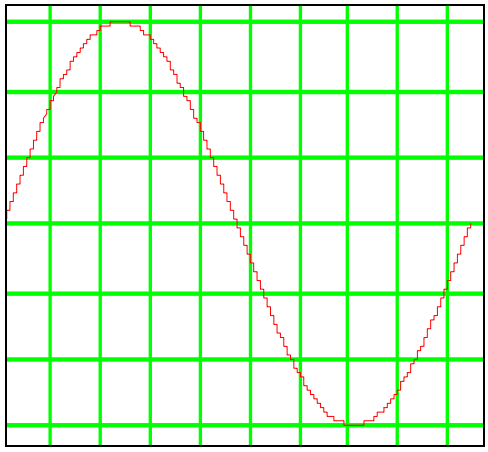


Test Report

PPR 1740

145 kV Inline Cable Joint
EHVS-145-IL-WU-31-73-89
tested in accordance with
IEC 60840

Pages:	1 + 23
Appendix:	-
Date:	January 14, 2004

Tested by: Neetrac
Date: September, 2003

TYCO ELECTRONICS Raychem GmbH
Energy Division
Finsinger Feld 1
D-85521 Ottobrunn
Munich, Germany
Tel. +49 89 6089-380
Fax +49 89 6089-654

Type Testing of Cable Joints Rated 138kV (U_0 = 145kV) Under Wet Conditions According to IEC 60840/Rev. 3 – 2000

Performed for Tyco / Raychem Electronics Energy Division

NEETRAC Project Number: 02-323

September, 2003

A Research Center of
The Georgia Institute of Technology

Requested by: **Wolfgang Haverkamp / Ladi Kehl**
Tyco / Raychem Electronics

Principal Investigator: Raymond C. Hill, P.E.

Reviewed by: Rick Hartlein

Type Testing of Cable Joints Rated 138kV Under Wet Conditions According to IEC 60840/Rev. 3 - 2000

NEETRAC Project No. 02-323

September, 2003

SUMMARY

Messrs. Wolfgang Haverkamp and Ladi Kehl of Tyco / Raychem Electronics Energy Division requested the Georgia Tech / National Electric Energy Testing, Research & Applications Center (NEETRAC) to perform type testing, in water, on two extruded dielectric shielded cable joints rated 138kV according to IEC 60840/Rev. 3 - 2000, *Power Cables with Extruded Insulation and Their Accessories for Rated Voltages above 30kV (U_m = 36kV) up to 150kV (U_m = 170kV) – Test Methods and Requirements*. These cable joints are described as Tyco model number EHVS-145-IL-WU-31-73-89 and "straight joints, U_m = 145kV, premoulded, slip-on type for XLPE cable with a laminated sheath and conductor cross-section up to 1200 mm^2 Cu / Al".

Testing was performed at the NEETRAC High Voltage Laboratory in Forest Park, Georgia USA. The two cable joints were subjected to the type tests described in Sections 13.4.1 a), b), c), d), 13.5, 13.6, and 13.7 while under water. Additional tests were also performed at the request of the customer to fulfill the requirements of other test standards. For this reason, the cable joints were tested while under water. One of the cable joints incorporated a neutral screen "sectionalizer", however, sectionalizer testing is not included in this report. Both of the cable joints, described in this report, passed the type test requirements of IEC 60840/Rev. 3 - 2000, Sections 13.4.1 a), b), c), d), 13.5, 13.6, and 13.7 for a 138kV voltage class (U_m = 145kV) cable joint at a conductor temperature of 105°C while submerged in water.

INTRODUCTION & SCOPE

The purpose of this project was to perform type testing, in water, on two extruded dielectric shielded cable joints rated 138kV according to IEC 60840/Rev. 3 - 2000, *Power Cables with Extruded Insulation and Their Accessories for Rated Voltages above 30kV (U_m = 36kV) up to 150kV (U_m = 170kV) – Test Methods and Requirements*. Testing requirements were those found in Sections 13.4.1 a), b), c), d), 13.5, 13.6, and 13.7. Each cable joint was installed inside a water container with a one-meter water head pressure for testing as indicated above. U_o for this project was taken as 80kV. Load cycling was performed at a cable conductor temperature of 105°C ± 5°C. The cable thermal profile and load cycling temperature data are contained in Appendices A and B, respectively.

TEST SAMPLES

Joints

Two cable joints supplied by Tyco were provided and installed by Tyco / Raychem Electronics Energy Division personnel.

The Tyco reference model number is EHVS-145-IL-WU-31-73-89.

The cable joints are described by Tyco as "straight joints, U_m = 145kV, premoulded, slip-on type for XLPE cable with a laminated sheath and conductor cross-section up to 1200 mm^2 Cu / Al". For technical data, dimensions, and additional information, see Tyco drawing nos. 3.7 0347-00, 3.8 8035-01, and 3.8 8041.01.

Cable

The cable joints were installed on a domestically manufactured cable designated by AEIC CS7-93 as a 138kV class cable with 650 mils of XLPE insulation, a 1750 kcmil Al conductor, a concentric copper wire metallic shield, and an overall jacket.

Figure 1 - Cable Joint before Water Housing Installation

REFERENCES

1. IEC 60840/Rev. 3 - 2000, *Power Cables with Extruded Insulation and Their Accessories for Rated Voltages above 30kV (U_m = 36kV) up to 150kV (U_m = 170kV) – Test Methods and Requirements*
2. IEEE Standard 4-1995, *High Voltage Testing Techniques*
3. IEC 60060-1-1989, *High Voltage Test Techniques, Part 1, General Definitions and Test Requirements*

PROCEDURE

The test procedure followed IEC 60840/Rev.3 - 2000, Sections 13.4.1 a), b), c), d), 13.5, 13.6, and 13.7 *Type Tests on Cable Systems, Cable, and Accessories,* for 138 kV class cable joints. While one of the cable joints contained a screen interruption (sectionalizer), the sectionalizer tests of Annex E are not included in this test program. Appendix C contains photographs of the test set up. Both cable joints were under water for all tests. Following is a list of each test per Section 13.4.1 with descriptions and results for each.

Tests

1) *Partial Discharge Measurement at Ambient– Section 13.4.1 a) – per Section 13.5*
   a) This measurement was performed at ambient temperature and 120kV.
   b) The passing requirement is ≤ 5 pC @ 120kV.
   c) Result: **Pass**
   d) Figure 2 shows the partial discharge extinction graph.

