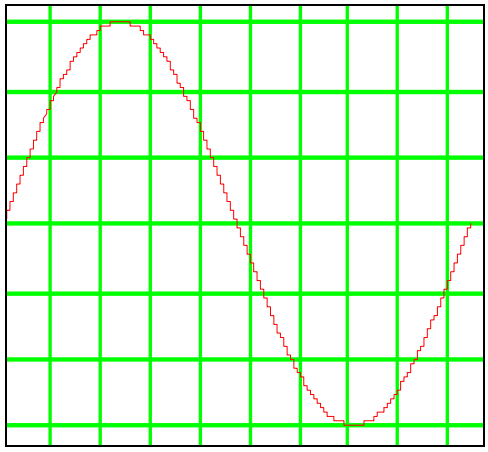

Test Report

PPR 1739

138 kV Inline Cable Joint
EHVS-145-IL-WU-31-73-89
tested in accordance with
IEEE 404-2000

Pages:	1 + 28
Appendix:	-
Date:	January 14, 2004

Tested by: Neetrac
Date: September, 2003

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Design Testing of Cable Joints Rated 138kV Under Wet Conditions According to IEEE Standard 404-2000

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

Design Testing of Cable Joints Rated 138kV Under Wet Conditions According to IEEE Standard 404-2000

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 design tests, in water, on two extruded dielectric shielded cable joints rated 138kV according to IEEE Standard 404-2000, *IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500V to 500,000V*. 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". Previously, two of the same type cable joints were subjected to the IEEE Standard 404-1993 design tests in air. Those results are reported in NEETRAC Project No. 01-086. The current test program completes the IEEE Standard 404-1993 *IEEE Standard for Cable Joints for Use With Extruded Dielectric Cable Rated 5000-138,000V and Cable Joints for Use With Laminated Dielectric Cable Rated 2500-500,000V* qualification requirement to test two joints in water and two in air.

Testing was performed at the NEETRAC High Voltage Laboratory in Forest Park, Georgia USA. The two cable joints were subjected to the design tests shown in Table 4, columns 1 and 3, of IEEE Standard 404-2000 while under water. Additional tests were also performed at the request of the customer to fulfill the requirements of other test standards. 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 design test requirements of IEEE Standard 404-2000, Table 4, columns 1 and 3, for a 138kV voltage class joint at a conductor temperature of 105°C.

INTRODUCTION & SCOPE

The purpose of this project was to perform design tests, in water, on two extruded dielectric shielded cable joints rated 138kV according to IEEE Standard 404-2000, *IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500V to 500,000V*. Testing requirements were those found in Table 4, columns 1 and 3. Each cable joint was installed inside a water container with a one-meter water head pressure for testing. 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. IEEE Standard 404-2000, *IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500V to 500,000V*
2. IEEE Standard 404-1993, *IEEE Standard for Cable Joints for Use With Extruded Dielectric Cable Rated 5000-138,000V and Cable Joints for Use With Laminated Dielectric Cable Rated 2500-500,000V*
3. IEEE Standard 4-1995, *High Voltage Testing Techniques*
4. NEETRAC Final Report Project No. 01-086, *138kV Cable Joint Design Qualification Tests for Tyco Electronics – Energy Division*

PROCEDURE

The test procedure followed IEEE Standard 404-2000, Section 7.2, *Design Tests and Testing Sequence*, Table 4, columns 1 and 3, for 138 kV class cable joints in water. While one of the cable joints contained a screen interruption (sectionalizer), the sectionalizer tests of Subclause 7.9 are not included in this test program. Also, the short time current, shielding, and connector thermal and mechanical tests were not a part of this 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 from Table 4, columns 1 and 3, with descriptions and results for each.

Tests

1) *Partial Discharge (Corona) Extinction Voltage Measurement – Subclause 7.4.1 – Initial*
   a) This measurement was performed at ambient temperature and 120kV.
   b) The passing requirement is ≤ 3 pC @ 120kV.
   c) Result: **Pass**
   d) Figure 2 shows the partial discharge extinction graph.

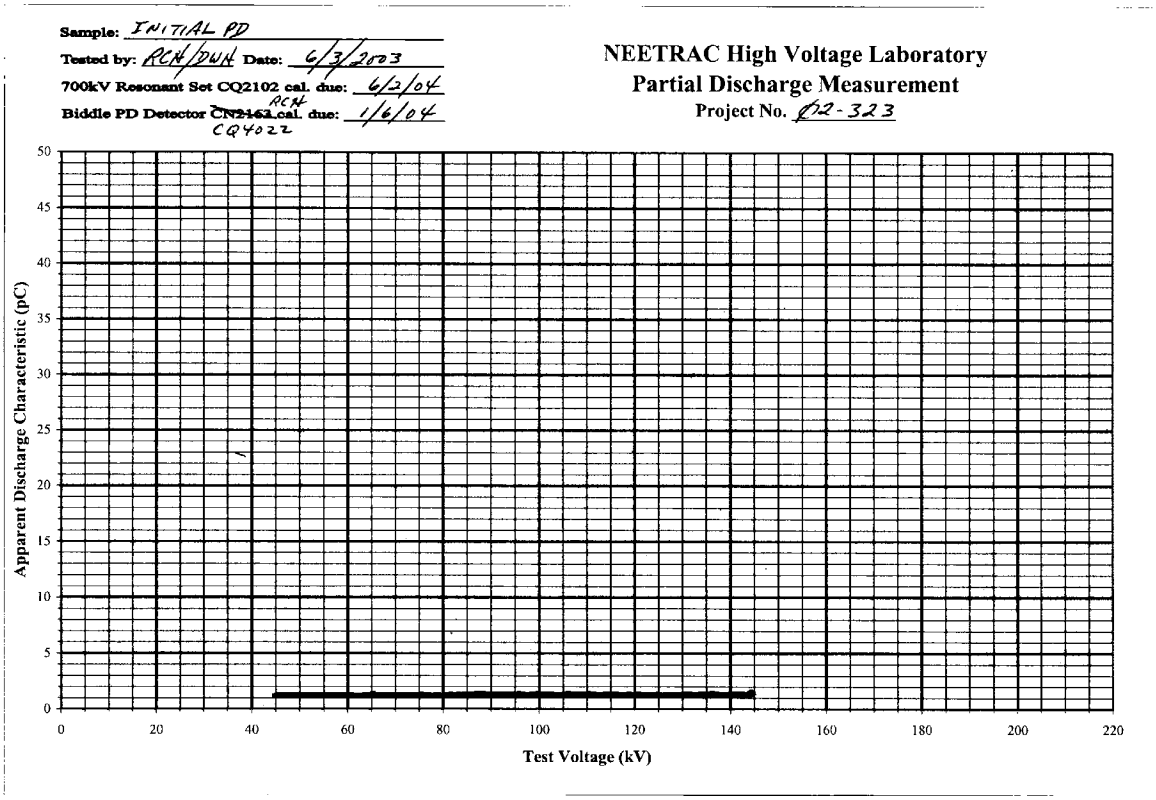


Figure 2 - Initial Partial Discharge Measurement

2) *AC Withstand Voltage - 15 Minutes – Subclause 7.5.1*
   a) This test was performed at ambient temperature and 240kV.
   b) The passing requirement is that there is no breakdown.
   c) Result: **Pass**

3) *DC Withstand Voltage – 15 Minute – Subclause 7.5.2*
   a) This test was performed at ambient temperature and 315kV.
   b) The passing requirement is that there is no breakdown.
   c) Result: **Pass**

4) *Impulse Withstand Voltage at Ambient – Subclause 7.5.3*
   a) This test was performed at ambient temperature 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.*
   d) The passing requirement is that there is no breakdown.
   e) Result: **Pass**

5) *Impulse Withstand Voltage at Emergency Temperature – Subclause 7.5.3*
   a) This test was performed at 105°C (± 5°) and 650kV.
   b) Ten positive and ten negative full-wave lightning impulses were applied.
   c) Lightning impulse data is contained in Appendix E. The crest of the impulse wave exhibits an oscillation; see above comment.
   d) The passing requirement is that there is no breakdown.
   e) Result: **Pass**

6) *Partial Discharge (Corona) Extinction Voltage Measurement – Subclause 7.4.1*
   a) This measurement was performed at ambient temperature and 120kV.
   b) The passing requirement is ≤ 3 pC @ 120kV.
   c) Result: **Pass**
   d) Figure 3 shows the partial discharge extinction graph.

