INTERNATIONAL STANDARD

ISO 12131-2

Second edition
2016-09-15

Plain bearings — Hydrodynamic plain thrust pad bearings under steady-state conditions —

Part 2:
Functions for the calculation of thrust pad bearings

Paliers lisses — Butées hydrodynamiques à patins géométrie fixe fonctionnant en régime stationnaire —

Partie 2: Fonctions pour le calcul des butées à segments

Reference number
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Foreword

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

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The committee responsible for this document is ISO/TC 123, *Plain bearings*.

This second edition cancels and replaces the first edition (ISO 12131-2:2001), of which it constitutes a minor revision.

ISO 12131 consists of the following parts, under the general title *Plain bearings — Hydrodynamic plain thrust pad bearings under steady-state conditions*:

- *Part 1: Calculation of thrust pad bearings*
- *Part 2: Functions for the calculation of thrust pad bearings*
- *Part 3: Guide values for the calculation of thrust pad bearings*

Introduction

Assuming hydrodynamic conditions with full lubrication, the functions of the type covered by this part of ISO 12131 are necessary for the calculation of oil-lubricated pad thrust bearings in accordance with ISO 12131-1. They are based on the premises and boundary conditions specified. The values necessary for the calculation can be determined by means of the given formulae, as well as from diagrams and tables. The formulae in this part of ISO 12131 are approximations of the numerically determined values traced as curves according to Reference [2]. The explanation of the symbols, as well as examples for the calculation, are included in ISO 12131-1.

Plain bearings — Hydrodynamic plain thrust pad bearings under steady-state conditions —

Part 2:
Functions for the calculation of thrust pad bearings

1 Scope

This part of ISO 12131 specifies functions for thrust pad bearings. It also covers the effect of dynamic viscosity on lubricant film temperature.

2 Normative references

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

ISO 12131-1, *Plain bearings — Hydrodynamic plain thrust bearings under steady-state conditions — Part 1: Calculation of thrust pad bearings*

3 Functions for the thrust pad bearing

3.1 Characteristic value of load carrying capacity, F_B^*, as a function of the relative bearing length, B/L, and the relative minimum lubricant film thickness, $h_{\min}/C_{\text{wed}}$

Approximation of the curves of Figure 1 (range of application: $0{,}1 \leq \dfrac{h_{\min}}{C_{\text{wed}}} \leq 10$).

$$F_B^* = 5 \times \left[\left(\frac{l_{\text{wed}}}{L}\right)^2 \times \left(\frac{h_{\min}}{C_{\text{wed}}}\right)^2 \times \ln \frac{1 + h_{\min}/C_{\text{wed}}}{h_{\min}/C_{\text{wed}}} + \frac{\dfrac{l_{\text{wed}}}{L} \times \dfrac{1}{h_{\min}/C_{\text{wed}}} \times \left(1 - \dfrac{l_{\text{wed}}}{L}\right)^2 - 2 \times \left(\dfrac{l_{\text{wed}}}{L}\right)^2 \times \left[2 \times \dfrac{h_{\min}}{l_{\text{wed}}} + 3 \times \left(1 - \dfrac{l_{\text{wed}}}{L}\right)\right]}{4 + 2 \times \left(4 - 3\dfrac{l_{\text{wed}}}{L}\right) \times \dfrac{1}{h_{\min}/C_{\text{wed}}} + 4 \times \left(1 - \dfrac{l_{\text{wed}}}{L}\right) \times \left(\dfrac{1}{h_{\min}/C_{\text{wed}}}\right)^2} \right]$$

$$\times \frac{A^* + B^* \times \left(1 - \dfrac{1}{h_{\min}/C_{\text{wed}}}\right) + C^* \times \left(1 - \dfrac{1}{h_{\min}/C_{\text{wed}}}\right)^2}{1 + \alpha \times \left(\dfrac{B}{L}\right)^{-2}} \times \left(\frac{1}{h_{\min}/C_{\text{wed}}}\right)^2$$

$$\alpha = \frac{10}{\left(1 + 2 \times \dfrac{h_{\min}}{C_{\text{wed}}}\right)^2} \times \left[\left[\frac{h_{\min}}{C_{\text{wed}}} + \left(\frac{h_{\min}}{C_{\text{wed}}}\right)^2\right]^2 + \frac{1 - 2 \times \left[\dfrac{h_{\min}}{C_{\text{wed}}} + \left(\dfrac{h_{\min}}{C_{\text{wed}}}\right)^2\right]}{12 \times \left[\left(1 + 2 \times \dfrac{h_{\min}}{C_{\text{wed}}}\right) \times \ln \dfrac{1 + h_{\min}/C_{\text{wed}}}{h_{\min}/C_{\text{wed}}} - 2\right]} \right]$$

