

IEC 60815: Guide for the selection and dimensioning of high-voltage insulators for polluted conditions
Part 1 - : Definitions, information and general principles

Introduction from the Project Leader

What's new ?

This draft takes into account the decisions taken at our Stockholm meeting.
 It integrates the work submitted by RM on figure 2/Table 3.

It also integrates the work submitted by WV on definitions, figure 1, rapid pollution, dust deposit gauges. Note that there is a suggested Figure 2b showing the applicability of the approaches and the influence of simple profile parameters.

I have left the schedule/content and orientation below so that we can keep them in mind and update as necessary.

I have included both RS and WV ESDD/NSDD measurement procedures in Annex B – we need to select the best from both.

Tasks, notes etc. arising from Renardières are outlined in yellow

Schedule

The following table shows the planned progress of the revision work. This schedule is based on the availability of resources within Working Group 11 and an average of two meeting per year. Since much of the content of the revision is based on the work of CIGRE TF 33.13.01, the schedule also takes into account the project plans of this Task Force.

The dates are by no means fixed, since the progress of work on the successive parts of IEC 60815 will depend on the degree of acceptance of the first drafts of parts 1 and 2.

Part	Expected availability
1 st complete draft Part I (1CD) – Guide for the choice of insulators under polluted conditions – Part 1: Definitions, information and general principles	May 2001
1 st complete draft Part II (1CD) – Part 2: Porcelain and glass insulators for a.c. systems	December 2001
1 st complete draft Part III (1CD)) – Part 3: Polymer insulators for a.c. systems	April 2002
1 st complete draft Part IV (1CD)) – Part 4: Porcelain and glass insulators for d.c. systems	End 2002 ?
1 st complete draft Part V (1CD)) – Part 5: Polymer insulators for d.c. systems	End 2003 ?

Content and orientation

In addition to the strategy and layout given by the task in 36/157/RVN, the orientation of the work on the revision of IEC 60815 is also based largely on the following list of areas where IEC 815 was perceived to be weak by CIGRE [1]:

- Performance of polymeric insulators
- Insulator orientation
- Extension of applicability to voltages above 525 kV a.c.
- Design for d.c. application
- Insulators with semi-conducting glaze
- Surge arrester housing performance, particularly with reference to polymeric materials
- Longitudinal breaks in interrupter equipment
- Radio interference, television interference, and audible noise of polluted insulators
- Effect of altitude
- Effect of heavy wetting

The revision of 60815 to take into account current experience, knowledge and practice related to polluted insulators in general, and specifically to include polymer insulators and to cover d.c. systems requires subdivision of the guide into the following five parts:

- Part 1: Definitions, information and general principles
- Part 2: Porcelain and glass insulators for a.c. systems
- Part 3: Polymer insulators for a.c. systems
- Part 4: Porcelain and glass insulators for d.c. systems
- Part 5: Polymer insulators for d.c. systems

So far the work on parts 1 and 2 has concentrated on the elaboration of the requirements for evaluation and measurement of site severity along with study of the relative applicability of profile parameters to different insulators, materials and technologies.

In addition to the aforementioned aspects, the following major changes have been made or are foreseen:

- Encouragement of the use of site pollution severity measurements, preferably over at least a year, in order to classify a site instead of the previous qualitative assessment;
- Addition of the influence of non-soluble deposit density (NSDD) as a parameter of severity;
- Use of the results of natural and artificial pollution tests to help with dimensioning;
- Recognition that creepage length is not always the sole determining parameter;
- Recognition of the influence other geometry parameters (e.g. large or small diameters, non-linearity ...).

**IEC 60815: Guide for the selection and dimensioning of high-voltage
insulators for polluted conditions
Part 1 - : Definitions, information and general principles**

1. Scope and object

This guide is applicable to the selection of insulators, and the determination of their relevant dimensions, to be used in high voltage systems with respect to pollution. For the purposes of this guide the insulators are divided into the following broad categories:

- Ceramic insulators for a.c. systems;
- Polymeric insulators for a.c. systems;
- Ceramic insulators for d.c. systems;
- Polymeric insulators for d.c. systems.

Ceramic insulators have an insulating part manufactured either of glass or porcelain, whereas polymeric insulators have an insulating body consisting of one or more organic materials. More precise definitions are given below.

This part of IEC 60815 gives general definitions and principles to arrive at an informed judgement on the probable behaviour of a given insulator in certain pollution environments. It also provides methods for the evaluation of pollution severity. The specific guidelines for each of the types of insulator mentioned above are given in the further parts of IEC 60815, as follows:

- 60815-2 - Ceramic insulators for a.c. systems;
- 60815-3 - Polymeric insulators for a.c. systems;
- 60815-4 - Ceramic insulators for d.c. systems;
- 60815-5 - Polymeric insulators for d.c. systems.

This structure is the same as that used in CIGRE 33.13 TF 01 documents [1, 2], which form a useful complement to this guide for those wishing to study the performance of insulators under pollution in greater depth.

This guide does not deal with the effects of snow or ice on polluted insulators. Although this subject is dealt with by CIGRE [3], current knowledge is very limited and practice is too diverse.

The aim of this guide is to give the user means to :

- Characterise the type and severity of the pollution at a site;
- Determine the nominal creepage distance for a "standard" insulator;
- Determine the corrections to the creepage distance to take into account the specific properties of the "candidate" insulators for the site, application and system type;
- Determine the relative advantages and disadvantages of the possible solutions;
- Assess the need and merits of "hybrid" solutions or palliative measures.

2. Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60507

IEC 61245

List to be updated

3. Definitions

For the purpose of this publication, the following definitions apply.

3.1. Line Post Insulator



A rigid insulator consisting of one or more pieces of insulating material permanently assembled with or without a metal base cap intended to be mounted rigidly on a supporting structure by means of a central stud or one or more bolts.

3.2. Cap and Pin (Disc) Insulator



An insulator comprising an insulating part having the form of a disk or bell and fixing devices consisting of an outside cap and an inside pin attached axially.

3.3. Long Rod Insulator



An insulator comprising an insulating part having a cylindrical shank provided with sheds, and equipped at the ends with external or internal metal fittings.

3.4. Station Post Insulator



A rigid insulator consisting of one or more pieces of insulating material permanently assembled and equipped at the ends with external metal fittings intended to be mounted rigidly on a supporting structure by means of one or more bolts.

3.5. Polymer Insulator



A polymer insulator is one made of at least two insulating parts, namely a shank and housing, and equipped with metal fittings. Polymer insulators can consist either of individual sheds mounted on the shank, with or without an intermediate sheath, or alternatively, of a housing directly moulded or cast in one or several pieces on the shank. Polymer insulators can be of the long rod, line post or station post type.

3.6. Insulator Shank (Ceramic Insulators)

The shank refers to the main body of the insulator and is designed to provide the required mechanical characteristics.

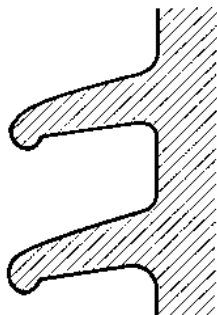
3.7. Insulator Shank (Polymer Insulators)

The shank is the internal insulating part of a polymer insulator and is designed to provide the required mechanical characteristics. It usually consists of continuous glass fibres which are positioned in a resin-based matrix in such a manner as to achieve maximum tensile strength.

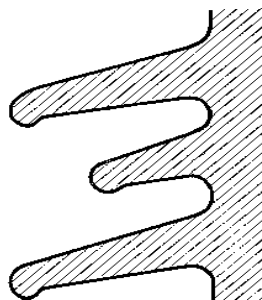
CE to combine

3.8. Sheds

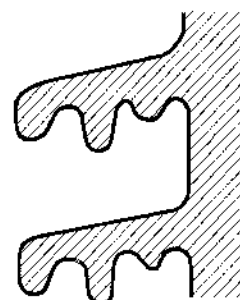
The sheds are the projections from the shank of an insulator intended to increase the creepage distance. Various typical types of shed and shed profiles are illustrated below.



Normal Shed

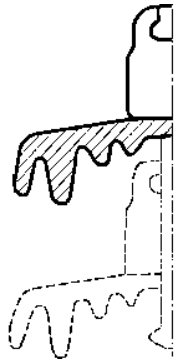


Alternating Shed

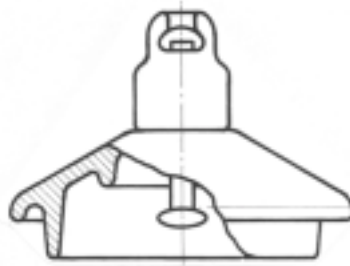


Under ribbed Shed

Drawings of shed profiles to be updated, SN for ceramic posts/long rods/hollws, CL/KK for cap & pin, RM/FS for composites.



