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!

Please visit us on the web at www.ppcinsulators.com

That’s what we deliver.
**Reduced dimensions and weight with increased strength and appearance**

**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!

**Design and Redesign**

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| Improvements | PAGE 4 |
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**K-value**

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- Standards | PAGE 7 |
- Dimensions | PAGE 7 |
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**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

Increased Pollution Performance
Equalized Field Distribution

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

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.

Basic Example

Average diameter is reduced while creepage distance and total height is unchanged. Results:
1. Reduced weight and volume.
2. Increased surface resistance against leakage currents therefore improved performance of creepage distance.

Progressive Example

Average diameter is reduced while creepage distance and total height is unchanged. Creepage distance concentration along the insulator is adapted to counterbalance the surface resistance against the electrical field from inside and outside equipment. Results:
1. Reduced weight and volume.
2. Increased surface resistance against leakage currents, thereby improving performance of the creepage distance.
3. Improved service performance and pollution properties by equalizing the electrical field.

Material and Specific Strength

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.

<table>
<thead>
<tr>
<th>Material</th>
<th>C 110</th>
<th>C 120</th>
<th>C 130</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength</td>
<td>M Pa</td>
<td>psi</td>
<td>M Pa</td>
</tr>
<tr>
<td>Cantilever Flange</td>
<td>18</td>
<td>2620</td>
<td>4350-4525</td>
</tr>
<tr>
<td>Cantilever</td>
<td>17</td>
<td>2465</td>
<td>3625-4350</td>
</tr>
<tr>
<td>Clamp</td>
<td>25</td>
<td>3625</td>
<td>4350-4525</td>
</tr>
<tr>
<td>Epoxy joint</td>
<td>3625</td>
<td>3625</td>
<td>3625</td>
</tr>
<tr>
<td>Inner</td>
<td>17</td>
<td>2465</td>
<td>3625-4350</td>
</tr>
</tbody>
</table>

Hollow Insulators

K-value

IEC 60507

International standard IEC 60507 defines form factor as:

\[ F = \int \frac{dl}{p(l)} \]

\( F \) is the creepage distance, \( p(l) \) is the circumference of the insulator as a function of \( l \).

Form factors and indices:
- IEC 60507: Form factor of an insulator
- IEC 60672: Material strength
- IEC 60815: Influence of the diameter

Standards:
- IEC 60233
- IEC 60233
- IEC 61264
- IEC 62155

Material and Specific Strength

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.

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.
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></td>
<td>Alt 1</td>
<td>Alt 2</td>
</tr>
<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>Terminal load</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Wind pressure</td>
<td>30%</td>
<td>100%</td>
</tr>
<tr>
<td>Ice load</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Seismic load</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Safety factor</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
- Ice loads: IEC 694 § 2.1.2
- Short circuit loads: IEC 694 § 2.1.2
- Seismic loads: IEC 56 § 1.7A (Loc 2.44)

#### Bending Moment

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

The simplified calculation is valid under this condition:

\[
\sigma_a \leq 0.25 \times \sigma_b
\]

where:

\[
\sigma_a = \frac{P \pi D_s^2}{32 D_c (D_c^2 + D_i^2)}
\]

Corresponds to the axial stress due to pressure \(P\).

\[
\sigma_b = \frac{M_{max} \pi}{32 D_c (D_c^4 - D_i^4)}
\]

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

### Example of hollow insulator:

- Design value: \(D_s = 260\) mm
- \(M_{max} = 20kNm\)

The bending moment can hereafter be calculated equivalent to the design pressure \(Mb = 3kNm\).
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.

**Level of Pollution Specific Creepage Distance**

<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.
- Mountainous areas.

Areas generally of moderate extent, subjected to conductive dusts and to 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.

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 close to the sea in any case exposed to relatively strong winds from the sea.

Areas generally of moderate extent, subjected to conductive dusts and to 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.

**The creepage distance should be increased in relation to the average diameter, \( D_m \):**

- \( D_m < 300 \text{ mm} \) \( k_d = 1.0 \)
- \( 300 \text{ mm} < D_m < 500 \text{ mm} \) \( k_d = 1.1 \)
- \( D_m > 500 \text{ mm} \) \( k_d = 1.2 \)

**Regular sheds**

\[ D_m = \frac{(D_e + D_c)}{2} \]

**Alternating sheds**

\[ D_m = \frac{(D_{e1} + D_{e2} + 2D_c)}{4} \]
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 $c \geq 30\,\text{mm}$.
   - For small insulators ($H < 550\,\text{mm}$) or overhang ($p \leq 40\,\text{mm}$), $c$ can be $\geq 20\,\text{mm}$.

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

3. Ratio $l_d/d$ between creepage distance and clearance
   - This ratio must be calculated for the "worst case" on any section ($l_{d1}/d_1$, $l_{d2}/d_2$).
   - It must be $\leq 5$.

4. Alternating shed
   - $p_1 : p_2 \geq 15\,\text{mm}$

**Parameters Characterizing Entire Insulator**

1. Creepage factor C.F.
   - $C.F. = \frac{l_t}{S_t}$
   - $C.F. \leq 3.5$ for pollution levels 1 and 2.
   - $C.F. \leq 4$ for pollution levels 3 and 4.

2. Profile factor P.F.
   - $P.F. = \frac{2p_1 + 2p_2 + s}{l}$
   - For alternating sheds
   - $P.F. > 0.8$ for pollution levels 1 and 2.
   - $C.F. > 0.7$ for pollution levels 3 and 4.


**Hollow Insulators**

**General Tolerances**

The tolerances in dimensions depend mainly on production process.

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

1. **Plastic process**
   - ± (0.04 \(d\) + 1.5 mm) when \(d \leq 300\) mm
   - ± (0.025 \(d\) + 6 mm) when \(d > 300\) mm

2. **Dry process**
   - ± 3 %

3. **Isostatic process**
   - ± 1.5 % (+ 1 mm)

**Deviation from Roundness**

The deviation from roundness is included in the general tolerances.

**Tolerance of Wall Thickness**

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

- \(a\) = tolerance on inner diameter
- \(x\) = tolerance on outer diameter
- \(y\) = tolerance on core diameter

**Wall thickness (mm)**

<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>

**Alignment of fixing holes**

The line between two opposite axes 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>Ra (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>1.6</td>
</tr>
</tbody>
</table>

**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

- **Alignment of fixing holes**
  - The line between two opposite axes of holes of the top fitting have to be in line with corresponding line of the bottom fitting within the specified angle.

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

- **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

- **Alignment of fixing holes**
  - The line between two opposite axes of holes of the top fitting have to be in line with corresponding line of the bottom fitting within the specified angle.

1° standard
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, inspections 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 lbf</td>
<td>8.8508 Nm</td>
<td>0.14504*10³ Pa</td>
</tr>
<tr>
<td>25.4 mm</td>
<td>4.4482 N</td>
<td>0.11299 Nm</td>
<td>6.8948*10³ Pa</td>
</tr>
<tr>
<td>1 m</td>
<td>1 R lb</td>
<td>1 R lb in</td>
<td>1 psi</td>
</tr>
</tbody>
</table>

Metric multiple units used

- M mega *10⁶
- k kilo *10³
- m milli *10⁻³
- µ micro *10⁻⁶