British Standard

Railway applications — Rubber suspension components — Rubber diaphragms for pneumatic suspension springs

The European Standard EN 13597:2003 has the status of a British Standard

ICS 21.160; 45.060.01

National foreword

This British Standard is the official English language version of EN 13597:2003.

The UK participation in its preparation was entrusted by Technical Committee RAE/3, Railway rolling stock material, to Subcommittee RAE/3/-/4, Suspension components, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

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Railway applications - Rubber suspension components - Rubber diaphragms for pneumatic suspension springs

Applications ferroviaires - Pièces de suspension à base d'élastomère - Membranes à base d'élastomère pour ressorts pneumatiques de suspension

Bahnanwendungen - Federungselemente aus Elastomer - Membranen aus Elastomer für pneumatische Tragfedern

This European Standard was approved by CEN on 21 November 2002.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Contents

Foreword

This document (EN 13597:2003) has been prepared by Technical Committee CEN/TC 256 "Railway applications", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2003, and conflicting national standards shall be withdrawn at the latest by August 2003.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association:

— Council Directive 96/48/EEC of 23 July 1996 on interoperability of the European high-speed train network [1)];

— Council Directive 93/38/EEC of 14 June 1993 coordinating the procurement procedures of entities operating in the water, energy, transport and telecommunications sectors [2)];

— Council Directive 91/440/EEC of 29 July 1991 on the development of the community's railways. [3)]

The annexes B and D are normative.

The annexes A and C and E are informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

[1)] Official Journal of the European Communities N° L 235 of 17.09.96

[2)] Official Journal of the European Communities N° L 199 of 09.08.93

[3)] Official Journal of the European Communities N° L 237 of 24.08.91

Introduction

Designing a suspension diaphragm requires knowledge of the mechanical system of which it forms part. Specific characteristics are therefore needed for each case, which only the customer can specify.

The requirements of the European Standard should operate in conjunction with the conditions for the supply of air spring suspension diaphragms.

This European Standard is the result of studies and research to improve the performances and quality of rubber diaphragms for pneumatic suspension springs in order to meet the requirements of railway rolling stock.

This European Standard is designed for the railway operators, the manufacturers and equipment suppliers of the railway industry as well as for the suppliers of rubber diaphragms for pneumatic suspensions springs.

1 Scope

This European Standard specifies:

- characteristics that suspension diaphragms achieves, together with applicable inspection and test methods to be carried out for verification;
- approval procedure to be implemented by the customer;
- guidelines for qualification of the product with specified requirements;
- quality monitoring of diaphragms in manufacture;
- supply requirements.

This European Standard applies to suspension diaphragms 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.

The European Standard does not detail the other components of pneumatic suspension assemblies or control systems such as air reservoirs, frames, stiffeners, emergency suspension systems or elastic supports (such as series springs), etc., which will affect the diaphragm performance.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 45020, *Standardization and related activities – General vocabulary (ISO/IEC Guide 2:1996).*

ISO 31-1, *Quantities and units – Part 1: Space and time.*

ISO 31-3, *Quantities and units – Part 3: Mechanics.*

ISO 36, *Rubber, vulcanized or thermoplastic – Determination of adhesion to textile fabric.*

ISO 48, *Rubber, vulcanized or thermoplastic – Determination of hardness (hardness between 10 IRHD and 100 IRHD [4])).*

ISO 471, *Rubber – Temperatures, humidities and times for conditioning and testing.*

ISO 1382, *Rubber – Vocabulary.*

ISO 1431-2, Rubber, *vulcanized or thermoplastic – Resistance to ozone cracking – Part 2: Dynamic strain test.*

ISO 1817, *Rubber, vulcanized – Determination of the effect of liquids.*

ISO 2781, *Rubber, vulcanized – Determination of density.*

[4]) IRHD : International Rubber Hardness Degrees

ISO 2921, *Rubber, vulcanized – Determination of low-temperature characteristics – Temperature – Retraction procedure (TR test).*

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

ISO 10209-1, *Technical product documentation – Vocabulary – Part 1: Terms relating to technical drawings: general and types of drawings.*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this European Standard, the terms and definitions in ISO 1382 together with the following apply.

3.1.1
bead
end feature of the diaphragm which enables it to be secured and sealed to the surrounding structure

NOTE A diaphragm has two beads.

3.1.2
bead core
reinforcing core, vulcanized in at both ends of the carcass

NOTE It assures permanent seating on a conical or other specifically shaped mounting part.

3.1.3
carcass
structure of reinforcing material, typically consisting of heavy duty fabric plies arranged crosswise, embedded in the elastomer for flexible force transmission

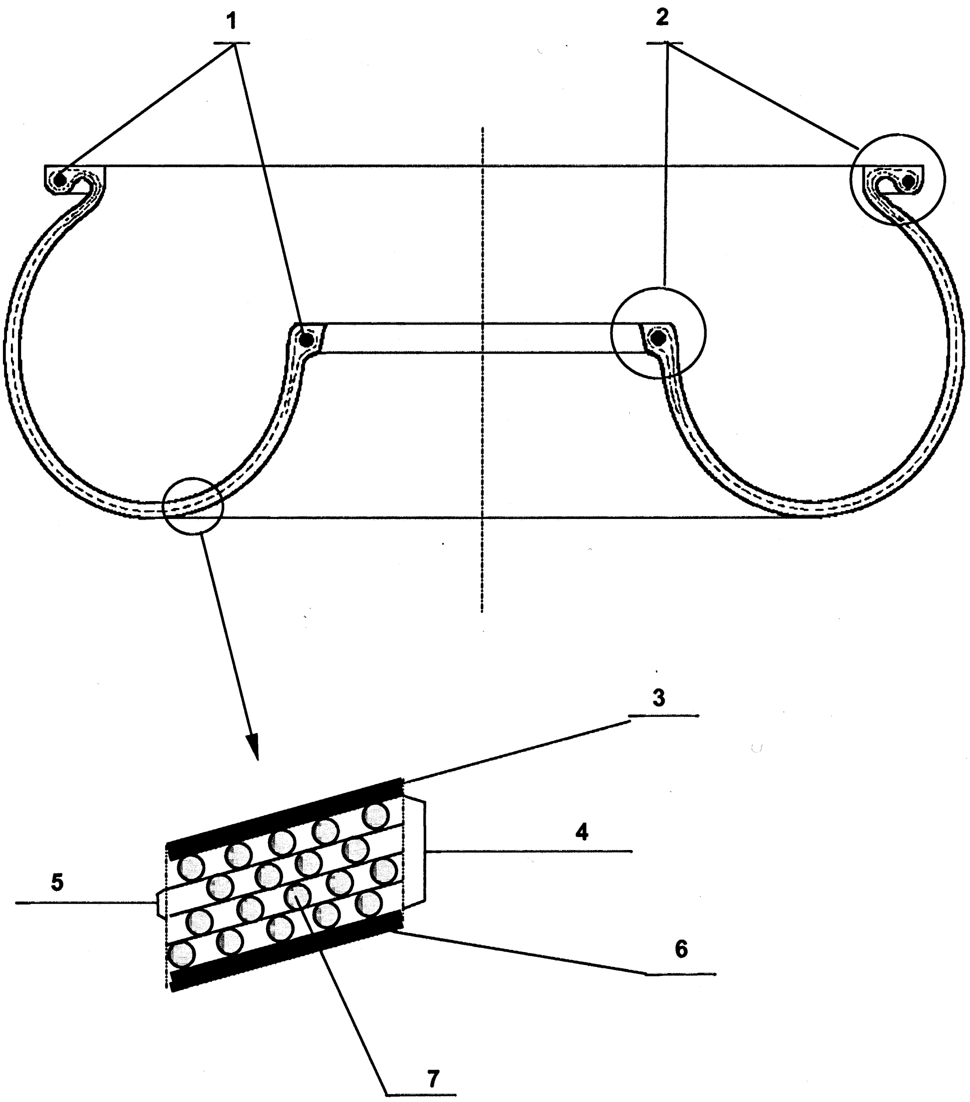
3.1.4
diaphragm
the term "diaphragm" herein applies to the finished product, comprising of carcass and beads for use as part of pneumatic suspension system

NOTE Different types of diaphragms are illustrated in annex A.

3.1.4.1
new diaphragm
diaphragm in new condition and never yet used

3.1.4.2
grown diaphragm
diaphragm which has been in use and, as a result, has changed dimensionally

3.1.5
ply
layer typically made up of rubberized fabric



Key

1 Bead cores
2 Beads
3 Inner layer of rubber
4 Carcass
5 Ply
6 Outer layer of rubber
7 Rubberized fabric

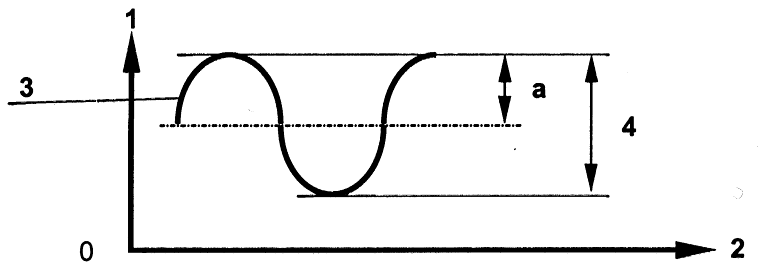
Figure 1 — Different parts of a diaphragm

3.2 Symbols and abbreviations

The majority of the symbols, used in this standard and defined in this sub-clause, are in accordance with ISO 31-1 and ISO 31-3.

Decimal multiples and submultiples of units defined in Table 1 can be used.

Table 1 — Symbols and abbreviations

Symbol Abbreviation	Unit	Explanation
A_e	m^2	Effective area of the diaphragm, with: — $A_e = F / p$ — $\Delta A_e / \Delta d$: Variation of the effective area in function of axial displacement. $\Delta A_e / \Delta d = ((F_{(j+1)} - F_j) / p) / (d_{(j+1)} - d_j)$
a	m or rad	Amplitude of the movement, with $a = \Delta d / 2$ or $a = \Delta \Theta / 2$.  **Key** 1 Displacement (d or Θ) 2 Time (t) 3 $d (t)$ or $\Theta (t)$ 4 Δd or $\Delta \Theta$ **Figure 2 — Amplitude definition**
D	m	Outer diameter of diaphragm (see Figures 5, A.1, A.2, A.3 and A.4), with: D_{pj} : Outer diameter of diaphragm for a given internal pressure (see explanation symbol p).
d	m	Linear displacement, with: d_M : Maximum operational displacement; Δd : Difference between peak movements measured on the "force versus linear displacement" diagram (see Figures 2 and 14). NOTE The above symbols state the direction of the displacement (see 3.3). For example, d_{Mx} corresponding to a maximum displacement parallel to axis O_x.
e	m	Thickness of test sample for verification of low temperature resistance (see 7.2.1).
F	N	Static force applied on the diaphragm, with: F_J : Various operational forces (F_1, F_2, F_3,.etc.), with : $0 \leq F_0 < F_j < F_M$; F_0 : Minimum operational force; F_M : Maximum operational force; ΔF : Difference between peak forces measured on the "force versus linear displacement" diagram (see Figure 14). NOTE The above symbols state the direction of the force (see 3.3). For example, F_{z0} corresponding to the minimum operational force applied on the diaphragm along axis O_z.

to follow

Table 1 *(continued)*

Symbol Abbreviation	Unit	Explanation
f	Hz	Frequency
H	m	Height of the diaphragm (see Figures 5, 6, A.1, A.2, A.3 and A.4), with: H_1 : Maximum overall dimension of the diaphragm in relation to its upper surface (supporting face of the upper bead) when the diaphragm is submitted to a radial displacement. H_2 : Minimum overall dimension of the diaphragm in relation to its upper surface (supporting face of the upper bead) when the diaphragm is submitted to a radial displacement. H_{pj} : Height of the diaphragm for a given internal pressure (see explanation symbol *p*).
h_N	m	Height of levelling of the diaphragm. Distance between the thrust surfaces of the diaphragm beads (see Figures 5, 6, A.1, A.2, A.3 and A.4). This dimension is essential when setting the height of pneumatic springs and shall be specified in the definition documents.
ks	N/m	Stiffness at constant velocity. Stiffness of the diaphragm measured along an axis, at constant velocity. NOTE 1 The above symbol states the direction of the characteristic (see 3.3). For example, ks_y corresponding to constant velocity stiffness measured about axis O_y. NOTE 2 It is permitted to define a flexibility at constant velocity instead of a stiffness at constant velocity, where flexibility is the inverse of stiffness (1/ks).
$k\Theta s$	N·m/rad	Rotational stiffness at constant velocity. Stiffness of the diaphragm measured around an axis, at constant velocity. NOTE 1 The above symbol states the direction of the characteristic (see 3.3). For example, $k\Theta s_z$ corresponding to rotational stiffness at constant velocity measured around axis O_z. NOTE 2 It is permitted to define a rotational flexibility at constant velocity instead of a rotational stiffness at constant velocity, where flexibility is the inverse of stiffness ($1/k\Theta s$).
kdyn	N/m	Stiffness under sinusoidal motion. Stiffness of the diaphragm measured along an axis, under a sinusoidal motion. NOTE 1 The above symbol states the direction of the characteristic (see 3.3). For example, $kdyn_z$ corresponding to stiffness measured about axis O_z under a sinusoidal motion. NOTE 2 It is permitted to define a flexibility under a sinusoidal motion instead of a stiffness under a sinusoidal motion, where flexibility is the inverse of stiffness (1/*kdyn*).

to follow

Table 1 *(continued)*

Symbol Abbreviation	Unit	Explanation
$k\Theta dyn$	N·m/rad	Rotational stiffness under sinusoidal motion. Stiffness of the diaphragm measured around an axis, under a sinusoidal motion. NOTE 1 The above symbol states the direction of the characteristic (see 3.3). For example, $k\Theta dyn_z$ corresponding to rotational stiffness measured around axis O_z under a sinusoidal motion. NOTE 2 It is permitted to define a rotational flexibility under a sinusoidal motion instead of a rotational stiffness under a sinusoidal motion, where flexibility is the inverse of stiffness ($1/k\Theta dyn$).
L_B	m	Half of the distance between the bogie pivots of the vehicle to which the diaphragm is fitted.
L_b	m	Distance from the diaphragm centre line to the bogie pivot.
l_0	m	Reference length of test piece for verification of low temperature resistance (see 7.2.1).
M	N·m	Moment applied around an axis of the diaphragm, with: M_J : Various operational moments (M_1, M_2, M_3,.etc.), with : $0 < M_j < M_{M.}$ M_M : Maximum operational moment corresponding to a maximum angular displacement $\Theta_{M.}$ ΔM : Difference between peak moments measured on the "moment versus angular displacement" diagram (see Figure 14). NOTE The above symbols state the axis of rotation (see 3.3). For example, M_{Mz} corresponding to the maximum moment applied around axis O_z.
p	Pa	Diaphragm relative internal pressure (above atmospheric pressure), with: p_j : Various internal pressures (p_1, p_2, etc.) when diaphragm is submitted to an axial static force F_j, with: $0 \leq p_0 < p_j < p_{M.}$ p_0 : Internal pressure when diaphragm is submitted to the minimum axial static force F_0. p_M : Internal pressure when diaphragm is submitted to the maximum axial static force F_M. p_B: Diaphragm bursting pressure. NOTE 1 1 Pa = 1 N/m² ; 1 bar = 100 kPa. NOTE 2 Use of this symbol as a suffix indicates a parameter which varies with internal pressure (which should be defined according to the above definitions).
R_1	m	Maximum overall dimension of the diaphragm in relation to the axis of the fixed section of the diaphragm when radially displaced (see Figure 6).
R_2	m	Minimum overall dimension of the diaphragm in relation to the axis of the fixed section of the diaphragm when radially displaced (see Figure 6).
R_c	m	Radius of the track curve.
r	%	Percentage of retraction of test piece for verification of low temperature resistance (see 6.2.1).

to follow

Table 1 *(concluded)*

Symbol Abbreviation	Unit	Explanation
t	s	Time, with: Δt : Period of oscillation (1/*f*).
V_D	m^3	Diaphragm air volume. Volume defined by the shell of the inner carcass surface and the two parallel planes formed by the inner edge of the beads (see Figures 3 and 4).
V_{AUX}	m^3	Auxiliary air volume. Any volume increase or reduction of V_D for testing (see Figures 3 and 4).
V_T	m^3	Total air volume Volume applied for testing, with: $V_T = V_D + V_{AUX}$ (see Figures 3 and 4).
Δm_A	g/m²	Variation in weight by surface unit of test piece for verification of oil and petroleum product resistance (see 6.2.3).
Θ	rad	Angle of displacement in a plane around an axis of the diaphragm, with: Θ_M : Maximum operational angular displacement around a clearly defined axis. $\Delta\Theta$: The difference between peak movements measured on the "moment versus angle of displacement" diagram (see Figures 2 and 14). NOTE 1 The above symbols state the axis of rotation (see 3.3). For example, Θ_{Mz} corresponding to a maximum angular displacement around axis O_z. NOTE 2 It is permissible to use angular units of degrees instead of radians.

