**Hubbell Power Systems, Inc.**
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Document: G12-06-04

# ANSI/IEEE Design Test Report

# Polymer Distribution

# Elbow & Parkingstand Arresters

This design test report records the results of laboratory tests performed on Elbow and Parkingstand Arresters which met or exceeded all applicable requirements of these standards:

ANSI/IEEE Standard C62.11-2005, "IEEE Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits"
ANSI/IEEE Standard 386-2006, "IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V"
ANSI/IEEE Standard 592-1990, "IEEE Standard for Exposed Semiconducting Shields on High-Voltage Cable Joints and Separable Insulated Connectors"

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# Design Test Report

Reports provide details of the tests according to the following table:

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## SECTION I

## INSULATION WITHSTAND TEST: ELBOW & PARKINGSTAND ARRESTER

Introduction and Sample Preparation

The test was conducted in accordance with Section 8.1 of ANSI/IEEE Standard C62.11-2005. Insulating inserts were used in place of MOV block modules.

Test Results

Table 1 summarizes the polymer housing minimum dielectric test requirements for each arrester rating. Each arrester housing exceeded the listed 60 Hz and impulse withstand requirements summarized in table 1.

| MCOV (kV) | Rated Voltage (kV) | DC for 15 minutes (kV) | 60Hz Withstand 1 minute (kV RMS) | 1.2/50µs Impulse Withstand (kV crest) |
|---|---|---|---|---|
| **15 kV Class** | | | | |
| 2.55 | 3.0 | 53 | 34.0 | 95.0 |
| 5.10 | 6.0 | 53 | 34.0 | 95.0 |
| 7.65 | 9.0 | 53 | 34.0 | 95.0 |
| 8.40 | 10.0 | 53 | 34.0 | 95.0 |
| 10.2 | 12.0 | 53 | 34.0 | 95.0 |
| 12.7 | 15.0 | 53 | 34.0 | 95.0 |
| 15.3 | 18.0 | 53 | 34.0 | 95.0 |
| **25 kV Class** | | | | |
| 7.65 | 9.0 | 78 | 40.0 | 125.0 |
| 8.40 | 10.0 | 78 | 40.0 | 125.0 |
| 10.2 | 12.0 | 78 | 40.0 | 125.0 |
| 12.7 | 15.0 | 78 | 40.0 | 125.0 |
| 15.3 | 18.0 | 78 | 40.0 | 125.0 |
| 17.0 | 21.0 | 78 | 40.0 | 125.0 |
| **35 kV Class** | | | | |
| 19.5 | 24.0 | 103 | 50.0 | 150.0 |
| 22.0 | 27.0 | 103 | 50.0 | 150.0 |
| 24.4 | 30.0 | 103 | 50.0 | 150.0 |

**Table 1**

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## SECTION II

## DISCHARGE VOLTAGE TEST: ELBOW & PARKINGSTAND ARRESTER

Sample Preparation

The discharge voltage tests were performed on a prorated sample consisting of a single 32mm diameter MOV disc element.

Test Procedure

The test was conducted in accordance with Section 8.3 of ANSI/IEEE Standard C62.11-2005 "IEEE Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits". The disc was subjected to 8/20 µs current waves with magnitudes ranging from 1.5 kA through 20 kA. In addition, Front-of-wave and switching surge discharge voltage tests were performed.

Test Results

The following oscillograms show the results of the individual discharge voltage tests. At the end of this section, a summary table compares the catalog protective characteristics versus the measured values extrapolated from the test data.

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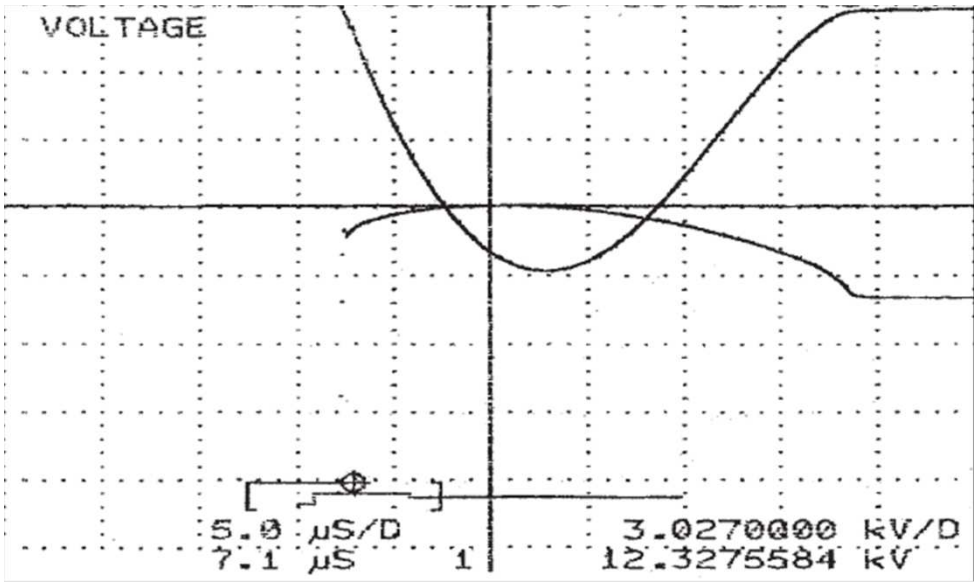
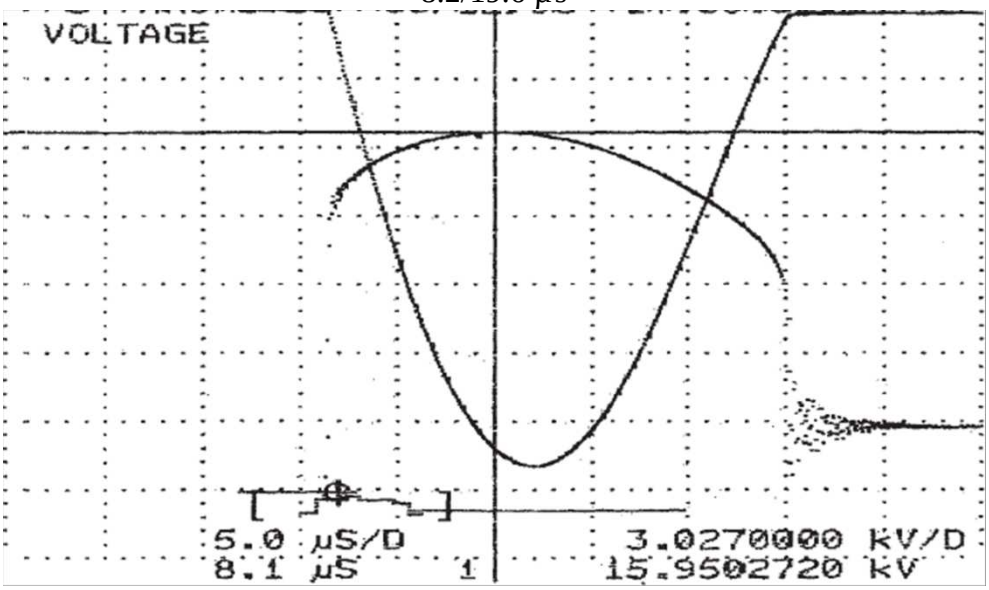
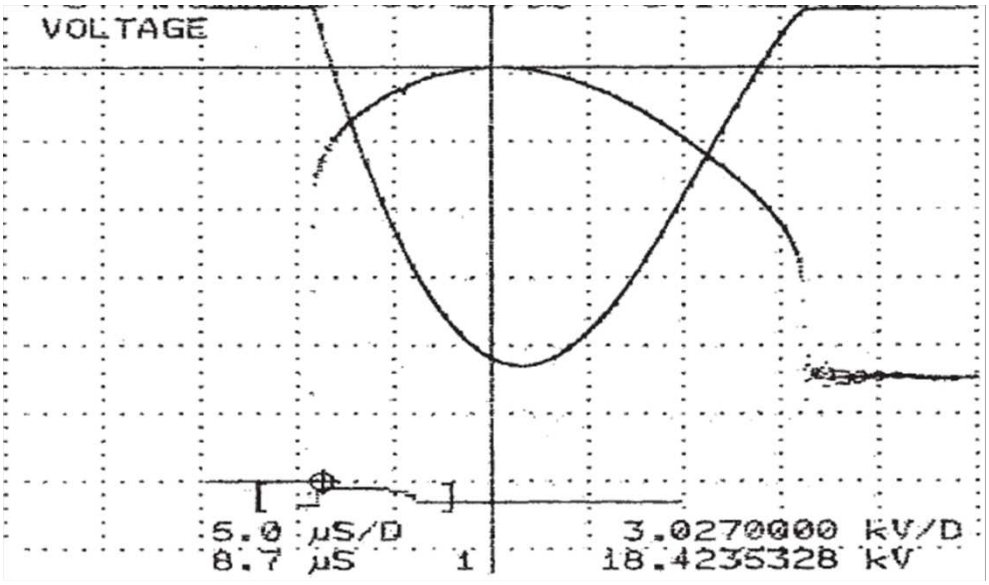
A.) 8/20 µs Discharge Voltage Oscillograms: Tests were performed per Section 8.3.1 for nominal 8/20 µs discharge current wave shapes.



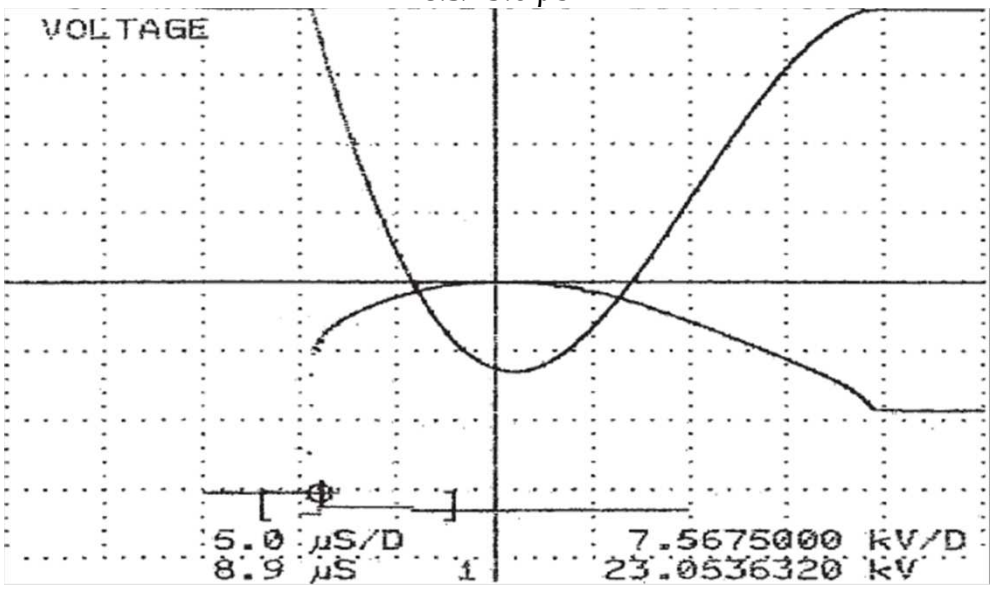

1.501 kA
12.328 kV
8.2/19.6 µs




10.173 kA
15.950 kV
8.3/18.9 µs




20.099 kA
18.424 kV
8.5/19.6 µs




40.19 kA
23.054 kV
8.1/19.6 µs

B.) Front-of-wave Oscillograms: Tests were performed per Section 8.3.2.1 for a nominal 5kA current surge with a time to voltage crest of 0.5 microseconds.

