DESIGN TEST REPORT

15/25 kV 600A T-Body Elbow Deadbreak Separable Connectors According to IEEE Std 386™ -2006
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I. OBJECTIVE

To evaluate the Chardon 15/25kV series 15/25-TB-600 and 15/25-TB-600T to the 28kV class performance requirements of IEEE Std 386-2006. Test values of 28kV class were obtained by linear interpolation.

II. SUMMARY

Samples were qualified to the full design testing sequences of IEEE Std 386-2006, including dielectric voltage withstand sequence, accelerated sealing life sequence, thermal cycle withstand, short time current, current cycling, capacitive test point, and shielding tests.

III. CONCLUSION

By passing the above test requirements, it is concluded that the 15/25kV series 15/25-TB-600 design is suitable for use as a fully shielded, fully separable submersible cable connection for 600A high voltage apparatus through 28kV.

IV. CABLE DATA

<table>
<thead>
<tr>
<th>Class:</th>
<th>28kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor:</td>
<td>750 kcmil - Al</td>
</tr>
<tr>
<td>Insulation:</td>
<td>280mils, TRXLPE (1.69” OD)</td>
</tr>
<tr>
<td>Insulation Shield:</td>
<td>Extruded</td>
</tr>
<tr>
<td>Jacket:</td>
<td>PVC (2.10” OD)</td>
</tr>
</tbody>
</table>
V. TEST SAMPLES

The required number of samples according to each specific test requirements were prepared and installed on the XLPE cable according to the installation instructions provided in Appendix 1.

VI. TESTING SEQUENCE

The samples were tested in accordance with IEEE 386-2006 standard. Table 1 shows the different test sequences and sections the samples were subjected to. The section numbers refer to the corresponding sections in the standard.

<table>
<thead>
<tr>
<th>Sequence</th>
<th>A</th>
<th>B</th>
<th>Individual</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Samples</td>
<td>10</td>
<td>4</td>
<td>various</td>
</tr>
<tr>
<td>Thermal cycle withstand</td>
<td>7.20</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Partial discharge test</td>
<td>7.4</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>AC withstand voltage</td>
<td>7.5.1</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>DC withstand voltage</td>
<td>7.5.2</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Impulse withstand voltage</td>
<td>7.5.3</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Short-time current</td>
<td>7.6</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Current cycling (uninsulated Components)</td>
<td>7.9</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Current cycling (Insulated connectors)</td>
<td>7.11</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Accelerated sealing life test</td>
<td>7.12</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Cable pull-out (tensile strength)</td>
<td>7.13</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Test Point cap</td>
<td>7.16</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Test Point</td>
<td>7.17</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Shielding</td>
<td>7.18</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Impulse withstand voltage</td>
<td>7.5.3</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Design test sequences

Samples were tested according to the sequence and quantities shown in Table 1.
VII. TESTING

1. Sequence A: Thermal cycle withstand test

Description - The purpose of this test is to demonstrate that non-elastomeric separable connector components can withstand the stresses of an accelerated thermal cycle test.

Requirement - Ten samples shall withstand the thermal cycle test without cracking or breaking and shall meet the requirements of the corona voltage level and ac withstand voltage tests.

Procedure:

1- Ten thermal cycles shall be conducted in air. The temperature cycles shall comply with the thermal cycle aging profile of Figure 1.

2- Perform Partial Discharge (PD) test. Determine PD Inception and Extinction voltages. Dwell for 60s. PD shall not exceed 3pC. Extinction voltage should not be less than 21.5kV.

3- Perform AC withstand voltage test at 45 kV rms for 1 min.

Results - All samples passed.
2. **Sequence A: “Dielectric Tests Sequence”**

**Description:** The purpose of these tests is to verify that the insulation of the test specimen will withstand the specified voltages.

**Requirement -** Ten T-Body samples shall satisfy the requirements of the tests described in sequence A (Table 1).

**Procedure:**

1- Make 10 Elbow assemblies on 28kV 750MCM cable as shown in the figure below.

![Cable rig](image)

2- Perform PD test. Determine PD Inception and Extinction voltages. Dwell for 60s. PD shall not exceed 3pC. Extinction voltage should not be less then 21.5kV.

3- Perform AC withstand voltage test at 45kV rms for 1 min.

4- Perform DC withstand voltage test at 88kV for 15 min.

