

First edition  
2003-12-01

Corrected version  
2004-09-15

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## Rolling bearings — Thermal speed rating — Calculation and coefficients

*Roulements — Vitesse de référence thermique — Calculs et facteurs  
de correction*

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Reference number  
ISO 15312:2003(E)

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Published in Switzerland

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## Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15312 was prepared by Technical Committee ISO/TC 4, *Rolling bearings*, Subcommittee SC 8, *Load ratings and life*.

In this corrected version of ISO 15312:2003, the status of both Annex A and Annex B has been changed from normative to informative.

# Rolling bearings — Thermal speed rating — Calculation and coefficients

## 1 Scope

This International Standard defines the thermal speed rating for oil bath lubricated rolling bearings and defines calculation principles for the determination of this parameter. The parameter determined in accordance with this International Standard applies to rolling bearings of the given series and sizes of standard design or of a design that, from a frictional point of view, can be related to a standard design bearing.

In most cases of standard assembly, the permissible temperature determines the maximum operating speed. Heating of the assembly is then generated by the bearing.

Thrust ball bearings are excluded from this International Standard as kinematic effects do not allow the thermal speed rating defined in this International Standard to be applied.

NOTE 1 In Annex A mean values for the coefficients  $f_{0r}$  and  $f_{1r}$  are given —  $f_{0r}$  for calculating viscous losses of oil bath lubricated bearings and  $f_{1r}$  for calculating frictional losses of bearings.

NOTE 2 In Annex B the reference conditions for grease lubrication are defined. The reference conditions are chosen such that the thermal speed rating for grease lubrication is identical to that for oil bath lubrication.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 76:1987, *Rolling bearings — Static load ratings*

ISO 1132-1:2000, *Rolling bearings — Tolerances — Part 1: Terms and definitions*

ISO 5593:1997, *Rolling bearings — Vocabulary*

ISO 5753:1991, *Rolling bearings — Radial internal clearance*

ISO 15241:2001, *Rolling bearings — Symbols for quantities*

### 3 Terms and definitions

For the purposes of this document the terms and definitions given in ISO 1132-1, ISO 5593 and the following apply.

**3.1**  
**thermal speed rating**  
inner ring or shaft washer rotational speed at which equilibrium is reached between the heat generated by the friction in the bearing and the heat flow emitted through the bearing seating (shaft and housing) under the reference conditions

NOTE 1 The thermal speed rating is one among various criteria which permit comparison of the different rolling bearing types and sizes with regard to their suitability for operation at high speed.

NOTE 2 Mechanical and kinematic criteria which could lead to further speed limitations are not taken into account by the thermal speed rating.

**3.2**  
**reference conditions**  
conditions for the thermal speed rating related to

- a) the mean temperature of the stationary outer ring or housing washer of the bearing, i.e. the reference temperature, and the mean environmental temperature, i.e. the reference ambient temperature;
- b) the factors determining the friction losses in the bearing, such as:
  - the magnitude and direction of the bearing load;
  - the method of lubrication, type of lubricant, its kinematic viscosity and quantity;
  - other general reference conditions;
- c) the heat flow emitted from the rolling bearing defined as the product of the "heat emitting reference surface area of the rolling bearing" and the "reference heat flow density specific to the rolling bearing".

NOTE The heat emission under the reference conditions is based on empirical values and represents the heat emission of the real bearing arrangement. It is, however, independent of the real design of the bearing arrangement.

**3.3**  
**heat emitting reference surface area**  
sum of the contact areas, between inner ring (shaft washer) and shaft and between outer ring (housing washer) and housing, through which the heat flow is emitted

**3.4**  
**reference load**  
bearing load, determined by the reference conditions, which causes the load-dependent frictional moment

**3.5**  
**reference heat flow**  
heat flow, emitted by thermal conduction through the heat emitting reference surface, and caused by frictional resistance, when the bearing is operating under the reference conditions

**3.6**  
**reference heat flow density**  
reference heat flow divided by the heat emitting reference surface area

**3.7**  
**reference ambient temperature**  
mean environmental temperature of the bearing arrangement under the reference conditions

## 3.8

**reference temperature**

mean temperature of the stationary outer ring or housing washer of the bearing under the reference conditions

## 4 Symbols and units

For the purposes of this document, the symbols given in ISO 15241 and the following apply.

