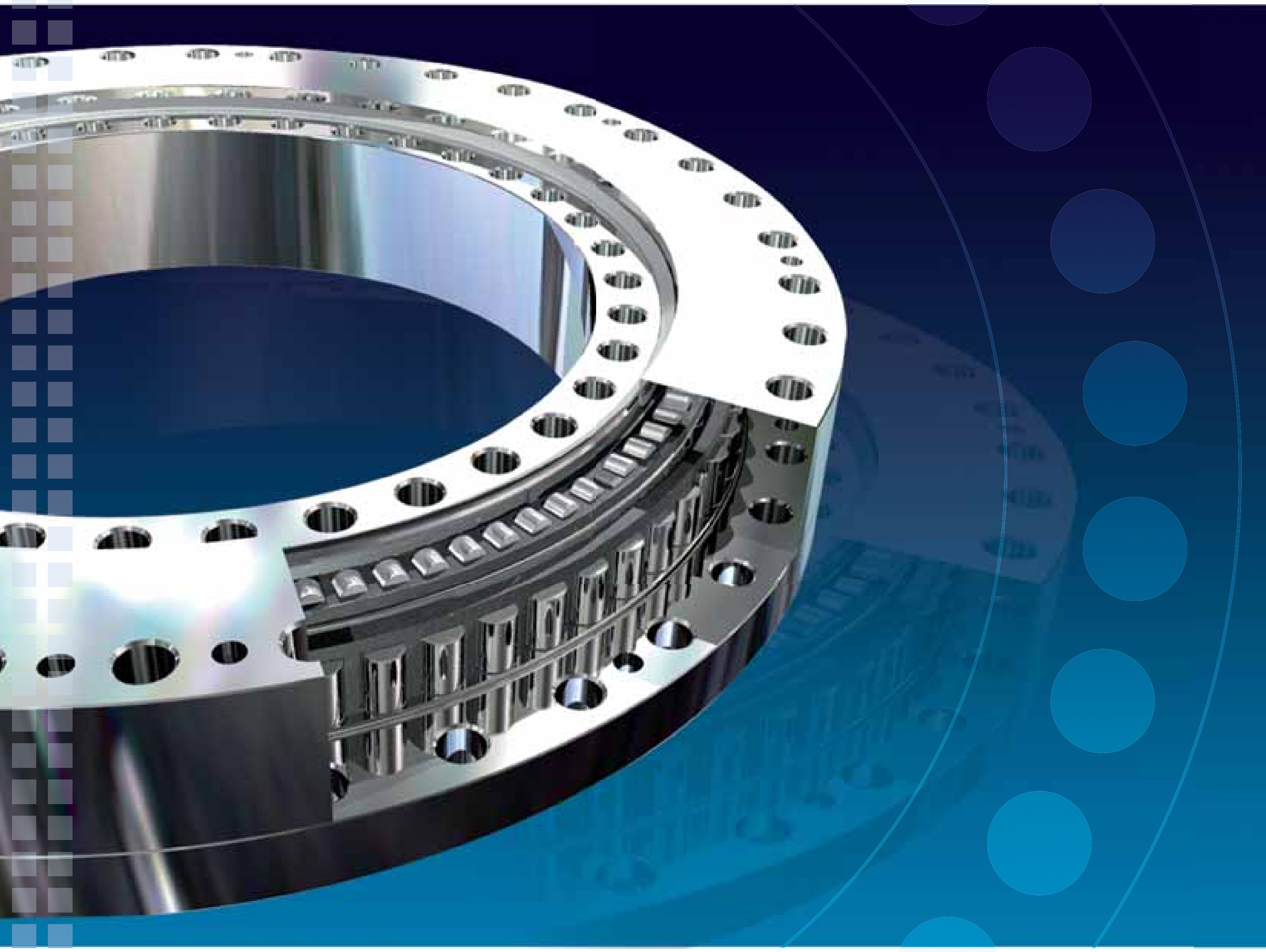
slewing rings



technical handbook

7/2001-TPO-A-Rev.1

7/2001-TPO-A-Rev. 1

Preface

PSL, a.s., Považská Bystrica is a producer of large-sized bearings called slewing rings with a many years tradition.

The present production assortment contains more than 500 types of standard and special slewing rings.

