

UltraSIL Polymer-Housed Evolution Surge Arrester Design Test

Third party verification testing of the Evolution Arrester performance characteristics was completed in June, 2010 at NEETRAC. This report details the results of the Front-of-Wave Impulse Sparkover Determination Test and the 1.2/50 Impulse Sparkover Determination Test. These tests were completed in accordance with IEEE Std C62.11™-2005 standard.

Cooper Power Systems
2300 Badger Drive
Waukesha, WI 53188
www.cooperpower.com
P: 877.CPS.INFO

Arrester Design Tests per IEEE C62.11™-2005

NEETRAC Project Number: 10-112

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Requested by: Mr. Jeff Kester
Cooper Power Systems

Principal Investigator: Raymond C. Hill
Raymond C. Hill, P.E.
Lead Engineer – High Voltage Lab

Reviewed by: Caryn M. Riley
Caryn M. Riley, Ph.D.
Program Manager

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Arrester Design Tests per IEEE C62.11™-2005 for Cooper Power Systems

NEETRAC Project No. 10-112

INTRODUCTION

Mr. Jeff Kester, Arrester Engineering Manager, of Cooper Power Systems, requested the Georgia Institute of Technology National Electric Energy Testing, Research & Applications Center (NEETRAC) to perform various arrester design tests per IEEE C62.11™-2005. The sample set requested for testing consisted of 10 kV, 18 kV, and 27 kV Cooper Evolution, heavy duty, distribution class arresters. The arrester test samples were provided by Cooper Power Systems. Testing was performed by NEETRAC personnel during the month of June, 2010, at the NEETRAC High Voltage Laboratory in Forest Park, Georgia USA. All tests were witnessed by Mr. Jon Woodworth, Consultant, of Arrester Works.

See Table 23 on page 19 for a summary of the results.

TEST SAMPLES

Test samples were provided by Cooper Power Systems. Sample descriptions are listed in Table 1.

Table 1 – Test Samples				
Sample Description	Qty.	Model No.	Date of Manufacture	Sample No.
Cooper Evolution 10 kV, heavy duty, distribution arrester with disconnecter and insulated bracket	4	URT 1005	06-10	10-1 thru 10-3 (with one spare for set up)
Cooper Evolution 18 kV, heavy duty, distribution arrester with disconnecter and insulated bracket	4	URT 1808	06-10	18-1 thru 18-3 (with one spare for set up)
Cooper Evolution 27 kV, heavy duty, distribution arrester with disconnecter and insulated bracket	4	URT 2711	06-10	27-1 thru 27-3 (with one spare for set up)

PROCEDURE & RESULTS

Tests were performed in accordance with IEEE C62.11™-2005 *Standard for Metal-Oxide Surge Arresters for AC Power Circuits (> 1 kV)* and IEEE Standard 4™-1995 *Standard Techniques for High-Voltage Testing*. The test program consisted of the following clauses from IEEE C62.11-2005:

1. Clause 8.4.2.1.1 *Front-of-wave impulse sparkover determination test*, and
2. Clause 8.4.2.2.1 *The 1.2/50 impulse sparkover determination test*.

The tests outlined in the above clauses of the standard are used to establish product ratings and do not contain pass/fail criteria. All of the above tests were performed on three samples of each voltage class. The fourth sample was used as a set up sample for some of the tests.

Clause 8.4.2.2.1 The 1.2/50 Impulse Sparkover Determination Test

Three each of the 10 kV, 18 kV, and 27 kV arresters were tested. The results from this test determined that the additional tests of Clause 8.4.2.2.2 were not required. Typical impulse test setups are shown in Figures 1 and 2.

According to the Cooper Evolution arrester published literature Document 235-99, dated May, 2009, the arrester discharge voltage at the classifying current of 10 kA is 25.4 kV for the 10 kV samples, 47.8 kV for the 18 kV samples, and 68.0 kV for the 27 kV samples.

The 1.2/50 impulse sparkover determination test results are shown in Tables 2 through 11. Circuit setup test shots were performed on the spare (fourth) sample of each voltage class. The full impulse log is contained in Appendix A.

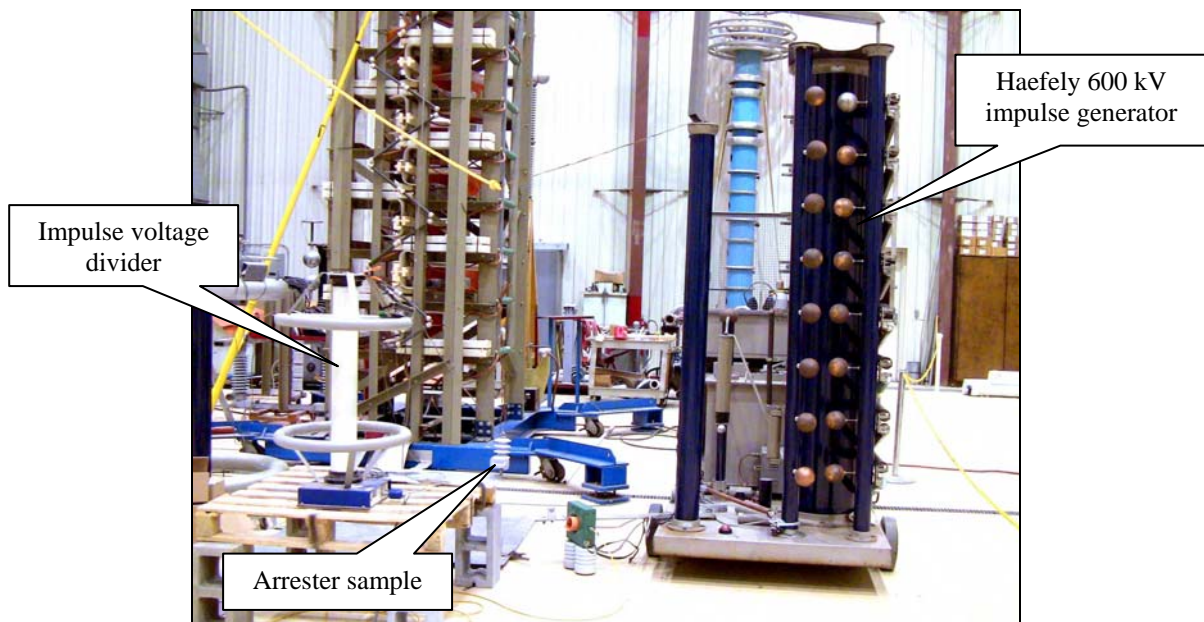


Figure 1 – Typical arrester impulse test setup

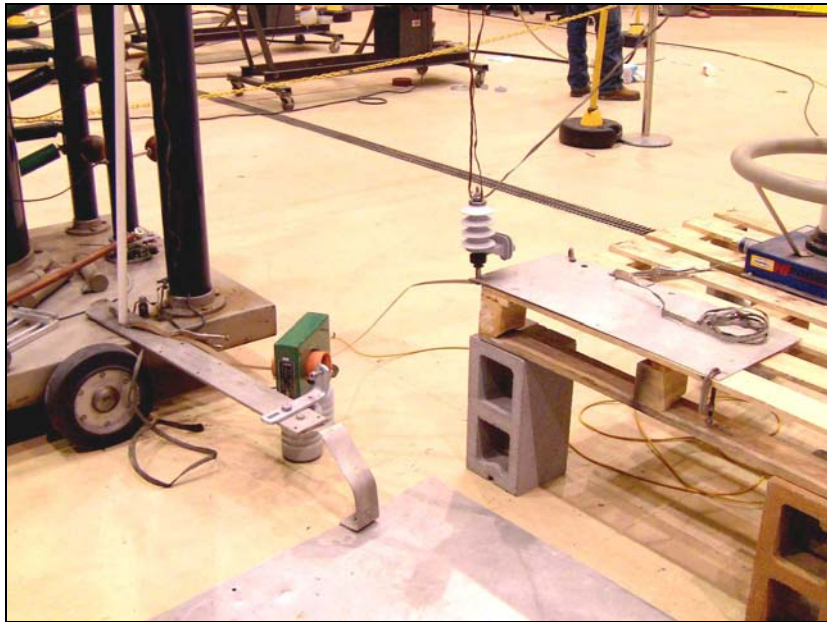


Figure 2 – Typical arrester impulse setup

Table 2 – Clause 8.4.2.2.1 – 10 kV Arrester Results – Sample 10-1				
Sample No. and Impulse Generator Charge Level	Description	Peak (kV)	Front Time / Time to Chop (µs)	Record No.
Sample 10-1 neg shot 1 94.5 kV _{chg}	Full Voltage	-22.0	0.167	98
Sample 10-1 neg shot 2 94.5 kV _{chg}	Full Voltage	-21.2	0.167	101
Sample 10-1 neg shot 3 94.5 kV _{chg}	Full Voltage	-22.0	0.167	104
Sample 10-1 neg shot 4 94.5 kV _{chg}	Full Voltage	-21.3	0.134	107
Sample 10-1 neg shot 5 94.5 kV _{chg}	Full Voltage	-21.5	0.134	110
Highest Peak		-22.0		
Sample 10-1 pos shot 1 94.5 kV _{chg}	Full Voltage	21.9	0.167	120
Sample 10-1 pos shot 2 94.5 kV _{chg}	No trigger	-	-	-
Sample 10-1 pos shot 3 94.5 kV _{chg}	Full Voltage	21.3	0.167	130
Sample 10-1 pos shot 4 94.5 kV _{chg}	Full Voltage	21.8	0.167	133
Sample 10-1 pos shot 5 94.5 kV _{chg}	Full Voltage	21.5	0.167	136
Sample 10-1 pos shot 6 94.5 kV _{chg}	Full Voltage	21.9	0.167	139
Highest Peak		21.9		

Table 3 – Clause 8.4.2.2.1 - 10 kV Arrester Results – Sample 10-2				
Sample No. and Impulse Generator Charge Level	Description	Peak (kV)	Front Time / Time to Chop (µs)	Record No.
Sample 10-2 neg shot 1 94.5 kV _{chg}	Full Voltage	-22.5	0.167	99
Sample 10-2 neg shot 2 94.5 kV _{chg}	Full Voltage	-24.0	0.134	102
Sample 10-2 neg shot 3 94.5 kV _{chg}	Full Voltage	-21.4	0.167	105
Sample 10-2 neg shot 4 94.5 kV _{chg}	Full Voltage	-22.4	0.167	108
Sample 10-2 neg shot 5 94.5 kV _{chg}	Full Voltage	-21.1	0.167	111
Highest Peak		-24.0		
Sample 10-2 pos shot 1 94.5 kV _{chg}	Full Voltage	21.8	0.167	121
Sample 10-2 pos shot 2 94.5 kV _{chg}	Full Voltage	21.7	0.167	128
Sample 10-2 pos shot 3 94.5 kV _{chg}	Full Voltage	22.1	0.167	131
Sample 10-2 pos shot 4 94.5 kV _{chg}	Full Voltage	21.8	0.167	134
Sample 10-2 pos shot 5 94.5 kV _{chg}	Full Voltage	22.0	0.167	137
Highest Peak		22.1		

Table 4 – Clause 8.4.2.2.1 - 10 kV Arrester Results – Sample 10-3				
Sample No. and Impulse Generator Charge Level	Description	Peak (kV)	Front Time / Time to Chop (μs)	Record No.
Sample 10-3 neg shot 1 94.5 kV _{chg}	Full Voltage	-21.3	0.167	100
Sample 10-3 neg shot 2 94.5 kV _{chg}	Full Voltage	-21.6	0.134	103
Sample 10-3 neg shot 3 94.5 kV _{chg}	Full Voltage	-22.2	0.167	106
Sample 10-3 neg shot 4 94.5 kV _{chg}	Full Voltage	-22.0	0.167	109
Sample 10-3 neg shot 5 94.5 kV _{chg}	Full Voltage	-22.3	0.134	112
Highest Peak		-22.3		
Sample 10-3 pos shot 1 94.5 kV _{chg}	Full Voltage	21.3	0.167	122
Sample 10-3 pos shot 2 94.5 kV _{chg}	Full Voltage	21.9	0.134	129
Sample 10-3 pos shot 3 94.5 kV _{chg}	Full Voltage	21.3	0.134	132
Sample 10-3 pos shot 4 94.5 kV _{chg}	Full Voltage	21.9	0.167	135
Sample 10-3 pos shot 5 94.5 kV _{chg}	Full Voltage	21.4	0.167	138
Highest Peak		21.9		

Table 5 – Clause 8.4.2.2.1 - 18 kV Arrester Results – Sample 18-1				
Sample No. and Impulse Generator Charge Level	Description	Peak (kV)	Front Time / Time to Chop (μs)	Record No.
Sample 18-1 pos shot 1 184 kV _{chg}	Full Voltage	43.8	0.167	146
Sample 18-1 pos shot 2 184 kV _{chg}	Full Voltage	43.4	0.167	149
Sample 18-1 pos shot 3 184 kV _{chg}	Full Voltage	43.6	0.167	152
Sample 18-1 pos shot 4 184 kV _{chg}	Full Voltage	44.8	0.200	155
Sample 18-1 pos shot 5 184 kV _{chg}	Full Voltage	43.1	0.167	158
Highest Peak		44.8		
Sample 18-1 neg shot 1 184 kV _{chg}	Full Voltage	-44.8	0.200	166
Sample 18-1 neg shot 2 184 kV _{chg}	Full Voltage	-45.9	0.167	173
Sample 18-1 neg shot 3 184 kV _{chg}	Full Voltage	-46.0	0.167	176
Sample 18-1 neg shot 4 184 kV _{chg}	Full Voltage	-46.8	0.167	179
Sample 18-1 neg shot 5 184 kV _{chg}	Full Voltage	-48.0	0.167	182
Highest Peak		-48.0		

Table 6 – Clause 8.4.2.2.1 - 18 kV Arrester Results – Sample 18-2				
Sample No. and Impulse Generator Charge Level	Description	Peak (kV)	Front Time / Time to Chop (µs)	Record No.
Sample 18-2 pos shot 1 184 kV _{chg}	Full Voltage	42.8	0.200	147
Sample 18-2 pos shot 2 184 kV _{chg}	Full Voltage	44.6	0.200	150
Sample 18-2 pos shot 3 184 kV _{chg}	Full Voltage	41.4	0.167	153
Sample 18-2 pos shot 4 184 kV _{chg}	Full Voltage	43.2	0.167	156
Sample 18-2 pos shot 5 184 kV _{chg}	Full Voltage	41.4	0.200	159
Highest Peak		44.6		
Sample 18-2 neg shot 1 184 kV _{chg}	Full Voltage	-44.8	0.200	167
Sample 18-2 neg shot 2 184 kV _{chg}	Full Voltage	-46.7	0.167	174
Sample 18-2 neg shot 3 184 kV _{chg}	Full Voltage	-44.9	0.200	177
Sample 18-2 neg shot 4 184 kV _{chg}	Full Voltage	-46.6	0.200	180
Sample 18-2 neg shot 5 184 kV _{chg}	Full Voltage	-47.4	0.167	183
Highest Peak		-47.4		

