# IEC 61300-2-24

Edition 2.0 2010-04

# INTERNATIONAL STANDARD

colour inside

## Fibre optic interconnecting devices and passive components – Basic test and measurement procedures –
## Part 2-24: Tests – Screen testing of ceramic alignment split sleeve by stress application



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# FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – BASIC TEST AND MEASUREMENT PROCEDURES –

## Part 2-24: Tests – Screen testing of ceramic alignment split sleeve by stress application

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International Standard IEC 61300-2-24 has been prepared by subcommittee 86B: Fibre optic interconnecting devices and passive components, of IEC technical committee 86: Fibre optics.

This second edition replaces the first edition published in 1999. This second edition constitutes a technical revision. Specific technical changes involve the addition of a dimension example of the reference gauge and the plate for the ceramic sleeve and a commonly used ceramic alignment sleeve for the 1,25 mm ceramic sleeve.

The text of this standard is based on the following documents:

| FDIS | Report on voting |
|---|---|
| 86B/2967/FDIS | 86B/3014/RVD |

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of IEC 61300 series, published under the general title, *Fibre optic interconnecting and passive components – Basic test and measurement procedures*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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# FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – BASIC TEST AND MEASUREMENT PROCEDURES –

# Part 2-24: Tests – Screen testing of ceramic alignment split sleeve by stress application

## 1 Scope

The purpose of this part of IEC 61300 is to identify weaknesses in a ceramic alignment split sleeve which could lead to early failure of the component.

## 2 General description

Ceramic alignment sleeves are important components often used in the adaptor of plug-adaptor-plug optical connector sets. By using the method described, the component is subjected to a proof stress greater than would be experienced under normal service conditions. This enables weak products to be screened out.

## 3 Apparatus

The apparatus and arrangement necessary to perform this screening procedure are shown in Figure 1. The material needed consists of the following:

a) a reference gauge made of ceramic with a sleeve-holding section, a tapered section and a stress-applying section. The diameter of each section is dependent on the dimensions of the product being screened. The length of the sleeve-holding section and the stress-applying section should be greater than the component being tested;
b) plates A and B, each having a clearance hole in the centre to allow the plate to move a sample of a ceramic alignment split sleeve on the reference gauge.

