Method for estimating contamination factor, η_c, based on lubricant cleanliness

A more detailed estimation of η_c for oil or grease lubrication is based on:

- oil cleanliness level or oil filter rating
- grease cleanliness levels related to operating conditions

ISO oil contamination classification and oil filter rating

The standard method for classifying the contamination level in a lubrication system is described in ISO 4406. In this classification system, the result of the solid particle count is converted into a code using a scale number (**table 1** and **diagram 1**).

One method for checking the contamination level of bearing oil is the microscope counting method. This method uses two particle size ranges: ≥ 5 µm and ≥ 15 µm. Another more modern method is to use an optical automatic particle counter in accordance with ISO 11171.

The calibration scale of the automatic counting method differs from that of the microscopic counting method. It uses three particle size ranges, indicated by the symbol (c), e.g. ≥ 4 µm(c), ≥ 6 µm(c) and ≥ 14 µm(c). Typically, only the two larger particle size ranges are used, as the larger particles have a more significant impact on bearing fatigue.

Typical examples of contamination level classifications for lubricating oils are –/15/12 (A) or 22/18/13 (B), as shown in **diagram 1**.

Example A indicates that the oil contains between 160 and 320 particles ≥ 5 µm and between 20 and 40 particles ≥ 15 µm per millilitre of oil.

A filter rating is an indication of filter efficiency and is expressed as a reduction factor (β). The higher the β value, the more efficient the filter is for the specified particle size. The filter rating β is expressed as a ratio between the number of specified particles before and after filtering. This can be calculated using

$$\beta_{x(c)} = \frac{n_1}{n_2}$$

where

$\beta_{x(c)}$ = filter rating related to a specified particle size x

x = particle size (c) [µm] based on the automatic particle counting method, calibrated in accordance with ISO 11171

n_1 = number of particles per volume unit larger than x, upstream of the filter

n_2 = number of particles per volume unit larger than x, downstream of the filter

The filter rating β only relates to one particle size in µm, which is shown in the index, such as $\beta_{3(c)}$, $\beta_{6(c)}$, $\beta_{12(c)}$, etc. For example, a complete rating "$\beta_{6(c)}$ = 75" means that only 1 in 75 particles, 6 µm or larger, passes through the filter.

