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**Railway applications — Suspension  
components —**

Part 1:  
**Characteristics and test methods for  
elastomer-mechanical parts**

*Applications ferroviaires — Pièces de suspension —*

*Partie 1: Caractéristiques et méthodes d'essai pour les pièces en  
caoutchouc et les pièces en caoutchouc-métal*

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 269, *Railway applications*, Subcommittee SC 2, *Rolling stock*.

A list of all parts in the ISO 22749 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

This document is based on EN 13913.

Designing an elastomer-mechanical part requires knowledge of the mechanical system of which it forms part. Therefore, specific characteristics are needed for each case, which only the customer can specify.

This document is the result of the studies and research to improve the performances and quality of elastomer-mechanical parts in order to meet the requirements of railway rolling stock.

This document is designed for railway operators, manufacturers and equipment suppliers of the railway industry as well as for the suppliers of elastomer-mechanical parts.

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# Railway applications — Suspension components —

## Part 1: Characteristics and test methods for elastomer-mechanical parts

### 1 Scope

This document applies to elastomer-mechanical parts designed to be fitted on railway vehicles and similar vehicles running on dedicated tracks with permanent guide systems, whatever the type of rail and the running surface.

Typical applications of the elastomer-mechanical parts include:

- vehicle suspension systems;
- equipment mounting systems;
- joints (e.g. end-mountings of dampers, rubber-based bearings, elastomer-mechanical parts used on mechanical couplings);
- limit stops.

These parts can be:

- made entirely of elastomer, operating on their own or in combination with other elastic parts;
- made up of elastomer and other materials, adherent together or not.

This document specifies characteristics that rubber and rubber to metal parts are to achieve, together with applicable inspection and test methods to be carried out for verification.

This document does not apply to:

- rubber diaphragms for pneumatic suspension springs;
- elastic parts of buffing and drawgear springs;
- diaphragms, bellows and seals;
- hoses and tubings;
- transmission belts.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 188, *Rubber, vulcanized or thermoplastic — Accelerated ageing and heat resistance tests*

ISO 1431-1, *Rubber, vulcanized or thermoplastic — Resistance to ozone cracking — Part 1: Static and dynamic strain testing*

ISO 1817, *Rubber, vulcanized or thermoplastic — Determination of the effects of liquids*

## ISO 22749-1:2021(E)

ISO 2781, *Rubber, vulcanized or thermoplastic — Determination of density*

ISO 4649, *Rubber, vulcanized or thermoplastic — Determination of abrasion resistance using a rotating cylindrical drum device*

ISO 9227, *Corrosion tests in artificial atmospheres — Salt spray tests*

ISO 23529, *Rubber — General procedures for preparing and conditioning test pieces for physical test methods*

ISO 80000-3, *Quantities and units — Part 3: Space and time*

ISO 80000-4, *Quantities and units — Part 4: Mechanics*

### 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

#### 3.1

##### **component**

elastomer-mechanical part

#### 3.2

##### **static creep**

displacement increase of a component subjected to a constant static force, occurring after a specified period of time

#### 3.3

##### **dynamic creep**

displacement increase of a component subjected to a dynamic force oscillating about a constant static force, occurring after a specified period of time

#### 3.4

##### **static relaxation**

force decrease of a component subjected to a constant displacement, occurring after a specified period of time

#### 3.5

##### **dynamic relaxation**

force decrease of a component submitted to a dynamic displacement oscillating about a constant static displacement, occurring after a specified period of time

#### 3.6

##### **phase angle**

difference in phase between the transmitted excitation and the response at a specific sinusoidal amplitude and frequency

### 4 Symbols and abbreviated terms

The units presented in ISO 80000-3 and ISO 80000-4 shall be used for the symbols in [Table 1](#).

Decimal multiples and submultiples of units defined below can be used.

**Table 1 — Symbols and abbreviations**

Symbol	Unit	Explanation
$a$	m or rad	<p>amplitude of the movement; see Figure 1.</p> <p><b>Key</b>  X time (<math>t</math>)  Y displacement (linear, <math>d</math>, or angular, <math>\theta</math>)  1 <math>d_{\max}</math> (or <math>\theta_{\max}</math>)  2 <math>d_{\min}</math> (or <math>\theta_{\min}</math>)  3 <math>d_p</math> (or <math>\theta_p</math>)</p> <p><b>Figure 1 — Amplitude of the movement</b></p>
$C$	N or Nm	<p>amplitude of the force (or the moment); see Figure 2.</p> <p><b>Key</b>  X time (<math>t</math>)  Y force (<math>F</math>) or moment (<math>M</math>)  1 <math>F_{\max}</math> (or <math>M_{\max}</math>)  2 <math>F_{\min}</math> (or <math>M_{\min}</math>)  3 <math>F_p</math> (or <math>M_p</math>)</p> <p><b>Figure 2 — Amplitude of the force (or the moment)</b></p>
$d$	m	linear displacement
$d_j$	m	displacement ( $d_1$ ; $d_2$ ; etc.) corresponding to a force $F_j$ with $d_0 < d_j < d_M$
$d_0$	m	lower data limit for the definition of the stiffness characteristics
$d_M$	m	upper data limit for the definition of the stiffness characteristics
$d_{\min}$	m	minimum displacement on a sinusoidal motion (see Figure 1)
$d_{\max}$	m	maximum displacement on a sinusoidal motion (see Figure 1)
$d_p$	m	mean displacement (see Figure 1)
$F$	N	static force

Table 1 (continued)

Symbol	Unit	Explanation
$F_j$	N	force ( $F_1; F_2; \text{etc.}$ ) corresponding to a displacement $d_j$ with $F_0 < F_j < F_M$
$F_0$	N	lower data limit for the definition of the stiffness characteristics
$F_M$	N	upper data limit for the definition of the stiffness characteristics
$F_{\min}$	N	minimum force on a sinusoidal motion (see Figure 2)
$F_{\max}$	N	maximum force on a sinusoidal motion (see Figure 2)
$F_p$	N	mean force (see Figure 2)
$F_C$	N	reference force taken into account for the creep test (static and dynamic)
$F_L$	N	reference force taken into account for the definition of the dimensions of the component under load
$F_s$	N	static force
$f$	Hz	frequency
$k_{\text{dyn}}$	N/m	stiffness under sinusoidal motion NOTE Characteristic of the component measured along an axis, under a sinusoidal motion.
$k_s$	N/m	characteristic "force as a function of linear displacement" at constant velocity NOTE Characteristic of the component measured along an axis, at constant velocity.
$k\theta_{\text{dyn}}$	Nm/rad	rotational stiffness under sinusoidal motion NOTE Characteristic of the component measured around an axis, under a sinusoidal motion.
$k\theta_s$	Nm/rad	characteristic "moment as a function of rotational displacement" at constant velocity NOTE Characteristic of the component measured around an axis, at constant velocity.
$L$	m	dimension of the component
$L_j$	m	dimension ( $L_1; L_2; \text{etc.}$ ) under a static force $F_j$
$L_0$	m	dimension at $F_0$ (or $M_0$ )
$L_D$	m	reference dimension taken into account for the definition of the force given by the component under deformation
$L_M$	m	dimension at $F_M$ (or $M_M$ )
$L_R$	m	reference dimension taken into account for the relaxation test (static and dynamic)
$M$	Nm	Moment applied around an axis of the component
$M_j$	Nm	moment ( $M_1; M_2; \text{etc.}$ ) corresponding to an angle of displacement $\theta_j$ with $M_0 < M_j < M_M$
$M_0$	Nm	lower limit value for the definition of the stiffness characteristics
$M_M$	Nm	upper limit value for the definition of the stiffness characteristics
$M_{\min}$	Nm	minimum moment on a sinusoidal motion (see Figure 2)
$M_{\max}$	Nm	maximum moment on a sinusoidal motion (see Figure 2)
$M_p$	Nm	mean moment (see Figure 2)
$O_{xyz}$	—	Cartesian reference point
$R_C$	m/decade	creep rate NOTE It is permissible to use % / decade instead of m/decade.
$T_e$	°C	ambient temperature (temperature of the air surrounding the component) in extreme and exceptional situations
$T_{e,\min}$	°C	ambient temperature (temperature of the air surrounding the component) in extreme and exceptional situations: lower temperature

Table 1 (continued)

Symbol	Unit	Explanation
$T_{e,max}$	°C	ambient temperature (temperature of the air surrounding the component) in extreme and exceptional situations: higher temperature
$\theta$	rad	angle of displacement in a plane around an axis of the component
$\theta_j$	rad	angle of displacement ( $\theta_1$ ; $\theta_2$ ; etc.) corresponding to a moment $M_j$ with $\theta_0 < \theta_j < \theta_M$
$\theta_0$	rad	lower limit value for the definition of the stiffness characteristics
$\theta_M$	rad	upper limit value for the definition of the stiffness characteristics
$\theta_{min}$	rad	minimum angle of displacement on a sinusoidal motion (see Figure 1)
$\theta_{max}$	rad	maximum angle of displacement on a sinusoidal motion (see Figure 1)
$\theta_p$	rad	mean angular displacement (see Figure 1) NOTE It is permissible to use angular units of degrees instead of radians.
$\delta$	rad	phase angle

## 5 Three-dimensional definition of characteristics

In the absence of any reference system and specific co-ordinates in the definition documents, the following arrangements shall be made.