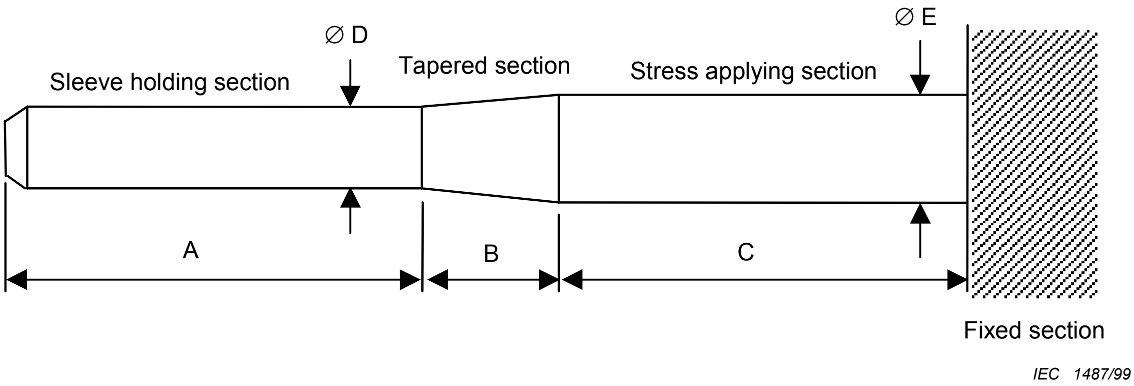


**Figure 1a – Reference gauge**

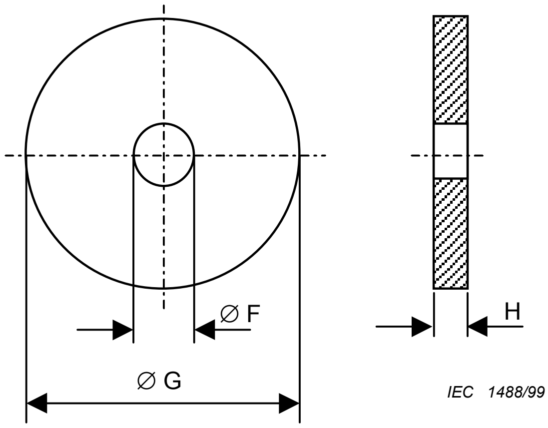


**Figure 1b – Plate A and plate B**

**Figure 1 – Apparatus used for screen testing of a ceramic alignment sleeve**

Table 1 shows the dimension of the reference gauge and the plate for the ceramic split sleeve. A dimension of the stress-applying section diameter (E) is shown for a commonly used ceramic alignment sleeve in Table 2.

**Table 1 – Dimension example of the reference gauge and the plate for the ceramic sleeve**

| **Reference** | **For 1,25 mm gauge**<br>**Dimension**<br>mm | **For 2,5 mm gauge**<br>**Dimension**<br>mm | **Notes** |
|---|---|---|---|
| A | 9 | 14 | NOTE 2 |
| B | 5 | 5 | |
| C | 9 | 14 | NOTE 2 |
| D | – | – | NOTE 1 |
| E | 1,259 0 ± 0,000 5 | 2,515 | |
| F | – | – | NOTE 3 |
| G | 20 | 20 | |
| H | 2 | 2 | |

NOTE 1 This diameter should be less than the inner diameter of the split sleeve.

NOTE 2 Surface finish in this area Ra = 0,2 µm.

NOTE 3 Dimension F should be greater than dimension E, and less than sleeve ØD.

**Table 2 – Dimension example of a commonly used ceramic alignment sleeve**

| Items | For 1,25 mm<br>Dimension<br>mm | For 2,5 mm<br>Dimension<br>mm |
|---|---|---|
| Length | 6,8 | 10,1 |
| Outer diameter | 1,62 | 3,2 |
| Inner diameter (ref.) | 1,246 | 2,49 |
| Split section width | 6,8 | 10,1 |

## 4 Procedure

This test should be carried out under a 23 °C ± 2 °C environmental temperature condition.

The procedure is as follows.

a) Insert plate A into the reference gauge and set it at the fixed end of the reference gauge.

b) Moisten the inside surface of a ceramic split sleeve sample with distilled water (for example using a cotton bud). Only touch the sleeve with suitable tools.

c) The sample sleeve is inserted onto the sleeve-holding part and set just in front of the tapered part of the reference gauge.

d) Insert plate B into the left-hand side of the sample sleeve and move the sample sleeve onto the stress-applying part until the sample sleeve touches plate A (within approximately 1 s).

e) The sample sleeve should be held for 3 s under the stressed state.

f) After 3 s, stress applied to the sample sleeve is removed by moving plate A to the left-hand side (within approximately 1 s).

g) In the course of the procedure from d) to f), samples without damage (breakage or crack) should be selected as acceptable sleeves.

## 5 Details to be specified

The following details shall be specified depending on the sample sleeve size in the detail specification:

– diameter of sleeve-holding part of reference gauge (ØD);

– diameter of stress-applying part of reference gauge (ØE);

– length of sleeve-holding part (A) and stress-applying part (C);

– diameter of the center hole of plates A and B (ØF);

– deviations from test procedure.

# Annex A
(informative)

# Static fatigue for zirconia alignment sleeve

## A.1 Prediction of failure probability by static fatigue

This annex applies primarily to 2,5 mm zirconia alignment sleeves supported by references [1] to [5][1]. For 1,25 mm zirconia sleeves, a comprehensive analysis is referenced [6] and the strength distribution is shown in Figure A.6. Micro-cracks essentially exist on the surface or inside of ceramics. Therefore, fracture due to static fatigue occurs in ceramics under lower stress than the characteristic strength of the materials because of crack propagation in ceramic materials [1] [2].

Assurance of reliable optical fibre connections requires the prediction of failure probability of the zirconia sleeves under working stress needed to align the ferrules.