Table 7 – Clause 8.4.2.2.1 - 18 kV Arrester Results – Sample 18-3				
Sample No. and Impulse Generator Charge Level	Description	Peak (kV)	Front Time / Time to Chop (µs)	Record No.
Sample 18-3 pos shot 1 184 kV _{chg}	Full Voltage	42.2	0.167	148
Sample 18-3 pos shot 2 184 kV _{chg}	Full Voltage	41.7	0.167	151
Sample 18-3 pos shot 3 184 kV _{chg}	Full Voltage	42.7	0.200	154
Sample 18-3 pos shot 4 184 kV _{chg}	Full Voltage	41.8	0.167	157
Sample 18-3 pos shot 5 184 kV _{chg}	Full Voltage	41.6	0.167	160
Highest Peak		42.7		
Sample 18-3 neg shot 1 184 kV _{chg}	Full Voltage	-44.7	0.200	168
Sample 18-3 neg shot 2 184 kV _{chg}	Full Voltage	-44.6	0.200	175
Sample 18-3 neg shot 3 184 kV _{chg}	Full Voltage	-44.8	0.167	178
Sample 18-3 neg shot 4 184 kV _{chg}	Full Voltage	-45.7	0.167	181
Sample 18-3 neg shot 5 184 kV _{chg}	Full Voltage	-45.2	0.200	184
Highest Peak		-45.7		

Table 8 – Clause 8.4.2.2.1 - 27 kV Arrester Results – Sample 27-1				
Sample No. and Impulse Generator Charge Level	Description	Peak (kV)	Front Time / Time to Chop (µs)	Record No.
Sample 27-1 neg shot 1 264 kV _{chg}	Full Voltage	-63.2	0.200	196
Sample 27-1 neg shot 2 264 kV _{chg}	Full Voltage	-64.2	0.167	199
Sample 27-1 neg shot 3 264 kV _{chg}	Full Voltage	-64.6	0.167	202
Sample 27-1 neg shot 4 264 kV _{chg}	Full Voltage	-66.5	0.167	205
Sample 27-1 neg shot 5 264 kV _{chg}	Full Voltage	-64.6	0.167	208
Highest Peak		-66.5		
Sample 27-1 pos shot 1 315 kV _{chg}	Full Voltage	59.0	0.200	251
Sample 27-1 pos shot 2 315 kV _{chg}	Full Voltage	61.3	0.200	254
Sample 27-1 pos shot 3 315 kV _{chg}	Full Voltage	61.7	0.200	257
Sample 27-1 pos shot 4 315 kV _{chg}	Full Voltage	62.4	0.167	260
Sample 27-1 pos shot 5 315 kV _{chg}	Full Voltage	59.6	0.167	263
Highest Peak		62.4		

Table 9 – Clause 8.4.2.2.1 - 27 kV Arrester Results – Sample 27-2				
Sample No. and Impulse Generator Charge Level	Description	Peak (kV)	Front Time / Time to Chop (µs)	Record No.
Sample 27-2 neg shot 1 264 kV _{chg}	Full Voltage	-64.9	0.167	197
Sample 27-2 neg shot 2 264 kV _{chg}	Full Voltage	-66.4	0.167	200
Sample 27-2 neg shot 3 264 kV _{chg}	Full Voltage	-66.4	0.167	203
Sample 27-2 neg shot 4 264 kV _{chg}	Full Voltage	-65.5	0.167	206
Sample 27-2 neg shot 5 264 kV _{chg}	Full Voltage	-64.3	0.200	209
Highest Peak		-66.4		
Sample 27-2 pos shot 1 315 kV _{chg}	Full Voltage	62.2	0.167	252
Sample 27-2 pos shot 2 315 kV _{chg}	Full Voltage	61.4	0.167	255
Sample 27-2 pos shot 3 315 kV _{chg}	Full Voltage	64.4	0.200	258
Sample 27-2 pos shot 4 315 kV _{chg}	Full Voltage	60.5	0.167	261
Sample 27-2 pos shot 5 315 kV _{chg}	Full Voltage	62.2	0.167	264
Highest Peak		64.4		

Table 10 – Clause 8.4.2.2.1 - 27 kV Arrester Results – Sample 27-3				
Sample No. and Impulse Generator Charge Level	Description	Peak (kV)	Front Time / Time to Chop (µs)	Record No.
Sample 27-3 neg shot 1 264 kV _{chg}	Full Voltage	-63.6	0.167	198
Sample 27-3 neg shot 2 264 kV _{chg}	Full Voltage	-64.4	0.167	201
Sample 27-3 neg shot 3 264 kV _{chg}	Full Voltage	-64.4	0.200	204
Sample 27-3 neg shot 4 264 kV _{chg}	Full Voltage	-63.7	0.200	207
Sample 27-3 neg shot 5 264 kV _{chg}	Full Voltage	-63.0	0.200	210
Highest Peak		-64.4		
Sample 27-3 pos shot 1 315 kV _{chg}	Full Voltage	63.8	0.167	253
Sample 27-3 pos shot 2 315 kV _{chg}	Full Voltage	60.9	0.167	256
Sample 27-3 pos shot 3 315 kV _{chg}	Full Voltage	58.5	0.200	259
Sample 27-3 pos shot 4 315 kV _{chg}	Full Voltage	58.5	0.200	262
Sample 27-3 pos shot 5 315 kV _{chg}	Full Voltage	64.0	0.200	265
Highest Peak		64.0		

From IEEE C62.11-1995, Clause 8.4.2.2.1, “The maximum arrester voltage recorded during the five positive and five negative polarity standard lightning impulses shall be compared to the discharge voltage obtained with the currents in Table 6 (of C62.11). If the classifying current discharge voltage exceeds the voltage values measured during the impulse test described earlier, the classifying current discharge voltage is the 1.2/50 impulse protective level, and no further testing is required on this wave shape. If the voltage measured during the impulse test exceeds the classifying current discharge voltage, proceed to 8.4.2.2.2 to determine the 1.2/50 impulse protective level.”

A comparison of the results from this test and each sample’s voltage class respective classifying current discharge voltage is shown in Table 11. According to IEEE Standard 4-1995, Clause 7.5 Tolerances: “If not otherwise specified by the appropriate apparatus standard, the following differences are accepted between values for the standard impulse and those actually recorded: a) Peak value $\pm 3\%$ ” IEEE C62.11-2005 does not designate a tolerance for the results in Clause 8.4.2.2.1; therefore, the tolerance from IEEE Standard 4-1995 is used. Since the highest 1.2/50 sparkover voltage measured for each sample did not exceed the classifying current discharge voltage, within measurement tolerance, the tests described in Clause 8.4.2.2.2 *The 1.2/50 Impulse sparkover test* were not necessary.

Table 11 – Clause 8.4.2.2.1 The 1.2/50 Impulse Sparkover Determination Test Results Summary			
Voltage Class (kV)	Classifying Current Discharge Voltage @ 10 kA (kV)	Highest 1.2/50 Sparkover Voltage Measured (kV)	Meets or Exceeds Classifying Current Discharge Voltage?
10	25.4	-24.0	Meets
18	47.8	-48.0	Meets, within tolerance
27	68.0	-66.5	Meets

Clause 8.4.2.1.1 Front-of-Wave Impulse Sparkover Determination Test

Three each of the 10 kV, 18 kV, and 27 kV arresters were tested. The rate of rise (slew rate) was determined by *definition 3.54 nominal rate of rise (of an impulse wave front)* from IEEE C62.11-2005 which states that it is the slope of the line that determines the virtual zero. From IEEE Standard 4-1995 *High Voltage Testing Techniques*, the line that determines the virtual zero of an impulse voltage wave front is drawn through the 30% and 90% points of the impulse peak. Therefore, the rate of rise for this test was determined by the slope of the line drawn through these points. Since no tolerance was stated for the rate of rise in IEEE C62.11-2005, a value of $\pm 5\%$ was agreed upon. Table 12 contains the parameters for this impulse test.

Table 12 – Clause 8.4.2.1.1 Front-of-Wave Impulse Parameters			
Sample	Nominal Rate of Rise (kV/μs)	Arrester Discharge Voltage at Classifying Current of 10 kA (kV)	Minimum Prospective Impulse Peak (kV)
10 kV	83.3	25.4	30.5
18 kV	150.0	47.8	57.4
27 kV	225.0	68.0	81.6

Five impulse applications of each polarity were required. Tables 13 through 22 contain the results of the front-of-wave impulse sparkover determination test. The full impulse logs are contained in Appendix A. The complete front-of-wave spread sheet is contained in Appendix B.

Table 13 – Sample 27-1 Front-of-Wave Results			
27-1 Positive Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*1}	Peak (kV)	Slew Rate (kV/us)	Record No.
385	63.3	223.6	280
385	63.4	226.8	283
385	63.7	224.2	286
385	63.8	224.2	289
385	63.0	226.0	292
	63.8	Highest Peak	
27-1 Negative Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*1}	Peak (kV)	Slew Rate (kV/us)	Record No.
-385	-66.7	226.5	308
-385	-64.6	222.6	311
-385	-65.5	226.9	314
-385	-65.3	218.5	317
-385	-64.9	222.9	320
	-66.7	Highest Peak	

Table 14 – Sample 27-2 Front-of-Wave Results			
27-2 Positive Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*1}	Peak (kV)	Slew Rate (kV/us)	Record No.
385	63.2	225.1	281
385	62.0	222.3	284
385	63.4	222.3	287
385	63.0	224.0	290
385	63.1	222.7	293
	63.4	Highest Peak	
27-2 Negative Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*1}	Peak (kV)	Slew Rate (kV/us)	Record No.
-385	-64.8	224.0	309
-385	-65.1	225.0	312
-385	-66.9	229.5	315
-385	-65.4	227.7	318
-385	-65.6	224.8	321
	-66.9	Highest Peak	

Note 1: Total impulse generator charge level is $V_{\text{gen charge}} \times 10^{-3} \times 75 \text{ kV} \times 6 \text{ stages}$.

Table 15 – Sample 27-3 Front-of-Wave Results			
27-3 Positive Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*1}	Peak (kV)	Slew Rate (kV/us)	Record No.
385	63.8	224.9	282
385	62.3	223.3	285
385	63.0	226.4	288
385	63.3	224.4	291
385	62.5	220.0	294
	63.8	Highest Peak	
27-3 Negative Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*1}	Peak (kV)	Slew Rate (kV/us)	Record No.
-385	-64.9	224.6	307
-385	-65.6	226.1	310
-385	-64.5	221.4	313
-385	-64.9	224.1	316
-385	-65.0	224.0	319
	-65.6	Highest Peak	

Note 1: Total impulse generator charge level is $V_{\text{gen charge}} \times 10^{-3} \times 75 \text{ kV} \times 6 \text{ stages}$.

Table 16 – Sample 18-1 Front-of-Wave Results			
18-1 Positive Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*2}	Peak (kV)	Slew Rate (kV/us)	Record No.
355	43.6	147.1	356
355	44.1	148.8	359
355	43.7	149.4	362
355	43.9	148.2	365
355	44.0	148.0	368
	44.1	Highest Peak	
18-1 Negative Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*2}	Peak (kV)	Slew Rate (kV/us)	Record No.
-355	-48.8	147.1	335
-355	-47.9	146.7	338
-355	-49.1	144.8	341
-355	-46.3	147.7	344
-355	-45.8	147.4	347
	-49.1	Highest Peak	

Note 2: Total impulse generator charge level is $V_{\text{gen charge}} \times 10^{-3} \times 75 \text{ kV} \times 4 \text{ stages}$.

Table 17 – Sample 18-2 Front-of-Wave Results			
18-2 Positive Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*2}	Peak (kV)	Slew Rate (kV/us)	Record No.
355	41.7	148.0	357
355	41.8	147.2	360
355	41.3	148.9	363
355	42.1	148.9	366
355	42.0	146.1	369
355	42.1	Highest Peak	
18-2 Negative Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*2}	Peak (kV)	Slew Rate (kV/us)	Record No.
-355	-47.6	146.8	336
-355	-48.8	147.6	339
-355	-47.7	146.0	342
-355	-47.1	146.1	345
-355	-51.1	145.1	348
	-51.1	Highest Peak	

Table 18 – Sample 18-3 Front-of-Wave Results			
18-3 Positive Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*2}	Peak (kV)	Slew Rate (kV/us)	Record No.
355	42.9	149.1	358
355	43.5	147.7	361
355	44.8	147.3	364
355	42.8	147.9	367
355	42.9	149.2	370
355	44.8	Highest Peak	
18-3 Negative Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*2}	Peak (kV)	Slew Rate (kV/us)	Record No.
-355	-47.7	145.8	337
-355	-46.1	147.4	340
-355	-48.3	145.6	343
-355	-46.8	146.7	346
-355	-48.5	144.9	349
	-48.5	Highest Peak	

Note 2: Total impulse generator charge level is $V_{\text{gen charge}} \times 10^{-3} \times 75 \text{ kV} \times 4 \text{ stages}$.

Table 19 – Sample 10-1 Front-of-Wave Results			
10-1 Positive Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*3}	Peak (kV)	Slew Rate (kV/us)	Record No.
340	22.7	83.0	376
340	22.6	82.9	379
340	22.1	82.6	382
340	22.5	81.7	385
340	22.9	83.6	388
	22.9	Highest Peak	
10-1 Negative Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*3}	Peak (kV)	Slew Rate (kV/us)	Record No.
-340	-23.2	83.6	397
-340	-23.4	82.3	400
-340	-23.2	82.3	403
-340	-22.8	82.9	406
-340	-22.7	84.5	409
	-23.4	Highest Peak	

Table 20 – Sample 10-2 Front-of-Wave Results			
10-2 Positive Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*3}	Peak (kV)	Slew Rate (kV/us)	Record No.
340	23.3	83.0	377
340	23.5	82.8	380
340	22.9	70.5 (low)	383
340	23.2	83.6	386
340	23.4	83.5	389
340	23.3	85.0	391
	23.5	Highest Peak	
10-2 Negative Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*3}	Peak (kV)	Slew Rate (kV/us)	Record No.
-340	-23.6	81.8	398
-340	-23.6	82.9	401
-340	-24.3	81.7	404
-340	-23.6	85.1	407
-340	-24.1	87.7	410
	-24.3	Highest Peak	

Note 3: Total impulse generator charge level is $V_{gen\ charge} \times 10^{-3} \times 75\ kV \times 2\ stages$.

Table 21 – Sample 10-3 Front-of-Wave Results			
10-3 Positive Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*3}	Peak (kV)	Slew Rate (kV/us)	Record No.
340	22.9	83.7	378
340	23.1	84.1	381
340	22.5	80.4	384
340	22.7	82.4	387
340	23.0	82.9	390
	23.1	Highest Peak	
10-3 Negative Impulse Front-of-Wave 8.4.2.1.1			
V_{gen charge}^{*3}	Peak (kV)	Slew Rate (kV/us)	Record No.
-340	-23.5	83.0	399
-340	-23.2	83.2	402
-340	-23.7	82.6	405
-340	-23.6	86.1	408
-340	-24.1	85.6	411
	-24.1	Highest Peak	

Note 3: Total impulse generator charge level is $V_{\text{gen charge}} \times 10^{-3} \times 75 \text{ kV} \times 2 \text{ stages}$.

Table 22 below summarizes the highest measured peak value for each voltage class in the Clause 8.4.2.1.1 *Front-of-wave impulse sparkover determination test*.

