CONTENTS

FOREWORD ........................................................................................................................................4
Introduction from the Project Leader (to be deleted in the final text) ...........................................6

Scope and object ..................................................................................................................................7
Normative references ...........................................................................................................................8
Definitions ............................................................................................................................................8
Abbreviations .....................................................................................................................................10
Proposed approaches for the selection and dimensioning of an insulator ....................................10
Input parameters for the selection and dimensioning of insulators ................................................12
System requirements .........................................................................................................................12

Environmental conditions ..............................................................................................................13
Identification of types of pollution ....................................................................................................13
Type A pollution ...............................................................................................................................14
Type B pollution ...............................................................................................................................14
General types of environments ........................................................................................................14
Pollution Severity .............................................................................................................................14

Evaluation of site pollution severity ............................................................................................15
Site pollution severity ......................................................................................................................15
Site pollution severity evaluation methods .......................................................................................16
Site pollution severity (SPS) classes ...............................................................................................17

Insulation selection and dimensioning ..........................................................................................20
General description of the process ....................................................................................................20
General guidance on materials ..........................................................................................................21
General guidance on profiles ...........................................................................................................21
Considerations for exceptional or specific applications or environments .......................................22
Hollow core insulators .....................................................................................................................22
Arid areas ........................................................................................................................................23
Proximity effects .............................................................................................................................23
Orientation .......................................................................................................................................23
Maintenance and palliative methods .................................................................................................24

Flowchart representation of the design approaches .........................................................................25

Pollution Flashover mechanisms ....................................................................................................28
Description of the pollution flashover mechanism under type A pollution ....................................28
Description of the pollution flashover mechanism under type B pollution ....................................29
Conductive Fog ................................................................................................................................29
Bird Streamers ...............................................................................................................................29

The pollution flashover mechanism on hydrophobic surfaces .......................................................30

Measurement of ESDD and NSDD ....................................................................................................31
Introduction .......................................................................................................................................31
Necessary equipment to measure pollution degree ........................................................................32
Pollution collection methods for ESDD and NSDD measurement ..................................................32
Procedure using a swab technique ..................................................................................................32
Procedure using washing technique (cap and pin insulators) .........................................................33
C.4 Determining ESDD and NSDD .................................................................33
   C.4.1 ESDD calculations .................................................................33
   C.4.2 NSDD calculations .................................................................35
C.5 Chemical analysis of pollutants ...........................................................................36
Annex D Evaluation of Type B pollution severity .........................................................37
   D.1 Introduction ..............................................................................37
   D.2 Evaluation of SES for type B pollution by leakage current measurement ..........37
      D.2.1 Measurement of surface conductance ..................................37
      D.2.2 Measurement of surface leakage currents ..........................37
      D.2.3 Calibration by a salt-fog test ..............................................37
   D.3 Evaluation of SES for type B pollution by measurement of insulator flashover stress ...........................................................................37
   D.4 How to estimate SPS for type B pollution ........................................38
Annex E Directional Dust Deposit Gauge Measurements ............................................39
   E.1 Introduction ..............................................................................39
   E.2 Measurement procedure ..........................................................40
   E.3 Determination of the SPS class from the DDDG measurements ...............41
   E.4 Correction for climatic influences ............................................41
Annex F Use of laboratory test methods .................................................................43
Annex G Deterministic and statistical approaches for artificial pollution test severity and acceptance criteria .................................................................44
   G.1 Deterministic approach ............................................................44
   G.2 Statistical approach .................................................................44
Annex H Example of a questionnaire to collect information on the behaviour of insulators in polluted areas .................................................................46
Annex I Form Factor .........................................................................................50
Annex J Correspondence between specific creepage distance and USCD ..............51
Annex K Bibliographic References ........................................................................52
FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.

3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.

4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

5) The IEC provides no marking procedure to indicate its approval and cannot be held responsible for any equipment declared to be in conformity with one of its standards.

6) Attention is drawn to the possibility that some of the elements of this technical specification may be the subject of patent rights. The IEC shall not be held liable for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical specification when

• the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
• The subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 60815-1, which is a technical specification, has been prepared by technical committee 36: Insulators.

The text of this technical specification is based on the following documents:

<table>
<thead>
<tr>
<th>Enquiry draft</th>
<th>Report on voting</th>
</tr>
</thead>
<tbody>
<tr>
<td>XX/XX/DTS</td>
<td>XX/XX/RVC</td>
</tr>
</tbody>
</table>

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.
The committee has decided that the contents of this publication will remain unchanged until ______. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.
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 60815:1986 was perceived by CIGRE to be weak [1]:

- Performance of polymeric insulators
- Insulator orientation and mounting angle
- 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 IEC 60815:1986 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 Technical Specification into the following five parts:

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

As work on part 1 has progressed, it has become evident that the requirements for evaluation and measurement of site pollution severity (SPS) were a major concern. The content of part 1 now principally covers determination of SPS, description of the flashover mechanism, approaches for selection and dimensioning and testing techniques.

The following major changes have been made with respect to the 1st edition of IEC 60815:

- 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;
- Recognition that "solid" pollution on insulators has two components, one soluble quantified by ESDD, the other insoluble quantified by NSDD;
- Recognition that in some cases measurement of layer conductivity should be used for SPS determination;
- 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 and of the varying importance of parameters according to the size and type of insulators;
- Recognition of the varying importance of parameters according to the type of pollution.
- The adoption of correction factors to attempt to take into account the influence of the above pollution and insulator parameters.
IEC 60815: Selection and dimensioning of high-voltage insulators for polluted conditions

Part 1: Definitions, information and general principles

1 Scope and object

This Technical Specification 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 Technical Specification the insulators are divided into the following broad categories, each dealt with in a specific part as follows:

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

This part of IEC 60815 gives general definitions, methods for the evaluation of pollution site severity (SPS) and outlines the principles to arrive at an informed judgement on the probable behaviour of a given insulator in certain pollution environments.

This Technical Specification is generally applicable to all types of external insulation, including insulation forming part of other apparatus. The term “insulator” is used hereafter to refer to any type of insulator.

This structure is based on that used in CIGRE C4.13 TF 01 documents [1, 2], which form a useful complement to this Technical Specification for those wishing to study in greater depth the performance of insulators under pollution.

This Technical Specification does not deal with the effects of snow, ice or altitude on polluted insulators. Although this subject is dealt with by CIGRE [1, 3], current knowledge is very limited and practice is too diverse.

The aim of this Technical Specification is to give the user means to:

- Understand and identify the parameters of the system, application, equipment and site influencing the pollution behaviour of insulators;
- Understand and choose the appropriate approach to the design and selection of the insulator solution based available data, time and resources;
- Characterise the type of the pollution at a site and determine the site pollution severity;
- Determine the reference Unified Specific Creepage Distance (USCD) from the SPS;
- Determine the corrections to the “reference” USCD to take into account the specific properties (notably insulator profile) 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;
- Apply correction factors for insulator shape, size and position etc. to the reference USCD;
- If required, determine the appropriate test methods and parameters to verify the performance of the selected insulators.
2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60038 IEC Standard voltages
IEC 60305 Insulators for overhead lines with a nominal voltage above 1000 V - Ceramic or glass insulator units for a.c. systems - Characteristics of insulator units of the cap and pin type
IEC 60433 Insulators for overhead lines with a nominal voltage above 1 000 V - Ceramic insulators for a.c. systems - Characteristics of insulator units of the long rod type
IEC 60507 Artificial pollution tests on high voltage insulators to be used on a.c. systems
IEC 61245 Artificial pollution tests on high-voltage insulators to be used on d.c. systems

3 Definitions

For the purpose of this publication, the following definitions apply. The definitions given below are those which either do not appear in IEC 60050(471) or differ from those given in IEC 60050(471).

3.1 Reference Cap and Pin Insulator
A U120B or U160B cap and pin insulator (according to IEC 60305) normally used in strings of 7 to 9 units to measure site pollution severity.

3.2 Reference Long Rod Insulator
A L100 long rod insulator (according to IEC 60433) with plain sheds without ribs used to measure site pollution severity. The top angle of the shed is between 14° and 24°, the bottom angle between 8° and 16°. At least 14 sheds are necessary.

3.3 Insulator Trunk
The central insulating part of an insulator from which the sheds project. Note: Also known as shank on smaller diameter insulators.

3.4 Sheds
Projections from the trunk of an insulator intended to increase the creepage distance. Some typical shed profiles are illustrated in 10.3.

3.5 Creepage distance (modify IEV to follow this definition)
The shortest distance, or the sum of the shortest distances, along the insulating parts of the insulator between those parts which normally have the operating voltage between them.

NOTE 1 The surface of cement or of any other non-insulating jointing material is not considered as forming part of the creepage distance.

NOTE 2 If high resistance coating is applied to parts of the insulating part of an insulator such parts are considered to be effective insulating surfaces and the distance over them is included in the creepage distance.
3.6 Unified Specific Creepage Distance (USCD)
The creepage distance of an insulator divided by the maximum operating voltage across the insulator (for a.c. systems usually the highest voltage for equipment $U_m/\sqrt{3}$) It is generally expressed in mm/kV.

NOTE This definition differs from that of Specific Creepage Distance where the phase-to-phase value of the highest voltage for the equipment is used. For phase to earth insulation, this definition will result in a value that is $\sqrt{3}$ times that given by the definition of Specific Creepage Distance in IEC 60815 (1986). See Annex J for details.

3.7 Insulator profile parameters
Set of geometrical parameters that have an influence on pollution performance.

3.8 Salt Deposit Density (SDD) (move to IEV)
The amount of sodium chloride (NaCl) in an artificial deposit on a given surface of the insulator (metal parts and assembling materials are not included in this surface) divided by the area of this surface; generally expressed in mg/cm².