Using the X-Y-Z axes to orientate the vehicle in space, a Cartesian reference point,  $O_{xyz}$ , related to the vehicle and with a supposedly fixed point within the mechanical system to which the component belongs as origin, is established as follows:

- axis  $O_x$  parallel to the longitudinal axis of vehicle X;
- axis  $O_y$  parallel to the transverse axis of vehicle Y;
- axis  $O_z$  parallel to the vertical axis of vehicle (or normal axis) Z.

The displacements corresponding to the degrees of freedom are:

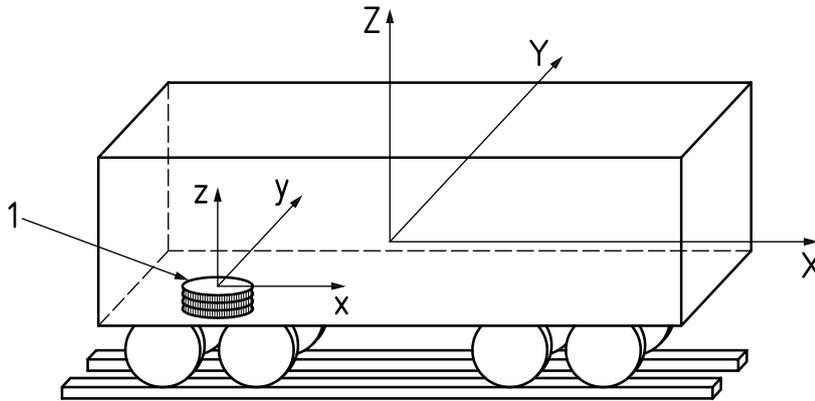
- displacement parallel to axis  $O_x$ :  $d_x$
- displacement parallel to axis  $O_y$ :  $d_y$
- displacement parallel to axis  $O_z$ :  $d_z$
- rotation around axis  $O_x$ :  $\theta_x$
- rotation around axis  $O_y$ :  $\theta_y$
- rotation around axis  $O_z$ :  $\theta_z$

The positive direction of rotation is clockwise looking from the origin.

The mechanical characteristics associated with the displacements are:

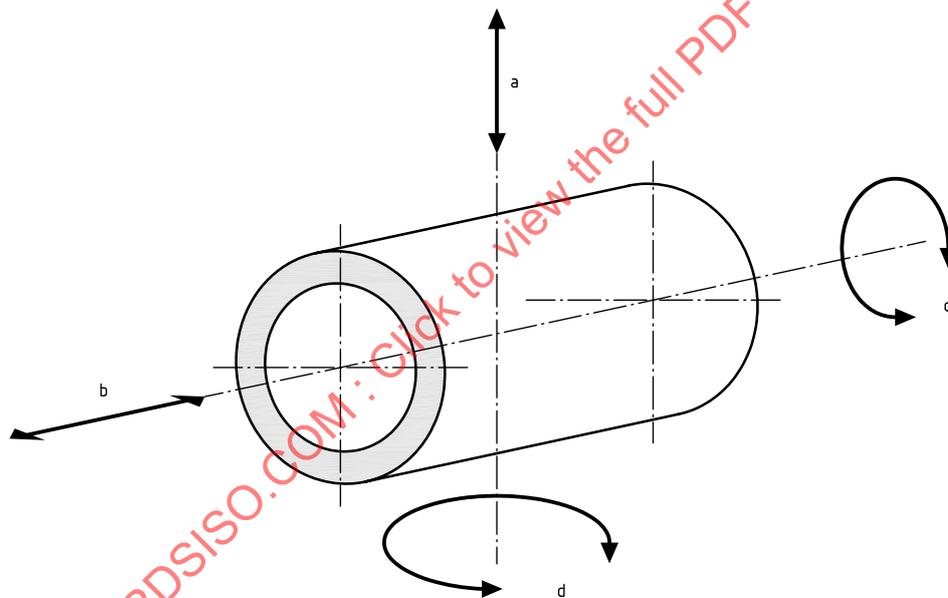
- for  $d_x$ : stiffnesses  $k_{sx}$  and  $k_{dynx}$  ; force  $F_x$
- for  $d_y$ : stiffnesses  $k_{sy}$  and  $k_{dyny}$  ; force  $F_y$
- for  $d_z$ : stiffnesses  $k_{sz}$  and  $k_{dynz}$  ; force  $F_z$
- for  $\theta_x$ : stiffnesses  $k\theta_{sx}$  and  $k\theta_{dynx}$  ; moment  $M_x$
- for  $\theta_y$ : stiffnesses  $k\theta_{sy}$  and  $k\theta_{dyny}$  ; moment  $M_y$
- for  $\theta_z$ : stiffnesses  $k\theta_{sz}$  and  $k\theta_{dynz}$  ; moment  $M_z$

These provisions are illustrated by [Figure 3](#). [Figures 4](#) and [5](#) illustrate the main directions defining the characteristics of a joint and spring, respectively.



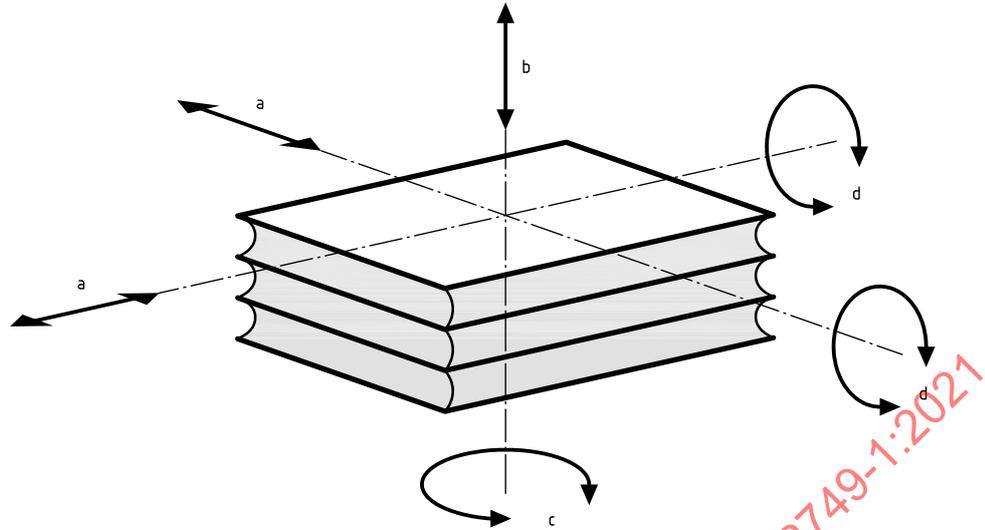
**Key**  
1 component

**Figure 3 — Three-dimensional definition of characteristics**



**Key**  
a Radial.  
b Axial.  
c Torsional.  
d Conical.

**Figure 4 — Main directions defining the characteristics of a joint (example: elastic bush)**

**Key**

- a Radial.
- b Axial.
- c Torsional.
- d Conical.

**Figure 5 — Main directions defining the characteristics of a spring (example: layer spring)**

## 6 Conditions of use

### 6.1 Environmental conditions

According to its position on the vehicle and its service conditions (including storage, depot and qualification test of the vehicle), the component can be subject to attack from sources such as:

- chemical products (cleaning products for example);
- organic waste;
- oil sprays;
- environmental conditions.

These conditions shall be defined in the technical specification.

### 6.2 Operating temperatures

The operating temperature range shall be defined in the technical specification.

### 6.3 Operating loading conditions

During its service life, the component is subjected to loading conditions such as vibration, forces and displacements (linear and angular), due to the function of the mechanical system to which it is fitted.

These loading conditions shall be taken into consideration for the definition of the component. Therefore, they shall be defined in the technical specification.

**6.4 Recycling**

The technical specification may specify requirements relating to the final disposal of the component.

The supplier of the component shall inform the customer of the recyclability of the materials used.

**7 Definition of the product**

**7.1 General**

**7.1.1 Definition of characteristics**

The necessary characteristics for the definition of the component according to its usage and operating conditions shall be indicated in the technical specification.

These characteristics shall be selected from those specified in [Tables 2](#) and [3](#).

The selected characteristics shall be defined according to the instructions of this document.

The component shall comply with the selected criteria defined in the technical specification.

Recommended tolerances are given in [Annex C](#).

**7.1.2 Mounting conditions**

Any mounting conditions which can have an influence on the characteristics (e.g. component prestressed when installed) shall be defined in the technical specification.

**7.1.3 Ambient conditions**

Unless otherwise specified, the characteristics of the component are defined with an ambient temperature of  $(23 \pm 2) ^\circ\text{C}$ .

Specific characteristics may be defined for different conditions. In this case, the technical specification shall specify:

- the characteristics concerned;
- the temperature;
- the criteria.

