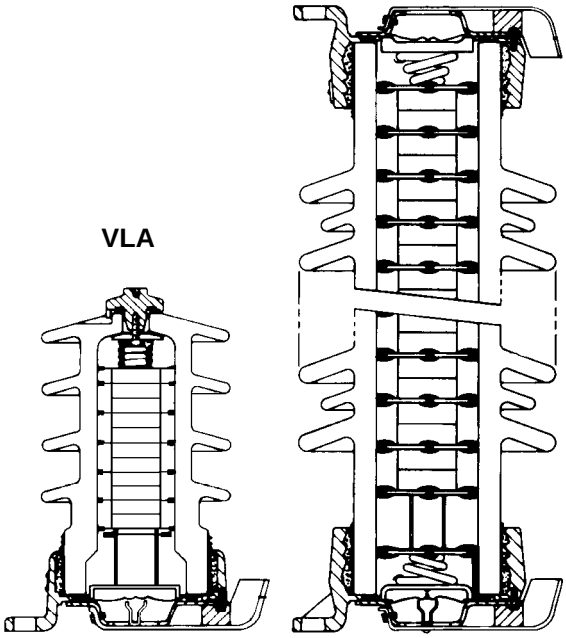
Design Test Report

DynaVar VL/VLA Arrester

I. Insulation Withstand Test
II. Discharge Voltage Test
III. High Current/Short Duration Test
IV. Transmission Line Discharge Test
V. Duty Cycle Test
VI. Accelerated Aging Test
VII. Temporary Overvoltage Capability Test
VIII. Internal Ionization and RIV Test
IX. Contamination Test
X. Pressure Relief Test

VL

VLA



This design test report records the results of laboratory tests made on the Ohio Brass DynaVar Type VL/VLA arrester.

Test references were the procedures of ANSI/IEEE Standard C62.11-1993.

The DynaVar Type VL/VLA arrester meets or exceeds all applicable requirements of this standard.

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NOTE: Because Hubbell has a policy of continuous product improvement, we reserve the right to change design and specifications without notice.

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SECTION I

INSULATION WITHSTAND: VL ARRESTERS

Introduction

Insulation withstand tests were performed in accordance with Section 8.1 of IEEE Std C62.11-1993. The following table lists the Type VL arresters' minimum strike distance, minimum leakage distance, and required power frequency wet and 1.2/50 impulse withstand levels as defined in Section 8.1.3. All housings meet or exceed these levels of voltage.

DYNAVAR VL HOUSING INSULATION DATA

Catalog Number	MCOV (kV)	Strike Distance (inches)	Minimum Leakage Distance (inches)	60-Hz Withstand		1.2/50 Withstand (kV)
				Dry (kV)	Wet (kV)	
216003	2.55	4.5	6.2	21	20	60
216005	5.1	4.5	6.2	27	24	75
219508	7.65	4.5	6.2	35	30	95
219509	8.4	4.5	6.2	35	30	95
219510	10.2	6.1	11.1	50	45	110
219513	12.7	6.1	11.1	50	45	110
216015	15.3	9.1	20	50	45	110
219517	17.0	9.1	20	70	60	150
219519	19.5	9.1	20	70	60	150
216022	22	13.5	31.7	70	60	150
216024	24.4	13.5	31.7	95	80	200
219529	29	13.5	31.7	95	80	200
216031	31.5	17.25	41	120	100	250
219536	36.5	17.25	41	120	100	250
219539	39	17.25	41	120	100	250

DYNAVAR VLA HOUSING INSULATION DATA

Catalog Number	MCOV (kV)	Strike Distance (inches)	Minimum Leakage Distance (inches)	60-Hz Withstand		1.2/50 Withstand (kV)
				Dry (kV)	Wet (kV)	
217003	2.55	8.4	11.1	21	20	60
217005	5.1	8.4	11.1	27	24	75
217008	7.65	8.4	11.1	35	30	95
217009	8.4	8.4	11.1	35	30	95
218510	10.2	8.4	11.1	50	45	110
217013	12.7	12.5	20	50	45	110
217015	15.3	12.5	20	50	45	110
218517	17.0	12.5	20	70	60	150
218519	19.5	12.5	20	70	60	150
217022	22	16.5	28.5	70	60	150

SECTION II

DISCHARGE VOLTAGE TEST: TYPE VL ARRESTER

Sample Preparation

The discharge voltage tests were performed on a single 60 mm diameter mov disc element.

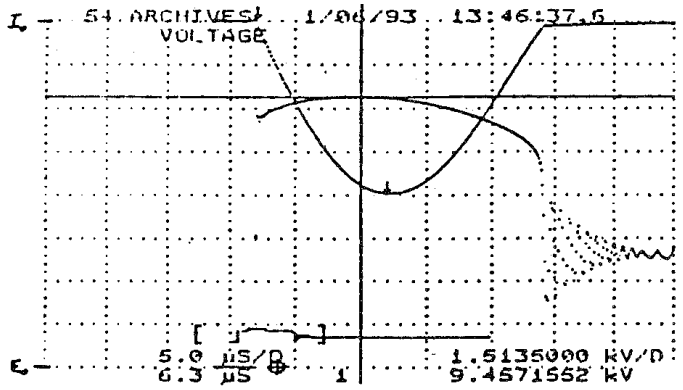
Test Procedure

The discharge voltage test was performed per Section 8.3 of ANSI C62.11-1993 Standard. The disc was subjected to 8/20 current waves with magnitudes ranging from 1.5 thru 40 kA. In addition, FOW and switching surge discharge voltage tests were performed.