Standard Disc Shed



Anti-Fog Disc Shed



Aerodynamic Disc Shed

3.9. Ceramic Insulator Materials

Porcelain (usually glazed) and Glass (usually toughened).

3.10. Polymer Insulator Materials

Comprise resins, Silicone, EP or co-polymer rubbers

Check "EP"

3.11. Creepage Distance

The shortest distance, or the sum of the shortest distances, along the contours of the external surfaces of the insulating parts of the insulator between those parts which normally have the operating voltage between them.

3.12. Specific Creepage Distance

The overall creepage distance of an insulator divided by the highest operating voltage across the insulator. It is generally expressed in mm/kV.

CE to check

3.13. Dry Arcing Distance

The shortest distance in air external to the insulator between those parts which normally have the operating voltage between them.

3.14. Profile factors

TBA

3.15. Pollution severities

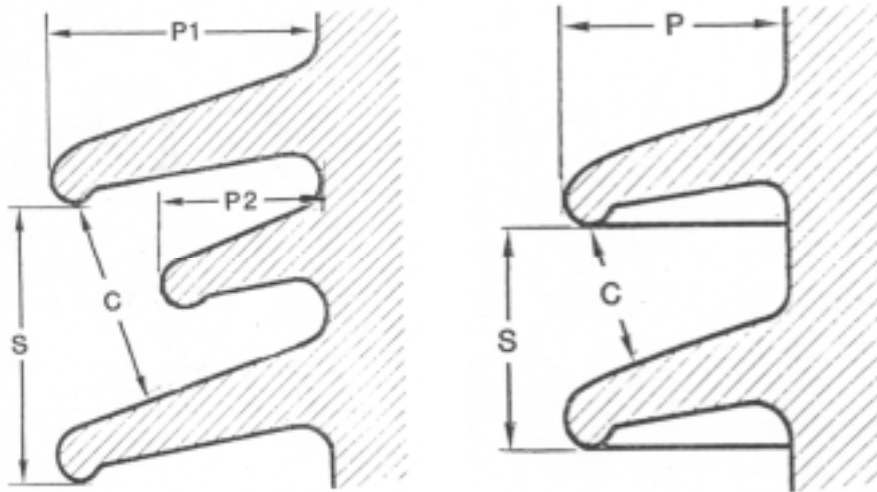
Site Severity - ?CL

Insulator Pollution – ESDD/NSDD/Surface conductivity ??? CL

4. Abbreviations

4.1. Shed Parameters

The important shed parameters are defined as follows:



P, P1, P2 = Shed Projection - The shed overhang

S = **Shed Spacing** - The vertical distance between two similar points of successive sheds.

C = **Shed Clearance** - the minimum distance between adjacent sheds of the same diameter, measured by drawing a perpendicular from the lowest point of the outer rib of the upper shed to the shed below of the same diameter.

S/P = Shed spacing-to-projection ratio -

4.2. Other abbreviations

M.S.C.D. : the Minimum Specific Creepage Distance

R.A.M. : Reliability, Availability, Maintainability.

ESDD : Equivalent Salt Deposit Density

NSDD : Non Soluble Deposit Density

TOV : Temporary Overvoltage

5. Pollution types and the flashover mechanism

5.1. Identification of types of pollution

There are two main forms of insulator pollution that can lead to flashover: **pre-deposited and instantaneous flashover occurs mainly at system voltage (U_n to U_m).** **BETTER TERMS NEEDED CL/DAS**

5.1.1. Pre-Deposit

Pre-deposit pollution is classified into two main categories, namely active pollution that forms a conductive layer, and inert pollution that forms a binding layer for the conductive pollution. These categories are described below.

5.1.1.1. Active pollution:

High solubility salts: NaCl, MgCl, NaSO₄ etc.

Low solubility salts: Gypsum, fly ash etc.

Acids: SO₂, SO₃, NO_x etc.

Active pollution is subdivided into conductive pollution (which is permanently conductive i.e. pollution with metallic conductive particles), high solubility salts (ie, salts that dissolve readily into water), and low solubility salts (that need a large volume of water to dissolve). Active pollution is measured in terms of an Equivalent Salt Deposit Density (ESDD) in mg/cm² [3].

5.1.1.2. Inert pollution

Hydrophilic pollution: Kaolin, clay, cement, etc.

Hydrophobic pollution: Silicone grease, oil, etc.

Inert pollution is classified as either hydrophilic (when it absorbs water) or hydrophobic (when it repels water). Inert pollution is measured in terms of Non-soluble Deposit Density (NSDD) in mg/cm².

5.1.1.3. High NSDD

This is a low conductivity pollution that builds up in thick layers, e.g. cement dust and fly ash, is termed as 'high NSDD'.

5.1.1.4. Low NSDD

This is a high conductivity 'thin' pollution layer, e.g. marine salt and SO₂, is termed as 'low NSDD'.

5.1.1.5. Sources of pre-deposit pollution

Possible sources of insulator pollutants and their effective distances of influence are given below.

The sea (about 20 km from the coastline).

Factories emitting contaminants such as SO₂ that can dissolve to form conductive layers during acid rain conditions (up to 15 km).

Mining activities that produce dust-containing substances such as gypsum or Illmenite (up to 15 km).

Agricultural activities such as crop spraying or ploughing (up to 2 km).

Bird droppings which are solidified or partially wet.

5.1.1.6. A brief description of the pollution flashover mechanism under pre-deposit pollution

For ease of understanding the pre-deposit pollution flashover process, it is divided into six phases described separately below. In nature these phases are not distinct but may tend to merge.

The pollution flashover process of insulators is greatly affected by the insulator's surface properties. Two surface conditions are recognised: either hydrophilic or hydrophobic. A hydrophilic surface is generally associated with glass and ceramic insulators whereas a hydrophobic surface is generally associated with polymeric insulators, especially silicone rubber. Under wetting conditions - such as rain, mist etc. - hydrophilic surfaces will wet out completely so that an electrolyte film covers the insulator. In contrast, water beads into distinct droplets on a hydrophobic surface under such wetting conditions.

The pollution flashover process is also significantly affected by the voltage waveform, a.c. or d.c. It has been amply demonstrated experimentally that, for the same pollution severity, the peak a.c. withstand voltage far exceeds the corresponding value under d.c. conditions. Arc-propagation across the insulator surface can take several cycles and, therefore, the arc is subject to an extinction and re-ignition process at around current zero.

A complicating feature is the breakdown of the air between neighbouring points of the insulator profile (e.g. between ribs or sheds) which reduces the flashover performance by shorting out some of the insulator surface. In addition, drops or streams of water may facilitate this reduction in performance.

The process is described below as encountered on hydrophilic surfaces, such as ceramic materials.

Phase 1: The insulator becomes coated with a layer of pollution. If the pollution is non-conductive (high resistance) when dry, some wetting process (phase 2) is necessary before flashover will occur.

Phase 2: The surface of the polluted insulator becomes wetted. The wetting of an insulator can occur in the following ways: by moisture absorption, condensation and precipitation. Heavy rain (precipitation) may wash away the electrolytic components of part or the entire pollution layer without initiating other phases in the breakdown process, or it may promote flashover by bridging the gaps between sheds. Moisture absorption occurs during periods of high relative humidity (>75%RH) when the temperature of the insulator and ambient air are the same [6,7]. Condensation occurs when the moisture in the air condenses on a surface whose temperature is lower than the dew point [6]. This condition usually occurs at sunrise or just before.

Phase 3: Once an energised insulator is covered with a conducting pollution layer, surface leakage currents flow and their heating effect starts within a few power frequency cycles to dry out parts of the pollution layer. This occurs where the current density is highest i.e. where the insulator is at its narrowest. These result in the formation of what are known as dry bands.

Phase 4: The pollution layer never dries uniformly, and in places the conducting path becomes broken by dry bands which interrupt the flow of leakage current.

Phase 5: The line-to-earth voltage appearing across dry bands (which may be only a few millimetres wide) causes air breakdown and the dry bands are bridged by arcs which are electrically in series with the resistance of the undried and conductive portion of the pollution layer. This causes a surge of leakage current each time the dry bands on an insulator spark over.

Phase 6: If the resistance of the undried part of the pollution layer is low enough, the arcs bridging the dry bands are sustained and will continue to extend along the insulator, bridging more and more of its surface. This in turn decreases the resistance in series with the arcs, increasing the current and permitting them to bridge even more of the insulator surface. Ultimately, it is completely bridged and a line-to-earth fault (flashover) is established.

One can summarise the whole process as an interaction between the insulator, pollutants, wetting conditions, and applied voltage (and source impedance in laboratory conditions).