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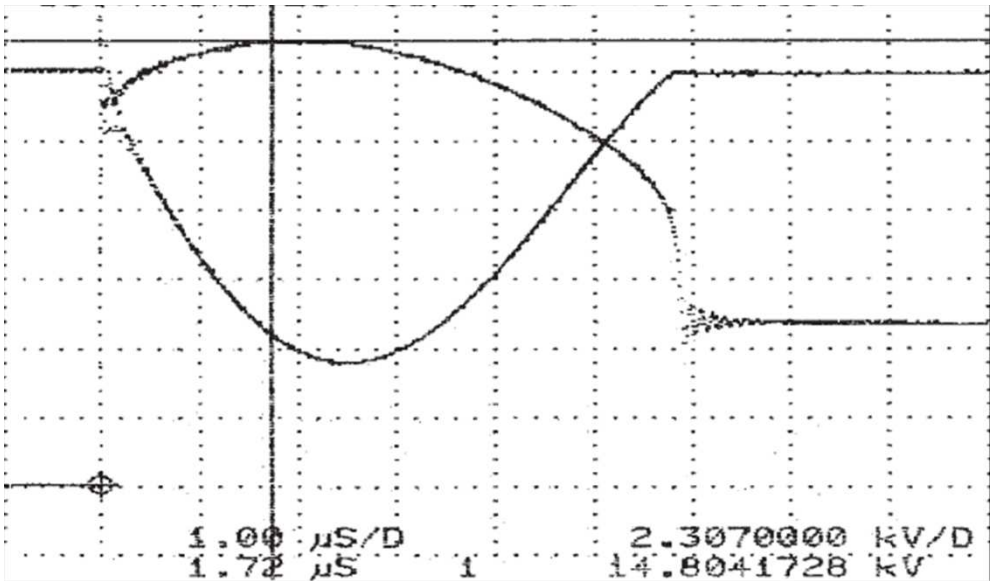
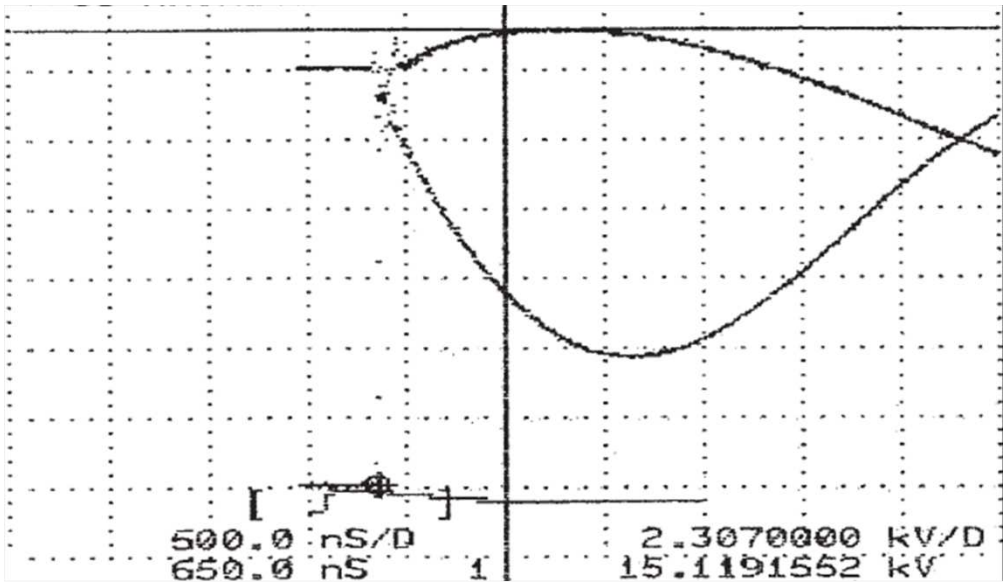
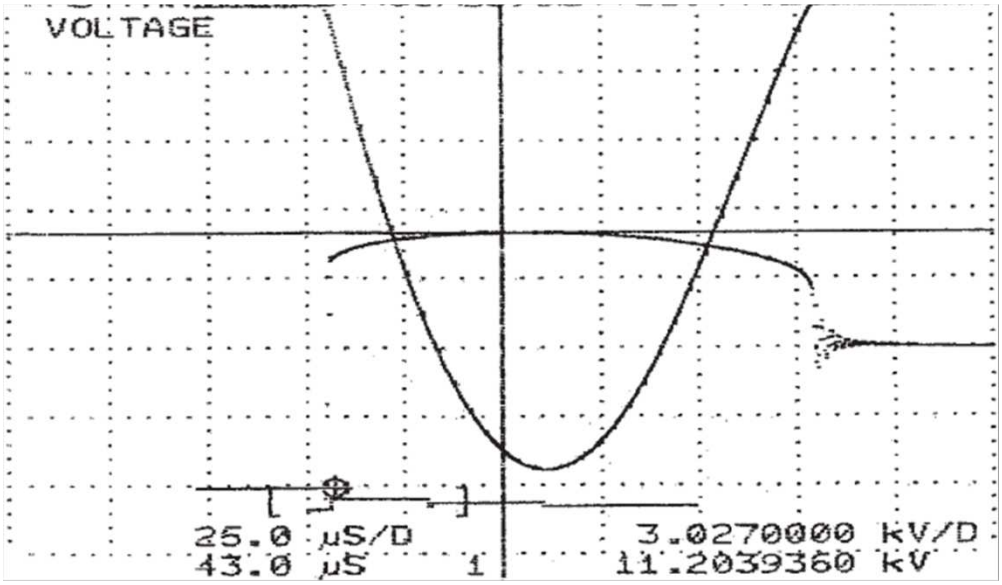



5.120 kA
14.804 kV
2.1/4.5 µs




5.030 kA
15.119 kV
1.0/2.5 µs

C.) Switching Surge Oscillograms: Tests were performed per Section 8.3.2.2 for switching surge current magnitude of 500A.




506A
11.204kV
45.0/98.5 µs

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**Elbow & Parkingstand Arrester**
**Protective Characteristics Comparison Table**

| MCOV (kV) | Rated Voltage (kV) | FOW 5kA IR | | 45/100µS 500A IR | | 8/20µS 1.5kA IR | | 8/20µS 3kA IR | |
|---|---|---|---|---|---|---|---|---|---|
| | | Catalog Maximum (kV) | Measured (kV) | Catalog Maximum (kV) | Measured (kV) | Catalog Maximum (kV) | Measured (kV) | Catalog Maximum (kV) | Measured (kV) |
| **15 kV Class** | | | | | | | | | |
| 2.55 | 3.0 | 12.5 | 11.18 | 8.50 | 8.28 | 9.80 | 9.12 | 10.3 | 9.83 |
| 5.10 | 6.0 | 25.0 | 22.36 | 17.0 | 16.57 | 19.5 | 18.23 | 20.5 | 19.66 |
| 7.65 | 9.0 | 33.5 | 30.56 | 23.0 | 22.64 | 26.0 | 24.92 | 28.0 | 26.87 |
| 8.40 | 10.0 | 36.0 | 31.60 | 24.0 | 23.42 | 27.0 | 25.77 | 29.5 | 27.79 |
| 10.2 | 12.0 | 50.0 | 44.72 | 34.0 | 33.14 | 39.0 | 36.46 | 41.0 | 39.33 |
| 12.7 | 15.0 | 58.5 | 52.92 | 40.0 | 39.21 | 45.5 | 43.15 | 48.5 | 46.54 |
| 15.3 | 18.0 | 67.0 | 61.11 | 46.0 | 45.29 | 52.0 | 49.83 | 56.0 | 53.75 |
| **25 kV Class** | | | | | | | | | |
| 7.65 | 9.0 | 33.5 | 30.56 | 23.0 | 22.64 | 26.0 | 24.92 | 28.0 | 26.87 |
| 8.40 | 10.0 | 36.0 | 31.60 | 24.0 | 23.42 | 27.0 | 25.77 | 29.5 | 27.79 |
| 10.2 | 12.0 | 50.0 | 44.72 | 34.0 | 33.14 | 39.0 | 36.46 | 41.0 | 39.33 |
| 12.7 | 15.0 | 58.5 | 52.92 | 40.0 | 39.21 | 45.5 | 43.15 | 48.5 | 46.54 |
| 15.3 | 18.0 | 67.0 | 61.11 | 46.0 | 45.29 | 52.0 | 49.83 | 56.0 | 53.75 |
| 17.0 | 21.0 | 73.0 | 64.95 | 49.0 | 48.13 | 55.0 | 52.96 | 60.0 | 57.12 |
| **35 kV Class** | | | | | | | | | |
| 19.5 | 24.0 | 92.0 | 83.47 | 63.0 | 61.86 | 71.5 | 68.06 | 76.5 | 73.41 |
| 22.0 | 27.0 | 100.5 | 91.67 | 69.0 | 67.93 | 78.0 | 74.75 | 84.0 | 80.62 |
| 24.4 | 30.0 | 108.5 | 97.42 | 74.0 | 72.19 | 81.1 | 79.44 | 88.5 | 85.68 |