Table 22 – Clause 8.4.2.1.1 Front-of-Wave Impulse Sparkover Determination Test Results Summary	
Sample Voltage Class	Highest Measured Peak (kV)
10 kV	-24.3
18 kV	-51.1
27 kV	-66.9

CONCLUSIONS

Tests were performed in accordance with IEEE C62.11-2005 *Standard for Metal-Oxide Surge Arresters for AC Power Circuits (> 1 kV)* and IEEE Standard 4-1995 *Standard Techniques for High-Voltage Testing*. The test program consisted of the following clauses from IEEE C62.11-2005:

1. Clause 8.4.2.2.1 *The 1.2/50 impulse sparkover determination test*, and
2. Clause 8.4.2.1.1 *Front-of-wave impulse sparkover determination test*.

The tests outlined in the above clauses of C62.11-2005 are used to establish product ratings and do not contain pass/fail criteria. Table 23 contains a summary of the results for each test clause.

Table 23 – Arrester Results Summary per Clause		
Voltage Class	8.4.2.2.1 1.2/50 Sparkover Highest Peak (kV)	8.4.2.1.1 Front-of-Wave Highest Peak (kV)
10 kV	-24.0	-24.3
18 kV	-48.0	-51.1
27 kV	-66.5	-66.9

EQUIPMENT

1. JMX Impulse Measurement System, CQ2232, cal. due 02/02/2012
2. Hipotronics RVD-300-1 300 kV Impulse Divider, CQ2226, cal. due 04/27/2011
3. Hipotronics RVD-300-2 300 kV Impulse Divider, CQ2227, cal. due 04/27/2011
4. Haefely 600 kV Impulse Generator

REFERENCES

1. IEEE C62.11TM-2005 *Standard for Metal-Oxide Surge Arresters for AC Power Circuits (> 1 kV)*
2. IEEE Standard 4TM-1995 *Standard Techniques for High-Voltage Testing*
3. Cooper Evolution arrester published literature dated May, 2009, Document 235-99

APPENDIX A - Full Impulse Data Log

Impulse Log Data Sheet

Project No. 10-112

NEETRAC - A Center of Georgia Tech

Impulse 2009 V9.0.0.23 | JMX Services, Inc. | 7/2/2010 11:12:53 AM

Temperature - n/a Barometric Pressure - n/a mmHg Humidity - n/a

Impulse / Channel Description	Pulse Type	Peak (kV/kA)	T1/Tr (us)	T2/Tc (us)	Date/Time	Record #	Div. Ratio
10kV - open circuit waveform 8.4.2.2.1	Full Voltage	-30.5 kV	0.969	53.7	6/23/2010 10:40	89	150.4
10kV - open circuit waveform 8.4.2.2.1	Current Wave	-0.03 kA	20.162	18.3	6/23/2010 10:40	89.5	200
Setup sample neg 1 (8.4.2.2.1) 210 chg*	Full Voltage	-25.54 kV	0.301	64.5	6/23/2010 10:51	93	150.4
Setup sample neg 1 (8.4.2.2.1) 210 chg	Current Wave	-0.25 kA	0.525	1.2	6/23/2010 10:51	93.5	200
Setup sample neg 2 - 210 chg	Current Wave	-0.26 kA	0.6	1.2	6/23/2010 10:56	94	200
Setup sample neg 2 - 210 chg*	Full Voltage	-26.01 kV	0.301	64.5	6/23/2010 10:56	94.5	150.4
Setup sample neg 3 - 210 chg*	Full Voltage	-25.54 kV	0.334	63.9	6/23/2010 11:08	95	150.4
Setup sample neg 3 - 210 chg	Current Wave	-0.18 kA	0.225	0.6	6/23/2010 11:08	95.5	20
Setup sample 420 chg	Current Wave	-0.42 kA	0.225	1.4	6/23/2010 11:14	96	20
Setup sample 420 chg*	Full Voltage	-24.82 kV	0.2	85	6/23/2010 11:14	96.5	150.4
Setup sample 630 chg - still 2 stages*	Full Voltage	-22.75 kV	0.167	92.5	6/23/2010 11:22	97	150.4
Setup sample 630 chg - still 2 stages	Current Wave	-0.64 kA	0.25	1.9	6/23/2010 11:22	97.5	20
Sample 10-1 neg 630chg 8.4.2.2.1 shot 1*	Full Voltage	-22.01 kV	0.167	93	6/23/2010 13:08	98	150.4
Sample 10-1 neg 630chg 8.4.2.2.1 shot 1	Current Wave	-0.63 kA	0.225	2.2	6/23/2010 13:08	98.5	20
Sample 10-2 neg shot 1 630chg 8.4.2.2.1	Current Wave	-0.63 kA	0.25	2.2	6/23/2010 13:18	99	20
Sample 10-2 neg shot 1 630chg 8.4.2.2.1*	Full Voltage	-22.48 kV	0.167	93	6/23/2010 13:18	99.5	150.4
Sample 10-3 neg shot 1 630chg 8.4.2.2.1*	Full Voltage	-21.34 kV	0.167	92.6	6/23/2010 13:29	100	150.4
Sample 10-3 neg shot 1 630chg 8.4.2.2.1	Current Wave	-0.63 kA	0.225	2.1	6/23/2010 13:29	100.5	20
Sample 10-1 neg shot 2 630chg*	Full Voltage	-21.19 kV	0.167	93	6/23/2010 13:40	101	150.4
Sample 10-1 neg shot 2 630chg	Current Wave	-0.63 kA	0.25	2.2	6/23/2010 13:40	101.5	20
Sample 10-2 neg shot 2 630chg*	Full Voltage	-24.04 kV	0.134	92.6	6/23/2010 13:50	102	150.4
Sample 10-2 neg shot 2 630chg	Current Wave	-0.63 kA	0.225	1.9	6/23/2010 13:50	102.5	20
Sample 10-3 neg shot 2 630chg	Current Wave	-0.63 kA	0.225	2.2	6/23/2010 14:00	103	20
Sample 10-3 neg shot 2 630chg*	Full Voltage	-21.63 kV	0.134	92.8	6/23/2010 14:00	103.5	150.4
Sample 10-1 neg shot 3 630 chg	Current Wave	-0.63 kA	0.25	2.2	6/23/2010 14:11	104	20
Sample 10-1 neg shot 3 630 chg*	Full Voltage	-21.96 kV	0.167	92.1	6/23/2010 14:11	104.5	150.4
Sample 10-2 neg shot 3 630chg*	Full Voltage	-21.35 kV	0.167	92.3	6/23/2010 14:23	105	150.4
Sample 10-2 neg shot 3 630chg	Current Wave	-0.63 kA	0.225	2.1	6/23/2010 14:23	105.5	20
Sample 10-3 neg shot 3 630chg*	Full Voltage	-22.15 kV	0.167	92.2	6/23/2010 14:33	106	150.4
Sample 10-3 neg shot 3 630chg	Current Wave	-0.63 kA	0.275	2.2	6/23/2010 14:33	106.5	20
Sample 10-1 neg shot 4 630chg*	Full Voltage	-21.27 kV	0.134	92.8	6/23/2010 14:46	107	150.4
Sample 10-1 neg shot 4 630chg	Current Wave	-0.63 kA	0.225	2.2	6/23/2010 14:46	107.5	20
Sample 10-2 neg shot 4 630chg*	Full Voltage	-22.39 kV	0.167	92.7	6/23/2010 14:57	108	150.4
Sample 10-2 neg shot 4 630chg	Current Wave	-0.63 kA	0.275	2.2	6/23/2010 14:57	108.5	20
Sample 10-3 neg shot 4 630chg*	Full Voltage	-22.05 kV	0.167	93.1	6/23/2010 15:08	109	150.4
Sample 10-3 neg shot 4 630chg	Current Wave	-0.64 kA	0.25	2.1	6/23/2010 15:08	109.5	20
Sample 10-1 neg shot 5 630chg	Current Wave	-0.63 kA	0.25	2.2	6/23/2010 15:18	110	20
Sample 10-1 neg shot 5 630chg*	Full Voltage	-21.50 kV	0.134	91.7	6/23/2010 15:18	110.5	150.4
Sample 10-2 neg shot 5 630chg	Current Wave	-0.62 kA	0.225	2.2	6/23/2010 15:33	111	20
Sample 10-2 neg shot 5 630chg*	Full Voltage	-21.14 kV	0.167	92.7	6/23/2010 15:33	111.5	150.4
Sample 10-3 neg shot 5 630chg*	Full Voltage	-22.33 kV	0.134	92.6	6/23/2010 15:44	112	150.4
Sample 10-3 neg shot 5 630chg	Current Wave	-0.63 kA	0.25	2.2	6/23/2010 15:44	112.5	20
Open circuit neg 630chg	Full Voltage	-91.6 kV	1.002	53.7	6/23/2010 15:47	113	150.4
Open circuit neg 630chg	Current Wave	0.01 kA	0.1	147.7	6/23/2010 15:47	113.5	20
Open circuit neg 630chg	Full Voltage	-91.6 kV	1.002	53.8	6/23/2010 15:47	114	150.4
Open circuit neg 630chg	Current Wave	0.02 kA	0.125	147.7	6/23/2010 15:47	114.5	20
Open circuit pos 210chg	Full Voltage	30.7 kV	1.002	53.8	6/23/2010 15:52	115	150.4
Open circuit pos 210chg	Current Wave	0.01 kA	185.04	-161.1	6/23/2010 15:52	115.5	20
Open circuit pos 210chg	Current Wave	0.01 kA	194	-153	6/23/2010 15:54	116	20
Open circuit pos 210chg	Full Voltage	30.5 kV	0.969	53.6	6/23/2010 15:54	116.5	150.4
Open circuit pos 420chg	Current Wave	0.01 kA	1	152.4	6/23/2010 15:57	117	20
Open circuit pos 420chg	Full Voltage	60.9 kV	1.002	53.9	6/23/2010 15:57	117.5	150.4
Open circuit pos 630chg	Full Voltage	91.5 kV	0.969	53.9	6/23/2010 16:01	118	150.4
Open circuit pos 630chg	Current Wave	-0.02 kA	0.125	0.2	6/23/2010 16:01	118.5	20
Open circuit pos 630chg	Full Voltage	91.3 kV	1.002	54	6/23/2010 16:03	119	150.4
Open circuit pos 630chg	Current Wave	0.02 kA	0.675	151.6	6/23/2010 16:03	119.5	20
Sample 10-1 pos shot 1 630chg*	Full Voltage	21.88 kV	0.167	94.1	6/23/2010 16:10	120	150.4
Sample 10-1 pos shot 1 630chg	Current Wave	0.63 kA	0.225	2.2	6/23/2010 16:10	120.5	20
Sample 10-2 pos shot 1 630chg*	Full Voltage	21.77 kV	0.167	93.8	6/23/2010 16:21	121	150.4
Sample 10-2 pos shot 1 630chg	Current Wave	0.62 kA	0.25	2.2	6/23/2010 16:21	121.5	20
Sample 10-3 pos shot 1 630chg	Current Wave	0.63 kA	0.25	2.2	6/23/2010 16:32	122	20
Sample 10-3 pos shot 1 630chg*	Full Voltage	21.29 kV	0.167	94.2	6/23/2010 16:32	122.5	150.4
warm up	Full Voltage	30.8 kV	1.002	53.2	6/24/2010 8:17	123	150.4
warm up	Current Wave	0.01 kA	184.48	-161.6	6/24/2010 8:17	123.5	20
warm up	Full Voltage	30.6 kV	0.969	53.1	6/24/2010 8:18	124	150.4
warm up	Current Wave	0.00 kA	20.05	84.4	6/24/2010 8:18	124.5	20
warm up	Full Voltage	50.0 kV	0.418	69.4	6/24/2010 8:19	125	150.4
warm up	Current Wave	0.02 kA	0.15	147.8	6/24/2010 8:19	125.5	20
warm up	Full Voltage	61.4 kV	1.002	53.9	6/24/2010 8:20	126	150.4
warm up	Current Wave	-0.02 kA	0.15	0.3	6/24/2010 8:20	126.5	20
warm up	Full Voltage	92.3 kV	1.002	54	6/24/2010 8:21	127	150.4
warm up	Current Wave	-0.02 kA	0.125	0.2	6/24/2010 8:21	127.5	20
Sample 10-2 pos shot 2 630chg	Current Wave	0.63 kA	0.225	2.2	6/24/2010 8:35	128	20
Sample 10-2 pos shot 2 630chg*	Full Voltage	21.74 kV	0.167	93.4	6/24/2010 8:35	128.5	150.4
Sample 10-3 pos shot 2 630chg	Current Wave	0.64 kA	0.225	2.1	6/24/2010 8:46	129	20
Sample 10-3 pos shot 2 630chg*	Full Voltage	21.89 kV	0.134	93.6	6/24/2010 8:46	129.5	150.4
Sample 10-1 pos shot 3 630chg	Current Wave	0.63 kA	0.25	2.2	6/24/2010 8:56	130	20
Sample 10-1 pos shot 3 630chg*	Full Voltage	21.26 kV	0.167	94.6	6/24/2010 8:56	130.5	150.4
Sample 10-2 pos shot 3 630chg*	Full Voltage	22.07 kV	0.167	93.1	6/24/2010 9:09	131	150.4
Sample 10-2 pos shot 3 630chg	Current Wave	0.63 kA	0.225	2.1	6/24/2010 9:09	131.5	20