The likelihood of flashover increases with higher leakage current, and it is mainly the surface layer resistance that determines the current magnitude. It can therefore be concluded that the surface layer resistance is the underlying factor determining whether an insulator will flash over or not, in terms of the above model.

Because pollution on the surface of a high-voltage insulator needs to become well wetted before it can cause a flashover to occur, it may seem somewhat puzzling – upon a cursory consideration – that pollution flashover can be a big problem in very dry areas such as deserts. The explanation often lies with the “thermal lag” at sunrise between the temperature of the surface of the insulator and the rapidly rising temperature of the ambient air. This difference in temperature need only be a few degrees centigrade for substantial condensation to take place, even at fairly low values of relative humidity [1]. The thermal capacity and thermal conductivity of the insulating material control the rate at which its surface warms up. –
From DAS, needs editing

More information on pollution flashover processes and models is available in CIGRE 158.


5.1.2. Instantaneous pollution

5.1.2.1. Conductive Fog

'Instantaneous pollution' refers to a contamination of high conductivity which quickly deposits on insulator surfaces, resulting in the condition where the insulator changes from an acceptably clean, low conductive state to flashover in a short (< 1 hour) time and then returns to a low conductive state when the event has passed.

For ease of understanding instantaneous pollution flashover the same process as described in section 5.1.1.6 applies. However, the instantaneous pollution is normally deposited as a highly conductive layer of liquid electrolyte, e.g. salt spray, salt fog or industrial acid fog, thus phases 3 to 6 above may happen immediately. In nature these phases are not distinct but they do merge. These only refer to hydrophilic surfaces. Areas most at risk are those situated close chemical plants, or areas close to the coast with a known history of temperature inversions.

5.1.2.2. Bird Streamer

A particular case of 'instant' pollution is bird streamer. This is a type of **bird excrement**,  which, on release, forms a continuous, highly (20-40 kΩ/m) conductive stream of such length that the air gap is sufficiently reduced to cause flashover. In this case, the insulator geometry and characteristics play little or no role [8].

5.2. A brief description of the pollution flashover mechanism on hydrophobic surfaces

Due to the dynamic nature of a hydrophobic surface and the resulting complex interaction with pollutants - both conducting and non-conducting - and wetting agents, there exists today no generally adopted model of pollution flashover for hydrophobic insulator surfaces. However, a qualitative picture for the pollution flashover mechanism is emerging which involves such elements as the migration of salt into water drops, water drop instability, formation of surface liquid filaments and discharge development between filaments or drops when the electric field is sufficiently high.

However, in service the hydrophobic materials are submitted to a dynamic process of pollution deposition, wetting, localised discharges or high electric field which can combine to cause parts or all of the surface to become temporarily more hydrophilic. Thus much of the physics of the flashover process of hydrophilic surfaces also applies, albeit locally or for limited periods of time, to nominally "hydrophobic" materials or surfaces.

6. Parameters and approaches for the insulator selection and dimensioning

The selection and dimensioning of outdoor insulators is an involved process; a large number of parameters must be considered for a successful result to be obtained. For a given site or project, the required inputs are in three categories: system requirements, environmental conditions of the site, and insulator parameters from manufacturer's catalogues. Each of these three categories contains a number of parameters as indicated in table 1 below. These parameters are further discussed in later chapters

Table 1 - Parameters for insulator selection and dimensioning

System requirements	Environmental Conditions	Insulator parameters
Application	Pollution level and types	Type
Withstand voltages	Rain, fog, dew, ...	Material
Reliability, availability, maintainability. (R.A.M.)	Wind	Profile
Costs	Temperature, humidity	Creepage
Installation position, clearance, ...	Altitude	Form factor (diameter)
	Lightning	Arcing distance
	Earthquakes	
	Vandalism	

To select suitable insulators from the catalogues based on the system requirements and the environmental conditions, three approaches (A, B, C, in figure 1 below) are recommended. The applicability of each approach depends on available data, time and economics involved in the project. The degree of confidence that the correct type and size of insulator has been selected varies also according to the decisions taken during the process. It is intended that if “shortcuts” have been taken in the selection process then the resulting solution will represent over-design rather than one with a high failure risk in service.

Figure 1 shows the data and decisions needed within each approach. **PLEASE STUDY AND COMMENT**

In reality, the pollution performance of the insulator is determined by the complicated and dynamic interactions among the environmental and the insulator parameters. Such interactions are well represented on an operating line or substation and can be represented in a test station. Such interactions can not be fully represented by laboratory tests, e.g. the tests specified in IEC 60507 and IEC 61245. In approach C, such interaction can only be represented in a limited degree by the correction factors. Approach C is simple and cheap for the dimensioning process but the whole costs, including the R.A.M requirements have to be considered when choosing among the three approaches. Whenever circumstances permit, the approach A should be adopted.

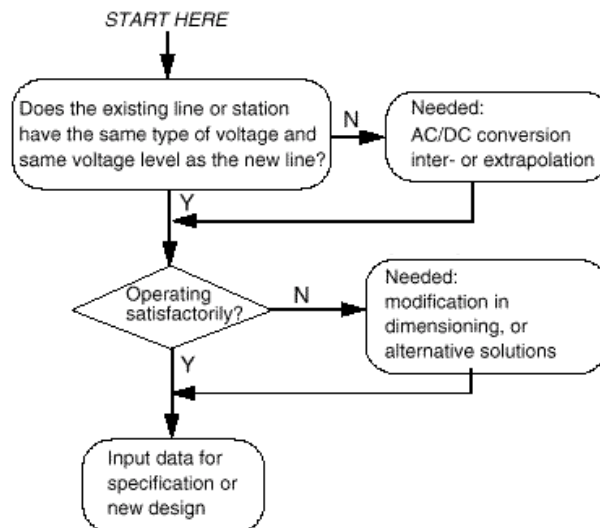
Figure 2b shows domains of preferred applicability of these approaches as a function of pollution severity and type.

		APPROACH A	APPROACH B	APPROACH C						
Input Data		<ul style="list-style-type: none">Use existing field or test station experience to chooseand size insulation for the same site, a nearby site or a site with similar conditions.	<ul style="list-style-type: none">Measure or estimate site pollution severity.Select candidate insulators using profile and creepage guidance hereafter.Choose applicable laboratory test and test criteria.Verify/adjust candidates	<ul style="list-style-type: none">Measure or estimate site pollution severity.Use this data to choose type and size of insulation based on profile and creepage guidance hereafter.						
		<ul style="list-style-type: none">System requirements.Environmental conditions.Insulator parameters.Performance history.	<ul style="list-style-type: none">System requirements.Environmental conditions.Insulator parameters.Time and resources available.	<ul style="list-style-type: none">System requirementsEnvironmental conditions.Insulator parameters.Time and resources available.						
		<ul style="list-style-type: none">Does the existing insulation satisfy the project requirements?	<ul style="list-style-type: none">Is there time to measure site pollution severity ?	<ul style="list-style-type: none">Is there time to measure site pollution severity ?						
Decisions		<table><tr><td>YES Use the same insulation.</td><td>NO Use different insulation or different size.</td></tr></table>	YES Use the same insulation.	NO Use different insulation or different size.	<table><tr><td>YES Measure</td><td>NO Estimate</td></tr></table>	YES Measure	NO Estimate	<table><tr><td>YES Measure</td><td>NO Estimate</td></tr></table>	YES Measure	NO Estimate
	YES Use the same insulation.	NO Use different insulation or different size.								
	YES Measure	NO Estimate								
YES Measure	NO Estimate									
	<ul style="list-style-type: none">Is a different material, type or profile to be used?	<ul style="list-style-type: none">Type of pollution determines the laboratory testSite severity determines the test values								
	<table><tr><td>NO Use the same insulation.</td><td>YES Use different insulation or different size.</td></tr></table>	NO Use the same insulation.	YES Use different insulation or different size.							
NO Use the same insulation.	YES Use different insulation or different size.									
Selection Process		<ul style="list-style-type: none">If necessary, use the profile and creepage guidance hereafter to adapt the parameters of the existing insulation to the new choice using approach B or C.	<ul style="list-style-type: none">Select candidatesTestAdjust selection/size according to the test results if necessary.	<ul style="list-style-type: none">Use the type of pollution and climate to select appropriate profiles using the guidance hereafter.Use the pollution level and profile factors to size the insulation using the guidance hereafter.						
Result		<ul style="list-style-type: none">A selection with high confidence of good performance.	<ul style="list-style-type: none">A qualified selection with confidence of good performance varying following the degree of errors and/or shortcuts in the site severity evaluation	<ul style="list-style-type: none">A possibly over-designed solution compared to A or BA selection with confidence of good performance varying following the degree of errors and/or shortcuts in the site severity evaluation						

Figure 1 - The three approaches to insulator selection and dimensioning

6.1.1. Approach A

To obtain the operational experience of the existing line or substation, an example of a questionnaire is given in Annex C. To utilise obtained information the flowchart below may be followed.