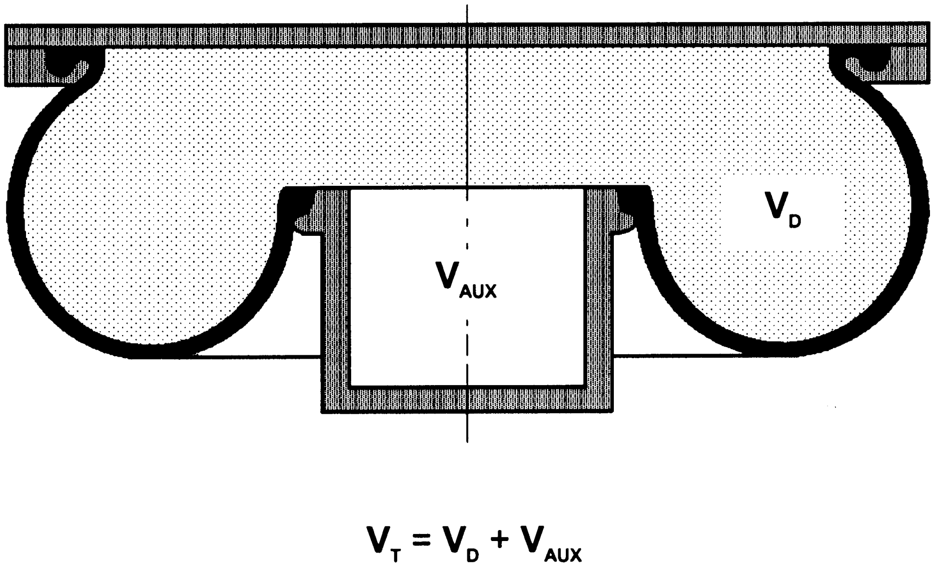
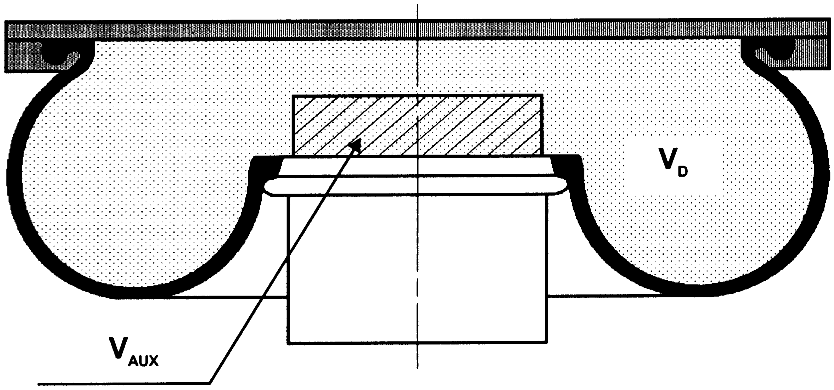


Figure 3 — Definition of air volumes (example with positive auxiliary air volume)



$$V_T = V_D - V_{AUX}$$

Figure 4 — Definition of air volumes (example with negative auxiliary air volume)

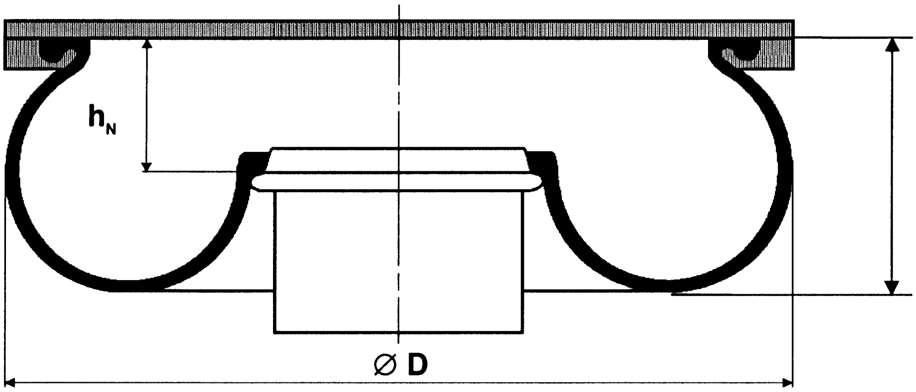
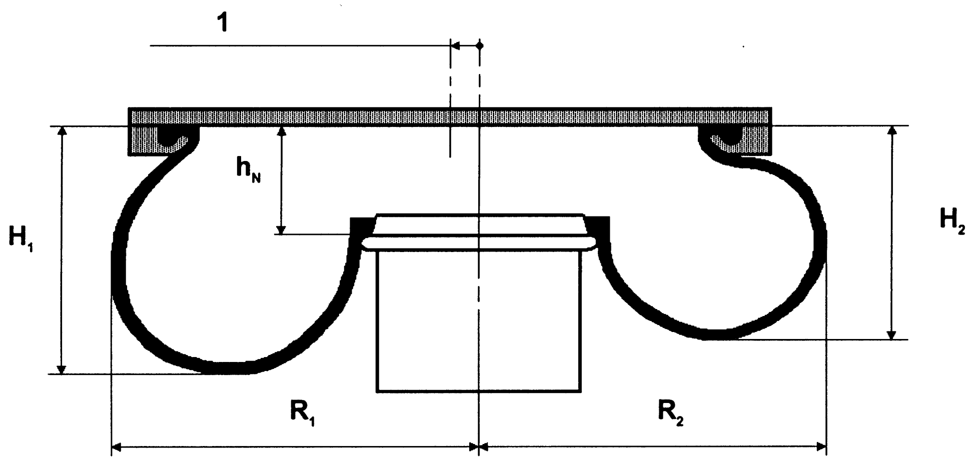


Figure 5 — Main dimensions when diaphragm is in a centred position



Key

1 Setting over

Figure 6 — Main dimensions when diaphragm is radially displaced

3.3 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 diaphragm 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 : Θ_x ;

— rotation around axis O_y : Θ_y ;

— rotation around axis O_z : Θ_z ;

The positive direction of rotation is clock wise looking from the origin.

The mechanical characteristics associated with the displacements are:

— for d_x : stiffnesses ks_x and $kdyn_x$; force F_x ;

— for d_y : stiffnesses ks_y and $kdyn_y$; force F_y ;

— for d_z : stiffnesses ks_z and $kdyn_z$; force F_z ;

— for Θ_x : stiffnesses $k\Theta s_x$ and $k\Theta dyn_x$; moment M_x ;

— for Θ_y : stiffnesses $k\Theta s_y$ and $k\Theta dyn_y$; moment M_y ;

— for Θ_z : stiffnesses $k\Theta s_z$ and $k\Theta dyn_z$; moment M_z.

These provisions are illustrated by Figure 7.

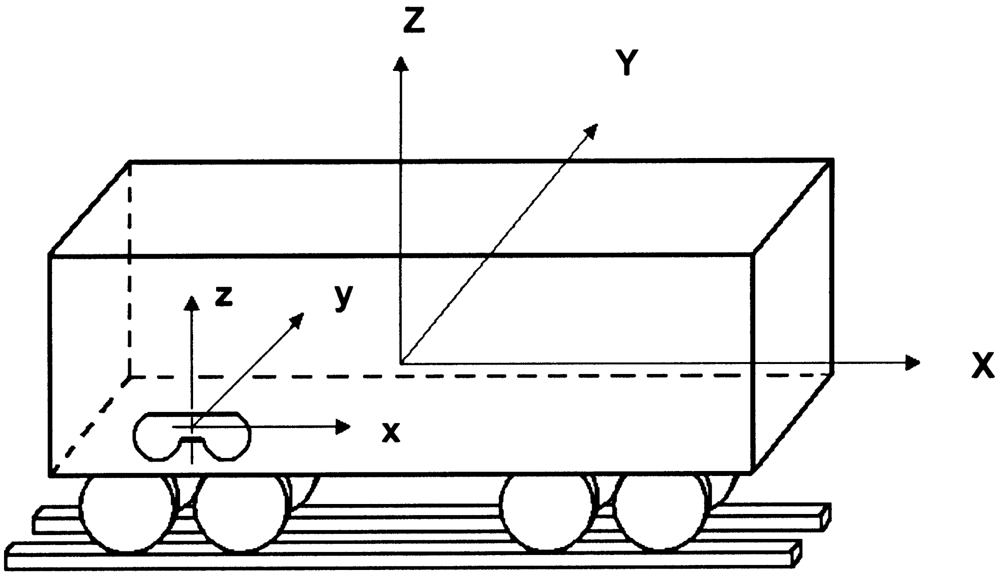


Figure 7 — Three dimensional definition of characteristics

4 Definition documents

4.1 General

Diaphragms shall be defined in a technical specification which consists of the following documents (see 4.2 and 4.3).

The definition of type of drawing is given in ISO 10209-1.

4.2 Documents to be provided by the customer

The customer shall provide a technical specification including:

a) Interface drawing (possibly, a general assembly drawing of the suspension or a sub-assembly drawing) showing at least:

— space envelope;

— functional dimensions and tolerances;

— position of marking.

b) Technical data detailing at least:

— conditions of utilisation (forces, movements, temperatures, assembly, environment, maintenance, storage, etc.);

— requirements (characteristics of the product, tolerances and expected service life);

— approval procedure and type test requirements (e.g.: characteristics to be checked and tests to be carried out, order of tests and checks).

4.3 Documents to be provided by the supplier

The supplier shall provide documentation describing the diaphragm and detailing at least:

- information required for use of the diaphragm (e.g.: performance data, mounting instruction, etc.);
- definition drawing including overall dimensions (diaphragm held in a centred position and during peak movements).

5 Conditions of utilisation

5.1 General

These conditions shall be defined in the customer's technical specification of the diaphragm.

5.2 Climatic and atmospheric conditions

The range of atmospheric temperatures (ambient temperature outside of the vehicle) to consider shall normally be ‘’– 25 °C to + 50 °C‘’.

However, a different range of atmospheric temperatures can be selected in case of special service conditions or particular geographical situation.

5.3 Environmental conditions

According to position on the vehicle and its service conditions, the diaphragm may be subject to attack from sources such as:

- chemical products (cleaning products for example);
- organic wastes;
- oil sprays;
- flying ballast;
- etc.

5.4 Mechanical conditions

During its life the diaphragm is subjected to forces and displacements (axial, radial, angular), due to the functional conditions of the vehicle to which it is fitted.

These forces and displacements shall be taken into consideration for the definition of the diaphragm and therefore have to be defined in the technical specification.

The technical specification, provided by the customer, shall specify at least:

a) axial static forces F_0, F_j (F_1, F_2, F_3,...) and F_M.

b) displacements:

- the maximum axial displacement in compression (- d_M) and extension (+ d_M) of the mechanical system, of which the diaphragm is a part, relative to height of levelling h_N ;

— the maximum radial displacement d_M as function of the axial static force F_j applied to the mechanical system, of which the diaphragm is a part;

— the maximum angular deformation Θ_M as function of the axial static force F_j applied to the mechanical system, of which the diaphragm is a part.

6 Definition of the product

6.1 General

The customer shall specify in the technical specification all the necessary characteristics for the definition of the diaphragm according to its usage and operating conditions.

These characteristics shall be selected among those specified in Table 2.

Table 2 — Diaphragm characteristics

CHARACTERISTIC	Characteristic definition (sub-clause)	Inspection and test method (sub-clause)
Resistance to operating conditions		
Low temperature	6.2.1	7.2.1
Ozone	6.2.2	7.2.2
Oil and petroleum product	6.2.3	7.2.3
Cleaning product	6.2.4	7.2.4
Abrasion	6.2.5	7.2.5
Fire behaviour	6.2.6	7.2.6
Other conditions	6.2.7	
Physical characteristics		
Appearance in new condition	6.3.1	7.3.1
Appearance under extreme deformations	6.3.2	7.3.2
Adherence between plies	6.3.3	7.3.3
Pressure resistance	6.3.4	7.3.4
Air-tightness	6.3.5	7.3.5
Fatigue resistance	6.3.6	7.3.6
Burst resistance	6.3.7	7.3.7
Geometrical and dimensional characteristics		
Space envelope	6.4.1	7.4.1; 7.4.2; 7.4.3
Overall dimensions of new diaphragms	6.4.2	7.4.1
Overall dimensions of grown diaphragms	6.4.3	7.4.1; 7.4.2; 7.4.3
Functional characteristics		
Axial stiffness at constant velocity	6.5.1.2	7.5.1.2.2
Radial stiffness at constant velocity	6.5.1.3	7.5.1.2.3
Rotational stiffness at constant velocity	6.5.1.4	7.5.1.2.4
Axial stiffness under sinusoidal motion	6.5.1.5	7.5.1.3.2
Radial stiffness under sinusoidal motion	6.5.1.6	7.5.1.3.3
Rotational stiffness under sinusoidal motion	6.5.1.7	7.5.1.3.4
Characteristic ″ pressure-force ″	6.5.2	7.5.2
Axial isobar characteristic	6.5.3	7.5.3

6.2 Resistance to operating conditions

6.2.1 Low temperature

Diaphragms shall be able to withstand low temperature.

Unless otherwise specified, diaphragms shall comply with the following limit:

Under the experimental conditions detailed in 7.2.1, the temperature corresponding to a percentage of retraction *r* of 10 % (temperature TR 10) shall be less than or equal to – 35 °C.

6.2.2 Ozone

Diaphragms shall be able to withstand ozone action.

Unless otherwise specified, diaphragms shall comply with the following limits:

Under the experimental conditions detailed in 7.2.2, no crack or fissure shall appear.

6.2.3 Oil and petroleum product

Diaphragms shall not be damaged by occasional oil sprays.

Unless otherwise specified, diaphragms shall comply with the following limits:

Under the experimental conditions detailed in 7.2.3, the variation in weight by surface unit Δm_A shall be less than or equal to 170 g/m².

6.2.4 Cleaning product

Diaphragms shall be able to withstand cleaning products without damage.

Unless otherwise specified, diaphragms shall comply with the following limits:

Under the experimental conditions detailed in 7.2.4, variations in hardness of test pieces shall be less than or equal to ± 5 IRHD.

The customer shall provide the supplier with details of cleaning products that the diaphragm may come into contact with.

6.2.5 Abrasion

Outside surfaces of diaphragms shall be able to withstand abrasion.

Unless otherwise specified, diaphragms shall comply with the following limits:

Under the experimental conditions detailed in 7.2.5, loss of volume of test pieces shall be less than or equal to 200 mm^3.

6.2.6 Fire behaviour

The customer shall inform the supplier of its requirements regarding effect of fire on the diaphragms.

Unless otherwise specified, diaphragms shall be classified with regard to fire reaction, opacity of smokes and toxicity of gas given off.

6.2.7 Other conditions

The customer shall specify any other operating conditions of diaphragms, in the technical specification.

6.3 Physical characteristics

6.3.1 Appearance of diaphragms in new condition

Diaphragms shall exhibit no signs of cracks, bulges or blisters.

Exudation and efflorescence shall only be tolerated when they can be removed simply by wiping.

Rubber shall not exhibit porosity nor tears, and shall not be oily on the surface.