PSL, a.s. has a developed, utilized and certified system of the quality assurance according to the standard DIN EN ISO 9001.

Enviromental Management System ISO 14001.

This publication contains basic technical information about PSL slewing rings, the procedure when designing and dimensioning of the arrangement using a suitable slewing ring and instructions for mounting, maintenance, preservation, packaging, transport and storaging of the slewing rings.

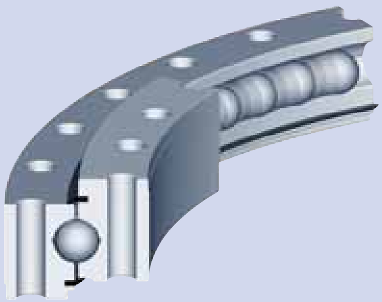
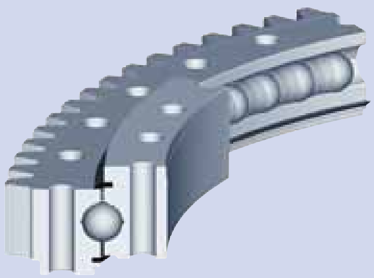
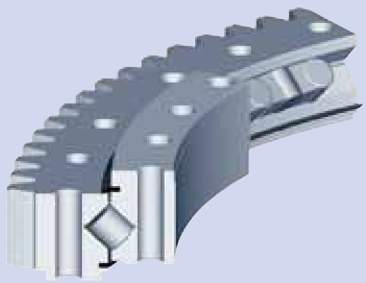
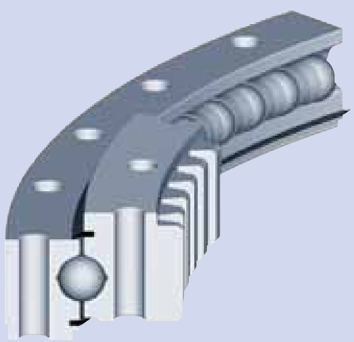
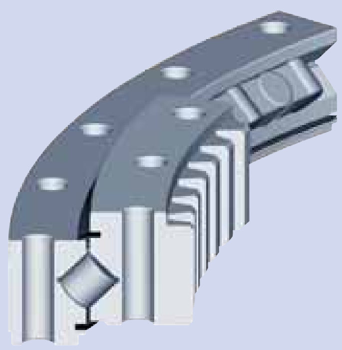
Solutions to complex applications of the PSL slewing rings can be provided by the experts of the PSL Technical Consultancy Department.

The contents of this catalogue have been carefully evaluated and checked but due to continued technical developments we reserve the right to effect technical changes or amendments without prior notice.

PSL Slewing Rings Characteristics

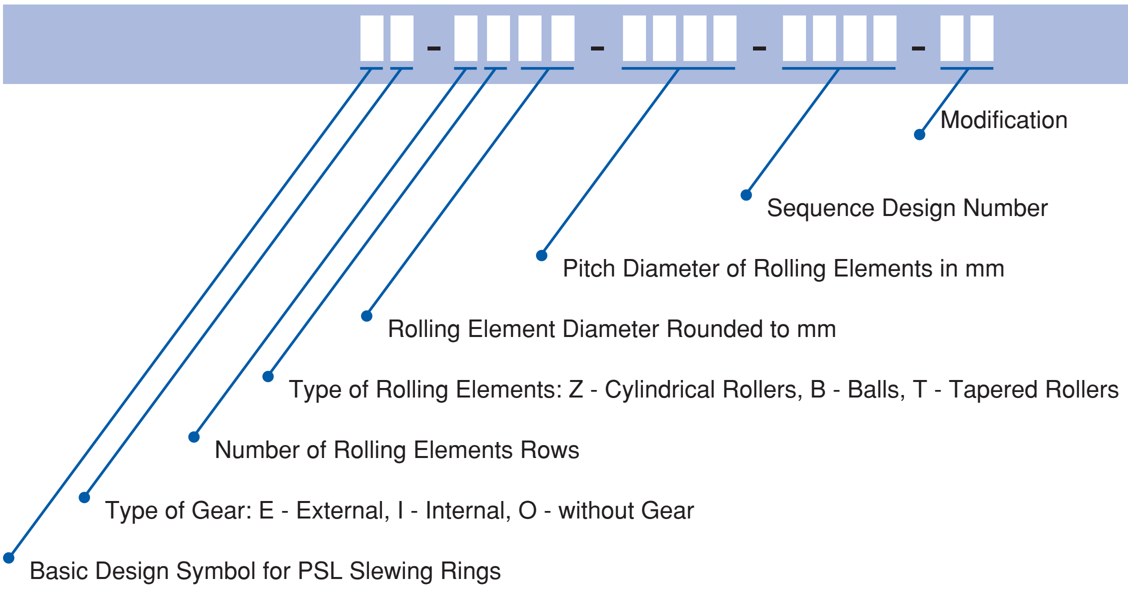
Slewing rings are large-sized bearings which are able to accommodate combined load, i.e. axial, radial loads and tilting moment. They are usually provided with holes for fixing bolts, internal or external gear, lubrication holes and seals, which allow a compact and economical arrangement. They often enable elimination of many components necessary in the classical bearing arrangement.

