TEST PERFORMED ON ECI COMPOSITE BUSHINGS

Purpose of this paper

The purpose of this paper is to explain the series of tests performed on the bushings designed and manufactured by ELECTRO COMPOSITES INC. These series of tests have been done to build the appropriate engineering database, which is used on a daily basis, to design and manufacture bushings for electrical applications; voltage range up to 46 kV and current range up to 3000 amps.
In order to proceed, various standards have been used such as IEC 137, IEC 707, IEC 1109, Canadian standard CEA LWWG-02 (91), ANSI C29.2, UL-94, ASTM G26

Type test

- High potential test are done at approximately twice the rated voltage during a one-minute period (refer to IEC or ANSI standards). The high potential level is specific to each bushing with a specific rated voltage. As an example, a bushing rated at 24–25 KV will be tested at 50 KV. During this test, no flash over should happen. After this test, the sheds should not show any degradation.

Type Test
(example for 24-25kV bushing)

Wet power-frequency voltage test	50 kV
Dry lightning impulse voltage test	150kV
Temperature-rise test (125 °C)	40°C
Thermal short-time current test (105 °C)	42°C
Cantilever load test	1250 N

• Dry lightning impulses (B.I.L.) are performed on each specific bushing having a new shed design. Fifteen positive shocks and fifteen negative shocks of standard waveform 1.2/50 micro sec. are applied to the bushing. The same waveform is used for IEC and ANSI standards. Electro Composites bushing designs support the following BIL: a) for rated voltage at 15 KV, BIL should be 125 KV, b) for rated voltage at 25 KV, BIL should be 150 KV, c) for rated voltage at 38 KV, BIL should be 200 KV. After the test, no degradation should be observed on the insulating material.

Routine Test

• Measurement of the dielectric dissipation factor tan d and the capacitance at ambient temperature Tan d < 0.6%
Capacitance < 150 rF

• The dry power-frequency voltage withstand test..

• The measurement of the partial discharge quantity.

• Measurement of partial discharge is one of the key measurement done to detect voids in the material. This test was performed at; a) 1.05 x rated voltage/√3, b) 1.5 x rated voltage/√3. The measurement should be respectively less than 5 Pico Coulomb for (a) and less than 10 Pico Coulomb for (b). Up to now, due to the design and process used for EC bushings, giving no significant porosity, the measurement of partial discharge was very low. The typical value is below 2 Pico Coulomb. This measurement was made on each bushing and is part of the EC standard test report. The measurement of capacitive value and power factor are also done. **This is part of the EC standard report on each bushing we produce.**

Test setup to measure partial discharge, capacitor value and power factor.

