



POWER SYSTEMS, INC.

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Cable Accessories Test Report Bulletin CPO 90.03-00

15 kV Class 200 Amp

Loadbreak Separable Connector System

CERTIFICATION

The Hubbell Power Systems three phase rated, 15 kV Class, 200 Amp, Loadbreak System is designed to meet or exceed the requirements of the IEEE Standard 386-2006, "Separable Insulated Connector Systems for Power Distribution Systems above 600 Volts". This product complies with the interface dimensions in Figures 5 and 6 of this standard.

This report certifies that the tests shown in the following table have been successfully performed on Hubbell Power Systems, 15 kV Class 200 Amp Loadbreak Connector System in accordance with IEEE 386-2006. Separate reports shown in the table provide details of the tests.

<u>Test</u>	<u>Standard</u>	<u>Section</u>	<u>Report No.</u>	<u>Issue Date</u>
Partial Discharge Test	IEEE 386-2006	7.4	Bulletin CPO 90.03-01	2006-11-10
Dielectric Tests (ac, dc, impulse)	IEEE 386-2006	7.5	Bulletin CPO 90.03-02	2006-11-10
Short-time Current Test	IEEE 386-2006	7.6	Bulletin CPO 90.03-03	2006-11-10
Switching Test	IEEE 386-2006	7.7	Bulletin CPO 90.03-04	2006-11-10
Fault-closure Test	IEEE 386-2006	7.8	Bulletin CPO 90.03-05	2006-11-10
Current-cycling Test	IEEE 386-2006	7.10	Bulletin CPO 90.03-06	2006-11-10
Accelerated Sealing Life Test	IEEE 386-2006	7.12	Bulletin CPO 90.03-07	2006-11-10
Cable Pull-out Test	IEEE 386-2006	7.13	Bulletin CPO 90.03-08	2006-11-10
Operating-force Test	IEEE 386-2006	7.14	Bulletin CPO 90.03-09	2006-11-10
Operating-eye Test	IEEE 386-2006	7.15	Bulletin CPO 90.03-10	2006-11-10
Test-point Cap Test	IEEE 386-2006	7.16	Bulletin CPO 90.03-11	2006-11-10
Test-point Test	IEEE 386-2006	7.17	Bulletin CPO 90.03-12	2006-11-10
Shielding Test	IEEE 386-2006	7.18	Bulletin CPO 90.03-13	2006-11-10
Interchangeability	IEEE 386-2006	7.7 & 7.8	Bulletin CPO 90.03-14	2006-11-10

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The Hubbell Power Systems three phase rated, 15 kV Class, 200 Amp, Loadbreak System consists of the following products.

Loadbreak Elbow Connector	9U01AAD, 9U01ABD
Insulated Cap	215ICI, 215ICC
Loadbreak Bushing Insert	215BI
Loadbreak Junction	215J2, 215J3, 215J4
Loadbreak Feed-thru	215FT, 215FTV
Loadbreak Feed-thru Bushing Insert	215FTI
Insulated Parking Bushing	215SB
Grounding Parking Bushing	215GB
Bimetal Compression Lug	200LUGB
Reducing Tap Plug	615LRTP (200 Amp Interface)
Elbow Tap Plug	615ETP (200 Amp Interface)
Dual Tap Plug	615DTP (200 Amp Interface)



TEST REPORT Bulletin CPO 90.03-01

Partial Discharge Test

TEST PROCEDURE:

Each test sample consisted of one cable ready 15 kV 200 Amp elbow, one 15 kV 200 Amp bushing insert and one bushing well. The test voltage was raised to 20% above the partial discharge minimum extinction voltage of 11 kV. If the partial discharge peak value exceeded 3 pC, the test voltage was lowered to 11 kV and was maintained at this level for at least 3 seconds but not more than 60 seconds. Partial discharge readings taken during this interval did not exceed 3 pC peak.

TEST RESULTS:

All samples tested met the requirements of Section 7.4 of IEEE Standard 386 - 2006. Table 1 shows a summary of the Partial Discharge Test results.

