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**GUIDE FOR THE ASSESSMENT OF  
OLD CAP & PIN AND LONG-ROD  
TRANSMISSION LINE INSULATORS  
MADE OF PORCELAIN OR GLASS:**

**WHAT TO CHECK AND  
WHEN TO REPLACE**

**Working Group  
B2.03**

**October 2006**



# **GUIDE FOR THE ASSESSMENT OF OLD CAP & PIN AND LONG-ROD TRANSMISSION LINE INSULATORS MADE OF PORCELAIN OR GLASS : WHAT TO CHECK AND WHEN TO REPLACE**

## **Working Group B2.03 (Insulators)**

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*This guide is published in honour of our common friend Claude de Tourreil*

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# **Guide for the Assessment of Old Cap & Pin and Long-Rod Transmission Line Insulators made of Porcelain or Glass: What to Check and When to Replace.**

**Working Group 03 (Insulators)  
of Study Committee B2**

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## **Key Words**

Old insulators, porcelain, glass, assessment, end of life

## **Summary / Abstract**

Based on the results of a series of standard IEC tests carried out on insulators that were in service for periods from 11 to 45 years, a test procedure has been established to determine the state of old insulators and to decide on the safe time for their replacement.

## 1. Scope

The aim of the document is to provide guidance to utilities and engineers who are in charge of the maintenance of transmission lines on how to check the state of insulators and how to decide on the safe time for replacement. This Guide does not apply to composite insulators and it does not consider the influence of pollution on the electrical characteristics of the insulators.

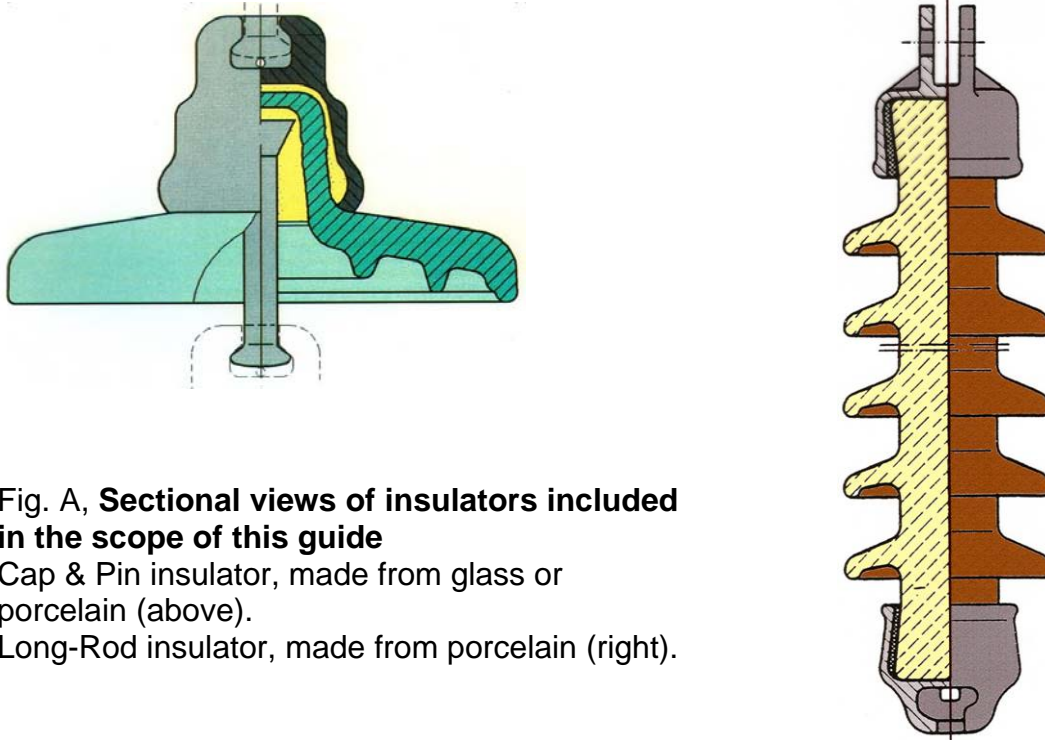


Fig. A, **Sectional views of insulators included in the scope of this guide**

Cap & Pin insulator, made from glass or porcelain (above).

Long-Rod insulator, made from porcelain (right).

## 2. Background

Many transmission lines have now been in operation for several decades. The different components of these lines have aged and it is important to assess their condition. CIGRE WG B2.03 of Study Committee B2 was asked to study this problem. Several utilities have indicated that the present line management policy is to optimise the cost of maintenance. To assist in this, guidance is given on what to check and when to replace old insulators. To reach the goal of this study, WG B2.03 selected a series of tests, based on IEC Standards, to be performed on old insulators retrieved from transmission lines. WG B2.03 wishes to thank the many utilities and manufacturers from many parts of the world that have made this study possible by participating in these tests. The B2.03 recommends that the findings of this study be introduced into future relevant standards.

Insulators are high-technology products expected to work with high reliability over a long period of time. A great number of successfully balanced design parameters, choice of materials as well as the mastering of manufacturing processes are required to ensure this high long term reliability. Nevertheless, because of the various stresses generated by service conditions, the insulators may be subjected during their useful service life to a number of different deterioration modes. Atmospheric conditions (pollution) may intensify some of

the mechanisms of deterioration e.g. erosion or pin-corrosion. Other mechanisms may be enhanced and/or accelerated by deviations from moderate climatic conditions or caused by conditions other than those defined at the time of specification. Of special importance are large and/or steep changes in ambient temperatures, high humidity and extreme high or low ambient temperatures possibly enhanced by solar radiation. These parameters may also be influenced by the interaction with adjacent line components. Inherent weaknesses of component materials or changes of their intrinsic properties may lead to degradation mechanisms.

There are a fairly large number of degradation modes. Some modes are easily detectable by visual inspection others need sophisticated methods. Degradation modes caused by easily detectable mechanisms like slip of metal fitting, pin corrosion or surface erosion are considered to be reason for replacement of insulators. Close visual inspection of the insulators taken from the line to detect the presence of such degradation will make it unnecessary to go through the procedure of this guide.

The project differs in two ways from usual practice: it does not analyze the influence of particular failure modes but it goes beyond the commonly applied mechanical failing tests. The determination of specific failure mechanisms is considered to be the field of specialised laboratories.

The effects of the corrosion of metal parts and electrical puncture of the insulating body are included in this study insofar as the proposed tests bring their consequences to light. These are: The reduced mechanical strength of the pin and the low withstand voltage in the electromechanical failing test. Attention is drawn to the fact that the reduction of mechanical strength caused by pin-corrosion is only noticeable once the loss of galvanizing protection has occurred. Pending risk may be detected by measuring periodically the thickness of the galvanized layer.

Studied in the project are Long-Rod insulators made of porcelain and Cap & Pin insulators made of porcelain or glass (Fig. A).

### 3. Definitions and Terminology

- **“As-received”**: A group of insulators tested as removed from the line without undergoing any test or any treatment which might influence the (electro-) mechanical failing load.
- **“TMP-tested”**: A group of insulators removed from the line and tested according to the Thermo-Mechanical-Performance procedure e.g. IEC 60383-1, §20 (this test concludes with the (electro-) mechanical failing load test).
- **“Meet the standard”**: These insulators comply with the standard requirements which are:
  - The product specifications, e.g. IEC 60305 (Cap & Pin) and IEC 60433 (Long-Rod).
  - The relevant national regulations.

- **“Aging”**: Existing or foreseeable deterioration of the mechanical characteristics.
- **“Rate of aging”**: If existing, it is calculated from the probability diagram data and is the speed of the reduction of the mechanical strength per year, observed at the 5% probability level.
- **“End of safe (or useful) lifetime”**: It is reached when the statistical probability for insulators to fail at the Specified Failing Load (SFL) is equal to or higher than 5%.
- **“Remaining safe (or useful) lifetime”**: It is calculated at the 5% probability level with the rate of aging at which end of the safe lifetime criterion is approached.

#### 4. Tests

A number of utilities located around the world have been approached to participate in this project. They were asked to retrieve from their transmission line systems insulators that had at least 30 years of service or that were considered by the utility to be old and to send them to a testing laboratory for evaluation.

Ten utilities accepted to participate. Seven batches of Long-Rod porcelain insulators and seven batches of Cap & Pin insulators have been received by the testing laboratory. The operating period was for the Long-Rod insulators between 29 and 45 years with an average of 37 years and for the Cap & Pin insulators between 11 and 39 years with an average of 25 years.

They have been submitted to a series of tests selected from IEC standards.

Table I presents a list of the tests used and indicates which specific tests were applied to the different insulator types.

