



ANSI DESIGN TEST REPORT
Report No. EU 1415-HR-00.7
Type PDV 65 Distribution Class
Surge Arrester

This report records the results of the design tests made on Type PDV 65 Normal Duty Distribution Class surge arresters in accordance with IEEE Standard C62.11-2012 "IEEE Standard for Metal Oxide Surge Arresters for AC Power Circuits (> 1kV)".

Type tests performed on PDV65 arresters demonstrate full compliance with the relevant clauses of the referenced standard and apply to all Hubbell PDV65 arresters of this design manufactured and assembled at the following ISO 9001:2008 certified Hubbell locations:

Hubbell Power Systems
 1850 Richland Avenue, East
 Aiken, South Carolina
 29801

Hubbell Electric (Wuhu) Company, Ltd.
 Exports Processing Zone, No 68
 North Jiuhua Road, Wuhu City
 Anhui Province, PR China

The above locations manufacture, assemble, and test utilizing manufacturing, quality, and calibration procedures developed from Hubbell Engineering Department Specifications. Engineering Department Specifications are controlled by Arrester Business Unit design engineering in the USA.

Saroni Brahma

Saroni Brahma
 Design Engineer

Dennis W. Lenk

Dennis W. Lenk P.E.
 Principal Engineer

Date: 10/31/2013

Separate reports provide details of the tests, according to the following table:

Report No.	Description	Clause	Issue Date
EU 1415-HR-01.3	Insulation Withstand	8.1	10/31/2013
EU 1415-HR-02.4	Discharge Voltage	8.2	10/31/2013
EU 1415-HR-03.2	Disc Accelerated Aging	8.5	01/22/2014
EU 1415-HR-04.3	Polymer Accelerated Ageing	8.6	10/31/2013
EU 1415-HR-05.2	Salt Fog Accelerated Ageing⁴	8.7	12/16/2014
EU 1415-HR-06.3	Partial Discharge	8.11	10/31/2013
EU 1415-HR-07.4	High Current, Short Duration	8.12	10/31/2013
EU 1415-HR-08.4	Low Current, Long Duration	8.13	10/31/2013
EU 1415-HR-09.4	Duty Cycle	8.14	10/31/2013
EU 1415-HR-10.5	Temporary Overvoltage	8.15	10/31/2013
EU 1415-HR-11.4	Short Circuit for Polymer-Housed Arrester	8.18	10/31/2013
EU 1415-HR-12.4	Maximum Design Cantilever Load-Static	8.22	10/31/2013
EU 1415-HR-13.3	Arrester Seal Integrity Test	8.9	10/31/2013
EU 1415-HR-14.3	Arrester Disconnect Tests	8.21	10/31/2013
EU 1415-HR-15.4	Verification of Thermally Prorated Section	7.2.2	10/31/2013



TYPE TEST REPORT No. EU 1415-HR-01.3

Insulation Withstand Tests on PDV 65 Arrester Housing

CERTIFICATION

This is to certify that insulation withstand design tests have been successfully performed on Ohio Brass Type PDV 65 Distribution Class surge arresters.

Saroni Brahma
Saroni Brahma
Design Engineer

Dennis W. Lenk
Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT

Type PDV 65 Distribution Class Surge Arrester

TITLE: Arrester Insulation Withstand Tests:

OBJECTIVE: To demonstrate that the voltage withstand capability of the arrester housing external insulation meets the requirements as specified in the Insulation Withstand Table of IEEE Standard C62.11-2012.

CONCLUSION: Table 1 lists PDV65 arrester minimum strike distance and minimum leakage distance as well as minimum required 1.2/50 impulse withstand, 60 Hz wet, and 60 Hz dry withstand capabilities.

All PDV65 arrester ratings meet or exceed these levels of withstand voltage.

Table 1
Summary Data - Insulation Withstand Test

Catalog Number	MCOV (kV)	Rated Voltage (kV)	Arrester Strike Distance (in.)	Strike Distance w/ NEMA Bracket (in.)	Leakage Distance (in.)	60 Hz 10 s Wet Withstand (kV) crest	Required Bracket 10 sec wet 60 Hz Withstand kVrms	1.2/50 μ s Impulse Withstand (kV) crest
217253	2.55	3	6.1	5.2	15.4	9.9	3.8	20.3
217255	5.1	6	6.1	5.2	15.4	19.8	7.7	40.5
217258	7.7	9	6.1	5.2	15.4	29.7	11.5	55.4
217259	8.4	10	6.1	5.2	15.4	32.7	12.6	58.9
217560	10.2	12	6.1	5.2	15.4	39.7	15.3	80.9
213263	12.7	15	9.7	6.5	25.5	49.4	19.1	88.6
213265	15.3	18	9.7	6.5	25.5	59.5	23	103.1
213267	17.0	21	9.7	6.5	25.5	66.1	25.5	112.2
217570	19.5	24	11.5	8.0	30.8	75.8	29.3	139.3
213272	22.0	27	15.0	10.0	40.9	85.5	33	158.3
213274	24.4	30	15.0	10.0	40.9	94.9	36.6	182.8
213279	29.0	36	18.2	12.2	51.0	112.8	43.5	221.5



TYPE TEST REPORT No. EU 1415-HR-02.4

Discharge Voltage Characteristic PDV65 Distribution Arresters

CERTIFICATION

This is to certify that the discharge voltage characteristic design tests have been successfully performed on Ohio Brass Type PDV65 Normal Duty Distribution Class surge arresters.

A handwritten signature in black ink that reads "Saroni Brahma".

Saroni Brahma
Design Engineer

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DESIGN TEST REPORT

Type PDV65 Distribution Class Surge Arrester

Introduction: Discharge voltage tests were performed on three 29mm diameter x 42mm long MOV discs. Tests were conducted in accordance with clause 8.3 of ANSI/IEEE Standard C62.11-2012“ IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (>1kV)”. Individual MOV discs were subjected to 8/20 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 results of the discharge voltage tests for each MOV are summarized on Table 1, which shows the actual voltage measurements on each MOV disc at each wave shape and current level. On the right side of table 1, for each disc, the measured residual voltage levels are normalized against that disc’s 8/20 5 kA IR. For each current level/wave shape, the highest ratio has been bolded. It is this bolded factor (for each current magnitude/wave shape) that is used to verify that all protective levels derived from the 8/20 5 kA IR for each arrester rating do not exceed the guaranteed maximum discharge voltage for that rating.

Table 1
Sample Discharge Voltage Data Summary

Impulse Current (A)	Wave Shape	Discharge Voltage (kV)			Discharge Voltage Ratio		
		Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
500	60/100	17.719	17.702	17.685	0.809	0.808	0.810
1,500	8/20	15.552	15.560	15.535	0.878	0.879	0.878
3,000	8/20	16.690	16.682	16.648	0.942	0.942	0.941
5,000	8/20	17.719	17.702	17.685	1	1	1
10,000	8/20	19.396	19.417	19.417	1.095	1.097	1.098
20,000	8/20	22.212	22.254	22.254	1.254	1.257	1.258
10,000	1/2	18.741	18.867	18.791	1.058	1.066	1.063

Conclusions: Arresters are assembled from discs accumulated within the 5 kA IR ranges that are specified for each arrester rating. To verify that catalog maximum IR levels were not exceeded, a discharge voltage ratio was established in Table 1 for each current level based on the MOV disc’s 8/20 5 kA IR. Table 2 utilizes the discharge voltage ratio factors and extrapolates the expected discharge voltage values for each arrester build and compares that with the catalog discharge voltage values for that arrester rating. As Table 2 verifies, in all cases the extrapolated IR values are less than the catalog guaranteed values. Note that the FOW values for each arrester has been corrected, per Section 8.2.2.3 of C62.11-2012 Standard, to include the affects of arrester inductive voltage drop.

Table 2
PDV65 Arrester Discharge Voltage Summary

		IR Multipliers	0.81	0.876	0.942	1	1.098	1.258	1.066	FOW including Ldi/dt
		Impulse Wave	60/100	8/20	8/20	8/20	8/20	8/20	0.5μsecV	Total FOW
MCOV	Rating	I Magnitude (A)	500	1500	3000	5000	10000	20000	10000	kV
2.55	3	Prorated Sect Max IR Catalog Maximum IR	7.71 7.79	8.34 8.42	8.97 9.06	9.52 9.62	10.45 10.56	11.98 12.10	10.15 10.25	10.85 10.96
5.1	6	Prorated Sect Max IR Catalog Maximum IR	15.51 15.67	16.78 16.94	18.04 18.22	19.15 19.34	21.03 21.24	24.09 24.33	20.41 20.62	21.11 21.33
7.65	9	Prorated Sect Max IR Catalog Maximum IR	23.22 23.45	25.11 25.37	27.01 27.28	28.67 28.96	31.48 31.79	36.07 36.43	30.56 30.87	31.26 31.57
8.4	10	Prorated Sect Max IR Catalog Maximum IR	24.87 25.12	26.89 27.16	28.92 29.21	30.70 31.01	33.71 34.05	38.62 39.01	32.73 33.05	33.43 33.76
10.2	12	Prorated Sect Max IR Catalog Maximum IR	31.02 31.33	33.55 33.89	36.08 36.44	38.30 38.68	42.05 42.47	48.18 48.66	40.83 41.24	41.53 41.94
12.7	15	Prorated Sect Max IR Catalog Maximum IR	37.30 37.30	40.34 40.34	43.38 43.38	46.05 46.05	50.56 50.56	57.93 57.93	49.09 49.09	50.19 50.19
15.3	18	Prorated Sect Max IR Catalog Maximum IR	44.87 45.32	48.53 49.02	52.19 52.71	55.40 55.95	60.83 61.44	69.69 70.39	59.06 59.65	60.16 60.76
17	21	Prorated Sect Max IR Catalog Maximum IR	50.06 50.56	54.14 54.68	58.22 58.80	61.80 62.42	67.86 68.53	77.74 78.52	65.88 66.54	66.98 67.65
19.5	24	Prorated Sect Max IR Catalog Maximum IR	62.05 62.67	67.10 67.77	72.16 72.88	76.60 77.37	84.11 84.95	96.36 97.33	81.66 82.47	83.06 83.89
22	27	Prorated Sect Max IR Catalog Maximum IR	68.10 68.78	73.65 74.38	79.19 79.99	84.07 84.91	92.31 93.23	105.76 106.82	89.62 90.51	91.37 92.28
24.4	30	Prorated Sect Max IR Catalog Maximum IR	75.90 76.66	82.08 82.90	88.27 89.15	93.70 94.64	102.88 103.91	117.87 119.05	99.88 100.88	101.63 102.65
29	36	Prorated Sect Max IR Catalog Maximum IR	89.75 90.65	97.06 98.03	104.37 105.42	110.80 111.91	121.66 122.87	139.39 140.78	129.69 130.98	131.84 133.16



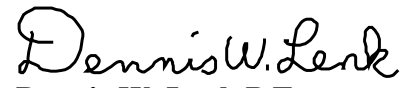
TYPE TEST REPORT No. EU 1415-HR-03.3

Disc Accelerated Aging

CERTIFICATION

This is to certify that the disc accelerated aging design tests have been successfully performed on Ohio Brass Type PDV 65 Distribution Class Surge arresters.


