TECHNICAL SPECIFICATION OF HV COMPOSITE INSULATORS

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ANNEXES

1 SCOPE

The aim of this document is to provide technical requirements for the supply of High Voltage Composite Insulators (HVCI) to be used in overhead lines (OHL) with a nominal voltage greater than 36 kV and frequencies of 50 - 60 Hz, in the Enel Group distribution networks and in the companies listed below:

Country	Distribution Company
Brasil	Ampla Coelce
Chile	Chilectra
Colombia	Codensa
España	Endesa Distribución Eléctrica
Peru	Edelnor
Romania	Enel Distributie Banat Enel Distributie Dobrogea Enel Distributie Muntenia

Table 1 – Enel Group DSO affected by this standard

This standard applies to string (suspension/tension) insulator outdoor units of the composite long rod type as well as the fittings used with such insulators.

The object of this standard is to define standard dimensions and specifications for HV composite insulators, define types of the couplings in order to permit the assembly of insulators supplied by different manufacturers and to allow, whenever practical, interchangeability with existing installations, show the required tests and the conditions of designing, manufacturing and supplying of HV composite insulators. This standardization shall provide a list of insulators for global group purchases which means an opportunity of high volumes and good prices.

2 LIST OF COMPONENTS – COMMON LIST

In this standardization process, 4 groups of insulators have been taken in account (BIL – 325/550/650/1050):

Designation (HVCI)	SML	EFT	EFC	BIL	MAD	MCD	NIL	GS Code
CS 120 SB-325/1.815	120	S-16	B-16	325	570	1.815	762	GSCH004/1
CS 120 SB-325/2.250	120	S-16	B-16	325	570	2.250	762	GSCH004/2
CS 120 EB-325/1.815	120	E-24	B-16	325	570	1.815	762	GSCH004/3
CS 120 EB-325/2.250	120	E-24	B-16	325	570	2.250	762	GSCH004/4
CS 120 SS-550/3.075	120	S-16	S-16	550	1.005	3.075	1.280	GSCH004/5
CS 120 SS-550/3.813	120	S-16	S-16	550	1.005	3.813	1.280	GSCH004/6
CS 160 SS-550/3.813	160	S-20	S-20	550	1.005	3.813	1.330	GSCH004/7
CS 120 SB-650/3.625	120	S-16	B-16	650	1.195	3.625	1.380	GSCH004/8
CS 120 SB-650/4.500	120	S-16	B-16	650	1.195	4.500	1.380	GSCH004/9
CS 120 EB-650/3.625	120	E-24	B-16	650	1.195	3.625	1.380	GSCH004/10
CS 120 EB-650/4.500	120	E-24	B-16	650	1.195	4.500	1.380	GSCH004/11
CS 210 SB-650/4.500	210	S-20	B-20	650	1.195	4.500	1.380	GSCH004/12

Designation (HVCI)	**SML**	**EFT**	**EFC**	**BIL**	**MAD**	**MCD**	**NIL**	**GS Code**
CS 120 SB-1.050/6.125	120	S-16	B-16	1.050	1.970	6.125	2.336	GSCH004/13
CS 120 SB-1.050/7.595	120	S-16	B-16	1.050	1.970	7.595	2.336	GSCH004/14
CS 160 SB-1.050/7.595	160	S-20	B-20	1.050	1.970	7.595	2.391	GSCH004/15

Table 2 – List of components – Data and GS codes

Specified Mechanical Load (kN)	**SML**
End Fitting Tower side (type-mm)	**EFT**
End Fitting Conductor side (type-mm)	**EFC**
Maximum Operational Voltage (kV) - Lighting impulse voltage	**BIL**
Minimum Arcing Distance (mm - flashover)	**MAD**
Minimum Creepage Distance(mm)	**MCD**
Nominal Insulator Length (mm)	**NIL**

Table 3 – List of components – Key.

3 REFERENCE LAWS AND STANDARS

Under any doubt or discrepancy prevails the indication of the referenced standards. Likewise, any change in the reference Standards updates this document.

3.1 Laws

Each country must observe its own legislation and this standard cannot conflict with local laws.

3.2 International Standards

The following standards and technical documents are needful for the application of this Global Standard and/or are referenced in this document:

- CIGRE 33-204. Considerations on the design of composite suspension insulators based on experience from natural ageing testing and electric field calculations.
- EN 61006:2004. Electrical insulating materials - Methods of test for the determination of the glass transition temperature.
- IEC 60060-1. High-voltage test techniques - Part 1: General definitions and test requirements.
- IEC 60071-1. Insulation co-ordination - Part 1: Definitions, principles and rules.
- IEC 60071-2. Insulation co-ordination - Part 2: Application guide.
- IEC 60120. Dimensions of ball and socket couplings of string insulator units.
- IEC 60372. Locking devices for ball and socket couplings of string insulator units - Dimensions and tests.
- IEC 60383-1. Insulators for overhead lines with a nominal voltage above 1000 V - Part 1: Ceramic or glass insulator units for a.c. systems - Definitions, test methods and acceptance criteria. (Zinc Coating Test).
- IEC 60383-2. Insulators for overhead lines with a nominal voltage above 1000 V - Part 2: Insulator strings and insulator sets for a.c. systems – Def, test methods and acceptance criteria.
- IEC 60437. Radio interference test on high-voltage insulators.

- IEC 60471. Dimensions of clevis and tongue couplings of string insulator units.
- IEC 60507. Artificial pollution tests on high-voltage ceramic and glass insulators to be used on a.c. systems.
- IEC 60587. Electrical insulating materials used under severe ambient conditions - Test methods for evaluating resistance to tracking and erosion.
- IEC 60695-11-10. Fire hazard testing - Part 11-10: Test flames - 50 W horizontal and vertical flame test methods.
- IEC 60815-1. Selection and dimensioning of high-voltage insulators intended for use in polluted conditions - Part 1: Definitions, information and general principles.
- IEC 60815-3. Selection and dimensioning of high-voltage insulators intended for use in polluted conditions - Part 3: Polymer insulators for a.c. systems.
- IEC 61109. Insulators for overhead lines - Composite suspension and tension insulators for a.c. systems with a nominal voltage greater than 1 000 V - Definitions, test methods and acceptance criteria.
- IEC 61284. Overhead lines - Requirements and tests for fittings.
- IEC 61466 -1. Composite string insulator units for overhead lines with a nominal voltage greater than 1000 V - Part 1: Standard strength classes and end fittings.
- IEC 61466 -2. Composite string insulator units for overhead lines with a nominal voltage greater than 1000 V - Part 2: Dimensional and electrical characteristics.
- IEC 61621. Dry, solid insulating materials - Resistance test to high-voltage, low-current arc discharges.
- IEC 62217. Polymeric HV insulators for indoor and outdoor use - General definitions, test methods and acceptance criteria.
- IEC 62631. Dielectric and resistive properties of solid insulating materials.
- IEC TR 62662. Technical Requirement: Guidance for production, testing and diagnostics of polymer insulators with respect to brittle fracture of core materials.
- IEC TR 62039. Technical Requirement: Selection guide for polymeric materials for outdoor use under HV stress.
- IEC TS 62073. Technical Specification: Guidance on the measurement of wettability of insulator surfaces.
- ISO 1172. Textile-glass-reinforced plastics -- Prepregs, moulding compounds and laminates -- Determination of the textile-glass and mineral-filler content -- Calcination methods.
- ISO 1461. Hot dip galvanized coatings on fabricated iron and steel articles -- Specifications and test methods.
- ISO 34-1. Rubber, vulcanized or thermoplastic -- Determination of tear strength -- Part 1: Trouser, angle and crescent test pieces.
- Project 36-6-2 from CEI WG 36-07. Minimum test requirements to cover brittle fracture of line composite insulators.