		Long-Rod insulators		Cap & Pin (Disc) insulators	
Tests on insulators	IEC 60383-1	Lot A	Lot B	Lot A	Lot B
1. Visual inspection	27	x	x	x	x
2. Verification of dimensions	17	x	x	x	x
3. Galvanizing	26	x	x	x	x
4. Displacements	21	x	x	x	x
5. Locking system	22	x	x	x	x
6a. Routine mechanical test	28		x	x	x
6b. Routine electrical test	16			x	x
7. Temperature cycle test/Thermal shock test	23/24		x	x	x
8. Thermal-mechanical performance test	20		x		x
9a. Mechanical failing load test	19	x	x	x (glass)	x (glass)
9b. Electromechanical failing load test	18			x (porcelain)	x (porcelain)
10. Porosity test	25		x	x (porcelain)	x (porcelain)
Tests on hardware	IEC 61284				
1. Visual inspection	7	x	x	x	x
2. Galvanizing	26	x	x	x	x
3. Mechanical damage and failure load test	11	x	x	x	x

Table 1: List of tests in chronological order of application

The testing sequence starts with a number of non-destructive tests and includes quantifiable visual tests (e.g. degree of corrosion) as well as thermal, mechanical and the combined thermal-mechanical tests. Some of the tests check the dimensions and tolerances. This first series of tests is followed by destructive mechanical tests. To obtain recognizable trends, the tests have been performed on several units. The number of tested units per lot is 6 to 8 for Long-Rod insulators and from 7 to 30 for Cap & Pin insulators.

## **5. General assessment of test results**

Actual or foreseeable changes of the mechanical characteristics have been chosen as the most relevant elements for the assessment of the insulators. The general assessment of the results of all the tests indicates that the most useful information can be obtained from the comparison between the mechanical failing load of as-received insulators with the mechanical failing load of samples that have first been subjected to the thermal-mechanical performance procedure. All other tests did not show a significant change to their initial rated values. In particular, corrosion, power arc or any other visual detectable deterioration were not found to be a problem for the insulators tested in this project. The fact that utilities did not include such insulators for the tests was attributed to a screening of insulators for obvious degradation before dispatch to the testing laboratory.

## **6. Mechanical condition and remaining safe lifetime**

The correlation between the service experience and the mechanical failing load test results of insulators with long service record (old insulators) has, within the limits of statistical confidence, led to the following conclusion:

*The comparison between the results of the failing load tests performed on a group of insulators as-received from the line and performed on a second group that has first been subjected to the thermal-mechanical test can be used to predict the actual condition of the insulators.*

The following procedure has been followed for the evaluation:

A probability diagram based on normal distribution is used to analyze the failing load test results. With the probability (risk) for failure on the ordinate and the failing load on the abscissa the failing load characteristics are represented as straight lines. In that way changes in strength become easily visible.

Distributions other than normal (Gaussian) have been evaluated (e.g. Weibull) but have not shown to improve the evaluation of test results.

## **7. Determination of present condition of the insulators and their remaining lifetime**

1. A number of insulators removed from the transmission line is required. For Cap & Pin insulators a sample of 60 units and for Long-Rod insulators a sample of 12 units is recommended.
2. These insulators are divided into 2 equal lots A and B and are subjected to a visual inspection.
3. Lot A is tested on a traction test machine and the (electro-) mechanical failing loads are recorded.
4. Lot B is first subjected to the thermal-mechanical performance test (TMP) before the application of the failing load test. The failing load values are recorded. (For reference to the TMP-test see Table 1).
5. The arithmetic mean and the standard deviation are calculated for both sets of failing load test results.
6. This information is used to create the failure probability diagram. If available, the mean and the standard deviation of the results of tests, done on these insulators a sufficient number of years earlier or at the time of shipping to the customer, are also introduced into the diagram.

To help the user of this Guide, a number of typical cases of analysis of test results called here “Reference Scenarios” have been prepared. They are useful for the assessment of the present condition of the insulators

Note1: If the assessment of lot A leads to the conclusion that similar insulators that are still in operation on the transmission line are safe or on the contrary have to be replaced then the tests with lot B become unnecessary. In case of any doubt as to the interpretation and/or the applicability of the reference scenarios to actual test results, a re-test procedure with lots A and B is recommended.

Note 2: Aging has been defined as the reduction of mechanical strength. Safe lifetime comes to an end when the mechanical strength at 5% risk for the insulators is below the SFL (Specified Failing Load of the insulator).

## **8. Selected reference scenarios to help for the assessment of the insulators**

Figures1 to 6 present a number of typical reference diagrams. They are based on the information obtained from the experimental data (~ 35 diagrams) reported in Annex:

- A1; CP1 to CP7b (Cap & Pin insulators tested for the B2.03 project)
- A2; CPIEC1 to CPIEC21 (Cap & Pin insulators data from IEC Pub. 60575 Ed.1, 1977)
- B1; LP1 to LP7b (Long-Rod insulators tested for the B2.03 project)
- B2; LPIEC1 to LPIEC9 (Long-Rod insulators data from IEC Pub. 60575 Ed.1, 1977).

A number of diagrams which correspond to tests performed on new insulators have been selected from IEC tests (CGIEC11, CGIEC12, CPIEC14 and LPIEC1 to 9). The operating records for the insulators of these diagrams are not known. The tests were made on insulators that had been supplied by various manufacturers. These diagrams have been used in the present study as further examples to demonstrate the assessment process. They show that the proposed process may also be used to assess new insulators. Means and standard deviations have been calculated from the ultimate breaking load values or load values when puncture occurred whichever was the lower. For insulators found punctured after the TMP-test, the TMP-test load (60% of SFL) was used.

Whenever available the origin of ultimate failure is given. In addition the reference diagram (scenario) used for the evaluation is indicated (F1 to F6). Attention is drawn to the fact that for insulators with good service record the failure mode for Cap & Pin insulators and Long-Rod porcelain insulators is essentially of different nature. Usually, with Cap & Pin insulators it is the pin that fails while with Long-Rod porcelain insulators it is the insulating body that fails. The abscissa of the diagram shows the per-unit failing load based on the SFL. Thus, the SFL divides the diagram into 2 parts. The part to the right contains the failing load values which are above SFL and the part to the left of the SFL contains the failing load values below SFL. All the failing load values that are below the SFL do not fulfil the standard requirements.

The probability of failure in % is indicated on the vertical, ordinate axis. The 16% and 84% levels on that ordinate axis correspond to the probabilities of failure for the mean minus and plus  $1 \times$  standard deviation. The ordinate axis is truncated at a risk of 5% and 95%. A risk of 5% is commonly accepted in standardisation.

The diagrams have been qualified for some typical properties like the scatter and the relative load at the intersection with the 5% failure risk. The scatter (standard deviation) of the 'as-received' lot is assessed as 'normal' or 'high'. 'Normal' is used up to about 15% of the mean and 'high' is used above. The TMP-tested lot has been qualified in a similar way but the scatter and the mean were qualified in comparison with the 'as-received' lot using the expressions 'similar', 'higher' or 'lower'.

Note: The SFL is a characteristic of the insulator and its value should always be higher than the design load specific to the transmission line multiplied by a safety factor (partial load factor). A series of SFL values have been standardised. If a selected SFL value is higher than that required by the line design, the insulators are not stressed to their rated level.

The failing load characteristics are represented by:

- A dashed line for the insulators sample tested when new.
- A solid line for the insulators as-received from the line.
- A dashed/dotted line for the insulators which have been submitted to the TMP-test.

The SFL is marked with a solid vertical line.

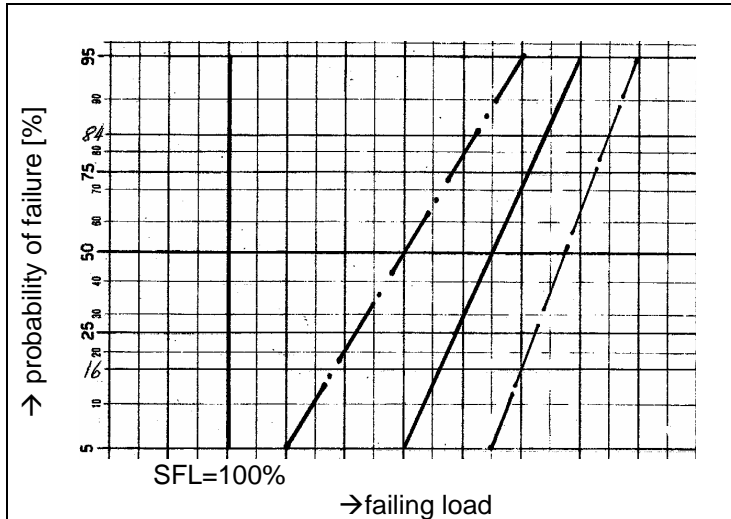


Fig. 1a

Reference scenario F1a illustrates the case where:

- All failing load lines:
  1. are to the right of the SFL
  2. have normal dispersion.

→ The insulators of this transmission line fulfil the standard requirements:

1. At time of erection of the line.
2. As-received from the transmission line today.
3. After the TMP-test.

Note 1: The reductions in strength shown in this diagram are not representative of good quality products. Age and TMP-test have only negligible influence on good products (see e.g. Annex A1 diagram CP2 and Annex B1, diagram LP2).

Note 2: A high standard deviation (scatter) of any of the failing load lines and particularly a higher scatter of the TMP-test line are an indication for possible problems. Re-testing either immediately or within a short period relatively to the actual age of the insulators is recommended.

