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Report R16-01-08

## ANSI Design Test Report ANSI 52-11 Glass Bells Catalog # PSN21156

This design test report records the results of laboratory tests performed on the ANSI 52-11 Glass Bells which met or exceeded all performed tests of these standards:

ANSI/NEMA C29.2B-2013, "American National Standard for Insulators Wet Process Porcelain and Toughened Glass— Transmission Suspension Type"

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## 8.2.1 LOW-FREQUENCY DRY FLASHOVER TEST

### Test Procedure

Three insulators shall be tested in accordance with 4.2 of ANSI C29.1. Failure of the average dry flashover value of these three insulators to equal or exceed 95 percent of the rated dry flashover value, 95% of 80kV = 76kV, shall constitute failure to meet the requirements of this standard.

### Test Results

All samples tested met the requirements of Section 8.2.1 of ANSI/NEMA C29.2B - 2013. Table 1 shows individual results of the Low Frequency Dry Flashover Test.

|         | Unit 1                           |                                | Unit 2                           |                                | Unit 3                           |                                |
|---------|----------------------------------|--------------------------------|----------------------------------|--------------------------------|----------------------------------|--------------------------------|
|         | Uncorrected<br>kV <sub>RMS</sub> | Corrected<br>kV <sub>RMS</sub> | Uncorrected<br>kV <sub>RMS</sub> | Corrected<br>kV <sub>RMS</sub> | Uncorrected<br>kV <sub>RMS</sub> | Corrected<br>kV <sub>RMS</sub> |
| 1       | 84                               | 92                             | 83                               | 90                             | 83                               | 90                             |
| 2       | 81                               | 88                             | 83                               | 90                             | 84                               | 91                             |
| 3       | 81                               | 88                             | 82                               | 89                             | 81                               | 88                             |
| 4       | 85                               | 93                             | 84                               | 91                             | 81                               | 88                             |
| 5       | 92                               | 101                            | 85                               | 92                             | 79                               | 85                             |
| 6       | 84                               | 92                             | 86                               | 93                             | 83                               | 90                             |
| 7       | 87                               | 95                             | 80                               | 86                             | 86                               | 94                             |
| 8       | 82                               | 89                             | 78                               | 84                             | 87                               | 95                             |
| 9       | 83                               | 90                             | 84                               | 91                             | 80                               | 87                             |
| 10      | 82                               | 89                             | 88                               | 96                             | 87                               | 95                             |
| Average | 84                               | 92                             | 83                               | 90                             | 83                               | 90                             |

Table 1



## 8.2.2 LOW-FREQUENCY WET FLASHOVER TEST

### Test Procedure

Three insulators shall be tested in accordance with 4.3 of ANSI C29.1. Failure of the average dry flashover value of these three insulators to equal or exceed 90 percent of the rated wet flashover value, 90% of 50kV = 45kV, shall constitute failure to meet the requirements of this standard.

### Test Results

All samples tested met the requirements of Section 8.2.2 of ANSI/NEMA C29.2B - 2013. Table 2 shows individual results of the Low Frequency Wet Flashover Test.

|         | Unit 1                           |                                | Unit 2                           |                                | Unit 3                           |                                |
|---------|----------------------------------|--------------------------------|----------------------------------|--------------------------------|----------------------------------|--------------------------------|
|         | Uncorrected<br>kV <sub>RMS</sub> | Corrected<br>kV <sub>RMS</sub> | Uncorrected<br>kV <sub>RMS</sub> | Corrected<br>kV <sub>RMS</sub> | Uncorrected<br>kV <sub>RMS</sub> | Corrected<br>kV <sub>RMS</sub> |
| 1       | 50                               | 52                             | 51                               | 53                             | 57                               | 59                             |
| 2       | 50                               | 51                             | 52                               | 54                             | 50                               | 52                             |
| 3       | 56                               | 58                             | 52                               | 53                             | 49                               | 51                             |
| 4       | 47                               | 48                             | 50                               | 52                             | 54                               | 56                             |
| 5       | 48                               | 49                             | 54                               | 56                             | 51                               | 53                             |
| 6       | 48                               | 49                             | 52                               | 54                             | 51                               | 52                             |
| 7       | 47                               | 49                             | 53                               | 55                             | 51                               | 53                             |
| 8       | 51                               | 52                             | 53                               | 54                             | 49                               | 50                             |
| 9       | 48                               | 50                             | 53                               | 55                             | 52                               | 53                             |
| 10      | 48                               | 50                             | 50                               | 52                             | 53                               | 55                             |
| Average | 49                               | 51                             | 52                               | 54                             | 52                               | 53                             |

