, were exposed to conditions beyond their qualification levels and thus anomalies were inadvertently introduced into the substrates. Therefore, cables are considered part of the test setup and this testing did not attempt to follow the original cable's qualification parameters and does not constitute a change in qualification for the cables in the test program.

9.5 Nuclear Plant Transition Splices

This category included a total of 8 samples. Table 13 shows the list of samples and summarizes the qualification test results.

SPECIMEN NO.	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rad) Actual	Test Circuit	Time Energized Trans1/Trans2	RESULTS
80 Black	Tray 1	878 hr @ 302°F	1.964E+08	25A (5)	8 min/591.25 hrs	Qualified
80 Blue					8 min/591.25 hrs	
80 Orange					8 min/591.25 hrs	
80 White					8 min/591.25 hrs	
81* Black	Tray 1	878 hr @ 302°F	1.964E+08	25A (5)	Removed after Transient 1	Qualified
81 Blue					8 min/591.25 hrs	
81 Orange					8 min/591.25 hrs	
81 White					8 min/591.25 hrs	
82 Black	Tray 1	878 hr @ 302°F	1.964E+08	25A (5)	8 min/591.25 hrs	Qualified
82 Blue					8 min/591.25 hrs	
82* Orange					Removed after Transient 1	
82 White					8 min/591.25 hrs	
83 Black	Tray 3	N/A	1.488E+08	25A (4)	8 min/643 hrs	Qualified
83 Blue					8 min/643 hrs	
83 Orange					8 min/643 hrs	
83 White					8 min/643 hrs	
84 Black	Tray 1	878 hr @ 302°F	1.964E+08	25A (5)	8 min/591.25 hrs	Qualified
84* Blue					8 min/49.25 hrs	
84* Orange					8 min/49.25 hrs	
84 White					8 min/546.5 hrs	
85 Black	Tray 1	878 hr @ 302°F	1.964E+08	25A (5)	8 min/591.25 hrs	Qualified
85* Blue					Removed after Transient 1	
85 Orange					8 min/591.25 hrs	
85 White					8 min/591.25 hrs	
86 Black	Tray 1	878 hr @ 302°F	1.951E+08	25A (5)	8 min/591.25 hrs	Qualified
86* Blue					8 min/340 hrs	
86* Orange					Removed after Transient 1	
86* White					8 min/49.25 hrs	

Table 13: Nuclear Plant Transition Splices qualification results. Radiation doses represent (accident + ambient) for aged samples or accident only for unaged samples.

SPECIMEN NO.	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rad)	Test Circuit	Time Energized Trans1/Trans2	RESULTS
87 Black	Tray 1	878 hr @ 302°F	1.951E+08	25A (5)	8 min/591.25 hrs	Qualified
87 Blue					8 min/591.25 hrs	
87* Orange					8 min/49.25 hrs	
87 White					8 min/591.25 hrs	

Table 13: Nuclear Plant Transition Splices qualification results (Cont.).

The unmarked test specimens did not exhibit any anomalies during the LOCA exposure and passed the acceptance criteria. The total durations of the transients were – Transient #1: 8 minutes and Transient #2: 728.3 hours. Some specimens were not energized for the entire duration because they were in circuits that experienced performance problems with other specimens. These specimens are considered to meet the criteria of being energized throughout the entire LOCA simulation based on the fact that they were found intact with no evidence of failure and that similar samples have completed the requirements and passed the final tests. The samples identified by asterisks were not energized during the entire LOCA exposure and were removed at different points of time (see Table 13) as a result of high leakage currents that blew the test circuit fuses. Full investigation of these samples could not be done until the end of the test.

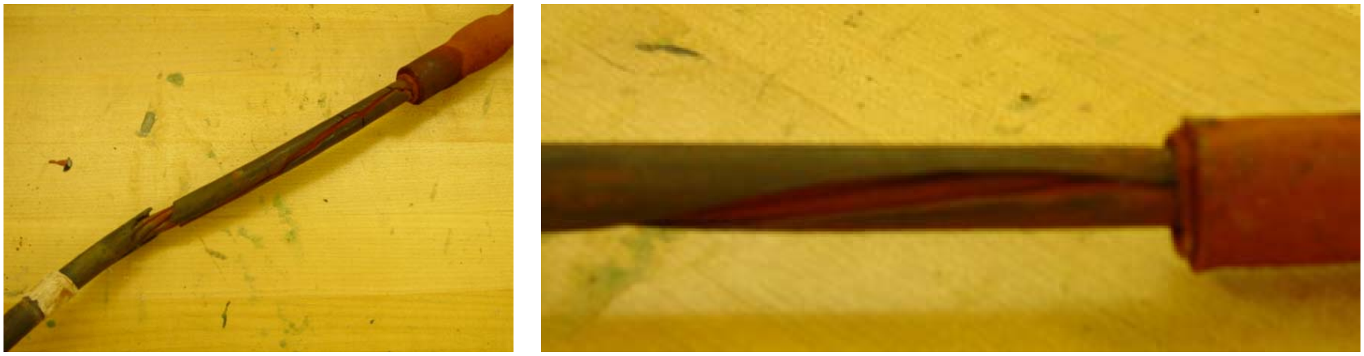
After depressurization and cool down from the LOCA simulation, the test vessel was opened and the test specimens carefully removed by cutting the test leads inside the chamber. The asterisk marked specimens and test leads were removed from the trays and carefully examined to identify damage. These specimens were then subjected to immersion IR testing to identify any obvious degradation or damage. Table 14 summarizes the results of these examinations and IR tests. Upon careful investigation, the splices were found to be intact. For specimens #81, #82 and #84, no reason for anomalous behavior during the LOCA was found either on the specimens or the removed portion of the leads. On specimens #86 and #87, a sample lead wire split was found very close to the test splice.

Subsequently, all the specimens were subjected to and passed the specified post-LOCA functional tests, except for IR values measured during tests for specimen 80 and 83. All the function test results are presented in Table 15.

SPECIMEN	IR with the splice only submersed	IR with the splice and available sample leads submersed	Results / Remarks
81 (all)	1.0E12	1.5E11	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
82 (all)	1.0E11	1.0E11	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
84 (all)	1.0E9	2.0E7	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
85 (all)	1.6E08	Short	One of the sample lead wires split at the edge of the Raychem overall tube.
86 (all)	1.5E12	1.2E11	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
87 (White)	Short	N/A	Sample lead wire split just outside the splice.

Table 14: Results of examination of the asterisk marked samples in Table 13.

The multi-conductor cable jacket of all 8 samples cracked, exposing the underlying single conductor wires. Subsequent IR testing of the samples while immersed in water demonstrated the sealing and insulating properties of the inner splice sleeves but could not be used to verify the seal between the breakout body and the overall splice sleeve nor the breakout fingers and individual single conductor cables. Examples of cracked jackets are shown in the Figure 11. Samples #80, #81, #82, #83, #86, and #87 were repaired by covering the cracked jacket with a new piece of WCSF tubing, exemplified in Figure 12. Samples 84 and 85 had been dissected just after the LOCA test for an initial visual integrity confirmation.



Sample #80 Sample #81

Figure 11: Cracked jackets on Samples #80 and #81.

Sample #80 Sample #81

Figure 12: Samples #80 and #81 after repairing cracked jacket with WCSF tubing

To further investigate the sealing integrity of the samples, a small window was cut in each splice, in order to visually inspect the interior of the splice assembly, in the area between the breakout body and the multi-conductor cable jacket seal. All samples appeared in good condition, exhibiting no evidence of moisture ingress. See Figure 13.

Figure 13: Samples were inspected for mechanical integrity and then a single conductor was exposed.

In each sample, the conductor of a single conductor wire was exposed, and then the entire open area was covered with a piece of WCSF tubing. See Figure 14. Each sample was subsequently immersed in water for 24 hours after which IR measurements were taken between the end of the same wire which had its conductor exposed and the ground (water.) All samples passed with IR measurements > 1.0E10Ω.

Figure 14: Exposed conductors were covered with WCSF tubing.

These samples are considered to be qualified based on successful completion of the post-LOCA examinations and tests.

Table 15 shows the functional test results of Nuclear Plant Transition Splice samples. The measurements were carried out between each of the four individual wires (as HV electrode) and the water bath (as the return electrode) with all the other wires left open. Furthermore, other measurements were made between each individual wire (as the HV electrode) and the other three wires connected together (as the return electrode).

	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
80	Black	1.4E10	2400	410	6.8E12	2400	280	8.1E10	2400	400	8.0E07	2400	150
	Blue	4.0E10	2400	400	4.0E12	2400	280	8.0E10	2400	400	4.0E06	2400	100
	Orange	1.5E10	2400	400	6.2E12	2400	290	7.6E10	2400	400	1.4E09	2400	60
	White	5.0E10	2400	400	3.5E12	2400	280	8.0E10	2400	400	4.0E08	2400	80
	Bl + Or + Wt	3.5E10	2400	450	1.2E12	2400	420	6.6E10	2400	400	3.5E12	2400	180
	Bk + Or +Wt	1.7E10	2400	440	1.4E12	2400	400	6.6E10	2400	400	4.0E05	2400	375
	Bk + Bl + Wt	3.5E10	2400	450	1.1E12	2400	400	6.4E10	2400	400	3.0E12	2400	175
	Bk + Bl + Or	4.0E10	2400	410	1.5E12	2400	400	6.6E10	2400	380	3.0E05	2400	350
81	Black	5.2E10	2400	390	6.2E12	2400	290	7.6E10	2400	400	2.4E12	2400	260
	Blue	5.2E10	2400	380	3.5E12	2400	290	6.8E10	2400	400	3.0E12	2400	260
	Orange	6.2E10	2400	400	4.0E12	2400	290	7.4E10	2400	400	4.0E12	2400	260
	White	5.4E10	2400	400	2.8E12	2400	290	8.0E10	2400	400	3.0E12	2400	260
	Bl + Or + Wt	5.0E10	2400	420	2.0E12	2400	400	6.1E10	2400	380	3.5E12	2400	300
	Bk + Or +Wt	2.8E10	2400	420	1.6E12	2400	420	4.0E10	2400	380	3.5E12	2400	300
	Bk + Bl + Wt	2.4E09	2400	430	2.2E12	2400	420	4.0E10	2400	380	3.5E12	2400	290
	Bk + Bl + Or	3.0E10	2400	420	1.8E12	2400	420	3.5E10	2400	380	4.5E12	2400	300
82	Black	5.8E10	2400	380	3.5E12	2400	320	5.0E10	2400	420	1.8E12	2400	90
	Blue	5.6E10	2400	390	4.0E12	2400	320	5.0E10	2400	440	1.0E12	2400	80
	Orange	5.4E10	2400	380	5.6E12	2400	300	5.8E10	2400	420	1.5E12	2400	100
	White	6.4E10	2400	360	6.4E12	2400	320	6.1E10	2400	460	1.2E12	2400	90
	Bl + Or + Wt	4.0E10	2400	410	3.0E12	2400	400	4.0E10	2400	420	3.4E12	2400	180
	Bk + Or +Wt	3.5E10	2400	410	1.5E12	2400	400	5.0E10	2400	420	4.8E12	2400	190
	Bk + Bl + Wt	3.5E10	2400	390	2.6E12	2400	400	4.0E10	2400	400	2.0E12	2400	190
	Bk + Bl + Or	3.0E10	2400	400	2.0E12	2400	400	4.0E10	2400	420	3.5E12	2400	170
83	Black	5.2E10	2400	460	N/A	N/A	N/A	6.2E10	2400	460	2.2E12	2400	270
	Blue	7.2E10	2400	460	N/A	N/A	N/A	3.0E10	2400	480	2.2E05	2400	260
	Orange	8.0E10	2400	460	N/A	N/A	N/A	6.2E10	2400	480	2.6E11	2400	260
	White	7.2E10	2400	440	N/A	N/A	N/A	3.0E10	2400	480	2.2E12	2400	260
	Bl + Or + Wt	4.5E10	2400	420	N/A	N/A	N/A	5.0E10	2400	420	2.2E12	2400	350
	Bk + Or +Wt	6.0E10	2400	420	N/A	N/A	N/A	3.0E10	2400	420	3.0E12	2400	340
	Bk + Bl + Wt	6.2E10	2400	420	N/A	N/A	N/A	3.5E10	2400	420	9.2E10	2400	340
	Bk + Bl + Or	5.8E10	2400	400	N/A	N/A	N/A	3.0E10	2400	420	2.4E12	2400	340

Table 15: Functional test results of the Nuclear Plant Transition Splice.

	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
84	Black	6.0E10	2400	380	2.6E12	2400	290	6.8E10	2400	400	4.0E12	2400	280
	Blue	7.2E10	2400	380	3.0E12	2400	260	7.2E10	2400	420	2.8E12	2400	280
	Orange	6.6E10	2400	380	3.0E12	2400	260	6.8E10	2400	400	2.8E12	2400	280
	White	7.0E10	2400	380	2.6E12	2400	280	7.4E10	2400	400	3.5E12	2400	300
	Bl + Or + Wt	2.6E10	2400	400	1.8E12	2400	400	4.0E10	2400	400	2.2E12	2400	340
	Bk + Or +Wt	2.6E10	2400	420	1.6E12	2400	425	5.0E10	2400	400	3.0E12	2400	320
	Bk + Bl + Wt	3.0E10	2400	400	1.4E12	2400	425	4.0E10	2400	400	2.2E12	2400	320
	Bk + Bl + Or	1.3E10	2400	400	2.4E12	2400	425	3.0E10	2400	400	2.8E12	2400	320
85	Black	4.0E10	2400	380	1.8E12	2400	270	7.4E10	2400	400	7.2E12	2400	260
	Blue	4.0E10	2400	380	2.0E12	2400	280	9.0E10	2400	420	6.0E12	2400	250
	Orange	5.6E10	2400	390	1.5E12	2400	280	7.8E10	2400	400	7.0E12	2400	260
	White	6.8E10	2400	360	2.2E12	2400	260	9.0E10	2400	420	5.2E12	2400	250
	Bl + Or + Wt	4.5E10	2400	400	2.0E12	2400	420	5.8E10	2400	400	5.4E12	2400	300
	Bk + Or +Wt	3.5E10	2400	400	1.8E12	2400	420	6.0E10	2400	400	6.2E12	2400	290
	Bk + Bl + Wt	3.5E10	2400	400	2.2E12	2400	420	5.0E10	2400	400	5.6E12	2400	290
	Bk + Bl + Or	3.0E10	2400	400	2.6E12	2400	425	6.2E10	2400	400	5.2E12	2400	300
86	Black	4.5E10	2400	340	3.0E12	2400	290	6.0E10	2400	400	1.5E12	2400	90
	Blue	5.6E10	2400	360	2.8E12	2400	290	7.4E10	2400	420	1.4E12	2400	100
	Orange	6.0E10	2400	340	3.4E12	2400	290	7.0E10	2400	420	1.0E12	2400	75
	White	4.5E10	2400	350	3.5E12	2400	290	7.6E10	2400	400	1.5E12	2400	80
	Bl + Or + Wt	3.5E10	2400	400	1.4E12	2400	400	5.0E10	2400	400	4.0E12	2400	130
	Bk + Or +Wt	3.0E10	2400	400	1.0E12	2400	425	5.0E10	2400	400	5.0E12	2400	140
	Bk + Bl + Wt	4.0E10	2400	380	1.3E12	2400	400	5.0E10	2400	400	3.0E12	2400	150
	Bk + Bl + Or	5.0E10	2400	410	1.6E12	2400	425	5.0E10	2400	400	3.5E12	2400	120
87	Black	5.0E10	2400	340	2.8E12	2400	280	6.4E10	2400	420	1.4E12	2400	80
	Blue	5.2E10	2400	360	2.6E12	2400	280	7.0E10	2400	440	3.0E12	2400	90
	Orange	5.8E10	2400	340	2.2E12	2400	280	9.0E10	2400	440	2.0E12	2400	90
	White	6.5E10	2400	360	2.4E12	2400	290	9.4E10	2400	440	3.5E12	2400	100
	Bl + Or + Wt	3.5E10	2400	390	1.1E12	2400	410	6.2E10	2400	400	4.5E12	2400	125
	Bk + Or +Wt	3.5E10	2400	410	1.5E12	2400	410	5.4E10	2400	400	4.0E12	2400	100
	Bk + Bl + Wt	4.0E10	2400	400	1.2E12	2400	400	6.1E10	2400	420	2.5E12	2400	120
	Bk + Bl + Or	3.5E10	2400	400	1.6E12	2400	400	7.1E10	2400	400	5.0E12	2400	110

Table 15: Functional test results of the Nuclear Plant Transition Splice.

Two of the IR measurements (carried out at 500 VDC) of Sample #80 in Table 15 are lower that the limit of the acceptance criteria of Section (8.6). However, the same configuration withstood 2400 V without excessive leakage current. The results may suggest that the insulation is breached between the blue and the white wires (but not between either and the ground). Detailed examination of these cables did not reveal any evidence of such damage. The results are contradictory and suggest an error in measurement.

Table 16 shows the IR measurements carried on the monitoring circuits during the LOCA exposure.

Circuit	Pre 1st peak	Pre 2nd peak	213 hr point	386 hr point	720 hr point
25 A (4)	2.0E10 @500 VDC	5.4 E10 @500 VDC	1.1E07 @500 VDC	1.4E06 @500 VDC	1.6E05 @10 VDC
25 A (5)	1.1E10 @500 VDC	3.0E06 @500 VDC	1.6E05 @10 VDC	1.1E06 @500 VDC	2.0E05 @10 VDC

Table 16: IR measurements during LOCA simulation.

The results confirm the qualification of the nuclear plant transition splice configuration using the products made from the new compounds.

It must be noticed that during this testing it was necessary to stress, through accelerated aging and LOCA simulation, the WCSF compounds to demonstrate their integrity in a degraded state. A natural result was that the cables, used as the substrate, were exposed to conditions beyond their qualification levels and thus anomalies were inadvertently introduced into the attached cables. Therefore, cables are considered part of the test setup and this testing did not attempt to follow the original cable's qualification parameters and does not constitute a change in qualification for the cables in the test program. Due to the destruction of the Hypalon cable jacket in this case during the LOCA simulation, the sealing of the internal cavity of overall sleeve was not maintained where the sleeve was designed to seal over the cable jacket. The functional tests' IR measurements did not demonstrate the sealing of the cavity since the internal components were sealed individually using the WCSF tubing which resulted in high IR values anyway. Visual inspection of the molded parts (breakout boot and end caps) under the WCSF overall sleeve as well as the later inspection and testing showed that they were in good condition and not significantly degraded by the test conditions.

9.6 Terminal Block Replacement Kits

This category included a total of 18 samples covering three configurations; 1/C to 1/C (Samples #88 to #93), 1/C to 2/C (Samples #94 to #99) and 2/C to 2/C (Samples #100 to #105). Table 17 shows the list of samples and summarizes the qualification test results.

SPECIMEN NO.	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rad)	Test Circuit	Time Energized Trans1/Trans2	RESULTS
			Actual			
88	12	878 hr @ 302°F	1.964E+08	18A (2)	8 min/702.75 hrs	Qualified
89	12	878 hr @ 302°F	1.964E+08	18A (2)	8 min/702.75 hrs	Qualified
90	12	878 hr @ 302°F	1.964E+08	18A (4)	8 min/727.5 hrs	Qualified
91	13	N/A	1.487E+08	18A (6)	8 min/727.5 hrs	Qualified
92	13	N/A	1.487E+08	18A (5)	8 min/727.5 hrs	Qualified
93	13	N/A	1.487E+08	18A (5)	8 min/727.5 hrs	Qualified
94	12	878 hr @ 302°F	1.964E+08	18A (4)	8 min/727.5 hrs	Qualified
95	12	878 hr @ 302°F	1.964E+08	18A (4)	8 min/727.5 hrs	Qualified
96	12	878 hr @ 302°F	1.964E+08	18A (4)	8 min/727.5 hrs	Qualified
97	13	N/A	1.487E+08	18A (5)	8 min/727.5 hrs	Qualified
98	13	N/A	1.487E+08	18A (5)	8 min/727.5 hrs	Qualified
99	13	N/A	1.487E+08	18A (7)	8 min/720.5 hrs	Qualified
100	12	878 hr @ 302°F	1.964E+08	18A (6)	8 min/727.5 hrs	Qualified
101	12	878 hr @ 302°F	1.964E+08	18A (6)	8 min/727.5 hrs	Qualified
102	12	878 hr @ 302°F	1.964E+08	18A (6)	8 min/727.5 hrs	Qualified
103*	13	N/A	1.487E+08	18A (7)	8 min/684.75 hrs	Qualified
104	13	N/A	1.487E+08	18A (7)	8 min/720.5 hrs	Qualified
105*	13	N/A	1.487E+08	18A (7)	8 min/363 hrs	Qualified

Table 17: Terminal Blocks Replacement Kits qualification results. Radiation dose represent (accident + ambient) for aged samples or accident only for unaged samples.

All the unmarked test specimens passed the acceptance criteria and were qualified. The total durations of the transients were – Transient #1: 8 minutes and Transient #2: 728.3 hours. Some specimens were not energized for the entire duration because they were in circuits that experienced performance problems with other specimens. These specimens are considered to meet the criteria of being energized throughout the entire LOCA simulation based on the fact that they were found intact with no evidence of failure and that similar samples have completed the requirements and passed the final tests. The samples identified by asterisks were not energized throughout the entire LOCA exposure. These samples were removed at different times after the leakage current fuses of their respective circuits had blown and their sample loops were identified as problematic (Table 17).

After depressurization and cool down from the LOCA simulation, the test vessel was opened and the test specimens carefully removed by cutting the test leads inside the chamber. The asterisk marked specimens and test leads were removed from their mandrels and carefully examined to identify damage. These specimens were then subjected to immersion IR testing to identify any obvious degradation or damage. Table 18 summarizes the results of these examinations and IR tests. Upon careful investigation, the splices were found to be intact and no reason for anomalous behavior during the LOCA was found either on the specimens or the removed portion of the leads.

Subsequently, all the specimens were subjected to, and passed the specified post-LOCA functional tests. All the function test results are presented in Table 19. Full investigation of these samples could not be done until the end of the test and the splices were found to be intact (see Table 18). These samples are considered to be qualified based on successful completion of the post-LOCA examinations and the fact that similarly constructed specimens passed the entire test program and the functional tests and satisfied the acceptance criteria (Section 8.6).

SPECIMEN	IR with the splice only submersed	IR with the splice and available sample leads submersed	Results / Remarks
103	1.5E12	3.0E11	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber
105	1.5E12	4.0E11	No reason was found for anomalous behavior during LOCA, based on the splice, the sample leads and the portion of the test leads remained attached to the sample after removal from LOCA chamber

Table 18: Results of examination of the asterisk marked samples in Table 17.

Table 19 shows the functional test results for the Terminal Block Replacement Kits.

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
88	8.0E10	2400	360	6.2E10	2400	480	3.0E11	2400	420	2.6E12	2400	520
89	1.2E11	2400	360	1.5E11	2400	500	3.0E11	2400	415	2.4E12	2400	500
90	1.6E10	2400	380	1.5E11	2400	460	3.0E11	2400	400	2.4E12	2400	500
91	4.0E12	2400	360	N/A	N/A	N/A	5.4E11	2400	380	2.0E12	2400	500
92	4.0E12	2400	360	N/A	N/A	N/A	5.0E11	2400	380	2.2E12	2400	600
93	4.0E12	2400	360	N/A	N/A	N/A	5.0E11	2400	400	3.0E12	2400	550
94	6.0E10	2400	480	1.1E11	2400	600	1.6E11	2400	380	2.4E12	2400	630
95	4.5E10	2400	460	1.3E11	2400	600	1.7E11	2400	520	2.2E12	2400	300
96	5.2E10	2400	460	1.1E11	2400	600	1.5E11	2400	520	2.6E12	2400	620
97	4.0E12	2400	470	N/A	N/A	N/A	5.0E11	2400	470	3.5E12	2400	700
98	5.2E12	2400	460	N/A	N/A	N/A	4.0E11	2400	520	3.5E12	2400	650
99	5.2E12	2400	460	N/A	N/A	N/A	5.4E11	2400	500	3.5E12	2400	700
100	5.6E10	2400	560	7.0E10	2400	700	2.0E11	2400	680	2.2E12	2400	730
101	5.0E10	2400	580	7.2E10	2400	720	2.0E11	2400	670	2.2E12	2400	740
102	3.5E10	2400	560	1.0E11	2400	680	1.8E11	2400	580	2.2E12	2400	720
103	3.5E12	2400	580	N/A	N/A	N/A	3.5E11	2400	580	1.5E12	2400	240
104	4.0E12	2400	580	N/A	N/A	N/A	4.0E11	2400	620	2.2E12	2400	675
105	3.5E12	2400	580	N/A	N/A	N/A	4.0E11	2400	600	1.5E12	2400	240

Table 19: Functional test results of the Terminal Block Replacement Kits.

Table 20 shows the IR measurements carried on the monitoring circuits during the LOCA exposure.

Circuit	Pre 1st peak	Pre 2nd peak	213 hr point	386 hr point	720 hr point
18A (2)	1.2E11 @500 VDC	1.2E11 @500 VDC	7.6E07 @500 VDC	3.5E06 @500 VDC	3.5E06 @500 VDC
18A (4)	1.1E11 @500 VDC	1.1E11 @500 VDC	3.5E06 @500 VDC	4.0E06 @500 VDC	1.4E06 @500 VDC
18A (5)	7.2E10 @500 VDC	8.0E09 @500 VDC	5.0E05 @10 VDC	2.6E05 @10 VDC	1.6E05 @10 VDC
18A (6)	4.0E10 @500 VDC	1.8E06 @500 VDC	1.0E08 @500 VDC	8.0E07 @500 VDC	2.2E07 @500 VDC
18A (7)	3.5E10 @500 VDC	2.4E06 @500 VDC	7.4E05 @500 VDC	8.2E05 @500 VDC	8.0E05 @500 VDC

Table 20: IR measurements during LOCA simulation.

The results confirm the qualification of WCSF-115-9/3-N tubing in conjunction with the S1119-2 sealing mastic (for the 2/C side) as a terminal block replacement with 1" (25 mm) seal length and a maximum application range of 2.0x on the 2/C side when installed in the horizontal position. This restriction of the application range is meant to apply to the 1/C-2/C (Y configuration) and the 2/C-2/C (H configuration) but not to the 1/C-1/C In-Line Splice configuration which is covered in Section 9.3.

9.7 Nuclear Grade NJRT Jacket Repair Sealing Tape

This category included a total of six samples made out of NJRT tape used to repair a cable (Samples #109 to #111 and #115 to #117).

Table 21 shows the list of samples and summarizes the qualification test results.

SPECIMEN NO.	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rad)	TEST CIRCUIT	TIME ENERGIZED Trans1/Trans2	RESULTS
			Actual			
109	14	878 hr @ 302°F	1.964E+08	95A	8 min/655.5 hrs	Qualified
110	14	878 hr @ 302°F	1.964E+08	95A	8 min/655.5 hrs	Qualified
111	14	878 hr @ 302°F	1.964E+08	95A	8 min/655.5 hrs	Qualified
115*	15	N/A	1.487E+08	95A	8 min/655.5 hrs	Failed
116	14	878 hr @ 302°F	1.964E+08	95A	8 min/655.5 hrs	Qualified
117	14	878 hr @ 302°F	1.964E+08	95A	8 min/655.5 hrs	Qualified

Table 21: Jacket repair tape qualification results.

All the unmarked test specimens passed the acceptance criteria and are qualified. The total durations of the transients were – Transient #1: 8 minutes and Transient #2: 728.3 hours. The specimens were not energized for the entire duration because they were in a circuit that experienced performance problems with other specimens during a part of the 350°F plateau. The specimens are considered to meet the criteria of being energized throughout the entire LOCA simulation based on the fact that they were found intact with no evidence of failure and that they maintained the voltage and current throughout the rest of the LOCA exposure and have completed the requirements and passed the final tests. After the LOCA exposure, it was found that Sample #115 had suffered a longitudinal split along its entire length (Figure 15). Close examination of the sample revealed that one side of the repair tape was installed on the sacrificial cable jacket contrary to the installation instructions. It appears that a split of the cable jacket (Hypalon) led to the propagation of the tear in the repair tape, which had bonded to the jacket material. None of the other samples exhibited the same performance problem, although they all suffered from jacket splits which indicates that the proper fabrication prevents split propagation into the splice. These samples are considered to be qualified based on successful completion of the entire test program and functional tests. The single splice failure is attributed in a fabrication error. It is interesting to notice that the Sample #115 maintained voltage and current throughout the LOCA exposure in spite of the insulation split.

Figure 15: Split of NJRT tape on Sample #115.

Table 22 shows the functional test results for the NJRT samples.

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
109	2.5E11	3600	760	2.4E10	3600	1000	6.2E10	3600	960	2.6E08	3600	450
110	3.0E11	3600	800	4.0E10	3600	1000	5.8E10	3600	360	1.0E12	3600	1200
111	4.3E11	3600	780	4.5E10	3600	1000	5.0E10	3600	360	1.0E12	3600	1200
115	1.4E10	3600	880	N/A	N/A	N/A	1.5E11	3600	780	Short	FAILED	>10k
116	4.5E10	3600	780	4.5E10	3600	1000	5.0E10	3600	970	8.6E11	3600	1100
117	5.0E10	3600	790	5.0E10	3600	1000	5.0E10	3600	950	1.0E12	3600	1200

Table 22: Functional test results of the Nuclear Jacket Repair Tape.

Table 23 shows the IR measurements carried on the monitoring circuits during the LOCA exposure.

Circuit	Pre 1st peak	Pre 2nd peak	213 hr point	386 hr point	720 hr point
95A	1.2E10 @500VDC	2.0E10 @500VDC	1.1E6 @500VDC	2.0E5 @10 VDC	3.0E05 @10 VDC

Table 23: IR measurements during LOCA simulation.

The results confirm the equivalency of the NJRT jacket repair tape kits made from the WBTF tape using the new compound to those made from the old compound in Form, Fit and Function. The results also confirm the qualification of the tested configuration.

The results show that the NJRT is qualified when used over a qualified substrate (insulation or Jacket).

10. 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 323-1974, 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 WCSF tubingfor a service life of 40 years (based on a DBE of 140 Mrads and life aging of 50 Mrads).

2. The qualification of the WSCF tubing thermally aged for 1379 hours at 150°C and subjected to an irradiation dose of 218 Mrads.

3. The qualification equivalency of the product manufactured with modified compound for the tubing (WCSF) 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. This equivalence also applies to all types of qualified products that have utilized components made from the old formulations.

4. The qualification of the Jacket Repair Tape kit, NJRT, for a service life of 40 years (based on a DBE of 140 Mrads and life aging of 50 Mrads).

5. The qualification of the Breakout boot (-52) molded part in a kit configuration for a service life of 40 years (based on a DBE of 140 Mrads and life aging of 50 Mrads).

6. The qualification of the increased use range (up to 2.5x) of the thick wall WCSF tubing. This increased use range does not apply to the WCSF-050 size. The use range over a bolted connection and for hardware, that may have sharp corners or edges, should be limited to 2.0x for WCSF-300 and smaller tubing. WCSF-300 and smaller should not be used above 2.0x. For WCSF-500 and larger, the use of bolt pads is recommended for

situations where the hardware may have sharp corners/edges and if the use range is 2.0x – 2.5x.

7. The qualification of the shorter seal length of 1″ (25mm) of the WCSF tubing up to WCSF-200-18/5-N.

8. The qualification of WCSF-050-3/1-N tubing as an in-line splice with a 1″ (25 mm) seal length and a maximum 1.4x cable substrate OD over a crimp connector. When used as a shim, the use range can be extended to 2.5x.

9. That Raychem products were not the weak points in the sample loops and performed as good or better than the cable substrates under the test conditions.

10. That the WCSF tubings (old and new formulations) are intermixable.

11. That the use of WCSF-115-9/3-N tubing in conjunction with the S1119-2N mastic to provide sealing, instead of a breakout boot, for the 1/C to 2/C and 2/C to 2/C terminal block replacement kits is qualified with 1″ (25 mm) seal length and a maximum application range of 2.0x on the 2/C side in the horizontal position.

