INTERNATIONAL STANDARD

ISO 7902-3

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Hydrodynamic plain journal bearings under steady-state conditions — Circular cylindrical bearings —

Part 3:
Permissible operational parameters

Paliers lisses hydrodynamiques radiaux fonctionnant en régime stabilisé — Paliers circulaires cylindriques —

Partie 3: Paramètres opérationnels admissibles

Reference number
ISO 7902-3:1998(E)

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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 7902-3 was prepared by Technical Committee ISO/TC 123, *Plain bearings*, Subcommittee SC 4, *Methods of calculation of plain bearings*.

ISO 7902 consists of the following parts, under the general title *Hydrodynamic plain journal bearings under steady-state conditions — Circular cylindrical bearings*:

— *Part 1: Calculation procedure*

— *Part 2: Functions used in the calculation procedure*

— *Part 3: Permissible operational parameters*

Annex A of this part of ISO 7902 is for information only.

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet central@iso.ch
X.400 c=ch; a=400net; p=iso; o=isocs; s=central

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Introduction

In order to attain sufficient operational reliability of circular cylindrical plain journal bearings when calculated in accordance with ISO 7902-1, it is essential that the calculated operational parameters h_{min}, T_B or T_{ex} and $\overline{p}$ do not lie above or below the permissible operational parameters h_{lim}, T_{lim} and $\overline{p}_{lim}$. The permissible parameters represent geometrically and technologically dependent operational limits within the plain bearing tribological system. They are empirical values which still enable sufficient operational reliability even for minor influences (see ISO 7902-1).

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Part 3:
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1 Scope

This part of ISO 7902 specifies empirical permissible values for h_{lim}, T_{lim} and $\bar{p}_{lim}$.

The empirical values stated can be modified for certain applications, for example if information supplied by the manufacturer is to be taken into account. The descriptions of the symbols and calculation examples are given in ISO 7902-1.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 7902. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 7902 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7902-1:1998, *Hydrodynamic plain journal bearings under steady-state conditions — Circular cylindrical bearings — Part 1: Calculation procedure.*

3 Operational parameters to avoid wear

3.1 The aim of keeping above the minimum permissible lubrication film thickness h_{lim} is to retain complete lubrication of the plain bearing in order to attain least possible wear and low susceptibility to faults. The lubricant should be free of contaminating particles, otherwise increased wear, scoring and local overheating can result, thus impairing correct functioning of the plain bearing. If necessary, appropriate filtering of the lubricant should be provided for.

3.2 The minimum permissible lubrication film thickness h_{lim}, as a characteristic parameter for the transition to mixed friction (see ISO 7902-1:1998, 6.6), can be determined from the following equation:

$$h_{lim} = Rz_B + Rz_J + \frac{1}{2}By + \frac{1}{2}y + h_{wav,eff} \qquad \ldots (1)$$

This takes into account

— the sum of the mean peak-to-valley heights of bearing and shaft at the ideal location (line X-X) [$Rz_B + Rz_J$]

— the misalignment (line Y-Y) within the bearing length [1/2 By]

— the mean deflection (line Z-Z) [1/2 y]

3.3 If wavy geometrical deviations occur in the sliding surfaces (bearing or shaft) in the circumferential direction, they are taken into account during the determination of h_{lim} by the effective waviness $h_{wav,eff}$ for the most unfavourable shaft position. In this case, $h_{wav,eff}$ is the effective waviness of the bearing under static loading or the effective waviness of the shaft under rotating loading, respectively.

The effective waviness $h_{wav,eff}$ and the maximum permissible effective waviness $h_{wav,eff,lim}$ at a given operating point (ε or h_{lim}) can be determined using figure 2 if roughnesses, deformations and tilt positions are known.

3.4 In accordance with equation (1), the following applies:

$$h_{lim} = m + h_{wav,eff}$$

where

$$m = Rz_B + Rz_J + \frac{1}{2} By + \frac{1}{2} y$$

$$h_{wav,eff} = \frac{E}{G} a$$

With a given minimum lubricant film thickness h_{min} the maximum permissible effective waviness amplitude is determined from

$$h_{wav,eff,lim} = h_{min} - m$$

The maximum permissible absolute waviness, $h_{wav,eff,lim}$, is determined from

$$h_{wav,lim} = \frac{G}{E} h_{wav,eff,lim}$$

3.5 An example of the determination of $h_{wav,eff}$, h_{lim}, $h_{wav,eff,lim}$ and $h_{wav,lim}$ (from figure 2) is as follows.