**Table 2**

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**Elbow & Parkingstand Arrester**
**Protective Characteristics Comparison Table**

| MCOV (kV) | Rated Voltage (kV) | 8/20µS 5kA IR | | 8/20µS 10kA IR | | 8/20µS 20kA IR | | 8/20µS 40kA IR | |
|---|---|---|---|---|---|---|---|---|---|
| | | Catalog Maximum (kV) | Measured (kV) | Catalog Maximum (kV) | Measured (kV) | Catalog Maximum (kV) | Measured (kV) | Catalog Maximum (kV) | Measured (kV) |
| **15 kV Class** | | | | | | | | | |
| 2.55 | 3.0 | 11.0 | 10.5 | 12.3 | 11.79 | 14.3 | 13.62 | 18.5 | 17.05 |
| 5.10 | 6.0 | 22.0 | 21.0 | 24.5 | 23.59 | 28.5 | 27.25 | 37.0 | 34.09 |
| 7.65 | 9.0 | 30.0 | 28.7 | 33.0 | 32.24 | 39.0 | 37.24 | 50.5 | 46.6 |
| 8.40 | 10.0 | 31.5 | 29.8 | 36.0 | 33.34 | 41.5 | 38.51 | 53.0 | 48.19 |
| 10.2 | 12.0 | 44.0 | 42.0 | 49.0 | 47.18 | 57.0 | 54.50 | 74.0 | 68.19 |
| 12.7 | 15.0 | 52.0 | 49.7 | 57.5 | 55.83 | 67.5 | 64.49 | 87.5 | 80.69 |
| 15.3 | 18.0 | 60.0 | 57.4 | 66.0 | 64.47 | 78.0 | 74.48 | 101.0 | 93.19 |
| **25 kV Class** | | | | | | | | | |
| 7.65 | 9.0 | 30.0 | 28.7 | 33.0 | 32.24 | 39.0 | 37.24 | 50.5 | 46.6 |
| 8.40 | 10.0 | 31.5 | 29.8 | 36.0 | 33.34 | 41.5 | 38.51 | 53.0 | 48.19 |
| 10.2 | 12.0 | 44.0 | 42.0 | 49.0 | 47.18 | 57.0 | 54.50 | 74.0 | 69.19 |
| 12.7 | 15.0 | 52.0 | 49.7 | 57.5 | 55.83 | 67.5 | 64.49 | 87.5 | 80.69 |
| 15.3 | 18.0 | 60.0 | 57.4 | 66.0 | 64.47 | 78.0 | 74.48 | 101.0 | 93.19 |
| 17.0 | 21.0 | 64.0 | 61.0 | 73.0 | 68.52 | 84.0 | 79.15 | 107.0 | 99.03 |
| **35 kV Class** | | | | | | | | | |
| 19.5 | 24.0 | 82.0 | 78.4 | 90.5 | 88.06 | 106.5 | 101.72 | 138.0 | 127.28 |
| 22.0 | 27.0 | 90.0 | 86.1 | 99.0 | 97.71 | 117.0 | 111.71 | 151.5 | 139.79 |
| 24.4 | 30.0 | 100.0 | 91.5 | 108.0 | 102.78 | 124.5 | 118.72 | 159.0 | 148.55 |

**Table 3**

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## SECTION III

## ACCELERATED AGING TEST: ELBOW & PARKINGSTAND ARRESTER

Introduction

This test is performed to measure the MOV disc aging characteristic. The measured watts values are used to develop elevated voltage ratios $K_c$ and $K_r$ which are used in the duty cycle and discharge current withstand tests to simulate the performance of arresters that have a service life equivalent to 2000 hours at 115°C.

Sample Preparation

Three 32 mm diameter x 28 mm long discs and three 32 mm diameter x 43 mm long discs were selected for testing. The three 43 mm long discs were designated as samples #1, 2, & 3 while the 28 mm long discs were designated as samples #4, 5, & 6. The discs, which represent the longest and shortest manufactured discs, were assembled inside fiberglass-epoxy wraps and inserted inside polymer housings prior to testing.

Test Procedure

The test was performed per Section 8.5 of ANSI/IEEE C62.11-2005 Standard. The six test samples were placed inside a 115°C ±2°C. oven and energized at MCOV for 2000 hours. The watts loss for each sample was measured at MCOV and duty cycle rated voltage two hours after energization and at the completion of the 2000 hour test duration. Table 4 summarizes the results of the 2000 hour accelerated aging tests. All watts values were measured with the samples at 115°C.

| Sample number | Watts Loss at 2Hr @ MCOV $P1_c$(W) | Watts Loss at 2000Hr @ MCOV $P2_c$(W) | Watts Loss at 2Hr @ Rating $P1_r$(W) | Watts Loss at 2000Hr @ Rating $P2_r$(W) | Elevation Factors | |
|---|---|---|---|---|---|---|
| | | | | | $K_c$ | $K_r$ |
| 1 | 0.568 | 0.474 | 2.201 | 1.365 | 1.0 | 1.0 |
| 2 | 0.543 | 0.481 | 1.947 | 1.354 | 1.0 | 1.0 |
| 3 | 0.544 | 0.480 | 1.925 | 1.354 | 1.0 | 1.0 |
| 4 | 0.363 | 0.325 | 0.708 | 0.563 | 1.0 | 1.0 |
| 5 | 0.418 | 0.367 | 0.946 | 0.697 | 1.0 | 1.0 |
| 6 | 0.382 | 0.354 | 0.779 | 0.639 | 1.0 | 1.0 |

**Table 4**

Test Results

For each test sample, the final watts loss at MCOV and rating is less than the initial watts measured. Therefore, the KC and K, factors equal 1.0. These values will be used in the duty cycle and discharge-current withstand tests.

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## SECTION IV

## HIGH CURRENT, SHORT DURATION TEST: ELBOW & PARKINGSTAND ARRESTER

Sample Preparation

This test was performed per Section 8.12 of IEEE Standard C62.11-2005. The test was performed on a thermally insulated full size 8.4kV MCOV arrester.

Test Procedure

Before and after the high current, short duration test, the 5 kA 8/20 µs discharge voltage of the test sample was measured.
The test sample was subjected to two 65 kA 4/10 µs discharges. Sufficient time was allowed between discharges for the sample to cool to ambient temperature (21°C).
Within 5 minutes after the second high current discharge, the sample was energized at recovery voltage. The sample watts loss was monitored until thermal stability was demonstrated.

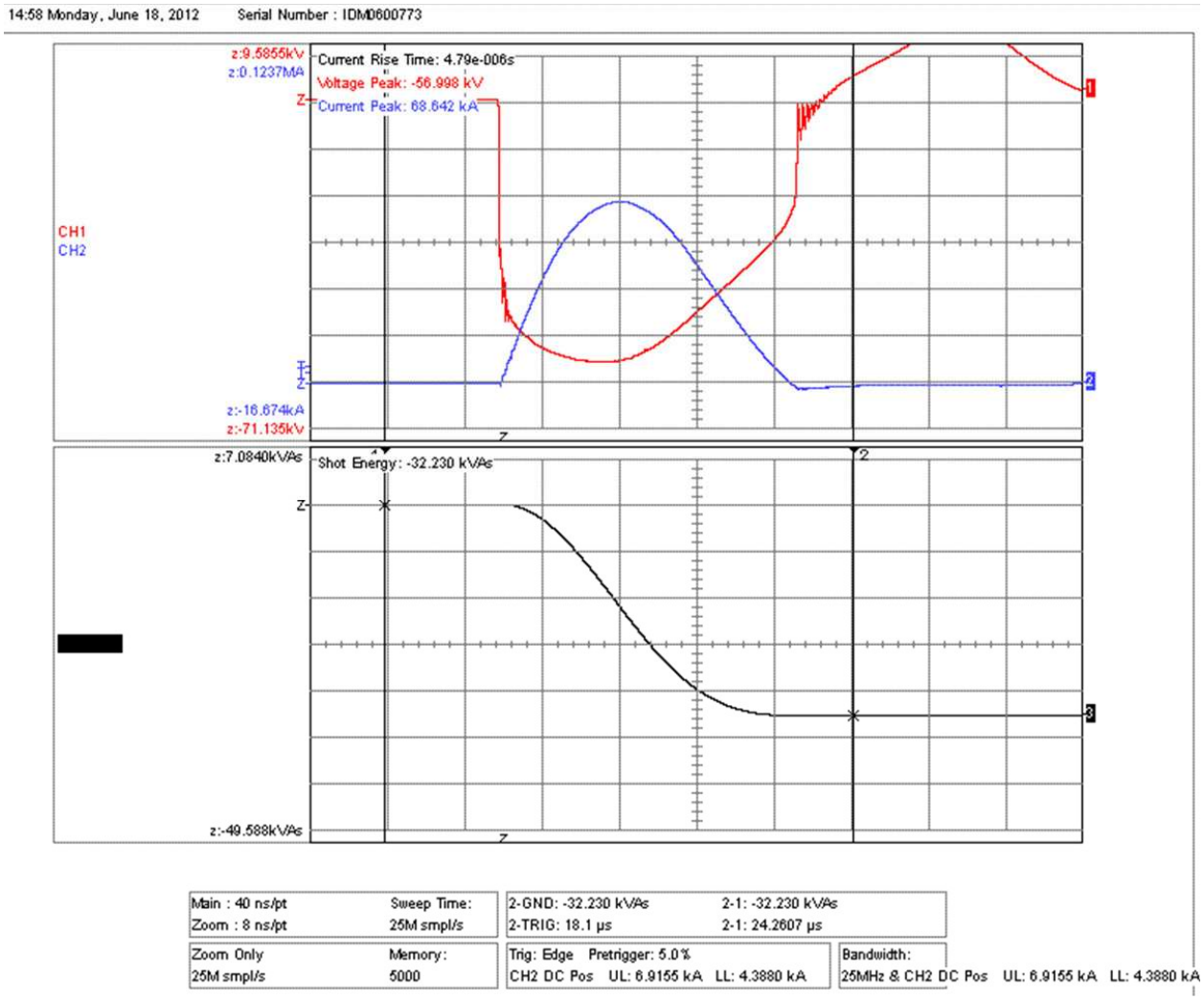
Test Results

The arrester was subjected to two nominal 65 kA 5.2/12.4 µs high current discharges. Table 5 summarizes the results of the 2 high current discharges.