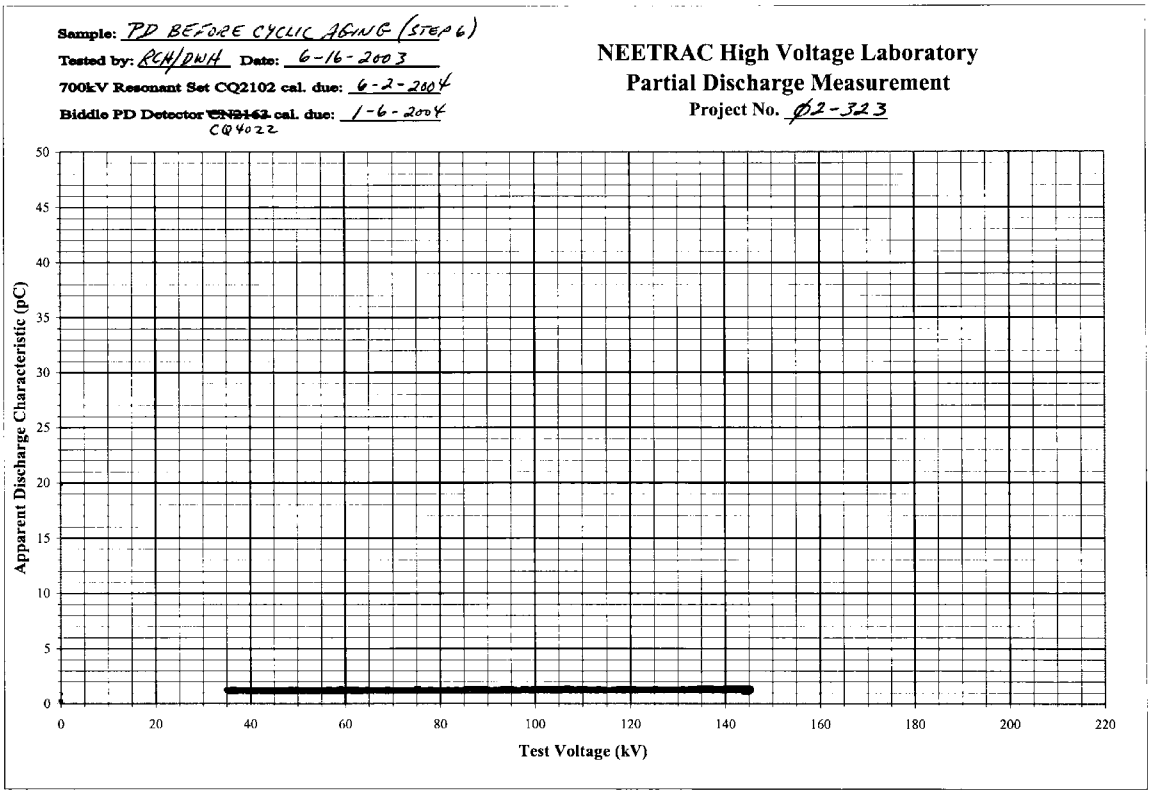


Figure 3 - Partial Discharge Measurement Before Load Cycling

7) *Cyclic Aging – Subclause 7.7.2*
   a) A thermal profile for the cable was established on a dummy section and is contained in Appendix A.
   b) This test was performed at 160kV and 105°C (± 5°) for thirty (30) heating (load) cycles.
   c) The load cycle was composed of fifteen (15) hours "ON" and nine (9) hours "OFF".
   d) At least six (6) hours of the "ON" time were within the temperature range of item a).
   e) The passing requirement is that no breakdown occurs.
   f) Result: **Pass**
   g) Appendices A and B contain the thermal data for this test.

8) *Partial Discharge (Corona) Extinction Voltage Measurement – Subclause 7.4.1 – after Cyclic Aging*
   a) This measurement was performed at ambient temperature and 120kV.
   b) The passing requirement is ≤ 3 pC @ 120kV.
   c) Result: **Pass**
   d) Figure 4 shows the partial discharge extinction graph.

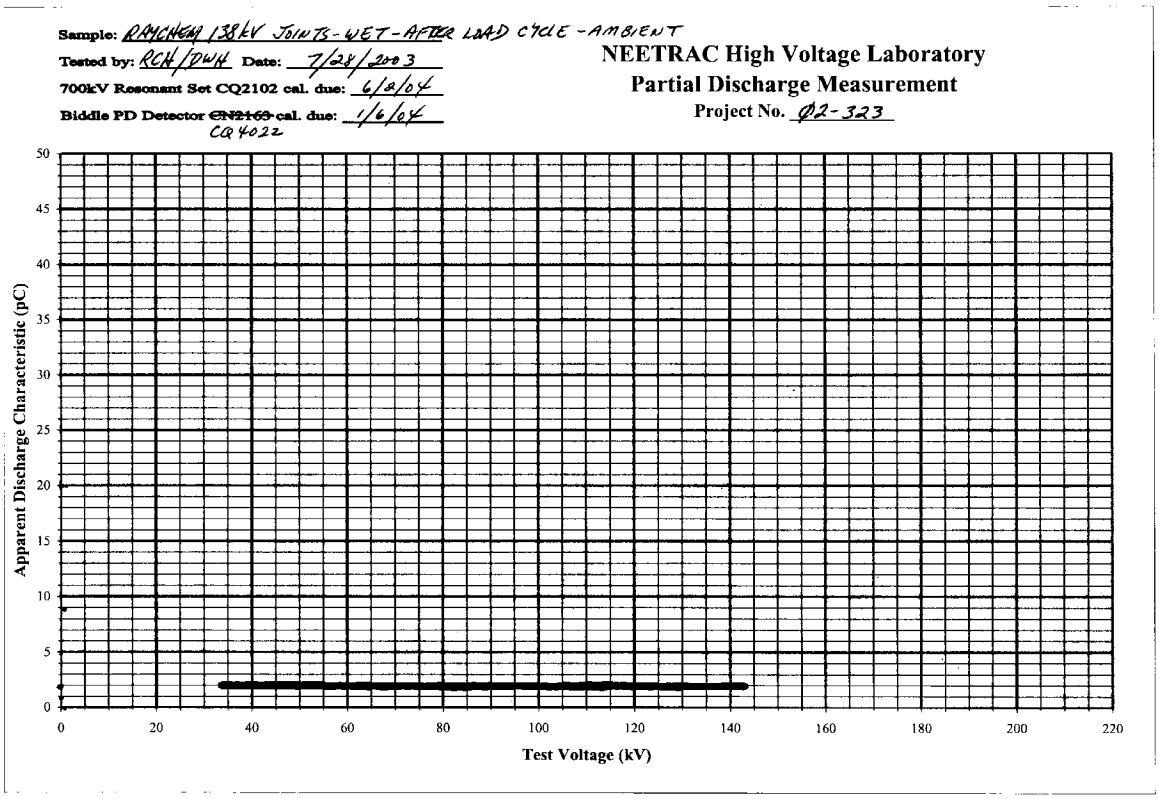


Figure 4 - Partial Discharge Measurement After Load Cycling

9) *High Voltage Time – Subclause 7.8*
   a) This test was performed at ambient temperature and 200kV for six (6) hours.
   b) The passing requirement is that no breakdown occurs.
   c) Result: **Pass**

