Hubbell Power Systems, Inc.
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CSA Design Test Report
CS-8 Glass Bells
Catalog # PCN160146

This design test report records the results of laboratory tests performed on the CS-8 Glass Bells which met or exceeded all performed tests of these standards:

CSA Standard C411.1-10, "AC suspension insulators"

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Contents

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1 TEST SCHEDULE

The Insulators were tested in accordance with schedule B of C411.1-10. Insulator groups were marked as shown in Figure 1; the report follows the sequence of testing.

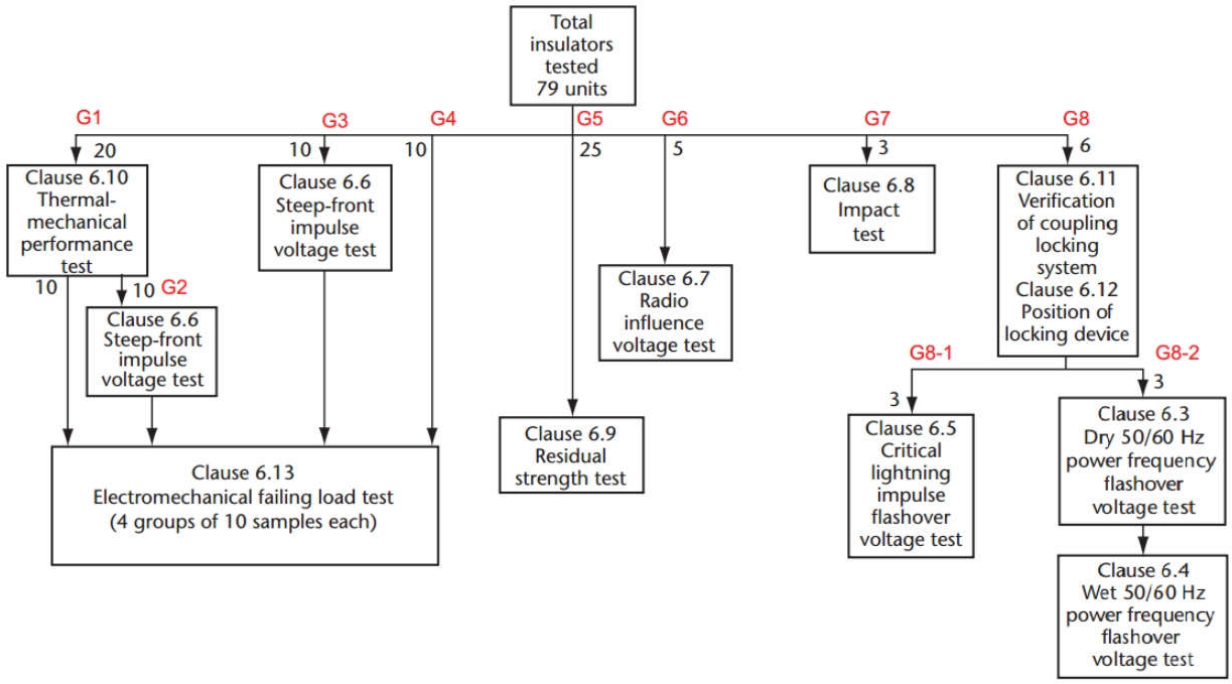

Figure 1

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6.10 THERMAL MECHANICAL PERFORMANCE TEST

Test Procedure

This test has an initial stage of thermal cycles, together with mechanical loading and unloading, and a concluding stage of testing the insulator unit to failure. The concluding stage is identical to an electromechanical failing load test carried out in accordance with Clause 6.13. The failing load test shall constitute the basis for judging the results of the thermal-mechanical performance test.

During the initial stage of the test, the insulator units shall be subjected to four 24 h cycles of cooling and heating, and to a tensile load equal to 70% of the specified electromechanical failing load. The tensile load shall be applied to the insulator units at room temperature before the first thermal cycle starts.

Each 24 h cycle shall consist of a cooling to –50 ± 5 °C and heating to +50 ± 5 °C. The temperatures refer to the surrounding air. The test equipment shall be such that the minimum and maximum temperatures are maintained for at least eight consecutive hours of the temperature cycle.The tensile load shall be completely removed and reapplied at the end of each of the first three heating periods. On completion of the fourth 24 h cycle and cooling to room temperature, the tensile load shall be removed.

Test Results

20 Units (group 1) were subjected to this sequence. There are no tests performed during this sequence, parts subjected to this sequence will be tested further as group 2 in clause 6.6 and group 1 in clause 6.13

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6.6 STEEP-FRONT IMPULSE VOLTAGE TEST

Test Procedure

20 Insulators (Group 2 and 3) shall be subjected to a series of five positive, five negative, five positive and five negative are applied in this order with a time interval of 1 min to 2 min between consecutive impulses of the same polarity.