**Table 1 — Symbols and units**

Symbol	Term	Unit
$A_r$	Heat emitting reference surface area	mm <sup>2</sup>
$B$	Width of rolling bearing	mm
$C_{0a}$	Basic static axial load rating in accordance with ISO 76	N
$C_{0r}$	Basic static radial load rating in accordance with ISO 76	N
$d$	Bearing bore diameter	mm
$d_m$	Mean diameter of rolling bearing $d_m = 0,5 \times (D + d)$	mm
$d_1$	Outside diameter of the inner ring of thrust spherical roller bearing	mm
$D$	Bearing outside diameter	mm
$D_1$	Inside diameter of the outer ring of thrust spherical roller bearing	mm
$f_{0r}$	Coefficient for the load-independent frictional moment for the reference conditions	1
$f_{1r}$	Coefficient for the load-dependent frictional moment for the reference conditions	1
$M_0$	Load-independent frictional moment	N·mm
$M_{0r}$	Load-independent frictional moment under the reference conditions at the thermal speed rating, $n_{\theta r}$	N·mm
$M_1$	Load-dependent frictional moment	N·mm
$M_{1r}$	Load-dependent frictional moment under the reference conditions at the thermal speed rating, $n_{\theta r}$	N·mm
$n_{\theta r}$	Thermal speed rating	min <sup>-1</sup>
$N_r$	Bearing power loss under the reference conditions at the thermal speed rating, $n_{\theta r}$	W
$P_{1r}$	Reference load	N
$q_r$	Reference heat flow density	W/mm <sup>2</sup>
$T$	Total width of tapered roller bearing	mm
$\alpha$	Contact angle	°
$\theta_{Ar}$	Reference ambient temperature	°C
$\theta_r$	Reference temperature	°C
$\nu_r$	Kinematic viscosity of the lubricant under the reference conditions (at the reference temperature, $\theta_r$ , of the rolling bearing)	mm <sup>2</sup> /s
$\Phi_r$	Reference heat flow	W

## 5 Reference conditions

### 5.1 General

The reference conditions in this International Standard are mainly based on the operating conditions of the most frequently used bearing types and sizes.

### 5.2 Reference conditions determining the frictional heat generation

#### 5.2.1 Reference temperatures

Reference temperature of the bearing on the stationary outer ring or housing washer:  $\theta_r = 70\text{ }^{\circ}\text{C}$ .

Reference temperature of the bearing environment:  $\theta_{Ar} = 20\text{ }^{\circ}\text{C}$ .

#### 5.2.2 Reference load

- |  |   |                               |
|--|---|-------------------------------|
| <b>5.2.2.1</b> Radial bearings with contact angle $0^{\circ} \leq \alpha \leq 45^{\circ}$      | 5 % of the basic static radial load rating $C_{0r}$ as pure radial load.<br><br>In the case of a single-row angular contact bearing, the reference load refers to the radial component of that load which causes a purely radial displacement of the bearing rings in relation to each other. | $P_{1r} = 0,05 \times C_{0r}$ |
| <b>5.2.2.2</b> Thrust roller bearings with contact angle $45^{\circ} < \alpha \leq 90^{\circ}$ | 2 % of the basic static axial load rating $C_{0a}$ as centrally acting axial load.  | $P_{1r} = 0,02 \times C_{0a}$ |

#### 5.2.3 Lubrication

- |                                      |  |
|--------------------------------------|--|
| <b>5.2.3.1</b> Lubricant             | A mineral oil without EP additives having the following kinematic viscosity, $\nu_r$ , at $\theta_r = 70\text{ }^{\circ}\text{C}$ :<br><br>a) Radial bearings <span style="float: right;"><math>\nu_r = 12\text{ mm}^2/\text{s}</math> (ISO VG 32)</span><br>b) Thrust roller bearings <span style="float: right;"><math>\nu_r = 24\text{ mm}^2/\text{s}</math> (ISO VG 68)</span> |
| <b>5.2.3.2</b> Method of lubrication | Oil bath lubrication with an oil level up to the centre of the rolling element in the lowest position.   |

#### 5.2.4 Other reference conditions

- |   |  |
|---|--|
| <b>5.2.4.1</b> Bearing characteristics  | standard type bearings up to and including a bore diameter of 1 000 mm   |
| size range  | standard type bearings up to and including a bore diameter of 1 000 mm   |
| internal clearance  | complying with group "N" as specified in ISO 5753:1991   |
| seals   | not provided with contacting seals   |
| double row radial bearings and double direction thrust bearings                             | presumed to be symmetrical   |
| rolling bearings where the rolling elements operate directly on the shaft or in the housing | presumed that the running surface of the shaft or housing is equivalent in all respects to the raceway of the bearing ring or washer which it replaces |



**5.2.4.2 Arrangement of the bearing**

bearing rotational axis                      horizontal

NOTE      For thrust cylindrical roller and needle roller bearings care should be taken to supply oil to the upper rolling elements.