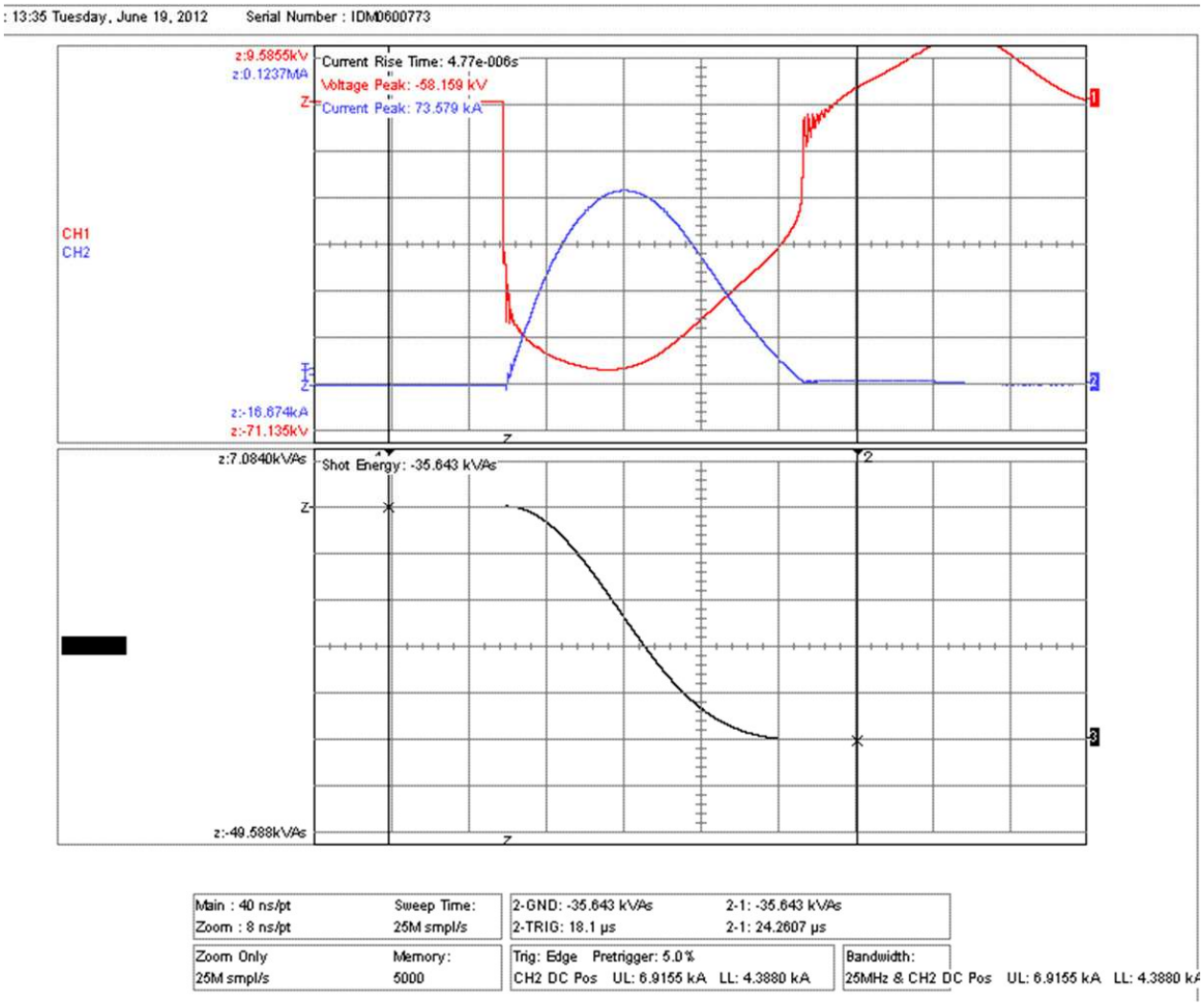
| Time | Date | Shot No. | KV | kA | Gen Charge |
|---|---|---|---|---|---|
| 14:58:43 | 06-18-2012 | 1 | 57.014 | 68.642 | -100.0 |
| 13:35:17 | 06-19-2012 | 2 | 58.176 | 73.579 | -115.0 |

**Table 5**

The following traces show the actual current values.




Sample 1
Shot 1
Discharge Current = 68.64 kA
Discharge Voltage = 57.01 kV



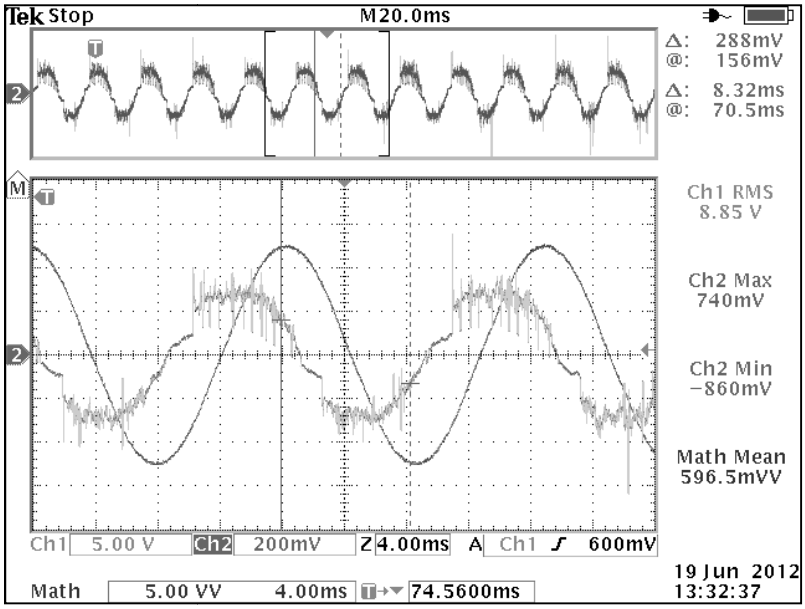

Sample 1
Shot 2
Discharge Current = 67.46 kA
Discharge Voltage = 56.31 kV

Within 5 minutes of the second high current discharge, the sample was energized at recovery voltage (8.82 kV rms) to represent the maximum allowed watts loss disc. The sample remained energized until thermal stability was demonstrated. Table 6 summarizes the measured watts of the test sample during the recovery portion of the test.

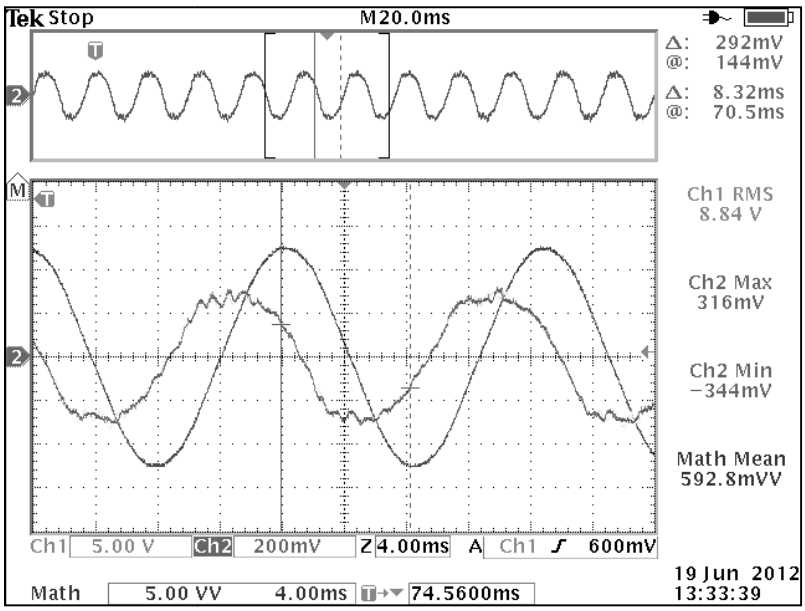
| Elapsed Time | Vrecovery (KVrms) | It (mA) | Ir (mA) | Watts |
|---|---|---|---|---|
| 0:00:00 | 8.85 | -2.16 | -0.30 | 1.50 |
| 0:00:30 | 8.84 | -0.87 | -0.38 | 1.54 |
| 0:01:00 | 8.85 | -0.86 | -0.39 | 1.49 |
| 0:02:00 | 8.67 | -0.82 | -0.34 | 1.31 |
| 0:05:00 | 8.69 | -0.78 | -0.27 | 1.16 |
| 0:10:00 | 8.71 | 0.76 | 0.22 | 1.04 |
| 0:20:00 | 8.63 | 0.83 | 0.19 | 0.89 |
| 0:30:00 | 8.68 | 0.89 | 0.13 | 0.83 |

Table 6

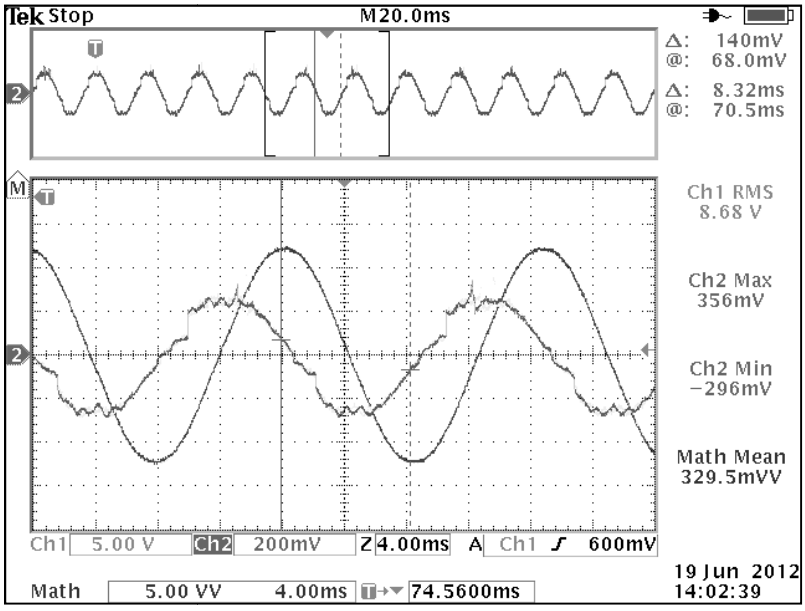
The following traces show the actual current, voltage values and wave shapes during the recovery period:




Sample #1 Recovery @ Time 0+
Ch1: 1kV/V Ch2: 2.508 mA/V




Sample #2 Recovery @ Time 1 Min.
Ch1: 1kV/V Ch2: 2.508 mA/V




Sample #3 Recovery @ Time 30 Min.
Ch1: 1kV/V Ch2: 2.508 mA/V

The sample 5 kA 8/20 µs discharge voltage was measured before and after the high current test. The measured values are summarized in table 7.

| | Sample No. | Shot | Time | Date | IR (KVc) | I (kA) | Chg KV | Result |
|---|---|---|---|---|---|---|---|---|
| Before | 1 | 1 | 11:27:52 | 6/20/2012 | 29.643 | 5.003 | 37.7 | Pass |
| After | 1 | 1 | 11:31:50 | 4/14/2012 | 30.986 | 5.037 | 37.2 | Pass |

**Table 7**

Test Summary

The test sample successfully completed the high current test and demonstrated thermal stability during the recovery test. The 5 kA 8/20 µs discharge voltage changed by an acceptable +4.5%, within the allowable 10% acceptance limit. Disassembly revealed no evidence of physical damage to the test sample. Therefore, the test sample has successfully fulfilled the high current, short duration requirements of the Dead-Front Type Arrester.

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## SECTION V
## LOW CURRENT, LONG DURATION TEST: ELBOW & PARKINGSTAND ARRESTER

Sample Preparation

This test was performed per Section 8.12 of IEEE Standard C62.l1-2005. The test was performed on a thermally insulated 8.4kV MCOV Arrester.

Test Procedure

Before and after the low current, long duration test, the 5 kA 8/20 µs discharge voltage of the test sample was measured.

The test sample was subjected to three groups of six consecutive operations followed by one group of two operations with a time interval between consecutive operations of 50-60 seconds. Sufficient time was allowed between groups of discharges for the sample to cool to ambient temperature (21°C). Prior to the l9$^{th}$ operation, the sample was heated to 85 °C. Within 5 minutes after the 20$^{th}$ low current discharge, the sample was energized at recovery voltage. The samples watts loss was monitored until thermal stability was demonstrated.

