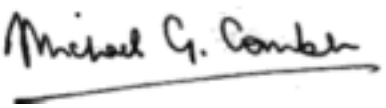
ANSI DESIGN TEST REPORT
Report No. EU1502-H-00
Type PVNA Station Class
Surge Arrester

This report records the results of the design tests made on Type PVNA Station Class surge arresters in accordance with IEEE Standard C62.11-1999 “IEEE Standard for Metal Oxide Surge Arresters for AC Power Circuits (> 1kV)”.

To the best of our knowledge and within the usual limits of testing practices, tests performed on the Type PVNA arresters demonstrate full compliance with the relevant clauses of the referenced standard.



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Date: 10/31/2001

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

Report No.	Description	Clause	Issue Date
EU1502-H-01	Insulation Withstand	8.1	10/2001
EU1502-H-02	Discharge Voltage	8.3	10/2001
EU1502-H-03	Disc Accelerated Aging	8.5	10/2001
EU1502-H-04	Polymer Accelerated Aging	8.6	10/2001
EU1502-H-05	Contamination	8.7	10/2001
EU1502-H-06	Internal Ionization and RIV	8.9	10/2001
EU1502-H-07	High Current, Short Duration	8.10.1	10/2001
EU1502-H-08	Transmission Line Discharge	8.10.2	10/2001
EU1502-H-09	Duty Cycle	8.11	10/2001
EU1502-H-10	Temporary Overvoltage	8.12	10/2001
EU1502-H-11	Pressure Relief	8.13	10/2001
EU1502-H-12	Maximum Design Cantilever Load-Static	8.19	10/2001

TYPE TEST REPORT No. EU1502-H-01

Insulation Withstand Tests on PVNA Arrester Housing

CERTIFICATION

This is to certify the insulation withstand test capability of the Ohio Brass Type PVNA Station Class surge arresters.

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Manager – Engineering
Ohio Brass & Chardon Products

Dennis W. Lenk P.E.
Principal Engineer

October, 2001
Attachments

DESIGN TEST REPORT

Type PVNA Station 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 Table 4 of IEEE C62.11-1999 Standard.

CONCLUSION: Table 1 lists PVNA arrester minimum strike distance and leakage distance as well as required 1.2/50 impulse withstand, 60 Hz wet, and 60 Hz dry withstand capabilities. All PVNA arrester ratings meet or exceed these required levels of withstand voltage.

Table 1

Summary Data - Insulation Withstand Test

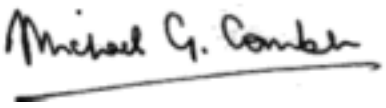
Catalog No.	MCOV (kV_{rms})	Rated Voltage (kV_{rms})	Arrester Strike Distance (in)	Arrester Leakage Distance (in)	Required 1.2/50 Impulse Withstand (kV_c)	Required 60 HZ 1 Minute Dry W/S (kV_{rms})	Required 60 HZ 10 second Wet W/S (kV_{rms})
310703	2.55	3	5.6	15.4	60	21	20
310705	5.1	6	5.6	15.4	75	27	24
310708	7.65	9	5.6	15.4	95	35	30
310709	8.4	10	5.6	15.4	110	50	45
310710	10.2	12	5.6	15.4	110	50	45
310713	12.7	15	10.8	30.8	110	50	45
310715	15.3	18	10.8	30.8	150	70	60
310717	17	21	10.8	30.8	150	70	60
310720	19.5	24	10.8	30.8	150	70	60
310722	22	27	16.1	46.2	200	95	80
310724	24.4	30	16.1	46.2	200	95	80
310729	29	36	16.1	46.2	200	95	80
310731	31.5	39	21.3	61.6	250	120	100
310736	36.5	45	21.3	61.6	250	120	100
310739	39	48	21.3	61.6	250	120	100
310742	42	54	26.5	77	215	-	88
310748	48	60	26.5	77	241	-	99
310757	57	72	31.7	92.4	290	-	119

TYPE TEST REPORT No. EU 1502-H-02

Discharge Voltage Characteristic

CERTIFICATION

This is to certify that the discharge voltage characteristic design tests have been successfully performed on Ohio Brass Type PVNA Station Class surge arresters.



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DESIGN TEST REPORT
Type PVNA Station Class Surge Arrester

TITLE: Discharge-voltage characteristic

TEST OBJECTIVE: These measurements are used to obtain the maximum discharge voltages at various current magnitudes and waveshapes.

TEST PROCEDURE: Discharge voltage tests were performed on three single disc test samples. Tests were conducted in accordance with clause 8.3 of ANSI/IEEE Standard C62.11. Test samples 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. c

TEST SAMPLES: Arresters are assembled from discs accumulated within 10 kA IR ranges as specified for each arrester rating. To verify catalog maximum IR levels were not exceeded, a discharge voltage ratio was established at each current level based on the test sections 10 kA IR (Table 1). That ratio was multiplied by the maximum allowed 10 kA IR accumulation specified for each rating. As summarized on Table 2, the IR calculated based on the prorated test sections do not exceed the maximum declared catalog levels.

TEST RESULTS: Figures 1-11 contain oscillograms for test section 1 at each current and wave shape.