CONCLUSION

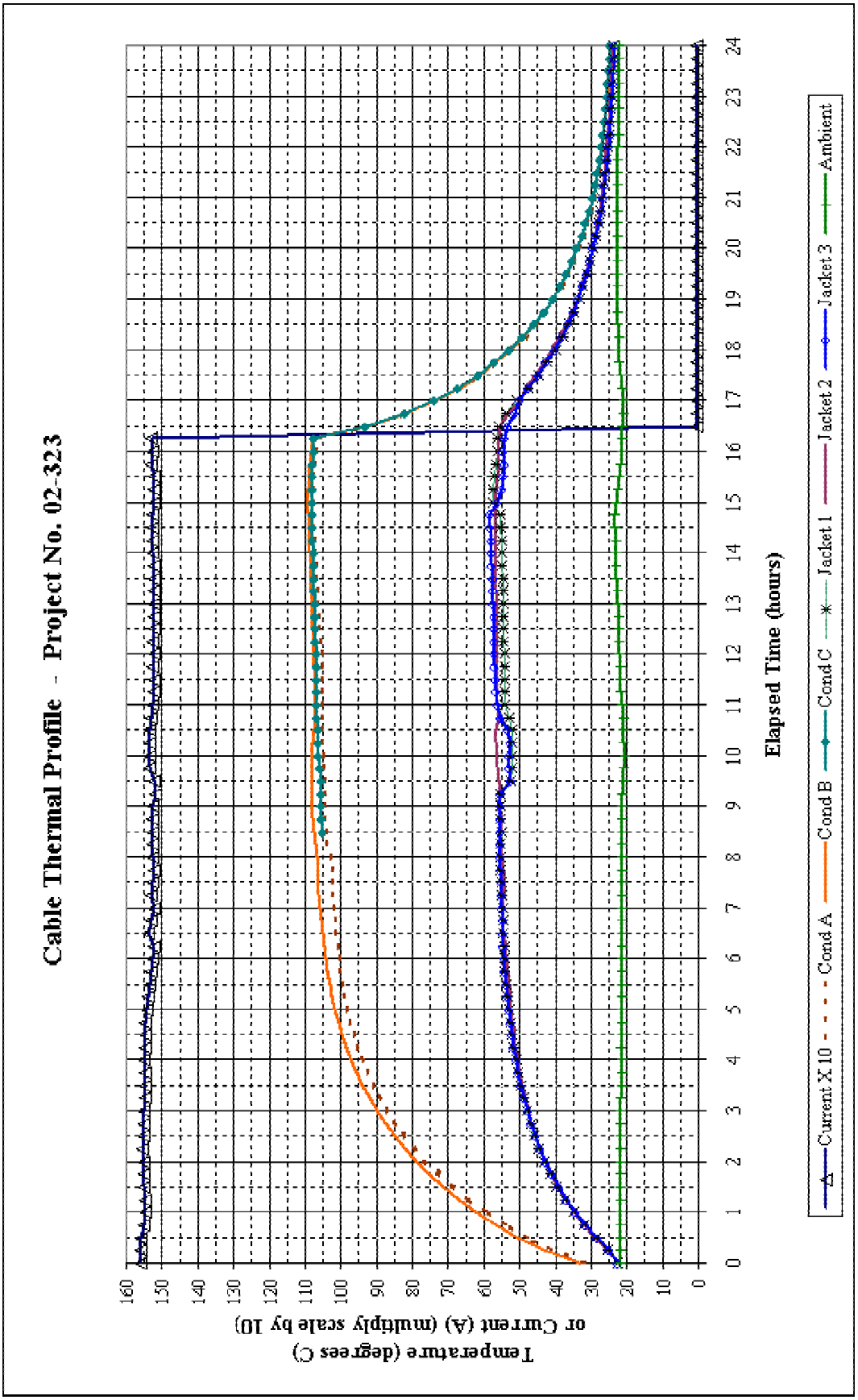
The two premolded cable joints, described as Tyco model number EHVS-145-IL-WU-31-73-89 in the "*Sample Description" section*, passed the design test requirements of IEEE Standard 404-2000, Section 7.4, Table 4, columns 1 and 3, for 138kV voltage class joints under water at a conductor temperature of 105°C.