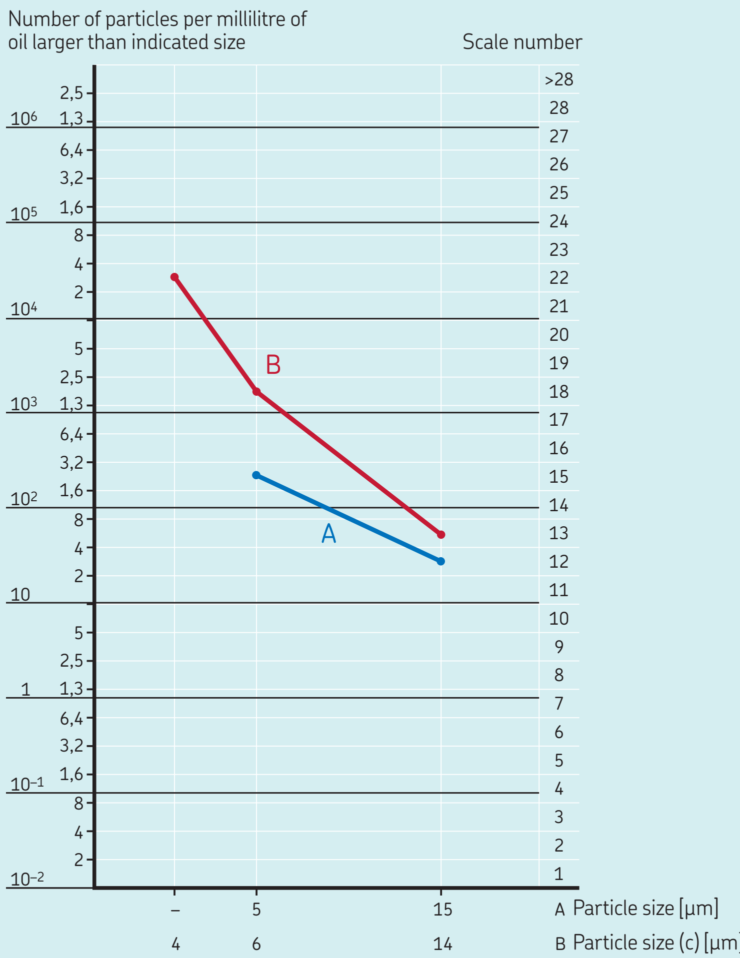
Table 1

ISO classification – allocation of scale number

Number of particles per millilitre oil over	incl.	**Scale number**
2 500 000		> 28
1 300 000	2 500 000	28
640 000	1 300 000	27
320 000	640 000	26
160 000	320 000	25
80 000	160 000	24
40 000	80 000	23
20 000	40 000	22
10 000	20 000	21
5 000	10 000	20
2 500	5 000	19
1 300	2 500	18
640	1 300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2,5	5	9
1,3	2,5	8
0,64	1,3	7
0,32	0,64	6
0,16	0,32	5
0,08	0,16	4
0,04	0,08	3
0,02	0,04	2
0,01	0,02	1
0,00	0,01	0

Diagram 1

ISO classification of contamination level and examples for particle counting



A = microscope particle count (–/15/12)
B = automatic particle count (22/18/13)

Table 2

Factors to determine contamination levels for an oil lubricated application in accordance with ISO 281

Filtration ratio $\beta_{x(c)}$	ISO 4406 Basic code	Circulating oil lubrication with in-line filters c_1	c_2	Oil lubrication without filtration or with off-line filters c_1	c_2
$\beta_{6(c)}$ = 200	–/13/10	0,0864	0,5663	0,0864	0,6796
$\beta_{12(c)}$ = 200	–/15/12	0,0432	0,9987	0,0288	1,141
$\beta_{25(c)}$ = 75	–/17/14	0,0288	1,6329	0,0133	1,67
$\beta_{40(c)}$ = 75	–/19/16	0,0216	2,3362	0,00864	2,5164
–	–/21/18	–	–	0,00411	3,8974

Determining η_c when the contamination level is known

Once the oil contamination level is known, either from the microscope counting method or the automatic particle counting method (both in accordance with ISO 4406) or indirectly as a result of the filtration ratio that is applied in an oil circulation system, this information can be used to determine the factor η_c.

The factor η_c cannot be derived solely from a particle count. It depends largely on the lubrication conditions, such as κ, and the size of the bearing. A simplified method in accordance with ISO 281 is presented here to obtain the η_c factor for a given application. From the oil contamination code (or filtration ratio of the application), the contamination factor η_c is obtained, using the bearing mean diameter $d_m = 0,5\,(d + D)$ [mm] and the viscosity ratio κ for that bearing.

Oil lubrication

Diagrams 2 to **5**, **page 3** and **4**, provide typical values for the factor η_c for circulating oil lubrication systems with in-line filters.

Diagrams 6 to **10**, **page 4** and **5**, provide typical values for the factor η_c for oil lubrication without filtration or with off-line filters.

Similar contamination factors can be applied in applications where an oil bath shows virtually no increase in the contamination particles present in the system. Alternatively, if the number of particles in an oil bath continues to increase over time, due to excessive wear or the ingress of contaminants, this must be reflected in the choice of the factor η_c used for the oil bath system as indicated in ISO 281.

As an alternative to the diagrams, the following simplified equation can be used

$$\eta_c = a \left(1 - \frac{c_2}{\sqrt[3]{d_m}}\right)$$

where $a = c_1\,\kappa^{0,68}\,d_m^{0,55}$ and $a \le 1$

The values of c_1 and c_2 are listed in **table 2**.

Diagram 2

η_c factor for circulating oil lubrication with online filters – $\beta_{6(c)} = 200$, ISO 4406 code –/13/10

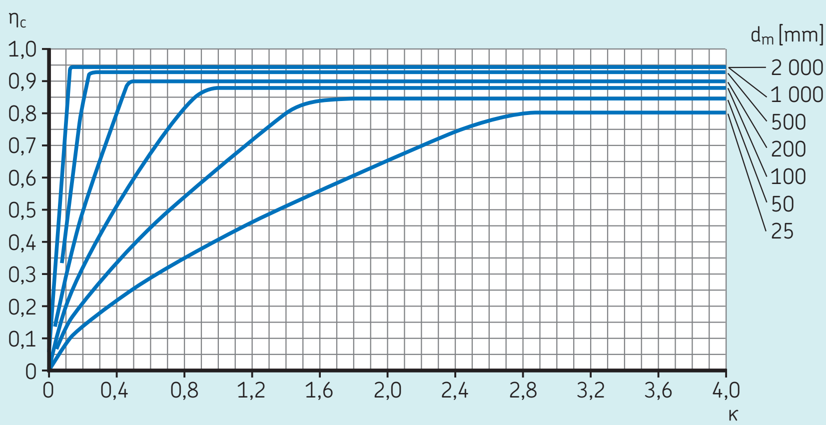


Diagram 3

η_c factor for circulating oil lubrication with online filters – $\beta_{12(c)} = 200$, ISO 4406 code –/15/12

