The very Best.

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Only a company that develops, produces and delivers products worldwide can provide the optimal solution for your requirements.

The specialists of PPC Insulators are dedicated to supplying you with superior advice and global support. PPC Insulators quality products and service provide time-tested value to fulfill your needs!

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Hollow Insulators - Custom Design

That's what we deliver.
Design has long been restricted by limitations in material and production, complicating introduction of new insulator styles. Long lead times required for engineering, preparation and tooling has mandated product uniformity and strict recommendations at the cost of function-specific design.

New Development

The traditional high voltage insulator is subject to new development focusing on improved performance with reduced sizes.

Design has long been restricted by limitations in material and production, complicating introduction of new insulator styles. Long lead times required for engineering, preparation and tooling has mandated product uniformity and strict recommendations at the cost of function-specific design.

Major improvements now set new standards.

- Isostatic process with shorter lead-times, tighter tolerances and flexible design offer unprecedented possibilities for development and prototype production.

- Integrated computer systems including CAE/CAD/CAM and on-line scheduling speeds introduction of new types.

- K-value, the essential calculation of insulator pollution performance, consider creepage distance and shape to open new opportunities for optimization.

We are at your service to develop custom tailored insulators for your specific requirements!
**Hollow Insulators**

**Design and Redesign**

**Possibilities**

- Optimized shed configuration
- Adaptive core and wall
- Tailored inside and outside

**Improvements**

- Increased
  - mechanical performance
  - electrical performance
  - pollution performance
  - seismic performance
  - visual appearance
  - safety

- Reduced
  - number of units and joints
  - number of different types
  - dimensions and weight
  - volume and space
  - tolerances
  - total cost

**Flexibility**

PPC Insulators promote optimized design of all high voltage insulators.

Integration of CAE/CAD/CAM systems and advanced production process offer flexibility and development of contemporary insulator design.
**Hollow Insulators**

**K-value**

**Increased Pollution Performance**

**Equalized Field Distribution**

K-value design is a method to improve traditional creepage distance.

In its full extent, K-value design is a method to reduce:

- Weight
- Volume
- Space

while improving properties in service by increasing pollution performance and equalizing the electrical field.

**K-value Design**

Form factor used as a design method is referred to as K-value and can be used for different improvements.

Creepage distance considers a leakage current as traveling along the exterior contour of the insulator, identifying only the linear distance.

K-value considers a leakage current as traveling along the insulator over its surface. K-value identifies an insulator’s total shape, i.e., geometric (ohmic) resistance against leakage currents. It is necessary to calculate the shape of the surface of the insulator for reaching optimum pollution performance.

Traditional calculation of creepage distance is still used, but to achieve best performance in relation to material and space used, K-value design is essential. PPC Insulators offers complete computer design of K-value, integrated with traditional requirements.

**Material and Specific Strength**

The mechanical strength of an insulator depends on different parameters.

- Material strength
- Design
- Material and design of fixing and fitting arrangement

Material properties meet specifications stated in IEC publication 60672.

Typical values of specific strength for complete insulator with traditional design are given by basic formula and in the table below. Optimizing design can often increase strength.

**Dimensions**

Dimensional values are general and may vary according to design. Many parameters must be considered, as ratio between height and core diameter, weight and wall thickness, and different inner diameters. Dimensions are continuously subject to improvements.
The design of the insulator will mostly depend on mechanical requirements determined by the equipment manufacturer in relation with apparatus design. The main parameters are:

- **Design pressure.** The difference between maximum absolute pressure when the equipment is carrying its rated normal current at maximum ambient temperature and outside pressure. In special cases, as for circuit breakers, the transient pressure rise that occurs during breaker operation must also be taken into account.
- **Type test withstand bending moment.** A combination of the different loads, which may occur under service conditions.
- **Dimensions of the apparatus.**
- **Environmental conditions on site** (creepage distance, shed design and form factor)

### Determination of Type Test Withstand Bending Moment

Factors that may contribute to the bending stress that may occur in electrical equipment are mass, internal pressure, terminal, short-circuit, ice, wind and seismic load. See table.