3.9 Equivalent Salt Deposit Density (ESDD) (Add to IEV)
The amount of sodium chloride (NaCl) that, when dissolved in demineralised water, gives the same volume conductivity as that of the natural deposit removed from a given surface of the insulator divided by the area of this surface; generally expressed in mg/cm².

3.10 Non Soluble Deposit Density (NSDD) (Add to IEV)
The amount of the non-soluble residue removed from a given surface of the insulator divided by the area of this surface; generally expressed in mg/cm².

3.11 Site Equivalent Salinity (SES)
The salinity of a salt fog test according to IEC 60507 that would give comparable peak values of leakage current on the same insulator as produced at the same voltage by natural pollution at a site, generally expressed in kg/m³.

3.12 Dust Deposit Gauge Index – Soluble (DDGIS)
The volume conductivity, generally expressed in µS/cm, of the pollutants collected by a dust deposit gauge over a given period of time when dissolved in a given quantity of demineralised water.

3.13 Dust Deposit Gauge Index – Non-Soluble (DDGIN)
The mass of non soluble residue collected by a dust deposit gauge over a given period of time, generally expressed in mg.

3.14 Site Pollution Severity (SPS)
The maximum value of either ESDD/NSDD, SES or DDGIS/DDGIN, recorded over an appropriate period of time.

3.15 Site Pollution Severity Class
Classification of the pollution severity at a site, from very light to very heavy, as a function of the SPS.
4 Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C&lt;sub&gt;f&lt;/sub&gt;</td>
<td>Climatic Factor (for DDDG)</td>
</tr>
<tr>
<td>DDDG</td>
<td>Directional Dust Deposit Gauge</td>
</tr>
<tr>
<td>DDDGIS</td>
<td>Dust Deposit Gauge Index – Soluble</td>
</tr>
<tr>
<td>DDDGIN</td>
<td>Dust Deposit Gauge Index – Non-Soluble</td>
</tr>
<tr>
<td>D&lt;sub&gt;m&lt;/sub&gt;</td>
<td>Dry Months (for DDDG)</td>
</tr>
<tr>
<td>ESDD</td>
<td>Equivalent Salt Deposit Density</td>
</tr>
<tr>
<td>F&lt;sub&gt;d&lt;/sub&gt;</td>
<td>Fog Days (for DDDG)</td>
</tr>
<tr>
<td>FF</td>
<td>Form Factor</td>
</tr>
<tr>
<td>NSDD</td>
<td>Non Soluble Deposit Density</td>
</tr>
<tr>
<td>PI</td>
<td>Pollution Index (for DDDG)</td>
</tr>
<tr>
<td>SDD</td>
<td>Salt Deposit Density</td>
</tr>
<tr>
<td>SES</td>
<td>Site Equivalent Salinity</td>
</tr>
<tr>
<td>SPS</td>
<td>Site Pollution Severity</td>
</tr>
<tr>
<td>TOV</td>
<td>Temporary Overvoltage</td>
</tr>
<tr>
<td>USCD</td>
<td>Unified Specific Creepage Distance</td>
</tr>
</tbody>
</table>

5 Proposed approaches for the selection and dimensioning of an insulator

To select suitable insulators from catalogues based on the system requirements and the environmental conditions, three approaches (A, B, C, in table 1 below) are recommended. These approaches are also shown in flowchart form in Annex A.

Table 1 shows the data and decisions needed within each approach. 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.

In reality, the pollution performance of the insulator is determined by complicated and dynamic interactions between the environment and the insulator. Annex B gives a brief summary of the pollution flashover mechanism. In approach A such interactions are well represented on an operating line or substation and can also be represented in a test station. In approach B these interactions cannot be fully represented by laboratory tests, e.g. the tests specified in IEC 60507 and IEC 61245. In approach C, such interactions can only be represented and catered for to a limited degree by the correction factors. Approach C can be rapid and economical for the selection and dimensioning process but may lead to a less economical solution due to over-design or underestimation of SPS. The overall costs, including imposed performance requirements, have to be considered when choosing from the three approaches. Whenever circumstances permit, approaches A or B should be adopted.

The time-scales involved in the three approaches are:

- For service experience (Approach A) a period of satisfactory operation of five to ten years can be considered as acceptable. This period may be longer or shorter according to the frequency and severity of climatic and pollution events.
- For test station experience (Approach A) a period of investigation of two to five years can be considered as typical. This period may be longer or shorter according to the test protocol and severity.
- For measurement of site severity (Approach B & C) a period of at least one year is necessary (see 9.2).
- For estimation of site severity (Approach B & C) it is necessary to carry out research into the climate, the environment and to identify and analyse all possible pollution sources. Hence estimation is not necessarily an immediate process and may require several weeks or months.
- For laboratory testing (Approach B) the necessary time is a matter of weeks or months depending on the type and scale of tests.
### Table 1 - The three approaches to insulator selection and dimensioning

<table>
<thead>
<tr>
<th>Approach A (Use past experience)</th>
<th>Approach B (Measure and test)</th>
<th>Approach C (Measure and design)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Use existing field or test station experience for the same site, a nearby site or a site with similar conditions.</td>
<td>• Measure or estimate site pollution severity.</td>
<td>• Use these data to choose type and size of insulation based on profile and creepage guidance hereafter.</td>
</tr>
<tr>
<td><strong>Input Data</strong></td>
<td><strong>Measure or estimate site pollution severity.</strong></td>
<td><strong>Select candidate insulators using profile and creepage guidance hereafter.</strong></td>
</tr>
<tr>
<td>• System requirements.</td>
<td>• Insulator parameters.</td>
<td>• Choose applicable laboratory test and test criteria.</td>
</tr>
<tr>
<td>• Environmental conditions.</td>
<td>• Time and resources available.</td>
<td>• Verify/adjust candidates</td>
</tr>
<tr>
<td>• Insulator parameters.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Performance history.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Decisions</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does the existing insulation satisfy the project requirements and is it intended to use the same insulation design?</td>
<td><strong>Supprimé : different</strong></td>
<td><strong>Supprimé : different</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Supprimé : different</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Selection Process</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td><strong>Supprimé : different</strong></td>
<td><strong>Supprimé : different</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Supprimé : different</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>A selection with a good accuracy.</td>
<td><strong>Supprimé : different</strong></td>
<td><strong>Supprimé : different</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Supprimé : different</strong></td>
<td></td>
</tr>
</tbody>
</table>

The following clauses give more information on system requirements, environment and site pollution severity determination.
An example of a questionnaire that can be used in approach A to obtain operational experience from an existing line or substation is given in Annex H.

Guidelines for using laboratory tests in approach B are described in general terms in Annex F. Both deterministic and statistical design methods are available to design and select appropriate insulator solutions based on SPS and laboratory test results; a short description of these two methods is given in Annex G. Commercial software is becoming available for the statistical approach.

For approach C, required minimum unified specific creepage distance and correction factors are given in the relevant parts of this publication.

6 Input parameters for the selection and dimensioning of insulators

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 2 below. These parameters are further discussed in later clauses.

### Table 2 – Input parameters for insulator selection and dimensioning

<table>
<thead>
<tr>
<th>System Requirements</th>
<th>Environmental Conditions</th>
<th>Insulator Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of system</td>
<td>Pollution types and levels</td>
<td>Overall length</td>
</tr>
<tr>
<td>Maximum operating voltage across the insulation</td>
<td>Rain, fog, dew, snow and ice...</td>
<td>Type</td>
</tr>
<tr>
<td>Insulation coordination parameters</td>
<td>Wind, storms, rain, fog, dew, snow and ice...</td>
<td>Material</td>
</tr>
<tr>
<td>Imposed performance requirements</td>
<td>Temperature, humidity</td>
<td>Profile</td>
</tr>
<tr>
<td>Clearances, imposed geometry, dimensions</td>
<td>Lightning, Earthquakes</td>
<td>Creepage distance</td>
</tr>
<tr>
<td>Live line working and maintenance practice</td>
<td>Vandalism, animals</td>
<td>Diameters</td>
</tr>
<tr>
<td></td>
<td>Biological growths</td>
<td>Arcing distance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical and electrical design</td>
</tr>
</tbody>
</table>

NOTE Non pollution related parameters are given in italics and are not dealt with in this Publication; however they may influence or limit the choice of the type of insulator to be used.

7 System requirements

System requirements have 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 and from laboratory test results that, for the same pollution conditions, some d.c. insulation may require a somewhat higher value of unified specific creepage distance compared to a.c. insulation. This effect is dealt with in detail in parts 4 and 5 of this publication.

- **Maximum operating voltage across the insulation**
  Usually an a.c. system is characterised by the highest voltage for equipment $U_m$, see IEC 60071-1.

  Phase-to-earth insulation is stressed with the phase-to-earth voltage $U_{ph-e} = U_m/\sqrt{3}$.
  Phase-to-phase insulation is stressed with the phase-to-phase voltage $U_{ph-ph} = U_m$. 

  Supprimé : 60071-1.
In the case of a d.c. system, usually the maximum system voltage is equal to the maximum line-to-earth voltage. In the case of mixed voltage waveforms the r.m.s. value of the voltage may need to be used.

Overvoltages

The effects of transient 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.

NOTE The duration of the TOV depends on the structure of the system and can last for up to a half an hour, or even longer in the case of an isolated neutral system. Depending on the duration of the TOV and its probability of occurrence the combined effect of TOV and insulator pollution may have to be considered. CIGRE 158 [1] gives information on this subject.