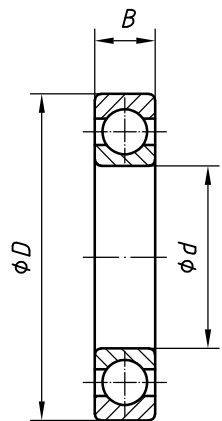
outer ring or housing washer                      stationary

angular contact bearing setting                      zero operating clearance

**5.3 Reference conditions determining the heat emission****5.3.1 Heat emitting reference surface area**

The following surface areas are defined as the heat emitting reference surface area  $A_r$ .

a) For radial bearings with the exception of tapered roller bearings, see Figure 1.

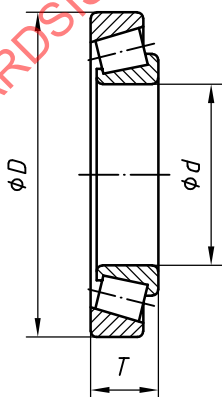


$$A_r = \pi \times B (D + d)$$

(1)

**Figure 1**

b) For tapered roller bearings; see Figure 2.



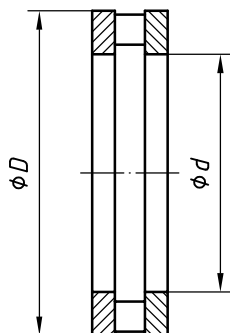
$$A_r = \pi \times T (d + D)$$

(2)

NOTE      The total width of the bearing has been used instead of the individual ring widths to give results that align more correctly with empirical data.

**Figure 2**

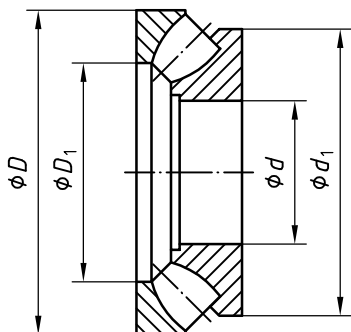
c) For thrust cylindrical roller bearings and thrust needle roller bearings, see Figure 3.



$$A_r = 0,5 \times \pi (D^2 - d^2) \quad (3)$$

Figure 3

d) For thrust spherical roller bearings, see Figure 4.



$$A_r = 0,25 \times \pi (D^2 + d_1^2 - D_1^2 - d^2) \quad (4)$$

Figure 4

### 5.3.2 Reference heat flow density

The reference heat flow density,  $q_r$ , is defined as:

$$q_r = \frac{\Phi_r}{A_r} \quad (5)$$

For normal applications the following values for the heat flow density  $q_r$  may be assumed, when the temperature difference  $\theta_r - \theta_{Ar}$  equals 50 °C:

Radial bearings (see Figure 5, curve 1)

— for  $A_r \leq 50\,000 \text{ mm}^2$   
 $q_r = 0,016 \text{ W/mm}^2$

— for  $A_r > 50\,000 \text{ mm}^2$

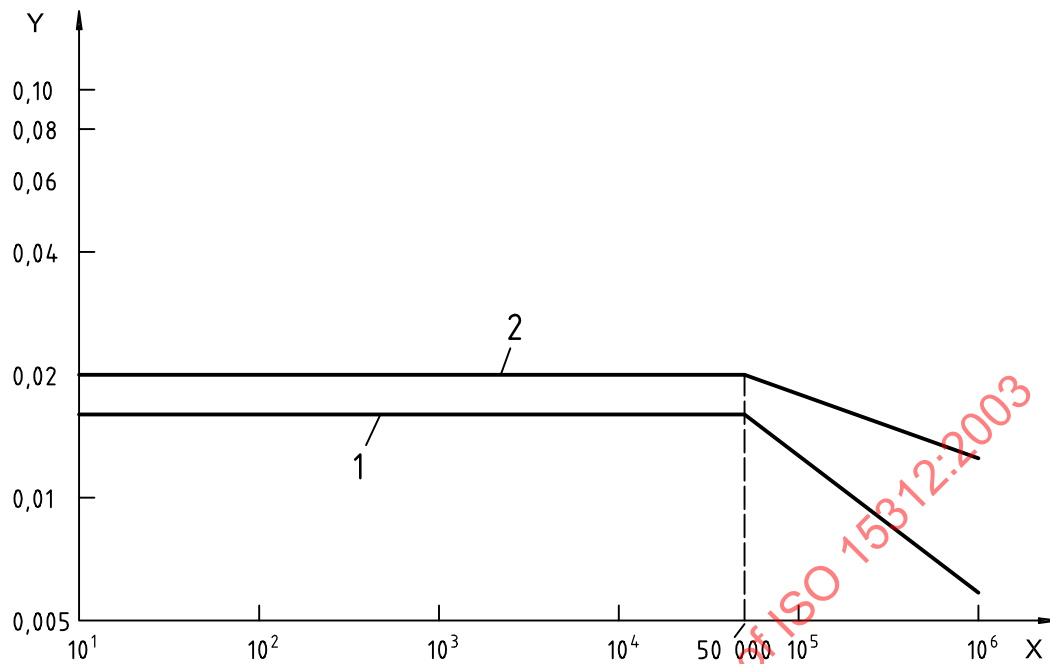
$$q_r = 0,016 \times \left( \frac{A_r}{50\,000} \right)^{-0,34} \text{ W/mm}^2$$