6.3.2 Appearance of diaphragms under extreme horizontal deformations

Under the experimental conditions of 7.3.2, diaphragms shall not exhibit sharp folds or splits.

Slight undulations may be permitted within the limits laid down in the technical specification.

6.3.3 Adherence between plies

Unless otherwise specified, diaphragms shall comply with the following limits.

Under the experimental conditions of 7.3.3, adherence between plies shall be at least 6 N per mm of width.

6.3.4 Pressure resistance

Diaphragms shall be able to withstand the test defined in 7.3.4 without any damage such as tearing, cracks, wear, etc.

6.3.5 Air-tightness

Diaphragms when fastened in their mounting shall be airtight.

Under the experimental conditions of 7.3.5, loss of pressure (p) shall be less or equal to 0,015 MPa (0,15 bar).

6.3.6 Fatigue resistance

Diaphragms shall be able to withstand all stresses and forces to which they are subject when operating.

The fatigue resistance of diaphragms can be evaluated by a fatigue test simulating the movements and the forces encountered in service.

The test programme (see 7.3.6) and the acceptance criteria shall be completely defined in the technical specification.

Unless otherwise specified, diaphragms shall:

— exhibit no deterioration, such as tearing, cracks, wear, etc.;

— furthermore comply with the requirements of 6.3.5 on air-tightness.

6.3.7 Burst resistance

The burst pressures of new diaphragms and grown diaphragms shall be specified in the technical specification.

The burst pressures p_B (on new diaphragms and grown diaphragms) shall be at least that specified in the technical specification.

Unless otherwise specified, p_B shall be equal or greater than three times p_M with a minimum of 1,6 MPa (16 bar).

6.4 Geometrical and dimensional characteristics

6.4.1 Space envelope

The space envelope available for the diaphragm shall be defined by the customer for a given height of levelling h_N, and for given functioning conditions.

For each functioning condition which is taken into account, the following parameters shall be specified:

— radial displacement (*d*);

— axial displacement (*d*);

— axial static force (*F*).

Unless otherwise specified in the technical specification:

— the space envelope shall be defined for extreme functioning conditions (maximum operational displacements d_M in radial and axial, maximum operational force F_M);

— the overall dimensions of diaphragms shall be measured on grown diaphragms, because their volume may increase over time (see 6.4.3).

The overall dimensions of the diaphragm (new and grown) shall always remain within the specified space envelope.

6.4.2 Overall dimensions of new diaphragms

Unless otherwise specified in the technical specification, overall dimensions of new diaphragms shall be defined, with their tolerances, when placed in a centred position at height of levelling h_N, and submitted to an axial static force F_M.

Under the experimental conditions in 7.4.1, the overall dimensions of new diaphragms when installed shall:

— correspond to those specified in the technical specification;

— remain within the specified space envelope (see 6.4.1).

6.4.3 Overall dimensions of grown diaphragms

As a general rule, overall dimensions of grown diaphragms are illustrated by either curves representing the variations of the principal dimensions (H_1, H_2, R_1, R_2 on Figure 6) or by curves representing the profile of diaphragms, for a clearly defined height of levelling h_N, according to:

— axial static force (F_j) applied to the mechanical system, of which the diaphragm is part;

— radial displacement (*d*) and for a given axial static force F_j applied to the mechanical system, of which the diaphragm is part;

— axial displacement (*d*) and for a given axial static force F_j applied to the mechanical system, of which the diaphragm is part.

Unless otherwise specified in the technical specification, overall dimensions of grown diaphragms shall be defined when submitted to an axial static force F_M.

Under the experimental conditions in 7.4.1, 7.4.2 and 7.4.3, the overall dimensions of grown diaphragms when installed shall:

— correspond to those specified in the technical specification;

— remain within the specified space envelope (see 6.4.1).

6.5 Functional characteristics

6.5.1 Stiffnesses of diaphragms

6.5.1.1 General

There are three principal stiffnesses (at constant velocity and under sinusoidal motion):

a) the axial stiffnesses. These are measured perpendicular to the thrust surfaces of the diaphragm.

b) the radial stiffnesses. These are measured in a plane parallel to the thrust surfaces of the diaphragm.

c) the rotational stiffnesses. These are measured around the axis of the diaphragm.

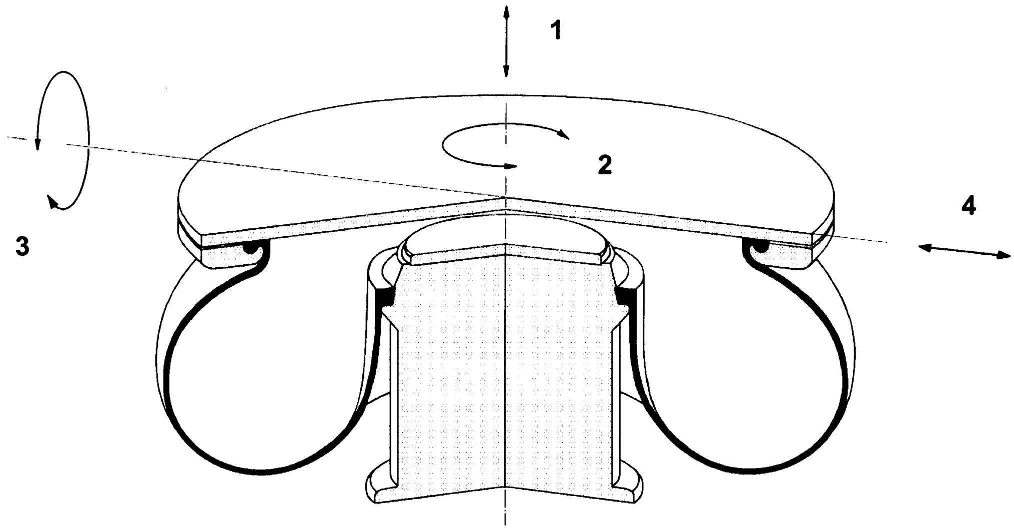
There may also be conical stiffnesses. These are measured around any radial axis of the diaphragm.

These characteristics are illustrated in Figure 8.

However, the customer shall specify in the technical specification only the necessary characteristics of stiffness.

Any characteristic selected shall be defined according to requirements of the present standard.

The stiffnesses (at constant velocity and under sinusoidal motion) of diaphragms shall be defined in relation to the three axes O_x, O_y and O_z (see 3.3).



Key

1 Axial
2 Rotational
3 Conical
4 Radial

Figure 8 — Representation of the three directions defining characteristics of a diaphragm

Stiffness characteristics are illustrated, in the technical specification of the diaphragm, by curves such as:

— stiffness at constant velocity versus amplitude of the movement;

— stiffness at constant velocity versus axial static force;

— stiffness under sinusoidal motion versus frequency;

— etc.

NOTE Stiffnesses measured under sinusoidal motion are generally higher than the same stiffnesses measured under constant velocity.

Figure 9 illustrates an example of "stiffness at constant velocity (*ks*) versus amplitude of the movement (*a*)" curves.

Figure 10 illustrates an example of "stiffness at constant velocity (*ks*) versus axial static force (*F*)" curves.

There are two types of characteristics to be distinguished in the technical specification:

a) the required characteristics.

These characteristics shall be defined by envelope curves (tolerances).

The envelope curves are determined from the definition curve, for any given variable, by the variation of stiffness of a value equal to that of the held tolerance (see Figure 9).

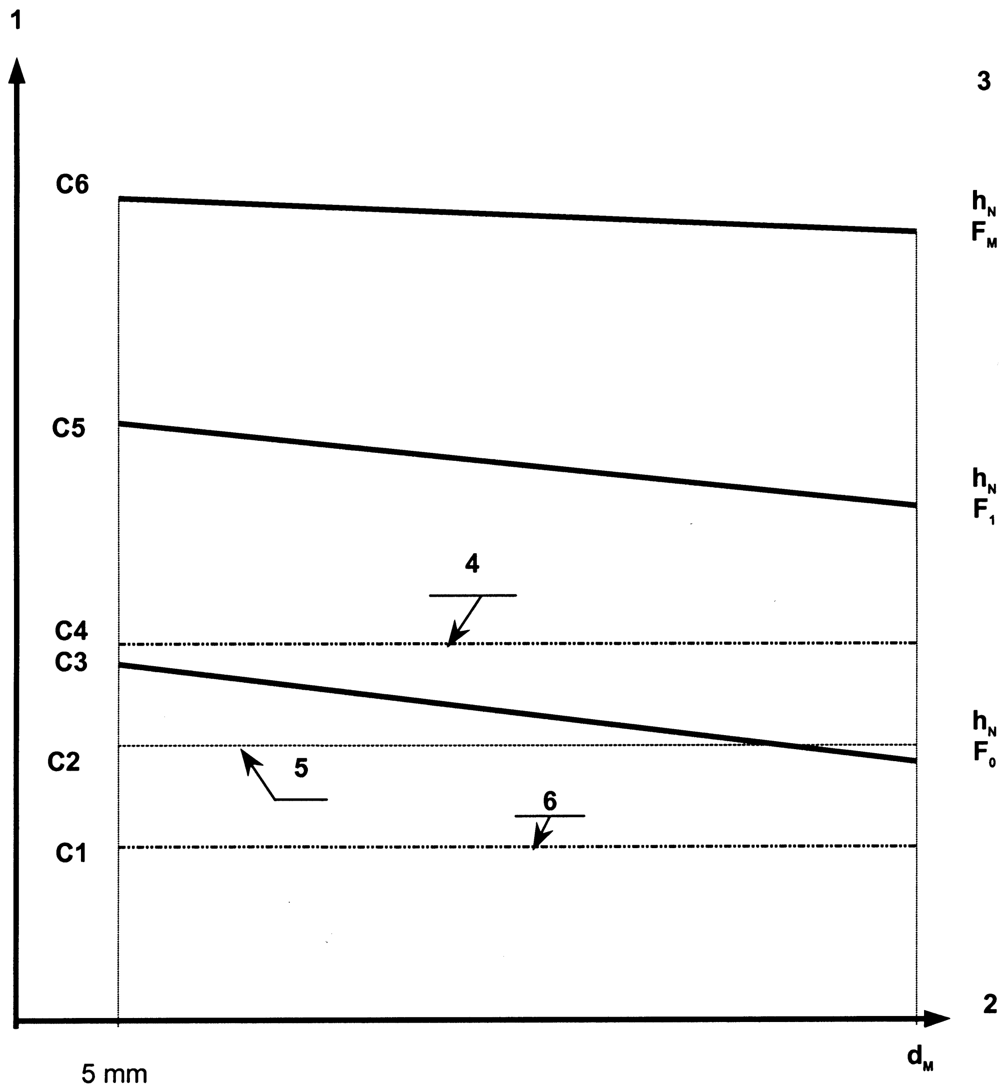
Recommended tolerances are given in annex E.

b) The characteristics given as indicative values.

In this case, the curves are represented without tolerances.

Any part of the interface, having an influence on the characteristics, shall be defined in the technical specification.

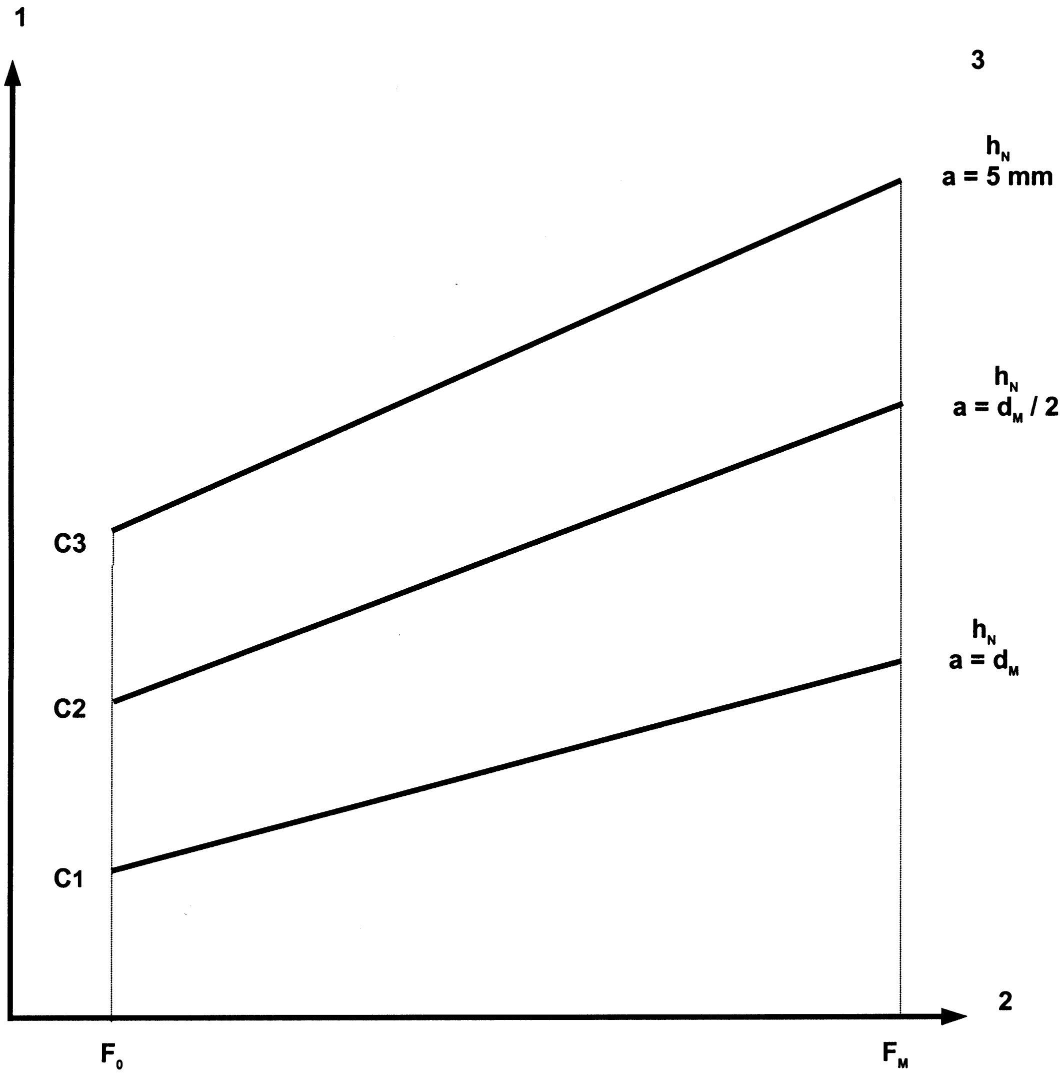
Typical examples are shown in annex A.



Key

1 Stiffness *ks*
2 Amplitude *a*
3 Parameters
4 Maximal
5 Nominal
6 Minimal
C2 Definition curve (theoretical curve)
C1 and C4 Envelope curves
C3, C5 and C6 Specific characteristics of a diaphragm, with:
C3: Required characteristic;
C5 and C6: Characteristics given as indicative values.

Figure 9 — Stiffness at constant velocity (example of curves plotting *ks* versus *a*)



Key

1 Stiffness *ks*

2 Axial static force *F*

3 Parameters

C1, C2 and C3 Specific characteristics of a diaphragm given as indicative values.

Figure 10 — Stiffness at constant velocity (example of curves plotting *ks* versus *F*)

6.5.1.2 Axial stiffness at constant velocity

This characteristic is defined by "axial stiffness at constant velocity (*ks*) versus amplitude of the axial movement (*a*)" curves and possibly by "axial stiffness at constant velocity (*ks*) versus axial static force (*F*)" curves.

Each curve is established for a combination of the remaining parameters:

— amplitude of the axial movement (*a*);

— axial static force (*F*);

— height of levelling (h_N);

— air volume (V_T).

The axial stiffness at constant velocity, if required, shall be specified together with the above parameters in the customer's technical specification.

6.5.1.3 Radial stiffness at constant velocity

This characteristic is defined by "radial stiffness at constant velocity (*ks*) versus amplitude of the radial movement (*a*)" curves and possibly by "radial stiffness at constant velocity (*ks*) versus axial static force (*F*)" curves.

Each curve is established for a combination of the remaining parameters:

— amplitude of the radial movement (*a*);

— axial static force (*F*);

— height of levelling (h_N).