Given quantities:

$B/D = 0,5$

$C/2 = 85 \times 10^{-6}$ m

$m = 6 \times 10^{-6}$ m

$h_{wav} = 5 \times 10^{-6}$ m

$i = 6$

$h_{min} = 8,5 \times 10^{-6}$ m

$$\varepsilon = 1 - \frac{h_{min}}{C/2} = 0,9$$

With $B/D = 0{,}5$, figure 2 gives $E = 0{,}86$.

With $i = 6$ and $\varepsilon = 0{,}9$, figure 2 gives $G = 1{,}85$.

Hence

$$h_{\text{wav,eff}} = \frac{0{,}86}{1{,}85} \times 5 \times 10^{-6}\ \text{m} = 2{,}32 \times 10^{-6}\ \text{m}$$

and

$$h_{\text{lim}} = 6 \times 10^{-6}\ \text{m} + 2{,}32 \times 10^{-6}\ \text{m} = 8{,}32 \times 10^{-6}\ \text{m}$$

Since $h_{\text{min}} > h_{\text{lim}}$, $h_{\text{min}} = 8{,}5 \times 10^{-6}$ m is permissible.

$$h_{\text{wav,eff,lim}} = 8{,}5 \times 10^{-6}\ \text{m} - 6 \times 10^{-6}\ \text{m} = 2{,}5 \times 10^{-6}\ \text{m}$$

$$h_{\text{wav,lim}} = \frac{1{,}85}{0{,}86} \times 2{,}5 \times 10^{-6}\ \text{m} = 5{,}38 \times 10^{-6}\ \text{m}$$

3.6 In general, deviations of form are irregular. For the determination of $h_{\text{wav,eff}}$, the waves in the sliding surface area under load are significant.

For running-in processes under low load and sliding velocity, it is possible to allow a lower minimum film thickness owing to the smoothing and adjusting of the sliding surfaces. If necessary, a bearing material having a good running-in ability shall be used.

Table 1 gives empirical permissible values for h_{lim}, in which a mean peak-to-valley height of $Rz_{\text{J}} \leqslant 4$ µm for the shaft, minor geometrical errors of the sliding surfaces, careful assembly and adequate filtering of the lubricant are assumed.