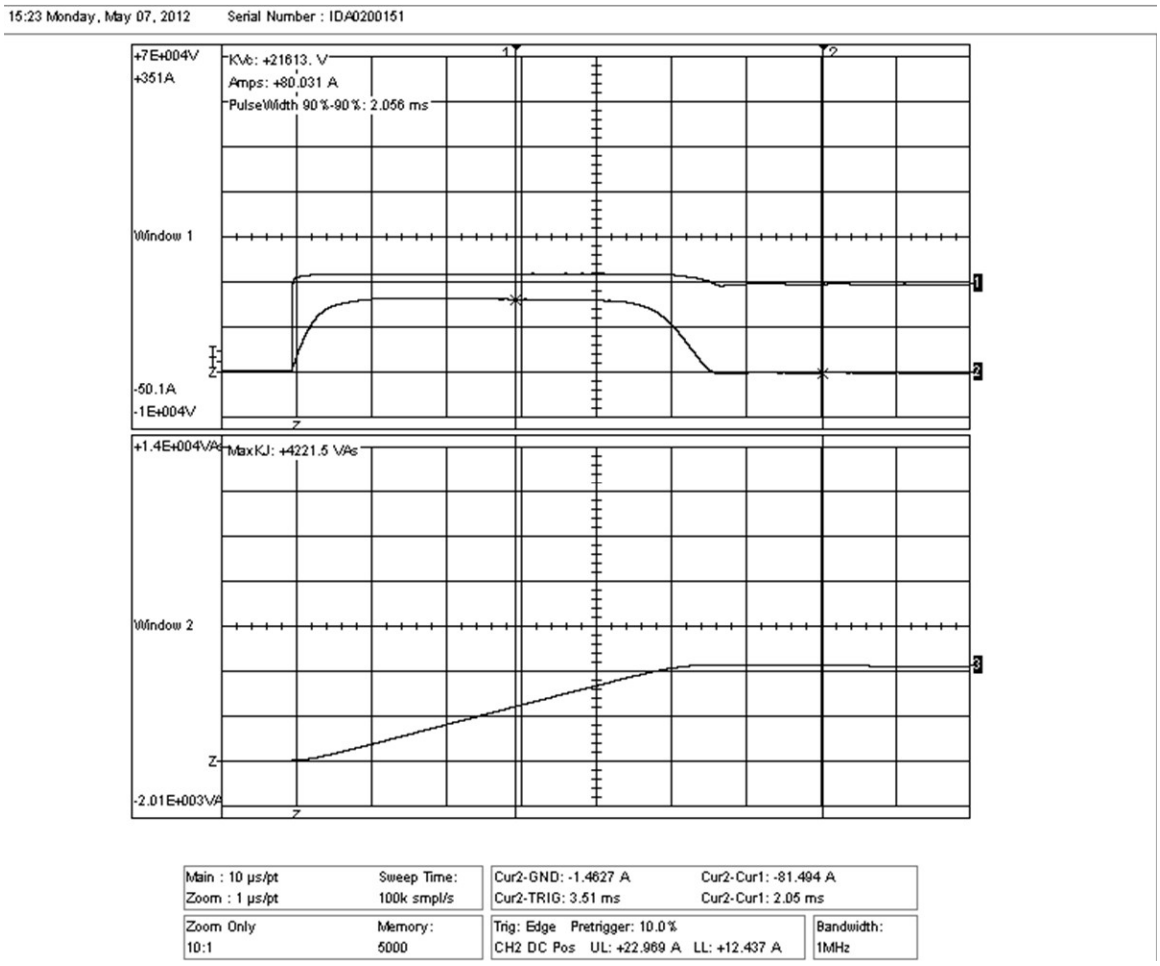
Test Results

The arrester was subjected to twenty long duration surges of 2000 microseconds. Current magnitude ranged from 75.4 to 83.8 amps during the 20 shot test. Table 8 summarizes the results of the 20 discharges.

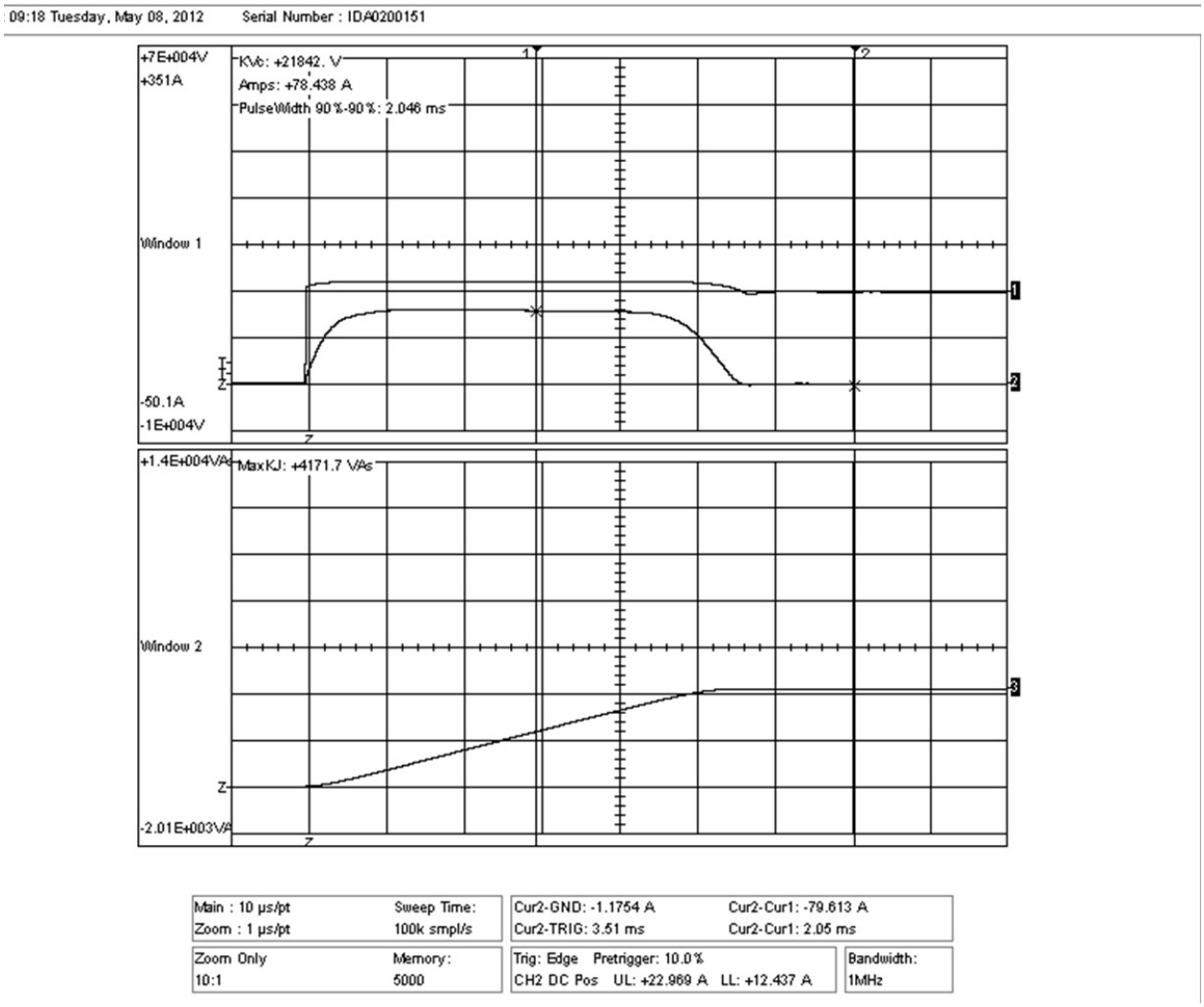
| Shot No. | Spec No. | Time | Date | KVc | Amps | KJ/Shot | Result | Trace |
|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 15:22:30 | 07 May 12 | 21.572 | 83.8 | 4.39 | Pass | |
| 2 | 3 | 15:23:16 | 07 May 12 | 21.613 | 80.0 | 4.22 | Pass | 1 |
| 3 | 3 | 15:24:01 | 07 May 12 | 21.655 | 77.5 | 4.11 | Pass | |
| 4 | 3 | 15:24:47 | 07 May 12 | 21.738 | 77.9 | 4.12 | Pass | |
| 5 | 3 | 15:25:32 | 07 May 12 | 21.842 | 80.4 | 4.26 | Pass | |
| 6 | 3 | 15:26:18 | 07 May 12 | 21.822 | 78.6 | 4.16 | Pass | |
| | | | | | | | | |
| 7 | 3 | 16:40:12 | 07 May 12 | 21.655 | 81.5 | 4.28 | Pass | |
| 8 | 3 | 16:40:57 | 07 May 12 | 21.717 | 79.4 | 4.19 | Pass | |
| 9 | 3 | 16:41:43 | 07 May 12 | 21.759 | 76.5 | 4.07 | Pass | |
| 10 | 3 | 16:42:28 | 07 May 12 | 21.801 | 78.2 | 4.15 | Pass | |
| 11 | 3 | 16:43:13 | 07 May 12 | 21.863 | 78.2 | 4.14 | Pass | |
| 12 | 3 | 16:43:59 | 07 May 12 | 21.884 | 75.9 | 4.05 | Pass | |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 13 | 3 | 09:15:47 | 08 May 12 | 21.655 | 81.4 | 4.28 | Pass | |
| 14 | 3 | 09:16:32 | 08 May 12 | 21.738 | 79.3 | 4.19 | Pass | |
| 15 | 3 | 09:17:18 | 08 May 12 | 21.759 | 78.4 | 4.16 | Pass | |
| 16 | 3 | 09:18:03 | 08 May 12 | 21.801 | 78.6 | 4.18 | Pass | |
| 17 | 3 | 09:18:48 | 08 May 12 | 21.842 | 78.4 | 4.17 | Pass | |
| 18 | 3 | 09:19:34 | 08 May 12 | 21.863 | 78.2 | 4.18 | Pass | |
| Specimen preheated to 85±5 ℃ Prior to shot 19 | | | | | | | | |
| 19 | 3 | 08:12:02 | 14 May 12 | 21.895 | 75.8 | 4.06 | Pass | |
| 20 | 3 | 08:12:48 | 14 May 12 | 21.978 | 75.4 | 4.03 | Pass | 2 |

**Table 8**




Shot 2. Trace 1



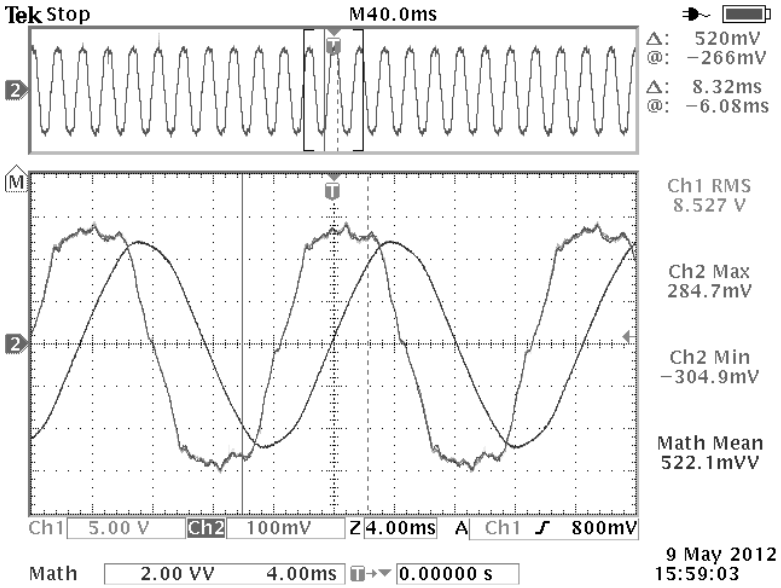

Shot 20, Trace 2

Within 5 minutes of the twentieth long duration discharge, the sample was energized at the recovery voltage (8.66 kV rms) to represent the maximum allowed watts loss disc. The sample remained energized until thermal stability was demonstrated. Table 9 summarizes the measured watts loss of the test sample during the recovery portion of the test.