3.3 Local Standards

Local Standards may be applied in those cases not covered by this Standard.

3.4 Replaced Local Standards

Similar components referred in Local Standards must be replaced by the components of this Global Standard.

4 SERVICE CONDITIONS

Composite insulators to be supplied against this specification shall be suitable for satisfactory continuous operation under following conditions:

- Maximum Ambient Air Temperature: +40 ºC.
- Minimum Ambient Air Temperature: -40 ºC.
- Maximum relative humidity: 95% **(*).** For higher values see IEC 60071-1 and IEC 60071-2.
- Maximum altitude above mean sea level: 1.000 m **(*).** For higher values see IEC 60071-1 and IEC 60071-2.
- Maximum solar radiation: 1.000 W/m^2

(*) Insulation strength increases with absolute humidity up to the point where condensation forms on the insulator surfaces. Insulation strength decreases with decreasing air density. The selection of a Um value equal to or higher than the next standard value of Um may arise when the equipment has to be installed at an altitude higher than 1.000 m in order to compensate the decrease of withstand voltage of the external insulation.

This table shows the general DSO network features for insulators that are considered in this document:

	Nominal Voltage U_n (kV)	**Maximum Voltage** (V_{max}) U_m (kV)	**Lighting impulse withstand voltage (BIL)** (1,2/50 µs, dry) U_i (kV)	**Power frequency withstand voltage** (45-65 Hz, 1 min, wet) U_f (kV)
Ampla	69	72,5	325	140
	138	145	650	275
Coelce	69	72,5	325	140
Chilectra	*110*	*145*	*650*	*230*
	220	245	1.050	460
Codensa	57,5	72,5	325	140
	115	*145*	*650*	*275*
	230	245	1.050	460
Edelnor	60	72,5	325	140
	220	245	1.050	460
Endesa	*45*	*72,5*	*325*	*140*
	66	72,5	325	140
	110	*145*	*650*	*230*
	132	145	650	275
Banat Dogrobea Muntenia	110	123	550	230

Table 4 – General DSOs lines features for insulators

Next table assigns a nominal voltage, a maximum voltage and a pollution degree for each listed insulator:

Designation (HVCI)	V_n (kV)	V_{max} (kV)	Pollution Level
CS 120 SB-325/1.815	57,5/60/66/69	72,5	Light → Strong
CS 120 SB-325/2.250	57,5/60/66/69	72,5	Very Strong
CS 120 EB-325/1.815	57,5/60/66/69	72,5	Light → Strong
CS 120 EB-325/2.250	57,5/60/66/69	72,5	Very Strong
CS 120 SS-550/3.075	110	123	Light → Strong
CS 120 SS-550/3.813	110	123	Very Strong
CS 160 SS-550/3.813	110	123	Light → Very Strong
CS 120 SB-650/3.625	110/115/132/138	145	Light → Strong
CS 120 SB-650/4.500	110/115/132/138	145	Very Strong
CS 120 EB-650/3.625	110/115/132/138	145	Light → Strong
CS 120 EB-650/4.500	110/115/132/138	145	Very Strong
CS 210 SB-650/4.500	110/115/132/138	145	Light → Very Strong
CS 120 SB-1.050/6.125	220/230	245	Light → Strong
CS 120 SB-1.050/7.595	220/230	245	Very Strong
CS 160 SB-1.050/7.595	220/230	245	Light → Very Strong

Table 5 – HVCI - Nominal and maximum voltage - Pollution level

5 TECHNICAL REQUIREMENTS

5.1 Definitions

Furthermore of concepts defined at IEC 60303-1, here are shown definitions for the usage of this standard:

5.1.1 High Voltage Composite Insulator (HVCI)

In this case a HVCI is referred to a composite/silicon rubber/polymer long rod insulator to be use in lines over 36 kV and consisting of silicone rubber housing, fiberglass rod and end fittings (Annex A).

5.1.2 Composite insulator string

Assembly formed by the composite insulator, couplings, links and, if required, grading rings.

5.1.3 Insulation level (IL)

It is considered the minimum standard level of insulation required to withstand surge voltage (peak value, frequency, time or duration, ...).

Voltage (kV)		IL (kV)	
Nominal Voltage U_n	Maximum Voltage U_m	Lighting impulse withstand voltage (BIL) (1,2/50 µs, dry) U_i	Power frequency withstand voltage (45-65 Hz, 1 min, wet) U_f
45	52	250	95
57,5	72,5	325	140
60	72,5	325	140
66	72,5	325	140
69	72,5	325	140

110	123	550	230
115	123	550	230
132	145	650	275
138	145	650	275
220	245	1.050	460
230	245	1.050	460

Table 6 – Standardized Insulation Levels vs Nominal and Maximum network voltages

5.2 Designation

Each HVCI is designed according to the IEC 61466-2 standard:

CS		SLM		EFT	EFC	-	BIL	/	MCD
		120		S	B		325		1.815
		160		E	S		650		2.250
		210					1.050		3.625
									4.500
									6.125
									7.595

Key:

SLM	Specified Mechanical Load (kN)
EFT	End Fitting Tower side (type)
EFC	End Fitting Conductor side (type)
BIL	Basic insulation level (kV)
MCD	Minimum Creepage Distance (mm)

Example: **CS 120 SB-650/3.625** refers to the HVCI with a specified mechanical load of 120 kN, Socket coupling at the tower side, Ball coupling at thr conductor side, 650 kV of lighting impulse withstand voltage (1,2/50 μs, dry) and a creepage distance greater or equal than 3.625 mm.

6 CONSTRUCTION CHARACTERISTICS

6.1 Design and material of composite insulator strings

Four blocks make up the composite insulator string:

- Dielectric Insulator Core
- Hydrophobic insulation housing
- Connection Zone (Triple junction point)
- End fittings/Couplings
- Grading/Corona rings

Furthermore cores, housing and end fittings must be designed and assembled to ensure that no moisture, water or external substances reach the core surface. Design has to provide superior performance by preventing moisture penetration between the silicone rubber and end-fitting interface. The design is based on redundant seals that provide unmatched protection to the fiberglass core rod (connection zone completely encapsulated). It is also important to deal with the crimping process in order to create a more uniform stress distribution and to ensure the mechanical integrity of the insulator.

The insulators are required to maintain satisfactory electrical and mechanical performance throughout their lifetime, which should be specified as 40 years.

6.1.1 Dielectric Insulator Core

It shall transmit the mechanical stresses produced by conductors to the tower and shall provide the necessary electrical insulation.