Test Results

The following oscillograms show the results of the individual discharge voltage tests. At the end of this section, a summary table compares the catalog protective characteristics versus the measured values extrapolated from the test data. The test specimen with a 10 kA 8/20 IR of 11.35 kV represents the maximum discharge voltage for a 3.77 kV rms Type VL arrester.

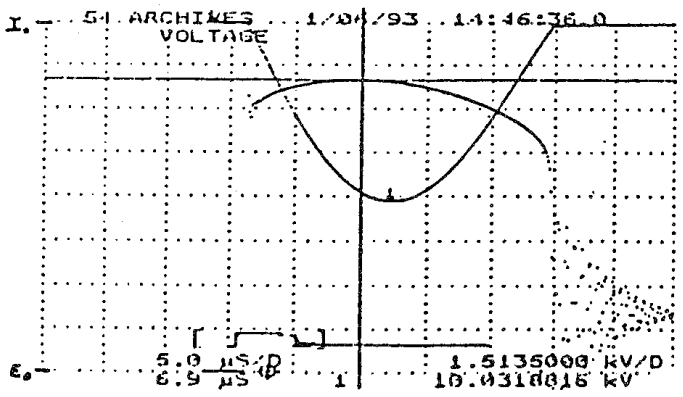
A. 8/20 Discharge Voltage Oscillograms: Tests were performed per Section 8.3.1 for nominal 8/20 discharge current waveshapes.



1.51 kA

9.46 kV

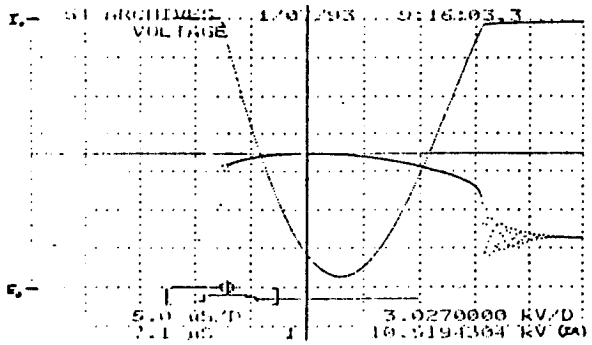
8.4/180



3.14 kA

10.03 kV

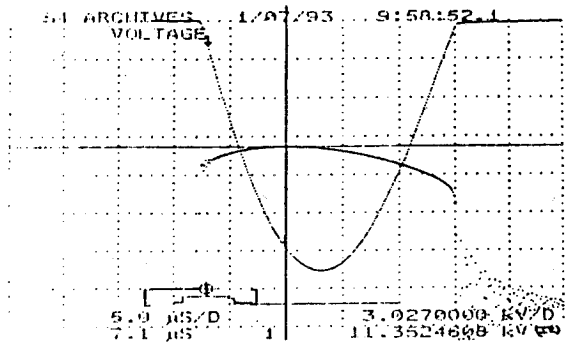
8.0/19.3



5.14 kA

10.52 kV

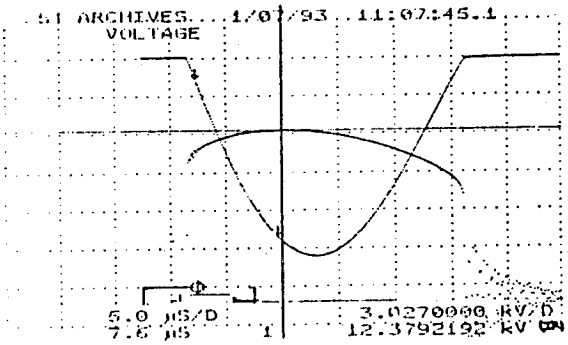
8.6/18.9



9.99 kA

11.35 kV

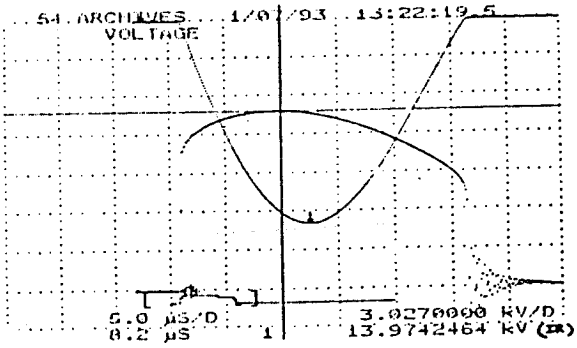
8.6/18.8



19.94 kA

12.38 kV

8.8/20

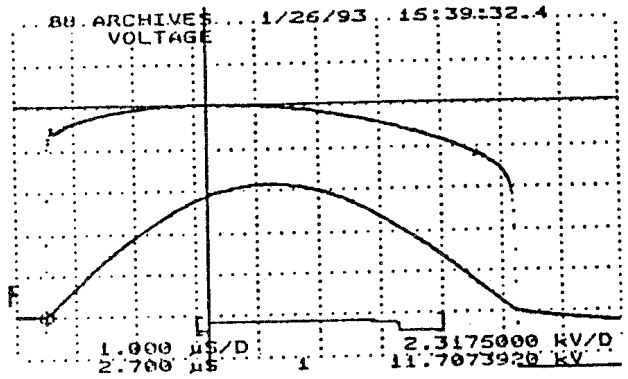


40.46 kA

13.97 kV

8.8/20.3

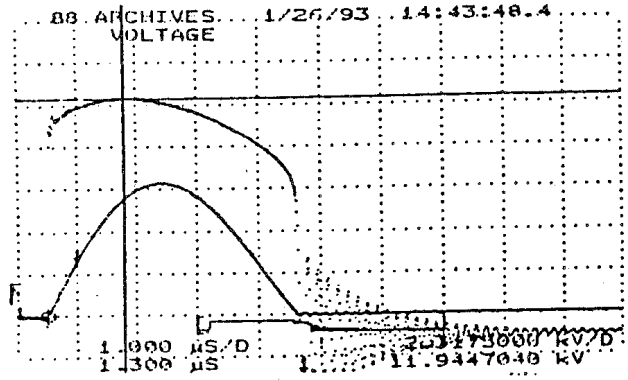
B. FOW Oscillograms: Tests were performed per Section 8.3.2.1 for nominal 10 kA current surges with times to voltage crest approaching .5 microseconds.



