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CERAM INSULATORS

PP

The very Best.

That's what we deliver.

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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PPC INSULATORS

Revision 1/2003

CERAM INSULATORS

PP

The very Best.

Hollow Insulators – Custom Design

PPC INSULATORS

The Design Specialist
At Your Service

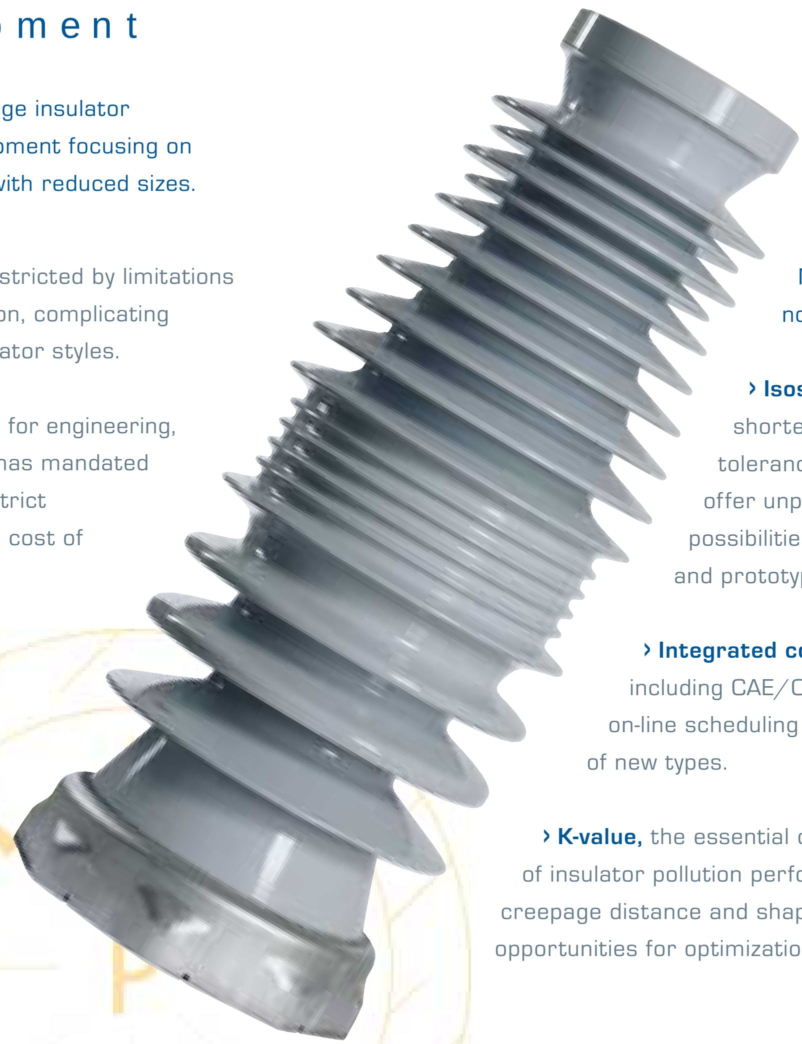
Reduced dimensions
and weight with increased
strength and appearance

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.

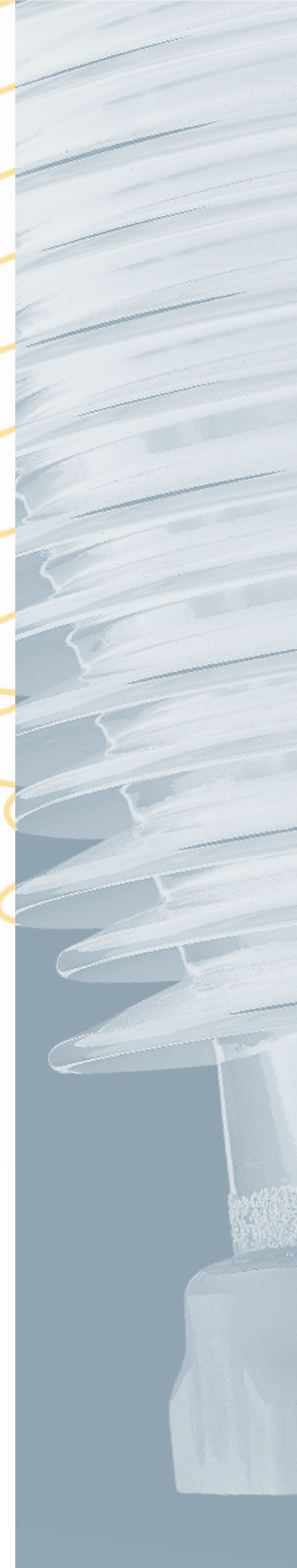
› **K-value,** the essential calculation of insulator pollution performance, consider creepage distance and shape to open new opportunities for optimization.