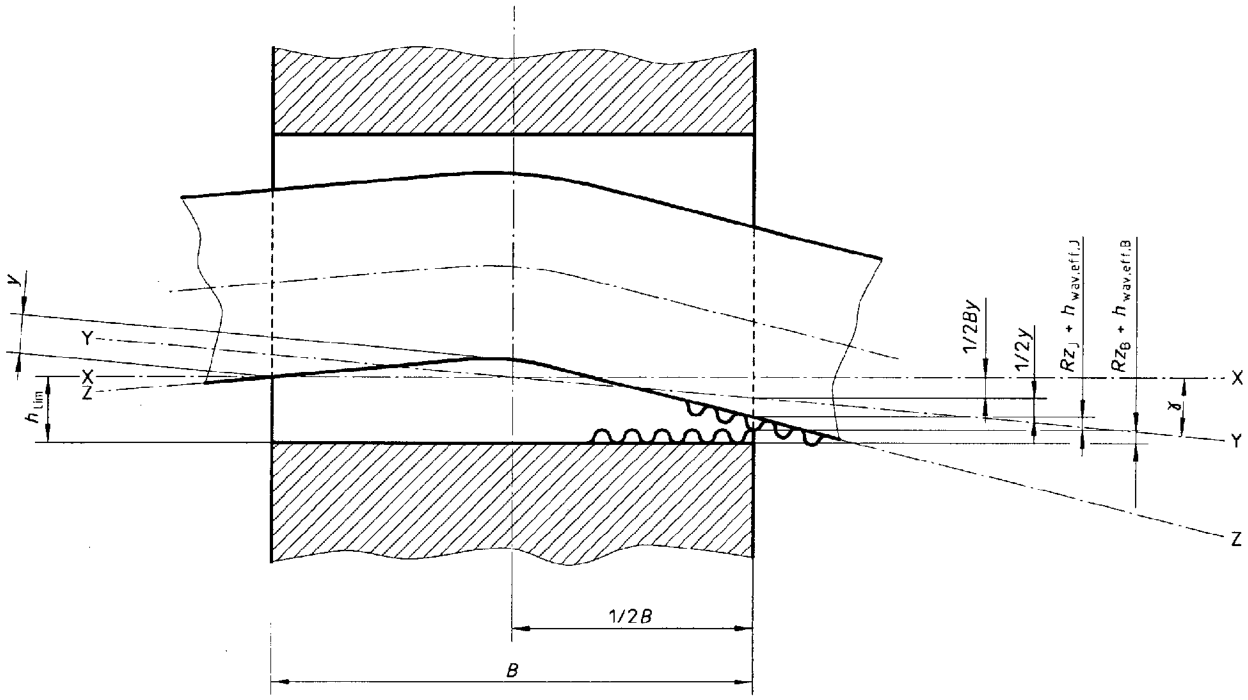


Figure 1 — Minimum permissible lubrication film thickness when no running-in process is allowed

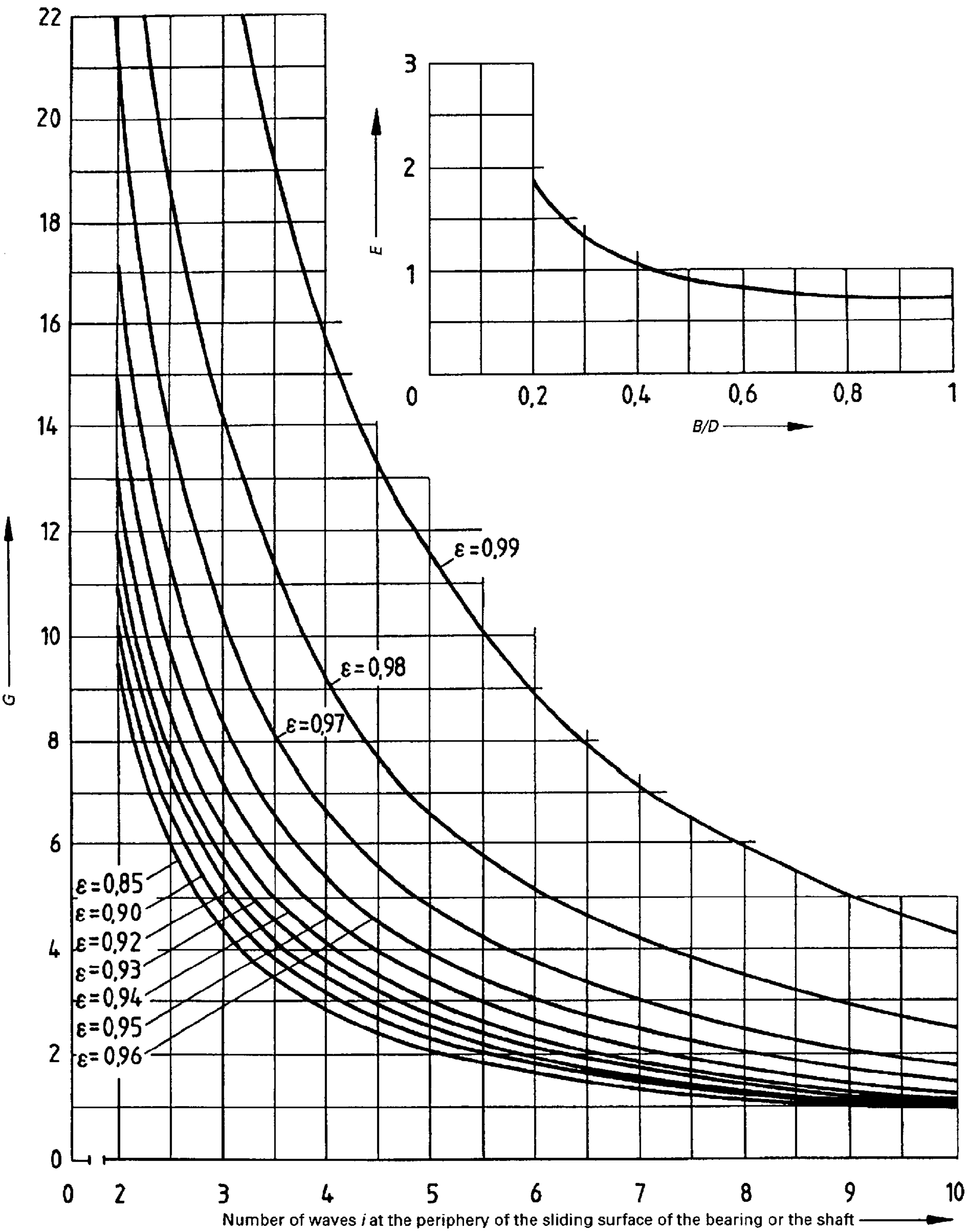
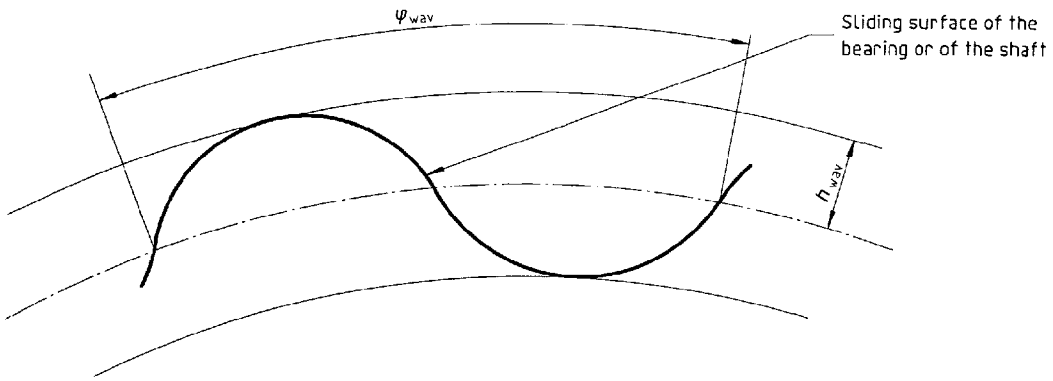