Figure 1
500A, 10.636, 56/99 Waveshape

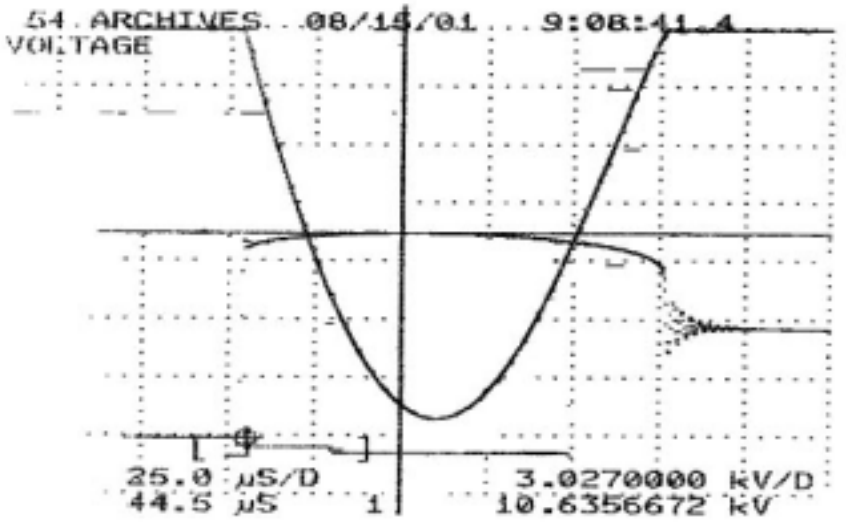

Figure 2
1 kA, 11.049kV, 56/99 Waveshape

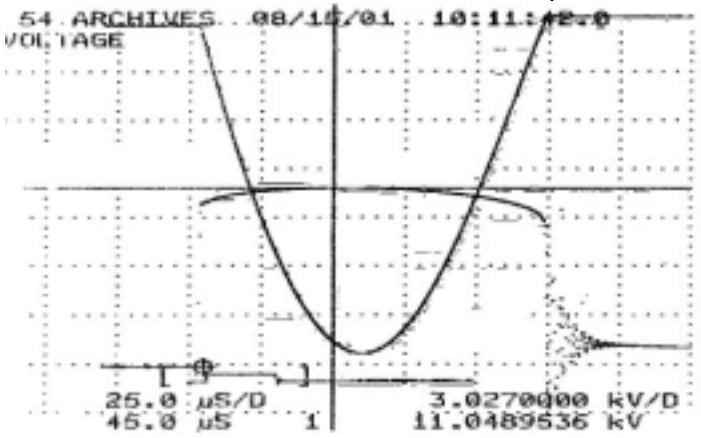

Figure 3
1.5 kA, 11.372 kV, 8.4/18.4 Waveshape

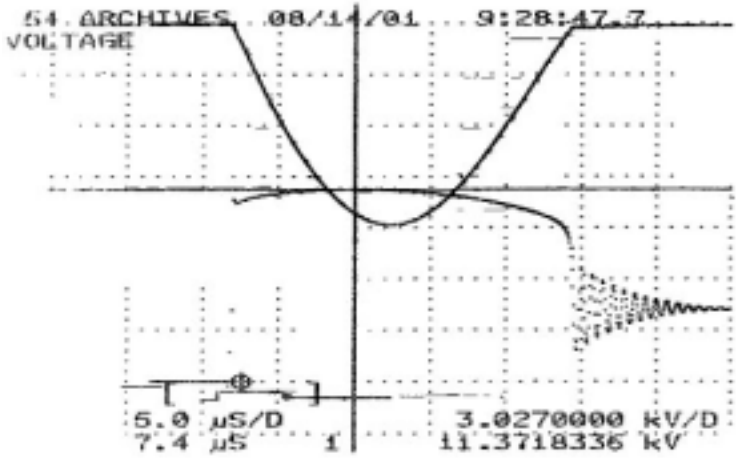

Figure 4
3 kA, 12.011 kV, 8.4/18.4 Waveshape

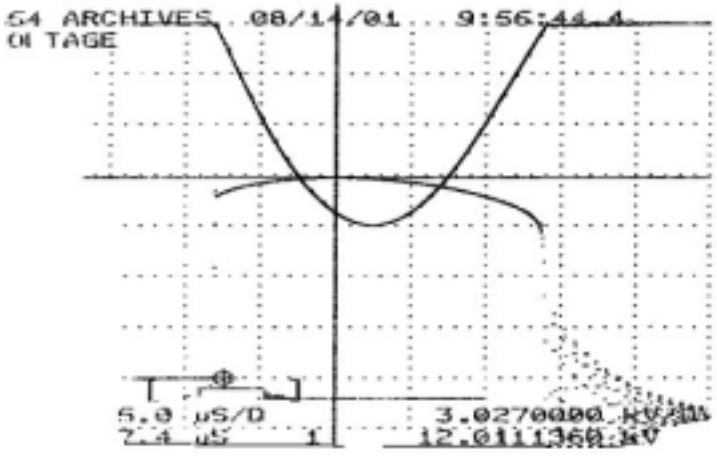

Figure 5
5 kA, 12.573 kV, 8.4/18.4 Waveshape

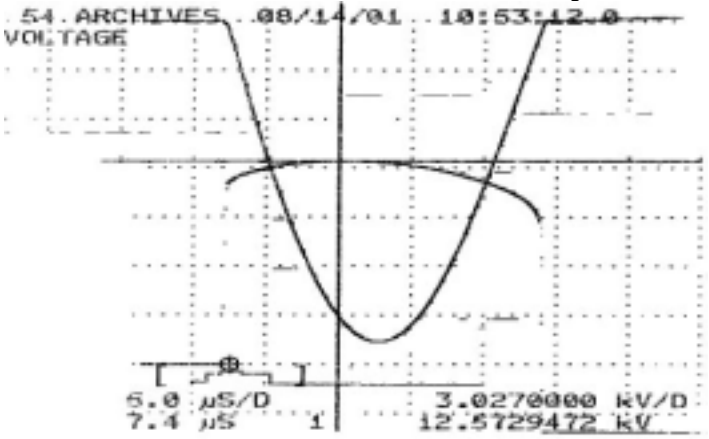

Figure 6
10 kA, 13.561 kV, 8.7/19.0 Waveshape

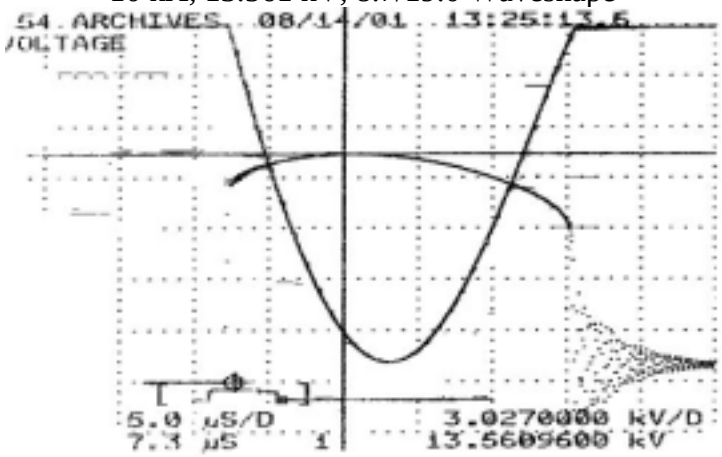

Figure 7
20 kA, 15.007 kV, 8.2/18.7 Waveshape

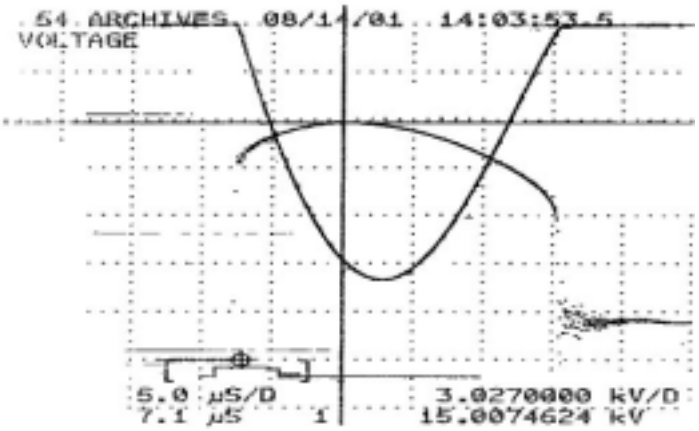

Figure 8
40 kA, 16.912 kV, 8.5/19.4 Waveshape

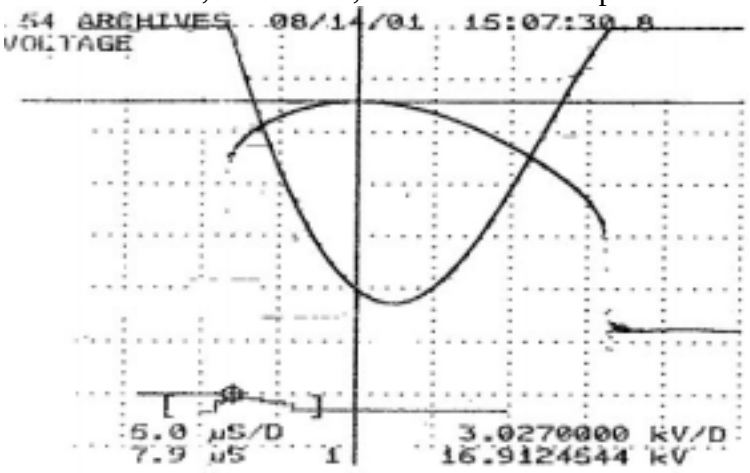

Figure 9
10 kA FOW, 13.944 kV @1.06microseconds to voltage crest

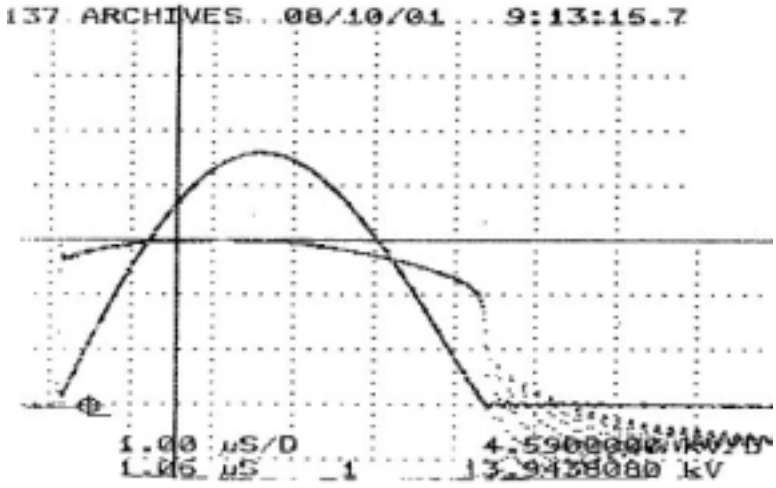

Figure 10
10 kA FOW, 14.257 kV @ .425 microseconds to voltage crest

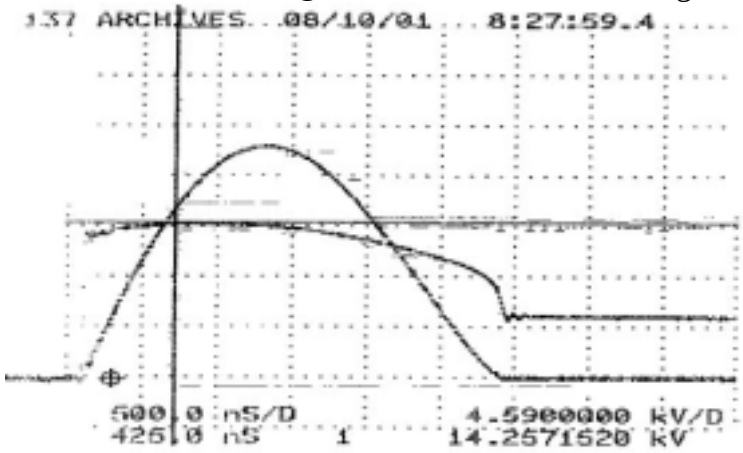

Figure 11
10 kA FOW, 14.727 kV @ .48 microseconds to voltage crest

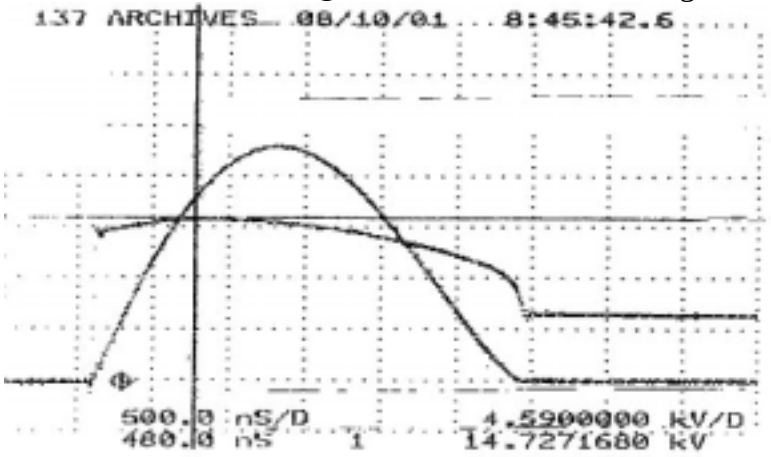

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Table 1
Sample Discharge Voltage Data Summary

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	10.636	10.900	10.584	0.784	0.782	0.778
1000	60/100	11.049	11.301	11.010	0.815	0.811	0.810
1,500	8/20	11.372	11.649	11.385	0.839	0.836	0.837
3,000	8/20	12.011	12.308	12.024	0.886	0.883	0.884
5,000	8/20	12.573	12.922	12.586	0.927	0.927	0.926
10,000	8/20	13.561	13.942	13.606	1.000	1.000	1.000
20,000	8/20	15.007	15.382	15.027	1.107	1.104	1.105
40,000	8/20	16.912	17.264	16.971	1.247	1.239	1.248
10,000	_	14.257	14.727	14.257	1.052	1.057	1.048
10,000	2/4	13.944	14.257	13.944	1.029	1.023	1.025
		Time to Crest Voltage (μs)					
10,000	8/20	7.300	8.200	7.900			
10,000	_	0.425	0.480	0.400			
10,000	2/4	1.060	1.080	1.140			