Thrust bearings (see Figure 5, curve 2)

— for  $A_r \leq 50\,000 \text{ mm}^2$   
 $q_r = 0,020 \text{ W/mm}^2$

— for  $A_r > 50\,000 \text{ mm}^2$

$$q_r = 0,020 \times \left( \frac{A_r}{50\,000} \right)^{-0,16} \text{ W/mm}^2$$

**Key**

- 1 radial bearings
- 2 thrust bearings
- X Heat emitting reference surface,  $A_r$ , mm<sup>2</sup>
- Y Reference heat flow density,  $q_r$ , W/mm<sup>2</sup>

**Figure 5****6 Calculation of the thermal speed rating**

The calculation of the thermal speed rating is based on the energy balance in the rolling bearing system under the reference conditions. The frictional heat generated in the bearing under the reference conditions and at the thermal speed rating equals the heat flow emitted from the bearing:

$$N_r = \Phi_r \quad (6)$$

The frictional heat of a bearing running at the thermal speed rating under the reference conditions is calculated as follows:

$$\begin{aligned} N_r &= \frac{\pi \times n_{\theta r}}{30 \times 10^3} (M_{0r} + M_{1r}) \\ &= \frac{\pi \times n_{\theta r}}{30 \times 10^3} [10^{-7} \times f_{0r} (v_r \times n_{\theta r})^{2/3} \times d_m^3 + f_{1r} \times P_{1r} \times d_m] \end{aligned} \quad (7)$$

$$M_{0r} = [10^{-7} \times f_{0r} (v_r \times n_{\theta r})^{2/3} \times d_m^3] \quad (8)$$

$$M_{1r} = f_{1r} \times P_{1r} \times d_m \quad (9)$$

The heat flow emitted from the rolling bearing under the reference conditions is calculated from the reference heat flow density,  $q_r$ , and the heat emitting reference surface area,  $A_r$ :

$$\Phi_r = q_r \times A_r \quad (10)$$

With equation (7) for the frictional heat generated and equation (10) for the heat flow emitted, the equation for the determination of the thermal speed rating  $n_{\theta r}$  is given as:

$$\frac{\pi \times n_{\theta r}}{30 \times 10^3} [10^{-7} \times f_{0r} (v_r \times n_{\theta r})^{2/3} \times d_m^3 + f_{1r} \times P_{1r} \times d_m] = \times q_r \times A_r \quad (11)$$

The thermal speed rating  $n_{\theta r}$  is determined from equation (11) by iteration.

## 7 Explanatory notes

The maximum permissible speed for a bearing can be limited by various criteria, such as the permissible temperature (the most frequently found limiting criterion), ensuring satisfactory lubrication when taking account of centrifugal forces, avoiding fracture of any bearing component, the rolling kinematics, vibrations, noise generation, the running speed of the sealing lips, etc.

In this International Standard, the bearing temperature is used as the limiting criterion to rate the speed capability of the bearing.

The speed capability is expressed as the thermal speed rating. It is calculated for uniform reference conditions. The thermal speed rating may differ appreciably from the speeds so far published by bearing manufacturers in their catalogues as the reference conditions selected for this International Standard may be different.

Friction in the bearing is transformed into heat, so that the bearing temperature increases until an equilibrium is reached between the heat generated and the heat emitted.

The load-independent frictional moment,  $M_0$ , takes account of the viscous friction in the bearing and depends on the rolling bearing type, size (mean rolling bearing diameter), speed and lubrication conditions. These conditions include the method of lubrication, the type of lubricant, its kinematic viscosity and quantity.