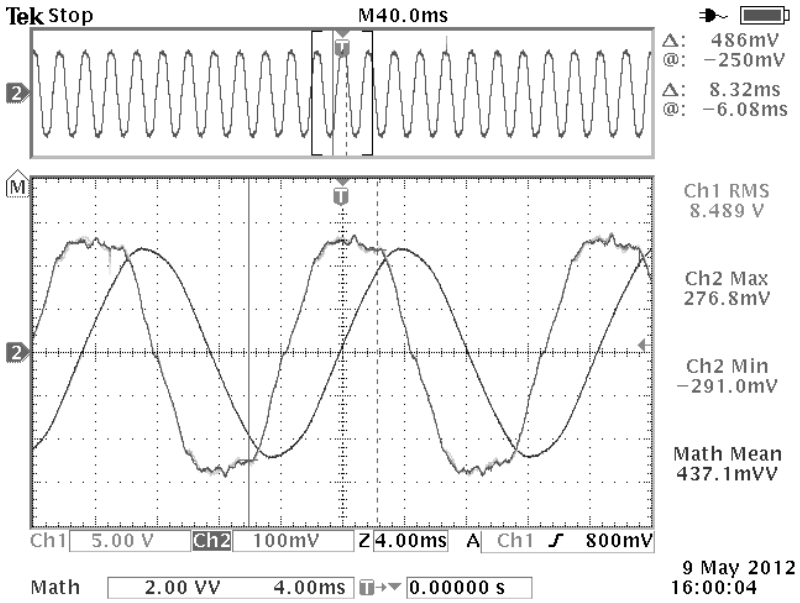
| Data No. | Elapsed Time | $KV_{RMS}$ | It (mA) | Ir (mA) | Watts | Trace |
|---|---|---|---|---|---|---|
| 1 | 00:00:00 | 8.747 | -1.19 | -0.70 | 1.14 | 3 |
| 2 | 00:00:30 | 8.740 | -1.22 | -1.00 | 1.07 | |
| 3 | 00:01:00 | 8.741 | -1.17 | -0.80 | 1.02 | 4 |
| 4 | 00:02:00 | 8.740 | -0.75 | -0.60 | 0.92 | |
| 5 | 00:04:00 | 8.512 | -0.70 | -0.57 | 0.75 | |
| 6 | 00:06:00 | 8.498 | -0.71 | -0.54 | 0.70 | |
| 7 | 00:08:00 | 8.519 | -0.69 | -0.54 | 0.67 | |
| 8 | 00:10:00 | 8.485 | -0.69 | -0.55 | 0.63 | |
| 9 | 00:12:00 | 8.503 | -0.68 | -0.54 | 0.61 | |
| 10 | 00:14:00 | 8.503 | -0.68 | -0.52 | 0.59 | |
| 11 | 00:16:00 | 8.475 | -0.69 | -0.52 | 0.56 | |
| 12 | 00:18:00 | 8.481 | -0.69 | -0.52 | 0.54 | |
| 13 | 00:20:00 | 8.469 | -0.67 | -0.51 | 0.52 | |
| 14 | 00:22:00 | 8.473 | -0.67 | -0.50 | 0.50 | |
| 15 | 00:24:00 | 8.475 | -0.69 | -0.51 | 0.49 | |
| 16 | 00:26:00 | 8.486 | -0.69 | -0.49 | 0.47 | |
| 17 | 00:28:00 | 8.481 | -0.67 | -0.52 | 0.46 | |
| 18 | 00:30:00 | 8.493 | -0.67 | -0.50 | 0.45 | 5 |

**Table 9**

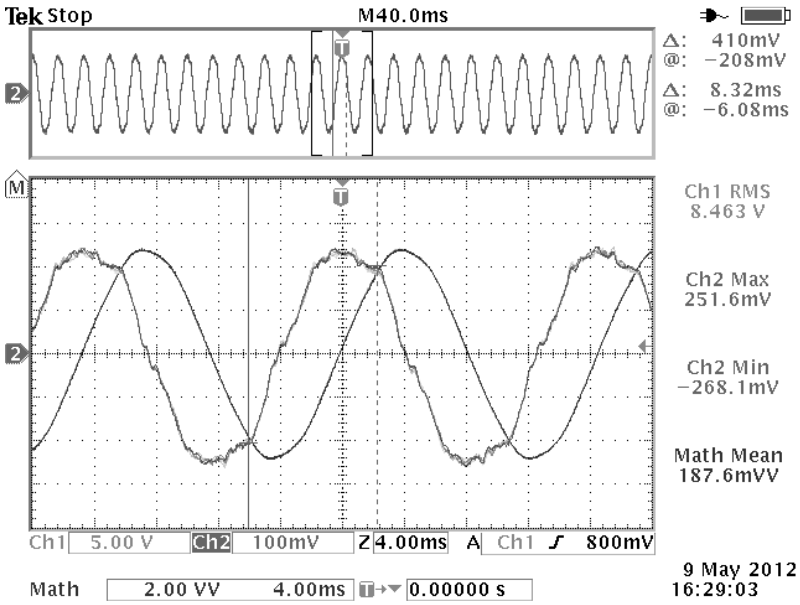
The following traces show the actual current, voltage values and wave shapes during the recovery period:




Trace 3
Recovery @ Time 0 – 1kV/V 2.508mA/V




Trace 4
Recovery @ 1 Min. – 1kV/V 2.508mA/V




Trace 5
Recovery @ 30 Min. – 1kV/V 2.508mA/V

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The sample's 5 kA 8/20 µs discharge voltage was measured before and after the high current test. The measured values are summarized in table 10.

| | Sample No. | Shot | Time | Date | IR (KVc) | I (kA) | Chg KV | Result |
|---|---|---|---|---|---|---|---|---|
| Before | 1 | 1 | 10:58:17 | 4/25/2012 | 29.374 | 5.182 | 37.25 | Pass |
| After | 1 | 1 | 15:15:07 | 5/11/2012 | 29.180 | 5.116 | 37.25 | Pass |

**Table 10**

Test Summary

The test sample successfully completed the low current, long duration test and demonstrated thermal stability during the recovery test. The 5 kA 8/20 µs discharge voltage changed an acceptable -0.7%, within the allowable 10% acceptance limit. Disassembly revealed no evidence of physical damage to the test sample. Therefore, the test sample successfully fulfilled the low current, long duration requirements of the Dead-Front Type Arrester.

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## SECTION VI

## DUTY CYCLE TEST: ELBOW & PARKINGSTAND ARRESTER

Sample Preparation

This test was performed per Section 8.14 of IEEE Standard C62.11-2005. The test was performed on a thermally insulated full size 8.4kV MCOV arrester.

Test Procedure

Before and after the duty cycle test, the 5 kA 8/20 µs discharge voltage of the test sample was measured.

The test sample was then energized at duty cycle rated voltage and subjected to (20) 5 kA 8/20 µs discharges spaced one minute apart. Per the standard, these 5 kA discharges were electrically timed to occur at approximately 60° before 60-Hz voltage crest.

The test sample was preheated to 85 °C and was subjected to two additional 5 kA 8/20 µs duty cycle operations while energized at MCOV. After the twenty-second duty cycle operation, the sample was energized at recovery voltage. The sample's watts loss was monitored until thermal stability was demonstrated.

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Test Results

The arrester was energized at duty cycle rated voltage (14.2 kV rms ) and subjected to (20) 5 kA surges spaced one minute apart. Table 11 summarizes the results of the 20 surges.

| Shot No. | Shot Time | Impulse (kA) | $V_{RATED}$ ($KV_C$) | 60Hz $I_t$ (mA) | 60Hz $I_r$ (mA) | Watts |
|---|---|---|---|---|---|---|
| 1 | 9:34:35 | 5.1 | 14.191 | 0.96 | 0.25 | 0.63 |
| 2 | 9:35:26 | 5.1 | 14.201 | -0.87 | -0.15 | 0.66 |
| 3 | 9:36:17 | 5.1 | 14.226 | 0.91 | 0.28 | 0.77 |
| 4 | 9:37:07 | 5.0 | 14.201 | 1.32 | 0.23 | 0.80 |
| 5 | 9:37:58 | 5.0 | 14.181 | 3.48 | 0.33 | 0.72 |
| 6 | 9:38:49 | 4.9 | 14.201 | 0.97 | 0.33 | 0.89 |
| 7 | 9:40:30 | 4.9 | 14.224 | 2.08 | 0.35 | 0.90 |
| 8 | 9:41:21 | 5.0 | 14.211 | 1.36 | 0.30 | 0.97 |
| 9 | 9:42:12 | 5.0 | 15.469 | -3.53 | -0.18 | 0.88 |
| 10 | 9:43:02 | 4.9 | 15.441 | 3.49 | 0.28 | 0.98 |
| 11 | 9:43:53 | 5.0 | 14.287 | 3.49 | 0.33 | 0.78 |
| 12 | 9:44:43 | 4.9 | 14.210 | -1.04 | -0.30 | 1.15 |
| 13 | 9:45:34 | 4.9 | 14.173 | 3.53 | 0.30 | 0.81 |
| 14 | 9:46:24 | 4.9 | 14.240 | 1.00 | 0.30 | 1.23 |
| 15 | 9:47:15 | 5.0 | 14.199 | -0.85 | -0.35 | 1.23 |
| 16 | 9:48:06 | 5.0 | 14.154 | 1.40 | 0.45 | 1.26 |
| 17 | 9:48:56 | 5.0 | 14.188 | 1.14 | 0.35 | 1.30 |
| 18 | 9:49:47 | 4.9 | 14.146 | 1.02 | 0.40 | 1.34 |
| 19 | 9:50:38 | 4.9 | 14.105 | -1.13 | -0.25 | 1.31 |
| 20 | 9:51:28 | 4.9 | 14.140 | -0.98 | -0.28 | 1.35 |

**Table 11**

After successful completion of the (20) shot test, the sample was preheated to 85 °C and subjected to an additional two 5 kA surges spaced one minute apart with the sample energized at MCOV (8.5 kV rms). Table 12 summarizes the results of the 2 additional surges.

| Shot No. | Shot Time | Impulse (kA) | $V_{RECOVERY}$ ($KV_{RMS}$) | 60Hz $I_t$ (mA) | 60Hz $I_r$ (mA) | Watts |
|---|---|---|---|---|---|---|
| 21 | 13:04:36 | 4.8 | 8.472 | -0.63 | -0.08 | 0.36 |
| 22 | 13:05:27 | 4.7 | 8.479 | 1.27 | 0.15 | 0.42 |