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

› ISO 9001 › IEC

Index

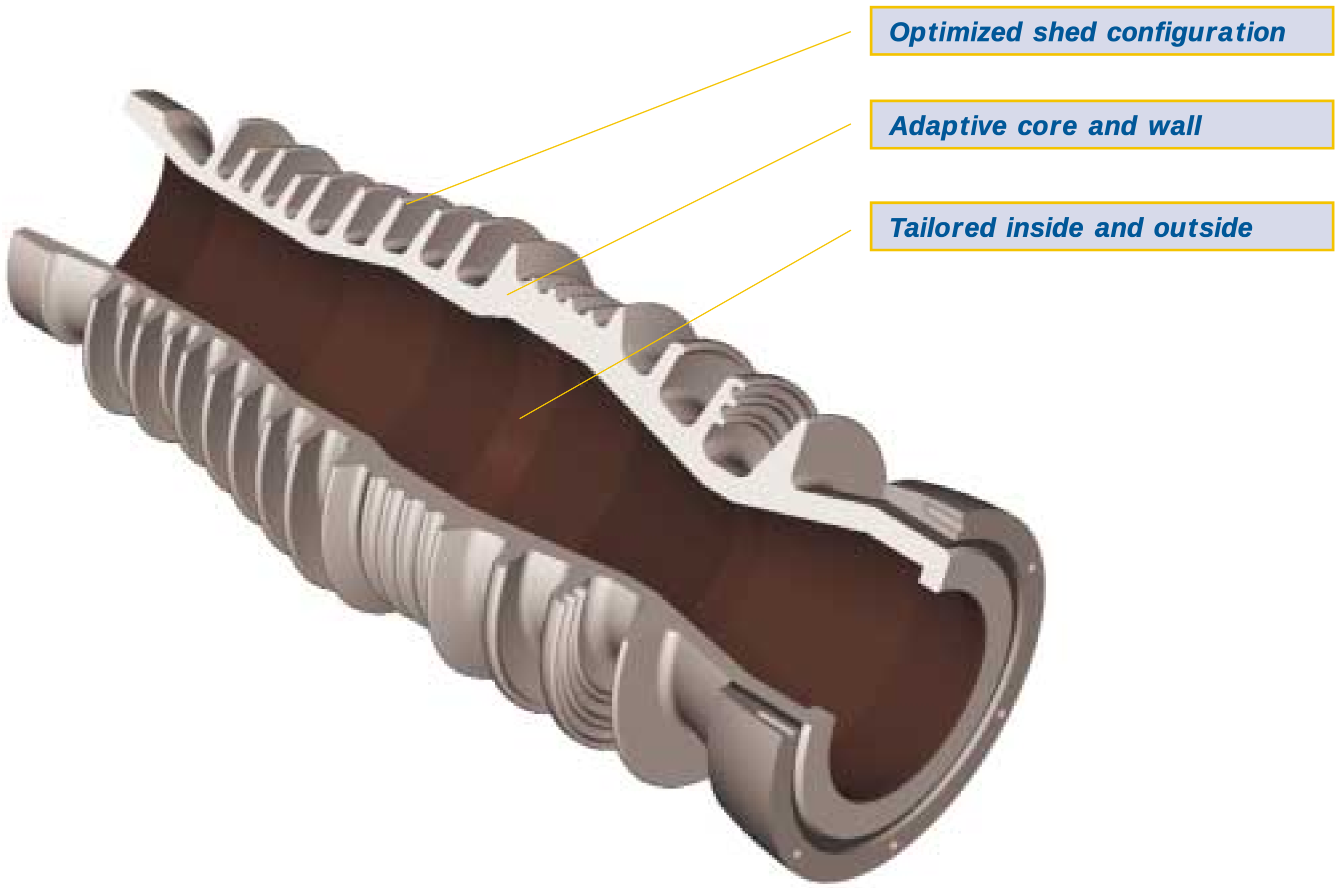
PPC INSULATORS



Hollow Insulators
Introduction

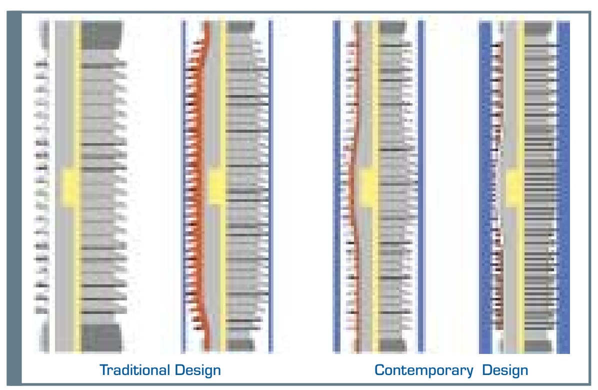
Hollow Insulators
Design and Redesign

Possibilities



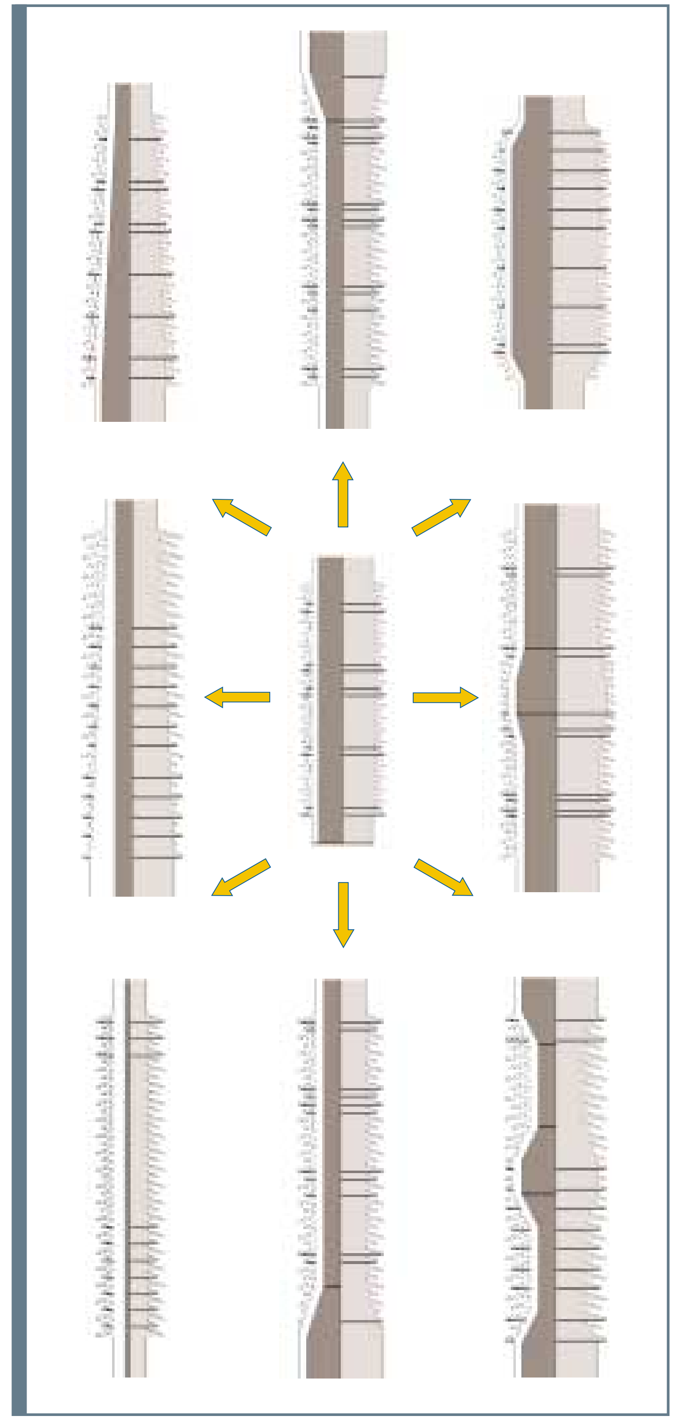
Improvements Increased

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



Improvements 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 and** › **space**
while improving properties in service by increasing pollution performance and equalizing the electrical field.

IEC 60507

International standard **IEC 60507** define form factor as:

$$F = \int dl / p(l)$$

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

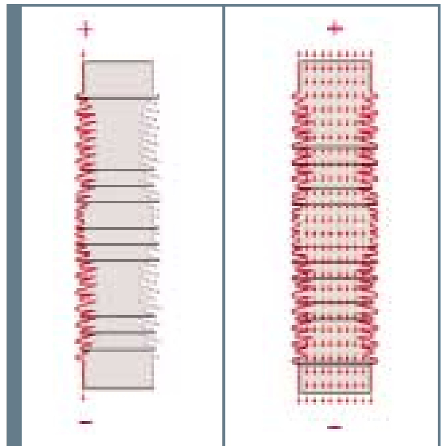
IEC standards and guides	
IEC 60507 §3.4	Form factor of an insulator
IEC 60507 §16.1	Layer conductivity
IEC 60815 §5.3	Influence of the diameter
IEEE DEIS publications	