Assuming aligned ferrules of optical connectors, the zirconia sleeves are allowed to stand under a constant stress, as working stress $\sigma_a$. Based on the theories of Weibull statistics and slow crack growth for brittle materials, cumulative failure probability $F$ of the zirconia sleeves suffering from working stress is given by the following equation:

$$\ln\frac{1}{1-F}=\frac{m}{N-1}\ln\sigma_a^N\,t_a+\ln\gamma \tag{A.1}$$

with

$$\gamma\equiv\frac{V_\mathrm{e}}{\sigma_0^m\;\beta^{m/(N-2)}}$$

$$\beta\equiv\frac{2}{(N-2)\,AY^2\,K_{IC}^{(N-2)}}$$

where

| | |
|---|---|
| $t_a$ | is the working time during which the working stress $\sigma_a$ is applied; |
| $m$, $V_e$ and $\sigma_0$ | are the Weibull modulus, effective volume, and normalization constant to express the failure probability by the Weibull statistics theory, respectively; |
| $Y$ | is the geometry constant; |
| $K_{IC}$ | is the critical stress intensity factor; |
| $A$ and $N$ | are crack propagation constants of the brittle materials [2]. |

[1] Figures in square brackets refer to the Bibliography.

These crack propagation constants depend on environmental conditions such as temperature, humidity, atmosphere, and material characteristics. Therefore, if $m$, $N$ and $\gamma$ values are estimated, the static fatigue life time of sleeves is predicted. The $N$ value is estimated by the dynamic fatigue test that measures the strength of a sleeve corresponding variable of the proportional increased stress coefficient $\sigma'$ in MPa/s. On the other hand, the relationship between $F$, strength $\sigma_f$ of sleeves and $\sigma'$ is given by executing the sleeve destructive test. The slope $m$ and the intercept $\ln\sigma$ are estimated from equation (A.2).

$$\ln\frac{1}{1-F} = m\ \ln\frac{\sigma_f^{(N+1)/(N-1)}}{\{(N+1)\sigma'\}^{1/(N-2)}} + \ln\gamma \qquad \text{(A.2)}$$

## A.2 Reliability improvement by proof test

In order to improve the reliability of the zirconia sleeve against fracture due to static fatigue, a proof test that initially eliminates weak zirconia sleeves by applying a greater stress (called proof stress) than the working stress is effective. Fatigue also occurs under the proof stress. However, the proof test conditions should be decided in order to take into consideration fatigue during the proof test [3] [4].

When the proof test is performed, the proof stress $\sigma_p$ applied to the zirconia changes trapezoidally along with time as shown in Figure A.1. In this figure, stress change is defined as follows:

$0 < t \le t_l$ : $\sigma(t) = \sigma' t$

$t_l < t \le t_l + t_p$ : $\sigma(t) = \sigma_p$

$t_l + t_p < t \le t_l + t_p + t_u$ : $\sigma(t) = \sigma_p - \sigma' t$

where

$$\sigma' = \sigma_p / t_l = \sigma_p / t_u$$

The cumulative failure probability $F_r$ after proof testing is given by equation (A.3):

$$\ln\frac{1}{1-F_r} = \ln\left[\left\{\left(\sigma_a^{N}t_a\right)^{(N_p-2)/(N-2)} + \zeta^{(N_p-2)}\delta^{(N_p-2)/m}\right\}^{m/(N_p-2)} - \zeta^m\delta\right] + \ln\gamma \qquad \text{(A.3)}$$

with

$$\zeta \equiv \left(\sigma_p^{N_p} t_e\right)^{1/(N_p-2)}$$

$$\delta \equiv \frac{\gamma_p}{\gamma} \equiv \left(\frac{\beta^{1/(N-2)}}{\beta_p^{1/(N_p-2)}}\right)^m$$

$$\gamma_p \equiv \frac{V_e}{\sigma_0^m \beta_p^{m/(N_p-2)}}$$

$$t_e \equiv t_p + \frac{t_u + t_l}{N_p + 1}$$

where $N_p$ and $\beta_p$ are $N$ and $\beta$ value under the proof test environment, respectively.