6.1.1.1. Core material

The core of the HVCI shall be a Boron-free (Br) dielectric core rod, corrosion-resistant ECR glass-fiber (Electric grade glass, Corrosion Resistant) and fiber reinforced plastic rod (FRP rod), impregnated with epoxy resin. The glass fiber rods must have extremely high hydrolysis and acid resistance in order to avoid the risk of so-called brittle fracture. The fibers' glass transition temperature must be higher than 100 ºC, in accordance with EN 61006. The Glass fibers distribution in the core cross section must be uniform and free of gaps, so that the core should be free of air bubbles, strange substances or defects in manufacture, as well as, maintain a cylindrical shape.

The value of the core volume resistivity shall be over 10^{10} $\Omega \cdot m$ (IEC 62631).

6.1.2 Hydrophobic Insulation Housing

The hydrophobic insulation housing, both sheath and sheds, must protect the core from external agents providing sealing and preventing the formation of a continuous film of water. The minimum coating thickness shall be set to 3 mm, so that the resistant core shall be protected from external agents. The coating shape shall provide the necessary creepage distance so the required insulation of the surface is reached.

Sheath and sheds shall be silicone-rubber (VMQ - Vinyl-Methyl-Polysiloxane, with filler additives) free of EPDM and other organic rubbers. Sheds may have different diameters and their shape have to be designed according to the IEC TS 60815-3 recommendations.

The color of the silicone-rubber must facilitate the integration with the environment, so it should be preferably gray.

6.1.2.1. Silicone-rubber

Silicone rubbers consist of long-chain polysiloxanes and various filler additives, such as pyrogenic silica. They are converted into silicone elastomers by vulcanization and are classified according to the curing method, the viscosity of the base polymer, and whether they cure at high or room temperature. Those types of silicone-rubber admitted in this standard are:

1. **HTV (High Temperature Vulcanized – solid silicone rubber):** The core of the Solid silicone rubbers are cured at elevated temperature (200 ºC approx), either by means of organic peroxides or with platinum catalyst. The cured rubber is compounded with reinforcing fillers to give it its mechanical strength.

2. **LSR (Liquid Silicone Rubber):** Liquid silicone rubbers are also members of the group of high-temperature-vulcanizing rubbers (100 – 200 ºC). This kind of silicone rubbers are characterized by a low viscosity compared to solid silicone rubbers (HTV). Liquid silicone rubbers are two-part compounds mixed to be vulcanized.

The core of the composite insulator shall be completely covered by a continuous housing consisting of a waterproof and insulating coating. The housing of the insulators, i.e. sheds and core rod sheath, shall be a one-piece with only one internal interface throughout the whole insulator, namely the boundary interface between the housing and the FRP core rod.

Molding manufacturing process:

The molding process (silicone- rubber injected into a mold) is carried out in an enclosed system to avoid contact with the air and ensure that the silicone-rubber does not contain bubbles. The surface of the silicone-rubber shall be free of burrs, even on the edge of the weathersheds the maximum admitted burr must be shorter than 3 mm.

Assembly manufacturing process:

Composite insulators may be also manufactured by assembling their different elements. Prefabricated sheds are installed and glued over a HTV-coated FPR rod. These sheds have to be vulcanized in order to get a one-piece housing.

6.1.2.2. Physical rubber features

Silicone-rubbers of insulators shall have a resistance to tracking and electric erosion with a classification of Class 1A 4,5 according to IEC 60857 and shall resist the effects of corona discharges and ozone. It shall withstand a low-intensity-electric arc for more than 180 seconds under the conditions indicated in standard IEC 61621.

The tear strength (cohesion) of the silicone-rubber must be higher than 8 N/mm based on ISO 34-1 standard. At every existing interface from the composite insulator, the adhesion strength of the interface (interface resistance) shall be higher than the tear strength of the silicone (breaking stress of the silicone rubber).

The silicone-rubber must be type V0 according to the IEC 60695-11-10. If the fire resistance is evaluated under specifications of the ASTM D2863, its LOI must be higher than 25%. At the same time the silicone rubber shall have highly hydrophobic features and must be classified type WC1 as specified in IEC TS 62073.

The value of the silicone-rubber volume resistivity shall be over 10^{10} $\Omega \cdot m$ (IEC 62631).

6.1.3 Connection Zone (triple junction point)

The triple junction point is de point located where the core meets the metal coupling and where the silicone-rubber coating ends (end fitting, core and rubber housing).

A special care has to be taken in that point/zone because it is a very singular point for the e-field (where usually the highest electrical field strength is concentrated) and a critical moisture-water penetration-interface.

The connection zone must be absolutely water- and air-tight sealed during manufacturing and along the insulator lifetime (no gaps rubber-metal allowed). The design shall ensure a total enclosure of that most sensitive part of a silicone insulator.

Sealing systems must provide superior performance by preventing moisture penetration between the silicone rubber and end-fitting interface. The design might be based on redundant seals that provide unmatched protection to the fiberglass core rod or based on one-piece HTV silicone housing to the FRP core rod combined with overmolding design systems that completely embedded in the silicone housing the connection zone, as well as other systems to ensure that critical point.

The end fittings must be directly attached to the FRP core rod by a radial (at least 8 compression points) or a circumferential crimping process (complete compression mitigates moisture egress into the connection).

It is not admitted end fittings assembled by others but the insulator manufacturer, during the manufacturing process.

6.1.4 End fittings/Couplings

The end fittings, made of hot-dip galvanized forged steel, must apply IEC 61284 and shall be mechanically and directly attached to the FRP core rod. Tensions have to be transmitted from conductor to tower.

Coatings applied by hot dip galvanizing shall be in accordance with ISO 1461 with the minimum local coating thickness greater or equal than 75 μm.

6.1.4.1. Types of end fittings

End fittings, to be considered in this standard shall be:

- End Fittings of the Tower side (EFT) – upper ends: Sockets (S) and Eyes (E).
- End Fittings of the Conductor side (EFC): Balls (B) and Sockets (S).

