

POWERTECH LABS INC.

Final Report

**DESIGN TESTS ON
COMPOSITE SUSPENSION INSULATORS
25000 lbs**

**MANUFACTURED BY
HUBBELL POWER SYSTEMS**

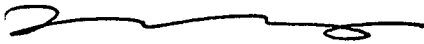
PROJECT 17514-27/A

May 2008


ABSTRACT: Design Tests were performed on 16 mm core diameter composite suspension insulators, Catalog No. S025032S0010 & S025008S0010E, specified mechanical load 25,000 lb, manufactured by Hubbell Power Systems. The tests, as noted in Clause 4, were performed in accordance with IEC 61109(1992): "Composite Insulators for AC Overhead Lines with a Nominal Voltage Greater than 1000 V - Definitions, Test Methods and Acceptance Criteria", Section 5: Design Tests" and IEC 61109-am1(1995). The insulators passed all the requested tests.

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1. SUMMARY

The composite suspension insulators, Catalog No. S025032S0010 & S025008S0010E, specified mechanical load 25,000 lb, manufactured by Hubbell Power Systems, successfully passed each of the Design Tests listed below in clause 4.

2. REQUEST

Allen Bernstorff, Hubbell Power Systems, requested tests on 16 mm core diameter composite suspension insulators, Catalog No. S025032S0010 & S025008S0010E, manufactured by Hubbell Power Systems. The requested tests are listed in Clause 4 below.

3. TEST STANDARD

The tests were performed in accordance with IEC 61109(1992): "Composite Insulators for AC Overhead Lines with a Nominal Voltage Greater than 1000 V - Definitions, Test Methods and Acceptance Criteria", Section 5: Design Tests" and IEC 61109-am1(1995).

4. TESTS PERFORMED

The individual Design Tests performed were as follows:

| | IEC 61109(1992) Clause |
|--|------------------------|
| <u>Tests on interfaces and connections of metal fittings</u> | 5.1 |
| Test specimens and preliminary tests | 5.1.1 |
| Dry power frequency voltage test | 5.1.2 |
| Prestressing | 5.1.3 |
| Verification tests | 5.1.4 |
| <u>Assembled core load-time test</u> | 5.2 |
| Test specimens: visual and dimensional check | 5.2.1 |
| Mechanical load test | 5.2.2 |
| <u>Test of housing: tracking and erosion test</u> | 5.3 |
| <u>Test for the core material</u> | 5.4 |
| Dye penetration test | 5.4.1 |
| Water diffusion test | 5.4.2 |
| <u>Flammability tests</u> | 5.5 |

5. INSULATOR MANUFACTURER AND IDENTIFICATION

Manufactured by Hubbell Power Systems,
Catalog Number: S025032S0010
DWG. No.: PSXIT-SX
Catalog Number: S025008S0010E (insulator for tracking and erosion test)
Ground fitting: Chain_eye
Line fitting: ANSI_ball
Specified mechanical load: 25000 pounds
Routine test load rating: 12500 pounds

The insulators were in accordance with the attached manufacturer's drawing shown in Figure 1 and photographs in Figure 2.

6. TEST DATES

The tests were performed during the period of August to November 2007.

7. TEST LOCATION AND TEST EQUIPMENT

The tests were performed in the High Voltage Laboratory and the Mechanical Laboratory of Powertech Labs Inc., Surrey, British Columbia, Canada. Appendix I lists the test equipment used for the tests.

8. TEST RESULTS

8.1 *Test on Interfaces and Connection of Metal Fittings*

8.1.1 Test Specimens and Preliminary Tests

8.1.1.1 Visual Check and Dimension Verification

Test date: August 7, 2007

The three insulators samples were examined visually and the dimensions were checked that they conformed to the drawing.

8.1.1.2 Mechanical Routine Test

Test date: August 8, 2007

The three insulators were subjected, at ambient temperature, to a tensile load of 12,500 lb (50% of the specified mechanical load of 25,000 lb) for 10 seconds.

8.1.2 Dry Power Frequency Flashover Voltage Test

Test date: 7 August 2007

The dry power frequency flashover voltage was determined on the three insulators.