Basic design series

Four-Point Contact Ball Slewing Rings		Crossed Roller Slewing Rings
	without gear	
	with external gear	
	with internal gear	

PSL Slewing Ring Destgnation

The meaning and sequence of symbols used for PSL slewing ring designation:



The designation is placed on a non-functional surface of the slewing ring. It is made either electrochemically, or by punching or by a label fastened to the slewing ring.

Materials

For PSL slewing rings production carbon standard or heat treated steels, as well as chrome-molybdenum and chrome-vanadium steels are used.

Table 1 shows the survey of the steels. The bearing steel 100 Cr Mn 6 (14209 according to STN) is used for the rolling element production.

Separators or cages are mostly made of plastic, or for low, or high operating temperatures they are made of metals (aluminium or brass).

Table 1

Materials of the slewing ring rings	
Destgnation according to DIN (STN)	Utilization
50 Cr V4 (15260-STN)	according to treatment - for geared rings, as well as rings without gear
C 45 N	mainly for rings without gear
S 48C N	for less stressed rings without gear
S 48C V	for less stressed geared rings
46 Cr2 N	for medium stressed rings without gear
46 Cr2 V	for medium stressed geared rings
46 Cr4 N	for medium stressed rings without gear
46 Cr4 V	for medium stressed geared rings
42 CrMo4 N	for high stressed rings without gear
42 CrMo4 V	for high stressed geared rings

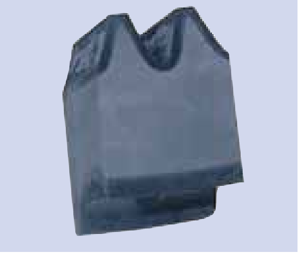
Quality Assurance

The quality of the production is ensured systematically, in a complex way with the goal to meet the customers needs in all phases of the manufacturing process.

Pre-production Phase:
- pre-sales service - professional services for customers
- marketing - market research from the technical and commercial point of view, development trends, ...

Production Phase:
- modern manufacturing methods, tools and procedures
- new materials and methods of heat-treatment
- continuous innovation of the inspection means and methods
- product testing on specialized test beds
- continuous improvement through TQM

Post-production Phase:
- testing of product quality in operation with the feedback to utilization property improvement
- after-sales service - help by application of the products, ...



DET NORSKE VERITAS
MANAGEMENT SYSTEM CERTIFICATE

Certificate No.: CERT-13612-2003-AQ-ESN-TGA

This is to certify that

PSL, a.s.
Robotnicka ul
01701 Povazská Bystrica - Slovakia (Slovak Republic)

has been found to conform to the Management System Standard

ISO 9001:2000

This certificate is valid for the following product or service ranges:

Development, design, manufacturing and sales of roller and ball bearings, slewing rings, bearing components and worm drives

Initial Certification date: 07.11.2003
This certificate is valid: 30.10.2006 - 30.09.2009
The audit has been performed under the supervision of Jürgen Weißbauer, *Lead Auditor*

TGA-ZM-04-92-00

Place and date: Essen, 17.10.2008
Nikolaus Kim, *Management Representative*

This certificate replaces the issue of 30.10.2006.

CERTIFICATE

SLOVAK ASSOCIATION FOR QUALITY AND MANAGEMENT SYSTEMS, Ltd.