CEIDP 1998, 2A-6	Development trends ...
CEIDP 2000, 3A-10	Optimized design ...
Patent	
SE 9700508-6	Insulator with equalized field strength

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.



Distance | Distance and Diameter

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 performace 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 curents, thereby improving performance of the creepage distance.
3. Improved service performance and pollution properties by equalizing the electrical field.

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.

Height Single Porcelain	Height Jointed Porcelain	Outside Diameter
2800 mm	8500 mm	950 mm
110.2 inches	334.6 inches	37.4 inches

Standards

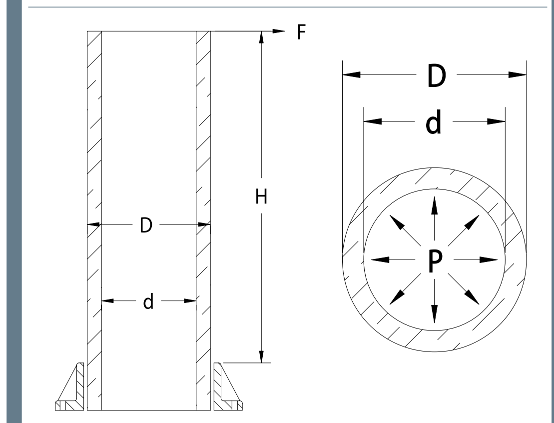
Standards	
Material	IEC 60672
Dimensions, form, position	IEC 60233
Tests	IEC 60233 IEC 61264 IEC 62155
Many other standards and customer specifications are considered on request.	

