GLACIER GARLOCK BEARINGS

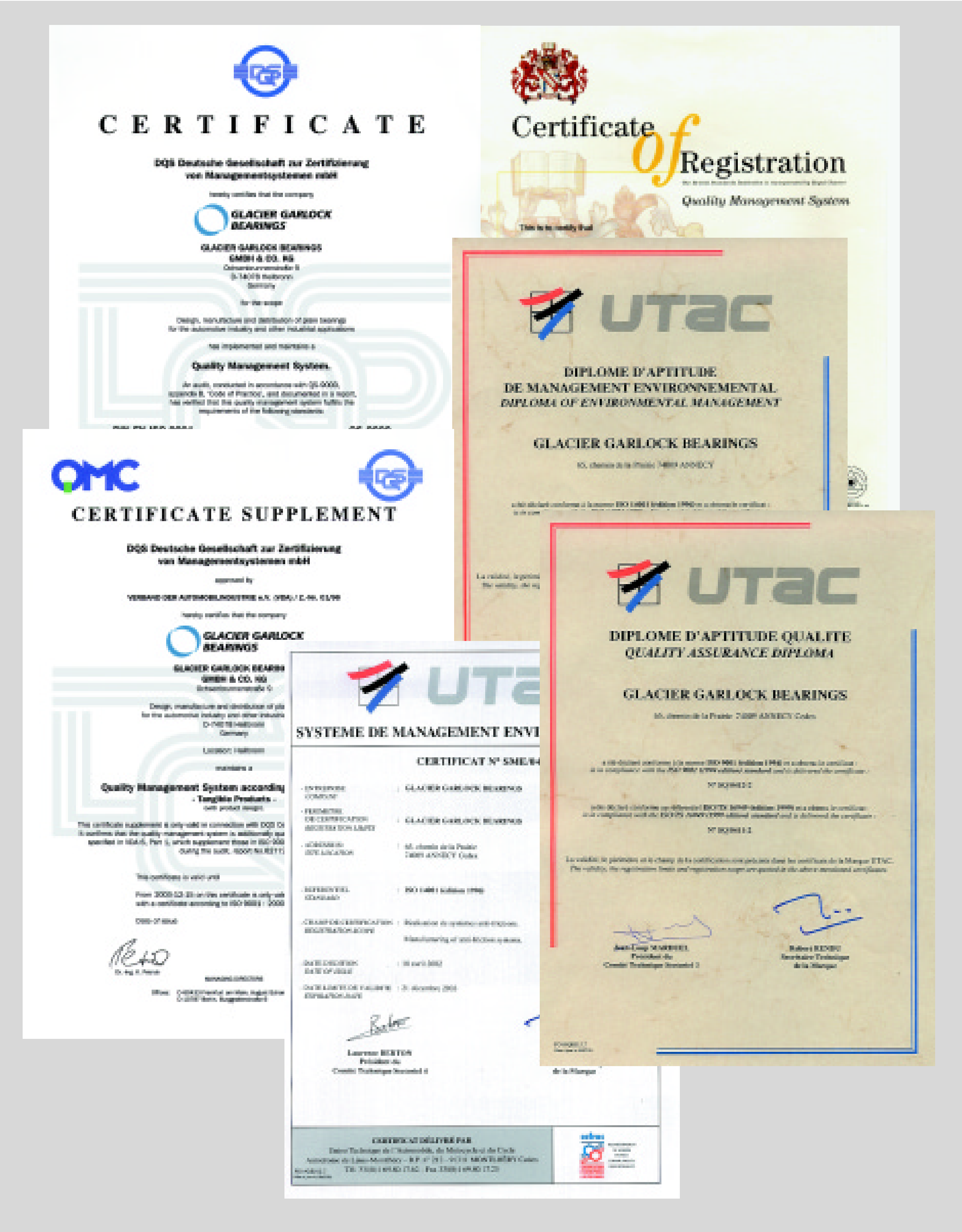
DP4

Maintenance-free

Designer¥s Handbook

Quality

All the products described in this handbook are manufactured under DIN ISO 9001/2 or QS 9000 approved quality management systems.



Formula Symbols and Designations

Formula Symbol	Unit	Designation
A	mm^2	Surface area of DP4 bearing
A_M	mm^2	Surface area of mating surface in contact with DP4 bearing (slideway)
a_B	-	Bearing size factor
a_C	-	Application factor for bore burnishing or machining
a_E	-	High load factor
a_{E1}	-	Specific load factor (slideways)
a_{E2}	-	Speed, temperature and material factor (slideways)
a_{E3}	-	Relative contact area factor (slideways)
a_L	-	Life correction constant
a_M	-	Mating surface material factor
a_T	-	Temperature application factor
B	mm	Nominal bush length
C	1/min	Dynamic load frequency
C_D	mm	Installed diametral clearance
C_i	mm	Inside chamfer
C_o	mm	Outside chamfer
C_T	-	Total number of dynamic load cycles
D_C	mm	Diameter of burnishing tool
D_{fl}	mm	Nominal bush flange OD
D_H	mm	Housing diameter
D_i	mm	Nominal bush and thrust washer ID
$D_{i,a}$	mm	Bush ID when assembled in housing
D_J	mm	Shaft diameter
D_{Nth}	nvt	Max. thermal neutron dose
D_o	mm	Nominal bush and thrust washer OD
d_D	mm	Dowel hole diameter
d_L	mm	Oil hole diameter
d_P	mm	Pitch circle diameter for dowel hole
D_g	Gy	Max. Gamma radiation dose G_y = J/kg
F	N	Bearing load
F_{ch}	N	Test load
F_i	N	Insertion force
f	-	Coefficient of friction

Formula Symbol	Unit	Designation
L	mm	Strip length
L_H	h	Bearing service life
L_S	mm	Length of stroke (slideway)
N	1/min	Rotational speed
N_E	1/min	Equivalent rotational speed for oscillating movement
N_{osz}	1/min	Oscillating movement frequency
$\bar{p}$	N/mm^2	Specific load
$\bar{p}_{lim}$	N/mm^2	Specific load limit
$\bar{p}_{sta,max}$	N/mm^2	Maximum static load
$\bar{p}_{dyn,max}$	N/mm^2	Maximum dynamic load
Q	-	Number of load/movement cycles
R_a	µm	Surface roughness (DIN 4768, ISO/DIN 4287/1)
R_{OB}	Ω	Electrical resistance
S_3	mm	Bush wall thickness
S_{fl}	mm	Flange thickness
S_S	mm	Strip thickness
S_T	mm	Thrust washer thickness
T	°C	Temperature
T_{amb}	°C	Ambient temperature
T_{max}	°C	Maximum temperature
T_{min}	°C	Minimum temperature
t_a	mm	Depth housing recess
U	m/s	Sliding speed
W	mm	Strip width
W_u	mm	Maximum usable strip width
Z_T	-	Total number of cycles
α_1	$1/10^6K$	Coefficient of linear thermal expansion parallel to surface
α_2	$1/10^6K$	Coefficient of linear thermal expansion normal to surface
σ_c	N/mm^2	Compressive yield strength
λ	W/mK	Thermal conductivity
φ	°	Angular displacement
η	Ns/mm^2	Dynamic viscosity

Contents

1 Introduction

DP4™ is a composite steel-backed polymer-lined bearing material. It was developed for high duty, oil lubricated, hydraulic applications as for example in automotive suspension McPherson struts and shock absorbers, hydraulic cylinders, gear pumps and motors and axial and radial piston pumps and motors. DP4 is designed for use mainly under lubricated conditions and shows excellent wear resistance, low static and dynamic friction coefficient and a high resistance to both cavitation and flow erosion damage of the polymer bearing surface by the lubricant. DP4 is suitable for sliding, oscillating, reciprocating and rotating applications.

DP4 is also suitable for use with non-lubricating fluids and in light duty unlubricated applications.

2 Basic Forms

Standard Components

These products are manufactured to International, National or Glacier Garlock Bearings standards. The following components are standard stock products:

- **Cylindrical Bushes**
- **Flanged Bushes**
- **Strip Material**

Fig. 1: Standard stock products

Non-Standard Components

These products are manufactured to customer's requirements and include for example:

- **Modified Standard Components**
- **Thrust Washers**
- **Flanged Washers**
- **Half Bearings**
- **Flat Components**
- **Deep Drawn Parts**
- **Pressings**
- **Stampings**

Fig. 2: Non-Standard Components

3 Structure and Composition

DP4 consists of a steel backing to which is bonded a porous sinter bronze interlayer which is overlaid and impregnated with Polytetrafluoroethylene (PTFE) containing a mixture of inorganic fillers and special polymer fibres. The steel backing provides mechanical strength and the bronze sinter layer provides a strong mechanical bond for the filled bearing lining.

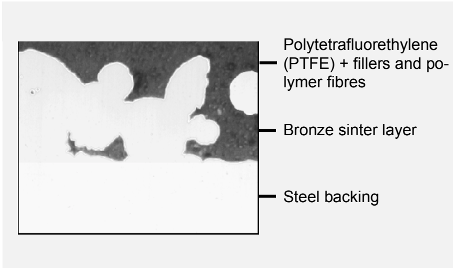


Fig. 3: DP4-microsection

4 Properties

4.1 Physical and Mechanical Properties

		Symbol	Value	Unit	Comment
Physical Properties	Coefficient of linear thermal expansion :				
	parallel to surface	α_1	11	$1/10^6$ K	
	normal to surface	α_2	30	$1/10^6$ K	
	Maximum Operating Temperature	T_{max}	+280	°C	
	Minimum Operating Temperature	T_{min}	–200	°C	
Mechanical Properties	Compressive Yield Strength	σ_c	350	N/mm^2	measured on disc 5 mm diameter x 2.45 mm thick.
	Maximum Load				
	Static	$\bar{p}_{sta,max}$	250	N/mm^2	
	Dynamic	$\bar{p}_{dyn,max}$	140	N/mm^2	

Table 1: Physical and mechanical Properties of DP4

4.2 Chemical Properties

The following table provides an indication of the chemical resistance of DP4 to various chemical media.

It is recommended, that the chemical resistance is confirmed by testing if possible.

4 Properties

	Chemical	%	°C	Rating
Strong Acids	**Hydrochloric Acid**	5	20	**-**
	Nitric Acid	5	20	**-**
	Sulphuric Acid	5	20	**-**
Weak Acids	**Acetic Acid**	5	20	**-**
	Formic Acid	5	20	**-**
Bases	**Ammonia**	10	20	**o**
	Sodium Hydroxide	5	20	**o**
Solvents	**Acetone**		20	**+**
	Carbon Tetrachloride		20	**+**
Lubricants and fuels	**Paraffin**		20	**+**
	Gasolene		20	**+**
	Kerosene		20	**+**
	Diesel Fuel		20	**+**
	Mineral Oil		70	**+**
	HFA-ISO46 High Water Fluid		70	**+**
	HFC-Water-Glycol		70	**+**
	HFD-Phosphate Ester		70	**+**
	Water		20	**o**
	Sea Water		20	**-**

Table 2: Chemical resistance of DP4

+	**Satisfactory:** Corrosion damage is unlikely to occur.
o	**Acceptable:** Some corrosion damage may occur but this will not be sufficient to impair either the structural integrity or the tribological performance of the material.
-	**Unsatisfactory:** Corrosion damage will occur and is likely to affect either the structural integrity and/or the tribological performance of the material.

4.3 Frictional Properties

DP4 bearings show negligible 'stick-slip' and provide smooth sliding between adjacent surfaces. The coefficient of friction of DP4 depends upon:

- The specific load $\overline{p}$ [N/mm^2]
- The sliding speed U [m/s]
- The roughness of the mating running surface R_a [µm]
- The bearing temperature T [°C].

A typical relationship is shown in Fig. 4, which can be used as a guide to establish the actual friction under clean, dry conditions after running in.

Exact values may vary by ±20 % depending on operating conditions. Before running in, the friction may be up to 50 % higher.

After progressively longer periods of dwell under load (e.g. hours or days) the static coefficient of friction on the first movement may be between 1.5 and 3 times greater, particularly before running in.

Effect of Temperature for unlubricated applications

The coefficient of friction of DP4 varies with temperature. Typical values are shown in Fig. 5 for temperatures up to 250 °C.

Friction increases at bearing temperatures below 0 °C.

Where frictional characteristics are critical to a design they should be established by prototype testing.

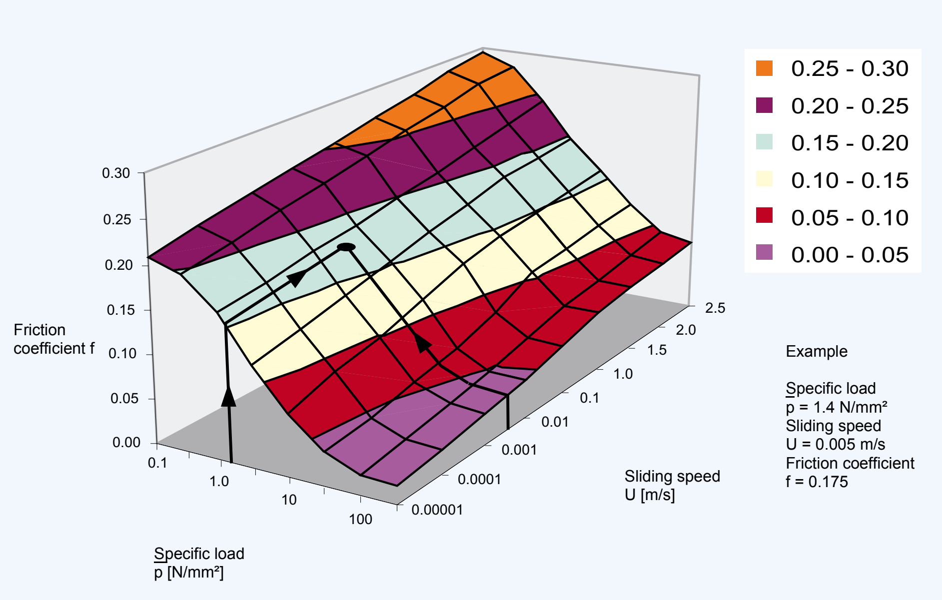


Fig. 4: Variation of friction coefficient f with specific load p̄ and speed U at temperature T = 25 °C

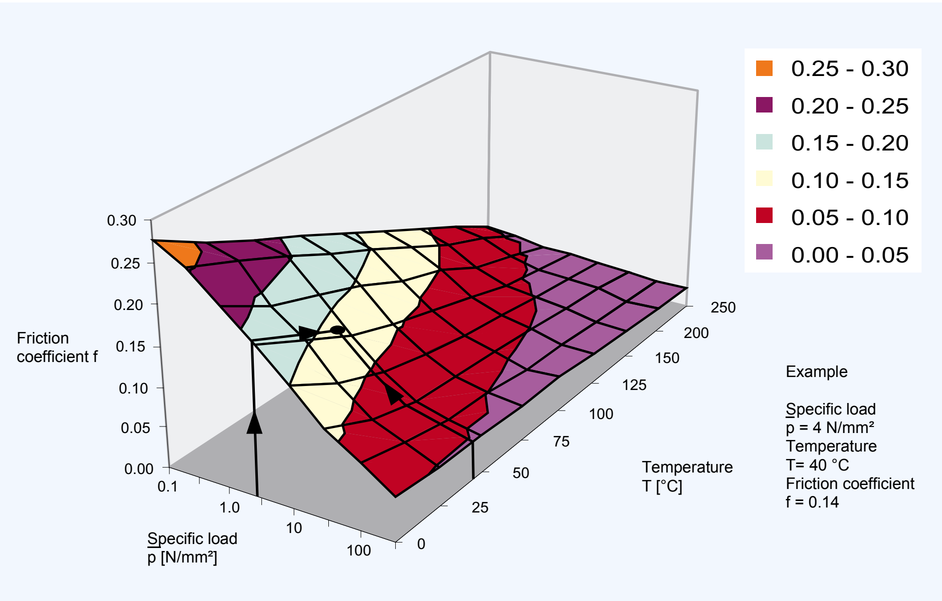


Fig. 5: Variation of friction coefficient f with specific load p̄ and temperature T at speed U = 0.01 m/s

5 Bearing Performance

5.1 McPherson Strut Applications

DP4 has been developed to provide improved wear, erosion resistance and reduced friction in McPherson strut piston rod guide bush applications under the most demanding of operating conditions. In the following sections, the performance of DP4 is compared with that of the material used in the majority of this type of application.