Table 2



### 8.2.3 CRITICAL IMPULSE FLASHOVER TESTS – POSITIVE AND NEGATIVE

#### Test Procedure

Three insulators shall be subjected to a critical impulse flashover test, positive and three to the critical impulse flashover test, negative, in accordance with 4.7 of ANSI C29.1. Failure of the average critical impulse flashover value of these three insulators to equal or exceed 92 percent of the rated critical impulse flashover value, 92% of 125kV = 115kV Positive / 92% of 130kV = 120kV Negative, shall constitute failure to meet the requirements of this standard.

#### Test Results

All samples tested met the requirements of Section 8.2.3 of ANSI/NEMA C29.2B - 2013. Tables 3, 4 and 5 show individual results of the Critical Impulse Flashover Test.

| Unit 1  |             |       |              |              |                        |             |       |              |              |                        |
|---------|-------------|-------|--------------|--------------|------------------------|-------------|-------|--------------|--------------|------------------------|
| Impulse | Positive    |       |              |              |                        | Negative    |       |              |              |                        |
|         | Charge (kV) | FO/FW | Impulse (kV) | FO Time (μS) | Corrected Impulse (kV) | Charge (kV) | FO/FW | Impulse (kV) | FO Time (μS) | Corrected Impulse (kV) |
| 1       | 34          | FW    | 120          |              | 125                    | 32          | FW    | 115          |              | 119                    |
| 2       | 35          | FO    | 124          | 3.3          | 130                    | 33          | FO    | 119          | 4.08         | 124                    |
| 3       | 34          | FO    | 126          | 3.7          | 131                    | 32          | FO    | 117          | 4.08         | 122                    |
| 4       | 32          | FW    | 115          |              | 120                    | 30          | FW    | 108          |              | 113                    |
| 5       | 34          | FO    | 121          | 3.7          | 127                    | 31          | FW    | 112          |              | 116                    |
| 6       | 32          | FW    | 115          |              | 120                    | 33          | FO    | 119          | 5.08         | 124                    |
| 7       | 33          | FW    | 119          |              | 124                    | 31          | FW    | 113          |              | 117                    |
| 8       | 34          | FO    | 122          | 4.5          | 128                    | 32          | FO    | 116          | 5.48         | 120                    |
| 9       | 32          | FO    | 116          | 4.9          | 121                    | 31          | FW    | 112          |              | 116                    |
| 10      | 31          | FW    | 111          |              | 116                    | 32          | FO    | 116          | 4.48         | 120                    |
| 11      | 33          | FO    | 120          | 4.9          | 125                    | 31          | FW    | 111          |              | 115                    |
| 12      | 32          | FW    | 115          |              | 120                    | 32          | FW    | 116          |              | 120                    |
| 13      | 33          | FO    | 120          | 4.3          | 125                    | 33          | FO    | 120.9        | 4.08         |                        |
| 14      | 32          | FW    | 115          |              | 120                    | 32          | FO    | 116          | 3.88         | 120                    |
| 15      | 33          | FW    | 119          |              | 124                    |             | FW    | 113          |              | 117                    |
| 16      | 34          | FO    | 122          | 3.9          | 128                    | 33          | FO    | 118          | 4.88         | 123                    |
| 17      | 33          | FO    | 119          | 3.9          | 124                    | 32          | FO    | 115          | 4.08         | 119                    |
| 18      | 32          | FW    | 115          |              | 120                    | 31          | FW    | 112          |              | 116                    |
| 19      | 33          | FO    | 120          | 4.1          | 125                    | 32          | FW    | 117          |              | 122                    |
| 20      | 32          | FW    | 115          |              | 120                    | 33          | FO    | 119          | 4.28         | 124                    |
| Average |             |       | 118          |              | 123                    |             |       | 115          |              | 120                    |