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**

Cantilever | Inner Pressure



$$\sigma = \frac{F * H}{Wx} \qquad \sigma = L * P$$

$$Wx = \frac{\pi}{32} * \frac{D^4 - d^4}{D} \qquad L = \frac{D^2 + d^2}{D^2 - d^2}$$

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 IEC 60672	C 110	C 120	C 130
Strength	**MPa psi**	**MPa psi**	**MPa psi**
Cantilever Flange	18 2620	30-45 4350-6525	50-70 7250-10150
Cantilever Clamp	17 2465	22 3190	40 5800
Cantilever Core	25 3625	30-45 4350-6525	50-70 7250-10150
Cantilever Epoxy Joint	25 3625	25 3625	25 3625
Inner Pressure	17 2465	25-30 3625-4350	30-45 4350-6525

Hollow Insulator Design Criteria

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)

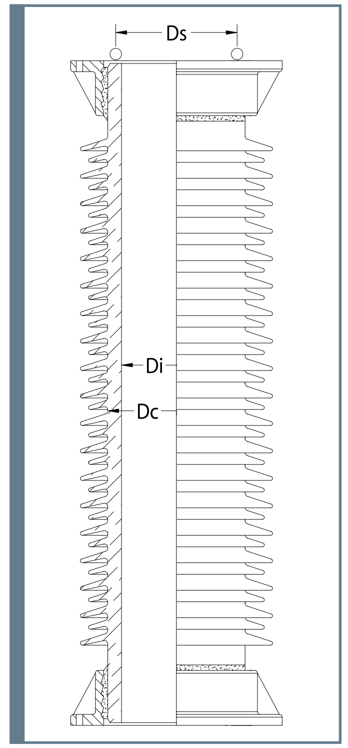
Determination of Type Test Withstand Bending Moment

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.

Stress	From routinely expected loads	From rarely occuring extreme loads		
		Alt 1	Alt 2	Alt 3
Loads		**Short circuit load**	**Ice load**	**Seismic load**
Design pressure	100%	100%	100%	100%
Mass	100%	100%	100%	100%
Rated terminal load	100%	50%	0%	70%
Wind pressure	30%	100%	0%	10%
Short circuit load	0%	100%	0%	0%
Ice load	0%	0%	100%	0%
Seismic load	0%	0%	0%	100%
Safety factor f	2.1	1.2	1.2	1.0

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 (17A [sec] 274)	



The alternative combinations are typical sets of loads for particular equipment for specific applications.
The most onerous of the applicable alternatives should be used to determine the test withstand bending stress.

From the test withstand bending stress, the test withstand bending moment can be calculated.

$$Mb = P * \frac{\pi}{32} * \frac{D_s^2(D_c^2+D_i^2)}{D}$$

P = Design pressure
Ds = Sealing diameter
Dc = Core diameter
Di = Inside diameter

The simplified calculation is valid under this condition:

$$\sigma_a \leq 0.25 * \sigma_b \quad \text{where: } \sigma_a = P * \frac{D_s^2}{D_c^2+D_i^2}$$

Corresponds to the axial stress due to pressure P.

$$\sigma_b = M_{max} \frac{\pi}{32} * \frac{D_c}{D_c^4-D_i^4}$$

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

Bending Moment

Relation between testing values and utilization values for a hollow insulator

Testing Values		Utilization Values	
Type test withstand	100%	$\frac{100}{1.0}$ =100%	Alt 3 (rarely)
		$\frac{100}{1.2}$ = 83.3%	Alt 1 Alt 2 (extreme)
Routine Test	70%		
		$\frac{100}{1.2}$ = 47.6%	(routinely)

Example of hollow insulator:

σ_a = 1.625 MPa

σ_b = 10.62 MPa

=> $\sigma_a \leq 0.25 * \sigma_b$

M_{max} = 20kNm

Dimensions	Bending Moments	
Dc = 300mm	Mass	10 kNm
Di = 220mm	Rated terminal load	10 kNm
Ds = 260 mm	Wind pressure	10 kNm
	Short circuit load	10 kNm
	Ice load	10 kNm
	Seismic load	10 kNm
	Inner Pressure	
	Design value	1 MPa

The bending moment can hereafter be calculated equivalent to the design pressure Mb ≈ 3 kNm.

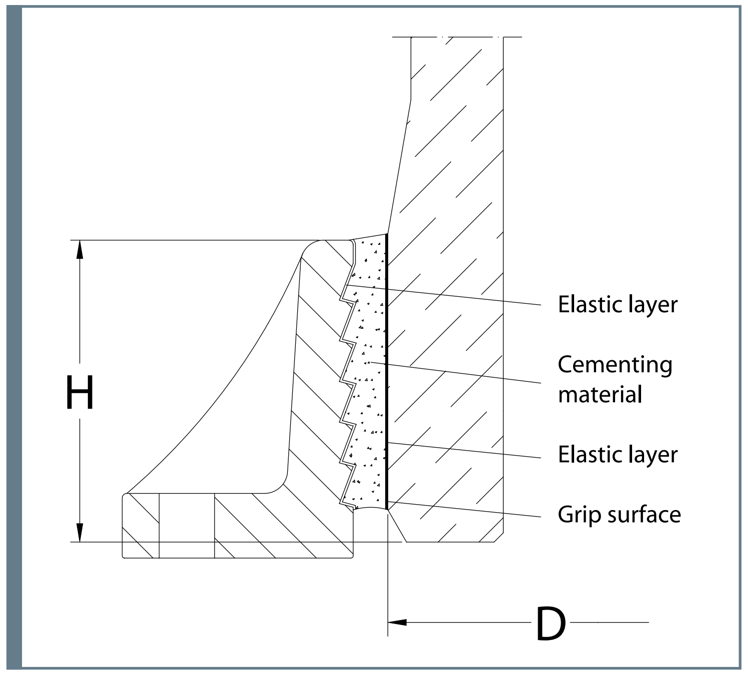
Determination of Type Test Withstand Design Pressure