The average of five flashover voltages on each insulator was corrected to normal standard atmospheric conditions in accordance with IEC 60-1. The flashover voltage was obtained by increasing the voltage linearly from zero within one minute.

| | | |
|-------------------------|---------------------------------------|------------|
| Atmospheric conditions: | Barometric Pressure: | 764.6 mmHg |
| | Temperature, Dry-Bulb | 20.8 °C |
| | Temperature, Wet-Bulb: | 14.8 °C |
| | Relative Humidity: | 52.7 % |
| | Air density Correction Factor K_d : | 1.0014 |
| | Humidity Correction Factor K_h : | 0.9921 |

The following flashover values were obtained:

| Insulator Untested samples | Uncorrected flashover values (kV) | Uncorrected flashover average (kV) | Corrected flashover value (kV) |
|----------------------------------|--------------------------------------|---|--------------------------------------|
| Sample 720-1 | 319.2, 322.4, 321.6, 317.6, 320.5 | 318.2 | 322.9 |
| Sample 720-2 | 320.0, 317.6, 315.2, 318.4, 318.4 | 317.9 | 320.2 |
| Sample 720-3 | 318.4, 324.8, 324.8, 324.8, 324.1 | 320.5 | 320.5 |

8.1.3 Prestressing

8.1.3.1 Sudden Load Release Test

Test date: 21 August 2007

This test was performed with the insulators at -24 °C (required range is -20 °C to -25 °C). Each of the three tested insulators was subjected to five sudden load releases from a tensile load of 7500 lb (30% of the SML of 25,000 lb).

8.1.3.2 Thermal-Mechanical Test

Test dates: 4-8 September, 2007

The three tested insulators were subjected to four 24-hour thermal cycles with a simultaneously applied tensile load of 12,500 lb (minimum required load is 50% of the SML of 25,000 lb). Each 24-hour cycle started with one cooling period of -35 ± 5 °C, followed by one heating period of +50 ± 5 °C. The tolerances on the temperature of the hot and cold

cycles were such that a minimum difference of 85 °C between the two extreme temperatures was achieved. The duration of the two temperature levels was 8 hours and 15 minutes.

Before commencing the test, the insulators were loaded, at the ambient temperature, at 1250 lb (minimum required load is 5% of SML of 25,000 lb) for one minute, during which the distance between two reference points was measured. At the end of the test the distance between the two reference points was measured again. The measured lengths were:

| Insulator | Initial Length | Final Length | Change |
|-----------|----------------|--------------|--------|
| 720-1 | 844.0 mm | 846.0 mm | 2 mm |
| 720-2 | 840.0 mm | 841.0 mm | 1 mm |
| 720-3 | 843.0 mm | 844.0 mm | 1 mm |

8.1.3.3 Water Immersion Test

Test date: 22 – 24 September 2007

The three tested insulators were immersed for 42 hours in boiling deionized water with 0.1% by weight of NaCl.

At the end of boiling, the insulators remained immersed until the water cooled to approximately 50 °C and maintained at this temperature until the verification tests started.

8.1.4 Verification Tests

Test date: 24-25 September 2007

8.1.4.1 Visual Examination

The insulators were inspected visually. No cracks were observed.

8.1.4.2 Steep-Front Impulse Voltage Test

| | | |
|-------------------------|------------------------|------------|
| Atmospheric conditions: | Barometric Pressure: | 765.4 mmHg |
| | Temperature, Dry-bulb | 22.1 °C |
| | Temperature, Wet-bulb: | 15.0 °C |
| | Relative Humidity: | 45.7 % |

The test voltage - an impulse with a steepness in the range of 1043-1259 kV/μs - was applied first between the upper and lower fitting.

Each insulator was stressed with 25 impulses of positive polarity and 25 impulses of negative polarity.

Each impulse, applied to all three insulators, caused an external flashover voltage between the fittings. No punctures of the sheds or the core were recorded.

8.1.4.3 Dry Power Frequency Voltage Test

| | | |
|-------------------------|---------------------------------------|------------|
| Atmospheric conditions: | Barometric Pressure: | 764.6 mmHg |
| | Temperature, Dry-bulb | 20.7 °C |
| | Temperature, Wet-bulb: | 14.8 °C |
| | Relative Humidity: | 52.6 % |
| | Air Density Correction Factor K_d : | 1.0014 |
| | Humidity Correction Factor K_h : | 0.9921 |

This test consisted of the following two tests:

- (a) dry power frequency flashover test
- (b) dry power frequency withstand test

8.1.4.3.1 Dry Power Frequency Flashover Test

The dry power frequency flashover voltage for each insulator tested was established once more, using the test procedure used in Clause 8.1.2 above. The average value of the flashover voltages should be at least 90% of the voltages established in Clause 8.1.2 above.