The radial stiffness at constant velocity, if required, shall be specified together with the above parameters in the customer's technical specification.

6.5.1.4 Rotational stiffness at constant velocity

This characteristic is defined by "rotational stiffness at constant velocity (*kΘs*) versus amplitude of the rotational movement (*a*)" curves and possibly by "rotational stiffness at constant velocity (*kΘs*) versus axial static force (*F*)" curves.

Each curve is established for a combination of the remaining parameters:

— amplitude of the rotational movement (*a*);

— axial static force (*F*);

— height of levelling (h_N).

The rotational stiffness at constant velocity, if required, shall be specified together with the above parameters in the customer's technical specification.

6.5.1.5 Axial stiffness under sinusoidal motion

This characteristic is defined by "axial stiffness under sinusoidal motion (*kdyn*) versus frequency (*f*)" curves and possibly by "axial stiffness under sinusoidal motion (*kdyn*) versus axial static force (*F*)" curves.

Each curve is established for a combination of the remaining parameters:

— amplitude of the axial movement (*a*);

— axial static force (*F*);

— height of levelling (h_N);

— frequency (*f*);

— air volume (V_T).

The axial stiffness under sinusoidal motion, if required, shall be specified together with the above parameters in the customer's technical specification.

6.5.1.6 Radial stiffness under sinusoidal motion

This characteristic is defined by "radial stiffness under sinusoidal motion (*kdyn*) versus frequency (*f*)" curves and possibly by "radial stiffness under sinusoidal motion (*kdyn*) versus axial static force (*F*)" curves.

Each curve is established for a combination of the remaining parameters:

— amplitude of the radial movement (*a*);

— axial static force (*F*);

— height of levelling (h_N);

— frequency (*f*).

The radial stiffness under sinusoidal motion, if required, shall be specified together with the above parameters in the customer's technical specification.

6.5.1.7 Rotational stiffness under sinusoidal motion

This characteristic is defined by "rotational stiffness under sinusoidal motion (*kΘdyn*) versus frequency (*f*)" curves and possibly by "rotational stiffness under sinusoidal motion (*kΘdyn*) versus axial static force (*F*)" curves.

Each curve is established for a combination of the remaining parameters:

— amplitude of the rotational movement (*a*);

— axial static force (*F*);

— height of levelling (h_N);

— frequency (*f*).

The rotational stiffness under sinusoidal motion, if required, shall be specified together with the above parameters in the customer's technical specification.

6.5.2 Characteristic "internal pressure versus axial static force"

This characteristic defines the relationship between the axial static force applied on the diaphragm and the resulting internal pressure.

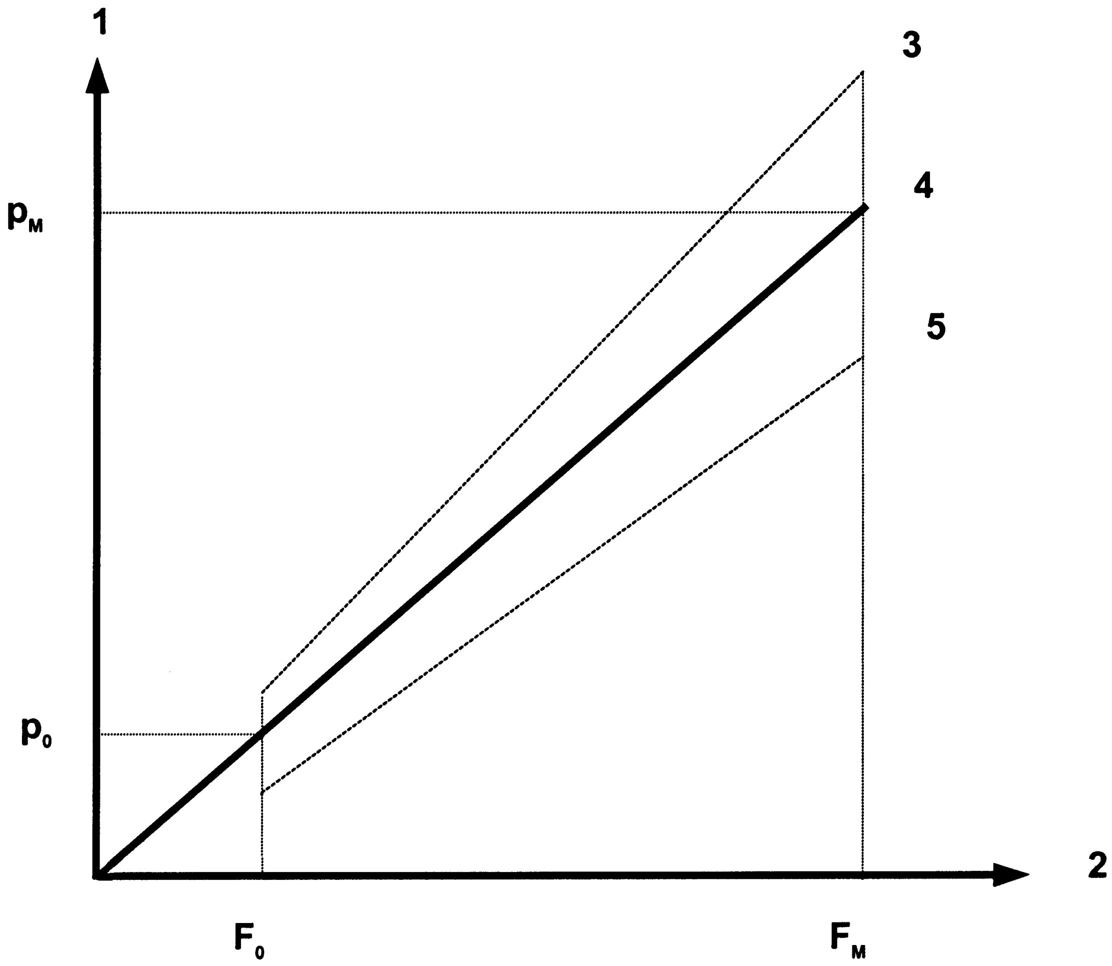
This characteristic shall be defined in the technical specification:

— either by a curve "internal pressure (*p*) versus axial static force (*F*)";

— or by internal pressure (*p*) values defined for one or more given static force (*F*).

The tolerance on the characteristic "*p* / *F*" shall be applied to internal pressure *p* at any given force *F* (see Figure 11).

Recommended tolerances are given in annex E.



Key

1 Internal pressure
2 Axial static force *F*
3 Maximal
4 Nominal
5 Minimal
Definition curve (theoretical curve)
Envelope curves

Figure 11 — Characteristic "internal pressure (*p*) versus axial static force (*F*)" (example)

6.5.3 Axial isobar characteristic

This characteristic defines the relationship between axial static force (*F*) and axial displacement (*d*) under constant internal pressure (p_j).

Each curve is established for a combination of the remaining parameters:

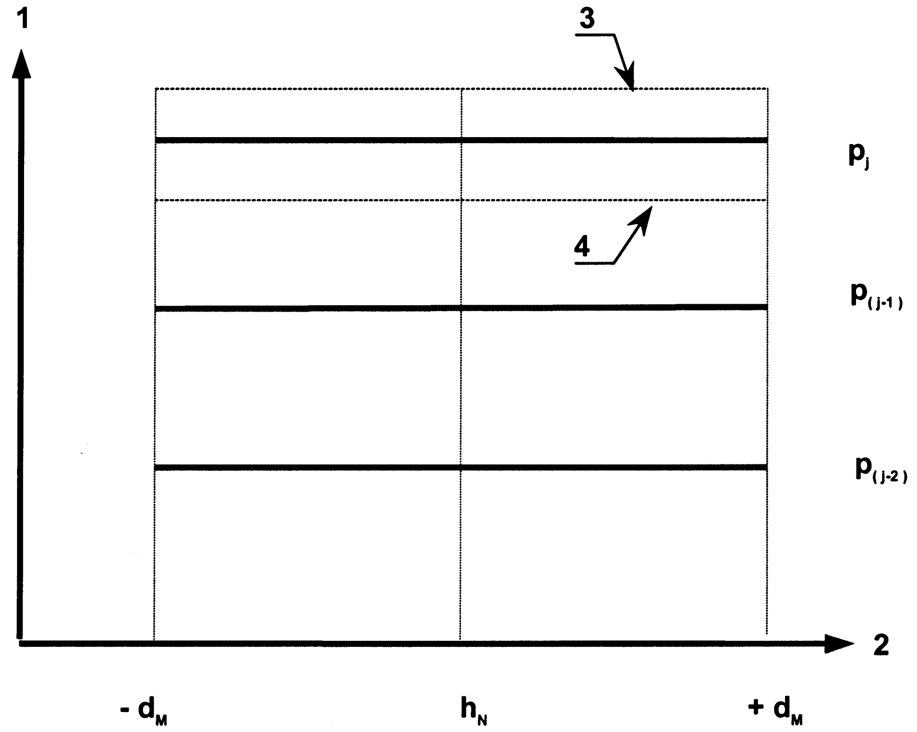
— axial displacement (- d_M; + d_M);

— height of levelling (h_N);

— internal pressure (p_j).

The tolerance on the axial isobar characteristic shall be applied to axial static force (*F*) at any given axial displacement (*d*) (see Figure 12).

Recommended tolerances are given in annex E.



NOTE with $p_j > p_{(j-1)} > p_{(j-2)}$

Key

1 Axial static force *F*

2 Axial displacement *d*

3 Maximal

4 Minimal

——— Specific characteristics of a diaphragm

------- Envelope curves (tolerances)

Figure 12 — Axial isobar characteristic (example)

7 Inspection and test methods

7.1 General

7.1.1 General test conditions

Unless otherwise specified, tests shall be carried out in 23-50 atmosphere with a temperature of (23 ± 2) °C and a relative humidity of (50 ± 5) %, in accordance with ISO 471.

Tests shall be performed within the specified parameter tolerances and actual values declared. Interpretation of the test results shall be agreed between the supplier and the customer.

Any change to the above shall only be made with customer agreement.

When carrying out the tests described in 7.3 (except for 7.3.3), 7.4 and 7.5 diaphragms shall be fastened in a device reproducing their assembly on the mechanical system for which they are designed.

Unless otherwise specified in the technical specification, all diaphragms shall be tested (for the tests described above) with a stiffener (such as a skirt), if diaphragms are fitted with one when in operation.

The burst resistance test may however be carried out with no stiffener when it has little effect on the diaphragm burst resistance. This shall be covered by an agreement between the supplier and the customer.

Some tests could be dangerous. All precautions shall be taken to ensure the safety of the operator.

7.1.2 Instrumentation

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

The measuring device used to test the internal pressure of diaphragms shall be accurate to 0,01 MPa.

7.1.3 Definition and preparation of test pieces

For all tests, except for verification of the resistance to operating conditions (see 7.2) and the adherence between plies (see 7.3.3), the test piece shall be the complete diaphragm.

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

Test pieces designed for the tests described in 7.2 and 7.3.3 shall be taken from a diaphragm that has passed the fatigue test (see 7.3.6) and the burst resistance test (see 7.3.7).

The zone for taking test pieces in the diaphragm is defined in annex B.

7.2 Verification of the resistance to operating conditions

7.2.1 Low temperature

Low temperature resistance shall be verified in conformance with ISO 2921, with the following values:

— reference length of test piece: $l_0 = (50 \pm 0{,}2)$ mm;

— thickness of test piece: $e = (1 \pm 0{,}2)$ mm.

Percentage of retraction *r* of test pieces shall be measured.

7.2.2 Ozone

Ozone resistance shall be checked in conformance with ISO 1431-2, operating method A, continuous dynamic exposure, with details as follows:

— the test shall be carried out after preparing the test pieces by leaving them at rest in the dark for a period of 48 h to 96 h;

— the deformation cycle shall be between 0 % and 20 % of elongation; its frequency shall be 0,5 Hz;

— test pieces shall be examined after seven days of exposure;

- test pieces dimensions shall be:
  - thickness : (1 ± 0,2) mm;
  - width : 10 mm minimum;
  - length : 40 mm minimum between jaws before elongation;
- ozone concentration shall be 50 pphm [5)];
- temperature shall be (40 ± 2) °C.

The test shall be carried out on three test pieces.

Both sides of each test pieces shall be examined.

7.2.3 Oil and petroleum product

Oil resistance shall be tested in conformance with ISO 1817 on test pieces with the same total thickness as the wall of diaphragms, and the external side being in contact with the oil.

Tests parameters shall be as follows:

- oil: IRM 902;
- test temperature: (70 ± 1) °C;
- immersion time: (72^{0}_{-2}) h.

Variation in weight by unit of surface Δm_A shall be measured.

7.2.4 Cleaning product

Cleaning product resistance shall be tested in conformance with ISO 1817 on test pieces taken from the outer layer of rubber of diaphragms.

Tests parameters shall be as follows:

- aqueous solution of oxalic acid with concentration by weight of 5 %;
- test temperature: (50 ± 1) °C;
- immersion time: (72^{0}_{-2}) h.

Variations of hardness IRHD shall be measured in accordance with ISO 48.

7.2.5 Abrasion

Abrasion resistance shall be tested in accordance with ISO 4649.

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

[5)] pphm: parts per hundred million by volume.

A test piece of 16 mm in diameter and thickness 6 mm shall be taken from the diaphragm, ensuring sufficient thickness of rubber in the surface.

The face of the test piece with its moulding skin (the outer layer of diaphragm), shall be rubbed with abrasive cloth.

If the carcass is reached, the test is not valid and shall be performed again.

The test piece shall be weighed before and after abrasion.

The volume removed by abrasion shall be calculated.

7.2.6 Fire behaviour

Test method shall be agreed between the customer and the supplier.

7.3 Verification of physical characteristics

7.3.1 Appearance of diaphragms in new condition

Diaphragms, with and without internal pressure, shall be subject to a visual inspection.

7.3.2 Appearance of diaphragms under extreme horizontal deformations

For the examination, diaphragms shall be in the following condition:

— radially displaced not lesser than d_M, with their thrust surfaces parallel;

— at a height of levelling not higher than the specified height of levelling h_N ;

— at an axial static force not more than $F_j = 0,7 \times F_0$.

Diaphragms shall be subject to a visual inspection. This inspection shall be made when diaphragms are submitted to a radial displacement (in only one direction taken at random).

However, this inspection can be required in more directions (e.g.: when diaphragms are fitted with an unidirectional stiffener). In this last case, directions to take in consideration shall be clearly defined in the technical specification.

7.3.3 Adherence between plies

Adherence between plies shall be checked in conformance with ISO 36.

7.3.4 Pressure resistance

Unless otherwise specified in the technical specification, pressure resistance test shall be carried out as follows.

Diaphragms shall be left to stabilise:

— in a centred position with their thrust surfaces parallel;

— for (2 ± 1) min;

— at the specified height of levelling $h_N \pm 2$ mm;

— at internal pressure $p > (1,3 \times p_M)$.

Diaphragms shall be subject to a visual inspection, which may be performed at reduced pressure according to safety regulations.

7.3.5 Air-tightness

Unless otherwise specified in the technical specification, test of air-tightness shall be carried out as follows.