**Table 2 — Component characteristics**

Characteristic	Characteristic definition	Inspection and test method
<b>Resistance to environmental conditions</b>		
Low temperature	<a href="#">7.2.2</a>	<a href="#">8.2.2</a>
High temperature	<a href="#">7.2.3</a>	<a href="#">8.2.3</a>
Ozone	<a href="#">7.2.4</a>	<a href="#">8.2.4</a>
Oil and petroleum products	<a href="#">7.2.5</a>	<a href="#">8.2.5</a>
Chemical products	<a href="#">7.2.6</a>	<a href="#">8.2.6</a>
Abrasion	<a href="#">7.2.7</a>	<a href="#">8.2.7</a>
Fire behaviour	<a href="#">7.2.8</a>	<a href="#">8.2.8</a>
Corrosion	<a href="#">7.2.9</a>	<a href="#">8.2.9</a>
Other conditions	<a href="#">7.2.10</a>	<a href="#">8.2.10</a>

Table 2 (continued)

Characteristic	Characteristic definition	Inspection and test method
<b>Resistance to operating conditions</b>		
Fatigue resistance	<a href="#">7.3.1</a>	<a href="#">8.3.1</a>
Static creep	<a href="#">7.3.2</a>	<a href="#">8.3.2</a>
Dynamic creep	<a href="#">7.3.3</a>	<a href="#">8.3.3</a>
Static relaxation	<a href="#">7.3.4</a>	<a href="#">8.3.4</a>
Dynamic relaxation	<a href="#">7.3.5</a>	<a href="#">8.3.5</a>
Electrical resistance	<a href="#">7.3.6</a>	<a href="#">8.3.6</a>
Other conditions	<a href="#">7.3.7</a>	<a href="#">8.3.7</a>
<b>Physical characteristics</b>		
Materials	<a href="#">7.4.1</a>	<a href="#">8.4.1</a>
Mass	<a href="#">7.4.2</a>	<a href="#">8.4.2</a>
<b>Geometrical and dimensional characteristics</b>		
Space envelope	<a href="#">7.5.1</a>	<a href="#">8.5.1</a>
Dimensions	<a href="#">7.5.2</a>	<a href="#">8.5.2</a>

Table 3 — Component characteristics

Functional characteristic	Characteristic definition	Inspection and test method
<b>Characteristics "force as a function of displacement" at constant velocity</b>		
In a new condition	<a href="#">7.6.3.2</a>	<a href="#">8.6.3.2</a>
After test	<a href="#">7.6.3.3</a>	<a href="#">8.6.3.3</a>
<b>Stiffnesses under sinusoidal motion</b>		
In new condition	<a href="#">7.6.4.2</a>	<a href="#">8.6.4.2</a>
After test	<a href="#">7.6.4.3</a>	<a href="#">8.6.4.3</a>
<b>Damping</b>		
In new condition	<a href="#">7.6.5.2</a>	<a href="#">8.6.5.2</a>
After test	<a href="#">7.6.5.3</a>	<a href="#">8.6.5.3</a>
<b>Other characteristics</b>		
Dimensions under load	<a href="#">7.6.1</a>	<a href="#">8.6.1</a>
Force under deformation	<a href="#">7.6.2</a>	<a href="#">8.6.2</a>
Bonding test	<a href="#">7.6.6</a>	<a href="#">8.6.6</a>

## 7.2 Resistance to environmental conditions

### 7.2.1 General

Some characteristics are defined on test pieces (see [8.2.1](#)). Results obtained on test pieces can differ from the actual performances of the component. This shall be taken into account when defining these characteristics.

### 7.2.2 Low temperature

Where the characteristic is selected, the component shall be able to withstand low temperature.

The extreme temperature  $T_{e,\min}$  shall be defined in the technical specification. If no value is specified,  $T_{e,\min}$  shall be taken as equal to  $-25\text{ °C}$ .

When the component operates at extreme temperature  $T_{e,\min}$ , criteria may be specified for concerned characteristics. If required, the technical specification shall specify:

- the characteristics concerned, for example: impact resistance;
- the criteria.

### 7.2.3 High temperature

Where the characteristic is selected, the component shall be able to withstand high temperature.

The extreme temperature  $T_{e,\max}$  shall be defined in the technical specification. If no value is specified,  $T_{e,\max}$  shall be taken as equal to  $+70\text{ °C}$ .

Criteria may be specified for the following characteristics:

- when the component operates at an extreme temperature,  $T_{e,\max}$ ;
- after heat ageing.

The test methods are defined in [8.2.3](#).

If required, the technical specification shall specify:

- the characteristics concerned;
- the criteria.

Requirements on the characteristic "force as a function of displacement" of the component, after temperature exposure or heat ageing, are defined in [7.6.3.3](#) and [7.6.4.3](#).

### 7.2.4 Ozone

In general, the ozone action on the products defined by this document does not generate significant damage which adversely affects the function of the product (small surfaces of elastomer exposed, elastomer compressed).

If severe exposure is expected to be a problem, then the technical specification shall specify requirements regarding the effect of ozone on the component. It shall also define the criteria and corresponding test method (see [8.2.4](#)).

### 7.2.5 Oil and petroleum products

Where the characteristic is selected, the component shall not be damaged by occasional oil sprays.

If severe exposure is expected to be a problem, then the technical specification shall specify the permissible variation of the characteristics after the test defined in [8.2.5](#), in relation to those measured on the component in a new condition.

In this case, the technical specification shall specify:

- the characteristics concerned;
- the criteria.

### 7.2.6 Chemical products

Where the characteristic is selected, the component shall not be damaged by occasional chemical products sprays.

If severe exposure is expected to be a problem, then the technical specification shall specify the permissible variation of the characteristics after the test defined in [8.2.6](#), in relation to those measured on the component in a new condition.

In this case, the technical specification shall specify:

- the concerned characteristics;
- the criteria.

### 7.2.7 Abrasion

Where the characteristic is selected, the technical specification shall define:

- the surfaces which shall be able to withstand abrasion;
- the criteria corresponding to the test method defined in [8.2.7](#).

Recommended acceptance criteria are given in [Table C.1](#).

### 7.2.8 Fire behaviour

Where the characteristic is selected, the requirements regarding the effect of fire on the component shall be stated (see [8.2.8](#)).

If required, the relevant standards and requirements shall be given in the technical specification.

### 7.2.9 Corrosion

Where the characteristic is selected, the non-elastomeric parts shall be protected against corrosion.

The technical specification shall specify the kind of protection and the corresponding surfaces to protect.

There are two kinds of corrosion protection system:

- a) Temporary protection: The specified surfaces shall be protected against corrosion prior to installation of the component on the vehicle, as a minimum.
- b) Permanent protection: The specified surfaces shall be protected against corrosion during a specified period of service of the component.

Unless otherwise specified, the characteristics of the protection system are those given by the salt spray test, defined in [8.2.9](#).

The criteria corresponding to this test method shall be specified in the technical specification.

Recommended acceptance criteria are given in [Table C.1](#).

The chosen protection systems shall be defined on the definition drawing of the component.

### 7.2.10 Other conditions

Any other environmental conditions of the component may be specified in the technical specification.

## 7.3 Resistance to operating conditions

### 7.3.1 Fatigue resistance

The component shall be able to withstand loading conditions to which it is subject when operating.

Where the characteristic is selected, the fatigue resistance of the component can be evaluated by a fatigue test simulating the movements and the forces encountered in service.

The test programme (see [8.3.1](#)) and the acceptance criteria shall be completely defined in the technical specification.

NOTE The properties and appearances of tested parts are not identical to the state at the beginning of test.

### 7.3.2 Static creep

Where the characteristic is selected, the technical specification shall specify:

- the value of the admissible static creep during a specific time (expressed in metre per decade or percentage per decade);
- the value of the force  $F_C$ .

The static creep is determined according to [8.3.2](#).

### 7.3.3 Dynamic creep

Where the characteristic is selected, the technical specification shall specify the permissible dynamic creep of the component and the conditions in which the dynamic creep is determined, according to [8.3.3](#).

### 7.3.4 Static relaxation

Where the characteristic is selected, the technical specification shall specify the permissible static relaxation of the component and the conditions in which the static relaxation is determined, according to [8.3.4](#).

### 7.3.5 Dynamic relaxation

Where the characteristic is selected, the technical specification shall specify the permissible dynamic relaxation of the component and the conditions in which the dynamic relaxation is determined, according to [8.3.5](#).

### 7.3.6 Electrical resistance

Where the characteristic is selected, the technical specification shall specify the permissible electrical resistance of the component and the conditions in which the electrical resistance is determined, according to [8.3.6](#).

### 7.3.7 Other conditions

The customer may specify any other operating conditions of the component in the technical specification.

## 7.4 Physical characteristics

### 7.4.1 Materials

Materials used for elastomers and other elements shall be defined.

### 7.4.2 Mass

Criteria on the mass of the component may be specified in the technical specification.

## 7.5 Geometrical and dimensional characteristics

### 7.5.1 Space envelope

Where the characteristic is selected, the space envelope available for the component as well as the interfaces shall be defined for given functioning conditions.

The overall dimensions of the component shall always remain within the specified space envelope.

### 7.5.2 Dimensions

The overall dimensions of the component in a free state (component not fitted and not submitted to an external stress) shall be defined in the technical specification if required.