The following flashover values (which exceed 90% of the values obtained in Clause 8.1.2) were obtained:

| Insulator | Uncorrected flashover values (kV) | Uncorrected flashover average (kV) | Corrected flashover value (kV) |
|-----------|-----------------------------------|------------------------------------|--------------------------------|
| 720-1 | 324.0, 324.8, 324.8, 324.0, 323.2 | 324.1 | 322.9 |
| 720-2 | 320.8, 320.8, 320.8, 321.6, 319.2 | 320.6 | 319.4 |
| 720-3 | 316.8, 317.6, 319.2, 315.2, 318.4 | 317.4 | 316.2 |

8.1.4.3.2 Dry Power Frequency Withstand Test

Each tested insulator (Samples 720-1, 720-2 & 720-3) was individually subjected for 30 minutes to 80% of the corrected flashover values obtained in Clause 8.1.2. The requirement of the standard is that during this test no puncture of the insulator shall occur and the temperature rise of the shank measured immediately after the test shall be no more than 20 °C.

The following voltages were applied to the individual insulators:

Sample 720-1: 258.3 kV (80% of 322.9 kV)

Sample 720-2: 256.2 kV (80% of 320.2 kV)

Sample 720-3: 256.4 kV (80% of 320.5 kV)

No puncture of the insulators and no measurable increase in temperature of the insulator shank were recorded. The measured temperatures were as follows:

| Insulator | Temperature (°C) | | | | | |
|-----------|------------------|-------|--------|-------|--------|-------|
| | Top | | Centre | | Bottom | |
| | before | after | before | after | before | after |
| 720-1 | 20.7 | 20.9 | 20.6 | 20.7 | 20.3 | 20.8 |
| 720-2 | 20.7 | 20.8 | 20.4 | 20.7 | 20.3 | 20.9 |
| 720-3 | 20.3 | 20.7 | 20.3 | 20.7 | 20.1 | 20.9 |

8.1.5 Test Result

The three tested insulators (Samples 720-1, 720-2 and 720-3) complied with the requirements of IEC 61109(1992), Clause 5.1: "Tests on interfaces and connections of metal fittings".

8.2 **Assembled Core Load-Time Test**

8.2.1 Test Specimens

Test date: 9 – 14 August 2007

The six insulators samples were examined visually and the dimension were checked that they conformed to the drawing.

8.2.2 Mechanical Load Test

This test was performed in two parts at the ambient temperature as described in the following two clauses.

8.2.2.1 Determination of the Average Failing Load of the Core of the Assembled Insulator

Test date: 9 August 2007

Three tests insulators (Samples 720-8, 720-9 & 720-10) were subjected to a tensile load. The tensile load was increased rapidly but smoothly from zero to 11,800 lb (approx 75% of the expected mechanical failing load). The load was then gradually increased until complete pull out of the fitting occurred. The following failing loads were recorded:

| Insulator | Failing load (lb) | Average failing load (lb) |
|-----------|-------------------|---------------------------|
| 720-4 | 29,918 | 28,667 |
| 720-5 | 26,607 | |
| 720-7 | 29,475 | |

8.2.2.2 Control of the Slope of the Strength-Time Curve of the Insulator

Test dates: 10-14 August 2007

The remaining three insulators (Samples 720-8, 720-9 & 720-10) were subjected to a tensile load of 17,200 lb (60 % of the average tensile failing load of 28,667 lb determined in Clause 8.2.2.1 above). This load was maintained for 96 hours.

No damage or length increase of the three tested samples was recorded after this test.

8.2.3 Test Result

The three tested insulators (Samples 720-8, 720-9 & 720-10) complied with the requirements of IEC 61109(1992), Clause 5.2: "Assembled core load-time test".