The insulator shall withstand 4.25 times the design pressure for 5 minutes.

Hollow Insulator Design Criteria

Influence of Fitting and Clamping Design

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.



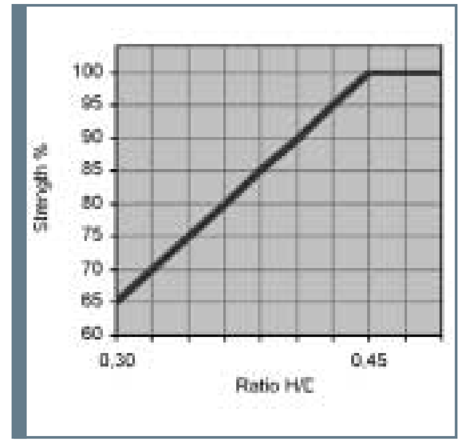
The relation between height of fitting (H) and diameter of porcelain (D) is important.

Elastic layer on metal part is an epoxy or a bituminous paint. On porcelain this layer is bituminous paint.

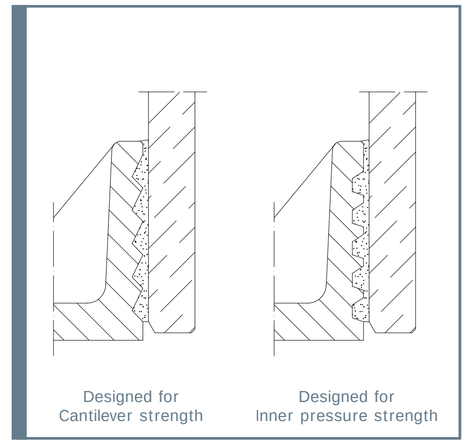
Cement is Portland or sulphur.

Grip surface is comprised of porcelain grains embedded in glaze and/or glazed grooves in porcelain.

Influence of Fitting High and Cantilever Strength

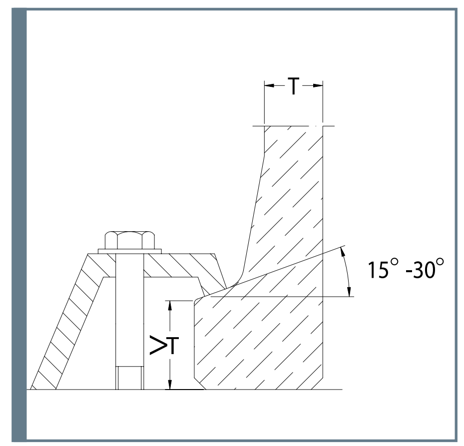


Influence of Internal Grooves



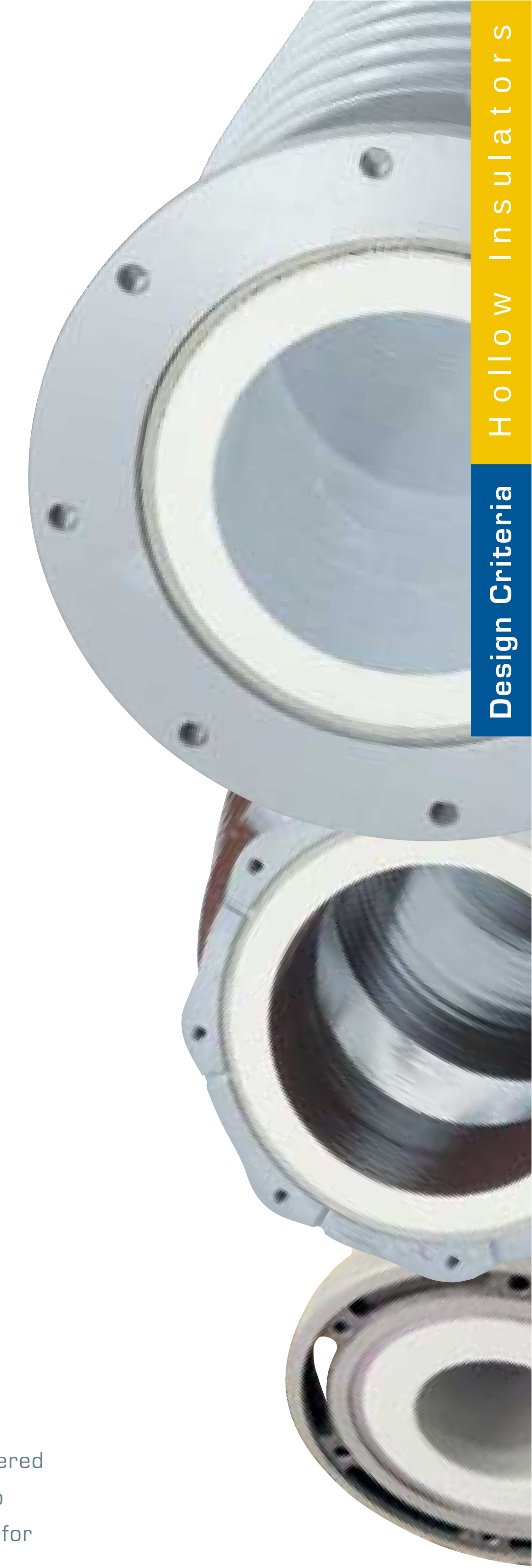
Internal grooves can be designed to distribute stress for different strength configurations.