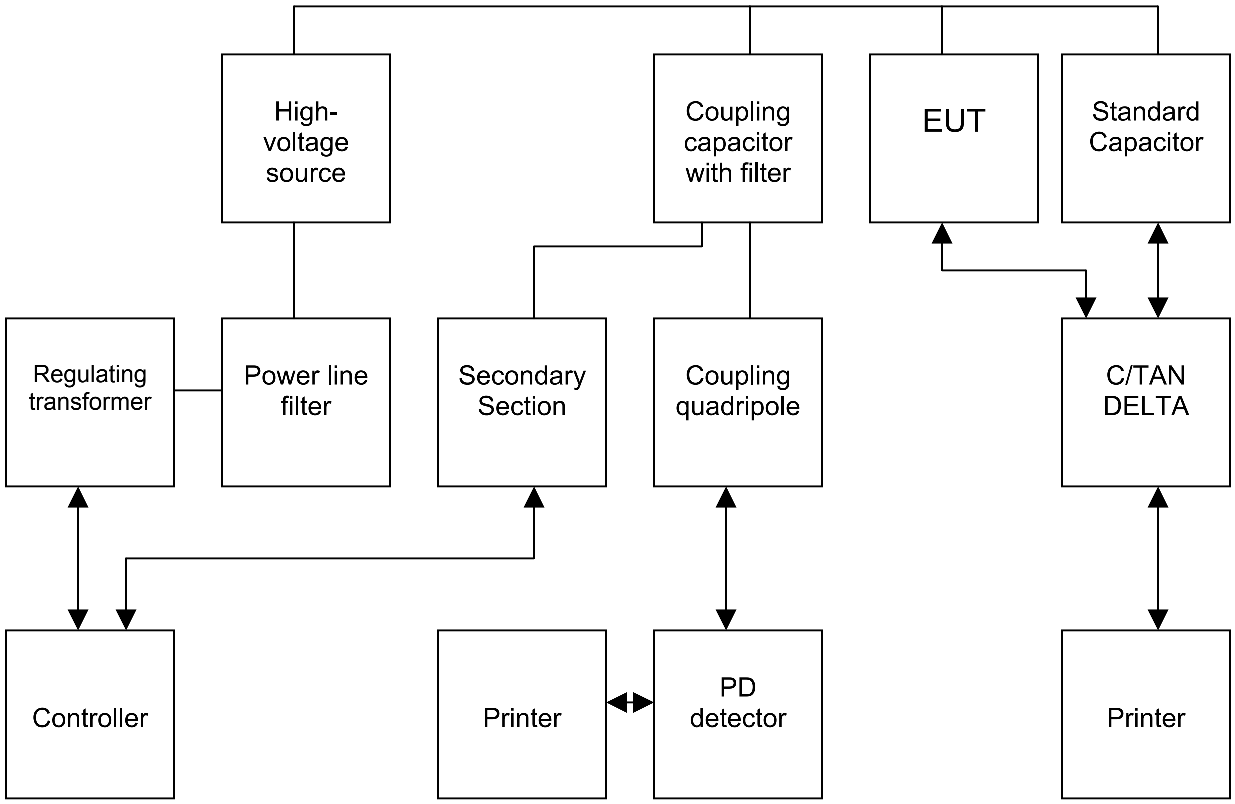


Figure 1

State of the art instrumentation was used to perform these tests. A Farady cage was used to reduce the noise level to a minimum.

- The temperature rise measurement is done when the current reaches the rated current value. The temperature rise on the conductor surface was recorded up to the time where the temperature would not vary more than +/-2 degrees Kelvin during a 2 hour period. The permanent temperature should be less than the maximum temperature that the insulating material can support. In the case of EC bushing design, the insulating material can support 125 degrees C. The EC design criteria has fixed a maximum temperature rise of 30 degrees C to permit a normal operation at a maximum temperature of +60 degrees C for air or oil system.

- A short circuit test was performed to verify the temperature rise during a certain time period. In the case of breakers, the short was applied during a 1 second period. In the case of transformers, the short circuit was applied during a 2 second period. Before we apply the short circuit current, the rated current should be reached. The value of the short circuit current should be 25 times the rated current. During this test, we recorded the temperature rise. At the end of the test, the temperature rise should not damage the insulating envelop; especially on the interface. between the conductor and the insulating material.

- A cantilever load test was performed when the bushing was mounted on a casing and attached with the appropriate mechanical system. The load was applied perpendicularly to the bushing axis during a 60 second period. Sometimes, due to the type of loading, it would be necessary to apply an overload for the 60-second period. After the test, no visual cracks or other mechanical defects should be observed.

A test on the interface between the copper rod and insulating envelop.

This test has been developed to verify the seal between the copper rod and the insulating material by applying a cantilever load and a thermal cycling. At the end of the cycling, the bushing was put in a water vessel for a specified period of time. The temperature of the water was maintained at 100 degrees C. After that, we applied an electrical impulse test. Normally if the seal is no good, the bushing will explode.

