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

Introduction from the Project Leader

What's new?
This draft takes into account many of the decisions taken at our Milan meeting.

Remaining tasks, notes etc. are outlined in yellow

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

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

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

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

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

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

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

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

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

- Encouragement of the use of site pollution severity measurements, preferably over at least a year, in order to classify a site instead of the previous qualitative assessment;
- Addition of the influence of non-soluble deposit density (NSDD) as a parameter of severity;
- Use of the results of natural and artificial pollution tests to help with dimensioning;
- Recognition that creepage length is not always the sole determining parameter;
- Recognition of the influence other geometry parameters (e.g. large or small diameters, non-linearity ...).
IEC 60815: Guide for the selection and dimensioning of high-voltage insulators for polluted conditions
Part 1 - : Definitions, information and general principles

1. Scope and object

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

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

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

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

- 60815-2 - Ceramic 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 structure is based that used in CIGRE 33.13 TF 01 documents [1, 2], which form a useful complement to this guide for those wishing to study the performance of insulators under pollution in greater depth.

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

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

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

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

IEC 60507
IEC 61245
IEC 61471
IEC 60071-2

List to be updated

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 U120/146 cap and pin insulator (according to IEC 60305).

3.2. Insulator Trunk

The central insulating part of an insulator from which the sheds project. (Also known as shank on smaller insulators).

3.3. Sheds

The sheds are the projections from the trunk of an insulator intended to increase the creepage distance. Various typical types of shed and shed profiles are illustrated in Figure 1.

3.4. Dry Arcing Distance

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

3.5. Creepage distance (from IEC 61325, supersedes IEV 471-01-08)

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. - The surface of cement or of any other non-insulating jointing material is not considered as forming part of the creepage distance. 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. Surfaces of the insulating parts of the insulator between those parts which normally have the operating voltage between them.

3.6. Unified Specific Creepage Distance

The creepage distance of an insulator divided by the r.m.s. value of the highest operating voltage across the insulator. 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 ground insulation, this definition will result in a value that is \(\sqrt{3}\) times that of the previous definition of IEC 815 (1986).
3.7. Profile parameters
Set of geometrical values that have an influence on pollution withstand performance.

3.8. Pollution severities

Site Pollution Severity Class – Very light to very heavy See ELECTRA 1978/1994 ?DAS

Site Pollution Severity See doc 105 either peak ESDD/NSDD or SES

3.9. Check for others……..

4. Abbreviations

- U.S.C.D.: the Unified Specific Creepage Distance
- ESDD: Equivalent Salt Deposit Density
- NSDD: Non Soluble Deposit Density
- DDDG: Directional Dust Deposit Gauge
- TOV: Temporary Overvoltage
- SES: Site Equivalent Salinity
- SPS: Site Pollution Severity

Check for others……..

5. Input parameters for the insulator selection and dimensioning

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

Table 1 - Parameters for insulator selection and dimensioning (non pollution related parameters in italic)

<table>
<thead>
<tr>
<th>System requirements</th>
<th>Environmental Conditions</th>
<th>Insulator parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Pollution level and types</td>
<td>Type</td>
</tr>
<tr>
<td>Withstand voltages</td>
<td>Rain, fog, dew, ...</td>
<td>Material</td>
</tr>
<tr>
<td>Reliability, availability, maintainability. (R.A.M.)</td>
<td>Wind</td>
<td>Profile</td>
</tr>
<tr>
<td>Costs</td>
<td>Temperature, humidity</td>
<td>Creepage distance</td>
</tr>
<tr>
<td>Installation position, clearance, ...</td>
<td>Altitude</td>
<td>Diameters</td>
</tr>
<tr>
<td></td>
<td>Lightening</td>
<td>Arcing distance</td>
</tr>
<tr>
<td></td>
<td>Earthquakes</td>
<td>Overall length</td>
</tr>
<tr>
<td></td>
<td>Vandalism</td>
<td></td>
</tr>
</tbody>
</table>

6. System requirements

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

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

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

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

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

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

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

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

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

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

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

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

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

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

7. **Pollution types and severity (needs cleaning up)**

7.1. **Identification of types of pollution**

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

**Type A - Solid-layer type**: where solid pollution with or without 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 measurements.
Type B - Salt-fog type: where liquid electrolytes are deposited on the insulator with no non-soluble components. This type of pollution can be best characterised by conductance measurements.