<table>
<thead>
<tr>
<th>Stress</th>
<th>From routinely expected loads</th>
<th>From rarely occurring extreme loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design pressure</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Mass</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Rated terminal load</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Wind pressure</td>
<td>30%</td>
<td>0%</td>
</tr>
<tr>
<td>Ice load</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Seismic load</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Safety factor f</td>
<td>2.1</td>
<td>1.2</td>
</tr>
</tbody>
</table>

The following sources should be used for determining the values necessary for calculating the relevant loads:

- **Terminal loads** IEC 56 § 6.101.6.1
- **Wind loads** IEC 56 § 6.101.6.1, IEC 694 § 2.1.2
- **Ice loads** IEC 56 § 6.101.6.1, IEC 694 § 2.1.2
- **Short circuit loads** should be determined from the rated level of the equipment.
- **Seismic loads** IEC 56 (1.7A [LOC] 2.7A)

### Bending Moment

Relation between testing values and utilization values for a hollow insulator.

<table>
<thead>
<tr>
<th>Testing Values</th>
<th>Utilization Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type test withstand</td>
<td>100%</td>
</tr>
<tr>
<td>Routine Test</td>
<td>100%&lt;br&gt;1.2</td>
</tr>
<tr>
<td>Alt 1</td>
<td>100%&lt;br&gt;1.2</td>
</tr>
</tbody>
</table>

The simplified calculation is valid under this condition:

\[
\sigma_a \leq 0.25 \times \sigma_b \text{ where: } \sigma_a = \frac{P \cdot D_s^2}{32 \cdot (D_c^2 + D_i^2)} \text{ and } \sigma_b = \frac{M_{\text{max}} \cdot D_c}{32 \cdot D_s^4 - D_i^4}.
\]

Corresponds to the axial stress due to pressure P.

Corresponds to the axial stress due to the maximum permanent bending moment in service.

### Example of hollow insulator:

Example of hollow insulator:

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Design pressure</th>
<th>Bending Moment</th>
<th>Mass</th>
<th>Rated terminal load</th>
<th>Wind load</th>
<th>Ice load</th>
<th>Seismic load</th>
<th>Safety factor f</th>
</tr>
</thead>
<tbody>
<tr>
<td>D_s</td>
<td>300 mm</td>
<td>1 MPa</td>
<td>15 kNm</td>
<td>10 kNm</td>
<td>10 kNm</td>
<td>10 kNm</td>
<td>10 kNm</td>
<td>2.1</td>
</tr>
<tr>
<td>D_c</td>
<td>220 mm</td>
<td></td>
<td>10 kNm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D_i</td>
<td>260 mm</td>
<td></td>
<td>10 kNm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Determination of Type Test Withstand Design Pressure

The insulator shall withstand 4.25 times the design pressure for 5 minutes.
The method and dimension of fixing arrangement is most important for the structural strength of the insulator. Cemented fittings and flanges generally offer maximum strength. As an alternative, it is also possible to use clamping devices.

**Influence of Fitting and Clamping Design**

The relation between height of fitting (H) and diameter of porcelain (D) is important.

- Elastic layer on metal part is an epoxy or a bituminous paint.
- On porcelain this layer is bituminous paint.
- Cement is Portland or sulphur.
- Grip surface is comprised of porcelain grains embedded in glaze and/or glazed grooves in porcelain.

**Influence of Fitting High and Cantilever Strength**

Internal grooves can be designed to distribute stress for different strength configurations.

**Influence of Internal Grooves**

A smooth design with tapered adaptation between clamp and wall is recommended for best performance.

The fixing lugs require the forces from the clamping jaws to be evenly distributed and that the grip is very firm. It is essential that the clamping arrangement is not allowed to bend backwards.
Pollution Levels

Guidance on design and selection of creepage distance with respect to environmental conditions can be found in IEC recommendation 60815. Basic levels of pollution are qualitatively defined with examples of typical environment situations. Corresponding minimum nominal creepage distance is given in mm/kV.