- **Imposed performance requirements**
  
  Longitudinal insulation used for synchronisation can be stressed up to a value of 2.5 times the phase to earth voltage.
  
  Some customers may require performance levels for outdoor insulation with regard to availability, maintainability and reliability. This may be specified, for example, as the maximum number of pollution flashovers allowed per station, or per 100 km line length, over a given time. Such requirements may also include a maximum outage time after a flashover.

  In addition to the insulator dimensioning according to the site conditions, imposed requirements could become the controlling factor for the insulator parameters.

- **Clearances, imposed geometry and dimensions**
  
  There could be several cases, or a combination thereof, where special solutions for insulation types and dimensions are required.

  Examples are:
  
  - compact lines;
  - unusual position of an insulator;
  - unusual design of towers and substations;
  - insulated conductors;
  - lines or substations with a low visual impact.

8 Environmental conditions

8.1 Identification of types of pollution

There are two main basic types of insulator pollution that can lead to flashover:

**Type A**: where solid pollution with a non-soluble component is deposited onto the insulator surface. This deposit becomes conductive when wetted. This type of pollution can be best characterised by ESDD/NSDD and DDGIS/DDGIN measurements.

NOTE The ESDD of a solid pollution layer may also be evaluated by surface conductivity under controlled wetting conditions.

**Type B**: where liquid electrolytes are deposited on the insulator with very little or no non-soluble components. This type of pollution can be best characterised by conductance or leakage current measurements.

Combinations of the two types can arise.

Annex A gives a short description of the pollution flashover mechanisms for type A and type B pollution.
8.1.1 Type A pollution

Type A pollution is most often associated with inland, desert or industrially polluted areas (see 8.2). Type A pollution can also arise in coastal areas in cases where a dry salt layer builds up and then rapidly becomes wetted by dew, mist, fog or drizzle.

Type A pollution has two main components, namely soluble pollution that forms a conductive layer when wetted, and non-soluble pollution that forms a binding layer for soluble pollution. These are described below.

- **Soluble pollution:**
  Soluble pollution is subdivided into high solubility salts (e.g. salts that dissolve readily into water), and low solubility salts (e.g. salts that hardly dissolve). Soluble pollution is measured in terms of an Equivalent Salt Deposit Density (ESDD) in mg/cm².

- **Non-soluble pollution**
  Examples of non-soluble pollution are dust, sand, clay, oils etc. Non-soluble pollution is measured in terms of Non-soluble Deposit Density (NSDD) in mg/cm².

**NOTE** – The influence of the solubility of salts on the pollution withstand voltage is not taken into account in this Technical Specification and is currently under consideration. Similarly the influence of the type of non-soluble pollution is not taken into account. Furthermore the non-soluble component may contain conductive pollution (e.g. pollution with metallic conductive particles).

Reference [1] gives more information on the influence of types of pollutant materials.

8.1.2 Type B pollution

Type B pollution is most often associated with coastal areas where salt water or conductive fog is deposited onto the insulator surface. Other sources of type B pollutions are, for example, crop spraying, chemical mists and acid rain.

8.2 General types of environments

For the purposes of this Publication, environments are described by the following five types. These types describe the typical pollution characteristics for a region. **Examples of the type of pollution (A or B according to 8.1) are shown in the text. In practice most polluted environments comprise more than one of these types, for example coastal regions with sandy beaches; in such cases it is important to determine which pollution type (A or B) is dominant.**

- **“Desert” type environments**

  These are areas which is characterised by sandy soils with extended periods of dry conditions. These areas can be extensive. The pollution layer in these areas normally comprises salts that dissolve slowly in combination with a high NSDD level (A). The insulators are polluted mainly by wind borne pollution. Natural cleaning can occur under the infrequent periods of rain or by “sand blasting” during strong wind conditions. The infrequency of rain together with the type of pollution (slow dissolving salts) causes natural cleaning not to be very effective. Critical wetting, which poses a risk for insulator flashover, can occur relatively frequently in the form of dew on the insulators.

- **“Coastal” type environments**

  These areas are typically in direct vicinity of the coast, but in some cases it can be as far as 10-20 km inland. Pollution is deposited onto the insulators mainly by spray, wind and fog. The pollution build-up is generally rapid, especially during spray or conductive fog conditions (B). A build-up of pollution over a longer term can also occur through a deposit of wind-borne particles, where the pollution layer on the insulators consists of quick dissolving salts with a degree of inert component (A) which depends on the local ground characteristics. Natural cleaning of the insulators is typically effective as the active pollution consists mainly of fast dissolving salts.
• “Industrial” type environments

These are areas located in close proximity to an industrial pollution source, and it may affect only a few installations. The pollution layer may constitute conductive particulate pollution -- such as coal, metallic deposits -- or dissolved gasses -- such as NOx, SOx (B) -- or pollution that dissolves slowly -- such as cement, gypsum (A). The pollution layer may have a medium to high inert component (medium to high NSDD) (A). The effectiveness of natural cleaning in industrial areas can vary greatly depending on the type of pollution present. The pollution is often heavy particles which settle on horizontal surfaces.

• “Agricultural” type environments

These are areas which is situated in the vicinity of agricultural activity. Typically this will be areas subjected to ploughing (A) or crop spraying (B). The pollution layer on the insulators consist mostly of fast or slow dissolving salts such as chemicals, bird droppings, or salts present in the soil. The pollution layer will normally have a medium to high inert component (medium to high NSDD). Natural cleaning of the insulators can be quite effective depending on the type of salt deposited. The pollution is often heavy particles which settle on horizontal surfaces, but it may also be wind borne pollution.

• “Inland” type environments

These are areas with a low level of pollution without any clearly identifiable sources of pollution.

8.3 Pollution Severity

Pollution severity at a site (SPS) is generally expressed in terms of:
- ESDD and NSDD for Type A pollution;
- Site Equivalent Salinity (SES) for Type B pollution;
- DDGIS and DDGIN for both types.

Pollution severity on naturally polluted insulators is generally expressed in terms of:
- ESDD and NSDD for Type A pollution;
- Surface conductivity for Type B pollution.

NOTE In some cases ESDD measurements can be used for type B pollution.

Pollution severity in artificial pollution tests on insulators is generally expressed in terms of:
- SDD and NSDD for solid layer methods;
- Fog salinity (kg/m³) for salt-fog methods.

9 Evaluation of site pollution severity

9.1 Site pollution severity

The Site Pollution Severity (SPS) is the maximum value(s) of either ESDD and NSDD (in the case of cap and pin insulators, average ESDD/NSDD for top and bottom surfaces), or SES, or DDGIS and DDGIN, measured according to the methods given in this Technical Specification and recorded over an appreciable period of time – i.e. one or more years – and with a certain measurement interval. The measurement interval (continuous, every month, three months, six months, every year etc. – see Annexes C and D) may be chosen according to knowledge of local climate and environmental conditions.

If rain occurs during this measuring period, the measurements should be repeated at appropriate intervals to determine the effect of natural washing; SPS is then the largest value recorded during this series of measurements.

NOTE Even if the highest values of ESDD and NSDD (or DDGIS and DDGIN) do not occur at the same time, then SPS is – nonetheless – taken as the combination of these highest values.
9.2 Site pollution severity evaluation methods

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

1) from measurements in situ;
2) from information on the behaviour of insulators from lines and substations already in service on or close to the site (see Annex H);
3) from simulations that calculate the pollution level from weather and other environmental parameters (See CIGRE 158 [1]);
4) 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 insulators (see Annex C) for Type A pollution sites;
  or SES from on-site current/surface conductance of reference insulators or a monitor (see Annex D) for Type B pollution sites;
  or DDGIS , DDGIN of the pollutant collected by means of a DDDG (see Annex E) for Type A or B pollution sites;
- 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 ESDD/NSDD and SES methods characterise the pollution severity of the site with respect to a reference insulator. The DDDG method gives the measure of the amount of the ambient pollution. In all cases, information on rainfall and wetting should be separately obtained using appropriate meteorological equipment.

The accuracy of all these methods depends upon the frequency of measurement and the duration of the study. Accuracy may be improved by using two or more methods in combination.

The method based on total flashovers needs expensive test facilities. Reliable information can be obtained from test insulators having a length close to the projected length and flashing over at a voltage near the actual 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. They have been developed to assess the rate of pollution build-up. When related to test data, they can be used to indicate that the pollution is still at a safe level or to signal that washing or another palliative is required. These two methods allow direct determination of the minimum USCD necessary for the tested insulators at the site.

When measurements are carried out on reference insulators it can be very useful to include insulators with other profiles and orientations in order to study the deposit and self-cleaning mechanisms for the site. 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 a measurement period of at least one year is necessary to take into account any seasonal effects. 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 (see 10.4.2).

Note: Future industrial development, transport networks etc. should be taken into account. It is advisable to continue monitoring pollution severity after installation.

9.3 Site pollution severity (SPS) classes

For the purposes of standardisation, five classes of pollution characterising the site severity are qualitatively defined, from very light pollution to very heavy pollution as follows:

a – Very light  
b – Light  
c – Medium  
d – Heavy  
e – Very heavy.

NOTE 1 These letter classes do not correspond directly to the previous number classes of IEC 60815:1986.

NOTE 2 The change from one class to another is gradual, therefore the absolute SPS value can be taken into account when determining insulator dimensions.

For type A pollution, figures 1 and 2 show the ranges of ESDD/NSDD values corresponding to each SPS class for the reference cap and pin and long rod insulators respectively. 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. These figures are only applicable to the reference insulators and take into account their specific pollution accumulation properties.