Combinations of the two types can arise.

7.1.1. Type A pollution

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

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

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

7.1.1.1. Sources of Type A pollution

Examples of possible sources of Type A insulator pollutants are given below.

The sea.
The ground, such as salt pans or some deserts.
Roads and railways.
Factories emitting contaminants.
Mining activities that produce dust-containing substances such as gypsum.
Agricultural activities such as crop spraying or ploughing.
Bird droppings.

7.1.2. Type B pollution

Insert description similar to Type A

7.1.2.1. Sources of Type B pollution

Examples of possible sources of Type B insulator pollutants are given below.

The sea.
Factories emitting gaseous contaminants such as \( \text{SO}_2 \) that can dissolve to form conductive layers during acid rain conditions.

7.2. Pollution Severity

Pollution severity at a site is expressed in terms of:

- ESDD and NSDD for Type A pollution,
- Site Equivalent Salinity (SES) for Type B pollution.

Pollution severity on naturally polluted insulators is expressed in terms of:

- ESDD and NSDD for Type A pollution,
• ESDD for Type B pollution.

Pollution severity in artificial pollution tests on insulators is expressed in terms of:

• SDD and NSDD for solid layer methods,
• Fog salinity (kg/m³) for salt-fog methods.

7.2.1. Evaluation of site pollution severity

Add "definition" from doc 105

SEE CE & WP document

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

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

• from measurements in situ.
• from information on the behaviour of insulators from lines and substations already in service on or close to the site (see Annex Y),
• If not otherwise possible, qualitatively from indications given in Table 3,

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

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

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

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

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

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

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

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

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

7.3. Site pollution severity levels

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

A – Very light

E – Very heavy.

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

Figure 2 gives ranges of ESDD/NSDD values for standard cap and pin insulators. These values are deduced from field measurements, experience and pollution tests. The values are the maximum values that can be found from regular measurements taken over a minimum one year period.

Some insulator characteristics, for example profile, have an important influence on the pollution quantity deposited on insulators themselves. Therefore, these typical values are only available for standard glass or ceramic cap and pin insulators.
Figure 2 - Relation between ESDD/NSDD and site severity for standard profile cap and pin insulators.
Table 3 - Examples of typical environments and appropriate pollution evaluation methods

<table>
<thead>
<tr>
<th>Example</th>
<th>Description of typical environments</th>
<th>SPS Class</th>
<th>Evaluation Type</th>
</tr>
</thead>
</table>
| ![Example](image1) | > 50 km \(^1\) from the sea, a desert, or open dry land  
> 10 km from man-made pollution sources \(^2\)  
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 | A | Very Light Fill in acc to FS tab 3 |
| ![Example](image2) | 10-50 km \(^1\) from the sea, a desert, or open dry land  
5-10 km from man-made pollution sources \(^2\)  
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 | B | Light |
| ![Example](image3) | 3-10 km \(^{iii}\) from the sea, a desert, or open dry land  
1-5 km from man-made pollution sources \(^{ii}\)  
Within a shorter distance than mentioned above of pollution sources, but:  
• prevailing wind not directly from these pollution sources  
• and/or with regular monthly rain washing  
Further away from pollution sources than mentioned above (distance in the range specified for “Light” areas) but:  
• dense fog (or drizzle) often occurs after a long (several weeks or months) dry pollution accumulation season  
• and/or the present heavy rain with high conductivity  
• and/or there is a high NSDD level, between 5 and 10 times the ESDD | C | Medium A/B |
| ![Example](image4) | Within 3 km \(^{iii}\) of the sea, a desert, or open dry land  
Within 1 km of man-made pollution sources \(^{ii}\)  
With a longer distance from pollution sources than mentioned above (distance in the range specified for “Medium” areas) but:  
• dense fog (or drizzle) often occurs after a long (several weeks or months) dry pollution accumulation season  
• and/or the present heavy rain with high conductivity  
• and/or there is a high NSDD level, between 5 and 10 times the ESDD | D | Heavy A/B |
| ![Example](image5) | 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 | D | Very heavy B |

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

8. **Proposed approaches for the insulator selection and dimensioning**

To select suitable insulators from the catalogues based on the system requirements and the environmental conditions, three approaches (A, B, C, in figure 1 below) are recommended.  
The applicability of each approach depends on available data, time and economics involved in the project. The degree of confidence that the correct type and size of insulator has been selected varies also according to the decisions taken during the process. It is intended that if...
"shortcuts" have been taken in the selection process then the resulting solution will represent over-design rather than one with a high failure risk in service. Table 2 shows the data and decisions needed within each approach.