<table>
<thead>
<tr>
<th>Level</th>
<th>Pollution</th>
<th>Specific Creepage Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Light</td>
<td>16 mm/kV 0.630 inch/kV</td>
</tr>
<tr>
<td>2</td>
<td>Medium</td>
<td>20 mm/kV 0.787 inch/kV</td>
</tr>
<tr>
<td>3</td>
<td>Heavy</td>
<td>25 mm/kV 0.984 inch/kV</td>
</tr>
<tr>
<td>4</td>
<td>Very Heavy</td>
<td>31 mm/kV 1.220 inch/kV</td>
</tr>
</tbody>
</table>

*Areas without industry and with low housing density equipped with heating plants.*
*Areas with low density of industry or houses but subjected to frequent winds and/or rainfall.*
*Agricultural areas.*
*Mountains areas.*

The creepage distance should be increased in relation to the average diameter, \( D_{m} \).

\[
D_{m} <300 \text{ mm} \quad k_{d} = 1.0 \\
300 \text{ mm} < D_{m} < 500 \text{ mm} \quad k_{d} = 1.1 \\
D_{m} > 500 \text{ mm} \quad k_{d} = 1.2
\]

---

Regular sheds

\[ D_{m} = \frac{(D_{e} + D_{c})}{2} \]

Alternating sheds

\[ D_{m} = \frac{(D_{e1} + D_{e2} + (2 \times D_{c})}{4} \]

*Industrial areas not producing particulate polluting smoke and/or with average housing density equipped with heating plants.*
*Areas with high density of houses and/or industry but subjected to frequent winds and/or rainfall.*
*Areas exposed to wind from the sea but not too close to the coast (at least several kilometers distant).*

Areas generally of moderate extent, subjected to conductive dusts and industrial smoke producing particularly thick conductive deposits.
Areas generally of moderate extent, very close to the coast and exposed to sea-spray or to very strong and polluting winds from the sea.
Desert areas, characterized by no rain for long periods, exposed to strong winds carrying sand and salt, and subjected to regular condensation.
Hollow Insulators

Pollution Performance

Shed Design

The plain alternative shed design offers high specific creepage distance together with good self-cleaning properties and usually provides best performance. Using flexible shed design can optimize most insulators.

Parameters Characterizing Insulator Profile

1. Minimum distance, c, between sheds
   - Generally c ≥ 30 mm.
   - For small insulators (H < 550 mm) or overhang (p ≤ 40 mm), c can be ≥ 20 mm.

2. Ratio s/p between spacing and overhang
   - Sheds without under ribs ≥ 0.65.
   - Sheds with under ribs ≥ 0.8.

3. Ratio l_d/d between creepage distance and clearance
   - This ratio must be calculated for the “worst case” on any section (l_d1/d1, l_d2/d2).
   - It must be < 5.

4. Alternating shed
   - p1 : p2 ≥ 15 mm

Parameters Characterizing Entire Insulator

1. Creepage factor C.F.
   - C.F. = l_t / S_t
   - C.F. ≥ 0.8 for pollution levels 1 and 2.
   - C.F. ≥ 0.7 for pollution levels 3 and 4.

2. Profile factor P.F.
   - P.F. = \frac{2p1+2p2+s}{l_t}
     - Alternating sheds
   - P.F. = \frac{2p+s}{l_t}
     - All other sheds

<table>
<thead>
<tr>
<th>C.F.</th>
<th>P.F.</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 0.8</td>
<td>≥ 3.5</td>
<td>for pollution levels 1 and 2.</td>
</tr>
<tr>
<td>≥ 0.7</td>
<td>≥ 4</td>
<td>for pollution levels 3 and 4.</td>
</tr>
</tbody>
</table>
**Hollow Insulators**

**Tolerances**

**General Tolerances**

The tolerances in dimensions depend mostly on production process.

General tolerances given may be improved by design and repeated production.

1. **Plastic process**
   - $\pm [0.04 d + 1.5 \text{ mm}]$ when $d \leq 300 \text{ mm}$
   - $\pm [0.025 d + 6 \text{ mm}]$ when $d > 300 \text{ mm}$

2. **Dry process**
   - $\pm 3 \%$

3. **Isostatic process**
   - $\pm 1.5 \% (+1 \text{ mm})$

**Deviation from Roundness**

The deviation from roundness is included in the general tolerances.