$$A^{*} = 1{,}2057 - 0{,}243\,44 \times \left(\frac{B}{L}\right) + 0{,}126\,25 \times \left(\frac{B}{L}\right)^{2} - 0{,}021\,554 \times \left(\frac{B}{L}\right)^{3}$$

$$B^{*} = -\,0{,}256\,34 + 0{,}361\,14 \times \left(\frac{B}{L}\right) - 0{,}199\,58 \times \left(\frac{B}{L}\right)^{2} + 0{,}038\,633 \times \left(\frac{B}{L}\right)^{3}$$

$$C^{*} = -\,0{,}010\,765 + 0{,}009\,350\,1 \times \left(\frac{B}{L}\right) - 0{,}002\,752\,7 \times \left(\frac{B}{L}\right)^{2} + 0{,}000\,184\,46 \times \left(\frac{B}{L}\right)^{3}$$

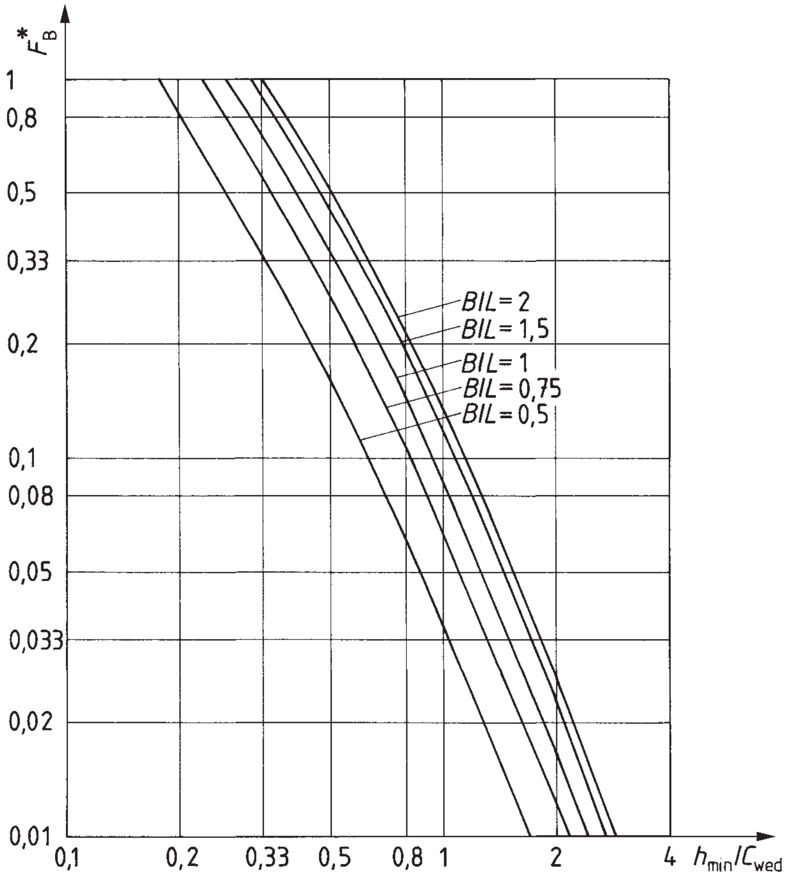

Figure 1 — Characteristic value of load carrying capacity for thrust pad bearings, F_B^*, as a function of the relative bearing width, B/L, and the relative minimum lubricant film thickness, $h_{\text{min}}/C_{\text{wed}}$, for l_{wed}/L = 0,75

Table 1 — Values to Figure 1 where $F_{\mathrm{B}}^{*} = f(B/L, h_{\mathrm{min}}/C_{\mathrm{wed}}, l_{\mathrm{wed}}/L = 0{,}75)$