5- Perform Impulse withstand test at 140kV crest, 3 positive and 3 negative full-wave impulses.

6- Apply test voltage to the conductor system of the T-Body and measure voltage at Test Point of T-Body and Test Point of Insulating Plug with “vm50dd” HV meter.
7- Measure capacitances from Test Point to cable and Test Point to ground for every T-Body and Insulating Plug. 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.

Results - All samples passed.

3. **Sequence B: “Accelerated Life Tests Sequence”**.

**Description:** The purpose of this test is to demonstrate that the T-Body connector can maintain a long-term seal at all interfaces to prevent the entrance of moisture.

**Requirement -** Four T-Body samples shall satisfy the requirements of the accelerated life tests described in sequence B (Table 1).

**Procedure:**

1- Construct 4 T-Body assemblies on 28kV 750MCM test cables as shown in the figure below.

![Cable rig](image)

2- Perform PD test. Determine PD Inception and Extinction voltages. Dwell for 60s. PD shall not exceed 3pC. Extinction voltage should not be less than 21.5kV.

3- Perform AC withstand voltage test at 45kV rms for 1 min.
4- Replace 28kV XLPE dielectric test cables with aging cables during the oven aging portion of this test. Place assemblies in an oven having 121 °C temperature for three weeks.

5- Remove samples from oven and operate once using an appropriate location on the axis of the separable interface.

6- Construct a cycling test loop with 4 T-Body assemblies, test cables, and control cable as shown in the figure below.

7- Run 50 cycles of the following sequence:

   a- 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 4 hours;

   b- The assemblies shall be de-energized and within 3 min, submerged in 25 °C ± 10 °C conductive water (5000 Ω-cm maximum) to a depth of 30 cm (1 ft) for 2 hours.
8- Perform Impulse withstand test at 140kV crest, 3 positive and 3 negative full-wave impulses.

9- Apply test voltage to the conductor system of the T-Body and measure voltage at Test Point of T-Body and Insulating Plug with "vm50dd" HV meter.

10- Measure capacitances from Test Point to cable and Test Point to ground for every T-Body and Insulating Plug. 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

Results - All samples passed.

4. Section 7.6: "Short-time Current Test".

Description - The purpose of this test is to verify that the T-Body connector is capable of withstanding short-time current of the magnitude 25,000 A rms symmetrical for 0.17 seconds and 10,000A rms symmetrical for 3.00 seconds. The connector shall be mounted in a manner approximating service conditions.

Requirement - Connectors shall withstand the current without separation of interfaces or impairing the ability to meet the other requirements of the standard.

Results - All samples passed.
5. **Section 7.9: "Current Cycling For Uninsulated Components".**

**Description** - The purpose of this test is to demonstrate the ability of the uninsulated components of the connector system to maintain their required continuous current-carrying capability when subjected to cyclical loads.

**Requirement** - Tests shall be conducted in accordance with ANSI C119.4. A 750 kcmil aluminum conductor shall be used for 600 A T-Bodys.

**Results** - All samples passed. The details of the test are described in EDR-5476.

6. **Section 7.11: "Current Cycling For Insulated Components".**

**Description** - The purpose of this test is to demonstrate that 600 A insulated T-Body connectors can carry rated current under usual service conditions. Successful completion of the test listed within this subclass shall be considered as evidence that the T-Body connector meets its rating.

**Requirement:** The temperature of the hottest spot of the connector shall be measured every ten cycles and shall not exceed the temperature of the conductor of the control cable.

**Procedure:**

1- Construct cycling test loop according to Figure 2. Attach thermocouples to each Compression Connector prior to T-Body installation.
2- Run 50 cycles of following sequence in air:

   a. The assemblies shall be heated using sufficient current to raise the temperature of the conductor of the control cable to 90 °C ± 5 °C for 6 hours;

   b. The assemblies shall be de-energized for 6 hours.

3- The temperature shall be measured at the approximate center of the control cable.

Results - All samples passed.
7. Section 7.13: "Cable Pull-out (Tensile Strength)"

**Description -**
The purpose of this test is to determine if the connection between the cable conductor and compression lug of the connector is capable of withstanding a tensile force of 890 N (200 lbf).

**Requirement -**
The connection shall withstand the applied force for 1 min without impairing the connector's ability to meet the other requirements of the IEEE 386-2006 standard.