SKQS confirms on the basis of the certification audit that:

PSL, a.s.
Robotnicka ul.
017 01 Považská Bystrica, Slovakia

scope of application

Development, design, manufacturing and sales of through-hardened antifriction roller and ball bearings and large diameter bearings made of steel and ferrous materials at the site Robotnicka ul., Považská Bystrica

has implemented and maintains the environmental management system in conformance with the requirements of the international standard

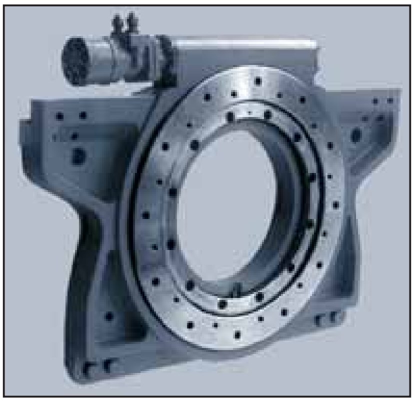
ISO 14001:2004

The validity of this certificate is 3 years.
Scope number 18

Certificate No.: 233-3/06
Certificate expiry date: 18. 12. 2009
Žilina 19. 12. 2006

Ing. J.M. Šima, PhD.
Head of Certification Body - Director SKQS

PSL Slewing Rings Applications

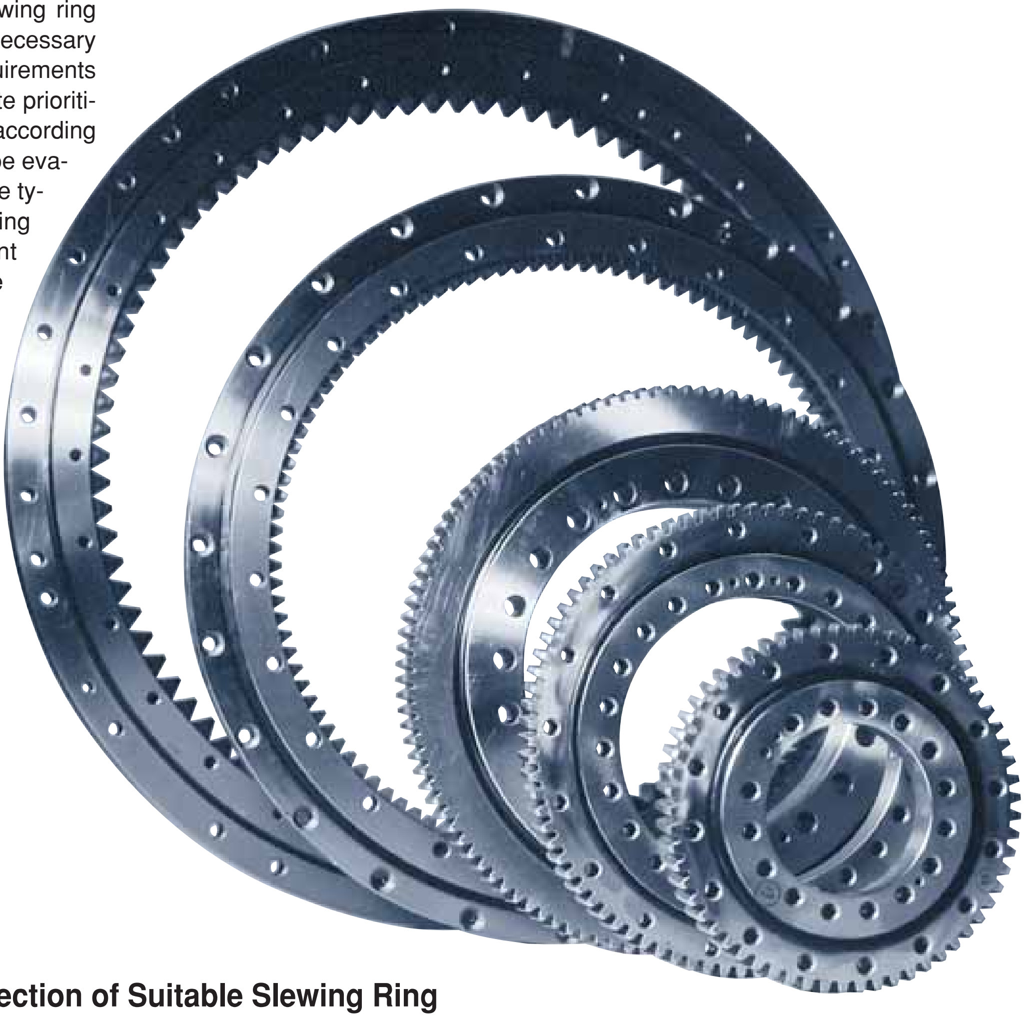


Compactness, accuracy and smoothness of operation at a relatively high rigidity, simple mounting, unpretentious maintenance and reliable operation are properties which enable broad utilization of these bearings in all industrial areas.

PSL slewing rings are used in:
- excavators,
- universal earth machines,
- felling machines,
- loaders,
- hydraulic grippers,
- axles and undercarriages,
- assembly and access platforms,
- robots,
- manipulators and positioners,
- machine tools and fixtures,
- cleaning and bottle filling machines,
- rescue vehicles,
- aerials,
- cutter loaders,
- drilling rigs,
- wind-power plants ...

Selection of Slewing Ring Type and Size

When selecting a suitable slewing ring for the given application it is necessary to find out and analyse all requirements on the arrangement and to state priorities of individual requirements, according to which the arrangement will be evaluated. Then to select a suitable type and size of the slewing ring and to solve the arrangement including optimization of the connecting part design and instructions for maintenance.



Data Necessary for Selection of Suitable Slewing Ring - Criteria for Evaluation of Slewing Ring Suitability for Given Application