Table 1. Summary of Partial Discharge Tests

Sample	Result
1	Passed
2	Passed
3	Passed
4	Passed
5	Passed
6	Passed
7	Passed
8	Passed
9	Passed
10	Passed



TEST REPORT Bulletin CPO 90.03-02

Dielectric Tests (ac, dc, and Impulse Withstand Tests)

TEST PROCEDURE:

Each test sample consisted of one cable ready 15 kV 200 Amp elbow, one 15 kV 200 Amp bushing insert, and one bushing well. For ac withstand tests, the test voltage was raised to 34 kV rms in not more than 30 seconds. The connector withstood the specified test voltage for one minute without flashover or puncture. For dc withstand tests, the test voltage had a negative polarity and was raised to 53 kV. The connector withstood the specified test voltage for 15 minutes without flashover or puncture. For impulse withstand tests, the test voltage had a 1.2/50 microsecond waveshape with a crest value (BIL) of 95 kV. All connectors were subjected to three positive and three negative full-wave impulses.

TEST RESULTS:

All samples tested met the requirements of Section 7.5 of IEEE Standard 386 - 2006. Table 1 shows a summary of the Dielectric Test results.

Table 1. Summary of Dielectric Tests

Sample	ac - 34 kV rms	dc - 53 kV	Impulse - 95 kV crest
	(1 Minute)	(15 minutes)	(3 Pos. 3 Neg.)
1	Passed	Passed	Passed
2	Passed	Passed	Passed
3	Passed	Passed	Passed
4	Passed	Passed	Passed
5	Passed	Passed	Passed
6	Passed	Passed	Passed
7	Passed	Passed	Passed
8	Passed	Passed	Passed
9	Passed	Passed	Passed
10	Passed	Passed	Passed



TEST REPORT Bulletin CPO 90.03-03

Short-time Current Test

TEST PROCEDURE:

Test samples were mounted in a manner approximating service conditions and the test voltage was below the rated voltage of the test samples. Current magnitudes were measured in accordance with IEEE C37-09, "IEEE Standard Test Procedure for ac High-voltage Circuit Breakers Rated on a Symmetrical Current Basis".

Each test sample consisted of:

- 15 kV 200A elbow
- 15 kV 200A bushing insert
- 15 kV bushing well
- Compression connector: bi-metal
- Cable conductor type: aluminum
- Cable conductor size: 1/0 AWG.

TEST RESULTS:

The test samples withstood the current without separation of interfaces or impairing the ability to meet the requirements of partial discharge, ac and impulse voltage withstand tests. All samples tested met the requirements of Section 7.6 of IEEE Standard 386 - 2006. Table 1 shows a summary of the Short-time Current Test results.

Table 1. Summary of Short-time Current Test

Sample Number	Current (kA)	Duration (s)	Result
1	3.5	3.09	Passed
	10	0.23	Passed
2	3.5	3.09	Passed
	10	0.23	Passed
3	3.5	3.09	Passed
	10	0.23	Passed
4	3.5	3.09	Passed
	10	0.23	Passed



TEST REPORT Bulletin CPO 90.03-04

Switching Test

TEST PROCEDURE:

Each test sample, consisting of a 15 kV 200A elbow and a bushing insert was subjected to 10 complete switching operations under the conditions listed in Figure 19 and Table 7 of IEEE Standard 386 - 2006. The test circuit complies with Figure 19 (b) of the Standard. Switching was performed manually with the operator closing the connector after the steady-state voltage and current were achieved. The test samples were operated using the parallel method of switching. Each switching operation was recorded by an oscillogram.

TEST RESULTS:

As indicated in Table 1, twenty-four consecutive successful tests were recorded in this test series. In each successful test, the sample withstood 10 complete switching operations without arcing to ground or impairing the ability to meet the other requirements of the Standard. The test samples met the requirements of Section 7.7 of IEEE Standard 386 – 2006.

Table 1. Summary of Switching Test

Sample Number	Pass/Fail	Sample Number	Pass/Fail
1	F	16	P (12)
2	P	17	P (13)
3	P	18	P (14)
4	F	19	P (15)
5	P (1)	20	P (16)
6	P (2)	21	P (17)
7	P (3)	22	P (18)
8	P (4)	23	P (19)
9	P (5)	24	P (20)
10	P (6)	25	P (21)
11	P (7)	26	P (22)
12	P (8)	27	P (23)
13	P (9)	28	P (24)
14	P (10)	29	F
15	P (11)	30	P

Note: () – Consecutive successful test.