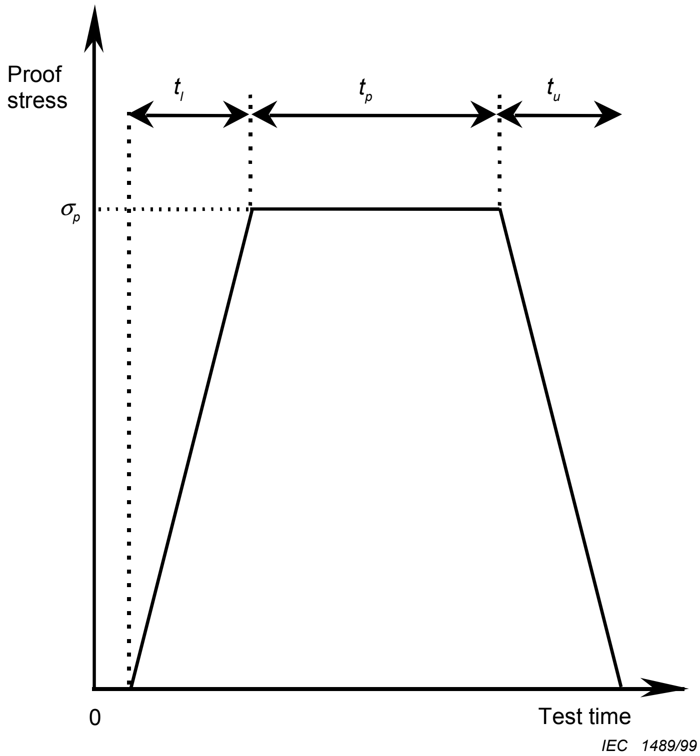


**Figure A.1 – Model of time-varying proof stress for a zirconia sleeve**

## A.3 Method of proof test

### A.3.1 Stress design for zirconia alignment sleeve

Figure A.2 shows calculated contour lines of the gauge retention force $f_r$ and working stress $\sigma_a$ along with inner and outer diameters of a zirconia sleeve. Modelling the zirconia sleeve as a curved beam, the gripping force and the working stress are calculated analytically. In calculation, length, maximum static frictional coefficient and Young's modulus of the zirconia sleeve are 11,4 mm, 0,1 and 196 GPa, respectively. Considering operational difficulty and a low yield rate in proof testing, proof stress shall be kept as small as possible. For example, as the maximum gauge retention force and the maximum working stress satisfies the above-mentioned condition and the safety coefficient of around 10 against zirconia characteristic strength of 1 200 MPa respectively, the outer diameter of zirconia sleeve is designed with a value of 3,2 mm. From Figure A.2, the maximum working stress with a 3,2 mm outer diameter becomes 130 MPa (gauge retention force is 3,9 N, inner diameter is 2,490 mm).

*Dimensions in millimetres*

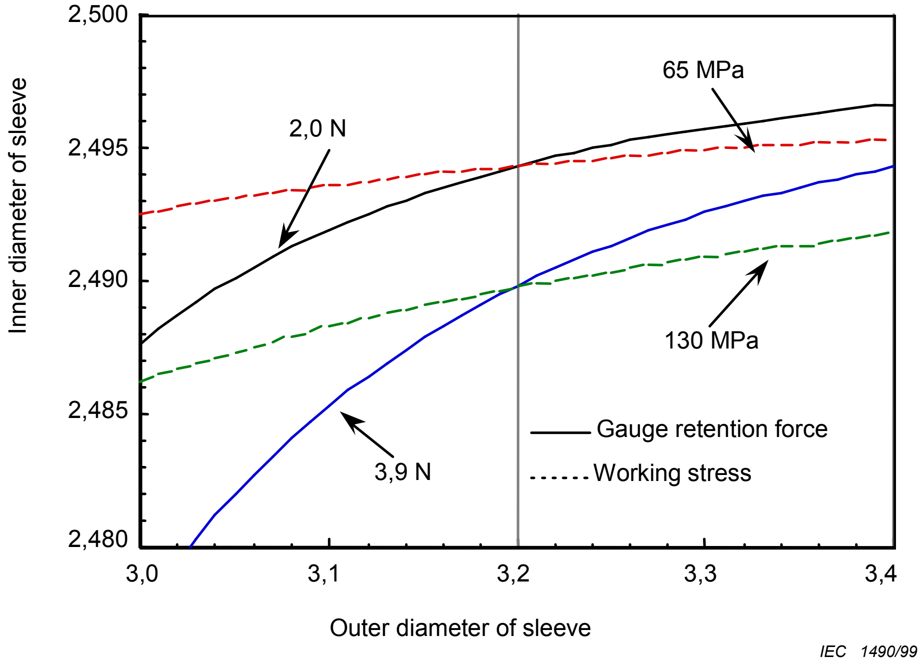


**Figure A.2 – Calculated contour lines of gauge retention force and working stress along with inner and outer diameter of a zirconia sleeve**