6.1.2. Approach B

To utilise the existing test results or to specify new laboratory tests (methods and test severity), the pollution level and type of the site should be obtained first. This subject is presented in 6. The information obtained from existing lines or test stations can also be used. For the laboratory test methods one can find them in corresponding IEC standards IEC 60507 (a.c.) and IEC 61245 (d.c.). Non-standard methods may be used, especially to represent specific or special cases of pollution.

6.1.3. Approach C

To obtain the pollution level the method given in X should be followed. The required minimum specific creepage distance and correction factors are given in chapter X.

7. Pollution Severity

CL & DAS find appropriate terms

7.1.1. Active pollution

Active pollution can itself be classified in two types :

- conductive pollution : metallic deposits, bird droppings, acid rain, salt fog ...
- soluble pollution : wind-borne dry salt deposit from the sea, salt contained in desert sand, gypsum coming from the ground or quarries, cement, fly ash, chemical pollution due to industrial activity or use of fertilisers and treatments in agriculture ...

The global conductance of the pollution layer is the principal element in the severity level. In the case of soluble salts, the global conductance depends on the amount of pollution in a dissolved state and therefore on the amount of water spread on the insulator surface.

Two salt characteristics, the solubility and the time to dissolve, are important (see table 2).

For example, the more the pollution is soluble and fast dissolving, the less the pollution layer needs water (rain, fog...) and time to form a highly conductive layer. On the other hand, this type of pollution is generally easily leached or washed away by natural wetting events.

For a same severity level, the insulator withstand voltage will then depend on the salt properties and on the wetting process characteristics.

In Figure 2 active pollution is characterised by means of the ESDD value. For soluble pollution, these values are given for a completely dissolved state.

PARA by CE to cover risk under heavy wetting etc.

Table 2 - Classification of salts according to their solution properties

	Low solubility salts	High solubility salts
Fast dissolving salts		MgCl ₂ , NaCl, CaCl ₂ , KCl
Slow dissolving salts	MgSO ₄ , Na ₂ SO ₄ , CaSO ₄	NaNO ₃ , Ca(NO ₃) ₂ , ZnCl ₂

7.1.2. Inert pollution

This type of pollution is not conductive but can indirectly influence the withstand voltage of an insulator.

If the material constituting inert pollution is hydrophilic, as for example kaolin and tonoko used in artificial pollution tests, water does stay in the shape of droplets but forms a film. In addition, a thicker water film is retained on the insulator surface. During wetting periods, more soluble salts are dissolved in a continuous film of solution and therefore the global conductance is higher.

In addition, heavy or frequent deposits of non-soluble pollution onto hydrophobic materials can mask the hydrophobic properties of the material. However, for many hydrophobic rubbers the hydrophobic properties of the material transfer to the surface of the pollution layer thus restoring the flashover performance.

In Figure 2 inert pollution is characterised at means of the NSDD value.

7.1.3. Evaluation of pollution severity

Need same for marine CE & WP

The application of this guide is directly related to the knowledge of the pollution severity of the site where the insulators are to be installed.

The evaluation of the pollution severity can be made with a decreasing degree of confidence :

- from measurements in situ.
- from information on the behaviour of insulators from lines and substations already in service on or close to the site (see Annex Y),

If not otherwise possible qualitatively from indications given in Table 3,

For measurements in situ, different methods are generally used. They are :

- either,
 - ESDD and NSDD on the insulator surface of reference standard insulators (see annex B) for “pre-deposit”;
- or
 - SES from on site current/surface conductance of reference standard insulators for marine;
- volume conductivity and sediment analysis for the pollutant collected by means of directional gauges (see annex A);
- total number of flashovers of insulators of various lengths;
- leakage current of sample insulators.

The first three methods do not require expensive equipment and can be easily performed. The volume conductivity method gives no direct information by itself on the frequency and on the severity of the contamination events on a natural site. The ESDD/NSDD method characterises the pollution severity of the site. Information on wetting shall be separately obtained.

The accuracy of all these methods depends upon the frequency of measurement and the duration of the study.

For other pollution environments, such as for sites close to industries where pollution deposit is regular, weekly or monthly measurements could be sufficient.

The method based on total flashovers needs expensive test facilities. Reliable information can be obtained only for insulators having a length close to the actual length and flashing over at a voltage near the operating voltage.

The last two methods which need a power source and special recording equipment have the advantage that the effects of pollution are continuously monitored. These techniques have been developed for assessing the pollution rate and the results, when related to test data, are used to indicate that the pollution is still at a level known to be safe for operational service or whether washing or re-greasing is required.

In any case where measurements are carried out on standard profile insulators it can be very useful to include insulators with other profiles and orientations in order to determine the influence of self-cleaning and deposit mechanism for the site under study. This information can then be used to refine the choice of an appropriate profile.

Pollution events are often seasonal and related to the climate, therefore the measurement period has to last at least one year. Longer periods may be necessary to take exceptional pollution events into account or to identify trends. Equally it may be necessary to measure over at least three years for arid areas.

7.2. Pollution severity levels

For the purposes of standardisation, five levels of pollution characterising the site severity are qualitatively defined, from very light pollution to very heavy pollution.

Table 3 gives, for each level of pollution, an approximate description of some typical corresponding environments. The list of environments is not exhaustive and the descriptions should preferably not be used alone to determine the severity level of a site.

Figure 2 gives ranges of ESDD/NSDD values for standard cap and pin insulators. These values are deduced from field measurements, experience and pollution tests. The values are

the maximum values that can be found from regular measurements taken over a minimum one year period.

Some insulator characteristics, for example profile, have an important influence on the pollution quantity deposited on insulators themselves. Therefore, these typical values are only available for standard glass or ceramic cap and pin insulators.

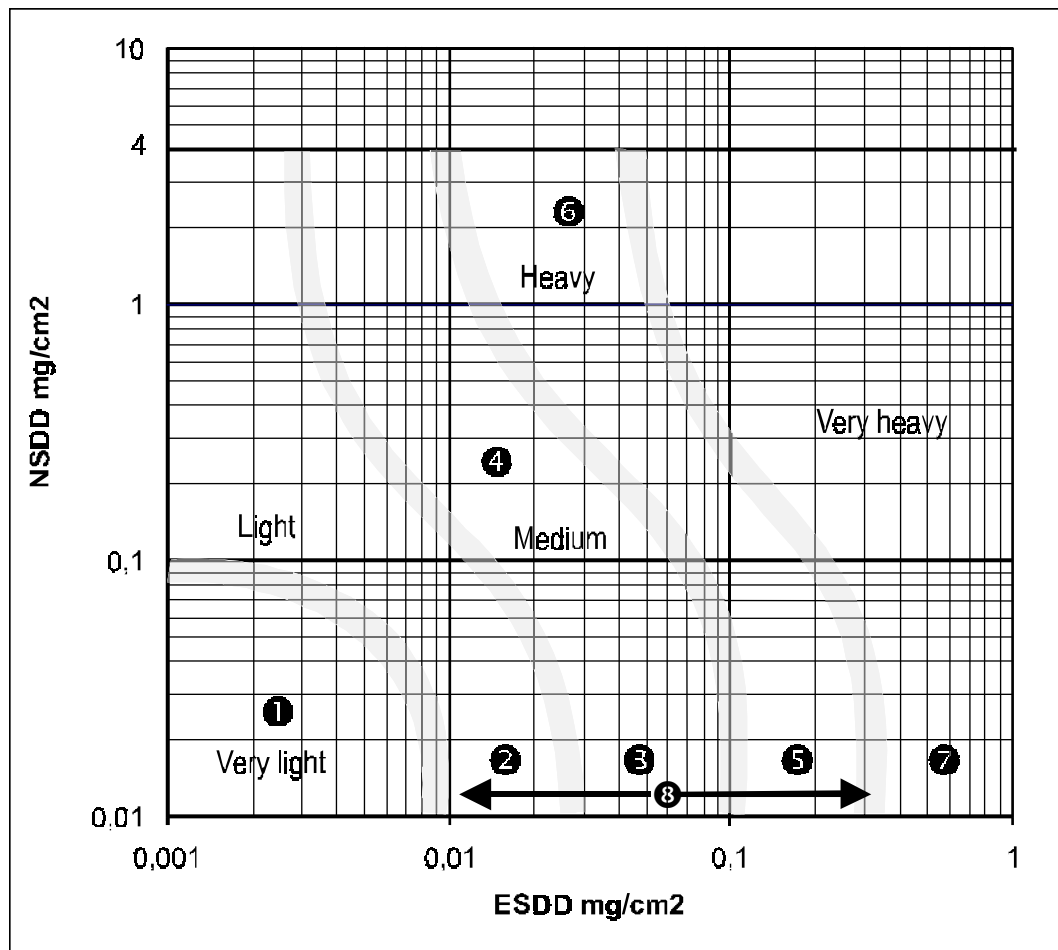


Figure 2 - Relation between ESDD/NSDD and site severity for standard profile cap and pin insulators.