TEST REPORT Bulletin CPO 90.03-05

Fault-closure Test

TEST PROCEDURE:

15 kV 200A elbow and bushing insert connectors that were subjected to the switching test (Bulletin CPO 90.03-04) were then subjected to the fault-closure test with the fault current given in Table 2 and under the conditions listed in Figure 20 and Table 9 of IEEE Standard 386 - 2006. The test was conducted on the samples in the same sequence used for the switching test. The test circuit complies with Figure 20 (b) of the Standard. The closing operation was performed manually and each operation was recorded by an oscillogram.

TEST RESULTS:

As shown in Table 1, fourteen consecutive successful tests were recorded meeting the criteria that their oscillograms showed no external ground current and that all parts remained within the closed connector assembly. The samples tested met the requirements of Section 7.8 of the Standard.

Table 1. Summary of Fault-closure Test

Sample Number	Pass/Fail	Sample Number	Pass/Fail
1	*	16	P (14)
2	P (1)	17	**
3	P (2)	18	**
4	*	19	**
5	P (3)	20	**
6	P (4)	21	**
7	P (5)	22	**
8	P (6)	23	**
9	P (7)	24	**
10	P (8)	25	**
11	P (9)	26	**
12	P (10)	27	**
13	P (11)	28	**
14	P (12)	29	*
15	P (13)	30	**

Note: () - Consecutive successful test.

* - Sample failed in switching test.

** - Sample not tested since fault-closure test requirements have been met.



TEST REPORT Bulletin CPO 90.03-06

Current-Cycling Test for 200 Amp Insulated Connectors

1. Accelerated Thermal Test

TEST PROCEDURE:

Four test samples were assembled in series on 1/0 AWG insulated aluminum conductors having a length of 36 in. A control cable was installed in the current-cycling loop between two equalizers. The length of the control cable is 72 in. 15 kV rated cables with insulation thickness of 220 mils were used. The equalizers were in accordance with ANSI C119.4-1991, "Conductors for Use between Aluminum-to-Aluminum or Aluminum-to-Copper Bare Overhead Connectors". Two bushing bus bars were used and they are 14 in long, 4 in wide and 3/8 in thick. The tests were conducted at an ambient temperature of 20 °C in a space free of drafts. The current-cycle amperes were adjusted during the current-on period of the first five cycles to result in a steady-state temperature of 100 to 105 °C on the control cable. The temperature was measured at the approximate center of the conductor. The test consisted of 50 current cycles, with current-on for 4 hours and current-off for 2 hours for each cycle. At the end of each current-on cycle, the assembly was de-energized and within 10 seconds was submerged in water at 5 to 10 °C for the remainder of the current-off cycle. At the end of the 9th, 25th and 39th cycles, after the samples had returned to room temperature, a short time ac current of 3500 ± 300 Amp rms was applied to each sample for a minimum of 3 seconds.

The temperature of the following current transfer points was measured. Typical results are shown in Table 1.

- a) Probe to compression lug
- b) Probe to female contact
- c) Piston to copper container
- d) Bushing well to bushing insert.

The dc resistance of the connector system was measured. Table 2 shows a summary of the test results. The dc resistance measurements were made between the adjacent elbow cable equalizer and the bushing well stud of each sample.

Each test sample consisted of:

- 15 kV 200 A elbow
- 15 kV 200 A bushing insert
- Bushing well
- Compression lug.



TEST RESULTS:

The temperature measured at the current transfer points of each sample did not exceed the temperature of the control conductor. All samples tested met the requirements of Section 7.10.1 of IEEE Standard 386 - 2006.

Table 1. Summary of Current-Cycling Test for 200 Amp Insulated Connectors
 (Temperature measurements)

Sample	Current Transfer Point	Cycle 9 (°C)	Cycle 21 (°C)	Cycle 30 (°C)	Cycle 39 (°C)	Cycle 50 (°C)
1	a	63.2	61.1	61.8	61.9	60.2
1	b	45.7	42.5	43.4	43.5	43.0
1	c	43.3	41.0	42.3	40.2	40.0
1	d	41.9	38.1	39.9	37.8	38.2
2	a	64.5	61.8	64.1	62.9	63.8
2	b	45.9	43.3	45.7	44.2	44.8
2	c	43.9	41.8	43.1	43.8	42.4
2	d	42.5	39.1	40.6	39.7	39.6
3	a	60.7	57.8	60.8	58.2	58.4
3	b	46.5	42.7	44.2	43.7	43.9
3	c	43.4	39.7	42.4	43.6	41.7
3	d	40.7	36.9	39.8	37.9	37.6
4	a	61.4	58.9	61.3	59.3	59.4
4	b	39.0	35.8	39.2	37.7	37.6
4	c	43.8	42.6	44.4	42.7	40.2
4	d	41.8	37.9	39.0	35.9	35.8
Water	-	6.2	5.5	5.8	6.3	6.6
Control Conductor	-	100.3	101.0	103.1	103.4	103.4