## 7.6 Functional characteristics

### 7.6.1 Dimensions under load

Where the characteristic is selected, the technical specification shall define:

- the magnitude and the direction of the reference force,  $F_L$ ;
- the dimensions of the component under  $F_L$ , with its tolerances;
- the method of measurement (see [8.6.1](#)).

### 7.6.2 Force under deformation

This is the force given by the component deformed to the reference dimension  $L_D$ .

Where the characteristic is selected, the technical specification shall define:

- the reference dimension,  $L_D$ ;
- the force given by the component deformed to the dimension  $L_D$ , with its tolerances;
- the method of measurement (see [8.6.2](#)).

### 7.6.3 Characteristic "force as a function of displacement" at constant velocity

#### 7.6.3.1 Definition

##### 7.6.3.1.1 Conditions

Typically, the characteristic "force as a function of displacement" at constant velocity can be defined in terms of displacements corresponding to either:

- uniaxial cycles; or
- multiaxial cycles, one of the forces remaining constant both in magnitude and direction.

##### 7.6.3.1.2 Data limits

For any characteristic "force as a function of displacement" at constant velocity specified in the technical specification, the definition limits of this characteristic shall be defined.

These limits are:

- $F_0$  and  $F_M$  when data are forces;

- $M_0$  and  $M_M$  when data are moments;
- $d_0$  and  $d_M$  when data are linear displacements;
- $\theta_0$  and  $\theta_M$  when data are angular displacements.

**7.6.3.1.3 Methods of definition**

The characteristic "force as a function of displacement" at constant velocity can be defined in the technical specification according to one of the following methods:

NOTE The characteristic "force as a function of displacement" at constant velocity can be defined in the technical specification without criteria (indicative values). In this case, only the data limits are defined.

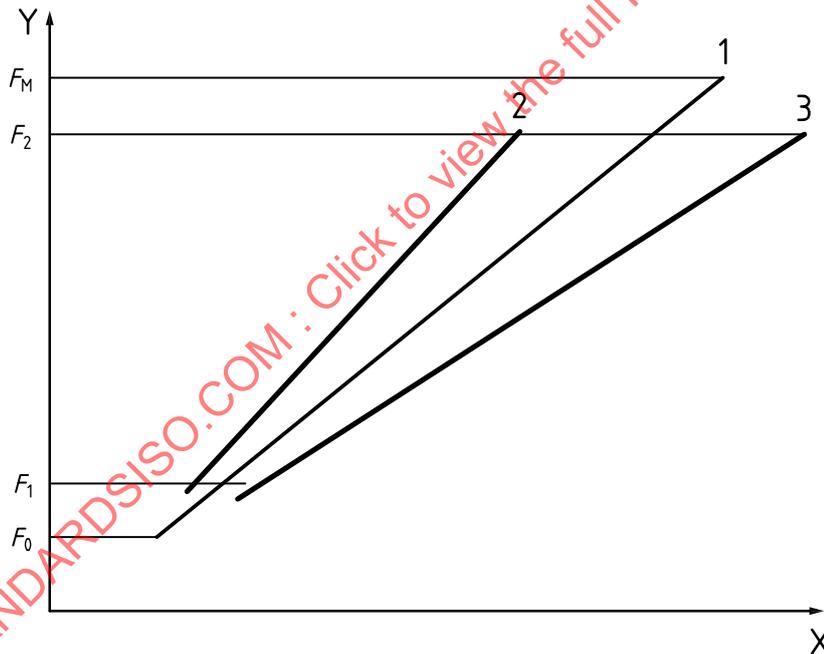
a) Force (or moment) as a function of displacement curves.

Figures 6 and 7 illustrate an example of a "force as a function of linear displacement" curve.

If required, tolerances shall be defined between the two data limits either by:

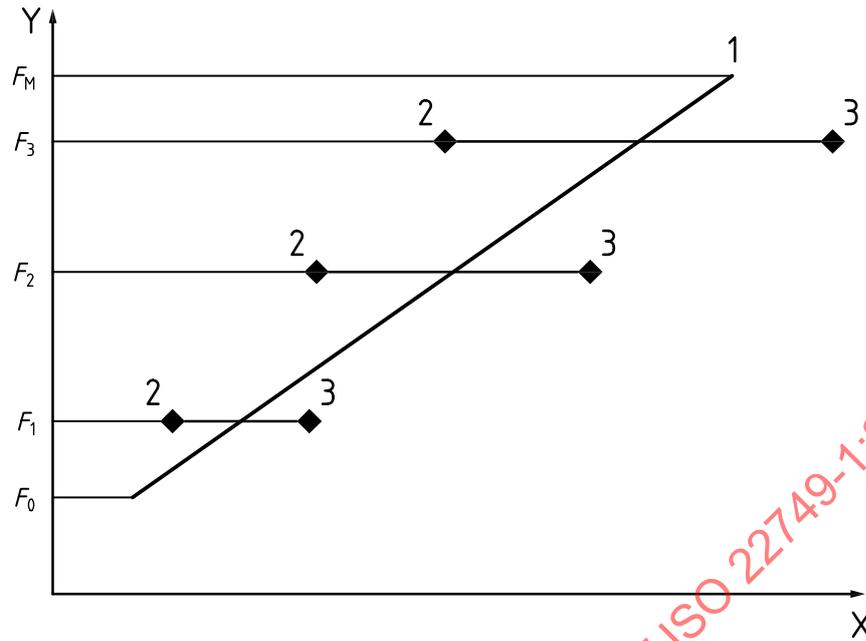
- envelope curves (see Figure 6); or
- target values established for discrete data (see Figure 7).

Recommended tolerances are given in Table C.4.



- Key**
- X displacement,  $d$
  - Y force,  $F$
  - 1 theoretical curve
  - 2 maximum
  - 3 minimum

**Figure 6 — Envelope curves (example)**

**Key**

- X displacement,  $d$
- Y force,  $F$
- 1 theoretical curve
- 2 maximum
- 3 minimum

**Figure 7 — Target values (example)**

- b) Ratio of change of force (or moment) to the corresponding change of displacement.

[Figure 8](#) illustrates an example for the calculation of the stiffness of the "force as a function of linear displacement" curve.

The technical specification shall specify:

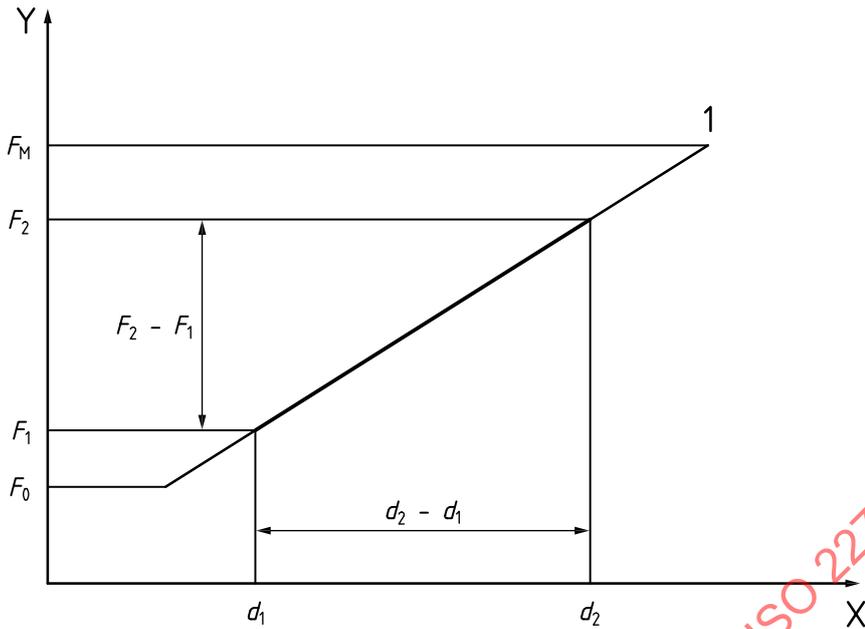
- the data  $(F_1, F_2)$  and  $(d_1, d_2)$ , or  $(M_1, M_2)$  and  $(\theta_1, \theta_2)$ ;
- the tolerances, if required.

Recommended tolerances are given in [Table C.4](#).

The characteristic "force as a function of displacement" at constant velocity is determined using [Formulae \(1\)](#) and [\(2\)](#):

$$k_s = (F_2 - F_1) / (d_2 - d_1) \text{ where } F_0 < F_1 < F_2 < F_M \quad (1)$$

$$k_{\theta_s} = (M_2 - M_1) / (\theta_2 - \theta_1) \text{ where } M_0 < M_1 < M_2 < M_M \quad (2)$$



**Key**

- X displacement,  $d$
- Y force,  $F$  (data)
- 1 theoretical curve

**Figure 8 — Change of force as a function of change of displacement (example)**

**7.6.3.2 Characteristic "force as a function of displacement" at constant velocity in a new condition**

Where the characteristic is selected, the characteristic "force as a function of displacement" at constant velocity shall be defined in the technical specification, according to [7.6.3.1](#).

**7.6.3.3 Characteristic "force as a function of displacement" at constant velocity after test**

Where the characteristic is selected, the characteristic "force as a function of displacement" at constant velocity after test (for example, static creep, dynamic creep, dynamic relaxation, heat ageing), shall be defined in the technical specification according to [7.6.3.1](#).