Figure promised by Germany

Figure 2a - Relation between ESDD/NSDD and site severity for standard profile long rod insulators.

Table 3 - Examples of typical environments

Site severity	Examples of typical environments
Very Light ①	> 50 km ^I from the sea, a desert, or open dry land > 10 km from man-made pollution sources ^{II} Within a shorter distance than mentioned above of pollution sources, but: <ul style="list-style-type: none"> • prevailing wind not directly from these pollution sources • and/or with regular monthly rain washing
Light ②	10-50 km ^I from the sea, a desert, or open dry land 5-10 km from man-made pollution sources ^{II} Within a shorter distance than mentioned above of pollution sources, but: <ul style="list-style-type: none"> • prevailing wind not directly from these pollution sources • and/or with regular monthly rain washing
Medium ③	3-10 km ^{III} from the sea, a desert, or open dry land 1-5 km from man-made pollution sources ^{II} Within a shorter distance than mentioned above of pollution sources, but: <ul style="list-style-type: none"> • prevailing wind not directly from these pollution sources • and/or with regular monthly rain washing
④	Further away from pollution sources than mentioned above (distance in the range specified for “Light” areas) but: <ul style="list-style-type: none"> • dense fog (or drizzle) often occurs after a long (several weeks or months) dry pollution accumulation season • and/or the present heavy rain with high conductivity • and/or there is a high NSDD level, between 5 and 10 times the ESDD
Heavy ⑤	Within 3 km ^{IV} of the sea, a desert, or open dry land Within 1 km of man-made pollution sources ^{II}
⑥	With a longer distance from pollution sources than mentioned above (distance in the range specified for “Medium” areas) but: <ul style="list-style-type: none"> • dense fog (or drizzle) often occurs after a long (several weeks or months) dry pollution accumulation season • and/or the present heavy rain with high conductivity • and/or there is a high NSDD level, between 5 and 10 times the ESDD
Very heavy ⑦	Within the same distance of pollution sources as specified for “Heavy” areas and: <ul style="list-style-type: none"> • directly subjected to sea-spray or dense saline fog • or directly subjected to contaminants with high conductivity, or cement type dust with high density, and with frequent wetting by fog or drizzle Desert areas with fast accumulation of sand and salt, and regular condensation
Light to heavy ⑧	Within 3 km ^{IV} of the sea, Within 1 km of man-made pollution sources ^{II} Associated with the possibility of heavy sea-fog and/or industrial particulate fog.

I. during a storm, the ESDD level at such a distance from the sea may reach a much higher level.

II. the presence of a major city will have an influence over a longer distance, i.e. the distance specified for sea, desert and dry land.

III. depending on the topography of the coastal area and the wind intensity

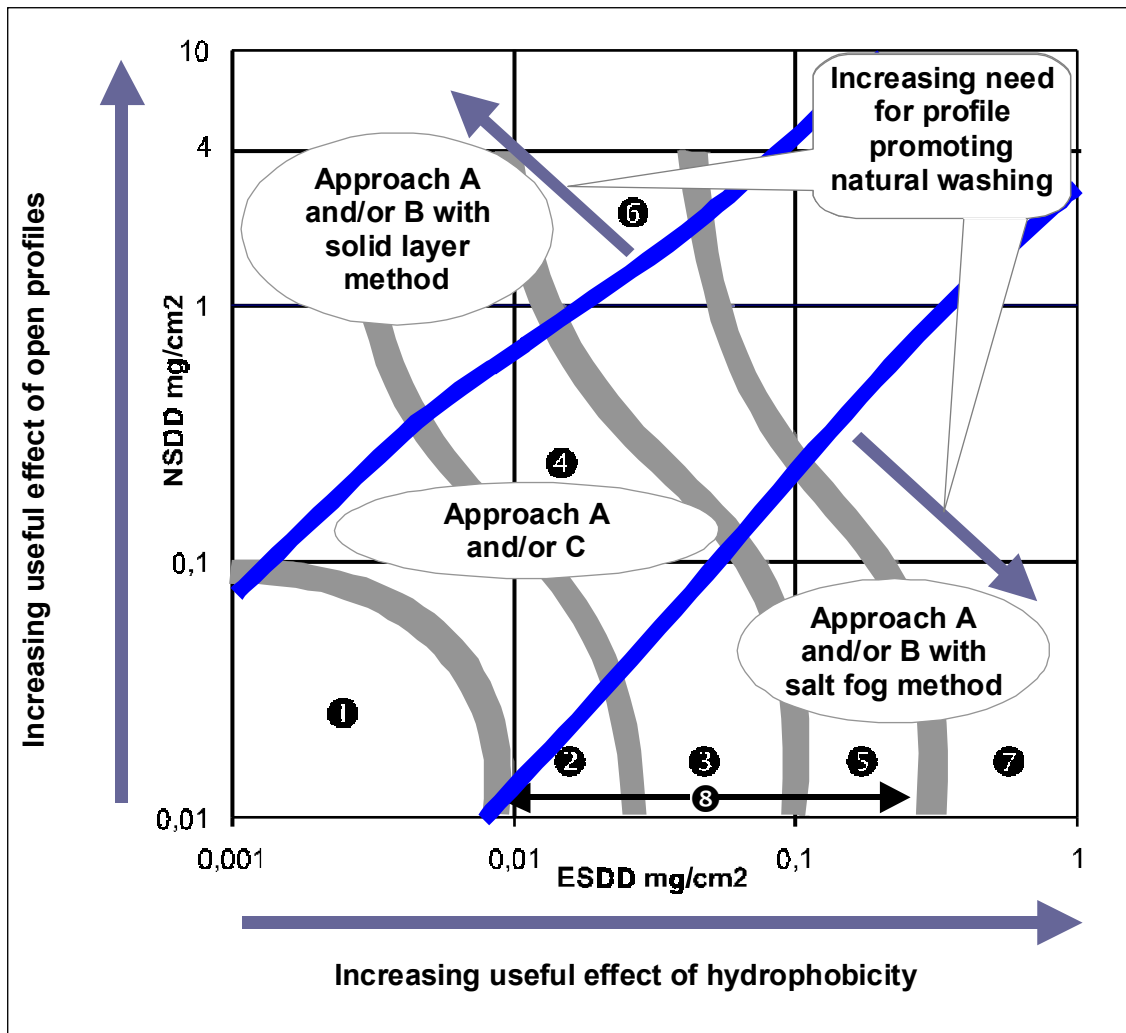


Figure 2b – Trends in applicability of approaches and profiles.

8. System requirements

Besides the information on the environmental conditions, system requirements have also to be taken into account for the selection and dimensioning of outdoor insulation. The following points may strongly influence insulator dimensioning and therefore need, to be considered.

- Type of system (a.c. or d.c.)

It is well known from service experiences and from laboratory test results, that a d.c. insulation requires a much higher value of specific creepage distance compared to a.c. insulation for the same site conditions. This effect is dealt with in detail in parts 2 to 5.

- Maximum operating voltage across the insulation

Usually an a.c.-system is characterised by the voltage U_m , which is the highest r.m.s. phase-to-phase voltage for which an equipment is designed in respect of its insulation. U_m is the maximum value of the highest voltage of the system for which the equipment may be used (IEC 60071-1, 1976, Clause 4).

Line-to-earth insulation is stressed with the line-to-earth voltage $U_{l-e} = U_m/\sqrt{3}$.

Phase-to-phase insulation is stressed with the phase-to-phase voltage $U_{ph-ph} = U_m$ [IEC 60071-1, Clause 7.5].

In the case of a d.c.-system usually the maximum system voltage is equal to the maximum line-to-earth voltage stressing the line-to-earth insulation.

The maximum operating voltage across an insulator requires a minimum arcing. In contrast insulation co-ordination may require also a maximum arcing distance [IEC 60071-1, Clause xx].

- **Overvoltages**

Lightning and switching overvoltages need not be considered due to their short duration.

Temporary overvoltages (TOV) may occur due to a sudden load release of generators and lines or line-to-earth faults. The duration of the TOV depends on the structure of the system and can last for less than 2 seconds to half a hour or even more in the case of a grounded neutral system. See IEC 60071-2 for more information on the definition of TOV and CIGRE 158 for information their influence.

Depending on the duration of the TOV and its probability of occurrence the TOV may have to be considered.