8.3 Test of Housing: Tracking and Erosion Test

8.3.1 Test Procedure

Test dates: 25 February – 10 April 2008

Test sample: 756-1; 756-2

Two sample insulators were energized at 16.5 kV_{rms} (based on leakage distance of 569 mm) while subjected to a salt fog atmosphere with a salt content of 10 kg/m³. The insulators would pass the test if they withstood the test conditions for 1000 hrs with no more than three overcurrent trip-outs with the current trip set to 1 A_{rms}, if no tracking occurred, if erosion does not reach the glassfibre core and if no sheds are punctured. The core shall not be visible.

8.3.2 Test Results

Figure 3 shows the two sample insulators after the test. There was one overcurrent trip-outs, no tracking, no erosion and no shed punctures. The insulators pass this test.

The insulators passed the requirements of IEC 1109(1992), Clause 5.3: "Test of housing: tracking and erosion test".

8.4 Tests for the Core Material

Two fully assembled insulators were used for the following two tests (the insulators were too short to cut all samples from one insulator. The end fittings were cut off and all the sheds were carefully removed (by knife) from the shank in such a way that the shank diameter of 23 mm was maintained for the full length of the shank.

8.4.1 Dye Penetration Test

Test date: 9 August 2007

Sample: 720-6 (10 mm long specimens)

8.4.1.1 Test Specimens

Ten specimens were cut from the insulator shank. The cuts were made at 90° to the axis of the core using a diamond-coated circular saw blade under running cold water. The cut surfaces were smoothed by means of fine abrasive cloth (grain size 180). The length of the specimens was 10 ± 0.2 mm.

8.4.1.2 Test Procedure, Acceptance Criterion and Results

The specimens were placed (with fibres in vertical position) on a layer of glass beads (diameter 2 mm) in a glass vessel. A dye (1 % alcohol solution of fuchsin) was poured into the vessel, with its level 2.5 mm above the glass beads. The time taken for the dye to rise (by capillary action) through the specimens should be longer than 15 minutes.

Results: There were no traces of dye penetration after 15 minutes.

8.4.2 Water Diffusion Test

Test date: 30 July – 4 August 2007

Insulator sample 720-12 (30 mm long specimens)

8.4.2.1 Test Specimens

Six specimens were cut from the insulator shank by the same method as described in Clause 8.4.1.1 above. The length of the specimens was 30 ± 0.2 mm.

8.4.2.2 Prestressing

The specimens were boiled in a glass container for 100 hour in deionized water with 0.1 % by weight of NaCl.

After boiling, the specimens were removed from the glass container and placed in another glass container filled with tap water at ambient temperature for 30 minutes. The voltage test, described in the following clause was carried out within the next two hours.

8.4.2.3 Voltage Test, Acceptance Criterion and Results

Immediately before the voltage test the specimens were removed from the glass container and their surfaces dried with filter paper.

Each specimen was placed between the test electrodes. The test voltage was increased at rate of approximately 1 kV/sec up to 12 kV, kept at this level for one minute and then decreased to zero.

During this test no puncture or external flashover occurred. The insulator core material leakage current did not exceed 53 μ A (maximum allowable current is 1 mA).

8.4.3 Test Result

The specimens prepared from one insulator complied with the requirements of IEC 61109(1992), Clause 5.4: "Tests for the core material".

8.5 *Flammability Test*

8.5.1 Test Procedure

Two sets of five samples (125 x 13 x 3 mm) of the composite insulator housing material provided by Hubbell were tested in accordance with IEC 60707-1999 and IEC 60695-11-10-1999. One set of five samples was conditioned at 70 ± 2 °C for 168 ± 2 hours. The second set of five samples was conditioned at 23 ± 2 °C for 48 hours.

8.5.2 Acceptance Criteria

The material passes the test if each of the five tested samples belongs to Category FV0 of IEC 707-1999, Clause 9.4. If only one sample from the set of five samples fails to comply with the requirements, another set of five samples shall be tested. If all samples from this second set shall pass the requirements, the material is deemed to pass the flammability test.