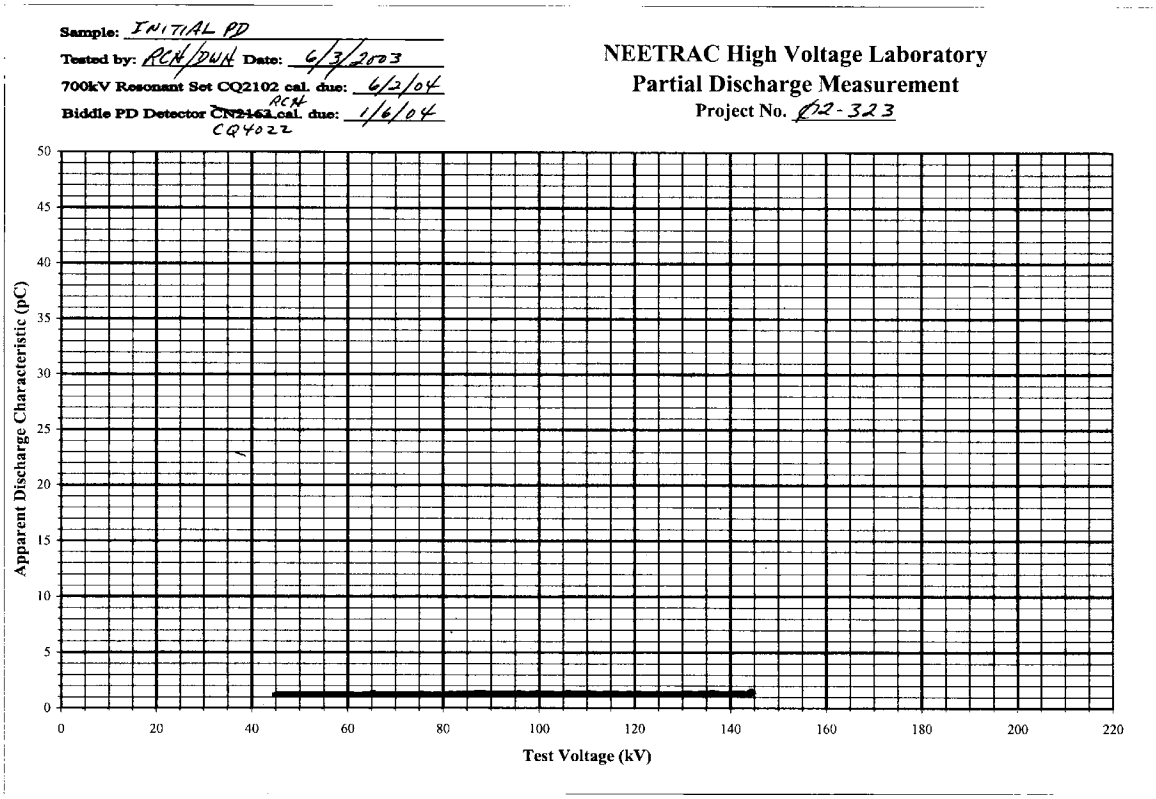


Figure 2 - Initial Partial Discharge Measurement

2) *Heat Cycling Voltage Test – Section 13.4.1 b) per Section 13.6*
   a) A thermal profile for the cable was established on a dummy section and is contained in Appendix A.
   b) The requirements for this test called for twenty (20) heating cycles with at least 2 hours at temperature with a U_0 of 76kV. In order to meet the requirements of other test standards, the more stringent requirements below were utilized.
   c) U_0 was taken as 80kV.
   d) This test was performed at 160kV and a conductor temperature of 105°C (± 5°) for thirty (30) heating cycles.
   e) The heating cycle was composed of fifteen (15) hours "ON" and nine (9) hours "OFF".
   f) At least six (6) hours of the "ON" time were within the temperature range of item d).
   g) The passing requirement is that no breakdown occurs.
   h) Result: **Pass**
   i) Appendices A and B contain the thermal data for this test.

3) *Partial Discharge Measurement at Ambient – Section 13.4.1 c) per Section 13.5*
   a) This measurement was performed at ambient temperature and 120kV.
   b) The passing requirement is ≤ 5 pC @ 120kV.
   c) Result: **Pass**
   d) Figure 3 shows the partial discharge extinction graph.