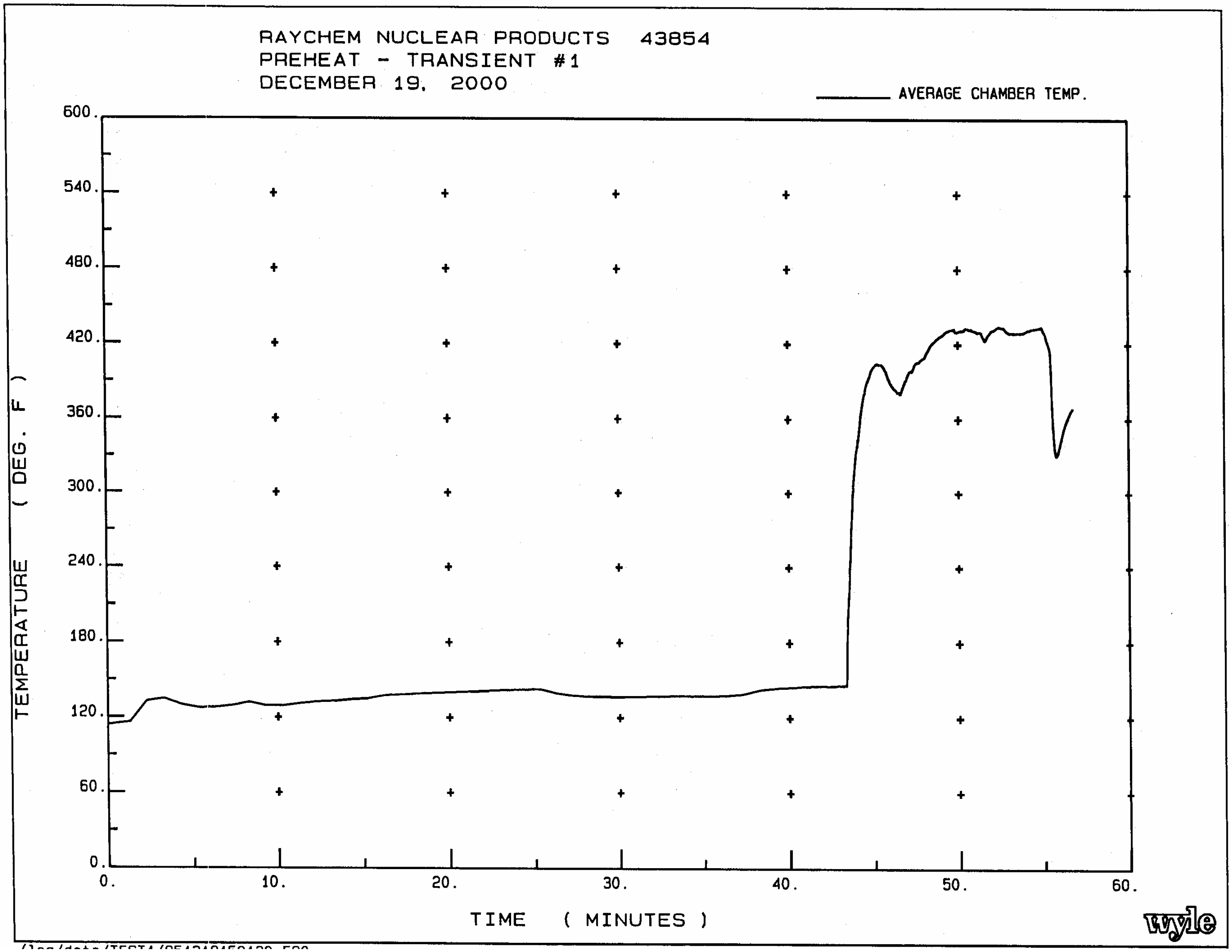
APPENDIX 1

Cables description

Cable Number	Reel #	Manufact.	Insulation material	Jacket Material	Insul. Diameter (in) Nominal	Insul. Thickness (in) Nominal	Jack. Diameter (in) Nominal	Wire AWG	# of Cond.
2	9810294G01	Rockbestos	XLPE	HYPALON	0.33	0.045	0.4	4	1
4	94D0343G	Rockbestos	XLPE	-	0.16	0.03	-	12	1
5	93K1442G	Rockbestos	XLPE	-	0.12	0.03	-	16	1
6	94D0344G	Rockbestos	XLPE	-	0.14	0.03	-	14	1
7	93A1418G	Rockbestos	XLPE	HYPALON	0.14	0.03	0.5	14	7
9	27551/B842-2	Harbour Ind.	PEEK	-	0.07	0.01	-	16	1

APPENDIX 2

LOCA Profile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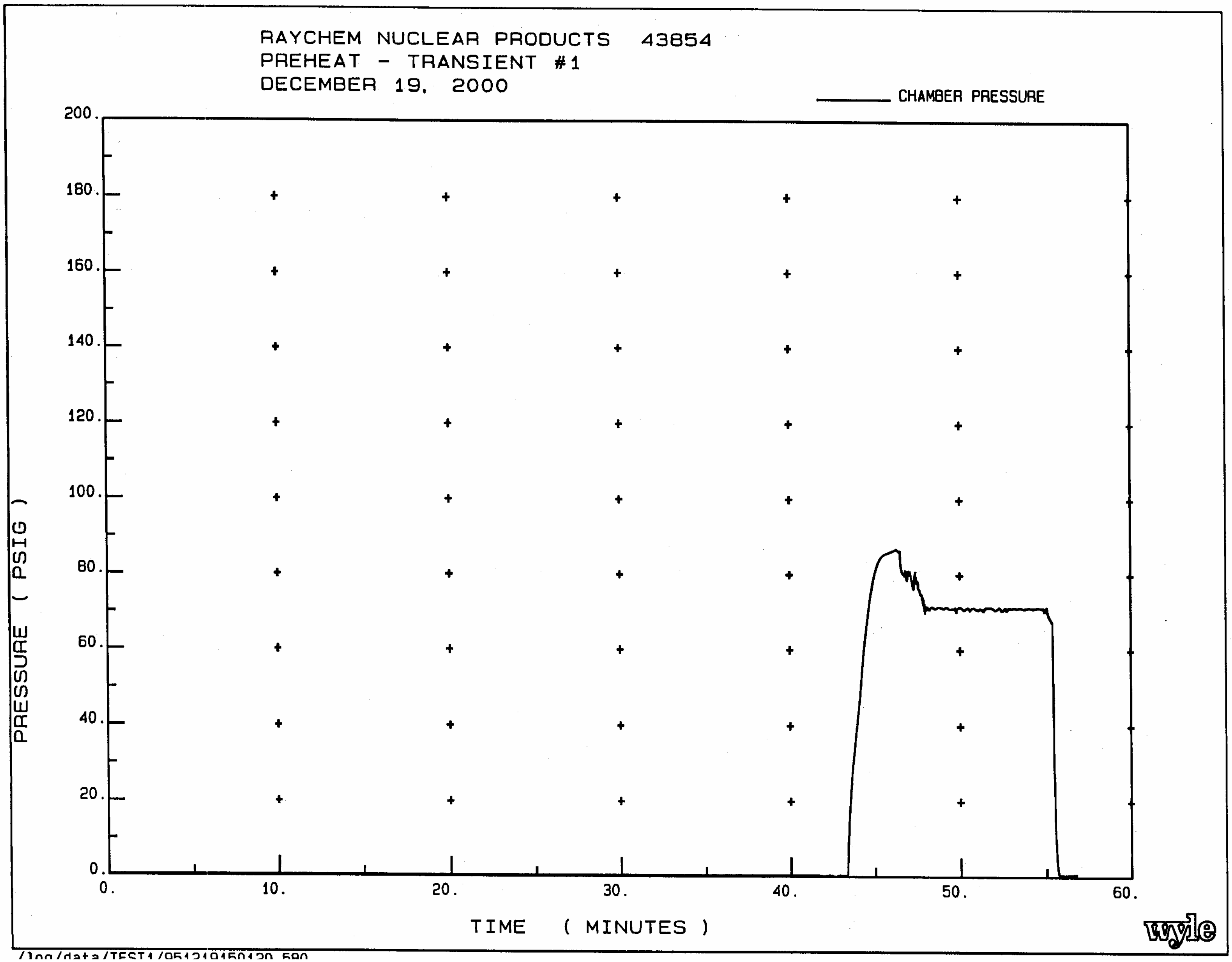
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
AVERAGE CHAMBER TEMP.
TEMPERATURE (DEG. F)
600.
540.
480.
420.
360.
300.
240.
180.
120.
60.
0.
0.
10.
20.
30.
40.
50.
60.
TIME (MINUTES)
wyle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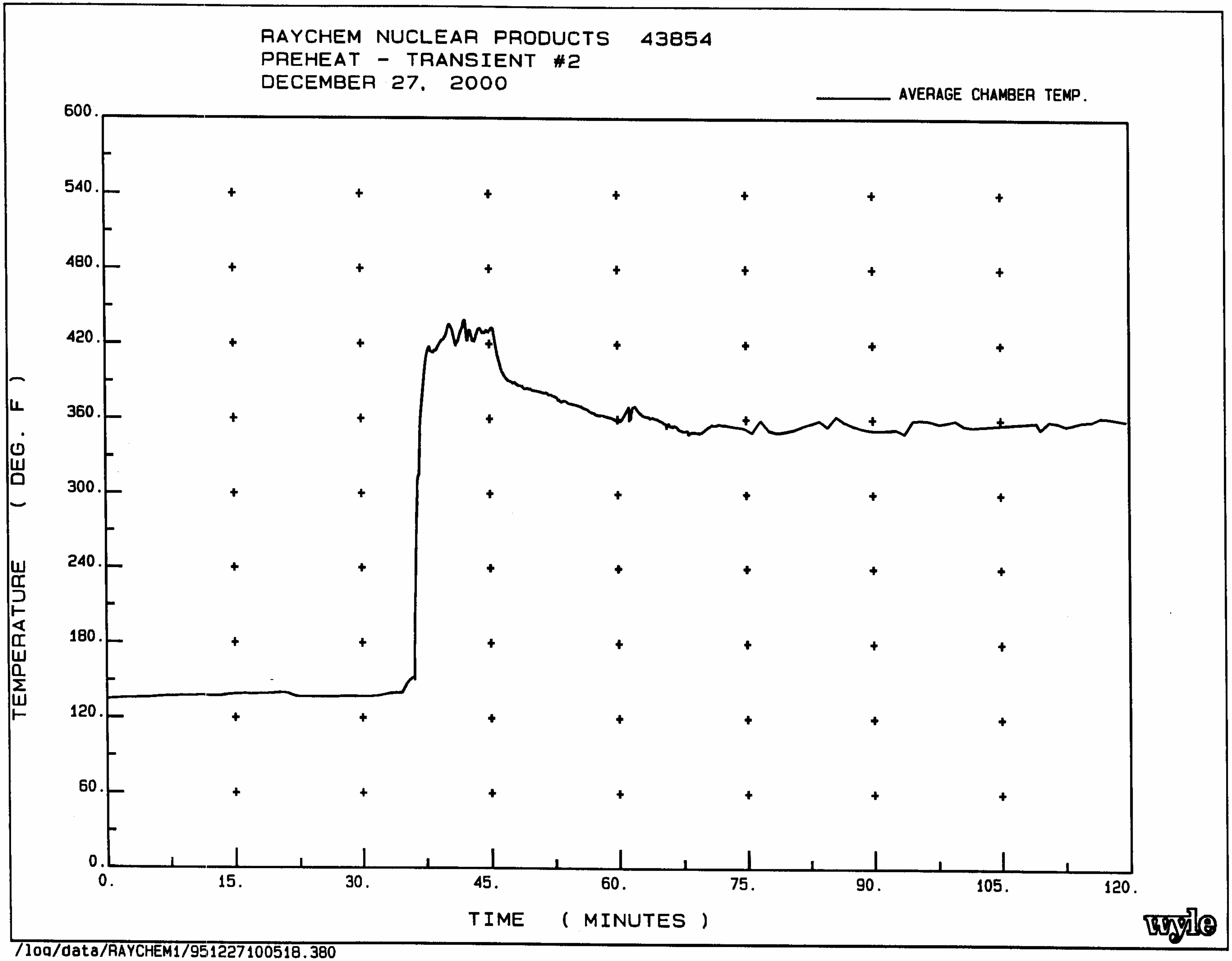
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
CHAMBER PRESSURE
PRESSURE (PSIG)
200.
180.
160.
140.
120.
100.
80.
60.
40.
20.
0.
0.
10.
20.
30.
40.
50.
60.
TIME (MINUTES)
wyle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PREHEAT - TRANSIENT #2
DECEMBER 27, 2000
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TEMPERATURE (DEG. F)
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540.
480.
420.
360.
300.
240.
180.
120.
60.
0.
0.
15.
30.
45.
60.
75.
90.
105.
120.
TIME (MINUTES)
wyle
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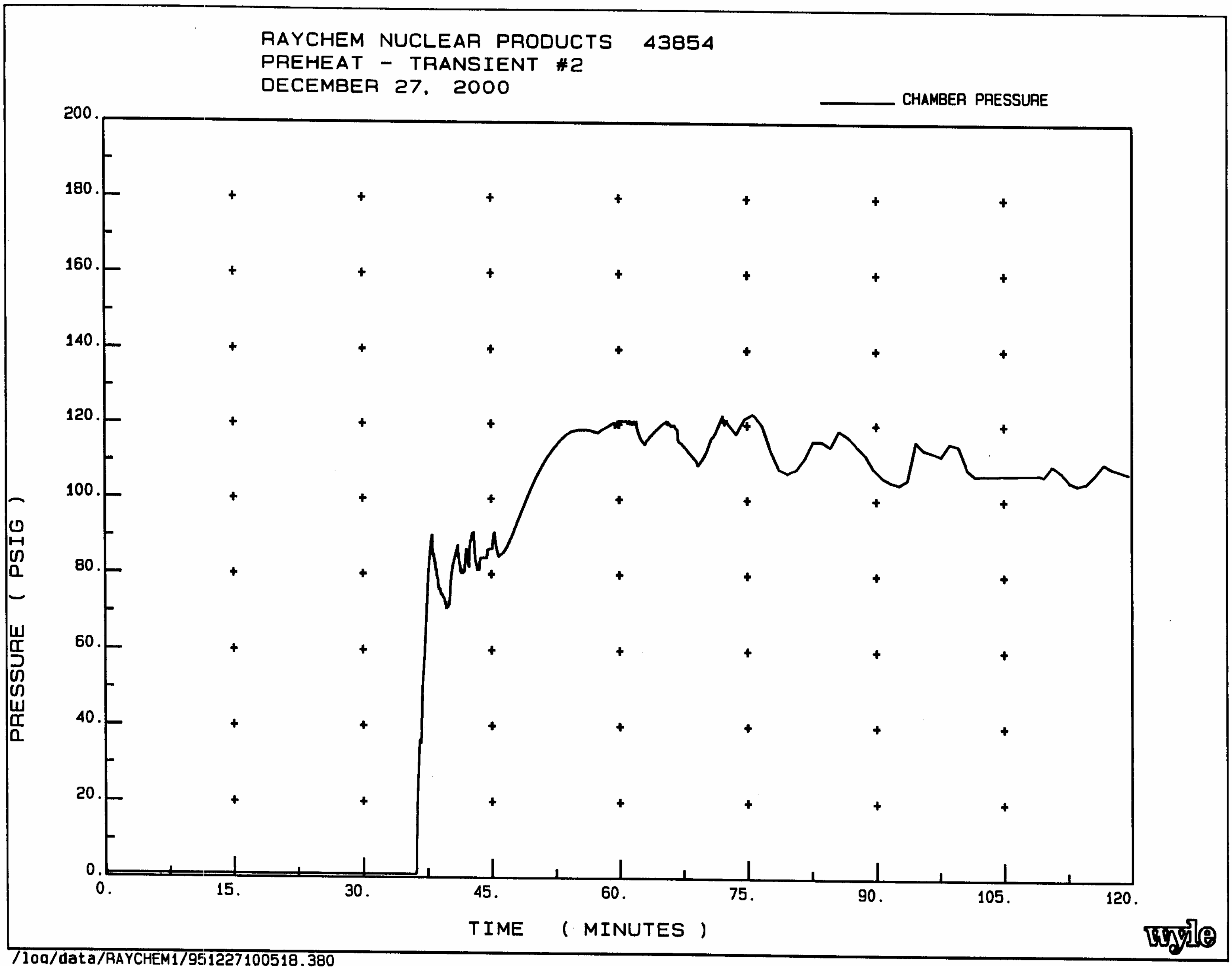
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DECEMBER 27, 2000
CHAMBER PRESSURE
200.
180.
160.
140.
120.
100.
80.
60.
40.
20.
0.
PRESSURE (PSIG)
0.
15.
30.
45.
60.
75.
90.
105.
120.
TIME (MINUTES)
wyle
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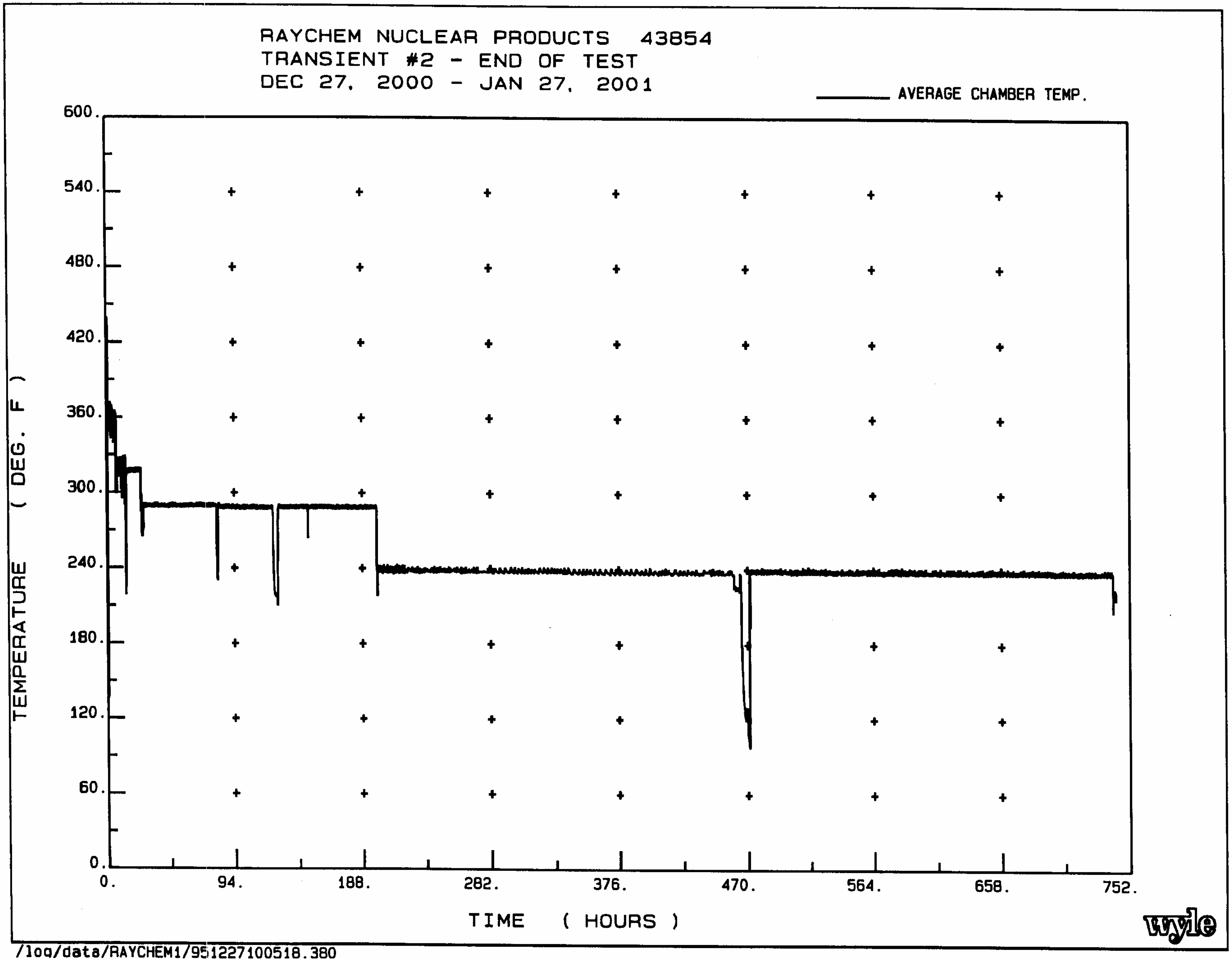
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TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
AVERAGE CHAMBER TEMP.
TEMPERATURE (DEG. F)
600.
540.
480.
420.
360.
300.
240.
180.
120.
60.
0.
0.
94.
188.
282.
376.
470.
564.
658.
752.
TIME (HOURS)
wyle
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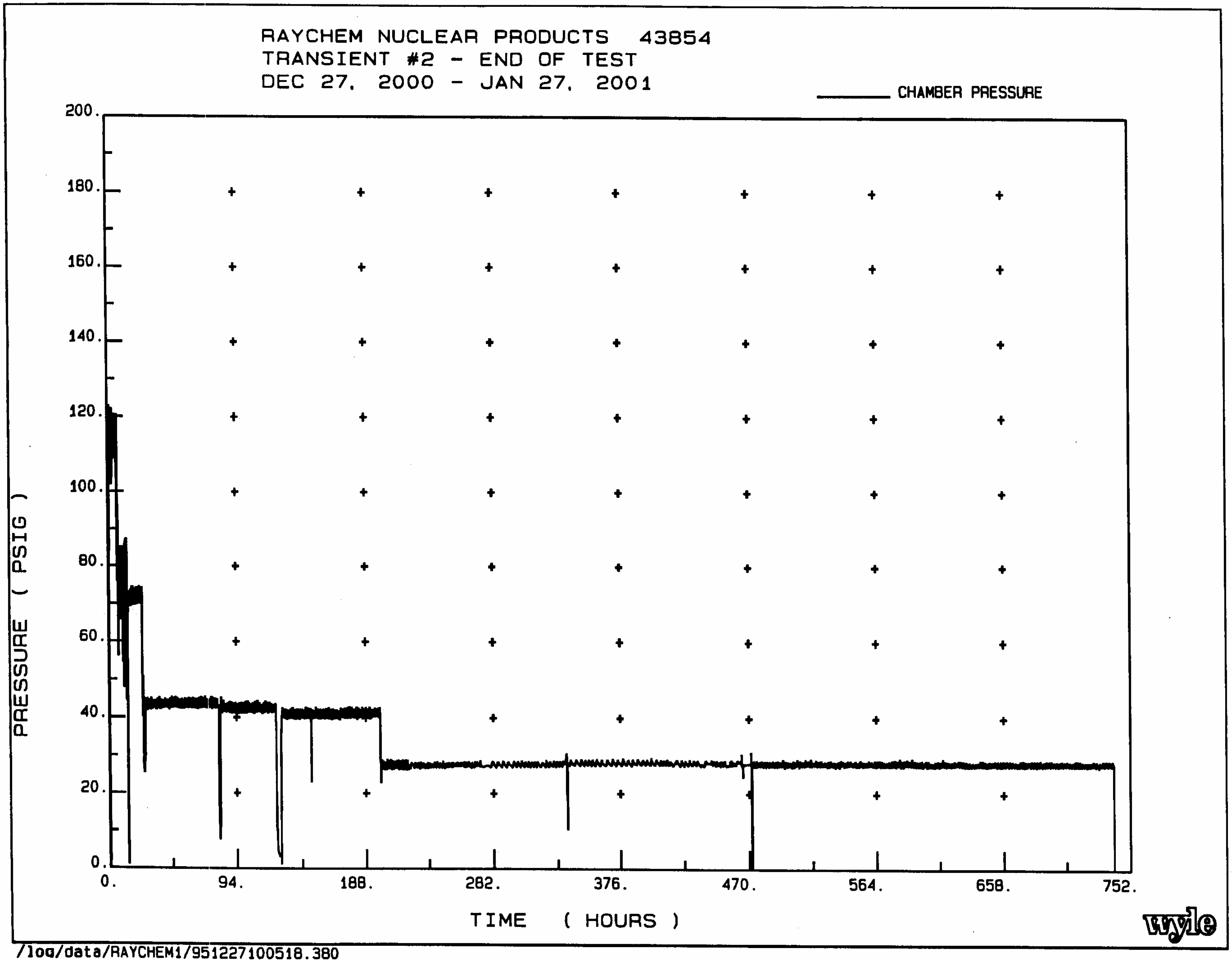
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DEC 27, 2000 - JAN 27, 2001
CHAMBER PRESSURE
PRESSURE (PSIG)
200.
180.
160.
140.
120.
100.
80.
60.
40.
20.
0.
0.
94.
188.
282.
376.
470.
564.
658.
752.
TIME (HOURS)
wyle
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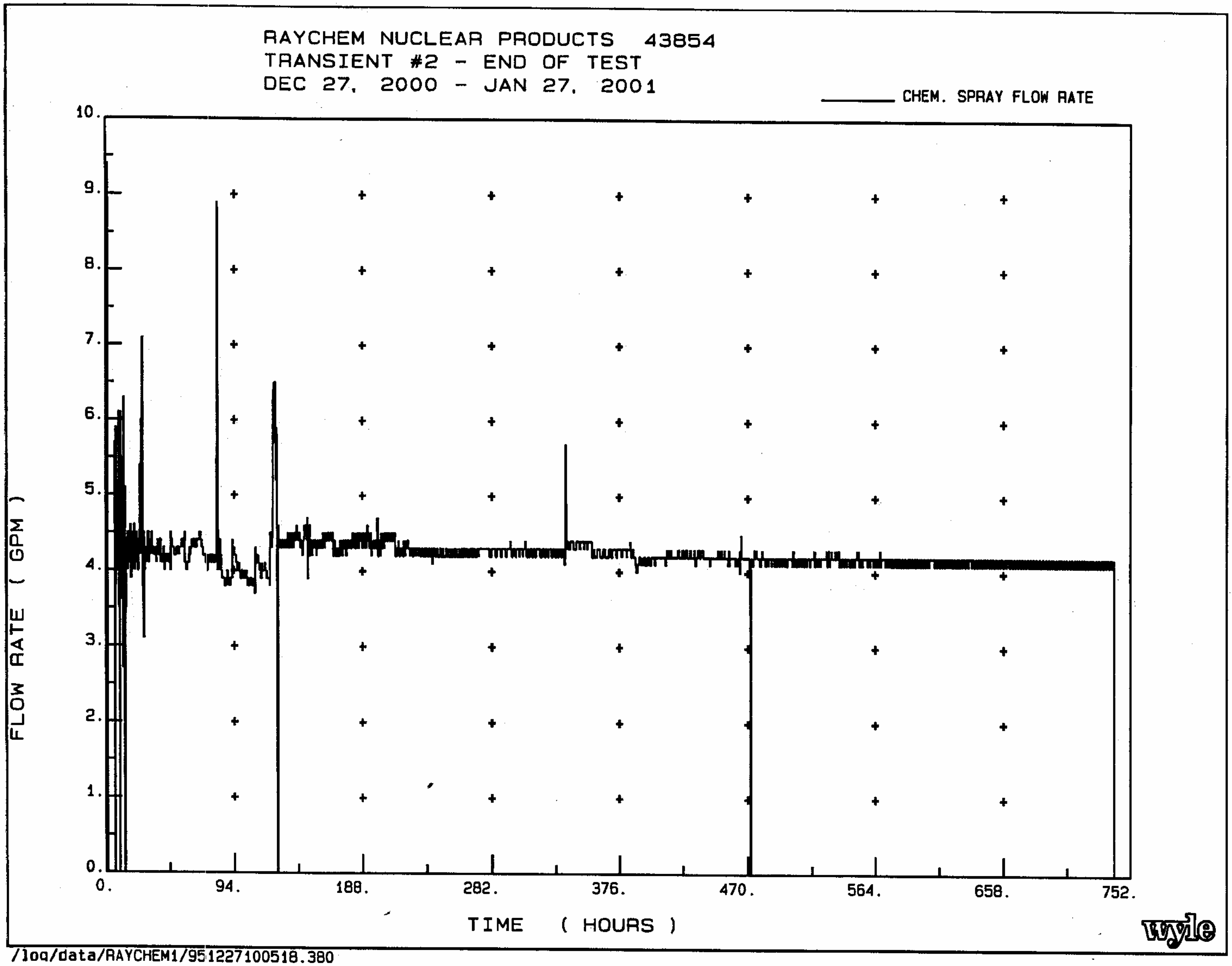

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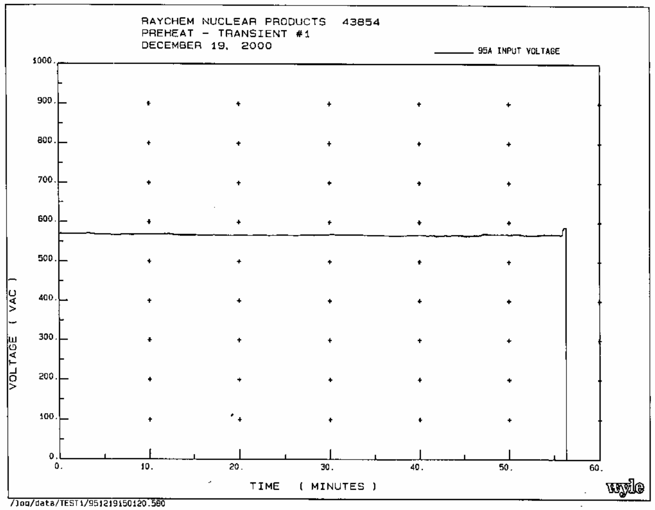
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95A INPUT VOLTAGE
VOLTAGE (VAC)
TIME (MINUTES)
wyle
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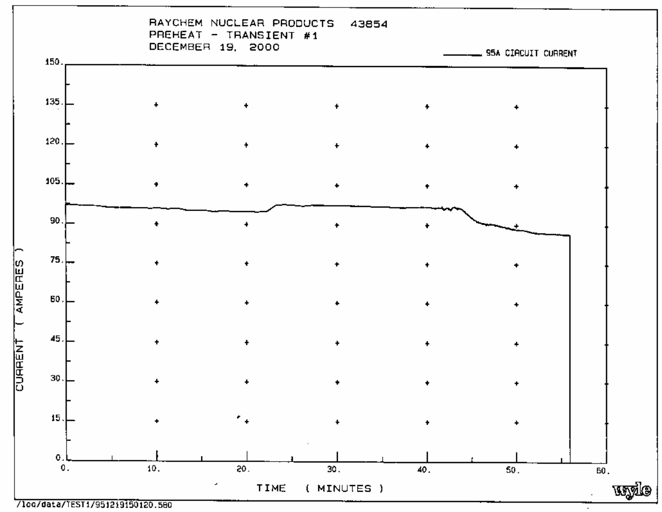
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PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
95A CIRCUIT CURRENT
CURRENT (AMPERES)
TIME (MINUTES)
wyle
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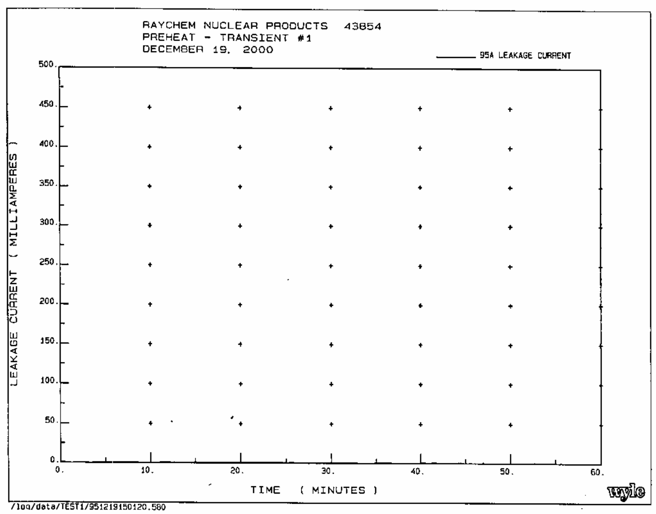
RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
95A LEAKAGE CURRENT
LEAKAGE CURRENT (MILLIAMPERES)
TIME (MINUTES)
wyle
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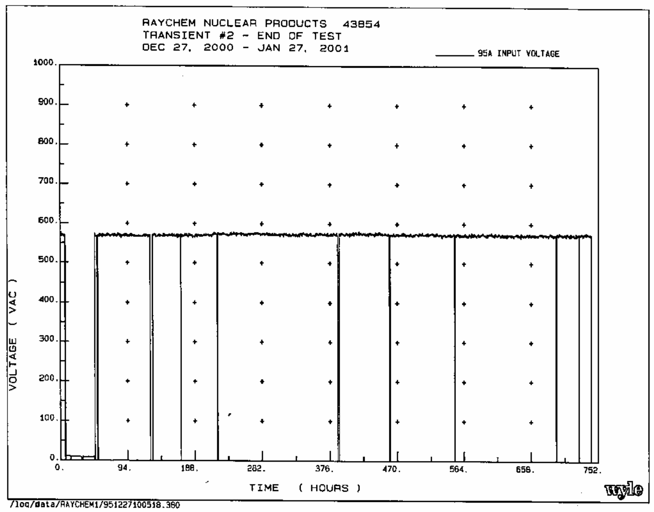
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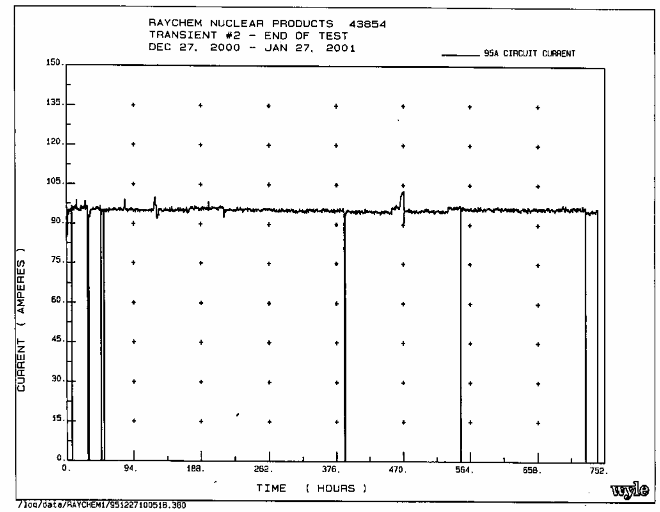
DEC 27, 2000 - JAN 27, 2001
95A INPUT VOLTAGE
VOLTAGE (VAC)
TIME (HOURS)
wyle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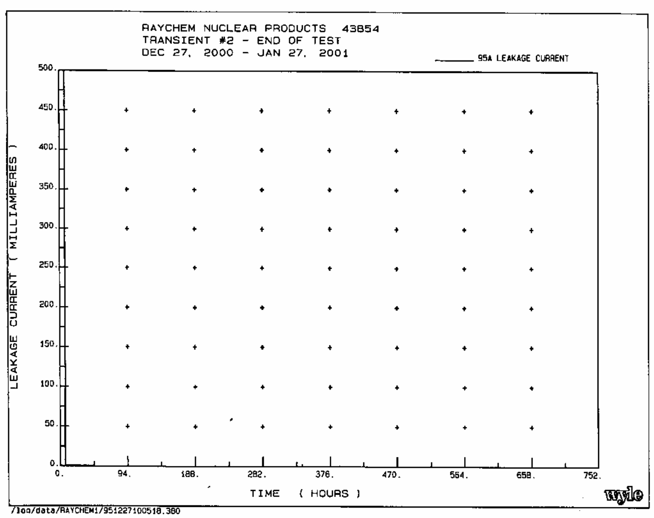
DEC 27, 2000 - JAN 27, 2001
95A CIRCUIT CURRENT
CURRENT (AMPERES)
TIME (HOURS)
wyle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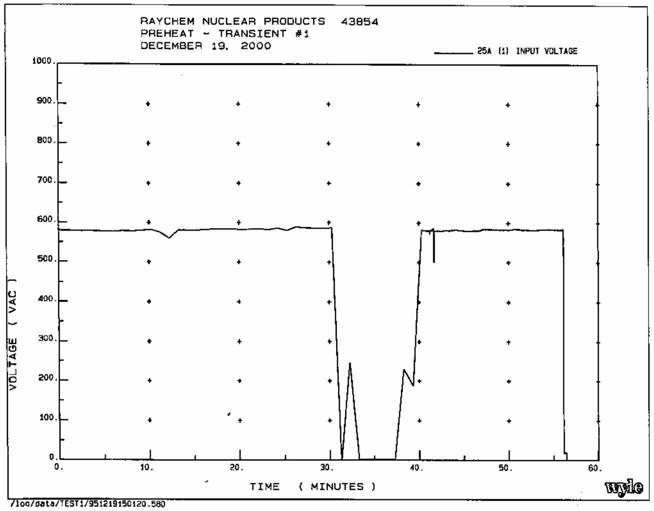
DEC 27, 2000 - JAN 27, 2001
95A LEAKAGE CURRENT
LEAKAGE CURRENT (MILLIAMPERES)
TIME (HOURS)
wyle