Saroni Brahma
Design Engineer


Dennis W. Lenk P.E.
Principal Engineer

1/22/2014
attachments

DESIGN TEST REPORT
PDV65 Distribution Class Surge Arrester

TITLE: Accelerated aging procedure

TEST PROCEDURE: Tests were performed to measure MOV disc aging characteristics. Measured watts values are used to develop elevated voltage ratios k_c and k_r for use in prorating test voltages applied to samples for durability design tests.

TEST SAMPLES: Two arrester modules each assembled with one 42 mm long disc, and three arrester modules each assembled with 21mm long disc were prepared.

TEST PROCEDURE: Tests were performed per Section 8.5 of ANSI/IEEE C62.11-2012 Standard. Samples were placed inside a $115\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$. oven and energized at MCOV for 1,000 hours. Watts loss was recorded @ MCOV at the start and conclusion of the 1000 hour test.

TEST RESULTS: Table 1 below summarizes test data from this test.

Table 1

Sample # (21mm)	Watts loss @ 2 hours @ MCOV $P_{1c}(w)$	Watts loss @ 1000 hours @ MCOV $P_{2c}(w)$	Elevation Factor k_c
1	0.85	0.45	1
2	0.53	0.32	1
3	0.51	0.31	1

Table 2

Sample # (42mm)	Watts loss @ 2 hours @ MCOV $P_{1c}(w)$	Watts loss @ 1000 hours @ MCOV $P_{2c}(w)$	Elevation Factor k_c
1	1.00	0.60	1
2	1.04	0.61	1
3	1.03	0.60	1

CONCLUSION: Each test sample demonstrated continually declining watts loss at MCOV. The watts loss at rating also declined. Therefore, k_c factor equals 1.0.



TYPE TEST REPORT No. EU 1415-HR-04.3
Polymer Accelerated Aging

CERTIFICATION

This is to certify that the polymer accelerated aging design tests have been successfully performed on Ohio Brass Type PDV 65 Distribution Class surge arresters.

A handwritten signature in black ink that reads "Saroni Brahma".

Saroni Brahma
Design Engineer

A handwritten signature in black ink that reads "Dennis W. Lenk".

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT

PDV 65 Distribution Class Surge arrester

TITLE: Accelerated aging tests of external polymeric insulating systems for distribution Arresters.

TEST PROCEDURE: These tests were performed per clause 8.6 of IEEE Standard C62.11-2012. Accelerated aging tests by exposure to light were performed per clause 8.6.1 test method 8.6.1.2.c. Tests on polymer housing and insulating bracket material using the fluorescent UV technique described in ASTM G53-1996. Test duration was 1000 hours on three samples of each material. Accelerated aging tests by exposure to electrical stress were performed per clause 8.6.2.

TEST SAMPLES: Three PDV-65 10.2 kV MCOV and three PDV-65 17 kV MCOV arresters were tested. These represent the highest MCOV stress based on leakage distance and arcing distance. Tests were performed by attaching arresters to a vertical Ferris wheel, where the arresters are continuously energized. As the wheel rotates, each arrester is sequentially sprayed with a 400 ohm-centimeter water spray. As the energized arrester rotates around the wheel, the arrester housing goes through a dry band arcing condition. The test continues until each arrester has reached 1000 hours of energized test time. Prior to and after the 1000 hour test, each arrester is subjected to a 5 kA 8/20 discharge to confirm its electrical integrity.

The final portion of the test procedure consists of subjecting each arrester insulating bracket to 20 hours on voltage with the insulating bracket energized at MCOV. At the completion of the above tests, the arresters are examined to ensure there is no evidence of surface tracking.

CONCLUSION: Both polymer housing and insulating bracket materials passed the test requirements of clause 8.6.1.3, as there were no cracks greater than the allowed depth of .1 mm. The arresters also passed the requirements of clause 8.6.2.4, as the arrester discharge voltage changed by less than 1 % as a result of the 1000 hour Ferris wheel test. There was no evidence of external flashovers, punctures, or internal breakdowns during the described tests. There was no evidence of surface tracking on the arrester housings after the 1000 hour on-voltage test or on the insulating bracket after the 20 hour on-voltage test.



TYPE TEST REPORT No. EU 1415-HR-05.2

Salt Fog Accelerated Aging Test PDV 65 Optima Arrester

CERTIFICATION

This is to certify that the salt fog accelerated aging design test has been successfully performed on Ohio Brass Type PDV 65 Optima Heavy Duty Distribution Class surge arresters.

A handwritten signature in black ink that reads "Saroni Brahma".

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Design Engineer

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12/16/2013
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DESIGN TEST REPORT
PDV 65 Optima Distribution Class Surge Arrester

TITLE: 1000 Hour Salt Fog Exposure Test

TEST OBJECTIVE: Perform 1000 hour salt fog exposure test per section 8.7 of C62.11 – 2012 Standard.

TEST SAMPLE: Two 29 kV MCOV arresters were tested. Arrester #1 was tested with its insulating support bracket attached to the base end of the arrester. Arrester #2 was tested without the insulating support bracket.

TEST PROCEDURE: The arresters were mounted vertically inside the salt fog chamber. Prior to and after the 1000 hour test, the reference voltage and partial discharge of the sample were measured. The 1000 hour test was performed with a spray having an NaCl salt content of 10 kg/m³ per the procedure specified in section 8.7.3 of the standard

TEST RESULTS: The test arrester passed the 1000 hour salt exposure. The physical condition of the polymer housings showed no signs of surface tracking or surface erosion. There was no evidence of housing or shed punctures. The following table summarizes the results of the electrical testing.

Sample #	Reference Voltage kVc Before Salt Fog	Reference Voltage kVc After Salt Fog	Reference Voltage % Change	Partial Discharge After Salt Fog PC
1	44.5	45.0	+1.1	<1
2	44.0	45.0	+2.3	<1

Photograph #1 shows the salt-contaminated surfaces of the two arresters after completion of the 1000 hour duration salt fog test. Photograph # 2 shows a close-up view of the undamaged condition of the polymer housings. There was no evidence of surface tracking, erosion, or shed punctures.

Photograph #1



Photograph #2



CONCLUSION: The physical condition of the test arrester and the electrical testing confirmed that the PDV 65 Optima arrester successfully passed the 1000 hour salt fog exposure test.



TYPE TEST REPORT No. EU 1415-HR-06.3

Partial Discharge Test

CERTIFICATION

This is to certify that the RIV and partial discharge design tests have been successfully performed on Ohio Brass Type PDV 65 Distribution Class surge arrester.

A handwritten signature in black ink that reads "Saroni Brahma".

Saroni Brahma
Design Engineer

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Principal Engineer

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DESIGN TEST REPORT

PDV 65 Distribution Class Surge Arrester

TITLE: Internal-ionization voltage (IIV) and RIV tests:

TEST PROCEDURE AND SAMPLE: Partial discharge and RIV testing was performed per section 8.11 of IEEE Standard C62.11-2012. The test was performed on a 36 kV rated, 29.0 kV MCOV PDV-65 arrester.

TEST EQUIPMENT: Equipment and test methods conformed to NEMA LA 1-1992 requirements. Prior to the test, the Stoddart Noise Meter NM-25T was calibrated using a General Radio Signal Generator Type 1001-A.

TEST RESULTS: With the unshielded 36 kV arrester placed in the circuit, a noise level of 1.0 μV was measured at the 30.5 kV test voltage. Partial discharge measured 0 picocoulomb at 30.5 kVrms.

CONCLUSION: The 36 kV rated PDV-65 arrester passed test requirements as the measured RIV was below the allowed 10 microvolt limit and the partial discharge was below the allowed 10 picocoulomb limit.



TYPE TEST REPORT No. EU 1415-HR-07.4

HIGH CURRENT, SHORT DURATION TEST PDV65 Normal Duty Distribution Arrester

CERTIFICATION

This is to certify that the high current, short duration design test has been successfully performed on Ohio Brass Type PDV65 Normal Duty Distribution Class surge arrester.

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Design Engineer

Dennis W. Lenk
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10/31/2013
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DESIGN TEST REPORT
PDV65 Normal Duty Distribution Class Surge Arrester
High Current, Short Duration Discharge Withstand Tests:

Introduction: High current, short duration discharge withstand tests were performed per clause 8.12 IEEE Standard C62.11-2012. Tests were performed per Normal Duty Distribution arrester requirements using a prorated test section, as required in clause 8.12.1.

Test Procedure: Per Clauses 8.12.2 and 8.12.3, test sections were subjected to two 65 kA 4-6/10-15 surges, with cooling to ambient between surges. Within 100 msec after the 2nd surge, recovery voltage is applied for 30 minutes during which the arresters Watts is monitored to demonstrate thermal stability after the 2nd lightning surge.

Test Results: Each test sample was subjected to two 65 kA, 4/10 discharges. Sufficient time was allowed between discharges for the sample to cool to ambient temperature 23 °C. Within 100 msec after the second high current discharge, the sample was energized at the prorated section recovery voltage. Watts loss was monitored over a 30 minute period demonstrating thermal stability. Figures #1 and 2 show oscillograms of the two 100 kA shots, including the start of the 30 minute recovery portion of the tests performed on Sample #1. These are typical oscillograms for the three tested samples.