- Test voltage (minimum): 2.8 p.u. of the average lightning impulse 50% flashover voltage determined on a short standard string.
- Average lightning impulse 50% flashover voltage determined on a short standard string. (5 units) = 574 kV.
- Test voltage (minimum) = 2,8 x 114,9 kV = 321,8 kV

Test Results Group 2

After the thermo-mechanical failing load test, the steep front impulse test was carried out on the same day. All samples of group 2 met the requirements of Section 6.6 of C411.1-10. Table 1 shows individual results of the Steep-Front Impulse Test.

Unit	Applied Shots	Results
2.1	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
2.2	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
2.3	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
2.4	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
2.5	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
2.6	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
2.7	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
2.8	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
2.9	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
2.10	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture

Table 1

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Test Results Group 3

All samples of group 3 met the requirements of Section 6.6 of C411.1-10. Table 2 shows individual results of the Steep-Front Impulse Test.

Unit	Applied Shots	Results
3.1	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
3.2	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
3.3	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
3.4	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
3.5	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
3.6	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
3.7	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
3.8	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
3.9	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture
3.10	5 (+) / 5 (-) / 5 (+) / 5 (-)	No puncture

Table 2

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6.13 ELECTRO-MECHANICAL FAILING LOAD TEST

Test Procedure

40 Insulators (Group 1, 2, 3 and 4) be subjected to a tensile load. The tensile load shall be increased from zero rapidly but smoothly up to approximately 75% of the electromechanical failing load specified in Table 2 (120kN) and shall then be gradually increased in a time between 15 and 45 s, corresponding respectively to rates of increase of 100% and 35% per minute of the electromechanical failing load specified in Table 2 (120kN), until failure occurs.

If failure of the insulating part occurs first, the corresponding load shall be recorded and taken as the electromechanical failing load, and the tensile load shall be increased until ultimate mechanical failure occurs. The failure modes shall be recorded for engineering information.

Test Results Group 1

After the thermo-mechanical failing load test, the steep front impulse test was carried out on the same day. All samples of group 1 met the requirements of Section 6.13 of C411.1-10. Table 3 shows individual results of the Electro-Mechanical Failing Load Test.

Unit	Ultimate Load (kN)	Failure Mode
1.1	226,61	Cap
1.2	244,27	Cap
1.3	233,97	Cap
1.4	211,41	Glass
1.5	214,84	Cap
1.6	229,45	Cap
1.7	235,43	Cap
1.8	219,25	Cap
1.9	233,48	Pin
1.10	238,87	Cap
Average $\bar{X}$	228,75	
St.Dev σ	10,68	

Table 3

$$Q = \frac{X \quad R}{\sigma} = \frac{228{,}75 \quad 160}{1{,}68} = 6{,}43$$

$$Q \geq 4$$

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Test Results Group 2

After the thermo-mechanical failing load test and steep-front impulse voltage test, the electro-mechanical failing load was carried out on the same day. All samples of group 2 met the requirements of Section 6.13 of C411.1-10. Table 4 shows individual results of the Electro-Mechanical Failing Load Test.

Unit	Ultimate Load (kN)	Failure Mode
2.1	241,33	Pin
2.2	224,65	Cap
2.3	194,73	Glass
2.4	216,80	Glass
2.5	242,80	Cap
2.6	233,97	Cap
2.7	241,82	Pin
2.8	216,80	Glass
2.9	234,46	Cap
2.10	232,01	Cap
Average $\bar{X}$	227,94	
St.Dev σ	15,09	

Table 4

$$\boldsymbol{Q = \frac{X \quad R}{\sigma} = \frac{227,93 \quad 160}{15,09} = 4,51}$$

$$\boldsymbol{Q \geq 4}$$

Test Results Group 3

After the steep-front impulse voltage test, the electro-mechanical failing load was carried out on the same day. All samples of group 3 met the requirements of Section 6.13 of C411.1-10. Table 5 shows individual results of the Electro-Mechanical Failing Load Test.

Unit	Ultimate Load (kN)	Failure Mode
3.1	225,14	Pin
3.2	225,14	Pin
3.3	200,12	Glass
3.4	225,14	Glass
3.5	213,86	Glass
3.6	231,52	Glass
3.7	222,20	Glass
3.8	241,82	Glass
3.9	227,10	Cap
3.10	222,69	Glass
Average $\bar{X}$	223,47	
St.Dev σ	10,88	

Table 5

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$$\boldsymbol{Q = \frac{X \quad R}{\sigma} = \frac{223,47 \quad 160}{10,8\ 8} = 5,8\ 4}$$
$$\boldsymbol{Q \geq 4}$$

Test Results Group 4

The electro-mechanical failing load was carried out on the same day. All samples of group 4 met the requirements of Section 6.13 of C411.1-10. Table 6 shows individual results of the Electro-Mechanical Failing Load Test.