During measurements, diaphragms shall be left to stabilise:

— in a centred position with their thrust surfaces parallel;

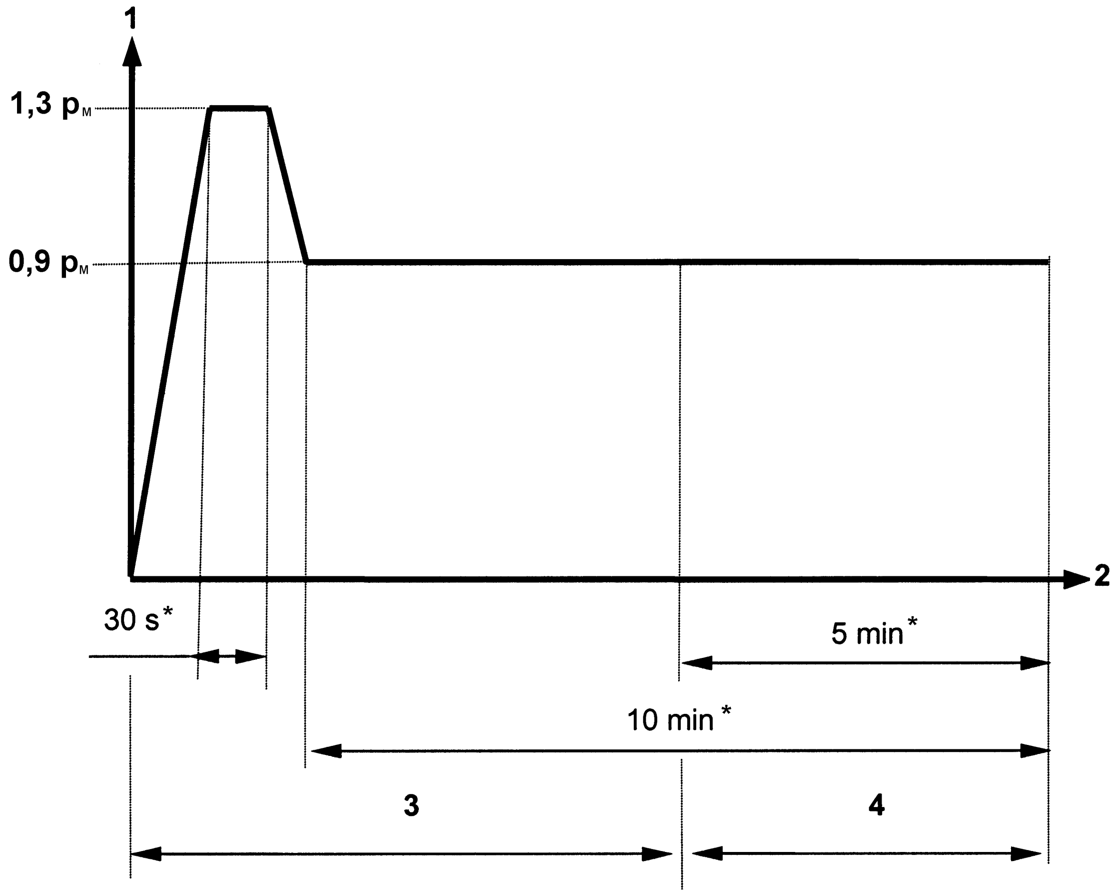
— at the specified height of levelling $h_N \pm 2$ mm.

Diaphragms shall be successively left to stabilise:

a) for 30 s minimum at internal pressure $p > (1{,}3 \times p_M)$;

b) for 10 min minimum at internal pressure $p > (0{,}9 \times p_M)$, with the air supply and drain systems of the test device turned off.

Variation of pressure during the last five minutes of the test shall be measured.



Key

1 Pressure (MPa)

2 Time

3 Preparation

4 Measurement

* Minimal

Figure 13 — Measurement programme

7.3.6 Fatigue resistance

Fatigue testing requirements shall be specified by the customer.

The test shall be carried out in accordance with the procedure.

a) Test machine

The test machine shall be designed to reproduce the principal forces and movements to which diaphragms are submitted when operating.

b) Test procedure

The fatigue test shall consist of repeating specified sequences of forces and movements, such as those indicated as examples in annex C.

The test procedure shall be defined in the technical specification.

c) Test procedure validation

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

d) Inspections

At the end of the fatigue test:

- the diaphragm shall be subject to a visual inspection;
- an air-tightness test shall be carried out in accordance with 7.3.5.

7.3.7 Burst resistance

This test shall be performed with water at an ambient temperature above 10 °C.

During the test, diaphragms shall be left to stabilise:

- in the centred position;
- at the specified height of levelling h_N ± 5 mm;

The test shall consist of gradually increasing the internal pressure of the diaphragm at the maximum speed of 0,5 MPa per min, until the diaphragm bursts.

Burst pressure p_B shall be recorded.

Unless otherwise specified, the burst pressure shall be measured only on a diaphragm that has passed the fatigue test in accordance with 7.3.6.

7.4 Verification of geometrical and dimensional characteristics

7.4.1 Overall dimensions of diaphragms in relation to axial static force

During measurements, diaphragms shall be left to stabilise:

- in a centred position, with their thrust surfaces parallel;
- at the specified height of levelling h_N ± 2 mm;

— at an axial static force F_j ± 2 % defined.

Only the overall dimensions defined in the technical specification shall be measured, according to conditions specified in the technical specification.

Where the overall dimensions measurements shall be made at different axial forces F_j, forces shall be applied in increasing order.

7.4.2 Overall dimensions of diaphragms in relation to radial deformation

During measurements, diaphragms shall be left to stabilise:

— with their thrust surfaces parallel;

— at the specified height of levelling h_N ± 2 mm;

— at an axial static force F_j ± 2 % defined;

— radially displaced (d_0^{+2}) mm.

Only the overall dimensions defined in the technical specification shall be measured, according to conditions specified in the technical specification.

Where the overall dimensions measurements shall be carried out at different axial forces F_j, forces shall be applied in increasing order.

Where the overall dimensions measurements shall be carried out at different radial displacements d, displacements shall be applied in increasing order.

Measurements shall be carried out when diaphragms are submitted to a radial displacement in only one direction (taken at random).

However, measurements can be required in more directions (e.g.: when diaphragms are fitted with an unidirectional stiffener). In this last case, directions to take in consideration shall be clearly defined in the technical specification.

7.4.3 Overall dimensions of diaphragms in relation to axial deformation

a) Diaphragms shall first be placed in the following condition:

— in a centred position, with their thrust surfaces parallel;

— at the specified height of levelling h_N ± 2 mm;

— at an axial static force F_j ± 5 % defined.

The systems designed to feed air to and from the test device shall be turned off during measurements.

b) Measurements

The overall dimensions shall be measured with diaphragms held at distance (d_0^{+2}) mm of the height of levelling h_N.

Where the overall dimensions measurements shall be carried out at different axial forces F_j, forces shall be applied in increasing order.

Where the overall dimensions measurements shall be made at different distances d of the height of levelling h_N, displacements shall be applied in descending order (+ d_M to - d_M).

Only the overall dimensions defined in the technical specification shall be measured, according to conditions specified in the technical specification.

7.5 Verification of functional characteristics

7.5.1 Stiffnesses

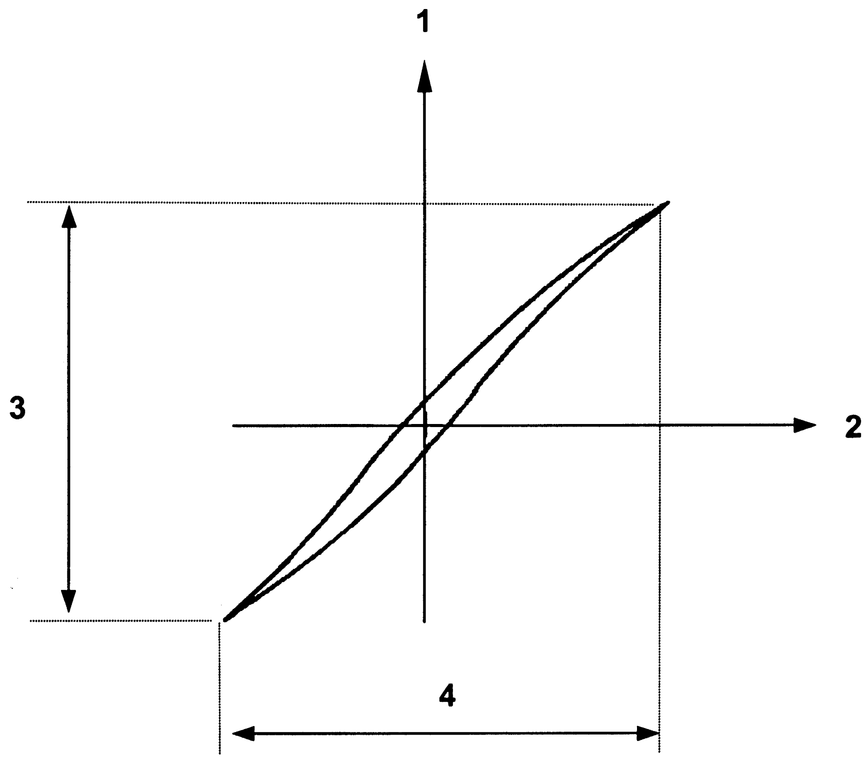
7.5.1.1 General

Diaphragms shall be stabilised for 24 h minimum, without internal pressure, before starting measurements of stiffness characteristics.

It is not mandatory to observe this stabilisation pause between two verifications of stiffness characteristics.

The systems designed to feed air and to and from the test device shall be turned off during work of measurements.

The stiffness curves are drawn from "force versus displacement amplitude (linear or angular)" diagrams (see Figure 14) read as follows.



Key

1 Force *F* or moment *M*

2 Linear displacement *d* or angular displacement *Θ*

3 ΔF or ΔM

4 Δd or $\Delta \Theta$

Figure 14 — Diagram "force versus displacement amplitude" (example)

The values of ΔF (or ΔM) and Δd (or $\Delta \Theta$) shall be measured between the points of the diagram.

Stiffness is defined as the ratio between the variation of force and the variation of displacement during a complete cycle:

$$k = (\Delta F / \Delta d) \text{ or } (\Delta M / \Delta \Theta)$$

7.5.1.2 Stiffnesses at constant velocity

7.5.1.2.1 General

Before every verification, diaphragms shall be positioned in the following condition:

— in a centred position, with the thrust surfaces parallel;

— at the specified height of levelling h_N ± 2 mm;

— at an axial static force F_M ± 2 %.

Measurements shall be carried out by applying an amplitude of the movement to diaphragms in a direction (in axial, in radial or in rotation around their axis) and recording the corresponding force (or moment).

For each configuration (axial static force and amplitude of the movement defined), three cycles shall be carried out successively.

In order to eliminate inertia during movement, the form of the movement as a function of time shall be triangular.

Diagrams "force versus amplitude of the movement" required for the determination of ΔF and Δd, or ΔM and $\Delta \Theta$ (see 7.5.1.1) shall be recorded at the second cycle.

7.5.1.2.2 Axial stiffness at constant velocity

Unless otherwise specified in the technical specification, measurements shall be carried out as follows:

a) Preliminary preparation

Diaphragms shall be successively:

— subject, in axial, to five cycles of amplitude *a* equal to d_M ;

— held in a centred position for (15 ± 2) min under an axial static force F_M ± 2 %.

b) Measurements

Speed of movement shall be (5 ± 0,5) mm/s.

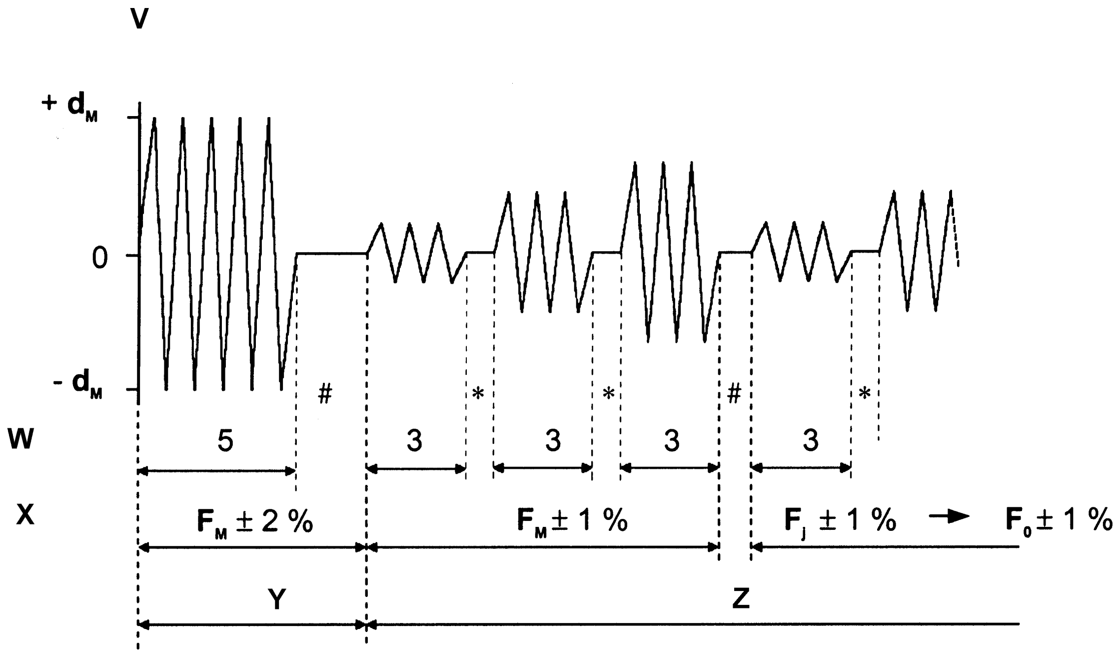
The stiffness measurements shall be carried out at different amplitudes of axial displacement, amplitudes shall be applied in increasing order and at intervals of 2 min to 3 min.

The displacement amplitudes to take in consideration are:

a = 5 mm; 10 mm; 15 mm and

a = 20 mm; ......; d_M in increments of 10 mm.

The stiffness measurements shall be carried out at different axial forces F_j, forces shall be applied, with a tolerance of ± 1 %, in descending order without interruption.



Key

V Amplitude *a*

W Cycles

X Force

Y Preparation

Z Measurements

Waiting time:

\# (15 ± 2) min

∗ (2 to 3) min

Figure 15 — Measurement programme

7.5.1.2.3 Radial stiffness at constant velocity

During measurements, diaphragms shall remain at their height of levelling h_N ± 2 mm.

Unless otherwise specified in the technical specification, measurements shall be carried out as follows:

a) Preliminary preparation

Diaphragms shall be successively:

— subject, in radial, to twenty cycles of amplitude *a* equal to d_M, under an axial static force F_M ± 2 %;

— held in a centred position for (60 ± 3) min under an axial static force F_0 ± 2 %.

b) Measurements

Speed of movement shall be (5 ± 0,5) mm/s.

The stiffness measurements shall be carried out at different amplitudes of radial displacement, amplitudes shall be applied in increasing order and at intervals of 2 to 3 min.

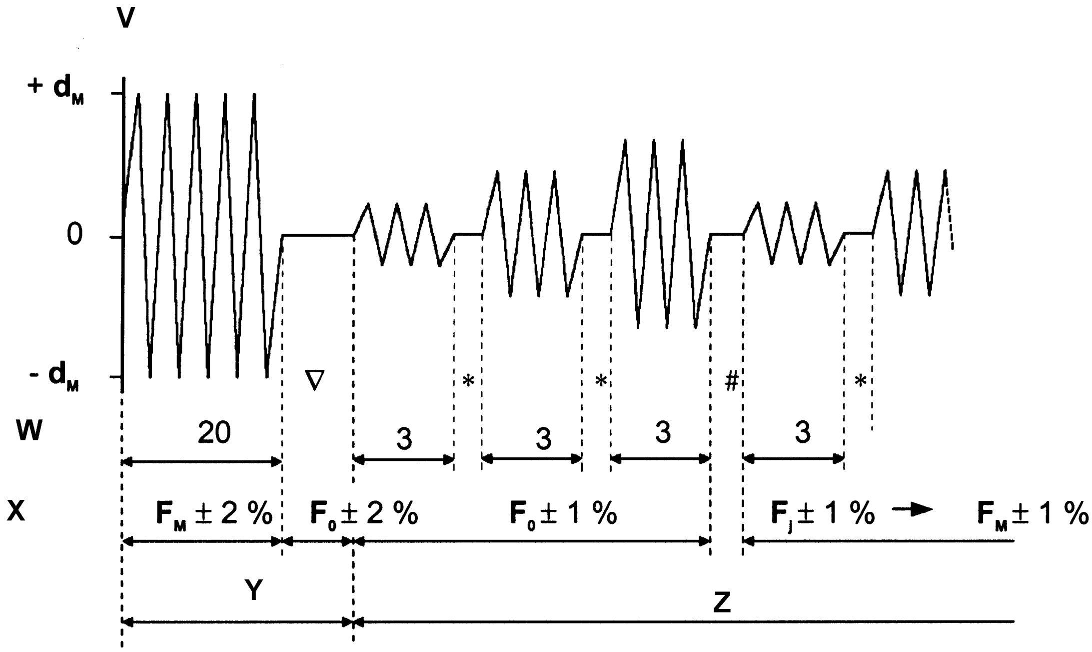
The amplitudes of displacement to take into consideration are:

— For $d_M \leq 20$ mm: a = 5 mm; ......; d_M in increments of 5 mm;

— For $d_M > 20$ mm: a = 5 mm; 10 mm; 15 mm; 20 mm and

a = 30 mm; ...; d_M in increments of 10 mm.

