Hubbell Power Systems, Inc.
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IEEE Design Test Report
35 kV Class 600 A 200 kV BIL
Deadbreak Connector System

This design test report records the results of laboratory tests performed on the 35 kV Class 600 A Deadbreak Connector System which met or exceeded all applicable requirements of these standards:

IEEE Std. 386-2016, "IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V"

IEEE Std. 592-2007, "IEEE Standard for Exposed Semiconducting Shields on High-Voltage Cable Joints And Separable Insulated Connectors."

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7.4 PARTIAL DISCHARGE TEST

Test Procedure

The test voltage shall be raised to 20% above the partial discharge minimum extinction voltage of 26 kV. If the partial discharge peak value exceeds 5 pC, the test voltage shall be lowered to the partial discharge minimum extinction voltage level of 26 kV and maintained at this level for at least 3 seconds but not more than 60 seconds. Partial discharge readings taken during this period shall not exceed 5 pC.

Test Results

All samples tested met the requirements of Section 7.4 of IEEE Std. 386 - 2016. Table 1 shows individual results of the Partial Discharge Test.

Sample	Result
A1	31.2 kV/0.8 pC
A2	31.4 kV/0.8 pC
A3	31.2 kV/0.8 pC
A4	31.2 kV/0.9 pC
A5	31.3 kV/0.8 pC
A6	31.3 kV/0.8 pC
A7	31.4 kV/0.8 pC
A8	31.2 kV/1.0 pC
A9	31.2 kV/0.8 pC
A10	31.3 kV/0.8 pC

Table 1

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7.5.1 AC WITHSTAND VOLTAGE TEST

Test Procedure

The test voltage shall be raised to 50 kV_{rms} in not more than 30 seconds. The connector shall withstand the specified test voltage for 1 minute without flashover or puncture.

7.5.3 IMPULSE WITHSTAND VOLTAGE TEST (BIL)

Test Procedure

The test voltage shall be 1.2/50 µs wave having the crest value (BIL) of 200 kV. The closed connector shall withstand three positive and three negative full-wave impulses without flashover or puncture.

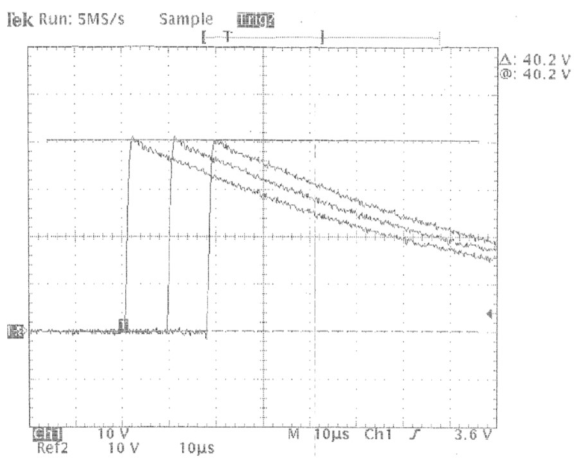

Figure 1

Impulse Withstand – Positive Wave

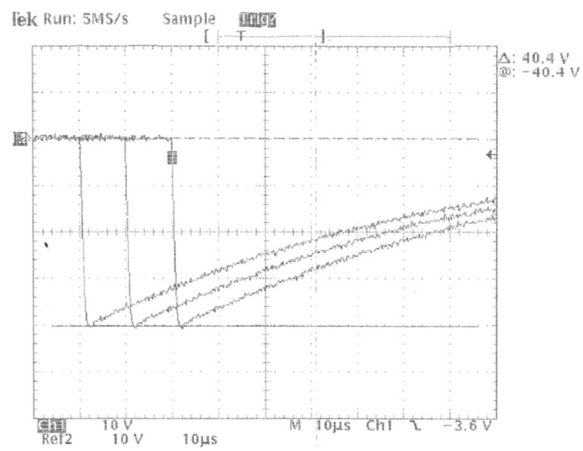

Figure 2

Impulse Withstand – Negative Wave

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Test Results

All samples tested met the requirements of Section 7.5 of IEEE Std. 386 - 2016. Table 2 shows individual results of the Dielectric Test.

Sample	AC – 50 kV_{rms}	200 kV crest
	(1 Minute)	(3 Pos. 3 Neg.)
A1	Passed	Passed
A2	Passed	Passed
A3	Passed	Passed
A4	Passed	Passed
A5	Passed	Passed
A6	Passed	Passed
A7	Passed	Passed
A8	Passed	Passed
A9	Passed	Passed
A10	Passed	Passed

Table 2

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7.11 CURRENT-CYCLING TEST FOR 600 A AND 900 A INSULATED CONNECTORS

Test Procedure

1. A control cable, used for the purpose of obtaining conductor temperature, shall be installed in the current-cycling loop between two equalizers. Its length shall be 1829 mm (72 in). The control cable shall be the same type as the cable used to join the connectors under test.