$h_{\mathrm{min}}/C_{\mathrm{wed}}$	B/L				
	2	1,5	1	0,75	0,5
10	0,000 3	0,000 3	0,000 2	0,000 2	0,000 1
2	0,026 7	0,023 0	0,016 7	0,012 1	0,006 8
1	0,134 1	0,116 9	0,086 5	0,063 7	0,036 4
0,5	0,522	0,462 8	0,355 2	0,27	0,161 2
0,33	1,010 7	0,908 1	0,716 4	0,559 8	0,348 3
0,2	2,067 5	1,887 5	1,547 5	1,252 5	0,83
0,1	4,52	4,21	3,62	3,08	2,24

3.2 Characteristic value of friction for thrust pad bearings, f_{B}^{*}, as a function of the relative bearing width, B/L, and the relative minimum lubricant film thickness, $h_{\mathrm{min}}/C_{\mathrm{wed}}$

Approximation of the curves of Figure 2 (range of application: $0{,}1 \le \dfrac{h_{\mathrm{min}}}{C_{\mathrm{wed}}} \le 10$).

$$f_{\mathrm{B}}^{*} = \left[4 \times \frac{l_{\mathrm{wed}}}{L} \times \frac{h_{\mathrm{min}}}{C_{\mathrm{wed}}} \times \ln \frac{1 + h_{\mathrm{min}}/C_{\mathrm{wed}}}{h_{\mathrm{min}}/C_{\mathrm{wed}}} + \left(1 - \frac{l_{\mathrm{wed}}}{L}\right) - \frac{3 \times \dfrac{l_{\mathrm{wed}}}{L} \times \dfrac{h_{\mathrm{min}}}{C_{\mathrm{wed}}} \times \left[2 \times \dfrac{h_{\mathrm{min}}}{C_{\mathrm{wed}}} + 3 \times \left(1 - \dfrac{l_{\mathrm{wed}}}{L}\right)\right]}{2 \times \left(\dfrac{h_{\mathrm{min}}}{C_{\mathrm{wed}}}\right)^{2} + \left(4 - 3 \times \dfrac{l_{\mathrm{wed}}}{L}\right) \times \dfrac{h_{\mathrm{min}}}{C_{\mathrm{wed}}} + 2 \times \left(1 - \dfrac{l_{\mathrm{wed}}}{L}\right)} \right]$$

$$\times \frac{6}{5} \times \left[1 + \left(\frac{B}{L}\right)^{-2} \times \alpha \right] \times A^{*} \times \frac{1}{h_{\mathrm{min}}/C_{\mathrm{wed}}} \times B^{*}$$

$$\alpha = \frac{10}{\left(1 + 2 \times \dfrac{h_{\mathrm{min}}}{C_{\mathrm{wed}}}\right)^{2}} \times \left[\left[\frac{h_{\mathrm{min}}}{C_{\mathrm{wed}}} + \left[\frac{h_{\mathrm{min}}}{C_{\mathrm{wed}}}\right]^{2} \right]^{2} + \frac{1 - 2 \times \left[\dfrac{h_{\mathrm{min}}}{C_{\mathrm{wed}}} + \left[\dfrac{h_{\mathrm{min}}}{C_{\mathrm{wed}}}\right]^{2} \right]}{12 \times \left[\left(1 + 2 \times \dfrac{h_{\mathrm{min}}}{C_{\mathrm{wed}}}\right) \times \ln \dfrac{1 + h_{\mathrm{min}}/C_{\mathrm{wed}}}{h_{\mathrm{min}}/C_{\mathrm{wed}}} - 2 \right]} \right]$$

$$A^{*} = -0{,}214\,59 + 0{,}880\,71 \times \left(\frac{B}{L}\right) - 0{,}297\,60 \times \left(\frac{B}{L}\right)^{2} + 0{,}037\,91 \times \left(\frac{B}{L}\right)^{3}$$

For $h_{\mathrm{min}}/C_{\mathrm{wed}} \ge 0{,}2$ is $B^{*} = 1$

For $h_{\mathrm{min}}/C_{\mathrm{wed}} < 0{,}2$ is $B^{*} = 1{,}1251 \times \left(\dfrac{B}{L}\right)^{-0{,}12939}$