This test is very severe and only a design like the EC bushing design could pass this type of test. This test will soon be part of the IEC standard. This test will insure that all future bushing designs, will provide an excellent interface between materials and hence, avoid any water penetration. In order to explain this test, we will use parameters previously applied on a specific EC bushing (see figure 2)

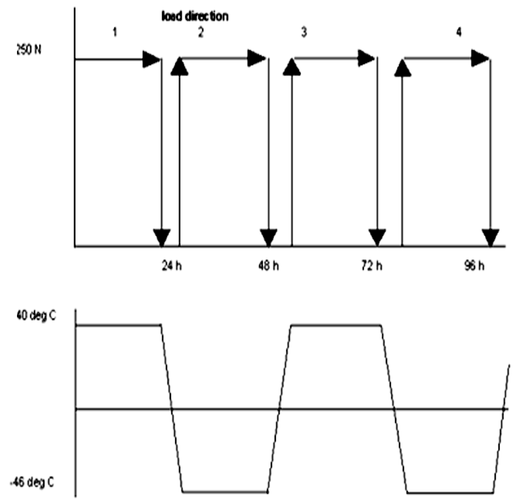


Figure 2

The following explanations are in relation to figure 2

- First, a force of 1250 Newton was applied in a given direction and while maintaining this force, we varied the temperature from + 40 degrees C to -46 degrees C. This was done during a 24-hour period.
- In the next 24 hours, we applied the load in the reverse direction. Again we varied the temperature from –46 degrees C to + 40 degrees C.
- We repeated this test to complete 4 cycles.
- After mechanical and thermal cycling, we put the bushing in a water bath at 100 degrees C for 48 hours.

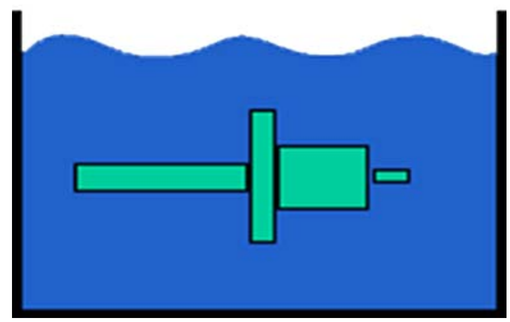


Figure 3: Test on interface and connections of end fitting

The following explanations are related to figure 2, 3 and 4.

- After 48 hours in a hot water vessel, the bushing was removed. At this point if the seal is broken, water should penetrate into the interface.
- The temperature of the bushing was kept at 50 degrees C and submitted to 25 electrical impulses with the shape shown on the figure 5 during 10 micro second.
- If there is water penetration between the copper rod and the insulating material, the bushing will explode.

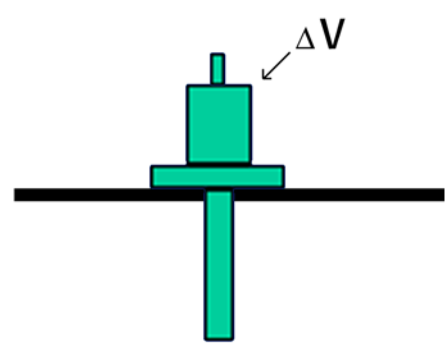


Figure 4: Test on interface an connections of end fitting

Tracking and Erosion test

- A Tracking and Erosion test was performed to see the influence of a polluted environment. Our equipment today has to deal with different types of pollution such as salty air during the winter period, industrial and urban fog, and salty air from the sea, etc. This test permits us to see the long-term effect on the shed surface, shed geometry and materials. The end result will also determine if the creep distance is sufficient for a specific application. To explain the test, we will use a typical test normally done by EC. Refer to figure 6, 7 and 8.

- The salt concentration was equivalent to medium pollution.
- After 1000 hours of testing, no tracking and/or erosion on the surface of the bushing was observed.
- This was a very severe test on the surface of the bushing. However the end result gave us a good indication about the aging that will result from pollution.

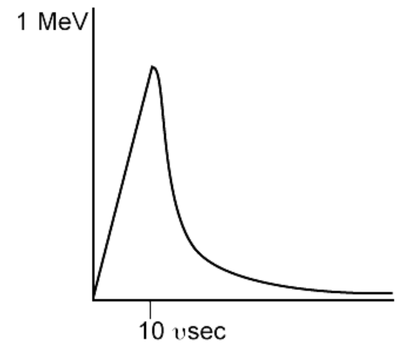


Figure 5 : Test on interface and connections of end fitting

Test of Housing :
Tracking and Erosion Test

Voltage	17 kV
Salt fog concentration	10 g/L
Temperature-rise test (125 °C)	40°C
Duration	1000 hr
Max allowable flashovers	3