Figure 2 — Determination of the effective waviness $h_{wav,eff}$ and the maximum permissible effective waviness $h_{wav,eff,lim}$

Table 1 — Empirical permissible values for the minimum permissible least lubricant film thickness, h_{lim}

Minimum permissible thicknesses in micrometres

Shaft diameter, D_J mm	Sliding velocity of shaft, U_J m/s				
	$U_J \leqslant 1$	$1 < U_J \leqslant 3$	$3 < U_J \leqslant 10$	$10 < U_J \leqslant 30$	$30 < U_J$
$24 < D_J \leqslant 63$	3	4	5	7	10
$63 < D_J \leqslant 160$	4	5	7	9	12
$160 < D_J \leqslant 400$	6	7	9	11	14
$400 < D_J \leqslant 1\,000$	8	9	11	13	16
$1\,000 < D_J \leqslant 2\,500$	10	12	14	16	18



Number of waves $i = \frac{360°}{\varphi_{wav}}$

Figure 3 — Absolute waviness amplitude, h_{wav}, period of waviness, φ_{wav} and number of waves, i, of the sliding surface

4 Operational parameters to avoid excessive mechanical loading

The maximum permissible specific bearing load, p_{lim}, is the result of the requirement that a deformation of the sliding surfaces may not result in impairment of correct functioning and the formation of cracks. In addition to the composition of the bearing material, there are many other decisive influencing factors, such as the method of manufacture, the material structure, the thickness of bearing material and the geometry and type of bearing liner backing. Independently of these, a check shall be made as to whether the bearing is subjected to the full load when starting. If the specific bearing load during starting, p, is greater than 2,5 N/mm² to 3 N/mm², it may be necessary to provide relief by pressurized oil (auxiliary hydrostatic device). Otherwise wear can occur on the sliding surfaces. Table 2 gives empirical values for $\bar{p}_{lim}$.

Table 2 — Empirical values for the maximum permissible specific bearing load, $\bar{p}_{lim}$

Bearing material group[1)]	$\bar{p}_{lim}$ [2) 3)] MPa
Pb and Sn alloys	5 (15)
Cu-Pb alloys	7 (20)
Cu-Sn alloys	7 (25)
Al-Sn alloys	7 (18)
Al-Zn alloys	7 (20)

1) ISO 4381, ISO 4382-1, ISO 4382-2 and ISO 4383.

2) The values in parentheses have, up to now, been realized for general mechanical engineering applications only in isolated instances, and are, in exceptional cases, permitted if there are special operational conditions, for example at very low sliding speeds.

3) 1 MPa = 1 N/mm²

5 Operational parameters to avoid excessive thermal loading

5.1 The maximum permissible bearing temperature, T_{lim}, is dependent on the bearing material and the lubricant.

With increasing temperature, hardness and strength of the bearing material decrease. This is particularly noticeable for lead and tin alloys because of their low melting points.