8.5.3 Test Date

28 September 2007

8.5.4 Test Results

All five samples complied with the requirements for Category FV0, Method FV. The test result details were as follows:

1. Specimens conditioned at 23±2°C for 48 hours:

| Specimen | t ₁ (sec)* | t ₂ (sec)* | t ₃ (sec) | t ₂ + t ₃ (sec) |
|----------|-----------------------|-----------------------|----------------------|---------------------------------------|
| 1 | <1 | <1 | <1 | <1 |
| 2 | <1 | <1 | <1 | <1 |
| 3 | <1 | <1 | <1 | <1 |
| 4 | <1 | <1 | <1 | <1 |
| 5 | <1 | <1 | <1 | <1 |

* Specimens extinguished immediately upon removal of flame

Note: No flaming particles fell from any of the specimens.

| Criteria conditions | V-0 | V-1 | V-2 | Sample |
|---|------|-------|-------|--------|
| 1. Individual test afterflame time (t ₁ and t ₂) | ≤10s | ≤30s | ≤30s | <10s |
| 2. Total set afterflame time t _f for any conditioning | ≤50s | ≤250s | ≤250s | <50s |
| 3. Individual test specimen afterflame plus afterglow time after the second application (t ₂ plus t ₃) | ≤30s | ≤60s | ≤60s | <30s |
| 4. Did the afterflame and/or afterglow progress up to the holding clamp? | No | No | No | No |
| 5. Was the cotton ignitor pad ignited by flaming particles or drops? | No | No | Yes | No |

Specimens conditioned at 70 ± 2°C for 168 ± 2 hours:

| Specimen | t ₁ (sec)* | t ₂ (sec)* | t ₃ (sec) | t ₂ + t ₃ (sec) |
|----------|-----------------------|-----------------------|----------------------|---------------------------------------|
| 1 | <1 | <1 | <1 | <1 |
| 2 | <1 | <1 | <1 | <1 |
| 3 | <1 | <1 | <1 | <1 |
| 4 | <1 | <1 | <1 | <1 |
| 5 | <1 | <1 | <1 | <1 |

* Specimens extinguished immediately upon removal of flame

Note: No flaming particles fell from any of the specimens.

| Criteria | V-0 | V-1 | V-2 | Sample |
|--|------|-------|-------|--------|
| 1. Individual test afterflame time (t_1 and t_2) | ≤10s | ≤30s | ≤30s | <10s |
| 2. Total set afterflame time t_f for any conditioning | ≤50s | ≤250s | ≤250s | <50s |
| 3. Individual test specimen afterflame plus afterglow time after the second application (t_2 plus t_3) | ≤30s | ≤60s | ≤60s | <30s |
| 4. Did the afterflame and/or afterglow progress up to the holding clamp? | No | No | No | No |
| 5. Was the cotton ignitor pad ignited by flaming particles or drops? | No | No | Yes | No |

The samples passed the flammability test in accordance with IEC 61109 (1992), Clause 5.5.

9. CONCLUSIONS

The 25000 lbs insulators manufactured by Hubbell Power Systems passed all the design tests specified in clause 4 of this report, in accordance with IEC 61109(1992) and IEC 61109-am1(1995).