- **Reliability, availability, maintainability (RAM)**

Some customers may request performance guarantees for the outdoor insulation, i. e. the numbers of pollution flashovers allowed per station or per 100 km line length in a given time period. These requirements may also include a maximum outage time after a flashover.

Besides the insulator dimensioning according to the site conditions, these demands could become a controlling factor for the choice of insulator parameters.

- **Clearances, imposed geometry, dimensions**

There could be several cases, or a combination thereof, where special solutions for insulation dimensioning are required.

Examples are:

- compact lines;
- unusual position of an insulator;
- unusual design of towers and substations;
- requirement for a low visual impact.

9. Insulator Characteristics

(All to be completed at the next WG meeting)

9.1. Materials

9.1.1. Glass

9.1.2. Porcelain

9.1.3. Porcelain with Semi-conducting Glaze

9.1.4. Polymers

9.1.5. Hybrids

Hybrid insulators as known today, consist of a shank of porcelain and a polymer housing. They are not common in service.

9.1.6. Hydrophobic Coatings

Ceramic insulators can be coated with a polymer layer thereby creating a hydrophobic surface.

9.2. Design

9.2.1. Line Insulators

9.2.2. Post Insulators

9.2.3. Hollow insulators

9.2.4. Profile Design

9.2.4.1. Purpose

The principal purpose of insulator surface profile is to extend the distance for a leakage current travelling on the polluted surface. In order to avoid local flashover which can damage the insulator or lead to total flashover, there are different important factors.

10. Creepage Distance and Form Factor

(All to be completed at the next WG meeting)

10.1.1.1. Form Factor

10.1.1.2. Minimum distance c between sheds.

10.1.1.3. Diameter(s)

10.1.1.4. Ratio s/p between spacing and shed overhang

10.1.1.5. Ratio ld/d between creepage distance and clearance

10.1.1.6. Alternating sheds

10.1.1.7. Inclination of sheds

10.1.1.8. Creepage factor

10.1.1.9. Profile factor

10.1.1.10. Orientation

10.1.1.11. Non-linearity (overall length)

11. Insulation selection and dimensioning

This clause will describe the general principles of how to use parts 2 to 5 for insulator selection and dimensioning, i.e.

determination of minimum creepage distance for candidate insulators,

correction for profile, design and material,

specific considerations for a given type/design/material,

Renard58 ,

considerations for exceptional or specific environments or applications.

R. Martin contribution

DAS – needs editing

In Tunisia, flashover problems with ceramic insulators still occur in some areas in spite of them having a specific creepage path of 52 mm/kV system [2]. Soil analysis has shown that local desert sand in this country contains calcium and sodium salts, which are blown on to the insulator's surface to produce a pollution severity of ESDD as great as 0.65 mg/cm squared. A semiconducting glaze provides a continuous flow of current – of about 1 mA – which helps to keep it dry in such conditions. As yet, I know of no publication that provides a definitive conclusion on the pollution flashover performance of polymeric insulators in such arid environments.

Annex A : Directional Dust Deposit Gauge Measurements

A.1 Introduction

Four dust gauges, each gauge set to one of the four cardinal points of the compass, are used to collect the pollution particles carried in the atmosphere. The pollution is collected in the four plastic containers attached to the bottom of the gauges. At monthly intervals these containers are removed and the contents collected is mixed with 500 ml of distilled water. The conductivity of this solution is measured and the pollution index is defined as the mean of the conductivities of the four gauges expressed in $\mu\text{S}/\text{cm}$ and normalised to a 30-day interval.

The advantage of this technique is its simplicity and the fact that it can be used at an unenergised site without insulators or facilities other than those required for the mounting of the gauges.

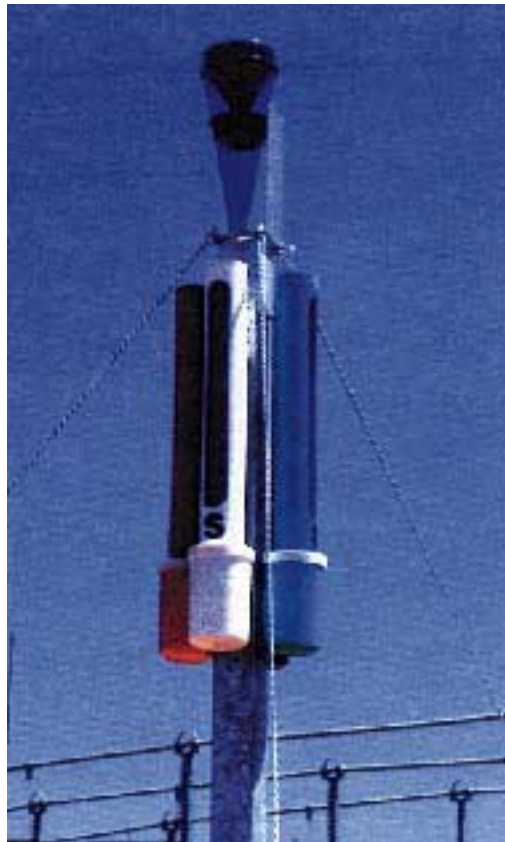


Figure A1: Directional Dust Deposit Gauges (Note: the rain gauge is an optional extra, used if the monthly rainfall at that site needs to be measured.)

The nominal dimensions are a 40mm wide slot with 20mm radii at each end. The distance between the centres of the radii is 351mm. (The overall slot length thus being 391mm). The tube is at 500mm long with 75mm outside diameter. Distance from the top of the tube to the top of the slot is 30mm. The tubes should be mounted with the bottom of the slot approximately 3 metres from the ground. This just keeps the gauge out of reach of casual tampering but the jars can be easily and safely changed.

Its major disadvantage is that actual insulators are not used and therefore it is not possible to assess the self-cleaning properties of insulators and the effect of the shed profile on the deposition process on the insulator surface. In areas of high rainfall, a higher index can be tolerated, whereas in areas of low rainfall but with a high occurrence of fog, the actual severity is higher than that indicated by the gauges.

A.2 Test equipment

- **Clip board, pencil and paper:** To record raw data results.
- **Portable ladder:** 2.5 metre ladder to reach dust containers.
- **Spray Bottle:** To spray residual pollutants from each dust gauge cylinders into container, using distilled water.
- **Measuring Cylinder:** To measure 500 ml distilled water to be poured into each container.
- **Distilled water:** Average 3 litres of water per set of containers. Volume conductivity should not exceed 5µS/cm.
- **Portable conductivity meter:** Values are given in µS/cm and are usually compensated to 20°C. If meter (e.g. Greisinger GLM 020) is not compensated to 20°C, specify conductivity and temperature readings in report.
- **Temperature probe:** Used to measure temperature of dust gauge solution if conductivity meter is not compensated to 20°C.
- **Tap water:** Used to clean vertical slots and containers after measurements have been taken.
- **Paper towels:** Used if additional cleaning is necessary.
- **Thick, black waterproof marker pen:** Used to mark location and date of testing on containers.
- **Extra set of containers:** If containers are taken back to the laboratory, a replacement set is needed, otherwise the current set is cleaned and replaced onto the dust gauge cylinders after measurements have been taken.

A.3 Test procedure

- The gauge slots to which the containers are connected must be sprayed with a little distilled water so that any residual pollutants in each dust gauge cylinder rinses into its container. This prevents any deposit build up from previous months washing into the container when rain occurs.
- Remove the four containers from the slots facing the four dominant wind directions, noting the date of instalment on the data result sheet
- Pour 500 ml of distilled water into each container and swirl contents to ensure that the soluble deposits are totally dissolved.
- Measure the conductivity of the distilled water as well as its temperature, if meter is not compensated to 20°C
- Measure the volume conductivity of the solution in the containers with the hand-held probe and record results.
- Record the number of days since the previous test measurement. The time interval should not be less than 20 days nor more than 40 days
- Wash and clean vertical slots and containers after measurements have been taken, with tap water and install clean containers to dust gauges. Write the date on the containers with black waterproof marker pen.

Annex B : Measurement of ESDD and NSDD

B.1 Introduction

When anti-pollution design of the insulator is made, it is indispensable to determine pollution degree. The pollution degree is generally determined by measuring equivalent salt deposit density (ESDD) on the insulators which are removed from the existing transmission lines and/or field testing stations. In addition to ESDD, non-soluble material deposit density (NSDD) should be measured, especially in case that much dust or sand is estimated to accumulate on the insulator surface in such an area as desert or industrial factories. This Appendix describes how to measure ESDD and NSDD, and how to make chemical analysis of the pollutants.

The equivalent salt deposit density (ESDD) is the equivalent deposit of NaCl in mg/cm² of the surface area of an insulator, which will have an electrical conductivity equal to that of the actual deposit dissolved in the same amount of water.