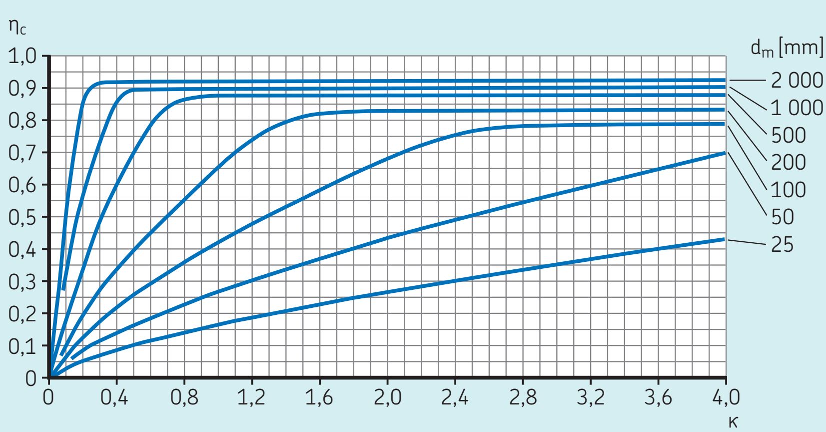


Diagram 4

η_c factor for circulating oil lubrication with online filters – $\beta_{25(c)} \geq 75$, ISO 4406 code –/17/14

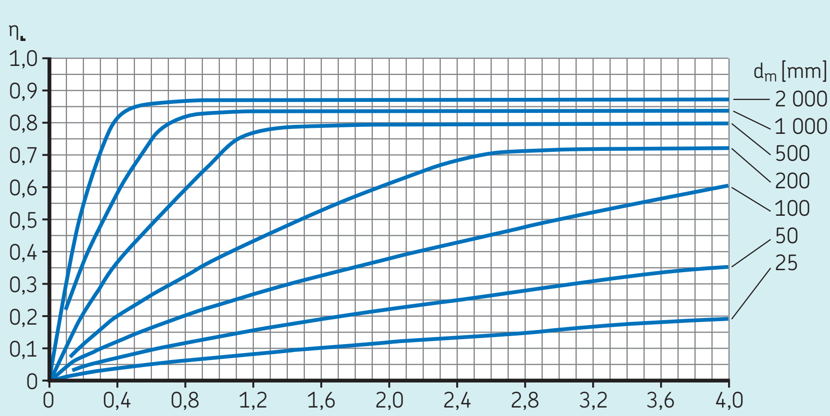


Diagram 5

η_c factor for circulating oil lubrication with online filters – $\beta_{40(c)} \geq 75$, ISO 4406 code –/19/16

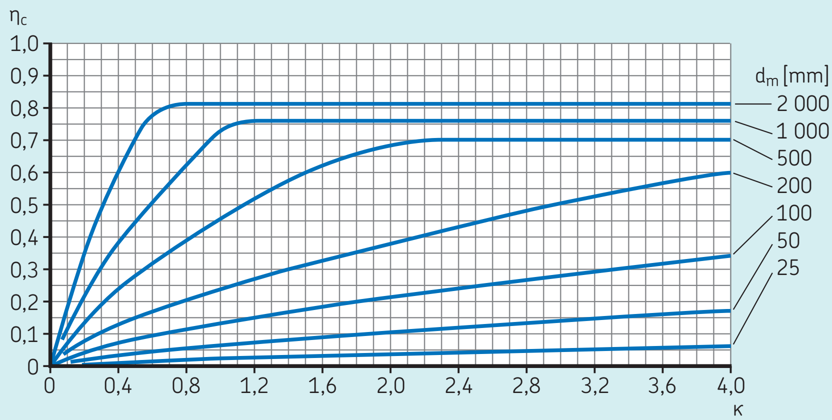


Diagram 6

η_c factor for oil lubrication without filtration or with off line filters – ISO 4406 code –/13/10