Wear and Friction Properties

The wear and frictional performance of DP4 has been evaluated in the piston rod guide bush application of a McPherson strut shock absorber using the test rig shown in Fig. 6. The test conditions are designed to simulate the operational duty of the test strut in service and differ in detail according to the strut manufacturer. The test conditions used are given in Table 3 and Table 4.

McPherson Strut Test Rig

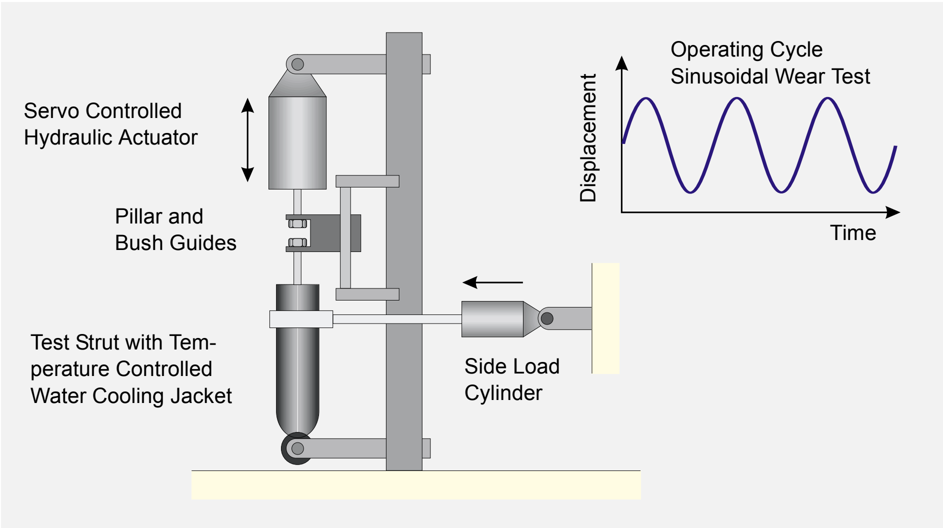


Fig. 6: Principle of the Strut Test Rig

Strut Wear - Test conditions

Waveform	Sine
Frequency	2.5 Hz
Side Load	890 N
Test Duration	100 hours
Stroke	100 mm
Mean Diametral Clearance	0.06 mm
Lubricant	TEX 0358
Foot Valve Temperature	70 °C

Table 3: McPherson strut wear test conditions

Strut Friction - Test conditions

Waveform	Sine
Frequency	0.1 Hz
Side Load	600 N
Stroke	70 mm
Mean Diametral Clearance	0.06 mm
Lubricant	TEX 0358
Foot Valve Temperature	Ambient

Table 4: McPherson strut friction test conditions

The relative wear and frictional performance of DP4 tested under these conditions are shown in Figures 7-9. Actual results for the wear rate and friction are not quoted because these depend strongly on the actual test conditions and design of the strut under test. The relative performance plots shown thus provide the best indication as to the benefits offered by DP4 in this class of application.

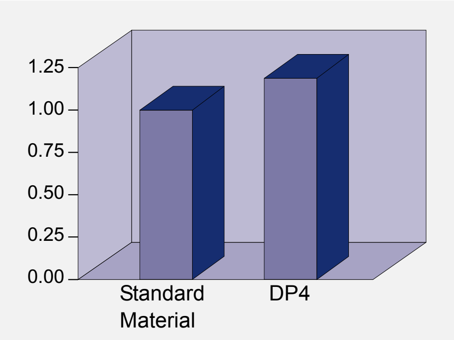


Fig. 7: Relative wear resistance

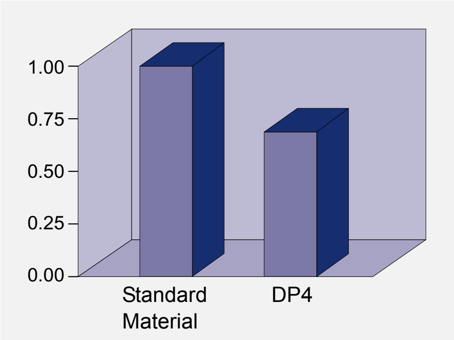


Fig. 9: Relative dynamic friction coefficient

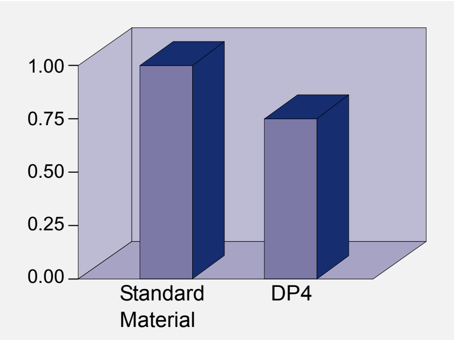


Fig. 8: Relative static friction coefficient

Cavitation Erosion Resistance

Under certain operating conditions, the PTFE lining of the McPherson strut piston rod guide bush can suffer erosion damage, due to cavitation and flow erosion effects from the oil film within the bearing. The test rig shown in Fig. 10 is designed to reproduce the cavitation erosion damage to the bearing lining of the test specimen. The test conditions are given in Table 5.

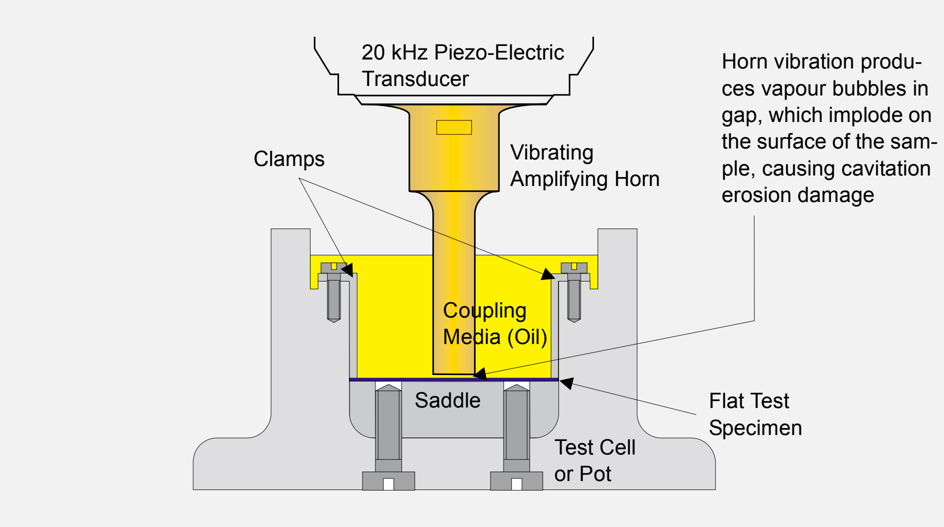


Fig. 10: Principle of the cavitation erosion test rig

Cavitation Erosion - Test Conditions

Amplitude	0.015 mm
Frequency	20 kHz
Separation	1 mm
Test Duration	30 minutes
Lubricant	TEX 0358
Temperature	Ambient

Table 5: Cavitation erosion test conditions

The relative resistance to cavitation damage of DP4 as evaluated on this test rig is shown in Fig. 11.

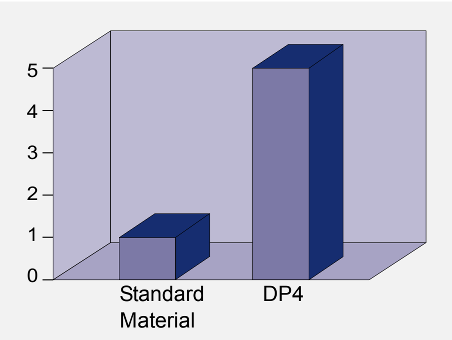


Fig. 11: Relative resistance to cavitation erosion

Flow Erosion Resistance

The test rig shown in Fig. 12 is designed to reproduce flow erosion damage to the bearing lining of the test specimen. The test conditions are given in Table 6.

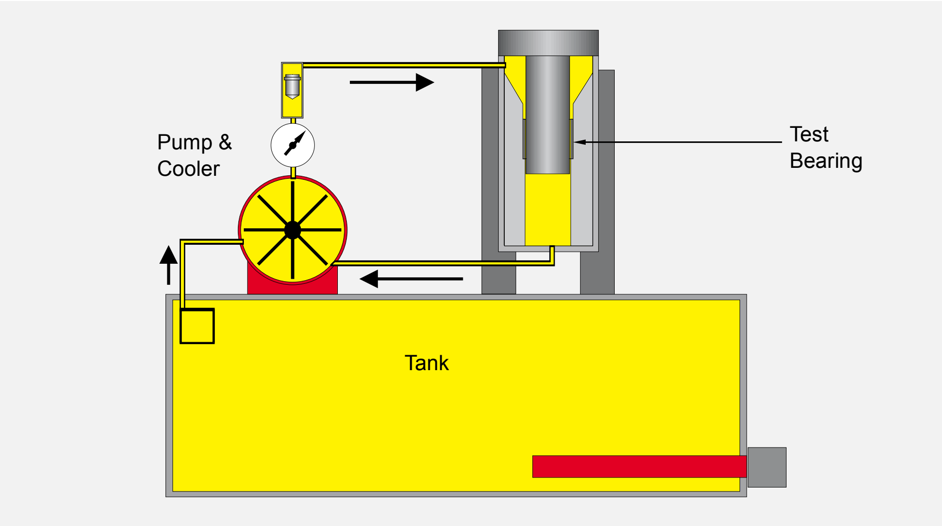


Fig. 12: Principle of the flow erosion test rig

Flow Erosion - Test Conditions

Bearing Diameter	20 mm
Bearing Length	15 mm
Diametral Clearance	0.11 mm
Pressure	13.8 MPa
Flow Rate	5 l/min
Test Duration	20 hours
Shaft Surface Finish	0.15 μm ±0.05
Temperature	Ambient

Table 6: Flow erosion test conditions

The relative resistance to flow erosion damage of DP4 as evaluated on this test rig is shown in Fig. 13.

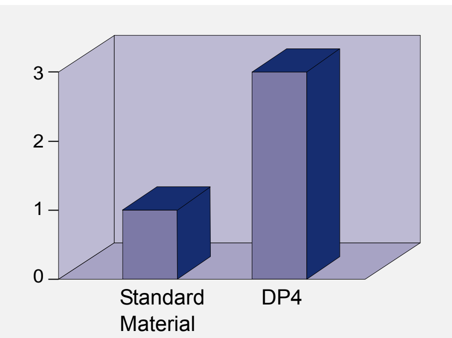


Fig. 13: Relative resistance to flow erosion

5.2 Hydraulic Applications

DP4 also shows excellent wear and frictional performance in a wide range of oil lubricated hydraulic applications.

The wear resistance of Glacier DP4 under steady load oil immersed boundary lubrication conditions has been evaluated using the test rig shown in Fig. 14. The test conditions are given in Table 7.

Glacier Garlock Bearings Jupiter Test Rig

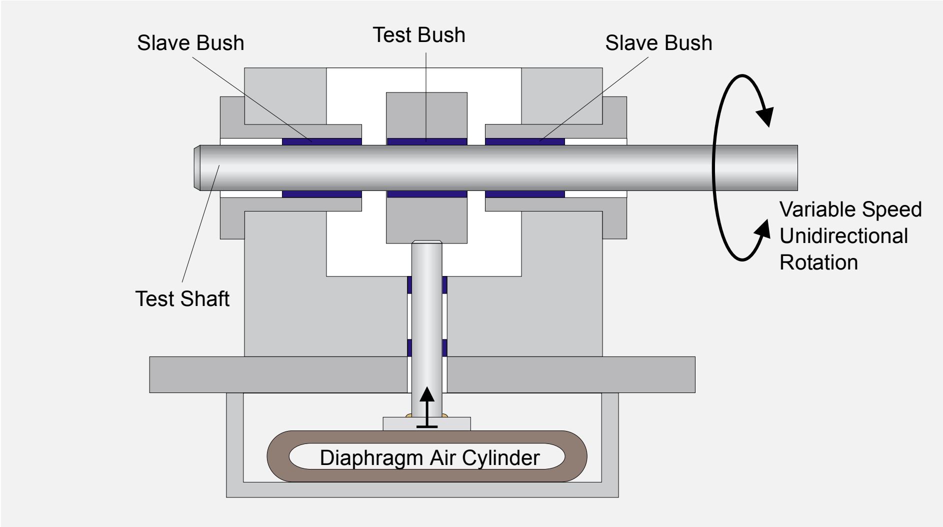


Fig. 14: Principle of the Glacier Garlock Bearings Jupiter test rig

Lubricated Wear - Test Conditions

Bearing Diameter	20 mm
Bearing Length	15 mm
Mean Diametral Clearance	0.10 mm
Speed	0.11 m/s
Lubricant	ISO VG 46 hydraulic oil

Table 7: Lubricated wear test conditions

The relative $\overline{p}U$ limits with boundary lubrication of DP4 and the material used in many high performance hydraulic pump applications as determined from these tests are shown in Fig. 15. The limiting $\overline{p}U$ depends upon the actual operating conditions and hence the relative performance only is given for guidance.

