INTERNATIONAL STANDARD

ISO 12131-2

First edition
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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
ISO 12131-2:2001(E)

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Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
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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 3.

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 part of ISO 12131 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 12131-2 was prepared by Technical Committee ISO/TC 123, *Plain bearings*, Subcommittee SC 4, *Methods of calculation of plain bearings*.

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 there specified. The values necessary for the calculation can be determined by means of the given equations as well as from diagrams and tables. The equations are approximations of the numerically determined values traced as curves according to [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 and also covers the effect of dynamic viscosity on lubricant film temperature.

2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this part of ISO 12131. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 12131 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

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 $h_{\text{min}}/C_{\text{wed}}$

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

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

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

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

$$A^* = 1{,}205\,7 - 0{,}243\,44 \times \left(\frac{B}{L}\right) + 0{,}126\,25 \times \left(\frac{B}{L}\right)^2 - 0{,}021\,554 \times \left(\frac{B}{L}\right)^3$$

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

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

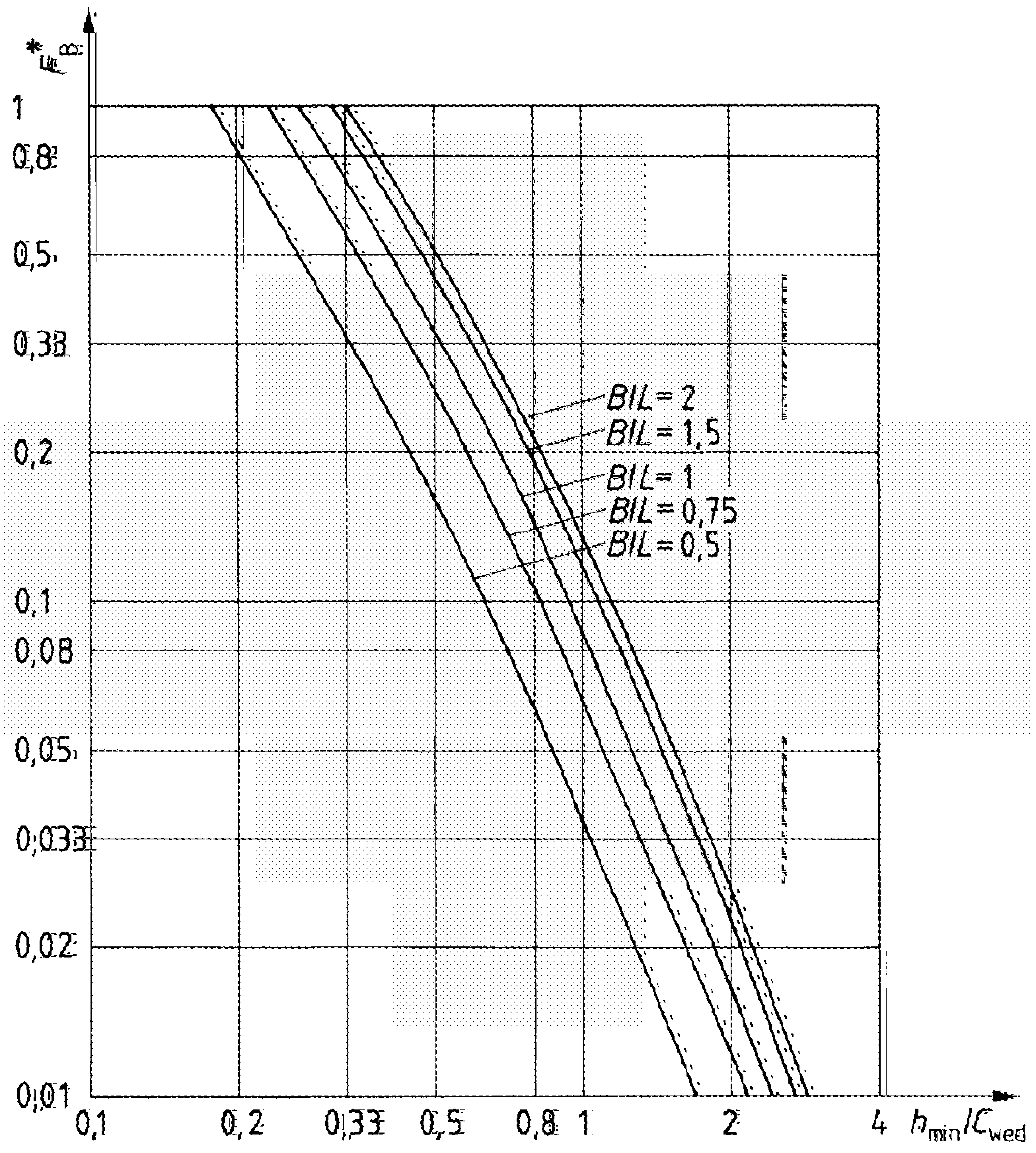

Figure 1 — Characteristic value of load carrying capacity for thrust pad bearings F_B^* as a function of the relative bearing width B/L and the relative minimum lubricant film thickness h_{min}/C_{wed} for l_{wed}/L = 0,75

Table 1 — Values to Figure 1 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	0,000 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 $h_{\min} / C_{\text{wed}}$

Approximation of the curves of Figure 2 (range of application: $0{,}1 \leqslant \frac{h_{\min}}{\mathrm{C}_{\text{wed}}} \leqslant 10$).

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

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

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

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

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

For $h_{\min} / C_{\text{wed}} < 0{,}2$ is $B^* = 1{,}1251 \times \left(\frac{B}{L} \right)^{-0{,}129\ 39}$