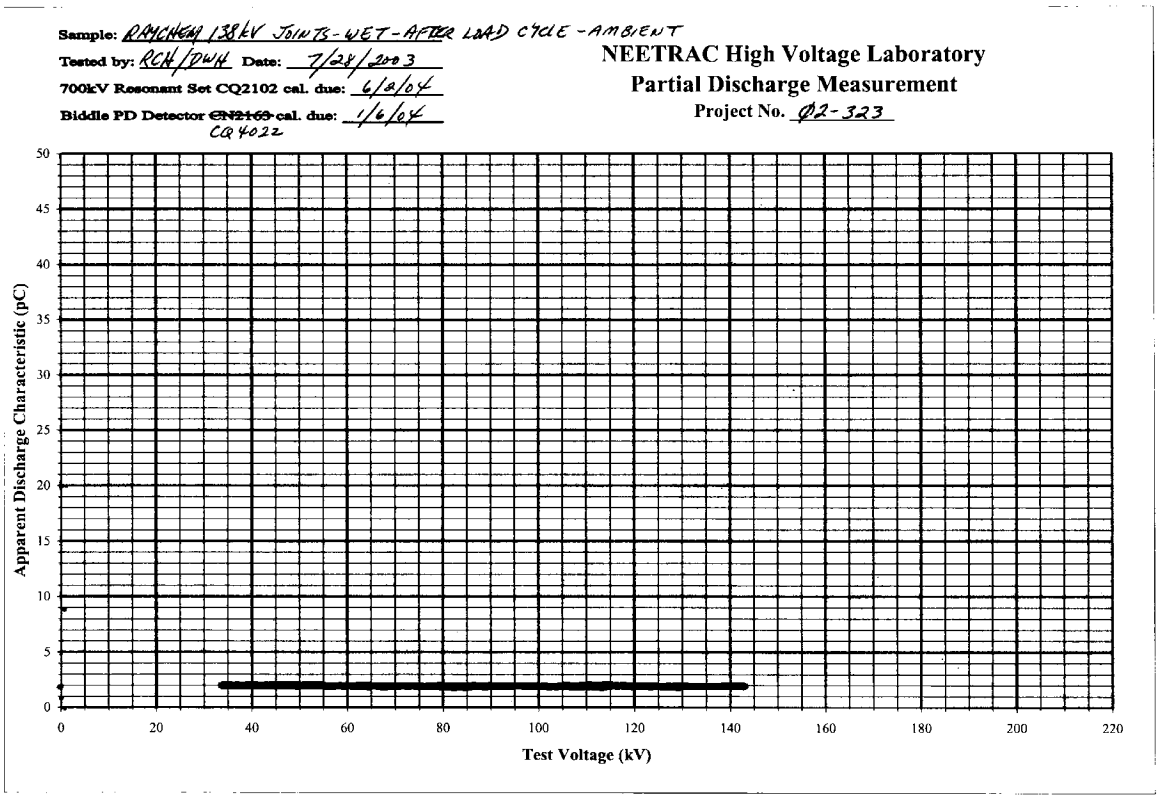


Figure 3 - Partial Discharge Measurement at Ambient after Heat Cycling

4) *Partial Discharge Measurement at Elevated Temperature – Section 13.4.1 c) per Section 13.5*
   a) This measurement was performed at a conductor temperature of 105°C ± 5°C and 120kV.
   b) The passing requirement is ≤ 5 pC @ 120kV.
   c) Result: **Pass**
   d) Figure 4 shows the partial discharge extinction graph.

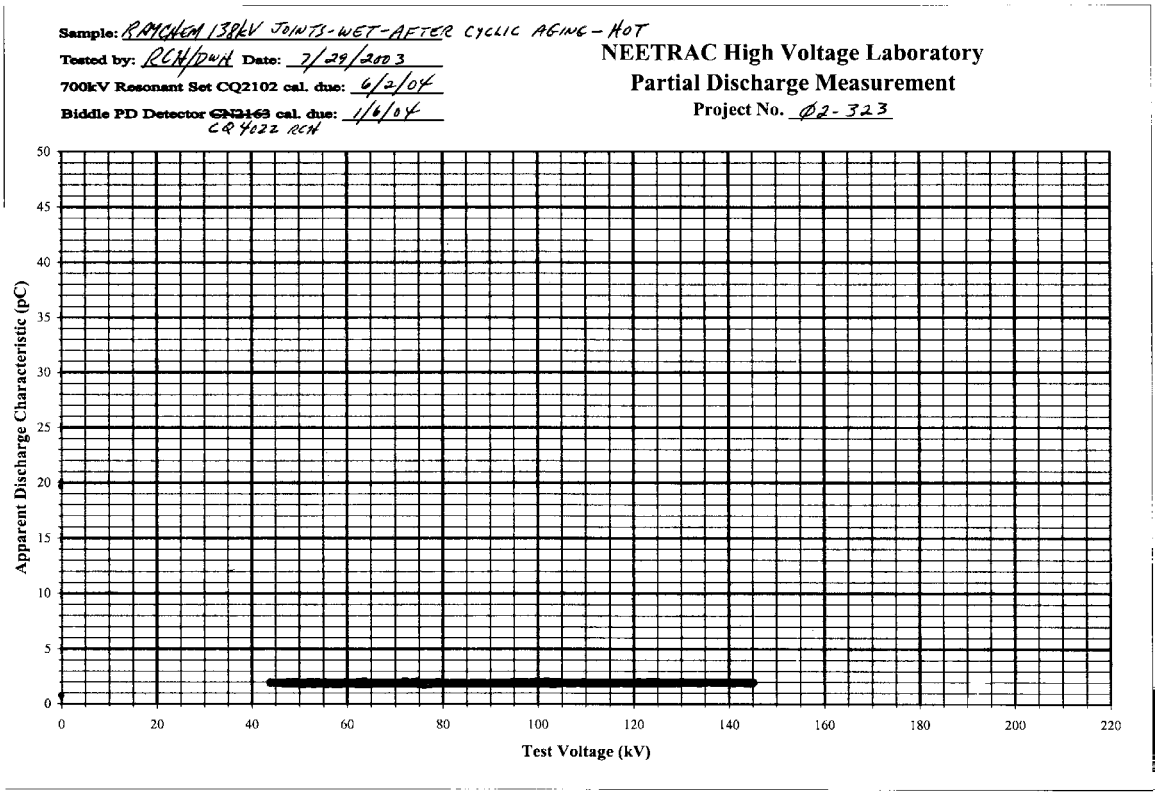


Figure 4 - Partial Discharge Measurement at Elevated Temperature after Heat Cycling

5) *Lightning Impulse Voltage Test at Elevated Temperature – Section 13.4.1 d) per Section 13.7*
   a) This test was performed at a conductor temperature of 105°C ± 5°C and 650kV.
   b) Ten positive and ten negative full-wave lightning impulses were applied.
   c) Lightning impulse data is contained in Appendix D. The crest of the impulse wave exhibits an oscillation. This oscillation is caused by a combination of the inductance of the long impulse lead, which connects the impulse generator located on north end of the lab, to the cable terminations, which are located on south end of the lab, and the large cable capacitance. The impulse analysis software utilized indicated that the waveform conforms to the full lightning impulse parameters required by IEEE Standard 4-1995, *High Voltage Testing Techniques* and IEC 60060-1-1989, *High Voltage Test Techniques.*
   d) The passing requirement is that there is no breakdown.
   e) Result: **Pass**

6) *Power Frequency Voltage Test after Hot Impulse – Section 13.4.1 d) per Section 13.7*
   a) This test was performed at 200kV (2.5 U_o) for fifteen (15) minutes.
   b) The passing requirement is that no breakdown occurs.
   c) Result: **Pass**