Influence of Clamp and Fixing



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 bakwards.



Hollow Insulators
Design Criteria

Hollow Insulators
Pollution Performance

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	Pollution	Specific Creepage Distance	
1	Light	16 mm/kV	0.630 inch/kV

- 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.

Level	Pollution	Specific Creepage Distance	
2	Medium	20 mm/kV	0.787 inch/kV

- 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).

Level	Pollution	Specific Creepage Distance	
3	Heavy	25 mm/kV	0.984 inch/kV

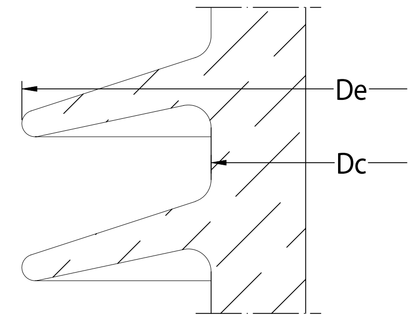
- Areas with high density of industries and suburbs of large cities with high density of heating plants producing pollution.
- Areas close to the sea in any case exposed to relatively strong winds from the sea.

Level	Pollution	Specific Creepage Distance	
4	Very Heavy	31 mm/kV	1.220 inch/kV

- 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.

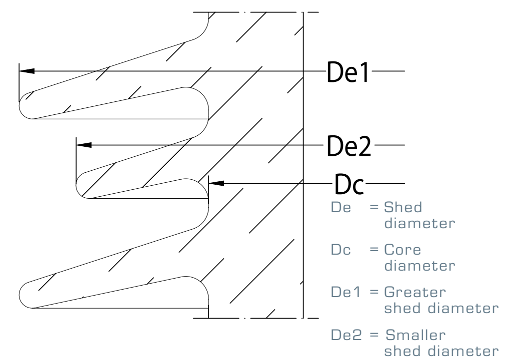
Regular sheds

$D_m = (De+Dc)/2$



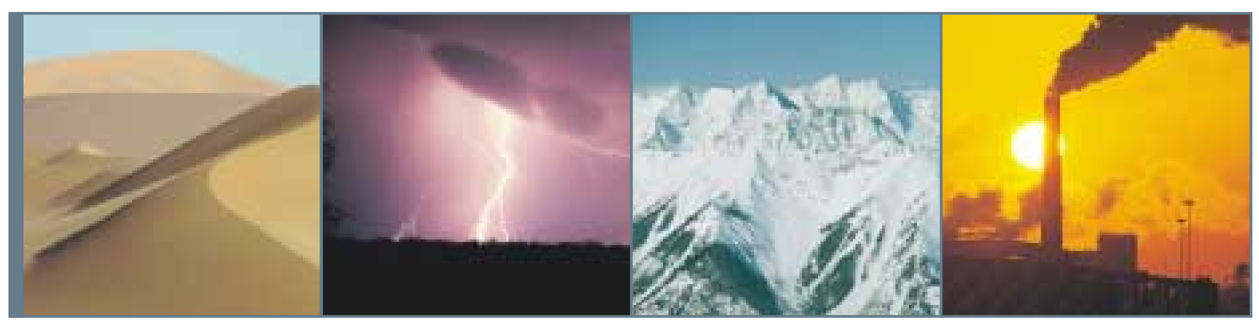
Alternating sheds

$D_m = (De1+De2+(2*Dc))/4$

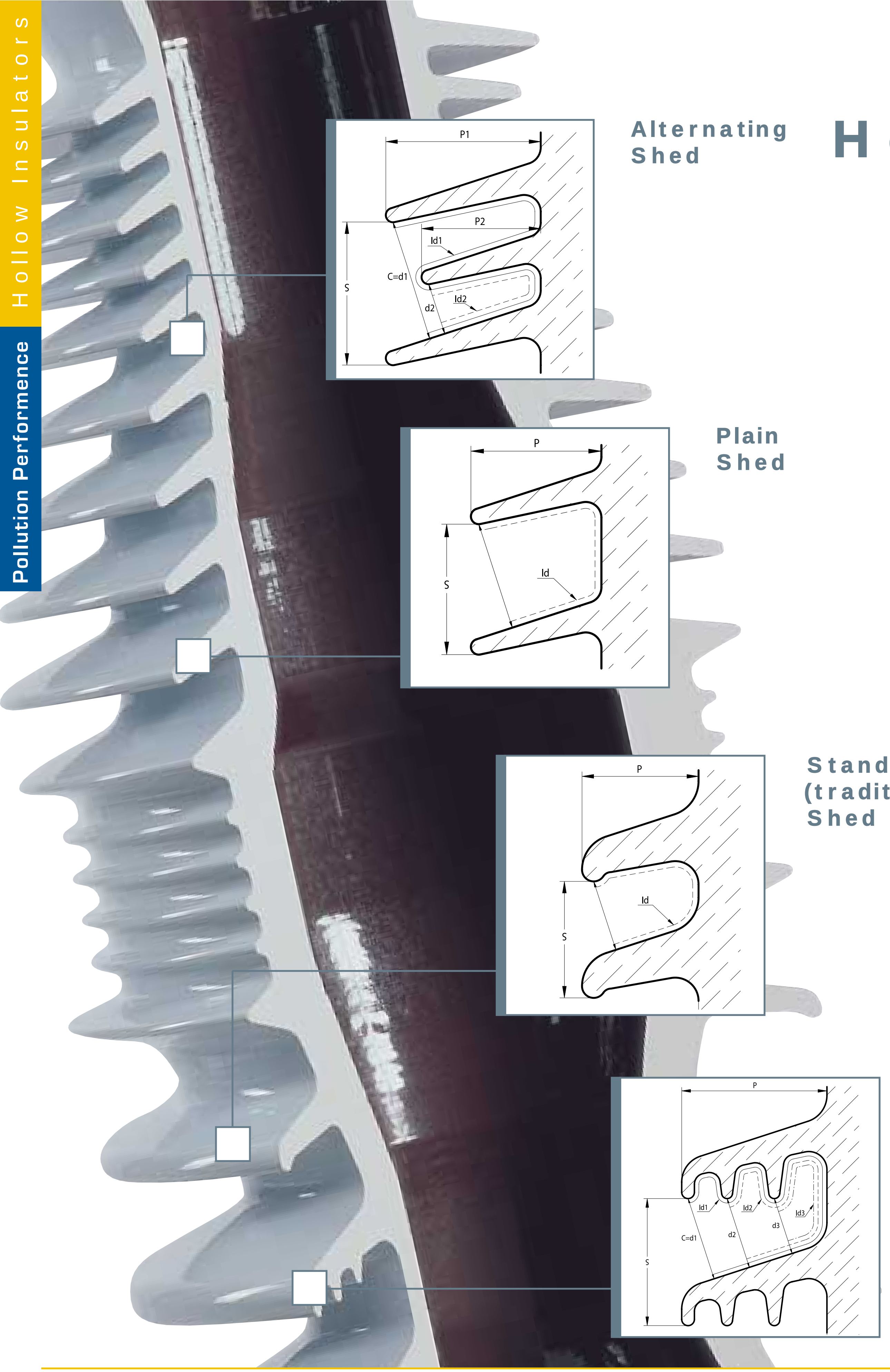