10.18 kA max @ 3.0 us

11.71 kV max @ 2.7 us

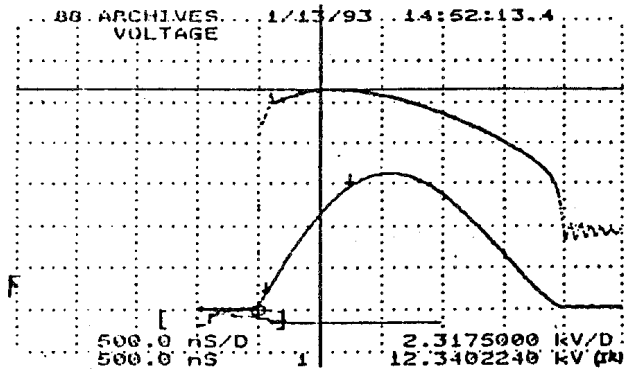
3.0/6.8 waveshape



10.03 kA max @ 1.5 us

11.94 kV max @ 1.3 us

1.5/3.3 waveshape

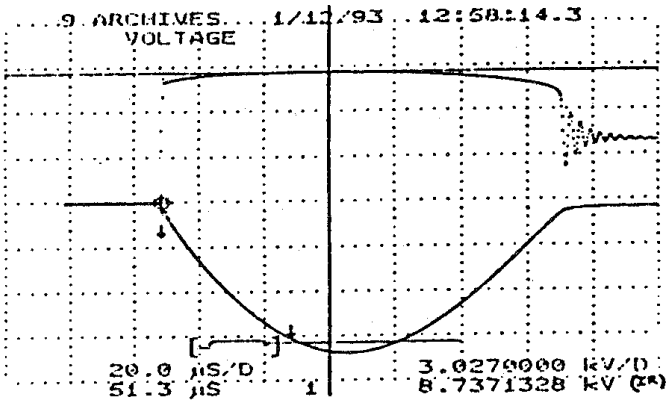


10.25 kA max @ .85 us

12.34 kV max @ .5 us

.85/1.9 waveshape

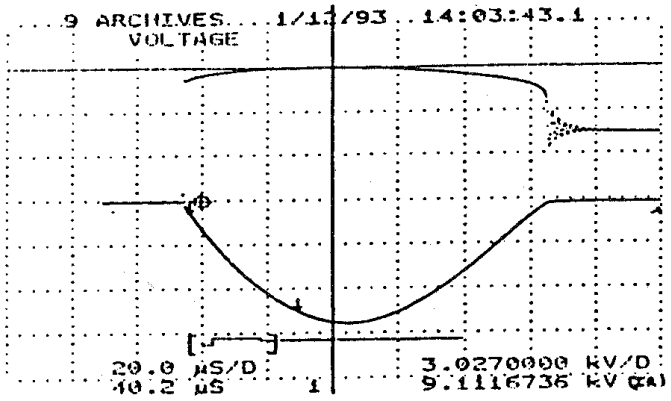
C. Switching Surge Oscillograms: Tests were performed per Section 8.3.2.2 for switching surge current magnitudes of 500 and 1000 amps.



514 Amps

8.74 kV

49.3/101



1058 Amps

9.11 kV

41.2/89.6

TYPE VL/VLA ARRESTERS

PROTECTIVE CHARACTERISTICS COMPARISON TABLE

Arrester MCOV	Arrester Rating	10 kA FOW IR Catalog Maximum (kV)	10 kA FOW IR Prorated Measured (kV)	500 Amp SS IR Catalog Maximum (kV)	500 Amp SS IR Prorated Measured (kV)	10 kA 8/20 IR Catalog Maximum (kV)	10 kA 8/20 IR Prorated Measured (kV)	20 kA 8/20 IR Catalog Maximum (kV)	20 kA 8/20 IR Prorated Measured (kV)
2.55	3	9.1	8.5	6.3	6.0	8.0	7.8	9.0	8.5
5.1	6	17.9	17.0	12.4	12.0	15.8	15.5	17.7	17.0
7.65	9	26.6	25.2	18.4	17.9	23.5	23.2	26.4	25.3
8.4	10	29.3	27.7	20.3	19.6	25.9	25.5	29.1	27.8
10.2	12	35.5	33.7	24.6	23.9	31.4	31.0	35.2	33.8
12.7	15	44.2	42.0	30.6	29.8	39.1	38.6	43.9	42.1
15.3	18	53.3	50.6	36.8	35.8	47.1	46.5	52.8	50.7
17.0	21	59.1	56.2	40.9	39.8	52.3	51.7	58.7	56.4
19.5	24	67.8	64.5	46.9	45.7	60.0	59.3	67.3	64.7
22.0	27	76.5	72.8	52.9	51.5	67.7	66.9	75.9	73.0
24.4	30	84.9	80.7	58.7	57.1	75.1	74.2	84.2	81.0
29.0	36	101	95.8	69.7	67.8	89.2	88.1	100	96.1
31.5	39	110	104	75.8	73.7	96.9	95.7	109	104.4
36.5	42	128	121	88.3	85.4	113	110.9	127	121.0
39.0	48	136	129	93.8	91.2	120	118.5	135	129.3

SECTION III

HIGH CURRENT, SHORT DURATION TEST: VL ARRESTER

Sample Preparation

This test was performed per Section 8.6.1 of IEEE Standard C62.11-1993 on a thermally prorated section of a full size arrester. The test sample consisted of (2) 60mm diameter x 35 mm long mov discs. The MCOV (7.69 kV rms) is assigned to represent the most severe condition; i.e., the minimum allowed discharge voltage level.