CONCLUSION

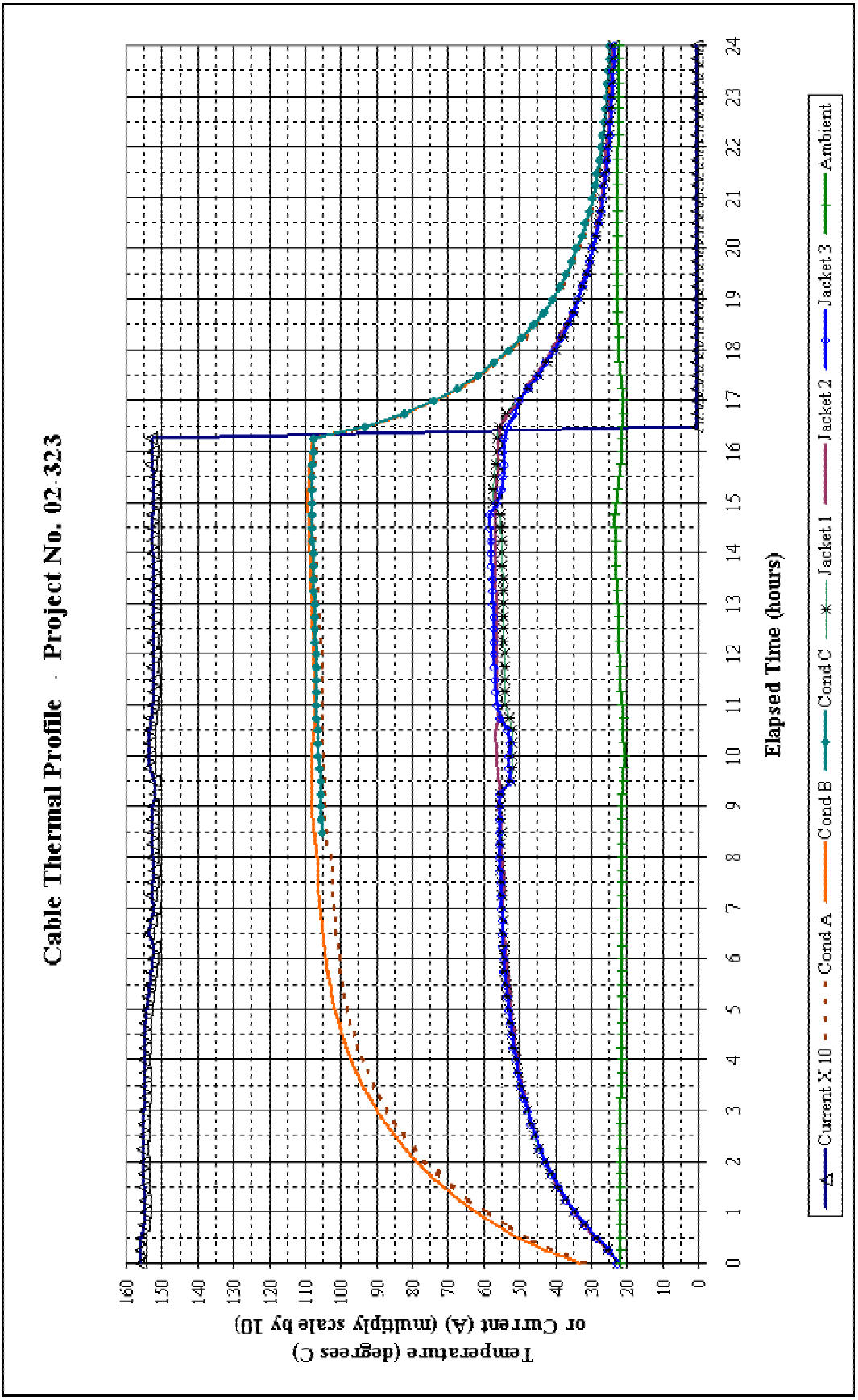
The two premolded cable joints, described as Tyco model number EHVS-145-IL-WU-31-73-89 in the "*Sample Description" section*, passed the type test requirements of IEC 60840/Rev. 3 - 2000, Sections 13.4.1 a), b), c), d), 13.5, 13.6, and 13.7 for a 138kV voltage class (U_m = 145kV) cable joint at a conductor temperature of 105°C while submerged in water.

EQUIPMENT LISTING

1. Biddle 700kV Series Resonant Test Set (kilovolt meter) – CQ2102
2. Biddle Model 27000 Partial Discharge Detector – CQ4022
3. Maxwell Laboratories 2.2MV Impulse Generator
4. Nicolet Power Pro Digital Impulse Scope – CQ2127
5. Hipotronics Impulse Voltage Divider – CQ2115
6. Fluke Hydra Data Bucket – calibration check 07/22/2002