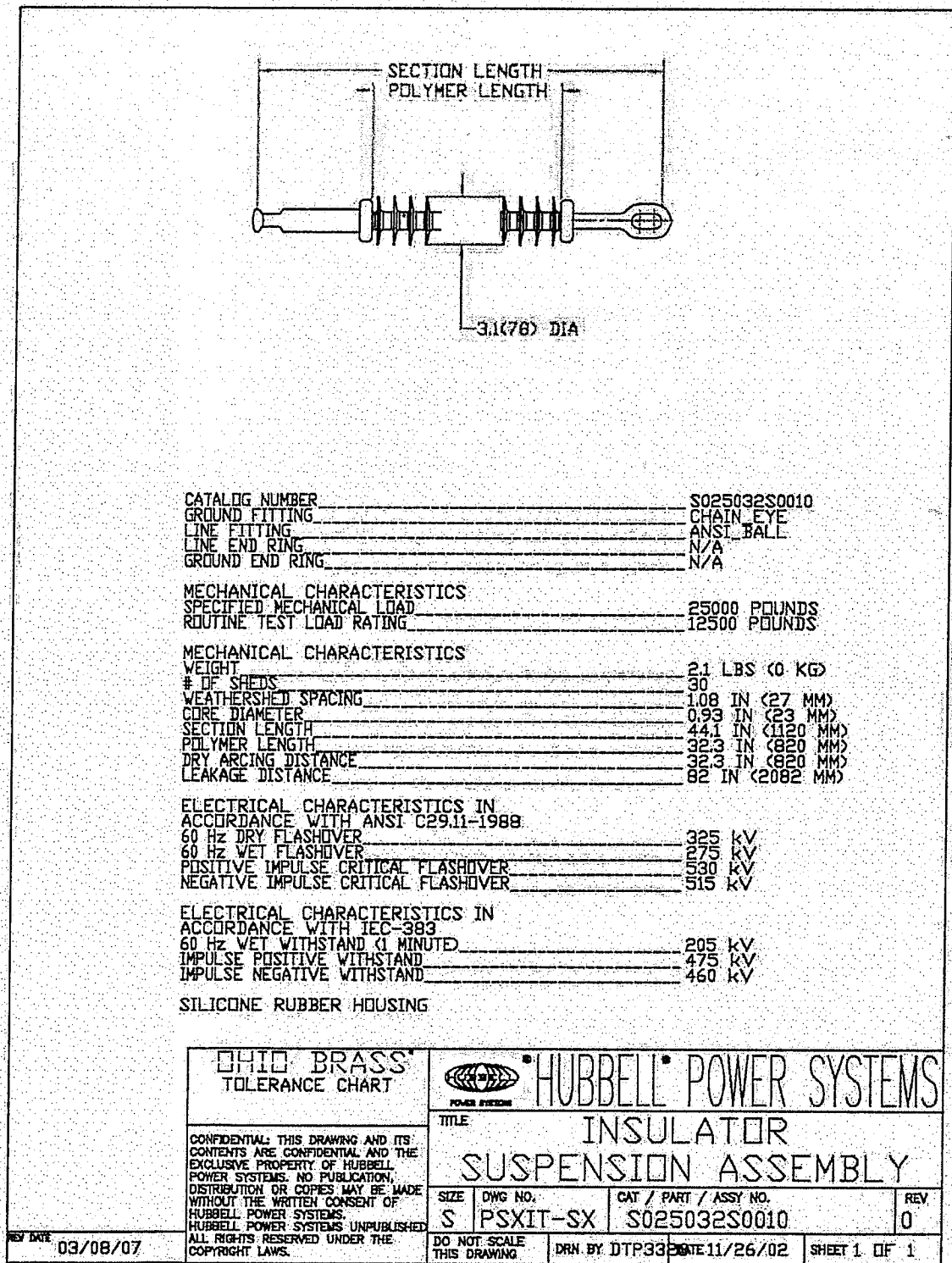


Figure 1A: Manufacturer's Drawing (long insulator)