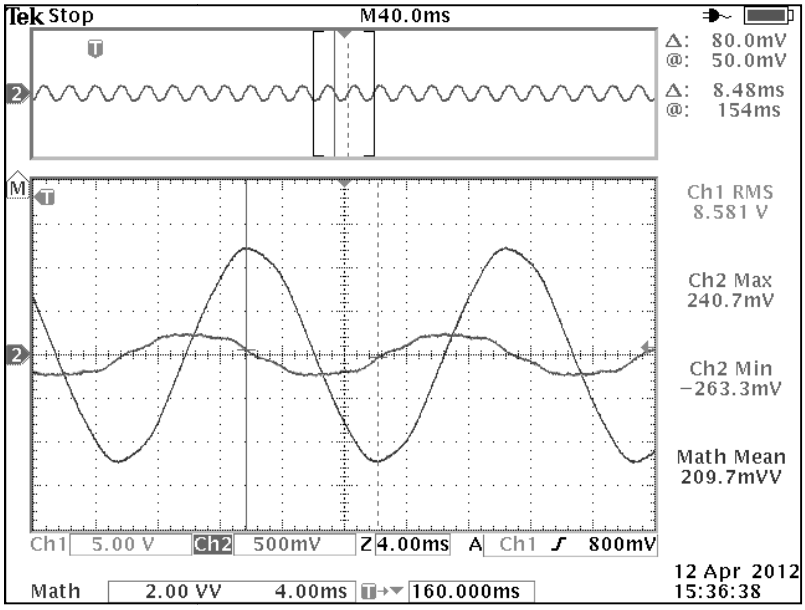
**Table 12**

The sample was energized after the 22nd 5 kA surge at recovery voltage until thermal stability was demonstrated. The recovery voltage represents the maximum allowed watts loss disc. Table 13 summarizes the results of the recovery voltage test.

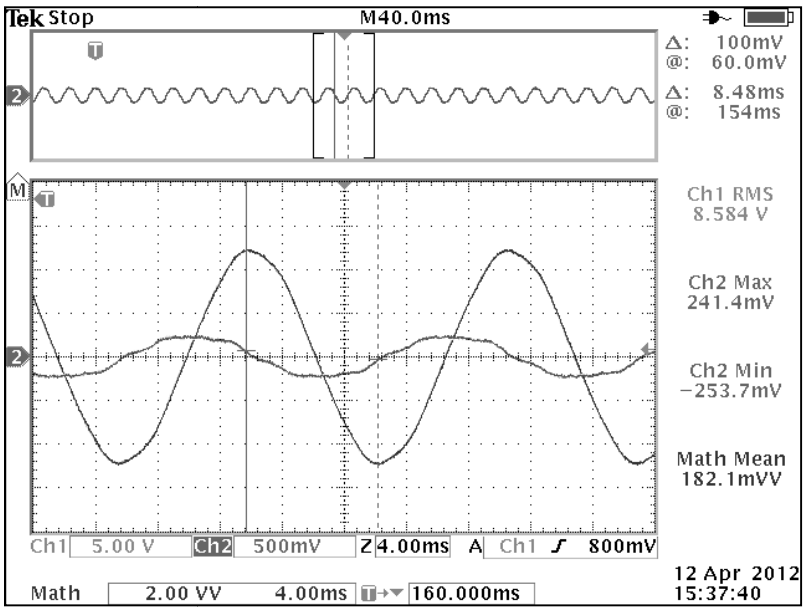
| Elapsed Time | $V_{RECOVERY}$ ($KV_{RMS}$) | 60Hz $I_t$ (mA) | 60Hz $I_r$ (mA) | Watts |
|---|---|---|---|---|
| 0:00:00 | 8.50 | -0.62 | -0.100 | 0.41 |
| 0:00:30 | 8.51 | -0.64 | -0.075 | 0.37 |
| 0:01:00 | 8.49 | -0.62 | -0.050 | 0.35 |
| 0:02:00 | 8.49 | -0.63 | -0.075 | 0.33 |
| 0:05:00 | 8.49 | -0.63 | -0.025 | 0.30 |
| 0:10:00 | 8.48 | -0.61 | -0.050 | 0.28 |
| 0:20:00 | 8.47 | -0.62 | -0.050 | 0.25 |
| 0:30:00 | 8.50 | -0.61 | -0.050 | 0.22 |

**Table 13**

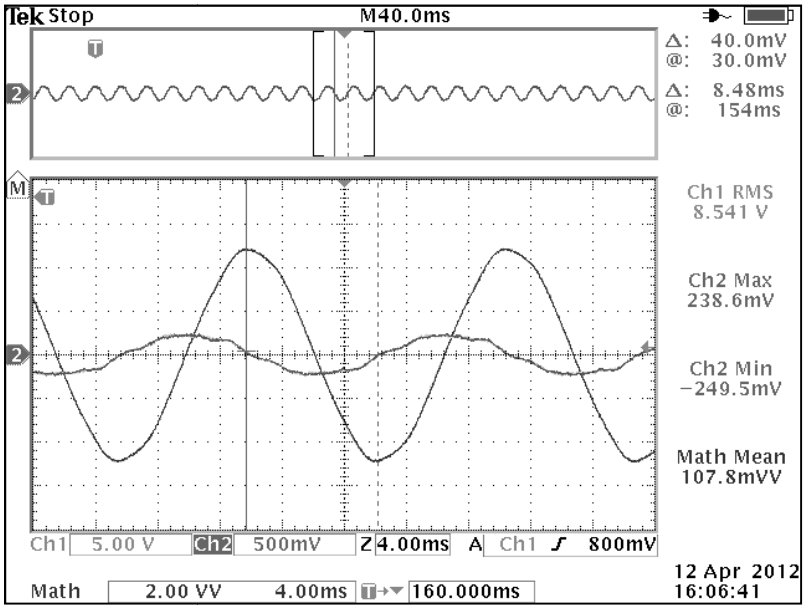
The following traces show the actual current, voltage values and wave shapes during the recovery period:




Sample #1 Recovery @ Time 0+
Ch1: 1kV/V Ch2: 2.508 mA/V




Sample #1 Recovery @ Time 1 Min.
Ch1: 1kV/V Ch2: 2.508 mA/V




Sample #1 Recovery @ Time 30 Min.
Ch1: 1kV/V Ch2: 2.508 mA/V

The sample 5 kA 8/20 µs discharge voltage was measured before and after the duty cycle test. The measured values are summarized in Table 14.

| | Sample No. | Shot | Time | Date | IR (KVc) | I (kA) | Chg KV | Result |
|---|---|---|---|---|---|---|---|---|
| Before | 1 | 1 | 11:27:52 | 4/09/2012 | 29.553 | 4.962 | 37.2 | Pass |
| After | 1 | 1 | 10:05:38 | 4/14/2012 | 30.986 | 5.037 | 37.2 | Pass |

**Table 5**

Conclusion

The test sample successfully completed the duty cycle test and demonstrated thermal stability while being energized at recovery voltage. The 5 kA 8/20 µs discharge voltage changed an acceptable +4.8%, within the allowable 10% acceptance limit. Disassembly revealed no evidence of physical damage to the test sample. Therefore, the test sample has successfully fulfilled the duty cycle requirements of the Dead-Front Type Arrester.

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## SECTION VII

## TEMPORARY OVERVOLTAGE CAPABILITY TEST: ELBOW & PARKINGSTAND ARRESTER

Introduction

This test was performed per Section 8.15 of IEEE Standard C62.11-2005. The tests were performed on (5) prorated test samples, selected to represent the most severe design conditions, i.e., the minimum allowed discharge voltage level.

Test Procedure

Per Section 8.15.1, each prorated sample is tested in (5) different time ranges ranging from (.01-.1 seconds) to (1,001-10,000 seconds). Per Section 8.15.3.1, the test is performed to demonstrate the temporary overvoltage (TOV) capability of the design under "no prior duty" conditions. For each TOV voltage setting, the test circuit applies the voltage to the sample (preheated to 85°C) for time duration sufficient to exceed that claimed on the "no prior duty" curve. Within 100 milliseconds after the TOV, a recovery voltage is applied for (30) minutes to demonstrate thermal stability. The recovery voltage level takes into account the maximum allowed watts loss for the sample.

Prior to and after the TOV application, the 5 kA discharge voltage of each sample is measured.

Test Results

Tests were successfully completed on (5) prorated samples in (5) specified time ranges. Each sample demonstrated thermal stability after TOV exposure. Table 15 summarizes the TOV values for the Normal Duty Elbow/Parkingstand arrester for "no prior" conditions.

| Sample Number | TOV Duration (Seconds) | No Prior Duty TOV (Per Unit MCOV) |
|---|---|---|
| 3, 5, 7, 8 & 9 | 0.1 | 1.63 |
| 3, 5, 7, 8 & 9 | 1. | 1.53 |
| 3, 5, 7, 8 & 9 | 3.0 | 1.49 |
| 3, 5, 7, 8 & 9 | 10 | 1.45 |
| 3, 5, 7, 8 & 9 | 1000 | 1.35 |

**Table 65**

Table 16 summarizes the 5 kA discharge voltages of the samples measured prior to and after the TOV test.

| Sample Number | 5 kA IR Before TOV Test | 5 kA IR After TOV Test | Percent Change |
|---|---|---|---|
| 3 | 27.186 kV | 27.300 | 0.42 |
| 5 | 26.960 kV | 27.316 | 1.32 |
| 7 | 26.977 kV | 27.300 | 1.20 |
| 8 | 27.009 kV | 27.396 | 1.43 |
| 9 | 27.025 kV | 27.283 | 0.95 |

**Table 16**

Conclusion

The 5 kA 8/20 µs discharge voltage of each sample changed less than 1.43% as a result of the TOV duty. Disassembly revealed no evidence of physical damage caused by the TOV testing. The individual test points successfully confirmed the claimed TOV capability curve. The following curve plots the individual "no prior duty" TOV data points on the TOV capability curve.