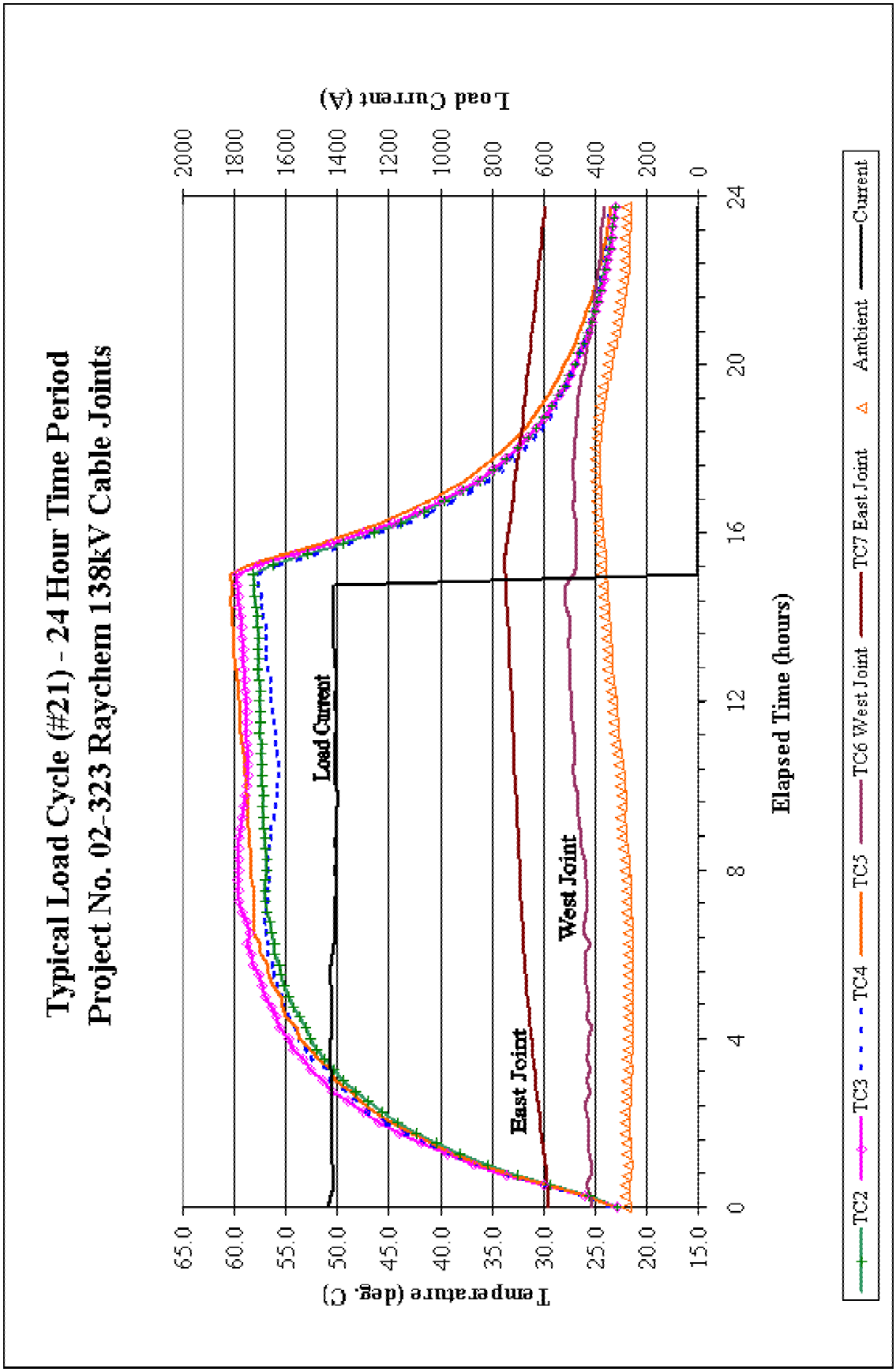
APPENDIX A

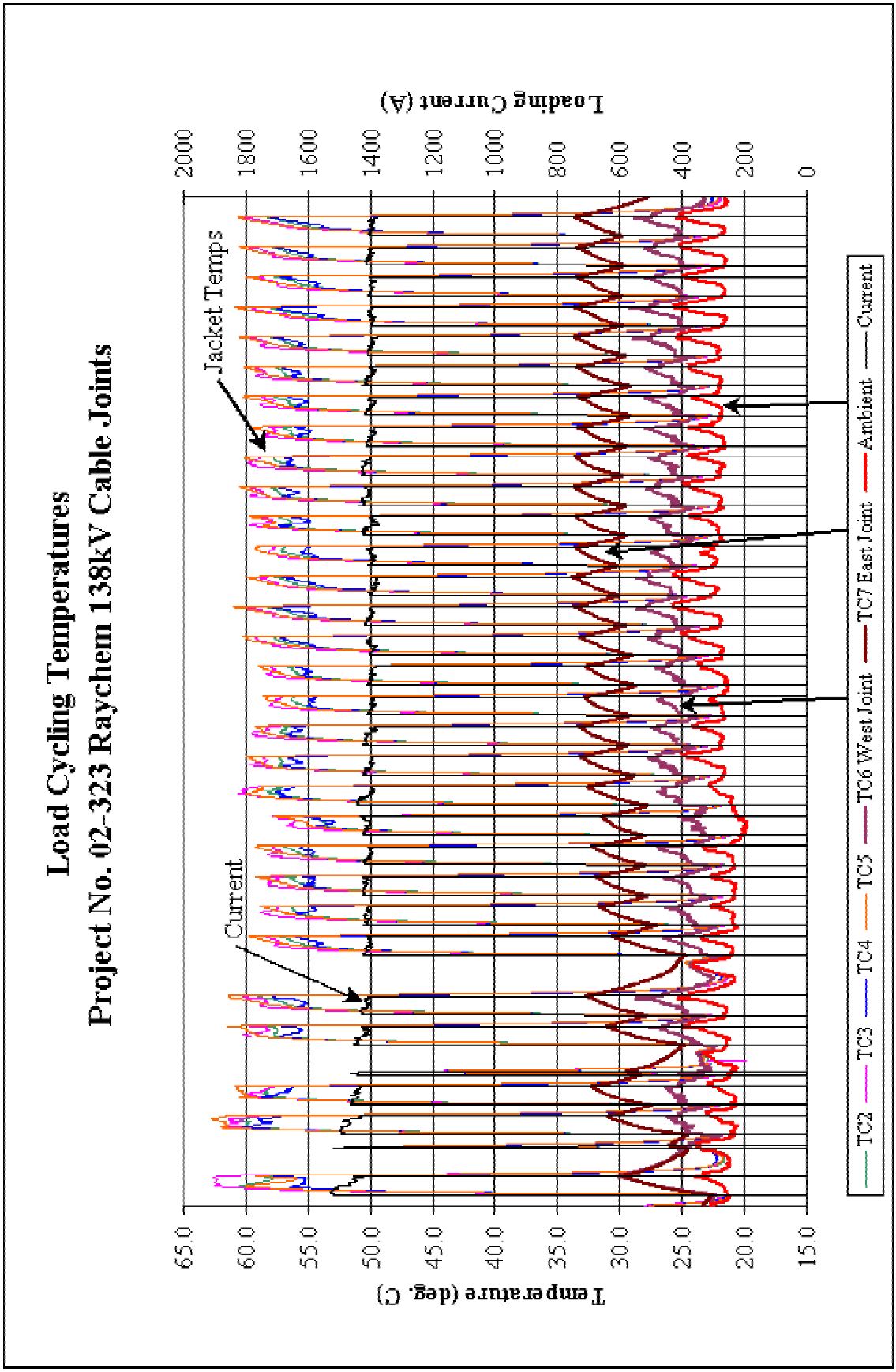
Cable Thermal Profile


Cable Thermal Profile - Project No. 02-323
Temperature (degrees C)
or Current (A) (multiply scale by 10)
Elapsed Time (hours)
Current X 10
Cond A
Cond B
Cond C
Jacket 1
Jacket 2
Jacket 3
Ambient

APPENDIX B

Load Cycling Temperature Data


Typical Load Cycle (#21) - 24 Hour Time Period
Project No. 02-323 Raychem 138kV Cable Joints
Temperature (deg. C)
Load Current (A)
Elapsed Time (hours)
Load Current
East Joint
West Joint
TC2
TC3
TC4
TC5
TC6 West Joint
TC7 East Joint
Ambient
Current
Thermocouples TC2 through TC5 are located on the cable jacket.



Thermocouples TC2 through TC5 are located on the cable jacket.