### A.3.2 Conditions for proof test

Ordinarily, components for switchboard and transmission equipment require very low failure probability (for example under 0,1 FIT during 20 years). In order to decide proof test conditions that make a zirconia sleeve satisfy required failure probability, parameters *m*, *N*, $N_p$, $\gamma$ and $\gamma_p$ in equation (A.3) shall be estimated. Table A.1 shows these estimated parameters using 3 mol % $Y_2O_3$-$ZrO_2$ sleeves. According to equation (A.3), by using parameters in Table A.1, a general relationship between $\sigma_p/\sigma_a$ and $t_e$, satisfying 0,1 FIT during 20 years use, is shown in Figure A.3.

**Table A.1 – Measured static fatigue parameters for zirconia sleeves**

| Parameters | 25 °C in water | 85 °C in water |
|---|---|---|
| *m* | 5,5 to 7,1 | 5,5 to 6,3 |
| *N* or $N_p$ | 28 to 40 | 22 to 35 |
| ln $\gamma$ or ln $\gamma_p$ | –43,3 to –53,9 | –40,7 to –47,8 |

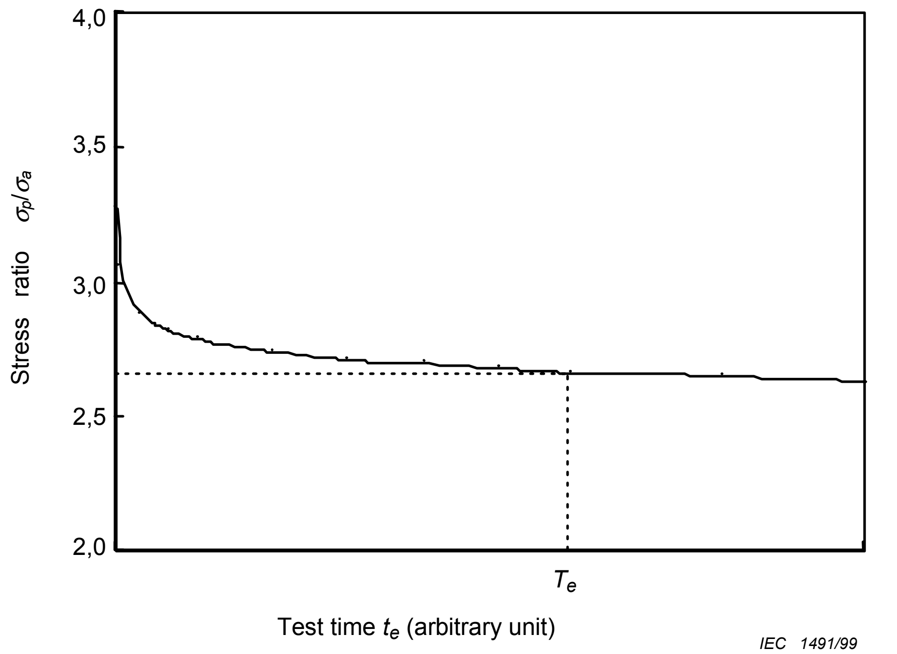


**Figure A.3 – Calculated general relationship between $\sigma_p/\sigma_a$ and $t_e$, satisfying 0,1 FIT for 20 years use**

Working and proof test environments are assumed as 85 °C in water and 25 °C in water respectively. From Figure A.3, "$T_e$" is the time for $\sigma_p/\sigma_a \approx 2,7$, which is almost saturated against $t_e$. Failure probability of zirconia sleeves, which are screened on the condition $\sigma_p/\sigma_a \approx 2,7$, $t_e = T_e$, and 0,1 FIT reference along with working time $t_a$ are shown in Figure A.4. It is clear that the proof test ensures the failure probability under 0,1 FIT during 20 years of use.