For a decision about size and design of the slewing ring it is necessary to know following data:

- size, direction and time behaviour of the operating load
- required life
- operating rotational speed, number of rotations for a time unit
- requirements on accuracy, smoothness of operation and arrangement rigidity
- requirements on bearing securing
- requirements on gear
- characteristics of working environment
- requirements on the space, maximum weight...
- requirements on mounting, dismounting and maintenance of the slewing ring in operation
- requirements on arrangement economy

These data are at the same time criteria for evaluation of the slewing ring suitability for given application. The priority of individual criteria varies and depends on the requirements on the arrangement as a unit.

E.g.:
- cranes - the priority criterion is reliable transmission of the load and life
- turntables of machine tools - the priority criterion is accuracy, smoothness of operation and arrangement rigidity

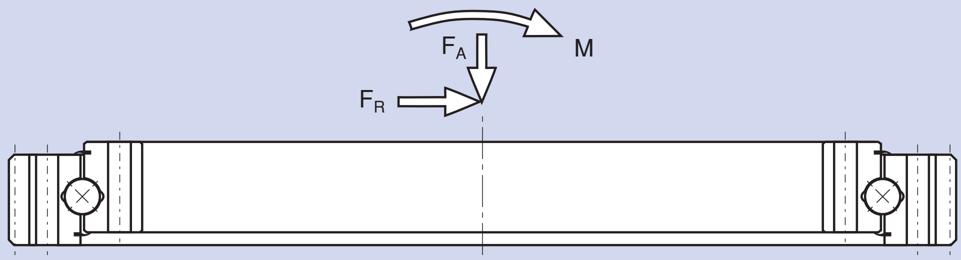
In most cases the slewing rings are used for equipment with cyclic activity, or at relatively low rotational speed. This shows that mostly the main criterion is a reliable transmission of the load, i.e. sufficient capacity of the raceways, gear and fixing bolts.

Slewing Ring Selection with Regard to Load Size, Life and Rotational Speed

The slewing rings enable to accommodate combined load, i.e. axial, radial forces and tilting moments from eccentric acting of these forces.

Typical Example of Load

Figure 1



Static Load Rating

Selection of a suitable slewing ring from the point of view of required static load rating can be carried out by means of curves for limiting static load. Curves for limiting static load rating of individual slewing rings are shown in the publication PSL No. 9/2001-OTO-A, Special Large-Sized Bearings - Slewing Rings, Production Programme.