Impulse / Channel Description	Pulse Type	Peak (kV/kA)	T1/Tr (us)	T2/Tc (us)	Date/Time	Record #	Div. Ratio
Sample 10-3 pos shot 3 630chg*	Full Voltage	21.30 kV	0.134	93.8	6/24/2010 9:22	132	150.4
Sample 10-3 pos shot 3 630chg	Current Wave	0.63 kA	0.25	2.2	6/24/2010 9:22	132.5	20
Sample 10-1 pos shot 4 630chg*	Full Voltage	21.83 kV	0.167	93.9	6/24/2010 9:34	133	150.4
Sample 10-1 pos shot 4 630chg	Current Wave	0.63 kA	0.25	2.2	6/24/2010 9:34	133.5	20
Sample 10-2 pos shot 4 630chg*	Full Voltage	21.85 kV	0.167	93.8	6/24/2010 9:45	134	150.4
Sample 10-2 pos shot 4 630chg	Current Wave	0.63 kA	0.25	2.2	6/24/2010 9:45	134.5	20
Sample 10-3 pos shot 4 630chg	Current Wave	0.63 kA	0.225	2.2	6/24/2010 9:56	135	20
Sample 10-3 pos shot 4 630chg*	Full Voltage	21.94 kV	0.167	93.6	6/24/2010 9:56	135.5	150.4
Sample 10-1 pos shot 5 630 chg*	Full Voltage	21.49 kV	0.167	94.3	6/24/2010 10:07	136	150.4
Sample 10-1 pos shot 5 630 chg	Current Wave	0.63 kA	0.25	2.2	6/24/2010 10:07	136.5	20
Sample 10-2 pos shot 5 630chg*	Full Voltage	21.98 kV	0.167	93.4	6/24/2010 10:20	137	150.4
Sample 10-2 pos shot 5 630chg	Current Wave	0.63 kA	0.25	2.2	6/24/2010 10:20	137.5	20
Sample 10-3 pos shot 5 630chg*	Full Voltage	21.42 kV	0.167	94	6/24/2010 10:32	138	150.4
Sample 10-3 pos shot 5 630chg	Current Wave	0.63 kA	0.25	2.2	6/24/2010 10:32	138.5	20
Sample 10-1 pos shot 6 630chg*	Full Voltage	21.93 kV	0.167	93.8	6/24/2010 10:46	139	150.4
Sample 10-1 pos shot 6 630chg	Current Wave	0.63 kA	0.25	2.2	6/24/2010 10:46	139.5	20
setup	Full Voltage	59.2 kV	1.136	48.2	6/24/2010 11:11	140	150.4
setup	Current Wave	0.01 kA	1.213	153.1	6/24/2010 11:11	140.5	20
setup 208chg	Full Voltage	58.5 kV	1.169	48.4	6/24/2010 11:13	141	150.4
setup 208chg	Current Wave	0.01 kA	1	152.4	6/24/2010 11:13	141.5	20
Setup 205chg	Full Voltage	57.5 kV	1.136	48.3	6/24/2010 11:15	142	150.4
setup 205chg	Current Wave	0.01 kA	0.725	152.5	6/24/2010 11:15	142.5	20
setup 410chg	Full Voltage	115.6 kV	1.169	48.7	6/24/2010 11:17	143	150.4
setup 410chg	Current Wave	0.02 kA	0.675	10.2	6/24/2010 11:17	143.5	20
Setup 615chg	Full Voltage	173.1 kV	1.136	48.6	6/24/2010 11:21	144	150.4
Setup 615chg	Current Wave	0.03 kA	0.875	9.5	6/24/2010 11:21	144.5	20
Setup 615chg	Full Voltage	173.0 kV	1.169	48.8	6/24/2010 11:22	145	150.4
Setup 615chg	Current Wave	-0.01 kA	44.038	107.7	6/24/2010 11:22	145.5	20
Sample 18-1 pos shot 1 615chg*	Full Voltage	43.78 kV	0.167	70.3	6/24/2010 13:03	146	150.4
Sample 18-1 pos shot 1 615chg	Current Wave	1.00 kA	0.25	1.4	6/24/2010 13:03	146.5	20
Sample 18-2 pos shot 1 615chg*	Full Voltage	42.77 kV	0.2	70.3	6/24/2010 13:16	147	150.4
Sample 18-2 pos shot 1 615chg	Current Wave	1.00 kA	0.275	1.4	6/24/2010 13:16	147.5	20
Sample 18-3 pos shot 1 615chg	Current Wave	1.02 kA	0.25	1.4	6/24/2010 13:27	148	20
Sample 18-3 pos shot 1 615chg*	Full Voltage	42.23 kV	0.167	70.6	6/24/2010 13:27	148.5	150.4
Sample 18-1 pos shot 2 615chg	Current Wave	1.00 kA	0.225	1.4	6/24/2010 13:38	149	20
Sample 18-1 pos shot 2 615chg*	Full Voltage	43.36 kV	0.167	69.9	6/24/2010 13:38	149.5	150.4
Sample 18-2 pos shot 2 615chg*	Full Voltage	44.61 kV	0.2	70	6/24/2010 13:51	150	150.4
Sample 18-2 pos shot 2 615chg	Current Wave	1.00 kA	0.25	1.4	6/24/2010 13:51	150.5	20
Sample 18-3 pos shot 2 615chg*	Full Voltage	41.71 kV	0.167	70.2	6/24/2010 14:03	151	150.4
Sample 18-3 pos shot 2 615chg	Current Wave	1.00 kA	0.225	1.4	6/24/2010 14:03	151.5	20
Sample 18-1 pos shot 3 615chg*	Full Voltage	43.55 kV	0.167	69.9	6/24/2010 14:18	152	150.4
Sample 18-1 pos shot 3 615chg	Current Wave	1.01 kA	0.225	1.4	6/24/2010 14:18	152.5	20
Sample 18-2 pos shot 3 615chg*	Full Voltage	41.39 kV	0.167	70.4	6/24/2010 14:30	153	150.4
Sample 18-2 pos shot 3 615chg	Current Wave	1.00 kA	0.25	1.4	6/24/2010 14:30	153.5	20
Sample 18-3 pos shot 3 615chg*	Full Voltage	42.73 kV	0.2	70.8	6/24/2010 14:42	154	150.4
Sample 18-3 pos shot 3 615chg	Current Wave	1.00 kA	0.25	1.4	6/24/2010 14:42	154.5	20
Sample 18-1 pos shot 4 615chg*	Full Voltage	44.85 kV	0.2	69.9	6/24/2010 14:54	155	150.4
Sample 18-1 pos shot 4 615chg	Current Wave	1.00 kA	0.25	1.4	6/24/2010 14:54	155.5	20
Sample 18-2 pos shot 4 615chg*	Full Voltage	43.24 kV	0.167	70.9	6/24/2010 15:05	156	150.4
Sample 18-2 pos shot 4 615chg	Current Wave	1.00 kA	0.25	1.4	6/24/2010 15:05	156.5	20
Sample 18-3 pos shot 4 615chg*	Full Voltage	41.80 kV	0.167	70.6	6/24/2010 15:16	157	150.4
Sample 18-3 pos shot 4 615chg	Current Wave	1.01 kA	0.25	1.4	6/24/2010 15:16	157.5	20
Sample 18-1 pos shot 5 615chg*	Full Voltage	43.10 kV	0.167	69.8	6/24/2010 15:27	158	150.4
Sample 18-1 pos shot 5 615chg	Current Wave	1.00 kA	0.225	1.4	6/24/2010 15:27	158.5	20
Sample 18-2 pos shot 5 615chg*	Full Voltage	41.37 kV	0.2	70.6	6/24/2010 15:38	159	150.4
Sample 18-2 pos shot 5 615chg	Current Wave	0.99 kA	0.225	1.4	6/24/2010 15:38	159.5	20
Sample 18-3 pos shot 5 615chg*	Full Voltage	41.60 kV	0.167	70.7	6/24/2010 15:49	160	150.4
Sample 18-3 pos shot 5 615chg	Current Wave	1.01 kA	0.25	1.4	6/24/2010 15:49	160.5	20
Setup 205chg	Current Wave	-0.02 kA	0.15	2.9	6/24/2010 15:54	161	20
Setup 205chg	Full Voltage	-57.6 kV	1.169	48.1	6/24/2010 15:54	161.5	150.4
Setup 205chg	Full Voltage	-57.6 kV	1.136	48.1	6/24/2010 15:56	162	150.4
Setup 205chg	Current Wave	0.01 kA	0.075	-180	6/24/2010 15:56	162.5	20
Setup 410chg	Full Voltage	-115.2 kV	1.136	48.3	6/24/2010 15:58	163	150.4
Setup 410chg	Current Wave	-0.02 kA	1.15	10.2	6/24/2010 15:58	163.5	20
Setup 615chg	Full Voltage	-172.7 kV	1.136	49.2	6/24/2010 16:01	164	150.4
Setup 615chg	Current Wave	-0.03 kA	1.025	10.3	6/24/2010 16:01	164.5	20
Setup 615chg	Full Voltage	-172.5 kV	1.169	49.3	6/24/2010 16:03	165	150.4
Setup 615chg	Current Wave	-0.03 kA	0.9	10.3	6/24/2010 16:03	165.5	20
Sample 18-1 neg shot 1 615chg*	Full Voltage	44.84 kV	0.2	72.1	6/24/2010 16:08	166	150.4
Sample 18-1 neg shot 1 615chg	Current Wave	-1.01 kA	0.25	1.4	6/24/2010 16:08	166.5	20
Sample 18-2 neg shot 1 615chg*	Full Voltage	-44.76 kV	0.2	49.5	6/24/2010 16:19	167	150.4
Sample 18-2 neg shot 1 615chg	Current Wave	-1.03 kA	0.225	1.4	6/24/2010 16:19	167.5	20
Sample 18-3 neg shot 1 615chg*	Full Voltage	-44.70 kV	0.2	70.4	6/24/2010 16:32	168	150.4
Sample 18-3 neg shot 1 615chg	Current Wave	-1.03 kA	0.25	1.4	6/24/2010 16:32	168.5	20
warm up	Full Voltage	-58.0 kV	1.169	48.1	6/25/2010 8:47	169	150.4
warm up	Current Wave	-0.01 kA	0.7	9.9	6/25/2010 8:47	169.5	20
warm up	Full Voltage	-58.1 kV	1.136	48	6/25/2010 8:47	170	150.4
warm up	Current Wave	-0.01 kA	1.15	10.6	6/25/2010 8:47	170.5	20
warm up	Full Voltage	-116.1 kV	1.169	48.4	6/25/2010 8:48	171	150.4
warm up	Current Wave	0.01 kA	52.5	-163.1	6/25/2010 8:48	171.5	20
warm up	Full Voltage	-174.4 kV	1.136	48.6	6/25/2010 8:49	172	150.4
warm up	Current Wave	-0.03 kA	1.213	10.8	6/25/2010 8:49	172.5	20
Sample 18-1 neg shot 2 615chg*	Full Voltage	-45.91 kV	0.167	72.1	6/25/2010 8:51	173	150.4
Sample 18-1 neg shot 2 615chg	Current Wave	-1.03 kA	0.25	1.4	6/25/2010 8:51	173.5	20
Sample 18-2 neg shot 2 615chg*	Full Voltage	-46.72 kV	0.167	70.1	6/25/2010 9:02	174	150.4
Sample 18-2 neg shot 2 615chg	Current Wave	-1.04 kA	0.25	1.4	6/25/2010 9:02	174.5	20