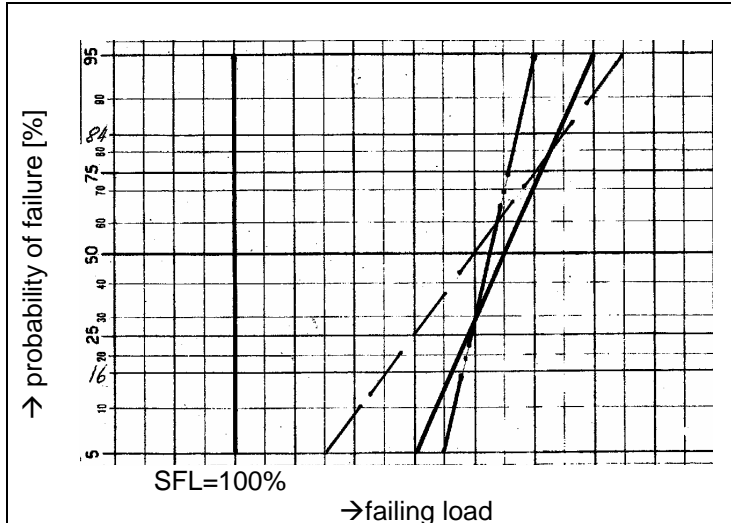


Fig. 1b

Fig. 1b is a possible variation of Fig. 1a. It illustrates the possible variation of the characteristic coming from the low number of tested insulators (in this study this may be the case for the low number of tested Long-Rod insulators).

Reference scenario F1b illustrates the case where:

- All failing load lines:
  1. are to the right of the SFL
  2. have normal dispersion.

→ The insulators of this transmission line fulfil the standard requirements:

1. At time of erection of the line.
2. As-received from the transmission line today.
3. After the TMP-test.

→ The characteristics for the insulators of this transmission line show no statistically proven mechanical changes.

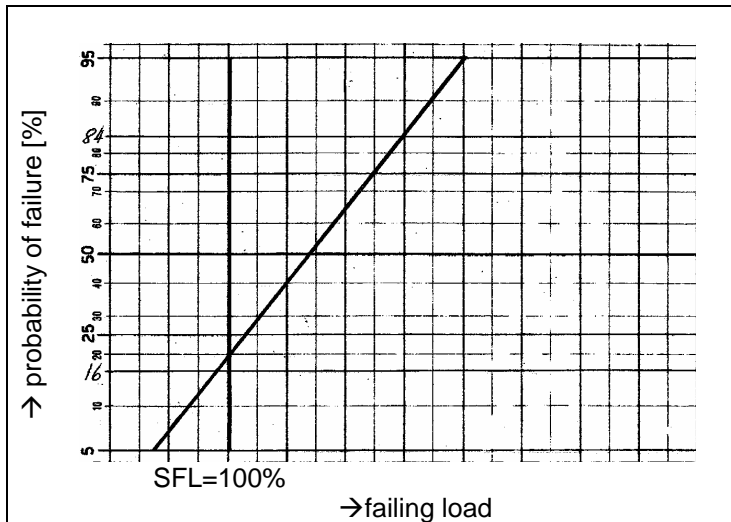


Fig. 2

Reference scenario F2, for insulators in the as-received condition shows:

- The line has an intersection with the SFL. A certain percentage (~20%) of the insulators installed in the transmission line no longer meets the standard. These insulators would fail at the SFL or below. In addition, this transmission line has had a poor service record.

→ The insulators of this transmission line have to be replaced.

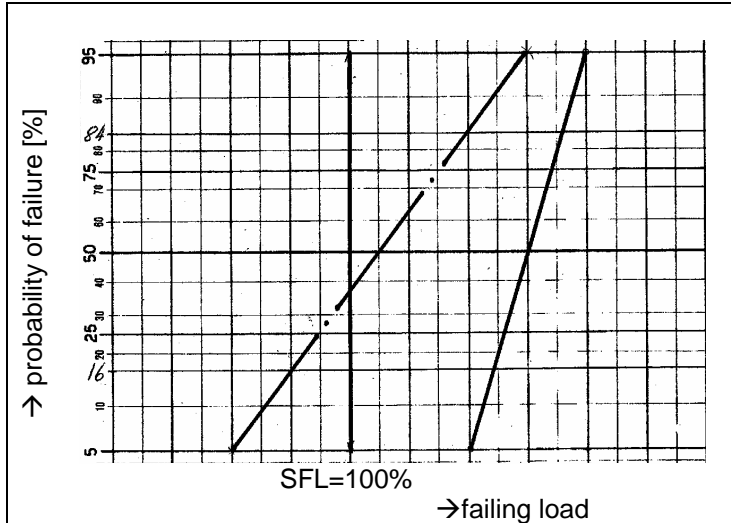


Fig. 3

Reference scenario F3 illustrates the case where:

- The as-received line is to the right of the SFL.
- At a failure risk of about 35% and below, the TMP-line is on the left of the SFL.
- The shift in the TMP-line shows that the insulators are likely to have their strength further reduced (continued aging).
- It demonstrates an acute risk for insulators installed in the transmission line to fail below the SFL (Annex A2: CPIEC5A and CPIEC21 have shown poor service record).

→ It is recommended that the insulators of this transmission line be:

- Re-tested and/or
- Closely watched and/or
- Replaced

Note: The same recommendation is made if any of the 2 lines comes close to the SFL (Annex A1: CP7b).

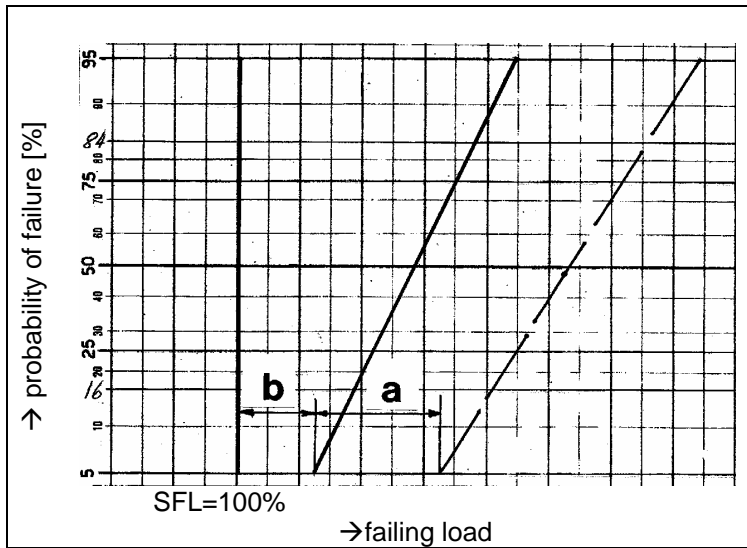


Fig. 4

Reference scenario F4 illustrates the calculation of the rate of aging:

- If the as-received solid line comes close to intersecting the SFL, then the question is, is it likely to cross it and when. Using the failing load dashed-line measured on insulators at the time of erection of the transmission line can answer this question. Normally the solid line is positioned to the left of the dashed line. This indicates a reduction in strength. Then the speed of reduction in strength and the remaining safe lifetime can be calculated.

The reduction in strength 'a' is measured at 5% probability to take into account a change in the scatter. The quantity 'a' corresponds to the number of years from the time of construction and 'b' corresponds to the remaining safe lifetime.

→ The decision as to when to repeat the test must be done on the basis of the remaining safe lifetime.

Note 1: Repeated tests over 35 years of observation [1] on Long-Rod insulators of the same manufacturing batch and taken from the same line have demonstrated that a linear reduction in strength may be assumed for the initial (15...20%) loss of strength.

For Cap & Pin insulators, information on the change of strength over time is given in [4] and may be obtained from the data presented in [2 and 3]. The reduction rate per year is between ~0% and ~3%. The insulators used for the evaluation of these rates have been in operation for 25, 30 and 5 years respectively. No information is given on the time history of loss of strength. For moderate losses (15...20%) linearity has been assumed.

Note 2: For simplicity reasons it is proposed to calculate the rate of reduction of strength by dividing the difference 'a' in [%] measured at the 5% probability level by the time in [years].

Note 3: The end of safe lifetime is reached when the as-received characteristic crosses the SFL line. The remaining lifetime [years] is calculated by dividing the gap 'b' [%] by the rate of reduction from Note 2.

Note 4: When calculating the speed of reduction in mechanical strength and the remaining lifetime it is important to be aware of possible changes in the time history of the failure mode or in changes of the failure mode itself, which might influence the speed of reduction.

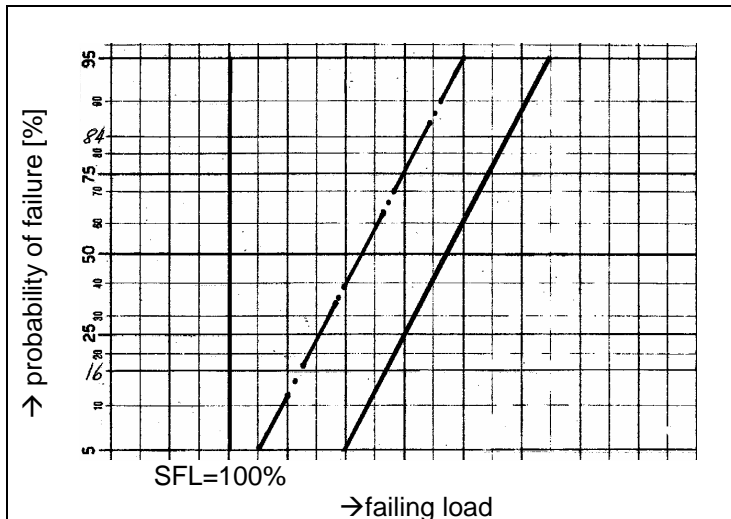


Fig. 5

Reference scenario F5 illustrates the case where:

- The failing load of insulators at time of erection of the transmission line is not known. In that case the introduction of the TMP-test may give an indication of the ageing performance.
- The TMP-test may be considered as an indicator of the mechanical stability of the insulator. The tests have shown that insulators with a long service record are affected by the TMP-test.
- The shift of the TMP line to the left implies a reduction in strength. In Fig. 5 the TMP-line is still to the right of the SFL and has a scatter that is similar to the as-received line (same slopes): These insulators still have a capability to age. But the speed at which strength is lost cannot be evaluated due to lack on information on the characteristics of the insulators when new. However it may be assumed that the insulators have already lost some mechanical strength compared to the new condition. Then it can be expected that the TMP-line will shift further to the left and eventually cross the SFL. It is likely that the as-received line will also with time shift to the left. Therefore it is recommended to re-test insulators from this transmission line in due time.