The permissible variation of the characteristic "force as a function of displacement" at constant velocity after the specified test, in relation to those measured on the component in a new condition, may be defined in the technical specification.

Recommended permissible variations are given in [Table C.2](#).

**7.6.4 Stiffnesses under sinusoidal motion**

**7.6.4.1 Definition**

**7.6.4.1.1 General**

There are three principal definition methods:

- characteristic "stiffness under sinusoidal motion ( $k_{dyn}$ ) as a function of amplitude of the displacement (linear or angular)";

- characteristic "stiffness under sinusoidal motion ( $k_{\text{dyn}}$ ) as a function of amplitude of the force (or the moment)";
- characteristic "stiffness under sinusoidal motion ( $k_{\text{dyn}}$ ) as a function of frequency".

Stiffnesses under sinusoidal motion may be defined in the technical specification without criteria (indicative values).

In that case, only the data limits shall be defined.

If required, tolerances shall be defined either:

- by envelope curves (see example on [Figure 6](#)); or
- by target values established for discrete data (see example on [Figure 7](#)).

Recommended tolerances are given in [Table C.4](#). It is recommended that these characteristics be defined for frequencies above 0,1 Hz. Definition of the static characteristics at the same amplitude is also recommended.

#### **7.6.4.1.2 Stiffnesses under sinusoidal motion ( $k_{\text{dyn}}$ ) as a function of amplitude of the displacement**

Each characteristic "stiffness under sinusoidal motion ( $k_{\text{dyn}}$ ) as a function of amplitude of the displacement" is defined for a specific frequency.

If the characteristic is defined by a curve, then the range of amplitudes of the displacement shall be specified in the technical specification together with the value of the frequency.

If the characteristic is defined at particular amplitudes of the displacement, then the value of these amplitudes shall be specified in the technical specification together with the value of the frequency.

#### **7.6.4.1.3 Stiffnesses under sinusoidal motion ( $k_{\text{dyn}}$ ) as a function of amplitude of the force (or moment)**

Each characteristic "stiffness under sinusoidal motion ( $k_{\text{dyn}}$ ) as a function of amplitude of the force (or moment)" is defined for a specific frequency.

If the characteristic is defined by a curve, then the range of amplitudes of the force (or moment) shall be specified in the technical specification together with the value of the frequency.

If the characteristic is defined at particular amplitudes of the force (or moment), then the value of these amplitudes shall be specified in the technical specification together with the value of the frequency.

#### **7.6.4.1.4 Stiffnesses under sinusoidal motion ( $k_{\text{dyn}}$ ) as a function of frequency**

Each characteristic "stiffness under sinusoidal motion ( $k_{\text{dyn}}$ ) as a function of frequency" is defined for a specific amplitude of displacement or force (or moment).

If the characteristic is defined by a curve, then the range of frequency shall be specified in the technical specification together with the value of the amplitude of the displacement or force (or moment).

If the characteristic is defined at a particular frequency, then the value of this frequency shall be specified in the technical specification together with the value of the amplitude of the displacement or force (moment).

#### **7.6.4.2 Stiffnesses under sinusoidal motion in new condition**

Where the characteristic is selected, stiffnesses under sinusoidal motion shall be defined in the technical specification, according to the requirements of [7.6.4.1](#).

### 7.6.4.3 Stiffnesses under sinusoidal motion after test

Where the characteristic is selected, stiffnesses under sinusoidal motion after test (for example: static creep, dynamic creep, dynamic relaxation, heat ageing), shall be defined in the technical specification according to the requirements of [7.6.4.1](#).

The permissible variation of the stiffnesses under sinusoidal motion after the specified test, in relation to those measured on the component in a new condition, may be defined in the technical specification.

Recommended permissible variations are given in [Table C.3](#).

## 7.6.5 Damping

### 7.6.5.1 Definition

#### 7.6.5.1.1 General

The phase angle  $\delta$  is given as a value for the elastomer damping.

These characteristics should be defined for frequencies above 0,1 Hz. Other damping parameters can be specified, if required.

The damping characteristic is generally defined according to one of [7.6.5.1.2](#) to [7.6.5.1.3](#).

#### 7.6.5.1.2 Characteristic "phase angle $\delta$ (or other parameter) as a function of amplitude of the displacement"

Each characteristic "phase angle  $\delta$  (or other parameter) as a function of amplitude of the displacement" is defined for a specific frequency.

If the characteristic is defined by a curve, then the range of amplitudes of the displacement shall be specified in the technical specification together with the value of the frequency.

If the characteristic is defined at particular amplitudes of the displacement, then the value of these amplitudes shall be specified in the technical specification together with the value of the frequency.

#### 7.6.5.1.3 Characteristic "phase angle $\delta$ (or other parameter) as a function of amplitude of the force (or the moment)"

Each characteristic "phase angle  $\delta$  (or other parameter) as a function of amplitude of the force (or moment)" is defined for a specific frequency.

If the characteristic is defined by a curve, then the range of amplitudes of the force (or moment) shall be specified in the technical specification together with the value of the frequency.

If the characteristic is defined at particular amplitudes of the force (or moment), then the value of these amplitudes shall be specified in the technical specification together with the value of the frequency.

#### 7.6.5.1.4 Characteristic "phase angle $\delta$ (or other parameter) as a function of frequency"

Each characteristic "phase angle  $\delta$  (or other parameter) as a function of frequency" is defined for a specific amplitude of the displacement or force.

If the characteristic is defined by a curve, then the range of frequencies shall be specified in the technical specification together with the value of the amplitude of the displacement or force.

If the characteristic is defined at particular frequencies, then the value of these frequencies shall be specified in the technical specification together with the value of the amplitude of the displacement or force.

### 7.6.5.2 Damping in new condition

Where the characteristic is selected, damping characteristics shall be defined in the technical specification, according to the requirements of [7.6.5.1](#).

### 7.6.5.3 Damping after test

Where the characteristic is selected, damping characteristics after test (for example static creep, dynamic creep, dynamic relaxation, heat ageing) shall be defined in the technical specification, according to the requirements of [7.6.5.1](#).

The permissible variation of the damping characteristics after the specified test, in relation to those measured on the component in a new condition, may be defined in the technical specification.

### 7.6.6 Bonding test

Where the characteristic is selected, the component shall show the requested bonding quality.

## 8 Inspection and test methods

### 8.1 General

#### 8.1.1 General test conditions

##### 8.1.1.1 General

The test methods and extent of the tests shall be defined in the technical specification and shall be documented following completion. Any deviations from the tests which have been defined in the technical specification shall only be made with the agreement of all the involved parties.

##### 8.1.1.2 Temperature

The measurements and the tests shall be carried out at the temperatures specified in the technical specification of the component.

Tests may be required at particular temperatures according to [8.2.2](#) and [8.2.3](#).

Unless otherwise specified, tests shall be carried out with an ambient temperature of  $(23 \pm 2) ^\circ\text{C}$ , in accordance with ISO 23529.

The applicable tolerance on a particular temperature is  $\pm 2 ^\circ\text{C}$ .

For any tests, the temperature shall be recorded and given with the measurement results.

##### 8.1.1.3 Force, displacement, velocity and frequency

Tests shall be performed within the specified parameter tolerances and actual values declared.

Uncertainties of measure shall be determined.

The relationship between the accuracy of the test equipment in use and the specified tolerance (on a test parameter or result) shall be agreed between the customer and the supplier.

Unless otherwise specified, the applicable tolerances are:

- time:  $\pm 10\%$  of the value;
- velocity:  $\pm 10\%$  of the value;

- frequency:  $\pm 10$  % of the value;
- force:  $\pm 1$  % of the maximum value applied for the measurements;
- moment:  $\pm 2$  % of the maximum value applied for the measurements;
- displacement:  $\pm 2$  % of the maximum value applied for the measurements.

The accuracy of the test equipment is defined in the ISO 7500 series.

### 8.1.2 Instrumentation

When the mounting conditions have an influence on the characteristics of the component, tests shall be carried out on a component fastened in a device reproducing its assembly on the mechanical system for which it is designed.

The test device shall be defined in the technical specification, according to the instructions given in [Annex A](#).

Details of the test devices and measuring systems shall be submitted to the customer for approval.

### 8.1.3 Definition and preparation of test pieces

For all tests, unless otherwise specified, the test piece shall be the complete component.

The piece shall be kept at ambient temperature for at least 72 h before starting tests and taking measurements.

NOTE 1 Depending on the size of the test piece, less time than 72 h can be defined in the technical agreement of all involved parties.

The piece shall be left in a location at the specified test temperature for at least 24 h before the tests.

NOTE 2 Depending on the size of the test piece, less time than 24 h can be defined in the technical agreement of all involved parties.

## 8.2 Resistance to environmental conditions

### 8.2.1 General

Moulded test pieces may be used for the characteristics defined in [8.2.4](#), [8.2.5](#), [8.2.6](#) and [8.2.7](#). The test pieces shall be representative of the surface exposed to the environmental conditions described.

### 8.2.2 Low temperature

The test method shall be agreed between the customer and the supplier and defined in the technical specification of the component.

### 8.2.3 High temperature

#### 8.2.3.1 Heat ageing

The component shall be submitted to heat ageing for 14 days at the specified temperature  $T_{e,max}$  in accordance with the requirements of the ISO 188.