The general technique for measurements of ESDD involves dissolving the surface deposits in a known quantity of water with a low conductivity, measuring the temperature of the solution and calculating the ESDD from the measured conductivity, the volume of water and the insulator surface area.

One of the important advantages of this technique is that it can be carried out on actual insulators, and the self-cleaning properties and shed profile performance can be assessed.

For site pollution severity measurement purposes we standardise the measurements by using a string of 7 glass cap and pin insulators (U120BS). The unenergized insulator string is located at a height as close as possible to that of the line or busbar insulators. Each disc of the insulator string is monitored at a defined interval e.g. every month, every three months, every six months, every year, after two years, etc.

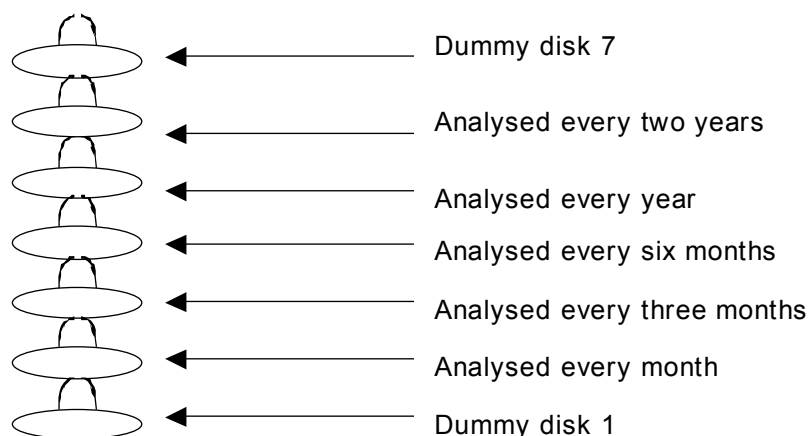


Figure B1: ESDD string

B.2 Measuring ESDD (Vosloo)

Test equipment

- **Measuring Cylinder:** To measure distilled water used for each insulator.
- **Distilled water:** Two litres of water per insulator. Volume conductivity should not exceed 5µS/cm. Take extra 2 litres along in case of spillage, etc.
- **Portable conductivity meter:** Values are given in µS/cm and are usually compensated to 20°C. If meter (e.g. Greisinger GLM 020) is not compensated to 20°C, specify conductivity and temperature readings in report.
- **Temperature probe:** Used to measure temperature of salt solution if conductivity meter is not compensated to 20°C.
- **Washing bowl:** The bowl should be large enough to hold an insulator. Preferably made of perspex or plastic.
- **Surgical gloves:** To ensure that no additional contaminants are added when washing insulator with hands. If not available, ensure that hands are thoroughly cleaned.
- **Tin foil or Plastic wrap:** Used to cover cap and pin of insulator prior to washing.
- **Tap water:** Used to clean bowl and wash gloves after measurements have been taken.
- **Paper towels:** Used to dry or clean bowl if necessary.
- **Thick, black waterproof marker pen:** Used to mark location, date of testing and insulator details on containers.
- **Set of containers:** Two containers per insulator. Wash water should be poured into the containers (top and bottom surfaces separately) and then measured.

Test procedure

- The unenergized string consists of seven discs as shown in the figure. The two end discs are excluded from the test - only 2, 3, 4, 5 and 6 are tested.
- The glass surfaces of the discs should not be touched to avoid any loss of pollution.
- Cover the cap and pin respectively with tin foil without covering the glass surface.
- Ensure that the bowl, which the discs are to be washed in, is clean. Clean rubber gloves (scientific) or thoroughly washed hands are a prerequisite to perform these tests.
- Measure down one litre of distilled water (1 - 5µS/cm) and pour into bowl.
- Place the test insulator on its foil-covered cap in the water and wash the top surface with gentle hand strokes without any wash water wetting the bottom surface (ribbed profile).
- After top surface has been washed, gently shake off any remaining water on the tin foil, remove insulator from bowl and pour water into a container. Take care that all deposits are removed from bowl.
- Rinse bowl before the commencement of next test.
- Measure down one litre of distilled water (1 - 2µS/cm) and pour into bowl.
- Place the same insulator as mentioned above on its cap in the bowl and gently wash pollution off the bottom surface (ribbed profile) with your hands.
- Pour water in second container taking care again that no deposits remain in the bowl.
- Swirl water content in containers to ensure that salts are totally dissolved prior to measuring.
- Use the hand-held conductivity probe to measure the volume conductivity (µ/cm).
- Disc 2 is tested monthly, disc 3 every three months, disc 4 every six months, disc 5 at the end of each year and disc 6 at the end of two years. Disc 1 and 7 are dummy discs used to ensure that the aerodynamic profile is maintained over discs 2 and 6.

NON SOLUBLE DEPOSIT DENSITY (NSDD)

This is basically a continuation of the ESDD tests whereby the non-soluble deposits (from the measured ESDD solution) are filtered and weighed using standard filter paper. The dry filter paper is weighed before and after the solution has been filtered through it in order to determine the weight of the non-soluble residue left behind (NSDD)

B.3 Necessary equipment to measure pollution degree (Suzuki)

The following equipment is necessary for measurement of both ESDD and NSDD.

- Conductivity meter
- Beaker/bottle
- Measuring cylinder
- Absorbent cotton/brush/sponge
- Filter paper
- Funnel
- Desiccator
- Balance
- Distilled water/demineralized water
- Gloves

Typical examples of measuring tools are shown in Table 1.

Portable tools such as a small bottle instead of a beaker are recommendable for in-situ measurement in the field.

Table 1 Typical examples of measuring tools

Tools	Item	Specifications
Conductivity meter	Measuring range	$1 \times 10^{-4} \text{ S/m} - 2 \text{ S/m}$
	Accuracy of conductivity	$\pm 2\%$
	Resolution of temperature	0.1°
Balance	Measuring range	0g - 60g
	Resolution	0,001g

B.4 Measuring ESDD (Suzuki)

B.4.1 Measuring procedure

For simple description, absorbent cotton, a beaker and distilled water are mentioned in the following procedures. In practice, other tools such as a brush or a sponge, demineralized water and a bottle can be used instead of absorbent cotton, distilled water and a beaker, respectively.

- a) A beaker, a measuring cylinder, etc. shall be washed well enough to remove electrolyte prior to the measurement. Gloved hands also shall be washed clean.
- b) Distilled water of 100-300 cm³ or more shall be put into a beaker and absorbent cotton shall be immersed into water. The conductivity of water with the immersed cotton shall be less than 0.001 S/m.
- c) The pollutants shall be wiped off separately from the top and the bottom surfaces of a cap and pin type insulator with the squeezed cotton. In the case of a long-rod or a post insulator, pollutants shall usually be collected from a part of the shed as shown in Fig.1.
- d) The cotton with pollutants shall be put back into the beaker as shown in Fig. 1. The pollutants shall be dissolved into the water by shaking and squeezing the cotton in the water.

- e) Wiping shall be repeated until no further pollutants remain on the insulator surface. If pollutants remain even after several wipings, pollutants shall be removed by a spatula, and be put into the water containing pollutants.
- f) Attention shall be taken not to lose the water. That is, the quantity shall not be changed very much before and after collecting pollutants.
- g) The conductivity of the water containing the pollutants shall be measured with a conductivity meter; at the same time the temperature of the water shall be measured. The measurements are made after enough stirring of the water. A short stirring time, e.g., a few minutes, is required for the high solubility pollutants. The low solubility pollutants generally require longer stirring time, e.g., 30-40 minutes.

NOTES: -

- 1) Careful attention should be paid to the specimen insulators, not touching the insulator surface until measurement starts.
- 2) For a close ESDD measurement in the range of 0.001 mg/cm², it is recommended to use very low conductivity water, e.g., less than a few 10⁻⁴ S/m. Normal distilled/demineralized water less than 0.001 S/m also can be used for this purpose by subtracting the equivalent salt amount of the water itself from the measured equivalent salt amount of the water containing pollutants.
- 3) Quantity of the distilled/demineralized water depends on kind and amount of pollutants. Large quantity of water is recommended for measurements of very heavy pollution or low solubility pollutants. In practice, 2-10 litres of water per m² of the cleaned surface can be used. In order to avoid underestimating the amount of pollutants, the quantity of the water would be so increased to have the conductivity less than around 0.2 S/m. If very high conductivity is measured, there might be some doubt of remaining pollutants not dissolved due to small amount of water.
- 4) Stirring time before conductivity measurement depends on kind of pollutants. For low solubility pollutants, conductivity is measured at some interval with time up to about 30-40 minutes and is determined when the measured values level off. To dissolve pollutants quickly, special methods such as boiling method and ultrasonic method can also be used.