Unit	Ultimate Load (kN)	Failure Mode
4.1	224,65	Glass
4.2	225,14	Glass
4.3	218,76	Glass
4.4	225,63	Glass
4.5	225,14	Glass
4.6	215,82	Glass
4.7	223,67	Glass
4.8	226,61	Glass
4.9	225,63	Glass
4.10	225,63	Cap
Average $\bar{X}$	223,67	
St.Dev σ	3,53	

Table 6

$$\boldsymbol{Q = \frac{X \quad R}{\sigma} = \frac{223,67 \quad 120}{3,51} = 18,12}$$
$$\boldsymbol{Q \geq 4}$$

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6.9 RESIDUAL STRENGTH TEST

Test Procedure

25 Insulators (group 5) shall be subjected to the following mechanical failing load test after preparation in accordance with Clause 6.9.2:

a) The test specimen shall be subjected individually to a tensile load applied between the metal parts.
b) The tensile load shall be increased from zero, rapidly but smoothly, up to approximately 50% of the specified electromechanical failing load of the complete insulator. The load shall then be increased gradually, at a rate of increase between 0.5% and 1% of the specified electromechanical failing load per second, until breakage occurs.
c) The maximum load reached during the test shall be recorded as the residual strength of the specimen.

The criteria for determining conformance to this standard are:

$$k = \frac{\bar{X} \quad 1.645\sigma}{R}$$

Where:
$\bar{X}$ = average residual strength of 25 units
σ = standard deviation of residual strength of the 25 units tested
R = Specified electromechanical failing load (160kN)
k = the acceptance constant, which shall be equal to or greater than 0.65

Test Results

All samples tested met the requirements of Section 8.2.7 of ANSI/NEMA C29.2B - 2011. Table 7 shows individual results of the Residual Strength Test.

$$k = \frac{\bar{X} \quad 1.645\sigma}{R} = \frac{181{,}39 \quad 1.645 \times 9{,}67}{160} = 1{,}03$$

$$k \geq 0{,}65$$

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Unit	Ultimate Tensile Load (kN)	Failure mode
1	173,15	Pin disassembled
2	182,47	Pin disassembled
3	172,66	Pin disassembled
4	181,49	Pin disassembled
5	176,58	Pin disassembled
6	189,82	Pin disassembled
7	192,28	Pin disassembled
8	179,52	Pin disassembled
9	175,60	Pin disassembled
10	183,45	Pin disassembled
11	183,45	Pin disassembled
12	186,39	Pin disassembled
13	147,15	Pin disassembled
14	179,03	Pin disassembled
15	181,49	Pin disassembled
16	181,49	Pin disassembled
17	179,03	Pin disassembled
18	185,90	Pin disassembled
19	187,37	Pin disassembled
20	191,30	Pin disassembled
21	196,20	Pin disassembled
22	193,26	Pin disassembled
23	186,39	Pin disassembled
24	173,64	Pin disassembled
25	175,60	Pin disassembled
Average $\bar{X}$	181,39	
Standard Deviation σ	9,67	

Table 7

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6.7 RADIO-INFLUENCE VOLTAGE TEST

Test Procedure

Five insulators (Group 6) shall be tested in accordance with 6.7 of C411.1-10. All insulators shall have less than 50µV RIV at 10kV supplied voltage.

Test Results

All samples tested met the requirements of Section 6.7 of C411.1-10. Tables 8 show individual results of the Radio Influence Voltage Test.

Unit	RIV @ $0kV_{RMS}$ (µV)	RIV @ $10kV_{RMS}$ (µV)
1	4,03	4,95
2	3,72	4,47
3	3,67	4,95
4	3,35	3,98
5	3,59	4,17

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6.8 IMPACT TEST

Test Procedure

Three insulators (group 7) shall be tested in accordance with 6.8 of C411.1-10. All insulators shall receive an impact of 45 Nm.

Test Results

All samples tested met the requirements of Section 6.8 of C411.1-10. Table 9 shows individual results of the Impact Test.

Unit	8900N Applied	Impact Passed	Voltage Applied (kV)	Result
1	✓	✓	50	Pass
2	✓	✓	50	Pass
3	✓	✓	50	Pass

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6.11 VERIFICATION OF COUPLING LOCKING SYSTEM

Test Procedure

Six ball-and-socket insulators (Group 8) shall be coupled in 3 strings of two units with the cotter key in the locking position. Each string shall then be subjected to an attempt to disengage the ball from the socket, applying relative movements by hand representative of those encountered in use. The disengagement of any ball shall constitute failure of the lot to meet the requirements of this standard.