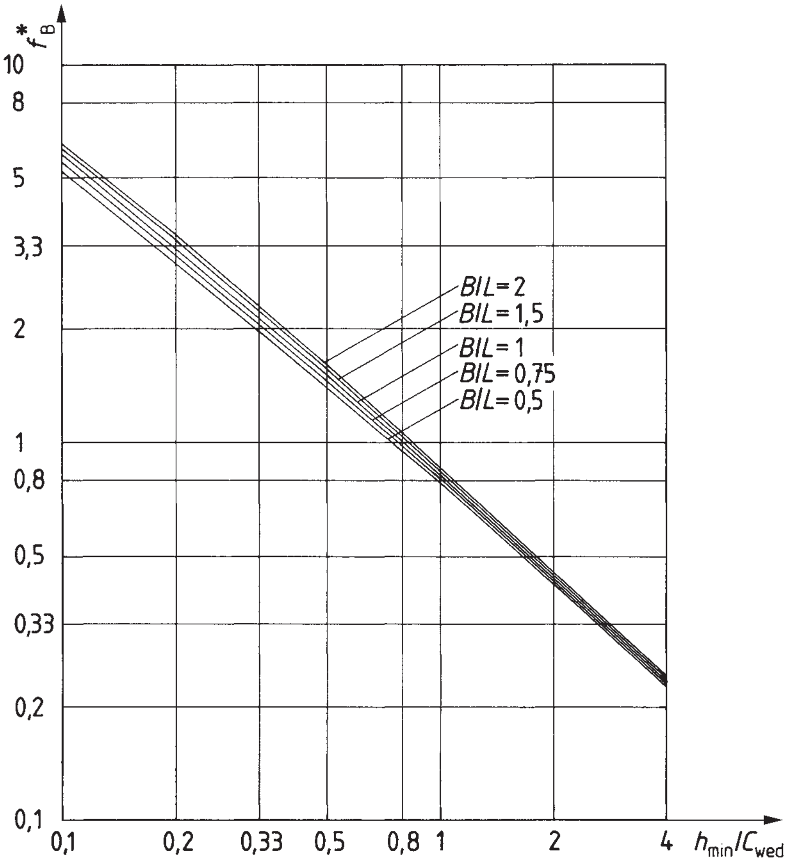

Figure 2 — Characteristic value of friction for pad thrust bearings, f_B^*, as a function of the relative bearing width, B/L, and the relative minimum lubricant film thickness, h_{min}/C_{wed}, for l_{wed}/L = 0,75

Table 2 — Values to Figure 2 where $f_B^* = f(B/L, h_{min}/C_{wed}, l_{wed}/L = 0{,}75)$

h_{min}/C_{wed}	B/L				
	2	1,5	1	0,75	0,5
10	0,096 7	0,096 6	0,096 6	0,096 6	0,096 5
2	0,444 3	0,442 2	0,438 7	0,436 1	0,433 1
1	0,844	0,834 6	0,818	0,805 6	0,790 6
0,5	1,599 2	1,568 2	1,511 8	1,467 2	1,410 6
0,33	2,301 6	2,249 1	2,151 3	2,071 5	1,965
0,2	3,574 5	3,488 5	3,324 5	3,185	2,987 5
0,1	6,194	6,061	5,804	5,574	5,223

3.3 Relative lubricant flow rates, Q_1^* and Q_3^*, as a function of the relative bearing width, B/L, and the relative minimum lubricant film thickness, $h_{\min}/C_{\mathrm{wed}}$

Approximation of the curves of Figures 3 and 4 (range of application: $0{,}1 \leq \dfrac{h_{\min}}{C_{\mathrm{wed}}} \leq 10$).

$$Q_i^* = \frac{\left(1+\dfrac{h_{\min}}{C_{\mathrm{wed}}}\right)\times\left(1-\dfrac{l_{\mathrm{wed}}}{L}+\dfrac{h_{\min}}{C_{\mathrm{wed}}}\right)\times\left[A_{\mathrm{i}}+B_{\mathrm{i}}\times\left(1-\dfrac{1}{h_{\min}/C_{\mathrm{wed}}}\right)\right]}{\left(1+2\times\dfrac{h_{\min}}{C_{\mathrm{wed}}}\right)\times\dfrac{l_{\mathrm{wed}}}{L}\times\dfrac{h_{\min}}{C_{\mathrm{wed}}}+2\times\left(1+\dfrac{h_{\min}}{C_{\mathrm{wed}}}\right)^2\times\left(1-\dfrac{l_{\mathrm{wed}}}{L}\right)}$$

with constants A_{i} and B_{i}

for $Q_i^* = Q_1^*$:

$$A_{\mathrm{i}} = A_1 = 1{,}7655 - 0{,}52423\times\left(\frac{B}{L}\right) + 0{,}11805\times\left(\frac{B}{L}\right)^2$$

$$B_{\mathrm{i}} = B_1 = -1{,}0048 + 0{,}78880\times\left(\frac{B}{L}\right) - 0{,}19357\times\left(\frac{B}{L}\right)^2$$

for $Q_i^* = Q_3^*$:

$$A_{\mathrm{i}} = A_3 = 2\times\left[0{,}4348 - 0{,}30823\times\left(\frac{B}{L}\right) + 0{,}06952\times\left(\frac{B}{L}\right)^2\right]$$

$$B_{\mathrm{i}} = B_3 = 2\times\left[-0{,}4704 + 0{,}37567\times\left(\frac{B}{L}\right) - 0{,}09217\times\left(\frac{B}{L}\right)^2\right]$$

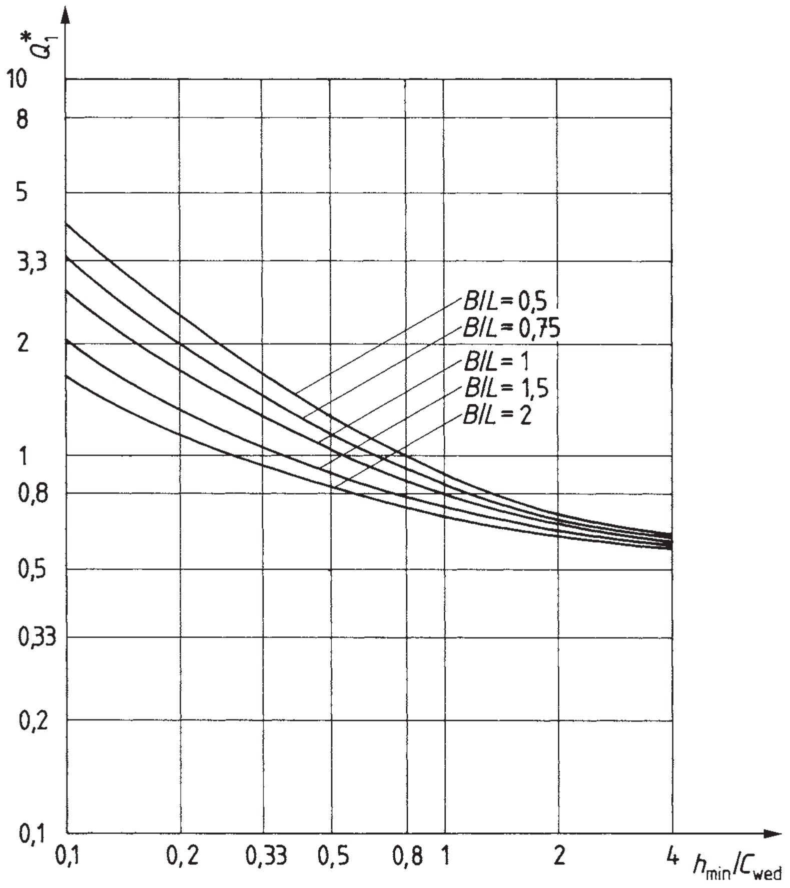

Figure 3 — Relative lubricant flow rate, Q_1^*, as a function of the relative bearing width, B/L, and the relative minimum lubricant film thickness, h_{min}/C_{wed}, for l_{wed}/L = 0,75

Table 3 — Values to Figure 3 where $Q_1^* = f(B/L, h_{min}/C_{wed}, l_{wed}/L = 0{,}75)$

h_{min}/C_{wed}	B/L				
	2	1,5	1	0,75	0,5
10	0,526 5	0,529 2	0,533 8	0,537 3	0,541 5
2	0,614 2	0,63	0,657 5	0,678	0,702 9
1	0,698 1	0,733 2	0,794 9	0,841 6	0,898 5
0,5	0,828 1	0,904 1	1,041	1,147 3	1,278 8
0,33	0,942	1,06	1,276 1	1,447 6	1,663
0,2	1,144 3	1,340 7	1,706 6	2,004 8	2,387 8
0,1	1,646	2,034 9	2,771 8	3,390 1	4,208 4