For extreme site pollution severities in the shaded areas to the right hand side of figures 1, 2 & 3, simple rules can no longer ensure satisfactory pollution performance. These areas require a careful study and a combination of insulating solutions and palliative measures are necessary (see 10.4.5).

NOTE Separate figures are given for the two types of reference insulator, since in the same environment they do not accumulate the same quantity of pollution. Generally the long rod reference insulator accumulates less pollution than the cap and pin reference. However, it is to be noted that in some conditions of rapid pollution deposit (e.g. coastal storms, typhoons) the accumulation ratio between the two types may be temporarily reversed.

For type B pollution, figure 3 shows the correspondence between SES measurements and SPS class for both types of reference insulator.

The correspondence between DDDG measurements and SPS class relevant to both Type A and Type B pollution is shown in tables 3 and 4.

The values in figures 1 to 3 are based on natural pollution deposited on reference insulators. These values should not be used directly to specify the severity of an artificial pollution test without corrections for the difference between natural and test conditions as well as for the difference between types of insulators (see Annex F). The transition from one SPS class to another is not abrupt, hence the boundary between each class in figures 1 to 3 is shaded.
WARNING: This figure shall not be directly used to determine laboratory test severities.

Figure 1 – Type A site pollution severity
Relation between ESDD/NSDD and SPS for the reference cap and pin.

Figure 2 – Type A site pollution severity
Relation between ESDD/NSDD and SPS for the reference long rod insulator.

Corresponding example in Table 5
Warning: This figure shall not be used to determine laboratory test severities.

Figure 3 – Type B site pollution severity
Relation between SES and SPS for reference insulators or a monitor

Table 3 – Directional dust deposit gauge pollution index in relation to SPS class.

<table>
<thead>
<tr>
<th>Directional dust deposit gauge pollution index, PI (μS/cm) (take whichever is the highest)</th>
<th>Site pollution severity class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average monthly value over one year</td>
<td>Monthly maximum over one year</td>
</tr>
<tr>
<td>&lt; 25</td>
<td>&lt; 50</td>
</tr>
<tr>
<td>25 to 75</td>
<td>50 to 175</td>
</tr>
<tr>
<td>76 to 200</td>
<td>176 to 500</td>
</tr>
<tr>
<td>201 to 350</td>
<td>501 to 850</td>
</tr>
<tr>
<td>&gt; 350</td>
<td>&gt; 850</td>
</tr>
</tbody>
</table>

a) If weather data for the site in question is available then the directional dust deposit gauge pollution index can be adjusted to take into account climatic influences. See annex E.

Table 4 – Correction of site pollution severity class as a function of DDDG NSD levels.

<table>
<thead>
<tr>
<th>Directional dust deposit gauge NSD (grams) (take whichever is the highest)</th>
<th>Site pollution severity class correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average monthly value over one year</td>
<td>Monthly maximum over one year</td>
</tr>
<tr>
<td>&lt; 0,5</td>
<td>&lt; 1,5</td>
</tr>
<tr>
<td>0,5 to 1,0</td>
<td>1,5 to 2,5</td>
</tr>
<tr>
<td>&gt; 1,0</td>
<td>&gt; 2,5</td>
</tr>
</tbody>
</table>

Table 5 gives, for each level of pollution, an example and 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. The examples E1 to E7 in table 5 are reproduced on figures 1, 2 and 3 to show typical SPS levels.

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 the reference cap and pin and long rod insulators.
### Table 5 – Examples of typical environments

<table>
<thead>
<tr>
<th>Example</th>
<th>Description of typical environments</th>
</tr>
</thead>
</table>
| E1      | > 50 km from any sea, desert, or open dry land  
> 10 km from man-made pollution sources  
Within a shorter distance than mentioned above of pollution sources, but:  
• prevailing wind not directly from these pollution sources  
• and/or with regular monthly rain washing |
| E2      | 10-50 km from the sea, a desert, or open dry land  
5-10 km from man-made pollution sources  
Within a shorter distance than E1 from pollution sources, but:  
• prevailing wind not directly from these pollution sources  
• and/or with regular monthly rain washing |
| E3      | 3-10 km from the sea, a desert, or open dry land  
1-5 km from man-made pollution sources  
Within a shorter distance than mentioned above of pollution sources, but:  
• prevailing wind not directly from these pollution sources  
• and/or with regular monthly rain washing |
| E4      | Further away from pollution sources than mentioned in E3, but:  
• dense fog (or drizzle) often occurs after a long (several weeks or months) dry pollution accumulation season  
• and/or heavy, high conductivity rain occurs  
• and/or there is a high NSDD level, between 5 and 10 times the ESDD |
| E5      | Within 3 km from the sea, a desert, or open dry land  
Within 1 km of man-made pollution sources  
With a greater distance from pollution sources than mentioned in E5, but:  
• dense fog (or drizzle) often occurs after a long (several weeks or months) dry pollution accumulation season  
• and/or there is a high NSDD level, between 5 and 10 times the ESDD |
| E6      | Within the same distance of pollution sources as specified for “Heavy” areas and:  
• 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  
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. |

### 10 Insulation selection and dimensioning

#### 10.1 General description of the process

The overall process of insulation selection and dimensioning can be summarised as follows:

- Determination of the appropriate approach A, B or C as a function of available knowledge, time and resources;
- Collection of the necessary input data, notably whether a.c. or d.c. energisation, system voltage, insulation application type (line, post, bushing etc.);
- Collection of the necessary environmental data, notably site pollution severity and class;

At this stage a preliminary choice of possible candidate insulators suitable for the applications and environment may be made (See 10.2 to 10.4).

- Determination of the reference Unified Specific Creepage Distance for the insulator types and materials, either using the indications in the relevant parts 2 to 5 of this Publication, or from service or test station experience in the case of Approach A;
- Modification, where necessary, of the reference USCD by factors depending on the size, profile, orientation etc. of the candidate insulators;
- Verification that the resulting candidate insulators satisfies the other system and line requirements in Table 2 (e.g. imposed geometry, dimensions, economics);
• Verification of the dimensioning, in the case of Approach B, by laboratory tests (see annex E).

NOTE The specific guidelines for each of the types of insulator mentioned above are given in the relevant parts 2 to 5 of IEC 60815.

10.2 General guidance on materials

The choice of material may be dictated entirely by environmental or system constraints. On the other hand, the selection of insulator material may be dictated solely by user policy and economics. The traditional materials used for outdoor insulation are glazed porcelain and glass. The use of polymers – either for a complete insulator or as a housing in combination with a glass fibre core is an alternative to glass and porcelain. The various profiles and material technologies associated with polymer insulators mean that pollution behaviour does not necessarily follow the same parameters as for traditional insulation.

Parts 2 & 4 deal with the choice and dimensioning of insulators made with traditional materials. Parts 3 & 5 deal with polymer insulators. See also ref [2].

10.3 General guidance on profiles

See figures 4 to 7 for typical profiles.

Different types of insulator and even different orientations of the same insulator type may accumulate pollution at different rates in the same environment. In addition, variations in the nature of the pollutant may make some shapes of insulator more effective than others. Condensed guidance on the selection of profile is provided in the following. It must be borne in mind that the minimum or maximum overall length of the insulation can also be an important imposed parameter in some cases e.g. for insulation coordination or tower height.

Standard profiles (Figure 4) are effective for use in ‘very light’ to ‘medium’ polluted areas where a long creepage distance or aerodynamically effective profile is not required.

Aerodynamic or open profiles (Figure 5) prove to be beneficial in areas where the pollution is deposited onto the insulator by wind, such as deserts, heavily polluted industrial areas or coastal areas which are not directly exposed to salt spray. This type of profile is especially effective in areas that are characterised by extended dry periods. Open profiles have good self-cleaning properties and are also more easily cleaned under maintenance.

Figure 4 – Typical “standard” profiles

Figure 5 – Typical “open” profiles
The use of anti-fog profiles with steep sheds or deep under-ribs, (Figure 6) are beneficial in areas exposed to a salt water fog or spray, or to other pollutants in the dissolved state. These profiles may also be effective in areas with a particulate pollution precipitation containing slow dissolving salts. Anti-fog profiles, (Figure 6) are effective in areas exposed to a salt water fog or spray, or to other pollutants in a dissolved state. They can also be effective in areas with low NSDD and slow dissolving salts.

Alternating shed arrangements (Figure 7) are in general feasible for all profiles, although steep sheds are less beneficial. They offer increased creepage distance per unit without penalising performance in heavy rain or icing. Similar benefits to open profiles are also provided by simple alternating profiles.

More advice on profiles is given in the relevant further parts of this publication.

10.4 Considerations for exceptional or specific applications or environments

10.4.1 Hollow core insulators

Polymeric and porcelain hollow core insulators are used for apparatus insulators, bushings and also as station posts. They are used, for example, as housings for capacitors, surge arresters, breaker chambers and supports, cable terminations, wall bushings, transformer bushings, measuring transformers and other measuring devices.

The pollution performance of complete hollow core insulators is not only a function of profile, leakage distance and diameter but also function of uniformity of voltage distribution. Two major parameters affecting voltage distribution are internal and external components and
uneven wetting (see 10.4.1.1 and 10.4.1.2). Care should be taken to design accordingly, especially at lower pollution levels where the effect of non-uniformity is more critical and can reduce flashover performance and also increase the risk of puncture.

10.4.1.1 Internal and external components

The presence of a conductor, shielding or grading devices within or outside the insulator housing can greatly affect the electrical performance of the assembly. In addition to the known behaviour difference found between empty housings and assembled apparatus with the same housing during impulse, dry or wet flashover tests, there are similar electrical behaviour differences when subjecting empty housings and assembled housings to pollution tests.