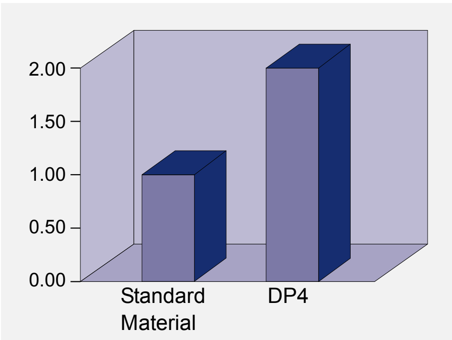


Fig. 15: Relative $\overline{p}U$ limits

5.3 Dry Wear Performance

Design Factors

The main parameters when determining the size or calculating the service life for a DP4 bearing are:

- Specific Load Limit $\bar{p}_{lim}$
- $\bar{p}U$ Factor
- Mating surface roughness R_a
- Mating surface material
- Temperature T
- Other environmental factors e.g. housing design, dirt, lubrication

The following calculation can be used to estimate the bearing service life of DP4 under dry running conditions.

Specific Load $\bar{p}$

For the purpose of assessing bearing performance the specific load $\bar{p}$ is defined as the working load divided by the projected area of the bearing and is expressed in N/mm².

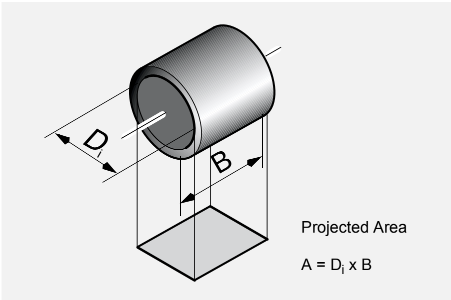


Fig. 16: Projected Area

Cylindrical Bush

(5.3.1) [N/mm²]

$$\bar{p} = \frac{F}{D_i \cdot B}$$

Thrust Washer

(5.3.2) [N/mm²]

$$\bar{p} = \frac{4F}{\pi \cdot (D_o^2 - D_i^2)}$$

Flanged Bush (Axial Loading)

(5.3.3) [N/mm²]

$$\bar{p} = \frac{F}{0.04 \cdot (D_{fl}^2 - D_i^2)}$$

Slideway

(5.3.4) [N/mm²]

$$\bar{p} = \frac{F}{L \cdot W}$$

Specific Load Limit $\bar{p}_{lim}$

The maximum load which can be applied to a DP4 bearing can be expressed in terms of the Specific Load Limit, which depends on the type of the loading. It is highest under steady loads. Conditions of dynamic load or oscillating movement which produce fatigue stress in the bearing result in a reduction in the permissible Specific Load Limit.

In general the specific load on a DP4 bearing should not exceed the Specific Load Limits given in Table 8.

The values of Specific Load Limit specified in Table 8 assume good alignment between the bearing and mating surface (Fig. 33).

Maximum specific load $\bar{p}_{lim}$

Type of loading	$\bar{p}_{lim}$ [N/mm²]									
steady load, rotating movement	140									
steady load, oscillating movement	140	140	115	95	85	80	60	44	30	20
No. of movement cycles Q	1000	2000	4000	6000	8000	10^4	10^5	10^6	10^7	10^8
dynamic load, rotating or oscillating movement	60	60	50	46	42	40	30	22	15	10
No. of load cycles Q	1000	2000	4000	6000	8000	10^4	10^5	10^6	10^7	10^8

Table 8: Specific load limit

Permanent deformation of the DP4 bearing lining may occur at specific loads above 140 N/mm². Under these conditions DP4 should only be used after consulting our application engineers or with slow intermittent movements.

The permissible maximum load on a thrust washer is higher than that on the flange of a flanged bush, and under conditions of high axial loads a thrust washer should be specified.

Sliding Speed U

Speeds in excess of 2.5 m/s sometimes lead to overheating, and a running in procedure may be beneficial.

This could consist of a series of short runs progressively increasing in duration from an initial run of a few seconds.

Calculation of Sliding Speed U

Continuous Rotation

Bushes

(5.3.5) [m/s]

$$U = \frac{D_i \cdot \pi \cdot N}{60 \cdot 10^3}$$

Thrust Washers

(5.3.6) [m/s]

$$U = \frac{\frac{D_o + D_i}{2} \cdot \pi \cdot N}{60 \cdot 10^3}$$

Oscillating Movement

Bushes

(5.3.7) [m/s]

$$U = \frac{D_i \cdot \pi}{60 \cdot 10^3} \cdot \frac{4\varphi \cdot N_{osz}}{360}$$

Thrust Washers

(5.3.8) [m/s]

$$U = \frac{\frac{D_o + D_i}{2} \cdot \pi}{60 \cdot 10^3} \cdot \frac{4\varphi \cdot N_{osz}}{360}$$

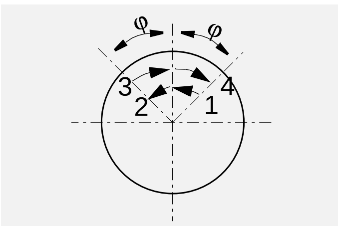


Fig. 17: Oscillating cycle φ

$\bar{p}$U Factor

The useful operating life of a DP4 bearing is governed by the $\bar{p}$U factor, the product of the specific load $\bar{p}$ [N/mm²] and the sliding speed U [m/s].

For thrust washers and flanged bush thrust faces the rubbing velocity at the mean diameter is used.

	DP4	Unit
p	140	N/mm²
U	2.5	m/s
$\bar{p}$U continuous	0.5	N/mm² x m/s
$\bar{p}$U intermittent	1.0	N/mm² x m/s

Table 9: Typical data $\bar{p}$, U, $\bar{p}$U

$\bar{p}$U factors up to 1.0 N/mm² x m/s can be accommodated for short periods, whilst for continuous rating, $\bar{p}$U factors up to 0.5 N/mm² x m/s can be used, depending upon the operating life required.

Calculation of $\bar{p}$U Factor

(5.3.9) [N/mm² x m/s]

$$\bar{p}U = \bar{p} \cdot U$$

Application Factors

The following factors influence the bearing performance of DP4 and must be considered in calculating the required dimensions or estimating the bearing life for a particular application.

Temperature

The useful life of a DP4 bearing depends upon the operating temperature.

Under dry running conditions frictional heat is generated at the rubbing surface of the bearing dependent on the $\bar{p}$U condition. For a given $\bar{p}$U factor the operating temperature of the bearing depends upon the temperature of the surrounding environment, the heat dissipation properties of the housing and the mating surface. Intermittent operation affects the heat dissipation from the assembly and hence the operating temperature of the bearing.

The effect of temperature on the operating life of DP4 bearings is indicated by the factor a_T shown in Table 10.

Mode of Operation	Nature of housing	Temperature of bearing environment T_{amb} [℃] and Temperature application factor a_T					
		25	**60**	**100**	**150**	**200**	**280**
Dry continuous operation	Average heat dissipating qualities	1.0	0.8	0.6	0.4	0.2	0.1
Dry continuous operation	Light pressings or isolated housing with poor heat dissipating qualities	0.5	0.4	0.3	0.2	0.1	-
Dry continuous operation	Non-metallic housings with bad heat dissipating qualities	0.3	0.3	0.2	0.1	-	-
Dry intermittent operation (duration less than 2 min, followed by a longer dwell period)	Average heat dissipating qualities	2.0	1.6	1.2	0.8	0.4	0.2

Table 10: Temperature application factor a_T

Mating Surface

The effect of mating surface material type on the operating life of DP4 bearings is indicated by the mating surface factor a_M and life correction constant a_L shown in Table 11.

Note:

The factor values given assume a mating surface finish of ≤0.4 µm R_a.

- A ground surface is preferred to fine turned.
- Surfaces should be cleaned of abrasive particles after polishing.
- Cast iron surfaces should be ground to <0.3 µm R_a.
- The grinding cut should be in the same direction as the bearing motion relative to the shaft.

Material	Mating Surface Factor a_M	Life correction constant a_L
Steel and Cast Iron		
Carbon Steel	1	400
Carbon Manganese Steel	1	400
Alloy Steel	1	400
Case Hardened Steel	1	400
Nitrided Steel	1	400
Salt bath nitrocarburised	1	400
Stainless Steel (7-10 % Ni, 17-20 % Cr)	2	400
Cast Iron (0.3 µm R_a)	1	400

Table 11: Mating surface factor a_M and life correction constant a_L

Bearing Size

The running clearance of a DP4 bearing increases with bearing diameter resulting in a proportionally smaller contact area between the shaft and bearing. This reduction in contact area has the effect of increasing the actual unit load and hence $\bar{p}U$ factor. The bearing size factor (Fig. 18) is used in the design calculations to allow for this effect.

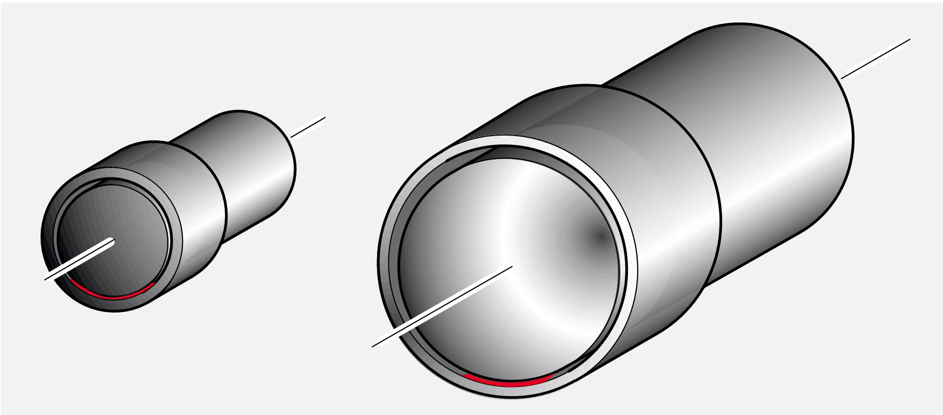


Fig. 18: Contact area between bearing and shaft

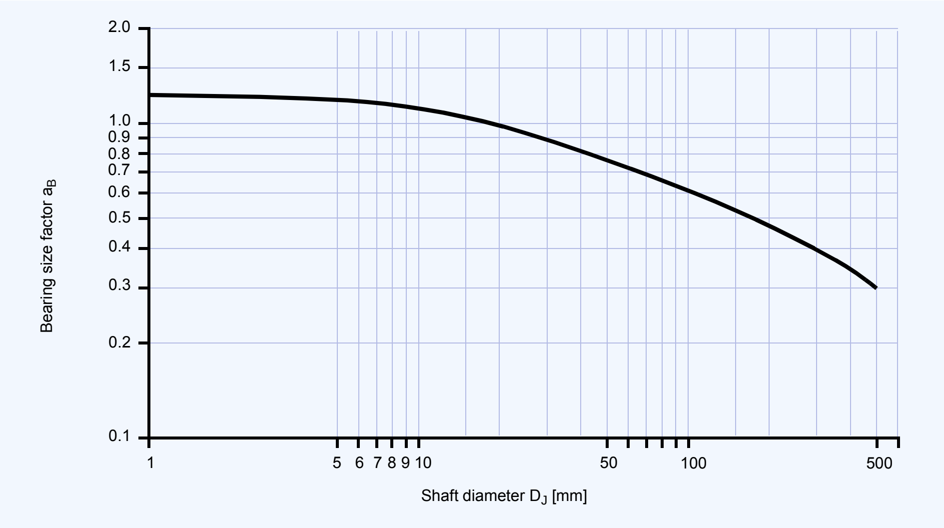


Fig. 19: Bearing size factor a_B

Bore Burnishing

Burnishing the bore of a DP4 bearing results in a reduction in the wear performance. The application factor a_C given in Table 12 is used in the design calculation to allow for this effect. Machining DP4 is not recommended.

Degree of sizing		Application factor a_C
Burnishing: Excess of burnishing tool diameter over mean bore size	0.025 mm	0.8
	0.038 mm	0.6
	0.050 mm	0.3

Table 12: Bore burnishing application factor a_C

Type of Load

The type of load is considered in formula (5.4.9), Page 19 and (5.4.10), Page 19.

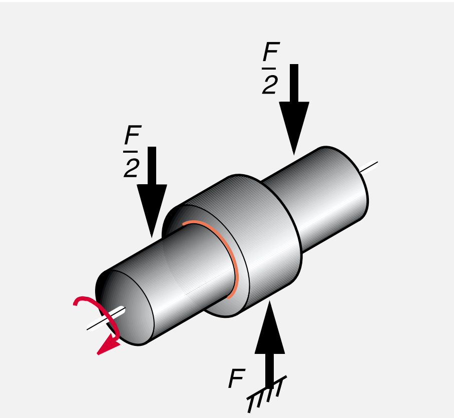


Fig. 20: Steady load, bush stationary, shaft rotating

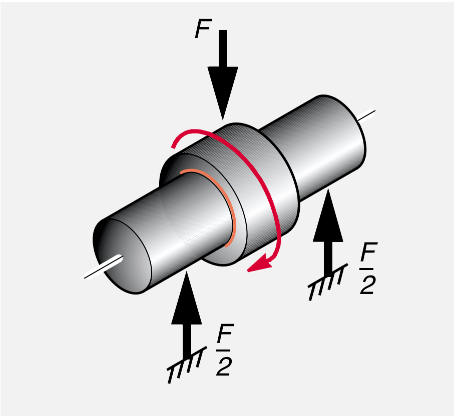


Fig. 21: Rotating load, shaft stationary, bush rotating

5.4 Calculation of Bearing Service Life

Where the size of a bearing is governed largely by the space available the following calculation can be used to determine whether its useful life will satisfy the requirements. If the calculated life is inadequate, a redesign should be considered.