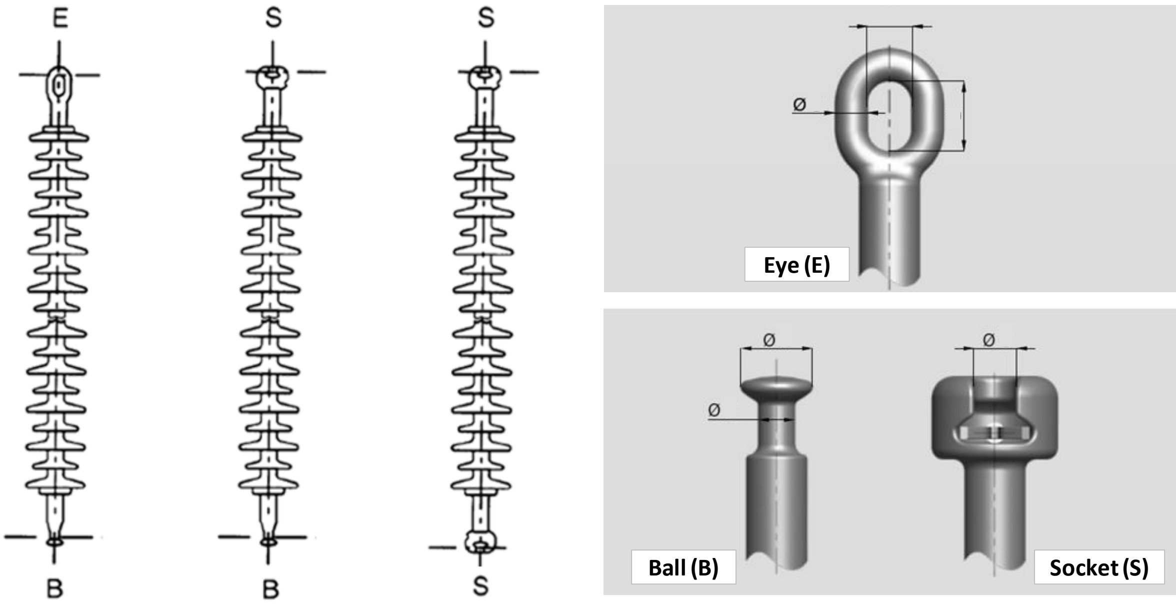

Image 1 – Composite Insulators and Coupling Types

6.1.4.2. Mechanical couplings features

The Specified Mechanical Load (SML) shall be set under conditions of the nominal tension of the conductor.

The specific values, related to coupling sizes, shall be in concordance with IEC 61466-1:

SML (kN)	Socket & Ball IEC 60120	Eye IEC 61466
70	16	17
100	16	24
120	16	24
160	20	25
210	20	25

Table 7 – Standardized SML vs Coupling sizes

6.1.5 Grading Rings

Grading/corona rings distribute the voltage at the insulator end next to the conductor. They will be required for nominal voltages equal to or greater than 220 kV.

The dimensions of the rings depend on the geometrical and electrical characteristics of the string. The composite insulators manufacturer shall supply the grading rings, as well.

6.2 Electrical characteristics

Composite string insulators units are standardized by the standard lightning impulse withstand voltage/ Basic insulation level. The wet power frequency withstand voltage shall be that given in IEC 60071-1.

Values of these parameters are given in the table of Insulating Level (IL) as a function of V_{max}.

6.3 Main composite insulator strings dimensions

Main insulators dimensions are defined by:

- **Creepage Distance or leakage distance:** Minimum Creepage Distance (MCD) means the shortest distance along the surface of the solid insulating material between the two conductive parts (Conductor (phase) – Tower (earth)). It depends on the maximum voltage (V_{max}) as well as the pollution level. The influence of the pollution degrees in the environment on the dimensioning of creepage distances is taken into account in the standard IEC 60071-2 (specific creepage distances are established in mm/kV depending on the pollution degree).

Pollution Level *(IEC 6815-1)*		**Specific Crepage Distance SCD** (mm/kV)	**Unified Specific Crepage Distance - USCD** (mm/kV)
I	Light	16	27,8
II	Medium	20	34,7
III	Strong	25	43,3
IV	Very Strong	31	53,7

Table 8 – Standardized specific creepage distance and Unified specific creepage distance vs pollution level

In particular cases of extreme pollution, specific creepage distances of 35 mm/kV might be considered.

- **Arcing Distance or dry arc distance:** Minimum Arcing Distance (MAD) is the shortest distance in air external to the insulator, the clearance, between the two conductive parts which normally have the operating voltage between them (Conductor (phase) – Tower (earth)). Clearance shall be dimensioned according to the required impulse withstand voltage. The standard IEC 61466-2 + ADM1 specifies arcing distances and lighting impulse voltage.

Lighting impulse withstand voltage (BIL) (1,2/50 μs, dry) U_i (kV)	**Minimum Arcing Distance** MAD (mm)
250	435
325	570
450	815
550	1.005
650	1.195
950	1.775
1.050	1.970

Table 9 – Minimum Arcing Distance for different values of lighting impulse withstand voltage

- **Nominal Insulator Length:** This length is established as a parameter in order to coordinate the minimum distances phase-earth in towers but keeping the required MAD. It has been named "nominal" due to the length differences depending on the end fittings of the composite insulator string. Small tolerances are permitted.

- **Diameter of the insulating part (sheds):** Shed diameters are usually of interest in conditions of heavy ice or snow accretion. Because crescents accumulate on the windward side of the shed which spanning the full diameter of the insulator. The diameter of the sheds shall not exceed the value given in the IEC 61466-2 + ADM1 (≤ 200 mm).

As a review of the data shown above, the insulators' minimum dimensional values requested are:

Nominal Voltage U_n	**Maximum Voltage** U_m	**Lighting impulse withstand voltage (BIL) (1,2/50 µs, dry)** U_i	**Minimum Arcing Distance** MAD	**Max. Diameter of the insulator** D_{max}	**Minimum Creepage Distance (MCD) vs Pollution Level - Total Length** Light	Medium	Heavy	Very Heavy
(kV)	(kV)	(kV)	(mm)	(mm)	MCD (mm)	MCD (mm)	MCD (mm)	MCD (mm)
45	52	250	435	200	832	1.040	1.300	1.615
57,5	72,5	325	570	200	1.160	1.450	1.815	2.250
60	72,5	325	570	200	1.160	1.450	1.815	2.250
66	72,5	325	570	200	1.160	1.450	1.815	2.250
69	72,5	325	570	200	1.160	1.450	1.815	2.250
110	123	550	1.005	200	1.970	2.460	3.075	3.815
110/115 (*)	145	650	1.195	200	2.320	2.900	3.625	4.495
132	145	650	1.195	200	2.320	2.900	3.625	4.495
138	145	650	1.195	200	2.320	2.900	3.625	4.495
220 (**)	245	1.050	1.970	200	3.920	4.900	6.125	7.595
230 (**)	245	1.050	1.970	200	3.920	4.900	6.125	7.595

Table 10 – Minimum dimensional values of insulators

(*) Chilectra/Codensa considerations.

(**) Values shown in the table have to consider the whole block (HVCI + Grading Rings) assembled.

6.4 Quality issues

The technical conformity of a particular design of composite insulator strings shall be determined by accomplishing design tests, type tests, sample tests and routine test related in this document. Additionally, it is recommended that manufacturers take into account the conclusions given in the document CIGRÉ 33-204.

- **Molding Parting Lines**. Parting lines are lines along the surface of the insulating rubber and contained in the plane in which the two halves of the mold meet. It is a very important part of the insulator design because it is a witness line, an unavoidable result of two mating mold members and a weaknesses for the insulator. These lines, in case they are parallel to the electric field, cause erosion and degradation of the insulating and distortion on the electric field.

  To the extent possible, the design and the molding process shall provide a parting line perpendicular to the electric field lines.

- **Distance between the last shed and the metal end fitting of the conductor side**. The design of the area close to end fitting and the distance between the shed and the fitting shall be based on static and dynamic considerations of the electric field, avoiding to consider the specific needs of the creepage distance and the minimum distance required by an electric arc.

Electrostatic considerations lead to geometries in which the last shed is either separated more than 40 mm from the fitting or integrated therein. Electrodynamics considerations lead to geometries that facilitate the direct flashover between end fittings when a fast-front overvoltage occurs.

The manufacturer shall ensure that its design has the right balance between both behaviors (electrostatic vs electrodynamics).

- **Triple junction point (connection zone)**. In this point the insulator design have to provide a control system for the electric field distribution.