<table>
<thead>
<tr>
<th>APPROACH A</th>
<th>APPROACH B</th>
<th>APPROACH C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input Data</strong></td>
<td><strong>Input Data</strong></td>
<td><strong>Input Data</strong></td>
</tr>
<tr>
<td>• System requirements.</td>
<td>• System requirements.</td>
<td>• System requirements</td>
</tr>
<tr>
<td>• Environmental conditions.</td>
<td>• Environmental conditions.</td>
<td>• Environmental conditions.</td>
</tr>
<tr>
<td>• Insulator parameters.</td>
<td>• Insulator parameters.</td>
<td>• Insulator parameters.</td>
</tr>
<tr>
<td>• Performance history.</td>
<td>• Performance history.</td>
<td>• Performance history.</td>
</tr>
<tr>
<td><strong>Decisions</strong></td>
<td><strong>Decisions</strong></td>
<td><strong>Decisions</strong></td>
</tr>
<tr>
<td>Does the existing insulation satisfy the project requirements?</td>
<td>Is there time to measure site pollution severity?</td>
<td>Is there time to measure site pollution severity?</td>
</tr>
<tr>
<td><strong>Selection Process</strong></td>
<td><strong>Selection Process</strong></td>
<td><strong>Selection Process</strong></td>
</tr>
<tr>
<td>• A verified selection with high confidence of good performance.</td>
<td>• A qualified selection with confidence of good performance varying following the degree of errors and/or shortcuts in the site severity evaluation</td>
<td>• A possibly over-designed solution compared to A or B</td>
</tr>
<tr>
<td><strong>Result</strong></td>
<td><strong>Result</strong></td>
<td><strong>Result</strong></td>
</tr>
<tr>
<td>• Use existing field or test station experience to choose</td>
<td>• Measure or estimate site pollution severity.</td>
<td>• Measure or estimate site pollution severity.</td>
</tr>
<tr>
<td>and size insulation for the same site, a nearby site or a site with similar conditions.</td>
<td>• Select candidate insulators using profile and creepage guidance hereafter.</td>
<td>• Use this data to choose type and size of insulation based on profile and creepage guidance hereafter.</td>
</tr>
<tr>
<td>• Measure or estimate site pollution severity.</td>
<td>• Choose applicable laboratory test and test criteria.</td>
<td>• System requirements</td>
</tr>
<tr>
<td>• Select candidate insulators using profile and creepage guidance hereafter.</td>
<td>• Verify/adjust candidates</td>
<td>• Environmental conditions.</td>
</tr>
<tr>
<td>• Choose applicable laboratory test and test criteria.</td>
<td>• Measure or estimate site pollution severity.</td>
<td>• Insulator parameters.</td>
</tr>
<tr>
<td>• Verify/adjust candidates</td>
<td>• Use this data to choose type and size of insulation based on profile and creepage guidance hereafter.</td>
<td>• Time and resources available.</td>
</tr>
<tr>
<td>• Is there time to measure site pollution severity?</td>
<td>• Site severity determines the test values</td>
<td>• Is there time to measure site pollution severity?</td>
</tr>
<tr>
<td><strong>YES</strong></td>
<td><strong>YES</strong></td>
<td><strong>YES</strong></td>
</tr>
<tr>
<td>Use the same insulation.</td>
<td>Measure</td>
<td>Measure</td>
</tr>
<tr>
<td><strong>NO</strong></td>
<td><strong>NO</strong></td>
<td><strong>NO</strong></td>
</tr>
<tr>
<td>Use different insulation or different size.</td>
<td>Estimate</td>
<td>Estimate</td>
</tr>
<tr>
<td>• Does the existing insulation satisfy the project requirements?</td>
<td><strong>YES</strong></td>
<td><strong>YES</strong></td>
</tr>
<tr>
<td><strong>NO</strong></td>
<td>Measure</td>
<td>Measure</td>
</tr>
<tr>
<td>Use the same insulation.</td>
<td>Estimate</td>
<td>Estimate</td>
</tr>
<tr>
<td>• Is a different material, type or profile to be used?</td>
<td><strong>YES</strong></td>
<td><strong>YES</strong></td>
</tr>
<tr>
<td>Use the same insulation.</td>
<td>Select candidates</td>
<td>Select candidates</td>
</tr>
<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>• Test</td>
<td>• Test</td>
</tr>
<tr>
<td>• Test</td>
<td>Adjust selection/size according to the test results if necessary.</td>
<td>Adjust selection/size according to the test results if necessary.</td>
</tr>
<tr>
<td>• Adjust selection/size according to the test results if necessary.</td>
<td><strong>YES</strong></td>
<td><strong>YES</strong></td>
</tr>
<tr>
<td>** NO**</td>
<td>Measure</td>
<td>Measure</td>
</tr>
<tr>
<td>Estimate</td>
<td>Estimate</td>
<td>Estimate</td>
</tr>
</tbody>
</table>