After this treatment, the component shall be left for 24 h at the ambient temperature.

Then, the characteristics designed in the technical specification shall be measured according to the test methods defined in this document.

### 8.2.3.2 Other tests

Any other test method not mentioned [8.2.3.1](#) shall be requested and defined in the technical specification of the component.

### 8.2.4 Ozone

Ozone resistance shall be tested in accordance with ISO 1431-1.

The test method shall be agreed upon and defined in the technical specification of the component.

### 8.2.5 Oil and petroleum products

Oil and petroleum product resistance shall be tested in accordance with ISO 1817.

The test method shall be agreed upon and defined in the technical specification of the component.

### 8.2.6 Chemical products

Chemical product resistance shall be tested in accordance with ISO 1817.

The test method shall be agreed upon and defined in the technical specification of the component.

### 8.2.7 Abrasion

Abrasion resistance shall be tested in accordance with Method A of ISO 4649.

The relative density of the elastomer shall be measured in accordance with ISO 2781.

### 8.2.8 Fire behaviour

Test methods shall be agreed and defined in the technical specification of the component.

### 8.2.9 Corrosion

Corrosion resistance shall be tested in accordance with ISO 9227.

The position of the test piece in the test machine shall be coherent with the location of exposed surfaces in services.

### 8.2.10 Other conditions

Test methods shall be agreed and defined in the technical specification of the component.

## 8.3 Resistance to operating conditions

### 8.3.1 Fatigue resistance

#### 8.3.1.1 Test machine

The test machine shall be designed to reproduce the critical forces and movements to which the component is submitted when operating.

#### 8.3.1.2 Test procedure

The fatigue test shall consist of repeating specified sequences of forces and movements, such as those indicated as examples in [Annex B](#).

The test procedure shall be defined in the technical specification.

### 8.3.1.3 Test procedure validation

When it is possible, the test shall be validated by applying it to a component that has the same or a similar function, and which has a known operating performance.

### 8.3.1.4 Inspections

Before and after the test:

- the component shall be subject to a visual inspection;
- the specified characteristics shall be checked.

## 8.3.2 Static creep

### 8.3.2.1 General

The technical specification shall specify:

- the magnitude and the direction of the static force,  $F_c$ ;
- the dimension to measure;
- the ambient temperature, if specified (see [8.1.1](#)).

Before the test, the component shall be subjected to a static force,  $F_c$ , at the specified ambient temperature, and the dimension of the component shall be measured.

Then, the component shall be subjected to the static force,  $F_c$ , maintained constant, and the variation of the selected dimension shall be recorded, without releasing the force,  $F_c$ , as a function of the time.

During the test, the variation of the ambient temperature shall be recorded.

### 8.3.2.2 Determination of the creep rate

The static force shall be applied from 0 to  $F_c$  within the first 30 s of the test.

The selected dimension shall be measured at times (including the loading time):

- $t_0$  1 min
- $t_2$  100 min

This results in [Formula \(3\)](#):

$$t_2 - t_0 = 99 \text{ min} \quad (3)$$

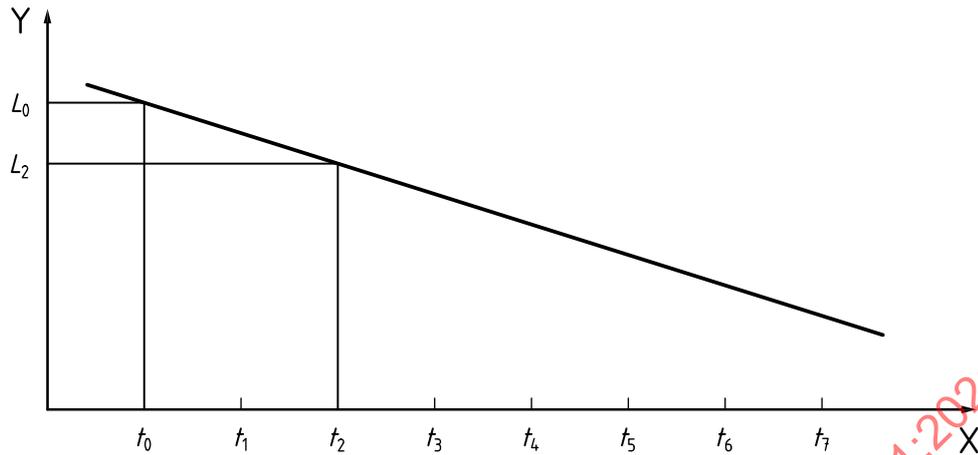
Time  $(t_2 - t_0)$  shall be divided into the two logarithmic decades of 9 min and 90 min.

The creep rate,  $R_c$ , (expressed in m/decade) shall be calculated with [Formula \(4\)](#):

$$R_c = (L_0 - L_2) / 2 \quad (4)$$

The ambient temperature between  $t_0$  and  $t_2$  shall not vary by more than 2 °C.

[Figure 9](#) shows the static creep in function of the logarithm of time.

**Key**

X time

Y dimension

 $t_0$  1 min $t_1$  10 min $t_2$  1 h 40 min $t_3$  16 h 40 min $t_4$  6 days and 22 h 40 min $t_5$  69 days and 10 h 40 min $t_6$  694 days and 10 h 40 min (approx. 2 years) $t_7$  6 944 days and 10 h 40 min (approx. 19 years)**Figure 9 — Static creep in function of the logarithm of time**

The value of the static creep shall be calculated at the time specified in the technical specification.

The linear creep extrapolation shown above is unlikely to be able to capture the full creep property of test pieces. In such cases the value of static creep cannot be extrapolated after a short time period. Testing over an increased time period may be required. The creep calculation over the design life shall consider all test measurements.

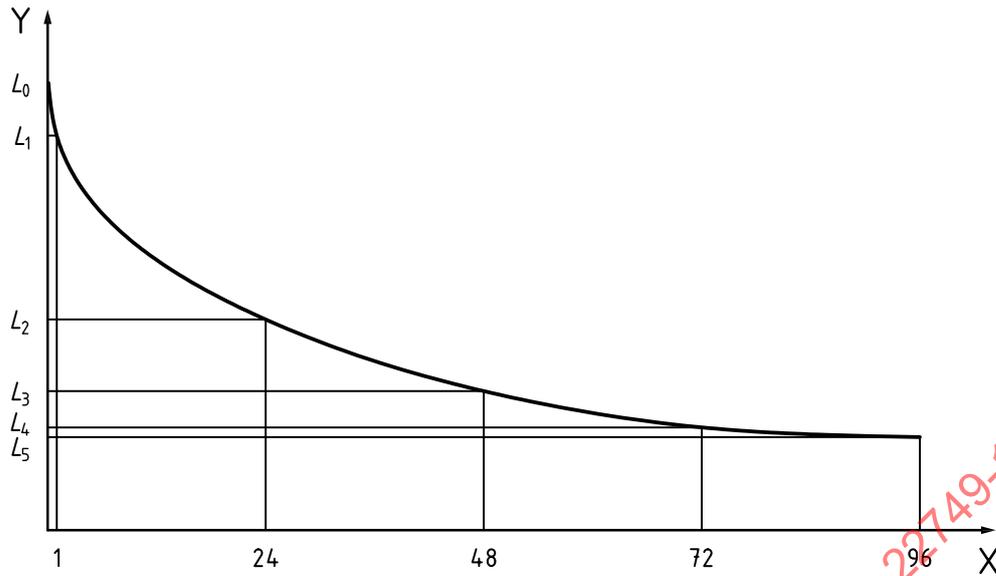
NOTE Other methods can also be proposed to extrapolate creep of the design life.

**8.3.2.3 Stabilization test**

The test defined in [8.3.2.2](#) shall be continued until the stabilization of the component.

The component is deemed stabilized when the change of length over 24 h is less than 10 % of the change of length between  $t = 1$  h and  $t = 24$  h.

[Figure 10](#) gives an example of a component stabilized after a test duration of 96 h.



**Key**

X time (h)  
 Y dimension

NOTE  $L_4 - L_5 < 0,1 \times (L_1 - L_2)$

**Figure 10 — Stabilization test (example)**

The characteristics of the component, specified in the technical specification, shall be measured just after this test.

The force,  $F_c$ , shall not be released between the stabilization test and the measurements. If not possible to make the test in the same machine, the proposed test procedure shall be subject to the agreement.

**8.3.3 Dynamic creep**

Before the test, the component shall be stabilized under a static force,  $F_c$ , at a specific ambient temperature, and the dimension of the component shall be measured.

The test procedure and requirements for testing dynamic creep shall be defined in the technical specification.

**8.3.4 Static relaxation**

The component shall be deflected at a constant dimension,  $L_R$ , at a specific ambient temperature, and the force given by the component shall be measured.

The technical specification shall specify:

- the dimension  $L_R$ ;
- the time from 0 to  $L_R$ ;
- the ambient temperature, if it is a particular temperature (see 8.1.1).

Then, the variation of the force given by the component, deflected at a constant dimension,  $L_R$ , shall be recorded as a function of the time. Recording shall start  $(10 \pm 2)$  s after reaching  $L_R$ .