RAYCHEM NUCLEAR PRODUCTS 43854
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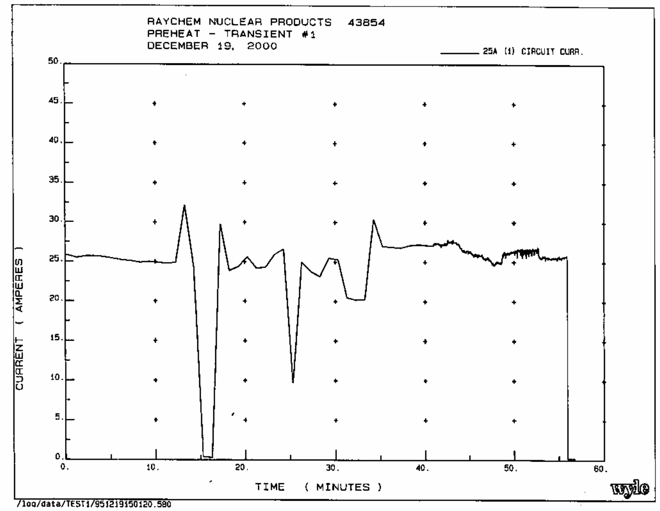
DECEMBER 19, 2000
25A (1) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (MINUTES)
wyle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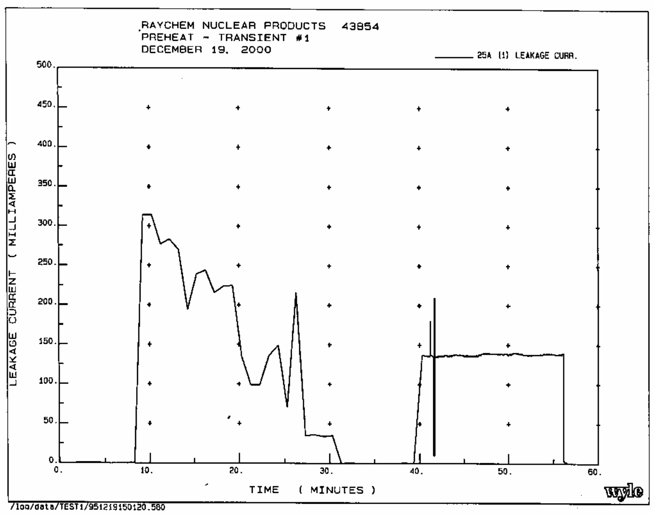
DECEMBER 19, 2000
25A (1) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (MINUTES)
wyle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DECEMBER 19, 2000
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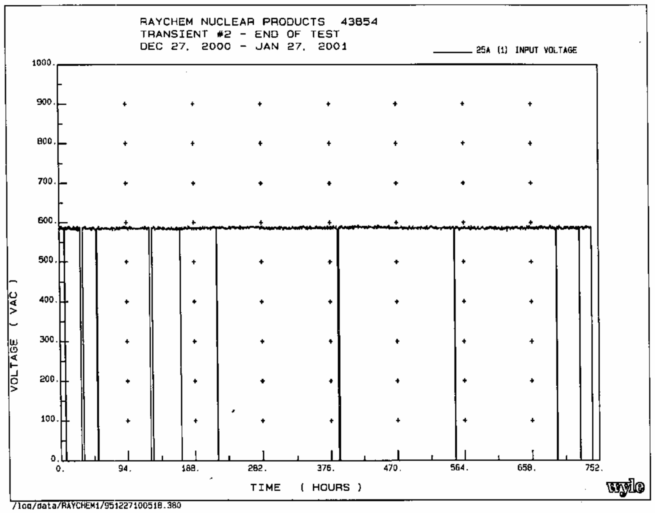
LEAKAGE CURRENT (MILLIAMPERES)
TIME (MINUTES)
wyle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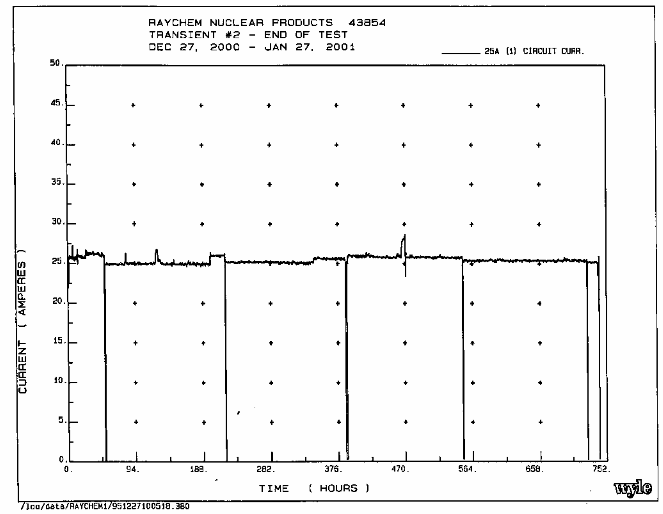
DEC 27, 2000 - JAN 27, 2001
25A (1) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (HOURS)
wyle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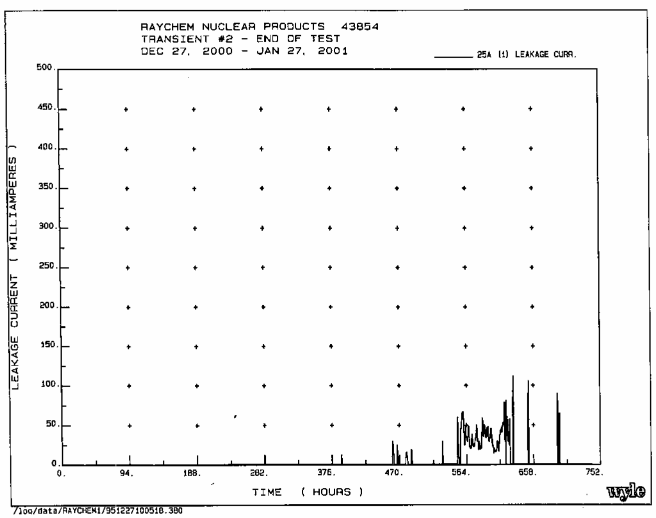
25A (1) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (HOURS)
wyle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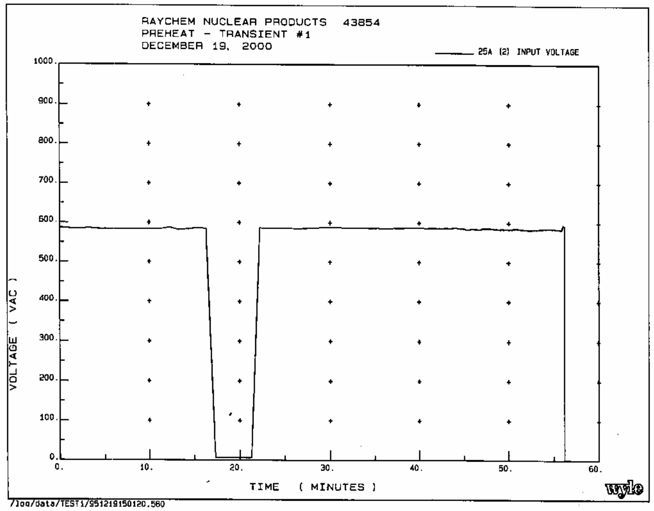
LEAKAGE CURRENT (MILLIAMPERES)
TIME (HOURS)
wyle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VOLTAGE (VAC)
TIME (MINUTES)
wyle
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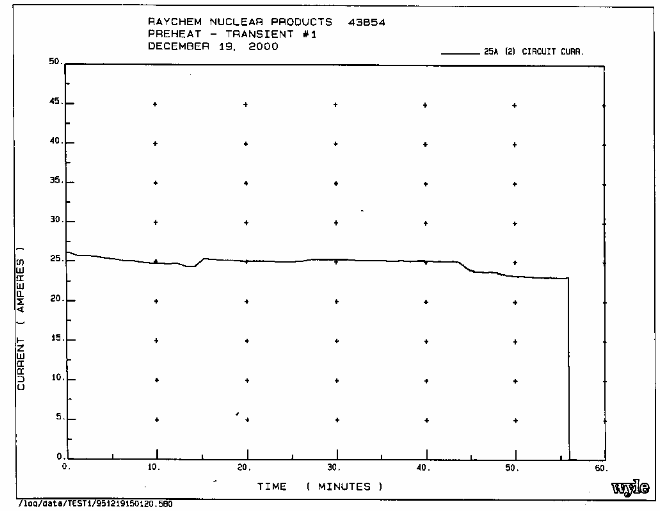
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PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
25A (2) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (MINUTES)
wyle
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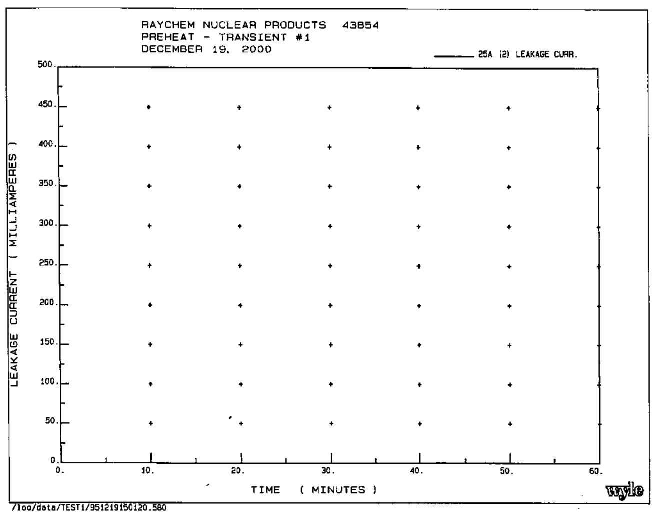
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DECEMBER 19, 2000
25A (2) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (MINUTES)
wyle
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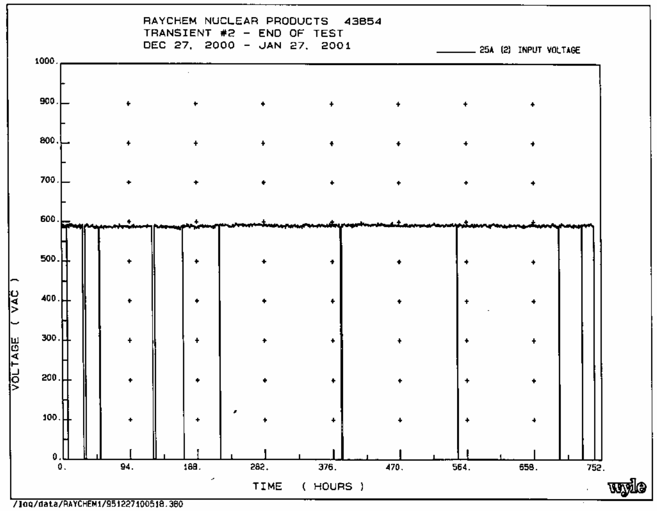
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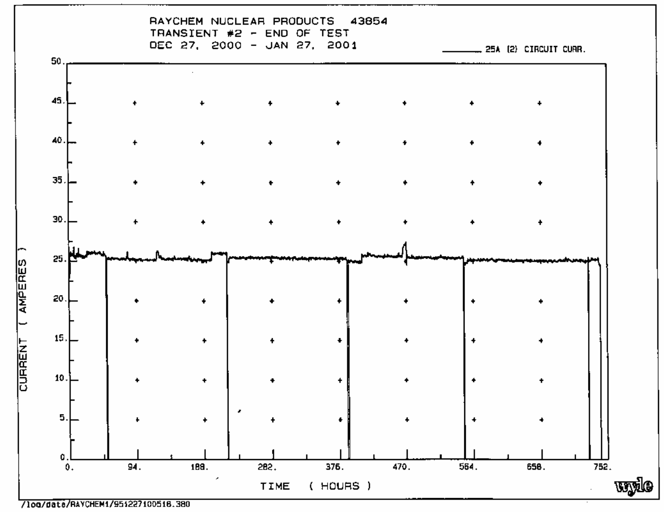
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
25A (2) INPUT VOLTAGE
VOLTAGE (VAC)
1000.
900.
800.
700.
600.
500.
400.
300.
200.
100.
0.
0.
94.
188.
282.
376.
470.
564.
658.
752.
TIME (HOURS)
/log/data/RAYCHEM1/951227100518.380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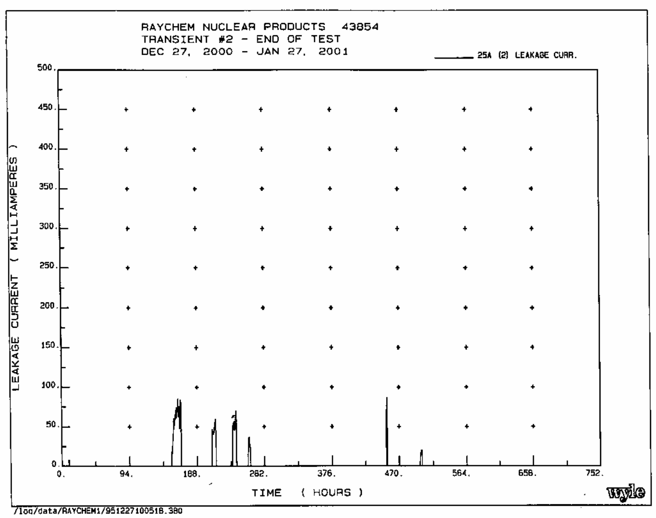
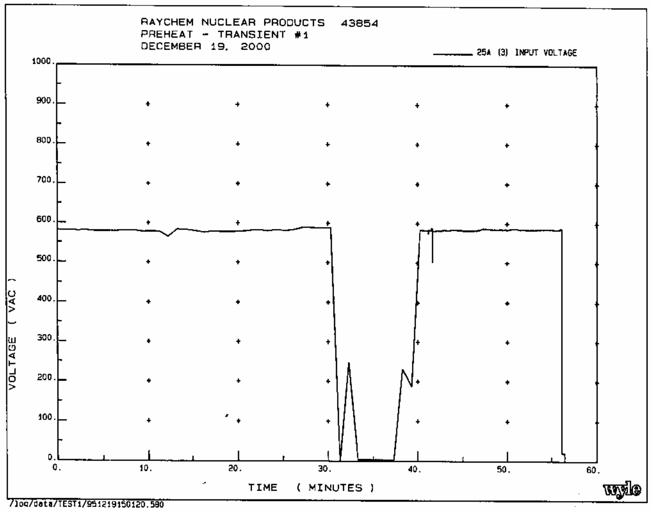
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
25A (2) CIRCUIT CURR.
CURRENT (AMPERES)
50.
45.
40.
35.
30.
25.
20.
15.
10.
5.
0.
0.
94.
188.
282.
376.
470.
564.
658.
752.
TIME (HOURS)
/log/data/RAYCHEM1/951227100518.380


RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
25A (2) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
500.
450.
400.
350.
300.
250.
200.
150.
100.
50.
0.
0.
94.
188.
282.
376.
470.
564.
658.
752.
TIME (HOURS)
/log/data/RAYCHEM1/951227100518.380


RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
25A (3) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (MINUTES)
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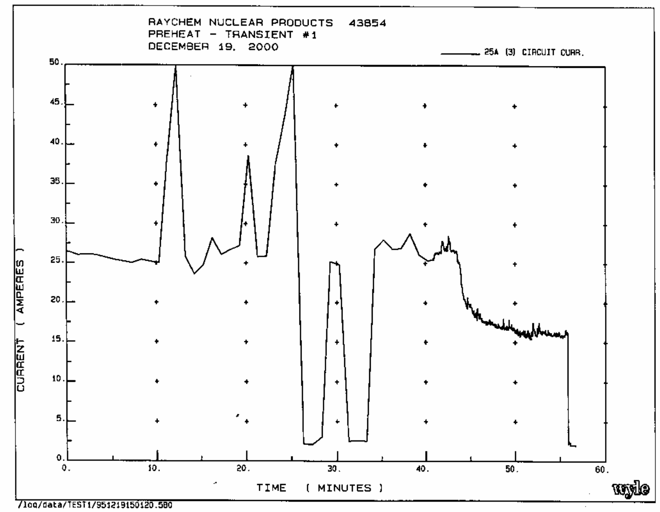
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PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
25A (3) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (MINUTES)
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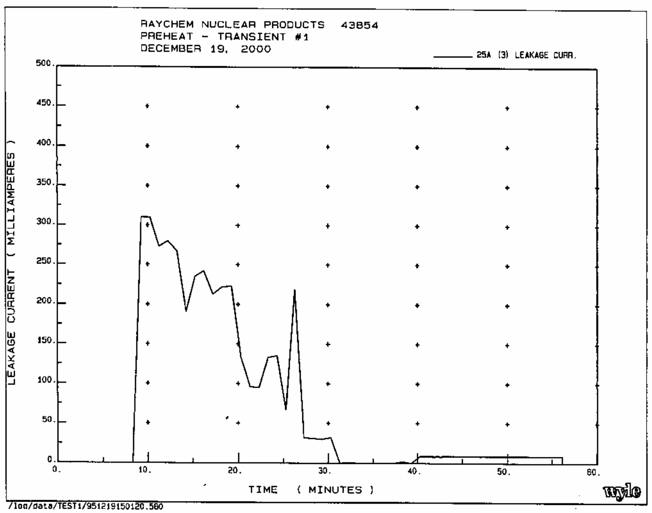
RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
25A (3) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (MINUTES)
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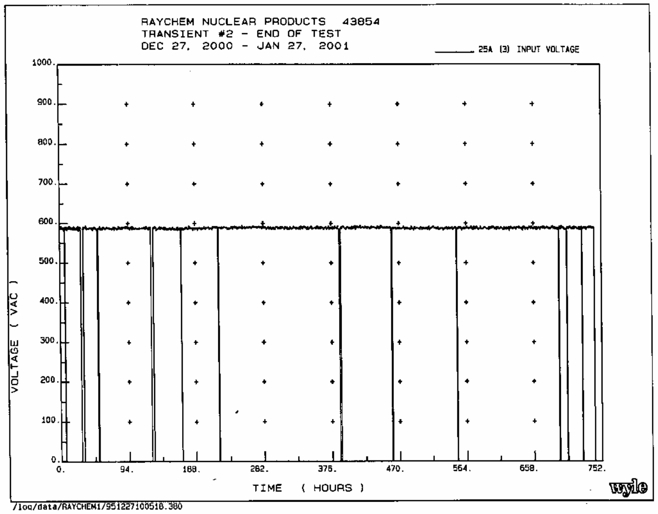
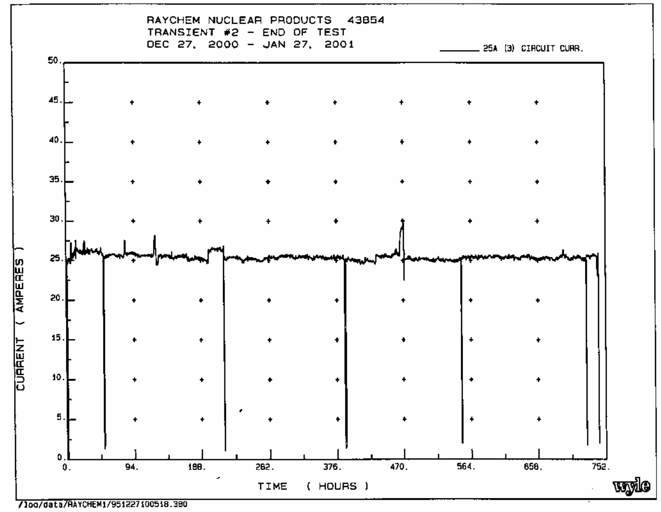

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
25A (3) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (HOURS)
wyle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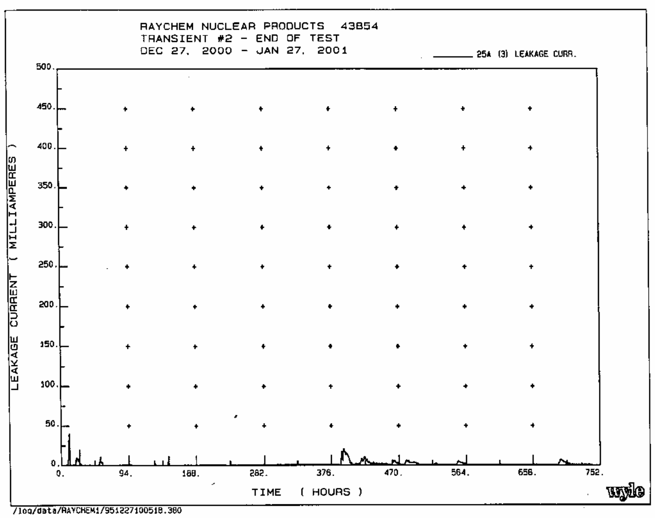
DEC 27, 2000 - JAN 27, 2001
25A (3) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (HOURS)
wyle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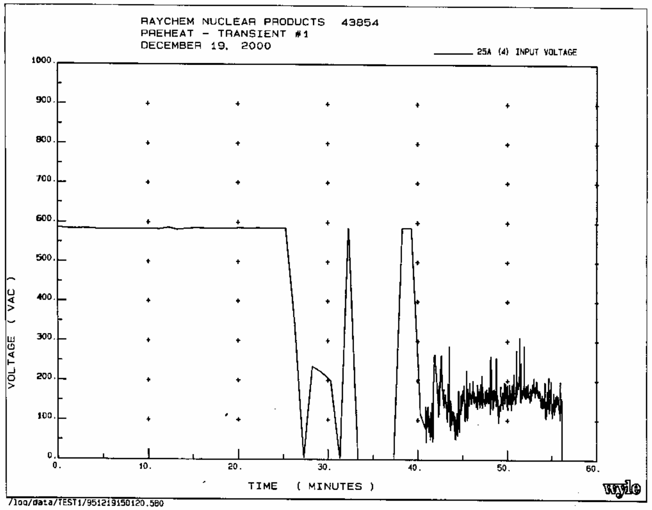
25A (3) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (HOURS)
wyle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VOLTAGE (VAC)
TIME (MINUTES)
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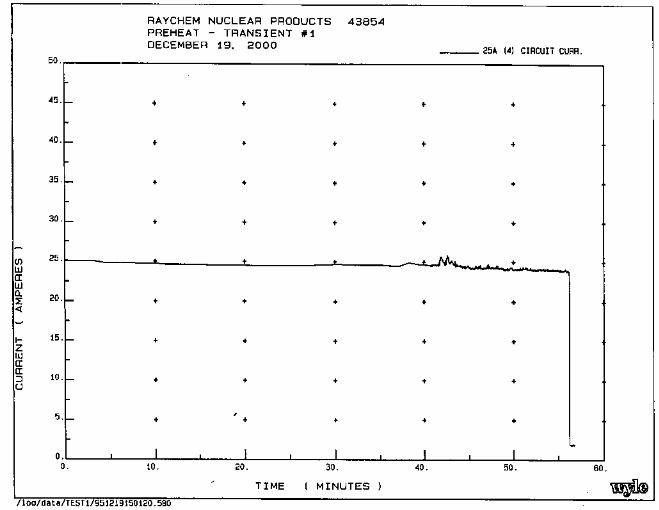
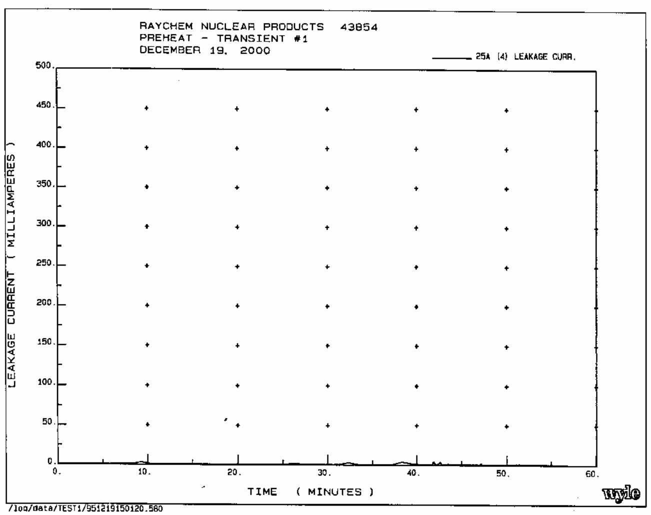
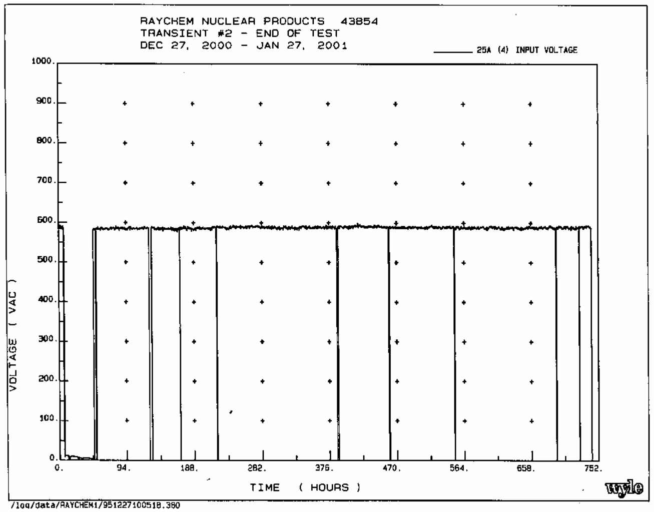
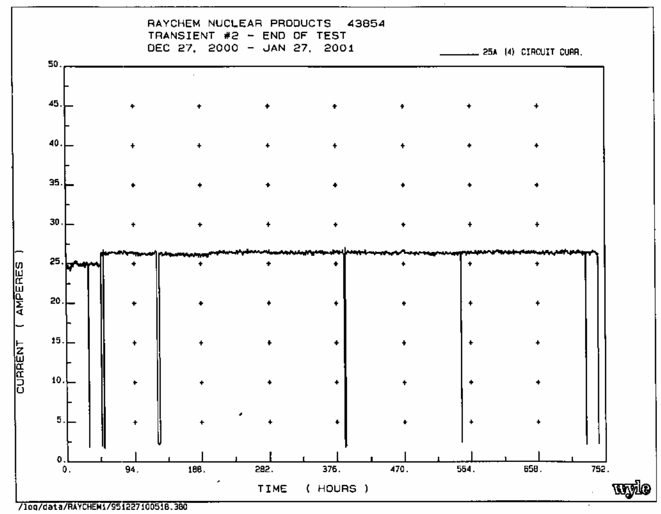
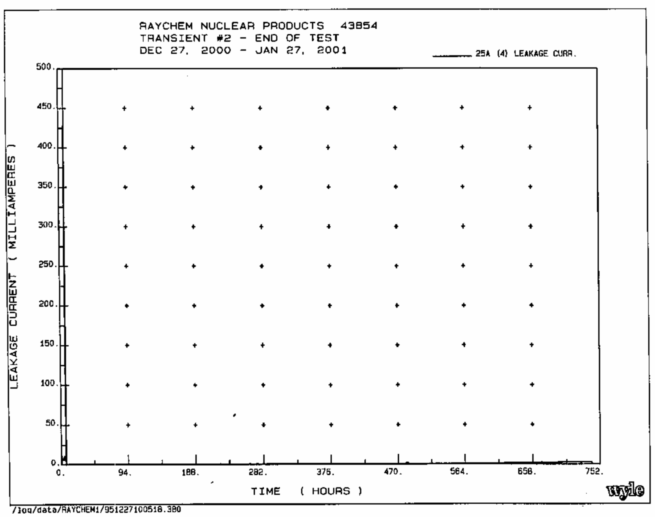
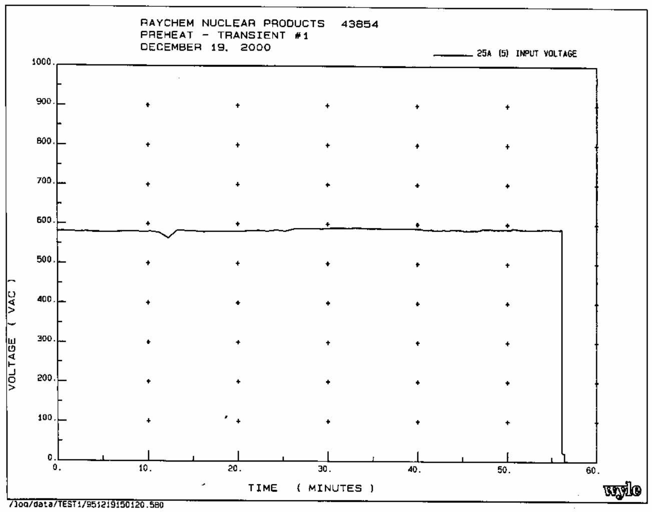

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
25A (4) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (MINUTES)
/log/data/TEST1/951219150120.580

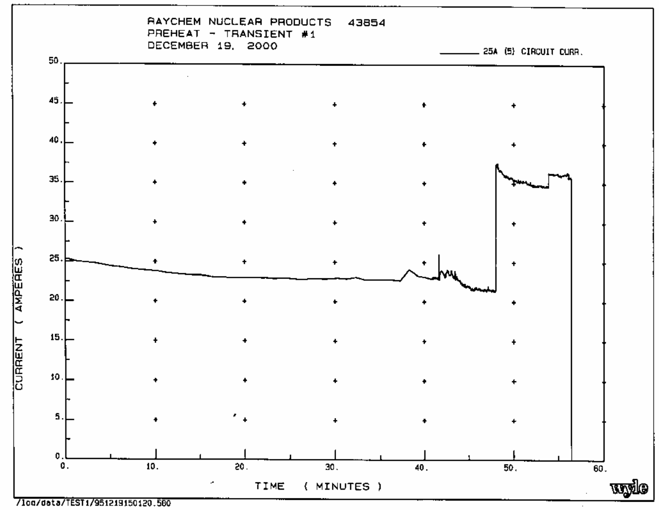

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
25A (4) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (MINUTES)
/log/data/TEST1/951219150120.580

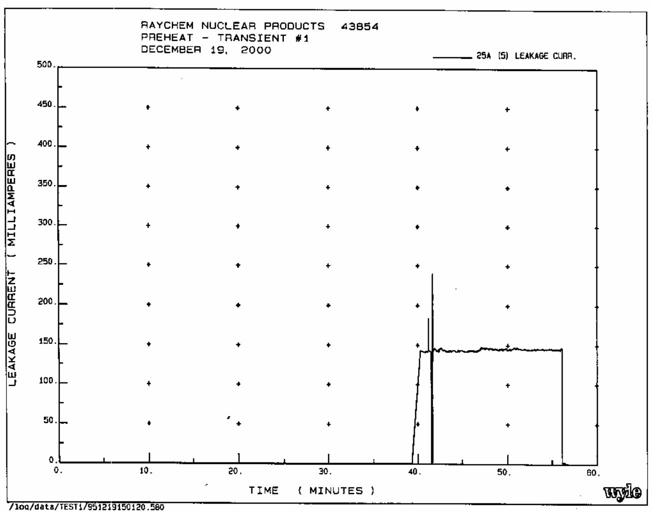

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
25A (4) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (HOURS)
/log/data/RAYCHEM1/951227100518.380