Impulse / Channel Description	Pulse Type	Peak (kV/kA)	T1/Tr (us)	T2/Tc (us)	Date/Time	Record #	Div. Ratio
Sample 18-3 neg shot 2 615chg	Current Wave	-1.04 kA	0.25	1.4	6/25/2010 9:14	175	20
Sample 18-3 neg shot 2 615chg*	Full Voltage	-44.61 kV	0.2	70.8	6/25/2010 9:14	175.5	150.4
Sample 18-1 neg shot 3 615chg*	Full Voltage	-46.00 kV	0.167	70.3	6/25/2010 9:25	176	150.4
Sample 18-1 neg shot 3 615chg	Current Wave	-1.02 kA	0.25	1.4	6/25/2010 9:25	176.5	20
Sample 18-2 neg shot 3 615chg*	Full Voltage	-44.91 kV	0.2	71.6	6/25/2010 9:36	177	150.4
Sample 18-2 neg shot 3 615chg	Current Wave	-1.04 kA	0.225	1.4	6/25/2010 9:36	177.5	20
Sample 18-3 neg shot 3 615chg*	Full Voltage	-44.80 kV	0.167	70.6	6/25/2010 9:47	178	150.4
Sample 18-3 neg shot 3 615chg	Current Wave	-1.03 kA	0.25	1.4	6/25/2010 9:47	178.5	20
Sample 18-1 neg shot 4 615chg*	Full Voltage	-46.79 kV	0.167	70	6/25/2010 9:58	179	150.4
Sample 18-1 neg shot 4 615chg	Current Wave	-1.02 kA	0.25	1.4	6/25/2010 9:58	179.5	20
Sample 18-2 neg shot 4 615chg	Current Wave	-1.04 kA	0.25	1.4	6/25/2010 10:08	180	20
Sample 18-2 neg shot 4 615chg*	Full Voltage	-46.59 kV	0.2	70.2	6/25/2010 10:08	180.5	150.4
Sample 18-3 neg shot 4 615chg	Current Wave	-1.03 kA	0.25	1.4	6/25/2010 10:20	181	20
Sample 18-3 neg shot 4 615chg*	Full Voltage	-45.73 kV	0.167	70.4	6/25/2010 10:20	181.5	150.4
Sample 18-1 neg shot 5 615chg*	Full Voltage	-48.01 kV	0.167	70.3	6/25/2010 10:30	182	150.4
Sample 18-1 neg shot 5 615chg	Current Wave	-1.02 kA	0.25	1.4	6/25/2010 10:30	182.5	20
Sample 18-2 neg shot 5 615chg*	Full Voltage	-47.35 kV	0.167	69.8	6/25/2010 10:41	183	150.4
Sample 18-2 neg shot 5 615chg	Current Wave	-1.04 kA	0.25	1.4	6/25/2010 10:41	183.5	20
Sample 18-3 neg shot 5 615chg*	Full Voltage	-45.17 kV	0.2	70.7	6/25/2010 10:52	184	150.4
Sample 18-3 neg shot 5 615chg	Current Wave	-1.03 kA	0.25	1.4	6/25/2010 10:52	184.5	20
setup	Full Voltage	-63.0 kV	1.202	45.8	6/25/2010 11:14	185	150.4
setup	Current Wave	-0.01 kA	1	11.1	6/25/2010 11:14	185.5	20
setup	Full Voltage	-62.3 kV	1.202	46	6/25/2010 11:17	186	150.4
setup	Current Wave	-0.01 kA	0.987	10.8	6/25/2010 11:17	186.5	20
setup 5 stages 225chg	Full Voltage	-77.9 kV	1.202	44.4	6/25/2010 11:19	187	150.4
setup	Current Wave	-0.01 kA	0.9	10.6	6/25/2010 11:19	187.5	20
setup	Current Wave	-0.01 kA	1.137	10.6	6/25/2010 11:21	188	20
setup 230chg	Full Voltage	-79.8 kV	1.169	44.4	6/25/2010 11:21	188.5	150.4
Setup 5stages 235chg	Full Voltage	-81.9 kV	1.202	44.3	6/25/2010 11:23	189	150.4
Setup 5stages 235chg	Current Wave	-0.01 kA	1.275	11.4	6/25/2010 11:23	189.5	20
Setup 5stages 235chg	Full Voltage	-81.3 kV	1.169	44.4	6/25/2010 11:24	190	150.4
Setup 5stages 235chg	Current Wave	-0.01 kA	1.275	11.4	6/25/2010 11:24	190.5	20
Setup 5stages 470chg	Full Voltage	-163.3 kV	1.169	44.7	6/25/2010 11:28	192	150.4
Setup 5stages 470chg	Current Wave	-0.03 kA	1.225	11.2	6/25/2010 11:28	192.5	20
Setup 5stages 705chg	Full Voltage	-244.6 kV	1.169	45	6/25/2010 11:31	193	150.4
Setup 5stages 705chg	Current Wave	-0.04 kA	1.025	10.5	6/25/2010 11:31	193.5	20
warm up	Current Wave	0.01 kA	186.7	-159.6	6/25/2010 12:57	194	20
warm up	Full Voltage	-104.5 kV	1.169	44.8	6/25/2010 12:57	194.5	150.4
warm up	Current Wave	-0.04 kA	1.15	10.7	6/25/2010 12:58	195	20
warm up	Full Voltage	-244.7 kV	1.169	45.3	6/25/2010 12:58	195.5	150.4
Sample 27-1 neg shot 1 705chg*	Full Voltage	-63.22 kV	0.2	64.1	6/25/2010 13:02	196	150.4
Sample 27-1 neg shot 1 705chg	Current Wave	-1.40 kA	0.225	1.3	6/25/2010 13:02	196.5	20
Sample 27-2 neg shot 1 705chg*	Full Voltage	-64.92 kV	0.167	61.9	6/25/2010 13:13	197	150.4
Sample 27-2 neg shot 1 705chg	Current Wave	-1.42 kA	0.25	1.3	6/25/2010 13:13	197.5	20
Sample 27-3 neg shot 1 705chg*	Full Voltage	-63.64 kV	0.167	62.1	6/25/2010 13:24	198	150.4
Sample 27-3 neg shot 1 705chg	Current Wave	-1.41 kA	0.25	1.4	6/25/2010 13:24	198.5	20
Sample 27-1 neg shot 2 705chg*	Full Voltage	-64.22 kV	0.167	62	6/25/2010 13:35	199	150.4
Sample 27-1 neg shot 2 705chg	Current Wave	-1.40 kA	0.25	1.4	6/25/2010 13:35	199.5	20
Sample 27-2 neg shot 2 705chg*	Full Voltage	-66.41 kV	0.167	63.9	6/25/2010 13:46	200	150.4
Sample 27-2 neg shot 2 705chg	Current Wave	-1.42 kA	0.25	1.3	6/25/2010 13:46	200.5	20
Sample 27-3 neg shot 2 705chg*	Full Voltage	-64.39 kV	0.167	61.9	6/25/2010 13:57	201	150.4
Sample 27-3 neg shot 2 705chg	Current Wave	-1.41 kA	0.25	1.4	6/25/2010 13:57	201.5	20
Sample 27-1 neg shot 3 705chg*	Full Voltage	-64.60 kV	0.167	63	6/25/2010 14:09	202	150.4
Sample 27-1 neg shot 3 705chg	Current Wave	-1.40 kA	0.25	1.4	6/25/2010 14:09	202.5	20
Sample 27-2 neg shot 3 705chg*	Full Voltage	-66.35 kV	0.167	62	6/25/2010 14:22	203	150.4
Sample 27-2 neg shot 3 705chg	Current Wave	-1.42 kA	0.25	1.3	6/25/2010 14:22	203.5	20
Sample 27-3 neg shot 3 705chg*	Full Voltage	-64.40 kV	0.2	61.8	6/25/2010 14:33	204	150.4
Sample 27-3 neg shot 3 705chg	Current Wave	-1.44 kA	0.25	1.1	6/25/2010 14:33	204.5	20
Sample 27-1 neg shot 4 705chg*	Full Voltage	-66.46 kV	0.167	61.7	6/25/2010 14:44	205	150.4
Sample 27-1 neg shot 4 705chg	Current Wave	-1.42 kA	0.25	1.3	6/25/2010 14:44	205.5	20
Sample 27-2 neg shot 4 705chg*	Full Voltage	-65.53 kV	0.167	61.7	6/25/2010 14:55	206	150.4
Sample 27-2 neg shot 4 705chg	Current Wave	-1.41 kA	0.25	1.3	6/25/2010 14:55	206.5	20
Sample 27-3 neg shot 4 705chg	Current Wave	-1.41 kA	0.25	1.4	6/25/2010 15:06	207	20
Sample 27-3 neg shot 4 705chg*	Full Voltage	-63.69 kV	0.2	61.8	6/25/2010 15:06	207.5	150.4
Sample 27-1 neg shot 5 705chg	Current Wave	-1.39 kA	0.25	1.4	6/25/2010 15:17	208	20
Sample 27-1 neg shot 5 705chg*	Full Voltage	-64.56 kV	0.167	62	6/25/2010 15:17	208.5	150.4
Sample 27-2 neg shot 5 705chg*	Full Voltage	-64.29 kV	0.2	63.7	6/25/2010 15:28	209	150.4
Sample 27-2 neg shot 5 705chg	Current Wave	-1.43 kA	0.25	1	6/25/2010 15:28	209.5	20
Sample 27-3 neg shot 5 705chg*	Full Voltage	-62.99 kV	0.2	61.8	6/25/2010 15:39	210	150.4
Sample 27-3 neg shot 5 705chg	Current Wave	-1.44 kA	0.25	1.1	6/25/2010 15:39	210.5	20
Warm up 6 stages 250chg	Full Voltage	103.2 kV	1.202	42	6/28/2010 11:13	242	150.4
Warm up 6 stages 250chg	Current Wave	0.02 kA	20.75	170.2	6/28/2010 11:13	242.5	20
Warm up 6 stages pos 250chg	Full Voltage	102.9 kV	1.169	41.9	6/28/2010 11:15	243	150.4
Warm up 6 stages pos 250chg	Current Wave	-0.01 kA	19.15	67.8	6/28/2010 11:15	243.5	20
Warm up 6 stages pos 500chg	Full Voltage	206.0 kV	1.202	42.3	6/28/2010 11:18	244	150.4
Warm up 6 stages pos 500chg	Current Wave	0.09 kA	0.15	0.3	6/28/2010 11:18	244.5	20
Warm up 6 stages pos 500chg	Full Voltage	206.2 kV	1.202	42.3	6/28/2010 11:20	245	150.4
Warm up 6 stages pos 500chg	Current Wave	0.09 kA	0.15	0.3	6/28/2010 11:20	245.5	20
Misfired	Tail Chopped	287.0 kV	1.202	3.57	6/28/2010 11:22	246	150.4
Misfired	Current Wave	2.99 kA	0.225	0.4	6/28/2010 11:22	246.5	20
Warm up 6 stages pos 700chg	Full Voltage	288.1 kV	1.169	42.5	6/28/2010 11:27	247	150.4
Warm up 6 stages pos 700chg	Current Wave	0.07 kA	0.125	2.7	6/28/2010 11:27	247.5	20
Warm up 6 stages pos 700chg	Full Voltage	288.2 kV	1.202	42.5	6/28/2010 11:29	248	150.4
Warm up 6 stages pos 700chg	Current Wave	-0.04 kA	0.125	40.6	6/28/2010 11:29	248.5	20
Setup sample 27kV pos 700chg*	Full Voltage	63.96 kV	0.167	57.7	6/28/2010 11:33	249	150.4
Setup sample 27kV pos 700chg	Current Wave	1.55 kA	0.275	1.4	6/28/2010 11:33	249.5	20
warm up 6 stages 350chg	Full Voltage	143.8 kV	1.202	42.2	6/28/2010 12:54	250	150.4

Impulse / Channel Description	Pulse Type	Peak (kV/kA)	T1/Tr (us)	T2/Tc (us)	Date/Time	Record #	Div. Ratio
warm up 6 stages 350chg	Current Wave	-0.07 kA	0.05	0.1	6/28/2010 12:54	250.5	20
Sample 27-1 pos 6stages shot 1 700chg*	Full Voltage	59.05 kV	0.2	58	6/28/2010 12:57	251	150.4
Sample 27-1 pos 6stages shot 1 700chg	Current Wave	1.58 kA	0.25	1.4	6/28/2010 12:57	251.5	20
Sample 27-2 pos shot 1 700chg	Current Wave	1.56 kA	0.25	1.4	6/28/2010 13:07	252	20
Sample 27-2 pos shot 1 700chg*	Full Voltage	62.24 kV	0.167	58	6/28/2010 13:07	252.5	150.4
Sample 27-3 pos shot 1 700chg*	Full Voltage	63.77 kV	0.167	57.6	6/28/2010 13:19	253	150.4
Sample 27-3 pos shot 1 700chg	Current Wave	1.58 kA	0.275	1.4	6/28/2010 13:19	253.5	20
Sample 27-1 pos shot 2 700chg*	Full Voltage	61.32 kV	0.2	57.8	6/28/2010 13:30	254	150.4
Sample 27-1 pos shot 2 700chg	Current Wave	1.58 kA	0.25	1.4	6/28/2010 13:30	254.5	20
Sample 27-2 pos shot 2 700chg*	Full Voltage	61.40 kV	0.167	57.8	6/28/2010 13:41	255	150.4
Sample 27-2 pos shot 2 700chg	Current Wave	1.55 kA	0.275	1.4	6/28/2010 13:41	255.5	20
Sample 27-3 pos shot 2 700chg*	Full Voltage	60.90 kV	0.167	57.6	6/28/2010 13:51	256	150.4
Sample 27-3 pos shot 2 700chg	Current Wave	1.60 kA	0.275	1.4	6/28/2010 13:51	256.5	20
Sample 27-1 pos shot 3 700chg*	Full Voltage	61.72 kV	0.2	57.6	6/28/2010 14:01	257	150.4
Sample 27-1 pos shot 3 700chg	Current Wave	1.58 kA	0.25	1.4	6/28/2010 14:01	257.5	20
Sample 27-2 pos shot 3 700chg*	Full Voltage	64.35 kV	0.2	43.7	6/28/2010 14:12	258	150.4
Sample 27-2 pos shot 3 700chg	Current Wave	1.57 kA	0.275	1.4	6/28/2010 14:12	258.5	20
Sample 27-3 pos shot 3 700chg*	Full Voltage	58.54 kV	0.2	57.5	6/28/2010 14:23	259	150.4
Sample 27-3 pos shot 3 700chg	Current Wave	1.59 kA	0.25	1.4	6/28/2010 14:23	259.5	20
Sample 27-1 pos shot 4 700chg*	Full Voltage	62.41 kV	0.167	57.9	6/28/2010 14:35	260	150.4
Sample 27-1 pos shot 4 700chg	Current Wave	1.57 kA	0.275	1.4	6/28/2010 14:35	260.5	20
Sample 27-2 pos shot 4 700chg*	Full Voltage	60.50 kV	0.167	57.9	6/28/2010 14:48	261	150.4
Sample 27-2 pos shot 4 700chg	Current Wave	1.60 kA	0.25	1.4	6/28/2010 14:48	261.5	20
Sample 27-3 pos shot 4 700chg*	Full Voltage	58.50 kV	0.2	57.6	6/28/2010 15:00	262	150.4
Sample 27-3 pos shot 4 700chg	Current Wave	1.57 kA	0.25	1.4	6/28/2010 15:00	262.5	20
Sample 27-1 pos shot 5 700chg*	Full Voltage	59.55 kV	0.167	57.5	6/28/2010 15:10	263	150.4
Sample 27-1 pos shot 5 700chg	Current Wave	1.61 kA	0.25	1.4	6/28/2010 15:10	263.5	20
Sample 27-2 pos shot 5 700chg*	Full Voltage	62.25 kV	0.167	57.6	6/28/2010 15:21	264	150.4
Sample 27-2 pos shot 5 700chg	Current Wave	1.59 kA	0.275	1.4	6/28/2010 15:21	264.5	20
Sample 27-3 pos shot 5 700chg	Current Wave	1.59 kA	0.25	1.4	6/28/2010 15:33	265	20
Sample 27-3 pos shot 5 700chg*	Full Voltage	63.96 kV	0.2	57.5	6/28/2010 15:33	265.5	150.4
Warm up 6stages 250chg 8.4.2.1.1 FOW	Full Voltage	145.2 kV	1.169	41.9	6/29/2010 8:46	270	150.4
Warm up 6stages 250chg	Current Wave	0.03 kA	0.625	151.7	6/29/2010 8:46	270.5	20
Warm up 6stages 250chg	Full Voltage	144.8 kV	1.202	41.8	6/29/2010 8:47	271	150.4
Warm up 6stages 250chg	Current Wave	-0.07 kA	0.125	0.3	6/29/2010 8:47	271.5	20
Warm up 6stages 318chg	Full Voltage	131.4 kV	1.169	42.2	6/29/2010 8:49	272	150.4
Warm up 6stages 318chg	Current Wave	-0.02 kA	16.363	14.8	6/29/2010 8:49	272.5	20
Setup 27kV pos 318chg 187.0slew*	Full Voltage	63.20 kV	0.267	51.4	6/29/2010 9:00	273	150.4
Setup 27kV pos 318chg 187.0slew	Current Wave	0.71 kA	0.25	0.7	6/29/2010 9:00	273.5	20
Setup 27kV pos 330chg 196.0slew*	Full Voltage	62.80 kV	0.234	51.2	6/29/2010 9:06	274	150.4
Setup 27kV pos 350chg 208.2slew*	Full Voltage	63.10 kV	0.234	52	6/29/2010 9:10	275	150.4
Setup 27kV pos 370chg 217.4slew*	Full Voltage	64.80 kV	0.234	52.2	6/29/2010 9:15	276	150.4
Setup 27kV pos 375chg 219.8slew*	Full Voltage	62.30 kV	0.2	52.2	6/29/2010 9:19	277	150.4
Setup 27kV pos 380chg 218.4slew*	Full Voltage	63.00 kV	0.234	51.4	6/29/2010 9:24	278	150.4
Setup 27kV pos 390chg 229.4slew*	Full Voltage	64.23 kV	0.234	52.6	6/29/2010 9:27	279	150.4
Sample 27-1 pos shot 1 385chg 223.6slew*	Full Voltage	63.3 kV	0.234	52	6/29/2010 9:35	280	150.4
Sample 27-2 pos shot 1 385chg 225.1slew*	Full Voltage	63.2 kV	0.234	53	6/29/2010 9:46	281	150.4
Sample 27-3 pos shot 1 385chg 224.9slew*	Full Voltage	63.8 kV	0.2	53.7	6/29/2010 9:57	282	150.4
Sample 27-1 pos shot 2 385chg 226.8slew*	Full Voltage	63.4 kV	0.2	52.6	6/29/2010 10:09	283	150.4
Sample 27-2 pos shot 2 385chg 222.3slew*	Full Voltage	62.0 kV	0.2	52.7	6/29/2010 10:19	284	150.4
Sample 27-3 pos shot 2 385chg 223.3slew*	Full Voltage	62.3 kV	0.2	53.2	6/29/2010 10:30	285	150.4
Sample 27-1 pos shot 3 385chg 224.2slew*	Full Voltage	63.7 kV	0.234	52.6	6/29/2010 10:43	286	150.4
Sample 27-2 pos shot 3 385chg 222.3slew*	Full Voltage	63.4 kV	0.2	53.9	6/29/2010 10:54	287	150.4
Sample 27-3 pos shot 3 385chg 226.4slew*	Full Voltage	63.0 kV	0.2	52.7	6/29/2010 11:05	288	150.4
Sample 27-1 pos shot 4 385chg 224.2slew*	Full Voltage	63.8 kV	0.2	52.4	6/29/2010 11:15	289	150.4
Sample 27-2 pos shot 4 385chg 224.0slew*	Full Voltage	63.0 kV	0.234	51.9	6/29/2010 11:26	290	150.4
Sample 27-3 pos shot 4 385chg 224.4slew*	Full Voltage	63.3 kV	0.2	52.4	6/29/2010 11:37	291	150.4
Sample 27-1 pos shot 5 385chg 226.0slew*	Full Voltage	63.0 kV	0.2	53.3	6/29/2010 11:47	292	150.4
Sample 27-2 pos shot 5 385chg 222.7slew*	Full Voltage	63.1 kV	0.2	52.3	6/29/2010 11:58	293	150.4
Sample 27-3 pos shot 5 385chg 220.0slew*	Full Voltage	62.5 kV	0.2	52.4	6/29/2010 12:09	294	150.4
Sample 27-1 neg shot 1 385chg 156.7slew - Low*	Full Voltage	-65.0 kV	0.234	51.2	6/29/2010 13:54	302	150.4
Sample 27-2 neg shot 1 385chg 174.0slew - Low*	Full Voltage	-63.7 kV	0.2	52	6/29/2010 14:05	303	150.4
Setup sample 27kV 420chg 244.9slew*	Full Voltage	-65.23 kV	0.2	55.4	6/29/2010 14:13	304	150.4
Setup sample 27kV 400chg 238.2slew*	Full Voltage	-68.5 kV	0.2	51.7	6/29/2010 14:18	305	150.4
Setup sample 27kV 385chg 226.8slew*	Full Voltage	-72.37 kV	0.234	49.2	6/29/2010 14:23	306	150.4
Sample 27-3 neg shot 1 385chg 224.6slew*	Full Voltage	-64.9 kV	0.2	55.4	6/29/2010 14:29	307	150.4
Sample 27-1 neg shot 2 385chg 226.5slew*	Full Voltage	-66.7 kV	0.234	51.1	6/29/2010 14:40	308	150.4
Sample 27-2 neg shot 2 385chg 224.0slew*	Full Voltage	-64.8 kV	0.234	51.2	6/29/2010 14:50	309	150.4
Sample 27-3 neg shot 2 385chg 226.1slew*	Full Voltage	-65.6 kV	0.2	51.6	6/29/2010 14:56	310	150.4
Sample 27-1 neg shot 3 385chg 222.6slew*	Full Voltage	-64.6 kV	0.234	51.2	6/29/2010 15:02	311	150.4
Sample 27-2 neg shot 3 385chg 225.0slew*	Full Voltage	-65.1 kV	0.2	51.4	6/29/2010 15:08	312	150.4
Sample 27-3 neg shot 3 385chg 221.4slew*	Full Voltage	-64.5 kV	0.2	51.4	6/29/2010 15:13	313	150.4
Sample 27-1 neg shot 4 385chg 226.9slew*	Full Voltage	-65.5 kV	0.234	51.9	6/29/2010 15:19	314	150.4
Sample 27-2 neg shot 4 385chg 229.5slew*	Full Voltage	-66.9 kV	0.234	50.7	6/29/2010 15:25	315	150.4
Sample 27-3 neg shot 4 385chg 224.1slew*	Full Voltage	-64.9 kV	0.234	51.2	6/29/2010 15:31	316	150.4
Sample 27-1 neg shot 5 385chg 218.5slew*	Full Voltage	-65.3 kV	0.2	55.1	6/29/2010 15:36	317	150.4
Sample 27-2 neg shot 5 385chg 227.7slew*	Full Voltage	-65.4 kV	0.2	51.5	6/29/2010 15:42	318	150.4
Sample 27-3 neg shot 5 385chg 224.0slew*	Full Voltage	-65.0 kV	0.2	51.4	6/29/2010 15:48	319	150.4
Sample 27-1 neg shot 6 385chg 222.9slew*	Full Voltage	-64.9 kV	0.2	51.2	6/29/2010 15:54	320	150.4
Sample 27-2 neg shot 6 385chg 224.8slew*	Full Voltage	-65.6 kV	0.2	51.6	6/29/2010 15:59	321	150.4
Setup 18kV neg 300chg 125.6slew	Full Voltage	-32.3 kV	0.267	60.6	6/29/2010 16:20		150.4
warm up	Full Voltage	-32.5 kV	0.234	61.9	6/29/2010 16:24		150.4
Setup 18kV neg 355chg 154.2slew*	Full Voltage	-49.1 kV	0.234	63.5	6/29/2010 16:31		150.4
Setup 18kV neg 350chg 149.5slew*	Full Voltage	-49.3 kV	0.234	62.2	6/29/2010 16:35	327	150.4
warm up Setup sample 250chg	Full Voltage	-31.9 kV	0.334	58.6	6/30/2010 8:23		150.4
warm up Setup sample 250chg	Full Voltage	-31.8 kV	0.301	58.7	6/30/2010 8:24		150.4
warm up Setup sample 250chg	Full Voltage	-33.5 kV	0.334	55.1	6/30/2010 8:25		150.4
warm up setup sample 350chg	Full Voltage	-32.6 kV	0.234	61.9	6/30/2010 8:26		150.4
warm up setup sample 350chg 144.7slew	Full Voltage	-32.0 kV	0.234	63.3	6/30/2010 8:27		150.4