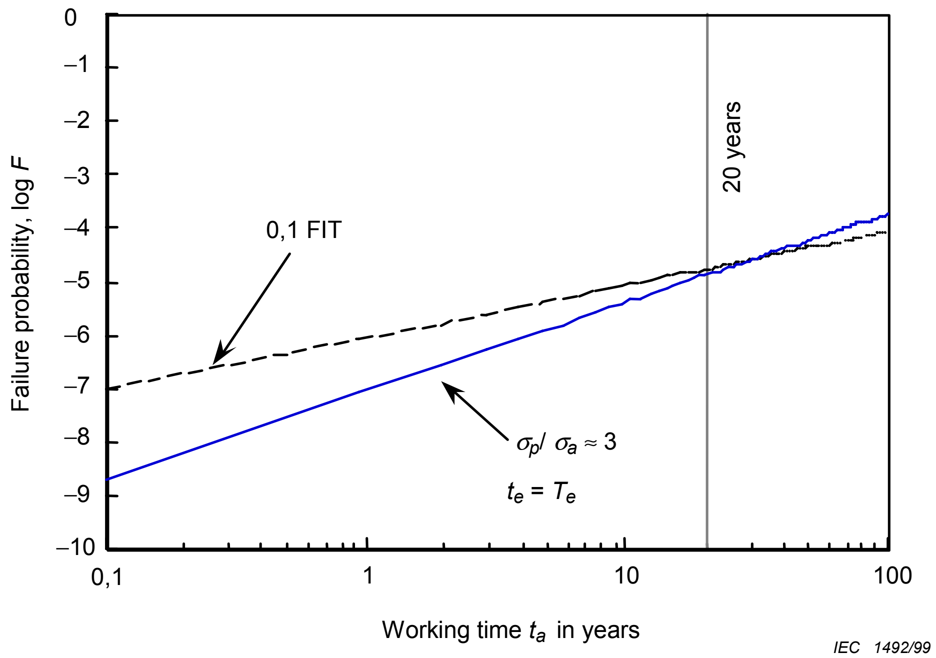


**Figure A.4 – Calculated failure probability of screened zirconia sleeves along with working time**

### A.3.3 Experimental verification of proof test

Applying the above-mentioned theory for the proof test to real zirconia sleeves, improvement of reliability is experimentally verified. The assumed working time is around 20 years, therefore the verification in a practical environment entails considerable difficulties. Consequently, by performing two kinds of comparison between theory and experiment, validity of the proof test is confirmed.

### A.3.4 Strength distribution after proof test

Effective elimination of weak sleeves by proof test is experimentally verified. Destroying screened sleeves that just passed the proof test, by a proportional increased stress $\sigma'$, with a cumulative failure probability $F_r$ of the screened sleeves is given by equation (A.4):

$$\ln\frac{1}{1-F_r}=\ln\left[\left\{\frac{\sigma_f^{\,N_p+1}}{\sigma'(N_p+1)}+\zeta^{N_p-2}\right\}^{m/(n_p-2)}-\zeta^m\right]+\ln\gamma_p \qquad (A.4)$$

Figure A.5 shows measured strength distribution of 2,5 mm zirconia sleeves and calculated results using equation (A.4). To emphasize the efficiency of the proof test, a 1 000 MPa proof stress $\sigma_p$ and 10 s of testing time $t_p$, $t_u$ and $t_l$ were adopted as the proof test conditions. The calculation was carried out using the values of $m$ = 7,1, $N_p$ = 34 and ln $\gamma_p$ = –53,9. The constants $m$, $N_p$ and ln $\gamma_p$ were estimated by previously mentioned dynamic fatigue test and destructive test conditions. According to the strength distribution of Figure A.5, it is clear that the reliability of zirconia sleeves is considerably improved by proof testing which eliminates initially weak sleeves. The measured and calculated distributions agree well, therefore, the validity of the theory is proved. Figure A.6 shows measured strength distribution of 1,25 mm zirconia sleeves using specified proof test conditions shown in Table A.1.