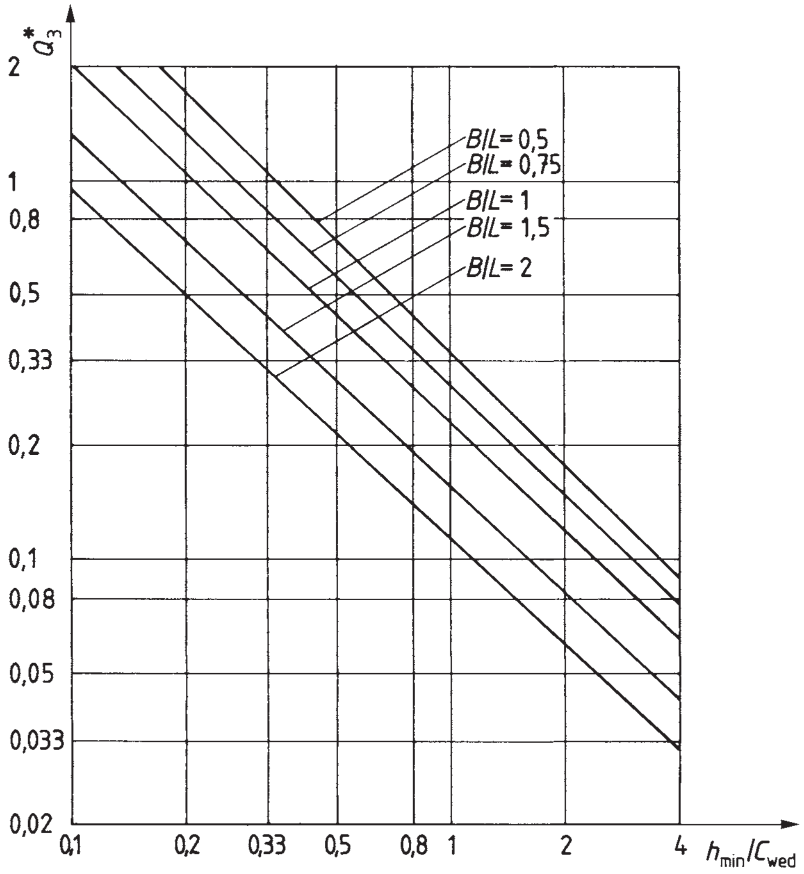

Figure 4 — Relative lubricant flow rate, Q_3^*, as a function of the relative bearing width, B/L, and the relative minimum lubricant film thickness, h_{min}/C_{wed}, for l_{wed}/L = 0,75

Table 4 — Values to Figure 4 where Q_3^* = ×(B/L, h_{min}/C_{wed}, l_{wed}/L = 0,75)

h_{min}/C_{wed}	B/L				
	2	1,5	1	0,75	0,5
10	0,012 8	0,016 4	0,025 2	0,030 8	0,037 2
2	0,061 2	0,083 4	0,121 8	0,15	0,183 4
1	0,117	0,160 2	0,236 2	0,293 4	0,362 4
0,5	0,220 2	0,303 4	0,453 0	0,569 4	0,713 4
0,33	0,320 6	0,443 4	0,667 4	0,845 4	1,07
0,2	0,506	0,701 8	1,065 6	1,362 2	1,744
0,1	0,963 2	1,340 2	2,051 6	2,647 4	3,434 8

4 Effective dynamic viscosity of the lubricant, η_{eff}, as a function of the effective lubricant film temperature, T_{eff}

For liquid lubricants, the Vogel formula is generally applicable.[3]

$$\eta = K_\mathrm{I} \times \exp\left(\frac{K_2}{T + K_3}\right)$$

For mineral oils, this formula can be completed with sufficient accuracy by the constant K_3 = 95 °C.[4]

Reference [2] shows the operational viscosity, η, for mineral oils can also be calculated directly from the ISO VG.

With density, ρ, in kg/m^3, it gives:

$$\ln \frac{\eta}{\eta_x} = \left(\frac{159{,}56}{T + 95\,^\circ\mathrm{C}} - 0{,}181\,913 \right) \times \ln \frac{\rho \times \mathrm{VG}}{10^6 \times \eta_x}$$

In this formula, $\eta_x = 0{,}18 \times 10^{-3}\,\mathrm{Pas}$, and is a constant coefficient.

The viscosity of ISO-compliant oils is given for a mean density ρ = 900 kg/m^3 in Figure 5.

Engine and gear box oils for road vehicles are standardized according to international viscosity classes SAE.