Specific load $\bar{p}$

Bushes

(5.4.1) [N/mm²]

$$\bar{p} = \frac{F}{D_i \cdot B}$$

Flanged Bushes

(5.4.2) [N/mm²]

$$\bar{p} = \frac{F}{0.04 \cdot (D_{fl}^2 - D_i^2)}$$

Thrust Washers

(5.4.3) [N/mm²]

$$\bar{p} = \frac{4F}{p \cdot (D_o^2 - D_i^2)}$$

High load factor a_E

If a_E is negative then the bearing is overloaded. Increase the bearing diameter and/or length.

(5.4.4) [–]

$$a_E = \frac{\bar{p}_{lim} - \bar{p}}{\bar{p}_{lim}}$$

$\bar{p}$lim see Tab. 8, page 14

Modified $\bar{p}$U Factor

Bushes

(5.4.5) [N/mm² x m/s]

$$\bar{p}U = \frac{5.25 \cdot 10^{-5} F \cdot N}{a_E \cdot B \cdot a_T \cdot a_M \cdot a_B}$$

Flanged Bushes

(5.4.6) [N/mm² x m/s]

$$\bar{p}U = \frac{6.5 \cdot 10^{-4} F \cdot N}{a_E \cdot (D_{fl} - D_i) \cdot a_T \cdot a_M \cdot a_B}$$

Thrust Washers

(5.4.7) [N/mm² x m/s]

$$\bar{p}U = \frac{3.34 \cdot 10^{-5} F \cdot N}{a_E \cdot (D_o - D_i) \cdot a_T \cdot a_M \cdot a_B}$$

For oscillating movement, calculate the average rotational speed.

(5.4.8) [1/min]

$$N_E = \frac{4\varphi \cdot N_{osz}}{360}$$

Estimation of bearing life L_H

Bushes (Steady load)

(5.4.9) [h]

$$L_H = \frac{265}{\bar{p}U} - a_L$$

Bushes (Rotating load)

(5.4.10) [h]

$$L_H = \frac{530}{\bar{p}U} - a_L$$

Flanged Bushes (Axial load)

(5.4.11) [h]

$$L_H = \frac{175}{\bar{p}U} - a_L$$

a_L see Table 11, Page 17

Thrust Washers

(5.4.12) [h]

$$L_H = \frac{175}{\bar{p}U} - a_L$$

Bore Burnishing

If the DP4 bush is bore burnished then this must be allowed for in estimating the bearing life by the application factor a_C (Table 12, Page 18).

Estimated Bearing Life

(5.4.13) [h]

$$L_H = L_H \cdot a_C$$

a_C see Table 12, Page 18

For Oscillating Movements or Dynamic loads

Calculate estimated number of cycles Z_T

(5.4.14) [cycles]

$$Z_T = L_H \cdot N_{osz} \cdot 60$$

(5.4.15) [cycles]

$$Z_T = L_H \cdot C \cdot 60$$

If the required bearing life is known, the total number of cycles can be determined.

Check that Z_T is less than total number of cycles Q for the operating specific load $\bar{p}_{lim}$ (Table 8, Page 15).

If Z_T <Q, bearing life will be limited by wear after Z_T cycles.

If Z_T >Q, bearing life will be limited by fatigue after Z_T cycles.

Slideways

Specific load factor

(5.4.16) [–]

$$a_{E1} = A - \frac{F}{\bar{p}_{lim}}$$

If negative the bearing is overloaded and the bearing area should be increased.

Speed, temperature and material application factor

(5.4.17) [–]

$$a_{E2} = \frac{280 \cdot a_T \cdot a_M}{F \cdot U}$$

a_T see Table 10, Page 16
a_M see Table 11, Page 17

Relative contact area factor

(5.4.18) [–]

$$a_{E3} = \frac{A}{A_M}$$

Estimated bearing life

(5.4.19) [–]

$$L_H = a_{E1} \cdot a_{E2} \cdot a_{E3} - a_L$$

Note:

Estimated bearing lives greater than 4000 hours are subject to error due to inaccuracies in the extrapolation of test data.

5.5 Worked Examples

Cylindrical Bush

Given:			
Load Details	Steady Load	Inside Diameter D_i	40 mm
	Continuous Rotation	Length B	30 mm
Shaft	Steel	Bearing Load F	5000 N
	Unlubricated at 25 °C	Rotational Speed N	25 1/min

Calculation Constants and Application Factors		
Specific Load Limit p_{lim}	140 N/mm²	(Table 8, Page 15)
Application Factor a_T	1.0	(Table 10, Page 16)
Material Application Factor a_M	1.0	(Table 11, Page 17)
Bearing Size Factor a_B	0.85	(Fig. 19, Page 18)
Life Correction Constant a_L	400	(Table 11, Page 17)

Calculation	Ref	Value
Specific Load p [N/mm²]	(5.4.1), page 18	$\bar{p} = \frac{F}{D_i \cdot B} = \frac{5000}{40 \cdot 30} = 4.17$
Sliding Speed U [m/s]	(5.3.5), page 14	$U = \frac{D_i \cdot \pi \cdot N}{60 \cdot 10^3} = \frac{40 \cdot \pi \cdot 25}{60000} = 0.052$
High Load Factor a_E [-] (must be >0)	(5.4.4), page 18	$a_E = \frac{\bar{p}_{lim} - \bar{p}}{\bar{p}_{lim}} = \frac{140 - 4.17}{140} = 0.970$
Modified pU Factor [N/mm² x m/s]	(5.4.5), page18	$\bar{p}U = \frac{5.25 \cdot 10^{-5} \cdot F \cdot N}{a_E \cdot B \cdot a_T \cdot a_M \cdot a_B} = \frac{6.5625}{24.265} = 0.27$
Life L_H [h]	(5.4.9), page 18	$L_H = \frac{265}{\bar{p}U} - a_L = \frac{265}{0.27} - 400 = 581$

Thrust washer

Given:			
Load Details	Axial Load	Inside Diameter D_i	38 mm
	Continuous Rotation	Outside Diameter D_o	62 mm
Shaft	Steel	Bearing Load F	6500 N
	Unlubricated at 25 °C	Rotational Speed N	10 1/min

Calculation Constants and Application Factors		
Specific Load Limit p_{lim}	140 N/mm²	(Table 8, Page 15)
Application Factor a_T	1.0	(Table 10, Page 16)
Material Application Factor a_M	1.0	(Table 11, Page 17)
Bearing Size Factor a_B	0.85	(Fig. 19, Page 18)
Life Correction Constant a_L	400	(Table 11, Page 17)

Calculation	Ref	Value
Specific Load p [N/mm²]	(5.4.3), page 18	$\bar{p} = \frac{4 \cdot F}{\pi \cdot (D_o^2 - D_i^2)} = \frac{4 \cdot 6500}{\pi \cdot (62^2 - 38^2)} = 3.45$
Sliding Speed U [m/s]	(5.3.6), page 14	$U = \frac{\frac{D_o + D_i}{2} \cdot \pi \cdot N}{60 \cdot 10^3} = \frac{\frac{62 + 38}{2} \cdot \pi \cdot 10}{60 \cdot 10^3} = 0.026$
High Load Factor a_E [-] (must be >0)	(5.4.4), page 18	$a_E = \frac{\bar{p}_{lim} - \bar{p}}{\bar{p}_{lim}} = \frac{140 - 3.45}{140} = 0.975$
Modified pU Factor [N/mm² x m/s]	(5.4.7), page 18	$\bar{p}U = \frac{3.34 \cdot 10^{-5} \cdot F \cdot N}{a_E \cdot (D_o - D_i) \cdot a_T \cdot a_M \cdot a_B} = \frac{2.171}{19.28} = 0.113$
Life L_H [h]	(5.4.17), page 19	$L_H = \frac{175}{\bar{p}U} - a_L = \frac{175}{0.113} - 400 = 1149$

Flanged Bush

Given:			
Load Details	Axial Load	Flange Outside Diameter D_{fl}	23 mm
	Continuous Rotation	Inside Diameter D_i	15 mm
Shaft	Steel	Bearing Load F	250 N
	Unlubricated at 25 °C	Rotational Speed N	5 1/min

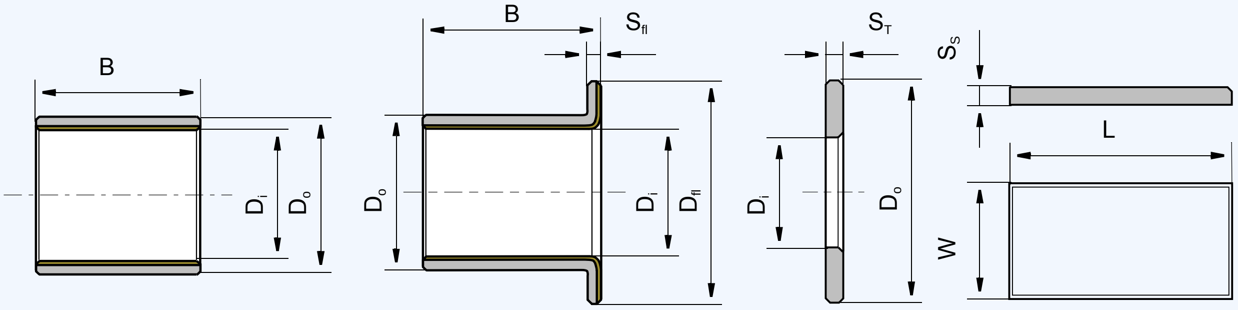
Calculation Constants and Application Factors		
Specific Load Limit p_{lim}	140 N/mm²	(Table 8, Page 15)
Application Factor a_T	1.0	(Table 10, Page 16)
Material Application Factor a_M	1.0	(Table 11, Page 17)
Bearing Size Factor a_B	1.0	(Fig. 19, Page 18)
Life Correction Constant a_L	400	(Table 11, Page 17)

Calculation	Ref	Value
Specific Load p [N/mm²]	(5.4.2), page 18	$\bar{p} = \frac{F}{0.04 \cdot (D_{fl}^2 - D_i^2)} = \frac{250}{0.04 \cdot (23^2 - 15^2)} = 20.55$
Sliding Speed U [m/s]	(5.3.6), page14	$U = \frac{\frac{D_{fl} + D_i}{2} \cdot \pi \cdot N}{60 \cdot 10^3} = \frac{\frac{23 + 15}{2} \cdot \pi \cdot 5}{60 \cdot 10^3} = 0.005$
High Load Factor a_E [-] (must be >0)	(5.4.4), page 18	$a_E = \frac{\bar{p}_{lim} - \bar{p}}{\bar{p}_{lim}} = \frac{140 - 20.55}{140} = 0.853$
Modified pU Factor [N/mm² x m/s]	(5.4.6), page 18	$\bar{p}U = \frac{6.5 \cdot 10^{-4} \cdot F \cdot N}{a_E \cdot (D_{fl} - D_i) \cdot a_T \cdot a_M \cdot a_B} = \frac{0.8125}{6.82} = 0.119$
Life L_H [h]	(5.4.11), page 18	$L_H = \frac{175}{\bar{p}U} - a_L = \frac{175}{0.119} - 400 = 1071$

6 Data Sheet

Application:

6.1 Data for bearing design calculations



☐ Cylindrical Bush ☐ Flanged Bush ☐ Thrust Washer ☐ Slideplate ☐ Special (Sketch)

☐ Rotational movement ☐ Steady load ☐ Rotating load ☐ Oscillating movement ☐ Linear movement

☐ Existing Design ☐ New Design

Quantity		

Dimensions in mm

Inside Diameter	D_i	
Outside Diameter	D_o	
Length	B	
Flange Diameter	D_{fl}	
Flange Thickness	S_{fl}	
Length of slideplate	L	
Width of slideplate	W	
Thickness of slideplate	S_S	

Load

Radial load	F [N]	
or specific load	$\bar{p}$ [N/mm²]	
Axial load	F [N]	
or specific load	$\bar{p}$ [N/mm²]	

Movement

Rotational speed	N [1/min]	
Speed	U [m/s]	
Length of Stroke	L_S [mm]	
Frequency of Stroke	[1/min]	
Oscillating cycle	φ [°]	
Oscillating frequency	N_{osz} [1/min]	

Service hours per day

Continuous operation	
Intermittent operation	
Operating time	
Days per year	

Fits and Tolerances

Shaft	D_J	
Bearing Housing	D_H	

Operating Environment

Ambient temperature	T_{amb} [°]	

- Housing with good heat transfer properties ☐
- Light pressing or insulated housing which poor heat transfer properties ☐
- Non metal housing with poor heat transfer properties ☐
- Alternate operation in water and dry ☐

Mating surface

Material		
Hardness	HB/HRC	
Surface finish	R_a [µm]	

Lubrication

- Dry ☐
- Continuous lubrication ☐
- Process fluid lubrication ☐
- Initial lubrication only ☐
- Hydrodynamic conditions ☐

Process Fluid		
Lubricant		
Dynamic viscosity	η	

Service life

Required service life	L_H [h]	

Customer Data
Company: City:
Street: Post Code:

Project:
Name:
Tel.:

Date:
Signature:
Fax:

7 Lubrication

DP4 provides excellent performance in lubricated applications. The following sections describe the basics of lubrication and provide guidance on the application of DP4 in such environments.

7.1 Lubricants

DP4 can be used with most fluids including:

- water
- lubricating oils
- engine oil
- turbine oil
- hydraulic fluid
- solvent
- refrigerants

In general, the fluid will be acceptable if it does not chemically attack the filled PTFE overlay or the porous bronze interlayer.

Where there is doubt about the suitability of a fluid, a simple test is to submerge a sample of DP4 material in the fluid for two to three weeks at 15-20 °C above the operating temperature.

The following will usually indicate that the fluid is not suitable for use with DP4:

- A significant change in the thickness of the DP4 material,
- A visible change in the bearing surface other than some discolouration or staining,
- A visible change in the microstructure of the bronze interlayer.

7.2 Tribology

There are three modes of lubricated bearing operation which relate to the thickness of the developed lubricant film between the bearing and the mating surface:

- Hydrodynamic lubrication
- Mixed film lubrication
- Boundary lubrication.

These three modes of operation depend upon:

- Bearing dimensions
- Clearance
- Load
- Speed
- Lubricant Viscosity
- Lubricant Flow

Hydrodynamic lubrication

Characterised by:

- Complete separation of the shaft from the bearing by the lubricant film
- Very low friction and no wear of the bearing or shaft since there is no contact
- Coefficients of friction of 0.001 to 0.01

Hydrodynamic conditions occur when

(7.2.1) [N/mm²]

$$\bar{p} \leq \frac{U \cdot \eta}{7.5} \cdot \frac{B}{D_i}$$

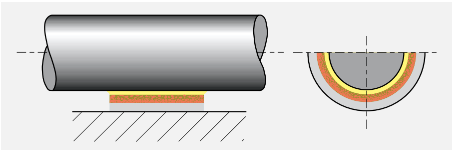


Fig. 22: Hydrodynamic lubrication

Mixed film lubrication

Characterised by:

- Combination of hydrodynamic and boundary lubrication.
- Part of the load is carried by localised areas of self pressurised lubricant and the remainder supported by boundary lubrication.
- Friction and wear depend upon the degree of hydrodynamic support developed.
- DP4 provides low friction and high wear resistance to support the boundary lubricated element of the load.