Table 2 - The three approaches to insulator selection and dimensioning

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

8.1.1. Approach A

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

![Flowchart](image)

8.1.2. Approach B

To utilise the existing test results or to specify new laboratory tests (methods and test severity), the pollution level and type of the site should be obtained first. This subject is presented in 6. The information obtained from existing lines or test stations can also be used. For the laboratory test methods one can find them in corresponding IEC standards IEC 60507 (a.c.) and IEC 61245 (d.c.). Non-standard methods may be used, especially to represent specific or special cases of pollution. Refer to CE annex on test values (generic in part 1, specific in parts 2-5).

8.1.3. Approach C

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

9. Insulator Characteristics

*(All to be completed at the next WG meeting)*

9.1. Materials

9.1.1. Glass

9.1.2. Porcelain

9.1.3. Porcelain with Semi-conducting Glaze

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

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

9.2. Design

9.2.1. Line Insulators

9.2.2. Post Insulators

9.2.3. Hollow Insulators

9.2.4. Profile Design

9.3. Shed Parameters
The important shed parameters are defined as follows:

P, P1, P2 = Shed Projection - The shed overhang
S = Shed Spacing - The vertical distance between two similar points of successive sheds.
C = Shed Clearance - the minimum distance between adjacent sheds of the same diameter, measured by drawing a perpendicular from the lowest point of the outer rib of the upper shed to the shed below of the same diameter.
S/P = Shed spacing-to-projection ratio -

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

10. Creepage Distance and Form Factor

[All to be completed at the next WG meeting]
10.1.1.1. Form Factor
10.1.1.2. Minimum distance c between sheds.
10.1.1.3. Diameter(s)
10.1.1.4. Ratio s/p between spacing and shed overhang
10.1.1.5. Ratio ld/d between creepage distance and clearance
10.1.1.6. Alternating sheds
10.1.1.7. Inclination of sheds
10.1.1.8. Creepage factor
10.1.1.9. Orientation
10.1.1.10. Non-linearity (overall length)

11. Insulation selection and dimensioning

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

11.1 determination of minimum creepage distance for candidate insulators,  
11.2 correction for profile, design and material,  
11.3 specific considerations for a given type/design/material,  
11.3.x Effect of axial voltage distribution on hollow core insulators.

[Note from CL – we decide to include this text here, but it now seems to me that it should rather be included in Part III – composite insulators]

Composite and porcelain hollow core insulators are used for apparatus insulators, bushings and also as station posts. There are used as housings for capacitors, surge arresters, breaker chambers and supports, cable terminations, wall bushings, transformers bushings, measuring transformers (CT, CCVT, voltage transformers..) and optical measuring devices. [This paragraph is superfluous ???]

The pollution performance of complete hollow core insulators is not only a function of profile and leakage distance but also function of uniformity of voltage distribution. Care should be taken to design accordingly especially at lower pollution levels where the effect of non-uniformity is more critical.

Internal components

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

The best or reference performance is obtained with an empty or complete bushing housing with a uniform linear and radial voltage distribution, typically devices with capacitive grading.

The effect of non-uniformity of voltage distribution is more evident at lower pollution level (0.01-0.03 mg/cm2). 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 more dominant and
therefore reduce the effect of non-uniformity of voltage distribution. This effect is observed during laboratory tests, where similar results are gathered on either empty insulator housings or complete ones.