Figure #1
First Shot
70.142 kA Magnitude

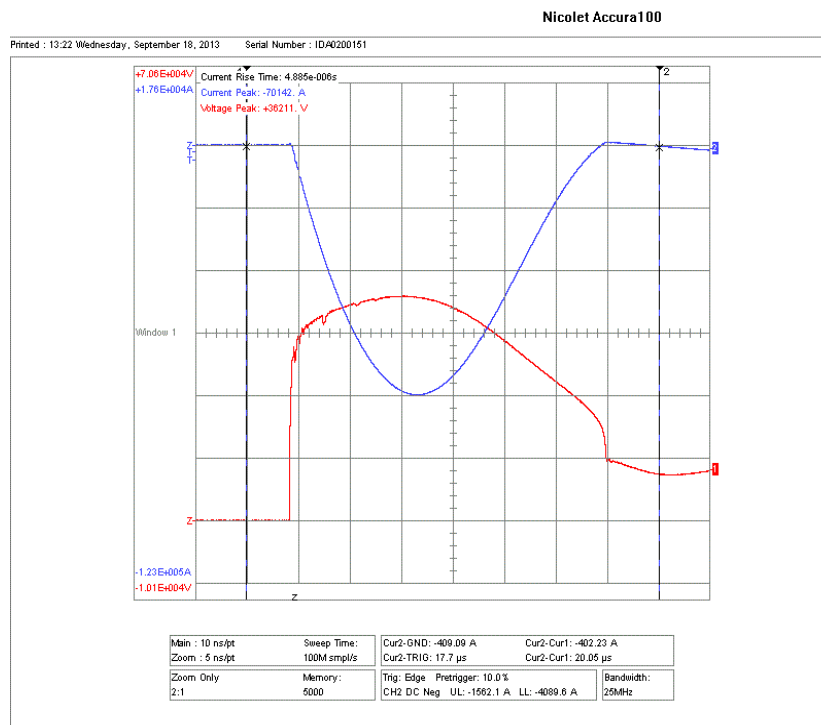


Figure #2
Second Shot, Including 84 msec application of recovery voltage
65.953 kA Magnitude

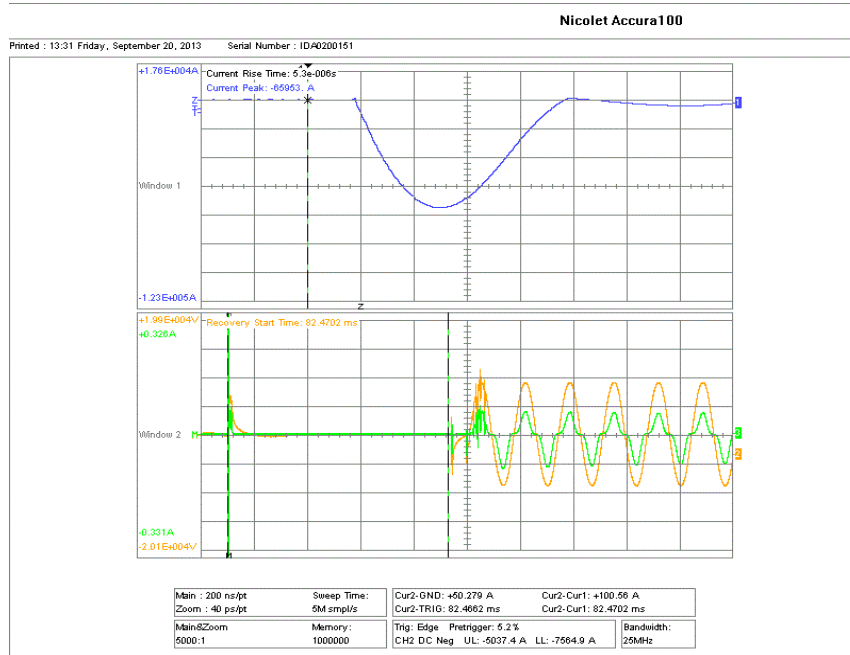


Table #1 summarizes the results of the two 65 kA shots and the watts measured during the 30 minute recovery test performed on the three test samples.

Table #1

Shot No.	Section 1 kA	Section 4 kA	Section 3 kA
1	70.142	66.010	66.192
2	65.953	69.390	68.403
N.O. Vacuum switch closed @ 84 msec			
Elapsed Time	Section 1 Watts	Section 4 Watts	Section 3 Watts
0:00:00	43.61	75.02	68.78
0:00:30	8.79	18.98	12.80
0:01:00	4.77	10.51	6.42
0:02:00	2.56	5.41	3.52
0:05:00	1.25	2.62	1.71
0:10:00	0.81	1.63	1.12
0:20:00	0.54	1.00	0.70
0:30:00	0.47	0.80	0.54

Residual voltage was measured on each test sample prior to and after the 65 kA surge duty test. Table #2 summarizes the results this testing.

Table #2

Sample #	5 kA IR Before - kVc	5 kA IR After – kVc	% Change
1	18.07	18.801	+4
4	18.05	18.500	+2.5
3	17.86	18.834	+5.5

Conclusion: The three prorated test samples successfully completed the high current test and demonstrated thermal stability during the recovery test. The 5 kA residual voltage increase ranged from 2.5 to 5.5%, less than the allowed 10%. Disassembly revealed no evidence of physical damage to the test sample. There was no detonation of the disconnect during the 2-shot 65 kA duty test. Two 12kV PDV65 sample were tested along with insulating brackets. The insulating brackets did not detonate while the two 65kA shots were applied. The PDV65 design successfully met the High Current, Short Duration requirements of a Normal Duty Distribution Class Arrester.



TYPE TEST REPORT No. EU 1415-HR-08.4

**LOW CURRENT, LONG DURATION TEST
PDV65 Normal Duty Distribution Arrester**

CERTIFICATION

This is to certify that the low current, long duration design test has been successfully performed on Ohio Brass Type PDV65 Normal Duty Distribution Class surge arrester.

A handwritten signature in black ink that reads "Saroni Brahma".

Saroni Brahma
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DESIGN TEST REPORT
PDV65 Normal Duty Distribution Class Surge Arrester
Low Current, Long Duration Discharge Withstand Tests

Introduction: The low current, long duration discharge withstand test was performed per clause 8.13 IEEE Standard C62.11-2012. Tests were performed per Normal Duty distribution arrester requirements using 6 kV rated test samples.

Test Samples: Per section 8.21.2.1, a ground lead disconnecter (GLD) was connected in series with each of the three LCLD 6 kV rated test samples.

Procedure: Per section 8.13.3, each test sample was subjected to six sets of three 75 A, 2000 μ s discharges. Sufficient time was allowed between sets of discharges for the section to cool to room ambient temperature. Per section 8.13.4, the 5 kA residual voltage of each MOV disc section was measured prior to and after the (18) shot LCLD test.

Results: Table 1 summarizes the results of the 18 shot test performed on the three test samples.

Table 1

Shot No.	Sample #1		Sample #2		Sample #3	
	Amps	KJ/Shot	Amps	KJ/Shot	Amps	KJ/Shot
1	80.0	2.46	77.8	2.40	76.9	2.38
2	80.0	2.46	79.2	2.46	77.8	2.42
3	81.3	2.51	79.2	2.45	76.8	2.40
4	81.3	2.50	78.5	2.43	78.6	2.44
5	82.1	2.53	77.7	2.41	75.6	2.36
6	82.5	2.55	79.0	2.46	76.8	2.40
7	81.2	2.51	79.0	2.45	77.8	2.42
8	78.6	2.43	77.3	2.40	77.3	2.41
9	80.5	2.49	79.2	2.47	76.6	2.39
10	80.2	2.47	78.9	2.45	75.7	2.36
11	79.9	2.47	77.7	2.41	76.5	2.39
12	80.4	2.49	79.0	2.46	75.3	2.36
13	78.3	2.42	78.4	2.44	70.5	2.20
14	79.7	2.47	76.6	2.39	74.7	2.34
15	81.7	2.54	78.7	2.45	76.1	2.39
16	76.5	2.36	74.3	2.31	73.0	2.28
17	75.9	2.35	74.2	2.31	76.1	2.38
18	78.3	2.43	77.4	2.42	76.2	2.39

Figures 1 and 2, respectively show oscillograms of the 1st and 18 shots performed on sample #2. These oscillograms are typical for all three test samples.

Figure #1

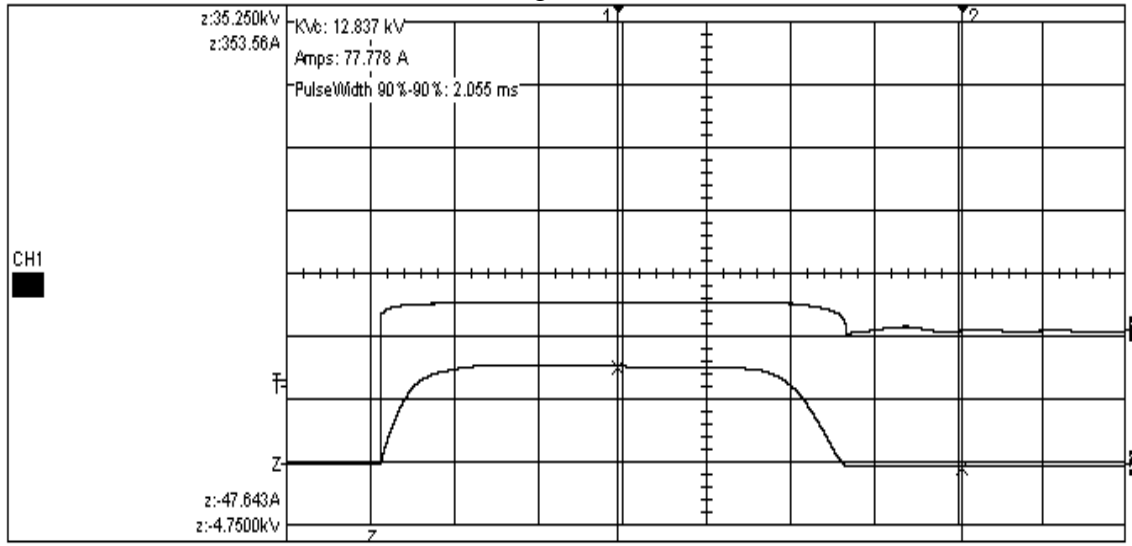
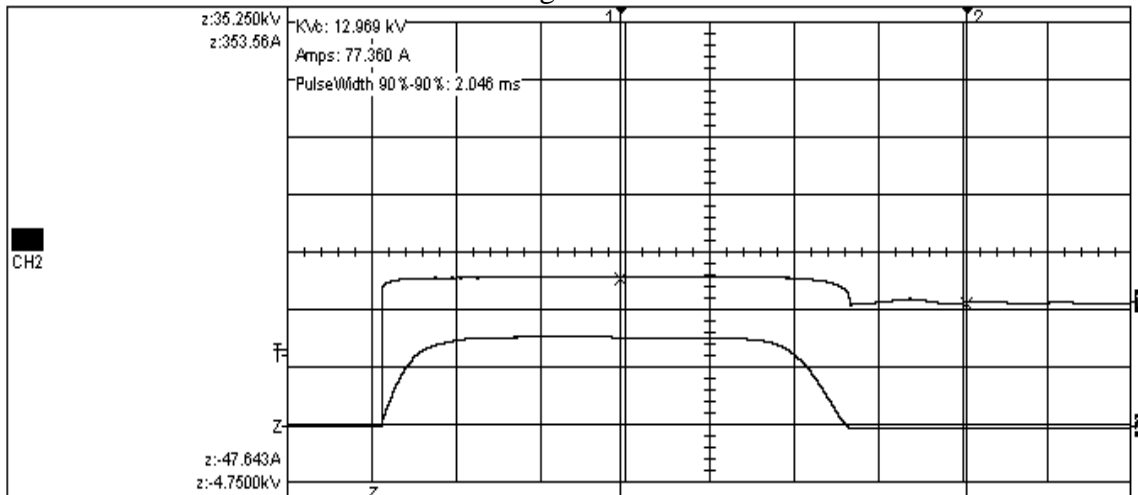


Figure #2



Residual voltage at 5 kA was measured prior to and following the 18-shot 75 A discharge tests. Table 2 summarizes the results of the 5 kA discharge voltage testing.