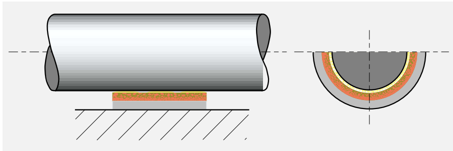


Fig. 23: Mixed film lubrication

Boundary lubrication

Characterised by:

- Rubbing of the shaft against the bearing with virtually no lubricant separating the two surfaces.
- Bearing material selection is critical to performance.
- Shaft wear is likely due to contact between bearing and shaft.
- The excellent properties of DP4 material minimises wear under these conditions.
- The dynamic coefficient of friction with DP4 is typically 0.05 to 0.3 under boundary lubrication conditions.
- The static coefficient of friction with DP4 is typically slightly above the dynamic coefficient of friction under boundary lubrication conditions.

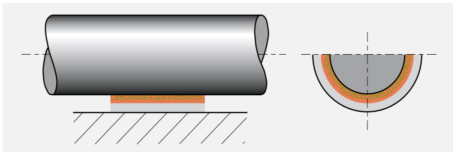


Fig. 24: Boundary lubrication

7.3 Characteristics of Lubricated Bearings

DP4 is particularly effective in the most demanding of lubricated applications where full hydrodynamic operation cannot be maintained, for example:

- **High load conditions**
  In highly loaded applications operating under boundary or mixed film conditions DP4 shows excellent wear resistance and low friction.
- **Start up and shut down under load**
  With insufficient speed to generate a hydrodynamic film the bearing will operate under boundary or mixed film conditions.
  - DP4 minimises wear
  - DP4 requires less start-up torque than conventional metallic bearings.
- **Sparse lubrication**
  Many applications require the bearing to operate with less than the ideal lubricant supply, typically with splash or mist lubrication only.
  DP4 requires significantly less lubricant than conventional metallic bearings.
- **Non lubricating fluids**
  DP4 operates satisfactorily in low viscosity and non lubricating fluids such as water and some process fluids.

Note the following however:

If a DP4 bearing is required to run dry after running in water under non hydrodynamic conditions then the wear resistance will be substantially reduced due to an increased amount of bedding in wear.

Fig. 25, Page 25 shows the three lubrication regimes discussed above plotted on a graph of sliding speed vs the ratio of specific load to lubricant viscosity.

In order to use Fig. 24

- Using the formula in Section 5:
  - Calculate the specific load p,
  - Calculate the shaft surface speed U.
- Using the viscosity temperature relationships presented in Table 13:
  - Determine the viscosity in centipoise of the lubricant.

Note:

Viscosity is a function of operating temperature. If the operating temperature of the fluid is unknown, a provisional temperature of 25 °C above ambient can be used.

7.4 Design Guidance

	cP														
Temperature (°C)	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**
Lubricant															
ISO VG 32	310	146	77	44	27	18	13	9.3	7.0	5.5	4.4	3.6	3.0	2.5	2.2
ISO VG 46	570	247	121	67	40	25	17	12	9.0	6.9	5.4	4.4	3.6	3.0	2.6
ISO VG 68	940	395	190	102	59	37	24	17	12	9.3	7.2	5.8	4.7	3.9	3.3
ISO VG 100	2110	780	335	164	89	52	33	22	15	11.3	8.6	6.7	5.3	4.3	3.6
ISO VG 150	3600	1290	540	255	134	77	48	31	21	15	11	8.8	7.0	5.6	4.6
Diesel oil	4.6	4.0	3.4	3.0	2.6	2.3	2.0	1.7	1.4	1.1	0.95				
Petrol	0.6	0.56	0.52	0.48	0.44	0.40	0.36	0.33	0.31						
Kerosene	2.0	1.7	1.5	1.3	1.1	0.95	0.85	0.75	0.65	0.60	0.55				
Water	1.79	1.30	1.0	0.84	0.69	0.55	0.48	0.41	0.34	0.32	0.28				

Table 13: Viscosity

Explanation to Fig. 24

Area 1

The bearing will operate with boundary lubrication and $\bar{p}U$ factor will be the major determinant of bearing life. DP4 bearing performance can be calculated using the method given in Section 5, although the result will probably underestimate the bearing life.

Area 2

The bearing will operate with mixed film lubrication and $\bar{p}U$ factor is no longer a significant parameter in determining the bearing life. DP4 bearing performance will depend upon the nature of the fluid and the actual service conditions.

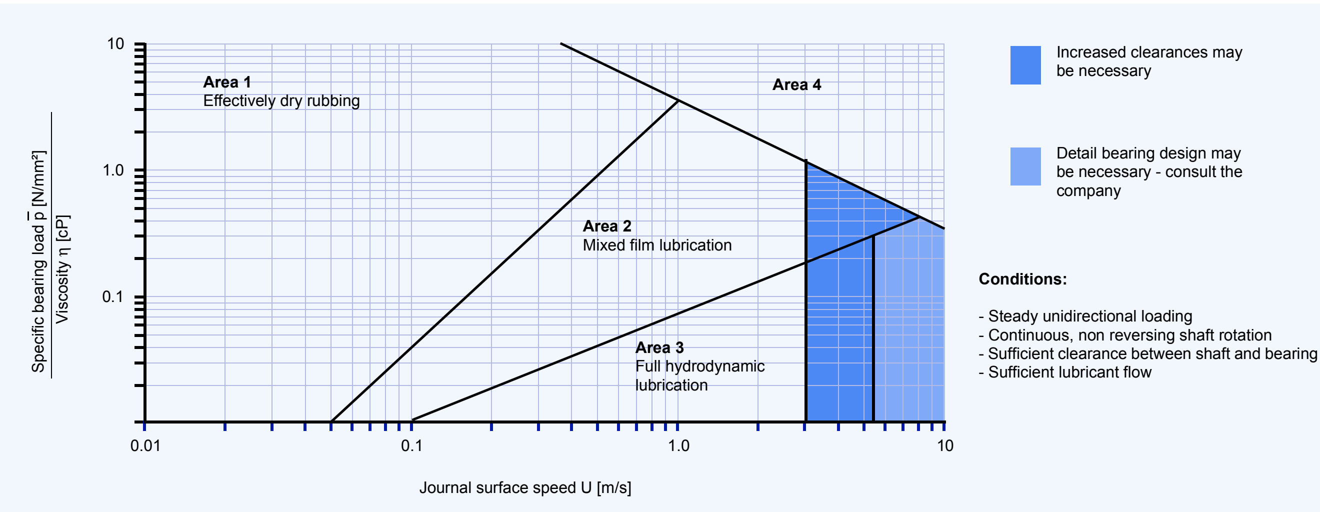


Fig. 25: Design guide for lubricated application

Area 3

The bearing will operate with hydrodynamic lubrication. Bearing wear will be determined only by the cleanliness of the lubricant and the frequency of start up and shut down.

Area 4

These are the most demanding operating conditions. The bearing is operated under either high speed or high bearing load to viscosity ratio, or, a combination of both.

These conditions may cause

- excessive operating temperature and/or
- high wear rate.

Bearing performance may be improved by the addition of one or more grooves to the bearing and a shaft surface finish <0.05 µm R_a.

7.5 Clearances for lubricated operation

The recommended shaft and housing diameters given for standard DP4 bushes will provide sufficient clearance for applications operating with boundary lubrication.

For bearings operating with mixed film or hydrodynamic lubrication it may be necessary to improve the fluid flow through the bearing by reducing the recommended shaft diameter by approximately 0.1 %, particularly when the shaft surface speed exceeds 2.5 m/s.

7.6 Grooving for lubricated operation

In demanding applications an axial oil groove will improve the performance of DP4. Fig. 26 shows the recommended form and location of a single groove with respect to the applied load and the bearing split. Glacier Garlock Bearings can manufacture special DP4 bearings with embossed or milled grooves on request.

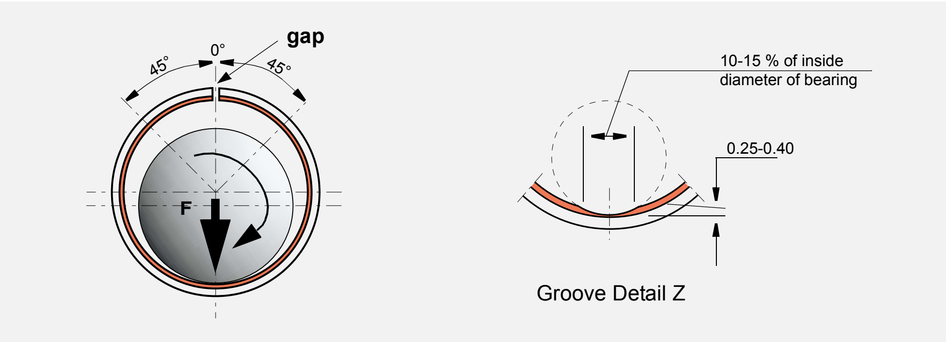


Fig. 26: Location of grooves

7.7 Mating Surface Finish for lubricated operation

- R_a ≤0.4 µm Boundary lubrication
- R_a = 0.1-0.2 µm Mixed film or hydrodynamic conditions
- R_a ≤0.05 µm for the most demanding operating conditions

7.8 Grease Lubrication

DP4 is not generally recommended for use with grease lubrication.

In particular the following must be avoided:

- Dynamic loads - which can result in erosion of the PTFE bearing surface.
- Greases with EP additives or fillers such as graphite or MoS_2 which can cause rapid wear of DP4.

8 Bearing Assembly

Dimensions and Tolerances

DP4 bushes are prefinished in the bore, and except in very exceptional circumstances, must not be burnished, broached or otherwise modified. It is essential that the correct running clearance is used and that both the diameter of the shaft and the bore of the housing are finished to the limits given in the tables. Under dry running conditions any increase in the clearances given will result in a proportional reduction in performance.

If the bearing housing is unusually flexible the bush will not close in by the calculated amount and the running clearance will be more than the optimum. In these circumstances the housing should be bored slightly undersize or the journal diameter increased, the correct size being determined by experiment.

Where free running is essential, or where light loads (less than 0.1 N/mm²) prevail and the available torque is low, increased clearance is required and it is recommended that the shaft size quoted in the table be reduced by 0.025 mm.

8.1 Allowance for Thermal Expansion

For operation in high temperature environments the clearance should be increased by the amounts indicated by Fig. 27 to compensate for the inward thermal expansion of the bearing lining.

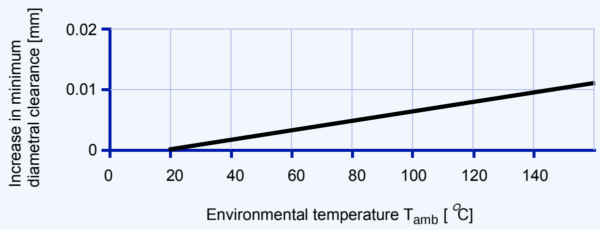


Fig. 27: Increase in diametral clearance

If the housing is non-ferrous then the bore should be reduced by the amounts given in Table 14, in order to give an increased interference fit to the bush, with a similar reduction in the journal diameter additional to that indicated by Fig. 27.

Housing material	Reduction in housing diameter per 100 °C rise	Reduction in shaft diameter per 100 °C rise
Aluminium alloys	0.1 %	0.1 % + values from Fig. 27
Copper base alloys	0.05 %	0.05 % + values from Fig. 27
Steel and cast iron	–	values from Fig. 27
Zinc base alloys	0.15 %	0.15 % + values from Fig. 27

Table 14: Allowance for high temperature

8.2 Tolerances for minimum clearance

Where it is required to keep the variation of assembled clearance to a minimum, closer tolerances can be specified towards the upper end of the journal tolerance and the lower end of the housing tolerance.

If housings to H6 tolerance are used, then the journals should be finished to the following limits.

D_i	D_J
<25 mm	-0.019 -0.029
>25 mm < 50 mm	-0.021 -0.035

Table 15: Shaft tolerances for use with H6 housings

The sizes in Table 16 give the following nominal clearance range.

D_i	C_D
10 mm	0.005 - 0.078
50 mm	0.005 - 0.130

Table 16: Clearance vs bearing diameter

Sizing

The burnishing of the bore of an assembled DP4 bush in order to achieve a smaller clearance tolerance is only permissible if a substantial reduction in dry wear performance is acceptable. Fig. 28 shows a recommended burnishing tool for the sizing of DP4 bushes.

The coining section of the burnishing tool should be case hardened (case depth 0.6-1.2 mm, HRC 60±2) and polished ($R_Z \approx 1\mu m$).

Note: Ball burnishing or fine boring of DP4 bushes is not recommended.

Assembled bush Inside-∅	Required bush Inside-∅	Required burnishing tool-∅ D_C
$D_{i,a}$	$D_{i,a}$ + 0.025	$D_{i,a}$ + 0.06
$D_{i,a}$	$D_{i,a}$ + 0.038	$D_{i,a}$ + 0.08
$D_{i,a}$	$D_{i,a}$ + 0.050	$D_{i,a}$ + 0.1

Table 17: Burnishing Tool Tolerances

The values given in Table 17 indicate the dimensions of the burnishing tool required to give specific increases in the bearing bore diameter.

Exact values must be determined by test.

The reduction in bearing performance as a result of burnishing is allowed for in the bearing life calculation by the application factor a_C (Table 12, Page 18).