Test Procedure

Before and after the high current, short duration test, the 10 kA 8/20 discharge voltage of the test sample was measured.

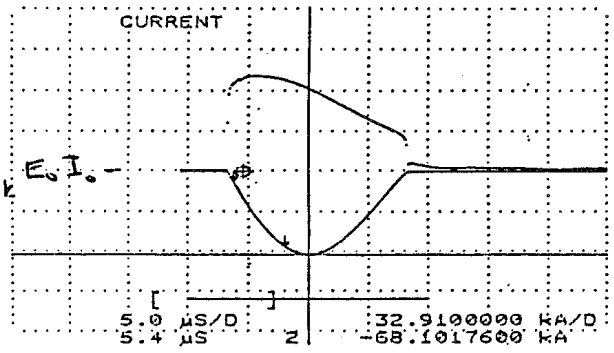
The test sample was subjected to (2) nominal 65 kA 4/10 discharges. Sufficient time was allowed between discharges for the sample to cool to ambient temperature (25°C.).

Within 5 minutes after the second high current discharge, the sample was energized at recovery voltage. The sample watts loss was monitored until thermal stability was demonstrated.

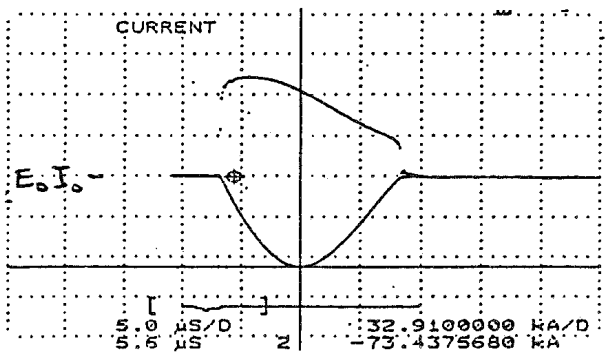
Test Results

The prorated section was subjected to two nominal 65 kA 5.25/11.8 high current discharges. The following traces show the actual current values.

Discharge # 1 (68.1 kA)



Discharge # 2 (73.4 kA)



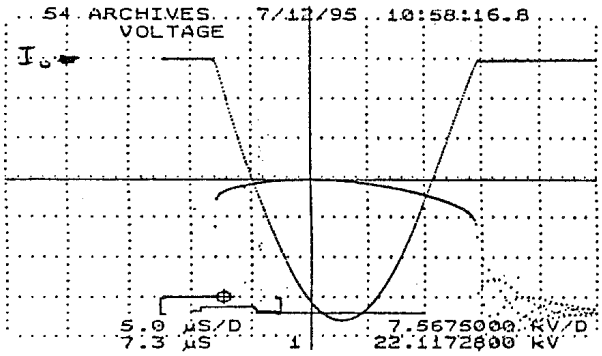
Within 5 minutes of the second high current discharge, the sample was energized at recovery voltage (8.68 kV rms) to represent the maximum allowed watts loss disc. The sample remained energized until thermal stability was demonstrated. The following table summarizes the measured watts of the test sample during the recovery portion of the test.

Applied Voltage (kV rms)	Time (Minutes)	Sample Watts
8.68	0+	3.10
8.68	1	2.25
8.68	5	1.90
8.68	10	1.75
8.68	20	1.70
8.68	30	1.60

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

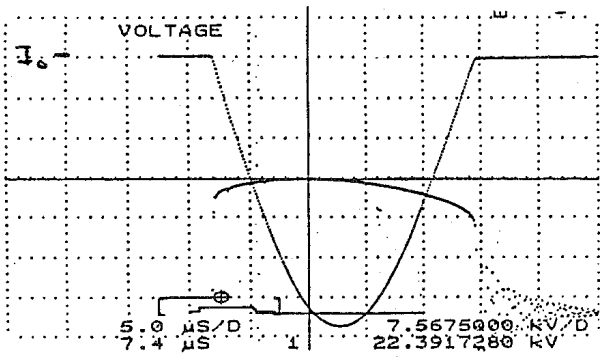
Before HCSD

Discharge Current = 10.05 kA
Discharge Voltage = 22.12 kV



After HCSD

Discharge Current = 10.3 1 kA
Discharge Voltage = 22.39 kV



Test Summary

The prorated test sample successfully completed the high current test per Section 8.6.1 of IEEE C62.11-1993 standard and demonstrated thermal stability during the recovery test. The 10 kA 8/20 discharge voltage changed an acceptable +1.2%, within the allowable 10% acceptance limit. Disassembly revealed no evidence of physical damage to the test sample. Therefore, the test sample has successfully fulfilled the high current, short duration requirements of the Type VL Station Class arrester.