→ The decision as to when to repeat the test depends on the reliability level required by the utility. It is related to the actual age of the insulators, their change in strength in comparison to the as-received condition and how close the TMP-line is to the SFL.

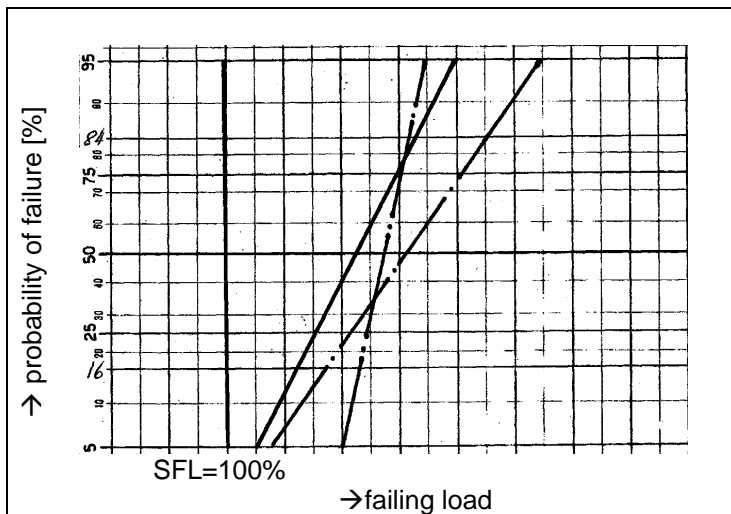


Fig. 6

Reference scenario F6 gives information on an additional replacement criterion for porcelain Long-Rod insulators:

This is illustrated by the diagram presenting the results of tests on 2 insulator groups, LP4 and LP7. Detailed results are found in Annex B1. For these transmission lines poor service record was reported and the line operators had already decided to replace the insulators.

- Both TMP lines are essentially to the right of the as-received solid line. This implies an increase in strength. This somewhat unexpected behaviour might be explained by a conditioning process that occurred in the zone where the load is transferred between the metal fitting and the insulating body of the Long-Rod insulator. In both these cases the poor service records forced the utilities to replace the insulators.

→ For Long-Rod porcelain insulators when the TMP-line is to the right of the as-received line the insulators should be replaced.

Note: These results show the importance of the TMP-test.

## 9. Conclusions and Recommendations

Although the number of specimens in each tested lot was barely sufficient to allow a clearly meaningful statistical treatment of the results, the testing programme did involve almost 1000 insulators and these were submitted to more than ten different tests.

The results of these tests and their detailed analyses have shown that the majority of the insulator batches evaluated had sufficiently retained their characteristics to still provide satisfactory service. In addition, the statistical analysis of the data facilitated the establishment of a simple procedure that can be used by engineers in utilities and laboratories to check the state of old insulators taken from transmission lines and also to evaluate their remaining safe lifetime. The use of the procedure described in this document for the evaluation of larger insulator lots should confirm its validity. It is proposed that this procedure be introduced in future issues of the relevant IEC Standards.

### Literature

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**Annex A1:  
Cap & Pin insulator tests (WG B2.03)**

**Cap & Pin Insulators, porcelain: line operation record received.**

<b>Line: CP1</b>	<b>Operation record: good</b>	<b>Age in line [years]: 39</b>	<b>Rated strength (SFL) [kN]: 160</b>
Lot A as-received, failures*: 2×b, 28×p.---Lot B TMP-tested, failures*: 4×b, 3×i, 23×p.			
<p>→ Failing load Solid line: As-received Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): As-received: SFL + 34%, scatter: normal TMP-tested: SFL + 36%, scatter: ~ similar Mean: ~higher. Rate of aging: Not known Reference scenario: F1</p> <p>Diagnosis/Recommendation/Comment: The insulators of this line</p> <ul style="list-style-type: none"> <li>• meet the standard</li> </ul> <p>→ Repeat the tests in ~10 years</p>	

<b>Line: CP2</b>	<b>Operation record: good</b>	<b>Age in line [years]: 11</b>	<b>Rated strength (SFL) [kN]: 177</b>
Lot A as-received, failures*: 5×i, 6×p.-----Lot B TMP-tested, failures*: 5×i, 5×p; New, failures*: 6×p?.			
<p>→ Failing load Solid line: As-received Dashed/dotted line: TMP-tested Dashed line: New</p>		<p>Characteristic (related to SFL at 5% risk): As-received: SFL + 5%, scatter: normal TMP-tested: SFL + 2.5%, scatter: ~ similar Mean: similar. New: SFL + 18%, scatter very small, Mean: ~higher Rate of aging: reduction from +18% to +5% over 11 years → ~1%/year. Reference scenario: F1, F4, F5</p> <p>Diagnosis/Recommendation/Comment: The insulators of this line</p> <ul style="list-style-type: none"> <li>• meet the standard</li> <li>• are approaching the end of safe lifetime</li> </ul> <p>→ Repeat the tests before 5 years → ~5 years of remaining safe life time left for the insulators of this line Note: The small scatter when new is probably due to only pin failures.</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, p→broken pin, ?→not available

**Cap & Pin Insulators, porcelain: line operation record received.**

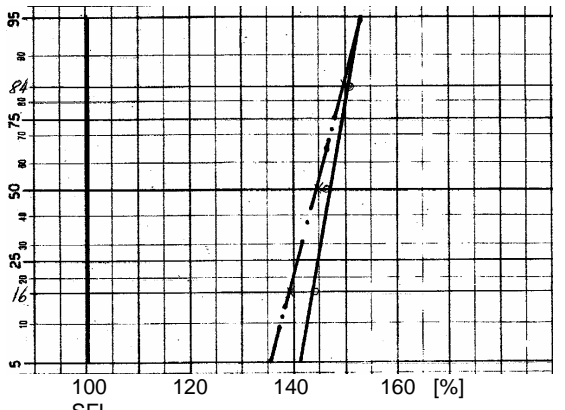
<b>Line: CP3</b>	<b>Operation record: good</b>	<b>Age in line [years]: 14</b>	<b>Rated strength (SFL) [kN]: 177</b>
Lot A as-received, failures*: 6×i, 13×p.-----Lot B TMP-tested, failures*: 1×b, 5×i, 14×p. New, failures*: 6×p?.			
<p>Solid line: As-received Dashed/dotted line: TMP-tested; dashed line: New</p>		<p>Characteristic (related to SFL at 5% risk):                      As-received: SFL - 8%, scatter: normal                      TMP-tested: SFL + 5%, scatter: smaller                      Mean: ~higher.                      New: SFL + 18%, scatter very small,                      Mean: ~higher                      Rate of aging: reduction from +18% to -8% over 14 years → ~2% per year.                      Reference scenario: F2, F4</p> <p>Diagnosis/Recommendation/Comment:</p> <ul style="list-style-type: none"> <li>• Useful lifetime exceeded</li> <li>• Pending failures.</li> </ul> <p>→ Replace the insulators of this line                      Note: The small scatter when new is probably due to only pin failures.</p>	

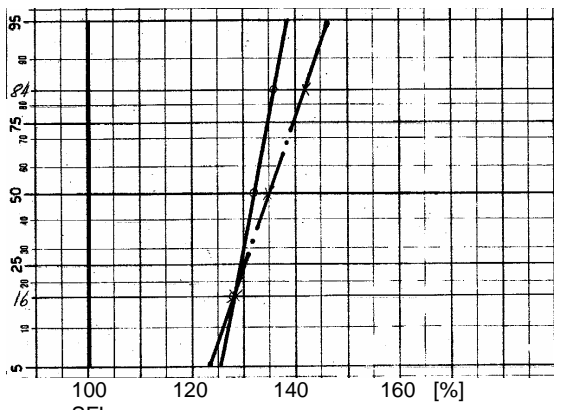
**Cap & Pin Insulators, glass: line operation record received.**

<b>Line: CG4</b>	<b>Operation record: good</b>	<b>Age in line [years]: 31</b>	<b>Rated strength (SFL) [kN]: 150</b>
Lot A as-received, failures*: 11×b, 19×p.-----Lot B TMP-tested, failures*: 7×b, 1×c, 22×p.			
<p>Solid line: As-received Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk):                      As-received: SFL + 10%, scatter: normal                      TMP-tested: SFL + 1%, scatter: similar                      Mean: ~lower.                      Rate of aging: Not known                      Reference scenario: F1, F5, (F3 Note)</p> <p>Diagnosis/Recommendation/Comment:                      The insulators of this line</p> <ul style="list-style-type: none"> <li>• meet the standard</li> <li>• are approaching the end of safe lifetime</li> </ul> <p>→ Repeat the tests before 5 years</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, p→broken pin, ?→not available