Table 2. Summary of Current-Cycling Test for 200 Amp Insulated Connectors
 (dc resistance measurements)

Sample	Cycle 9 (μΩ)	Cycle 21 (μΩ)	Cycle 30 (μΩ)	Cycle 39 (μΩ)	Cycle 50 (μΩ)
1	416	414	413	411	401
2	639	637	637	630	626
3	417	415	416	413	412
4	633	631	630	630	321
Ambient	20 °C	20 °C	20 °C	20 °C	20 °C



2. Thermal Test with Off-axis Operation

TEST PROCEDURE:

Each connector was subjected to 6 complete test cycles, each cycle consisting of the mechanical operations followed by current cycling.

Each elbow was assembled with a one-half inch wide pulling band for application of an off-axis opening force. Each mechanical operation consisted of a 10° minimum rotation about the probe axis, followed by 5 off-axis open/close operations with the closure force applied to the pulling eye.

Four test samples were assembled in series on 1/0 AWG insulated aluminum conductors having a length of 36 in. A control cable was installed in the current-cycling loop between two equalizers. The length of the control cable was 72 in. 15 kV rated cables with insulation thickness of 175 mils were used. The equalizers were in accordance with ANSI C119.4-1991, "Conductors for Use between Aluminum-to-Aluminum or Aluminum-to-Copper Bare Overhead Connectors". The current-cycle amperes were adjusted so that the temperature on the control conductor was 85 to 95 °C. The temperature was measured at the approximate center of the conductor. Each current cycle consisted of 8 continuous cycles with current-on for 3 hours and current-off for 3 hours.

The complete test consisted of (30) open/close mechanical operations and (48) current cycles.

The temperature of the following current transfer points was measured:

- e) Probe to compression lug
- f) Probe to female contact
- g) Piston to copper container.

Each test sample consisted of:

- 15 kV 200 A elbow
- 15 kV 200 A bushing insert
- Bushing well
- Compression lug.



TEST RESULTS:

The temperature measured at the current transfer points of each sample did not exceed the temperature of the control conductor. All samples tested met the requirements of Section 7.10.2 of IEEE Standard 386 - 2006. Table 3 shows a summary of the test results.

Table 3. Summary of Current-Cycling Test for 200 Amp Insulated Connectors
(with Off-axis Operation)

Sample	Current Transfer Point	Cycle 10 (°C)	Cycle 20 (°C)	Cycle 30 (°C)	Cycle 40 (°C)	Cycle 48 (°C)
1	e	68.2	65.1	66.2	67.4	67.5
1	f	61.5	59.4	60.0	61.2	61.1
1	g	59.3	57.3	57.9	58.8	58.9
2	e	65.5	64.2	65.7	66.7	66.0
2	f	57.7	57.5	58.4	59.7	58.6
2	g	55.5	55.4	56.1	57.2	56.4
3	e	63.1	62.6	70.7	69.4	70.2
3	f	56.5	56.8	65.4	64.3	64.8
3	g	54.4	54.3	61.5	60.5	61.0
4	e	67.0	66.2	68.2	69.8	66.2
4	f	60.8	60.9	62.7	64.8	60.5
4	g	58.3	58.2	59.9	61.4	58.0
Ambient	-	24.1	23.9	23.8	23.1	23.9
Control Conductor	-	91.0	91.3	90.2	88.1	88.4



TEST REPORT Bulletin CPO 90.03-07

Accelerated Sealing Life Test

TEST PROCEDURE:

Four connector assemblies were placed in an oven with $121^{\circ}\text{C} \pm 3^{\circ}\text{C}$ temperatures and remained there for three weeks. After this time elapsed, the four samples were removed from the oven, each operated once, connected in series, and subjected to 50 cycles of the following sequence of operations.