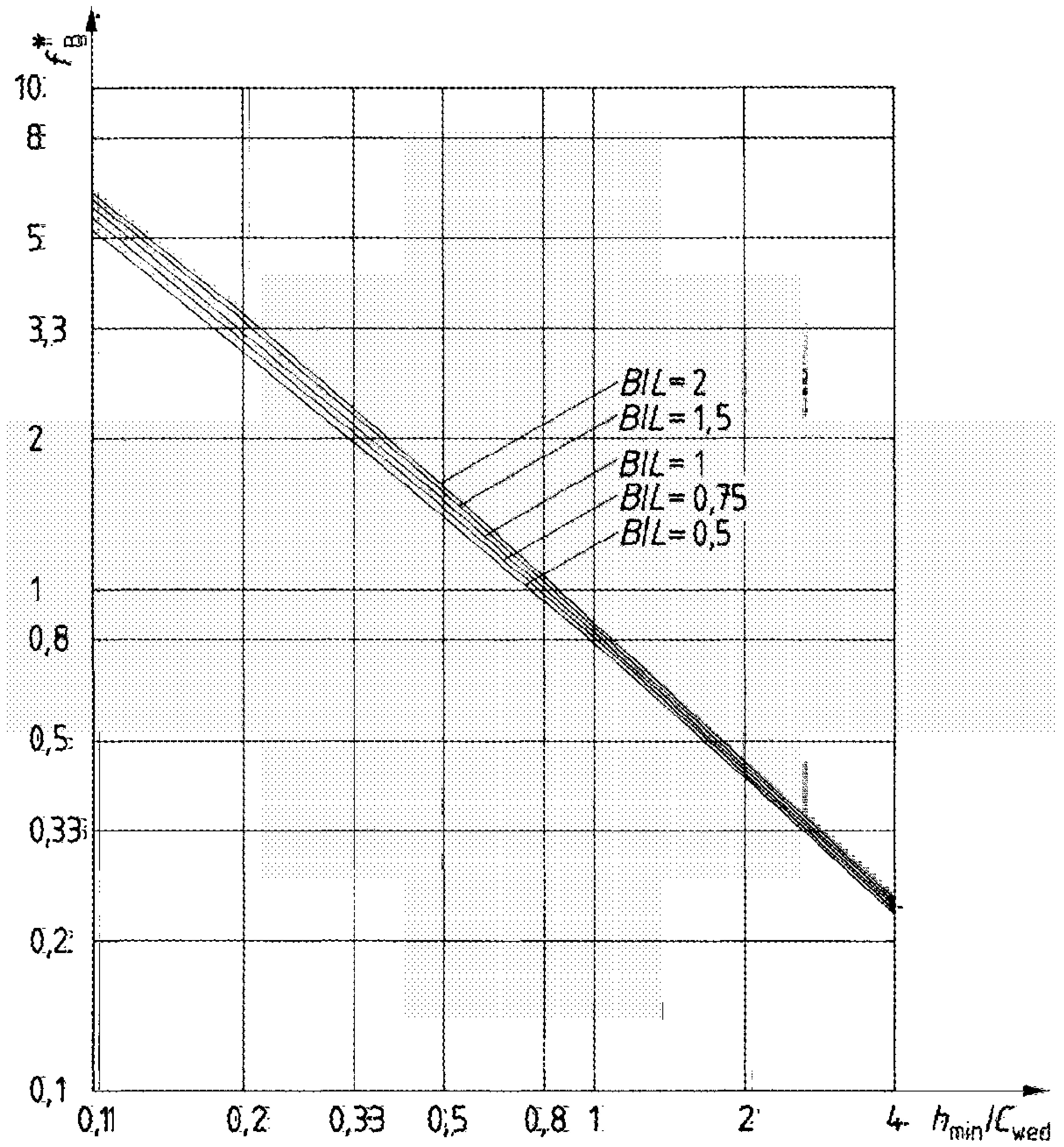

Figure 2 — Characteristic value of friction for pad thrust bearings f_B^* as a function of the relative bearing width B/L and the relative minimum lubricant film thickness h_{min}/C_{wed} for l_{wed}/L = 0,75

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 $h_{\text{min}}/C_{\text{wed}}$

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

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

with constants A_i and B_i

for $Q_\text{i}^* = Q_1^*$:

$$A_\text{i} = A_1 = 1{,}765\ 5 - 0{,}524\ 23\times\left(\frac{B}{L}\right)+0{,}118\ 05\times\left(\frac{B}{L}\right)^2$$

$$B_\text{i} = B_1 = -1{,}004\ 8 + 0{,}788\ 80\times\left(\frac{B}{L}\right)-0{,}193\ 57\times\left(\frac{B}{L}\right)^2$$

for $Q_\text{i}^* = Q_3^*$:

$$A_\text{i} = A_3 = 2\times\left[0{,}434\ 8 - 0{,}308\ 23\times\left(\frac{B}{L}\right)+0{,}069\ 52\times\left(\frac{B}{L}\right)^2\right]$$

$$B_\text{i} = B_3 = 2\times\left[-0{,}470\ 4 + 0{,}375\ 67\times\left(\frac{B}{L}\right)-0{,}092\ 17\times\left(\frac{B}{L}\right)^2\right]$$