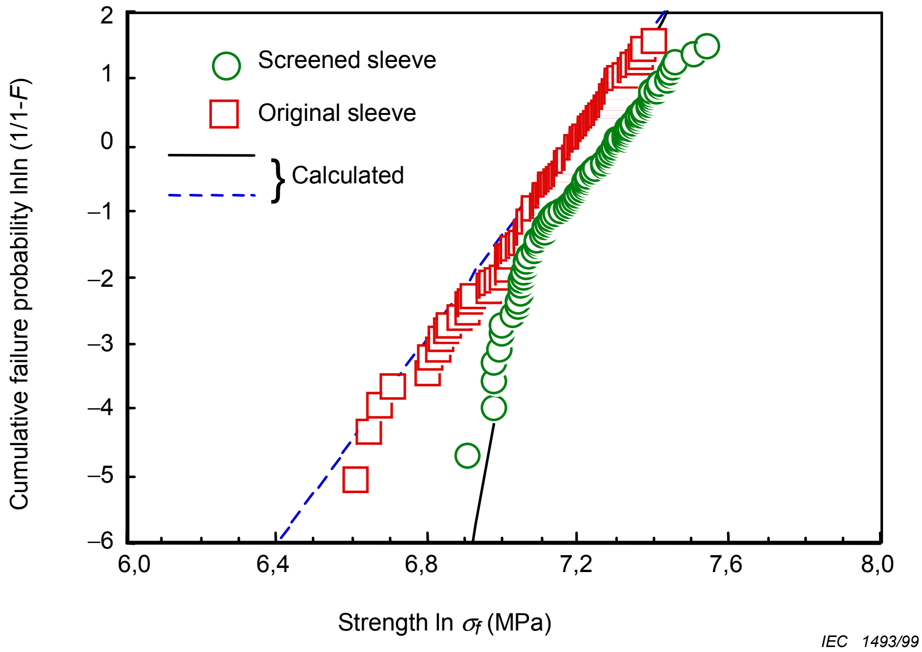


**Figure A.5 – Measured and calculated strength distribution of 2,5 mm zirconia sleeves (comparison between sleeves, extended proof tested or not)**

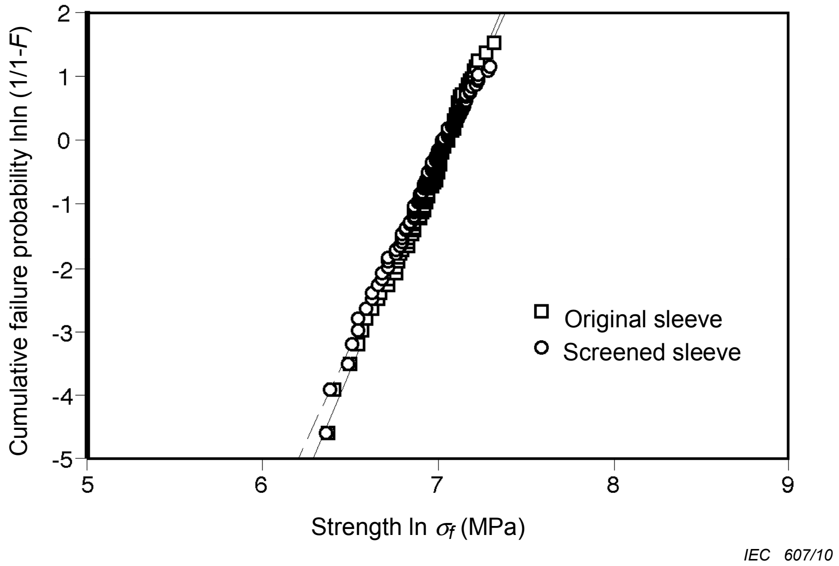


**Figure A.6 – Measured strength distribution of 1,25 mm zirconia sleeves (comparison between sleeves, extended proof tested or not)**

## A.4 Conclusion

The gauge retention force of the zirconia sleeve has been prescribed as between 2,0 N and 3,9 N bearing in mind its practical application.

Concerning fracture prevention of zirconia ceramics due to static fatigue, it has been clarified that the proof test, which initially eliminates weak sleeves by applying a greater stress than the working stress, assures sufficient strength reliability under high temperature and humidity environments (under 0,1 FIT during 20 years use). The conditions for proof testing have been derived theoretically and the validity of the test has been confirmed experimentally. The adequate proof stress is about three times larger than the actual stress [5], [6].

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