Test Results

All samples tested met the requirements of Section 6.11 of C411.1-10.

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6.12 POSITION OF LOCKING DEVICE

Test Procedure

For cotter key types, the legs shall not protrude in the locking position beyond the entry of the socket, and it shall be possible to introduce a tool into the eye to pull the cotter key from the locking position to the coupling position. In order to do this, the eye of the cotter key shall protrude a distance approximately equal to its diameter.

Test Results

All samples tested (Group 8) met the requirements of Section 6.12 of C411.1-10.

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6.5 CRITICAL LIGHTNING IMPULSE FLASHOVER VOLTAGE TEST

Test Procedure

Impulses of both positive and negative polarity shall be used. The critical (50%) lightning impulse flashover voltage shall be determined by the following procedure:

a) A voltage, U_k, believed to lie at or near the 50% flashover voltage level, shall be chosen. A voltage interval, ΔU, approximately 3% of U_k, shall also be chosen. One impulse shall be applied at the level U_k. If this does not cause flashover, the level of the next impulse should be: $U_k' = U_k + \Delta U$. If flashover occurs at the level U_k, the next impulse should have a level: $U_k' = U_k - \Delta U$. After each impulse test, the result, U_k', shall become the starting point, U_k, for calculating the new impulse value.

b) This procedure shall be repeated a number of times, each impulse having a level determined by the effect of the preceding impulse. The number of impulses, n_v, applied at each voltage level, U_v, shall be counted, and the 50% flashover voltage shall be determined by the formula:

$$U_{50\%} = \frac{\sum n_v U_v}{\sum n_v}$$

c) In the formula in Item (b), the first level taken into account should be one at which two or more impulses are applied. This will partially correct the error that could be introduced if Uk is too low or too high. The total number of impulses taken into account shall be equal to 30. The critical lightning impulse flashover voltage determined by this procedure shall be corrected in accordance with Clauses 6.2.5 and 6.2.6 of the C411.1-10.

3 Insulators (Group 8-1) were tested.

Test Results

All samples tested met the requirements of Section 6.5 of C411.1-10. Table 10 shows individual results of the Critical Lightning Impulse Flashover Voltage Test.

Atmospheric Conditions		
P (mm Hg)	T(°C)	H(g/m^3)
672	22,5	7,8

Unit	Polarity	Voltage (kV)	Difference (%)	Results
1	+	151,52	121,21	Pass
	-	151,52	116,56	Pass
2	+	149,58	119,66	Pass
	-	151,22	116,33	Pass
3	+	151,62	121,30	Pass
	-	149,99	115,38	Pass

Table 10

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6.3 DRY POWER FREQUENCY FLASHOVER VOLTAGE TEST

Test Procedure

The dry power frequency flashover voltage of the insulator shall be determined by increasing the voltage gradually from approximately 75% of the expected power frequency flashover voltage with a rate of rise per second of approximately 2% of this voltage. The flashover voltage shall be the arithmetic mean of five consecutive readings, and the value after correction to standard atmospheric conditions (see Clauses 6.2.5 and 6.2.6) shall be recorded. 3 Insulators (Group 8-2) were tested.

Test Results

All samples tested met the requirements of Section 6.3 of C411.1-10. Table 11 shows individual results of the Dry Power Frequency Flashover Voltage Test.

Atmospheric Conditions		
P (mm Hg)	T(°C)	H(g/m^3)
672	21,4	8,8

Unit	Low-Frequency Dry flashover value as given in table 3 kV	average flashover voltage (corrected value) kV	Difference (%)	Results
1	80	102,50	128,12	Pass
2		98,68	123,34	Pass
3		100,99	126,24	Pass

Table 11

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6.4 WET POWER FREQUENCY FLASHOVER VOLTAGE TEST

Test Procedure

The wet power frequency flashover voltage of the insulator shall be determined by increasing the voltage gradually from approximately 75% of the expected power frequency flashover voltage with a rate of rise per second of approximately 2% of this voltage. The flashover voltage shall be the arithmetic mean of five consecutive readings, and the value after correction to standard atmospheric conditions (see Clauses 6.2.5 and 6.2.6) shall be recorded. 3 Insulators (Group 8-2) were tested.

Test Results

All samples tested met the requirements of Section 6.5 of C411.1-10. Table 12 shows individual results of the Wet Power Frequency Flashover Voltage Test.

Atmospheric Conditions		
P (mm Hg)	T(°C)	H(g/m^3)
672	21,4	8,8

Unit	Low-Frequency Dry flashover value as given in table 3 kV	average flashover voltage (corrected value) kV	Difference (%)	Results
1	45	54,25	120,55	Pass
2		53,98	119,96	Pass
3		52,68	117,06	Pass

Table 12