The creepage distance should be increased in relation to the average diameter, D_m.

D_m	<300 mm	$k_d = 1.0$
D_m	300-500 mm	$k_d = 1.1$
D_m	>500 mm	$k_d = 1.2$



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 $c \geq 30$ mm.
- For small insulators (H < 550 mm) or overhang ($p \leq 40$ 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}/d_2).
- It must be < 5.

4. Alternating shed

- $p_1 - p_2 \geq 15$ mm

Parameters Characterizing Entire Insulator

1. Creepage factor C.F.

$$C.F. = lt / St$$

lt= creepage distance
St= arcing distance

- C.F. ≤ 3.5 for pollution levels 1 and 2.
- C.F. ≤ 4 for pollution levels 3 and 4.

2. Profile factor P.F.

$$P.F. = \frac{2p1 + 2p2 + s}{l}$$ alternating sheds

$$P.F. = \frac{2p + s}{l}$$ all other sheds

l = creepage distance of the insulated leakage path measured between the two points which define s.

- P.F. > 0.8 for pollution levels 1 and 2.
- C.F. > 0.7 for pollution levels 3 and 4.

Hollow Insulators
Tolerances

General Tolerances

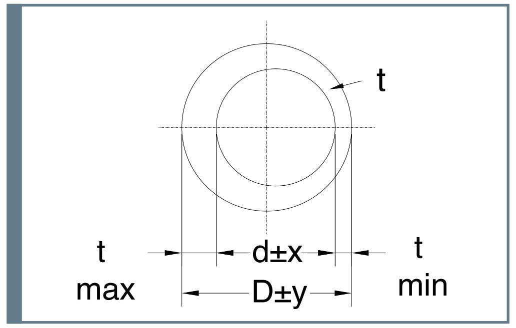
The tolerances in dimensions depend mostly on production process.
General tolerances given may be improved by design and repeated production.