  The special design of this point should minimize the electrical field strength, corona phenomena and partial discharges inside the junction zone as well as on the silicone housing surface. This reliably prevents corrosion of the insulating material and eliminates the risk of subsequent failure of the insulator.

  The insulator manufacturing process shall protect the interface with a design that separates the tangential E-field component from the triple point and improve the electric field distribution inside and around the sealing point.

  Above reflections should be made in conjunction with the consideration of the distance of the last shed because its proximity to the junction point should be taken into account in the overall design.

6.4.1 Polymer insulator profiles

The shape of the sheds shall observe requirements to ensure their proper function in different environmental conditions such as rain, snow, ice or pollution. For that reason some parameters/ratios defined in IEC TS 60815-3 shall satisfy the next criteria as following:

- Spacing versus shed overhang: $\frac{s}{p} > 0{,}75$

  Where:
  - *s*: Shed-to-shed spacing (equal sheds, sheds of the same diameter).
  - *p*: Shed overhang.

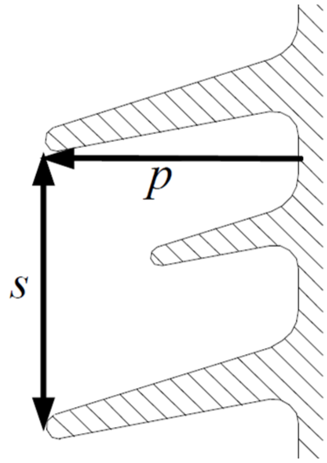

Image 2 – Parameters *s* and *p* for alternating shed profile.

- Creepage distance versus clearance: $\frac{l}{d}$ < 4,5 at any point of the insulator (the highest ratio found in any section).

  Where:
  - *l*: The part of the creepage distance measured between the above two points.
  - *d*: Straight air distance between two parts points on the insulating part or between a point on the insulating part and another on metal part.

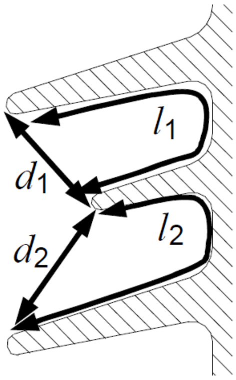

Image 3 – Parameters *l* and *d* for alternating shed profile.

- Creepage factor: $\frac{L}{A}$ < 4,75.

  Where:
  - *L*: The total creepage distance of the insulator.
  - *A*: The arcing distance of the insulator.

- Minimum distance between sheds:

  c > 25 mm for profiles of sheds with the same diameters (uniform sheds).

  c > 40 mm for alternating shed profiles.
  - *c:* The minimum distance between adjacent sheds of the same diameter, measured by drawing a perpendicular from the lowest point of rim of the upper shed to the next shed below of the same diameter.

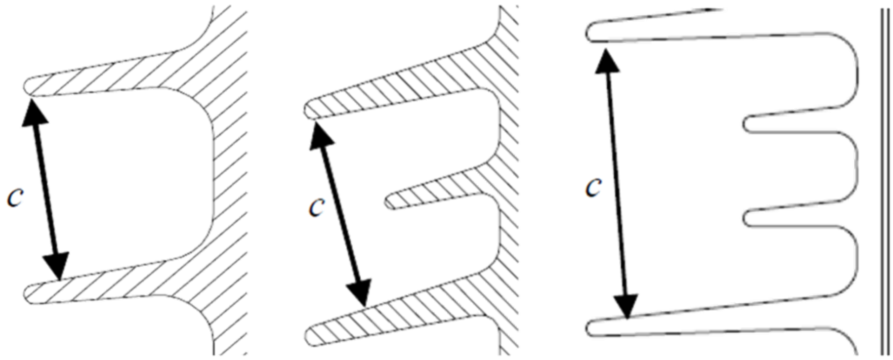

Image 4 – Several sheds profiles.

- Shed angle: $5^o < \alpha < 20^o$.

  Where:

  - α: The angle between the upper surface of the shed and the horizontal line. For rounded sheds α is measured at the mid-point.

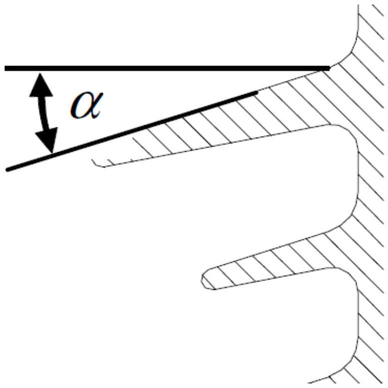

Image 5 – Shed angle.

6.5 Marking

Each insulator shall be clearly and indelibly marked, as it is specified in IEC 61466-1, with:

- The name or trademark of the manufacturer.
- The year of manufacture.
- The specified mechanical load (SML) – kN.
- Elements' references that permit identification of each of the component parts.

7 TESTING

This Standard shall apply as described in IEC 61109 for the classification, implementation and test criteria. For this purpose tests are divided into four groups as follows:

- Design tests
- Type tests
- Sample tests
- Routine tests

The prescribed test methods do not include requirements dealing with the choice of insulators for specific/special operating conditions.

7.1 Design Tests

These tests are intended to verify the suitability of the designs, materials and methods of manufacture (technology). A composite suspension insulator design is defined by:

- Materials of the core, housing and their manufacturing method.
- Material of the end fittings, their design and method of attachment (excluding the coupling).
- Layer thickness of the housing over the core (including a sheath where used).
- Diameter of the core.

A HVCI submitted to the design tests, becomes a parent insulator for a given design and the results shall be considered valid for that design only. This tested parent insulator defines a particular design of insulators which have all the following characteristics:

- Same materials for the core and housing and same manufacturing method.
- Same or greater cross-diameter of the core.
- Same or smaller stress under mechanical loads.
- Same material of the fittings, the same connection zone design, the same assembly and fixing processes and the same housing-to-fitting interface geometry.
- Same or greater minimum layer thickness of the housing over the core (including a sheath where used).
- Equivalent housing profile parameters (see ANNEX C – Table 1 from IEC 61109:2008, a) and b) considerations).

When changes in the design occur, tests must be carried out, again, in accordance with Table 1 of the IEC 61109:2008 (see Annex C).

Design tests consist of the tests prescribed in IEC 62217, as listed below, and a specific assembled core load-time test. These tests are performed only once and the results are recorded in a test report.

Tests on interfaces and connections of end fittings	
Pre-stressing	– Sudden load release pre-stressing – Thermal-mechanical pre-stressing
Water immersion pre-stressing	
Verification tests:	
Visual examination	
Steep-front impulse voltage test	
Dry power-frequency voltage test	
Tests on shed and housing material	
Hardness test	
Accelerated weathering test	
Tracking and erosion test	
Flammability test	
Tests on the core material	
Dye penetration test	
Water diffusion test	
Assembled core load-time test	
Determination of the average failing load of the core of the assembled insulator	
Control of the slope of the strength-time curve of the insulator	
Test on resistance of FRP cores against stress corrosion	

Table 11 – Design Tests.

Each part can be performed independently on new test specimens, where appropriate. The HVCI of a particular design shall be qualified only when all insulators or test specimens pass the design tests.