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

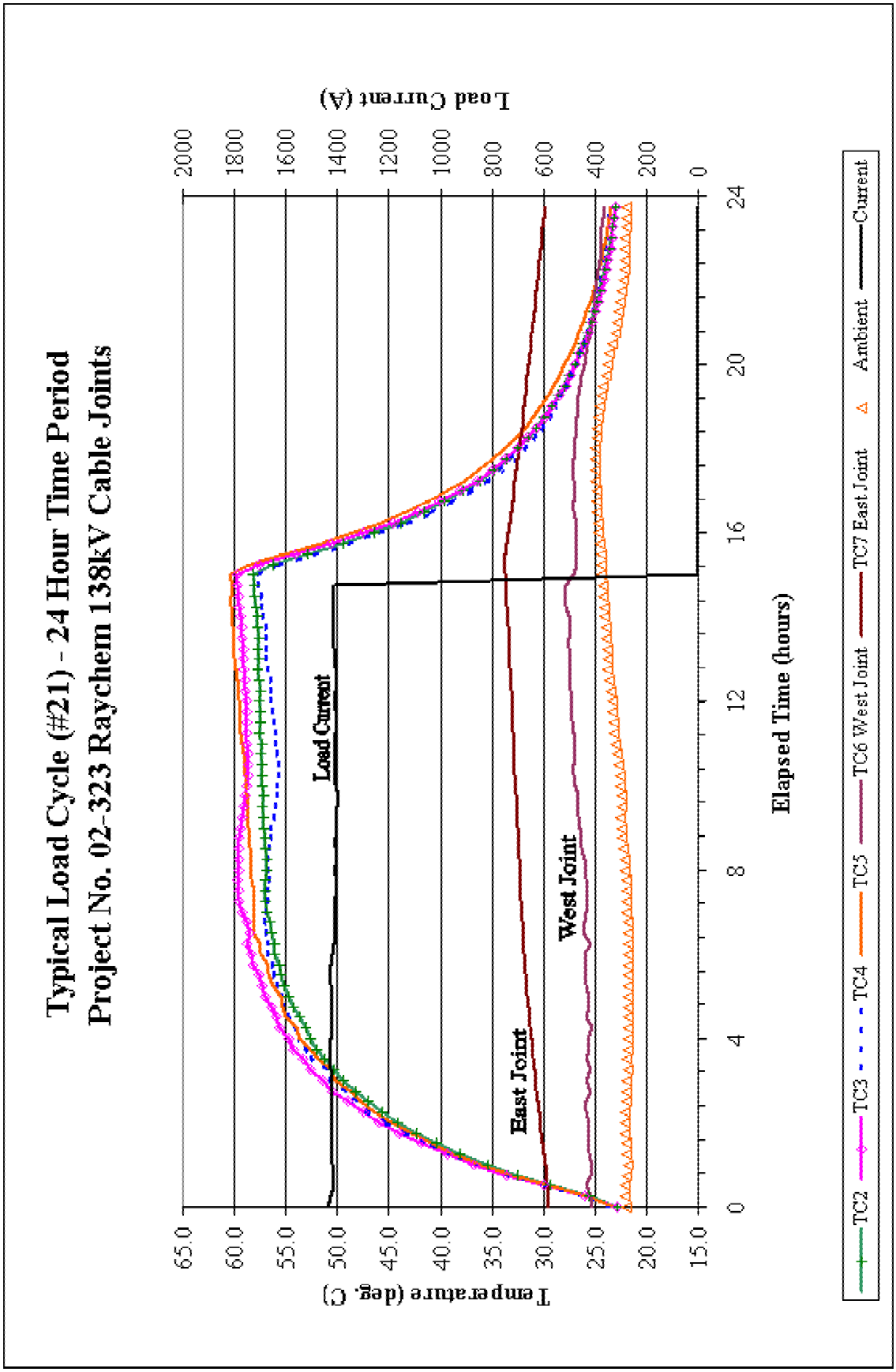
APPENDIX A

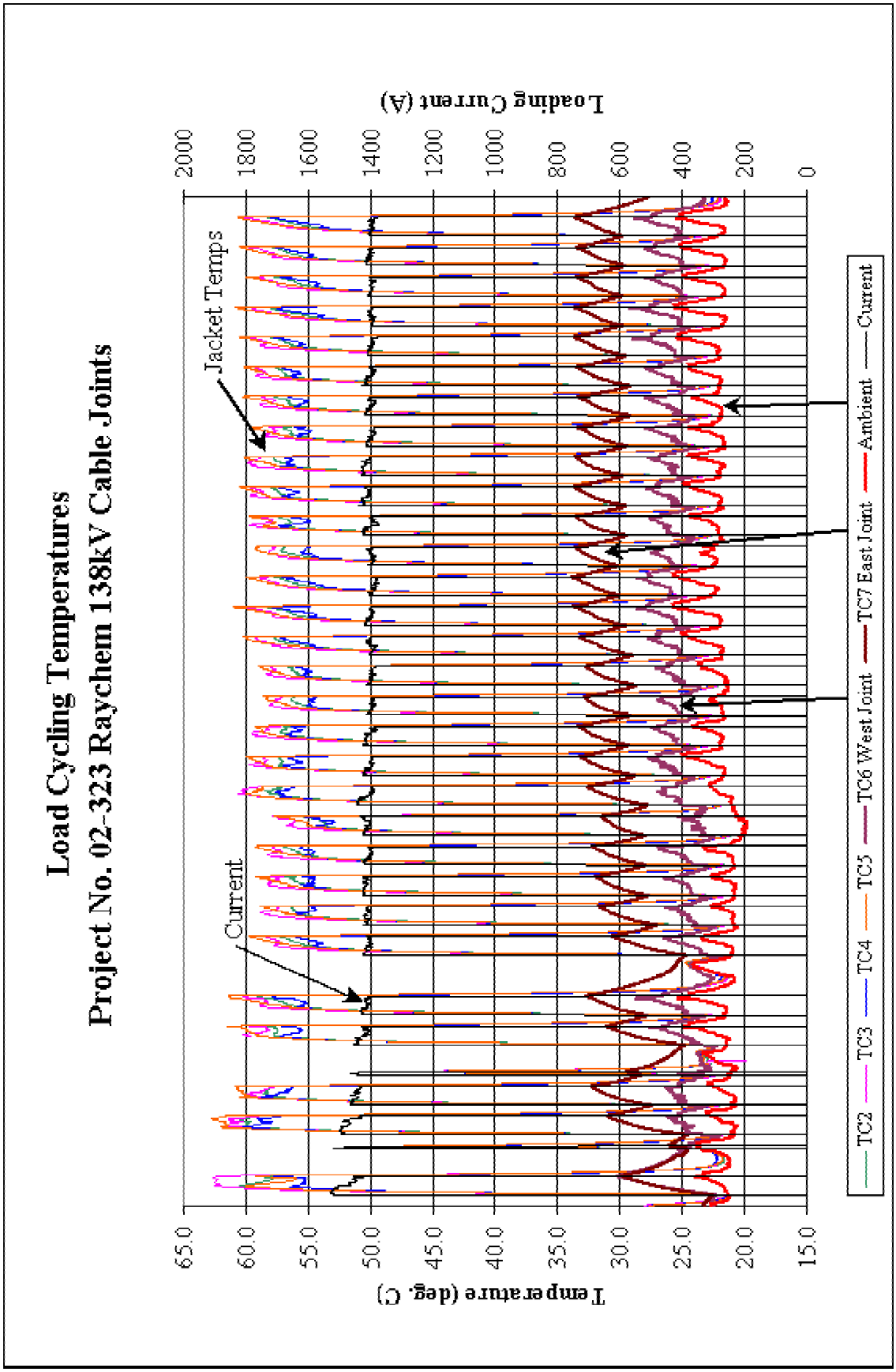
Cable Thermal Profile


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

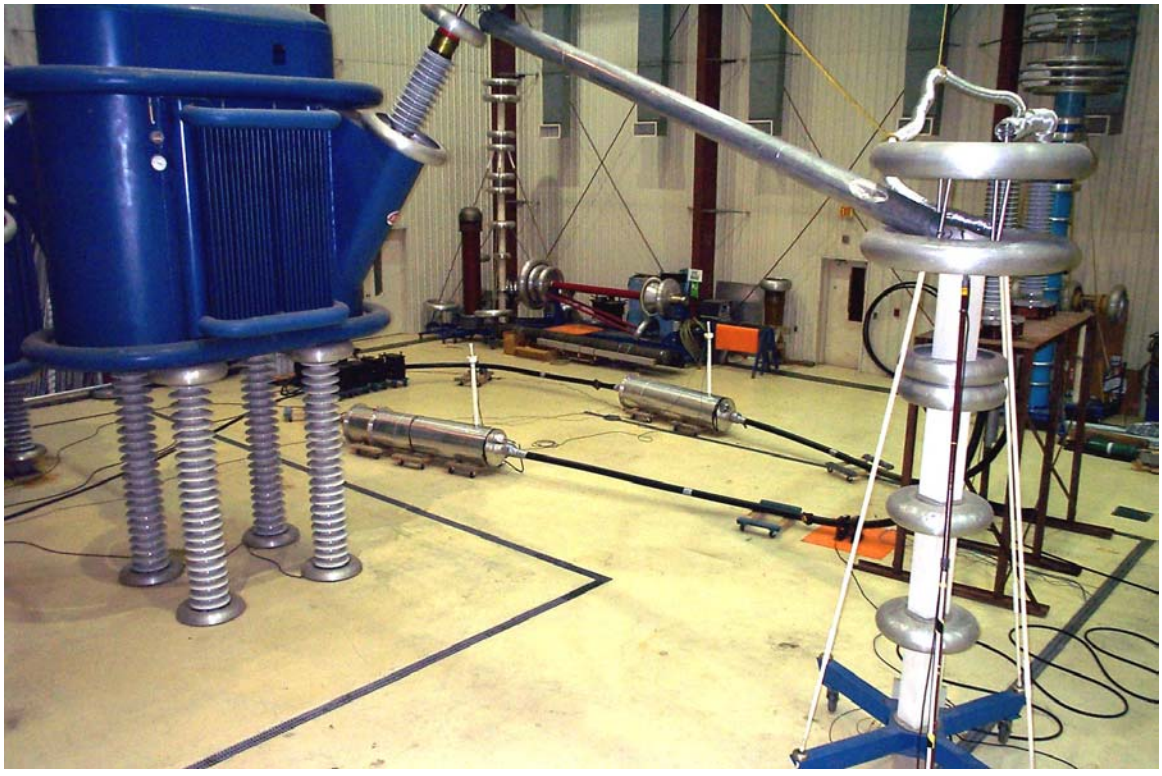


Figure 6 - Test Setup

Figure 7 - Test Setup

Figure 8 - Test Setup

Figure 9 - West Joint in Water Housing

Figure 10 - East Joint in Water Housing

APPENDIX D

Initial Ambient Impulse
Data Log
&
Waveforms

Ga. Tech / NEETRAC High Voltage Laboratory

Impulse Data Log: "Initial Ambient"