1. The assemblies were heated in air using sufficient current to raise the temperature of the conductor of the control cable to $90^{\circ}\text{C} \pm 5^{\circ}\text{C}$ for 1 hour.
2. The assemblies were de-energized and within 3 minutes, submerged in $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$ conductive water ($5000\Omega/\text{cm}$ maximum) to a depth of 30 cm for 1 hour.

Each sample assembly consisted of:

- 15 kV 200 A elbow
- 15 kV 200 A bushing insert
- Bushing well
- Cable conductor type: aluminum
- Cable conductor size: 1/0 AWG.

TEST RESULTS:

After the 50th cycle, each connector and cable assembly withstood a design impulse test. The test point was capable of passing the voltage test. All samples tested met the requirements of Section 7.12 of IEEE Standard 386 - 2006. Table 1 shows individual results of the Accelerated Sealing Life Test.

Table 1. Summary of Accelerated Sealing Life Test

Sample Number	Impulse Withstand (95 kV BIL)	Test Point Indication
1	Passed	Passed
2	Passed	Passed
3	Passed	Passed
4	Passed	Passed



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TEST REPORT Bulletin CPO 90.03-08

Cable Pull-out Test (Tensile Strength)

TEST PROCEDURE:

Four connector/cable assemblies were tested. The compression lug was held in a manner that did not affect the strength of the connection. A tensile force of 200 lbf was applied to the cable conductor for 1 minute.

Each sample assembly consisted of:

- 200 A compression lug: bi-metal
- Cable insulation thickness: 175 mils
- Cable insulation type: TRXLPE
- Cable conductor type: aluminum
- Cable conductor size: 1/0 AWG conc. stranded
- Compression tool: Burndy MD-6
- Compression die: Burndy W-243 (4 impressions).

TEST RESULTS:

All samples tested met the requirements of Section 7.13 of IEEE Standard 386 - 2006.



TEST REPORT Bulletin CPO 90.03-09

Operating-force Test

TEST PROCEDURE:

Each test sample, consisting of a 15 kV 200 A elbow with its probe and compression lug and a bushing insert, was assembled and lubricated in accordance with the manufacturer's instruction. Each test consisted of closing and then reopening the connector within 10 minutes. The force was gradually applied at a constant rate of 5 inches per minute to the operating-eye parallel to the axis of the probe. The temperature of the connector was $-20\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$, $25\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$, and $65\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$, respectively, for three separate tests.

TEST RESULTS:

All samples tested met the requirements of Section 7.14 of IEEE Standard 386 - 2006. The forces required to open or close the connection were within the range of 50 to 200 lbf. A summary of the test results is shown in Table 1.

Table 1. Summary of Operating-force Test

Elbow Number	Loadmake (lbf) @-20°C	Loadbreak (lbf) @-20°C	Loadmake (lbf) @25°C	Loadbreak (lbf) @25°C	Loadmake (lbf) @65°C	Loadbreak (lbf) @65°C
1	Passed	Passed	Passed	Passed	Passed	Passed
2	Passed	Passed	Passed	Passed	Passed	Passed
3	Passed	Passed	Passed	Passed	Passed	Passed
4	Passed	Passed	Passed	Passed	Passed	Passed



TEST REPORT Bulletin CPO 90.03-10

Operating-eye Test

TEST PROCEDURE:

A static tensile force of 500 lbf was gradually applied to the operating-eye of each elbow in the direction of normal operation. The force was applied for a minimum of one minute. A rotational force of 120 lbf-in was applied with a suitable live-line tool to the operating-eye in a clockwise direction and in a counter-clockwise direction. After the tensile and rotational forces were applied, each elbow was subjected to the Partial Discharge Test. All tests were performed at ambient temperature of $25\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$.

TEST RESULTS:

All samples tested met the requirement of Section 7.15 of IEEE Standard 386 – 2006. There was little or no distortion to the operating-eye on all samples tested. A summary of test results is shown in Table 1.