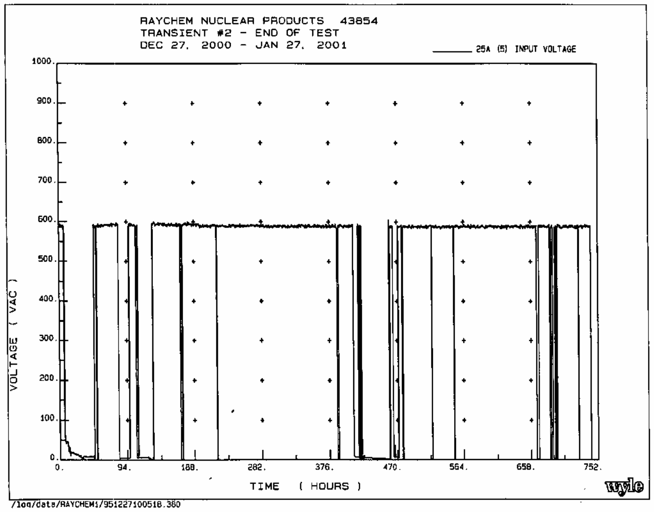

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
25A (4) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (HOURS)
/log/data/RAYCHEM1/951227100518.380

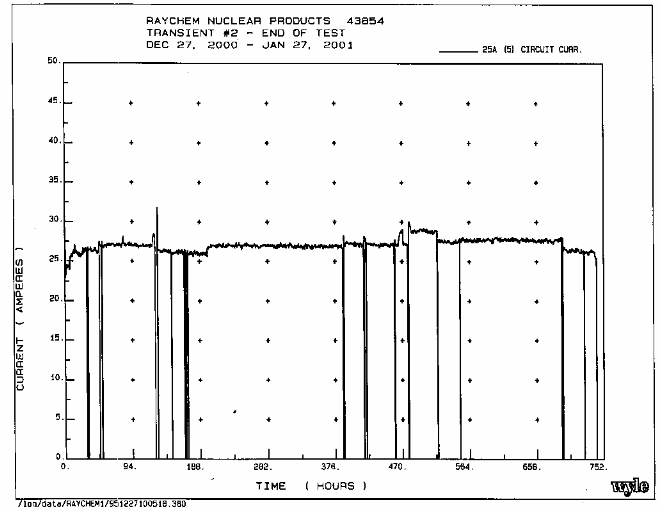

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
25A (4) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (HOURS)
/log/data/RAYCHEM1/951227100518.380

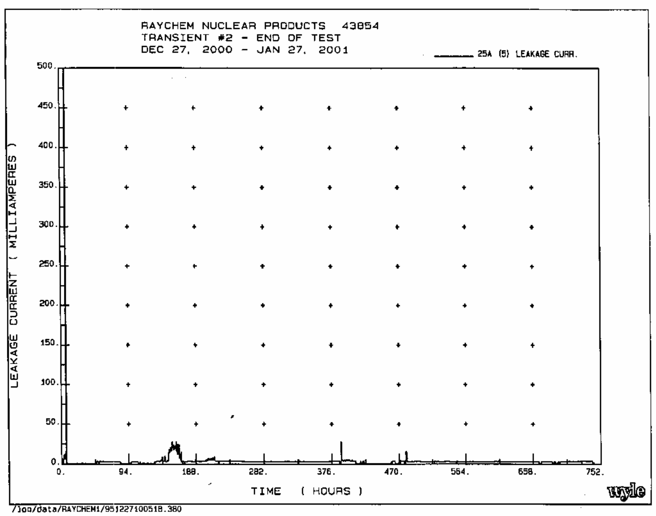

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
25A (5) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580

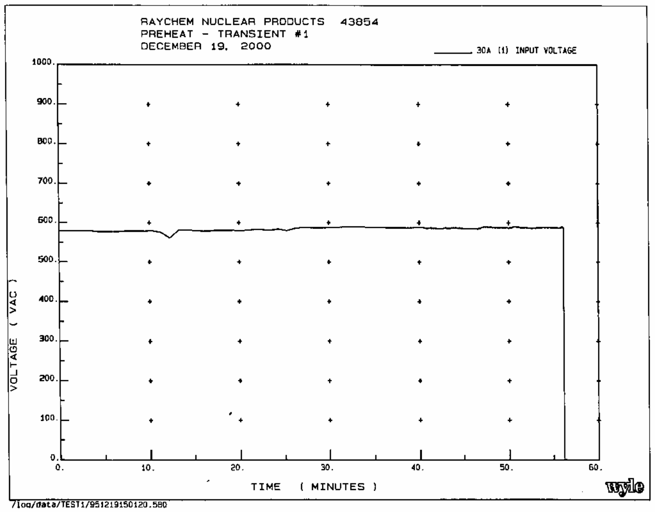

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
25A (5) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580

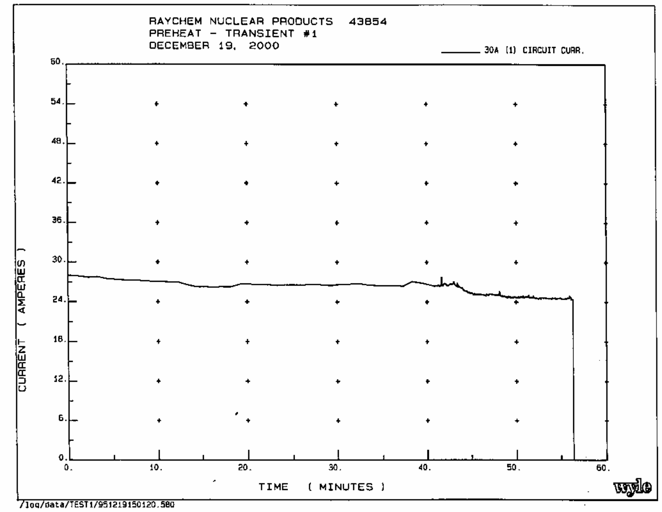

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
25A (5) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580

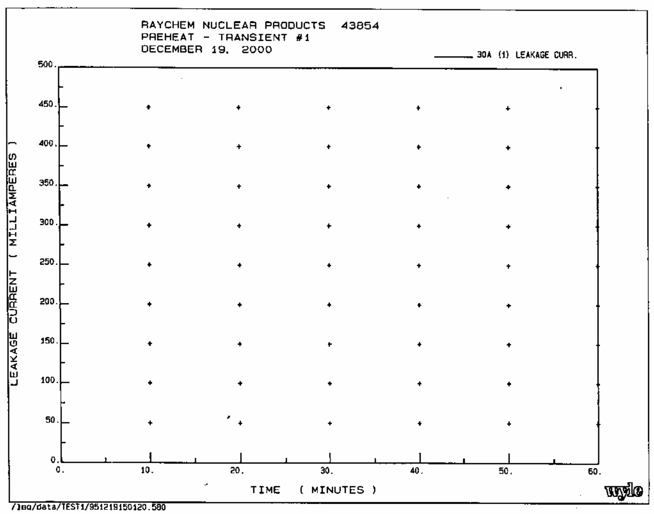

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
25A (5) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (HOURS)
/loa/data/RAYCHEM1/951227100518.380

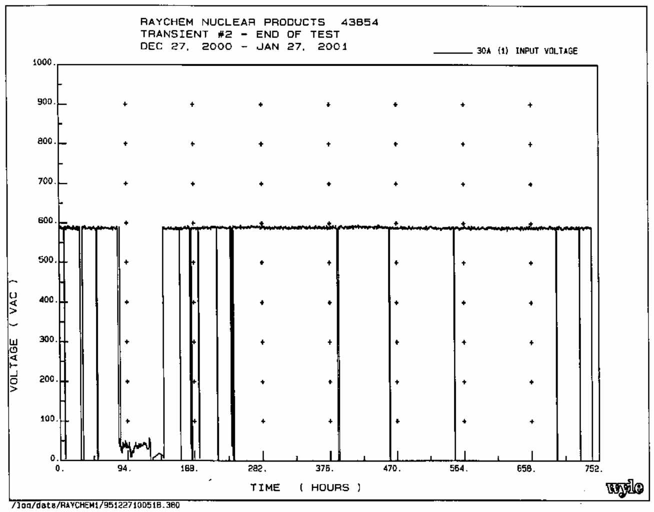

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
25A (5) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (HOURS)
/loa/data/RAYCHEM1/951227100518.380

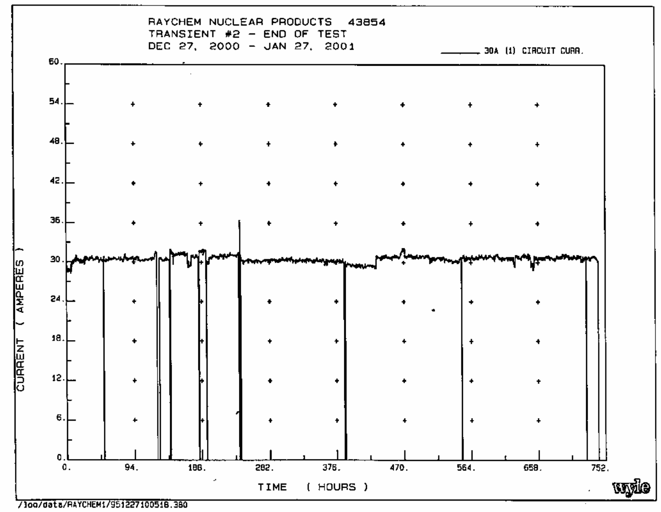

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
25A (5) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (HOURS)
/loa/data/RAYCHEM1/951227100518.380

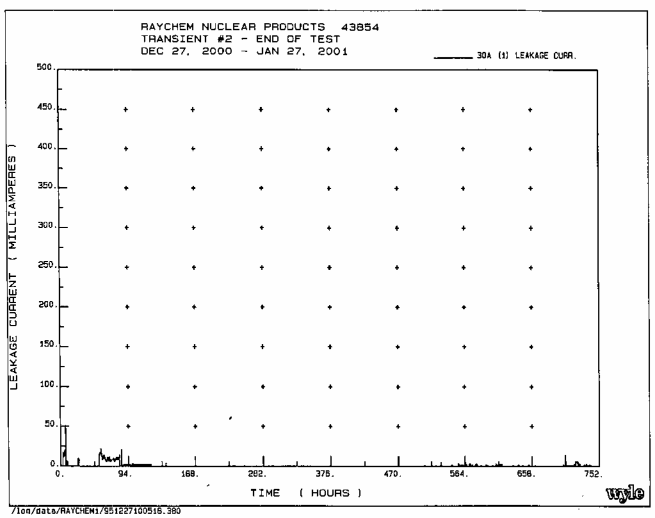

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
30A (1) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580

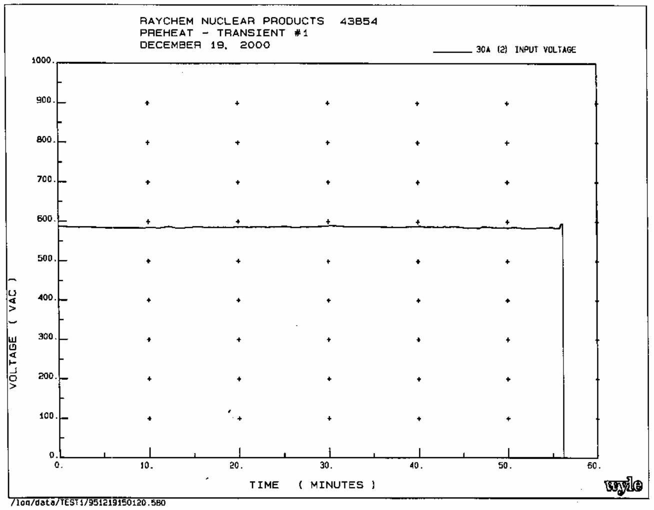

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
30A (1) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580


RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
30A (1) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580


RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
30A (1) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (HOURS)
wyle


RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
30A (1) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (HOURS)
wyle


RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
30A (1) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (HOURS)
wyle


RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
30A (2) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (MINUTES)
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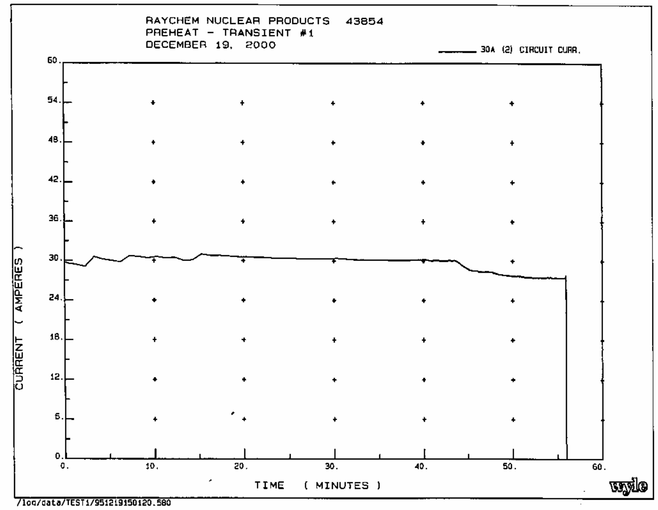
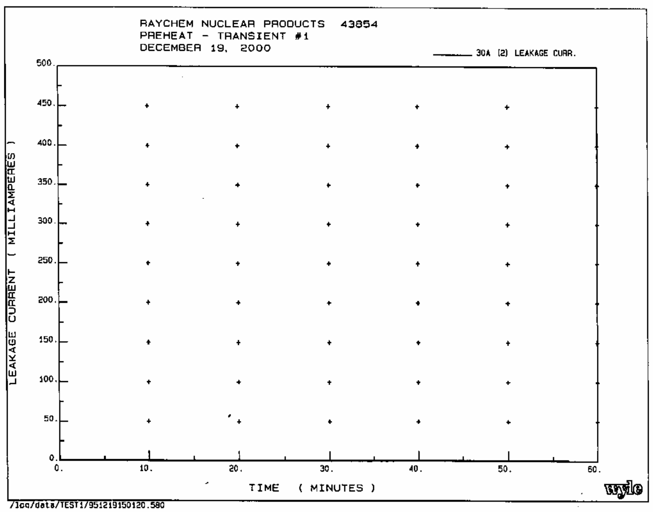
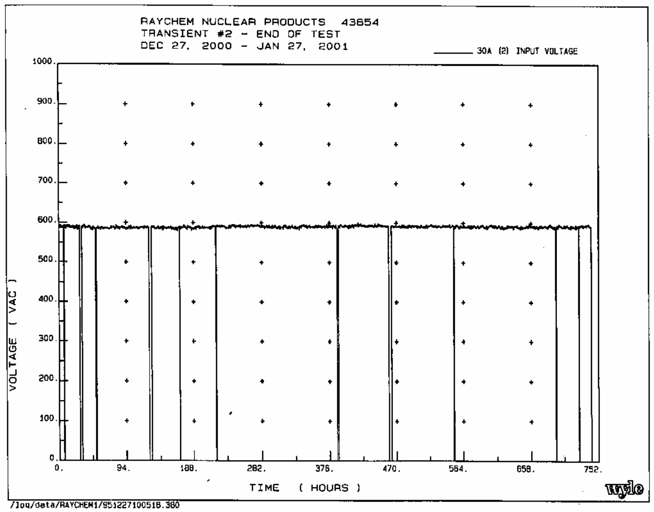
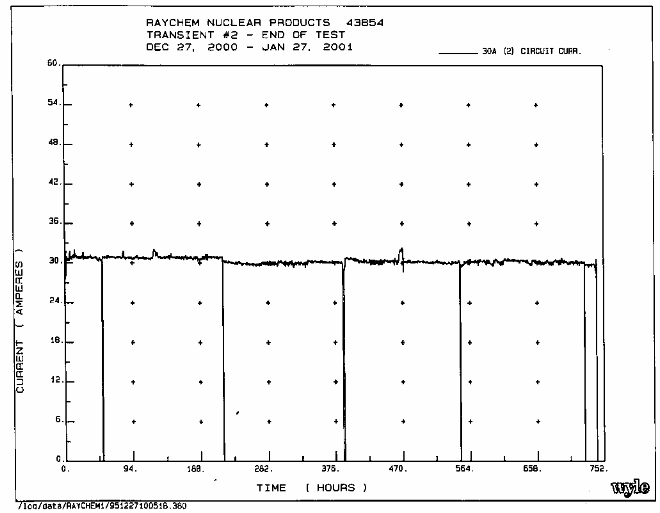
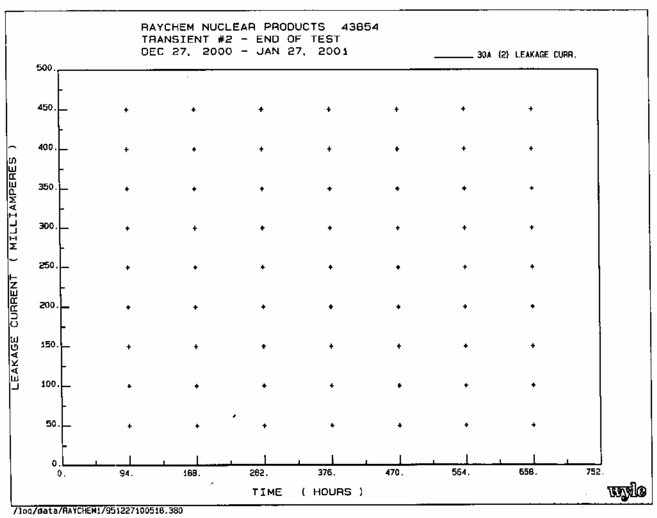
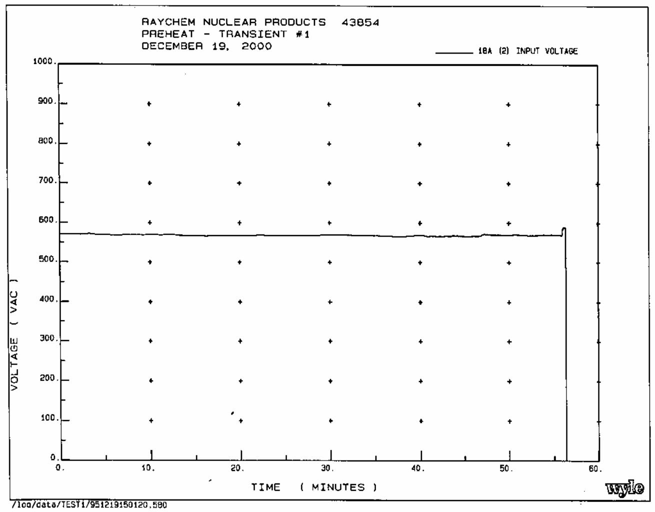

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
30A (2) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (MINUTES)
/loq/data/TEST1/951219150120.580

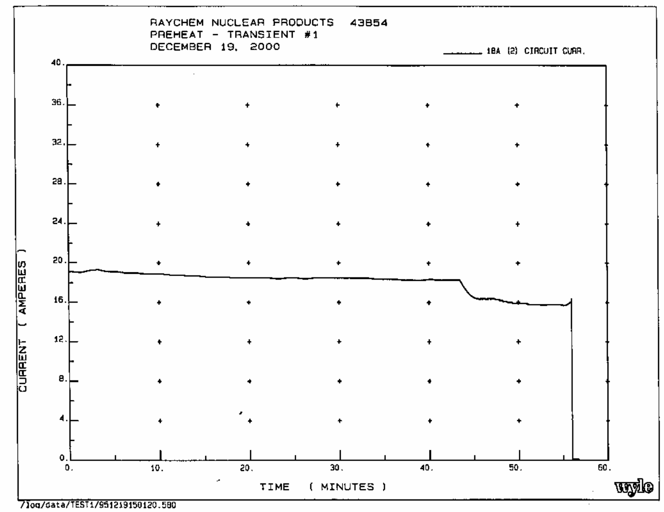

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
30A (2) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (MINUTES)
/loq/data/TEST1/951219150120.580

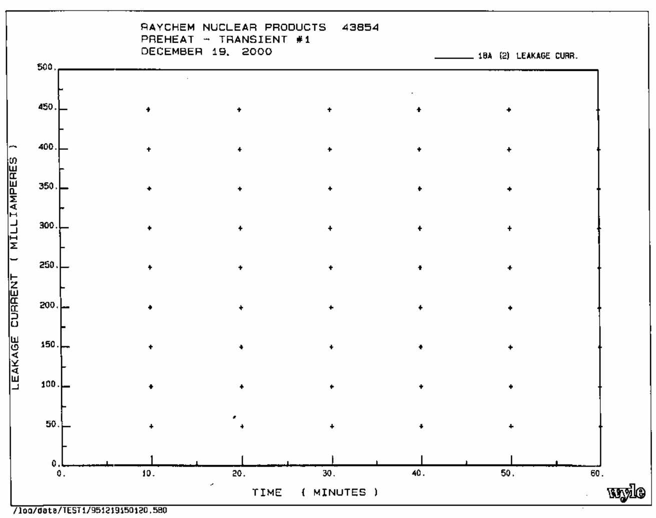

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
30A (2) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (HOURS)
/loq/data/RAYCHEM1/951227100518.380

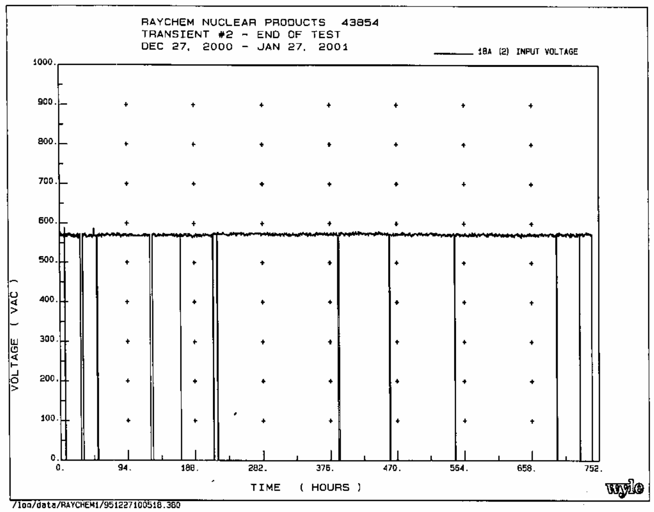

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
30A (2) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (HOURS)
/loq/data/RAYCHEM1/951227100518.380

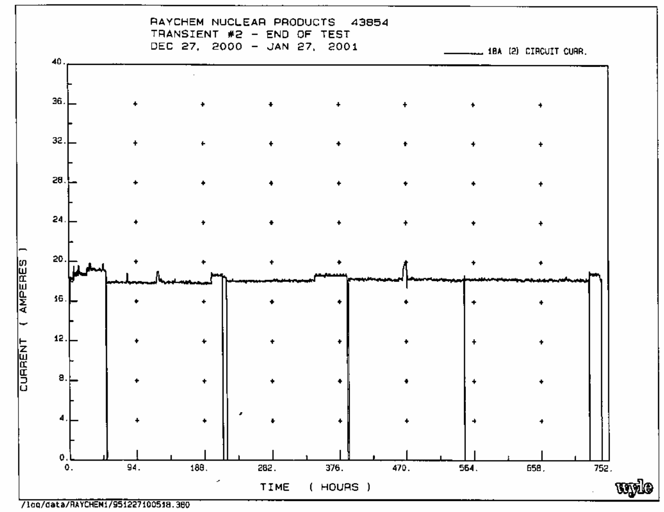

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
30A (2) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (HOURS)
/loq/data/RAYCHEM1/951227100518.380

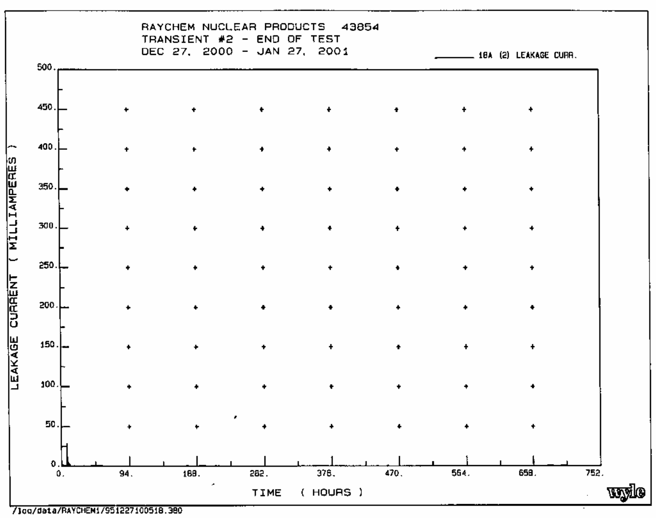

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (2) INPUT VOLTAGE
VOLTAGE (VAC)
0. 100. 200. 300. 400. 500. 600. 700. 800. 900. 1000.
0. 10. 20. 30. 40. 50. 60.
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580

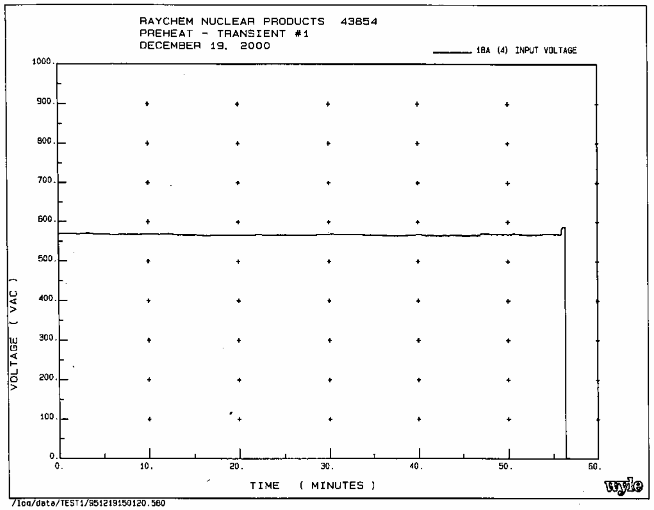

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (2) CIRCUIT CURR.
CURRENT (AMPERES)
0. 4. 8. 12. 16. 20. 24. 28. 32. 36. 40.
0. 10. 20. 30. 40. 50. 60.
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580

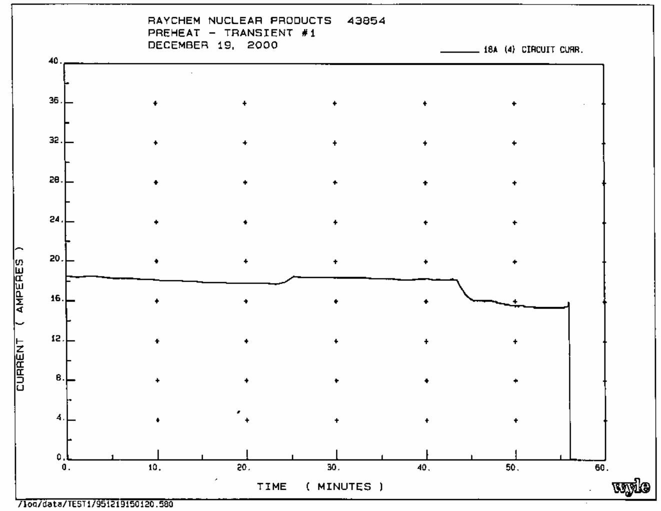

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (2) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
0. 50. 100. 150. 200. 250. 300. 350. 400. 450. 500.
0. 10. 20. 30. 40. 50. 60.
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580

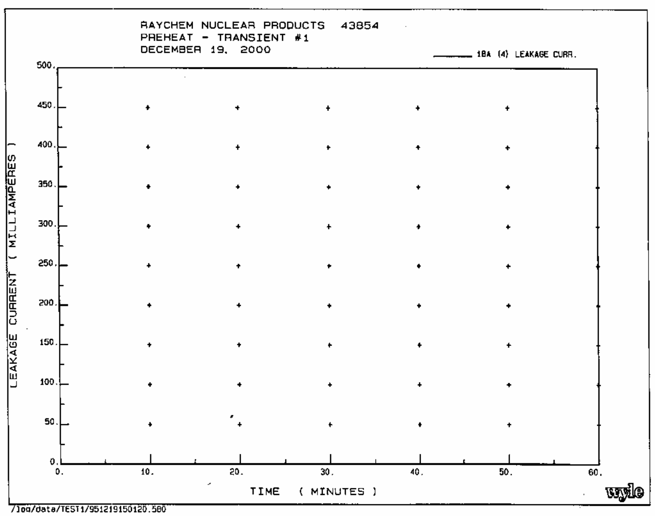

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (2) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (HOURS)
wyle

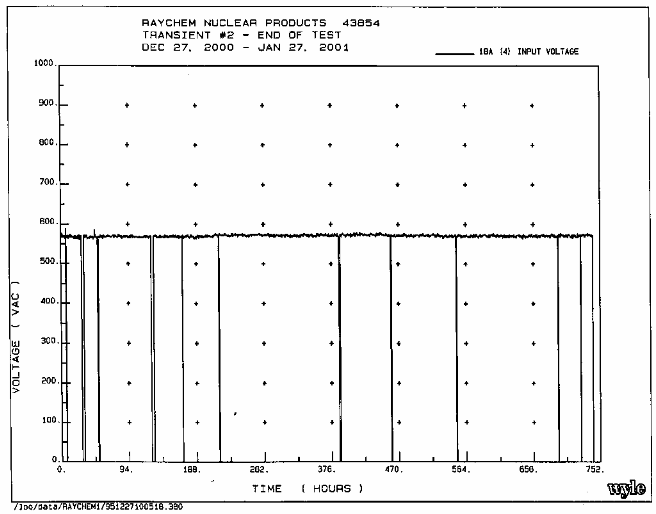

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (2) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (HOURS)
wyle

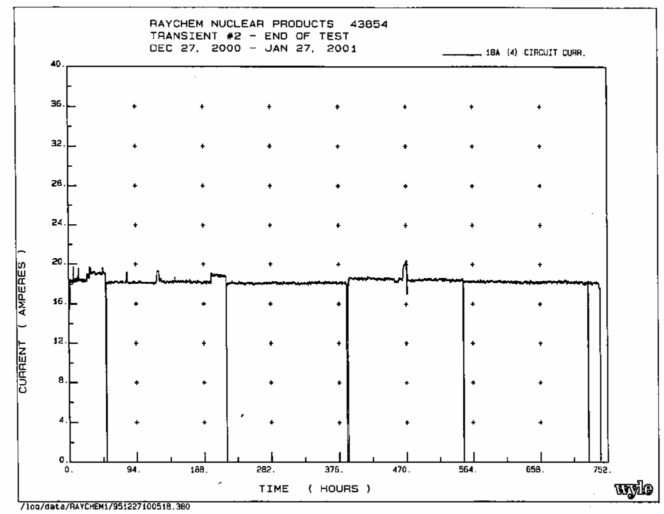

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (2) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (HOURS)
wyle

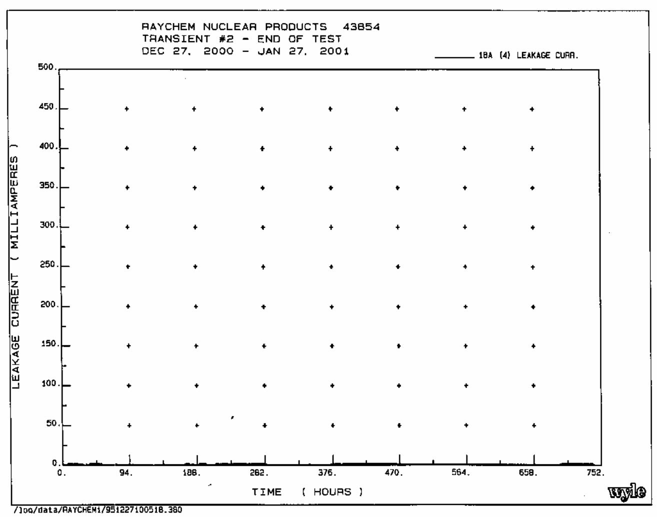

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (4) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (MINUTES)
wyle
/loo/data/TEST1/951219150120.580

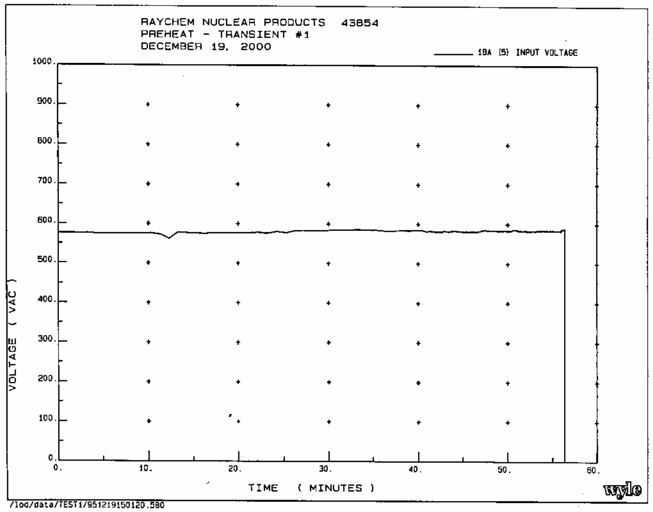

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (4) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (MINUTES)
wyle
/loo/data/TEST1/951219150120.580

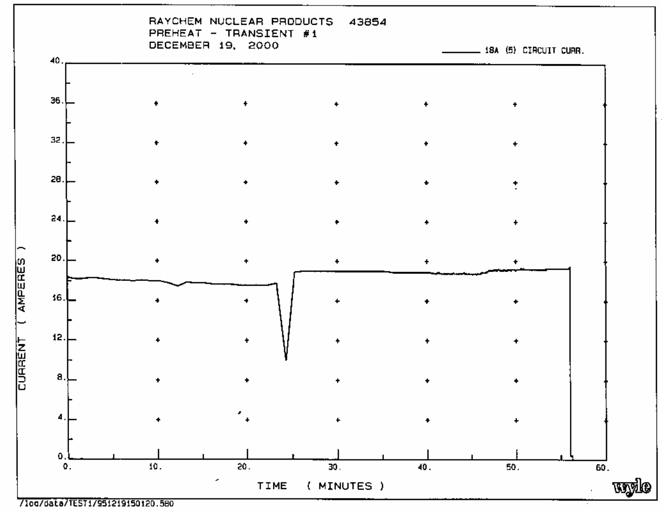

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (4) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (MINUTES)
wyle
/loo/data/TEST1/951219150120.580