Project No. 02-323

Date: 6/4/2003

Time	Description	V peak (kV)	Front Time (us)	Tail Time (us)	Overshoot (%)
15:27:13	Initial Amb Neg Reduced	-448.8	1.80	65.70	2.3
15:33:57	Reduced	-549.4	1.75	54.17	
15:38:42	1st Neg	-649.9	1.70	50.27	
15:43:14	2nd	-671.9	1.77	52.15	
15:47:39	3rd	-653.6	1.78	53.58	
15:50:05	4th	-658.0	1.78	53.23	
15:52:32	5th	-654.4	1.78	53.38	
16:03:15	null	-605.1	1.58	59.38	7.8
16:06:12	6th	-654.7	1.78	53.33	
16:08:28	7th	-656.7	1.77	53.13	
16:10:36	8th	-655.2	1.77	53.23	
16:13:05	9th	-654.6	1.78	53.37	
16:15:41	10th	-654.7	1.78	53.38	
16:20:40	Reduced Pos	406.1	1.90	69.30	1.2
16:22:41	Reduced	412.7	1.86	69.13	1.4
16:25:12	Reduced	532.1	1.78	58.40	
16:28:04	1st Pos	647.8	1.76	53.03	
16:31:15	2nd	649.3	1.78	53.66	
16:33:28	3rd	652.1	1.77	53.58	
16:36:18	4th	665.5	1.81	54.09	
16:38:37	5th	650.1	1.78	53.90	
16:41:24	6th	652.1	1.77	53.58	
16:43:36	7th	651.3	1.77	53.72	
16:45:46	8th	650.7	1.77	54.00	
16:48:35	9th	648.8	1.78	54.17	
16:51:04	10th	651.2	1.78	53.83	