The stiffness measurements shall be carried out at different axial forces F_j, forces shall be applied, with a tolerance of ± 1%, in increasing order without interruption.



Key

V Amplitude *a*

W Cycles

X Force

Y Preparation

Z Measurements

Waiting time:

∇ : (60 ± 3) min

: (15 ± 2) min

∗ : (2 to 3) min

Figure 16 — Measurement programme

7.5.1.2.4 Rotational stiffness at constant velocity

During measurements, diaphragms shall remain at their height of levelling h_N ± 2 mm.

Unless otherwise specified in the technical specification, measurements shall be carried out as follows:

a) Preliminary preparation

Diaphragms shall be successively:

— subject, in rotation around their axis, to five cycles of amplitude a equal to Θ_M under an axial static force F_M ± 2 %;

— held in a centred position for (15 ± 2) min under an axial static force F_0 ± 2 %.

b) Measurements

Speed of movement shall be (5 × 10^{-3}) rad/s ± (0,5 × 10^{-3}) rad/s.

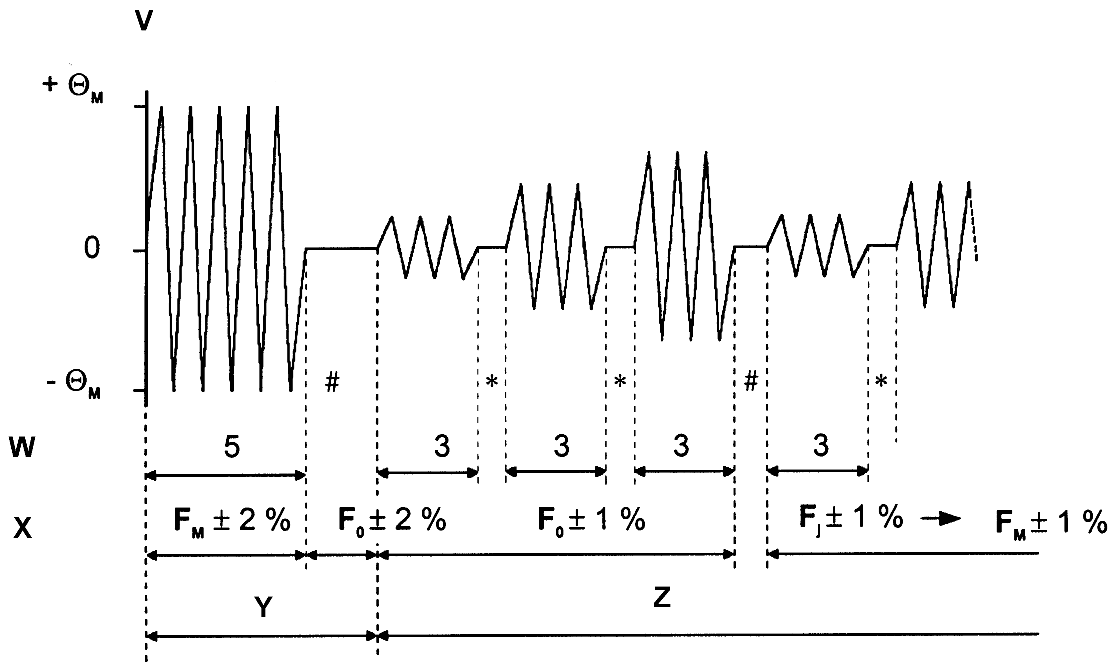
The stiffness measurements shall be carried out at different amplitudes of angular displacement Θ, amplitudes shall be applied in increasing order and at intervals of 2 min to 3 min.

The amplitudes of displacement to take in consideration are:

— For Θ_M ≤ (60 × 10^{-3}) rad: a = (30 × 10^{-3}) rad and (60 × 10^{-3}) rad.

— For Θ_M > (60 × 10^{-3}) rad: a = (90 × 10^{-3}) rad; ...; Θ_M in increments of (30 × 10^{-3}) rad.

The stiffness measurements shall be carried out at different axial forces F_j, forces shall be applied, with a tolerance of ± 1 %, in increasing order without interruption.



Key

V Amplitude a

W Cycles

X Force

Y Preparation

Z Measurements

Waiting time:

(15 ± 2) min

∗ (2 to 3) min

Figure 17 — Measurement programme

7.5.1.3 Stiffnesses under sinusoidal motion

7.5.1.3.1 General

Before every verification, diaphragms shall be positioned in the following condition:

— in a centred position, with the thrust surfaces parallel;

— at the specified height of levelling $h_N \pm 2$ mm;

— at an axial static force $F_M \pm 2$ %.

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

Only those recordings made during the last two seconds of every operation shall be used.

The test consists in applying a dynamic oscillation $d\,(t)$ to the diaphragms at various frequencies and of recording the corresponding force $F\,(t)$.

Stiffnesses *kdyn* shall be measured from the forces that cause movements of the form:

$$d\,(t) = a \times \sin\,(2 \times \pi \times f \times t)$$ where:

— $d\,(t)$: instantaneous movement;

— a : amplitude of the displacement;

— f : frequency;

— t : time.

7.5.1.3.2 Axial stiffness under sinusoidal motion

Unless otherwise specified in the technical specification, measurements shall be carried out as follows:

a) Preliminary preparation

Diaphragms shall be successively:

— subject, in axial, to five cycles of amplitude a equal to d_M, at a frequency f = 0,1 Hz and under an axial static force $F_M \pm 2$ %;

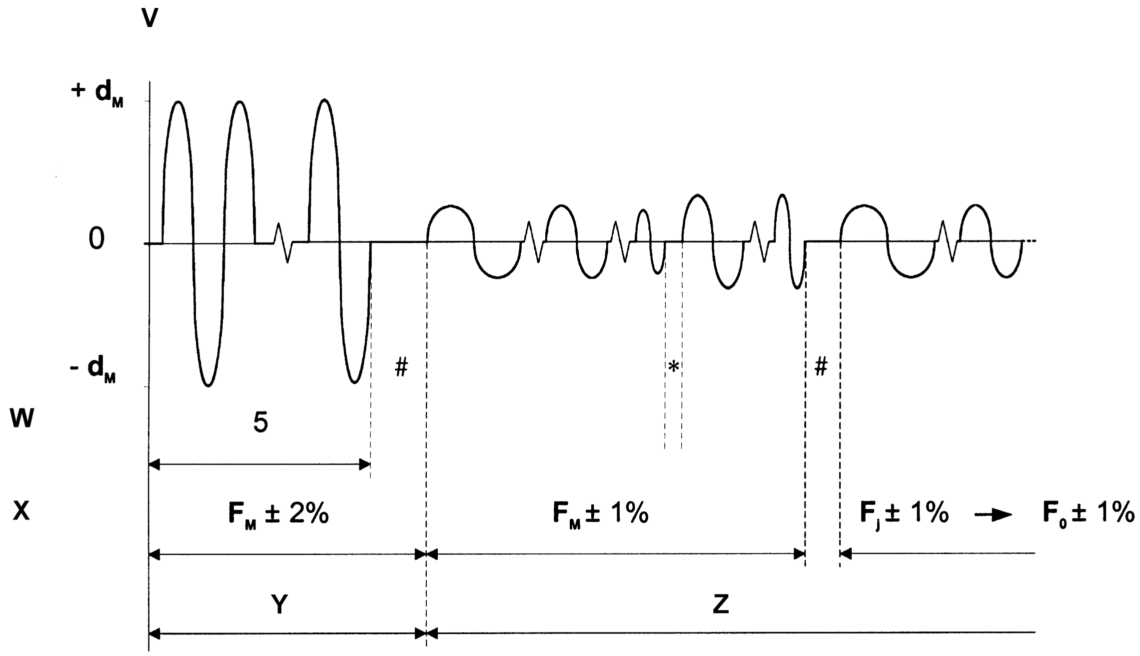
— held in a centred position for (15 ± 2) min under an axial static force $F_M \pm 2$ %.

b) Measurements

The stiffness measurements shall be carried out at different amplitudes of axial displacement, amplitudes shall be applied in increasing order and at intervals of 2 min to 3 min.

The stiffness measurements shall be carried out at different axial forces F_j , forces shall be applied, with a tolerance of ± 1 %, in descending order without interruption.

The stiffness measurements shall be carried out at different frequencies f, frequencies shall be applied, with a tolerance of ± 1 %, in increasing order.



Key

V Amplitude *a*
W Cycles
X Forces
Y Preparation
Z Measurements
Waiting time:
(15 ± 2) min
∗ (2 to 3) min

Figure 18 — Measurement programme

7.5.1.3.3 Radial stiffness under sinusoidal motion

During measurements, diaphragms shall remain at their height of levelling h_N ± 2 mm.

Unless otherwise specified in the technical specification, measurements shall be carried out as follows:

a) Preliminary preparation

Diaphragms shall be successively:

— subject, in radial, to twenty cycles of amplitude *a* equal to d_M, under an axial static force F_M ± 2 % and at a frequency f = 0,1 Hz;

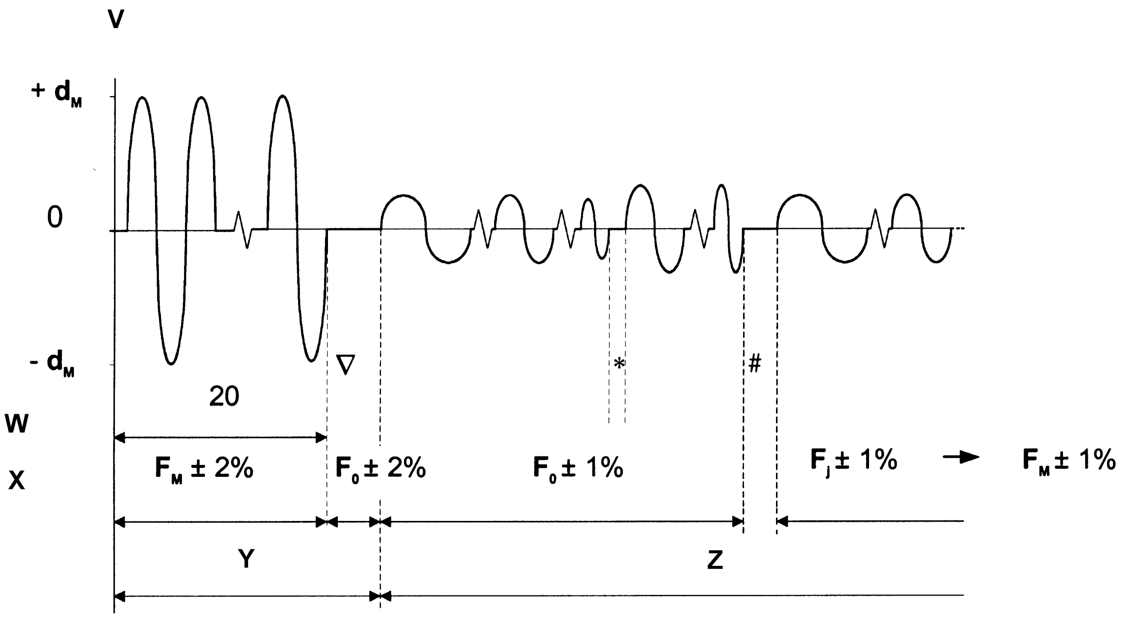
— held in a centred position for (60 ± 3) min under an axial static force F_0 ± 2 %.

b) Measurements

The stiffness measurements shall be carried out at different amplitudes of axial displacement, amplitudes shall be applied in increasing order and at intervals of 2 min to 3 min.

The stiffness measurements shall be carried out at different axial forces F_j , forces shall be applied, with a tolerance of ± 1 %, in increasing order without interruption.

The stiffness measurements shall be carried out at different frequencies *f*, frequencies shall be applied, with a tolerance of ± 1 %, in increasing order.



Key

V Amplitude *a*

W Cycles

X Force

Y Preparation

Z Measurements

Waiting time:

∇ : (60 ± 3) min

: (15 ± 2) min

∗ : (2 to 3) min

Figure 19 — Measurement programme

7.5.1.3.4 Rotational stiffness under sinusoidal motion

During measurements, diaphragms shall remain at their height of levelling h_N ± 2 mm.

Unless otherwise specified in the technical specification, measurements shall be carried out as follows:

a) Preliminary preparation

Diaphragms shall be successively:

— subject, in rotation around their axis, to five cycles of amplitude *a* equal to Θ_M, under an axial static force F_M ± 2 % and at a frequency *f* = 0,1 Hz;

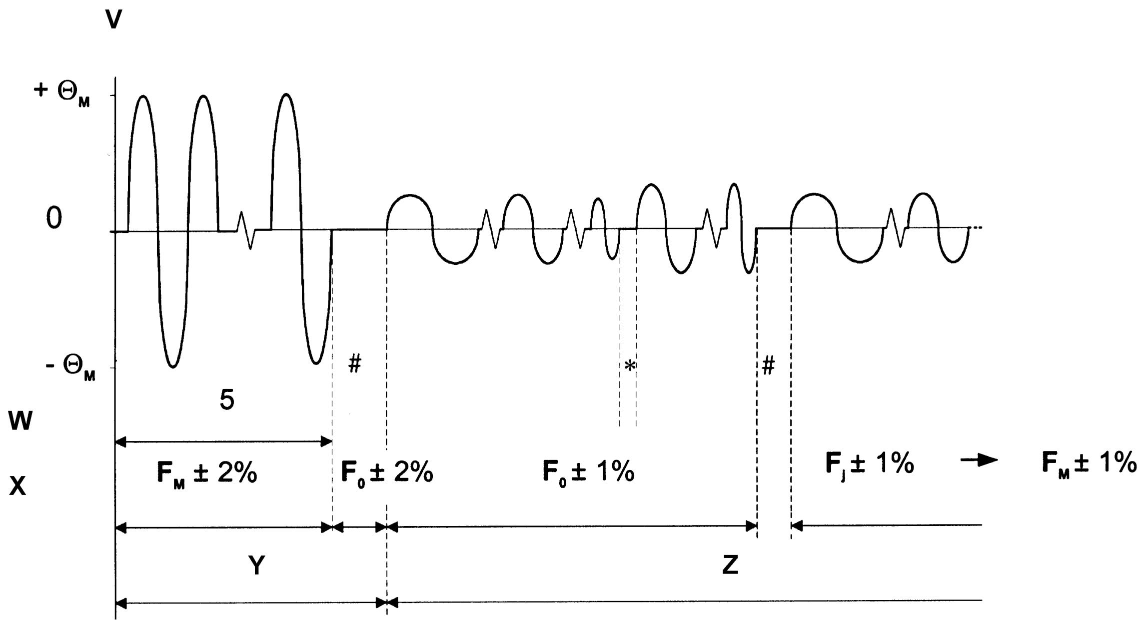
— held in a centred position for (15 ± 2) min under an axial static force F_0 ± 2 %.

b) Measurements

The stiffness measurements shall be carried out at different amplitudes of angular displacement, amplitudes shall be applied in increasing order and at intervals of 2 min to 3 min.

The stiffness measurements shall be carried out at different axial forces F_j , forces shall be applied, with a tolerance of ± 1 %, in increasing order without interruption.

The stiffness measurements shall be carried out at different frequencies *f*, frequencies shall be applied, with a tolerance of ± 1 %, in increasing order.