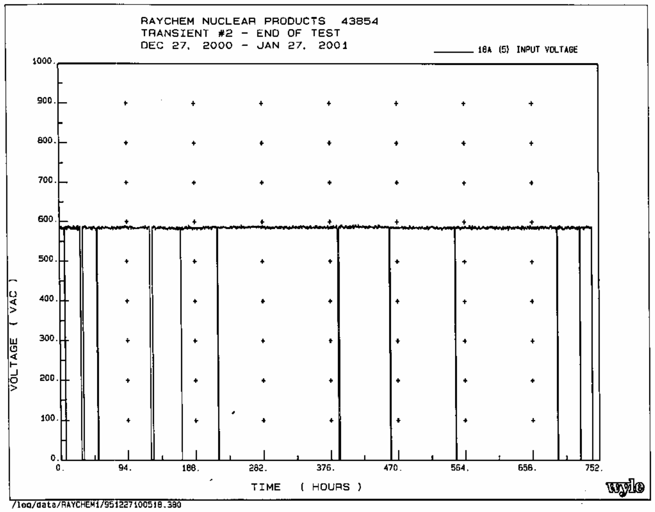

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (4) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (HOURS)
wyle
/loq/data/RAYCHEM1/951227100518.380

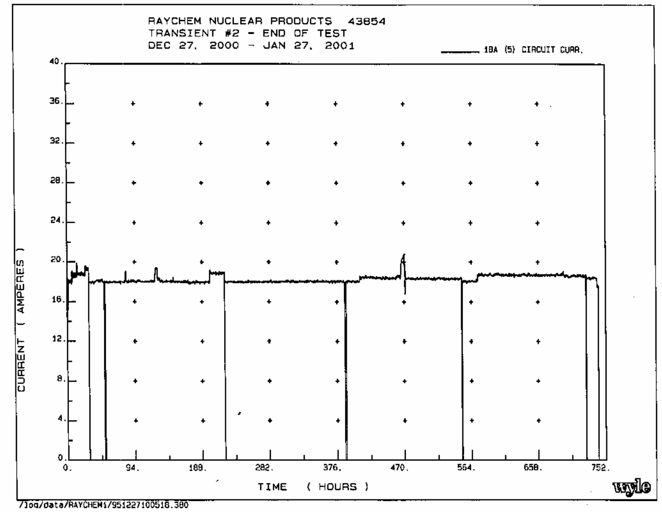

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (4) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (HOURS)
wyle
/loq/data/RAYCHEM1/951227100518.380

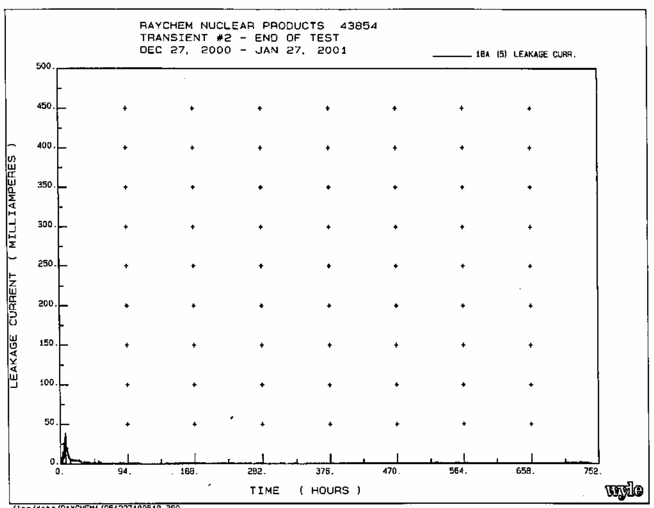

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (4) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (HOURS)
wyle
/loq/data/RAYCHEM1/951227100518.380

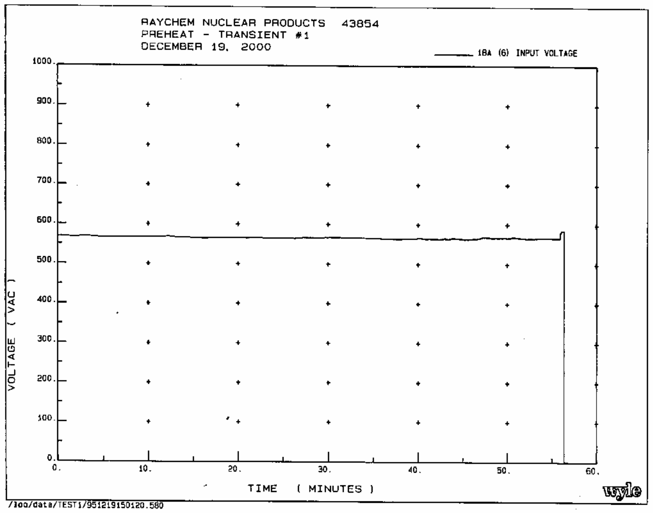

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (5) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (MINUTES)
wyle

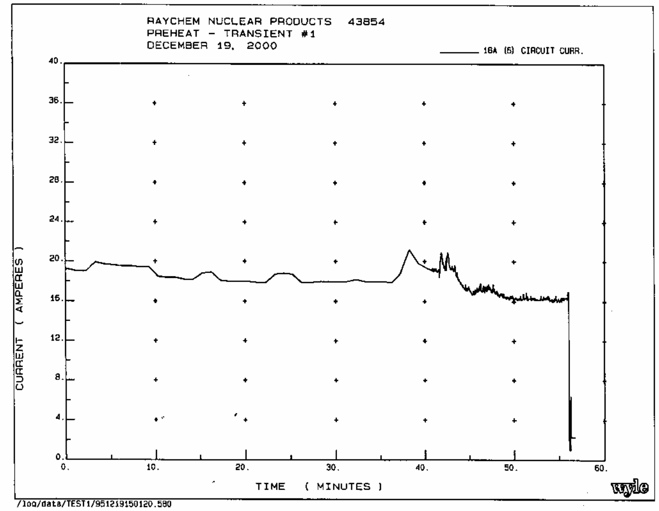

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (5) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (MINUTES)
wyle

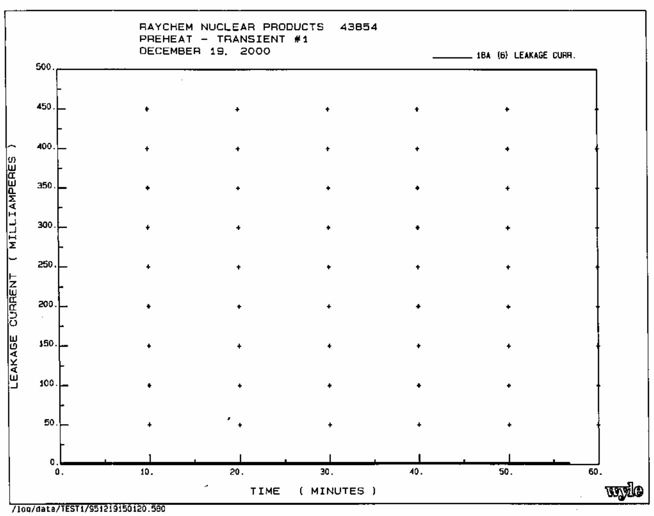

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (5) INPUT VOLTAGE
VOLTAGE (VAC)
1000.
900.
800.
700.
600.
500.
400.
300.
200.
100.
0.
0.
94.
188.
282.
376.
470.
564.
658.
752.
TIME (HOURS)
wyle
/log/data/RAYCHEM1/951227100518.380

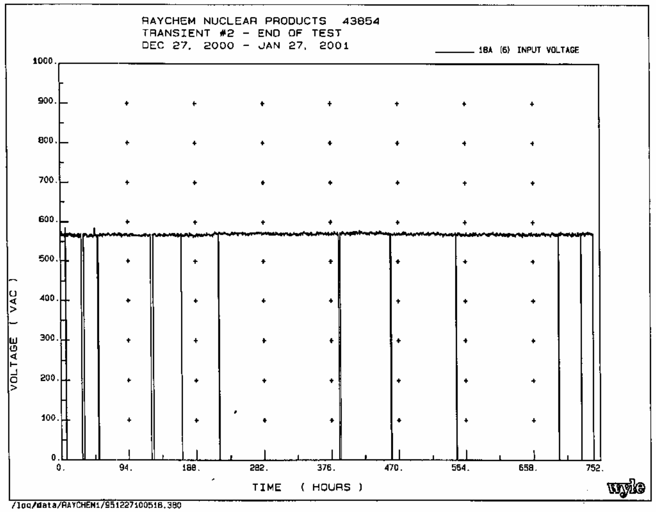

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (5) CIRCUIT CURR.
CURRENT (AMPERES)
40.
36.
32.
28.
24.
20.
16.
12.
8.
4.
0.
0.
94.
188.
282.
376.
470.
564.
658.
752.
TIME (HOURS)
wyle
/log/data/RAYCHEM1/951227100518.380

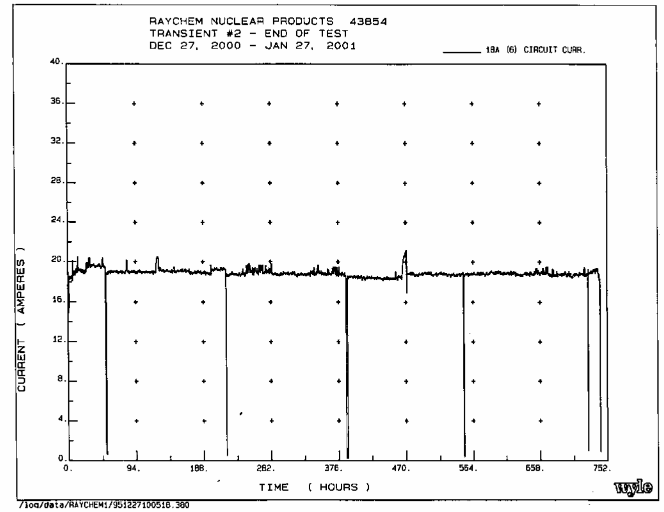

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (5) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
500.
450.
400.
350.
300.
250.
200.
150.
100.
50.
0.
0.
94.
188.
282.
376.
470.
564.
658.
752.
TIME (HOURS)
wyle
/log/data/RAYCHEM1/951227100518.380

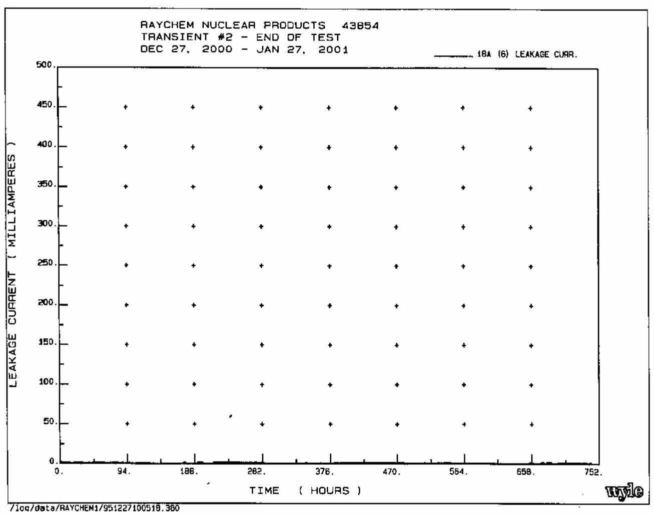

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (6) INPUT VOLTAGE
VOLTAGE (VAC)
1000.
900.
800.
700.
600.
500.
400.
300.
200.
100.
0.
0.
10.
20.
30.
40.
50.
60.
TIME (MINUTES)
/log/data/TEST1/951219150120.580

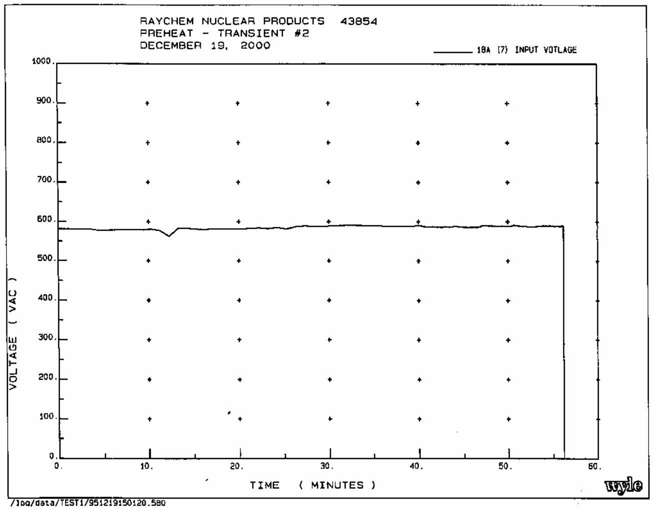

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (6) CIRCUIT CURR.
CURRENT (AMPERES)
40.
36.
32.
28.
24.
20.
16.
12.
8.
4.
0.
0.
10.
20.
30.
40.
50.
60.
TIME (MINUTES)
/log/data/TEST1/951219150120.580

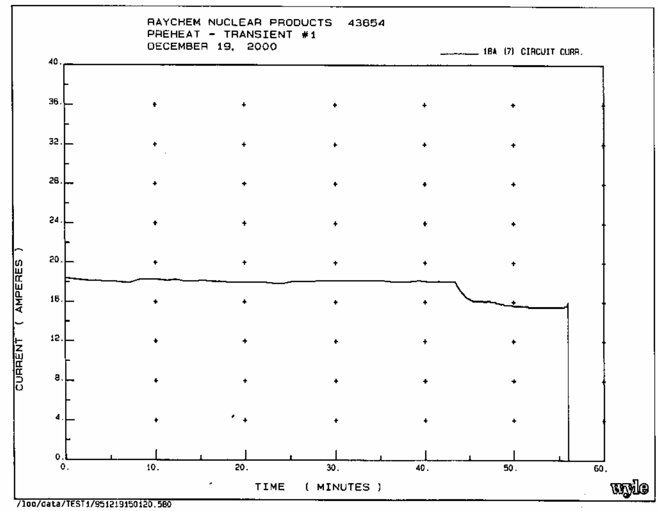

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (6) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
500.
450.
400.
350.
300.
250.
200.
150.
100.
50.
0.
0.
10.
20.
30.
40.
50.
60.
TIME (MINUTES)
/log/data/TEST1/951219150120.580

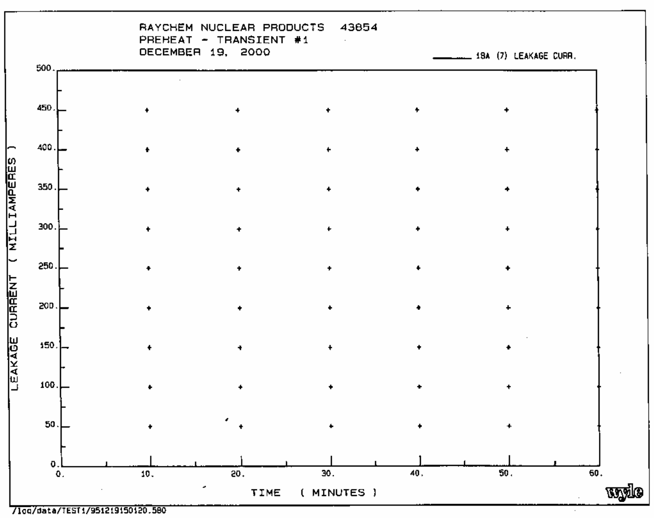

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (6) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (HOURS)
/loc/data/RAYCHEM1/951227100518.380

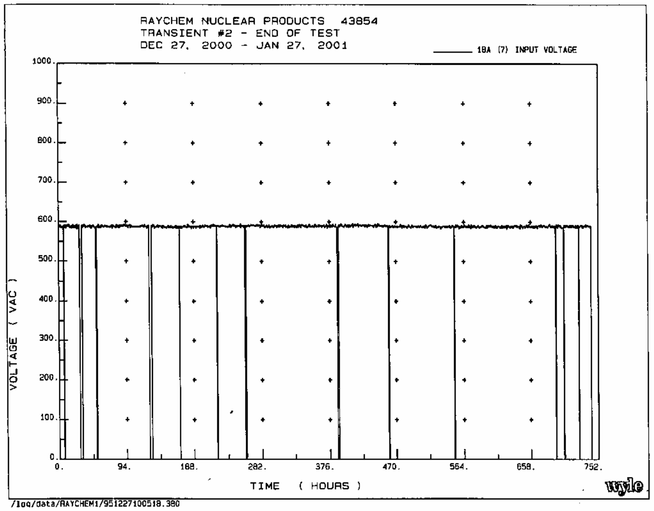

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (6) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (HOURS)
/loc/data/RAYCHEM1/951227100518.380

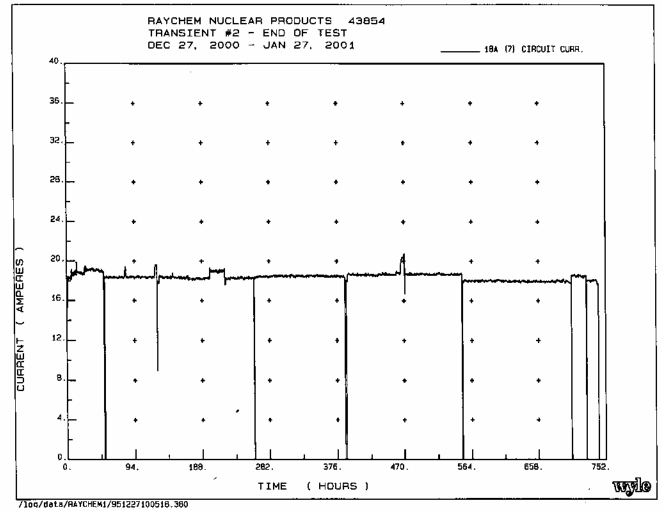

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (6) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (HOURS)
/loc/data/RAYCHEM1/951227100518.380

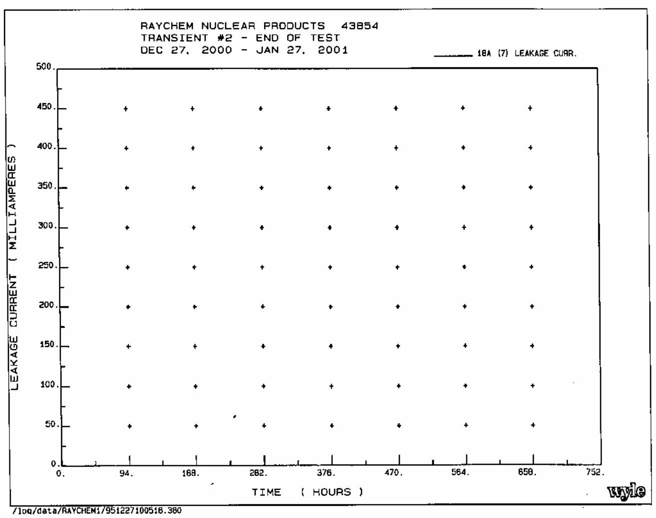

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #2
DECEMBER 19, 2000
18A (7) INPUT VOTLAGE
VOLTAGE (VAC)
1000.
900.
800.
700.
600.
500.
400.
300.
200.
100.
0.
0.
10.
20.
30.
40.
50.
60.
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580

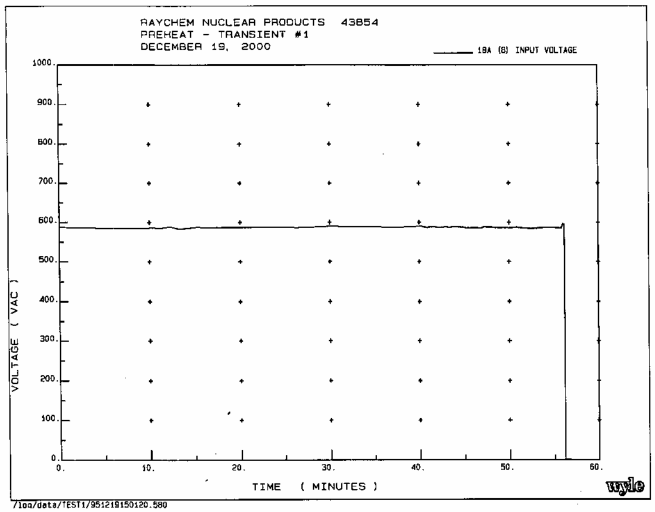

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (7) CIRCUIT CURR.
CURRENT (AMPERES)
40.
36.
32.
28.
24.
20.
16.
12.
8.
4.
0.
0.
10.
20.
30.
40.
50.
60.
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580

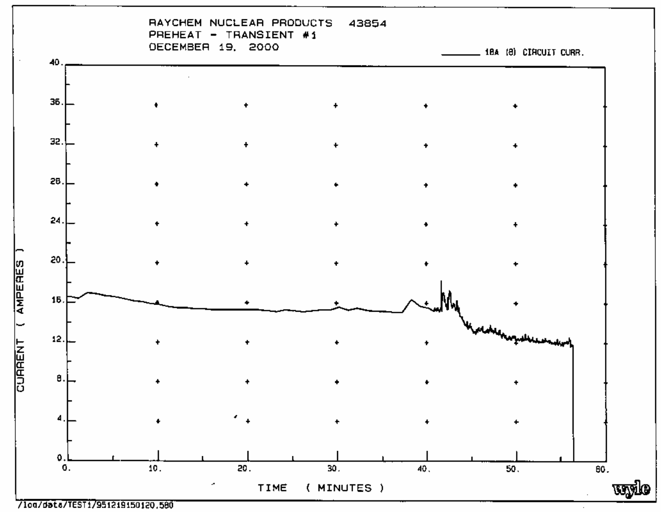

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (7) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
500.
450.
400.
350.
300.
250.
200.
150.
100.
50.
0.
0.
10.
20.
30.
40.
50.
60.
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580

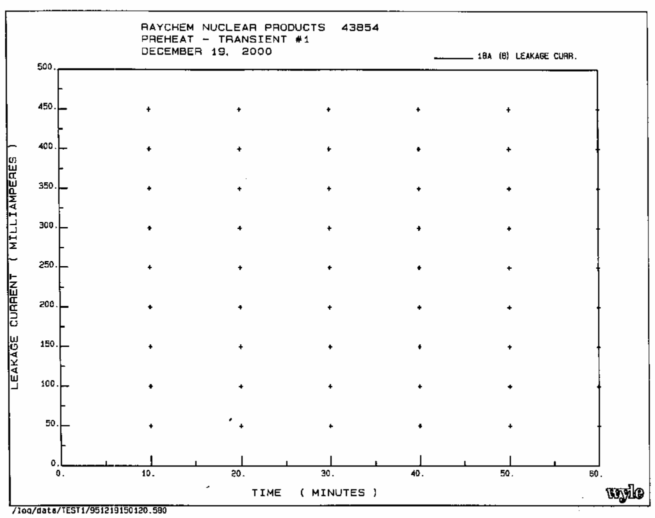

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (7) INPUT VOLTAGE
VOLTAGE (VAC)
TIME (HOURS)
wyle

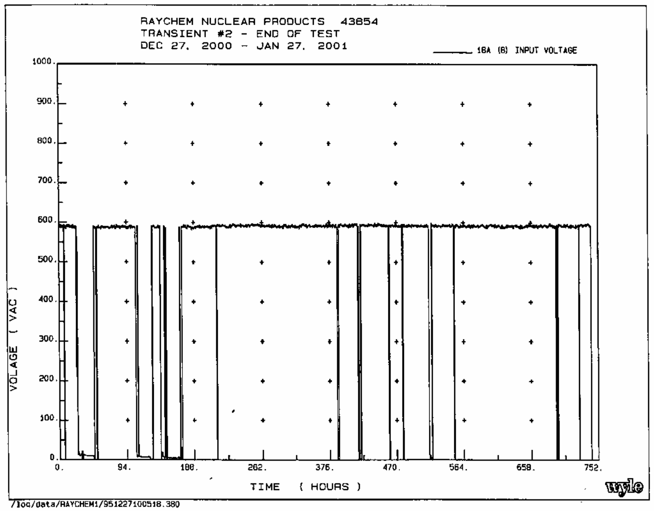

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (7) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (HOURS)
wyle

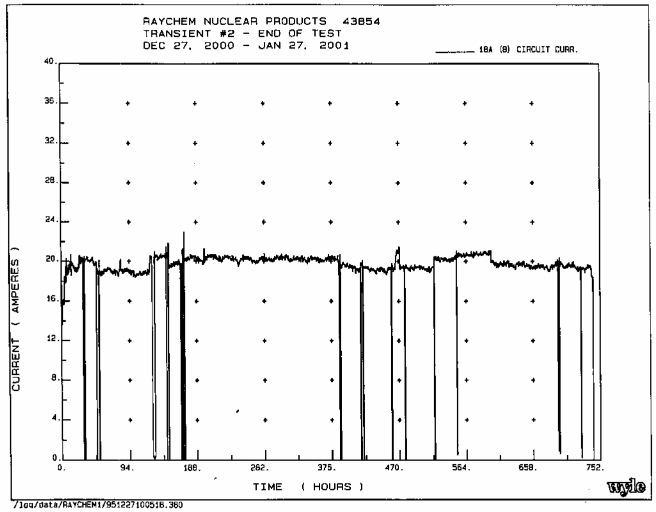

RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (7) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (HOURS)
wyle

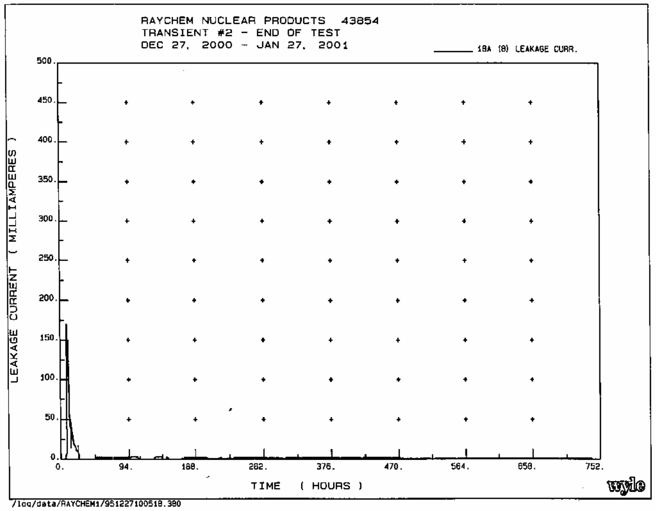

RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (8) INPUT VOLTAGE
VOLTAGE (VAC)
0.
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.
0.
10.
20.
30.
40.
50.
60.
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580


RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (8) CIRCUIT CURR.
CURRENT (AMPERES)
0.
4.
8.
12.
16.
20.
24.
28.
32.
36.
40.
0.
10.
20.
30.
40.
50.
60.
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580


RAYCHEM NUCLEAR PRODUCTS 43854
PREHEAT - TRANSIENT #1
DECEMBER 19, 2000
18A (8) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
0.
50.
100.
150.
200.
250.
300.
350.
400.
450.
500.
0.
10.
20.
30.
40.
50.
60.
TIME (MINUTES)
wyle
/log/data/TEST1/951219150120.580


RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (8) INPUT VOLTAGE
VOLAGE (VAC)
TIME (HOURS)
/loq/data/RAYCHEM1/951227100518.380


RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (8) CIRCUIT CURR.
CURRENT (AMPERES)
TIME (HOURS)
/loq/data/RAYCHEM1/951227100518.380


RAYCHEM NUCLEAR PRODUCTS 43854
TRANSIENT #2 - END OF TEST
DEC 27, 2000 - JAN 27, 2001
18A (8) LEAKAGE CURR.
LEAKAGE CURRENT (MILLIAMPERES)
TIME (HOURS)
/loq/data/RAYCHEM1/951227100518.380

APPENDIX 3

Sample Test Conditions

Sample Type	SPECIMEN NO.	Cable Number	CONNECTION WIRE (AWG)	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rad)		APPLIED CURRENT DURING LOCA (AMPS)
						Target	Actual	
In-Line Splice with Crimp Connector	1	9	16	1	878 hr @ 302°F	2.15E+08	1.964E+08	18
	2	9	16	1	878 hr @ 302°F	2.15E+08	1.964E+08	18
	3	9	16	1	878 hr @ 302°F	2.15E+08	1.964E+08	18
	4	9	16	1	878 hr @ 302°F	2.15E+08	1.964E+08	18
	5	9	16	1	878 hr @ 302°F	2.15E+08	1.964E+08	18
	6	9	16	1	878 hr @ 302°F	2.15E+08	1.964E+08	18
	7	6	14	1	878 hr @ 302°F	2.15E+08	1.964E+08	25
	8	6	14	1	878 hr @ 302°F	2.15E+08	1.964E+08	25
	9	6	14	1	878 hr @ 302°F	2.15E+08	1.964E+08	25
	10	6	14	1	878 hr @ 302°F	2.15E+08	1.964E+08	25
	11	6	14	1	878 hr @ 302°F	2.15E+08	1.964E+08	25
	12	6	14	1	878 hr @ 302°F	2.15E+08	1.964E+08	25
	13	9	16	2	N/A	1.65E+08	1.487E+08	18
	14	9	16	2	N/A	1.65E+08	1.487E+08	18
	15	9	16	2	N/A	1.65E+08	1.487E+08	18
	16	9	16	2	N/A	1.65E+08	1.487E+08	18
	17	9	16	2	N/A	1.65E+08	1.487E+08	18
	18	9	16	2	N/A	1.65E+08	1.487E+08	18
	19	6	14	2	N/A	1.65E+08	1.487E+08	25
	20	6	14	2	N/A	1.65E+08	1.487E+08	25
	21	6	14	2	N/A	1.65E+08	1.487E+08	25
	22	6	14	2	N/A	1.65E+08	1.487E+08	25
	23	6	14	2	N/A	1.65E+08	1.487E+08	25
	24	6	14	2	N/A	1.65E+08	1.487E+08	25
	25	9	16	3	878 hr @ 302°F	2.15E+08	1.964E+08	18
	26	9	16	3	878 hr @ 302°F	2.15E+08	1.964E+08	18
	27	9	16	3	878 hr @ 302°F	2.15E+08	1.964E+08	18
	31	9	16	4	N/A	1.65E+08	1.487E+08	18
	32	9	16	4	N/A	1.65E+08	1.487E+08	18

Sample Type	SPECIMEN NO.	Cable Number	CONNECTION WIRE (AWG)	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rad)		APPLIED CURRENT DURING LOCA (AMPS)
						Target	Actual	
In-Line Splice with Crimp Connector	33	9	16	4	N/A	1.65E+08	1.487E+08	18
	37	9	16	5	1379 hr @ 302°F	2.40E+08	2.184E+08	18
	38	9	16	5	1379 hr @ 302°F	2.40E+08	2.184E+08	18
	39	9	16	5	1379 hr @ 302°F	2.40E+08	2.184E+08	18
	40	9	16	5	1379 hr @ 302°F	2.40E+08	2.184E+08	18
	41	9	16	5	1379 hr @ 302°F	2.40E+08	2.184E+08	18
	42	9	16	5	1379 hr @ 302°F	2.40E+08	2.184E+08	18
	127	9	16	4	N/A	1.65E+08	1.487E+08	18
	128	9	16	4	N/A	1.65E+08	1.487E+08	18
	129	9	16	4	N/A	1.65E+08	1.487E+08	18
	130	7(1C/7)	14	3	878 hr @ 302°F	2.15E+08	1.964E+08	25
	131	7(1C/7)	14	3	878 hr @ 302°F	2.15E+08	1.964E+08	25
	132	7(1C/7)	14	3	878 hr @ 302°F	2.15E+08	1.964E+08	25
In-Line Splice with Bolted Connection	43	4	12	6	878 hr @ 302°F	2.15E+08	1.964E+08	30
	44	4	12	6	878 hr @ 302°F	2.15E+08	1.964E+08	30
	45	4	12	6	878 hr @ 302°F	2.15E+08	1.964E+08	30
	46	4	12	6	878 hr @ 302°F	2.15E+08	1.964E+08	30
	47	4	12	6	878 hr @ 302°F	2.15E+08	1.964E+08	30
	48	4	12	6	878 hr @ 302°F	2.15E+08	1.964E+08	30
	49	2	4	Tray 2	878 hr @ 302°F	2.15E+08	1.951E+08	95
	50	2	4	Tray 2	878 hr @ 302°F	2.15E+08	1.951E+08	95
	51	2	4	Tray 2	878 hr @ 302°F	2.15E+08	1.951E+08	95
	52	4	12	6	878 hr @ 302°F	2.15E+08	1.964E+08	30
	53	4	12	6	878 hr @ 302°F	2.15E+08	1.964E+08	30
	54	4	12	6	878 hr @ 302°F	2.15E+08	1.964E+08	30
	55	4	12	6	878 hr @ 302°F	2.15E+08	1.964E+08	30
	56	4	12	6	878 hr @ 302°F	2.15E+08	1.964E+08	30
	57	4	12	6	878 hr @ 302°F	2.15E+08	1.964E+08	30
	58	4	12	8	N/A	1.65E+08	1.487E+08	30