SECTION IV

TRANSMISSION LINE DISCHARGE TEST: TYPE VL ARRESTER

Sample Preparation

This test was performed per Section 8.6.2.1 of IEEE Standard C62.11-1993 on a thermally prorated section of a full size arrester. The test sample consisted of (1) 60mm diameter x 35mm long disc. The MCOV (3.86 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 Type VL 84 kV MCOV arrester applied on a 138 kV system. The system parameters were derived from Table 5 of the C62.11 Standard. The system and prorated section parameters are defined as follows:

System Surge Impedance	450 Ohn
System Charge	307.6 kV
System Capacitance	1.8 Microfarad
Line Length	150 Miles
Equivalent Duration (TD)*	1620 Microseconds
Prorated Test Sample MCOV	3.86 kV RMS
Pro-ratio Factor (K)	21.76
Required Generator Surge Impedance	20.68 Ohm
Required Generator Charge	14.14 kV
Required Generator Capacitance	39.17 Microfarad
Measured Generator Impedance (Zg)	19.13 Ohm
Measured Line Discharge Duration	1770 Microseconds
Equivalent Generator Line Length	165 Miles
Number of Generator Sections	8

*TD = miles times 10.8

Test procedure

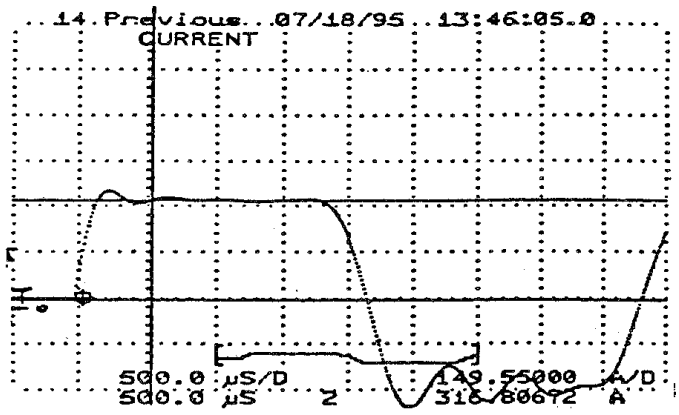
Before and after the transmission line discharge test, the 10 kA 8/20 discharge voltage of the test sample was measured.

The procedure was performed per Section 8.6.2.1.3 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°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

Figure No. 1 measures the surge impedance and confirms the duration of the transmission line generator.

Figure 1



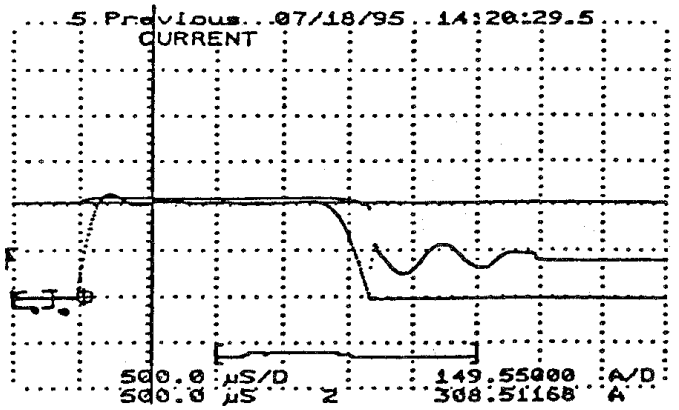
Zg = 6060 Kv/316.8 Amps

Zg = 19.13 Ohms

Duration = 165 Miles

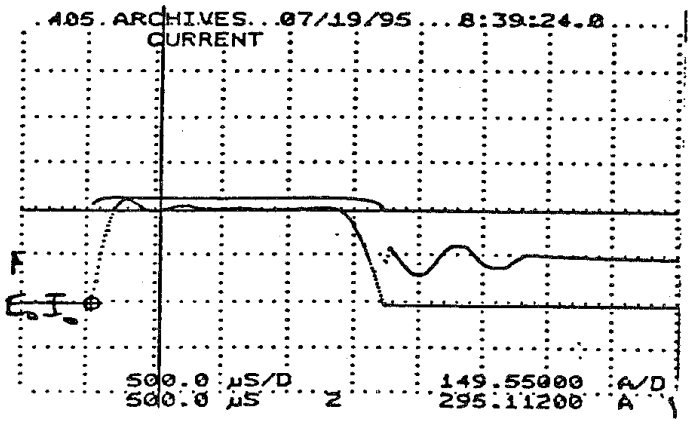
Figure 2 is an oscillographic record of the first transmission line discharge through the test sample.

Figure 2



Shot 1

After successful completion of the (18) shot test, the sample was preheated to 60°C and subjected to two additional transmission line discharges spaced one minute. Figure No. 3 is an oscillographic record of the 20th shot.



Shot 20

After the 20th shot, the sample was energized at recovery voltage (4.36 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
4.36	0+	2.25
4.36	1	1.90
4.36	5	1.85
4.36	10	1.70
4.36	20	1.60
4.36	30	1.55

Test Summary

The prorated test sample successfully completed the transmission line discharge test per Section 8.6.2.1 of IEEE C62.11-1993 standard and demonstrated thermal stability when energized at recovery voltage. The 10 kA 8/20 discharge voltage changed an acceptable +.4%, within the allowable 10% acceptance limit. Disassembly revealed no evidence of physical damage to the test sample. Therefore, the Type VL test sample has successfully fulfilled the transmission line discharge requirements of a Station Class Arrester applied to a 138 kV system.

SECTION V

DUTY CYCLE TEST: TYPE VL ARRESTER

Sample Preparation

This test was performed per Section 8.7 of ANSI/IEEE Standard C62.11-1993 on a thermally prorated section of a full size arrester. The MCOV and duty cycle rating of the prorated section are assigned to represent the most severe condition; i.e., the minimum allowed discharge voltage level.