7.1.1 Tests on interfaces and connections of end fittings

Three insulators assembled on the production line shall be tested. The insulation length (metal to metal spacing) shall be not less than 800[1] mm. Both end fittings shall be the same as on standard production insulators. The end fittings shall be assembled so that the insulating part from the fitting to the closest shed shall be identical to that of the production line insulator. If spacers, joining rings or other features are used in the insulator design (notably for longer insulators), the sample shall include any such devices in a typical position.

According to clause 9.2 of IEC 62217:2012, the test sequence consists of:

- Reference dry power frequency test
- Pre-stressing
- Verification test (Visual examination, Steep-front impulse test, Dry power frequency test)

7.1.1.1. Reference dry power frequency test

According to clause 9.2.4 of IEC 62217:2012.

7.1.1.2. Sudden *load release*

According to clause 10.3.1 of IEC 61109:2008.

7.1.1.3. Thermal-mechanical pre-stress

According to clause 10.3.2 of IEC 61109:2008.

7.1.1.4. Water immersion pre-stressing

According to clause 9.2.6 of IEC 62217:2012.

7.1.1.5. Visual examination

According to clause 9.2.7.2 of IEC 62217:2012.

7.1.1.6. Steep-front impulse voltage test

According to clause 9.2.7.3 of IEC 62217:2012.

7.1.1.7. Dry power frequency voltage test

According to clause 9.2.7.4 of IEC 62217:2012.

The time interval between the three last tests on interfaces and end fittings (visual examination, steep-front impulse voltage test, dry power-frequency voltage test) shall be such that the verification tests are completed within 48 h.

7.1.2 Tests on shed and housing material

To evaluate the hardness, service life, erosion and fire resistances.

7.1.2.1. Hardness Test

According to clause 9.3.1 of IEC 62217:2012.

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[1] If the manufacturer only has facilities to produce insulators shorter than 800 mm, the design tests may be performed on insulators of those lengths available to him, but the results are only valid for up to the lengths tested.

7.1.2.2. Accelerated weathering test

According to clause 9.3.2 of IEC 62217:2012.

7.1.2.3. Tracking and erosion test (1.000 h salt fog test)

According to clauses 10.2.2 of IEC 61109:2008 and 9.3.3 of IEC 62217:2012.

7.1.2.4. Flammability test

According to clause 9.3.4 of IEC 62217:2012.

7.1.3 Tests on the core material

To check the performance of core material against water penetration the following tests shall be carried out. These tests can be carried out on specimens either with or without housing material, according to the prescriptions of the relevant product standard.

7.1.3.1. Porosity Test (Dye penetration test)

According to clause 9.4.1 of IEC 62217:2012.

7.1.3.2. Water diffusion test

According to clause 9.4.2 of IEC 62217:2012.

7.1.4 Assembled core load-time test

According to clause 10.4 of IEC 61109:2008.

This test involves two parts/sub-tests:

- Determination of the average failing load of the core of the assembled insulator - M_{AV}: According to clause 10.4.1.1 of IEC 61109:2008.
- Verification of the 96 h withstand load: According to clause 10.4.2.2 of IEC 61109:2008.

7.1.5 Test on resistance of FRP cores against stress corrosion

This test came up in the mid-80s but it does not evaluate the suitability of an insulator design (housing) against brittle fracture. It is purely a screening test that measures the acid resistance of bare rods (core materials and design). A test on the free length of the insulator should be selected to avoid interference of the superimposed stresses in the crimping area.

Tensile strength in unidirectional fiber composites is typically a fiber-dominated phenomenon. Transverse failures occur across fiber bundles normally at the ultimate tensile strength of the composite. This failure so-called brittle fracture occurs at unusually low loads of the string, when the composite is exposed to adverse chemical environments, and it is called acid attack brittle fracture.

During the test the rod is subjected to a constant tensile load while immersing a portion of the gauge section in a 1N Nitric Acid (HNO_3) solution for a period of 96 hours. This test shall be performed at ambient temperature to confirm the mechanical resistance against corrosion stress of the FRP cores and shall follow indications of the IEC Project 36-6-2 on WG 36-07.

7.1.5.1. Test Specimen

One insulator from the production line or one specimen is used. The specimen shall have a length between end fittings of at least 10 times the core diameter. The end fittings shall be identical to those used in the production.

The test applies to a bare part of the rod, so the housing of the insulator shall be removed in the middle part of the insulator on a length of al least 150 mm. The visible core surface has to be smoothed by means of a fine abrasive cloth (grain size 180). Remaining parts of the housing have to be removed thoroughly. An acid container made of polyethylene shall be arranged surrounding the visible core surface in such a way that the liquid can simply be poured into the container and no acid comes into contact with the end fittings. The size of the acid container shall be adapted in such a way that the FRP core is surrounded by a liquid thickness not less than 1 cm and a liquid level of not less than 4 cm. The container shall be covered to prevent liquid evaporations greater than 5% of its volume during the test period.

7.1.5.2. Performance of the test

The insulator is subjected to a tensile load applied between the metal parts. The tensile load shall be increased rapidly but smoothly, from zero up to 67% of the specified mechanical load (SML) and then maintained at this value for 96 h. Immediately after applying the load, a nitric acid of a concentration of 1N (i.e. 1 N = 63 g conc. HNO_3 added to 937 g of water) shall be poured into the acid container. The acid must not come into contact with the end fittings.

The 1N solution is the recommended concentration by the industry standards and exhibits a pH of 0. Pure nitric acid is typically used in order to dissolve the polymer matrix, but it is not expected that a concentration higher than 1N would exist even in the high electrical environments of overhead conductors.

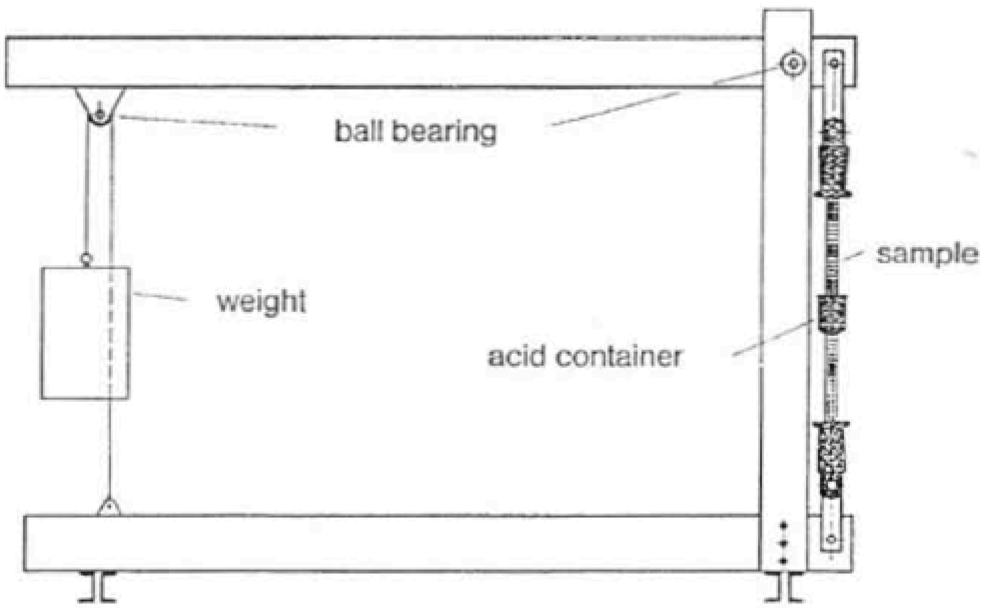


Image 6 – Test set up for the corrosion stress tests of FRP cores

7.1.5.3. Evaluation of the test

The test is passed if no fracture of the core occurs during the 96 h. test (no failures occur, and macroscopic inspection reveals no damage or change in the composite after the exposure). If no failures or damages are detected, results indicate that the polymer composite used is immune to brittle fracture under the conditions specified in industry-standard test protocols and under more aggressive acidic environments.