**Cap & Pin Insulators, porcelain: line operation record received.**

Line: CP5	Operation record: good	Age in line [years]: 23	Rated strength (SFL) [kN]: 156
Lot A as-received, failures*: 4×i, 3×p.-----Lot B TMP-tested, failures*: 3×b, 4×i.			
 <p data-bbox="194 907 502 985">                     → Failing load                      Solid line: As-received                      Dashed/dotted line: TMP-tested                 </p>		<p data-bbox="774 465 1262 678">                         Characteristic (related to SFL at 5% risk):                          As-received: SFL + 42%, scatter: small                          TMP-tested: SFL + 36%, scatter: ~similar                          Mean: ~similar.                          Rate of aging: Not known                          Reference scenario: F1                     </p> <p data-bbox="774 689 1238 869">                         Diagnosis/Recommendation/Comment:                          The insulators of this line                         <ul style="list-style-type: none"> <li>• meet the standard</li> </ul>                         → Repeat the tests in ~10 years                     </p>	

Line: CP6	Operation record: good	Age in line [years]: 23	Rated strength (SFL) [kN]: 110
Lot A as-received, failures*: 4×i, 3×p.-----Lot B TMP-tested, failures*: 3×b, 4×i.			
 <p data-bbox="194 1668 502 1747">                     → Failing load                      Solid line: As-received                      Dashed/dotted line: TMP-tested                 </p>		<p data-bbox="774 1227 1262 1440">                         Characteristic (related to SFL at 5% risk):                          As-received: SFL + 26%, scatter: small                          TMP-tested: SFL + 23%, scatter: ~similar                          Mean: ~similar.                          Rate of aging: Not known                          Reference scenario: F1                     </p> <p data-bbox="774 1451 1238 1630">                         Diagnosis/Recommendation/Comment:                          The insulators of this line                         <ul style="list-style-type: none"> <li>• meet the standard</li> </ul>                         → Repeat the tests in ~10 years                     </p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, p→broken pin

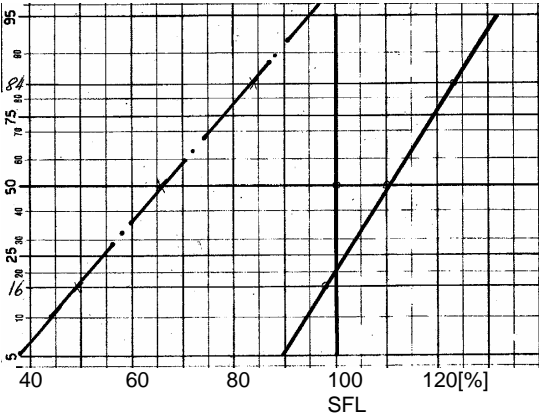
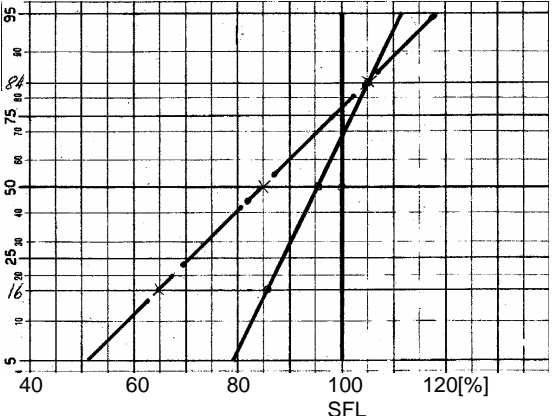
**Cap & Pin Insulators, porcelain: line operation record received.**

Line: CP7a	Operation record: good	Age in line [years]: 37	Rated strength (SFL) [kN]: 205
Lot A as-received, failures*: 1×i, 29×p.-----Lot B TMP-tested, failures*: 1×b, 29×p.			
<p>Solid line: As-received Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): As-received: SFL - 5%, scatter: small TMP-tested: SFL - 1%, scatter: similar Mean: higher. Rate of aging: Not known Reference scenario: F2</p> <p>Diagnosis/Recommendation/Comment:</p> <ul style="list-style-type: none"> <li>Useful lifetime exceeded</li> </ul> <p>→ Replace the insulators of this line</p> <p>Note 1: The small scatter is due to 97% pin failures. Note 2: The failure 1×i appeared in the temperature cycle test. It is included with 0 kN. Note 3: The design load is only 55 kN (27% of SFL). The minor shift of the TMP-line to the right of the as-received line suggests a negligible aging rate. It is therefore at the owner's risk that the insulators are not replaced: → Watch the insulators of this line closely → Repeat the tests before 5 years</p>	

Line: CP7b	Operation record: good	Age in line [years]: 37	Rated strength (SFL) [kN]: 205
Lot A as-received (without failure* 1×i): 29×p.-----Lot B TMP-tested, failures*: 1×b, 29×p.			
<p>Solid line: As-received Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): As-received: SFL - 2%, scatter: small TMP-tested: SFL - 1%, scatter: similar Mean: ~higher. Rate of aging: Not known Reference scenario: F2</p> <p>Diagnosis/Recommendation/Comment:</p> <ul style="list-style-type: none"> <li>Useful lifetime exceeded</li> </ul> <p>→ Replace the insulators of this line</p> <p>Note 1: CP7a and b are calculated from the same insulator sample. CP7b is without the 1×i failure. This failure due to its rareness was only received by chance. For this and similar diagrams see F3. Note 2: A re-test is recommended.</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, p→broken pin

**Annex A2:**  
**Tests performed in 1970/71 for IEC Pub. 60575 (1977)**  
**Cap & Pin Insulators, porcelain: line operation record received.**

Line: C PIEC1	Operation record: poor	Age in line [years]: ~31	Rated strength (SFL) [kN]: 75
Lot A as-received, failures*: 2xc, 5xi, 2xp.-----Lot B TMP-tested, failures*: 2xc, 4xi, 3xp.			
 <p>→ Failing load                      Solid line: As-received                      Dashed/dotted line: TMP-tested</p>		Characteristic (related to SFL at 5% risk): As-received: SFL - 10%, scatter: normal TMP-tested: SFL - 65%, scatter: ~similar Mean: lower. Rate of aging: Not known Reference scenario: F2	
		Today's diagnosis for time of test/ Recommendation/Comment: <ul style="list-style-type: none"> <li>• Useful lifetime exceeded</li> </ul> → Replace the insulators of this line	
Line: C PIEC3	Operation record: poor	Age in line [years]: 17	Rated strength (SFL) [kN]: 68
Lot A as-received, failures*: 14xi.-----Lot B TMP-tested, failures*: 12xi.			
 <p>→ Failing load                      Solid line: As-received                      Dashed/dotted line: TMP-tested</p>		Characteristic (related to SFL at 5% risk): As-received: SFL - 21%, scatter: normal TMP-tested: SFL - 48%, scatter: ~higher Mean: lower. Rate of aging: Not known Reference scenario: F2	
		Today's diagnosis for time of test/ Recommendation/Comment: <ul style="list-style-type: none"> <li>• Useful lifetime exceeded</li> </ul> → Replace the insulators of this line	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, p→broken pin

**Cap & Pin Insulators, porcelain: line operation record received.**  
**These tests have been performed in 1970/71 for IEC 60575 (1977).**

Line: C PIEC5A	Operation record: poor	Age in line [years]: ~19	Rated strength(SFL) [kN]: 90
Lot A as-received, failures*: 10×b, 2×p.-----Lot B TMP-tested, failures*: 11×b, 1×p.			
<p>Solid line: As-received Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk):                      As-received: SFL + 7%, scatter: high                      TMP-tested: SFL - 22%, scatter: similar                      Mean: lower.                      Rate of aging: Not known                      Reference scenario: F3</p> <p>Today's diagnosis for time of tests/                      Recommendation/Comment:</p> <ul style="list-style-type: none"> <li>Useful lifetime exceeded</li> </ul> <p>→ Replace the insulators of this line</p>	

(Line): C PIEC5B	Operation record: not installed	Age in store [years]: ~20	Rated strength (SFL) [kN]: 90
Lot A as-received, failures*: 10×b.-----Lot B TMP-tested, failures*: 10×b.			
<p>Solid line: As-received Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk):                      As-received: SFL - 12%, scatter: high                      TMP-tested: SFL - 25%, scatter: similar                      Mean: lower.                      Rate of aging: Not known                      Reference scenario: F2</p> <p>Today's diagnosis for time of tests/                      Recommendation/Comment:</p> <ul style="list-style-type: none"> <li>Useful lifetime exceeded</li> </ul> <p>→ Replace the insulators of this line</p> <p>These insulators are from the same manufacturing batch as C PIEC5A. They had been in store for 20 years before testing. To note: Lower means than C PIEC5A and tendency to higher scatter for 'as-received' insulators.</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, p→broken pin

**Cap & Pin Insulators, porcelain: line operation record received.**  
**These tests have been performed in 1970/71 for IEC 60575 (1977).**