Test Procedure

Before and after the duty cycle test, the 10 kA 8/20 discharge voltage of the test sample was measured.

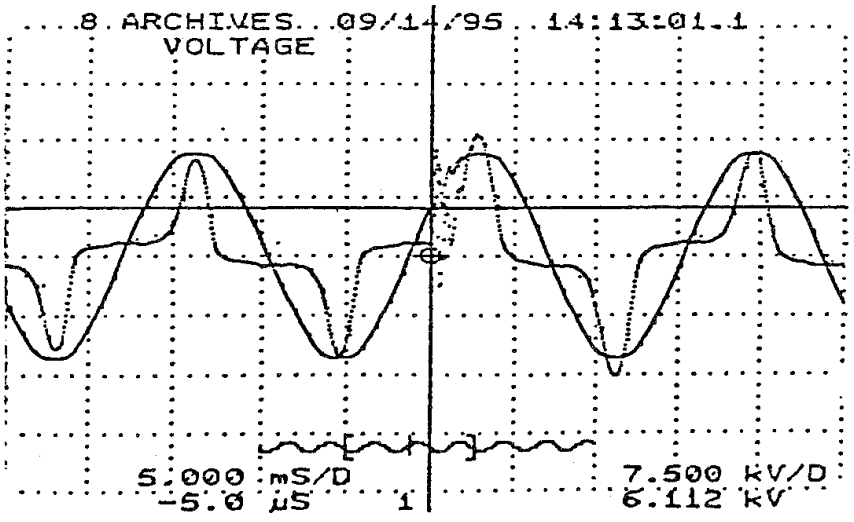
The test sample was then energized at duty cycle rated voltage and subjected to (20) 10 kA 8/20 discharges spaced one minute apart. Per the standard, these 10 kA discharges were electrically timed to occur at approximately 60° before 60-Hz voltage crest.

The test sample was next preheated to 60°C and subjected to two additional 10 kA 8/20 duty cycle operations while energized at MCOV. After the second duty cycle operation, the sample was energized at recovery voltage and the sample watts loss was monitored until thermal stability was demonstrated.

Test Results

The prorated section was energized at duty cycle rated voltage (9.42 kV RMS) and subjected to (20) 10 kA surges spaced one minute apart. The sample watts was monitored throughout the test. The watts increased from 15 after the first discharge to 98 immediately after the twentieth discharge. Figure 1 illustrates a typical duty cycle discharge operation (Shot #20).

Figure 1



After successful completion of the (20) shot test, the sample was preheated to 60°C. and subjected to two additional 10 KA surges spaced one minute apart with the sample energized at MCOV (7.59 kV ms). The sample was energized after the second 10 kA surge at recovery voltage (8.55 kV rms) until thermal stability, was demonstrated. The following table summarizes the measured watts of the test sample during the recovery portion of the test.

Recovery Voltage (kV rms)	Time (Minutes)	Sample Watts
8.55	0+	4.1
8.55	1	3.7
8.55	5	3.2
8.55	10	3.1
8.55	20	3.0
8.55	30	2.9

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

Sample No.	10 KA IR Before Duty Cycle	10 KA IR After Duty Cycle
1	21.89 kV	22.10 kV

Test Summary

The prorated test sample successfully completed the duty cycle test and demonstrated thermal stability during the recovery voltage test. The 10 kA 8/20 discharge voltage changed an acceptable +1.0%, within the allowable 10% acceptance limit. Disassembly revealed no evidence of physical damage to the test sample. Therefore, the VL test sample has successfully fulfilled the duty cycle requirements of the Station Class Surge Arrester.

SECTION VI

ACCELERATED AGING TEST: TYPE VL ARRESTER

Introduction

This test is performed to measure the MOV disc aging characteristic. The measured watts values are used to develop elevated voltage ratios kc and kr which are used in the duty cycle and discharge current withstand tests to simulate the performance of arresters that have a service life equivalent to 1000 hours at 115°C.

Sample Preparation

Three 60 mm diameter x 23 mm long discs and three 60 mm diameter x 41 mm long discs were selected for testing. The three 23 mm long discs are designated as samples #1, 2, & 3 while the 41 mm long discs are designated as samples #4, 5, & 6.

Test Procedure

The test was performed per Section 8.5 of ANSI/IEEE C62.11-1987 Standard. The three test samples were placed inside a 115 plus/minus 2°C. oven and energized at MCOV for 1000 hours. The watts loss of each sample was measured at MCOV and duty cycle rated voltage three hours after energization and at the completion of the 1000 test duration. The following table summarizes the results of the 1000 hour accelerated aging tests. All watts values were measured with the samples at 115°C.

Sample No.	Initial Watts @MCOV	Final Watts @MCOV	Initial Watts @Rating	Final Watts @Rating
1	1.53	1.42	3.14	2.80
2	1.29	1.25	3.05	2.72
3	1.31	1.22	2.34	2.10
4	2.66	2.59	6.87	6.24
5	2.36	2.26	7.12	6.31
6	2.68	2.50	7.23	6.39

Test Results

For each test sample, the final watts loss at MCOV and rating is less than the initial watts measured. Therefore, the kc and kr factors equals 1.0 in the design tests requiring demonstration of thermal stability.

SECTION VII

TEMPORARY OVERVOLTAGE CAPABILITY TEST: TYPE VL ARRESTER

Introduction

This test was performed per Section 8.15 of IEEE Standard C62.11-1993 on (5) prorated test samples, selected to represent the most severe design conditions, i.e., the minimum allowed discharge voltage level and material volume.