7.2 Type Tests

The type tests are intended to verify the main characteristics of a polymeric insulator, which depend mainly on its shape and size. Type tests shall be applied to polymeric insulators belonging to an already qualified design class. The type tests shall be repeated only when the type of the polymeric insulator is changed. The parameters defining a type of polymeric insulator and the applicable type tests are given in the relevant product standard.

Electrical tests (U_m < 300 kV)
Dry lightning impulse withstand voltage test
Wet power-frequency test
Test of the tightness of the interface between end fittings and insulator housing and damage limit proof test
Radio interference test
Additional tests on grading rings

Table 12 – Type Tests.

Furthermore, Table 1 of the IEC 61109 outlines the insulator design characteristics that, when changed, also require a repeat of the type tests (see Annex B).

7.2.1 Electrical tests

An insulator type is electrically defined by the arcing distance, creepage distance, shed inclination, shed diameter and shed spacing.

The electrical type tests (see 11.1 in IEC 61109:2008) shall be performed on insulators only once, satisfying the conditions above, and shall be performed with arcing or field control devices (which are generally necessary on composite insulators at transmission voltages) if they are an integral part of the insulator type.

The electrical tests shall be performed in accordance with IEC 60383-2 to confirm the specified values. Interpolation of electrical test results may be used for insulators of intermediate length, provided that the factor between the arcing distances of the insulators whose results form the end points of the interpolation range, is less than or equal to 1,5. Extrapolation is not allowed.

7.2.1.1. Dry lightning impulse withstand voltage test

The test is passed if no fracture of the core occurs during the 96 h test (no failures occur, and macroscopic inspection

7.2.1.2. Wet power-frequency test

According to clause 9.4.2 of IEC 60383-2:1993.

7.2.2 Damage limit proof test and test of the tightness of the interface between end fittings and insulator housing

An insulator type is mechanically defined principally by a maximum SML for the given core diameter, method of attachment and coupling design.

The mechanical type tests shall be performed only once on insulators satisfying the criteria for each type, according to clause 10.2 of IEC 61109:2008.

7.2.3 Radio interference test

According to IEC 60437.

7.2.4 Additional tests on grading rings

Additional tests shall be carried out on grading/corona rings when they exist:

- Visual examination.
- Dimensional conformity (verification of dimensions).
- Determination of the zinc coating thickness.

The Manufacturer/Supplier shall provide the following electrical values of the composite insulator with gradient rings installed:

- Lighting impulse withstand voltage (1,2/50 μs, dry, both polarities)
- Power frequency withstand voltage (wet)

7.3 Sample Tests

The sample tests are for the purpose of verifying other characteristics of composite insulators, including those which depend on the quality of manufacture and on the materials used. They are made on insulators taken at random from lots offered for acceptance.

Verification of dimensions (E1 + E2)
Verification of the locking system (E2)
Verification of the tightness of the interface between end fittings and insulator housing (E2)
Verification of the specified mechanical load (E1)
Galvanizing test (E2)

Table 13 – Sample Tests.

For the sample tests, two samples are used, E1 and E2. The sizes of these samples are indicated below. If more than 10.000 insulators are concerned, they shall be divided into an optimum number of lots comprising between 2.000 and 10.000 insulators. The results of the tests shall be evaluated separately for each lot.

Lot Size	**Sample Size**	
N	**E1**	**E2**
N ≤ 300	Subject to agreement	
300 < N ≤ 2.000	4	3
2.000 < N ≤ 5.000	8	4
5.000 < N ≤ 10.00	12	6

Table 14 – Size of samples for Sample Tests.

The insulators shall be selected from the lot at random. The purchaser has the right to make the selection. The samples shall be subjected to the applicable sampling tests.

In the event of a failure of the sample to satisfy a test, the re-testing procedure shall be applied as prescribed in 12.6 of IEC 61109:2008.

Insulators of sample E2 only can be used in service and only if the galvanizing test is performed with the magnetic method.

7.3.1.1. Verification of dimensions

According to clause 12.2 of IEC 61109:2008.

7.3.1.2. Verification of the locking system

According to clause 12.3 of IEC 61109:2008.

7.3.1.3. Verification of the tightness of the interface between end fittings and insulator housing

According to clause 12.4 of IEC 61109:2008.

7.3.1.4. Verification of the specified mechanical load

According to clause 12.4 of IEC 61109:2008.

7.3.1.5. Galvanizing test

According to clauses 12.5 of IEC 61109:2008 and 26 of IEC 60383-1:1993.

7.4 Routine Tests

The aim of these tests is to eliminate composite insulators with manufacturing defects. They are made on every composite insulator offered for acceptance.

Mechanical routine test
Identification of the composite insulator
Visual examination

Table 15 – Sample Tests.

7.4.1.1. Mechanical routine test

According to clause 13.1 of IEC 61109:2008.

7.4.1.2. Identification of the composite insulator

In addition to the requirements of IEC 62217, each insulator shall be marked with the SML. It is recommended that each insulator be marked or labeled by the manufacturer to show that it has passed the routine mechanical test.

7.4.1.3. Visual examination

According to clause 13.2 of IEC 61109:2008.

8 TECHNICAL CONFORMITY

The supplying of components and equipments to all Enel Global Infrastructure and Networks Countries requires a Technical Conformity Assessment (TCA) process. This process must be performed in accordance with Enel standard GSCG002.

Technical Conformity must be issued by Enel Group and must be supported by accomplishing all of the Design, Type and Sample tests on every type of insulator to be accredited. Design and Type tests shall be performed once, during the TCA process. On contrary, Sample and Routine tests must be carried out on every singular purchased lot, as an acceptance tests.

All tests on insulators must be carried out as specified in this standard. Manufacturer/Supplier shall communicate with sufficient advance (14/21 working days for domestics/international trips) the tests date for the purpose of Enel to attend, if it would be consider necessary.

9 SUPPLY REQUIREMENTS

Manufacturers of insulators shall provide appropriate instructions and information covering general conditions during transport, storage and installation of the insulators. These instructions must include recommendations for handling, cleaning or maintenance.