Table 2
Type PVNA Arrester Discharge Voltage Summary

		IR Multipliers	0.784	0.815	0.839	0.886	0.927	1.000	1.107	1.247	1.057
		Impulse Wave	60/100	60/100	8/20	8/20	8/20	8/20	8/20	8/20	0.5usec
MCOV	Rating	I Magnitude (A)	500	1000	1500	3000	5000	10000	20000	40000	10000
2.55	3	Specimen Measured IR	6.2	6.5	6.6	7.0	7.3	7.9	8.8	9.9	8.4
		Catalog Maximum IR	6.3	6.5	6.7	7.1	7.4	8.0	8.9	10.0	8.5
5.10	6	Specimen Measured IR	12.4	12.9	13.3	14.0	14.7	15.8	17.5	19.8	16.7
		Catalog Maximum IR	12.5	13.0	13.4	14.2	14.8	16.0	17.7	20.0	16.9
7.65	9	Specimen Measured IR	18.6	19.3	19.9	21.0	22.0	23.7	26.2	29.5	25.0
		Catalog Maximum IR	18.7	19.5	20.1	21.2	22.2	23.9	26.5	29.8	25.3
8.4	10	Specimen Measured IR	20.3	21.1	21.7	22.9	24.0	25.9	28.6	32.3	27.4
		Catalog Maximum IR	20.5	21.3	21.9	23.1	24.2	26.1	28.9	32.5	27.6
10.2	12	Specimen Measured IR	24.6	25.6	26.3	27.8	29.1	31.4	34.7	39.1	33.2
		Catalog Maximum IR	24.9	25.8	26.6	28.1	29.4	31.7	35.1	39.5	33.5
12.7	15	Specimen Measured IR	31.0	32.2	33.2	35.0	36.6	39.5	43.7	49.3	41.8
		Catalog Maximum IR	31.3	32.5	33.5	35.4	37.0	39.9	44.2	49.8	42.2
15.3	18	Specimen Measured IR	37.1	38.6	39.7	42.0	43.9	47.4	52.4	59.1	50.1
		Catalog Maximum IR	37.5	39.0	40.1	42.4	44.3	47.8	52.9	59.6	50.5
17	21	Specimen Measured IR	40.6	42.2	43.4	45.9	48.0	51.8	57.3	64.5	54.7
		Catalog Maximum IR	41.0	42.6	43.9	46.3	48.5	52.3	57.9	65.2	55.3
19.5	24	Specimen Measured IR	49.2	51.1	52.7	55.6	58.2	62.8	69.5	78.3	66.3
		Catalog Maximum IR	49.7	51.7	53.2	56.2	58.8	63.4	70.2	79.1	67.0
22	27	Specimen Measured IR	55.7	57.9	59.6	62.9	65.9	71.0	78.6	88.6	75.1
		Catalog Maximum IR	56.3	58.5	60.2	63.6	66.6	71.8	79.5	89.5	75.9
24.4	30	Specimen Measured IR	60.9	63.3	65.1	68.8	72.0	77.6	85.9	96.8	82.1
		Catalog Maximum IR	61.5	63.9	65.8	69.5	72.7	78.4	86.8	98	82.9
29	36	Specimen Measured IR	73.8	76.7	79.0	83.4	87.3	94.1	104.2	117.4	99.5
		Catalog Maximum IR	74.6	77.5	79.8	84.3	88.2	95.1	105	119	101
31.5	39	Specimen Measured IR	77.7	80.8	83.2	87.8	91.9	99.1	109.7	123.6	104.8
		Catalog Maximum IR	78.5	81.6	84.0	88.7	92.8	100.1	110.8	124.8	105.8
36.5	45	Specimen Measured IR	89.8	93.3	96.1	101.5	106.2	114.5	126.8	142.8	121.0
		Catalog Maximum IR	90.7	94.3	97.1	102.5	107.3	115.7	128.1	144.3	122.3
39.0	48	Specimen Measured IR	98.4	102.3	105.3	111.2	116.4	125.5	139.0	156.5	132.7
		Catalog Maximum IR	99.4	103.3	106.4	112.3	117.5	126.8	140.4	158.1	134.0
42	54	Specimen Measured IR	105.8	109.9	113.2	119.5	125.1	134.9	149.3	168.2	142.6
		Catalog Maximum IR	106.8	111.0	114.3	120.7	126.3	136.2	150.8	169.8	144.0
48.0	60	Specimen Measured IR	118.7	123.4	127.0	134.1	140.3	151.4	167.6	188.8	160.0
		Catalog Maximum IR	119.9	124.6	128.3	135.5	141.7	152.9	169.3	191	161.6
57	72	Specimen Measured IR	143.3	149.0	153.4	161.9	169.4	182.8	202.3	227.9	193.2
		Catalog Maximum IR	144.7	150.4	154.9	163.6	171.1	184.6	204	230	195

TYPE TEST REPORT No. EU1502-H-03

Disc Accelerated Aging

CERTIFICATION

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

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October, 2001
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DESIGN TEST REPORT
PVNA Station Class Surge Arrester

TITLE: Accelerated aging procedure

TEST OBJECTIVE: 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 determination of proratio factor of duty cycle and discharge current withstand test samples.

TEST SAMPLES: Three arrester modules were prepared. The (3) modules consisted of the longest 50 mm diameter MOV disc , spring, end terminals, barrier film and fiberglass/epoxy wrap using standard module construction.

TEST PROCEDURE: Tests were performed per Section 8.5 of ANSI/IEEE C62.11 Standard. Samples were placed inside a 115 °C ±2 °C. oven and energized at MCOV for 1,000 hours. As with the durability tests, MCOV and rated test voltages were prorated to design limits based on 7 ma Vref.

TEST RESULTS: Watts loss for each sample was recorded at MCOV and duty cycle rated voltage two hours after energization and at the completion of the 1000 hour test duration. The following table summarizes test data.

Accelerated aging test data

Sample Number	Watts Loss at 2 Hr @MCOV P_{1c} (w)	Watts Loss at 1000 Hr @MCOV P_{2c} (w)	Watts Loss at 2 Hr @Rating P_{1r} (w)	Watts Loss at 1000 Hr @Rating P_{2r} (w)	Elevation K_c	Factors K_r
1	3.67	2.23	8.18	6.59	1.0	1.0
2	3.54	2.19	8.64	6.84	1.0	1.0
3	3.54	2.00	8.88	7.06	1.0	1.0

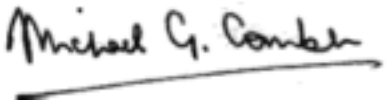
CONCLUSION: Each test sample demonstrated decreasing watts loss at MCOV. The watts loss at rating also declined. Therefore, K_c and K_r factors equal 1.0.

TYPE TEST REPORT No. EU1502-H-04

Polymer Accelerated Aging

CERTIFICATION

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



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DESIGN TEST REPORT

PVNA Station Class Surge Arrester

TITLE: Accelerated aging tests of external polymeric insulating systems :

TEST OBJECTIVE: These tests were performed per clause 8.6 of IEEE Standard C62.11-1999. While this test was written for polymer-housed Distribution Class arresters, the polymer-housing portion of the design test was performed on the PVNA arrester housing.

TEST SAMPLES: Three PVNA 17 kV MCOV arresters were tested. These represent the highest MCOV stress based on leakage distance and arcing distance.

TEST PROCEDURE: Accelerated aging tests by exposure to electrical stress were performed per clause 8.6.2. Tests were performed by attaching arresters to a vertical Ferris wheel. As the wheel rotates, each arrester is sequentially dipped into a 400 ohm-centimeter water bath. Each arrester is allowed to drip off excessive contaminant and is then energized at MCOV to force the arrester housing into a dry band corona condition. The arrester test is performed 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 10 kA 8/20 discharge to confirm its electrical integrity.

CONCLUSION: Both polymer housing sizes 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 PVIA arrester housings after the 1000 hour on-voltage test.

TYPE TEST REPORT No. EU1502-H-05

Contamination Test

CERTIFICATION

This is to certify that the contamination design test has been successfully performed on Ohio Brass Type PVNA Station Class surge arresters.

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DESIGN TEST REPORT
PVNA Station Class Surge Arrester

TITLE: Contamination tests:

TEST SAMPLE: Tests were performed in accordance with clause 8.7 of IEEE Standard C62.11-1999 on the highest rated arrester (72 kV).

TEST PROCEDURE: Contaminant was prepared per clause 8.7.2.2 and the test procedure run per clause 8.7.2.3. The arrester was energized at MCOV for 1 hour prior to application of the slurry mixture. The arrester watts loss was measured throughout the test to monitor thermal stability.

Immediately following the 1 hour preheat, slurry was applied to the bottom half of the arrester. Within 3 minutes, MCOV was applied and watts loss measured for 15 minutes. At the end of this 15 minute test, the arrester was de-energized and the second slurry coating was applied. The arrester was then energized for an additional 15 minutes. At the end of this second 15-minute test, the arrester was maintained at MCOV until thermal stability was demonstrated.

TEST RESULTS: The following table summarizes the results of this test.

Time (min)	Applied Voltage (kV rms)	Arrester Watts Loss (w)	Arrester Total Current ma_{peak}
0	57	3.1	.71
15	57	2.8	.74
30	57	2.9	.74
60	57	2.9	.74
Partial Wetting Slurry Application			
0	57	19	1.10
1	57	18	1.16
5	57	17	1.07
10	57	16	.96
15	57	5.3	.73
Partial Wetting Slurry Application			
0	57	22	1.28
1	57	21	1.28
5	57	19	1.19
10	57	19	1.10
15	57	17	1.03
Thermal Recovery			
0	57	17	1.03
10	57	4.6	.76
20	57	4.1	.74
30	57	3.6	.72

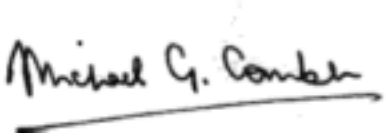
CONCLUSION: The PVNA 72 kV rated arrester successfully passed the contamination test as specified in Section 8.7 of IEEE C62.11-1999 Standard.

TYPE TEST REPORT No. EU1502-H-06

INTERNAL IONIZATION and RIV

CERTIFICATION

This is to certify that the internal ionization and RIV design tests have been successfully performed on Ohio Brass Type PVNA Station Class surge arrester.



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DESIGN TEST REPORT
PVNA Station Class Surge Arrester

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

TEST PROCEDURE AND SAMPLE: Internal ionization and RIV testing was performed per clause 8.9 of IEEE Standard C62.11-1999. The test was performed on a 72 kV rated, 57 kV MCOV PVNA 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: A background noise level of 0.7 μV was measured at an open circuit voltage of 100 kV. With the unshielded 72 kV rated arrester placed in the circuit, a noise level of 0.8 μV was measured at 60 kV (1.05 times MCOV) and 72 kV (rated) test voltages.

CONCLUSION: The 72 kV rated PVNA arrester passed test requirements per Section 8.9 of IEEE C62.11-1999 Standard, as measured noise levels were well within the 10 μV test limit.