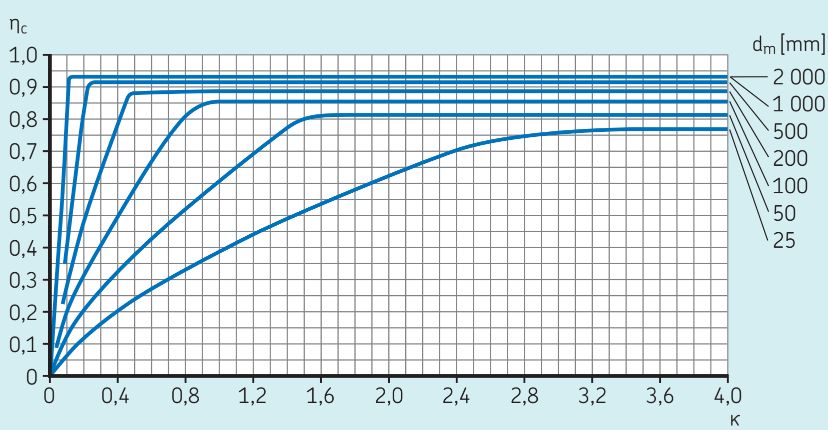


Diagram 7

η_c factor for oil lubrication without filtration or with off line filters – ISO 4406 code –/15/12

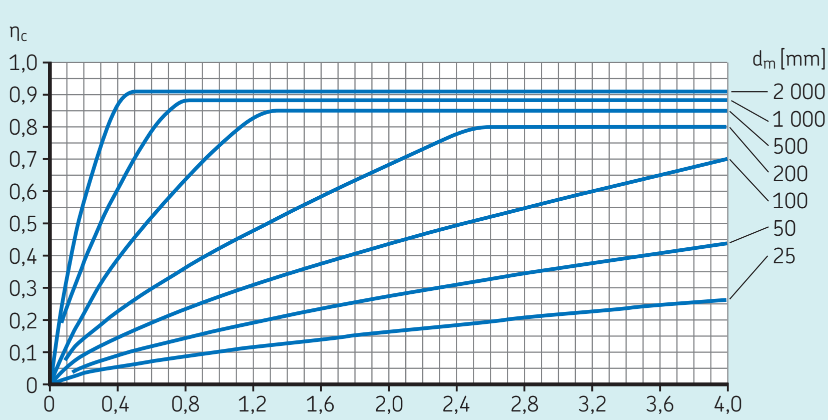


Diagram 8

η_c factor for oil lubrication without filtration or with off line filters – ISO 4406 code –/17/14

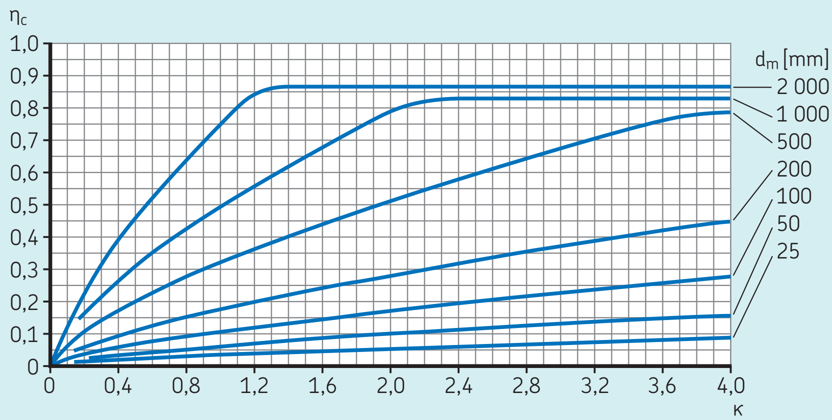


Diagram 9

η_c factor for oil lubrication without filtration or with off line filters – ISO 4406 code –/19/16