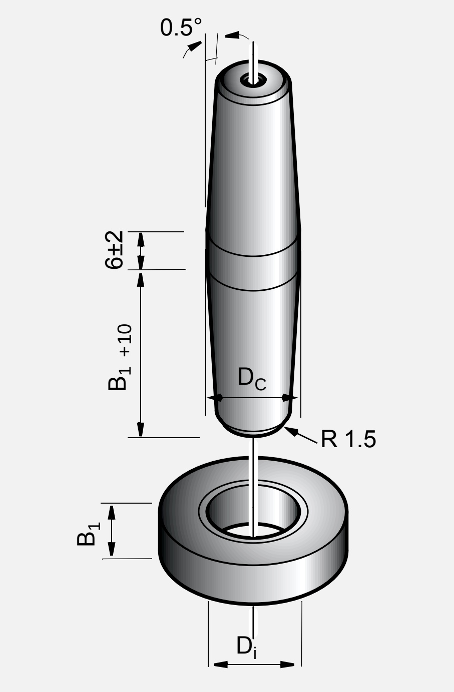


Fig. 28: Burnishing Tool

8.3 Counterface Design

The suitability of mating surface materials and recommendations of mating surface finish for use with DP4 are discussed in detail on page 16.

DP4 is normally used in conjunction with ferrous journals and thrust faces, but in damp or corrosive surroundings, particularly without the protection of oil or grease, stainless steel, hard chromium plated mild steel, or hard anodised aluminium is recommended. When plated mating surfaces are specified the plating should possess adequate strength and adhesion, particularly if the bearing is to operate with high fluctuating loads.

The shaft or thrust collar used in conjunction with the DP4 bush or thrust washer must extend beyond the bearing surface in order to avoid cutting into it. The mating surface must also be free from grooves or flats, the end of the shaft should be given a lead-in chamfer and all sharp edges or projections which may damage the soft overlay of the DP4 must be removed.

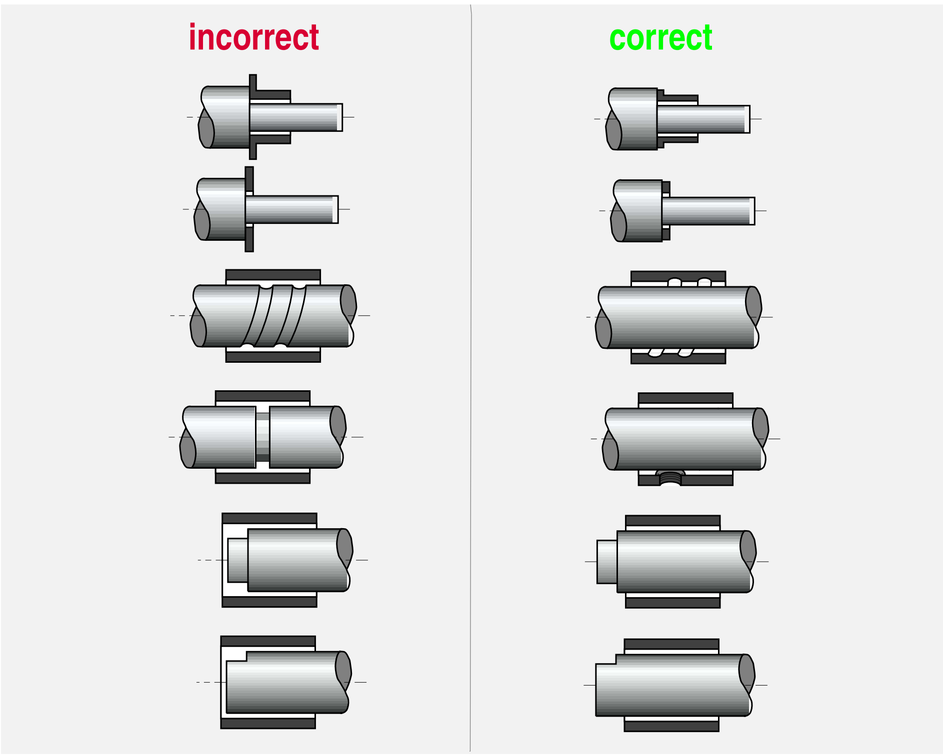


Fig. 29: Counterface design

8.4 Installation

Fitting of cylindrical Bushes

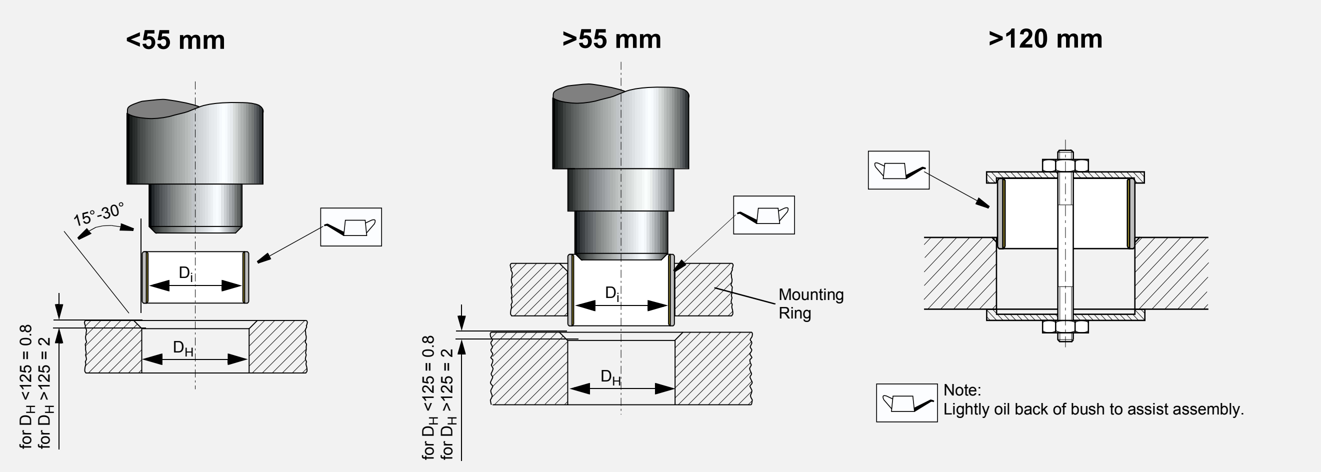


Fig. 30: Fitting of cylindrical bushes

Fitting of flanged bushes

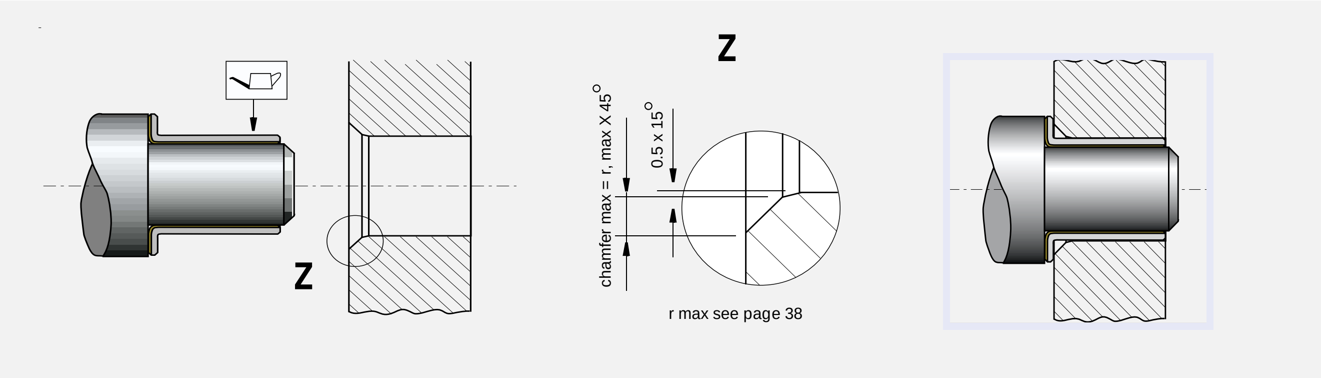


Fig. 31: Fitting of flanged bushes

Insertion Forces

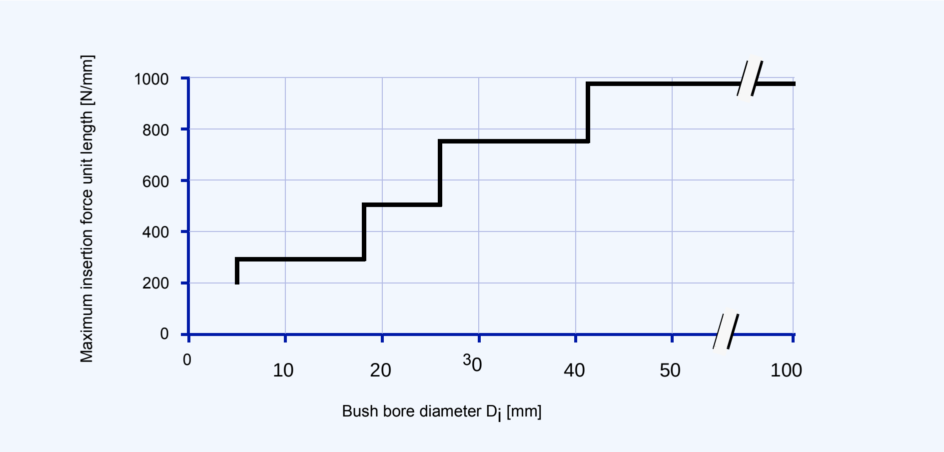


Fig. 32: Maximum insertion force F_i

Alignment

Accurate alignment is an important consideration for all bearing assemblies. With DP4 bearings misalignment over the length of a bush (or pair of bushes), or over the diameter of a thrust washer should not exceed 0.020 mm as illustrated in Fig. 33.

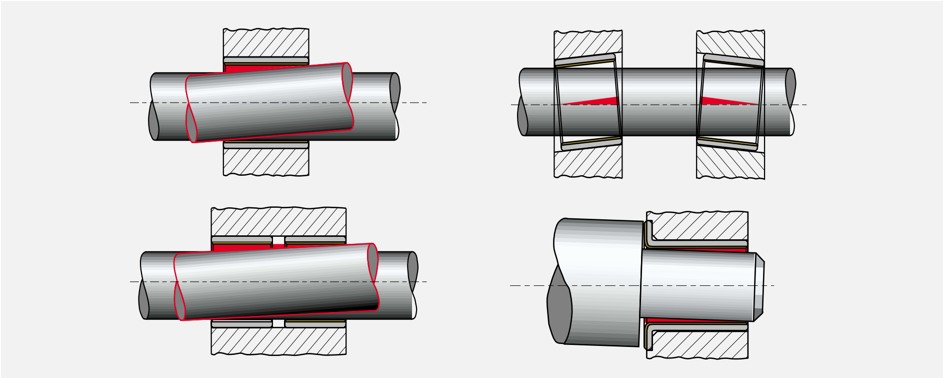


Fig. 33: Alignment

Sealing

While Glacier DP4 can tolerate the ingress of some contaminant materials into the bearing without loss of performance, where there is the possibility of highly abrasive material entering the bearing, a suitable sealing arrangement, as illustrated in Fig. 34 should be provided.

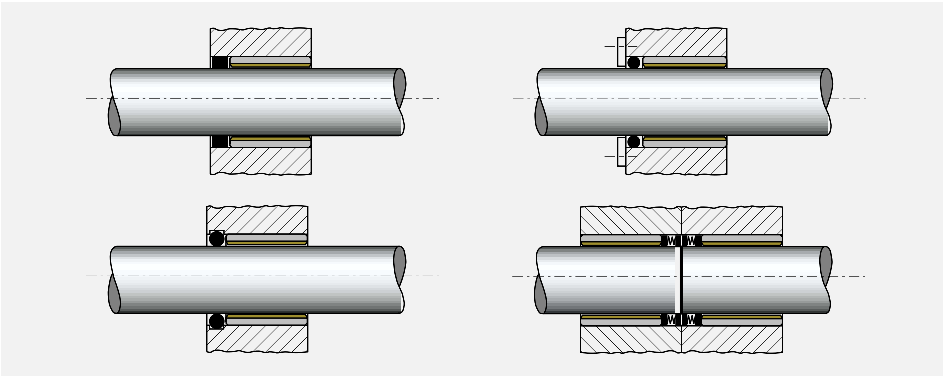


Fig. 34: Recommended sealing arrangements

8.5 Axial Location

Where axial location is necessary, it is advisable to fit DP4 thrust washers in conjunction with DP4 bushes, even when the axial loads are low.

Fitting of Thrust Washers

DP4 thrust washers should be located in a recess as shown in Fig. 35. For the recess diameter the tolerance class [D10] is recommended. The recess depth is given in the product tables, page 40 and following.

If a recess is not possible one of the following methods may be used:

- Two dowel pins
- Two screws
- Adhesive
- Soldering (temperature <320 °C).

Important Note

- Ensure the washer ID does not touch the shaft after assembly
- Ensure that the washer is mounted with the steel backing to the housing
- Dowels pins should be recessed 0.25 mm below the bearing surface
- Screws should be countersunk 0.25 mm below the bearing surface
- DP4 must not be heated above 320 °C
- Contact adhesive manufacturers for guidance selection of suitable adhesives
- Protect the bearing surface to prevent contact with adhesive.

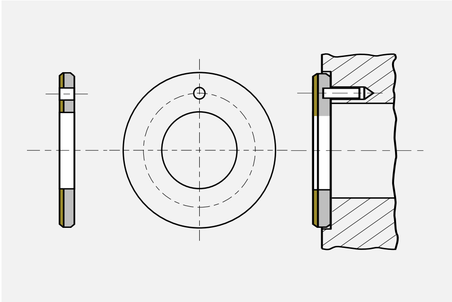


Fig. 35: Installation of Thrust-Washer

Grooves for Wear Debris Removal

Tests with thrust washers have demonstrated that for optimum dry wear performance at specific loads in excess of 35 N/mm², four wear debris removal grooves should be machined in the bearing surface as shown in Fig. 36.

Grooves in bushes have not been found to be beneficial in this respect.

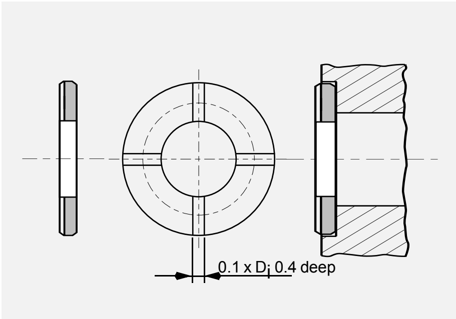


Fig. 36: Debris removal Grooves

Slideways

DP4 strip material for use as slideway bearings should be installed using one of the following methods:

- Countersunk screws
- Adhesives
- Mechanical location as shown in Fig. 37.