Table 3



| Unit 2  |             |       |              |              |                        |             |       |              |              |                        |
|---------|-------------|-------|--------------|--------------|------------------------|-------------|-------|--------------|--------------|------------------------|
| Impulse | Positive    |       |              |              |                        | Negative    |       |              |              |                        |
|         | Charge (kV) | FO/FW | Impulse (kV) | FO Time (μS) | Corrected Impulse (kV) | Charge (kV) | FO/FW | Impulse (kV) | FO Time (μS) | Corrected Impulse (kV) |
| 1       | 34          | FO    | 122          | 4            | 128                    | 32          | FW    | 117          |              | 122                    |
| 2       | 33          | FW    | 119          |              | 124                    | 33          | FO    | 119          | 6.6          | 124                    |
| 3       | 34          | FW    | 121          |              | 127                    | 32          | FW    | 116          |              | 120                    |
| 4       | 35          | FO    | 126          | 3.6          | 131                    | 33          | FO    | 121          | 4.8          | 126                    |
| 5       | 34          | FO    | 122          | 3.6          | 128                    | 32          | FW    | 117          |              | 122                    |
| 6       | 32          | FW    | 115          |              | 120                    | 33          | FW    | 121          |              | 126                    |
| 7       | 33          | FW    | 119          |              | 124                    | 34          | FO    | 122          | 4.2          | 127                    |
| 8       | 34          | FO    | 121          | 3.6          | 127                    | 33          | FO    | 119          | 4.2          | 124                    |
| 9       | 33          | FW    | 119          |              | 124                    | 32          | FW    | 115          |              | 119                    |
| 10      | 34          | FO    | 122          | 3.6          | 128                    | 33          | FW    | 119          |              | 124                    |
| 11      | 33          | FO    | 119          | 3.6          | 124                    | 34          | FO    | 123          | 4            | 128                    |
| 12      | 32          | FW    | 115          |              | 120                    | 33          | FO    | 119          | 4            | 124                    |
| 13      | 33          | FO    | 120          | 4.8          | 125                    | 32          | FO    | 117          | 6.6          | 122                    |
| 14      | 32          | FO    | 116          | 4.8          | 121                    | 31          | FW    | 115          |              | 119                    |
| 15      | 31          | FW    | 113          |              | 118                    | 32          | FW    | 115          |              | 119                    |
| 16      | 32          | FW    | 112          |              | 117                    | 33          | FO    | 118          | 4.2          | 123                    |
| 17      | 33          | FO    | 121          | 4.8          | 127                    | 32          | FW    | 116          |              | 120                    |
| 18      | 32          | FW    | 117          |              | 122                    | 33          | FO    | 118          | 4.6          | 123                    |
| 19      | 33          | FW    | 121          |              | 127                    | 32          | FO    | 115          | 6.2          | 119                    |
| 20      | 34          | FO    | 122          | 4.8          | 128                    | 31          | FW    | 113          |              | 117                    |
| Average |             |       | 119          |              | 124                    |             |       | 118          |              | 123                    |