Table 2

Sample #	5 kA IR-kVc (Before)	5 kA IR-kVc (After)	5 kA IR % Change
1	17.525	17.479	-0.26
2	17.761	17.701	-0.34
3	17.735	17.764	+0.16

Conclusion: The prorated test samples successfully completed the 18-shot low current, long duration test. The maximum sample discharge voltage change was 0.16% well below the 10% change allowed in Section 8.13.4 of IEEE C62.11-2012 Standard. Disassembly revealed no evidence of physical damage to the test samples. The ground lead disconnectors did not detonate during the 18 shot test series. The insulating brackets were tested for detonation with heavy duty distribution class arresters (PDV100 and PVR rise pole) and withstood 250A for 2ms, thereby complying to 75A, 2ms LCLD test for insulating brackets requirements.

The PDV65 arrester successfully met the LCLD requirements of the Normal Duty Distribution Class arrester.



TYPE TEST REPORT No. EU1415-HR-09.4

DUTY CYCLE TEST

Type PDV 65 Normal Duty Distribution Arresters

CERTIFICATION

This is to certify that the duty cycle design test has been successfully performed on the Ohio Brass Type PDV 65 Normal Duty Distribution Class surge arrester per Clause 8.16 of IEEE C62.11-2012 Standard.

A handwritten signature in black ink that reads "Saroni Brahma".

Saroni Brahma
Design Engineer

A handwritten signature in black ink that reads "Dennis W. Lenk".

Dennis W. Lenk
Principal Engineer

10/31/ 2013
Attachments

DESIGN TEST REPORT

PDV 65 Normal Duty Distribution Class Surge Arrester

Duty Cycle Test

Introduction: Duty cycle tests were performed per clause 8.16 of IEEE Standard C62.11-2013. Tests were performed on the PDV 65 prorated sections per Normal Duty Distribution arrester requirements. As required by clause 8.21, tests were performed on three prorated sections with a ground lead disconnecter (GLD) to demonstrate that the GLD does not detonate during the test procedure.

Test Procedure: The prorated test section was energized at its rated voltage and subjected to twenty 5 kA, 8/20 μ s discharges spaced at 1 minute intervals. Following the twentieth impulse, the test section was placed in an oven at 66°C. After reaching 66°C, the sample was subjected to two additional 5 kA, 8/20 μ s discharges. Within 5 minutes after the second high current discharge, the sample was energized at the prorated recovery voltage. Watts loss was monitored over a 30 minute period demonstrating thermal stability.

Test Results: Tests were successfully completed on three prorated sections, each assembled with a GLD. The following data summarizes the results of tests performed on prorated section #1.

The following data summarizes the results of the duty cycle test performed on prorated section #1. Figures 1 and 2 show the 1st and 20th shot performed during the rated voltage portion of the duty cycle test.

Figure 1

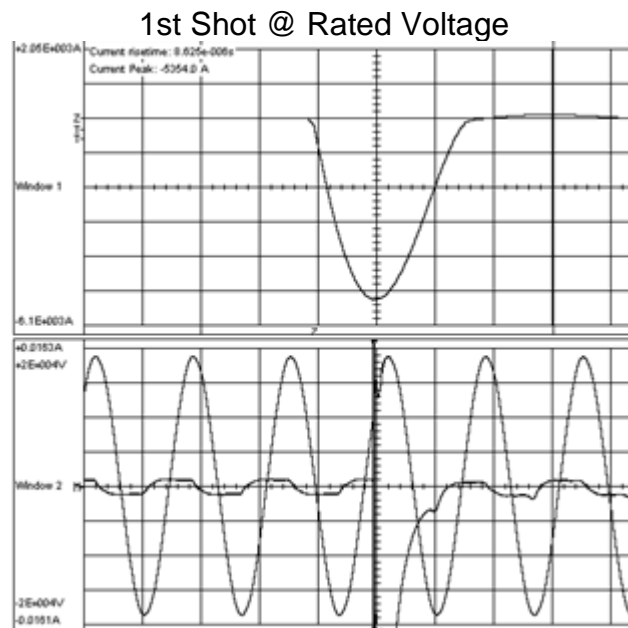


Figure 2

20th Shot @ Rated Voltage

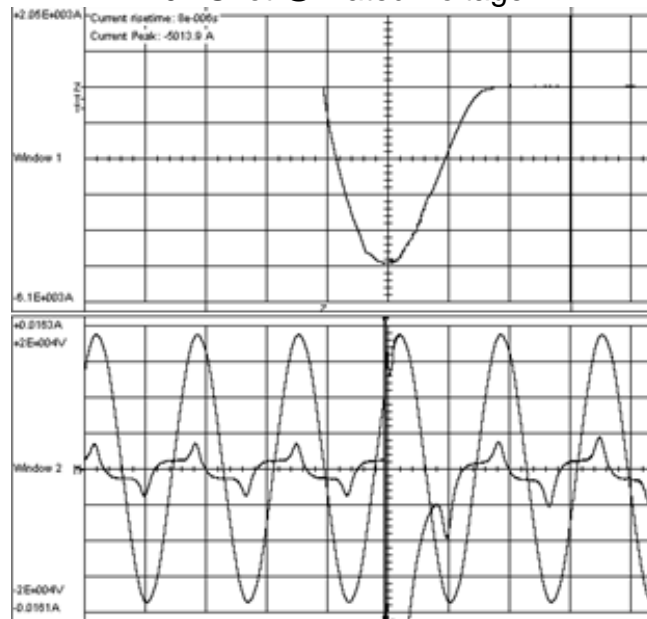
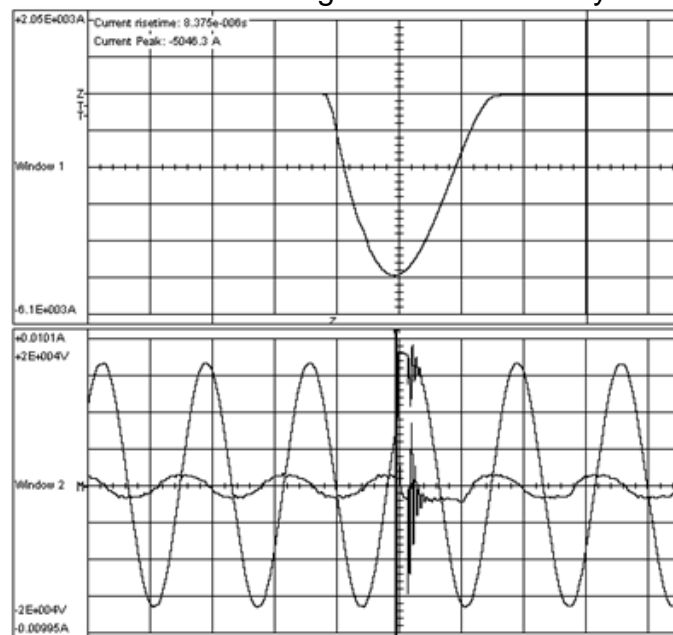


Figure 3 shows the oscillogram for the 2nd 5 kA impulse applied to the prorated section #1 during the recovery portion of the duty cycle test.

Figure 3

2nd 5 kA Discharge Prior to Recovery



Figures 4 and 5 show oscillograms of the prorated section #1 grading current through the test section at time zero and 30 minutes after application of recovery voltage, demonstrating thermal recovery has occurred.

Figure 4

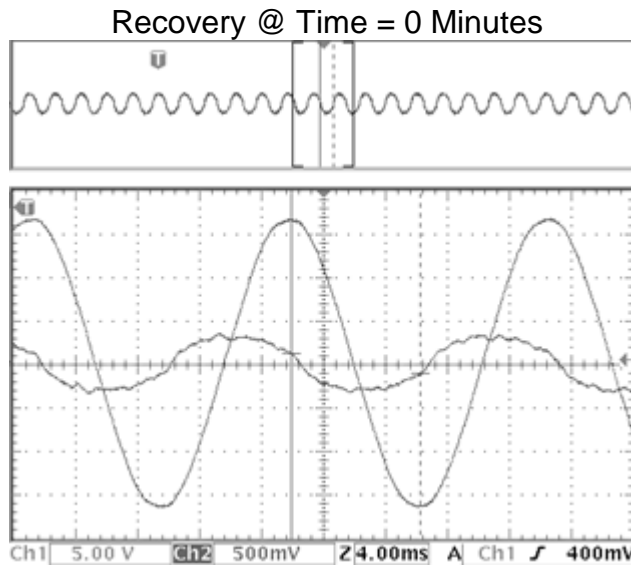
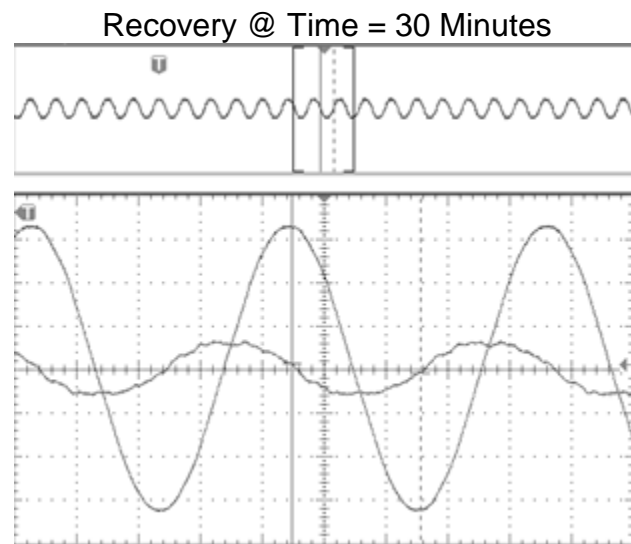


Figure 5



Prior to and after the duty cycle test, the 5 kA, 8/20 μ s discharge voltage was measured on the three prorated sections. Table 1 summarizes this test data.