TYPE TEST REPORT No. EU1502-H-07

HIGH CURRENT, SHORT DURATION TEST

CERTIFICATION

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

Michael G. Comber
Manager – Engineering
Ohio Brass & Chardon Products

Dennis W.Lenk P.E.
Principal Engineer

October, 2001
Attachments

DESIGN TEST REPORT
PVNA Station Class Surge Arrester

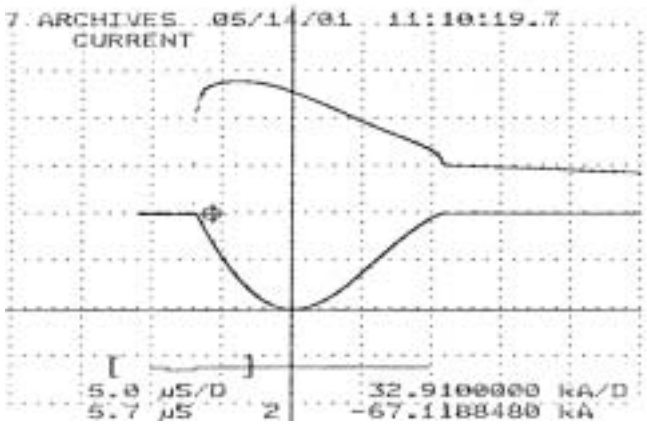
TITLE: High Current, Short Duration Discharge Withstand Test

TEST PROCEDURE: High current, short duration discharge withstand tests were performed per clause 8.10.1 of IEEE Standard C62.11-1999.

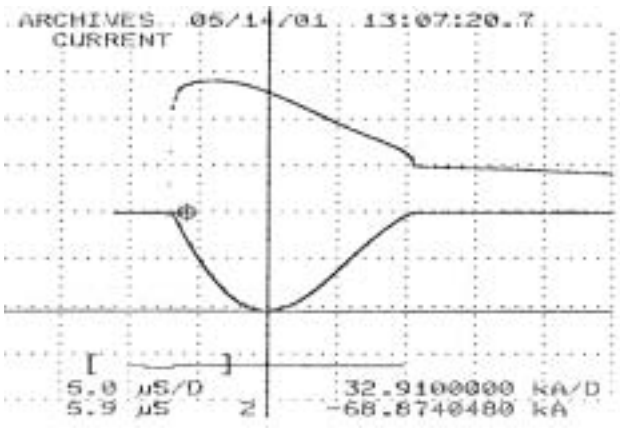
TEST SAMPLE: As required by clause 7.2.2, the prorated sample contains the minimum MOV mass allowed for the design. MCOV voltage was also prorated per unit Vref to reflect the lowest margin case of the standard voltage ratings offered in this design. Assigned MCOV of the prorated section was 9.10 kVrms.

TEST RESULTS: The 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 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.

First Shot
67.1 kA Magnitude
5.5/13.0 Waveshape

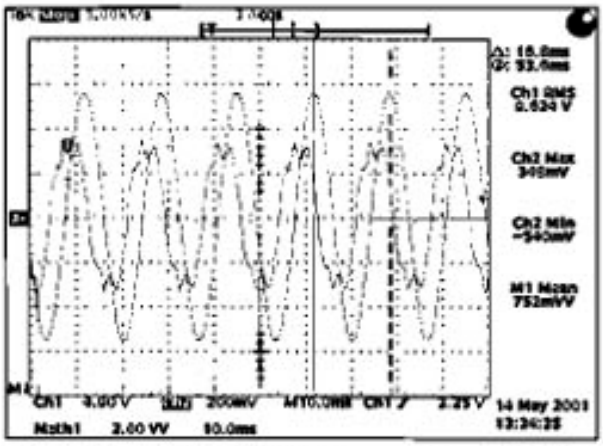


Second Shot
68.8 kA Magnitude
5.4/13.0 Waveshape



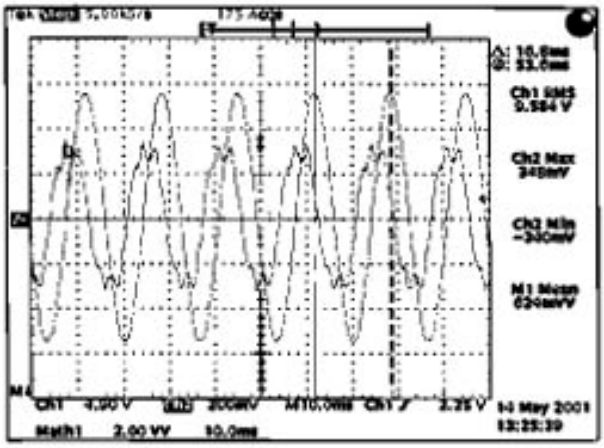
The following oscillograms monitor the arrester voltage and grading current during the 30-minute recovery test.

Osc 1



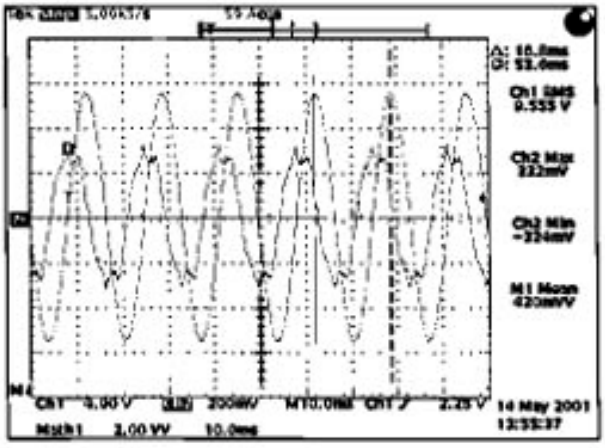
PVNA #8W Recovery @ Time 0 1kV/V 2.508mA/V

Osc 2



PVNA #8W Recovery @ 1 min 1kV/V 2.508mA/V

Osc 3



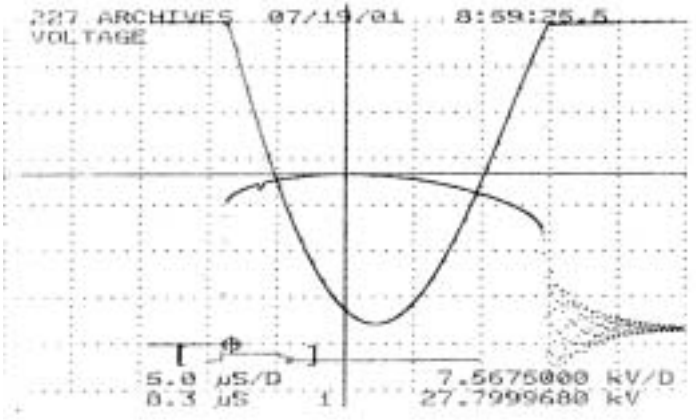
PVNA #8W Recovery @ 30 min 1kV/V 2.508mA/V

The following table summarizes the thermal recovery portion of the HCSD test.

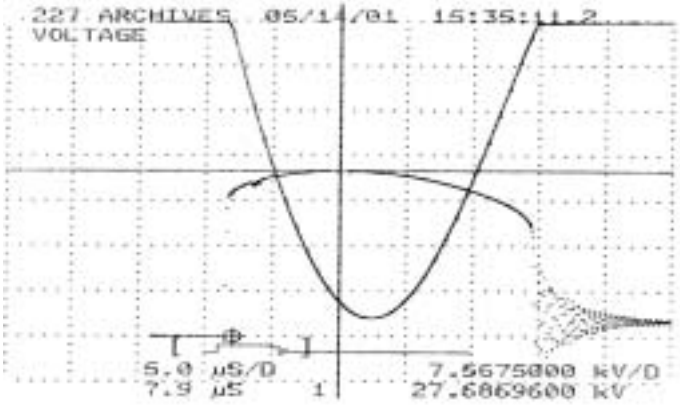
Time (minutes)	Recovery Volts (kVrms)	Section Watts	Section Current (mac)
0	9.62	1.89	1.35
1	9.58	1.57	.85
2	9.61	1.50	.85
5	9.58	1.34	.84
10	9.58	1.24	.84
20	9.61	1.16	.83
30	9.56	1.05	.83

Residual voltage at 10 kA was measured prior to and after the 100 kA discharge and thermal recovery tests. The following oscillograms verified the 10 kA discharge voltage remained unchanged within acceptable limits.

10 kA IR Before HCSD Test = 27.799 kV



10 kA IR After HCSD Test = 27.687 kV



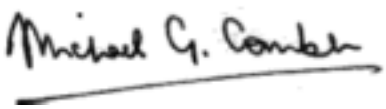
CONCLUSION: The prorated test sample successfully completed the high current test and demonstrated thermal stability during the recovery test. The 10 kA residual voltage increased 1.0%, less than the allowed 10%. Disassembly revealed no evidence of physical damage to the test sample. The PVNA design successfully met the High Current, Short Duration requirements of the Station Class Arrester.

TYPE TEST REPORT No. EU1502-H-08

TRANSMISSION LINE DISCHARGE TEST

CERTIFICATION

This is to certify that the transmission line discharge design test has been successfully performed on Ohio Brass Type PVNA Station Class surge arrester.



Michael G. Comber
Manager – Engineering
Ohio Brass & Chardon Products

Dennis W. Lenk P.E.
Principal Engineer

October, 2001
Attachments

DESIGN TEST REPORT
PVNA Station Class Surge Arrester

TITLE: Transmission Line Discharge Test: 161 kV System Application

OBJECTIVE: This test was performed per IEEE Standard C62.11 on a thermally prorated section of a full size arrester.

TEST SAMPLE: The test sample consisted of (2) 60mm diameter discs, 72mm total length. The MCOV (9.44 kV rms) is assigned to represent the most severe condition; i.e., the minimum allowed discharge voltage level.