Test Procedure

Per Section 8.15.1, each prorated sample is tested in (5) different time ranges ranging from (.01-.1 seconds) to (1001-10,000 seconds). Per Section 8.15.2, the test is performed to demonstrate the temporary overvoltage capability of the design under "no prior duty" conditions. For each TOV voltage setting, the test circuit applies the voltage to the sample (preheated to 600 C) for a time duration sufficient to exceed that claimed on the "no prior duty" curve. Within 100 milliseconds after the TOV, a recovery voltage is applied for (30) minutes to demonstrate thermal stability. The recovery voltage level takes into account the maximum allowed watts loss for the sample.

Prior to and after the TOV application, the 10 kA discharge voltage of each sample is measured.

Test Results

Five prorated section test specimen were tested in each of the following time ranges:

Range A (.01-.1 seconds)
Range C (1-10 seconds)
Range D (10-100 seconds)
Range E (100-1000 seconds)
Range F (1001-10,000 seconds).

Each sample demonstrated thermally stability after TOV exposure with recovery voltage applied. The following table summarizes the claimable TOV values for the Type VL Station Class Arrester for "no prior" and "prior" duty conditions.

TOV Duration (Seconds)	No Prior Duty TOV (Per Unit MCOV)	Prior Duty TOV (Per Unit MCOV)
.02	1.610	1.545
.1	1.535	1.475
1	1.445	1.385
10	1.375	1.320
100	1.325	1.285
1000	1.285	1.260

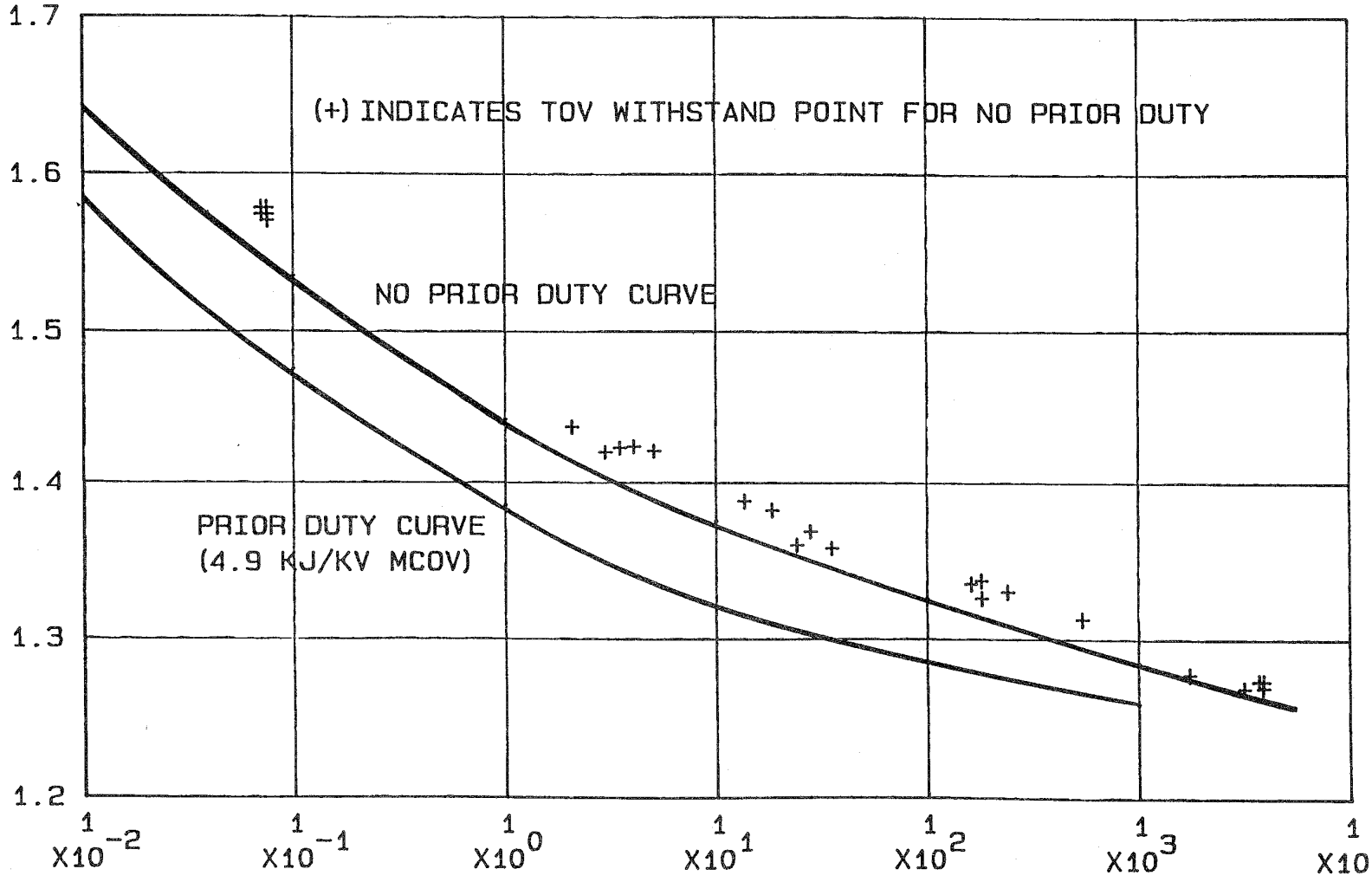
The following table summarizes the 10 kA discharge voltages of the samples measured prior to and after the TOV test.