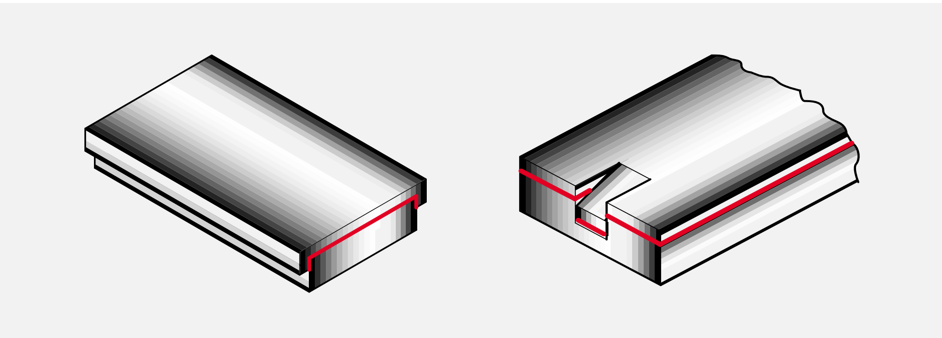


Fig. 37: Mechanical location of DP4 slideplates

9 Modification

9.1 Cutting and Machining

The modification of DP4 bearing components requires no special procedures. In general it is more satisfactory to perform machining or drilling operations from the PTFE side in order to avoid burrs. When cutting is done from the steel side, the minimum cutting pressure should be used and care taken to ensure that any steel or bronze particles protruding into the remaining bearing material, and all burrs, are removed.

Drilling Oil Holes

Bushes should be adequately supported during the drilling operation to ensure that no distortion is caused by the drilling pressure.

Cutting Strip Material

DP4 strip material may be cut to size by any one of the following methods.

Care must be taken to protect the bearing surface from damage and to ensure that no deformation of the strip occurs:

- Using side and face cutter, or slitting saw, with the strip held flat and securely on a horizontal milling machine.
- Cropping
- Guillotine (For widths less than 90 mm only)
- Water-jet cutting
- Laser cutting (see Health Warning).

9.2 Electroplating

DP4 Components

In order to provide some protection in mildly corrosive environments the steel back and end faces of standard range DP4 bearings are tin flashed.

DP4 can be electroplated with most of the conventional electroplating metals including the following:

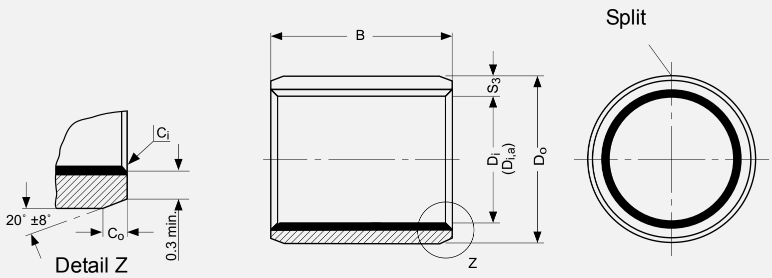
- zinc ISO 2081
- nickel ISO 1456
- hard chromium ISO 1456.

For the harder materials if the specified plating thickness exceeds approximately 5 μm then the housing diameter should be increased by twice the plating thickness in order to maintain the correct assembled bearing bore size.

Where electrolytic attack is possible tests should be conducted to ensure that all the materials in the bearing environment are mutually compatible.

10 Standard Products

10.1 DP4 Cylindrical bushes



Dimensions and Tolerances according to ISO 3547 and GSP-Specifications

Part No.	Nominal size		Wall thickness S_3	Length B	Shaft-ø D_J [h6, f7, h8]		Housing-ø D_H [H6, H7]		Bush i-ø $D_{i,a}$ when ass. in H7 housing	Clearance C_D
	D_i	D_o	max. min.	max. min.		max. min.		max. min.	max. min.	max. min.
0203 DP4	2	3,5	0.745 0.725	3.25 2.75	h6	2.000 1.994	H6	3.508 3.500	+2.058 +2.010	0.064 0.010
0303 DP4	3	4,5	0.750 0.730			3.000 2.994		4.508 4.500	+ 3.048 + 3.000	0.054 0.000
0306 DP4				6.25 5.75						
0404 DP4	4	5,5		4.25 3.75		4.000 3.992		5.508 5.500	+4.048 +4.000	0.056 0.000
0410 DP4				10.25 9.75						
0505 DP4	5	7	1.005 0.980	5.25 4.75	f7	4.990 4.978	H7	7.015 7.000	5.055 4.990	0.077 0.000
0508 DP4				8.25 7.75						
0510 DP4				10.25 9.75						
0606 DP4	6	8		6.25 5.75		5.990 5.978		8.015 8.000	6.055 5.990	
0608 DP4				8.25 7.75						
0610 DP4				10.25 9.75						
0710 DP4	7	9		10.25 9.75		6.987 6.972		9.015 9.000	7.055 6.990	0.083 0.003
0806 DP4	8	10		6.25 5.75		7.987 7.972		10.015 10.000	8.055 7.990	
0808 DP4				8.25 7.75						
0810 DP4				10.25 9.75						
0812 DP4				12.25 11.75						
1008 DP4	10	12		8.25 7.75		9.987 9.972		12.018 12.000	10.058 9.990	0.086 0.003
1010 DP4				10.25 9.75						
1012 DP4				12.25 11.75						
1015 DP4				15.25 14.75						
1020 DP4				20.25 19.75						

All dimensions in mm

10 Standard Products

Part No.	Nominal size		Wall thickness S_3	Length B	Shaft-ø D_J [h6, f7, h8]		Housing-ø D_H [H6, H7]		Bush i-ø $D_{i,a}$ when ass. in H7 housing	Clearance C_D
	D_i	D_o	max. min.	max. min.		max. min.		max. min.	max. min.	max. min.
1208 DP4	12	14	1.005 0.980	8.25 7.75	f7	11.984 11.966	H7	14.018 14.000	12.058 11.990	0.092 0.006
1210 DP4				10.25 9.75						
1212 DP4				12.25 11.75						
1215 DP4				15.25 14.75						
1220 DP4				20.25 19.75						
1225 DP4				25.25 24.75						
1310 DP4	13	15		10.25 9.75		12.984 12.966		15.018 15.000	13.058 12.990	
1320 DP4				20.25 19.75						
1405 DP4	14	16		5.25 4.75		13.984 13.966		16.018 16.000	14.058 13.990	
1410 DP4				10.25 9.75						
1412 DP4				12.25 11.75						
1415 DP4				15.25 14.75						
1420 DP4				20.25 19.75						
1425 DP4				25.25 24.75						
1510 DP4	15	17		10.25 9.75		14.984 14.966		17.018 17.000	15.058 14.990	
1512 DP4				12.25 11.75						
1515 DP4				15.25 14.75						
1520 DP4				20.25 19.75						
1525 DP4				25.25 24.75						
1610 DP4	16	18		10.25 9.75		15.984 15.966		18.018 18.000	16.058 15.990	
1612 DP4				12.25 11.75						
1615 DP4				15.25 14.75						
1620 DP4				20.25 19.75						
1625 DP4				25.25 24.75						
1720 DP4	17	19		20.25 19.75		16.984 16.966		19.021 19.000	17.061 16.990	0.095 0.006
1810 DP4	18	20		10.25 9.75		17.984 17.966		20.021 20.000	18.061 17.990	
1815 DP4				15.25 14.75						
1820 DP4				20.25 19.75						
1825 DP4				25.25 24.75						

All dimensions in mm

Part No.	Nominal size		Wall thickness S_3	Length B	Shaft-ø D_J [h6, f7, h8]		Housing-ø D_H [H6, H7]		Bush i-ø $D_{i,a}$ when ass. in H7 housing	Clearance C_D
	D_i	D_o	max. min.	max. min.		max. min.		max. min.	max. min.	max. min.
2010 DP4	20	23	1.505 1.475	10.25 9.75	f7	19.980 19.959	H7	23.021 23.000	20.071 19.990	0.112 0.010
2015 DP4				15.25 14.75						
2020 DP4				20.25 19.75						
2025 DP4				25.25 24.75						
2030 DP4				30.25 29.75						
2215 DP4	22	25		15.25 14.75		21.980 21.959		25.021 25.000	22.071 21.990	
2220 DP4				20.25 19.75						
2225 DP4				25.25 24.75						
2230 DP4				30.25 29.75						
2415 DP4	24	27		15.25 14.75		23.980 23.959		27.021 27.000	24.071 23.990	
2420 DP4				20.25 19.75						
2425 DP4				25.25 24.75						
2430 DP4				30.25 29.75						
2515 DP4	25	28		15.25 14.75		24.980 24.959		28.021 28.000	25.071 24.990	
2520 DP4				20.25 19.75						
2525 DP4				25.25 24.75						
2530 DP4				30.25 29.75						
2550 DP4				50.25 49.75						
2815 DP4	28	32	2.005 1.970	15.25 14.75		27.980 27.959		32.025 32.000	28.085 27.990	0.126 0.010
2820 DP4				20.25 19.75						
2825 DP4				25.25 24.75						
2830 DP4				30.25 29.75						
3010 DP4	30	34		10.25 9.75		29.980 29.959		34.025 34.000	30.085 29.990	
3015 DP4				15.25 14.75						
3020 DP4				20.25 19.75						
3025 DP4				25.25 24.75						
3030 DP4				30.25 29.75						
3040 DP4				40.25 39.75						
3220 DP4	32	36		20.25 19.75		31.975 31.950		36.025 36.000	32.085 31.990	0.135 0.015
3230 DP4				30.25 29.75						
3240 DP4				40.25 39.75						

All dimensions in mm

10 Standard Products

Part No.	Nominal size		Wall thickness S_3	Length B	Shaft-ø D_J [h6, f7, h8]		Housing-ø D_H [H6, H7]		Bush i-ø $D_{i,a}$ when ass. in H7 housing	Clearance C_D
	D_i	D_o	max. min.	max. min.		max. min.		max. min.	max. min.	max. min.
3520 DP4				20.25 19.75						
3530 DP4				30.25 29.75						
3535 DP4	35	39		35.25 34.75		34.975 34.950		39.025 39.000	35.085 34.990	
3540 DP4				40.25 39.75						
3550 DP4			2.005 1.970	50.25 49.75						0.135 0.015
3720 DP4	37	41		20.25 19.75		36.975 36.950		41.025 41.000	37.085 36.990	
4020 DP4				20.25 19.75						
4030 DP4	40	44		30.25 29.75		39.975 39.950		44.025 44.000	40.085 39.990	
4040 DP4				40.25 39.75						
4050 DP4				50.25 49.75						
4520 DP4				20.25 19.75						
4530 DP4				30.25 29.75						
4540 DP4	45	50		40.25 39.75		44.975 44.950		50.025 50.000	45.105 44.990	0.155 0.015
4545 DP4				45.25 44.75						
4550 DP4				50.25 49.75						
5020 DP4				20.25 19.75						
5030 DP4				30.25 29.75	f7		H 7			
5040 DP4	50	55		40.25 39.75		49.975 49.950		55.030 55.000	50.110 49.990	0.160 0.015
5050 DP4				50.25 49.75						
5060 DP4				60.25 59.75						
5520 DP4				20.25 19.75						
5525 DP4			2.505 2.460	25.25 24.75						
5530 DP4				30.25 29.75						
5540 DP4	55	60		40.25 39.75		54.970 54.940		60.030 60.000	55.110 54.990	
5550 DP4				50.25 49.75						
5555 DP4				55.25 54.75						
5560 DP4				60.25 59.75						0.170 0.020
6020 DP4				20.25 19.75						
6030 DP4				30.25 29.75						
6040 DP4	60	65		40.25 39.75		59.970 59.940		65.030 65.000	60.110 59.990	
6050 DP4				50.25 49.75						
6060 DP4				60.25 59.75						
6070 DP4				70.25 69.75						

All dimensions in mm

Part No.	Nominal size D_i	Nominal size D_o	Wall thickness S_3 max. min.	Length B max. min.	Shaft-ø D_J [h6, f7, h8]	Shaft-ø D_J max. min.	Housing-ø D_H [H6, H7]	Housing-ø D_H max. min.	Bush i-ø $D_{i,a}$ when ass. in H7 housing max. min.	Clearance C_D max. min.
6530 DP4	65	70	2.505 2.460	30.25 29.75	f7	64.970 64.940	H7	70.030 70.000	65.110 64.990	0.170 0.020
6550 DP4				50.25 49.75						
6570 DP4				70.25 69.75						
7040 DP4	70	75		40.25 39.75		69.970 69.940		75.030 75.000	70.110 69.990	
7050 DP4				50.25 49.75						
7070 DP4				70.25 69.75						
7580 DP4	75	80		80.25 79.75		74.970 74.940		80.030 80.000	75.110 74.990	
8060 DP4	80	85	2.490 2.440	60.50 59.50	h8	80.000 79.954		85.035 85.000	80.155 80.020	0.201 0.020
80100 DP4				100.50 99.50						
8530 DP4	85	90		30.50 29.50		85.000 84.946		90.035 90.000	85.155 85.020	0.209 0.020
8560 DP4				60.50 59.50						
85100 DP4				100.50 99.50						
9060 DP4	90	95		60.50 59.50		90.000 89.946		95.035 95.000	90.155 90.020	
90100 DP4				100.50 99.50						
9560 DP4	95	100		60.50 59.50		95.000 94.946		100.035 100.000	95.155 95.020	
95100 DP4				100.50 99.50						
10050 DP4	100	105		50.50 49.50		100.000 99.946		105.035 105.000	100.155 100.020	
10060 DP4				60.50 59.50						
100115 DP4				115.50 114.50						
10560 DP4	105	110		60.50 59.50		105.000 104.946		110.035 110.000	105.155 105.020	
105115 DP4				115.50 114.50						
11060 DP4	110	115		60.50 59.50		110.000 109.946		115.035 115.000	110.155 110.020	
110115 DP4				115.50 114.50						
11550 DP4	115	120		50.50 49.50		115.000 114.946		120.035 120.000	115.155 115.020	
11570 DP4				70.50 69.50						

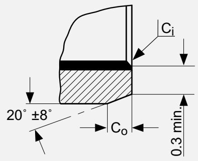
Outside C_o and Inside C_i chamfers

Wall thick-ness S_3	C_o (a) machined	C_o (a) rolled	C_i (b)
0.75	0.5 ± 0.3	0.5 ± 0.3	-0.1 to -0.4
1	0.6 ± 0.4	0.6 ± 0.4	-0.1 to -0.5
1.5	0.6 ± 0.4	0.6 ± 0.4	-0.1 to -0.7