The load-dependent frictional moment,  $M_1$ , takes account of the mechanical friction and depends on the rolling bearing type, size (mean rolling bearing diameter) and the magnitude and direction of the load.

The actual heat flow density may differ from the assumed values in this International Standard, depending on varying frictional resistance in relation to heat flow emission capacity; e.g., housing design, environmental conditions and bearing friction have a great influence on the heat flow density.

## Annex A (informative)

### Coefficients $f_{0r}$ and $f_{1r}$

Table A.1 contains values of coefficients  $f_{0r}$  and  $f_{1r}$  for use in the calculation of the thermal speed rating  $n_{\theta r}$  from equation (11) for different bearing types without contacting seals.

They are the result of extensive experimental investigations as well as the analysis of empirical values from literature.

Although the values for  $f_{0r}$  and  $f_{1r}$  naturally scatter, a mean value without tolerances is given in Table A.1, which makes it possible to calculate uniform thermal speed ratings.

The coefficients  $f_{0r}$  and  $f_{1r}$  are dependent on the bearing type.

The dimension series referred to in Table A.1 are those defined in ISO 15 and ISO 104.

**Table A.1 — Coefficients  $f_{0r}$  and  $f_{1r}$**




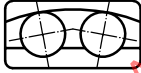


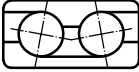
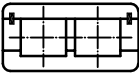


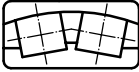

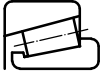


Bearing type	Dimension series	$f_{0r}$	$f_{1r}$	Bearing type	Dimension series	$f_{0r}$	$f_{1r}$
Single-row deep groove ball bearings 	18	1,7	0,000 10	Four-point contact ball bearings 	02	2	0,000 37
	28	1,7	0,000 10		03	3	0,000 37
	38	1,7	0,000 10	Single-row cylindrical roller bearings with cage 	10	2	0,000 20
	19	1,7	0,000 15		02	2	0,000 30
	39	1,7	0,000 15		22	3	0,000 40
	00	1,7	0,000 15		03	2	0,000 35
	10	1,7	0,000 15		23	4	0,000 40
	02	2	0,000 20		04	2	0,000 40
	03	2,3	0,000 20				
	04	2,3	0,000 20				
Self-aligning ball bearings 	02	2,5	0,000 08	Single-row angular contact ball bearings $22^\circ < \alpha \leq 45^\circ$ 	02	2	0,000 25
	22	3	0,000 08		03	3	0,000 35
	03	3,5	0,000 08	Single-row cylindrical roller bearings full complement 	18	5	0,000 55
	23	4	0,000 08		29	6	0,000 55
Single-row angular contact ball bearings $22^\circ < \alpha \leq 45^\circ$	02	2	0,000 25		30	7	0,000 55
	03	3	0,000 35		22	8	0,000 55
					23	12	0,000 55

Table A.1 (continued)

Bearing type	Dimension series	$f_{0r}$	$f_{1r}$	Bearing type	Dimension series	$f_{0r}$	$f_{1r}$
Double-row or paired single-row angular contact ball bearings	32 33	5 7	0,000 35 0,000 35	Double-row cylindrical roller bearings full complement	48 49 50	9 11 13	0,000 55 0,000 55 0,000 55
							
Needle roller bearings	48 49 69	5 5,5 10	0,000 50 0,000 50 0,000 50	Thrust cylindrical roller bearings	11 12	3 4	0,001 50 0,001 50
							
Spherical roller bearings	39 30 40 31 41 22 32 03 23	4,5 4,5 6,5 5,5 7 4 6 3,5 4,5	0,000 17 0,000 17 0,000 27 0,000 27 0,000 49 0,000 19 0,000 36 0,000 19 0,000 30	Thrust needle roller bearings	a	5	0,001 50
							
Tapered roller bearings	02 03 30 29 20 22 23 13 31 32	3 3 3 3 3 4,5 4,5 4,5 4,5 4,5	0,000 40 0,000 40 0,000 40 0,000 40 0,000 40 0,000 40 0,000 40 0,000 40 0,000 40 0,000 40	Thrust spherical roller bearings	92 93 94	3,7 4,5 5	0,000 30 0,000 40 0,000 50
							
				Thrust spherical roller bearings modified design (optimised internal construction)	92 93 94	2,5 3 3,3	0,000 23 0,000 30 0,000 33
							

<sup>a</sup> Dimension series for thrust needle roller bearings according to ISO 3031.