The best performance (high flashover voltage and low risk of puncture) is generally obtained on an insulation system with a uniform axial and radial voltage distribution, such as devices with capacitive grading. An insulator design that, firstly helps to even-out the total voltage distribution and secondly takes into account the inner associated components is therefore advantageous.

The effect of non-uniformity of voltage distribution is more evident at lower pollution levels (ESDD 0.01 to 0.03 mg/cm²), because the weaker resistive leakage currents cannot compensate for, correct or rectify sufficiently, the non-uniformity of voltage distribution.

For higher pollution levels, the resistive surface currents become dominant and therefore reduce the effect of non-uniformity of voltage distribution. This effect is observed during laboratory tests, where similar results are obtained on both empty insulator housings and complete ones.

10.4.1.2 Non-uniform wetting and uneven pollution deposit

Under rain, shading by buildings or other equipment can cause uneven wetting of bushings and housings. In some positions, the operating temperature of bushings can induce uneven wetting of the insulator by simple drying. Furthermore, uneven pollution deposits can occur in natural conditions. Therefore, even at higher pollution levels, the cancellation of non-uniform voltage distribution effect might not be as effective on apparatus such as horizontally mounted wall bushings.

10.4.2 Arid areas

Arid areas pose particular difficulties when selecting and dimensioning insulators. The long dry spells may lead to extreme ESDD and NSDD levels even in areas that are not in the direct vicinity of the coast. This is because the surrounding sand may have a high salt content.

The use of aerodynamic “self-cleaning” profiles can help reduce the impact of the pollution deposition in such cases, as can the use of polymeric insulators. Equally, a semi-conducting glaze on porcelain insulators provides a continuous flow of current of about 1 mA, which helps to avoid dew formation.

10.4.3 Proximity effects

Any insulators that are in close axial proximity, e.g live-tank circuit breaker interrupters and grading capacitors, some disconnectors and multiple string line insulators, can have an adverse effect on pollution performance. This is caused by voltage gradients arising from different field distributions during pollution induced discharge activity.

10.4.4 Orientation

The effect of the orientation of insulation on its flashover performance is not generally subject to simple rules. The insulator type and the size directly affect the performance of the polluted insulation in different orientations. In addition, the pollution severity at a site and the time taken for maximum contamination levels to build up may determine the effect of orientation.
The nature of the wetting process and the flashover mechanism (e.g. surface flashover or inter-shed breakdown) are also important factors affecting the influence of orientation and size.

Hence, the flashover strength of different insulator types and orientation is a balance between the various processes that directly influence such performance.

The information in this Technical Specification principally concerns vertical insulation. More information on the effect of orientation can be found in Reference [1].

10.4.5 Maintenance and palliative methods

In exceptional cases, pollution problems cannot be solved economically by a good choice of the insulator. For instance, in areas having very severe contamination or low annual rainfall, insulator maintenance may be required. This can also occur when the environment of an already built substation (or line) changes due to new pollution sources.

Maintenance and palliative methods may take one or more of the following forms

- **Cleaning or washing.** These methods may be applied manually or automatically. Some automatic washing methods may be used on energized insulators. These methods can reduce the pollution accumulated on the insulator.

- **Application of hydrophobic coatings, e.g. silicone rubber or grease.** The hydrophobic property of these coatings improves the pollution performance of the insulator.

- **Installation of additive components, e.g. booster sheds or creepage extenders.** Booster sheds improve the performance of the insulator mainly through barrier effects and the reduction of shed bridging by water drops. Creepage extenders increase the creepage distance of the insulator.

These methods have been widely used with good experience. The choice of the maintenance and palliative methods depends on the site conditions, type of insulators, practicality and economical requirements. More information can be found in [1] and [2].
Annex A
Flowchart representation of the design approaches

The following flowcharts show the approaches A, B and C from 5 in graphical form.

**Input Data**

- **System Requirements (Clause 7)**
  - Type of system
  - Maximum operating voltage
  - Overvoltage
  - Imposed performance
  - Clearances

- **Environmental Conditions (Clause 8)**
  - Pollution types and levels
  - Rain, fog, dew, snow and ice
  - Wind, storms
  - Temperature, humidity

- **Insulator Parameters**
  - Overall length/Type/Material/
  - Profile/Creepage distance/
  - Diameters/Arcing distance

**Service Experience (Refer to Annex G)**
Use existing field or test station experience for the same site, a nearby site or a site with similar conditions.

Does the existing insulation satisfy the project requirements?

- Yes
- No

Is the same material, type and profile to be used?

- Yes
- No

**Approach A**

- Use experience and, if necessary, the profile and creepage guidance to adapt the parameters of the existing insulation to the new choice using approach B or C.
- The profile and creepage guidance are given in the relevant clauses, i.e., choice of profile, basic USCD and its correction factors, of Parts 2-5 of IEC 60815.

Selections

Use the same insulation design

Use different insulation design or different size
Approach B

Is there time to measure site pollution severity?

Yes

Measure (Sub. Clause 9.1)

No

Estimate (Sub. Clause 9.2)

Determine SPS (Table 3, Fig. 5 and Fig. 6 of Sub. Clause 9.2)

Select candidate insulators

Choose applicable laboratory test and test criteria (Annex F)

Evaluate/Test
If necessary, adjust selection / size according to the test results

Unacceptable

Acceptable

Selections

Input Data

System Requirements (Clause 7)
Type of system
Maximum operating voltage
Overvoltage
Imposed performance
Clearances

Environmental Conditions (Clause 8)
Pollution type
Rain, fog, dew, snow and ice
Wind, storms
Temperature, Humidity

Insulator Parameters
Overall length/Type/Material/
Profile/Creepage distance/
Diameters/Arcing distance

Profile and Creepage Guidance
The profile and creepage guidance are given in the relevant clauses, i.e., choice of profile, basic USCD and its correction factors, of Parts 2-5 of IEC 60815.
Input Data

System Requirements (Clause 7)
- Type of system
- Maximum operating voltage
- Overvoltage
- Imposed performance
- Clearances

Environmental Conditions (Clause 8)
- Pollution type
  - Rain, fog, dew, *snow and ice*
  - Wind, *storms*, Temperature, Humidity

Insulator Parameters
- Overall length/Type/Material/
- Profile/Creepage distance/
- Diameters/Arcing distance

Profile and Creepage Guidance
The profile and creepage guidance are given in the relevant clauses, i.e., choice of profile, basic USCD and its correction factors, of Parts 2-5 of IEC 60815.

---

Approach C

Is there time to measure site pollution severity?

- Yes
  - Measure (Sub. Clause 9.1)
  - Estimate (Sub. Clause 9.2)
  - Determine SPS (Table 3, Fig.5 and Fig.6 of Sub. Clause 9.2)
  - Select appropriate profile
  - Size the insulators
  - Selections

- No
  - Is there time to measure site pollution severity?
Annex B
Pollution Flashover mechanisms

B.1 Description of the pollution flashover mechanism under type A pollution

For ease of understanding the pre-deposit pollution (type A) 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. 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. Condensation occurs when the moisture in the air condenses on a surface whose temperature is lower than the dew point. 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 still wet 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 still wet and conductive part of the pollution layer is low enough, the arcs bridging the dry bands are sustained and may finally 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. Surface layer resistance may be calculated – assuming uniform pollution distribution and wetting – using the form factor, see annex H.

Pollution flashover can be a 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. The thermal capacity and thermal conductivity of the insulating material control the rate at which its surface warms up.

More information on pollution flashover processes and models is available in CIGRE 158 [1].

**B.2 Description of the pollution flashover mechanism under type B pollution**

**B.2.1 Conductive Fog**

Type B ‘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 the instantaneous pollution flashover the same process as described in A.1 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 the process begins at phase 3 above and can progress rapidly to phase 6. 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.

**B.2.2 Bird Streamers**

A particular case of type B pollution is a 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 and the best solution may be to fit dissuasive devices or alternate perches, [appropriate to the local fauna and structure design](#).
B.3 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 the entire 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.
Annex C
Measurement of ESDD and NSDD

C.1 Introduction

The site pollution severity can be determined by measuring both equivalent salt deposit density (ESDD) and non-soluble material deposit density (NSDD) on reference insulators which come from existing installations and/or are installed in field testing stations. In addition, if possible, the measurement of ESDD and NSDD on the exact insulator to be selected will provide direct information to determine the required creepage distance of the insulator. Also chemical analysis of the pollutants is sometimes useful. This annex describes how to measure ESDD and NSDD, and how to make chemical analysis of the pollutants.

For site pollution severity measurement purposes the measurements are standardised by using a string of 7 reference cap and pin insulators (preferably 9 discs to avoid end effect) or a reference long rod insulator with at least 14 sheds. The unenergized insulators string shall be located at a height as close as possible to that of the line or bus bar insulators. Each disc or shed area of the insulator string is shall be monitored at a defined appropriate intervals e.g. every month (disc 2 / area 1), every three months (disc 3,4,5 / area 2,3,4), every six months (disc 5 / area 6), each every year (disc 7 / area 6), after two years (disc 8 / area 7), etc. before anticipating rainfall, dew and so on.

NOTE For d.c. applications, it may be useful to measure top and bottom surface ESDD and NSDD separately (see parts 4 & 5 of this publication).