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Impulse / Channel Description	Pulse Type	Peak (kV/kA)	T1/Tr (us)	T2/Tc (us)	Date/Time	Record #	Div. Ratio
warm up Setup sample 350chg 144.3slew*	Full Voltage	-47.5 kV	0.234	63.2	6/30/2010 8:30		150.4
warm up Setup sample 355chg 148.0slew*	Full Voltage	-47.4 kV	0.234	62	6/30/2010 8:34		150.4
Sample 18-1 neg shot 1 355chg 147.1slew*	Full Voltage	-48.8 kV	0.234	62.6	6/30/2010 8:41	335	150.4
Sample 18-2 neg shot 1 355chg 146.8slew*	Full Voltage	-47.6 kV	0.234	62.1	6/30/2010 8:47	336	150.4
Sample 18-3 neg shot 1 355chg 145.8slew*	Full Voltage	-47.7 kV	0.234	63.1	6/30/2010 8:53	337	150.4
Sample 18-1 neg shot 2 355chg 146.7slew*	Full Voltage	-47.9 kV	0.234	61.9	6/30/2010 8:58	338	150.4
Sample 18-2 neg shot 2 355chg 147.6slew*	Full Voltage	-48.8 kV	0.234	61.8	6/30/2010 9:04	339	150.4
Sample 18-3 neg shot 2 355chg 147.4slew*	Full Voltage	-46.1 kV	0.234	62.8	6/30/2010 9:09	340	150.4
Sample 18-1 neg shot 3 355chg 144.8slew*	Full Voltage	-49.1 kV	0.234	61.8	6/30/2010 9:15	341	150.4
Sample 18-2 neg shot 3 355chg 146.0slew*	Full Voltage	-47.7 kV	0.234	62.9	6/30/2010 9:20	342	150.4
Sample 18-3 neg shot 3 355chg 145.6slew*	Full Voltage	-48.3 kV	0.234	61.7	6/30/2010 9:26	343	150.4
Sample 18-1 neg shot 4 355chg 147.7slew*	Full Voltage	-46.3 kV	0.234	62.2	6/30/2010 9:32	344	150.4
Sample 18-2 neg shot 4 355chg 146.1slew*	Full Voltage	-47.1 kV	0.234	61.3	6/30/2010 9:38	345	150.4
Sample 18-3 neg shot 4 355chg 146.7slew*	Full Voltage	-46.8 kV	0.234	64.6	6/30/2010 9:44	346	150.4
Sample 18-1 neg shot 5 355chg 147.4slew*	Full Voltage	-45.8 kV	0.234	63.3	6/30/2010 9:50	347	150.4
Sample 18-2 neg shot 5 355chg 145.1slew*	Full Voltage	-51.1 kV	0.234	61.9	6/30/2010 9:56	348	150.4
Sample 18-3 neg shot 5 355chg 144.9slew*	Full Voltage	-48.5 kV	0.234	63	6/30/2010 10:01	349	150.4
warm up 250chg	Full Voltage	32.1 kV	0.301	57.2	6/30/2010 10:25		150.4
warm up 250chg	Full Voltage	32.1 kV	0.334	57.2	6/30/2010 10:26		150.4
warm up 250chg	Full Voltage	32.5 kV	0.334	57.4	6/30/2010 10:27		150.4
warm up 355chg	Full Voltage	31.3 kV	0.234	64.9	6/30/2010 10:28		150.4
Setup sample 18kV pos 355chg 147.1slew*	Full Voltage	45.74 kV	0.234	62.9	6/30/2010 10:29		150.4
Setup sample 18kV pos 355chg 146.8slew*	Full Voltage	45.63 kV	0.234	63.3	6/30/2010 10:32		150.4
Sample 18-1 pos shot 1 355chg 147.1slew*	Full Voltage	43.6 kV	0.234	63.8	6/30/2010 10:38	356	150.4
Sample 18-2 pos shot 1 355chg 148.0slew*	Full Voltage	41.7 kV	0.234	64.5	6/30/2010 10:43	357	150.4
Sample 18-3 pos shot 1 355chg 149.1slew*	Full Voltage	42.9 kV	0.234	64.2	6/30/2010 10:49	358	150.4
Sample 18-1 pos shot 2 355chg 148.8slew*	Full Voltage	44.1 kV	0.234	65.1	6/30/2010 10:57	359	150.4
Sample 18-2 pos shot 2 355chg 147.2slew*	Full Voltage	41.8 kV	0.234	65.5	6/30/2010 11:02	360	150.4
Sample 18-3 pos shot 2 355chg 147.7slew*	Full Voltage	43.5 kV	0.234	64.1	6/30/2010 11:08	361	150.4
Sample 18-1 pos shot 3 355chg 149.4slew*	Full Voltage	43.7 kV	0.234	63.8	6/30/2010 11:16	362	150.4
Sample 18-2 pos shot 3 355chg 148.9slew*	Full Voltage	41.3 kV	0.234	64.1	6/30/2010 11:22	363	150.4
Sample 18-3 pos shot 3 355chg 147.3slew*	Full Voltage	44.8 kV	0.234	63.6	6/30/2010 11:28	364	150.4
Sample 18-1 pos shot 4 355chg 148.2slew*	Full Voltage	43.9 kV	0.234	64.8	6/30/2010 11:34	365	150.4
Sample 18-2 pos shot 4 355chg 148.9slew*	Full Voltage	42.1 kV	0.234	64.2	6/30/2010 11:39	366	150.4
Sample 18-3 pos shot 4 355chg 147.9slew*	Full Voltage	42.8 kV	0.234	63.8	6/30/2010 11:45	367	150.4
Sample 18-1 pos shot 5 355chg 148.0slew*	Full Voltage	44.0 kV	0.234	63.9	6/30/2010 11:51	368	150.4
Sample 18-2 pos shot 5 355chg 146.1slew*	Full Voltage	42.0 kV	0.234	63.1	6/30/2010 11:56	369	150.4
Sample 18-3 pos shot 5 355chg 149.2slew*	Full Voltage	42.9 kV	0.2	63.6	6/30/2010 12:02	370	150.4
warm up 300chg	Full Voltage	15.9 kV	0.234	76.6	6/30/2010 13:32		150.4
warm up 300chg	Full Voltage	16.2 kV	0.234	75.8	6/30/2010 13:33		150.4
Setup 10kV 300chg 74.2slew*	Full Voltage	25.3 kV	0.234	75.4	6/30/2010 13:33		150.4
Setup 10kV 330chg 81.6slew*	Full Voltage	24.4 kV	0.2	78.8	6/30/2010 13:37		150.4
Setup 10kV 2stages 340chg 83.8slew*	Full Voltage	25.0kV	0.2	79.7	6/30/2010 13:40	375	150.4
Sample 10-1 pos shot 1 340chg 83.0slew*	Full Voltage	22.7 kV	0.2	81.3	6/30/2010 13:54	376	150.4
Sample 10-2 pos shot 1 340chg 83.0slew*	Full Voltage	23.3 kV	0.234	80.2	6/30/2010 14:00	377	150.4
Sample 10-3 pos shot 1 340chg 83.7slew*	Full Voltage	22.9 kV	0.2	81	6/30/2010 14:08	378	150.4
Sample 10-1 pos shot 2 340chg 82.9slew*	Full Voltage	22.6 kV	0.2	81.4	6/30/2010 14:15	379	150.4
Sample 10-2 pos shot 2 340chg 82.8slew*	Full Voltage	23.5 kV	0.2	80.3	6/30/2010 14:20	380	150.4
Sample 10-3 pos shot 2 340chg 84.1slew*	Full Voltage	23.1 kV	0.2	80.5	6/30/2010 14:26	381	150.4
Sample 10-1 pos shot 3 340chg 82.6slew*	Full Voltage	22.1 kV	0.2	81.6	6/30/2010 14:31	382	150.4
Sample 10-2 pos shot 3 340chg 70.5slew Low*	Full Voltage	22.9 kV	0.234	80	6/30/2010 14:37	383	150.4
Sample 10-3 pos shot 3 340chg 80.4slew*	Full Voltage	22.5 kV	0.2	81.1	6/30/2010 14:45	384	150.4
Sample 10-1 pos shot 4 340chg 81.7slew*	Full Voltage	22.5 kV	0.2	81.4	6/30/2010 14:51	385	150.4
Sample 10-2 pos shot 4 340chg 83.6slew*	Full Voltage	23.2 kV	0.2	80.5	6/30/2010 14:57	386	150.4
Sample 10-3 pos shot 4 340chg 82.4slew*	Full Voltage	22.7 kV	0.2	80.7	6/30/2010 15:03	387	150.4
Sample 10-1 pos shot 5 340chg 83.6slew*	Full Voltage	22.9 kV	0.2	80.6	6/30/2010 15:08	388	150.4
Sample 10-2 pos shot 5 340chg 83.5slew*	Full Voltage	23.4 kV	0.2	80.2	6/30/2010 15:14	389	150.4
Sample 10-3 pos shot 5 340chg 82.9slew*	Full Voltage	23.0 kV	0.234	81.2	6/30/2010 15:19	390	150.4
Sample 10-2 pos shot 6 340chg 85.0slew*	Full Voltage	23.3 kV	0.2	81.1	6/30/2010 15:30	391	150.4
warm up 10kV 250chg	Full Voltage	-16.2 kV	0.267	72.1	6/30/2010 15:45		150.4
warm up 10kV 250chg	Full Voltage	-16.9 kV	0.267	68.6	6/30/2010 15:46		150.4
warm up 10kV 250chg	Full Voltage	-16.8 kV	0.267	68.9	6/30/2010 15:47		150.4
warm up 10kV neg 340chg	Full Voltage	-16.2 kV	0.2	78.7	6/30/2010 15:49		150.4
Setup sample 10kV neg 340chg 84.0slew*	Full Voltage	-26.15 kV	0.234	78.1	6/30/2010 15:49		150.4
Sample 10-1 neg shot 1 340chg 83.6slew*	Full Voltage	-23.2 kV	0.2	80.8	6/30/2010 15:55	397	150.4
Sample 10-2 neg shot 1 340chg 81.8slew*	Full Voltage	-23.6 kV	0.2	80.9	6/30/2010 16:00	398	150.4
Sample 10-3 neg shot 1 340chg 83.0slew*	Full Voltage	-23.5 kV	0.234	81.2	6/30/2010 16:06	399	150.4
Sample 10-1 neg shot 2 340chg 82.3slew*	Full Voltage	-23.4 kV	0.2	81	6/30/2010 16:11	400	150.4
Sample 10-2 neg shot 2 340chg 82.9slew*	Full Voltage	-23.6 kV	0.234	80.6	6/30/2010 16:17	401	150.4
Sample 10-3 neg shot 2 340chg 83.2slew*	Full Voltage	-23.2 kV	0.234	81	6/30/2010 16:22	402	150.4
Sample 10-1 neg shot 3 340chg 82.3slew*	Full Voltage	-23.2 kV	0.2	81.2	6/30/2010 16:28	403	150.4
Sample 10-2 neg shot 3 340chg 81.7slew*	Full Voltage	-24.3 kV	0.2	79.6	6/30/2010 16:33	404	150.4
Sample 10-3 neg shot 3 340chg 82.6slew*	Full Voltage	-23.7 kV	0.2	80.5	6/30/2010 16:39	405	150.4
Sample 10-1 neg shot 4 340chg 82.9slew*	Full Voltage	-22.8 kV	0.2	80.7	6/30/2010 16:45	406	150.4
Sample 10-2 neg shot 4 340chg 85.1slew*	Full Voltage	-23.6 kV	0.2	80.9	6/30/2010 16:51	407	150.4
Sample 10-3 neg shot 4 340chg 86.1slew*	Full Voltage	-23.6 kV	0.2	81.8	6/30/2010 16:57	408	150.4
Sample 10-1 neg shot 5 340chg 84.5slew*	Full Voltage	-22.7 kV	0.2	82.1	6/30/2010 17:02	409	150.4
Sample 10-2 neg shot 5 340chg 87.7slew*	Full Voltage	-24.1 kV	0.2	80.7	6/30/2010 17:07	410	150.4
Sample 10-3 neg shot 5 340chg 85.6slew*	Full Voltage	-24.1 kV	0.2	80.9	6/30/2010 17:13	411	150.4