Table 1

Section #	5 kAQ IR kVc (Before)	5 kAQ IR kVc (After)	5 kA IR % Change
1	33.645	33.879	0.7%
2	33.624	33.771	0.4%
3	33.561	33.820	0.8%

CONCLUSION: The Type PDV 65 prorated test samples successfully completed Duty Cycle testing and demonstrated thermal stability during the recovery test. The 10 kA discharge voltage increased 0.8%, less than the allowed 10% limit specified in Section 8.16.4 of the IEEE C62.11-2012 standard. Disassembly revealed no evidence of physical damage to the test samples. The ground lead disconnect (GLD) on each prorated section successfully withstood the duty cycle testing without detonating. The Type PDV 65 arrester successfully met the Normal Duty Distribution arrester Duty Cycle requirements.



TYPE TEST REPORT No. EU 1415-HR-10.5

TEMPORARY OVERVOLTAGE TEST PDV 65 Normal Duty Distribution Arrester

CERTIFICATION

This is to certify that the temporary overvoltage design test has been successfully performed on Ohio Brass Type PDV 65 normal duty Distribution Class surge arrester per Clause 8.17 of the IEEE C62.11-2012 Standard.

A handwritten signature in black ink that reads "Saroni Brahma".

Saroni Brahma
Design Engineer

A handwritten signature in black ink that reads "Dennis W. Lenk".

Dennis W. Lenk
Principal Engineer

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DESIGN TEST REPORT
PDV 65 Normal Duty Distribution Class Surge Arrester
Temporary Over-Voltage Tests (TOV) Performed on Arrester Section
Without Insulating Bracket:

Introduction; Temporary over-voltage tests were performed per clause 8.17 of IEEE Standard C62.11-2012. Tests were performed per Normal Duty distribution arrester requirements using four prorated test sections.

Test Sections: Nominally 6 and 12 kV rated prorated sections were used to facilitate testing. The short time data points were generated using 6 kV rated sections while the longer time data points used 12 kV rated sections. As both sizes of arresters were thermally equivalent to the highest rated PVR arrester, the results of these tests cover ratings 3 - 36 kV with corresponding MCOV levels of 2.55 - 29.0 kV.

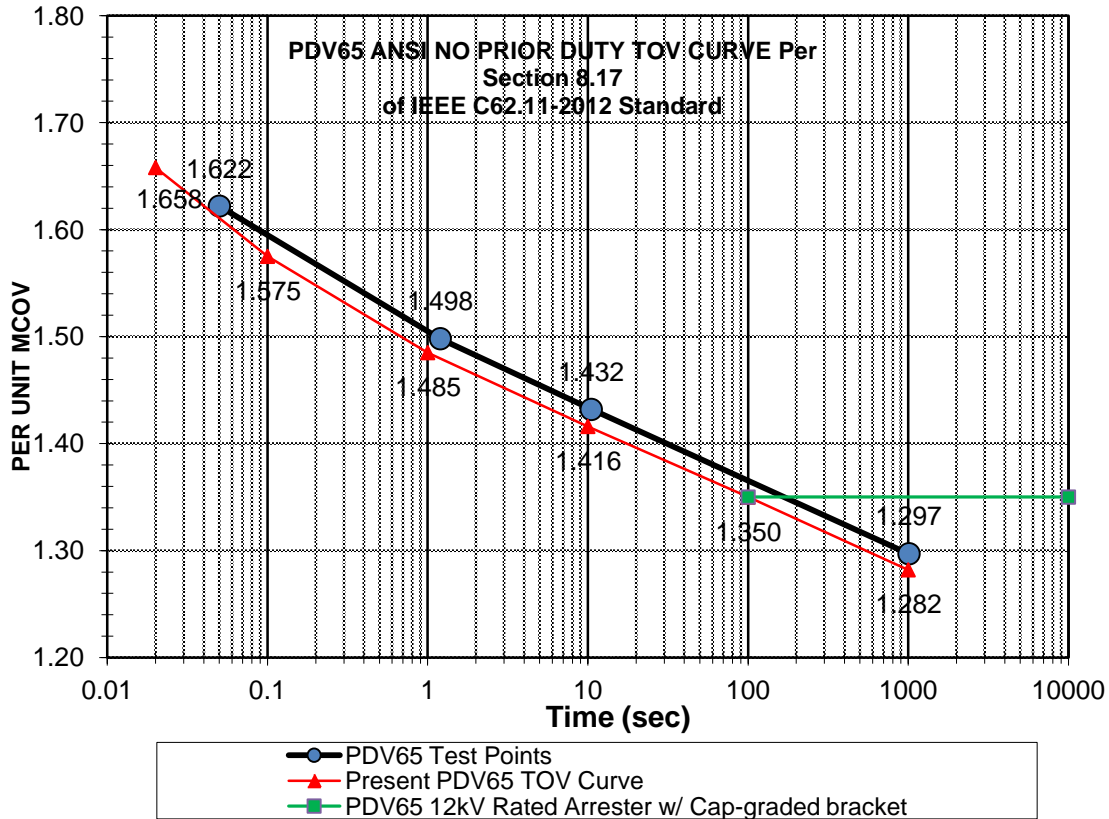
Results: Per clause 8.17.3, each prorated sample was tested within four of the six designated time ranges a - f, spanning over-voltage durations of .01 - 10,000 seconds. The tests were performed demonstrating TOV capability of the design under "no prior duty" conditions. For each TOV voltage setting, the test circuit applied voltage to the sample (preheated to 66°C) for a time duration sufficient to exceed that claimed on the "no prior duty" curve. TOV voltage was superimposed over recovery voltage such that when TOV was removed, there was no delay prior to application of recovery voltage. Recovery voltage was applied for 30 minutes to demonstrate thermal stability. As required by Section 8.17.3, Table 1 summarizes the Type PDV 65 No Prior Duty TOV data points for the arrester assembled without the ground lead disconnecting (GLD) bracket.

Table 1

Time-Seconds	TOV Per Unit Times MCOV
0.02	1.658
0.1	1.575
1	1.485
10	1.416
100	1.350
1000	1.282

Figure 1 summarizes the results of the TOV testing performed on the prorated sections without the ground lead disconnecting (GLD) bracket. The single 1.355 per unit MCOV/10,000 second data point was generated using a 12 kV rated section connected in series with the GLD bracket, validating the claimed 1.35 per unit MCOV/10,000 second claim for the 12 kV arrester mounted on the GLD insulating support bracket.

Figure 1



Per Section 8.17.4, the 5 kA discharge voltage for each test section was measured prior to and after TOV testing. Table 2 summarizes the results of that testing.

Table 2

Data Range	Time Seconds	Section Size	10 kA Discharge Voltage -kVc		
			Before TOV	After TOV	% Change
a	0.1	6 kV	17.332	17.224	-0.6%
c	1.2	6 kV	17.170	17.392	1.3%
d	10.5	12 kV	33.624	34.009	1.1%
f	1300	12 kV	33.624	34.139	1.5%

Conclusion: Tests were successfully completed on four prorated samples in four specified time ranges. Each sample demonstrated thermal stability after TOV exposure. Residual voltage at 10 kA measured prior to and after the TOV test series changed much less than the allowed 10%. There was no evidence of physical damage to the test sections, validating the PDV65 arrester TOV capability claim.

DESIGN TEST REPORT

PDV 65 Optima Distribution Class Surge Arrester

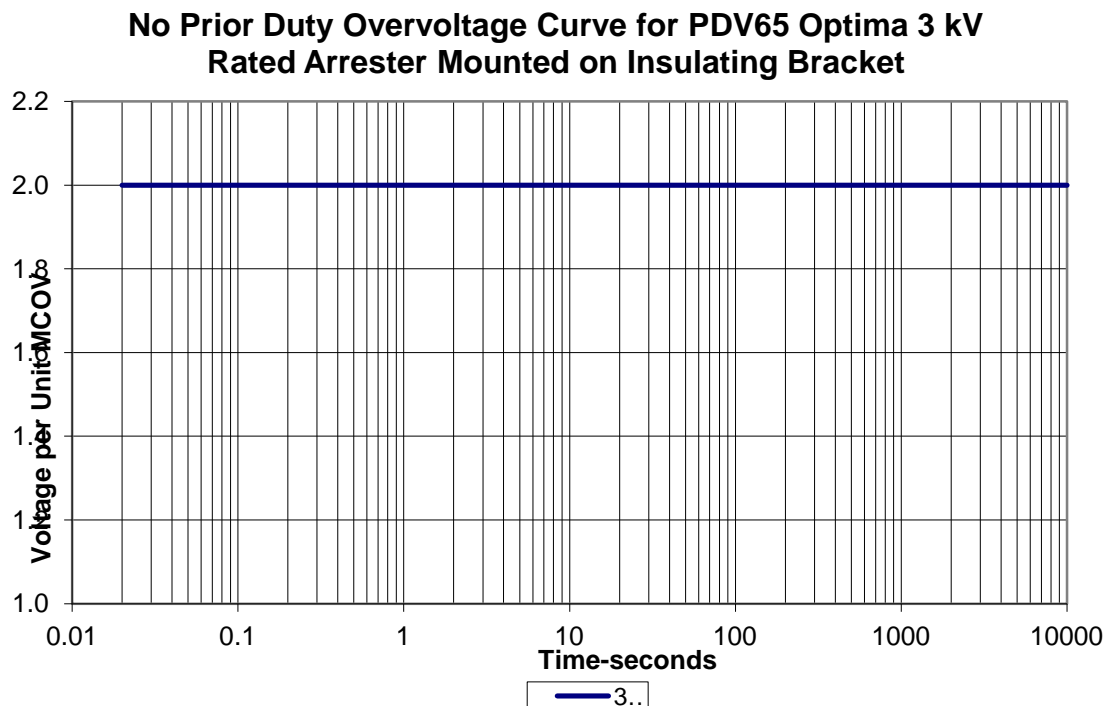
TITLE: Temporary over-voltage tests (TOV) performed on arrester with insulating bracket):

OBJECTIVE: Laboratory testing reveals that attachment of the PDV 65 Optima arrester to the insulating bracket significantly improves the long time TOV capability of the arrester assembly. The degree of improvement is a function of the individual arrester ratings. The following curves show the improved TOV characteristic of the various arrester ratings mounted to the insulating bracket.