Table 1. Summary of Operating-eye Test

Sample Number	Static Force (500 lbf)	Rotational Force (120 lbf-in)	Partial Discharge Test
1	Passed	Passed	Passed
2	Passed	Passed	Passed
3	Passed	Passed	Passed
4	Passed	Passed	Passed



TEST REPORT Bulletin CPO 90.03-11

Test-point Cap Test

1. Test-Point Cap Operating Force

TEST PROCEDURE:

A tensile force was 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:

The force required to remove the test-point cap was within the range of 8 to 49 lbf. All samples tested met the requirements of Section 7.16.1 of IEEE Standard 386 - 2006. Table 1 shows individual results of the Test-point Cap Operating Force Test.

Table 1. Test-point Cap Operating Force Test

Sample Number	Operating Force (lbf)		
	-20°C	25°C	65°C
1	Passed	Passed	Passed
2	Passed	Passed	Passed
3	Passed	Passed	Passed
4	Passed	Passed	Passed

2. Test-Point Cap Operating Withstand

TEST PROCEDURE:

A tensile force of 100 lbs was 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 Standard 386 - 2006.



TEST REPORT Bulletin CPO 90.03-12

Test-point Test

1. Test-point Capacitance Test

TEST PROCEDURE:

An elbow was installed on a cable of the type for which it is designed to operate. The shielding of the elbow was grounded in the normal manner. The capacitance from the test-point of the elbow to the cable conductor and the test-point to the shield was measured with suitable instruments and proper shielding techniques.

TEST RESULTS:

The capacitance between the test-point and the cable conductor was at least 1.0 pF. The ratio of the capacitance between the test-point and shield to the capacitance between test-point and cable conductor did not exceed 12. All samples tested met the requirements of Section 7.17.1 of IEEE Standard 386 - 2006. Table 1 shows individual results of the Test-point Capacitance Test.

Table 1. Summary of Test-point Capacitance Test (pF)

Sample Number	Test-point to Cable	Test-point to Ground	Capacitance Ratio
1	1.46	8.80	6.03
2	1.48	8.68	5.86
3	1.67	8.76	5.25
4	1.68	8.72	5.19
5	1.55	8.66	5.59
6	1.62	8.62	5.32
7	1.59	9.03	5.68
8	1.53	8.80	5.75
9	1.74	8.55	4.91
10	1.48	8.81	5.95



2. Test-point Voltage Test

TEST PROCEDURE:

A test voltage was applied to the conductor system of the connector. The response of a suitable sensing device (Portable HI-Z Voltmeter, Model VM25-A with a VMP5-A probe tip) on the test-point indicated an energized condition.

TEST RESULTS:

All samples tested met the requirements of Section 7.17.2 of IEEE Standard 386 - 2006. Table 2 shows individual results of the Test-point Voltage Test.

Table 2. Summary of Test-point Voltage Test

Sample Number	Applied Voltage (kV)	Test-point Voltage (kV)
1	10.0	9.5
2	10.0	9.5
3	10.0	10.5
4	10.0	10.5
5	10.0	10.0
6	10.0	10.5
7	10.0	10.5
8	10.0	10.0
9	10.0	11.0
10	10.0	9.5



TEST REPORT Bulletin CPO 90.03-13

Shielding Test

1. Shield Resistance Test

TEST PROCEDURE:

The test procedure and requirements were in accordance with IEEE Standard 592-1990, "IEEE Standard for Exposed Semiconducting Shields on Premolded High-Voltage Cable Joints and Separable Insulated Connectors".

The resistance of the semi-conducting shield of 15 kV 200 A elbow test samples was measured using the voltammeter method. The voltage was measured with the current adjusted to $1.0 \text{ mA} \pm 0.2 \text{ mA}$. 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 unaged 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 7.18 of IEEE Standard 386 - 2006. Resistance of all test samples did not exceed 5000 Ω . Table 1 shows individual results of the Shield Resistance Test.

Table 1. Summary of Shield Resistance Test

Sample Number	Unaged		Sample Number	Aged	
	20 °C	90 °C		20 °C	90 °C
1	Passed	Passed	5	Passed	Passed
2	Passed	Passed	6	Passed	Passed
3	Passed	Passed	7	Passed	Passed
4	Passed	Passed	8	Passed	Passed



2. Fault-current Initiation Test

TEST PROCEDURE:

The test procedure and requirements were in accordance with the Fault-Current Initiation Test in IEEE Standard 592-1990, "IEEE Standard for Exposed Semiconducting Shields on Premolded High-Voltage Cable Joints and Separable Insulated Connectors". The circuit parameters were 7 kV maximum and 10 kA rms symmetrical available short circuit current. The copper-tungsten faulting rod was located between the semiconducting shield and probe at the extremity farthest from the cable entrance. Each test sample was subjected to two tests causing initiation of a fault current arc to ground, each operation having minimum current flow duration of 10 cycles.