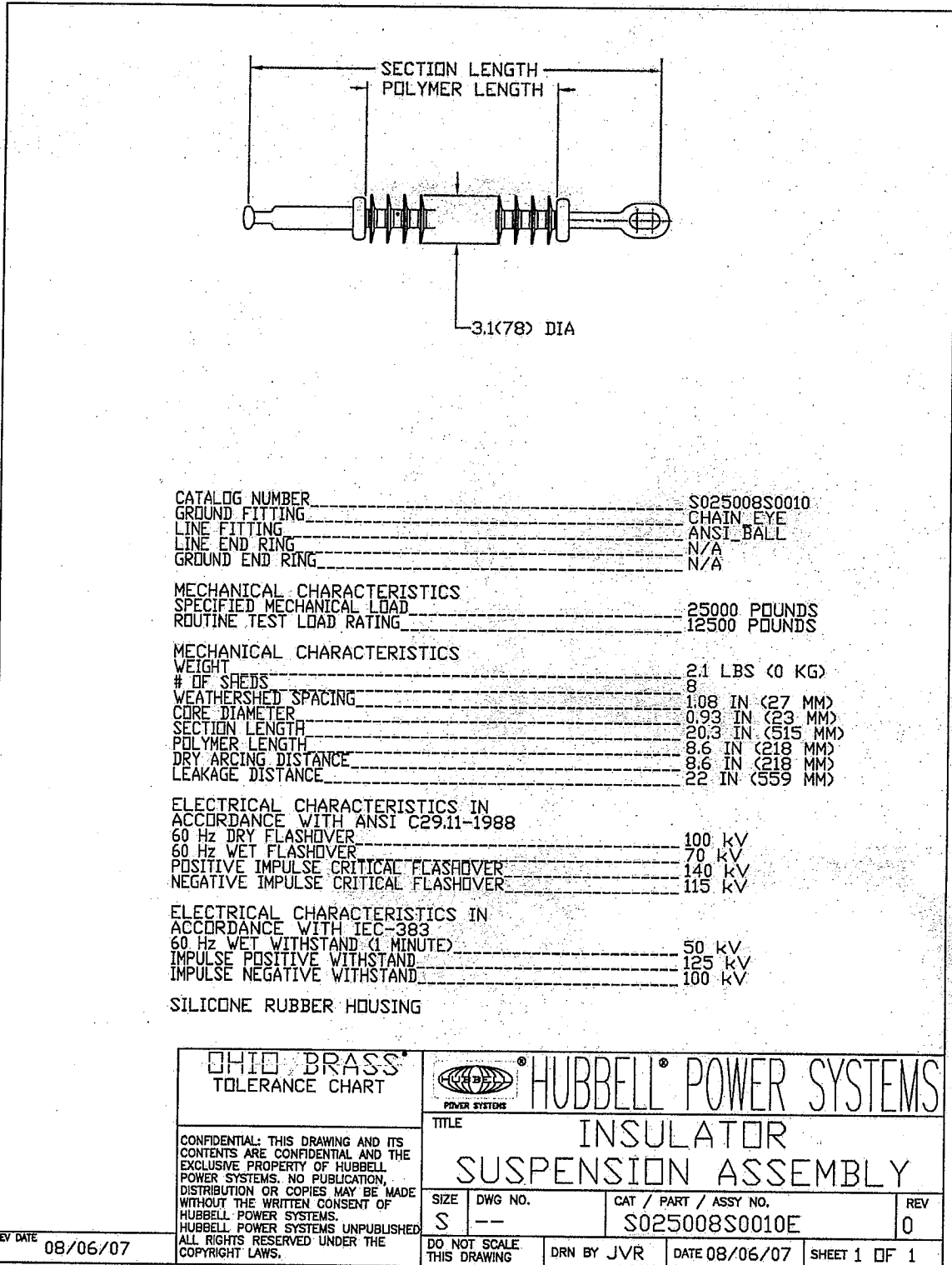


Figure 1B: Manufacturer's Drawing (short insulator)

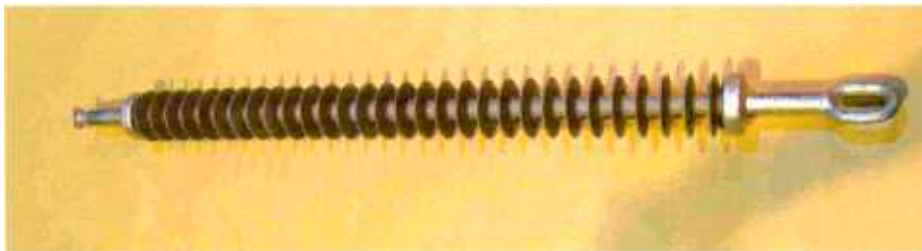


Figure 2: Photograph of a Tested Insulator



Figure 3A: Photograph of Housing: Tracking and Erosion Test Horizontal Insulator (after test)



Figure 3B: Photograph of Housing: Tracking and Erosion Test Vertical Insulator (after test)

Appendix I - TEST EQUIPMENT SPECIFICATIONS.

| | | |
|-------------------------------|---------------|--|
| 1. Resonant Test Set | Manufacturer: | American High Voltage Test Systems |
| | Rating: | 800 kV rms |
| 2. Voltage Divider | Manufacturer: | Haefely |
| | Type: | capacitive |
| | Rating: | 800 kV rms, 1000 pF |
| | Ratio: | 8000:1 |
| | Accuracy: | ± 1% |
| 3. Tensile Testing Machine | Manufacturer: | Tinius Olson |
| | Model: | 400 Super L |
| | Capacity: | 400,000 lb |
| | Ser. No.: | 162665 |
| 4. Environmental Chamber | Dimensions: | 3.65 m length 2.45 m width 2.70 m height |
| | Temperature: | -50 °C to +70 °C |
| | Humidity: | 10% to 90% |