Table 4



| Unit 3  |             |       |              |              |                        |             |       |              |              |                        |
|---------|-------------|-------|--------------|--------------|------------------------|-------------|-------|--------------|--------------|------------------------|
| Impulse | Positive    |       |              |              |                        | Negative    |       |              |              |                        |
|         | Charge (kV) | FO/FW | Impulse (kV) | FO Time (μS) | Corrected Impulse (kV) | Charge (kV) | FO/FW | Impulse (kV) | FO Time (μS) | Corrected Impulse (kV) |
| 1       | 33          | FO    | 119          | 4.97         | 124                    | 34          | FO    | 122          | 3.68         | 127                    |
| 2       | 32          | FW    | 115          |              | 120                    | 33          | FO    | 119          | 3.68         | 124                    |
| 3       | 33          | FW    | 119          |              | 124                    | 32          | FW    | 116          |              | 120                    |
| 4       | 34          | FW    | 122          |              | 128                    | 33          | FO    | 117          | 4.28         | 122                    |
| 5       | 35          | FO    | 126          | 3.17         | 131                    | 32          | FW    | 116          |              | 120                    |
| 6       | 34          | FW    | 114          |              | 119                    | 33          | FO    | 119          | 4.08         | 124                    |
| 7       | 35          | FO    | 124          | 4.37         | 130                    | 32          | FO    | 116          | 4.68         | 120                    |
| 8       | 34          | FW    | 121          |              | 127                    | 31          | FW    | 113          |              | 117                    |
| 9       | 35          | FO    | 124          | 2.77         | 130                    | 32          | FO    | 119          | 4.08         | 124                    |
| 10      | 34          | FO    | 121          | 2.97         | 127                    | 31          | FO    | 115          | 6.88         | 119                    |
| 11      | 33          | FW    | 119          |              | 124                    | 30          | FW    | 108          |              | 113                    |
| 12      | 34          | FO    | 121          | 2.97         | 127                    | 31          | FO    | 116          | 5.08         | 120                    |
| 13      | 33          | FO    | 119          | 2.97         | 124                    | 30          | FW    | 112          |              | 116                    |
| 14      | 32          | FW    | 115          |              | 120                    | 32          | FW    | 115          |              | 119                    |
| 15      | 33          | FW    | 117          |              | 122                    | 33          | FO    | 118          | 4.08         | 123                    |
| 16      | 34          | FO    | 121          | 4.97         | 127                    | 32          | FO    | 115          | 4.48         | 119                    |
| 17      | 33          | FW    | 119          |              | 124                    | 31          | FW    | 112          |              | 116                    |
| 18      | 34          | FO    | 121          | 4.97         | 127                    | 32          | FW    | 113          |              | 117                    |
| 19      | 33          | FO    | 117          | 4.97         | 122                    | 33          | FO    | 117          | 4.48         | 122                    |
| 20      | 32          | FW    | 115          |              | 120                    | 32          | FW    | 113          |              | 117                    |
| Average |             |       | 119          |              | 125                    |             |       | 115          |              | 120                    |

Table 5



## 8.2.4 RADIO-INFLUENCE VOLTAGE TEST

### Test Procedure

Three insulators shall be tested in accordance with 4.9 of ANSI C29.1. All insulators shall have less than 50 $\mu$ V RIV at 10kV supplied voltage.

### Test Results

All samples tested met the requirements of Section 8.2.4 of ANSI/NEMA C29.2B - 2013. Tables 6 show individual results of the Radio Influence Voltage Test.

| Unit | RIV @ 10kV <sub>RMS</sub><br>( $\mu$ V) | 50 $\mu$ V RIV<br>(kV <sub>RMS</sub> ) |
|------|---|--|
| 1    | 1.10                                    | 20.3                                   |
| 2    | 1.70                                    | 23.0                                   |
| 3    | 6.90                                    | 16.7                                   |

**Table 6**





## 8.2.5 THERMAL-MECHANICAL LOAD CYCLE TEST

### Test Procedure

Ten assembled insulators shall be subjected to the thermal-mechanical load cycle test. The insulators, which may be connected in series or parallel provided each is equally loaded, shall be subjected to four 24 hour cycles of ambient air cooling and heating with a simultaneously applied minimum tensile load maintained at 60 percent of the rated combined mechanical and electrical strength of the insulators as described in Figure 8. Each 24 hour cycle shall start with a cooling period during which a low temperature of  $-22^{\circ}\text{F}$  ( $-30^{\circ}\text{C}$ ) shall be maintained for at least a four hour period. A heating period will follow the cooling period.

During the heating period a high temperature of  $104^{\circ}\text{F}$  ( $40^{\circ}\text{C}$ ) shall be maintained for at least a four hour period. During the four hour extreme temperature periods, the ambient air temperature shall be maintained at the specified extreme temperature within  $9^{\circ}\text{F}$  ( $5^{\circ}\text{C}$ ). The rate of temperature change is not specified. The tensile load shall be applied at room temperature before starting the first thermal cycle. The tensile load shall be completely removed and reapplied after the first, second and third 24 hour thermal cycle. After the fourth thermal cycle, upon cooling to room temperature, the tensile load shall be removed. The ten insulators shall then be subjected to a Combined Mechanical and Electrical test in accordance with 5.2 of ANSI C29.1. The criteria for determining conformance with the standard are as given in 8.3.4 with the exception that no re-test procedure is applicable in this case.