When the component is stabilized, the test shall be stopped.

The component is deemed stabilized when the change of force over 24 h is less than 10 % of the change of force between  $t$  equal to 1 h and  $t$  equal to 24 h.

The value of the static relaxation is the difference between the start of force recording and at the end of the test.

### 8.3.5 Dynamic relaxation

The component shall be deflected at a constant dimension,  $L_R$ , at a specific ambient temperature, and the force given by the component shall be measured.

The test procedure and requirements for testing dynamic relaxation shall be defined in the technical specification.

### 8.3.6 Electrical resistance

Tests methods shall be agreed upon and defined in the technical specification of the component.

### 8.3.7 Other conditions

Tests methods shall be agreed upon and defined in the technical specification of the component.

## 8.4 Physical characteristics

### 8.4.1 Materials

Measurements of the material characteristics shall be carried out by the appropriate test relevant to the kind of material.

Test methods shall be agreed in the technical specification.

### 8.4.2 Mass

The mass shall be measured using test instruments adapted to the precision level required.

## 8.5 Geometrical and dimensional characteristics

### 8.5.1 Space envelope

The geometrical and dimensional characteristics shall be measured using test instruments adapted to the size of the component and to the precision level required.

### 8.5.2 Dimensions

The geometrical and dimensional characteristics shall be measured using test instruments adapted to the size of the component and to the precision level required.

## 8.6 Functional characteristics

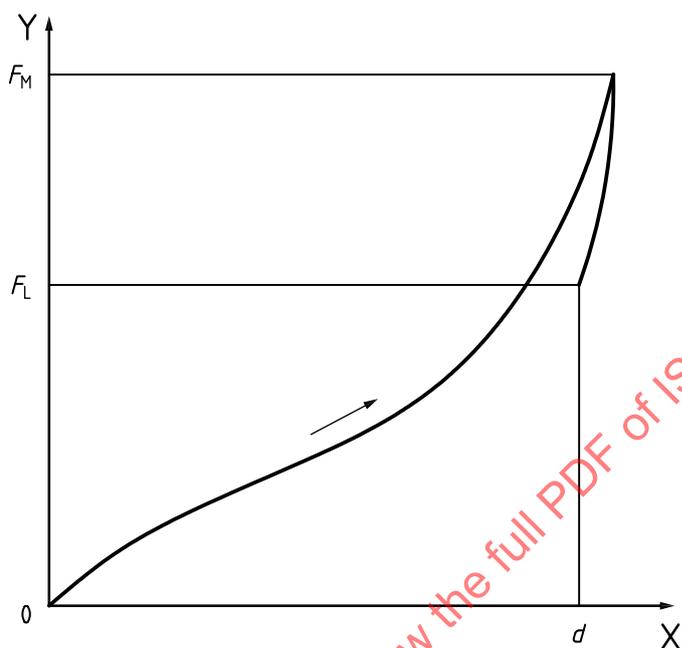
### 8.6.1 Dimensions under load

The dimensions of the component, under a specific load, shall be measured according to one of the following methods A - B, illustrated in [Figures 11](#) and [12](#) respectively.

Four cycles shall be applied successively at a constant velocity between 0 and  $F_M$ .

a) **Method A**

During the load-decreasing phase of the fourth cycle, the component shall be held under a constant force,  $F_L$ .



**Key**

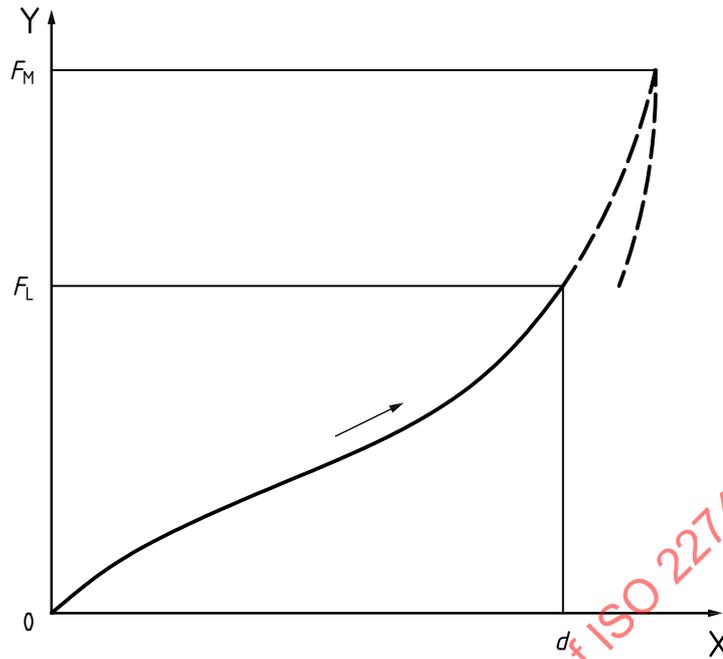
X displacement

Y force

**Figure 11 — Dimensions under load (method A)**

b) **Method B**

During the load-increasing phase of the fourth cycle, the component shall be held under a constant force,  $F_L$ .

**Key**

- X displacement  
Y force

**Figure 12 — Dimensions under load (method B)**

The dimensions of the component, which are specified in the technical specification, shall be recorded after a stabilization period of  $(10 \pm 2)$  s.

The technical specification shall define:

- the method to be used;
- the forces  $F_M$  and  $F_L$ , with  $F_M > F_L$ ;
- the velocity to be used.

The dimensions can be determined on a fourth cycle executed just after those carried out for the measurement of the characteristic "force as a function of displacement" at constant velocity (see 8.6.3). In this case, the velocity used for the fourth cycle need not be the same as that used for the first three.

### 8.6.2 Force under deformation

The force given by the component when it is deformed to a reference dimension shall be measured according to one of the following methods.

Four cycles of displacement shall be applied successively at a constant velocity between  $L_0$  and  $L_M$ .

- a) Method A: During the displacement decreasing phase of the fourth cycle, the component shall be held at a constant dimension  $L_D$ .
- b) Method B: During the displacement increasing phase of the fourth cycle, the component shall be held at a constant dimension  $L_D$ .

The force given by the component shall be recorded after a stabilization period of  $(10 \pm 2)$  s.

The technical specification shall define:

- the method to be used;
- the dimensions  $L_0$ ,  $L_D$  and  $L_M$ ;
- the velocity to be used.

The force under deformation can be determined on a fourth cycle executed just after those carried out for the measurement of the characteristic "force as a function of displacement" at constant velocity (see [8.6.3](#)). In this case, the velocity used for the fourth cycle does not need to be the same as that used for the first three.

### 8.6.3 Characteristics "force as a function of displacement" at constant velocity

#### 8.6.3.1 Measurements

##### 8.6.3.1.1 Method

According to the selected method for the definition of the characteristic (see [7.6.3.1.3](#)), measurements shall be carried out by applying either:

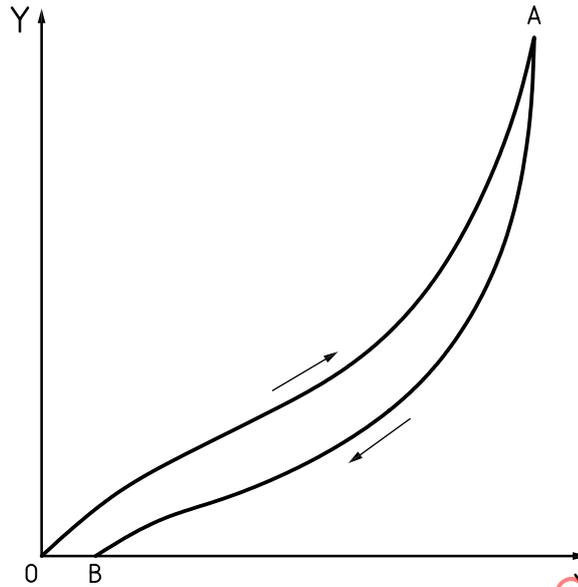
- a force (or a moment) and recording the corresponding displacement (linear or angular); or
- a displacement (linear or angular) and recording the corresponding force (or a moment).

For each configuration, three cycles shall be carried out successively at a constant velocity of displacement, without interruption. The third cycle shall be recorded.

NOTE The recorded cycle is a hysteresis loop, see [Figure 13](#) and [14](#).

##### 8.6.3.1.2 Determination of the characteristic "force as a function of displacement" at constant velocity on a non-alternating cycle

The characteristic shall be determined on the part of the recording corresponding to the increasing force (curve OA on the [Figure 13](#)).

**Key**

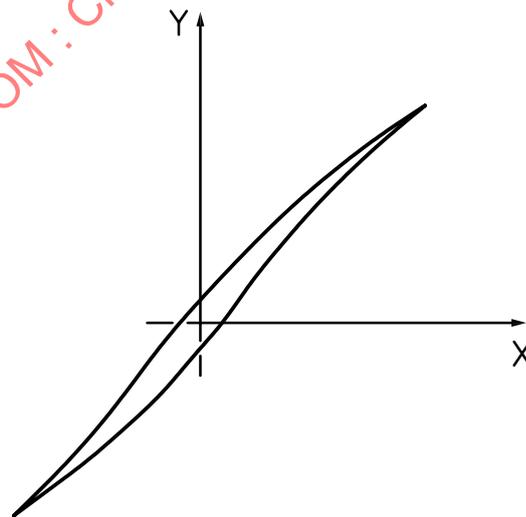
X displacement

Y force

**Figure 13 — Diagram force as a function of displacement (example of a non-alternating cycle)**

### 8.6.3.1.3 Determination of the characteristic "force as a function of displacement" at constant velocity on an alternating cycle

The method of the measurement and interpretation of results shall be clearly defined in the technical specification.