Sample Type	SPECIMEN NO.	Cable Number	CONNECTION WIRE (AWG)	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rad)		APPLIED CURRENT DURING LOCA (AMPS)
						Target	Actual	
In-Line Splice with Bolted Connection	59	4	12	8	N/A	1.65E+08	1.487E+08	30
	60	4	12	8	N/A	1.65E+08	1.487E+08	30
	61	4	12	8	N/A	1.65E+08	1.487E+08	30
	62	4	12	8	N/A	1.65E+08	1.487E+08	30
	63	4	12	8	N/A	1.65E+08	1.487E+08	30
	64	2	4	Tray 3	N/A	1.65E+08	1.488E+08	95
	65	2	4	Tray 3	N/A	1.65E+08	1.488E+08	95
	66	2	4	Tray 3	N/A	1.65E+08	1.488E+08	95
	67	4	12	8	N/A	1.65E+08	1.487E+08	30
	68	4	12	8	N/A	1.65E+08	1.487E+08	30
	69	4	12	8	N/A	1.65E+08	1.487E+08	30
	70	4	12	8	N/A	1.65E+08	1.487E+08	30
	71	4	12	8	N/A	1.65E+08	1.487E+08	30
	72	4	12	8	N/A	1.65E+08	1.487E+08	30
Nuclear Plant Transition Splice	80	7	14	Tray 1	878 hr @ 302°F	2.15E+08	1.951E+08	25
	81	7	14	Tray 1	878 hr @ 302°F	2.15E+08	1.951E+08	25
	82	7	14	Tray 1	878 hr @ 302°F	2.15E+08	1.951E+08	25
	83	7	14	Tray 3	N/A	1.65E+08	1.488E+08	25
	84	7	14	Tray 1	878 hr @ 302°F	2.15E+08	1.951E+08	25
	85	7	14	Tray 1	878 hr @ 302°F	2.15E+08	1.951E+08	25
	86	7	14	Tray 1	878 hr @ 302°F	2.15E+08	1.951E+08	25
	87	7	14	Tray 1	878 hr @ 302°F	2.15E+08	1.951E+08	25

Sample Type	SPECIMEN NO.	Cable Number	CONNECTION WIRE (AWG)	MANDREL NO.	AGING TIME & TEMP.	RADIATION DOSE (rad)		APPLIED CURRENT DURING LOCA (AMPS)
						Target	Actual	
1/C to 1/C Terminal Block Replacement Splice	88	5	16	12	878 hr @ 302°F	2.15E+08	1.964E+08	18
	89	5	16	12	878 hr @ 302°F	2.15E+08	1.964E+08	18
	90	5	16	12	878 hr @ 302°F	2.15E+08	1.964E+08	18
	91	5	16	13	N/A	1.65E+08	1.487E+08	18
	92	5	16	13	N/A	1.65E+08	1.487E+08	18
	93	5	16	13	N/A	1.65E+08	1.487E+08	18
1/C to 2/C Terminal Block Replacement Splice	94	5	16	12	878 hr @ 302°F	2.15E+08	1.964E+08	18
	95	5	16	12	878 hr @ 302°F	2.15E+08	1.964E+08	18
	96	5	16	12	878 hr @ 302°F	2.15E+08	1.964E+08	18
	97	5	16	13	N/A	1.65E+08	1.487E+08	18
	98	5	16	13	N/A	1.65E+08	1.487E+08	18
	99	5	16	13	N/A	1.65E+08	1.487E+08	18
2/C to 2/C Terminal Block Replacement Splice	100	5	16	12	878 hr @ 302°F	2.15E+08	1.964E+08	18
	101	5	16	12	878 hr @ 302°F	2.15E+08	1.964E+08	18
	102	5	16	12	878 hr @ 302°F	2.15E+08	1.964E+08	18
	103	5	16	13	N/A	1.65E+08	1.487E+08	18
	104	5	16	13	N/A	1.65E+08	1.487E+08	18
	105	5	16	13	N/A	1.65E+08	1.487E+08	18
Nuclear Grade NJRT Jacket Repair Splice Sealing Tape	109	2	4	14	878 hr @ 302°F	2.15E+08	1.964E+08	95
	110	2	4	14	878 hr @ 302°F	2.15E+08	1.964E+08	95
	111	2	4	14	878 hr @ 302°F	2.15E+08	1.964E+08	95
	115	2	4	15	N/A	1.65E+08	1.487E+08	95
	116	2	4	14	878 hr @ 302°F	2.15E+08	1.487E+08	95
	117	2	4	14	878 hr @ 302°F	2.15E+08	1.487E+08	95

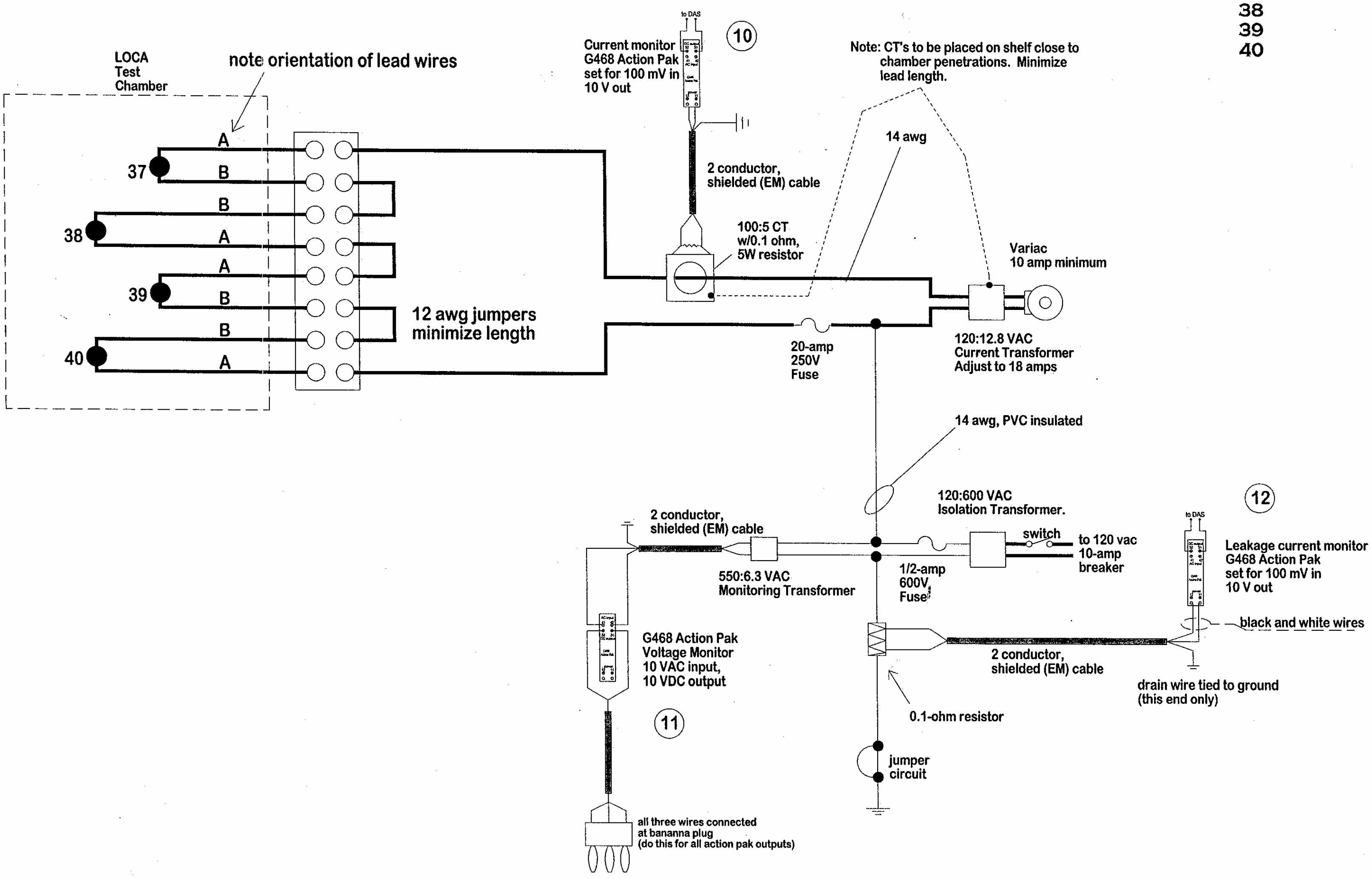
APPENDIX 4

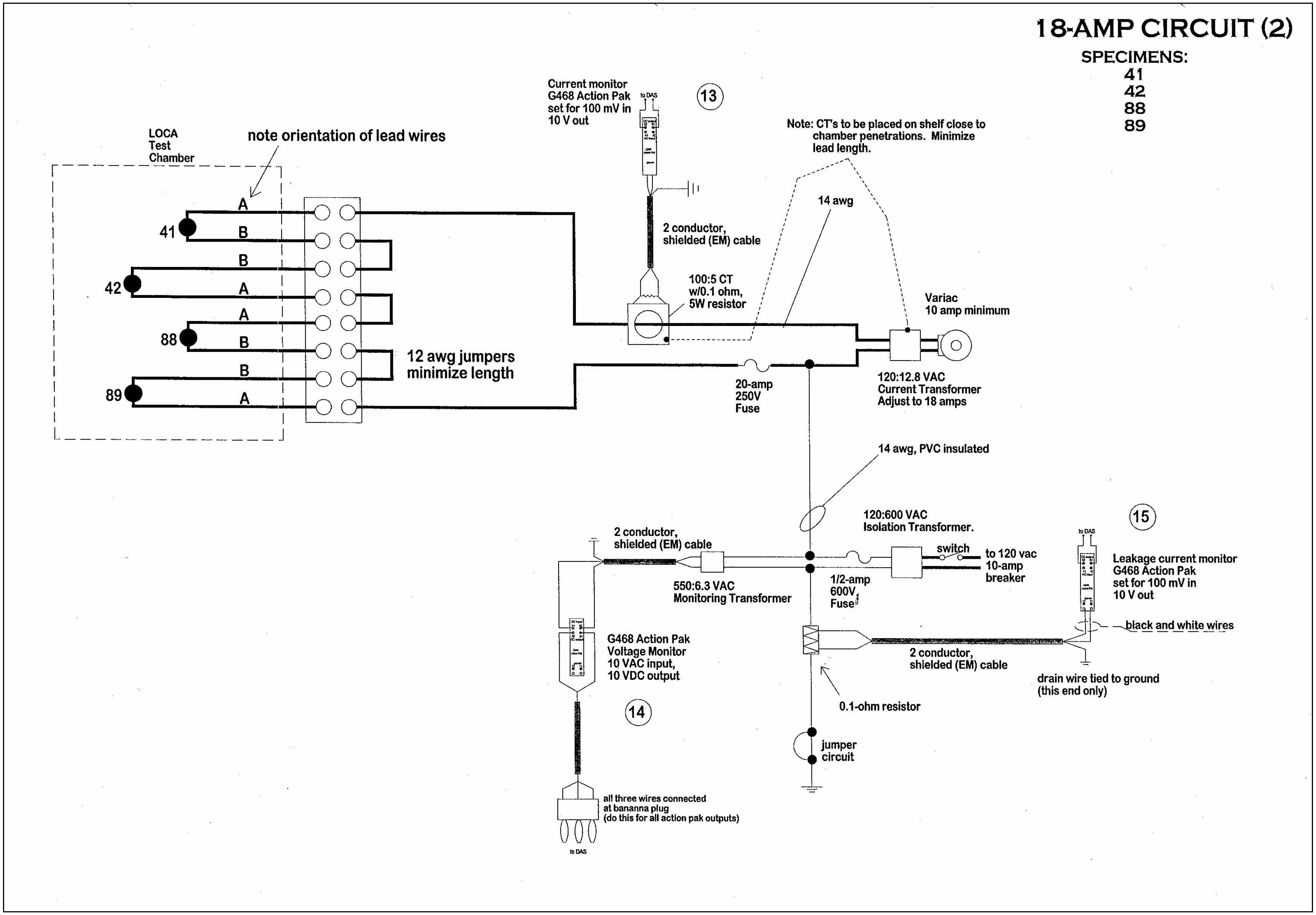
Sample monitoring circuits

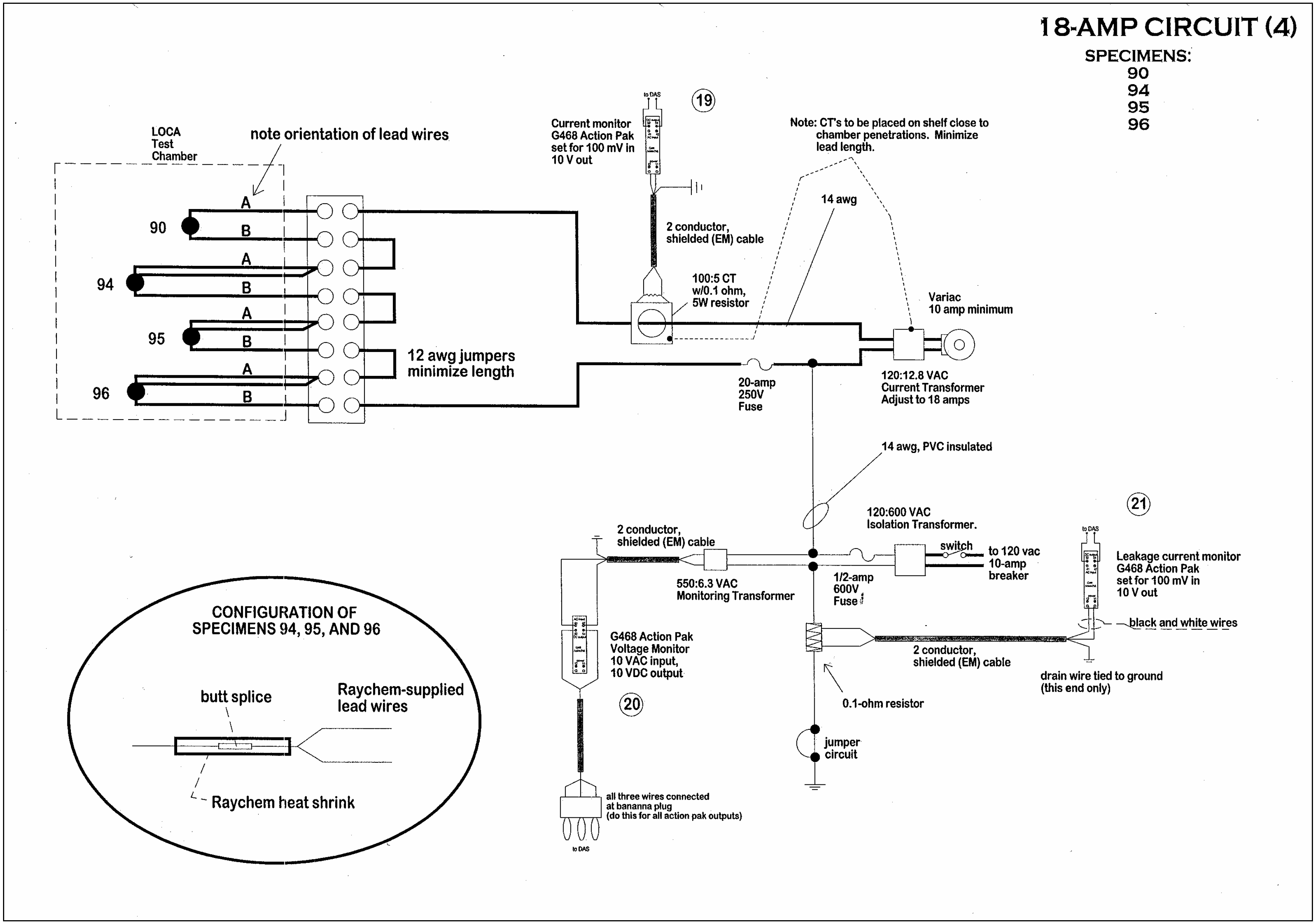
Note: Some test samples were of different construction and the results are not presented in this report.

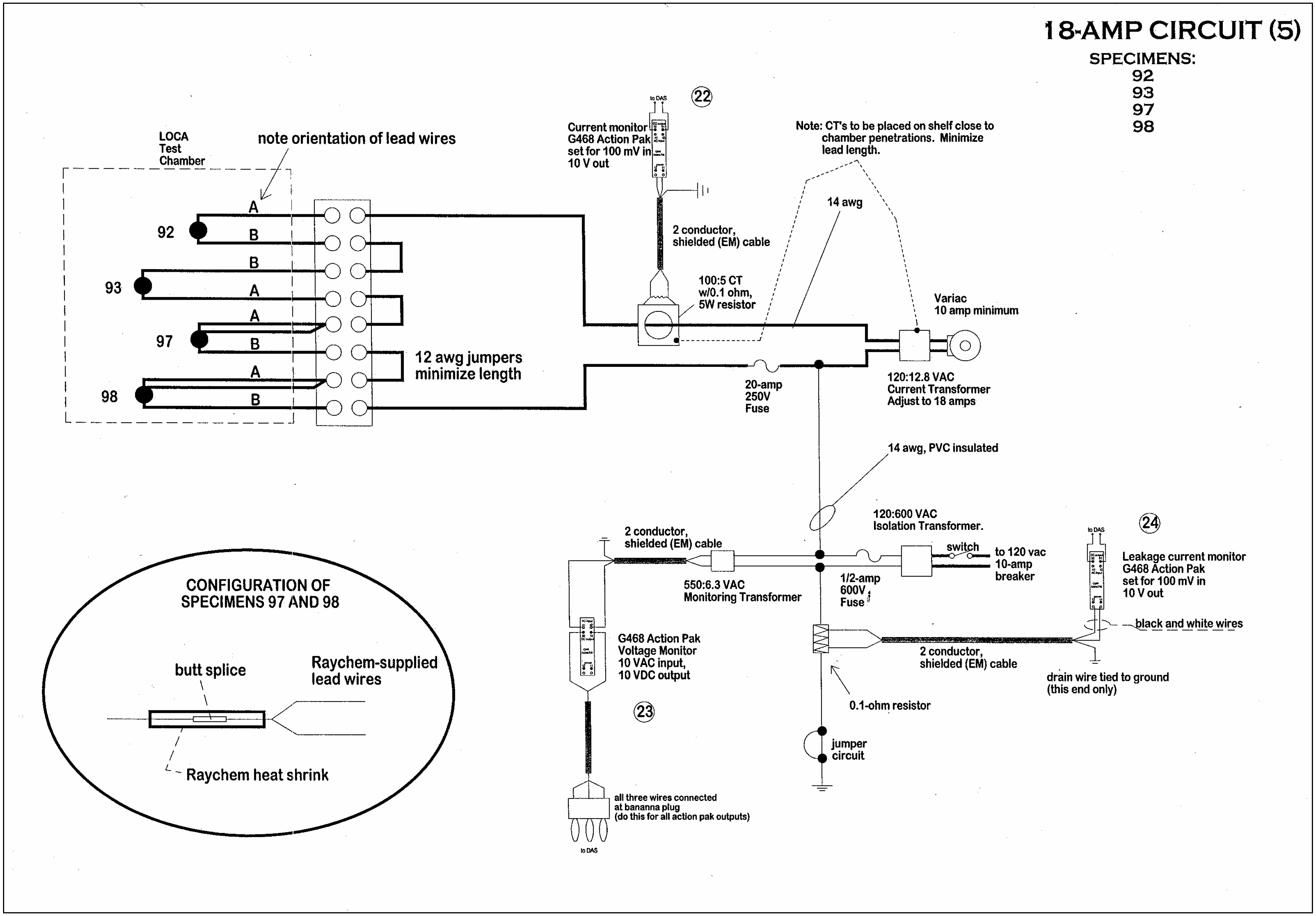
18-AMP CIRCUIT (1)

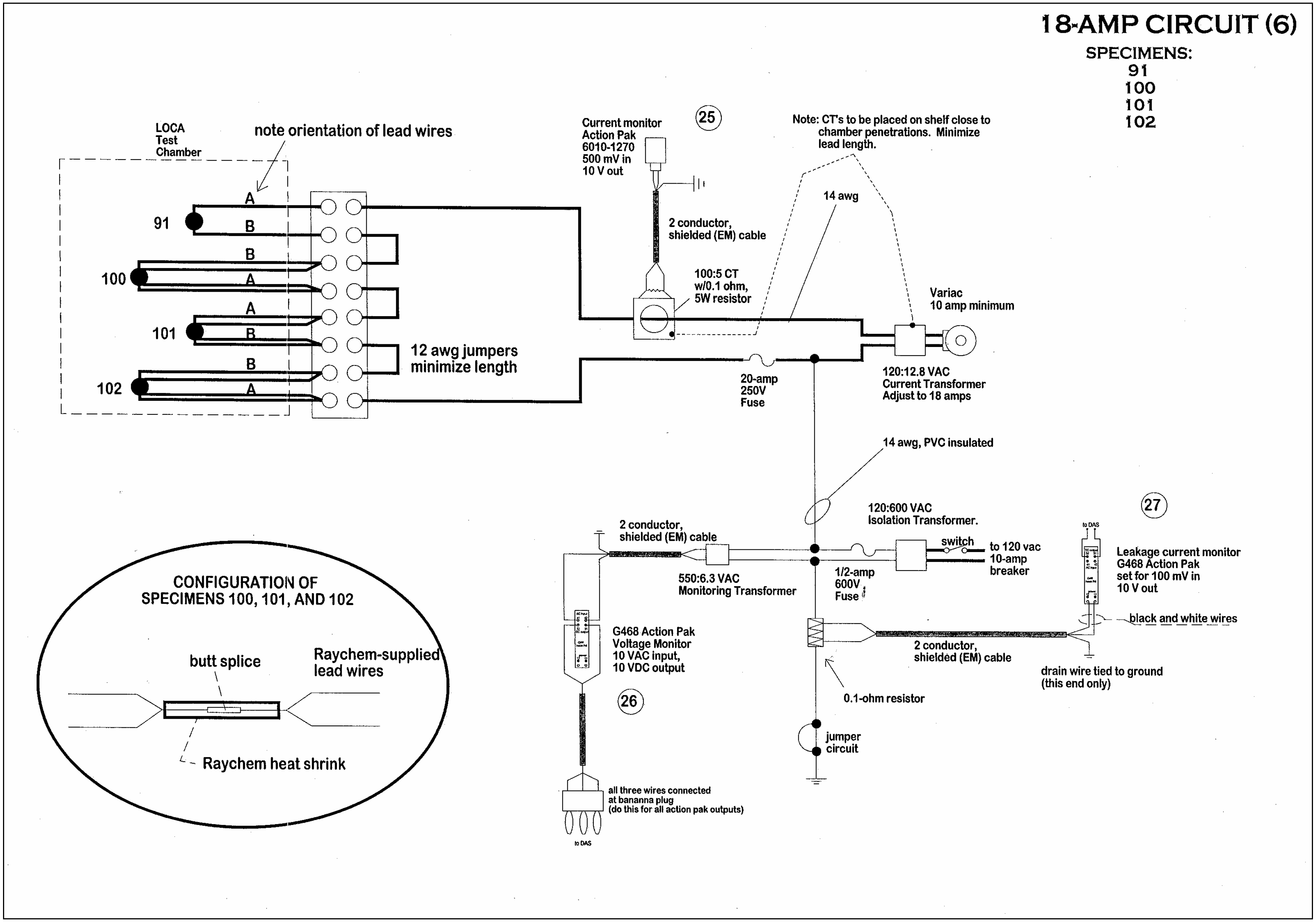
SPECIMENS:
37
38
39
40

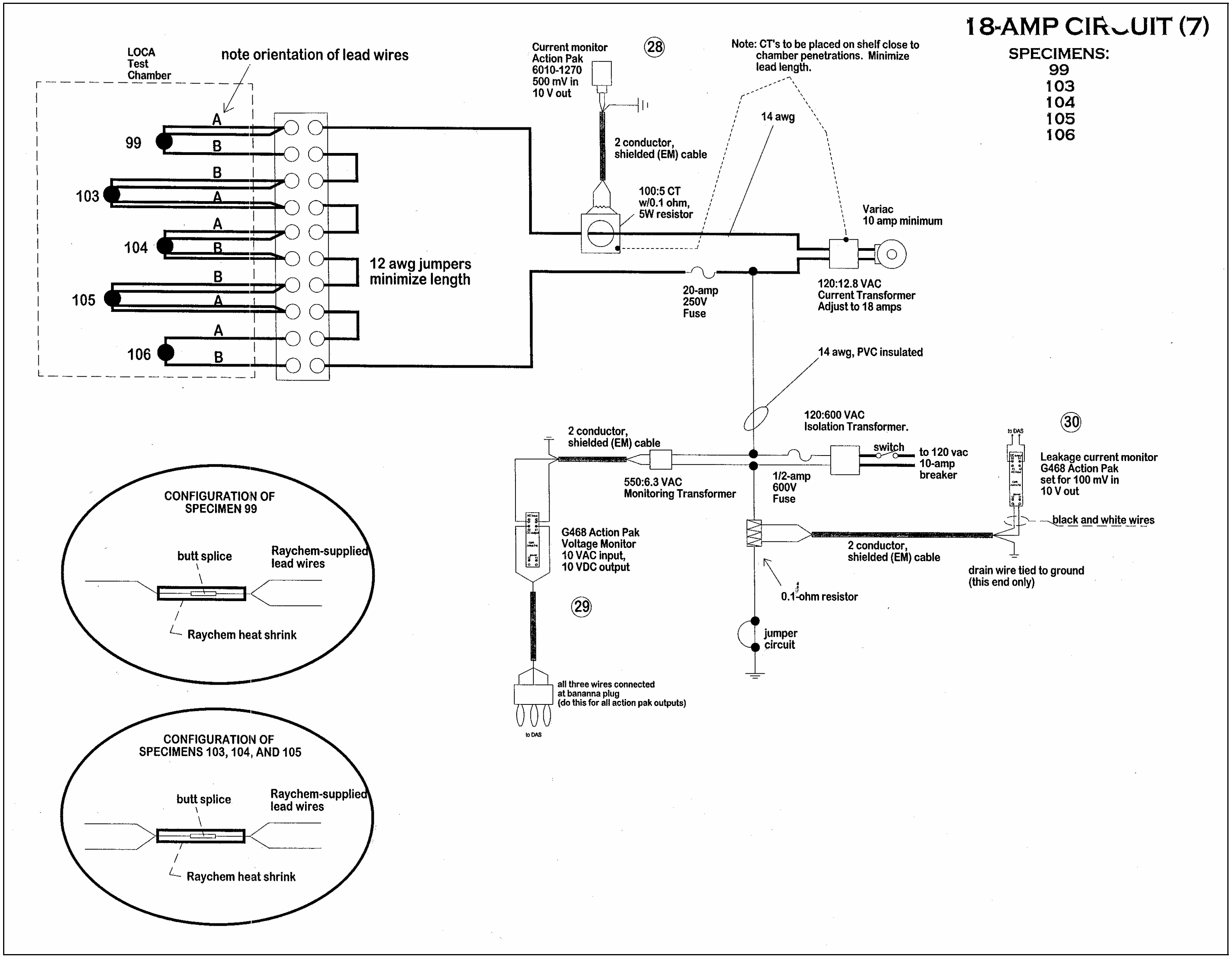


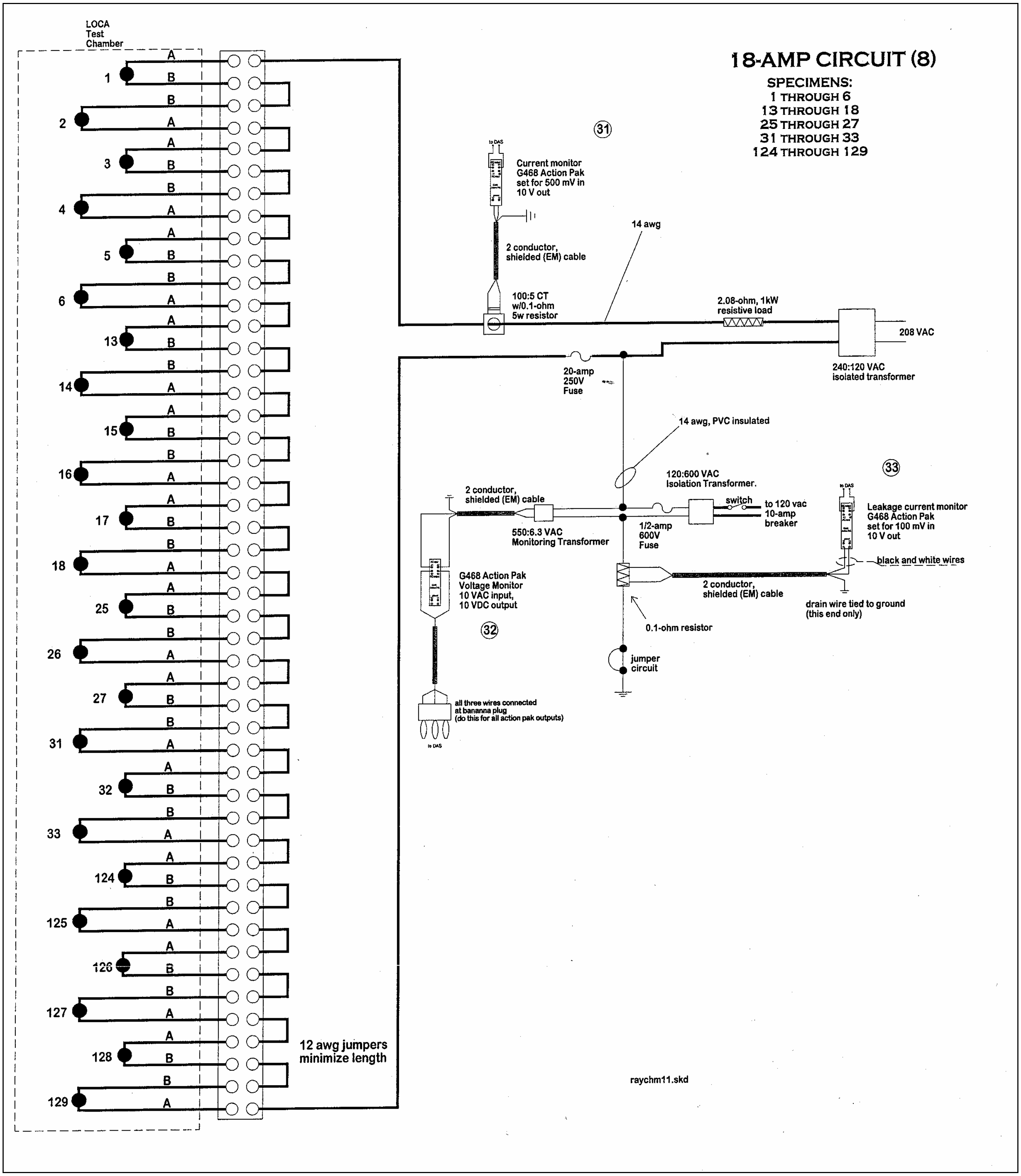

18-AMP CIRCUIT (2)
SPECIMENS:
41
42
88
89
LOCA Test Chamber
note orientation of lead wires
A
B
B
A
A
B
B
A
41
42
88
89
12 awg jumpers minimize length
Current monitor G468 Action Pak set for 100 mV in 10 V out
13
2 conductor, shielded (EM) cable
100:5 CT w/0.1 ohm, 5W resistor
Note: CT's to be placed on shelf close to chamber penetrations. Minimize lead length.
14 awg
Variac 10 amp minimum
120:12.8 VAC Current Transformer Adjust to 18 amps
20-amp 250V Fuse
14 awg, PVC insulated
120:600 VAC Isolation Transformer.
switch
to 120 vac 10-amp breaker
1/2-amp 600V Fuse
2 conductor, shielded (EM) cable
550:6.3 VAC Monitoring Transformer
G468 Action Pak Voltage Monitor 10 VAC input, 10 VDC output
14
all three wires connected at banana plug (do this for all action pak outputs)
15
Leakage current monitor G468 Action Pak set for 100 mV in 10 V out
black and white wires
2 conductor, shielded (EM) cable
drain wire tied to ground (this end only)
0.1-ohm resistor
jumper circuit