In addition, lubricant viscosity decreases as temperature increases. The load-carrying capacity of the plain bearing is therefore reduced, resulting, under certain circumstances, in mixed friction with wear. Furthermore, at temperatures greater than 80 °C, ageing of lubricants based on mineral oils increases.

5.2 During steady-state operation of the plain bearing, the temperature field is constant. When carrying out the plain bearing calculation in accordance with ISO 7902, the thermal bearing load may be described by the bearing temperature, T_B, or by the lubricant outlet temperature, T_{ex}, provided they do not exceed T_{lim}.

5.3 Table 3 gives general empirical values for T_{lim} in which it is taken into account that the maximum value of the temperature field is greater than the calculated bearing temperature, T_B, or than the calculated lubricant outlet temperature T_{ex}.

Table 3 — Empirical permissible values for the maximum permissible bearing temperature, T_{lim}

Type of bearing lubrication	T_{lim}, °C 1)	
	Ratio of overall lubricant volume to lubricant volume per minute (lubricant flow rate)	
	up to 5	greater than 5
Force-feed lubrication (circulating lubrication)	100 (115)	110 (125)
Lubrication without pressure (autolubrication)	90 (110)	
1) The values in parentheses may be permitted, in exceptional cases, under special operational conditions.		

5.4 From the total quantity of lubricant available for bearing lubrication, there is always only a small proportion for a limited period within the clearance gap and hence at an increased temperature level. This means that T_B or T_{ex} is important for the service life of the lubricant flow rate. This ratio is, in general, more favourable for circumferentially-lubricated bearings than for self-lubricated bearings.

6 Operational parameters for the bearing clearance

6.1 The bearing clearance greatly influences the operational behaviour of the plain bearing. Although its magnitude would actually be determined taking into account all other operational data, in practice the following approximate formula has proven of value. According to this formula, the mean relative bearing clearance, $\overline{\psi}$, in thousandths, is calculated as a function of the peripheral speed, U_J, in metres per second, only:

$$\overline{\psi} = 0{,}8\sqrt[4]{U_J}$$

Experience has shown that it is sometimes difficult to realize an appropriate clearance fit using the tolerances specified in ISO 286-2. Sometimes deviations greater than the mean value calculated using this formula occur.

For this reason, the bearing clearance should preferably be

0,56 0,8 1,12 1,32 1,6 1,9 2,24 3,15 (‰)

in which the main relative bearing clearances are in steps based on the preferred number series.

6.2 Table 4 gives general empirical values for $\overline{\psi}$, based not only on the peripheral speed but also on the diameter. The reason for this is that for the same Sommerfeld numbers and same B/D ratios, the highest temperature measured in the bearing increases as diameter decreases. Choosing bearing clearance from table 4 reduces this tendency.

Table 4 does not take into account exceptional influences such as:

— high shaft temperature due to thermal conduction from outside into the bearing;

— large elastic deformation due to the bearing load;

— large thermal deformation or large thermal expansion differentials between shaft and bearing;

— lubricants having a particularly high or low viscosity.

For the calculation of the operational bearing clearance, see ISO 7902-1:1998, 6.7.

Table 4 — Empirical permissible values for the mean relative bearing clearance, $\overline{\psi}$

Mean relative bearing clearances in thousandths

Shaft diameter, D_J mm	Sliding velocity of shaft, U_J m/s				
	$U_J \leqslant 1$	$1 < U_J \leqslant 3$	$3 < U_J \leqslant 10$	$10 < U_J \leqslant 30$	$30 < U_J$
$D_J \leqslant 100$	1,32	1,6	1,9	2,24	2,24
$100 < D_J \leqslant 250$	1,12	1,32	1,6	1,9	2,24
$250 < D_J$	1,12	1,12	1,32	1,6	1,9

Annex A
(informative)

Bibliography

[1] ISO 286-2:1988, *ISO system of limits and fits — Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts.*

[2] ISO 4381:1991, *Plain bearings — Lead and tin casting alloys for multilayer plain bearings.*

[3] ISO 4382-1:1991, *Plain bearings — Copper alloys — Part 1: Cast copper alloys for solid and multilayer thick-walled plain bearings.*

[4] ISO 4382-2:1991, *Plain bearings — Copper alloys — Part 2: Wrought copper alloys for solid plain bearings.*

[5] ISO 4383:1991, *Plain bearings — Multilayer materials for thin-walled plain bearings.*

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Descriptors: bearings, plain bearings, rules of calculation.

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