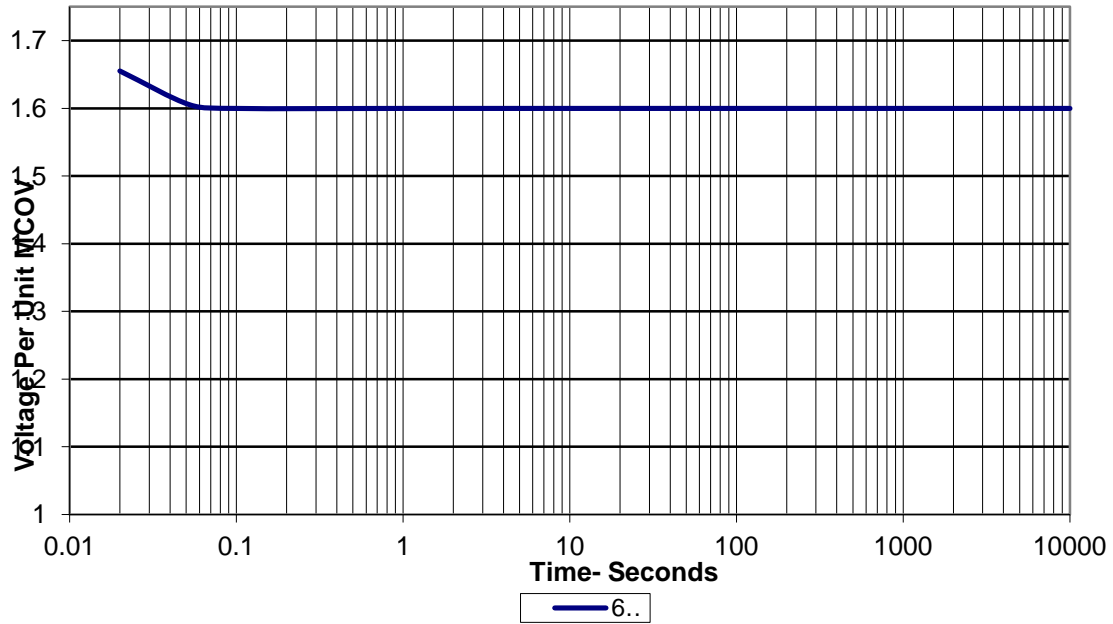
SAMPLES: Arresters ranging in rating from 3 thru 36 kV were assembled with the insulating bracket and subjected to TOV testing.

TEST RESULTS: The following tables summarize the claimable temporary overvoltage capability of the various PDV 65 Optima arrester ratings mounted on an insulating base bracket.

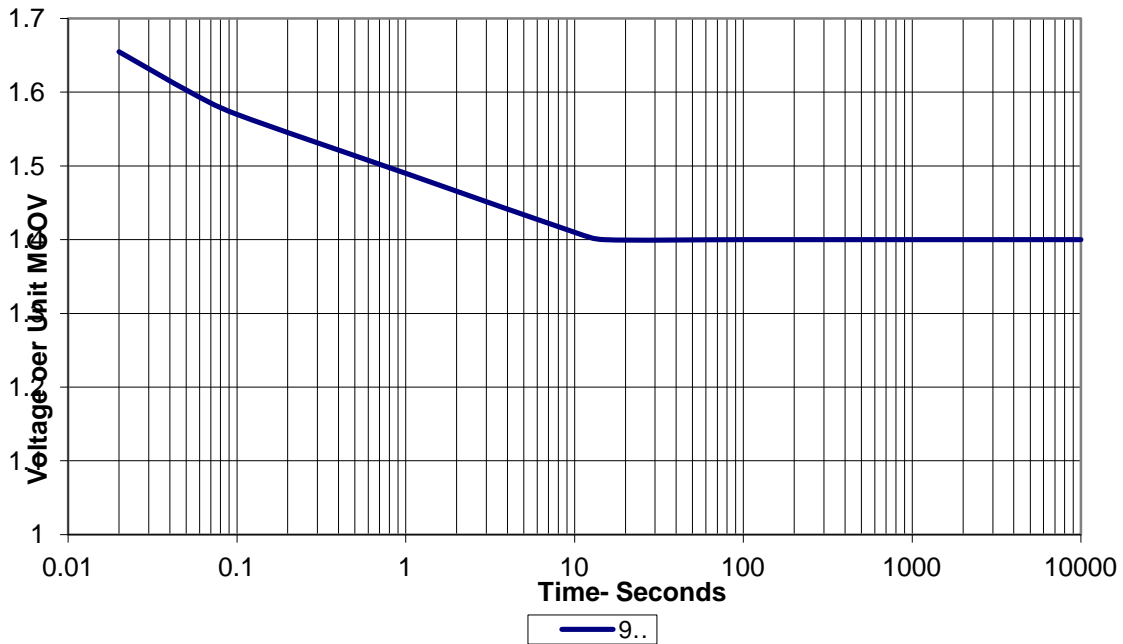
CONCLUSION (Arrester Mounted On Insulating Bracket): The following family of curves defines the overvoltage withstand capability of the various rated PDV 65 Optima bracket-mounted arresters when subjected to overvoltages with time durations ranging from .02 to 10,000 seconds duration.

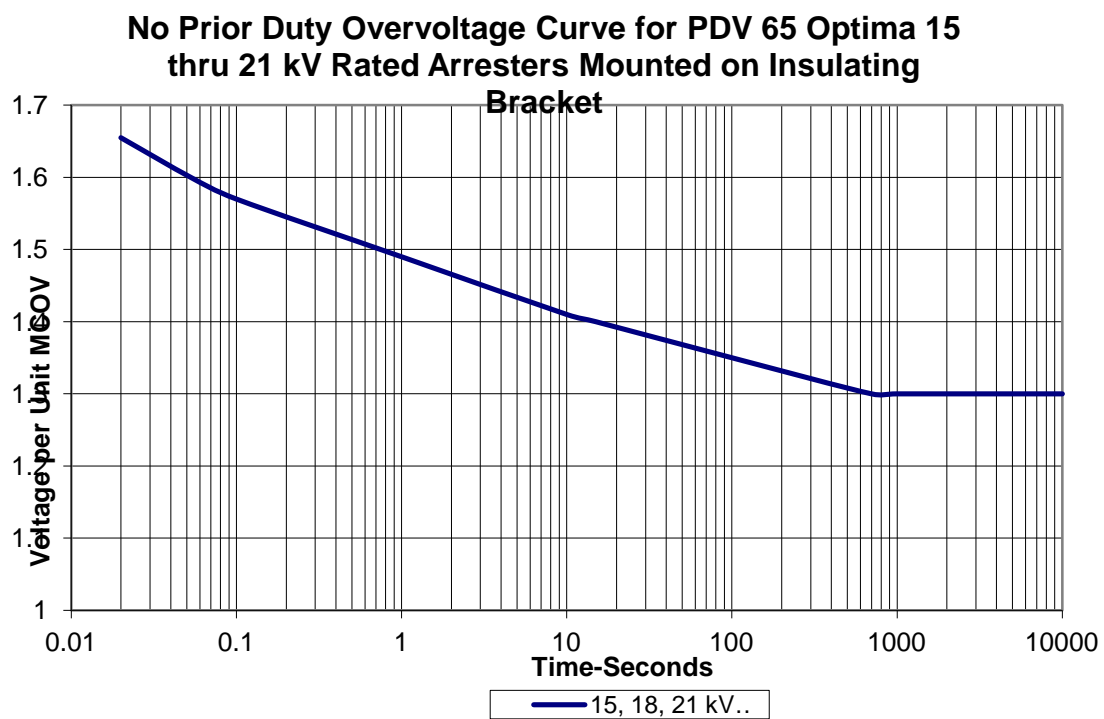
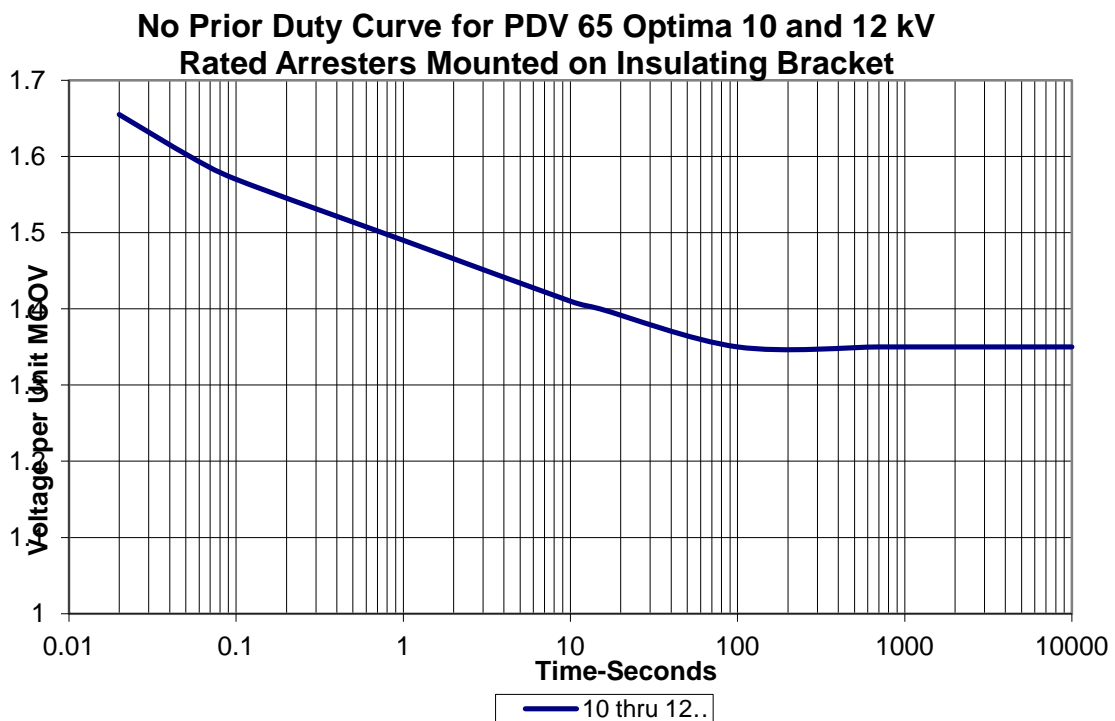