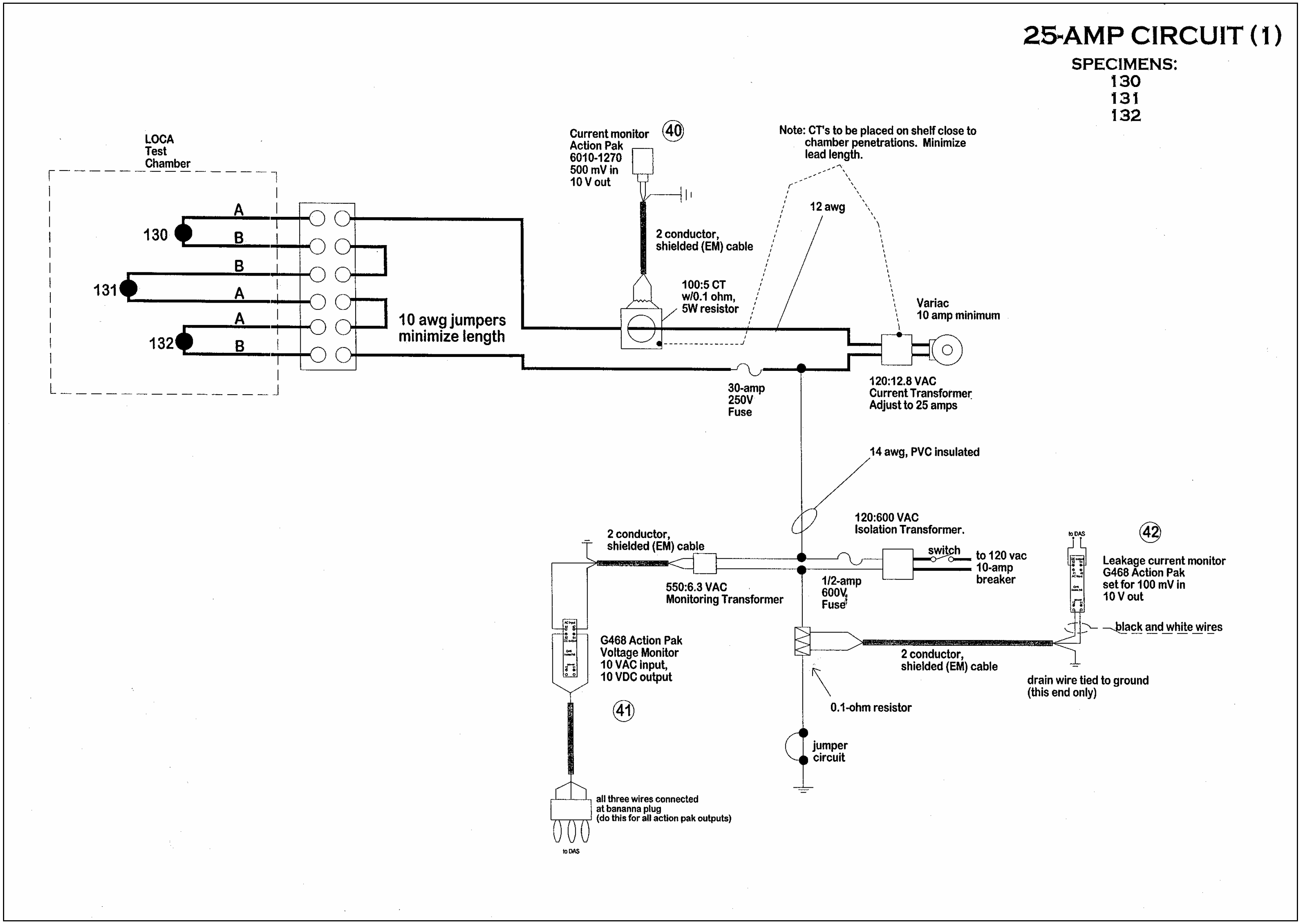

18-AMP CIRCUIT (4)
SPECIMENS:
90
94
95
96
LOCA Test Chamber
note orientation of lead wires
A
B
90
94
95
96
12 awg jumpers minimize length
Current monitor G468 Action Pak set for 100 mV in 10 V out
19
2 conductor, shielded (EM) cable
100:5 CT w/0.1 ohm, 5W resistor
Note: CT's to be placed on shelf close to chamber penetrations. Minimize lead length.
14 awg
Variac 10 amp minimum
20-amp 250V Fuse
120:12.8 VAC Current Transformer Adjust to 18 amps
14 awg, PVC insulated
120:600 VAC Isolation Transformer.
21
switch
to 120 vac 10-amp breaker
2 conductor, shielded (EM) cable
550:6.3 VAC Monitoring Transformer
1/2-amp 600V Fuse
Leakage current monitor G468 Action Pak set for 100 mV in 10 V out
black and white wires
G468 Action Pak Voltage Monitor 10 VAC input, 10 VDC output
20
2 conductor, shielded (EM) cable
drain wire tied to ground (this end only)
0.1-ohm resistor
jumper circuit
all three wires connected at bananna plug (do this for all action pak outputs)
CONFIGURATION OF SPECIMENS 94, 95, AND 96
butt splice
Raychem-supplied lead wires
Raychem heat shrink

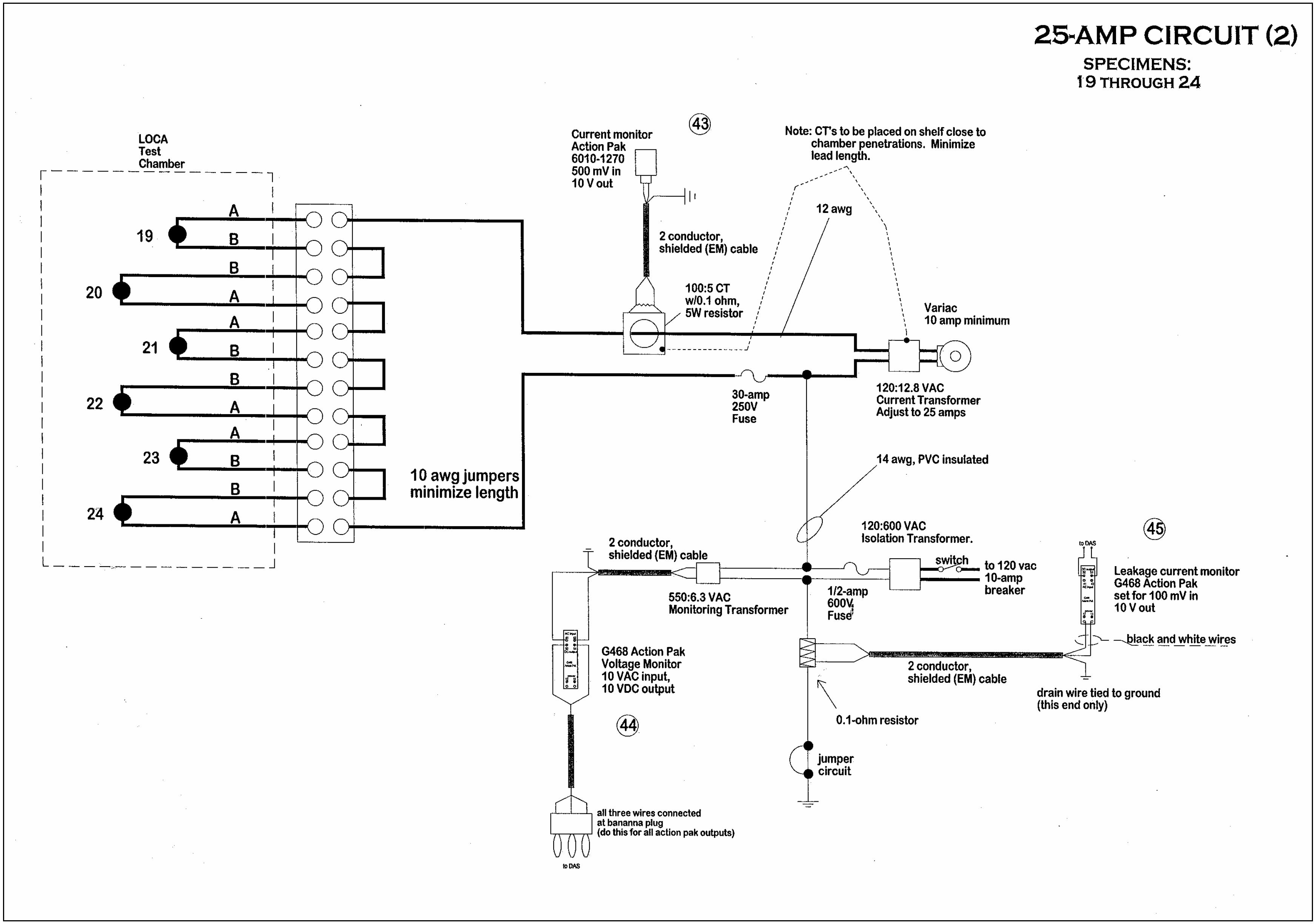

18-AMP CIRCUIT (5)
SPECIMENS:
92
93
97
98
LOCA Test Chamber
note orientation of lead wires
A
B
92
93
97
98
12 awg jumpers minimize length
Current monitor G468 Action Pak set for 100 mV in 10 V out
22
2 conductor, shielded (EM) cable
100:5 CT w/0.1 ohm, 5W resistor
Note: CT's to be placed on shelf close to chamber penetrations. Minimize lead length.
14 awg
Variac 10 amp minimum
120:12.8 VAC Current Transformer Adjust to 18 amps
20-amp 250V Fuse
14 awg, PVC insulated
120:600 VAC Isolation Transformer.
switch
to 120 vac 10-amp breaker
2 conductor, shielded (EM) cable
550:6.3 VAC Monitoring Transformer
1/2-amp 600V Fuse
24
Leakage current monitor G468 Action Pak set for 100 mV in 10 V out
black and white wires
2 conductor, shielded (EM) cable
drain wire tied to ground (this end only)
0.1-ohm resistor
jumper circuit
G468 Action Pak Voltage Monitor 10 VAC input, 10 VDC output
23
all three wires connected at bananna plug (do this for all action pak outputs)
CONFIGURATION OF SPECIMENS 97 AND 98
butt splice
Raychem-supplied lead wires
Raychem heat shrink


18-AMP CIRCUIT (6)
SPECIMENS:
91
100
101
102
LOCA
Test
Chamber
note orientation of lead wires
A
B
91
B
100
A
A
101
B
B
102
A
12 awg jumpers
minimize length
Current monitor
Action Pak
6010-1270
500 mV in
10 V out
25
2 conductor,
shielded (EM) cable
100:5 CT
w/0.1 ohm,
5W resistor
Note: CT's to be placed on shelf close to
chamber penetrations. Minimize
lead length.
14 awg
Variac
10 amp minimum
20-amp
250V
Fuse
120:12.8 VAC
Current Transformer
Adjust to 18 amps
14 awg, PVC insulated
120:600 VAC
Isolation Transformer.
2 conductor,
shielded (EM) cable
switch
to 120 vac
10-amp
breaker
550:6.3 VAC
Monitoring Transformer
1/2-amp
600V
Fuse
27
Leakage current monitor
G468 Action Pak
set for 100 mV in
10 V out
black and white wires
G468 Action Pak
Voltage Monitor
10 VAC input,
10 VDC output
2 conductor,
shielded (EM) cable
drain wire tied to ground
(this end only)
0.1-ohm resistor
26
jumper
circuit
all three wires connected
at bananna plug
(do this for all action pak outputs)
CONFIGURATION OF
SPECIMENS 100, 101, AND 102
butt splice
Raychem-supplied
lead wires
Raychem heat shrink


18-AMP CIRCUIT (7)
SPECIMENS:
99
103
104
105
106
LOCA Test Chamber
note orientation of lead wires
A
B
99
103
104
105
106
12 awg jumpers minimize length
Current monitor Action Pak 6010-1270 500 mV in 10 V out
28
Note: CT's to be placed on shelf close to chamber penetrations. Minimize lead length.
14 awg
2 conductor, shielded (EM) cable
100:5 CT w/0.1 ohm, 5W resistor
Variac 10 amp minimum
20-amp 250V Fuse
120:12.8 VAC Current Transformer Adjust to 18 amps
14 awg, PVC insulated
120:600 VAC Isolation Transformer.
30
2 conductor, shielded (EM) cable
550:6.3 VAC Monitoring Transformer
1/2-amp 600V Fuse
switch
to 120 vac 10-amp breaker
Leakage current monitor G468 Action Pak set for 100 mV in 10 V out
black and white wires
G468 Action Pak Voltage Monitor 10 VAC input, 10 VDC output
2 conductor, shielded (EM) cable
drain wire tied to ground (this end only)
0.1-ohm resistor
29
jumper circuit
all three wires connected at bananna plug (do this for all action pak outputs)
to DAS
CONFIGURATION OF SPECIMEN 99
butt splice
Raychem-supplied lead wires
Raychem heat shrink
CONFIGURATION OF SPECIMENS 103, 104, AND 105
butt splice
Raychem-supplied lead wires
Raychem heat shrink

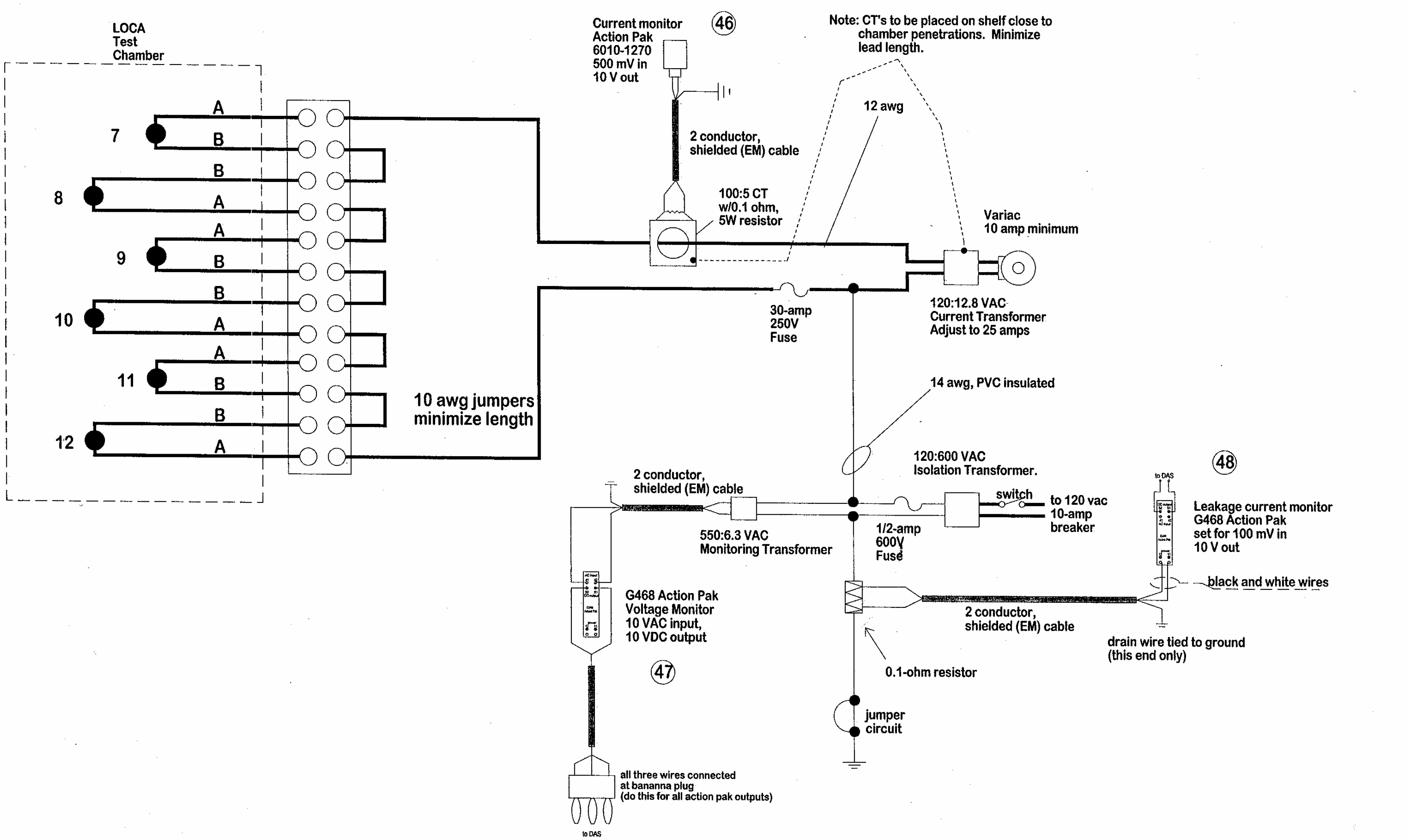

18-AMP CIRCUIT (8)
SPECIMENS:
1 THROUGH 6
13 THROUGH 18
25 THROUGH 27
31 THROUGH 33
124 THROUGH 129
LOCA Test Chamber
1
2
3
4
5
6
13
14
15
16
17
18
25
26
27
31
32
33
124
125
126
127
128
129
12 awg jumpers minimize length
31
Current monitor G468 Action Pak set for 500 mV in 10 V out
2 conductor, shielded (EM) cable
100:5 CT w/0.1-ohm 5w resistor
14 awg
2.08-ohm, 1kW resistive load
208 VAC
240:120 VAC isolated transformer
20-amp 250V Fuse
14 awg, PVC insulated
120:600 VAC Isolation Transformer.
switch
to 120 vac 10-amp breaker
33
Leakage current monitor G468 Action Pak set for 100 mV in 10 V out
black and white wires
2 conductor, shielded (EM) cable
drain wire tied to ground (this end only)
2 conductor, shielded (EM) cable
550:6.3 VAC Monitoring Transformer
1/2-amp 600V Fuse
G468 Action Pak Voltage Monitor 10 VAC input, 10 VDC output
32
0.1-ohm resistor
jumper circuit
all three wires connected at bananna plug (do this for all action pak outputs)
raychm11.skd

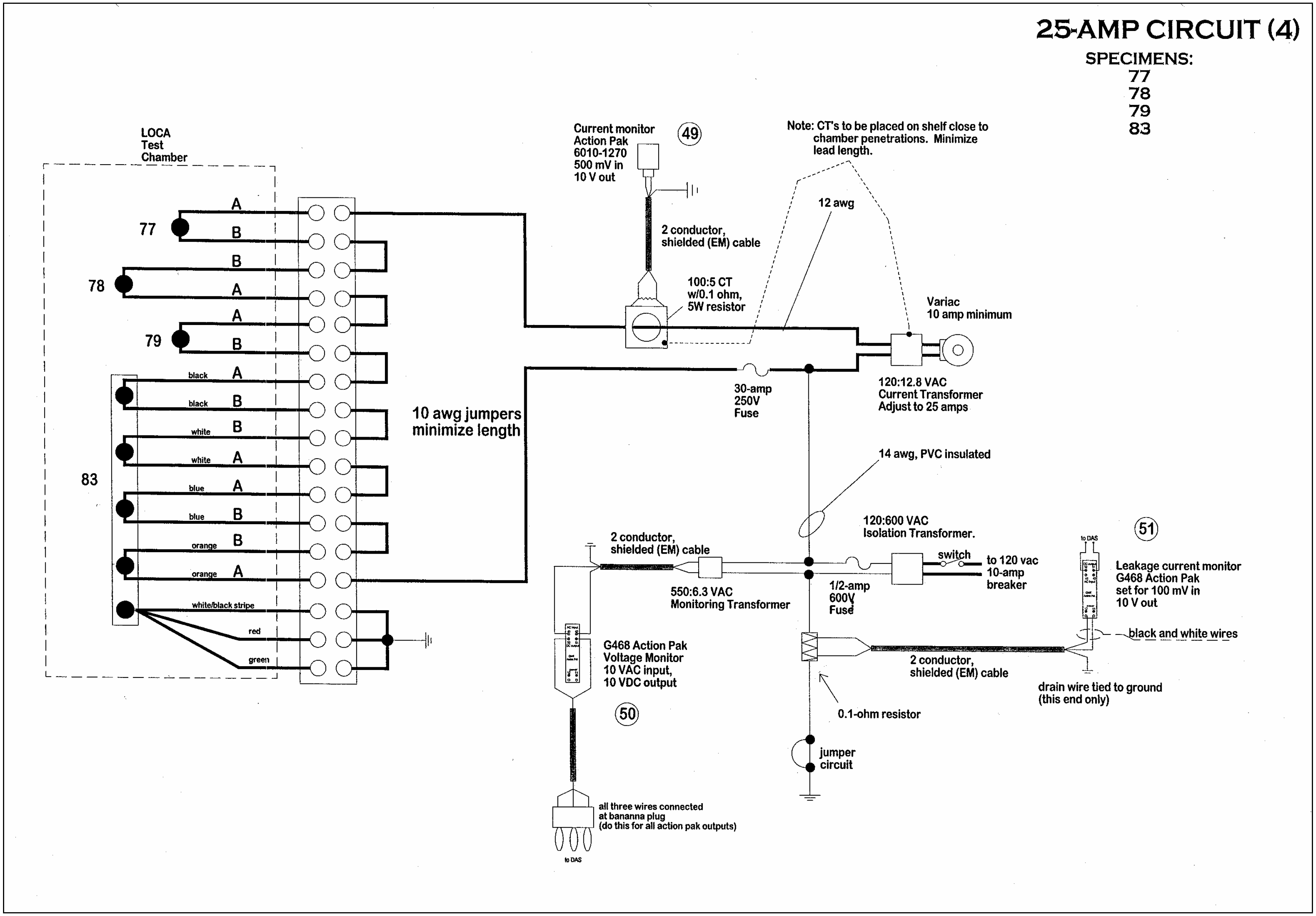

25-AMP CIRCUIT (1)
SPECIMENS:
130
131
132
LOCA Test Chamber
130
131
132
A
B
B
A
A
B
10 awg jumpers minimize length
Current monitor Action Pak 6010-1270 500 mV in 10 V out
40
2 conductor, shielded (EM) cable
100:5 CT w/0.1 ohm, 5W resistor
Note: CT's to be placed on shelf close to chamber penetrations. Minimize lead length.
12 awg
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
switch
to 120 vac 10-amp breaker
550:6.3 VAC Monitoring Transformer
1/2-amp 600V Fuse
42
Leakage current monitor G468 Action Pak set for 100 mV in 10 V out
to DAS
black and white wires
G468 Action Pak Voltage Monitor 10 VAC input, 10 VDC output
2 conductor, shielded (EM) cable
drain wire tied to ground (this end only)
41
0.1-ohm resistor
jumper circuit
all three wires connected at bananna plug (do this for all action pak outputs)
to DAS

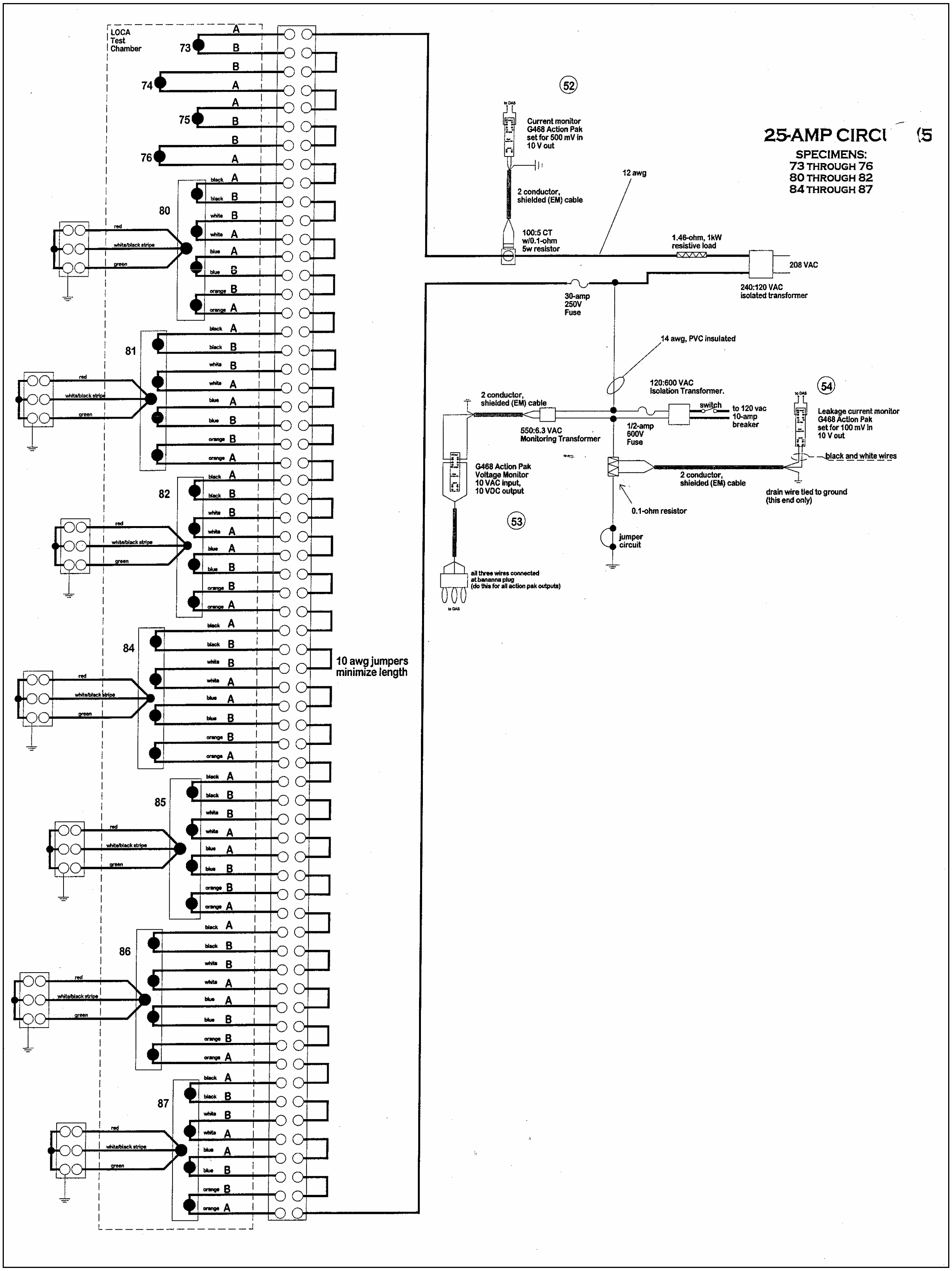

25-AMP CIRCUIT (2)
SPECIMENS:
19 THROUGH 24
LOCA Test Chamber
19
20
21
22
23
24
A
B
10 awg jumpers minimize length
Current monitor Action Pak 6010-1270 500 mV in 10 V out
43
2 conductor, shielded (EM) cable
100:5 CT w/0.1 ohm, 5W resistor
Note: CT's to be placed on shelf close to chamber penetrations. Minimize lead length.
12 awg
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.
switch
to 120 vac 10-amp breaker
2 conductor, shielded (EM) cable
550:6.3 VAC Monitoring Transformer
1/2-amp 600V Fuse
G468 Action Pak Voltage Monitor 10 VAC input, 10 VDC output
44
0.1-ohm resistor
jumper circuit
all three wires connected at bananna plug (do this for all action pak outputs)
to DAS
45
Leakage current monitor G468 Action Pak set for 100 mV in 10 V out
black and white wires
2 conductor, shielded (EM) cable
drain wire tied to ground (this end only)

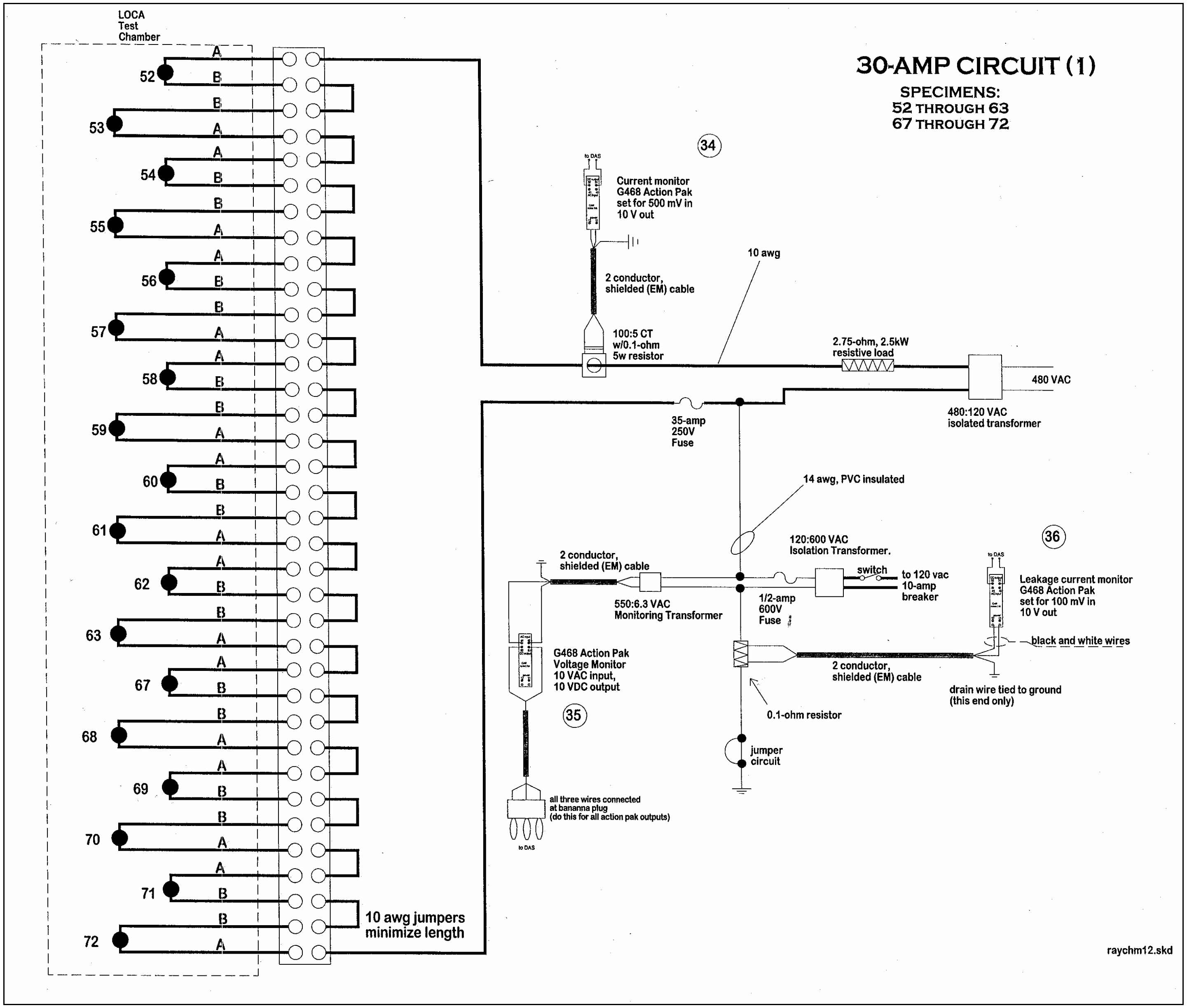
25-AMP CIRCUIT (3)