› **Plastic process**	**± (0.04 d + 1.5 mm)** when d ≤ 300 mm	
	± (0.025 d + 6 mm) when d > 300 mm	
› **Dry process**	± 3 %	
› **Isostatic process**	± 1.5 % (+ 1 mm)	

Deviation from Roundness

The deviation from roundness is included in the general tolerances.

Tolerance of Wall Thickness



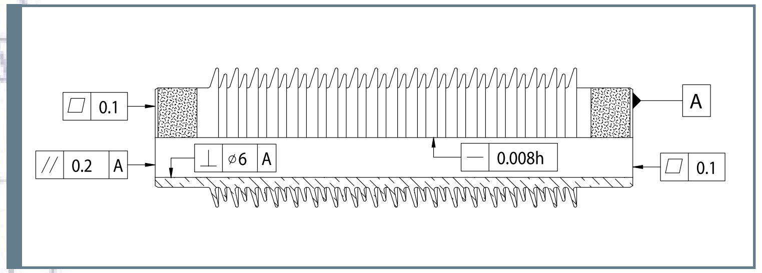
Wall thickness (mm)	Tolerance (mm)
< 10	+ a / -1.5
10-15	+ a / -2.0
15-20	+ a / -3.0
20-25	+ a / -3.5
25-30	+ a / -4.0
30-40	+ a / -4.5
40-55	+ a / -5.0
> 55	+ a / -6.0

$$a = \frac{x + y}{2}$$

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

Tolerances of Form and Position

Unassembled porcelain



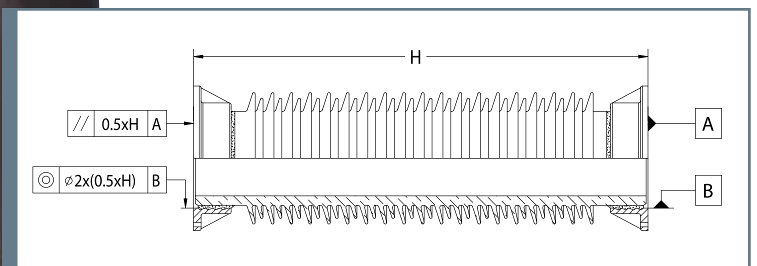
Evenness
The numerical value indicates the maximum admissible surface deviation.
0.10 mm standard tolerance
0.03 mm can be achieved on request

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

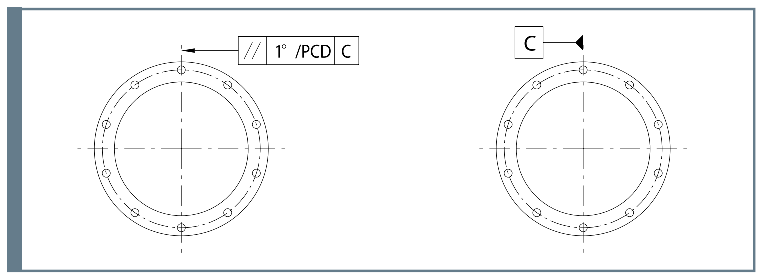
Assembled porcelain



Coaxiality and concentricity
The centerline of the pitch circle diameter of the two fittings should fit into a cylinder with diameter equal to
2 x (0.5 + height of insulator in meters) mm

Plane parallelity
0.5 x (height of insulator in meters) mm
0.2 x (height of insulator in meters) mm
(0.2 can only be reached on fittings with machined surface without protection)

Alignment of fixing holes



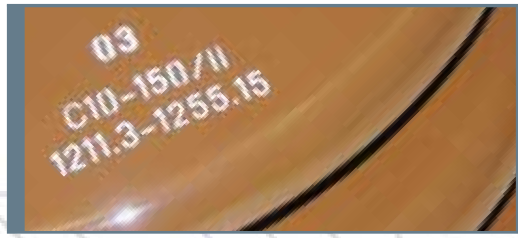
Alignment of fixing holes
The line between two opposite axes of holes of the top fitting have to be in line with corresponding line of the bottom fitting within the specified angle.
1° standard

Finish of Ground Surface

Classification of roughness	Ra (µm)
General purpose oil tight	6.3
Air tight	3.2
SF6-gas under pressure	1.6

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.

Tests	Type test	Sample test	Routine test
After firing			
Visual inspection			✓
Verification of dimensions		✓	
Porosity test		✓	
Temperature cycle test		✓	
After grinding			
Dimensional inspection of ground parts		✓	✓
Inner pressure test **			✓
Dye check on ground surface **			✓
Electrical routine test *		✓	✓
After cementing			
Bending test **	✓	✓	✓
Inner pressure test **	✓	✓	✓

* 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.

Metric

Metric multiple units used		
M	mega	$*10^{6}$
k	kilo	$*10^{3}$
m	milli	$*10^{-3}$
µ	micro	$*10^{-6}$

Conversion Table

Dimensions	Force	Moment of Force	Pressure, stress
1 mm	1N	1 Nm	1Pa
0.03937 in	0.22481 ft lb	8.8508 ft lb in	0.14504*10-3 psi
25.4 mm	4.4482N	0.11299 Nm	6.8948*103 Pa
1 in	1 ft lb	1 ft lb in	1 psi