TEST PARAMETERS: The test setup is intended to model a 98kV MCOV arrester applied on a 161 kV system. The system parameters were derived from Table 11 of the C62.11 Standard. The system and prorated section parameters are defined as follows:

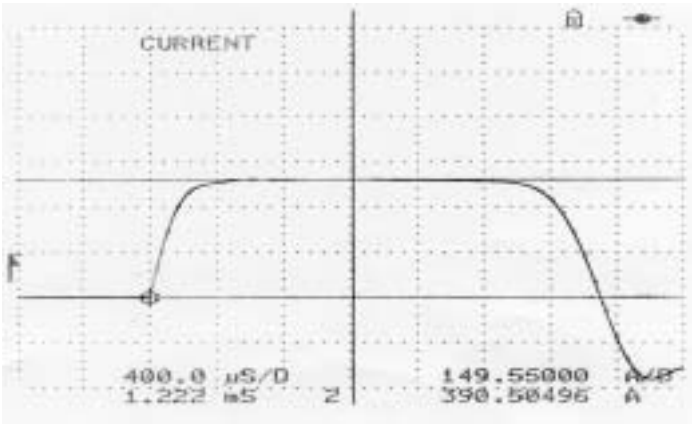
System Surge Impedance	400 Ohm
System Charge	359 kV
System Capacitance	2.44 Microfarad
Line Length	175 Miles
Equivalent Duration (TD)*	1890 Microseconds
Prorated Test Sample MCOV	9.44 kV RMS
Proratio Factor (K)	10.37
Required Generator Surge Impedance	38.53 Ohm
Required Generator Charge	34.58 kV
Required Generator Capacitance	25.53 Microfarad
Measured Generator Impedance (Zg)	36.75 Ohm
Measured Line Discharge Duration	2096 Microseconds
Equivalent Generator Line Length	194 Miles
Number of Generator Sections	10

*TD = miles times 10.8

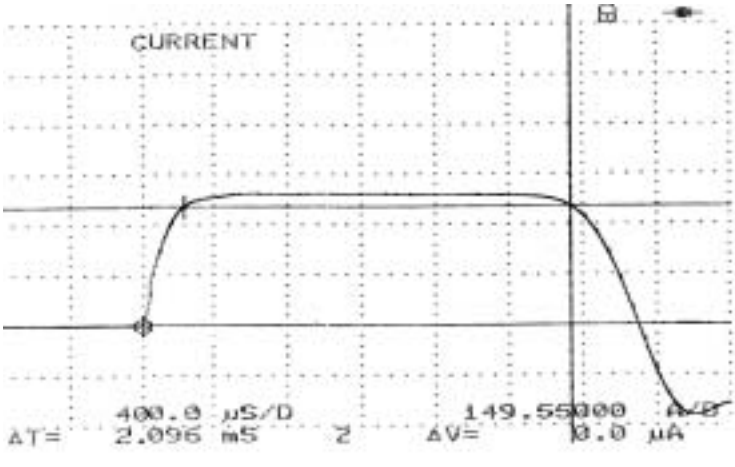
TEST PROCEDURE: Before and after the transmission line discharge test, the 10 kA 8/20 discharge voltage of the test sample was measured. The procedure was performed per Section 8.10.2.1.3 of the C62.11 Standard. The procedure consisted of subjecting the test specimen to three groups of six consecutive operations followed by one group of two operations with a time interval between consecutive operations of one minute. The test specimen was allowed to cool to ambient between Shots No. 6 and No. 7 and between Shots No. 12 and No. 13. After the eighteenth shot, the test sample was placed inside an oven and heated to 66^{o}C. After the heated test sample was subjected to Shots No. 19 and No. 20, the sample was energized at recovery voltage and thermal stability was demonstrated.

TEST RESULTS: The following figure measures the surge impedance and confirms the duration of the transmission line generator.

Zg = 14.35 Kv/390.5 Amps
Zg = 36.75 Ohms

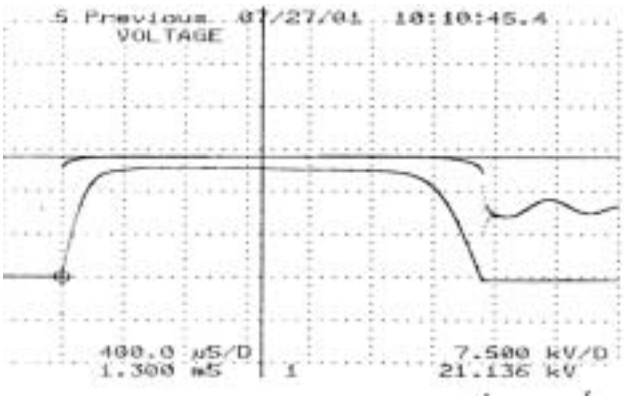


2096 Microsecond Duration = 194 Miles



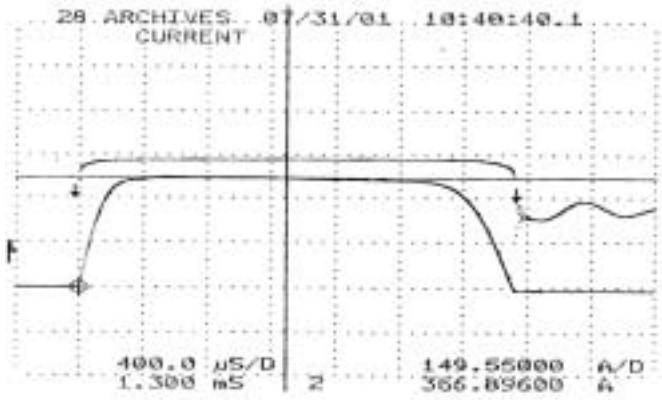
The following is an oscillographic record of the first transmission line discharge through the test sample.

Shot 1



After successful completion of the (18) shot test, the sample was preheated to 60oC. and subjected to two additional transmission line discharges spaced one minute. The following is an oscillographic record of the 20th shot.

Shot 20

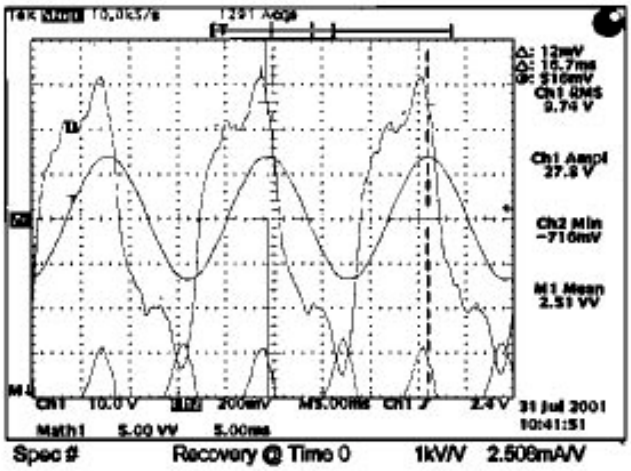


After the 20th shot, the sample was energized at recovery voltage (9.83 kV RMS). The sample remained energized until thermal stability was demonstrated. The following table summarizes the measured watts of the test sample during the recovery portion of the test.

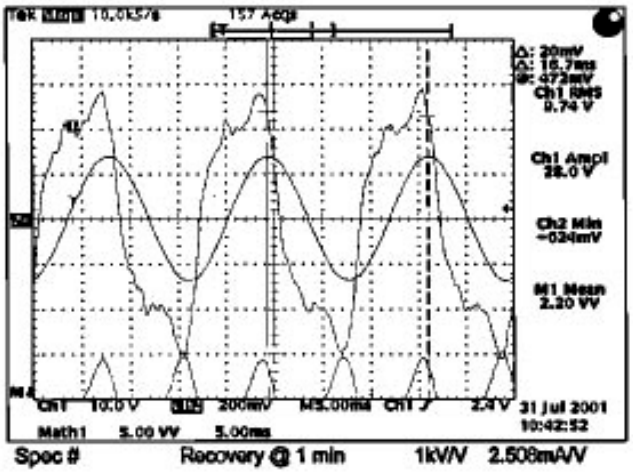
Applied Voltage (kV RMS)	Time (Minutes)	Sample Watts
9.83	0+	6.27
9.83	2	5.14
9.83	5	4.77
9.83	10	4.31
9.83	20	3.89
9.83	30	3.51

The following oscillograms show section grading current measured at time 0, 1 minute, and 30 minutes.

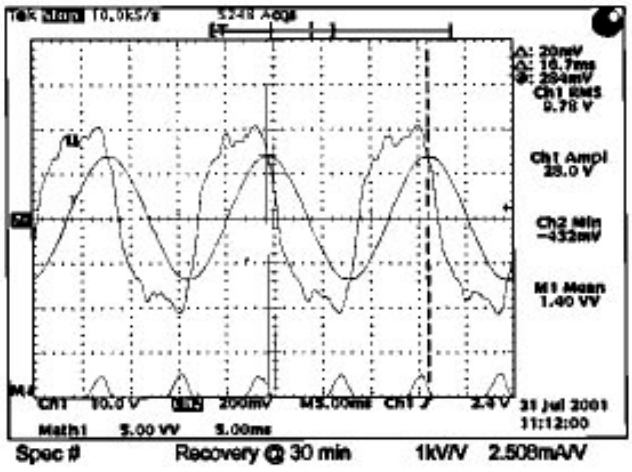
Osc 1



Osc 2

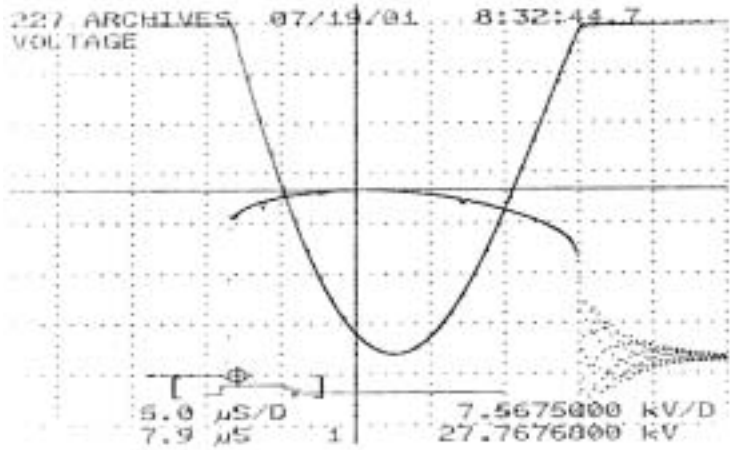


Osc 3

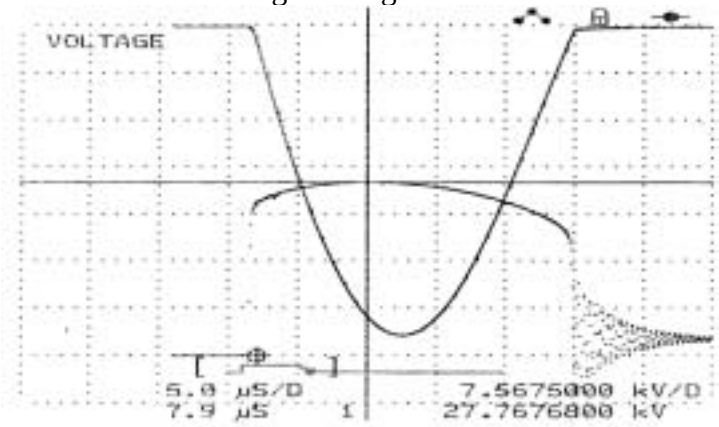


The sample 10 kA 8/20 discharge voltage was measured before and after the duty cycle test. The measured values are summarized below.