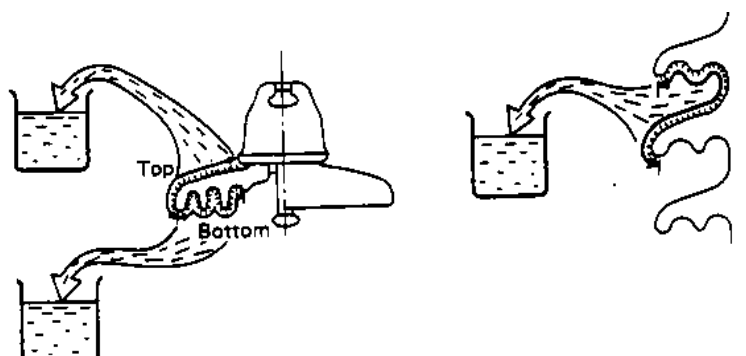


Fig. A1 Wiping of pollutants on insulator surface

B.4.2 Calculation of ESDD

The conductivity and the temperature of the water containing the pollutants shall be measured.

The conductivity correction shall be made using the formula (1). This calculation is based on Clause 16.2 and Clause 7 of IEC Standard 60507.

$$\sigma_{20} = \sigma_{\theta} [1 - b(\theta - 20)] \text{ -----(1)}$$

where:

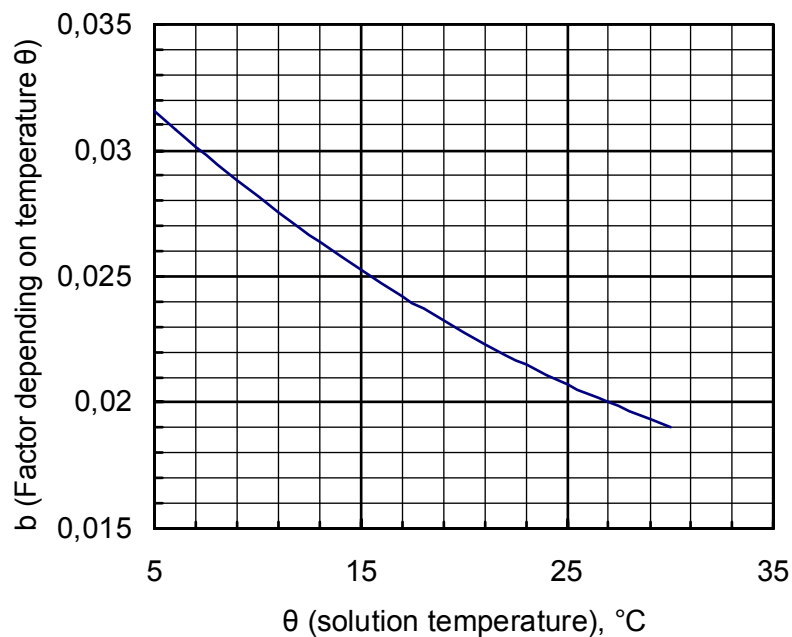
θ is the solution temperature (°C).

σ_{θ} is the volume conductivity at temperature of $\theta^{\circ}\text{C}$ (S/m).

σ_{20} is the volume conductivity at temperature of 20°C (S/m).

b is the factor depending on the temperature θ , as obtained by the formula (2), and as shown in Fig. 2.

$$b = -3.200 \times 10^{-8} \theta^3 + 1.032 \times 10^{-5} \theta^2 - 8.272 \times 10^{-4} \theta + 3.544 \times 10^{-2} \text{ --(2)}$$

**Fig.A2 – Value of b**

The ESDD on the insulator surface shall be calculated by the formulas (3) and (4). This calculation is based on Clause 16.2 of IEC Standard 60507. Relation between σ_{20} and Sa (Salinity, kg/m³) is shown in Fig.3.

$$Sa = (5.7\sigma_{20})^{1.03} \text{-----(3)}$$

$$ESDD = Sa \times V / A \text{-----(4)}$$

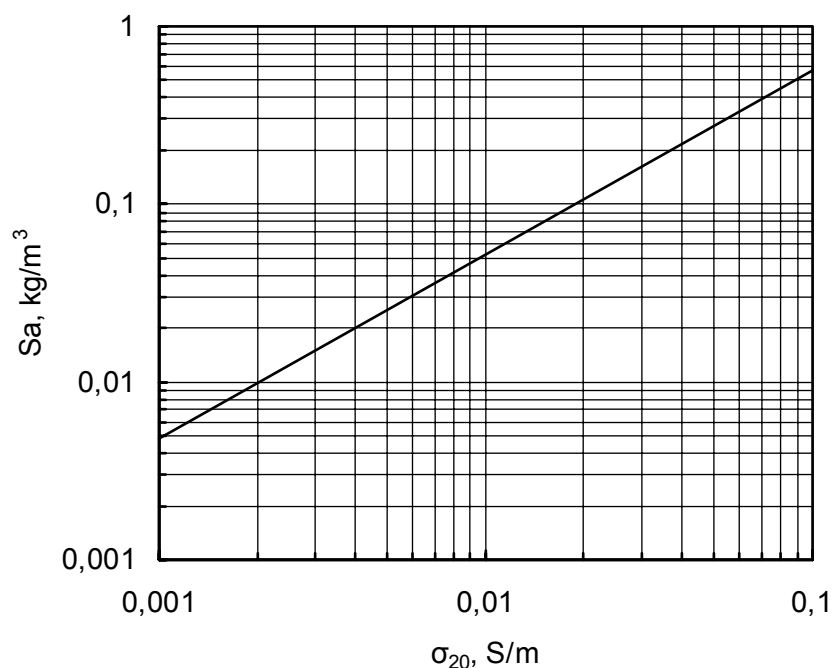
where:

σ_{20} is the volume conductivity at temperature of 20°C (S/m).

ESDD is Equivalent salt deposit density (mg/cm²).

V is the volume of distilled water (cm³).

A is the area of the insulator surface for collecting pollutants (cm²).

Fig.A3 Relation between σ_{20} and S_a

B.5 Measuring NSDD

The water containing pollutants after measuring ESDD shall be filtered out by funnel and filter paper.

The filter paper containing pollutants shall be dried, and then be weighed together with residuum of pollutants as shown in Fig.4.

The NSDD shall be calculated by the formula (5).

$$\text{NSDD} = 1000(W_f - W_i)/A \text{-----(5)}$$

where:

NSDD is non-soluble material deposit density (mg/cm^2).

W_f is the weight of the filter paper containing pollutants under dry condition (g).

W_i is the initial weight of the filter paper under dry condition (g).

A is the area of the insulator surface for collecting pollutants (cm^2).

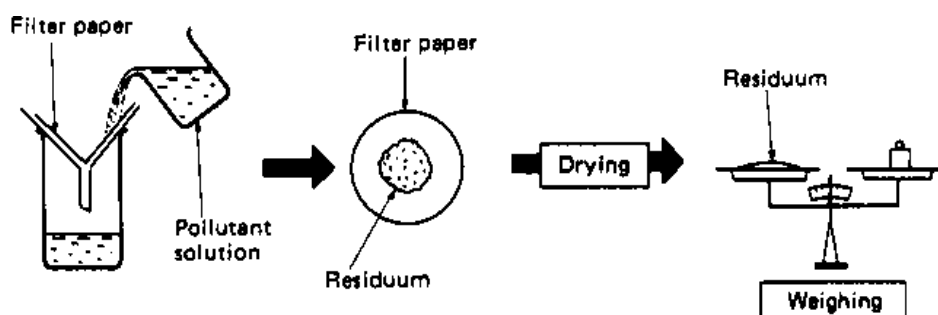


Fig. A4 - Procedure of measuring NSDD

Note: A quantitative chemical analysis can be made on pollutant solution and residuum after the measurement to identify chemical components of the pollutants. The analysis results can be useful for close examination of pollution conditions.

Annex C - Informative References

- 1 CIGRE Taskforce 33.13.01 - Polluted insulators: A review of current knowledge, CIGRE brochure N° 158-2000
- 2 CIGRE Taskforce 33.13.01 - Polluted insulators: Application guidelines, CIGRE brochure N° ???-2000
- 3 CIGRE Taskforce 33.13.07 - Influence of snow and ice...Electra April 2000

Annex D - Example of a questionnaire to collect information on the behaviour of insulators in polluted areas

The existing questionnaire of IEC 60815 will be included here, possibly with some minor revision/modification.

Annex E - Site severity measurement protocol

The relevant part of CIGRE 33.13 TF03 site severity measurement protocol (33-93_TF04-03_5IWD) will be inserted here, this will include recommendations for meteorological data.