**Procedure -**
The compression lug shall be held in a manner that will not affect the strength of the connection. The tensile force shall be applied to the cable conductor.

**Results -**
All samples passed.

8. Section 7.16: "Test Point Cap Test"

**Description -**
The purpose of this test is to demonstrate that the removal force of the test point cap meets the requirements and the cap operating eye is capable of withstanding the maximum operating force.

**Requirement -**
The cap operating eye shall be capable of withstanding a static operating force of 445 N (100 lbf) over the environmental temperature range of −20 °C to +65 °C.
Procedure:

1- Apply a tensile force gradually to the test point cap in the direction parallel with the operating interface axis at −20°C, +25°C, and +65 °C. The force required to remove the test-point cap shall be within the range of 36 N to 218 N (8 lbf to 49 lbf).

2- Apply a tensile force of 445 N (100 lbf) to the test point cap operating eye for 1 min at −20 °C, +25 °C, and +65 °C.

Results - All samples passed.

9. Section 7.16: "Shielding Test"

Description - The purpose of this test is to demonstrate that the shielding meets the requirements of 6.3. The test procedure shall be in accordance with IEEE Std 592.

Results - All samples passed.

VIII. TEST EQUIPMENT USED

<table>
<thead>
<tr>
<th>Equipment description</th>
<th>Calibration Number</th>
<th>Calibration due date</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Dielectric Test Set</td>
<td>51345</td>
<td>8/31/09</td>
</tr>
<tr>
<td>Capacitance and Tan δ Bridge</td>
<td>50762</td>
<td>8/31/09</td>
</tr>
<tr>
<td>AC test set</td>
<td>50763</td>
<td>8/31/09</td>
</tr>
<tr>
<td>VM50DD Voltmeter</td>
<td>S/N 081001-1</td>
<td>10/31/09</td>
</tr>
<tr>
<td>High Voltage DC Power Supply</td>
<td>50587</td>
<td>8/31/09</td>
</tr>
<tr>
<td>AC High Voltage Source</td>
<td>50596</td>
<td>8/31/09</td>
</tr>
<tr>
<td>Impulse Peak Voltmeter</td>
<td>50622</td>
<td>8/31/09</td>
</tr>
<tr>
<td>High Voltage Divider</td>
<td>50765</td>
<td>8/31/09</td>
</tr>
</tbody>
</table>
APPENDIX 1

Installation Instructions
**15/25-TB-600**
**15/25-TB-600T**

600A T-Body Elbow Connectors for jacketed concentric neutral (JCN) and concentric neutral (CN) cables up to 15/28kV class

### Kit Contents
1. Conductive cap
2. Insulating plug
3. Stud
4. T-Body
5. Compression lug (with crimp chart)
6. Cable adapter
7. Silicone lubricant
8. Installation instruction

### Suggested Installation Equipment (not supplied with kit)
- Cable preparation tools
- Clean, lint-free cloths
- Non-conducting abrasive cloth, 120 grit or finer
- Connector(s) and installation tools

### Safety Instructions

**DANGER:** When installing electrical power system accessories, failure to follow applicable personal safety requirements and written installation instructions could result in fire or explosion and serious or fatal injuries.

As Chardon has no control over field conditions which influence product installation, it is understood that the user must take this into account and apply his own experience and expertise when installing product.

All apparatus must be de-energized during installation or removal of parts.

### General Information

The Chardon 15/25-TB-600 and 15/25-TB-600T 15/25kV class 600A elbows are used to terminate high-voltage cable on deadfront apparatus transformers and switchgear or make separable splice or junction connections. They are fully shielded, fully submersible and are interchangeable with all other manufacturers that certify compliance with IEEE standard 386.
Installation Instructions

1. Check kit

Check kit components to insure proper fit with the cable diameter dimensions, conductor size, and mating products.

2. Cut cable

Position the cable so that it is parallel to the apparatus faceplate and is located in the final assembled position with enough slack to allow movement of elbow to insulated parking bushing. Cut cable 1-3/4" (45mm) from the centerline of the mating bushing. If using a jacket sealing device park it on the cable now. Follow instructions in the jacket sealing kit after elbow assembly is complete.