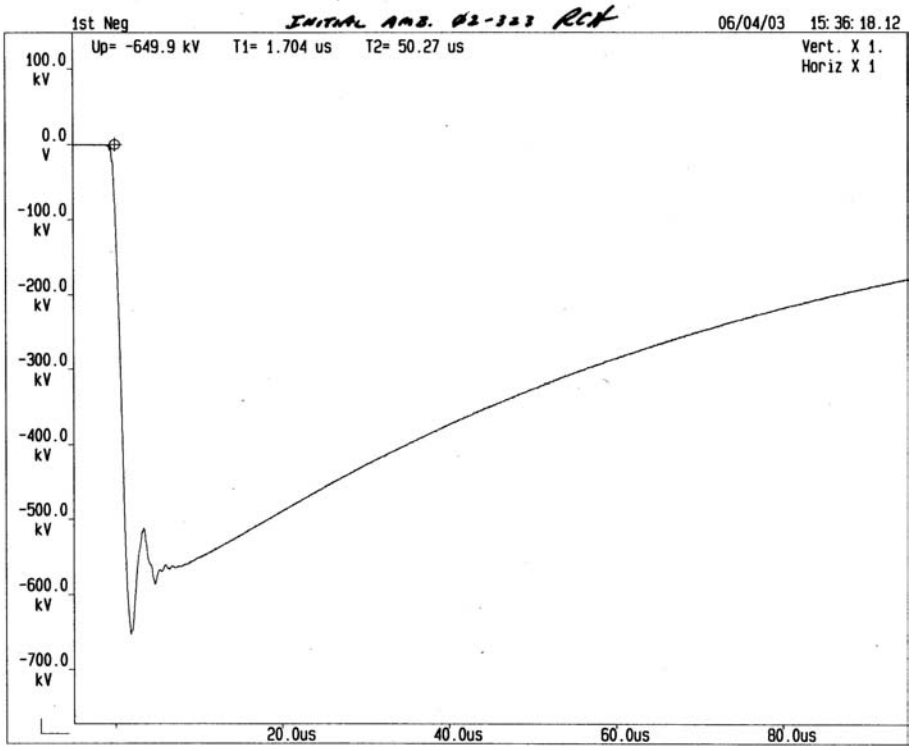


Figure 11 - Initial Ambient 1st Negative

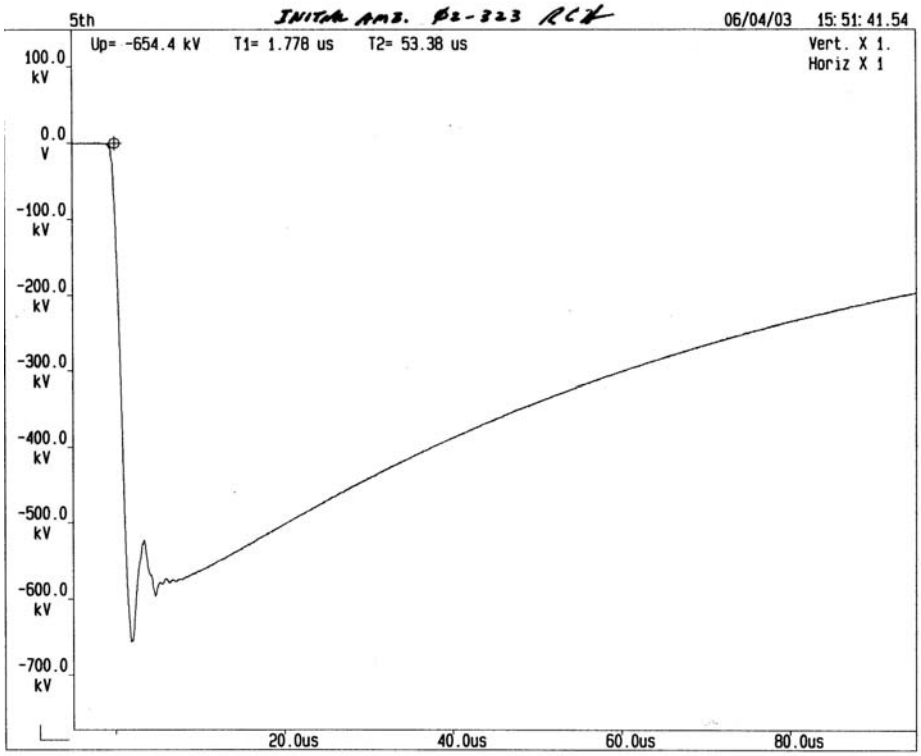


Figure 12 - Initial Ambient 5th Negative

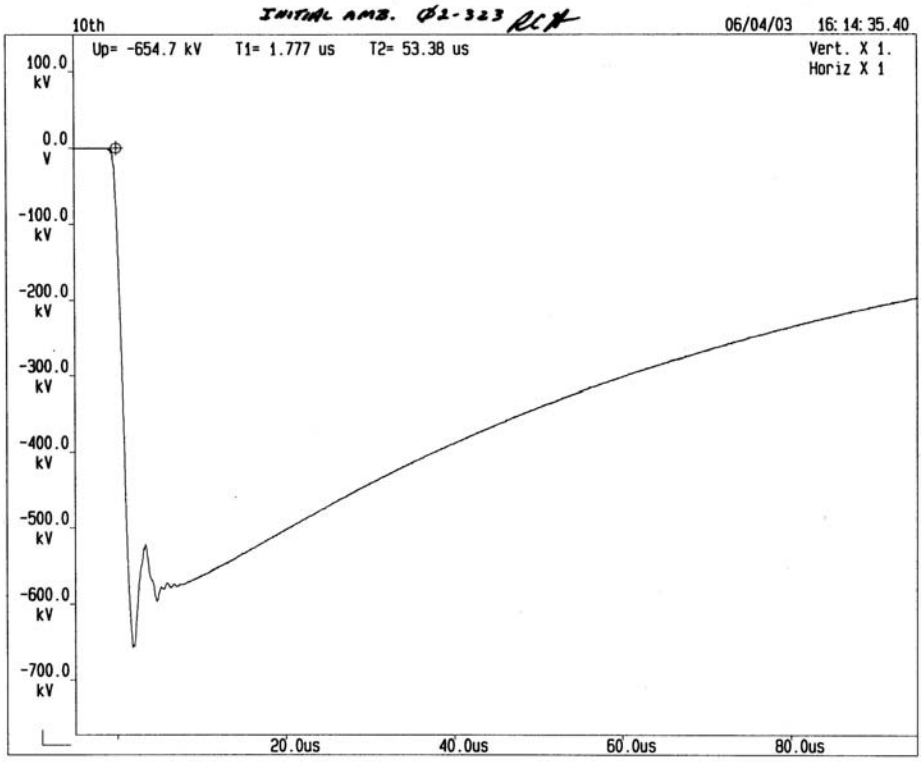


Figure 13 - Initial Ambient 10th Negative

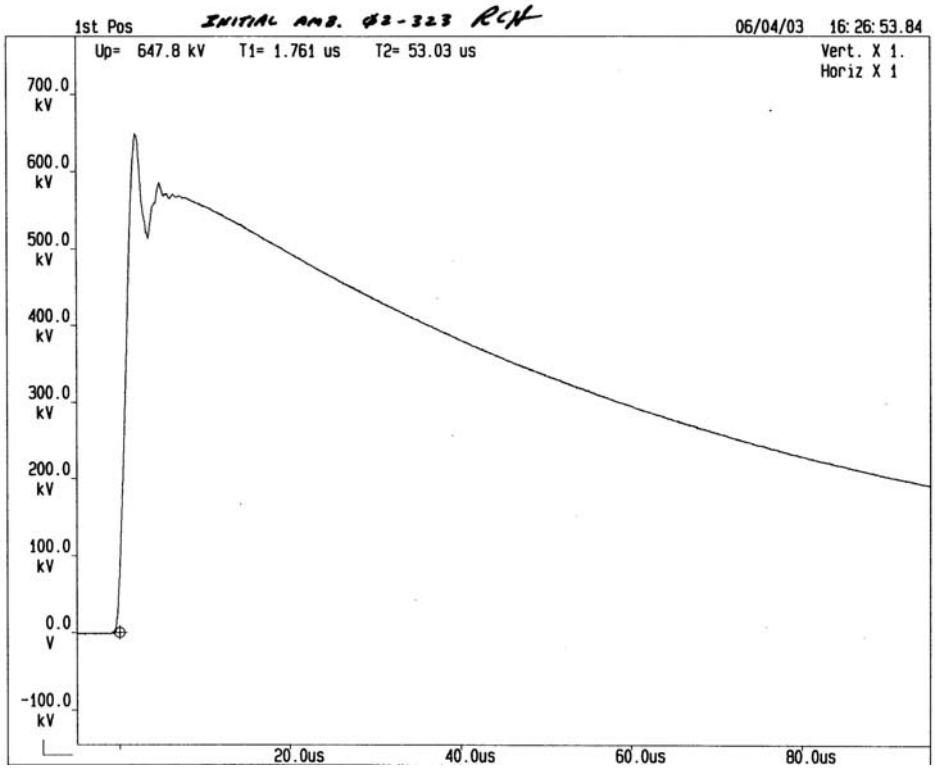


Figure 14 - Initial Ambient 1st Positive

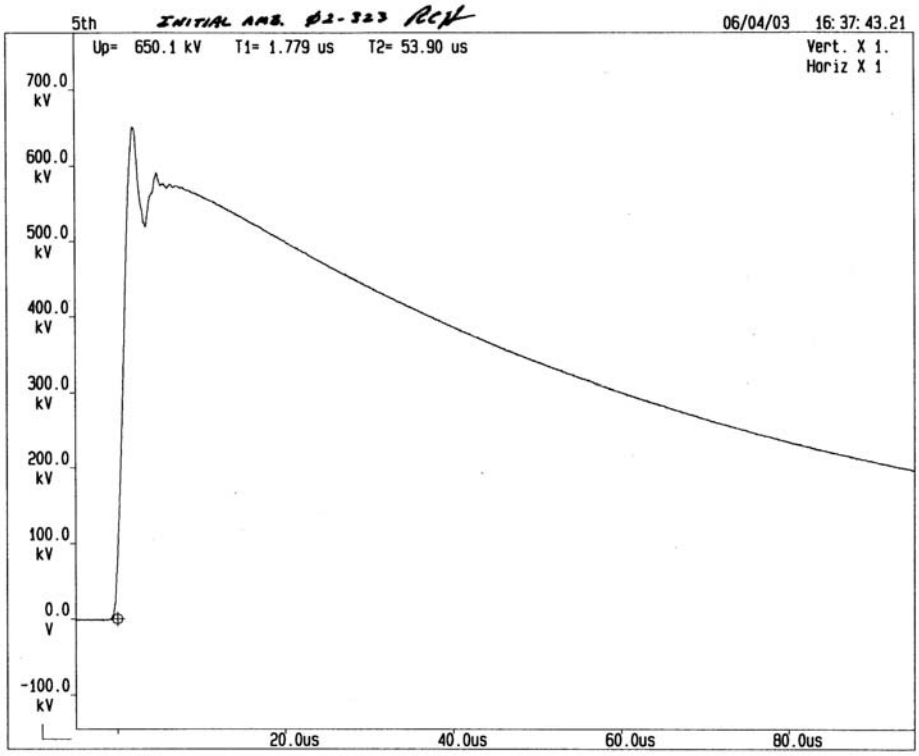


Figure 15 - Initial Ambient 5th Positive

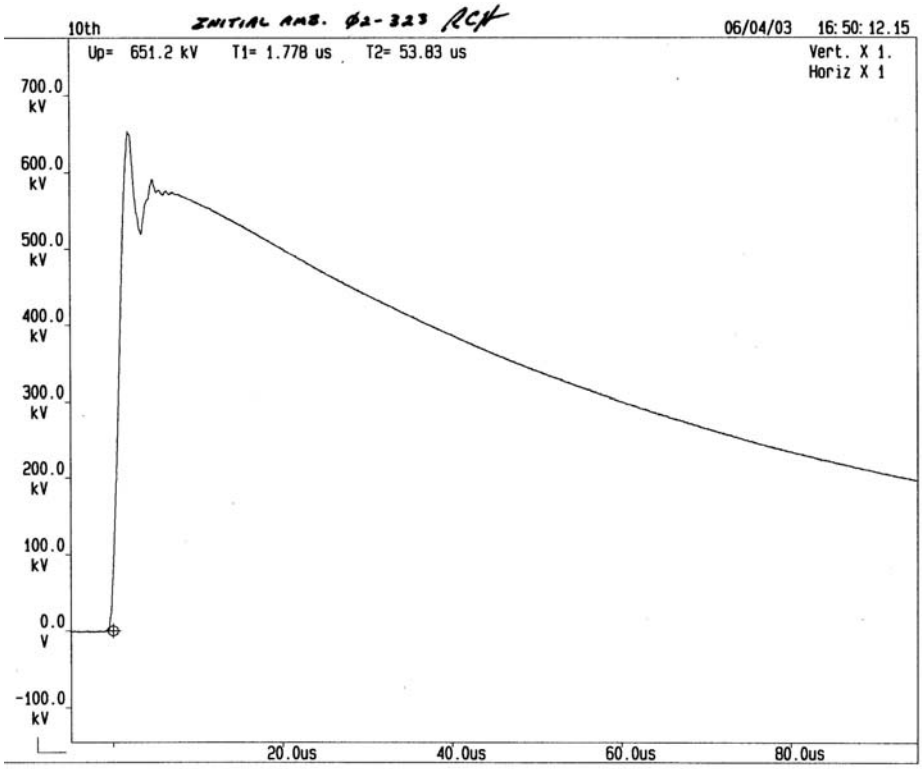


Figure 16 - Initial Ambient 10th Positive

APPENDIX E

Initial Hot Impulse
Data Log
&
Waveforms

Ga. Tech / NEETRAC High Voltage Laboratory

Impulse Data Log: "Initial Hot"