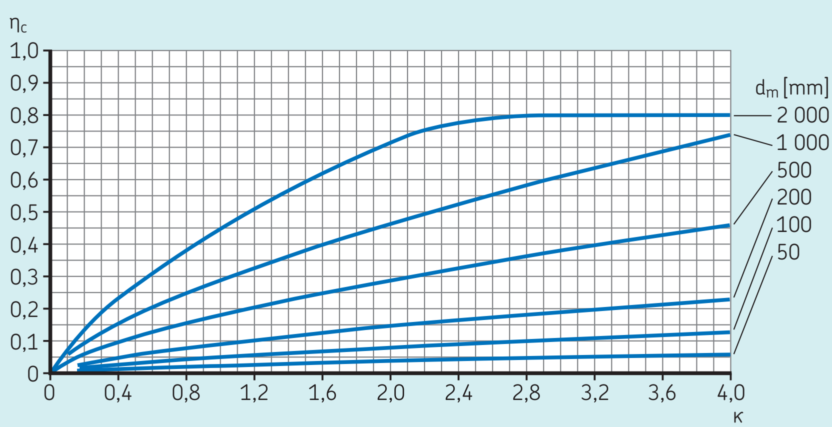


Diagram 10

η_c factor for oil lubrication without filtration or with off line filters – ISO 4406 code –/21/18

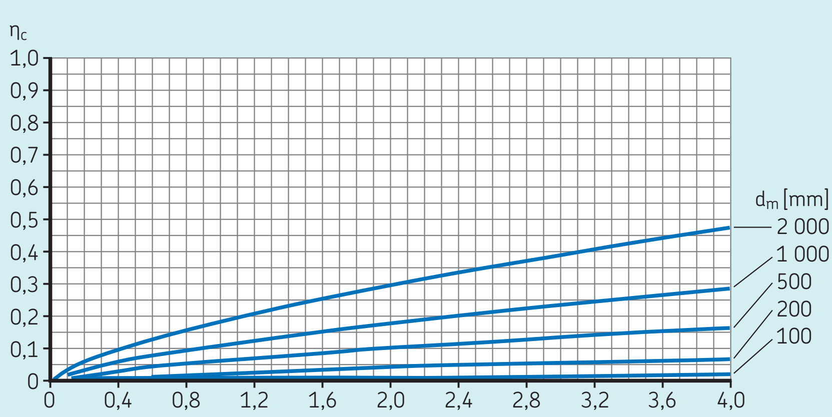


Table 3

Factors to determine contamination levels for a grease lubricated application in accordance with ISO 281

Contamination level	Operating conditions	c_1	c_2
High cleanliness	• very clean assembly; very good sealing system relative to the operating conditions; relubrication is continuous or at short intervals • sealed bearings that are greased for life, with appropriate sealing capacity for the operating conditions	0,0864	0,6796
Normal cleanliness	• clean assembly; good sealing system relative to the operating conditions; relubrication according to manufacturer's specifications • shielded bearings that are greased for life with appropriate sealing capacity for the operating conditions	0,0432	1,141
Slight to typical contamination	• clean assembly; moderate sealing capacity relative to the operating conditions; relubrication according to manufacturer's specifications	0,0177	1,887[1]
Severe contamination	• assembly in workshop; bearing and application not adequately washed prior to mounting; ineffective seal relative to the operating conditions; relubrication intervals longer than recommended by manufacturer	0,0115	2,662
Very severe contamination	• assembly in contaminated environment; inadequate sealing system; too long relubrication intervals	0,00617	4,06

[1] When $d_m \geq 500$ mm, use 1,677

Grease lubrication

Diagrams 11 to 15, **page 6 to 8**, provide typical values for the factor η_c for grease lubrication, considering five levels of contamination as shown in **table 3**. Here, the simplified equation can be used.

SKF recommends using the online SKF Bearing Calculator when estimating η_c for use in the SKF rating life calculation.