APPENDIX C

Test Setup

Figure 5 - Test Setup

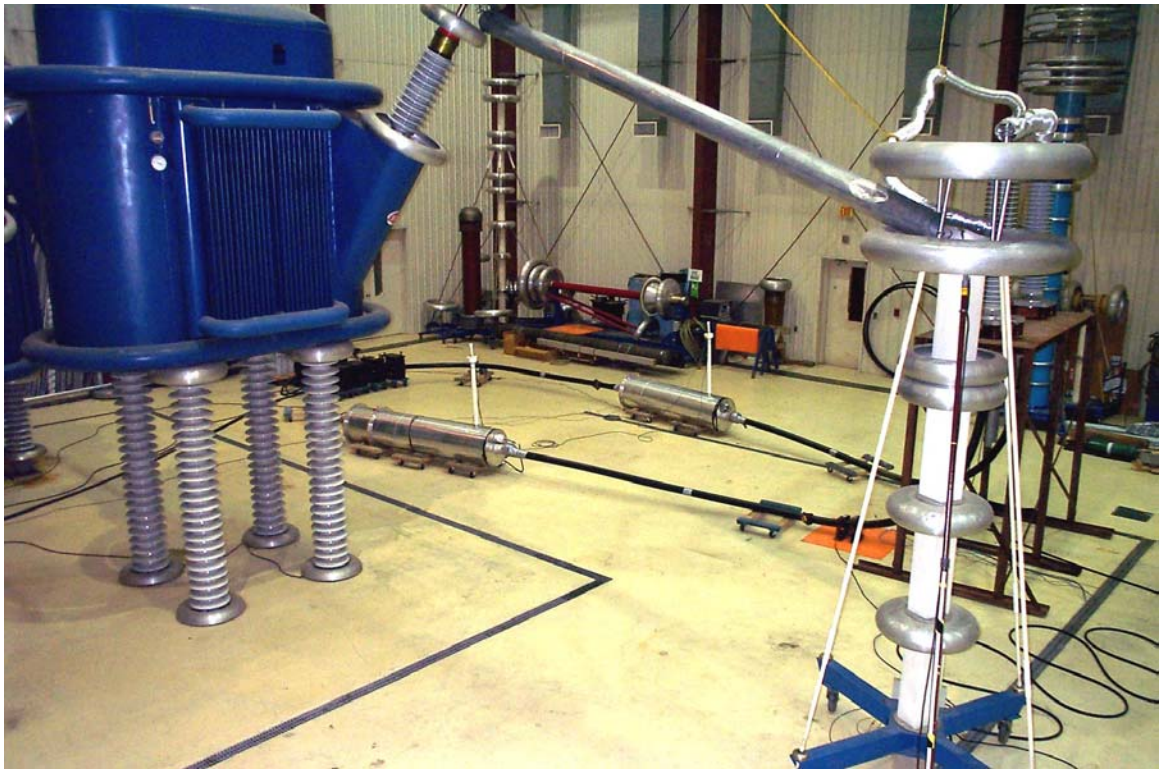


Figure 6 - Test Setup

Figure 7 - Test Setup

Figure 8 - Test Setup

Figure 9 - West Joint in Water Housing

Figure 10 - East Joint in Water Housing

APPENDIX D

Impulse
Data Log
&
Waveforms

Ga. Tech / NEETRAC High Voltage Laboratory

Impulse Data Log: "Final Hot"

Project No. 02-323

Date: 7/30/2003

Time	Description	V peak (kV)	Front Time (us)	Tail Time (us)	Overshoot (%)
13:45:11	reduced neg	-443.1	1.80	65.58	
13:49:58	reduced	-427.8	2.31	77.10	
13:53:40	reduced	-348.9	1.80	81.80	
13:56:51	reduced	-512.8	1.97	63.92	0.10%
14:01:53	1st BIL neg	-642.2	1.73	53.47	
14:04:28	2nd BIL	-646.4	1.65	54.52	
14:08:26	3rd	-651.4	1.70	54.13	
14:11:02	4th	-648.5	1.70	54.18	
14:14:08	5th BIL	-648.5	1.70	54.35	
14:17:24	6th	-648.7	1.69	54.24	
14:19:43	7th	-650.4	1.69	54.20	
14:21:57	8th	-650.9	1.69	54.16	
14:24:33	9th	-651.8	1.69	54.19	
14:27:18	10th	-651.2	1.70	54.14	
14:41:42	reduced pos	468.5	1.70	64.36	
14:43:44	reduced	467.3	1.65	65.49	1.40%
14:45:51	reduced	533.6	1.67	60.02	
14:48:15	reduced	533.9	1.67	60.55	
14:51:39	1st BIL pos	642.3	1.65	54.26	
14:54:58	2nd	644.8	1.67	54.78	
14:57:37	3rd	644.4	1.66	54.92	
15:00:25	4th	643.3	1.65	55.10	
15:03:09	5th BIL	658.0	1.65	54.52	
15:06:04	6th	644.9	1.66	54.81	
15:08:41	7th	646.3	1.65	54.68	
15:10:53	8th	645.5	1.64	54.78	
15:13:08	9th	643.7	1.66	54.98	
15:15:45	10th	643.0	1.65	55.03	