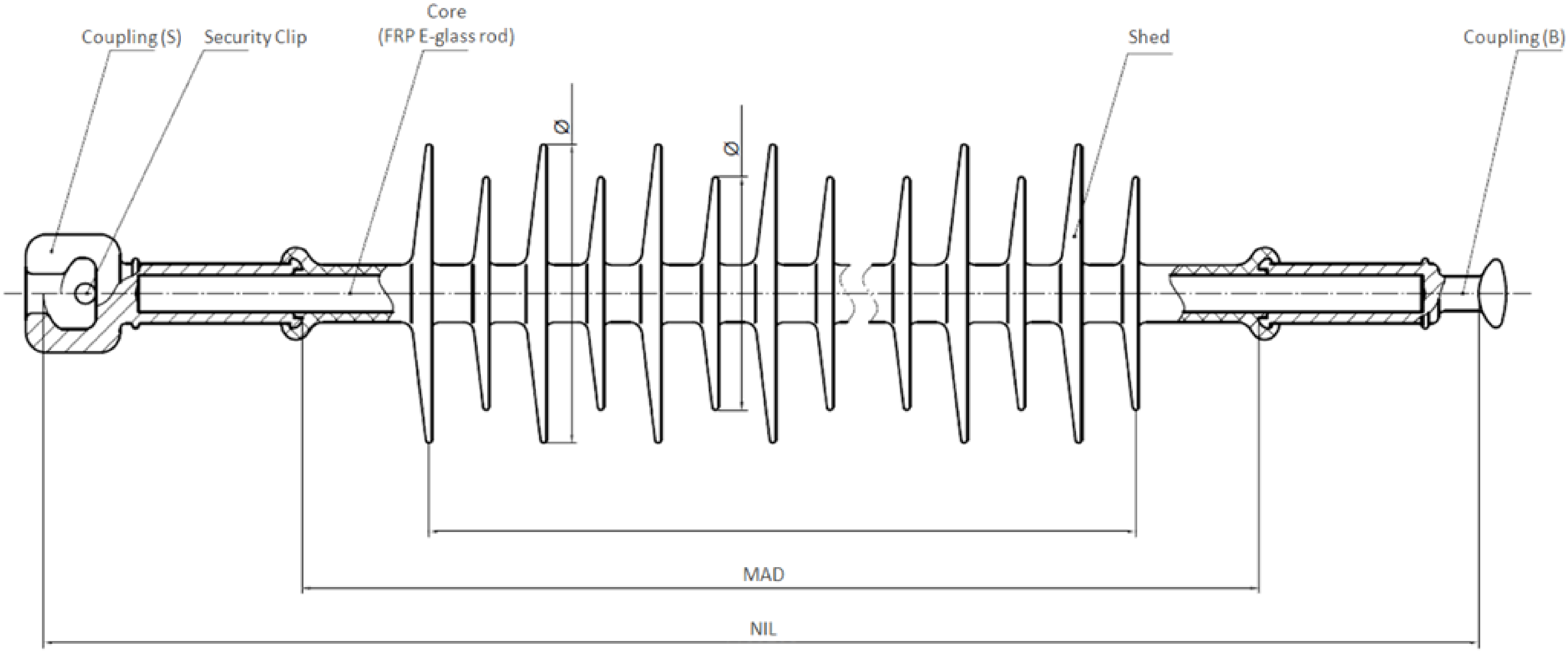
Insulators of the same batch must be packed in wood crates or hard cardboard boxes. Every box shall be marked with a code selected by the manufacturer for the purpose of identifying the fabrication lot and the type of insulator (insulators marking, as described in this document).

They shall be securely packaged to prevent end fittings from resting on the polymer weathershed material as well as ensuring that sheds shall not touch each other and the walls of the box. Along the insulator length, the boxes shall have pieces with appropriate holes to support the rods (avoiding rod bending and contact shed-shed shed-wall) and to clutch the metal end fittings. It shall be ensured that there is no damage to sheds during storing, loading & transportation.

Not more than 60 insulators shall be packed in a single box and they all shall be of the same type.

The consistency features of the boxes shall permit a three-ply storage/transportation and they shall be prepared for handling by forklift trucks and by boom cranes. They also must be treated to prevent degradation over time.

ANNEX A – COMPOSITE INSULATOR (TENSION/SUSPENSION SB INSULATOR)



MAD	*Minimum Arcing Distance (mm - flashover)*
NIL	*Nominal Insulator Length (mm)*

ANNEX B – HV COMPOSITE INSULATOR TESTS

N	Test	Test Type	TCA Process
1	Pre-stressing – Sudden load release pre-stressing	Design	X
2	Pre-stressing – Thermal-mechanical pre-stressing	Design	X
3	Water immersion pre-stressing	Design	X
4	Verification tests	Design	X
5	Visual examination	Design	X
6	Steep-front impulse voltage test	Design	X
7	Dry power-frequency voltage test	Design	X
8	Hardness test	Design	X
9	Accelerated weathering test	Design	X
10	Tracking and erosion test	Design	X
11	Flammability test	Design	X
12	Dye penetration test	Design	X
13	Water diffusion test	Design	X
14	Determination of the average failing load of the core of the assembled insulator	Design	X
15	Control of the slope of the strength-time curve of the insulator	Design	X
16	Test on resistance of FRP cores against stress corrosion	Design	X
17	Dry lightning impulse withstand voltage test (Electrical test)	Type	X
18	Wet power-frequency test (Electrical test)	Type	X
19	Test of the tightness of the interface between end fittings and insulator housing	Type	X
20	Damage limit proof test	Type	X
21	Radio interference test	Type	X
22	Additional tests on grading rings	Type	X
23	Verification of dimensions	Sample	X
24	Verification of the locking system	Sample	X
25	Verification of the tightness of the interface between end fittings and insulator housing	Sample	X
26	Verification of the specified mechanical load	Sample	X
27	Galvanizing test	Sample	X
28	Mechanical routine test	Routine	
29	Identification of the composite insulator	Routine	
30	Visual examination	Routine	

ANNEX C – TABLE 1 FROM IEC 61109:2008. TESTS TO BE REPEATED AFTER DESIGN CHANGES

IF the change in insulator design concerns:		**THEN** the following tests shall be repeated:									
		Design tests								**Type tests**	
		62217	61109	62217 Tests on housing material				62217 Tests on the core material		61109	
		Interfaces and connections of end fittings	Assembled core load–time tests	Hardness test	Accelerated weathering test	Tracking and erosion test	Flammability test	Dye penetration test	Water diffusion test	Electrical type tests	Mechanical type tests
1	Housing materials	X	X c)	X	X	X	X				
2	Housing profile a)	X				X				X	
3	Core material	X	X					X	X		X
4	Core diameter b)	X	X					X	X		X
5	Core and end-fitting manufacturing process	X	X					X	X		X
6	Core and end-fitting assembly process	X	X								X
7	Housing manufacturing process	X	X c)	X	X	X	X				X c)
8	Housing assembly process	X	X c)			X					X c)
9	End fitting material	X	X								X
10	End fitting connection zone design	X	X								X
11	Core/housing/end fitting interface design	X	X c)			X					X c)
12	Coupling type										X

a) Variations of the profile within following tolerances do not constitute a change:
- overhang : ± 10 %
- diameter : +15 %, -0 %
- thickness at base and tip : ± 15 %
- spacing : ± 15 %
- shed inclinations : ± 3°
- shed repetition : identical

b) Variations of the core diameter within ± 15 % do not constitute a change.

c) Not necessary if it can be demonstrated that the change has no influence on the assembled core strength.