



ANSI/IEEE Design Test Report

15 kV Class 200 A

Loadbreak Separable Connector System

This design test report records the results of laboratory tests performed on the 15 kV Class 200 A Loadbreak Separable Connector System which met or exceeded all applicable requirements of these standards:


- IEEE Standard 386-2006, "IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V"
- ANSI Standard C119.4-1991, "Conductors for Use between Aluminum-to-Aluminum or Aluminum-to-Copper Bare Overhead Connectors"
- IEE Standard 592-1990, "IEEE Standard for Exposed Semiconducting Shields on High-Voltage Cable Joints And Separable Insulated Connectors."

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

Loadbreak Elbow Connector	215LE, 215LEJ
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
Elbow Tap Plug	615ETP


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Design Test Report
15 kV Class 200 A Loadbreak Separable Connector System

Tests were performed in accordance with:

- a) IEEE Standard 386-2006, "IEEE Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V"

Reports provide details of the tests according to the following table:

Section	Description	Clause
I	Partial Discharge Test	7.4
II	Dielectric Tests	7.5
III	Short Time Current test	7.6
IV	Switching Test	7.7
V	Fault Closure test	7.8
VI	Current Cycling Test	7.10
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IX	Operating-Force Test	7.14
X	Operating-Eye Test	7.15
XI	Test Point Cap Test	7.16
XII	Test Point Test	7.17
XIII	Shielding Test	7.18
XIV	Switching And Fault-Closure Inter changeability Tests	7.7 and 7.8
Annex	Integral Seal Water Intrusion	N/A



SECTION I

PARTIAL DISCHARGE TEST

Test Procedure

Each test sample consisted of one cable ready 15 kV 200 A elbow, one 15 kV 200 A 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.

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

Table 1



**SECTION II
 DIELECTRIC TESTS
 (AC, DC, and Impulse Withstand Tests)**

Test Procedure

Each test sample consisted of one cable ready 15 kV 200 A elbow, one 15 kV 200 A 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 wave-shape 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 2 shows a summary of the Dielectric Test results.

Sample	AC – 34 kV rms	DC – 53 kV rms	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

Table 2



SECTION III 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 3 shows a summary of the Short-time Current Test results.

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

Table 3



SECTION IV 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 4, 14 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. A total of 25 samples withstood 10 complete switching operations. The test samples met the requirements of Section 7.7 of IEEE Standard 386 - 2006.

Sample	Pass/Fail	Sample	Pass/Fail
E1	P(1)	E16	P(7)
E2	P(2)	E17	P(8)
E3	P(3)	E18	P(9)
E4	P(4)	E19	P(10)
E5	P(5)	E20	P(11)
E6	P(6)	E21	P(12)
E7	NO TEST	E22	P(13)
E8	P(7)	E23	P(14)
E9	F	E24	F
E10	P(1)	E25	P(1)
E11	P(2)	E26	P(2)
E12	P(3)	E27	P(3)
E13	P(4)	E28	F
E14	P(5)	E29	P(1)
E15	P(6)	E30	F

Table 4

Note: () — Consecutive successful test.



SECTION V FAULT-CLOSURE TEST

Test Procedure

15 kV 200A elbow and bushing insert connectors that were subjected to the switching test (SECTION IV) 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 5, ten 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 IEEE Standard 386 - 2006.

Sample	Current Duration	Prestrike Voltage	Results	Sample	Current Duration	Prestrike Voltage	Results
	ms	kV _{peak}	Pass/Fail		ms	kV _{peak}	Pass/Fail
E1	184	18.7	Pass (1)	E7	No Test During Switching		
E2	183	21.3	Pass (2)	E8	183	22.1	Pass (7)
E3	176	13.9	Pass (3)	E9	Sample Failed during Switching		
E4	184	15.3	Pass (4)	E10	183	19.0	Pass (8)
E5	183	20.0	Pass (5)	E11	184	18.3	Pass (9)
E6	183	11.7	Pass (6)	E12	184	19.5	Pass (10)

Table 5



SECTION VI CURRENT-CYCLING TEST

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, 29th and 39th cycles, after the samples had returned to room temperature, a short time AC current of 3500 ±300 A 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.

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	42.4	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	43.4	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 6

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

Table 7



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 8 shows a summary of the test results.

Sample	Current Transfer Point	Cycle 9 (°C)	Cycle 21 (°C)	Cycle 30 (°C)	Cycle 39 (°C)	Cycle 50 (°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

Table 8



**SECTION VII
 ACCELERATED SEALING LIFE TEST**

Test Procedure

Four connector assemblies were placed in an oven with $121\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ 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 $90\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ for 1 hour.
2. The assemblies were de-energized and within 3 minutes, submerged in $25\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ conductive water (5000Q/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 9 shows individual results of the Accelerated Sealing Life Test.

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

Table 9



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SECTION VIII CABLE PULL-OUT TEST

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.



SECTION IX 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 10.

Sample	Close (lbf@-20 °C)	Open (lbf @ -20°C)	Close (lbf @ 25°C)	Open (lbf @ 25°C)	Close (lbf @ 65°C)	Open (lbf @ 65°C)
1	186	198	116	131	79	116
2	187	174	148	164	99	128
3	157	160	158	144	96	111
4	182	165	128	144	109	127

Table 10



SECTION X 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 °C ±5 °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 11.