**No Prior Duty Overvoltage Curve for PDV 65 Optima 6 kV
Rated Arrester Mounted on Insulating Bracket**

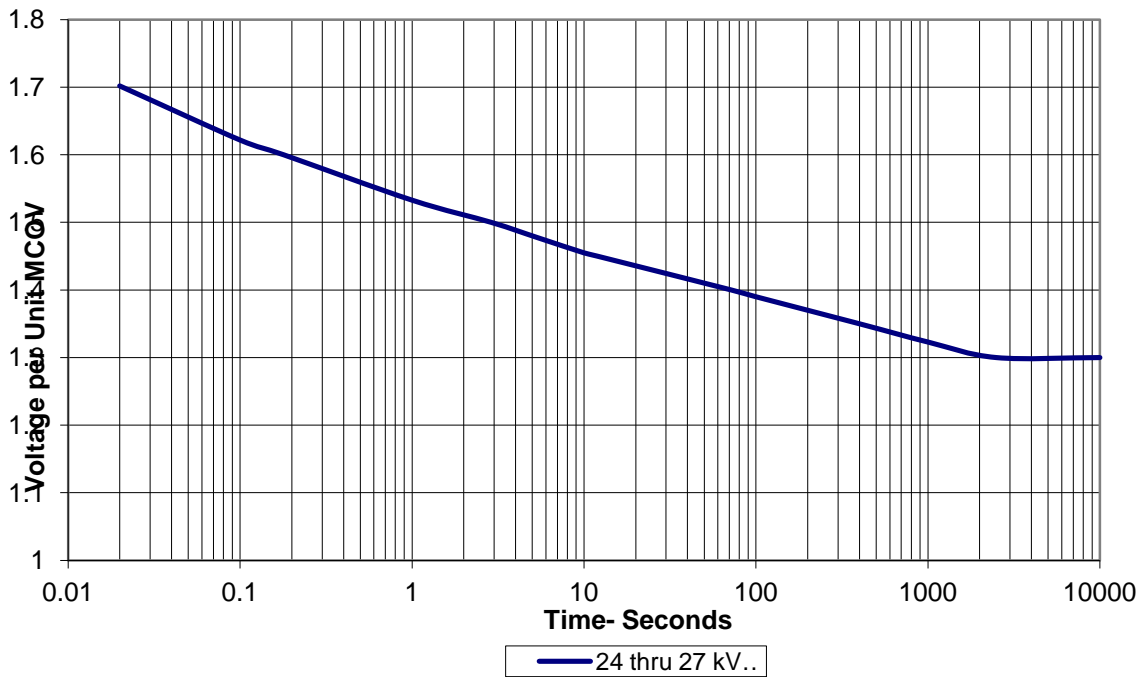


**No Prior Duty Overvoltage Curve for PDV 65 Optima 9 kV
Rated Arrester Mounted on Insulating Bracket**

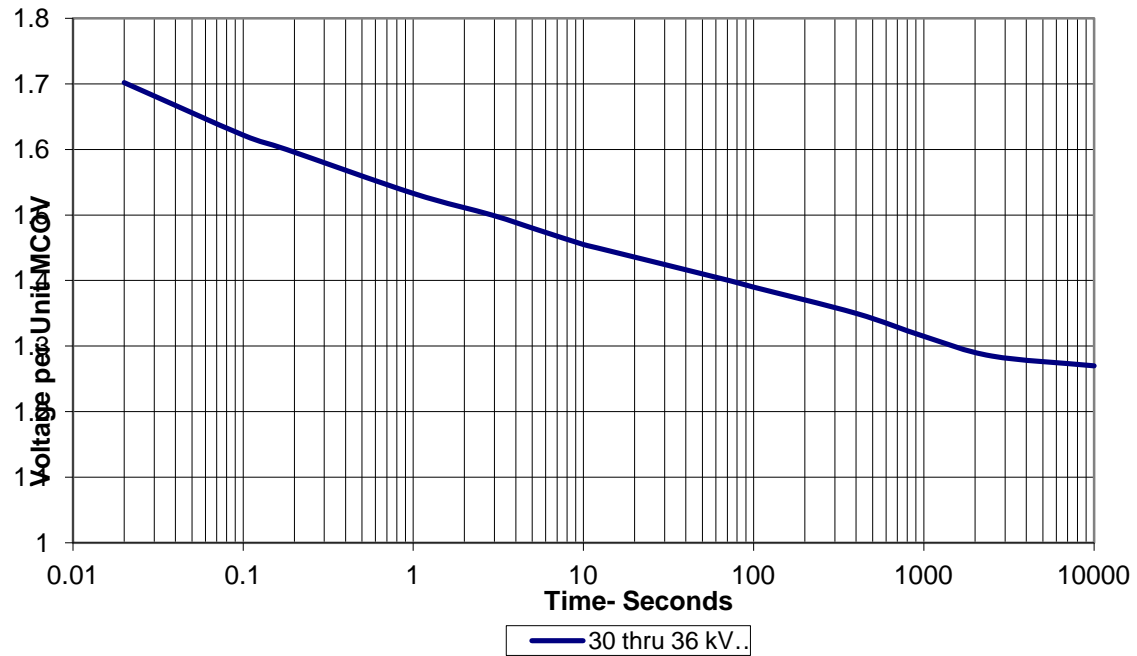




No Prior Duty Overvoltage Curve for PDV 65 Optima 24 thru 27 kV Rated Arresters Mounted on Insulating Bracket



No Prior Duty Overvoltage Curve for PDV 65 Optima 30 thru 36 kV Rated Arresters Mounted on Insulating Bracket





TYPE TEST REPORT No. EU 1415-HR-11.4

SHORT CIRCUIT TEST

CERTIFICATION

This is to certify that the short circuit design test has been successfully performed on Ohio Brass Type PDV 65 Distribution Class surge arrester.

A handwritten signature in black ink that reads "Saroni Brahma".

Saroni Brahma
Design Engineer

A handwritten signature in black ink that reads "Dennis W. Lenk".

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
Attachments

DESIGN TEST REPORT
PDV 65 Distribution Class Surge Arrester

TITLE: Short-circuit test for polymer housed distribution arresters:

OBJECTIVE: Short circuit tests were performed on the Type PDV 65 polymer-housed Distribution Class arrester per IEEE Standard C62.11-2012 Tests was performed per Table 14 of the referenced standard.

TEST SAMPLE: Fault current tests were performed on the longest mechanical section used to assemble the 12.7 thru 17 kV MCOV arresters, as required in Section 8.15.1 of the standard. As required in Section 8.15.1.1, two test samples for the high current test were assembled with a fuse wire oriented axially between the mov disc stack and the fiberglass-epoxy wrap. These samples were subjected to the full offset current test. In addition, six samples represented standard production arresters. These samples were failed using the specified 2-source failure mode procedure.

TEST RESULTS: Table 1 summarizes the results these tests which validated the claimed maximum 15 kA_{rms} symmetrical, 12 cycle fault current withstand capability of this design, with an applied ratio of 1.55 between total asymmetrical to symmetrical rms currents. This corresponds to a 2.6 ratio, in the first half loop of fault current, between the crest asymmetrical to rms symmetrical current, i.e., full offset. In addition to testing at the claimed maximum capability, tests were also performed, using the 2-source procedure, at half the claimed capability and at 600 amps as specified in Table 14 of the standard.

All tests were performed at full voltage. Therefore, the prospective fault current, as measured during the bolted fault test on the generator, is the claimable fault current capability of the design.

Table 1

Calibration Test 15.0 kA Symmetrical RMS 40.0 kA_c 1st Half Loop

Sample #	Failure Mode	Minimum Test Duration-seconds	Condition of Module/Polymer Housing After Test
1	Fuse Wire	.2	Module Intact/Hsg Torn but in Place
2	Fuse Wire	.2	Module Intact/Hsg Torn but in Place
3	2-Source	.2	Module Intact/Hsg Torn but in Place
4	2-Source	.2	Module Intact/Hsg Torn but in Place

Calibration Test 7.59 kA Symmetrical RMS No Asymmetrical Requirement

Sample #	Failure Mode	Minimum Test Duration-seconds	Condition of Module/Polymer Housing After Test
5	2-Source	.2	Module Intact/Hsg Torn but in Place
6	2-Source	.2	Module Intact/Hsg Torn but in Place

Calibration Test 600 Amp Symmetrical RMS No Asymmetrical Requirement

Sample #	Failure Mode	Minimum Test Duration-seconds	Condition of Module/Polymer Housing After Test
7	2-Source	1.0	Module Intact/Hsg Torn but in Place
8	2-Source	1.0	Module Intact/Hsg Torn but in Place

CONCLUSION: All eight test arresters, assembled with the longest mechanical unit, met the test evaluation criteria as specified in IEEE Standard C62.11-2012. In all tests, the arrester module remained intact on the insulating support bracket after the completion of each test. The flexible polymer housing wall section split, as intended, on all samples to allow venting of internal arcing gases to the outside of the arrester. In all cases, flames associated with the fault current test extinguished immediately after completion of the test, well within the allowed 2 minute duration. These tests have demonstrated the capability of the PDV 65 arrester design to discharge a maximum claimable 15 kA_{rms} symmetrical fault current using the test procedure defined in IEEE Standard C62.11-2012.



TYPE TEST REPORT No. EU 1415-HR-12.4

MAXIMUM DESIGN CANTILEVER LOAD-STATIC TEST

CERTIFICATION

This is to certify that the maximum design cantilever load-static (MDCL-static) test has been successfully performed on the Ohio Brass Type PDV 65 Distribution Class surge arrester.

A handwritten signature in black ink that reads "Saroni Brahma".

Saroni Brahma
Design Engineer

A handwritten signature in black ink that reads "Dennis W. Lenk".

Dennis W. Lenk P.E.
Principal Engineer

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DESIGN TEST REPORT
PDV 65 Distribution Class Surge Arrester

TITLE: Maximum design cantilever load-static (MDCL-static) test:

TEST SAMPLES: The maximum design cantilever load test was performed on a PDV 65 17 kV MCOV arrester, representing the longest PDV65 mechanical unit. Tests were performed on this 8.5" long arrester to validate the claimed 400 inch-pound continuous cantilever rating.

TEST PROCEDURE: Testing was performed per the procedures specified in Section 8.22 of IEEE Std C62.11-2012. The test arrester was rigidly mounted at its base and top end loading applied to develop 400 inch-pound cantilever load. With the arrester under load, the arrester rotated and exposed to temperature excursions as specified in Figure 4 of the standard. No measurable permanent deflection was recorded as a result of the conditioning. Subsequent to the thermo-mechanical conditioning, the test arrester was subjected to a 42 boiling water test as described in Section 8.22.3.3 of the standard.

RESULTS: After completion of the boiling water test, the test arrester was electrically tested and compared with the prior duty test results. The results of the 60 HZ testing at MCOV are summarized below.