<b>Line: CPIEC6</b>	<b>Operation record: acceptable</b>	<b>Age in line [years]: ~9</b>	<b>Rated strength (SFL) [kN]: 100</b>
Lot A as-received, failures*: 10×b, 2×i.-----Lot B TMP-tested, failures*: 4×b, 7×i, 1×p.			
<p>Solid line: As-received  Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk):  As-received: SFL + 10%, scatter: normal  TMP-tested: SFL + 5%, scatter: similar  Mean: ~similar.  Rate of aging: Not known  Reference scenario: F2, F5</p> <p>Today's diagnosis for time of tests/  Recommendation/Comment:  The insulators of this line</p> <ul style="list-style-type: none"> <li>• meet the standard</li> </ul> <p>→ Repeat the tests before 5 years</p> <p>The insulators of this line may have shown increasing failing rate since tested in 1970 (see Note to F3).</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, p→broken pin

**Cap & Pin Insulators, glass: line operation record received (1970/71 for IEC).**

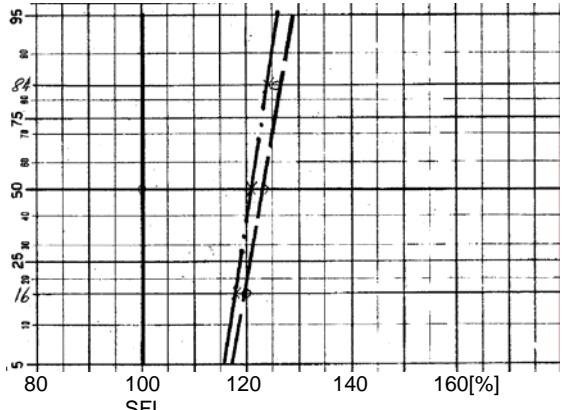
<b>Line: CGIEC8</b>	<b>Operation record: good</b>	<b>Age in line [years]: 5</b>	<b>Rated strength (SFL) [kN]: 190</b>
Lot A as-received, failures*: 9×b, 2×c, 2×i, 4×p.-----Lot B TMP-tested, failures*: 4×b, 3×c, 5×p.			
<p>Solid line: As-received; dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk):                      As-received: SFL + 29%, scatter: normal                      TMP-tested: SFL + 49%, scatter: smaller                      Mean: ~ higher.                      Rate of aging: Not known                      Reference scenario: F1</p> <p>Today's diagnosis for time of tests/                      Recommendation/Comment:                      The insulators of this line</p> <ul style="list-style-type: none"> <li>• meet the standard</li> </ul> <p>→ Repeat the tests in ~10 years</p>	

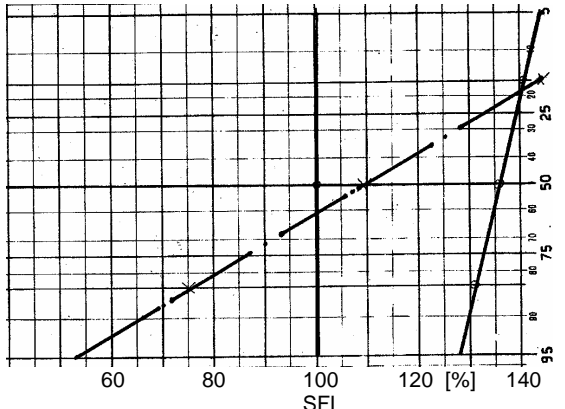
<b>Line: CGIEC11</b>	<b>Operation record: known to be good</b>	<b>Age in line [years]: new</b>	<b>Rated strength (SFL) [kN]: 80</b>
Lot A as-received, failures*: 9×b, 3×p.-----Lot B TMP-tested, failures*: 12×b.			
		<p>Characteristic (related to SFL at 5% risk):                      As-received: SFL + 44%, scatter: normal                      TMP-tested: SFL + 32%, scatter: similar                      Mean: lower.                      Rate of aging: Not known                      Reference scenario: F1</p> <p>Today's diagnosis for time of tests                      /Recommendation/Comment:                      The insulators of this line</p> <ul style="list-style-type: none"> <li>• meet the standard</li> </ul> <p>→ Repeat the tests in ~10 years</p>	

<b>Line: CGIEC12</b>	<b>Operation record: known to be good</b>	<b>Age in line [years]: new</b>	<b>Rated strength (SFL) [kN]: 110</b>
Lot A as-received, failures*: 11×b, 1×p.-----Lot B TMP-tested, failures*: 12×b.			
		<p>Characteristic (related to SFL at 5% risk):                      As-received: SFL + 18%, scatter: normal                      TMP-tested: SFL + 21%, scatter: ~similar                      Mean: similar.                      Rate of aging: Not known                      Reference scenario: F1</p> <p>Today's diagnosis for time of tests/                      Recommendation/Comment:                      The insulators of this line</p> <ul style="list-style-type: none"> <li>• meet the standard</li> </ul> <p>→ Repeat the tests in ~10 years</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, p→broken pin

**Cap & Pin Insulators, porcelain: line operation record received.**  
**These tests have been performed in 1970/71 for IEC 60575 (1977).**

Line: C PIEC14	Operation record: known to be good	Age in line [years]: new	Rated strength (SFL) [kN]: 210
Lot A as-received, failures*: 12×p.-----Lot B TMP-tested, failures*: 12×p.			
 <p data-bbox="194 862 502 952">Dashed line: As-received Dashed/dotted line: TMP-tested</p>		<p data-bbox="774 425 1268 638">Characteristic (related to SFL at 5% risk): As-received: SFL + 17%, scatter: normal TMP-tested: SFL + 16%, scatter: similar Mean: ~similar. Rate of aging: Not known Reference scenario: F1</p> <p data-bbox="774 649 1181 716">Today's diagnosis for time of tests /Recommendation/Comment: The insulators of this line</p> <ul data-bbox="821 761 1085 795" style="list-style-type: none"> <li>• meet the standard</li> </ul> <p data-bbox="774 828 1165 862">→ Repeat the tests in ~10 years</p>	

Line: C PIEC21	Operation record: poor	Age in line [years]: ~15	Rated strength (SFL) [kN]: 80
Lot A as-received, failures*: 4×i, 8×p.-----Lot B TMP-tested, failures*: 6×c, 5×i, 3×p.			
 <p data-bbox="194 1585 502 1675">Solid line: As-received Dashed/dotted line: TMP-tested</p>		<p data-bbox="774 1149 1268 1361">Characteristic (related to SFL at 5% risk): As-received: SFL + 28%, scatter: normal TMP-tested: SFL - 47%, scatter: higher Mean: lower. Rate of aging: Not known Reference scenario: F3</p> <p data-bbox="774 1373 1189 1440">Today's diagnosis for time of tests/ Recommendation/Comment: The insulators of this line</p> <ul data-bbox="821 1485 1220 1518" style="list-style-type: none"> <li>• do not meet today's standard</li> </ul> <p data-bbox="774 1552 1204 1585">→ Replace the insulators of this line</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, p→broken pin

**Annex B1:  
Long-Rod Insulator tests (WG B2.03)**

**Long-Rod Insulators, porcelain: line operation record received.**

<b>Line: LP1</b>	<b>Operation record: good</b>	<b>Age in line [years]: 42</b>	<b>Rated strength (SFL) [kN]: 160</b>
Lot A as-received, failures*: 6×?.-----Lot B TMP-tested, failures*: 6×?.			
<p>Solid line: As-received Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): As-received: SFL +5%, scatter: normal TMP-tested: SFL +5%, scatter: similar Mean: ~higher</p> <p>Rate of aging: Not known Reference scenario: F1, F5</p> <p>Diagnosis/Recommendation/Comment: The insulators of this line</p> <ul style="list-style-type: none"> <li>• meet the standard</li> <li>• are approaching the end of safe lifetime</li> </ul> <p>→ Repeat the tests before 10 years</p>	

<b>Line: LP2</b>	<b>Operation record: good</b>	<b>Age in line [years]: 39</b>	<b>Rated strength (SFL) [kN]: 120</b>
Lot A as-received, failures*: 3×is, 2×ie.-----Lot B TMP-tested, failures*: 3×is, 3×ie; New, failures*: 5×?.			
<p>Solid line: As-received Dashed/dotted line: TMP-tested Dashed line: New</p>		<p>Characteristic (related to SFL at 5% risk): As-received: SFL -7%, scatter: normal TMP-tested: SFL -2%, scatter: similar Mean: ~unchanged</p> <p>New: SFL -12%, scatter: normal Mean: ~unchanged</p> <p>Rate of aging: No statistically proven aging found Reference scenario: F1b, F2, F4</p> <p>Diagnosis/Recommendation/Comment: The insulators of this line</p> <ul style="list-style-type: none"> <li>• show no significant changes to new state</li> </ul> <p>→ Replace the insulators of this line</p> <p>Note: The design load is only ~10% of the SFL. The relative position of the 3 lines suggests a negligible aging rate. It is therefore at the owner's risk that the insulators are not replaced: → Watch the insulators of this line closely → Repeat the tests before 10 years</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, is→between sheds, ie→at end, p→pin, ?→not available

**Long-Rod Insulators, porcelain: line operation record received.**

<b>Line: LP3</b>	<b>Operation record: good</b>	<b>Age in line [years]: 29</b>	<b>Rated strength (SFL) [kN]: 105</b>
Lot A as-received, failures*: 3×c, 2×is, 3×ie.-----Lot B TMP-tested, failures*: 2×c, 4×is, 2×ie.			
<p>Solid line: As-received Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): As-received: SFL +7%, scatter: high TMP-tested: ~ SFL, scatter: ~ similar mean: ~ similar Rate of aging: Not known Reference scenario: F5, (F3 Note)</p> <p>Diagnosis/Recommendation/Comment: The insulators of this line</p> <ul style="list-style-type: none"> <li>• meet the standard</li> <li>• are approaching the end of safe lifetime</li> </ul> <p>→ Repeat the tests before 5 years</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, is→between sheds, ie→at end, p→pin