Sample	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

Table 11



**SECTION XI
 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 12 shows individual results of the Test-point Cap Operating Force Test.

Sample	Sample 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

Table 12

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.



SECTION XII 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 13 shows individual results of the Test-point Capacitance Test.

Sample	Test-point to Cable (pF)	Test-point to Ground (pF)	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

Table 13



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 14 shows individual results of the Test-point Voltage Test.

Sample	Applied Voltage (kV)	Test-point Voltage (kV)
1	10.0	9.5
2	10.0	10.5
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	10.0
10	10.0	9.5

Table 14



**SECTION XIII
 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 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 7.18 of IEEE Standard 386 - 2006. Resistance of all test samples did not exceed 5000 Ω. Table 15 shows individual results of the Shield Resistance Test.

Sample	Un-aged		Sample	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

Table 15



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 16 shows individual results of the Fault-current Initiation Test.

Sample	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

Table 16



**SECTION XIV
 SWITCHING AND FAULT-CLOSURE INTERCHANGEABILITY TESTS**

1. Switching Test Bushing Insert

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 17 through 20. 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.

Hubbell Bushing Insert with Cooper (RTE) Elbow (2604599B33MA)			
Sample	Pass/Fail	Sample	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

Table 17

Note: () — Consecutive successful test.



Hubbell Bushing Insert with Elastimold (T&B) Elbow (I67LR-G240)			
Sample	Pass/Fail	Sample	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

Table 18

Note: () — Consecutive successful test.

Hubbell Elbow with Cooper (RTE) Bushing Insert (2604797B01M)			
Sample	Pass/Fail	Sample	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	P
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

Table 19

Note: () — Consecutive successful test.



Hubbell Elbow with Elastimold (T&B) Bushing Insert (1601A3R)			
Sample	Pass/Fail	Sample	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

Table 20

Note: () — Consecutive successful test.



2. Fault-closure Test

Test Procedure

15kV 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 21 through 24, 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 continuation that the Hubbell switch module met or exceeded the fault-closure interchangeability requirements.

Hubbell Bushing Insert with Cooper (RTE) Elbow (2604599B33MA)			
Sample	Pass/Fail	Sample	Pass/Fail
1	*	16	P(11)
2	P (1)	17	***
3	F	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	***

Table 21

Note: ()-Consecutive successful test.

* - Sample failed in switching test

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



Hubbell Bushing Insert with Elastimold (T&B) Elbow (I67LR-G240)			
Sample	Pass/Fail	Sample	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	***

Table 22

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

Hubbell Elbow with Cooper (RTE) Bushing Insert (2604797B01M)			
Sample	Pass/Fail	Sample	Pass/Fail
1	P(1)	16	***
2	P(2)	17	***
3	P(3)	18	***
4	P(4)	19	***
5	P(5)	20	F
6	*	21	F
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	***

Table 23

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



Hubbell Elbow with Elastimold (T&B) Bushing Insert (1601A3R)			
Sample	Pass/Fail	Sample	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	***

Table 24

Note: ()-Consecutive successful test.

* - Sample failed in switching test

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



Annex
SWITCHING AND FAULT-CLOSURE INTERCHANGEABILITY TESTS

Samples and Sample Preparation:

The elbows used were production parts, catalog # 215LEJ45, assembled on a 15kV, 175MIL 1/0 Aluminum Cable, per the assembly instructions (IS200LEJ).

Test Procedure

The test was performed in accordance with the following test protocol:

- **Water Immersion**
All assemblies shall be immersed in water for a minimum of twenty four (24) hours in a tank that contains water. All parts of the assemblies, except leads, shall be at least 12" below the surface of the water
- **Heat Conditioning**
Each connector assembly shall be conditioned in an oven at $65\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ for a minimum of seventy two (72) hours. After the conditioning period, the assemblies shall be allowed to cool to ambient temperature.
- **Flex**
Each assembly shall be subject to the following:
 - The insulated conductor shall be securely clamped at a distance from the sealing point as follows:
 - For conductor that are #4 AWG and larger, fifteen (15) times the diameter of the insulated conductor.
 - For conductors that are smaller than #4 AWG, twenty-five (25) times the diameter of the insulated conductor.
 - The assemblies shall be bent ninety (90) degrees to one side, returned to the starting position, bent ninety (90) degrees in the opposite direction, and returned to the starting position. Each assembly shall be subjected to ten (10) such flexing cycles.
- **Twist**
While clamped as described under flex, the assembly shall be twisted around the conductor axis fifteen (15) degrees in one direction from the starting position, returned to the starting position, twisted fifteen (15) degrees in the opposite direction and returned to the starting position. Each assembly shall be subjected to five (5) such twisting cycles.
- **Cold Conditioning**
Each assembly shall be exposed for a minimum of four (4) hours in air having a temperature of -18C. Within five (5) minutes after removal from the cold conditioning the assemblies shall be tested in accordance with Flex and Twist as described above. Both tests shall be completed within the five (5) minute interval.



- **Heated Water Immersion**
Each connector assembly shall be conditioned in an oven at $65\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ for a minimum of twenty four (24) hours, immediately followed by a twenty four (24) hour water immersion as previously described.
- **Completion**
The test is completed successful if no water passes the sealing point during the completion of the test.

Test Results:

All assemblies met the requirements of this test, no water intrusion was found in the assemblies.