Sample #	Initial Ir (μA) @MCOV	Final Ir (μA) @MCOV	Initial PD (pC) @ 1.05*MCOV	Final PD (pC) @ 1.05*MCOV	Initial Watts @ MCOV	Final Watts @ MCOV
1	0.032	0.027	0	0	0.32	0.32

CONCLUSION: Per Section 8.22.4, the PD level was unchanged and the final resistive current after the 42 hour boiling water test was less than the allowable 20% increase. Visual examination revealed no evidence of mechanical damage. The above tests have validated the 400 inch-pound continuous cantilever rating of the base mounted PDV65 arrester.



TYPE TEST REPORT No. EU 1415-HR-13.3

SEAL INTEGRITY TEST

CERTIFICATION

This is to certify that the seal integrity design test has been successfully performed on Ohio Brass Type PDV 65 Distribution Class surge arrester.

A handwritten signature in black ink that reads "Saroni Brahma".

Saroni Brahma
Design Engineer

A handwritten signature in black ink that reads "Dennis W. Lenk".

Dennis W. Lenk P.E.
Principal Engineer

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DESIGN TEST REPORT
PDV65 Distribution Class Surge Arrester

TITLE: Distribution class surge arrester seal integrity design test:

OBJECTIVE: Seal integrity tests were performed per IEEE C62.11-2012 Standard.

TEST SAMPLES: Tests were run on three 18 kV rated arresters, catalog number 213265, constructed with single 18 kV rated modules and three 10kV rated arresters, catalog number 217259, constructed with single 10 kV rated modules.

TEST PROCEDURE: The seal integrity test consisted of the following steps:

- a) Initial Electric Test: Each arrester was energized at rating, watts loss and IIV was measured.
- b) Terminal Torquing: A ¼" diameter hard lead was inserted between the wire clamp and arrester end stud on one side only. The clamping nut was torqued to 22 ft-lb.
- c) Thermal Conditioning: Each arrester was placed in a $70^{\circ}\text{C} \pm 3^{\circ}\text{C}$ environment for 14 days, after which the arresters were stabilized at ambient room temperature and watts was measured.
- d) Seal Pumping: The arresters were heated to $60^{\circ}\text{C} \pm 3^{\circ}\text{C}$ for one hour, then placed into a $4^{\circ}\text{C} \pm 3^{\circ}\text{C}$ water bath for two hours, after which the samples were returned to the 60°C oven. Each arrester was subjected to ten repetitions of this cycle. The transfer time between media was 1-2 minutes.
- e) Final Electric Test: Procedure (a) was repeated.
- f) Final Inspection: The arresters were disassembled to verify no moisture penetration was evident.

Table 1
Seal Test Data Summary- Single Module 10 kV arrester

Sample Number	Applied Voltage (kV) rms	Initial Watts Loss	Final Watts Loss	Initial Internal Noise (μV)	Final Internal Noise (μV)
1	10	1.0	1.1	0.9	0.6
2	10	1.1	1.1	1.0	0.6
3	10	1.1	1.2	0.9	0.6

Table 2
Seal Test Data Summary-Two Module 18 kV Arrester

Sample Number	Applied Voltage (kV) rms	Initial Watts Loss	Final Watts Loss	Initial Internal Noise (μV)	Final Internal Noise (μV)
1	18	0.56	0.58	0.5	0.5
2	18	0.58	0.62	0.5	0.5
3	18	0.76	0.84	0.5	0.5

CONCLUSION: As indicated on Tables 1 and 2, all arresters demonstrated proper sealing with no evidence of internal moisture or change in watts loss or IIV. It should be noted that the noise levels measured represent background noise at the test location. This test confirms that the PDV 65 18 kV rated arrester, constructed with 2 short modules or a single long module, successfully passes the Normal Duty Distribution Class arrester seal integrity test as per IEEE C62.11-2012.



TYPE TEST REPORT No. EU 1415-HR-14.3

DISCONNECTOR TESTS PVR Riser Pole Arrester Insulating Bracket

CERTIFICATION

This is to certify that the disconnecter tests have been successfully performed on Ohio Brass Type PDV65 Normal Duty Distribution Class surge arrester insulating bracket.

A handwritten signature in black ink that reads "Saroni Brahma".

Saroni Brahma
Design Engineer

A handwritten signature in black ink that reads "Dennis W. Lenk".

Dennis W. Lenk
Principal Engineer

Attachments

DESIGN TEST REPORT

PVR Riser Pole Distribution Class Surge Arrester Insulating Bracket Disconnecter Tests

OBJECTIVE: Tests were performed per clause 8.21 of IEEE Standard C62.11-2012.

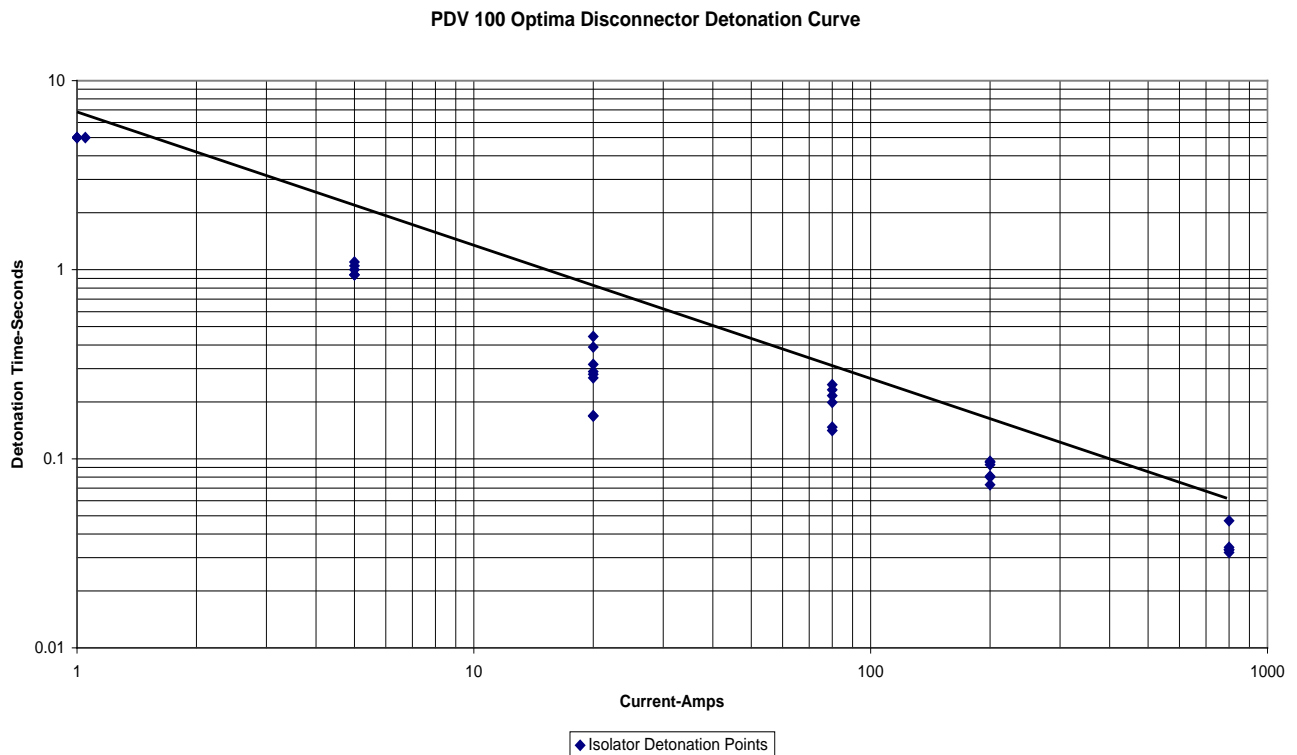
TEST PROCEDURES: High current short duration and low current long duration discharge duty tests and duty cycle tests were performed on thermally prorated test sections having the disconnecter assembly connected in series.

Disconnecter detonation testing was performed on five bracket/isolator assemblies each at 20, 80, 200, and 800 A_{rms}. In addition, detonation testing was also performed at 1 and 5 A_{rms}.

TEST RESULTS: Disconnectors did not operate when subjected to high current short duration and low current long duration discharge duty tests and duty cycle tests on the thermally prorated test sections. The disconnecter also did not operate when subjected to contamination tests.

In all cases, disconnectors separated during detonation tests at each of the required current levels.

CONCLUSION: The disconnecter passed all requirements of clause 8.21. The following figure shows the detonation curve for the PDV65 Normal Duty disconnecter.





TYPE TEST REPORT No. EU 1415-HR-15.4

VERIFICATION OF THERMALLY PRORATED SECTION

CERTIFICATION

This is to certify that verification tests demonstrating thermal equivalency were successfully performed on Ohio Brass Type PDV65 Normal Duty Distribution Class surge arrester.

A handwritten signature in black ink that reads "Saroni Brahma".

Saroni Brahma
Design Engineer

A handwritten signature in black ink that reads "Dennis W. Lenk".

Dennis W. Lenk P.E.
Principal Engineer

10/31/2013
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DESIGN TEST REPORT

PDV65 Normal Duty Distribution Class Surge Arrester

TITLE: Verification of thermally prorated arrester section:

INTRODUCTION: Tests were performed as required by clause 7.2.2.3 of IEEE C62.11-2012 Standard, to compare the cooling characteristics of the prorated test sections used for type tests with those of a full-size arrester unit.

PURPOSE: The purpose of this test is to verify that the thermal cooling curve for the Type PDV 65 prorated sections, when internally heated, will cool slower than that of a full size 21 kV rated arrester unit.

PROCEDURE: A full size single unit 21 kV rated Type PDV 65 arrester and a 12 kV and a 6 kV prorated section were heated up by applying a temporary overvoltage to the test samples. Per clause 7.2.2.3, all samples (the arrester and the prorated sections) were energized in approximately 10 minutes to a starting temperature of 140 °C, at which time the voltage was removed. The full size arrester and the two prorated sections were instrumented with (1) fiber-optic sensors located in the middle of the MOV disc stack. During the cooling portion of the test, the temperatures of the arrester and the test sections were monitored at 5 minute intervals to develop the cooling curve for each sample.

SUMMARY: As allowed in clause 7.2.2.3.5, the cooling curves for both the 12 kV and 6 kV prorated sections were adjusted higher to assure that, at no time during the 120 minute cooling period, do the section cooling curves drop below that of the full size arrester. The adjusted temperature shown for each rated section was added to the durability tests requiring a 60 degree C. preheat.

The cooling curve (Figure 1 below) confirms that the cooling rate of the 12 kV and 6 kV prorated sections is slower than that of the full size 21 kV Rated Type PDV65 arrester unit, confirming the thermal equivalency of the prorated sections to the full size arrester.

Figure 1