**Key**

X displacement

Y force

**Figure 14 — Diagram force as a function of displacement (example of an alternating cycle)**

#### 8.6.3.1.4 Velocity

The measurement velocity shall be specified in the technical specification.

Recommended velocities are given in [Annex D](#).

The velocity shall remain constant during the test.

#### 8.6.3.2 Characteristics "force as a function of displacement" at constant velocity in a new condition

Measurements shall be carried out according to the prescriptions of the technical specification of the component and of [8.6.3.1](#).

#### 8.6.3.3 Characteristics "force as a function of displacement" at constant velocity after test

Measurements shall be carried out immediately after the specified test, according to the technical specification of the component and [8.6.3.1](#).

### 8.6.4 Stiffnesses under sinusoidal motion

#### 8.6.4.1 Definition

##### 8.6.4.1.1 Stiffnesses under sinusoidal motion ( $k_{\text{dyn}}$ ) as a function of amplitude of the movement

The test consists of applying a dynamic oscillation  $d(t)$  or  $\theta(t)$  to the component at:

- the frequency specified in the technical specification;
- the various amplitudes of the movement specified in the technical specification;

and of recording the corresponding force  $F(t)$  or moment  $M(t)$ .

At every amplitude of the movement specified in the technical specification, the excitation shall be applied for at least ten cycles before recording.

Stiffnesses  $k_{\text{dyn}}$  shall be measured from the displacements that cause movements of the form:

- When the oscillation is a linear displacement, see [Formula \(5\)](#):

$$d(t) = (a \times \sin(2 \times \pi \times f \times t)) + d_p \quad (5)$$

where

$d(t)$  is instantaneous movement;

$d_p$  is mean displacement;

$a$  is amplitude of the displacement;

$f$  is frequency;

$t$  is time.

Stiffness  $k_{\text{dyn}}$  is defined as being equal to the ratio of the force variation to the displacement variation, as shown in [Formula \(6\)](#):

$$k_{\text{dyn}} = (F_{\text{max}} - F_{\text{min}}) / (2 \times a) \quad (6)$$

- When the oscillation is an angular displacement, see [Formula \(7\)](#):

$$\theta(t) = (a \times \sin(2 \times \pi \times f \times t)) + \theta_p \quad (7)$$

where

- $\theta(t)$  is instantaneous movement;
- $\theta_p$  is mean angular displacement;
- $a$  is amplitude of the angular displacement;
- $f$  is frequency;
- $t$  is time.

Stiffness  $k\theta_{\text{dyn}}$  is defined as being equal to the ratio of the moment variation to the displacement variation, as shown in [Formula \(8\)](#):

$$k\theta_{\text{dyn}} = (M_{\text{max}} - M_{\text{min}}) / (2 \times a) \quad (8)$$

#### 8.6.4.1.2 Stiffnesses under sinusoidal motion ( $k_{\text{dyn}}$ ) as a function of amplitude of the force (or moment)

The test consists of applying a dynamic oscillation  $F(t)$  or  $M(t)$  to the component at:

- the frequency specified in the technical specification;
- the various amplitudes of the force (or moment) specified in the technical specification;

and of recording the corresponding displacement  $d(t)$  or  $\theta(t)$ .

At every amplitude of the force (or moment) specified in the technical specification, the excitation shall be applied for at least ten cycles before recording.

Stiffnesses,  $k_{\text{dyn}}$ , shall be measured from the forces (or moments) that cause movements of the form:

- When the oscillation is a force, see [Formula \(9\)](#):

$$F(t) = (C \times \sin(2 \times \pi \times f \times t)) + F_p \quad (9)$$

where

- $F(t)$  is instantaneous force;
- $F_p$  is mean force;
- $C$  is amplitude of the force;
- $f$  is frequency;
- $t$  is time.

Stiffness,  $k_{\text{dyn}}$ , is defined as being equal to the ratio of the force variation to the displacement variation, [Formula \(10\)](#):

$$k_{\text{dyn}} = (2 \times C) / (d_{\text{max}} - d_{\text{min}}) \quad (10)$$

— When the oscillation is a moment, see [Formula \(11\)](#):

$$M(t) = (C \times \sin(2 \times \pi \times f \times t)) + M_p \quad (11)$$

where

$M(t)$  is instantaneous moment;

$M_p$  is mean moment;

$C$  is amplitude of the moment;

$f$  is frequency;

$t$  is time.

Stiffness,  $k_{\theta_{\text{dyn}}}$ , is defined as being equal to the ratio of the moment variation to the displacement variation, see [Formula \(12\)](#):

$$k_{\theta_{\text{dyn}}} = (2 \times C) / (\theta_{\text{max}} - \theta_{\text{min}}) \quad (12)$$

#### 8.6.4.1.3 Stiffnesses under sinusoidal motion ( $k_{\text{dyn}}$ ) as a function of frequency

The test consists of applying a dynamic oscillation  $d(t)$ ,  $\theta(t)$ ,  $F(t)$  or  $M(t)$  to the component at:

- the amplitude of the dynamic oscillation specified in the technical specification;
- the various frequencies specified in the technical specification;

and of recording the corresponding force  $F(t)$ , moment  $M(t)$ , displacement  $d(t)$ , or angular displacement  $\theta(t)$ .

At every frequency specified in the technical specification, the excitation shall be applied for at least ten cycles before recording.

According to the mode of oscillation, stiffnesses,  $k_{\text{dyn}}$ , shall be measured with the corresponding method (see [8.6.4.1.1](#) and [8.6.4.1.2](#)).

#### 8.6.4.2 Stiffnesses under sinusoidal motion in new condition

Measurements shall be carried out according to the prescriptions of the technical specification of the component and of [8.6.4.1](#).

#### 8.6.4.3 Stiffnesses under sinusoidal motion after test

Measurements shall be carried out immediately after the specified test, according to the prescriptions of the technical specification of the component and of [8.6.4.1](#).

## 8.6.5 Damping

### 8.6.5.1 Definition

#### 8.6.5.1.1 Characteristic "phase angle $\delta$ (or other parameter) as a function of amplitude of the movement"

The test consists of applying a dynamic oscillation  $d(t)$  or  $\theta(t)$  to the component at:

- the frequency specified in the technical specification;
- the various amplitudes of the movement specified in the technical specification;

and of recording together the variation of the deformation applied ( $d(t)$  or  $\theta(t)$ ) and the variation of the transmitted force  $F(t)$  or moment  $M(t)$ .

The difference in phase between the transmitted force and the deformation (phase angle,  $\delta$ ), shall be determined.

#### 8.6.5.1.2 Characteristic "phase angle $\delta$ (or other parameter) as a function of amplitude of the force (or the moment)"

The test consists of applying a dynamic oscillation  $F(t)$  or  $M(t)$  to the component at:

- the frequency specified in the technical specification;
- the various amplitudes of the force (or moment) specified in the technical specification;

and of recording together the variation of the deformation applied [ $d(t)$  or  $\theta(t)$ ] and the variation of the transmitted force  $F(t)$  or moment  $M(t)$ .

The difference in phase between the transmitted excitation and the response (phase angle,  $\delta$ ), shall be determined.

#### 8.6.5.1.3 Characteristic "phase angle $\delta$ (or other parameter) as a function of frequency"

The test consists of applying a dynamic oscillation  $d(t)$ ,  $\theta(t)$ ,  $F(t)$  or  $M(t)$  to the component at:

- the amplitude of the dynamic oscillation specified in the technical specification;
- the various frequencies specified in the technical specification;

and of recording together the variation of the deformation applied [ $d(t)$  or  $\theta(t)$ ] and the variation of the transmitted force  $F(t)$  or moment  $M(t)$ .

The difference in phase between the transmitted excitation and the response (phase angle,  $\delta$ ), shall be determined.

### 8.6.5.2 Damping in new condition

Measurements shall be carried out according to the prescriptions of the technical specification of the component and of [8.6.5.1](#).

### 8.6.5.3 Damping after test

Measurements shall be carried out immediately after the specified test, according to the technical specification of the component and of [8.6.5.1](#).

### 8.6.6 Bonding test

The test methods shall be agreed upon and defined in the technical specification of the component.

## 9 Marking

The technical specification shall specify any marking requirements, for example:

- supplier's logo;
- production plant code, if there is more than one plant;
- product reference;
- manufacturing date (month and year);
- additional indications, if required by the customer.

When it is possible, these markings shall be placed in a position where they are not likely to come into contact with surrounding parts.

If necessary, the prohibited areas for marking shall be defined in the technical specification.

The location of the markings shall be clearly identified on the part drawing.

To ensure traceability (see ISO 22749-2), these marks shall be readable throughout the working life of the component.

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