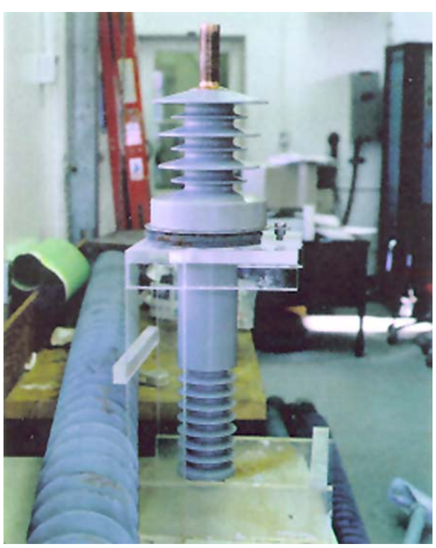


Figure 6

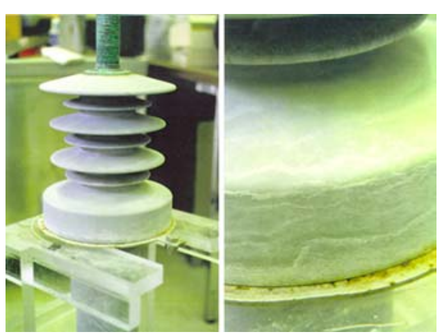
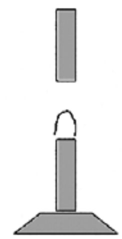


Figure 7

Figure 8

Flammability test

- The flammability Test, is based on IEC 707 or the equivalent standard UL-94. The object of this test is to determine the level of the flammability of solid electrical insulating materials when exposed to an ignition source. The materials formulated by EC meet class VO. Figure 9 will explain briefly the test.



Flammability Test

Method FV
Flame - Vertical specimen

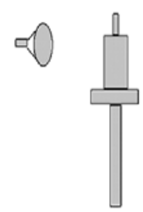
Specimen Thickness	Class
6 mm	V 1
12 mm	V 0

Figure 9

IEC 707 methods of test for the determination of the flammability of solid electronic insulating materials when exposed ton an igniting source. Section 9

Aging test

- The aging test was based on the ASTM G26. Bushing sheds are submitted to 1000 hours on an accelerated weathering to determine the effect of UV light on the material. A XENON arc lamp was used to stimulate UV source. During the test, rain was applied for 18 minutes every 2 hours. Xenon arc lamps have the closest energy distribution to sunlight.
- After 1000 hours, no surface defect such as blistering, crack or disruption should be observed.



Aging test

Source	Xenon arc lamp
Duration	1000 hr
Test method	ASTM G26
Result	No surface defect

Figure 10

CEA LW1WG-02 (91) Line post composite insulator for overhead distribution lines. Section 5.2

Thermal cycling test

- The thermal cycling test was done to verify the entire bushing behavior submitted to a large variation of temperature between +60 degrees C to –50 degrees C. The bushing was mounted on a metallic enclosure, as it would be in a real situation. The enclosure was internally equipped with a controlled heating system to maintain the inside temperature.

• During the 8 cycles, heat was applied to the enclosure and the outside temperature was stabilized at –50 degrees C for 12 hours. For the ninth and tenth cycle, the enclosure heating system was removed and the bushing was energized. A current equivalent to the rated current X 1.59, circulated in the bushing up to the temperature stabilization. The temperature was measured with thermocouples mounted on the bushing.

• After completion of the 10 cycles, the bushing was examined. No visible damage should be observed. A partial discharge was done. The value obtained should not indicate any change compared to the values measured before the test.

Impact test

• An impact test was performed using a pendulum. A pendulum hits the shed tips and the energy was recorded up to the moment the material breaks. Typically, the polymeric base materials are at least 25 times better than porcelain for the impact strength. The following figure gives some typical values.

Mechanical Impact Strength	
Polymer bushing	130 J/m
Porcelain bushing	5 J/m

Reference: ANSI C29.2 Insulator wet process porcelain and toughened glass suspension type. Section 5.1.2.2