**Non-uniform wetting and uneven pollution deposit.**

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 observed cancellation of non-uniform voltage distribution effect, might not be as effective.

11.4 Considerations for exceptional or specific environments or applications.

**R. Martin contribution on Altitude**

11.4.x Arid areas

In arid areas, for example in Tunisia, flashover problems with ceramic insulators still occur in spite of them having a specific creepage path of 52 mm/kV (phase to phase). Soil analysis has shown that local desert sand in such areas contains calcium and sodium salts, which are blown on to the insulator’s surface to produce an ESDD pollution severity of as great as 0.65 mg/cm².

In such cases a semi-conducting glaze on porcelain insulators provides a continuous flow of current of about 1 mA, which helps to keep it dry. Also, using aerodynamic "self-cleaning" profiles can help reduce the impact of the pollution deposition.

As yet, there are no definitive conclusions on the pollution flashover performance of polymeric insulators in such arid environments.
FIGURES

Figure 1a – Porcelain post, long rod and hollow insulator shed profiles

Drawings of shed profiles to be updated; CL/KK for cap & pin, RM/FS for composites.

Figure 1b – Cap and pin shed profiles

Figure 1c – Composite suspension insulator shed profiles

Figure 1d – Composite hollow insulator shed profiles
Annex A Pollution Flashover mechanisms

A.1 A brief description of the pollution flashover mechanism under pre-deposit pollution

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A.2 Instantaneous pollution

A.2.1 Conductive Fog

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

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

A.2.2 Bird Streamer

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

A.3 A brief description of the pollution flashover mechanism on hydrophobic surfaces

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

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

B.1 Introduction

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

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

![Figure C1: ESDD string](image)

B.2 Necessary equipment to measure pollution degree

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

- Distilled water/demineralized water
- Measuring cylinder
- Surgical gloves
- Plastic cling wrap
- Labeled container
- Washing bowl
- Absorbent cotton/brush/sponge
- Conductivity meter
- Temperature probe
- Filter paper
- Funnel
- Desiccator/drying oven
- Balance scale
B.3 Pollution collection methods for ESDD and NSDD measurement

- The surfaces of the insulator should not be touched to avoid any loss of pollution.
- Put on clean surgical gloves.
- A container, a measuring cylinder, etc. shall be washed well enough to remove electrolyte prior to the measurement.

B.3.1 Procedure using a swab technique

- Distilled water of 100 - 300 cm$^3$ (or more if required) shall be put into labelled containers and absorbent cotton shall be immersed into the water (other tools such as a brush or a sponge could be used). Conductivity of the water with the immersed cotton shall be less than 0.001 S/m.
- The pollutants shall be wiped off separately from the top and the bottom surfaces of a cap and pin type insulator with the squeezed cotton. In the case of a long-rod or a post insulator, pollutants shall usually be collected from a part of the shed as shown in Figure A.2.
- The cotton with pollutants shall be put back into the labelled containers as shown in Figure A.2. The pollutants should be 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, pollutants shall be removed by a spatula, and be put into the water containing the pollutants.
- Attention should be taken not to lose the water. That is, the quantity shall not be changed very much before and after collecting pollutants.

![Figure C.2: Wiping of pollutants on insulator surface](image)

B.3.2 Procedure using washing technique

- Cover the cap and pin respectively with plastic cling wrap without covering the insulator surface.
- Ensure that the bowl, which the discs are to be washed in, is clean.
- Measure down 500 - 1000 cm$^3$ of distilled water (<0.001 S/m) and pour into bowl.
- Place the test insulator on its cap in the water and wash the non-ribbed surface with gentle hand strokes up to the rim.
- Gently shake off any remaining water remove insulator from bowl and pour water into a labelled container. Take care that all deposits are removed from bowl.
- Rinse and clean bowl.
- Measure down 500 - 1000 cm$^3$ of distilled water (<0.001 S/m) and pour into bowl.
- Place the same insulator as mentioned above on its cap in the bowl and gently wash pollution off the ribbed surface with gentle hand strokes.
- Pour water in second labeled container taking care again that no deposits remain in the bowl.
B.4 Determining ESDD and NSDD

B.4.1 ESDD calculations

The conductivity and the temperature of the water containing the pollutants shall be measured. The measurements are made after enough stirring of the water. Short stirring time, e.g., a few minutes, is required for the high solubility pollutants. The low solubility pollutants generally require longer stirring time, e.g., 30 - 40 minutes. The conductivity correction shall be made using the formula (1). This calculation is based on Clause 16.2 and Clause 7 of IEC Standard 60507.