Project No. 02-323

Date: 6/13/2003

Time	Description	V peak (kV)	Front Time (us)	Tail Time (us)	Overshoot (%)
10:07:09	Reduced Hot Impulse Neg	-458.4	1.80	65.37	1.40%
10:11:20	Reduced	-476.3	2.20	69.52	
10:13:52	1st Neg	-647.7	1.68	51.91	
10:22:29	2nd	-656.6	1.71	52.87	
10:24:35	3rd	-657.4	1.71	53.00	
10:27:09	gen misfire	-556.3	4.44	68.26	
10:29:56	4th	-658.7	1.72	53.08	
10:32:09	5th	-657.3	1.71	53.16	
10:35:12	6th	-657.4	1.71	53.19	
10:37:30	7th	-658.1	1.71	53.01	
10:39:44	8th	-654	1.71	53.50	
10:43:56	9th	-656.5	1.71	53.25	
10:46:26	10th	-675.7	1.72	53.14	
10:53:55	Reduced Pos	469.6	1.67	63.54	2.70%
10:55:57	Reduced	469.7	1.73	64.72	2.00%
10:58:40	Reduced	540	1.74	58.92	
11:01:11	1st Pos	650.3	1.70	52.90	
11:04:08	2nd	672.2	1.72	53.03	
11:07:44	3rd	651.3	1.72	63.51	
11:10:18	4th	673.9	1.71	53.36	
11:12:38	5th	654.6	1.71	53.55	
11:16:00	6th	672.7	1.72	53.25	
11:18:18	7th	653.9	1.71	53.59	
11:20:33	8th	655.2	1.72	55.64	
11:22:50	9th	668.8	1.75	54.02	
11:25:01	10th	652.9	1.71	53.61	