### Test Results

All samples tested met the requirements of Section 8.2.5 of ANSI/NEMA C29.2B - 2013. Tables 7 show individual results of the Thermal-Mechanical Load Cycle Test.

| Unit              | Ultimate Load (lbs) | Failure mode |
|-------------------|---------------------|--------------|
| 1                 | 58,554              | Cap          |
| 2                 | 61,420              | Cap          |
| 3                 | 57,119              | Cap          |
| 4                 | 62,411              | Glass        |
| 5                 | 62,632              | Glass        |
| 6                 | 58,554              | Cap          |
| 7                 | 56,458              | Glass        |
| 8                 | 60,316              | Cap          |
| 9                 | 60,316              | Cap          |
| 10                | 60,206              | Cap          |
| Average $\bar{X}$ | 59,799              |              |
| St. Dev. $S$      | 2,098.2             |              |

Table 7

$$\bar{X} \geq \text{Rating} + 3 \times S$$

$$59,799\text{lbs} \geq 50,000\text{lbs} + 3 \times 2,098.2\text{lbs}$$

$$59,799\text{lbs} \geq 56,294\text{lbs}$$



## 8.2.6 THERMAL SHOCK TEST

### Test Procedure

Five insulators shall be tested for ten complete cycles in accordance with 5.5 of ANSI C29.1. The temperature of the hot water bath shall be approximately 205°F (96°C), and the temperature of the cold water bath shall be approximately 39°F (4°C). Failure of any insulator shall constitute failure to meet the requirements of this standard.

### Test Results

All samples tested met the requirements of Section 8.2.6 of ANSI/NEMA C29.2B - 2013. Table 8 shows individual results of the Thermal Shock Test.

| Unit | Uncorrected<br>kV <sub>RMS</sub> | Corrected<br>kV <sub>RMS</sub> |
|------|----------------------------------|--------------------------------|
| 1    | 82                               | 92                             |
| 2    | 83                               | 94                             |
| 3    | 81                               | 91                             |
| 4    | 84                               | 95                             |
| 5    | 82                               | 92                             |

**Table 8**



## 8.2.7 RESIDUAL STRENGTH TEST

### Test Procedure

Twenty-five insulators shall have the shells broken off. No portion of the shell shall remain outside the maximum diameter of the cap. Each unit shall then be subjected to a mechanical-strength test in accordance with 5.1 of ANSI C29.1. The criteria for determining conformance to this standard are:

$$\bar{X}_R \geq (1.2 \times \text{proof load}) + 1.645 \times S_R$$

Where:

$\bar{X}_R$  = average residual strength of 25 units

$S_R$  = standard deviation of residual strength of the 25 units tested

*Proof load* = tension proof load (25,000lbs)

### Test Results

All samples tested met the requirements of Section 8.2.7 of ANSI/NEMA C29.2B - 2013. Table 9 shows individual results of the Residual Strength Test.

$$60,132\text{lbs} \geq (1.2 \times 25,000\text{lbs}) + 1.645 \times 3,955\text{lbs}$$