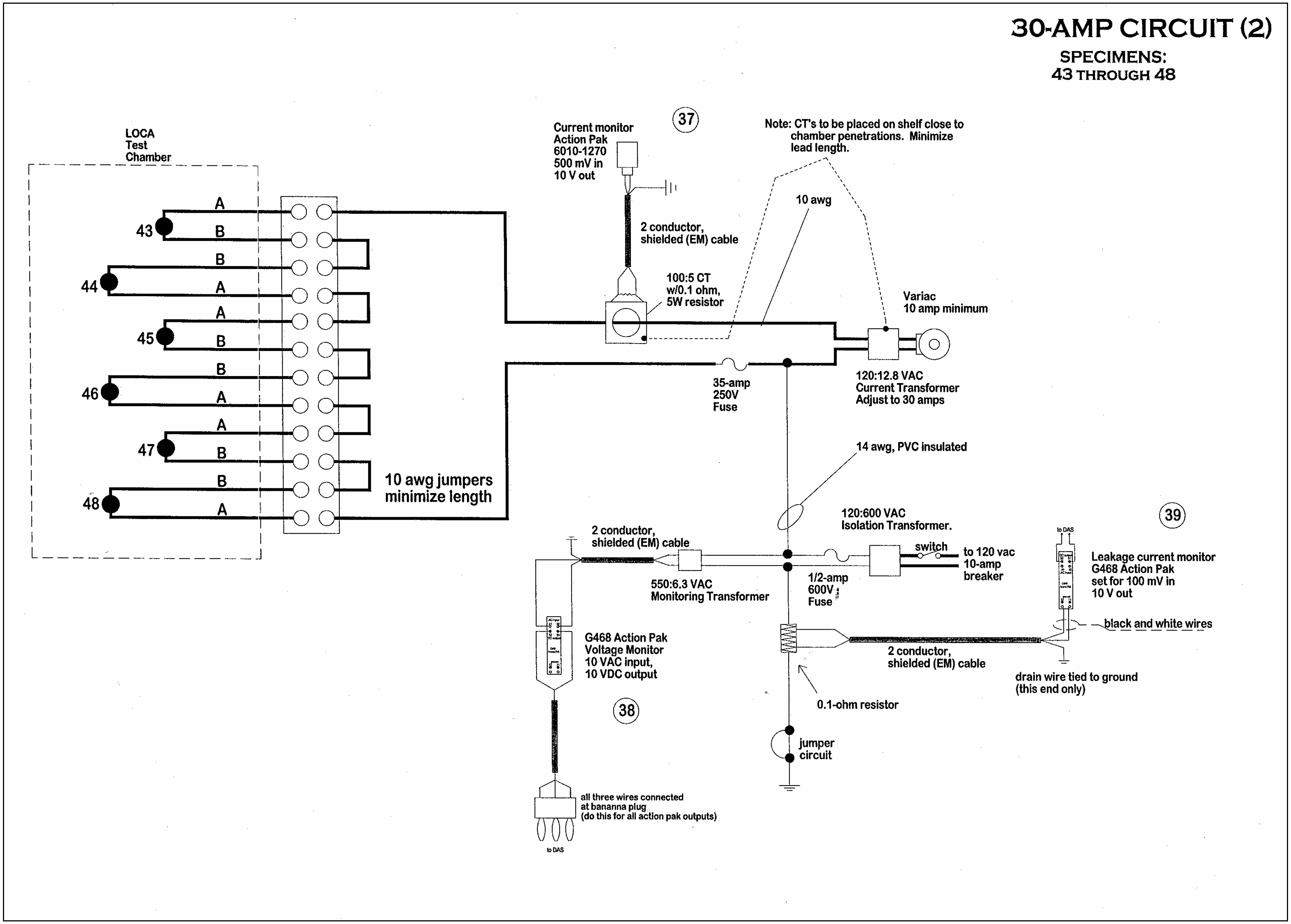
SPECIMENS:
7 THROUGH 12

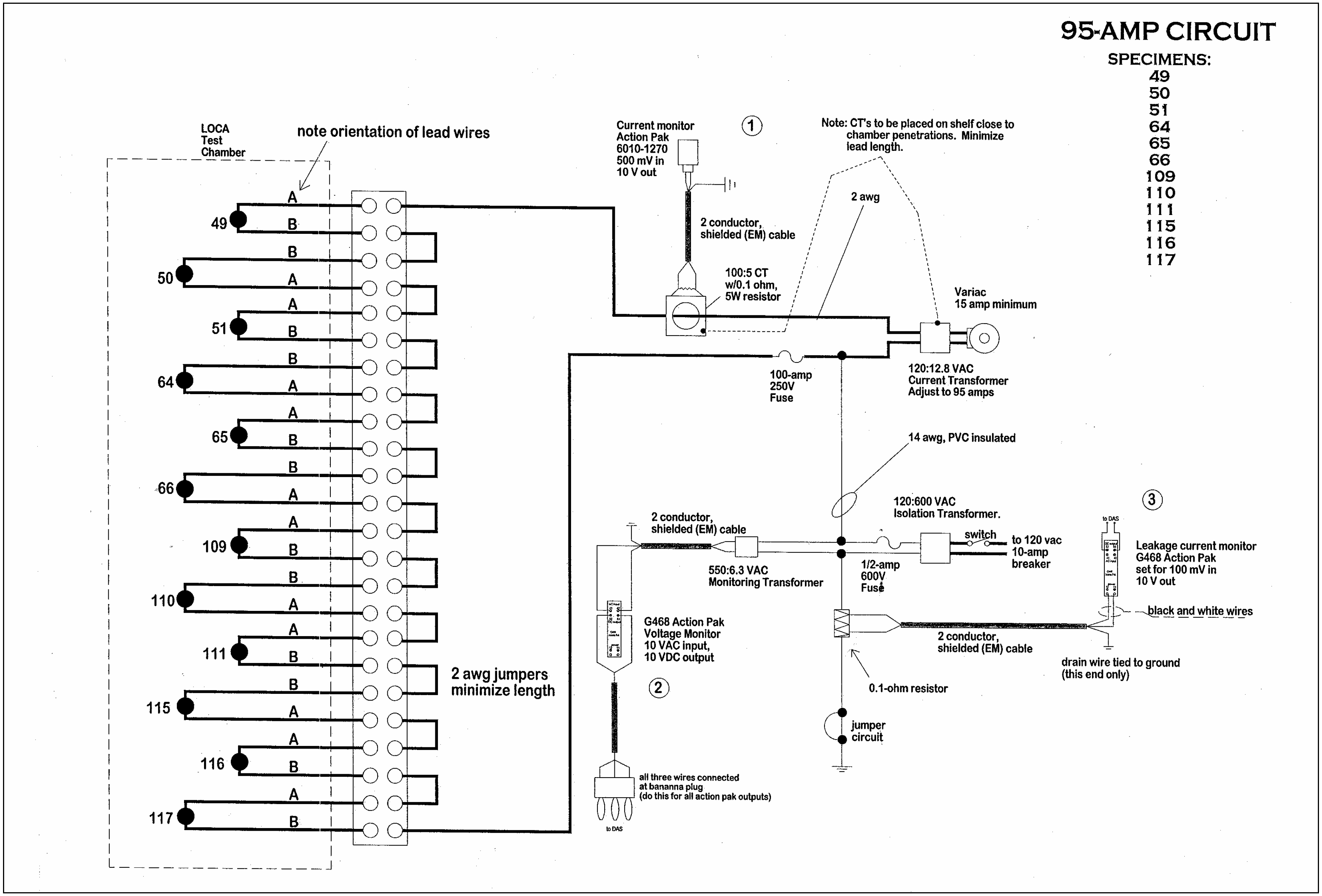



25-AMP CIRCUIT (4)
SPECIMENS:
77
78
79
83
LOCA Test Chamber
77
78
79
83
A
B
black
white
blue
orange
white/black stripe
red
green
10 awg jumpers minimize length
Current monitor Action Pak 6010-1270 500 mV in 10 V out
49
2 conductor, shielded (EM) cable
100:5 CT w/0.1 ohm, 5W resistor
Note: CT's to be placed on shelf close to chamber penetrations. Minimize lead length.
12 awg
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.
switch
to 120 vac 10-amp breaker
51
Leakage current monitor G468 Action Pak set for 100 mV in 10 V out
black and white wires
2 conductor, shielded (EM) cable
550:6.3 VAC Monitoring Transformer
1/2-amp 600V Fuse
2 conductor, shielded (EM) cable
drain wire tied to ground (this end only)
G468 Action Pak Voltage Monitor 10 VAC input, 10 VDC output
50
0.1-ohm resistor
jumper circuit
all three wires connected at bananna plug (do this for all action pak outputs)
to DAS


LOCA Test Chamber
25-AMP CIRCUIT 5
SPECIMENS:
73 THROUGH 76
80 THROUGH 82
84 THROUGH 87
52
Current monitor G468 Action Pak set for 500 mV in 10 V out
2 conductor, shielded (EM) cable
100:5 CT w/0.1-ohm 5w resistor
12 awg
1.46-ohm, 1kW resistive load
208 VAC
240:120 VAC isolated transformer
30-amp 250V Fuse
14 awg, PVC insulated
120:600 VAC Isolation Transformer.
switch
to 120 vac 10-amp breaker
54
Leakage current monitor G468 Action Pak set for 100 mV in 10 V out
black and white wires
2 conductor, shielded (EM) cable
550:6.3 VAC Monitoring Transformer
1/2-amp 600V Fuse
G468 Action Pak Voltage Monitor 10 VAC input, 10 VDC output
2 conductor, shielded (EM) cable
drain wire tied to ground (this end only)
0.1-ohm resistor
53
jumper circuit
all three wires connected at banana plug (do this for all action pak outputs)
10 awg jumpers minimize length
red
white/black stripe
green
black
white
blue
orange


30-AMP CIRCUIT (1)
SPECIMENS:
52 THROUGH 63
67 THROUGH 72
LOCA Test Chamber
52
53
54
55
56
57
58
59
60
61
62
63
67
68
69
70
71
72
Current monitor G468 Action Pak set for 500 mV in 10 V out
2 conductor, shielded (EM) cable
100:5 CT w/0.1-ohm 5w resistor
10 awg
2.75-ohm, 2.5kW resistive load
480 VAC
480:120 VAC isolated transformer
35-amp 250V Fuse
14 awg, PVC insulated
120:600 VAC Isolation Transformer.
switch
to 120 vac 10-amp breaker
1/2-amp 600V Fuse
2 conductor, shielded (EM) cable
550:6.3 VAC Monitoring Transformer
G468 Action Pak Voltage Monitor 10 VAC input, 10 VDC output
Leakage current monitor G468 Action Pak set for 100 mV in 10 V out
black and white wires
2 conductor, shielded (EM) cable
drain wire tied to ground (this end only)
0.1-ohm resistor
jumper circuit
all three wires connected at banana plug (do this for all action pak outputs)
10 awg jumpers minimize length
raychm12.skd


30-AMP CIRCUIT (2)
SPECIMENS:
43 THROUGH 48
LOCA Test Chamber
43
44
45
46
47
48
A
B
10 awg jumpers minimize length
Current monitor Action Pak 6010-1270 500 mV in 10 V out
37
Note: CT's to be placed on shelf close to chamber penetrations. Minimize lead length.
10 awg
2 conductor, shielded (EM) cable
100:5 CT w/0.1 ohm, 5W resistor
Variac 10 amp minimum
35-amp 250V Fuse
120:12.8 VAC Current Transformer Adjust to 30 amps
14 awg, PVC insulated
120:600 VAC Isolation Transformer.
39
2 conductor, shielded (EM) cable
switch
to 120 vac 10-amp breaker
550:6.3 VAC Monitoring Transformer
1/2-amp 600V Fuse
Leakage current monitor G468 Action Pak set for 100 mV in 10 V out
black and white wires
G468 Action Pak Voltage Monitor 10 VAC input, 10 VDC output
2 conductor, shielded (EM) cable
drain wire tied to ground (this end only)
0.1-ohm resistor
38
jumper circuit
all three wires connected at banana plug (do this for all action pak outputs)
to DAS


95-AMP CIRCUIT
SPECIMENS:
49
50
51
64
65
66
109
110
111
115
116
117
LOCA Test Chamber
note orientation of lead wires
Current monitor Action Pak 6010-1270 500 mV in 10 V out
1
Note: CT's to be placed on shelf close to chamber penetrations. Minimize lead length.
2 awg
2 conductor, shielded (EM) cable
100:5 CT w/0.1 ohm, 5W resistor
Variac 15 amp minimum
120:12.8 VAC Current Transformer Adjust to 95 amps
100-amp 250V Fuse
14 awg, PVC insulated
120:600 VAC Isolation Transformer.
3
2 conductor, shielded (EM) cable
switch
to 120 vac 10-amp breaker
550:6.3 VAC Monitoring Transformer
1/2-amp 600V Fuse
Leakage current monitor G468 Action Pak set for 100 mV in 10 V out
black and white wires
G468 Action Pak Voltage Monitor 10 VAC input, 10 VDC output
2 conductor, shielded (EM) cable
drain wire tied to ground (this end only)
2 awg jumpers minimize length
2
0.1-ohm resistor
jumper circuit
all three wires connected at bananna plug (do this for all action pak outputs)
to DAS

APPENDIX 5

Samples Irradiation Logs

Georgia Institute of Technology

Neely Nuclear Research Center
Hot Cell Operations
900 Atlantic Drive
Atlanta, Georgia 30332-0425
(404) 894-3600 FAX: (404) 894-9325
http://www.nnrc.gatech.edu/

November 2, 2000

Wyle Laboratories
7800 Highway 20 Weat
Huntsville, Al 35807

Attention: Bobby Hardy

Client Reference: HSV0018395
GT Reference: 00-17

The items covered by the above numbers have been irradiated in accordance with quality assurance requirements using Cobalt-60 (gamma energies 1.173 MeV, 1.331 MeV) to the total dose requested.

We certify the specifics of the irradiation as follows:

Irradiation Period	Intervals between 13:30 on 7/14/00 and 10:21 on 10/16/00 as shown on the enclosed Gamma Irradiation Log Sheets.
Dose Rate	Less than 1.0E6 Rads/hr average (Air Equivalent); maximum error plus or minus 2.69%.
Total Dose	Minimum of 2.40E8 Rads (Air Equivalent) as shown on the enclosed Gamma Irradiation Log Sheets; maximum error plus or minus 2.69%.
Dose Measurement	Keithley Autoranging Picoammeter Model 485 with LND Ionization Chamber Probe. Calibration completed by Georgia Institute of Technology traceable to NIST Cobalt-60.

The specific calculations for the irradiation are enclosed. Please let me know if any additional information is required.

Sincerely,

Dwayne P. Blaylock
Manager, Hot Cell Operations
Neely Nuclear Research Center

Enclosures

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:**	00-17a
Reference:	HSV0018395	**Total Dose:**	1.65E8 w/ Unc
Items:	Mandrels 2,4,8,13,15	**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
07/14/00	13:30	07/25/00	16:00	266.50	6.364E+05	1.696E+08	1.696E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	9.935E-07	6.322E+05
2	1.002E-06	6.385E+05
3	9.966E-07	6.345E+05
4	1.004E-06	6.399E+05
5	9.999E-07	6.369E+05

Average Dose Rate (Rads/hr): 6.364E+05

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

Completed: [signature] Date: 10/31/00

Reviewed: [signature] Date: 11-9-00

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:**	00-17b
Reference:	HSV0018395	**Total Dose:**	2.15E8 w/ Unc
Items:	Mandrels 1, 3, 5, 6, 12, 14	**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
07/27/00	13:45	08/11/00	7:45	354.00	6.326E+05	2.239E+08	2.239E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	9.956E-07	6.337E+05
2	9.986E-07	6.359E+05
3	9.909E-07	6.303E+05
4	9.959E-07	6.340E+05
5	9.898E-07	6.295E+05

Average Dose Rate (Rads/hr): 6.326E+05

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

Completed: [signature] Date: 10/31/00

Reviewed: [signature] Date: 11-9-00

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:**	2.4E8 w/ Unc
Items:	Mandrel #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
08/16/00	10:15	08/18/00	8:15	46.00	5.343E+05	2.458E+07	2.490E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	8.583E-07	5.343E+05

Average Dose Rate (Rads/hr): 5.343E+05

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

Completed: [signature] Date: 10/31/00

Reviewed: [signature] Date: 11-8-00

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:**	1.65E8 w/ Unc
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	5.529E+05	1.697E+08	1.697E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	8.871E-07	5.548E+05
2	8.835E-07	5.522E+05
3	8.829E-07	5.518E+05

Average Dose Rate (Rads/hr): 5.529E+05

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

Completed: [signature] Date: 10/31/00

Reviewed: [signature] Date: 11-9-00

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:**	00-17e
Reference:	HSV0018395	**Total Dose:**	2.15E8 w/ Unc
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	5.469E+05	7.684E+07	7.684E+07

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	8.703E-07	5.428E+05
2	8.760E-07	5.469E+05
3	8.736E-07	5.451E+05
4	8.777E-07	5.481E+05
5	8.840E-07	5.526E+05
6	8.748E-07	5.460E+05

Average Dose Rate (Rads/hr): 5.469E+05

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

Completed: [signature] Date: 10/31/00

Reviewed: [signature] Date: 11-9-00

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:**	2.15E8 w/ Unc
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	5.162E+05	1.457E+08	2.225E+08

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	8.302E-07	5.144E+05
2	8.328E-07	5.162E+05
3	8.337E-07	5.168E+05
4	8.302E-07	5.144E+05
5	8.331E-07	5.164E+05
6	8.373E-07	5.194E+05

Average Dose Rate (Rads/hr): 5.162E+05

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

Completed: [signature] Date: 10/31/00

Reviewed: [signature] Date: 11-8-00

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:**	00-17g
Reference:	HSV0018395	**Total Dose:**	3.96 E7 w/ Unc
Items:	Tray 8	**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
10/13/00	15:15	10/16/00	10:21	67.10	6.067E+05	4.071E+07	4.071E+07

Dose Rate Determination*

Dosimetry Measurement	Current (Amps)	Dose Rate (Rads/hr)
1	9.623E-07	6.093E+05
2	9.552E-07	6.041E+05

Average Dose Rate (Rads/hr): 6.067E+05

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

Completed: [signature] Date: 10/31/00

Reviewed: [signature] Date: 11-9-00

Georgia Institute of Technology

Neely Nuclear Research Center
Hot Cell Operations
900 Atlantic Drive
Atlanta, Georgia 30332-0425
(404) 894-3600 FAX: (404) 894-9325
http://www.nnrc.gatech.edu

Certificate of Calibration
July 20, 1999

Manufacturer:	LND PROBE
Model:	52120
Description:	Ionization Probe
Serial No.:	NNRC-109
Calibrated by:	Georgia Institute of Technology Neely Nuclear Research Center Atlanta, GA 30332-0425

Next Calibration Due 7/21/00 ± 25%

This certificate attests that this instrument has been calibrated with standards traceable to the National Institute of Standards and Technology.

NIST Traceability

Reference Test: 846/260730-98
HD9903
NIST DB 960/017

Georgia Institute of Technology

Neely Nuclear Research Center
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900 Atlantic Drive
Atlanta, Georgia 30332-0425
(404) 894-3600 FAX: (404) 894-9325
http://www.nnrc.gatech.edu

Certificate of Calibration

June 17, 1999

Manufacturer:	Keithley
Model:	485
Description:	Autoranging Picoammeter
Serial No.:	472783
Calibrated by:	Georgia Institute of Technology Neely Nuclear Research Center Atlanta, GA 30332-0425

Next Calibration Due 06/17/00 ± 25%

This certificate attests that this instrument has been calibrated with standards traceable to the National Institute of Standards and Technology.

Standards Used in Calibration

Keithley Picoampere Source, Model No. 263, SN 0558088

Calibrated:	November 5, 1998 Due 10/17/99 ± 25%
Calibrated by:	Applied Technical Services Incorporated 1190 Atlanta Industrial Drive Marietta, GA 30066

Traceability:

ATS Reference No.: M87555

Georgia Institute of Technology

Neely Nuclear Research Center
Hot Cell Operations
900 Atlantic Drive
Atlanta, Georgia 30332-0425
(404) 894-3600 FAX: (404) 894-9325
http://www.nnrc.gatech.edu

Certificate of Calibration

September 15, 2000

Manufacturer:	Keithley
Model:	485
Description:	Autoranging Picoammeter
Serial No.:	472783
Calibrated by:	Georgia Institute of Technology Neely Nuclear Research Center Atlanta, GA 30332-0425

Next Calibration Due 06/17/00 ± 25%

This certificate attests that this instrument has been calibrated with standards traceable to the National Institute of Standards and Technology.

Standards Used in Calibration

Keithley Picoampere Source, Model No. 263, SN 0558088

Calibrated:	October 19, 1999 Due 10/19/00 ± 25%
Calibrated by:	Applied Technical Services Incorporated 1190 Atlanta Industrial Drive Marietta, GA 30066

Traceability:

ATS Reference No.: M97996-1

APPENDIX 6

WYLE correspondence regarding the reporting error in the irradiation dose wyle laboratories

Wyle Letter No. EWS-GT21-017

May 22, 2002

Raychem Nuclear Products
Tyco Electronics Corporation/Energy Division
8000 Purfoy Road
Fuquay-Varina, NC 27526

Attention: Mr. Phil McCartney, QA Manager

Subject: Part 21 on Irradiations Performed with the Cobalt-60 Sources in the Georgia Tech Hot Cell -- PO No. N0020106

Dear Sir:

Pursuant to 10 CFR Part 21, Wyle presents this letter as notification to Raychem Nuclear Products of the existence of a reportable defect and its evaluation.

The defect is an error in irradiation dose units as identified in the attached letter from Georgia Tech dated March 15, 2002, which was received by Wyle on April 11, 2002. The error applies to all equipment irradiated with the cobalt-60 sources in the Georgia Tech hot cell from July 24, 1997 to July 6, 2001. Georgia Tech reported radiation doses in units of rads-air (absorbed dose in air), but the actual radiation dose units were Roentgens. Since one Roentgen is equal to 0.877 rad, the actual dose is less than the reported value.

Wyle performed an evaluation that determined the following:

1. Wyle projects that include irradiation with the cobalt-60 sources in the Georgia Tech hot cell from 7/24/1997 to 7/6/2001.

2. The actual dose absorbed by equipment in the projects identified in Item 1.

3. Whether the actual dose in the projects identified in Item 1 envelops the customer-specified requirements.

Unfortunately, one (or more) of the projects that Wyle performed for Raychem Nuclear Products is affected as discussed below.

Regarding the tests that are in process under the subject PO, it was reported to Raychem that the specimens were irradiated to cumulative doses detailed in the table below. The actual cumulative doses and required doses are detailed in the table below.

Wyle Laboratories, Inc. 7800 Highway 20 West P.O. Box 077777 Huntsville, AL 35807-7777 Tel: (256)837-4411

To: Raychem Nuclear Products / Phil McCartney, QA Manager
RE: Your Document Ref. No. N0020106
5/22/2002
Page 2

Specimen No.	Reported Dose (rads)	Actual Dose (rads)	Requirement with Margin (rads)
Mandrels 2, 4, 8, 13, & 15	1.696E8	1.487E8	1.650E8
Mandrels 1, 3, 6, 12, & 14	2.239E8	1.964E8	2.150E8
Mandrel 5	2.490E8	2.184E8	2.400E8
Trays 3 & 6	1.697E8	1.488E8	1.650E8
Trays 1, 2, 4, 5, & 7	2.225E8	1.951E8	2.150E8
Tray 8	4.071E7	3.570E7	3.960E7

Note: A table listing specimen placement in the trays or on the mandrels listed above has been provided to Raychem separately.

It is Wyle's understanding the following parameters apply to this program:

- The requirement for 1.650E8 rads represents a DBE dose only. Of that requirement, 1.500E8 rads is the actual DBE dose with 1.500E7 rads of margin

- The requirement for 2.15E8 rads represents a 40-year qualified life with a DBE dose included. This would represent 5.000E7 rads of normal aging with 1.650E8 rads of DBE (with the same margin as defined in the parameter above).

- The requirement for 2.400E8 rads represents a 60-year qualified life with a DBE dose included. This would include 7.500E7 rads of normal aging with 1.650E8 rads of DBE (same margin for DBE).

- Wyle does not have the parameters for aging and DBE for Tray 8.

By accounting for the full DBE dose (without margin), the remaining actual dose, if any, can be applied to the normal aging. The table below shows the Wyle-recommended qualified life using the aforementioned reasoning.

Specimen No.	Dose after accounting for 100% of DBE (actual dose minus 1.5E8) (rads)	Percent of Normal Aging Requirement	Qualified Life (years)
Mandrels 2, 4, 8, 13, & 15	None	N/A	N/A
Mandrels 1, 3, 6, 12, & 14	4.64E7	92.8	37.12
Mandrel 5	6.84E7	91.2	54.72
Trays 3 & 6	None	N/A	N/A
Trays 1, 2, 4, 5, & 7	4.51E7	90.2	36.08
Tray 8	Aging and DBE requirement not known to Wyle		

Radiation requirements provided by end-users typically are conservative and can contain unspecified margins. Also, radiation requirements are usually specified for a general area or room location in the nuclear power plant and are not item specific. Some of the time, the end-user may be able to reduce the radiation requirement by eliminating unspecified margin or determining the dose for a specific item location rather than a general area or room location. If this is possible, the radiation requirement may be reducible.

To: Raychem Nuclear Products / Phil McCartney, QA Manager
RE: Your Document Ref. No. N0020106
5/22/2002
Page 3

Wyle personnel are in the process of preparing the report detailing the changes in the radiation values. Please review the information contained in this letter and advise the undersigned within 30 days of receiving this letter should you have additional information regarding the radiation requirements. If you have such information and can provide it to Wyle, we will use this new information in the test report to be issued upon completing the test program. Wyle will transmit the revised report(s) to the person designated by Raychem Nuclear Products.

The NRC is being provided a copy of Wyle's evaluation report.

If you have any questions, please feel free to contact me by phone (256) 837-4411, Ext. 271, fax (256) 830-2109, or email esmith@hnt.wylelabs.com.

Sincerely,

Wyle Laboratories, Inc.

Edward W. Smith
Director, Contracts and Purchasing

cc: Nuclear Regulatory Commission (Wyle Evaluation Report only)
Sharif Kamel

wyle laboratories

April 12, 2002

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Potential Part 21 on irradiations performed with the cobalt-60 sources in the Georgia Tech hot cell

Reference: Georgia Tech letter dated 3/15/2002, received by Wyle 4/11/2002

Pursuant to the 10 CFR Part 21 requirements, this letter notifies the NRC of a Potential Part 21 condition.

An error in irradiation dose units is identified in the attached letter from Georgia Tech letter dated March 15, 2002, which was received by Wyle on April 11, 2002. The error applies to all equipment irradiated with the cobalt-60 sources in the Georgia Tech hot cell from 7/24/1997 to 7/6/2001. Georgia Tech reported radiation doses in units of rads-air (absorbed dose in air) instead of Roentgens. Since one Roentgen is equal to 0.877 rad, the actual dose is less than the reported value.

Wyle will perform an evaluation to determine:

1. Wyle projects that include irradiation with the cobalt-60 sources in the Georgia Tech hot cell from 7/24/1997 to 7/6/2001.
2. The actual dose absorbed by equipment in said projects.
3. Whether the actual dose in said projects envelops the customer-specified requirements.

Wyle Laboratories has the capability and chooses to perform the evaluation to determine if a defect exists. It is the responsibility to Wyle Laboratories to inform the purchaser(s), and any affected licensees.

Wyle will complete the specified evaluation of the circumstances within sixty (60) days of discovery of the potential defect. The NRC will be provided a copy of Wyle's evaluation report.

If you have any questions, please feel free to contact me by phone (256) 837-4411, Ext. 271, fax to (256) 830-2109, or e-mail to esmith@hnt.wylelabs.com.

Sincerely,

WYLE LABORATORIES, INC.

Edward W. Smith
Director, Contracts & Purchasing

283.EWS.rlf

RECEIVED 4-12-02
ERS

Georgia Institute of Technology

Neely Nuclear Research Center
Hot Cell Operations
900 Atlantic Drive
Atlanta, Georgia 30332-0425
(404) 894-3600 FAX: (404) 894-9325

March 15, 2002

Wyle Laboratories
7800 Highway 20 West
Huntsville, AL 35806

Dave McGuiness:

This is to inform you of an error in the dose units reported for irradiations performed with the cobalt-60 sources in the Georgia Tech hot cell. The reporting error was discovered in a recent internal audit. From the time period 7/24/1997 to 7/6/2001, we reported the radiation doses in Rads-air (absorbed dose in air). The doses should have been reported in roentgens. Please change the units from Rads-air to roentgens for work done during the aforementioned irradiation interval. We regret this unit change and ask that you contact me if you have further questions.

Thank you for your ongoing support of our hot cell operations.

Sincerely,

Dwayne P. Blaylock
Manager, Hot Cell Operations

Cc: N.E. Hertel
R.D. Ice
File

APPENDIX 7

Chronological Account of Events During the LOCA Exposure

DATE	TIME	EVENT
12/19/00	15:00	Start of the preheating period
12/19/00	15:43	Reached 420°F and then increased to 425°F in first transient
		Held 425°F for 8 minutes
12/19/00		Circuits 18-Amp (5), 25-Amp (1), 25-Amp (2), 25-Amp (3) and 25-Amp (5) blew voltage potential fuse.
12/19/00	15:55	Temperature dropped to 120°F
		Samples were de-energized for troubleshooting and change of external wiring
12/27/00	10:46	Reached 425°F in second transient.
		Held 425°F for 8 minutes
12/27/00	10:54	Temperature dropped to 350°F
		Held 350°F for 5 hours, 52 minutes
12/27/00	16:46	Temperature dropped to 320°F
12/27/00	16:47	Started Chemical Spray flow
12/27/00	16:47	55-Amp Circuit blew voltage potential fuse. *The circuit was left un-powered until 10:15 on 12/29/00. Specimens 133 and 137 were removed prior to re-powering.*
12/27/00	16:48	95-Amp and 25-Amp (5) blew voltage potential fuses. *The 95-Amp circuit was left un-powered until 10:15 on 12/29/00. Specimen 50 was removed prior to re-powering. The 25-Amp (5) circuit was left un-powered until 10:30 on 12/29/00. Specimen 74 was removed prior re-powering.*
12/27/00	16:50	25-Amp (4) blew voltage potential fuse. *The circuit was left un-powered until 10:45 on 12/29/00. Specimens 77 and 78 were removed prior to re-powering.*
		Held 320°F (w/flow) for 7 hours
12/27/00	23:47	Temperature dropped to 312°F
		Held 312°F for 11 hours, 25 minutes
12/28/00	11:10	Temperature dropped to 285°F
12/28/00	11:25	18-Amp (8) blew voltage potential fuse. *The circuit was left un-powered until 10:30 on 12/29/00. Specimens 1, 5, 6, and 27 were removed prior to re-powering.*
12/28/00	15:00	All voltages and currents on all circuits were turned off to facilitate specimen troubleshooting
12/28/00	18:30	All voltages and currents were turned back on
12/30/00	19:15	Temperature drops below the required 285°F due to equipment malfunction

DATE	TIME	EVENT
12/30/00	19:45	30-Amp (1) blew voltage potential fuse. *The circuit was left un-powered until 11:03 on 1/2/01. Specimen 68 was removed prior to re-powering.*
12/30/00	20:15	Temperature back at required 285°F. *Below 285°F requirement for 1 hour*
12/30/0 0	20:45	25-Amp (5) blew voltage potential fuse. *The circuit was left un-powered until 11:42 on 12/31/00. No specimens were removed prior to re-powering.*
12/31/0 0	20:33	18-Amp (8) blew voltage potential fuse. *The circuit was left un-powered until 19:18 on 1/1/01. Specimen 18 was removed prior to re-powering.*
12/31/0 0	20:48	25-Amp (5) blew voltage potential fuse. *The circuit was left un-powered until 19:33 on 1/1/01. Specimens 84-orange, 84-blue, 86-white, and 87-orange were removed prior to re-powering.*
1/1/01	12:18	Temperature drops below the required 285°F due to equipment malfunction
1/1/01	15:48	All voltages and currents on all circuits were turned off to facilitate specimen troubleshooting
1/1/01	16:18	Temperature back at required 285°F. *Below 285°F requirement for 4 hours*
1/1/01	19:18	All voltages and currents were turned back on
1/2/01	07:03	18-Amp (8) blew voltage potential fuse. *The circuit was left un-powered until 12:48. Specimen 32 was removed prior to re-powering.*
1/2/01	13:48	Temperature drops below the required 285°F due to equipment malfunction
1/2/01	14:03	Temperature back at required 285°F. *Below 285°F requirement for 15 minutes*
1/2/01	14:03	18-Amp (8) blew voltage potential fuse. *The circuit was left un-powered until 12:48 on 1/3/01. Specimens 25, 128, and 129 were removed prior to re-powering.*
1/3/01	10:33	All voltages and currents on all circuits were turned off to facilitate specimen troubleshooting
1/3/01	11:03	All voltages and currents were turned back on
1/3/01	13:03	25-Amp (5) blew voltage potential fuse. *The circuit was left un-powered until 13:48. No specimens were removed prior to re-powering.*
1/4/01	00:48	30-Amp (1) blew voltage potential fuse. *The circuit was left un-powered until 03:18. Specimen 72 was removed prior to re-powering.*
1/4/01	12:14	30-Amp (1) blew voltage potential fuse. *The circuit was left un-powered until 13:33. Specimen 62 was removed prior to re-powering.*
The 285°F plateau was held for 173 hours, 38 minutes with 5 hours, 15 minutes of that time below the specified temperature for a resulting total of 168 hours, 23 minutes at required temperature		

DATE	TIME	EVENT
1/4/01	16:48	Temperature dropped to 235°F
1/5/01	07:33	18-Amp (1) blew voltage potential fuse. *The circuit was left un-powered until 08:33. No specimens were removed prior to re-powering.*
1/5/01	07:33	18-Amp (2) blew voltage potential fuse. *The circuit was left un-powered until 08:18. Specimen 41 was removed prior to re-powering.*
1/5/01	13:33	All voltages and currents on all circuits were turned off to perform IR measurements
1/5/01	14:18	All voltages and currents were turned back on
1/6/01	11:03	30-Amp (1) blew voltage potential fuse. *The circuit was left un-powered until 13:03. Specimen 61 was removed prior to re-powering.*
1/7/01	00:00	18-Amp (7) blew voltage potential fuse. *The circuit was left un-powered until 07:00. Specimen 105 was removed prior to re-powering.*
1/12/01	13:03	All voltages and currents on all circuits were turned off to perform IR measurements
1/12/01	15:03	All voltages and currents were turned back on
1/13/01	11:33	25-Amp (5) blew voltage potential fuse. *The circuit was left un-powered until 18:03. No specimens were removed prior to re-powering.*
1/13/01	18:03	18-Amp (8) blew voltage potential fuse. *The circuit was left un-powered until 22:33. No specimens were removed prior to re-powering.*
1/13/01	22:48	25-Amp (5) blew voltage potential fuse. *The circuit was left un-powered until 14:33 on 1/15/01. No specimens were removed prior to re-powering.*
1/15/01	13:33	30-Amp (2) blew voltage potential fuse. *The circuit was left un-powered until 17:03. No specimens were removed prior to re-powering.*
1/15/01	14:03	Temperature drops below the required 235°F due to equipment malfunction
1/15/01	18:33	25-Amp (5) blew voltage potential fuse. *The circuit was left un-powered until 01:33 on 1/16/01. No specimens were removed prior to re-powering.*
1/16/01	01:33	Temperature back at required 235°F. *Below 235°F requirement for 11 hours, 30 minutes*

DATE	TIME	EVENT
1/16/01	07:33	25-Amp (5) blew voltage potential fuse. *The circuit was left un-powered until 09:03. Specimen 86-blue was removed prior to re-powering.*
1/17/01	21:33	18-Amp (8) blew voltage potential fuse. *The circuit was left un-powered until 02:03 on 1/18/01. Specimen 14 was removed prior to re-powering.*
1/24/01	04:33	25-Amp (5) blew voltage potential fuse. *The circuit was left un-powered until 07:33. No specimens were removed prior to re-powering.*
1/24/01	23:03	25-Amp (5) blew voltage potential fuse. *The circuit was left un-powered until 01:18 on 1/25/01. No specimens were removed prior to re-powering.*
1/25/01	03:48	25-Amp (5) blew voltage potential fuse. *The circuit was left un-powered until 07:48. No specimens were removed prior to re-powering.*
1/25/01	08:48	25-Amp (5) blew voltage potential fuse. *The circuit was left un-powered until 09:48. Specimen 84-white was removed prior to re-powering.*
1/25/01	18:18	18-Amp (7) blew voltage potential fuse. *The circuit was left un-powered until 18:48. Specimen 103 was removed prior to re-powering.*
1/26/01	15:18	All voltages and currents on all circuits were turned off to perform IR measurements
1/26/01	15:48	All voltages and currents were turned back on
1/27/01	06:03	End of test
		The 235°F plateau was held for 541 hours, 15 minutes with 11 hours, 30 minutes of that time below the specified temperature for a resulting total of 529 hours, 45 minutes at required temperature