TEST RESULTS:

All samples tested met the requirements of Section 7.18 of IEEE Standard 386 - 2006. Table 2 shows individual results of the Fault-current Initiation Test.

Table 2. Summary of Fault-current Initiation Test

Sample Number	Test Number	Test Voltage (kV)	Test Current (kA)	Duration (Cycles)
1	1	6.0	11	11.0
1	2	6.0	11	10.5
2	1	6.0	11	11.5
2	2	6.0	11	11.0
3	1	6.0	11	10.5
3	2	6.0	11	10.5
4	1	6.0	11	10.5
4	2	6.0	11	10.0



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TEST REPORT Bulletin CPO 90.03-14

Switching and Fault-closure Interchangeability Tests

1. Switching Test

TEST PROCEDURE:

Each test sample, consisting of a 15 kV 200A elbow and a bushing insert, was subjected to 10 complete switching operations under the conditions listed in Figure 19 and Table 7 of IEEE Standard 386 - 2006. The test circuit complies with Figure 19 (b) of the Standard. Switching was performed manually with the operator closing the connector after the steady-state voltage and current were achieved. The test samples were operated using the parallel method of switching. Each switching operation was recorded by an oscillogram.

Interchangeability switching testing was conducted on the Hubbell bushing insert mated with an elbow manufactured by Cooper (RTE) or Elastimold (Thomas & Betts), and the Hubbell elbow mated with a bushing insert manufactured by Cooper (RTE) or Elastimold (Thomas & Betts).

TEST RESULTS:

In each test series, at least 10 consecutive successful tests were recorded, as indicated in Tables 1 and 2. In each successful test, the sample withstood 10 complete switching operations without arcing to ground or impairing the ability to meet the other requirements of the Standard. The test samples met the requirements of Section 7.7 of IEEE Standard 386 – 2006. The results provide confirmation that the Hubbell switch module met or exceeded the switching interchangeability requirements.



Table 1. Summary of Switching Tests (Bushing Insert)

Test sample: Hubbell Bushing Insert with Cooper (RTE) Elbow (2604599B33MA)

Sample Number	Pass/Fail	Sample Number	Pass/Fail
1	F	16	P (10)
2	P	17	P (11)
3	F	18	P (12)
4	P	19	P (13)
5	P	20	P (14)
6	F	21	P (15)
7	P (1)	22	P (16)
8	P (2)	23	P (17)
9	P (3)	24	P (18)
10	P (4)	25	F
11	P (5)	26	P
12	P (6)	27	F
13	P (7)	28	P
14	P (8)	29	P
15	P (9)	30	P

Test sample: Hubbell Bushing Insert with Elastimold (T&B) Elbow (167LR-G240)

Sample Number	Pass/Fail	Sample Number	Pass/Fail
1	P	16	P (10)
2	P	17	P (11)
3	P	18	P (12)
4	P	19	P (13)
5	F	20	P (14)
6	F	21	P (15)
7	P (1)	22	P (16)
8	P (2)	23	P (17)
9	P (3)	24	F
10	P (4)	25	P
11	P (5)	26	P
12	P (6)	27	P
13	P (7)	28	P
14	P (8)	29	F
15	P (9)	30	P

Note: () – Consecutive successful test.



Table 2. Summary of Switching Tests (Elbow)

Test sample: Hubbell Elbow with Cooper (RTE) Bushing Insert (2604797B01M)

Sample Number	Pass/Fail	Sample Number	Pass/Fail
1	P	16	P (8)
2	P	17	P (9)
3	P	18	P (10)
4	P	19	P (11)
5	P	20	F
6	F	21	F
7	P	22	P
8	F	23	F
9	P (1)	24	P
10	P (2)	25	P
11	P (3)	26	P
12	P (4)	27	P
13	P (5)	28	P
14	P (6)	29	P
15	P (7)	30	P

Test sample: Hubbell Elbow with Elastimold (T&B) Bushing Insert (1601A3R)

Sample Number	Pass/Fail	Sample Number	Pass/Fail
1	P	16	P (3)
2	P	17	P (4)
3	P	18	P (5)
4	P	19	P (6)
5	P	20	P (7)
6	P	21	P (8)
7	P	22	P (9)
8	P	23	P (10)
9	P	24	P (11)
10	P	25	P (12)
11	P	26	P (13)
12	P	27	P (14)
13	F	28	F
14	P (1)	29	F
15	P (2)	30	P

Note: () – Consecutive successful test.