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

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\(^\circ\)C (S/m).

\(b\) is the factor depending on temperature of \(\theta\), as obtained by the formula (2), and as shown in Figure A.3.

\[
b = -3.200 \times 10^{-8} \theta^3 + 1.032 \times 10^{-5} \theta^2 + -8.272 \times 10^{-4} \theta + 3.544 \times 10^{-2}
\]  \hspace{1cm} (2)

Figure B.3: Value of \(b\)
The ESDD on the insulator surface shall be calculated by the formulas (3) and (4). This calculation is based on Clause 16.2 of IEC Standard 60507. The relation between $\sigma_{20}$ and $Sa$ (Salinity, kg/m$^3$) is shown in Figure A.4.

\[ Sa = (5.7 \sigma_{20})^{0.03} \]  
\[ ESDD = Sa \cdot \frac{V}{A} \]  

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$^2$).

![Figure A.4: Relation between $\sigma_{20}$ and $Sa$](image)

Notes:
1) For a close ESDD measurement in the range of 0.001 mg/cm$^2$, it is recommended to use very low conductivity water, e.g., less than a few $10^{-4}$ S/m. Normal distilled/demineralized water less than 0.001 S/m also can be used for this purpose by subtracting the equivalent salt amount of the water itself from the measured equivalent salt amount of the water containing pollutants.

2) Quantity of the distilled/demineralized water depends on kind and amount of pollutants. Large quantity of water is recommended for measurements of very heavy pollution or low solubility pollutants. In practice, 2-10 litres of water per m$^2$ 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.

3) 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.
**B.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 xxx).

The filter paper containing pollutants (residuum) shall be dried, and then be weighed as shown in Figure A.5.

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

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

where:
- **NSDD** is non-soluble material deposit density (mg/cm\(^2\)).
- \(W_f\) is the weight of the filter paper containing pollutants under dry condition (g).
- \(W_i\) is the initial weight of the filter paper under dry condition (g).
- \(A\) is the area of the insulator surface for collecting pollutants (cm\(^2\)).

![Figure B.5: Procedure of measuring NSDD.](image)

Note: The quantitative chemical analysis would be made on pollutant solution and residuum after the measurement to identify chemical components of the pollutants. The analysis results might be useful for close examination of pollution conditions.
Annex C : Directional Dust Deposit Gauge Measurements

C.1 Introduction

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

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

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

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

Its major disadvantage is that actual insulators are not used and therefore it is not possible to assess the self-cleaning properties of insulators and the effect of the shed profile on the deposition process on the insulator surface. In areas of high rainfall, a higher index can be tolerated, whereas in areas of low rainfall but with a high occurrence of fog, the actual severity is higher than that indicated by the gauges.
C.2 Test equipment

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

C.3 Test procedure

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

1. CIGRE Taskforce 33.13.01 - Polluted insulators: A review of current knowledge, CIGRE brochure N° 158-2000
2. CIGRE Taskforce 33.13.01 - Polluted insulators: Application guidelines, CIGRE brochure N° ???-2002
3. CIGRE Taskforce 33.13.07 - Influence of snow and ice...Electra April 2000

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

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

Annex F - Site severity measurement protocol

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

Annex G BITS REMOVED

11.1.1. Active pollution

Active pollution can itself be classified in two types:

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

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

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

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

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

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

SEE PARA by CE to cover risk under heavy wetting etc.

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

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

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

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

<table>
<thead>
<tr>
<th>NSDD mg/cm²</th>
<th>Approach A or B</th>
<th>Approach A or C</th>
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<tbody>
<tr>
<td>10</td>
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<tr>
<td>4</td>
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<td>0.01</td>
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<tr>
<td>0.001</td>
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</tbody>
</table>

For example, in the case of sites close to the sea, where pollution is essentially saline (easily washed by rain) and where exceptional events (storm) could be brief, daily or hourly measurements could be necessary.

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