![Diagram of insulator strings for measuring ESDD and NSDD](image-url)
C.2 Necessary equipment to measure pollution degree

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

- Distilled water/demineralised water
- Measuring cylinder
- Surgical gloves
- Plastic cling wrap
- Labelled container
- Washing bowl
- Absorbent cotton/brush/sponge
- Conductivity meter
- Temperature probe
- Filter paper
- Funnel
- Desiccator/drying oven
- Balance scale

C.3 Pollution collection methods for ESDD and NSDD measurement

The surfaces of the insulator should not be touched to avoid any loss of pollution.

Wear clean surgical gloves.

A container, a measuring cylinder, etc. shall be washed well enough to remove any electrolytes prior to the measurement.

C.3.1 Procedure using a swab technique

- Distilled water of 100 - 300 cm$^3$ (or more if required) shall be put into containers and absorbent cotton shall be immersed into the water (other tools such as a brush or a sponge may be used). The conductivity of the water with the immersed cotton shall be less than 0.001 S/m.
- The pollutants shall be wiped off from the area of the insulator surface, excluding any metal parts or assembly materials, with the squeezed cotton. In the case of cap and pin type insulator, the top and bottom surfaces may be measured separately, if necessary, in order to obtain useful information for evaluation as shown in figure C2. In the case of a long-rod or a post insulator, pollutants shall usually be collected from a part of the shed.
- The cotton with pollutants shall be put back into the containers. The pollutants are then dissolved into the water by shaking and squeezing the cotton in the water.
- Wiping shall be repeated until no further pollutants remain on the insulator surface. If pollutants remain even after wiping several times, the pollutants shall be removed by a spatula and be put into the water containing the pollutants.
- Attention should be taken not to lose any water. That is, the quantity shall not be changed very much before and after collecting pollutants.

![Figure C2 - Wiping of pollutants on insulator surface](image-url)
C.3.2 Procedure using washing technique (cap and pin insulators)

- Cover the cap and pin respectively with plastic cling wrap without covering the insulator surface.
- Ensure that the bowl in which the discs are to be washed in is clean.
- Measure 500 - 1000 cm³ (or more if required) of distilled water (σ<0.001 S/m) and pour into the bowl.
- Place the test insulator on its cap in the water and wash the surface facing the water with gentle hand strokes up to the rim.
- Place the same insulator on its pin in the bowl and gently wash the pollution off the under surface with gentle hand strokes.
- Pour the water into a container taking care again that no deposits remain in the bowl.

The above procedure can be used to collect top and bottom deposits separately.

C.4 Determining ESDD and NSDD

C.4.1 ESDD calculations

The conductivity and the temperature of the water containing the pollutants shall be measured. The measurements shall be made after enough stirring of the water. A short stirring time, e.g., a few minutes, is required for high solubility pollutants. The low solubility pollutants generally require longer stirring time, e.g., 30 - 40 minutes.

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

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

where:

- \( \theta \) is the solution temperature (°C).
- \( \sigma_{\theta} \) is the volume conductivity at temperature of \( \theta \) C (S/m).
- \( \sigma_{20} \) is the volume conductivity at temperature of 20°C (S/m).
- \( b \) is the factor depending on temperature of \( \theta \), as obtained by the formula (2), and as shown in figure C3.

\[
b = -3,200 \times 10^{-8} \theta^3 + 1,032 \times 10^{-5} \theta^2 - 8,272 \times 10^{-4} \theta + 3,544 \times 10^{-2}
\]
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 60507. The relation between $\sigma_{20}$ and $S_a$ (Salinity, kg/m$^3$) is shown in figure C4.

$$S_a = (5.7\sigma_{20})^{1.03}$$  \hspace{1cm} (C3)

$$\text{ESDD} = S_a \cdot V/A$$  \hspace{1cm} (C4)

where:

- $\sigma_{20}$ is the volume conductivity at temperature of 20°C (S/m).
- ESDD is Equivalent salt deposit density (mg/cm$^2$).
- $V$ is the volume of distilled water (cm$^3$).
- $A$ is the area of the insulator surface for collecting pollutants (cm$^2$).
If separate top and bottom ESDD measurements have been made the average ESDD can be calculated as follows (can also be used for average NSDD):

\[
\text{Average ESDD} = \frac{(ESDD_t \times A_t + ESDD_b \times A_b)}{A},
\]

where:
- \(ESDD_t\) is ESDD on top area (mg/cm²).
- \(ESDD_b\) is ESDD on bottom area (mg/cm²).
- \(A_t\) is the top area of the insulator surface (cm²).
- \(A_b\) is the bottom area of the insulator surface (cm²).
- \(A\) is the total area of the insulator surface (cm²).

**NOTE 1** For low ESDD measurements 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 or 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.

**NOTE 2** The quantity of the distilled or demineralized water depends on kind and amount of pollutants. A 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.

**NOTE 3** The 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.

**C.4.2 NSDD calculations**

The water containing pollutants after measuring ESDD shall be filtered out by using a funnel and pre-dried and weighed filter paper (grade GF/A 1,6 µm or similar).

The filter paper containing pollutants (residuum) shall be dried, and then weighed as shown in figure C5.

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

\[
\text{NSDD} = \frac{1000(W_f - W_i)}{A}
\]

where:

- \(\text{NSDD}\) is non-soluble material deposit density (mg/cm²).
- \(W_f\) 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 (cm²).

![Figure C5 - Procedure of measuring NSDD](image-url)
C.5 Chemical analysis of pollutants

Quantitative chemical analysis can be made on pollutants for close examination of pollution conditions. The analysis can be useful to identify chemical components of soluble salts. Chemical analysis of soluble salts is made by using solution after ESDD measurement by means of ion-exchange chromatography (IC), inductive coupled plasma-optical emission analytical spectrometry (ICP), etc. The analysis results can show amounts of positive ions, e.g. Na⁺, Ca²⁺, K⁺, Mg²⁺, and negative ions, e.g. Cl⁻, SO₄²⁻, NO₃⁻.
Annex D
Evaluation of Type B pollution severity

D.1 Introduction

Marine site contamination often belongs to the type of instantaneous pollution, occurring close to the coast. The duration of a pollution event may last from less than 1 hour to more than 24 hours. To determine the pollution severity in such a case a periodical measurement (for example every half an hour or hour) or a continuous measurement of surface currents on an insulator can be used. Alternatively measurement of insulator flashover stress can be adopted (see D.3). For all these cases, the measurements obtained are compared with values obtained in an artificial salt fog test to determine the Site Equivalent Salinity (SES).

In some cases, notably where dry salt build-up is expected, the methods for evaluation of SPS for Type A pollution are used for Type B pollution. D.4 gives some guidance on this method.

D.2 Evaluation of SES for type B pollution by leakage current measurement

D.2.1 Measurement of surface conductance

This periodical measurement is performed at a low voltage on an insulator with a simple shed shape or a reference cap and pin or long rod insulator. The applied voltage (2 minute interval) shall be low enough (for example 700 V\text{rms} per metre of creepage distance) to avoid dry band arcing. The current values shall be recorded in a suitable way.

Note: the surface conductance is not a comparable parameter for different insulators. Surface conductance can be converted into surface conductivity with the help of the form factor. –See Annex H

D.2.2 Measurement of surface leakage currents

This continuous measurement is performed on a string of reference cap and pin insulators or a reference long-rod insulator. The electrical stress used should maintain the insulator in a withstand condition for the expected site pollution severity class, e.g. no pollution flashover should occur during the test period. The current values shall be recorded in a suitable way.

D.2.3 Calibration by a salt-fog test

In both cases above the calibration for the current values is made by a salt fog test according to IEC 60507 on the same insulator and at the same voltage stress. The tests are made with increasing salinity from test to test, until peak values of leakage current (\(i_{\text{highest}}\)) comparable to those from the site measurement occur. The corresponding salinity is the SES.

NOTE 1 \(i_{\text{highest}}\) is the highest peak value of the leakage current measured on an insulator at withstand conditions during a sufficient test period (i.e. one or more years in case of outdoor test station or one hour in case of salt fog tests according to IEC 60507).

NOTE 2 If polymeric insulators are used for SES evaluation instead of the reference insulators defined in this Publication, it is to be noted that hydrophobic insulators submitted to the IEC 60507 salt-fog test can exhibit lower performance than can be expected in service due to the temporary loss of hydrophobicity caused by the preconditioning process.

D.3 Evaluation of SES for type B pollution by measurement of insulator flashover stress

This continuous measurement is performed on a string of reference cap and pin insulators or a reference long-rod insulator at an outdoor testing station and provides results that are closest to service experience. The insulator flashover stress is the flashover voltage divided by either the insulator length, or the insulator creepage length. Results over a period of time...
can be presented as either the minimum flashover stress, or as a relationship between flashover stress and frequency of flashover. The test procedure usually involves bridging out some insulators in a string with explosive fuses, so that after flashover the string is automatically lengthened (for more information see CIGRE 158 [1]). The minimum flashover stress can then be directly calibrated against salt fog test results according to IEC 60507 on the same reference insulator to obtain the SES for the outdoor testing station. In this way, Site Pollution Severity (SPS) can be correlated against SES for the reference insulator (see Section 9, Figure 3), where flashover, rather than leakage current is the criteria of performance. In addition, other pollution severity measurements (e.g. DDDG, surface conductance, surface leakage currents) can also be correlated against SPS for the reference insulator at the test site.

NOTE The SES represents an appropriate IEC 60507 salt fog withstand test for the reference insulator and should not be used directly to determine the severity of an artificial pollution test for other insulator designs (see Ref [2] for more information).