Before TLD Test
Discharge Current=10.00 kA
Discharge Voltage=27.77 kV



After TLD Test
Discharge Current=10.01 kA
Discharge Voltage=27.76 kV



CONCLUSION: The prorated test sample successfully completed the transmission line discharge test per IEEE C62.11 standard and demonstrated thermal stability when energized at recovery voltage. The 10 kA 8/20 discharge voltage was unchanged, within the allowable 10% acceptance limit. Disassembly revealed no evidence of physical damage to the test sample. Therefore, the Type PVNA test sample has successfully fulfilled the transmission line discharge requirements of a Station Class Arrester applied on a 161 kV system.

TYPE TEST REPORT No. EU1502-H-09

DUTY CYCLE TEST

CERTIFICATION

This is to certify that the duty cycle design test has been successfully performed on Ohio Brass Type PVNA Station Class surge arrester.

Michael G. Comber
Manager – Engineering
Ohio Brass & Chardon Products

Dennis W. Lenk P.E.
Principal Engineer

October, 2001
Attachments

DESIGN TEST REPORT
PVNA Station Class Surge Arrester

TITLE: Duty Cycle Test:

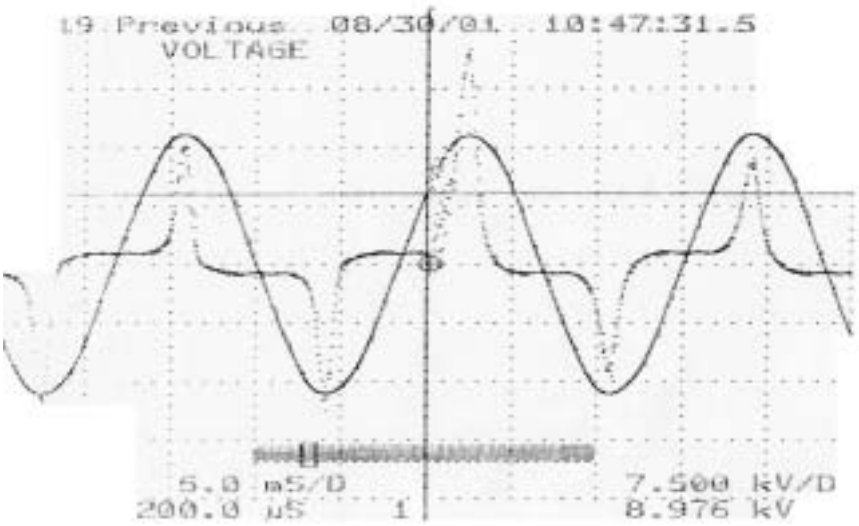
TEST OBJECTIVE: Section 8.11.1.3 specifies that the 20-shot rated voltage and 2-shot recovery portion of the Duty Cycle test on Station Class arresters be performed with 10 kA 8/20 lightning impulses.

TEST SAMPLE: As required by clause 7.2.2, prorated samples contained the minimum MOV mass per specified for the design. MCOV and rated voltages were also prorated per unit Vref to reflect the lowest margin case of the standard voltage ratings offered in this design.

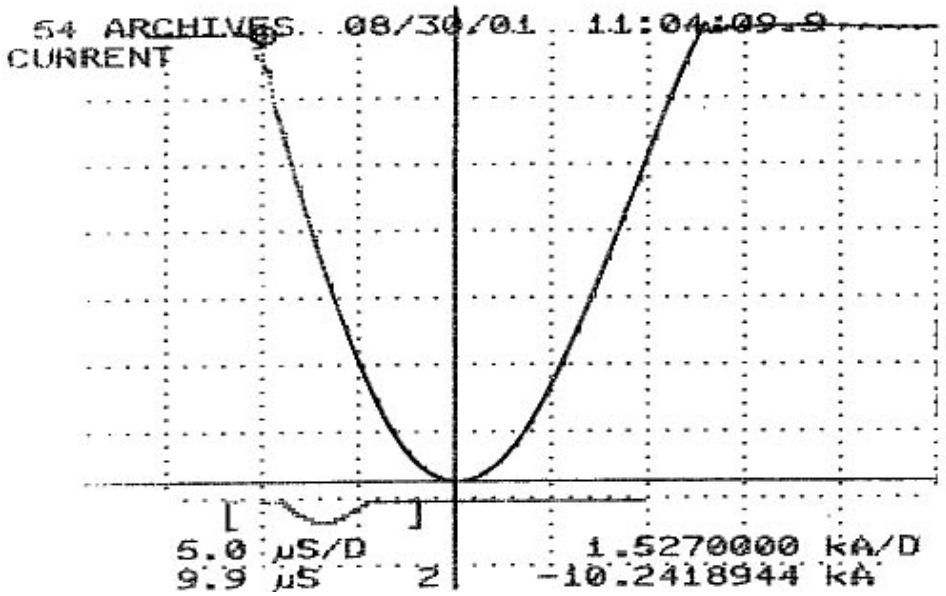
TEST PROCEDURE: The 9.42 kVrms MCOV test sample was energized at its 11.78 kV_{rms} rated voltage and subjected to twenty 10 kA, 8/20 discharges spaced at 1 minute increments. Following the twentieth impulse, the test section was placed in an oven at 60 ˚C. After reaching 60 ˚C, the sample was subjected to two 40 kA, 8/20 discharges. Within 5 minutes after the second high current discharge, the sample was energized at the prorated recovery voltage of 9.9 kV_{rms}. Watts loss was monitored over a 30 minute period demonstrating thermal stability.

TEST RESULTS: The following data summarizes the results of the duty cycle test.

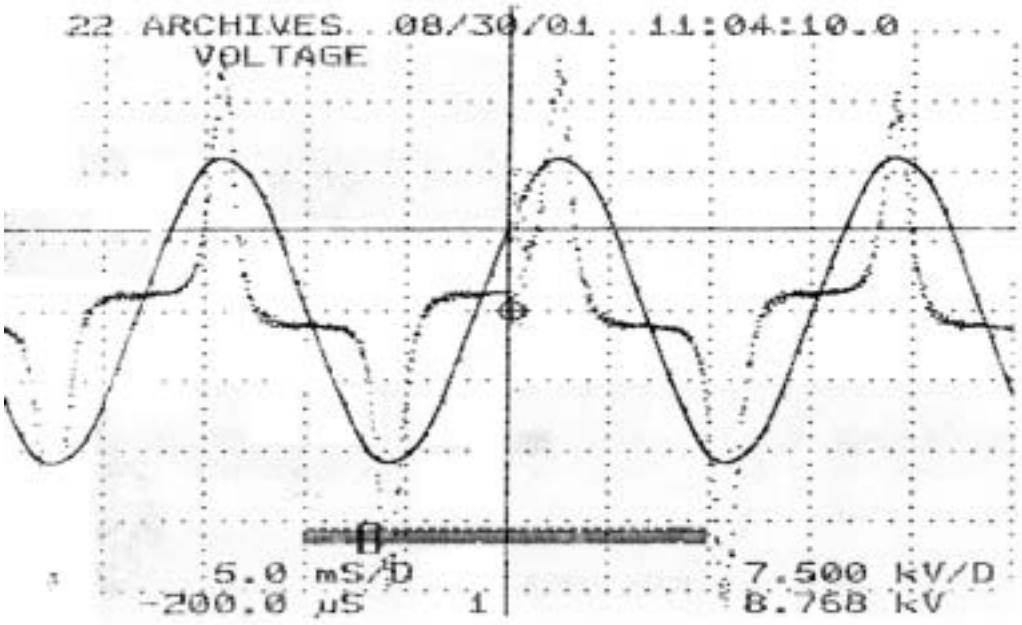
First Shot of 20 Shot Rated Voltage Duty Cycle Test



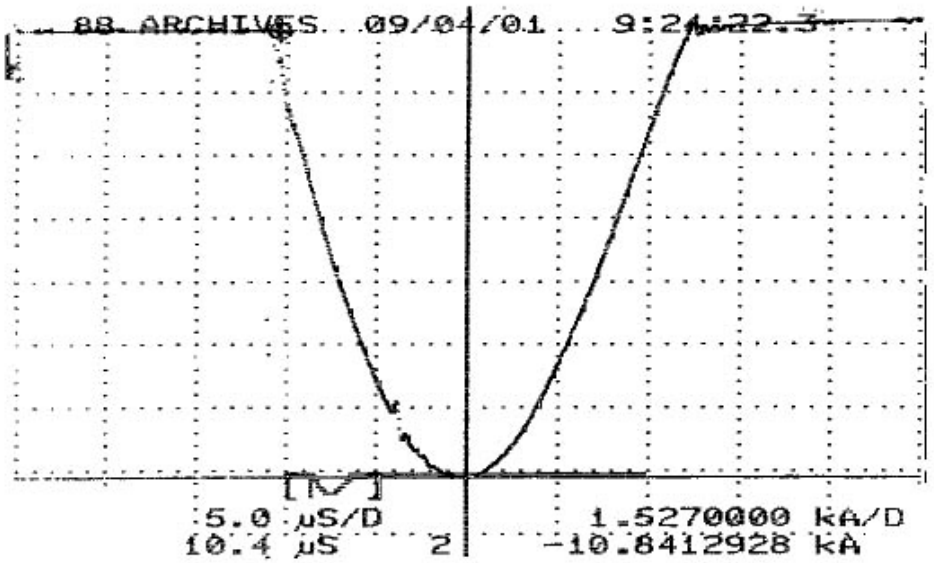
10 kA 8.1/18.8 Waveshape for 20 Shot Test



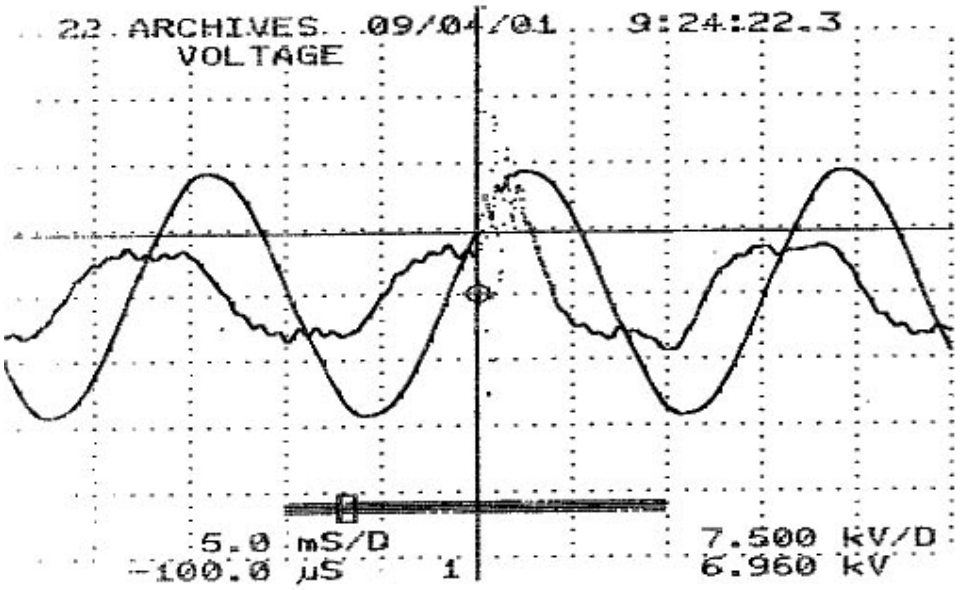
20th Shot of 20 Shot Rated Voltage Duty Cycle Test