$$60,132\text{lbs} \geq 36,328\text{lbs}$$



| Unit                     | Ultimate Tensile Load (lbs) | Failure mode       |
|--------------------------|-----------------------------|--------------------|
| 1                        | 60,561                      | Pin pulled out     |
| 2                        | 56,766                      | Pin pulled out     |
| 3                        | 59,221                      | Pin pulled out     |
| 4                        | 66,299                      | Steel pin yielded. |
| 5                        | 61,544                      | Pin pulled out     |
| 6                        | 64,726                      | Pin pulled out     |
| 7                        | 63,899                      | Steel pin yielded. |
| 8                        | 64,359                      | Pin pulled out     |
| 9                        | 60,314                      | Pin pulled out     |
| 10                       | 61,054                      | Pin pulled out     |
| 11                       | 64,392                      | Pin pulled out     |
| 12                       | 64,324                      | Steel pin yielded. |
| 13                       | 57,762                      | Pin pulled out     |
| 14                       | 62,306                      | Pin pulled out     |
| 15                       | 58,621                      | Pin pulled out     |
| 16                       | 53,422                      | Pin pulled out     |
| 17                       | 58,384                      | Pin pulled out     |
| 18                       | 57,333                      | Pin pulled out     |
| 19                       | 55,945                      | Pin pulled out     |
| 20                       | 61,242                      | Pin pulled out     |
| 21                       | 59,247                      | Pin pulled out     |
| 22                       | 61,193                      | Pin pulled out     |
| 23                       | 61,690                      | Pin pulled out     |
| 24                       | 48,232                      | Pin pulled out     |
| 25                       | 60,470                      | Pin pulled out     |
| Average $\bar{X}_R$      | 60,132                      |                    |
| Standard Deviation $S_R$ | 3,955                       |                    |

Table 9



## 8.2.8 IMPACT TEST

### Test Procedure

Three insulators shall be tested in accordance with 5.1.2.2 of ANSI C29.1. All insulators shall receive an impact of 60inch-lbs.

### Test Results

All samples tested met the requirements of Section 8.2.8 of ANSI/NEMA C29.2B - 2013. Table 10 shows individual results of the Impact Test.

| Unit | 2000lbs Applied | Impact Passed | Uncorrected $kV_{RMS}$ | Corrected $kV_{RMS}$ |
|------|-----------------|---------------|------------------------|----------------------|
| 1    | ✓               | ✓             | 88                     | 100                  |
| 2    | ✓               | ✓             | 81                     | 91                   |
| 3    | ✓               | ✓             | 81                     | 91                   |

**Table 10**



## 8.2.9 COTTER KEY TEST

### Test Procedure

For three test samples of ball-and-socket insulators, the disengagement force of the cotter key shall be between 25 and 150 pounds (111 and 667 Newton) force for three locking-to-unlocking operations. The cotter key shall be placed in the locking position and a tension load applied to the eye of the cotter key along its axis by means of an appropriate device. The loading shall be gradually increased until the cotter key moves to the unlocking position.

### Test Results

All samples tested met the requirements of Section 8.2.9 of ANSI/NEMA C29.2B - 2013. Table 11 shows individual results of the Cotter Key Test.

| Unit | Operation 1<br>(lbf) | Operation 2<br>(lbf) | Operation 3<br>(lbf) |
|------|----------------------|----------------------|----------------------|
| 1    | 52.5                 | 56.7                 | 54.0                 |
| 2    | 48.0                 | 56.4                 | 72.4                 |
| 3    | 57.0                 | 53.2                 | 52.8                 |

**Table 11**



### 8.3.5 PUNCTURE TEST

#### Test Procedure

Five assembled insulators shall be selected at random and tested in accordance with 4.11 of ANSI C29.1. The criterion for determining conformance to this standard is: No puncture shall occur below the specified puncture voltage (110kV). To provide information the test voltage may be raised until puncture occurs, and the puncture voltage recorded. The re-test procedure in section 4.4 is applicable to this test.

#### Test Results

All samples tested met the requirements of Section 8.3.5 of ANSI/NEMA C29.2B - 2013. Table 12 shows individual results of the Puncture Test.

| Unit | Voltage<br>kV <sub>RMS</sub> |
|------|------------------------------|
| 1    | 180                          |
| 2    | 181                          |
| 3    | 167                          |
| 4    | 180                          |
| 5    | 182                          |

Table 12



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## 8.3.6 VERIFICATION OF COUPLING LOCK SYSTEM

### Test Procedure

Six ball-and-socket insulators shall be coupled in 3 strings of two units with the cotter key in the locking position. Each string shall then be subjected to an attempt to disengage the ball from the socket, applying relative movements by hand representative of those encountered in use. The disengagement of any ball shall constitute failure of the lot to meet the requirements of this standard.

### Test Results

All samples tested met the requirements of Section 8.3.6 of ANSI/NEMA C29.2B - 2013.