**Tolerance of Wall Thickness**

![Diagram of wall thickness](image)

<table>
<thead>
<tr>
<th>Wall thickness (mm)</th>
<th>Tolerance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&lt; 10$</td>
<td>$+a -1.5$</td>
</tr>
<tr>
<td>$10-15$</td>
<td>$+a -2.0$</td>
</tr>
<tr>
<td>$15-20$</td>
<td>$+a -3.0$</td>
</tr>
<tr>
<td>$20-25$</td>
<td>$+a -3.5$</td>
</tr>
<tr>
<td>$25-30$</td>
<td>$+a -4.0$</td>
</tr>
<tr>
<td>$30-40$</td>
<td>$+a -4.5$</td>
</tr>
<tr>
<td>$40-55$</td>
<td>$+a -5.0$</td>
</tr>
<tr>
<td>$&gt; 55$</td>
<td>$+a -6.0$</td>
</tr>
</tbody>
</table>

\[ a = \frac{x + y}{2} \]

- $x$ = tolerance on inner diameter
- $y$ = tolerance on core diameter

**Tolerances of Form and Position**

- **Evenness**
  - The numerical value indicates the maximum admissible surface deviation.
  - 0.10 mm standard tolerance
  - 0.03 mm can be achieved on request

- **Perpendicularity**
  - The axis of the insulator has to be within the indicated value of the diameter of a cylinder, which is perpendicular to plane face A.
  - 6 mm standard tolerance
  - 4 mm can be achieved on request

- **Camber**
  - The centerline should be within a cylinder with the diameter equal to the tolerance times the length of the porcelain.
  - 0.8 $\%$ x height of porcelain + 1.5 mm

- **Plane parallelity**
  - The upper plane face is parallel to the lower reference plane A within indicated tolerance.
  - 0.2 mm

- **Coaxiality and concentricity**
  - The centerline of the pitch circle diameter of the two fittings should fit into a cylinder with diameter equal to $2 \times (0.5 + \text{ height of insulator in meters}) \text{ mm}$

**Alignment of fixing holes**

The line between two opposite axis of holes of the top fitting have to be in line with corresponding line of the bottom fitting within the specified angle.

- 1° standard

**Finish of Ground Surface**

<table>
<thead>
<tr>
<th>Classification of roughness</th>
<th>$R_a$ (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General purpose oil tight</td>
<td>6.3</td>
</tr>
<tr>
<td>Air tight</td>
<td>3.2</td>
</tr>
<tr>
<td>SF6-gas under pressure</td>
<td>1.8</td>
</tr>
</tbody>
</table>
Hollow Insulators

Test and Inspection

Marking

Each insulator is marked both with designation and serial number, making it possible to trace inspection procedures throughout production.

Inspections and Tests

After firing are usually made according to IEC 60233 and IEC 61264, IEC 62155.

<table>
<thead>
<tr>
<th>Tests</th>
<th>Type Test</th>
<th>Sample Test</th>
<th>Routine Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>After firing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual inspection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verification of dimensions</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porosity test</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature cycle test</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After grinding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimensional inspection of ground parts</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Inner pressure test **</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dye check on ground surface **</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical routine test *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After cementing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bending test **</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner pressure test **</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Electrical routine test is only performed on request for insulators made in one piece, but as routine test on epoxy jointed insulators.
** Only performed on request.

Conversion Table

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Force</th>
<th>Moment of Force</th>
<th>Pressure, stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.03937 m</td>
<td>0.22481 lb</td>
<td>8.8508 ft lb m</td>
<td>0.14504*10^3 Pa</td>
</tr>
<tr>
<td>25.4 mm</td>
<td>4.4482N</td>
<td>0.11299 Nm</td>
<td>6.8948*10^3 Pa</td>
</tr>
<tr>
<td>1 m</td>
<td>1 T, lb</td>
<td>1 T, lb</td>
<td></td>
</tr>
</tbody>
</table>

Metric

Metric multiple units used

- M mega *10^6
- k kilo *10^3
- m milli *10^-3
- µ micro *10^-6