Key

V Amplitude *a*

W Cycles

X Force

Y Preparation

Z Measurements

Waiting time:

: (15 ± 2) min

∗ : (2 to 3) min

Figure 20 — Measurement programme

7.5.2 Characteristic "internal pressure versus axial static force"

During measurements, diaphragms shall be left to stabilise:

— in a centred position with their thrust surfaces parallel;

— at the specified height of levelling h_N ± 2 mm.

Measurements shall be carried out by applying an axial static force F_j , with a tolerance of ± 1 %, and recording the corresponding internal pressure p_j.

The internal pressure shall be measured at different axial forces F_j, forces shall be applied in descending order without interruption.

If the characteristic " p / F " is defined by envelope curves, measurements shall be carried out as follows:

— recording of internal pressure p_M under axial static force F_M ;

— measurements in descending order of pressure (from p_M rounded off to 0,1 MPa lower up to p = 0) in increments of 0,1 MPa.

7.5.3 Axial isobar characteristic

Unless otherwise specified in the technical specification, measurements shall be carried out as follows:

a) Preliminary preparation

Before measurements, diaphragms shall be positioned in the following condition:

— in a centred position, with the thrust surfaces parallel;

— at the specified height of levelling h_N ± 2 mm;

— at an internal pressure p_M ± 5 % corresponding to the axial static force F_M.

Under a constant pressure p_M, diaphragms shall be successively:

— subject, in axial, to five cycles of amplitude from - d_M to + d_M ;

— held in a centred position for (15 ± 2) min.

b) Measurements

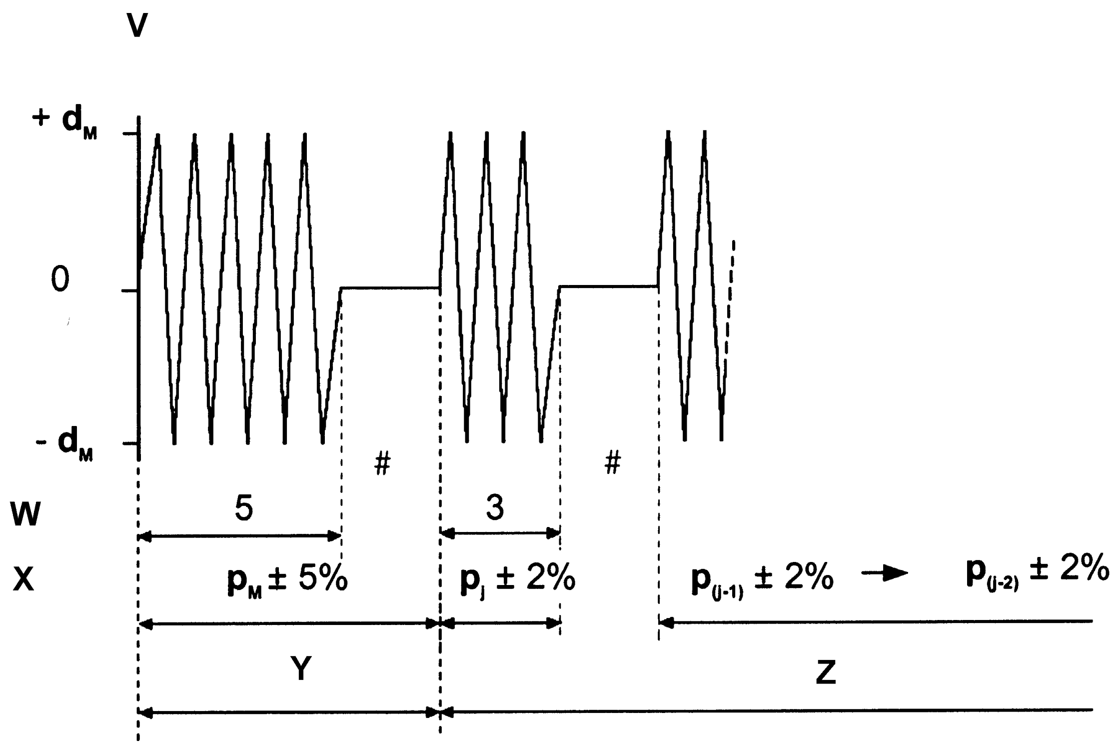
Measurements shall be carried out by applying a displacement amplitude to diaphragms in axial direction and recording the corresponding diagram "force versus displacement amplitude".

For each pressure, three cycles shall be carried out successively.

The second cycle shall be recorded.

During measurements, the internal pressure shall be maintained within ± 2 %.

Where measurements are taken at different pressures p_j, then these shall be carried out in descending order without interruption.



NOTE with $p_j > p_{(j\text{-}1)} > p_{(j\text{-}2)}$

Key

V Amplitude *a*

W Cycles

X Force

Y Preparation

Z Measurements

Waiting time:

: (15 ± 2) min

Figure 21 — Measurement programme

8 Marking

Every diaphragm shall be marked indelibly on its outside with the following information:

— supplier's logo;

— production plant code, if there is more than one plant;

— product reference;

— manufacturing date (month and year);

— unique serial number;

— additional indications, if required by the customer.

These markings shall be placed in a position where they are not likely to come into contact with surrounding parts (notably with the stiffener).

If necessary, the prohibited areas for marking shall be defined in definition documents established by the customer.

The location of the above markings shall be clearly identified on the part drawing established by the supplier.

To ensure traceability (see clause 9), these marks shall be readable throughout the working life of the diaphragm.

9 Traceability

Suppliers shall establish an identification and traceability system of the product.

Traceability shall be the subject of a contractual document between the customer and the supplier.

10 Supplier production plan qualification

It is recommended that manufacturing operations, including the manufacturing of the component parts of diaphragms, be performed by qualified suppliers, as defined in EN ISO 9000, possessing a certified quality assurance system in accordance with EN ISO 9001.

11 Approval and qualification of the product

11.1 Approval

Before it is fitted to a vehicle, a diaphragm could be subject to approval (according to definition in EN 45020) by the customer.

When such an approval is required, all conditions and procedures for approval shall be agreed between customer and supplier.

11.2 Qualification

11.2.1 General

The definitions given in EN ISO 9000 should apply.

Before being used on a vehicle, every new diaphragm (of a new or known supplier), or every existing diaphragm used for a new application (new technical specification), shall be qualified.

The characteristics and properties of diaphragms shall be verified (type test) according to the customer requirements.

The extent of testing shall be agreed between customer and supplier.

The minimum extent of testing is stated in annex D.

11.2.2 Test pieces

The definition and the preparation of test pieces are defined in 7.1.3.

All diaphragms taken as test pieces for qualification tests shall be taken from the same production batch and delivered together.

Test pieces shall be representative of the production technology, the materials employed and all the characteristics for which qualification is requested.

The number of test pieces and the distribution of tests and inspections on tests pieces, shall be specified in the technical specification.

11.2.3 Qualification procedure

The qualification procedure consist of verification of the conformity of the product to the stated requirements.

All the characteristics specified in the technical specification shall be verified on the product submitted for qualification.

The qualification procedure of the diaphragm, with the exception of those supplied by a new supplier, can be simplified in accordance with the quality system in force with the supplier.

The verification of known characteristics can be optional.

A simplified qualification process shall be, in any case, subject to a separate agreement between customer and supplier.

The checks shall be performed in accordance with the requirements of the technical specification.

The laboratory or laboratories that perform the qualification tests shall be designated after agreement of the customer.

11.2.4 Validity of the product qualification

After the qualification of the product, any modification in design, technology, composition, changes in manufacturing process or modifications in the manufacturing plant, shall be reported to the customer for approval before implementation.

The customer may in this case question the validity of the product qualification.

Qualification may also be thrown into doubt after:

— interruption of the manufacturing process for more than two years;

— operating incidents that throw doubt on the diaphragm's quality.

12 Inspection and quality surveillance

For the purposes of the present clause, the definitions given in EN ISO 9000 apply.

The supplier shall propose the methods for checking the manufacturing quality of his products within a quality plan submitted for the approval of the customer.

The customer may require verification of specific characteristics, according to Table 2.

Annex A
(informative)

Types of diaphragms

A.1 Object

To illustrate examples of diaphragms and typical installations.

A.2 Illustration of typical diaphragm installations

NOTE The examples shown diaphragm include interfaces which will influence the suspension characteristics. Others types of diaphragm installations could exist.

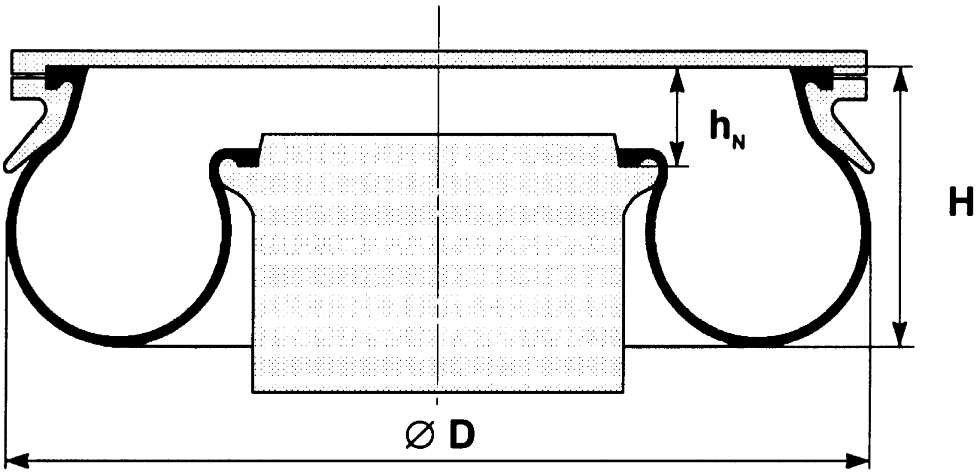


Figure A.1 — Unrestricted diaphragm (example)

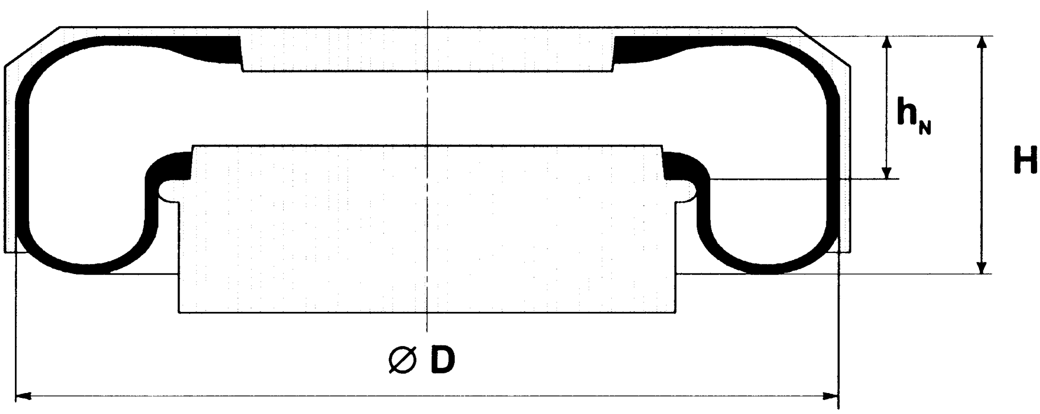


Figure A.2 — Restricted diaphragm (example)

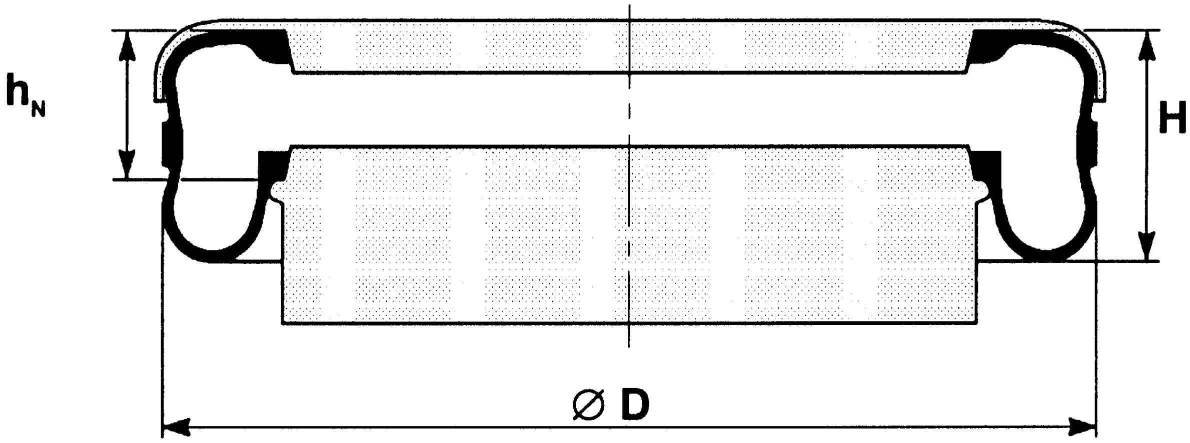


Figure A.3 — Belted diaphragm (example)

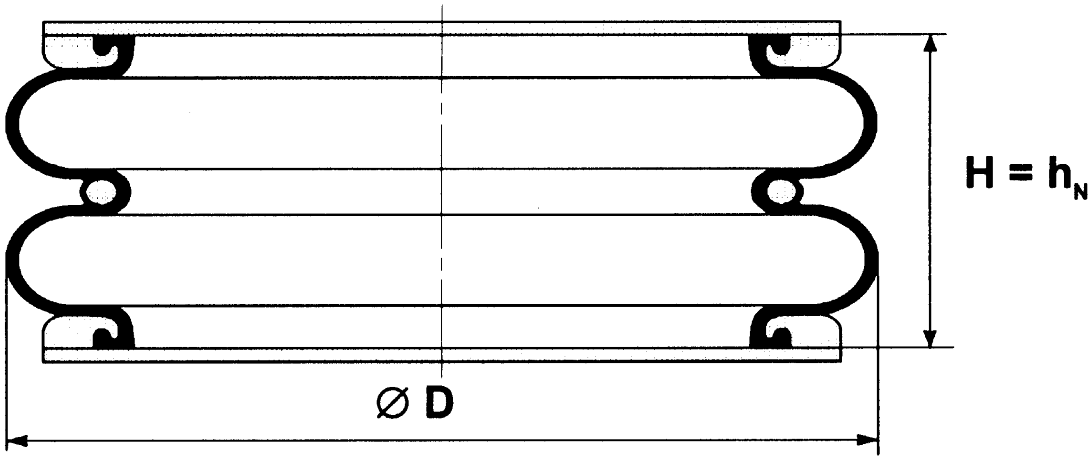


Figure A.4 — Convoluted diaphragm (example)

Annex B
(normative)

Test pieces taken from diaphragms

B.1 Object

To define zones for taking test pieces from a diaphragm.

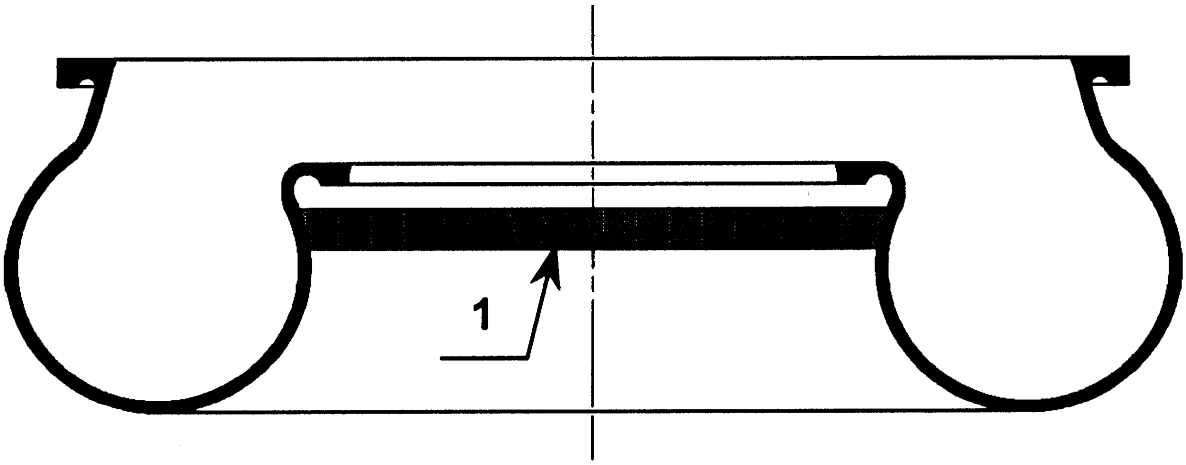
B.2 Preparation of test pieces

Tests pieces shall be prepared at least 24 h before tests in accordance with ISO 471.