D.4 How to estimate SPS for type B pollution

The Flowchart in Annexe A represents the general approach for estimating the SPS for a site with type B pollution. Analysis of potential contamination sources and frequency of wetting is important in assessing the SPS. Data from a number of pollution severity measurements will also help in determining the correct SPS for a location. For example, SPS for a coastal location, where salt water or conductive fog is deposited onto the insulator surface and non-soluble deposits may or may not be important, can be obtained from service experience, ESDD, DDDG, surface conductivity or leakage current results. The strengths and weaknesses of each method need to be considered when interpreting results (see CIGRE 158 [1] for more information). Therefore, in the above coastal example where non-soluble deposits are negligible and regular wetting of the reference insulator occurs, ESDD measurements are likely to be low due to regular cleaning of the insulator surface. Under such circumstances, a statistical approach is required to analyse collected data, and a maximum likelihood estimation of the distribution function should be used. The upper 2% value at 95% confidence level, for example, can then be used as the SPS dimensioning parameter to compensate for too low, or too few measurement values (see Ref. [2] for more information). This approach would be particularly important when designing insulation for critical installations.
Annex E
Directional Dust Deposit Gauge
Measurements

E.1 Introduction

The dust gauge, as shown in Figure E.1, is comprised of four vertical tubes each with a slot milled in the side - these being so arranged as to face north, south, east and west. A removable container which collects the deposits blown into the slots is attached to the bottom of each tube.

To facilitate international comparison of results, the slot size as shown in Figure D.1 shall be used. The nominal dimensions are a 40 mm wide slot with 20 mm radii at each end. The distance between the centres of the radii is 351 mm (the overall slot length thus being 391 mm). The tube is at least 500 mm long with 75 mm outside diameter. The distance from the top of the tube to the top of the slot is 30 mm. The tubes are mounted with the bottom of the slot approximately 3 metres from the ground; this keeps the gauge out of reach of casual tampering but the jars can be easily and safely changed. The gauges may be mounted lower if ground conditions allow.

These containers are removed at monthly intervals, their contents mixed with 500 ml of demineralised water, any obvious macroscopic debris (leaves, insects etc.) removed and the conductivities of the solutions measured. The pollution index is defined as the average of the conductivities of the four directions, expressed in mS/cm, and normalised to a 30-day interval.

Figure E.1: Directional dust deposit gauges as installed (a), and dimensions (b).
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.

The major disadvantage with the dust gauge 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. The climatic factor for the area is thus used to help correct for this phenomena.

E.2 Measurement procedure

The monthly measurement procedure is as follows:

On site....
1) Remove the four collection jars from the tube ends and close with the lids provided.
2) Record the date of removal on the jar label.
3) Attach four clean jars to the tubes, having completed the label on each jar to indicate the site, the direction and the date of installation.

At the measurement location...
1) Add 500 ml of demineralised water to each collection jar. The conductivity of the water must be less than 5 $\mu$S/cm. Should the vessel contain rain water, add demineralised water to make up the volume to 500 ml. If, owing to heavy rainfalls, there is more than 500 ml in the jar, no additional water is required.
2) Swirl or stir the contents until all the soluble salts are dissolved.
3) Measure the conductivity of the solution - preferably with a conductivity meter which automatically corrects the reading to 20 °C. If the meter is not compensated to 20 °C, then measure the temperature of the solution as well.
4) If the volume of the solution is not 500 ml, for example in the case of excessive rain having accumulated in the jar, measure the actual volume.
5) Calculate the corrected conductivity for each direction – this being the conductivity at 20 °C, expressed in $\mu$S/cm, and normalised to a volume of 500 ml and a 30-day month. The normalised DDDG value is calculated using the equation:

$$\text{DDDG} = \sigma_{20} \times \frac{V_d}{500} \times \frac{30}{D}$$ (E1)

where,

DDDG: directional deposit gauge conductivity, in $\mu$S/cm
D: days DGG installed.

If the conductivity reading is not compensated for temperature by the measuring instrument, the value can be corrected to 20 °C using Equations C1 and C2.

6) Calculate the Pollution Index (PI) for the month by taking the average of the four corrected directional conductivities, expressed in $\mu$S/cm, i.e.

$$\text{PI} = \frac{(\text{DDDGNorth} + \text{DDDGSouth} + \text{DDDGEast} + \text{DDDGWest})}{4}$$ (E2)

NOTES:
1) Some contamination can collect on the inside of the tubes and will be washed into the collection jars when it rains. The pollution indices for the wet months may therefore show slightly higher values than those when there was no precipitation. If the readings are averaged over a period then this makes no difference. However, if very
accurate monthly figures are required, then the internal walls of the tube can be rinsed off using a squeeze bottle of demineralised water before the collecting jars are removed for analysis.

2) For more detailed information on the nature and/or source of the pollution, the gauge contents may be sent to a laboratory for comprehensive chemical analysis.

If an assessment of the non-soluble deposit is required, following the conductivity measurements, the solutions shall be filtered using a funnel and pre-dried and weighed filter paper of grade GF/A 1,6 mm or similar. The paper shall then be dried and weighed again. The weight difference in grams then represents the Non-Soluble Deposit (NSD).

E.3 Determination of the SPS class from the DDDG measurements

The relationship between the site pollution severity (SPS) class and the pollution index, preferably measured over a period of at least one year, is provided in table D1, table D2 gives information on correction for NSD levels measured with the DDDG.

Table D.1: Directional dust deposit gauge pollution index in relation to site pollution severity class.

<table>
<thead>
<tr>
<th>Directional dust deposit gauge pollution index, PI (μS/cm) (take whichever is the highest)</th>
<th>Site pollution severity class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average monthly value over one year</td>
<td>Monthly maximum over one year</td>
</tr>
<tr>
<td>&lt; 25</td>
<td>&lt; 50</td>
</tr>
<tr>
<td>25 to 75</td>
<td>50 to 175</td>
</tr>
<tr>
<td>76 to 200</td>
<td>176 to 500</td>
</tr>
<tr>
<td>201 to 350</td>
<td>501 to 850</td>
</tr>
<tr>
<td>&gt; 350</td>
<td>&gt; 850</td>
</tr>
</tbody>
</table>

Table D.2: Correction of site pollution severity class as a function of DDDG NSD levels.

<table>
<thead>
<tr>
<th>Directional dust deposit gauge NSD (grams) (take whichever is the highest)</th>
<th>Site pollution severity class correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average monthly value over one year</td>
<td>Monthly maximum over one year</td>
</tr>
<tr>
<td>&lt; 0.5</td>
<td>&lt; 1.5</td>
</tr>
<tr>
<td>0.5 to 1.0</td>
<td>1.5 to 2.5</td>
</tr>
<tr>
<td>&gt; 1.0</td>
<td>&gt; 2.5</td>
</tr>
</tbody>
</table>

E.4 Correction for climatic influences

If weather data for the site in question is available then the directional dust deposit gauge pollution index can be adjusted to take into account climatic influences. This is done by multiplying the pollution index value (PI), as determined above, by the climatic factor (Cf).
The climatic factor is given by:

\[
C_f = \sqrt{\frac{F_d + D_m}{20 + \frac{3}{2}}}
\]  

(E3)

where,

- \( F_d \): number of fog days (\( \leq 1000 \text{ m} \) of horizontal visibility) per year.
- \( D_m \): number of dry months (< 20 mm of precipitation) per year.

NOTE – The relationship above (D.3) is based on the findings in South Africa measured at 80 sites for more than 4 years.
Annex F
Use of laboratory test methods

The relevant test method to be used is selected according to the type of pollution at the site, the type of insulator and the type of voltage. The tests given in IEC 60507 and IEC 61245 are directly applicable to ceramic and glass insulators. Up to now, there is no standard test directly applicable to polymeric insulators. As a general rule, the solid layer test is recommended for type A pollution and the salt-fog test for type B pollution.

The pollution severity used in the laboratory test is determined in three steps:

1) The pollution type present and the site pollution severity are determined by assessing the pollution at a site, as described in clause 9 and annexes C, D and E.

2) The site pollution severity level is corrected for any deficiency or inaccuracy in the determination of the SPS. The correction factors shall compensate for:
   • Differences in pollution catch of the insulator used for the site pollution severity measurement and the insulator to be tested, e.g. the influence of shed profiles and diameters;
   • Differences in types of the voltage applied on the insulator used for the site pollution severity measurement and the insulator to be tested, e.g. d.c. or a.c. voltage;
   • Other influences of importance.

3) The required pollution severity at which the laboratory test is performed is derived from the SPS to compensate for the differences between the actual in-service conditions of the insulation and those in the standard tests. These correction factors shall compensate for:
   • Difference in pollution type of the pollution deposit at site and in the test;
   • Differences in the uniformity of the pollution deposit at site and in the test;
   • Differences in the wetting conditions in service and those during the test;
   • The differences in the equipment assembly.

Other influences of importance may include:
   • The effect of ageing on the pollution catch and wettability of the insulation during the expected lifetime
   • The statistical uncertainty of performing a limited number of tests to verify the required pollution severity withstand level.

These are the general principles of this process. Details and guidance on the choice of values for the correction factors are provided in the further parts of this publication.

The use of non standard, or customised, laboratory pollution test methods may be considered, if agreed between the suppliers and customers. More information on such methods can be found in CIGRE 158 [1].
Annex G
Deterministic and statistical approaches for artificial pollution test severity and acceptance criteria

Deterministic approach

The deterministic approach has been widely used for the design of many electrical and mechanical components, apparatus, and systems. Components are then designed according to material selection and dimensioning (including insulator profile). In the present case, the insulation level is based on a worst-case analysis and safety factors to cover unknowns. It is assumed that there is a definitive maximum of the site severity that may stress the insulator, shown as the environment “S” curve in Fig. G1. It is also assumed that the insulation strength can be described by a minimum withstand pollution severity below which flashover is not possible; determined either from service performance or laboratory tests. The minimum insulation withstand pollution severity is then selected so that it exceeds the maximum stress by a safety margin which is chosen to cover only uncertainties in the designer’s evaluation of the strength and the stress parameters.