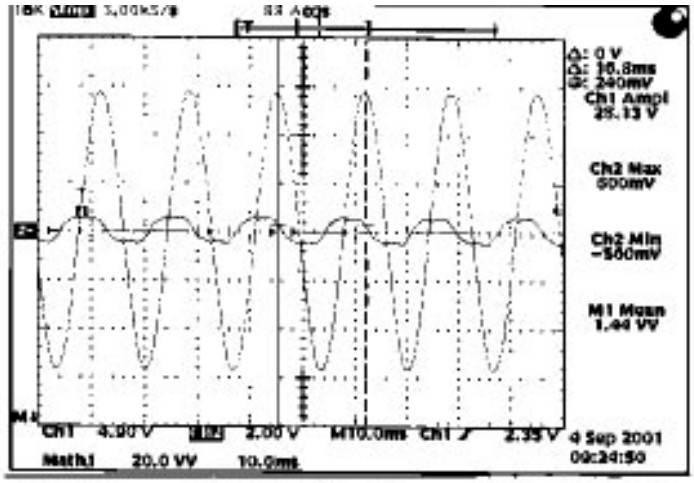
10.16kA 8.4/18.7 Waveshape for 2-Shot Test



Oscillogram of 22nd Shot

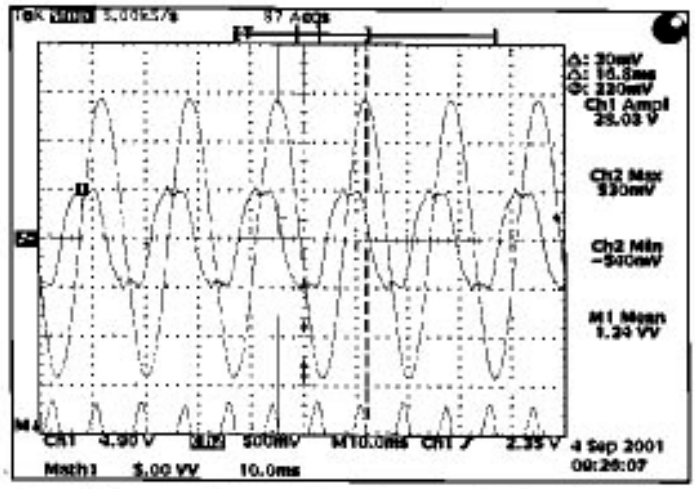


Immediately after the 22nd shot, the arrester section was energized at recovery voltage. The following oscillograms show section grading current measured at time 0, 1 minute, and 30 minutes.



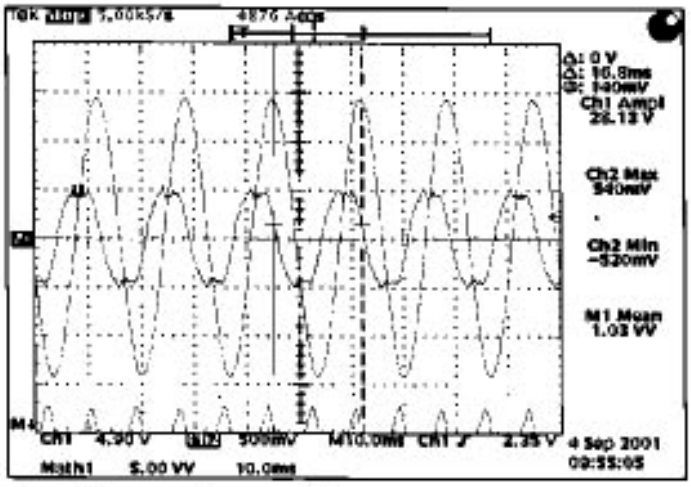
Spec #4 Recovery @ Time 0 1kV/V 2.508mA/V

Osc 2



Spec #4 Recovery @ 1 min 1kV/V 2.508mA/V

Osc 3



Spec #4 Recovery @ 30 min 1kV/V 2.508mA/V

The following table summarizes the results of the 20 shot rated duty cycle voltage test.

Shot No.	Applied Voltage (kV_{rms})	Watts	Grading Current (ma_c)	8/20 Impulse (kA)
1	11.82	22.47	9.92	10.1
2	11.78	20.85	9.51	10.1
3	11.92	26.52	12.55	10.1
4	11.92	28.34	12.35	10.2
5	11.92	29.96	13.77	10.1
6	11.92	28.74	13.56	10.3
7	11.89	30.36	13.36	10.3
8	11.92	31.78	13.77	10.2
9	11.89	33.00	13.77	10.3
10	11.89	34.82	14.57	10.3
11	11.89	37.04	14.78	10.2
12	11.85	39.47	16.19	10.2
13	11.85	42.31	16.80	10.2
14	11.89	45.75	18.02	10.2
15	11.85	49.39	18.22	10.2
16	11.78	52.23	19.03	10.0
17	11.78	57.09	20.65	10.1
18	11.78	63.56	22.27	10.3
19	11.82	72.47	24.70	10.3
20	11.78	77.73	26.72	10.3

The following table summarizes the 21st and 22nd shots after sample preheating to 60^{o}C.

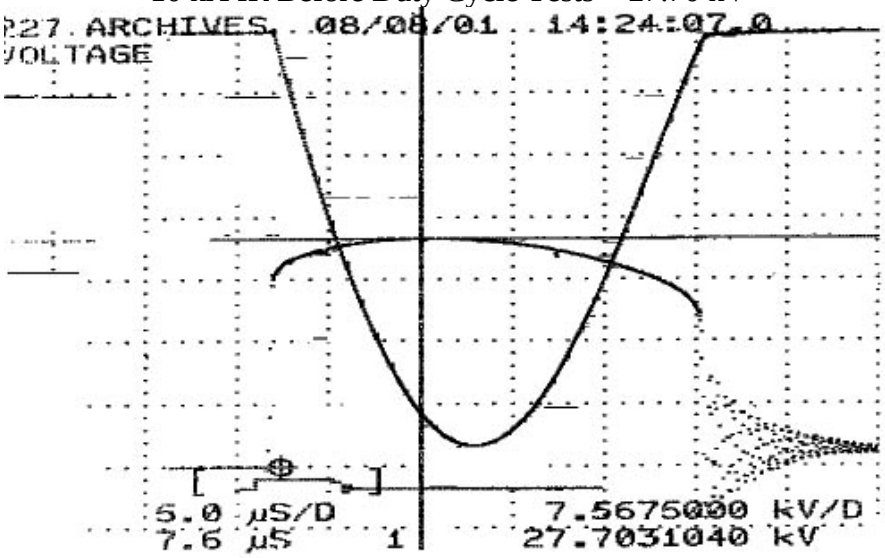
Shot No.	Applied Voltage (kV_{rms})	Watts	Grading Current (ma_c)	8/20 Impulse (kA)
21	9.91	2.78	1.40	10.3
22	9.91	3.09	1.43	10.2

The following table summarizes the recovery voltage portion of the duty cycle test.

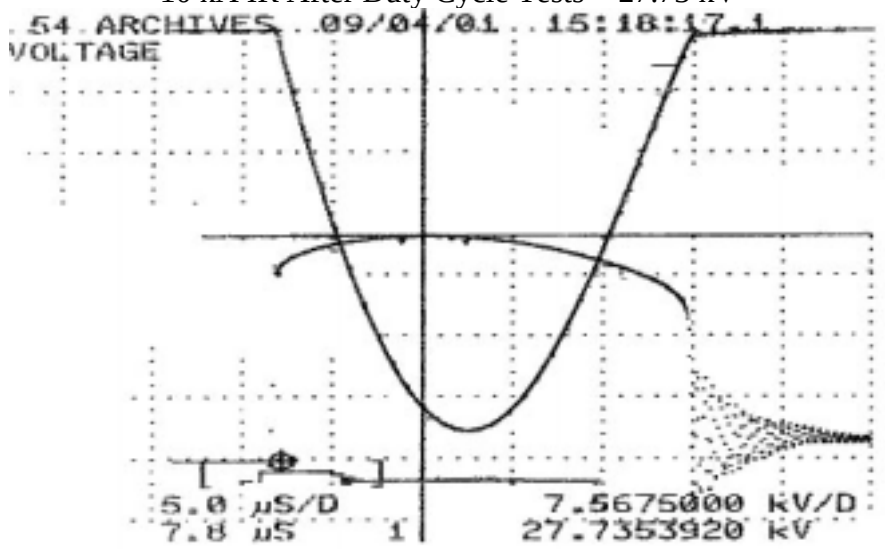
Time (minutes)	Applied Voltage (kV_{rms})	Watts	Grading Current (ma_c)
0	9.95	3.06	1.40
1	9.91	2.83	1.43
2	9.95	2.78	1.40
5	9.95	2.71	1.43
10	9.91	2.58	1.40
20	9.95	2.48	1.38
30	9.95	2.38	1.38

Residual voltage at 10 kA was measured prior to and following the Duty Cycle test series.

10 kA IR Before Duty Cycle Tests = 27.70 kV



10 kA IR After Duty Cycle Tests = 27.73 kV



Conclusion: The prorated test sample successfully completed Duty Cycle testing and demonstrated thermal stability during the recovery test. The 10 kA discharge voltage increased 0.1%, less than the acceptable 10% limit specified in Section 8.11.1.4 of C62.11-1999 Standard. Disassembly revealed no evidence of physical damage to the test sample. The PVNA arrester successfully met the Duty Cycle requirements of the Station Class arrester.