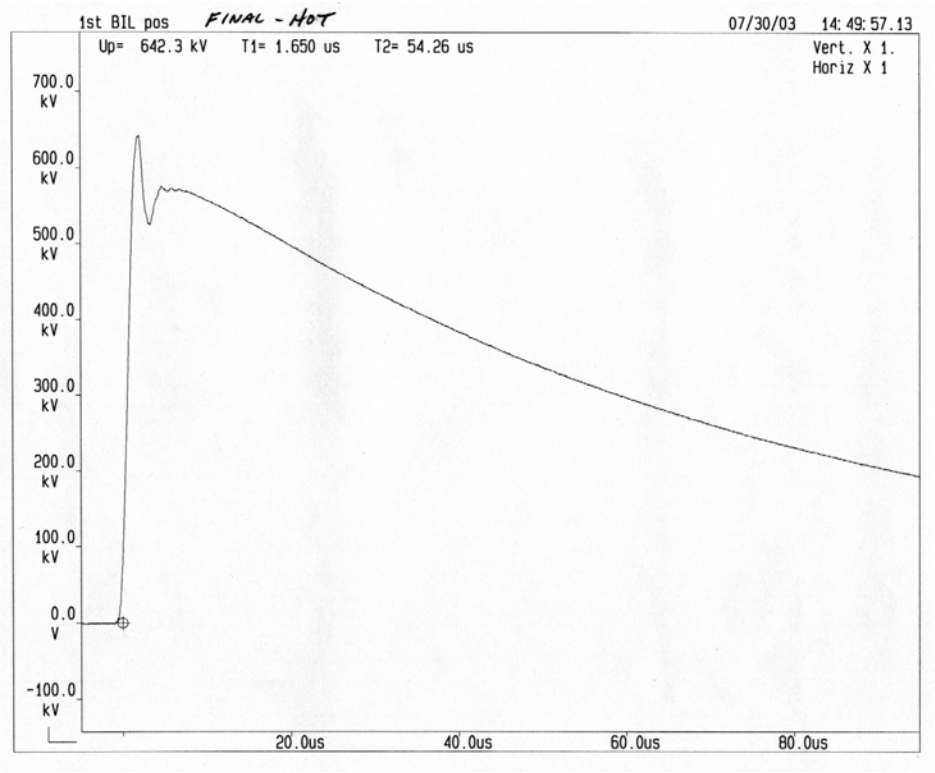


Figure 11 – Final Hot 1st Positive

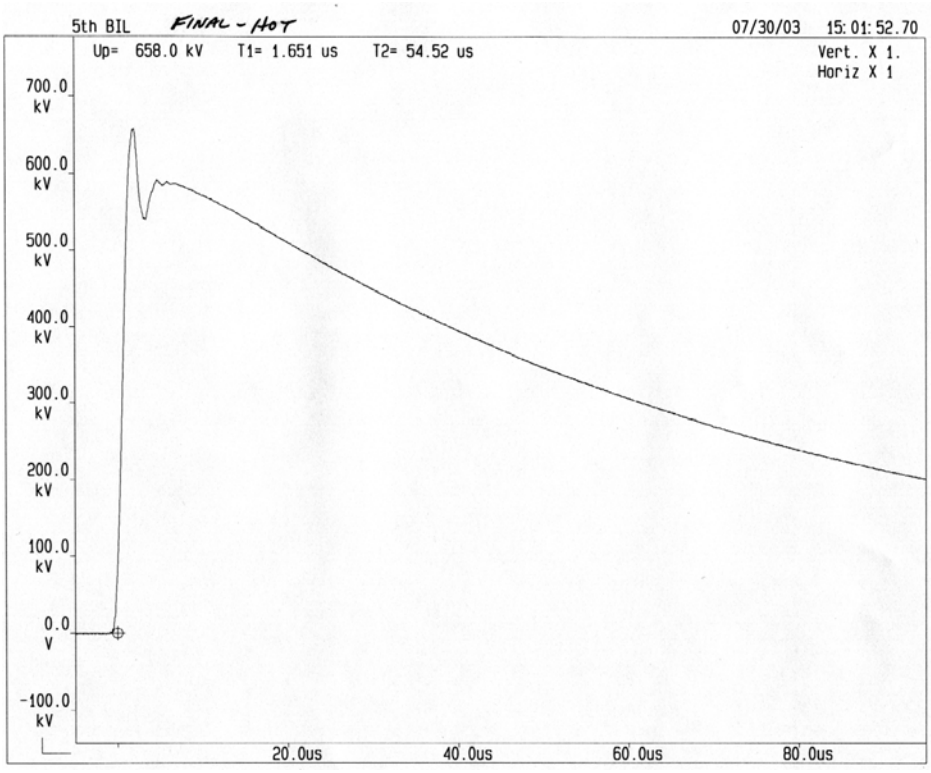


Figure 12 – Final Hot 5th Positive

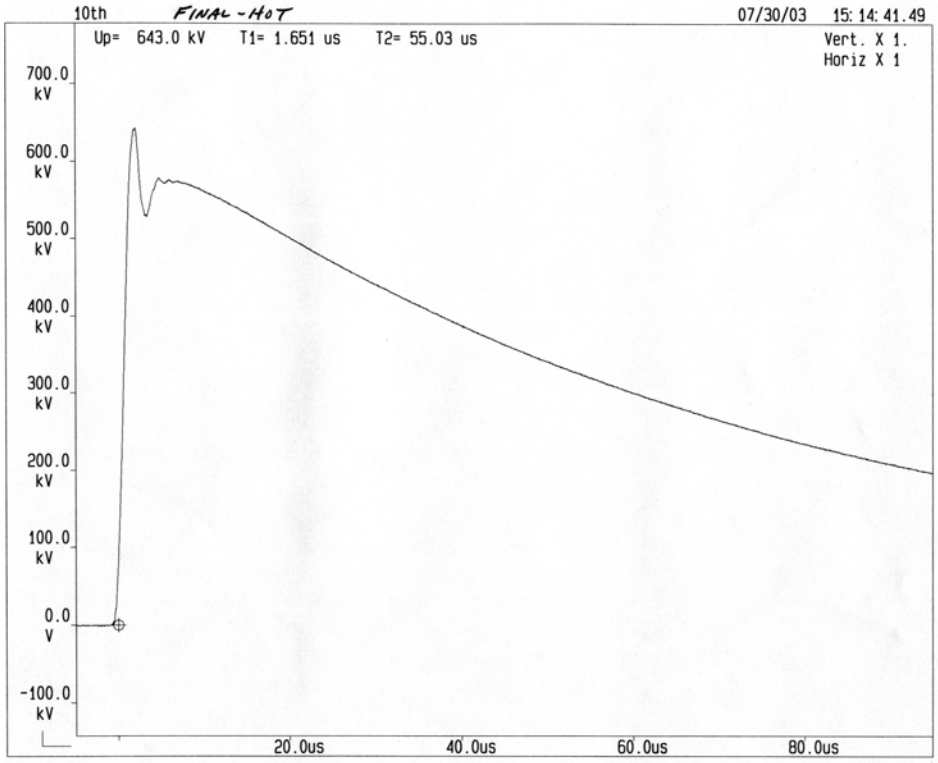


Figure 13 – Final Hot 10th Positive