Diagram 11

η_c factor for grease lubrication – high cleanliness

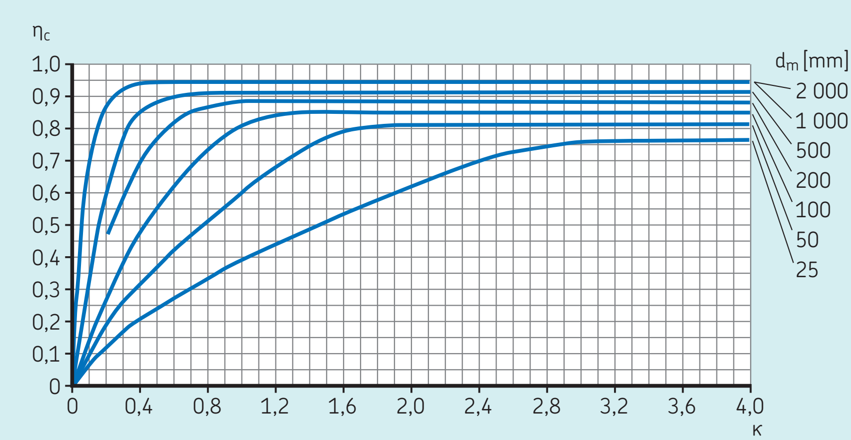


Diagram 12

η_c factor for grease lubrication – normal cleanliness

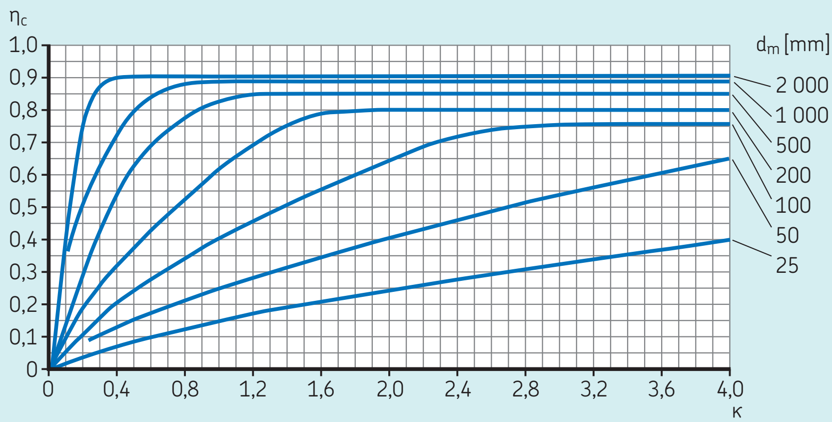


Diagram 13

η_c factor for grease lubrication – slight to typical contamination

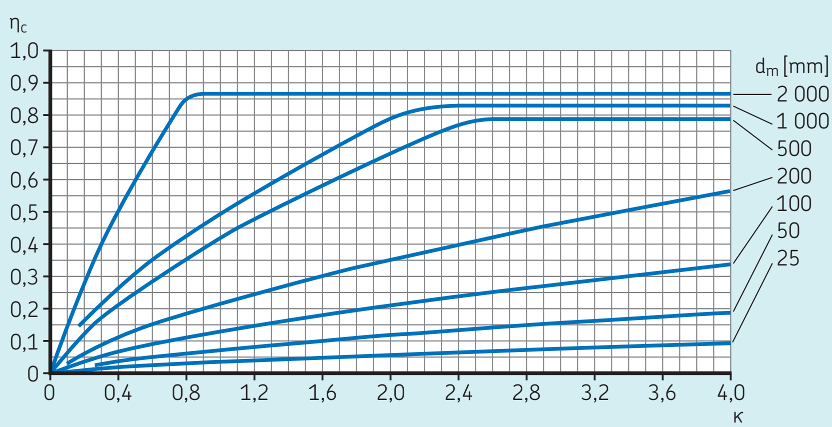


Diagram 14

η_c factor for grease lubrication – severe contamination

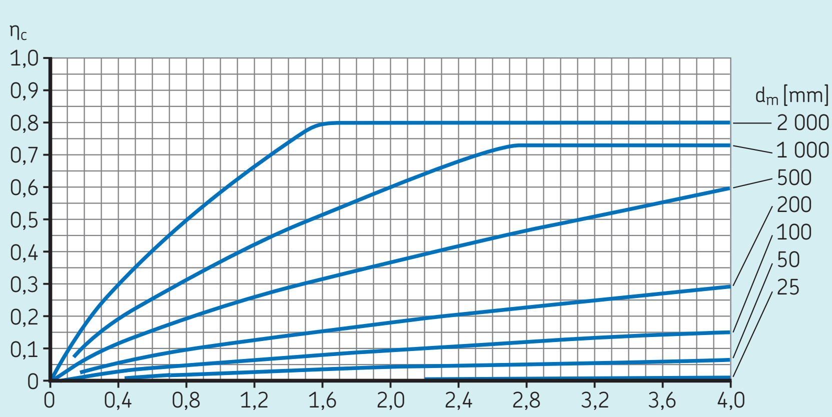


Diagram 15

η_c factor for grease lubrication – very severe contamination