**Long-Rod Insulators, porcelain: line operation record received.**

Line: LP4a	Operation record: poor	Age in line [years]: 30	Rated strength (SFL) [kN]: 140
Lot A as-received, failures*: 6×is, 2×ie.-----Lot B TMP-tested, failures*: 3×?, 4×is, 1×ie.			
<p>Solid line: As-received Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): As-received: SFL -15%, scatter: high TMP-tested: SFL +15%, scatter: smaller Mean: higher</p> <p>Rate of aging: Not known Reference scenario: F2, F6</p> <p>Diagnosis/Recommendation/Comment:</p> <ul style="list-style-type: none"> <li>Useful lifetime exceeded</li> </ul> <p>→ Replace the insulators of this line</p>	

From the 8 failures of lot A (as-received), 1 insulator failed below SFL at a value much different from the other specimens. This has increased the slope of the solid line and made it cross the SFL-line. Diagram LP4b has been prepared without this freak value included in diagram LP4a. The solid line no longer crosses the SFL. These 2 diagrams illustrate the importance of the TMP-test. In both diagrams the TMP-line is to the right of the solid line. This suggests replacement of the insulators and is in agreement with the operation record.

Line: LP4b	Operation record: poor	Age in line [years]: 30	Rated strength (SFL) [kN]: 140
Lot A as-received without freak value, failures*: 5×is, 2×ie. Lot B TMP-tested, failures*: 3×?, 4×is, 1×ie.			
<p>Solid line: As-received, low failure excluded Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): As-received: SFL +22%, scatter: normal TMP-tested: SFL +16%, scatter: larger Mean: (~higher)</p> <p>Rate of aging: Not known Reference scenario: F6</p> <p>Diagnosis/Recommendation/Comment:</p> <ul style="list-style-type: none"> <li>Useful lifetime exceeded</li> </ul> <p>→ Replace the insulators of this line</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, is→between sheds, ie→at end, p→pin, ?→not available

**Long-Rod Insulators, porcelain: line operation record received.**

Line: LP5a	Operation record: good	Age in line [years]: 40	Rated strength (SFL) [kN]: 160
Lot A as-received, failures*: 6×ie.-----Lot B TMP-tested, failures*: 6×ie.			
<p>→ Failing load Solid line: As-received in 2002 Dashed/dotted line: TMP-tested in 2002</p>		<p>Characteristic (related to SFL at 5% risk): As-received: SFL -10%, scatter: high TMP-tested: SFL -5%, scatter: smaller Mean: lower.</p> <p>Rate of aging: Not known Reference scenario: F2 (F1, F5)</p>	
<p>Diagnosis/Recommendation/Comment:</p> <ul style="list-style-type: none"> <li>Useful lifetime exceeded</li> </ul> <p>→ Replace the insulators of this line</p> <p>Note: When these insulators were put into operation, the definition of rated strength was 80% of today's SFL (100%). Therefore 80% of the SFL value may be used for the evaluation and the insulators may not be replaced: → Watch the insulators of this line closely → Repeat sample test before 5 years</p>			

Note: Diagram LP5b is for determination of rate of aging and remaining lifetime

Line: LP5b	Operation record: good	Age in line [years]: 40	Rated strength (SFL) [kN]: 160
Lot A as-received (the same as LP5a). Solid slim line as-received in 1986, failures*: 7×?.			
<p>→ Failing load Solid bolt line: As-received in 2002 Solid slim line: As-received in 1986</p>		<p>Characteristic (related to SFL at 5% risk): As-received in 2002: SFL -10%, scatter: high As-received in 1986: SFL +12.5% (slim line) scatter: similar</p> <p>Time since tested in 1986 [years]: 16 Rate of aging: Reduction between +12.5% to -10% over 16years: → ~1.4 % per year Reference scenario: F4</p>	
<p>Diagnosis/Recommendation/Comment:</p> <p>If evaluation of these insulators is based on 80% of SFL then the remaining strength capacity is 10%: → ~7 years of remaining safe life time for the insulators of this line</p>			

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, is→between sheds, ie→at end, p→pin, ?→not available

**Long-Rod Insulators, porcelain: line operation record received.**

<b>Line: LP6</b>	<b>Operation record: good</b>	<b>Age in line [years]: 36</b>	<b>Rated strength (SFL) [kN]: 105</b>
Lot A as-received, failures*: 1×is, 4×ie.-----Lot B TMP-tested, failures*: 1×is, 4×ie.			
<p>Solid line: As-received Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): As-received: SFL +13%, scatter: normal TMP-tested: SFL +6%, scatter: similar mean: lower</p> <p>Rate of aging: Not known Reference scenario: F1, F5</p> <p>Diagnosis/Recommendation/Comment: The insulators of this line • meet the standard</p> <p>→ Repeat the tests before 10 years</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, is→between sheds, ie→at end, p→pin

Note, explaining diagrams LP7a and LP7b:

This example illustrates again the importance of the TMP-test in respect to low failing load mavericks. Diagram LP7b is the result from failing load tests carried out on insulators from the same transmission line 1 year before CIGRE tests. Among the 9 failing loads recorded 1 value was well below SFL. What if this low value would not have been hit? This is shown in LP7b. The bolt line, which is for all recorded failing values, clearly crosses the SFL line, but the slim line which is for the same failing loads but excluding the low failing load maverick only just crosses the SFL. Without the low failing value there is no clear indication that these insulators have to be replaced. This message is coming from diagram LP7a where the mean value of the TMP-test shows a tendency to be higher and the TMP-line has higher scatter.

Tests represented in diagram LP7b have been performed in 2002 at the request of the utility in an other laboratory. The comparison between the slim solid line of diagram LP7b and the solid line of diagram LP7a (tests performed in 2003) indicates that there is good agreement between the testing done according to IEC procedures in different laboratories, yet it is also an indication for the possible variation of results due to the low number of insulators in the test.

**Long-Rod Insulators, porcelain: line operation record received.**

<b>Line: LP7a</b>	<b>Operation record:</b> poor	<b>Age in line</b> [years]: 46	<b>Rated strength (SFL)</b> [kN]: 120
Lot A as-received, failures*: 6×ie.-----Lot B TMP-tested, failures*: 4×is, 2×ie.			
<p>Solid line: As-received in 2003 Dashed/dotted line: TMP-tested in 2003</p>		<p>Characteristic (related to SFL at 5% risk): As-received: SFL -7%, scatter: normal TMP-tested: SFL -14%, scatter: higher mean: ~similar</p> <p>Rate of aging: Not known Reference scenario: F2, F3, F6</p>	
<p>Diagnosis/Recommendation/Comment:</p> <ul style="list-style-type: none"> <li>Useful lifetime exceeded</li> </ul> <p>→ Replace the insulators of this line</p>			

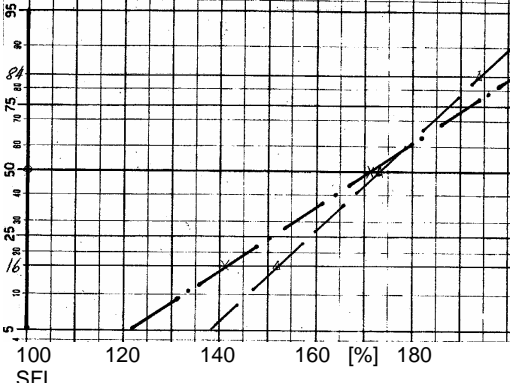
<b>Line: LP7b</b>	<b>Operation record:</b> poor	<b>Age in line</b> [years]: 45	<b>Rated strength (SFL)</b> [kN]: 120
Lot A as-received in 2002, failures*: 9×?.			
Lot A as-received in 2002 without low failure, failures*, 8×?.			
<p>Solid bolt line: As-received in 2002 Solid slim line: As-received in 2002 without freak failure</p>		<p>Characteristic (related to SFL at 5% risk): As-received (in 2002, all): SFL -17%, scatter: increased As-received (in 2002, without freak failure): SFL -3%, scatter: similar mean: similar</p> <p>Rate of aging: ~ Not defined Reference scenario: F2</p>	
<p>Diagnosis/Recommendation/Comment:</p> <ul style="list-style-type: none"> <li>Useful lifetime exceeded</li> </ul> <p>→ Replace the insulators of this line</p> <p>Slim solid line (without freak value) is within statistical limits in agreement with solid line of LP7a based on measurements taken 1 year later.</p>			

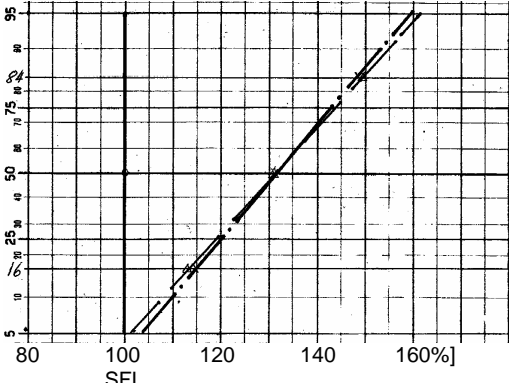
\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, is→between sheds, ie→at end, p→pin, ?→not available