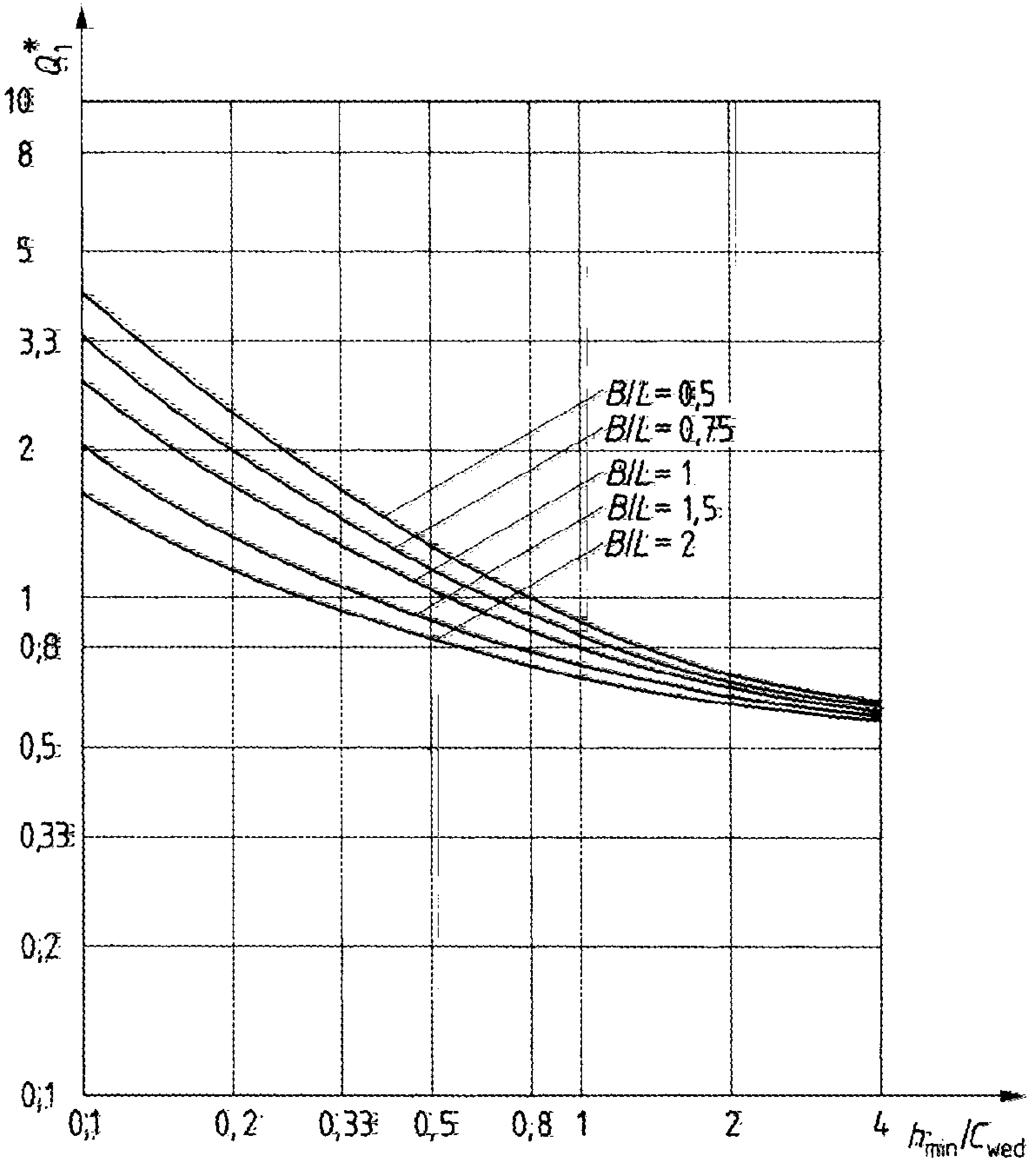

Figure 3 — Relative lubricant flow rate Q_1^* as a function of the relative bearing width B/L and the relative minimum lubricant film thickness h_{min}/C_{wed} for l_{wed}/L = 0,75