TYPE TEST REPORT No. EU1502-H-10

TEMPORARY OVERVOLTAGE TEST

CERTIFICATION

This is to certify that the temporary overvoltage design test has been successfully performed on Ohio Brass Type PVNA Station Class surge arrester.

Michael G. Comber
Manager – Engineering
Ohio Brass & Chardon Products

Dennis W. Lenk P.E.
Principal Engineer

October, 2001
Attachments

DESIGN TEST REPORT
PVNA Station Class Surge Arrester

TITLE: Temporary over-voltage tests (TOV):

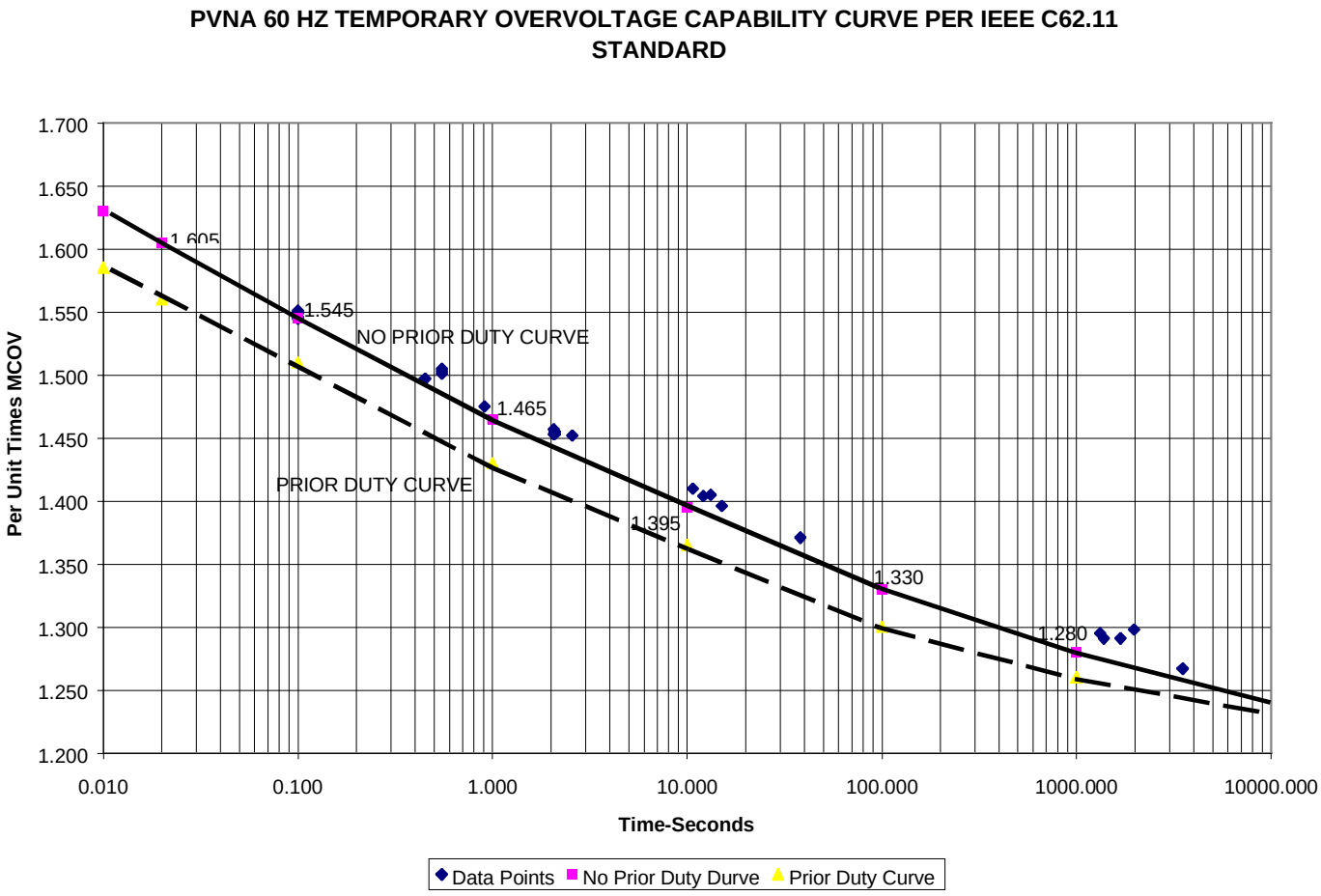
TEST SAMPLES: Temporary over-voltage tests were performed per clause 8.12 of IEEE Standard C62.11-1999. Tests were performed per Station Class arrester requirements using five prorated test sections. Prorated sections were used to facilitate testing of the lowest MOV mass, highest stressed arrester rating at voltages within available laboratory facility capabilities.

TEST PROCEDURE: Per clause 8.12.1, each prorated sample was tested within five of the six designated time ranges a - f, spanning over-voltage durations of .01 - 10,000 seconds. Per clause 8.12.2, 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 60^{o}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.

TEST RESULTS: Tests were successfully completed on five PVNA prorated samples in five specified time ranges. Each sample demonstrated thermal stability after TOV exposure having no signs of physical damage during inspection. Residual voltage at 10 kA measured prior to and following the complete TOV test series verified characteristics remained unchanged within acceptable limits. The following table summarizes the results of the TOV test program and applies to PVNA arresters through 72 kV rating.

TOV DURATION (SECONDS)	NO PRIOR DUTY TOV (PER UNIT MCOV)	PRIOR DUTY TOV (PER UNIT MCOV)
.02	1.605	1.560
.1	1.545	1.510
1	1.465	1.430
10	1.395	1.365
100	1.330	1.300
1000	1.280	1.260

The following curve plots the individual “no prior duty” data points on the claimed TOV capability curve.



TYPE TEST REPORT No. EU 1502-H-11

PRESSURE RELIEF TEST

CERTIFICATION

This is to certify that the pressure relief design test has been successfully performed on Ohio Brass Type PVNA Station Class surge arrester.

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Ohio Brass & Chardon Products

Dennis W. Lenk P.E.
Principal Engineer

October, 2001
Attachments

DESIGN TEST REPORT
PVNA Station Class Surge Arrester

TITLE: Pressure Relief Test For Polymer Housed Station Class Arrester:

TEST OBJECTIVE: Pressure relief tests were performed on the Type PVNA polymer-housed Station Class arrester per Section 8.15 of IEEE C62.11-1999 Standard.

TEST SAMPLES: Tests were performed on fusewire shorted and overvoltage failed arresters as defined in Table 14 of the referenced standard. Pressure relief tests were performed on the longest mechanical section, as required in Section 8.15.1 of the standard.

TEST PROCEDURE: 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. 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 pressure relief current capability of the design.

TEST RESULTS: The following table summarizes the results these tests which validated the claimed maximum 40 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.

Calibration Test 41.0 kA_{rms} Symmetrical 107 kA_{peak} Asymmetrical

Sample #	Failure Mode	Minimum Test Duration-seconds	Condition of Module/Polymer Housing After Test
1	Fuse Wire	.21	Module Intact/Housing Separated
2	Fuse Wire	.21	Module Intact/Housing Separated
3	2-Source	.21	Module Intact/Hsg Torn but in Place
4	2-Source	.21	Module Intact/Hsg Torn but in Place

Calibration Test 19.9 kA_{rms} Symmetrical 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 A_{rms} Symmetrical 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: The eight test arresters assembled with the longest mechanical unit met the test evaluation criteria as specified in Section 8.15.3 of IEEE C62.11-1999 Standard. In all tests, the arrester module remained intact 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 PVNA arrester design to discharge a maximum claimable 40 kA_{rms} symmetrical fault current using the test procedure defined in Section 8.15 of IEEE C62.11-1999 Standard.

TYPE TEST REPORT No. EU1502-H-12

MAXIMUM DESIGN CANTILEVER LOAD-STATIC TEST

CERTIFICATION

This is to certify that the maximum design cantilever load-static design test has been successfully performed on Ohio Brass Type PVNA Station Class surge arrester.

Michael G. Comber
Manager – Engineering
Ohio Brass & Chardon Products

Dennis W. Lenk P.E.
Principal Engineer

October, 2001
Attachments

DESIGN TEST REPORT
PVNA Station Class Surge Arrester

TITLE: Maximum Design Cantilever Load-Static Test

TEST SAMPLES: The maximum design cantilever load (static) test was performed on a PVNA 19.5 kV MCOV arrester, representing the longest PVNA mechanical unit assembled with a 3-lug base end casting. Tests were performed on this 11.0 long arrester to validate the claimed 2000 inch-pound continuous cantilever rating.

TEST PROCEDURE: Testing was performed per the procedures specified in Section 8.19.2 of IEEE Std C62.11-1999. Per paragraphs a) and b), the test arrester was rigidly mounted at its base and top end loading applied to develop 2000 inch-pound cantilever load. With the arrester under load, the arrester was energized at 1,05 times MCOV and internal ionization was measured. Also, top end deflection measured at this load. . Per paragraph c), successive testing was performed at 0^o, 90^o, 180^o, and 270^o. The results of this initial testing before temperature thermal cycling is summarized below.

TEST RESULTS: The following summarizes the results of these tests with .7 microvolts of background noise.

Mechanical Loading Tests Prior to Thermal Cycling

Arrester #	Direction of Applied 1200 in-lb Load (Degrees)	IIV @ 1.05 Times MCOV (Microvolts)	Top End Deflection (inches)
1	0	.7	.472
1	90	.7	.477
1	180	.6	.503
1	270	.7	.475

Per paragraph d), the arrester was placed inside a thermal cycling oven for 96 hours and subjected to a combination of 2000 inch-pound load rotations and temperature excursions as specified in Figure 3 of C62.11-1999 Standard.

After completion of the thermocycling testing, the testing per paragraphs b) and c) was repeated. The results of this testing is summarized below with .4 microvolts of background noise.

Mechanical Loading Tests After Thermal Cycling

Arrester #	Direction of Applied 1200 in-lb Load (Degrees)	IIV @ 1.05 Times MCOV (Microvolts)	Top End Deflection (inches)
1	0	.8	.518
1	90	.6	.505
1	180	.6	.533
1	270	.8	.503

CONCLUSION: Per Section 8.19.3, the internal ionization levels were unchanged and top end deflection measurements changed less than the allowed 10% as a result of the thermal cycling test. Visual examination revealed no evidence of mechanical damage. The above tests validated the 2000 inch-pound continuous cantilever rating of the PVNA arrester assembled with a 3-lug base end casting.