The SAE classification of these lubricants can only be compared incompletely with the ISO VG classification. The classification is inaccurate that for especially precise calculations, the supplier is requested to supply viscosity data.

As compared with pure mineral oils, multi-grade oils have more even viscosity-temperature behaviour.

Synthetic oils very often reach such conditions without intrinsically viscous additives as required for mineral oils.

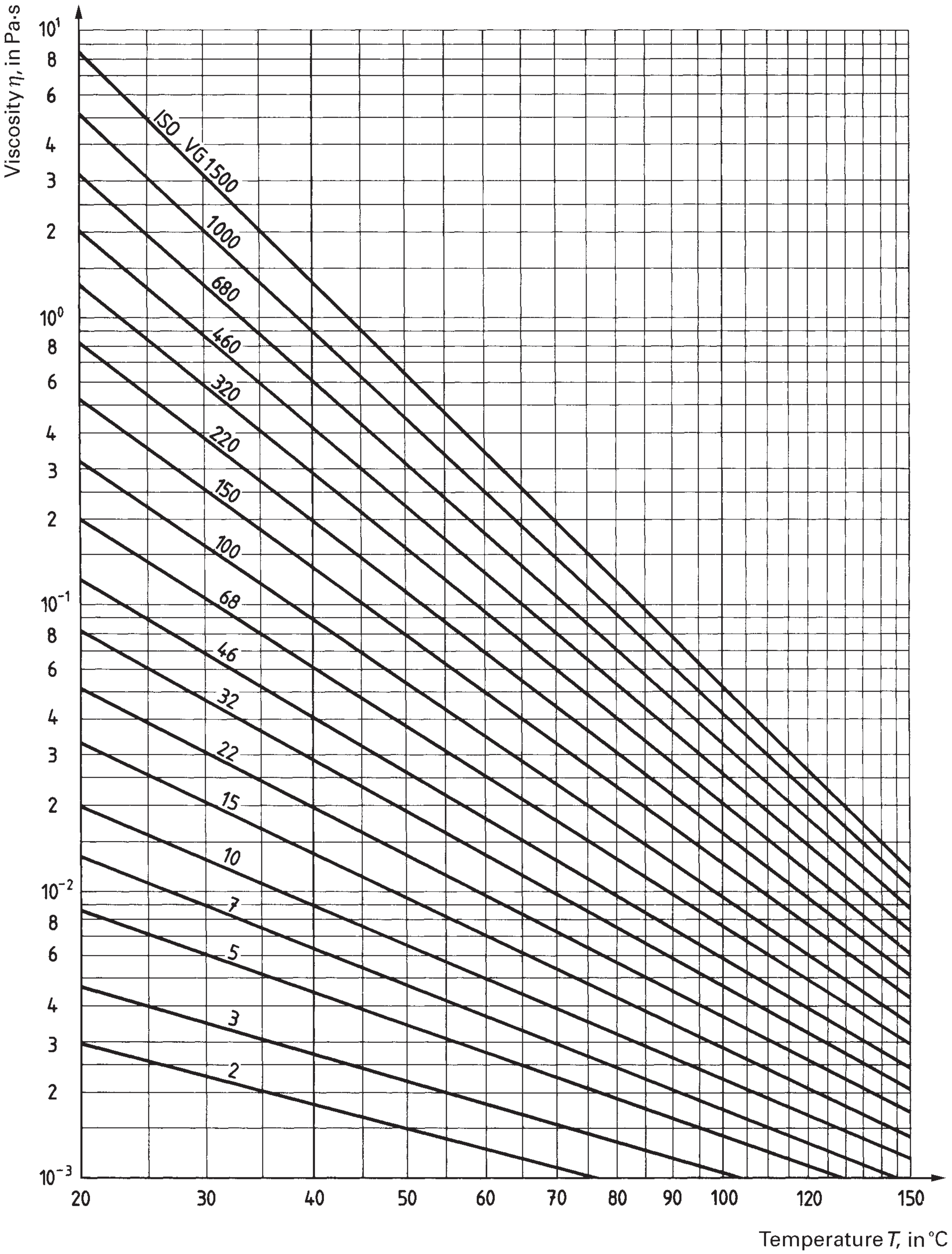

Figure 5 — Effective dynamic viscosity, η_{eff}, as a function of the effective lubricant film temperature, T_{eff}, at a density ρ = 900 kg/m^3

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