2. Four connectors shall be assembled in series on 750 kcmil insulated aluminum conductors having a length of 91 cm (36 in). The cable insulation thickness shall be selected according to its voltage class (see Table 10).

3. Equalizers used shall be in accordance with ANSI C119.4.

4. Current-cycling tests shall be conducted at an ambient temperature of 15°C-35°C in a space free of drafts.

5. The current-cycle amperes shall be adjusted to result in a steady-state temperature of 90°C ± 5°C on the surface of the conductor of the control cable. The temperature shall be measured at the approximate center of the control cable.

6. The test shall consist of 50 current cycles, with the current on 6 hours and off 6 hours for each cycle. The temperature of the hottest spot of the connector shall be measured every 10 cycles and shall not exceed the temperature of the conductor of the control cable.

Test Results

All samples tested met the requirements of Section 7.11 of IEEE Std. 386 - 2016. Table 3 shows individual results of the test.

Cycle	Sample				Cable Temp.	Room Temp.
	A05	A06	A07	A08		
10	73.2	79.2	71.8	73.6	90.4	21.2
20	72.2	77.0	71.7	74.4	89.4	20.3
30	72.1	76.8	70.3	74.2	89.6	20.7
40	74.4	79.1	73.6	77.4	90.3	21.5
50	73.8	78.9	73.1	77.3	90.3	18.2
Average	73.1	78.2	72.1	75.4	90.0	20.4
Result	Recorded temperatures of each sample are less than the temperature of the conductor of the control table.					

Table 3

7.12 ACCELERATED SEALING LIFE TEST

Test Procedure

Four samples shall be assembled on AWG No. 1/0 aluminum conductors. The four connector assemblies shall be placed in an oven having 121 °C temperature and remain there for three weeks. After this time has elapsed, the four samples shall be removed from the oven and each operated once by using the operating eye or an appropriate location on the axis of the separable interface.

The four connector assemblies shall then be subjected to 50 cycles of the following sequence of operations:
The assemblies shall be heated in air using sufficient current to raise the temperature of the conductor of the control cable to 90 °C ± 5 °C for 1 hour.
The assemblies shall be de-energized and within 3 minutes, submerged in 25 °C ± 10 °C conductive water (5000 Ω-cm maximum) to a depth of 30 cm (1 ft) for 1 hour.

After the 50th cycle, the connector and cable assembly shall withstand a design impulse test in accordance with section 7.5.3 of IEEE Std. 386 – 2016.
The test point, if provided, shall be capable of passing the voltage test specified in 7.17.2 of IEEE Std. 386 – 2016.

Test Results

All samples tested met the requirements of Section 7.12 of IEEE Std. 386 - 2016. Table 4 shows individual results of the Accelerated Sealing Life Test.

Sample	Pd Before	AC Withstand before	Imp. Withstand before	Imp. Withstand after	Indication
B1	32 kV / 1.1 pC	Pass	Pass	Pass	20.0 kV
B2	32 kV / 1.2 pC	Pass	Pass	Pass	19.0 kV
B3	32 kV / 1.2 pC	Pass	Pass	Pass	20.0 kV
B4	32 kV / 1.2 pC	Pass	Pass	Pass	19.0 kV

Table 4

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7.16.1 Test-Point Cap Operating Force Test

Test Procedure

A tensile force shall be gradually applied to the test point cap in the direction parallel with the probe axis at −20 °C, +25 °C, and +65 °C.

Test Results

All samples tested met the requirements of Section 7.16.1 of IEEE Std. 386 - 2016. Table 5 shows individual results of the Test-point Cap Operating Force Test.

7.16.2 Test-Point Cap Operating Withstand Test

Test Procedure

A tensile force of 445 N (100 lbf) shall be applied to the test point cap operating eye for 1 minute at −20 °C, +25 °C, and +65 °C.

Test Results

All samples tested met the requirements of Section 7.16.2 of IEEE Std. 386 - 2016. Table 5 shows individual results of the Test-point Cap Operating Withstand Test.

Sample	-20 °C		25 °C		65 °C	
	Pull Force (8 lbf – 49 lbf)	100 lbf	Pull Force (8 lbf – 49 lbf)	100 lbf	Pull Force (8 lbf – 49 lbf)	100 lbf
B01	23 lbf	Pass	24 lbf	Pass	13 lbf	Pass
B02	30 lbf	Pass	25 lbf	Pass	14 lbf	Pass
B03	29 lbf	Pass	23 lbf	Pass	19 lbf	Pass
B04	31 lbf	Pass	26 lbf	Pass	20 lbf	Pass

Table 5

7.17.1 TEST POINT CAPACITANCE TEST

The connector shall be installed on a cable of the type for which it is designed to operate, and the shielding shall be grounded in the normal manner. The capacitances from test point to cable and test point to ground shall be measured with suitable instruments and proper shielding techniques.