2. Fault-closure Test

TEST PROCEDURE:

15 kV 200A elbow and bushing insert connectors that were subjected to the switching test were then subjected to the fault-closure test with the fault current given in Table 2 and under the conditions listed in Figure 20 and Table 9 of IEEE Standard 386 - 2006. The test was conducted on the samples in the same sequence used for the switching test. The test circuit complies with Figure 20 (b) of the Standard. The closing operation was performed manually and each operation was recorded by an oscillogram.

Interchangeability fault-closure testing was conducted on the Hubbell bushing insert mated with an elbow manufactured by Cooper (RTE) or Elastimold (Thomas & Betts), and the Hubbell elbow mated with a bushing insert manufactured by Cooper (RTE) or Elastimold (Thomas & Betts).

TEST RESULTS:

For each combination of samples, as shown in Tables 3 and 4, at least ten consecutive tests were recorded meeting the criteria that their oscillograms showed no external ground current and that all parts remained within the closed connector assembly. The samples tested met the requirements of Section 7.8 of IEEE Standard 386 - 2006. The results provide confirmation that the Hubbell switch module met or exceeded the fault-closure interchangeability requirements.



Table 3. Summary of Fault-closure Test (Bushing Insert)

Test sample: Hubbell Bushing Insert with Cooper (RTE) Elbow (2604599B33MA)

Sample Number	Pass/Fail	Sample Number	Pass/Fail
1	*	16	P (11)
2	P (1)	17	***
3	*	18	***
4	P (2)	19	***
5	P (3)	20	***
6	*	21	***
7	**	22	***
8	P (4)	23	***
9	**	24	***
10	P (5)	25	*
11	P (6)	26	***
12	P (7)	27	*
13	P (8)	28	***
14	P (9)	29	***
15	P (10)	30	***

Test sample: Hubbell Bushing Insert with Elastimold (T&B) Elbow (167LR-G240)

Sample Number	Pass/Fail	Sample Number	Pass/Fail
1	P (1)	16	***
2	P (2)	17	***
3	P (3)	18	***
4	P (4)	19	***
5	*	20	***
6	*	21	***
7	P (5)	22	***
8	P (6)	23	***
9	P (7)	24	*
10	P (8)	25	***
11	P (9)	26	***
12	P (10)	27	***
13	P (11)	28	***
14	***	29	*
15	***	30	***

Note: () - Consecutive successful test.
 * - Sample failed in switching test.
 ** - Test not valid because of circuit malfunction.
 *** - Sample not tested since fault-closure test requirements have been met.



Table 4. Summary of Fault-closure Test (Elbow)

Test sample: Hubbell Elbow with Cooper (RTE) Bushing Insert (2604599B33MA)

Sample Number	Pass/Fail	Sample Number	Pass/Fail
1	P (1)	16	***
2	P (2)	17	***
3	P (3)	18	***
4	P (4)	19	***
5	P (5)	20	*
6	*	21	*
7	P (6)	22	***
8	*	23	*
9	P (7)	24	***
10	P (8)	25	***
11	P (9)	26	***
12	P (10)	27	***
13	***	28	***
14	***	29	***
15	***	30	***

Test sample: Hubbell Elbow with Elastimold (T&B) Bushing Insert (1601A3R)

Sample Number	Pass/Fail	Sample Number	Pass/Fail
1	P (1)	16	***
2	P (2)	17	***
3	P (3)	18	***
4	P (4)	19	***
5	P (5)	20	***
6	P (6)	21	***
7	P (7)	22	***
8	P (8)	23	***
9	P (9)	24	***
10	P (10)	25	***
11	***	26	***
12	***	27	***
13	*	28	*
14	***	29	*
15	***	30	***

Note: () - Consecutive successful test.
 * - Sample failed in switching test.
 *** - Sample not tested since fault-closure test requirements have been met.