APPENDIX B - Front-of-Wave Spreadsheet

Project No. 10-112

Cooper Arresters - Front of Wave Test

Sample: **27-1** **06-29-2010**
 Polarity: Positive
 Charge

385

280
 Peak

63.3

 kV
 30% 18.98 kV @

-0.08115

 us $\Delta V = 37.95$
 90% 56.93 kV @

0.08858

 us $\Delta t = 0.16973$
 Slew

223.6

 kV/us

Sample: **27-2** **281**
 Polarity: Positive
 Charge

385

 Peak

63.2

 kV
 30% 18.97 kV @

-0.07764

 us $\Delta V = 37.938$
 90% 56.91 kV @

0.09092

 us $\Delta t = 0.16856$
 Slew

225.1

 kV/us

Sample: **27-3** **282**
 Polarity: Positive
 Charge

385

 Peak

63.8

 kV
 30% 19.13 kV @

-0.07757

 us $\Delta V = 38.256$
 90% 57.38 kV @

0.09251

 us $\Delta t = 0.17008$
 Slew

224.9

 kV/us

Sample: **27-1** **283**
 Polarity: Positive
 Charge

385

 Peak

63.4

 kV
 30% 19.02 kV @

-0.09734

 us $\Delta V = 38.04$
 90% 57.06 kV @

0.07039

 us $\Delta t = 0.16773$
 Slew

226.8

 kV/us

Sample: **27-2** **284**
 Polarity: Positive
 Charge

385

 Peak

62.0

 kV
 30% 18.59 kV @

-0.1023

 us $\Delta V = 37.188$
 90% 55.78 kV @

0.06499

 us $\Delta t = 0.16729$
 Slew

222.3

 kV/us

Sample: **27-3** **285**
 Polarity: Positive
 Charge

385

 Peak

62.3

 kV
 30% 18.69 kV @

-0.101

 us $\Delta V = 37.38$
 90% 56.07 kV @

0.06637

 us $\Delta t = 0.16737$
 Slew

223.3

 kV/us

Sample: **27-1** **286**
 Polarity: Positive
 Charge

385

 Peak

63.7

 kV
 30% 19.12 kV @

-0.09421

 us $\Delta V = 38.244$
 90% 57.37 kV @

0.07637

 us $\Delta t = 0.17058$
 Slew

224.2

 kV/us

Sample: **27-2** **287**
 Polarity: Positive
 Charge

385

 Peak

63.4

 kV
 30% 19.01 kV @

-0.07917

 us $\Delta V = 38.01$
 90% 57.02 kV @

0.0918

 us $\Delta t = 0.17097$
 Slew

222.3

 kV/us

Sample: **27-3** **288**
 Polarity: Positive
 Charge

385

 Peak

63.0

 kV
 30% 18.90 kV @

-0.09587

 us $\Delta V = 37.806$
 90% 56.71 kV @

0.0711

 us $\Delta t = 0.16697$
 Slew

226.4

 kV/us

Sample: **27-1** **289**
 Polarity: Positive
 Charge

385

 Peak

63.8

 kV
 30% 19.14 kV @

-0.09894

 us $\Delta V = 38.286$
 90% 57.43 kV @

0.07182

 us $\Delta t = 0.17076$
 Slew

224.2

 kV/us

Sample: **27-2** **290**
 Polarity: Positive
 Charge

385

 Peak

63.0

 kV
 30% 18.89 kV @

-0.0784

 us $\Delta V = 37.776$
 90% 56.66 kV @

0.09023

 us $\Delta t = 0.16863$
 Slew

224.0

 kV/us

Sample: **27-3** **291**
 Polarity: Positive
 Charge

385

 Peak

63.3

 kV
 30% 19.00 kV @

-0.09803

 us $\Delta V = 37.992$
 90% 56.99 kV @

0.07125

 us $\Delta t = 0.16928$
 Slew

224.4

 kV/us

Sample: **27-1** **292**
 Polarity: Positive
 Charge

385

 Peak

63.0

 kV
 30% 18.90 kV @

-0.07988

 us $\Delta V = 37.806$
 90% 56.71 kV @

0.08744

 us $\Delta t = 0.16732$
 Slew

226.0

 kV/us

Sample: **27-2** **293**
 Polarity: Positive
 Charge

385

 Peak

63.1

 kV
 30% 18.92 kV @

-0.1002

 us $\Delta V = 37.83$
 90% 56.75 kV @

0.06969

 us $\Delta t = 0.16989$
 Slew

222.7

 kV/us

Sample: **27-3** **294**
 Polarity: Positive
 Charge

385

 Peak

62.5

 kV
 30% 18.75 kV @

-0.1024

 us $\Delta V = 37.506$
 90% 56.26 kV @

0.0681

 us $\Delta t = 0.1705$
 Slew

220.0

 kV/us

Sample: **27-1** **302**
 Polarity: Negative
 Charge

385

 Peak

65.0

 kV
 30% 19.49 kV @

-0.1667

 us $\Delta V = 38.988$
 90% 58.48 kV @

0.08218

 us $\Delta t = 0.24888$
 Slew

156.7

 kV/us

Sample: **27-2** **303**
 Polarity: Negative
 Charge

385

 Peak

63.7

 kV
 30% 19.10 kV @

-0.163

 us $\Delta V = 38.202$
 90% 57.30 kV @

0.05661

 us $\Delta t = 0.21961$
 Slew

174.0

 kV/us

Sample: **27-3** **307**
 Polarity: Negative
 Charge

385

 Peak

64.9

 kV
 30% 19.46 kV @

-0.1633

 us $\Delta V = 38.922$
 90% 58.38 kV @

0.009987

 us $\Delta t = 0.173287$
 Slew

224.6

 kV/us

Sample: **27-1** **308**
 Polarity: Negative
 Charge

385

 Peak

66.7

 kV
 30% 20.01 kV @

-0.1426

 us $\Delta V = 40.026$
 90% 60.04 kV @

0.03412

 us $\Delta t = 0.17672$
 Slew

226.5

 kV/us

Sample: **27-2** **309**
 Polarity: Negative
 Charge

385

 Peak

64.8

 kV
 30% 19.44 kV @

-0.1628

 us $\Delta V = 38.874$
 90% 58.31 kV @

0.01076

 us $\Delta t = 0.17356$
 Slew

224.0

 kV/us

Sample: **27-3** **310**
 Polarity: Negative
 Charge

385

 Peak

65.6

 kV
 30% 19.67 kV @

-0.143

 us $\Delta V = 39.33$
 90% 59.00 kV @

0.03094

 us $\Delta t = 0.17394$
 Slew

226.1

 kV/us

Sample: **27-1** **311**
 Polarity: Negative
 Charge

385

 Peak

64.6

 kV
 30% 19.39 kV @

-0.1452

 us $\Delta V = 38.784$
 90% 58.18 kV @

0.02907

 us $\Delta t = 0.17427$
 Slew

222.6

 kV/us

Sample: **27-2** **312**
 Polarity: Negative
 Charge

385

 Peak

65.1

 kV
 30% 19.54 kV @

-0.146

 us $\Delta V = 39.084$
 90% 58.63 kV @

0.02771

 us $\Delta t = 0.17371$
 Slew

225.0

 kV/us

Sample: **27-3** **313**
 Polarity: Negative
 Charge

385

 Peak

64.5

 kV
 30% 19.35 kV @

-0.1706

 us $\Delta V = 38.7$
 90% 58.05 kV @

0.004176

 us $\Delta t = 0.174776$
 Slew

221.4

 kV/us

Sample: **27-1** **314**
 Polarity: Negative
 Charge

385

 Peak

65.5

 kV
 30% 19.65 kV @

-0.1417

 us $\Delta V = 39.294$
 90% 58.94 kV @

0.03146

 us $\Delta t = 0.17316$
 Slew

226.9

 kV/us

Sample: **27-2** **315**
 Polarity: Negative
 Charge

385

 Peak

66.9

 kV
 30% 20.08 kV @

-0.1581

 us $\Delta V = 40.152$
 90% 60.23 kV @

0.01689

 us $\Delta t = 0.17499$
 Slew

229.5

 kV/us

Sample: **27-3** **316**
 Polarity: Negative
 Charge

385

 Peak

64.9

 kV
 30% 19.46 kV @

-0.1646

 us $\Delta V = 38.91$
 90% 58.37 kV @

0.009008

 us $\Delta t = 0.173608$
 Slew

224.1

 kV/us

Sample: **27-1** **317**
 Polarity: Negative
 Charge

385

 Peak

65.3

 kV
 30% 19.59 kV @

-0.1687

 us $\Delta V = 39.174$
 90% 58.76 kV @

0.01061

 us $\Delta t = 0.17931$
 Slew

218.5

 kV/us

Sample: **27-2** **318**
 Polarity: Negative
 Charge

385

 Peak

65.4

 kV
 30% 19.63 kV @

-0.1651

 us $\Delta V = 39.252$
 90% 58.88 kV @

0.007265

 us $\Delta t = 0.172365$
 Slew

227.7

 kV/us

Sample: **27-3** **319**
 Polarity: Negative
 Charge

385

 Peak

65.0

 kV
 30% 19.51 kV @

-0.1622

 us $\Delta V = 39.018$
 90% 58.53 kV @

0.012

 us $\Delta t = 0.1742$
 Slew

224.0

 kV/us

Sample: **27-1** **320**
 Polarity: Negative
 Charge

385

 Peak

64.9

 kV
 30% 19.46 kV @

-0.1481

 us $\Delta V = 38.928$
 90% 58.39 kV @

0.02656

 us $\Delta t = 0.17466$
 Slew

222.9

 kV/us

Sample: **27-2** **321**
 Polarity: Negative
 Charge

385

 Peak

65.6

 kV
 30% 19.69 kV @

-0.148

 us $\Delta V = 39.384$
 90% 59.08 kV @

0.02722

 us $\Delta t = 0.17522$
 Slew

224.8

 kV/us

Sample: Setup 18kV
 Polarity: Negative
 Charge

350

 Peak

49.3

 kV
 30% 14.80 kV @

-0.2001

 us $\Delta V = 29.604$
 90% 44.41 kV @

0.00213

 us $\Delta t = 0.197973$
 Slew

149.5

 kV/us

Sample: **18-1** **335**
 Polarity: Negative
 Charge

355

 Peak

48.8

 kV
 30% 14.65 kV @

-
0.08227

 us $\Delta V = 29.292$
 90% 43.94 kV @

0.1169

 us $\Delta t = 0.19917$
 Slew

147.1

 kV/us

Sample: **18-2** **336**
 Polarity: Negative
 Charge

355

 Peak

47.6

 kV
 30% 14.29 kV @

-0.0843

 us $\Delta V = 28.584$
 90% 42.88 kV @

0.1104

 us $\Delta t = 0.1947$
 Slew

146.8

 kV/us

Sample: **18-3** **337**
 Polarity: Negative
 Charge

355

 Peak

47.7

 kV
 30% 14.30 kV @

-0.08452

 us $\Delta V = 28.602$
 90% 42.90 kV @

0.1117

 us $\Delta t = 0.19622$
 Slew

145.8

 kV/us

Sample: **18-1** **338**
 Polarity: Negative
 Charge

355

 Peak

47.9

 kV
 30% 14.38 kV @

-0.08597

 us $\Delta V = 28.764$
 90% 43.15 kV @

0.1101

 us $\Delta t = 0.19607$
 Slew

146.7

 kV/us

Sample: **18-2** **339**
 Polarity: Negative
 Charge

355

 Peak

48.8

 kV
 30% 14.63 kV @

-0.08031

 us $\Delta V = 29.256$
 90% 43.88 kV @

0.1179

 us $\Delta t = 0.19821$
 Slew

147.6

 kV/us

Sample: **18-3** **340**
 Polarity: Negative
 Charge

355

 Peak

46.1

 kV
 30% 13.82 kV @

-0.08671

 us $\Delta V = 27.642$
 90% 41.46 kV @

0.1008

 us $\Delta t = 0.18751$
 Slew

147.4

 kV/us

Sample: **18-1** **341**
 Polarity: Negative
 Charge

355

 Peak

49.1

 kV
 30% 14.74 kV @

-0.0822

 us $\Delta V = 29.478$
 90% 44.22 kV @

0.1214

 us $\Delta t = 0.2036$
 Slew

144.8

 kV/us

Sample: **18-2** **342**
 Polarity: Negative
 Charge

355

 Peak

47.7

 kV
 30% 14.31 kV @

-0.08412

 us $\Delta V = 28.626$
 90% 42.94 kV @

0.1119

 us $\Delta t = 0.19602$
 Slew

146.0

 kV/us

Sample: **18-3** **343**
 Polarity: Negative
 Charge

355

 Peak

48.3

 kV
 30% 14.49 kV @

-0.08439

 us $\Delta V = 28.986$
 90% 43.48 kV @

0.1147

 us $\Delta t = 0.19909$
 Slew

145.6

 kV/us

Sample: **18-1** **344**
 Polarity: Negative
 Charge

355

 Peak

46.3

 kV
 30% 13.90 kV @

-0.06646

 us $\Delta V = 27.798$
 90% 41.70 kV @

0.1218

 us $\Delta t = 0.18826$
 Slew

147.7

 kV/us

Sample: **18-2** **345**
 Polarity: Negative
 Charge

355

 Peak

47.1

 kV
 30% 14.13 kV @

-0.06622

 us $\Delta V = 28.254$
 90% 42.38 kV @

0.1272

 us $\Delta t = 0.19342$
 Slew

146.1

 kV/us

Sample: **18-3** **346**
 Polarity: Negative
 Charge

355

 Peak

46.8

 kV
 30% 14.05 kV @

-0.08462

 us $\Delta V = 28.104$
 90% 42.16 kV @

0.1069

 us $\Delta t = 0.19152$
 Slew

146.7

 kV/us

Sample: **18-1** **347**
 Polarity: Negative
 Charge

355

 Peak

45.8

 kV
 30% 13.73 kV @

-0.08932

 us $\Delta V = 27.45$
 90% 41.18 kV @

0.09686

 us $\Delta t = 0.18618$
 Slew

147.4

 kV/us

Sample: **18-2** **348**
 Polarity: Negative
 Charge

355

 Peak

51.1

 kV
 30% 15.32 kV @

-0.0766

 us $\Delta V = 30.636$
 90% 45.95 kV @

0.1346

 us $\Delta t = 0.2112$
 Slew

145.1

 kV/us

Sample: **18-3** **349**
 Polarity: Negative