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

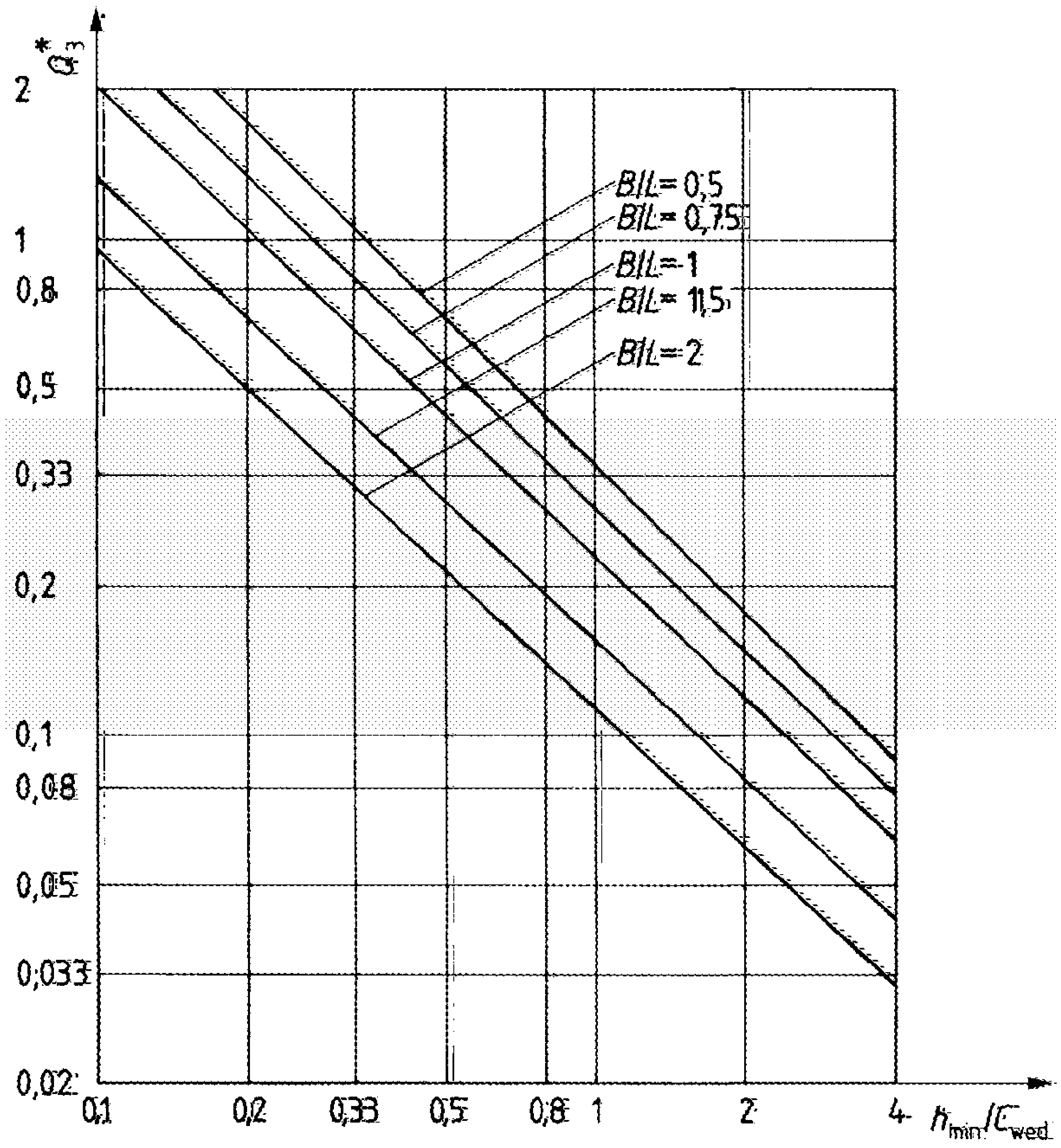

Figure 4 — Relative lubricant flow rate Q_3^* as a function of the relative bearing width B/L and the relative minimum lubricant film thickness h_{min}/C_{wed} for l_{wed}/L = 0,75

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

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 equation is generally applicable [3].

$$\eta = K_1 \times \exp\left(\frac{K_2}{T + K_3}\right)$$

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

Rodermund [2] showed that 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:

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

In this equation, $\eta_x = 0{,}18 \times 10^{-3}\ \text{Pa·s}$ and is a constant coefficient.

The viscosity of ISO standard 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 so inaccurate that for especially precise calculations the supplier should be requested to supply viscosity data.

As compared with pure mineral oils, multigrade oils have a more even viscosity-temperature behaviour.