2. Statistical approach

The statistical dimensioning of insulators entails the selection of the dielectric strength of an insulator, with respect to the voltage and environmental stresses (stress/strength concept), to fulfill a specific availability requirement. This is done by evaluating the risk for flashover of potential insulation options and selecting those yielding an acceptable performance.
With reference to Figure 2, the risk for flashover can be calculated as follows:

- A cumulative distribution function $P(\gamma)$ describing the strength of the insulation, i.e., the probability for flashover as a function of the same severity $\gamma$ as used to describe the pollution stress (e.g. ESDD) is obtained. These data normally come from laboratory tests, service experience or field tests. In case of laboratory tests, the SDD in laboratory should be corrected from ESDD in service according to Annex F.
- The $P(\gamma)$ function is then converted from a representation of a single insulator, to represent the performance of $m$ insulators installed on an entire line or line section, exposed to the same number of pollution events.
- The two functions $f(\gamma)$ and $P(\gamma)$ are subsequently multiplied to give the probability density for flashover, and the area under this curve expresses the risk for flashover during a pollution event.
- If the number of pollution events per year is known (e.g. salt storms in coastal areas, or light rain or dew in inland areas) the risk for flashover per year can be calculated.
Annex H
Example of a questionnaire to collect information on the behaviour of insulators in polluted areas

Company: Country

Identification of the project and/or location:
Line or substation

Contact person, address, fax, telephone, email:

1 – System Data/Requirements (see clause 7 of IEC 60815)

- Nominal voltage of the system and highest voltage for equipment
- Value and duration of temporary overvoltages
- Strategic importance
- Date of construction
- Date of energizing
- Type of system
- Cleaning yes/no frequency:
- Maintenance (not involving refurbishment)
- Washing yes/no frequency:
- Greasing yes/no frequency:

Overhead lines
- Type of tower or structure (include sketch)
- Number of circuits
- Ground clearance
- Type of insulator sets
- Insulator protective fittings

Substations
- Type of apparatus:
- Clearances

2 – Environmental and pollution conditions (see clause 8 of IEC 60815)

General information
- Map of areas crossed, routing and altitudes of the line
- Different climatic zones crossed by the line
- Place orientation and altitude of substations (show wall bushing orientation with respect to prevailing winds)
- Sheltering of the area by vegetation, structures or geological features

Climate
- Type of climate: temperate, tropical, equatorial, continental...
- Time without rainfall, in months
- Annual rainfall (mm): Monthly rainfall (if available)
- Dominant wind: direction, average speed (km/h): Monthly data (if available)
- Dew: yes/no frequency
- Fog: yes/no frequency
- Humidity: Monthly peak and average (if available)
Pollution types

Type A
- Sand-based pollution or ground dust (e.g. desert)
- Industrial pollution with large amounts of solid deposits (except cement)
- Industrial pollution with large amounts of cement (or other slow dissolving salts)
- Chemical or industrial pollution, smokes
- Agriculture

Type B
- Seaborne pollution – small amount of insoluble matter
- Saline pollution other than coastal – small amount of insoluble matter
- Chemical or industrial pollution, gas, acid rain

Combination of Type A and Type B
- Indicate the main components and their relative frequency

Pollution levels (SPS)
- SPS Class according to IEC 60815-1
- Method used to evaluate SPS
- Type of reference insulators, other insulators
- Measuring frequency
- Duration of study
- Yearly maxima of ESDD, NSDD, SES or DDDG measurements (monthly data if available)

Other constraints
- Lightning
- Seismic activity
- Vandalism

3 – Insulator parameters

Approach used to define the insulation
- IEC 60815-1 Approach A
- IEC 60815-1 Approach B
  - With site measurement?
  - Confirming test method/results
- IEC 60815-1 Approach C
  - With site measurement?

Overhead lines
- Position and type of string
- Type of insulator
- Insulator material
- Overall length of string, diameter(s)
- Profile
- Unitary/total creepage distance
- Arcing distance

Substations
- Position of the insulator
- Type of insulator (post, bushing etc.)
- Insulator material
- Overall length, diameter(s)
- Profile
- Total creepage distance
- Arcing distance
4 – Details of incidents

**General information**
- Date and time
- Situation of the tower or structure, apparatus, substation
- Meteorological conditions before/during the incident(s):
  - Relative humidity
  - Rain
  - Drizzle
  - Fog/sea mist
  - Temperature
  - Storms
  - Wind (direction, average and peak speed)
  - Time since last rainfall and incident
  - Other

**Type of incident and observations**
- Flashover
- Heavy corrosion of metal parts
- Puncture, tracking or erosion of the dielectric
- Other visible damage
- Localisation of damage on the insulator
- Any other observations or comments
Annex I
Form Factor

Form Factor \((Ff)\) is a dimensionless number that presents the length \((l)\) of the partial creepage distance divided by the integrated width \((p)\). For insulators, the length is in the direction of the creepage distance and the width is the circumference of the insulator as shown below.

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

where \(L\) is the total length along the surface (creepage distance).

Figure H1 – Form factor

In this case, \(Ff\) is equal to the integral of the reciprocal value of the insulator circumference versus the partial creepage distance counted from the end of the insulator up to the point reckoned. It is only dependent on the shape of the surface and not at all dependent on the size. See IEC 60507.

A surface that contains a uniformly distributed conducting layer, has a total conductivity dependent on

- the specific conductivity of the surface
- the \(Ff\).

The \(Ff\) gives an exact relation between the resistivity/conductivity of a uniformly conductive surface, for example the surface of a uniformly polluted and wetted insulator, and the total resistance/conductance of same surface.
Annex J
Correspondence between specific creepage distance and USCD

Specific creepage distance (SCD) as used in the previous edition of IEC 60815 was based on the system voltage. For a.c. systems this is the phase to phase voltage. The USCD refers to the voltage across the insulator, i.e. for a.c. systems the phase to ground voltage.

The following table gives the correspondence between commonly used values of SCD and USCD.

<table>
<thead>
<tr>
<th>Specific creepage distance for 3 phase a.c. systems</th>
<th>USCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>12,7</td>
<td>22</td>
</tr>
<tr>
<td>14,4</td>
<td>25</td>
</tr>
<tr>
<td>16</td>
<td>27,7</td>
</tr>
<tr>
<td>16,17</td>
<td>28</td>
</tr>
<tr>
<td>20</td>
<td>34,7</td>
</tr>
<tr>
<td>20,21</td>
<td>35</td>
</tr>
<tr>
<td>25</td>
<td>43,3</td>
</tr>
<tr>
<td>25,4</td>
<td>44</td>
</tr>
<tr>
<td>31</td>
<td>53,7</td>
</tr>
<tr>
<td>31,75</td>
<td>55</td>
</tr>
<tr>
<td>38,7</td>
<td>67</td>
</tr>
</tbody>
</table>
## Annex K
### Bibliographic References

1. CIGRE Taskforce 33.04.01 – “Polluted insulators: A review of current knowledge”, CIGRE brochure N° 158-2000

2. CIGRE Taskforce C4.13.01 – Guidelines for the selection and dimensioning of insulators for outdoor applications, CIGRE brochure N° ???-2004


4. CIGRE Taskforce 33.04.03 – “Insulator pollution monitoring”, Electra 152, February 1994
60038, and a pollution severity withstand level.

The pollution severity withstand level characterises the pollution performance of the insulation when energised to the co-ordination withstand voltage. The pollution severity withstand level is determined in three steps:

1) The pollution type present and the site pollution severity are determined by assessing the pollution at a site, as described in clause 9 and annexes B and C.

The site pollution severity level is adjusted for any differences between the reference insulator and the insulator to be tested. This corrected value is named the co-ordination pollution severity withstand level. The adjustment shall compensate for:

- Differences in pollution catch of the insulator used for the site pollution severity measurement and the insulator to be tested;
- Differences in types of the voltage applied on the insulator used for the site pollution severity measurement and the insulator to be tested;
- Differences in the diameter between the insulator used for the site pollution severity measurement and the insulator to be tested;
- Other influences of importance.

The required pollution severity withstand level, which is the severity at which the laboratory test is performed is derived from the co-ordination pollution severity withstand level to compensate for the differences between the actual in-service conditions of the insulation and those in the standard withstand tests. The correction factors shall compensate for:

- Difference in pollution type of the pollution deposit at site and in the test;
- Differences in the uniformity of the pollution deposit at site and in the test;
- Differences in the wetting conditions in service and those during the test;
- The differences in the equipment assembly;
- The dispersion in the product quality;
- The effect of ageing on the pollution catch and wettability of the insulation during the expected lifetime;
- The statistical uncertainty of performing a limited number of tests to verify the required pollution severity withstand level;
- Other influences of importance.

These are the general principles of this process. Details and guidance on the choice of values for the correction factors are provided in the further parts of this publication.

The relevant test method to be used is selected according to the type of pollution at the site, the type of insulator and the type of voltage. The tests given in IEC 60507 and IEC 61245 are directly applicable to ceramic and glass insulators. Up to now, there is no standard test directly applicable to polymeric insulators. More information on this issue is given in [2]. As a general rule, the solid layer test is recommended for type A pollution and the salt-fog test for type B pollution.
The use of non standard, or customised, laboratory pollution test methods may be considered, if agreed between the suppliers and customers. More information on such methods can be found in CIGRÉ 158 [1].