The capacitance between the test point and the conductor system shall be at least 1.0 pF. The ratio of the capacitance between test point and shield to the capacitance between test point and conductor system shall not exceed 12.0.

7.17.2 TEST POINT VOLTAGE TEST

A test voltage shall be applied to the conductor system of the connector. The response of a suitable sensing device on the test point shall indicate an energized condition.

<u>Test Results</u>

All samples tested met the requirements of Section 7.17 of IEEE Std. 386 - 2016. Table 6 shows individual results of the Test Point Tests results.

Sample	Test point capacitance test		Voltage Indication	Result
	Capacitance	Ratio		
A1	8.89 pF	1.22	✓	Passed
A2	10.67 pF	1.30	✓	Passed
A3	9.57 pF	1.33	✓	Passed
A4	9.28 pF	1.21	✓	Passed
A5	9.32 pF	1.51	✓	Passed
A6	9.28 pF	1.61	✓	Passed
A7	8.78 pF	1.48	✓	Passed
A8	8.59 pF	1.28	✓	Passed
A9	9.82 pF	1.12	✓	Passed
A10	8.46 pF	1.33	✓	Passed

Table 6

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7.20 THERMAL CYCLE WITHSTAND

Test Procedure

Ten thermal cycles shall be conducted in air. The temperature cycles shall comply with the thermal cycle profile shown in IEEE 386 Figure 22. The temperature extremes shall have a tolerance of ± 5°C.

After completion of the thermal cycles the non-elastomeric components shall be tested to the applicable dielectric withstand test levels for:

- Corona Voltage Level Section 7.4
- AC Withstand Voltage Section 7.5.1

Test Results

All samples tested met the requirements of Section 7.6 of IEEE Std. 386 - 2016. Table 7 shows individual results of the Short-time Current Test.

Sample	Current (kA)	Result
# 1	32 kV / 1.5 pC	70 kV / 1 min Pass
# 2	32 kV / 1.5 pC	70 kV / 1 min Pass
# 3	32 kV / 1.2 pC	70 kV / 1 min Pass
#4	32 kV / 1.2 pC	70 kV / 1 min Pass
# 5	32 kV / 1.0 pC	70 kV / 1 min Pass
# 6	32 kV / 1.0 pC	70 kV / 1 min Pass
# 7	32 kV / 1.0 pC	70 kV / 1 min Pass
# 8	32 kV / 1.0 pC	70 kV / 1 min Pass
# 9	32 kV / 1.2 pC	70 kV / 1 min Pass
# 10	32 kV / 1.2 pC	70 kV / 1 min Pass

Table 7

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IEEE Std. 592-4.2 Shield Resistance Test

Test Procedure

The test procedure and requirements were in accordance with IEEE Std. 592-2007, "IEEE Standard for Exposed Semiconducting Shields on Pre-molded High-Voltage Cable Joints and Separable Insulated Connectors".

The resistance of the semi-conducting shield between the cable entrance and the farthest extremity of the shield from the cable entrance was measured using the voltmeter - ammeter method. The voltage was measured with the current adjusted to 1.0 mA ± 0.2 mA. The current connections were made on the shield at the farthest shield extremity, using a circumferential connection at both locations to give a uniform current distribution. Resistance measurements were made on un-aged test specimens and samples that had been oven aged for 504 hours at 121 °C. Resistance measurements were made with the test specimen temperature at 20 °C and 90 °C.

Test Results

All samples tested met the requirements of Section 4.2 of IEEE Std. 592 - 2007. Table 8 shows individual results of the Shield Resistance Test.

Sample	Un-aged		Aged	
	27 °C	90 °C	27 °C	90 °C
I-25	794 Ω	630 Ω	632 Ω	596 Ω
I-26	832 Ω	815 Ω	808 Ω	790 Ω
I-27	678 Ω	615 Ω	626 Ω	617 Ω
I-25	1417 Ω	993 Ω	928 Ω	931 Ω

Table 8

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IEEE Std. 592-4.3 Fault Current Initiation Test

Test Procedure

The test procedure and requirements were in accordance with IEEE Std. 592-2007, "IEEE Standard for Exposed Semiconducting Shields on Pre-molded High-Voltage Cable Joints and Separable Insulated Connectors".
Testing performed at Powertech Labs Inc, Surrey BC Canada

The tests were performed at 12.5 kV phase-to-ground. The duration of current flow during each test was 10 cycles. The tests were performed at 60 Hz. As required by the Standard, the second test on each sample was initiated in the shortest practical time after the first test, without disturbing the test specimen. The test waveforms are shown in Figures 3 to 6.

The test circuit was characterized by the following parameters:

Test Voltage:	12.5 kV phase-to-ground (≥12.2kV is required)
Prospective current:	10.1 kA rms (≥10 kA rms is required)

The current was measured with a non-inductive shunt; the voltage was measured with a capacitive-resistive voltage divider.

Test Results

All samples tested met the requirements of Section 4.3 of IEEE Std. 592-2018.