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

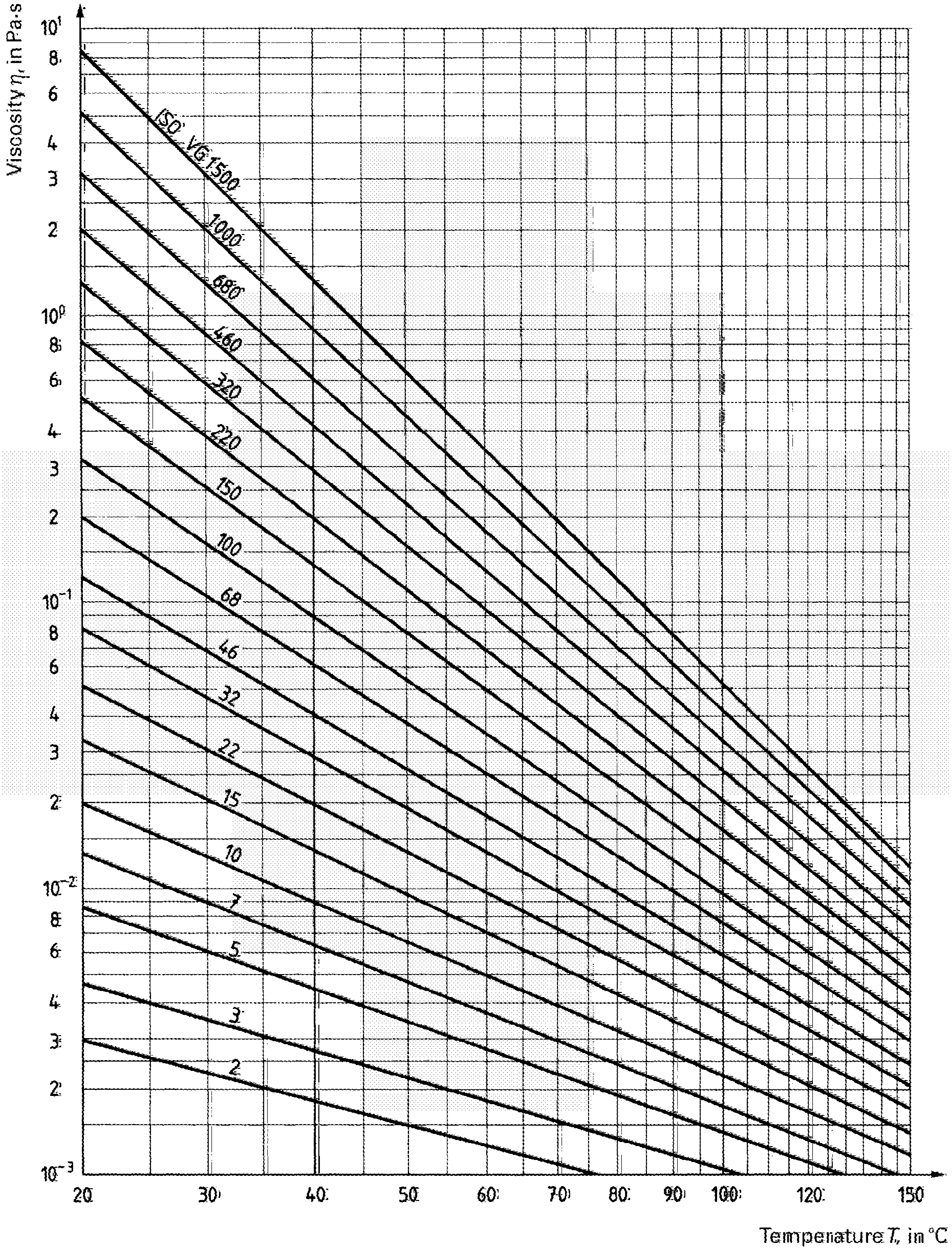

Figure 5 — Effective dynamic viscosity η_{eff} as a function of the effective lubricant film temperature T_{eff} at a density ρ = 900 kg/m^3

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