 Charge

355

 Peak

48.5

 kV
 30% 14.56 kV @

-0.08426

 us $\Delta V = 29.124$
 90% 43.69 kV @

0.1167

 us $\Delta t = 0.20096$
 Slew

144.9

 kV/us

Sample: **18-1** **356**
 Polarity: Positive
 Charge

355

 Peak

43.6

 kV
 30% 13.08 kV @

-0.1099

 us $\Delta V = 26.166$
 90% 39.25 kV @

0.06799

 us $\Delta t = 0.17789$
 Slew

147.1

 kV/us

Sample: **18-2** **357**
 Polarity: Positive
 Charge

355

 Peak

41.7

 kV
 30% 12.52 kV @

-0.1363

 us $\Delta V = 25.044$
 90% 37.57 kV @

0.03289

 us $\Delta t = 0.16919$
 Slew

148.0

 kV/us

Sample: **18-3** **358**
 Polarity: Positive
 Charge

355

 Peak

42.9

 kV
 30% 12.88 kV @

-0.1118

 us $\Delta V = 25.764$
 90% 38.65 kV @

0.06094

 us $\Delta t = 0.17274$
 Slew

149.1

 kV/us

Sample: **18-1** **359**
 Polarity: Positive
 Charge

355

 Peak

44.1

 kV
 30% 13.22 kV @

-0.1267

 us $\Delta V = 26.448$
 90% 39.67 kV @

0.05103

 us $\Delta t = 0.17773$
 Slew

148.8

 kV/us

Sample: **18-2** **360**
 Polarity: Positive
 Charge

355

 Peak

41.8

 kV
 30% 12.55 kV @

-0.1086

 us $\Delta V = 25.104$
 90% 37.66 kV @

0.06193

 us $\Delta t = 0.17053$
 Slew

147.2

 kV/us

Sample: **18-3** **361**
 Polarity: Positive
 Charge

355

 Peak

43.5

 kV
 30% 13.04 kV @

-0.1281

 us $\Delta V = 26.082$
 90% 39.12 kV @

0.04854

 us $\Delta t = 0.17664$
 Slew

147.7

 kV/us

Sample: **18-1** **362**
 Polarity: Positive
 Charge

355

 Peak

43.7

 kV
 30% 13.10 kV @

-0.119

 us $\Delta V = 26.19$
 90% 39.29 kV @

0.05626

 us $\Delta t = 0.17526$
 Slew

149.4

 kV/us

Sample: **18-2** **363**
 Polarity: Positive
 Charge

355

 Peak

41.3

 kV
 30% 12.40 kV @

-0.1062

 us $\Delta V = 24.798$
 90% 37.20 kV @

0.06033

 us $\Delta t = 0.16653$
 Slew

148.9

 kV/us

Sample: **18-3** **364**
 Polarity: Positive
 Charge

355

 Peak

44.8

 kV
 30% 13.45 kV @

-0.1277

 us $\Delta V = 26.892$
 90% 40.34 kV @

0.05492

 us $\Delta t = 0.18262$
 Slew

147.3

 kV/us

Sample: **18-1** **365**
 Polarity: Positive
 Charge

355

 Peak

43.9

 kV
 30% 13.16 kV @

-0.1267

 us $\Delta V = 26.322$
 90% 39.48 kV @

0.05086

 us $\Delta t = 0.17756$
 Slew

148.2

 kV/us

Sample: **18-2** **366**
 Polarity: Positive
 Charge

355

 Peak

42.1

 kV
 30% 12.62 kV @

-0.1133

 us $\Delta V = 25.248$
 90% 37.87 kV @

0.05628

 us $\Delta t = 0.16958$
 Slew

148.9

 kV/us

Sample: **18-3** **367**
 Polarity: Positive
 Charge

355

 Peak

42.8

 kV
 30% 12.83 kV @

-0.1335

 us $\Delta V = 25.65$
 90% 38.48 kV @

0.03992

 us $\Delta t = 0.17342$
 Slew

147.9

 kV/us

Sample: **18-1** **368**
 Polarity: Positive
 Charge

355

 Peak

44.0

 kV
 30% 13.19 kV @

-0.1098

 us $\Delta V = 26.382$
 90% 39.57 kV @

0.0685

 us $\Delta t = 0.1783$
 Slew

148.0

 kV/us

Sample: **18-2** **369**
 Polarity: Positive
 Charge

355

 Peak

42.0

 kV
 30% 12.59 kV @

-0.1356

 us $\Delta V = 25.188$
 90% 37.78 kV @

0.03676

 us $\Delta t = 0.17236$
 Slew

146.1

 kV/us

Sample: **18-3** **370**
 Polarity: Positive
 Charge

355

 Peak

42.9

 kV
 30% 12.86 kV @

-0.1242

 us $\Delta V = 25.716$
 90% 38.57 kV @

0.04816

 us $\Delta t = 0.17236$
 Slew

149.2

 kV/us

Sample: **Setup 10kV** **375**
 Polarity: Positive
 Charge

340

 Peak

25.0

 kV
 30% 7.49 kV @

-0.102

 us $\Delta V = 14.976$
 90% 22.46 kV @

0.07674

 us $\Delta t = 0.17874$
 Slew

83.8

 kV/us

Sample: **10-1** **376**
 Polarity: Positive
 Charge

340

 Peak

22.7

 kV
 30% 6.80 kV @

-0.1286

 us $\Delta V = 13.602$
 90% 20.40 kV @

0.03525

 us $\Delta t = 0.16385$
 Slew

83.0

 kV/us

Sample: **10-2** **377**
 Polarity: Positive
 Charge

340

 Peak

23.3

 kV
 30% 6.98 kV @

-0.1284

 us $\Delta V = 13.95$
 90% 20.93 kV @

0.03962

 us $\Delta t = 0.16802$
 Slew

83.0

 kV/us

Sample: **10-3** **378**
 Polarity: Positive
 Charge

340

 Peak

22.9

 kV
 30% 6.86 kV @

-0.1138

 us $\Delta V = 13.722$
 90% 20.58 kV @

0.05013

 us $\Delta t = 0.16393$
 Slew

83.7

 kV/us

Sample: **10-1** **379**
 Polarity: Positive
 Charge

340

 Peak

22.6

 kV
 30% 6.79 kV @

-0.1319

 us $\Delta V = 13.584$
 90% 20.38 kV @

0.03188

 us $\Delta t = 0.16378$
 Slew

82.9

 kV/us

Sample: **10-2** **380**
 Polarity: Positive
 Charge

340

 Peak

23.5

 kV
 30% 7.05 kV @

-0.1121

 us $\Delta V = 14.106$
 90% 21.16 kV @

0.05821

 us $\Delta t = 0.17031$
 Slew

82.8

 kV/us

Sample: **10-3** **381**
 Polarity: Positive
 Charge

340

 Peak

23.1

 kV
 30% 6.92 kV @

-0.1086

 us $\Delta V = 13.836$
 90% 20.75 kV @

0.05592

 us $\Delta t = 0.16452$
 Slew

84.1

 kV/us

Sample: **10-1** **382**
 Polarity: Positive
 Charge

340

 Peak

22.1

 kV
 30% 6.64 kV @

-0.1319

 us $\Delta V = 13.272$
 90% 19.91 kV @

0.02886

 us $\Delta t = 0.16076$
 Slew

82.6

 kV/us

Sample: **10-2** **383**
 Polarity: Positive
 Charge

340

 Peak

22.9

 kV
 30% 6.87 kV @

-0.12

 us $\Delta V = 13.74$
 90% 20.61 kV @

0.07483

 us $\Delta t = 0.19483$
 Slew

70.5

 kV/us

Sample: **10-3** **384**
 Polarity: Positive
 Charge

340

 Peak

22.5

 kV
 30% 6.75 kV @

-0.1374

 us $\Delta V = 13.494$
 90% 20.24 kV @

0.03045

 us $\Delta t = 0.16785$
 Slew

80.4

 kV/us

Sample: **10-1** **385**
 Polarity: Positive
 Charge

340

 Peak

22.5

 kV
 30% 6.74 kV @

-0.1311

 us $\Delta V = 13.476$
 90% 20.21 kV @

0.03376

 us $\Delta t = 0.16486$
 Slew

81.7

 kV/us

Sample: **10-2** **386**
 Polarity: Positive
 Charge

340

 Peak

23.2

 kV
 30% 6.96 kV @

-0.1125

 us $\Delta V = 13.92$
 90% 20.88 kV @

0.05393

 us $\Delta t = 0.16643$
 Slew

83.6

 kV/us

Sample: **10-3** **387**
 Polarity: Positive
 Charge

340

 Peak

22.7

 kV
 30% 6.80 kV @

-0.1144

 us $\Delta V = 13.608$
 90% 20.41 kV @

0.05066

 us $\Delta t = 0.16506$
 Slew

82.4

 kV/us

Sample: **10-1** **388**
 Polarity: Positive
 Charge

340

 Peak

22.9

 kV
 30% 6.87 kV @

-0.1329

 us $\Delta V = 13.734$
 90% 20.60 kV @

0.0313

 us $\Delta t = 0.1642$
 Slew

83.6

 kV/us

Sample: **10-2** **389**
 Polarity: Positive
 Charge

340

 Peak

23.4

 kV
 30% 7.02 kV @

-0.1304

 us $\Delta V = 14.034$
 90% 21.05 kV @

0.03762

 us $\Delta t = 0.16802$
 Slew

83.5

 kV/us

Sample: **10-3** **390**
 Polarity: Positive
 Charge

340

 Peak

23.0

 kV
 30% 6.90 kV @

-0.1119

 us $\Delta V = 13.8$
 90% 20.70 kV @

0.05454

 us $\Delta t = 0.16644$
 Slew

82.9

 kV/us

Sample: **10-2** **391**
 Polarity: Positive
 Charge

340

 Peak

23.3

 kV
 30% 6.98 kV @

-0.1073

 us $\Delta V = 13.95$
 90% 20.93 kV @

0.05681

 us $\Delta t = 0.16411$
 Slew

85.0

 kV/us

Sample: **10-1** **397**
 Polarity: Negative
 Charge

340

 Peak

23.2

 kV
 30% 6.96 kV @

-0.1016

 us $\Delta V = 13.926$
 90% 20.89 kV @

0.06503

 us $\Delta t = 0.16663$
 Slew

83.6

 kV/us

Sample: **10-2** **398**
 Polarity: Negative
 Charge

340

 Peak

23.6

 kV
 30% 7.09 kV @

-0.08478

 us $\Delta V = 14.172$
 90% 21.26 kV @

0.08854

 us $\Delta t = 0.17332$
 Slew

81.8

 kV/us

Sample: **10-3** **399**
 Polarity: Negative
 Charge

340

 Peak

23.5

 kV
 30% 7.04 kV @

-0.1007

 us $\Delta V = 14.082$
 90% 21.12 kV @

0.06892

 us $\Delta t = 0.16962$
 Slew

83.0

 kV/us

Sample: **10-1** **400**
 Polarity: Negative
 Charge

340

 Peak

23.4

 kV
 30% 7.01 kV @

-0.07904

 us $\Delta V = 14.028$
 90% 21.04 kV @

0.0914

 us $\Delta t = 0.17044$
 Slew

82.3

 kV/us

Sample: **10-2** **401**
 Polarity: Negative
 Charge

340

 Peak

23.6

 kV
 30% 7.08 kV @

-0.09838

 us $\Delta V = 14.166$
 90% 21.25 kV @

0.07252

 us $\Delta t = 0.1709$
 Slew

82.9

 kV/us

Sample: **10-3** **402**
 Polarity: Negative
 Charge

340

 Peak

23.2

 kV
 30% 6.95 kV @

-0.07929

 us $\Delta V = 13.902$
 90% 20.85 kV @

0.08781

 us $\Delta t = 0.1671$
 Slew

83.2

 kV/us

Sample: **10-1** **403**
 Polarity: Negative
 Charge

340

 Peak

23.2

 kV
 30% 6.97 kV @

-0.1015

 us $\Delta V = 13.944$
 90% 20.92 kV @

0.0679

 us $\Delta t = 0.1694$
 Slew

82.3

 kV/us

Sample: **10-2** **404**
 Polarity: Negative
 Charge

340

 Peak

24.3

 kV
 30% 7.28 kV @

-0.09605

 us $\Delta V = 14.568$
 90% 21.85 kV @

0.08228

 us $\Delta t = 0.17833$
 Slew

81.7

 kV/us

Sample: **10-3** **405**
 Polarity: Negative
 Charge

340

 Peak

23.7

 kV
 30% 7.11 kV @

-0.1013

 us $\Delta V = 14.22$
 90% 21.33 kV @

0.07083

 us $\Delta t = 0.17213$
 Slew

82.6

 kV/us

Sample: **10-1** **406**
 Polarity: Negative
 Charge

340

 Peak

22.8

 kV
 30% 6.83 kV @

-0.1028

 us $\Delta V = 13.65$
 90% 20.48 kV @

0.06188

 us $\Delta t = 0.16468$
 Slew

82.9

 kV/us

Sample: **10-2** **407**
 Polarity: Negative
 Charge

340

 Peak

23.6

 kV
 30% 7.07 kV @

-0.09939

 us $\Delta V = 14.13$
 90% 21.20 kV @

0.06664

 us $\Delta t = 0.16603$
 Slew

85.1

 kV/us

Sample: **10-3** **408**
 Polarity: Negative
 Charge

340

 Peak

23.6

 kV
 30% 7.09 kV @

-0.101

 us $\Delta V = 14.184$
 90% 21.28 kV @

0.06383

 us $\Delta t = 0.16483$
 Slew

86.1

 kV/us

Sample: **10-1** **409**
 Polarity: Negative
 Charge

340

 Peak

22.7

 kV
 30% 6.80 kV @

-0.08173

 us $\Delta V = 13.602$
 90% 20.40 kV @

0.07926

 us $\Delta t = 0.16099$
 Slew

84.5

 kV/us

Sample: **10-2** **410**
 Polarity: Negative
 Charge

340

 Peak

24.1

 kV
 30% 7.23 kV @

-0.09758

 us $\Delta V = 14.454$
 90% 21.68 kV @

0.06722

 us $\Delta t = 0.1648$
 Slew

87.7

 kV/us

Sample: **10-3** **411**
 Polarity: Negative
 Charge

340

 Peak

24.1

 kV
 30% 7.22 kV @

-0.1001

 us $\Delta V = 14.442$
 90% 21.66 kV @

0.06867

 us $\Delta t = 0.16877$
 Slew

85.6

 kV/us

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