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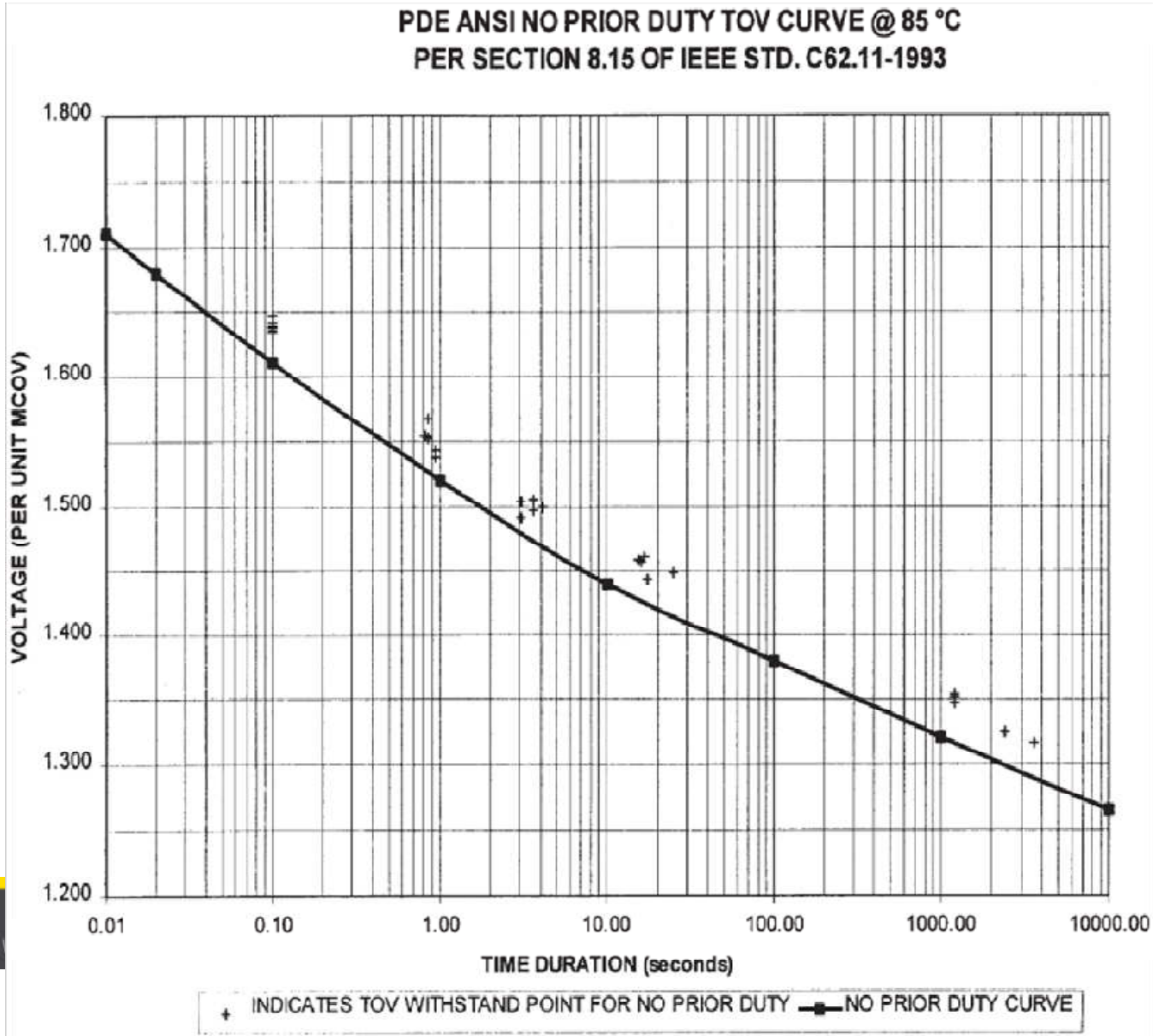

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## SECTION VIII

## ACCELERATED SEALING LIFE TEST: ELBOW & PARKINGSTAND ARRESTER

Introduction

This test was performed per Section 7.12 of IEEE/ANSI Standard 386-2006, "IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600V".

Test Setup

Per section 7.12 the four arresters were placed in an oven having l2l°C temperature for three weeks. The four samples were then removed and operated once using the operating eye.

The four arresters were then subjected to 50 cycles of being placed for l hour in a l21°C temperature oven then removed and submerged in 25°C ± l0°C conductive water for l hour.
At the completion of the 50th cycle the samples were measured for watts loss and subjected to the design impulse test (section 7.5.3 of IEEE/ANSI Standard 386-2006).

Test Results

No change in watts loss was observed and no puncture or flashover occurred when the samples were subjected to impulse. Table 17 summarizes the watts loss @ 8.4 kV before and after the Accelerated Sealing Life Test

| Sample Number | Initial Watts | Final Watts |
|---|---|---|
| 9 | 0.15 | 0.15 |
| 10 | 0.16 | 0.15 |
| 19 | 0.18 | 0.17 |
| 20 | 0.16 | 0.16 |

**Table 17**

Conclusion

The four samples successfully completed the accelerated sealing life test. They did not demonstrate an appreciable change in watts loss and did not flashover or puncture when subjected to impulse testing.

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## SECTION IX

## DEADFRONT ARRESTER FAILURE MODE: ELBOW & PARKINGSTAND ARRESTER FAULT CURRENT WITHSTAND TESTS

Introduction

This test was performed per Section 8.20 of IEEE Standard C62.1 1-2005.

Test Setup

Per section 8.20, the arresters were prefauled. An open-circuit test voltage was then applied within 5 minutes of the prefault mode. Three arresters were tested with a fault current of 500 A for a minimum duration of 0.3 s (20 c), three additional arresters were tested at a fault current of 10,000 A for a minimum duration of 0.17 s (10 c).

Test Results

Each of the samples subjected to fault current expelled the valve elements intact with release of the bottom grounded cap.

Conclusion

None of the samples tested fractured or ejected valve elements through the body of the arrester, therefore demonstrating conformance to the test standard. Oscillographic recordings showed conformance with the current magnitude and duration specified.

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## SECTION X

## PARTIAL DISCHARGE TEST: ELBOW & PARKINGSTAND ARRESTER

Introduction

This test was performed per Section 7.4 of ANSI/IEEE Standard 386-2006 "IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V".

Test Setup

The equipment and test methods conformed to ANSI/IEEE Standard 386-2006 "IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V" requirements. Prior to the test, the CDO 77A Corona Detector was calibrated by the Calibrator Type CDO-Cl.

Test Results

A background noise level of 0.5 pC was measured prior to energization of the arrester housing. The arrester housing noise level met the requirements of IEEE 386 -2006.

Conclusion

The Arresters successfully passed the internal ionization and PD tests by not exceeding the allowed 3 pC test limit. Internal ionization tests are routinely performed on all arresters.

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## SECTION XI

## OPERATING-FORCE TEST: ELBOW & PARKINGSTAND ARRESTER

Introduction

This test was performed per Section 7.14 of IEEE/ANSI Standard 386-2006 “IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V". The tests were performed on (4) assembled arresters.

Test Procedure

Per Section 7.14 each of the assembled elbow arresters were tested at -20°C, +25°C and + 65°C. Each test consisted of closing the connector and then reopening it within 10 min. The force was applied to the operating eye parallel to the axis of the probe at a rate of 5 in/min.

Test Results

Table 18 summarizes the results of the operating-force tests.

| Sample Number | Open -20°C (lbf) | Open +25°C (lbf) | Open +65°C (lbf) | Close -20°C (lbf) | Close +25°C (lbf) | Close +65°C (lbf) |
|---|---|---|---|---|---|---|
| 1 | 191 | 136 | 125 | 136 | 167 | 131 |
| 2 | 184 | 74 | 106 | 167 | 169 | 124 |
| 3 | 177 | 151 | 85 | 148 | 162 | 84 |
| 4 | 177 | 121 | 85 | 168 | 164 | 144 |

**Table 18**

Conclusion

The arresters performed within the 50 lbf — 200 lbf force requirement of IEEE/ANSI 386-2006 Standard.

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## SECTION XII

## OPERATING-EYE TEST: ELBOW ARRESTER

Introduction

This test was performed per Section 7.15 of IEEE/ANSI Standard 386-2006 “IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V".

Setup

Two separate tests were run on the operating-eye. For both tests, the elbow arresters were tested at ambient temperature. Four elbow arresters were used in each of the two tests. For the first test, four elbow arresters were pulled in tension until they broke. The purpose of this test was to obtain maximum load values for the operating-eye. For the second test, four elbow arresters were tested for partial discharge. Then the operating-eye was loaded with both a tensile force and a rotational force using a live-line tool. The purpose of this test was to demonstrate that the operating-eye could support a 14 N-m (120 lbf-in) rotational force, along with a static operating force of 2,224 N (500 lbf).

Procedure

Test 1: Average Maximum Load

a. Using the large cantilever, the 1,500 lb. tensile load cell, and the Omega meter, a tensile force was gradually applied to the operating-eye of each elbow arrester in the direction of normal operation.
b. The tensile force was gradually applied until the operating-eye failed by pulling away from the elbow arrester.
c. The maximum load was then recorded from the Omega meter for each elbow arrester and an average load was calculated.

Summary

Each of the operating-eyes was able to hold more than the required 2,224 N-m (500 lbf). Table 19 summarizes the results of the operating eye maximum force tests.

| Sample Number | Maximum Force (lbf) |
|---|---|
| 1 | 822.4 |
| 2 | 896.2 |
| 3 | 896.2 |
| 4 | 892.5 |

**Table 19**

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Test 2: Static Force and Rotational Force Test

Partial discharge levels were obtained for four elbow arrester housings. A tensile load of 500 lbf was applied to each of the elbow arresters normal to the operating eye for 60 seconds. Using the Chance live line tool a rotational force of 120 lbf-in (14 N-m) was applied in both clockwise and counterclockwise directions. Partial discharge levels were then obtained for all four elbow arresters and compared to the initial values.

Summary

Some distortion of the operating-eye was evident, however, this was acceptable because the elbow was still serviceable and passed partial discharge requirements of the standard.

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## SECTION XIII

## SHIELDING TEST: ELBOW & PARKINGSTAND ARRESTER

Introduction

This test was performed per Section 7.18 of ANSI/IEEE Standard 386-2006, "IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V". Section 7.18 states that the test procedure shall be in accordance with IEEE Std. 592-1990, "IEEE Standard for Exposed Semiconducting Shields on High Voltage Cable Joints and Separable insulated Connectors".

Test Setup

The equipment and test methods conformed to IEEE Std. 592-1990, "IEEE Standard for Exposed Semiconducting Shields on High-Voltage Cable Joints and Separable insulated Connectors".
*Shield Resistance Test*: Arrester shield resistance measurements were performed on unaged samples and air oven aged samples (121°C ±5°C for 504 hours). The measurements were taken with the test specimen temperature at 20°C ±5°C and at 90°C ±5°C. *Fault-Current Initiation Test*: Test samples were prepared in accordance with section 4.3 of IEEE Std. 592-1990.

Test Results

Each sample, before and after aging, measured less than 5000Ω shield resistance. Samples also successfully initiated two consecutive fault-current arcs to ground as specified in 4.3. Table 20 summarizes the results of the shielding tests.

| Sample Number | R @ 20°C Unaged | R @ 90°C Unaged | R @ 20°C Aged 504Hrs. @ 121°C | R @ 90°C Aged 504Hrs. @ 121°C |
|---|---|---|---|---|
| 1 | 440 Ω | 396 Ω | 460 Ω | 1,330 Ω |
| 2 | 610 Ω | 620 Ω | 584 Ω | 1,330 Ω |

**Table 20**

Conclusion

The housings meet the requirements of IEEE Std. 592-1990 by demonstrating shield resistance less than 5000Ω and capability of initiating two consecutive fault-current arcs to ground as specified in 4.3.