Sample No.	Before TOV Test		After TOV Test	
	Discharge Current (KAc)	Discharge Voltage (KVc)	Discharge Current (KAc)	Discharge Voltage (KVc)
1	10.04	22.10	10.07	22.44
2	10.04	22.21	10.14	22.47
3	9.90	22.13	10.06	22.52
4	9.87	22.08	10.07	22.39
5	10.03	22.17	9.99	22.45

Conclusion

The 10 kA 8/20 discharge voltage of each sample changed less than 1.8% as a result of the TOV duty, less than the allowed 10%. Disassembly revealed no evidence of physical damage caused by the TOV testing. The individual test points successfully confirmed the claimed “no prior duty” TOV capability curve for the Station Class Type VL arrester. The following curve plots the individual “no prior duty” TOV data points on the claimed TOV capability curve.

60 HZ TEMPORARY OVERVOLTAGE CAPABILITY TYPE VL STATION CLASS ARRESTER WITH AND WITHOUT PRIOR DUTY PER SECTION 8.15 OF IEEE C62.11-1993



-PER UNIT VOLTAGE MCOV-

TIME DURATION
-SECONDS-

8/1/95

SECTION VIII

INTERNAL IONIZATION AND RIV TESTS

Internal Ionization

Internal ionization is measured on each assembled arrester unit as part of the routine testing procedure. Each arrester is energized at 1.05 times the MCOV and internal ionization is measured. Arresters in excess of 10 microvolts are rejected at this voltage level.

Radio Influence Voltage

NEMA Standard LA 1 specifies limits on radio influence voltages for arresters. RIV limits are 250 microvolts for arrester duty cycle ratings through 15 kV, 650 microvolts for arrester duty cycle ratings 18 through 30 kV, 1,250 microvolts for arrester duty cycle ratings 36 through 72 kV, and 2,500 microvolts for arrester duty cycle ratings exceeding 72 kV. Specified energizing voltages are at 1.05 times the maximum line to ground voltage of the system to which the arrester is to be applied.

All Type VL arresters are guaranteed to exhibit an RIV level below 10 microvolts at 1.05 times arrester MCOV.

SECTION IX

CONTAMINATION TEST: TYPE VL ARRESTER

Introduction

This test was performed per Section 8.12 of IEEE Standard C62.11-1993. The tests were performed on a 39 kV MCOV Type VL arrester.

Test Procedure

The partial wetting test procedure was performed per Section 8.12.3 of C62.11-1993 Standard. Prior to the application of contaminant (455 ohm-cm resistivity), the arrester was energized at MCOV for 1 hour. After 1 hour of energization, the arrester was de-energized and slurry contaminant was applied over the entire porcelain surface of the bottom half of the arrester. After a 2-3 minute wait, the arrester was energized at MCOV for 15 minutes, at which time the voltage was turned off and the bottom half of the arrester re-sprayed with contaminant. Within 5 minutes of de-energization, the arrester was energized at MCOV. After 15 minutes, the arrester resistive component of current was recorded. After 30 additional minutes at MCOV, re-measurement of the resistive current confirmed thermal stability and the test was completed.

Test Results

The following table summarizes the results of partial wetting tests performed on the 39 kV MCOV arrester. The arrester demonstrated thermal stability after the second partial wetting test series. No arrester flashover occurred during the above testing.

Disassembly of the test arrester revealed no damage to the internal components as a result of the partial wetting contamination test.

SUMMARY OF PARTIAL WETTING TEST RESULTS ON VL-39 KV MCOV SINGLE-UNIT ARRESTER

Time (min.)	Applied Voltage (kV rms)	Total Current (Leakage Plus Grading)	Comments
0	39	1.3 mA_C	Voltage on - Start one-hour test
60	39	1.3 mA_C	Voltage off - Complete one-hour test
62	0	0	Spray bottom half of arrester with slurry
65	39	2 . 7 mA_C	Voltage on - Start first partial wetting test
67	39	2.0 mA_C	
70	39	1.3 mA_C	
80	39	1.3 mA_C	Voltage off - Complete first partial wetting test
82	0	0	Re-spray bottom half of arrester with slurry
85	39	2.6 mA_C	Voltage on - Start second partial wetting test
87	39	2.2 mA_C	
90	39	1.4 mA_C	
100	39	1.3 mA_C	Complete second partial wetting test (begin thermal stability test) IR = .70 mA_c
130	39	1.3 mA_C	IR = .60 mA_c indicating arrester is thermally stable - Voltage off

SECTION X

PRESSURE RELIEF TEST: TYPE VL ARRESTERS

Introduction

This test was performed per Section 8.9 of IEEE Standard C62.11-1993 on VL 5.1 kV MCOV and VL-39 kV MCOV arresters.

Test Procedure

Test specimen were prepared and mounted per Sections 8.9.1.1 and 8.9.1.2. The tests were monitored with a combination of high-speed photography and oscillographic recording of arrester current and arc voltage.

As permitted by the standard, the high current pressure relief tests were performed at a reduced voltage level. In such a case, the claimable fault current pressure relief capability is the smallest of the following three values, as measured at the first current crest in a successful test:

1. Peak asymmetrical amperes divided by 2.6
2. Asymmetrical amperes divided by 1.55
3. Symmetrical rms amperes

Test Results

The following table summarizes three tests which show compliance for both the low and high current pressure relief tests. The maximum high current pressure relief capability demonstrated by this test is 67 kA rms symmetrical. In all tests, the porcelain housing remained intact.

Unit Rating (MCOV)	Asymmetrical Current (kA rms)	Symmetrical Current (kA rms)	First Loop Peak Current (kA)	Current Duration (Cycles)	Comment
5.1		.49		63	Bottom vented in .4 seconds
5.1		.84		63	Bottom vented in .32 seconds
39	104.3	67.6	175.0	12.5	Arc transfer in 1/2 cycle