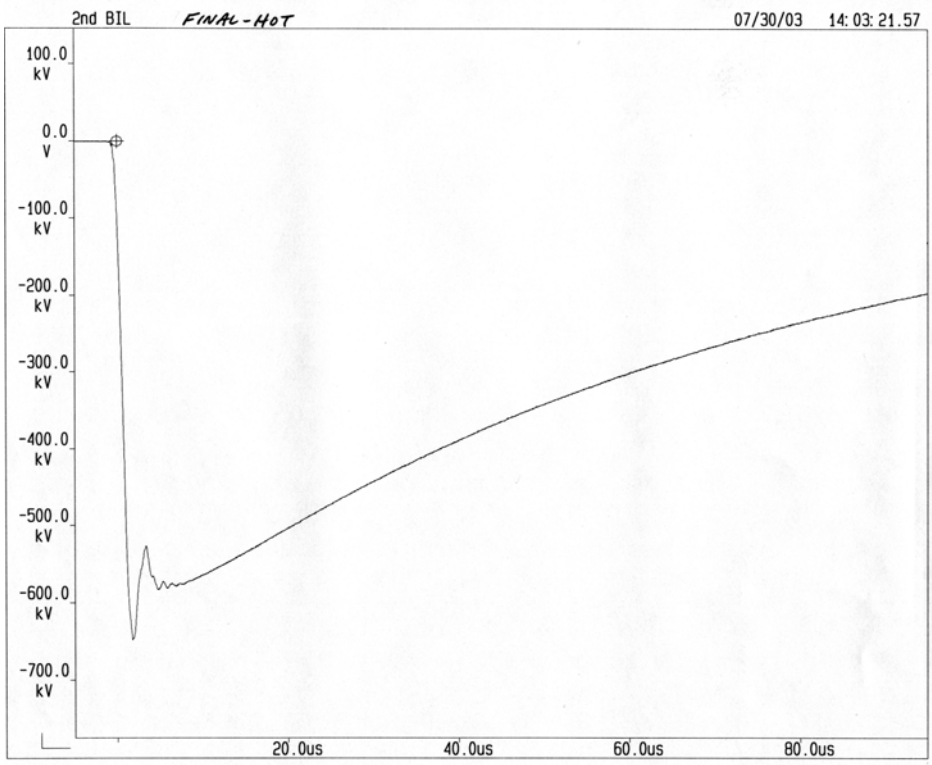


Figure 14 – Final Hot 2nd Negative

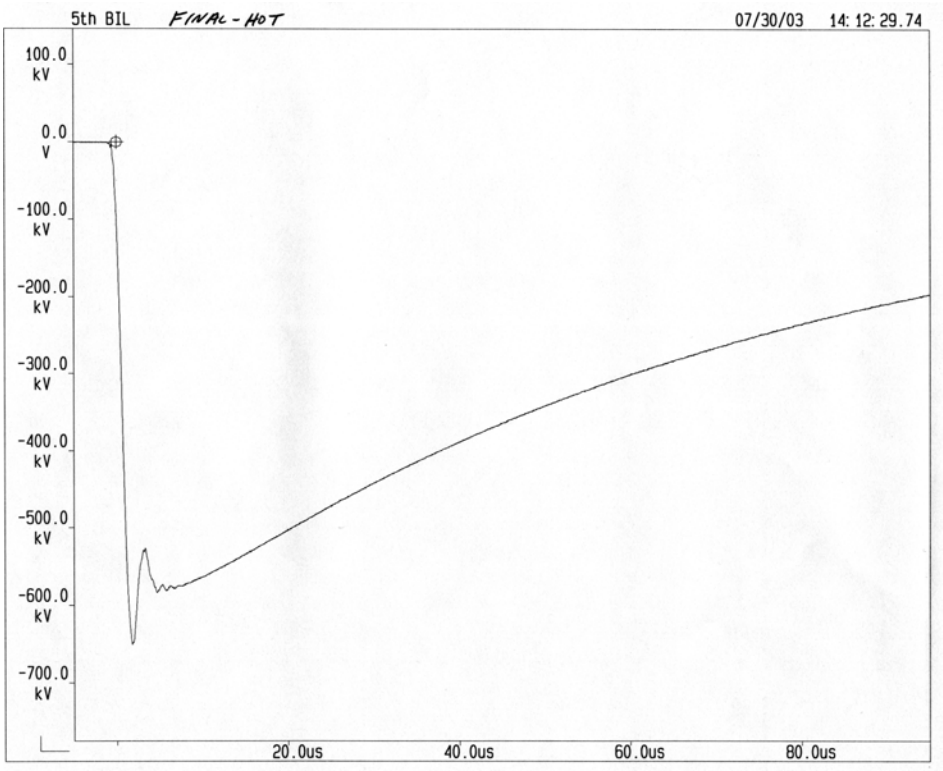


Figure 15 – Final Hot 5th Negative

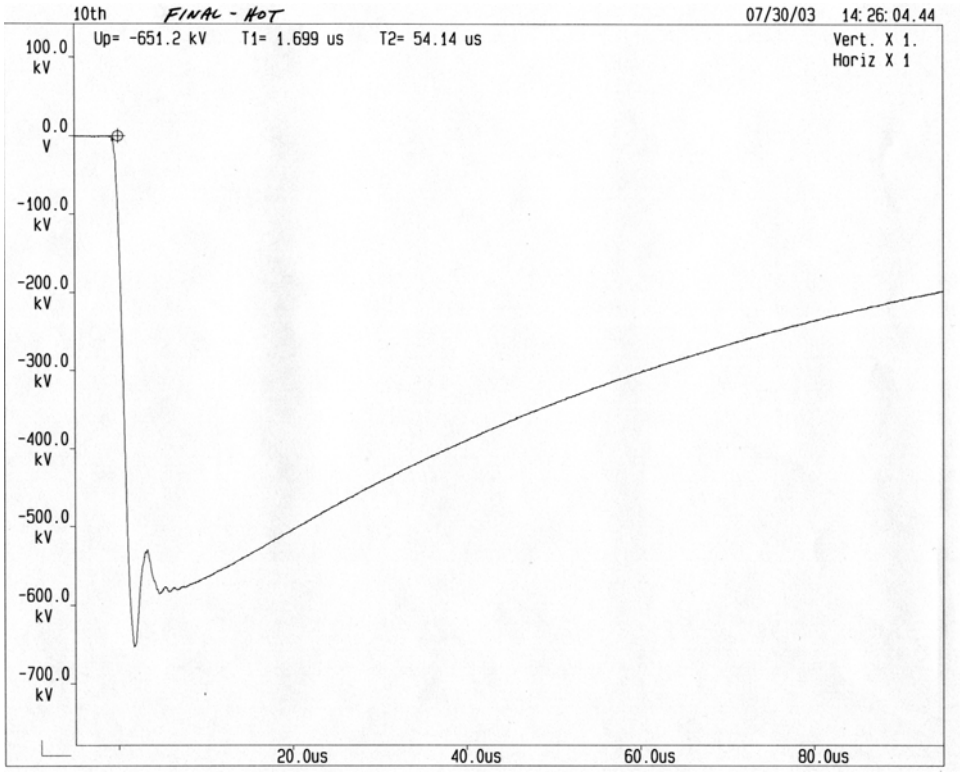


Figure 16 – Final Hot 10th Negative

Blank Page