**Annex B2:**

**Tests performed in 1970/71 for IEC Pub. 60575 (1977)**

**Long-Rod Insulators, porcelain: line operation record not known.**

Line: LPIEC1	Operation record: Not known	Age in line [years]: new	Rated strength (SFL) [kN]: 100
Lot A as-received, failures*: 9×is, 3×ie.-----Lot B TMP-tested, failures*: 10×is, 2×ie.			
 <p data-bbox="272 965 579 1039">→ Failing load Dashed line: From factory Dashed/dotted line: TMP-tested</p>		<p data-bbox="850 539 1337 680">Characteristic (related to SFL at 5% risk): From factory: SFL +38%, scatter: high TMP-tested: SFL +22%, scatter: higher mean: similar</p> <p data-bbox="850 687 1150 719">Rate of aging: Not known Reference scenario: F6</p> <p data-bbox="850 763 1249 831">Today's diagnosis for time of test/ Recommendation/Comment:</p> <p data-bbox="850 837 1453 981">The insulators of this line</p> <ul data-bbox="900 875 1453 981" style="list-style-type: none"> <li>• meet the standard</li> <li>• High scatter is an indication for limited safe life time.</li> </ul> <p data-bbox="850 1025 1378 1093">→ Watch the insulators of this line closely or → Do not install these insulators</p>	

Line: LPIEC2	Operation record: Not known	Age in line [years]: new	Rated strength (SFL) [kN]: 100
Lot A as-received, failures*: 2×c, 2×s, 8×is.-----Lot B TMP-tested, failures*: 1×c, 11×ie.			
 <p data-bbox="272 1682 596 1756">→ Failing load Dashed line: From factory Dashed/dotted line: TMP-tested</p>		<p data-bbox="850 1256 1337 1397">Characteristic (related to SFL at 5% risk): From factory: ~ SFL, scatter: high TMP-tested: ~ SFL, scatter: similar mean: similar</p> <p data-bbox="850 1404 1254 1471">Rate of aging: Not known Reference scenario: F5, (F3 Note)</p> <p data-bbox="850 1525 1249 1592">Today's diagnosis for time of test/ Recommendation/Comment:</p> <p data-bbox="850 1599 1147 1630">The insulators of this line</p> <ul data-bbox="900 1637 1361 1711" style="list-style-type: none"> <li>• meet the standard</li> <li>• are close to the end of safe lifetime</li> </ul> <p data-bbox="850 1749 1347 1780">→ Watch the insulators of this line closely</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, is→between sheds, ie→at end, p→pin

**Long-Rod insulators, porcelain: line operation record not known.  
These tests have been performed in 1970/71 for IEC 60575 (1977).**

Line: LPIEC3	Operation record: Not known	Age in line [years]: new	Rated strength(SFL) [kN]: 150
Lot A as-received, failures*: 1×b, 4×is.-----Lot B TMP-tested, failures*: 7×is, 5×ie.			
<p>→ Failing load Dashed line: From factory Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): From factory: SFL +33%, scatter: normal TMP-tested: SFL +29%, scatter: higher mean: higher</p> <p>Rate of aging: Not known Reference scenario: F2, F6</p> <p>Today's diagnosis for time of tests/ Recommendation/Comment: Higher scatter of the TMP-line together with the increased mean indicate that the safe lifetime if any will be limited. These insulators have no capacity to age.</p> <p>→ Do not install these insulators</p>	

Line: LPIEC4	Operation record: Not known	Age in line [years]: new	Rated strength (SFL) [kN]: 150
Lot A as-received, failures*: 5×b, 5×is, 2×ie.-----Lot B TMP-tested, failures*: 9×b, 2×is, 1×ie.			
<p>→ Failing load Dashed line: From factory Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): From factory: SFL -15%, scatter: high TMP-tested: SFL -100%, scatter: higher mean: lower</p> <p>Rate of aging: Not known Reference scenario: F2</p> <p>Today's diagnosis for time of tests/ Recommendation/Comment: These insulators</p> <ul style="list-style-type: none"> <li>do not meet the standard</li> </ul> <p>→ Do not install these insulators</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, is→between sheds, ie→at end, p→pin

**Long-Rod insulators, porcelain: line operation record not known.  
These tests have been performed in 1970/71 for IEC 60575 (1977).**

Line: LPIEC5	Operation record: Not known	Age in line [years]: new	Rated strength (SFL) [kN]: 150
Lot A as-received, failures*: 2×b, 4×ie.-----Lot B TMP-tested, failures*: 8×is, 4×ie.			
<p>→ Failing load Dashed line: From factory Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): From factory: SFL +35%, scatter: high TMP-tested: SFL +5%, scatter: higher mean: lower</p> <p>Rate of aging: Not known Reference scenario: F2, F5</p> <p>Today's diagnosis for time of tests/ Recommendation/Comment: The insulators of this line</p> <ul style="list-style-type: none"> <li>• meet the standard</li> <li>• are close the end of safe lifetime</li> </ul> <p>→ Watch these insulators closely or → Do not install these insulators</p>	

Line: LGIEC6	Operation record: Not known	Age in line [years]: new	Rated strength (SFL) [kN]: 150
Lot A as-received, failures*: 2×is, 10×ie.-----Lot B TMP-tested, failures*: 12×ie.			
<p>→ Failing load Dashed line: From factory Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): From factory: SFL - ~5%, scatter: high TMP-tested: SFL - ~5%, scatter: similar mean: lower</p> <p>Rate of aging: Not known Reference scenario: F2</p> <p>Today's diagnosis for time of tests/ Recommendation/Comment: These insulators</p> <ul style="list-style-type: none"> <li>• do not meet standard</li> </ul> <p>→ Do not install these insulators</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, is→between sheds, ie→at end, p→pin

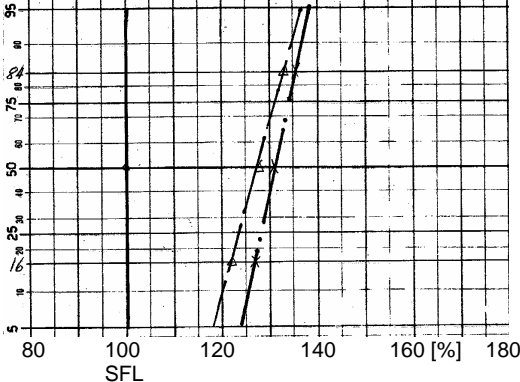
**Long-Rod insulators, porcelain: line operation record not known.  
These tests have been performed in 1970/71 for IEC 60575 (1977).**

Line: LPIEC7	Operation record: Not known	Age in line [years]: new	Rated strength (SFL) [kN]: 130
Lot A as-received, failures*: 5×is, 7×ie.-----Lot B TMP-tested, failures*: 6×is, 6×ie.			
<p>→ Failing load Dashed line: From factory Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): From factory: SFL +45%, scatter: normal TMP-tested: SFL +25%, scatter: higher mean: similar</p> <p>Rate of aging: Not known Reference scenario: F5, F6</p>	
		<p>Today's diagnosis for time of tests /Recommendation/Comment: The insulators of this line</p> <ul style="list-style-type: none"> <li>• meet the standard</li> <li>• High scatter is an indication for limited safe life time.</li> </ul> <p>→ Watch these insulators closely</p>	

Line: LPIEC8	Operation record: Not known	Age in line [years]: new	Rated strength (SFL) [kN]: 100
Lot A as-received, failures*: 10×b, 2×c.-----Lot B TMP-tested, failures*: 11×b, 1×c.			
<p>→ Failing load Dashed line: From factory Dashed/dotted line: TMP-tested</p>		<p>Characteristic (related to SFL at 5% risk): From factory: SFL +45%, scatter: small TMP-tested: SFL +45%, scatter: similar mean: similar</p> <p>Rate of aging: Not known Reference scenario: F1</p>	
		<p>Today's diagnosis at time of tests/ Recommendation/Comment: The insulators of this line</p> <ul style="list-style-type: none"> <li>• meet the standard</li> </ul> <p>→ Repeat the tests in ~10 years</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, is→between sheds, ie→at end, p→pin

**Long-Rod insulators, porcelain: line operation record not known.  
These tests have been performed in 1970/71 for IEC 60575 (1977).**

Line: LPIEC9	Operation record: Not known	Age in line [years]: new	Rated strength (SFL) [kN]: 165
Lot A as-received, failures*: 12×c.-----Lot B TMP-tested, failures*: 12×c.			
 <p data-bbox="272 913 794 987">                     → Failing load                      Dashed line: From factory                      Dashed/dotted line: TMP-tested                 </p>		<p data-bbox="850 495 1461 645">Characteristic (related to SFL at 5% risk): From factory: SFL +18%, scatter: small TMP-tested: SFL +25%, scatter: similar mean: ~ similar</p> <p data-bbox="850 645 1461 719">Rate of aging: Not known Reference scenario: F1</p> <p data-bbox="850 719 1461 792">Diagnosis at time of tests /Recommendation/Comment: The insulators of this line</p> <ul data-bbox="903 831 1166 869" style="list-style-type: none"> <li>• meet the standard</li> </ul> <p data-bbox="850 904 1238 943">→ Repeat the tests in ~10 years</p>	

\* ultimate failure: b→broken cap, c→cap pulled off, i→insulating part, is→between sheds, ie→at end, p→pin