B.3 Definition of zones for taking test pieces on diaphragms

Test pieces shall be taken from diaphragms in the positions defined below.

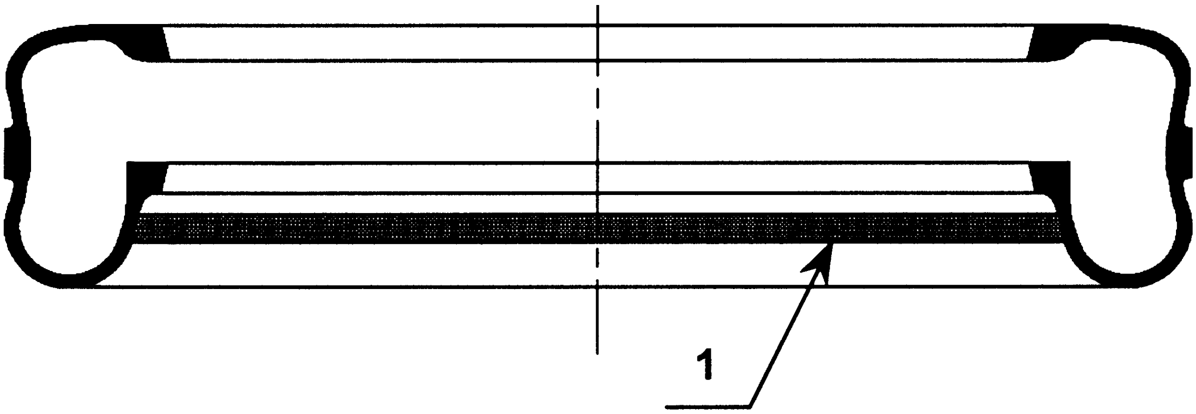
Where no example is given, the zone for taking test pieces shall be defined in the technical specification.



Key

1 Zone for taking test samples

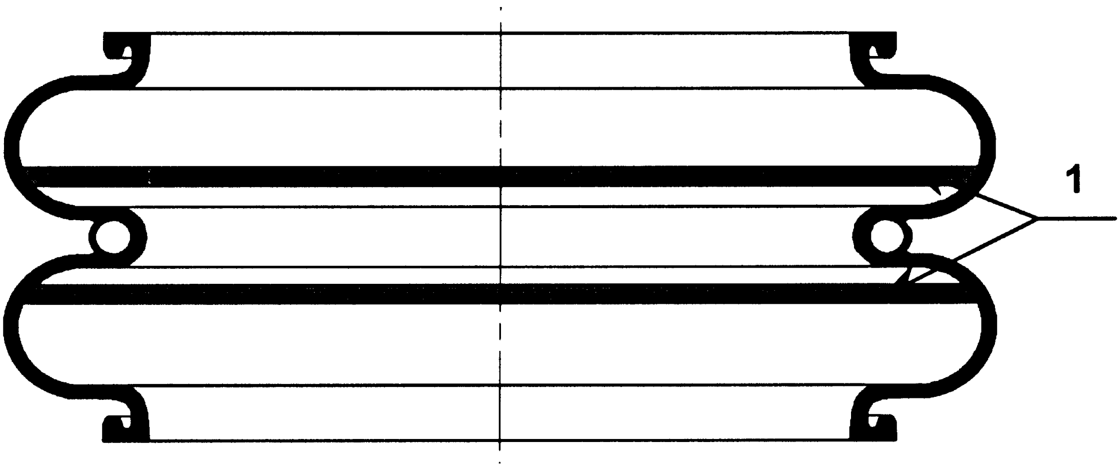
Figure B.1 — Unrestricted diaphragm (example)



Key

1 Zone for taking test samples

Figure B.2 — Belted diaphragm (example)



Key

1 Zone for taking test samples

Figure B.3 — Convoluted diaphragm (example)

Annex C
(informative)

Example of fatigue test programme

C.1 Object

To define a fatigue test programme applicable to diaphragms which are mounted in vertical secondary suspension of vehicles (between body and bogie).

This test should be carried out during the fatigue resistance inspection (see 7.3.6).

C.2 Test method

The test consists in applying alternating movements to the diaphragm radially, representative of those to which it is subject when the vehicle on which it is fitted or on which it is to be fitted, is running on a track of short radius of curvature.

If there is no specific customer requirements, the test device should allow:

— fastening of the diaphragm under conditions similar to those applying when it is mounted on bogies;

— application to one of the bases of the diaphragm of a horizontal alternating movement, around a vertical axis centred on the bogie pivot, with the other diaphragm base held fixed;

— positioning of the two diaphragms bases either in alignment or with a radial offset equal to the transverse clearance between body and bogie depending of the kind of the air spring;

— pressurisation of the diaphragm.

The test should consist of at least four sequences of 50 000 cycles. The other parameters, given in Table C.1 as examples, should be adjusted to validate the test.

Table C.1 — Test programme (example)

Sequence	Number of cycles	Pressure	Radial displacement of diaphragm bases
1	50 000	p_0	0
2	50 000	90 % of p_0	0
3	50 000	p_0	d_M
4	50 000	90 % of p_0	d_M

In all sequences, the amplitude of the movement imposed on one of the diaphragm bases should be:

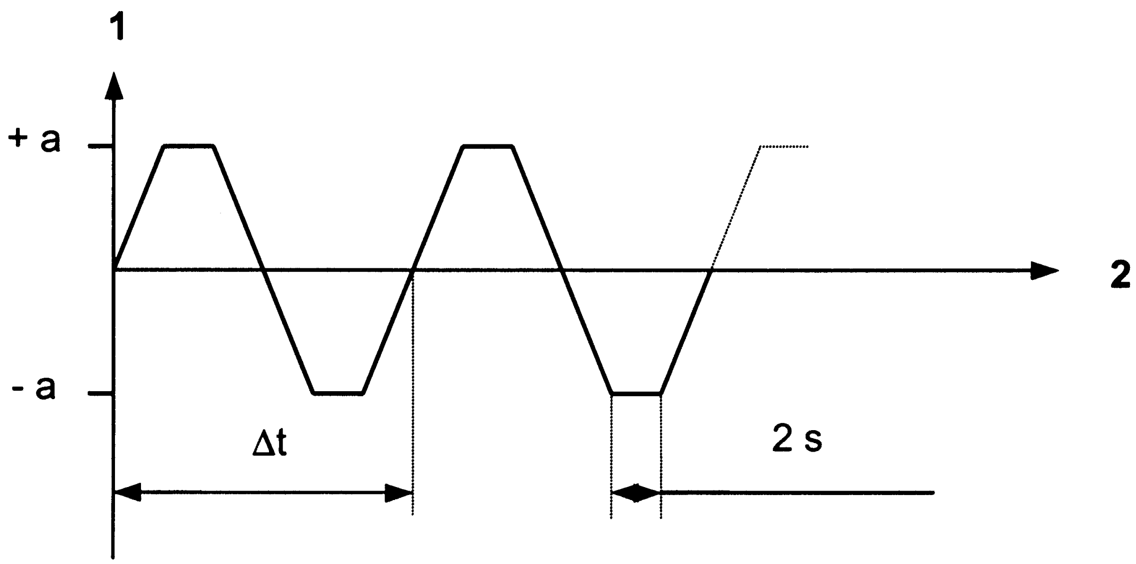
$a = (L_B \times L_b) / R_c$ where

L_B: half of the distance between the bogie pivots;

L_b: distance from the diaphragm to the bogie pivot;

R_c: radius of the track curve, taken as 150 m if not specified.

The movement applied to one of the diaphragm bases as a function of time is illustrated below:



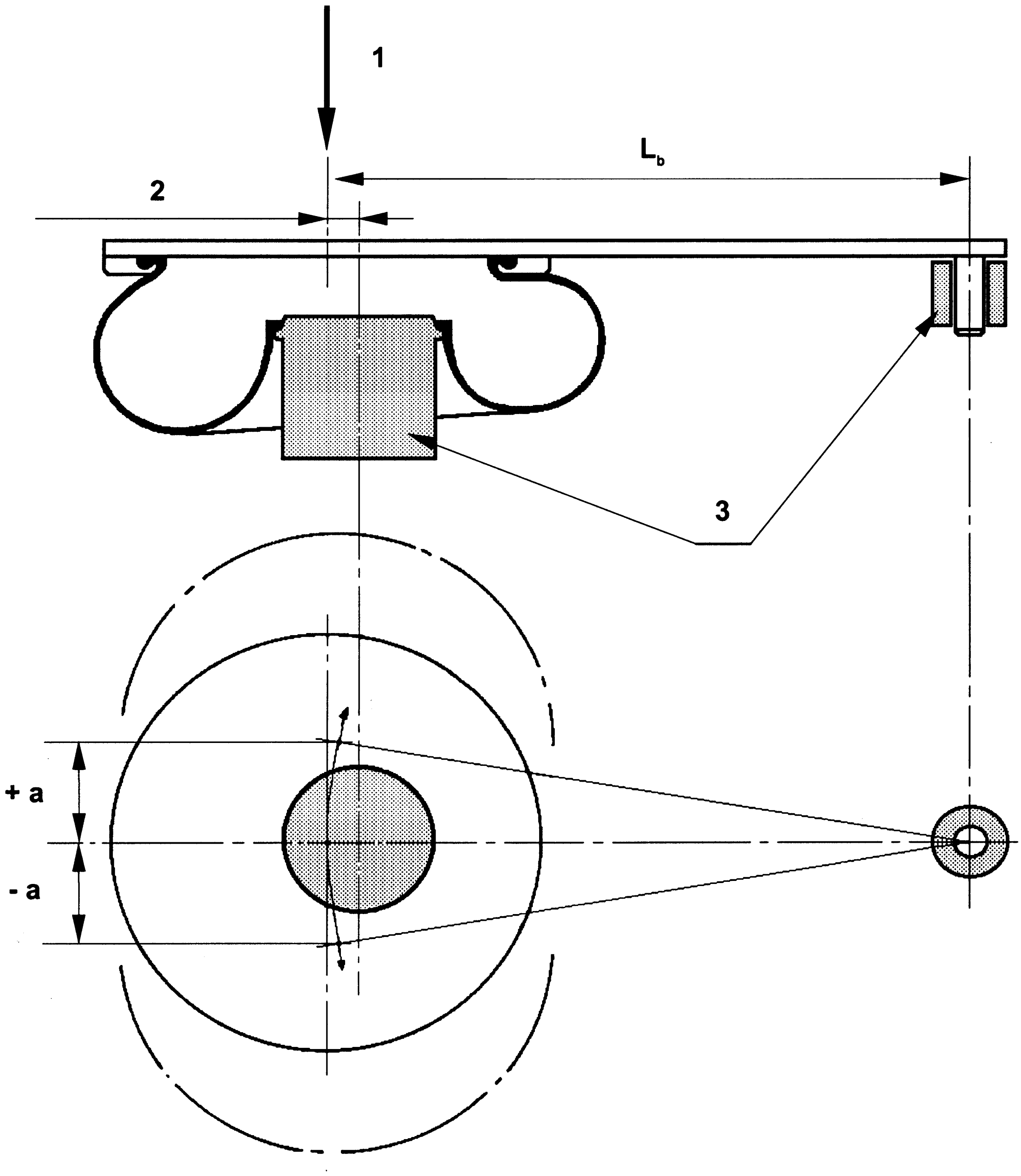
Key

1 Amplitude (*a*)

2 Time (*t*)

Figure C.1 — Diagram "amplitude versus time"

NOTE The period Δt should be adjusted in order to avoid any heating of the diaphragm.



Key

1 Axial static force F_j
2 Radial displacement
3 Fixed parts

Figure C.2 — Test principle

Annex D
(normative)

Qualification procedure

D.1 Object

To define the minimum testing requirements and the order in which they shall be performed.

D.2 Qualification procedure

The phases described below shall be carried out in the order given.

Table D.1 — Phase 1

Characteristic	Characteristic definition (sub-clause)	Inspection and test method (sub-clause)	Test or inspection
Appearance of diaphragms in new condition	6.3.1	7.3.1	mandatory
Appearance of diaphragms under extreme horizontal deformations	6.3.2	7.3.2	mandatory
Pressure resistance	6.3.4	7.3.4	mandatory
Air-tightness	6.3.5	7.3.5	mandatory
Overall dimensions of new diaphragms	6.4.2	7.4.1	mandatory

Table D.2 — Phase 2

Characteristic	Characteristic definition (sub-clause)	Inspection and test method (sub-clause)	Test or inspection
Axial stiffness at constant velocity	6.5.1.2	7.5.1.2.2	optional
Radial stiffness at constant velocity	6.5.1.3	7.5.1.2.3	optional
Rotational stiffness at constant velocity	6.5.1.4	7.5.1.2.4	optional
Axial stiffness under sinusoidal motion	6.5.1.5	7.5.1.3.2	optional
Radial stiffness under sinusoidal motion	6.5.1.6	7.5.1.3.3	optional
Rotational stiffness under sinusoidal motion	6.5.1.7	7.5.1.3.4	optional
Characteristic ″pressure-force″	6.5.2	7.5.2	optional
Axial isobar characteristic	6.5.3	7.5.3	optional

NOTE An optional test becomes mandatory when this characteristic is defined in the technical specification.

Table D.3 — Phase 3

Characteristic	Characteristic definition (sub-clause)	Inspection and test method (sub-clause)	Test or inspection
Fatigue resistance	6.3.6	7.3.6	mandatory
Overall dimensions of grown diaphragms	6.4.3	7.4.1; 7.4.2; 7.4.3	mandatory
Burst resistance	6.3.7	7.3.7	mandatory

NOTE All the characteristics specified in Table D.3, should be checked on the same diaphragm and in the order in which they are listed.

Table D.4 — Phase 4

Characteristic	Characteristic definition (sub-clause)	Inspection and test method (sub-clause)	Test or inspection
Low temperature	6.2.1	7.2.1	mandatory
Ozone	6.2.2	7.2.2	mandatory
Oil and petroleum product	6.2.3	7.2.3	mandatory
Cleaning product	6.2.4	7.2.4	optional
Abrasion	6.2.5	7.2.5	mandatory
Fire behaviour	6.2.6	7.2.6	optional
Adherence between plies	6.3.3	7.3.3	mandatory

NOTE An optional test becomes mandatory when this characteristic is defined in the technical specification.

Annex E
(informative)

Recommended tolerances to characteristics of diaphragms

E.1 Object

The present annex is a guide for the definition of tolerances applying on the functional characteristics of diaphragms.

NOTE The closest tolerances should be specified only where the application requires it. Closer tolerances demand stricter control during manufacture and, consequently, the cost of the product is increased.

E.2 Tolerance classes

Tolerances should be identified in the technical specification of the diaphragm.

Practical tolerance limits are shown in Table E.1, and wherever possible these should not be exceeded.

Where different tolerances are to be specified, these tolerances should be agreed between the supplier and the customer.

Table E.1 — Tolerances on functional characteristics

Characteristic	Close Tolerance	Normal Tolerance
Axial stiffness at constant velocity	± 5 %	± 7 %
Radial stiffness at constant velocity	± 10 %	± 15 %
Rotational stiffness at constant velocity	± 15 %	± 20 %
Characteristic ″pressure-force″	± 3 %	± 5 %
Axial isobar characteristic	± 3 %	± 5 %
Axial stiffness under sinusoidal motion	± 5 %	± 7 %
Radial stiffness under sinusoidal motion	± 10 %	± 15 %
Rotational stiffness under sinusoidal motion	± 15 %	± 20 %

Bibliography

[1] EN ISO 9000, *Quality management systems – Fundamentals and vocabulary (ISO 9000:2000).*

[2] EN ISO 9001, *Quality management systems – Requirements (ISO 9001:2000).*

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