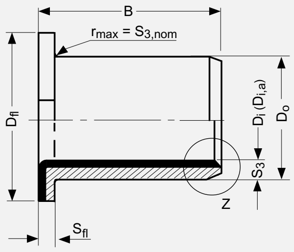
S_3	C_o (a) machined	C_o (a) rolled	C_i (b)
2	1.2 ± 0.4	1.0 ± 0.4	-0.1 to -0.7
2.5	1.8 ± 0.6	1.2 ± 0.4	-0.2 to -1.0

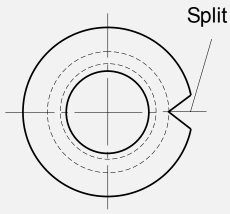
All dimensions in mm

10.2 DP4 Flanged bushes



Detail Z





Dimensions and Tolerances according to ISO 3547 and GSP-Specifications

Part No.	Nominal size		Wall thickness S_3	Flange thickness S_{fl}	Flange-ø D_{fl}	Length B	Shaft-ø D_J [f7]	Housing-ø D_H [H7]	Ass. Inside-ø $D_{i,a}$	Clearance C_D
	D_i	D_o	max. min.	max. min.	max. min.	max. min.	max. min.	max. min.	max. min.	max. min.
BB 0304 DP4	3	4,5	0.750 0.730	0.80 0.70	7.5 6.5	4,25 3,75	3.000 2.994	4.508 4.500	3.044 3.004	0.054 0.000
BB 0404 DP4	4	5,5			9.5 8.5	4,25 3,75	4.000 3.992	5.508 5.500	4.044 4.004	0.056 0.000
BB 0505 DP4	5	7	1.005 0.980	1.005 0.800	10.5 9.5	5,25 4,75	4.990 4.978	7.015 7.000	5.055 4.990	0.077 0.000
BB 0604 DP4	6	8			12.5 11.5	4.25 3.75	5.990 5.978	8.015 8.000	6.055 5.990	
BB 0608 DP4						8.25 7.75				
BB 0806 DP4	8	10			15.5 14.5	6.25 5.75	7.987 7.972	10.015 10.000	8.055 7.990	0.083 0.003
BB 0808 DP4						8.25 7.75				
BB 0810 DP4						10.25 9.75				
BB 1007 DP4	10	12			18.5 17.5	7.25 6.75	9.987 9.972	12.018 12.000	10.058 9.990	0.086 0.003
BB 1009 DP4						9.25 8.75				
BB 1012 DP4						12.25 11.75				
BB 1017 DP4						17.25 16.75				
BB 1207 DP4	12	14			20.5 19.5	7.25 6.75	11.984 11.966	14.018 14.000	12.058 11.990	0.092 0.006
BB 1209 DP4						9.25 8.75				
BB 1212 DP4						12.25 11.75				
BB 1217 DP4						17.25 16.75				
BB 1412 DP4	14	16			22.5 21.5	12.25 11.75	13.984 13.966	16.018 16.000	14.058 13.990	
BB 1417 DP4						17.25 16.75				
BB 1509 DP4	15	17			23.5 22.5	9.25 8.75	14.984 14.966	17.018 17.000	15.058 14.990	
BB 1512 DP4						12.25 11.75				
BB 1517 DP4						17.25 16.75				
BB 1612 DP4	16	18			24.5 23.5	12.25 11.75	15.984 15.966	18.018 18.000	16.058 15.990	
BB 1617 DP4						17.25 16.75				

All dimensions in mm

Part No.	Nominal size		Wall thickness S_3	Flange thickness S_{fl}	Flange-ø D_{fl}	Length B	Shaft-ø D_J [f7]	Housing-ø D_H [H7]	Ass. Inside-ø $D_{i,a}$	Clearance C_D
	D_i	D_o	max. min.	max. min.	max. min.	max. min.	max. min.	max. min.	max. min.	max. min.
BB 1812 DP4	18	20	1.005 0.980	1.000 0.800	26.5 25.5	12.25 11.75	17.984 17.966	20.021 20.000	18.061 17.990	0.095 0.006
BB 1817 DP4						17.25 16.75				
BB 1822 DP4						22.25 21.75				
BB 2012 DP4	20	23	1.505 1.475	1.600 1.400	30.5 29.5	11.75 11.25	19.980 19.959	23.021 23.000	20.071 19.990	0.112 0.010
BB 2017 DP4						16.75 16.25				
BB 2022 DP4						21.75 21.25				
BB 2512 DP4	25	28			35.5 34.5	11.75 11.25	24.980 24.959	28.021 28.000	25.071 24.990	
BB 2517 DP4						16.75 16.25				
BB 2522 DP4						21.75 21.25				
BB 3016 DP4	30	34	2.005 1.970	2.100 1.800	42.5 41.5	16.25 15.75	29.980 29.959	34.025 34.000	30.085 29.990	0.126 0.010
BB 3026 DP4						26.25 25.75				
BB 3516 DP4	35	39			47.5 46.5	16.25 15.75	34.975 34.950	39.025 39.000	35.085 34.990	0.135 0.015
BB 3526 DP4						26.25 25.75				
BB 4016 DP4	40	44			53.5 52.5	16.25 15.75	39.975 39.950	44.025 44.000	40.085 39.990	
BB 4026 DP4						26.25 25.75				
BB 4516 DP4	45	50	2.505 2.460	2.600 2.400	58.5 57.5	16.25 15.75	44.975 44.950	50.025 50.000	45.105 44.990	0.155 0.015
BB 4526 DP4						26.25 25.75				

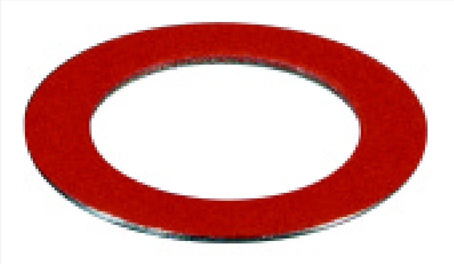
Outside C_o and Inside C_i chamfers

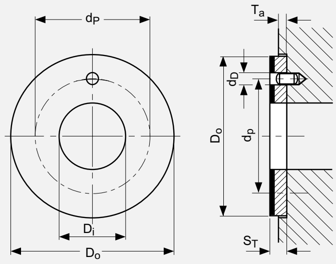
Wall thick-ness S_3	C_o (a)		C_i (b)
	machined	rolled	
0.75	0.5 ± 0.3	0.5 ± 0.3	-0.1 to -0.4
1	0.6 ± 0.4	0.6 ± 0.4	-0.1 to -0.5
1.5	0.6 ± 0.4	0.6 ± 0.4	-0.1 to -0.7

S_3	C_o (a)		C_i (b)
	machined	rolled	
2	1.2 ± 0.4	1.0 ± 0.4	-0.1 to -0.7
2.5	1.8 ± 0.6	1.2 ± 0.4	-0.2 to -1.0

All dimensions in mm

10.3 DP4 Thrust Washers

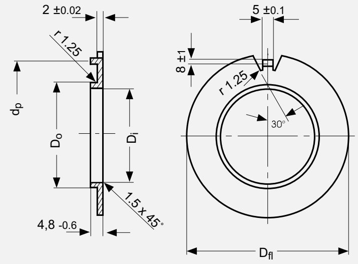




Part No.	Inside-ø D_i	Outside-ø D_o	Thickness S_T	Locating Hole-ø d_D	Pitch Circle-ø d_P	Recess depth T_a
	max. min.	max. min.	max. min.	max. min.	max. min.	max. min.
WC 08 DP4	10.25 10.00	20.00 19.75		No Hole	No Hole	
WC 10 DP4	12.25 12.00	24.00 23.75		1.875 1.625	18.12 17.88	
WC 12 DP4	14.25 14.00	26.00 25.75			20.12 19.88	
WC 14 DP4	16.25 16.00	30.00 29.75		2.375 2.125	22.12 21.88	
WC 16 DP4	18.25 18.00	32.00 31.75			25.12 24.88	
WC 18 DP4	20.25 20.00	36.00 35.75			28.12 27.88	
WC 20 DP4	22.25 22.00	38.00 37.75	1.50 1.45	3.375 3.125	30.12 29.88	1.20 0.95
WC 22 DP4	24.25 24.00	42.00 41.75			33.12 32.88	
WC 24 DP4	26.25 26.00	44.00 43.75			35.12 34.88	
WC 25 DP4	28.25 28.00	48.00 47.75			38.12 37.88	
WC 30 DP4	32.25 32.00	54.00 53.75			43.12 42.88	
WC 35 DP4	38.25 38.00	62.00 61.75			50.12 49.88	
WC 40 DP4	42.25 42.00	66.00 65.75		4.375 4.125	54.12 53.88	
WC 45 DP4	48.25 48.00	74.00 73.75			61.12 60.88	
WC 50 DP4	52.25 52.00	78.00 77.75	2.00 1.95		65.12 64.88	1.70 1.45
WC 60 DP4	62.25 62.00	90.00 89.75			76.12 75.88	

All dimensions in mm

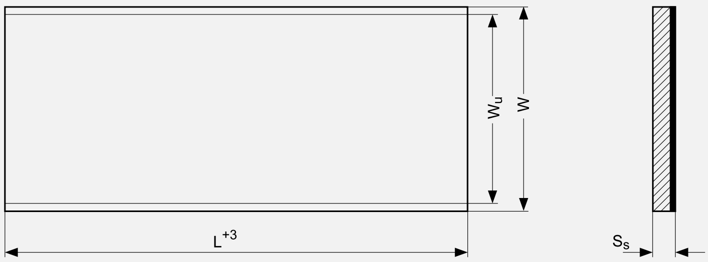
10.4 DP4 Flanged Thrust Washers



Part No.	Inside-ø D_i	Flange-ø D_{fl}	Outside-ø D_o	Locating Hole-ø d_P	Thickness S_T
	max. min.	max. min.	max. min.	max. min.	max. min.
BS 40 DP4	40.70 40.20	44.00 43.90	75.0 74.5	65.0 64.5	2.02 1.98
BS 50 DP4	51.50 51.00	55.00 54.88	85.0 84.5	75.0 74.5	
BS 60 DP4	61.50 61.00	65.00 64.88	95.0 94.5	85.0 84.5	
BS 70 DP4	71.50 71.00	75.00 74.88	110.0 109.5	100.0 99.5	
BS 80 DP4	81.50 81.00	85.00 84.86	120.0 119.5	110.0 109.5	
BS 90 DP4	91.50 91.00	95.00 94.86	130.0 129.5	120.0 119.5	
BS 100 DP4	101.50 101.00	105.00 104.86	140.0 139.5	130.0 129.5	

All dimensions in mm

10.5 DP4 Strip



Part No.	Length L	Width W	Usable Width W_u	Thickness S_S
				max. min.
S 07090 DP4	500	100	90	0.740 0.700
S 10200 DP4		227	215	1.010 0.970
S 15240 DP4				1.510 1.470
S 20240 DP4				1.980 1.940
S 25240 DP4				2.460 2.420

11 Test Methods

11.1 Measurement of Wrapped Bushes

It is not possible to accurately measure the external and internal diameters of a wrapped bush in the free condition. In its free state a wrapped bush will not be perfectly cylindrical and the butt joint may be open. When correctly installed in a housing the butt joint will be tightly closed and the bush will conform to the housing. For this reason the external diameter and internal diameter of a wrapped bush can only be checked with special gauges and test equipment.

The checking methods are defined in ISO 3547 Part 1 and 2 and ISO 12306 respectively.

Test A of ISO 3547 Part 2

Checking the external diameter in a test machine with checking blocks and adjusting mandrel.

Table 18: Test A of ISO 3547 Part 2

Test A of ISO 3547 Part 2 on 2015 DP4	
Test housing and mandrel $d_{ch,1}$	23.062 mm
Test load F_{ch}	4500 N
Limits for Δz	0 and -0.065 mm
Bush outside diameter D_o	23.035 to 23.075 mm

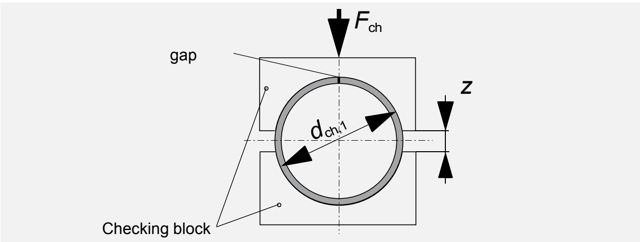


Fig. 38: Test A, Data for drawing

Test B (alternatively to Test A)

Check external diameter with GO and NOGO ring gauges.

Test C

Checking the internal diameter of a bush pressed into a ring gauge, which nominal diameter corresponds to the dimension specified in table 5 of ISO 3547 Part 1.

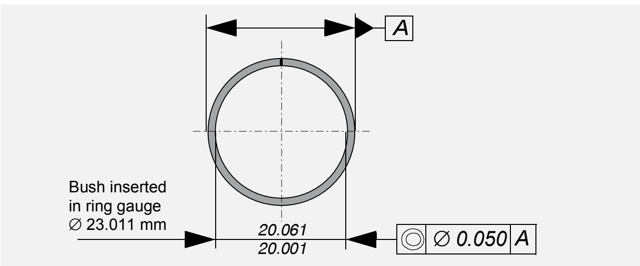


Fig. 39: Test C, Data for drawing (example D_i = 20 mm)

Measurement of Wall Thickness (alternatively to Test C)

The wall thickness is measured at one, two or three positions axially according to the bearing dimensions.

Table 19: Measurement position for wall thickness

B [mm]	X [mm]	measurement position
≤15	B/2	1
>15 ≤50	4	2
>50	6	2

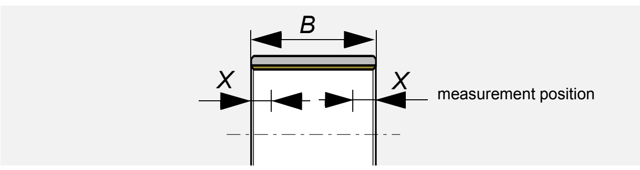


Fig. 40: Wall thickness measurement position

Test D

Check external diameter by precision measuring tape.

Health Hazard - Warning

Fabrication

At temperatures up to 250 °C the polytetrafluroethylene (PTFE) present in the lining material is completely inert so that even on the rare occasions in which DP4 bushes are drilled, or sized, after assembly there is no danger in boring or burnishing.

At higher temperatures however, small quantities of toxic fumes can be produced and the direct inhalation of these can cause an influenza type of illness which may not appear for some hours but which subsides without after-effects in 24-48 hours.

Such fumes can arise from PTFE particles picked up on the end of a cigarette. Therefore smoking should be prohibited where DP4 is being machined.

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