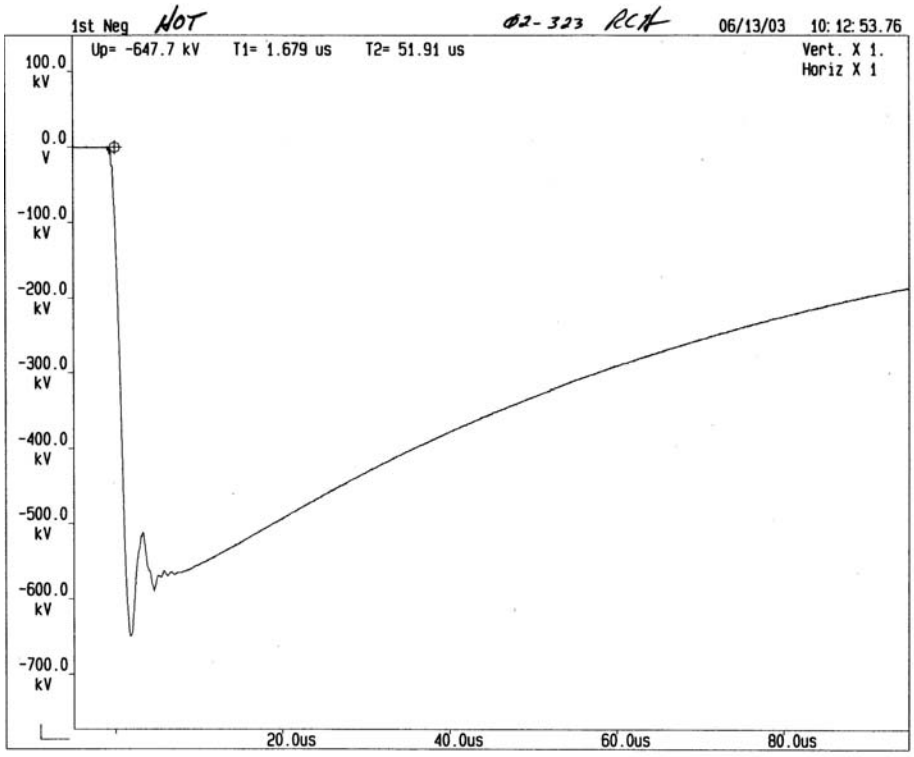


Figure 17 - Initial Hot 1st Negative

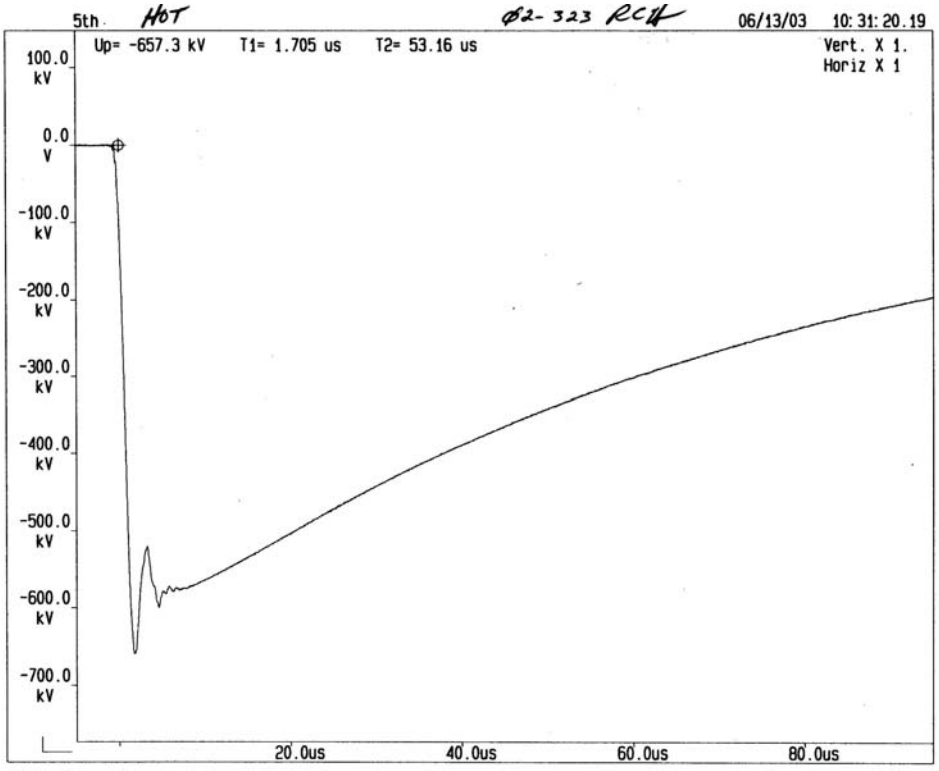


Figure 18 - Initial Hot 5th Negative

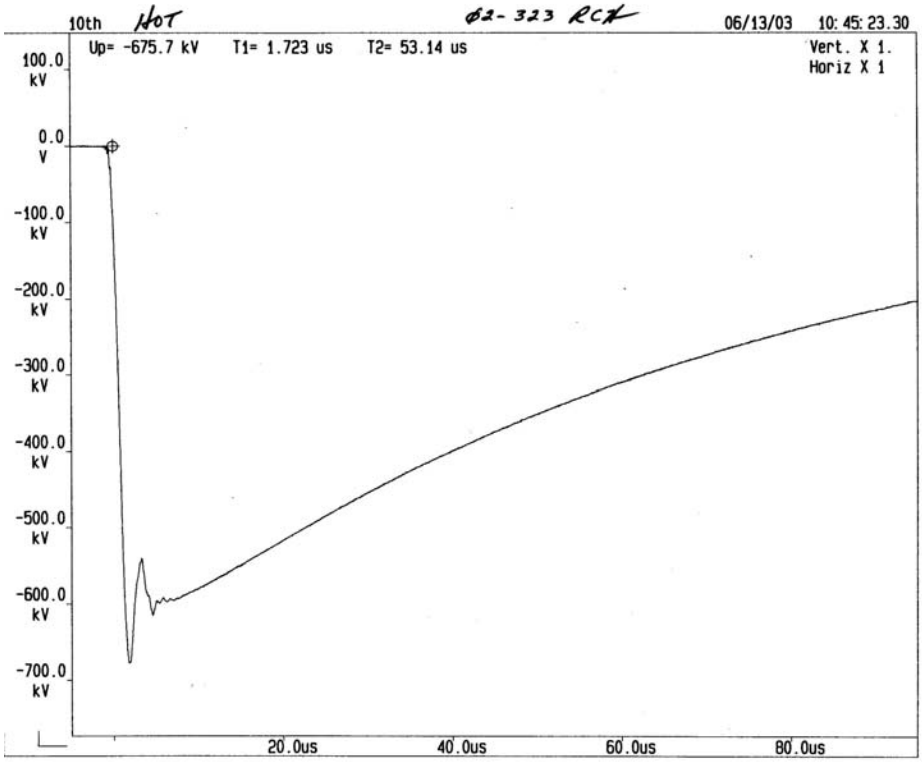


Figure 19 - Initial Hot 10th Negative

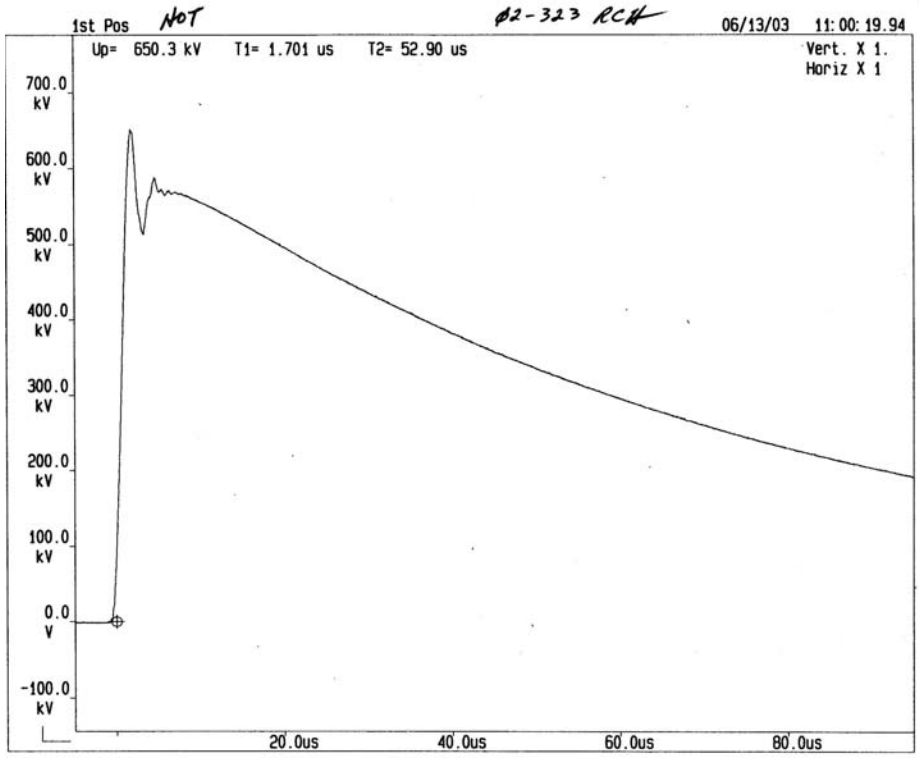


Figure 20 - Initial Hot 1st Positive

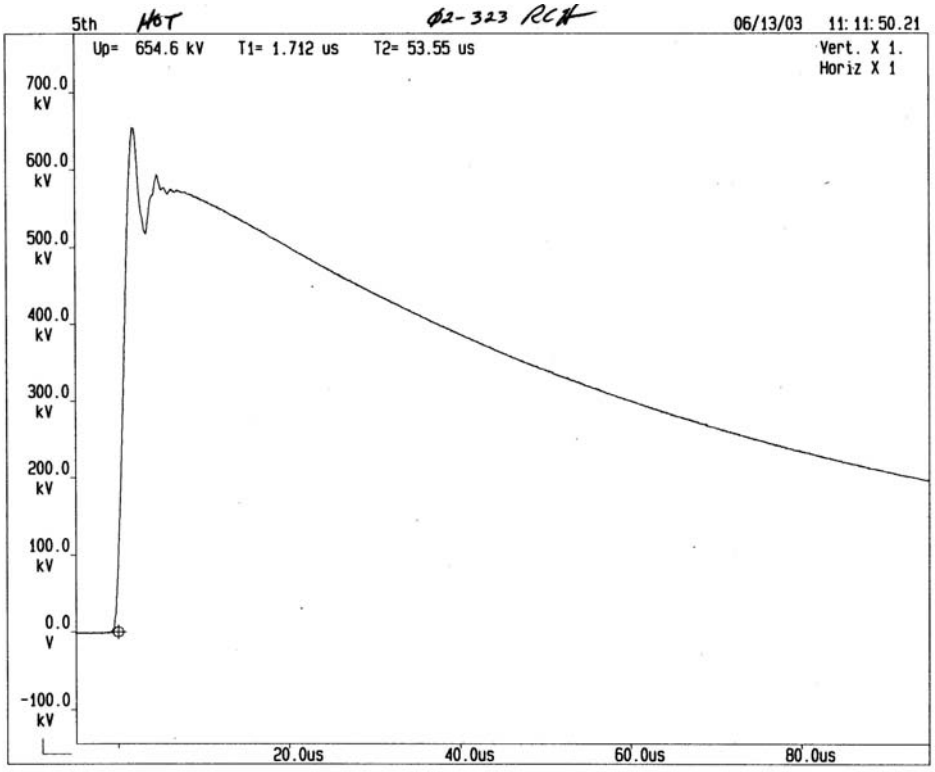


Figure 21 - Initial Hot 5th Positive

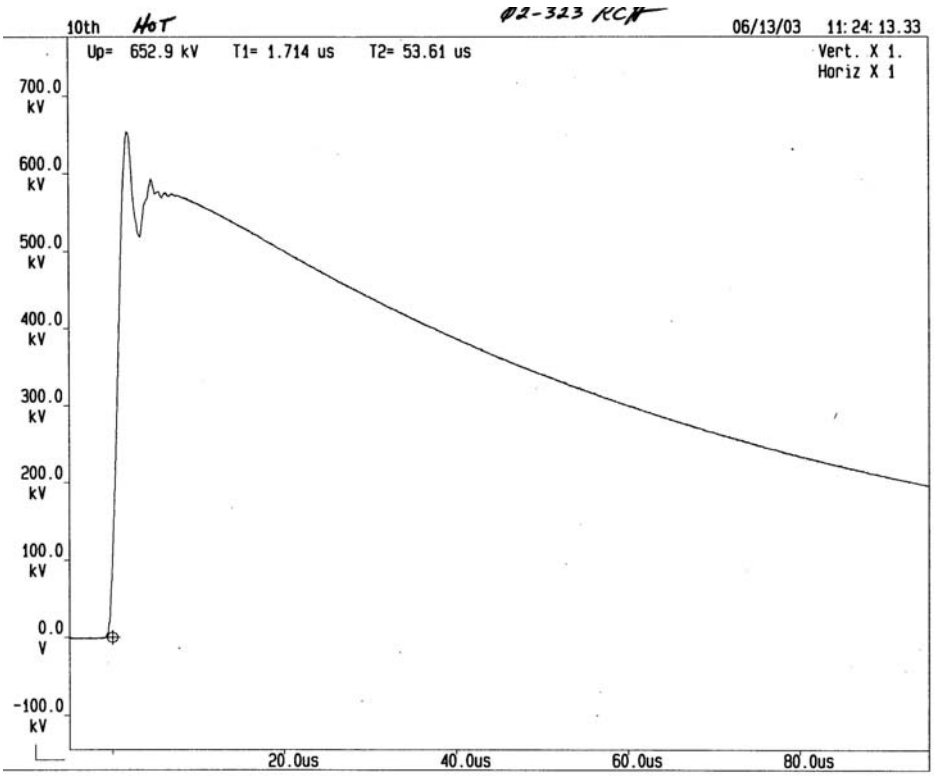


Figure 22 - Initial Hot 10th Positive

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