3. Prepare cable

If jacketed neutral cable, remove outer jacket 12" (304mm) from end of cable. If unjacketed neutral cable, bind neutral wires using red marking tape at 14"(355mm). Fold back neutral wires allowing enough extra length to connect to ground and allow elbow movement to insulated parking bushing. Remove semi-con insulation shield 9-3/4" (247mm) from the end of the cable with a straight, smooth, squared cut. Do not cut or nick the insulation. Wrap two turns of marking tape 1" (25mm) from end of semi-con shield. This will be a guide for the cable adapter location.

4. Remove insulation

Remove insulation exposing conductor between 4-3/8" and 4-5/8".
5. Chamfer and clean insulation

Remove sharp edge of insulation by chamfering the end of the cable insulation at a 45° angle, approximately 1/4" back. Thoroughly clean the insulation with a solvent dampened cloth, wiping from conductor toward cable semi-con shield. Ensure that all traces of conductive residue are removed.

6. Lubricate and install cable adapter

Lubricate exposed cable insulation with silicone grease always working toward cable semi-con shield. Lubricate inside of cable adapter. Install cable adapter, small end first, over cable using a twisting motion until it is flush with the edge of the tape marker.

7. Ensure position of cable adapter

The cable adapter has a step molded into the cable entrance.

When sliding the cable adapter on you should feel a positive stop when the step in the adapter meets the step in the semicon of the cable. The positive stop should be felt at the same location as the tape mark. DO NOT slide adapter past this step. If you suspect you have slid the adapter past the step pull adapter off and repeat step 7.

8. Install compression connector

Copper conductor: Remove protective cap and fully insert conductor into compression lug.

Aluminum conductor: Prepare aluminum conductor by wire brushing just prior to insertion into connector. Remove protective cap and fully insert conductor into compression lug.

Connector must be fully seated on cable conductor. Align flats of lug and bushing before crimping. Start crimps at the lug end 1/2" (13mm) below shoulder of compression connector and work down. Crimp the compression lug following the crimping instruction supplied with the lug. Wipe all excess inhibitor from connector and cable adapter surfaces.
9. Check dimension

The distance from the end of the lug to the cable adapter after crimping should be between 6-1/2" to 7-1/2" (165mm – 190mm). Otherwise redo assembly.

10. Install elbow on cable

Clean and evenly lubricate the entire surface of cable adapter with silicone grease. Lubricate inside the cable entrance of the T-Body wiping 360° around the entire surface and at least 2" (50mm) deep. If test point T-Body is used, ensure that test point is facing towards installer. Push T-Body onto cable adapter until lug eye is centered in the 600A interface. You must ensure that the cable adapter does not move while installing the elbow.

11. Assemble T-Body on bushing

Clean and lubricate the entire mating surfaces of bushing and T-Body interfaces. Push T-Body onto apparatus bushing.
12. Prepare insulating plug

Hand tighten the threaded stud into the insulating plug or mating part. Clean and lubricate the mating surfaces of insulating plug and T_Body interface.

13. Install insulating plug

Push plug into the T-Body and tighten to apparatus bushing using a torque wrench and 1” socket. Tighten plug clock-wise exerting 55 ft-lbs (75 N-m) of torque. The insulating plug provides a capacitive test point for detecting system voltage. The 15/25-TB-600T has an integral capacitive test point on the body. Follow VOLTAGE TEST directions on page 7.
14. Install conductive cap

Clean and lubricate inner surface of conductive cap with lubricant supplied. Push cap onto insulating plug until it snaps into place.

15. Ground system

Connect grounding eye of T-Body with a minimum #14 AWG copper drain wire to cable concentric neutral wires or to common ground point.
Capacitive Voltage Test

The Chardon 15/25-TB-600T is provided with an integral capacitive test point on the body. Both the 15/25-TB-600 and 15/25-TB-600T kits contain an insulating plug that has a test point as noted in step 13. Complete the following steps to use the test point:

- Remove test point cap with a hotstick. Rather than pulling directly in line with the test point assembly. **PEEL OFF AT AN ANGLE.**

- Using a suitable sensing device, determine if the cable is energized. **DANGER:** Use only voltage indicating instruments specifically designed for capacitive test points. Use of conventional voltage sensing devices may provide a false “No Voltage” indication. The test point must be dry and free of contaminants when checking for voltage. To prevent serious or fatal injury treat the elbow as energized until the “No Voltage” test point indication is confirmed by other means.

- After voltage detection has been made, clean and lubricate the inside surface of the test point cap with silicone grease and replace it on the test point with a hot stick.