Table 2

Calculation of Equivalent Axial and Moment Static Load		
Slewing Rings	**Formula**	**Conditions of Validity**
Four - point contact ball slewing rings	$F'_{OA} = (F_{OA} + 5.05 \cdot F_{OR}) \cdot s_O$ $M'_{OK} = M_{OK} \cdot s_O$	$0.1 < \frac{F_{OR}}{F_{OA}} < 8 \quad e > 2$
	$F'_{OA} = (1.23 \cdot F_{OA} + 2.68 \cdot F_{OR}) \cdot s_O$ $M'_{OK} = 1.23 \cdot M_{OK} \cdot s_O$	$0.1 < \frac{F_{OR}}{F_{OA}} < 8 \quad e \leq 2$
Crossed roller slewing rings	$F'_{OA} = (F_{OA} + 2.05 \cdot F_{OR}) \cdot s_O$ $M'_{OK} = M_{OK} \cdot s_O$	$0.1 < \frac{F_{OR}}{F_{OA}} < 8$

F_{OA} - Σ of axial static forces for a slewing ring [kN]
F_{OR} - Σ of radial static forces for a slewing ring [kN]
M_{OK} - Σ of tilting moments (static) for a slewing ring [kNm]
s_O - coefficient of static safety (values - see Table 3) [–]
$e = \frac{2000 \cdot M_{OK}}{F_{OA} \cdot D_S}$ - parameter of load eccentricity [–]
D_S - slewing ring mean diameter [mm]

Note: - if $\frac{F_{OR}}{F_{OA}} < 0.1$ - it is not neccessary to take into account the radial force when calculating the equivalent load.

Table 3

Values of Static Safety Coefficients for Various Operating Conditions and Applications			
Slewing Ring Motion	Kind of Load Requirements on Operation	Example	s_O
Rotary	Uniform load, quiet operation without impacts	• Turntables of the conveyer systems	0.5 ÷ 1.0
	Normal operating conditions, light impacts	• Cleaning and bottle filling machines • Barking machines • Machine tools	1.0 ÷ 1.25
	Great or considerable impact load	• Transport means • Vibration rollers • Radar aerials	1.25 ÷ 1.5
Swinging	Great swing angle with low frequency, uniform load without impacts	• Positioners • Stackers • Assembly cranes • Service cranes	0.8 ÷ 1.1
	Medium swing angle, normal load, light impacts	• Small and medium excavators • Car cranes • Building and ship cranes • Raiders • Robots and manipulators	1.25 ÷ 1.5
	Small up to medium swing angle with high frequency, great or considerable impact load	• Cranes with grab or magnet • Transfer cranes • Large excavators • Connecting joints of undercarriages of building, earth and felling machines	1.5 ÷ 2.5
Periodical turning or moving round a slight amount	Uniform load	• Mounting fixtures • Positioners	0.5 ÷ 0.8
	Normal load, light impacts	• Discharging conveyers • Aerials • Pan slewing rings	1.25 ÷ 1.5
	Great or considerable impact load	• Wind-power plants • Concrete pumps • Manipulators for nuclear power stations	1.5 ÷ 2.5

How to proceed when selecting a suitable slewing ring:
Calculated values of the equivalent axial and moment static load are defined by the coordinates of the working point in the diagram for limiting static load of the slewing ring. The working point must lie under the curve for limiting static load of the raceways of the selected slewing ring, as well as under the curve for limiting bolt load. Example of the diagram - see page 20, Figure 6.

Life

The following life calculation is only approximate because the slewing rings work in a cyclic way or at low rotational speed (tangential circumferential speed approximately 1m/s). The real life is also influenced by the maintenance in operation, quality and rigidity of the connecting construction and other factors.

According to our experience the real slewing ring life exceeds the theoretical value of the life L_{10}.

For calculation of the life L_{10} (90% reliability) is valid:

$$L_{10} = \left(\frac{C_a}{P_A}\right)^p$$

where:
- L_{10} - Life [10^6 rev]
- C_a - axial dynamic load rating according to the standard ISO 281 [kN]
- P_A - axial equivalent dynamic load [kN]
- p - factor p = 3 for ball slewing ring
  p = 10/3 for crossed roller slewing ring

Note:
Calculation of axial equivalent dynamic load is relatively complicated and requires much experience. The size of P_A depends mainly on the slewing ring application type (crane, excavator,...), range of load, number and angle of the working cycles, i.e. on operating conditions.

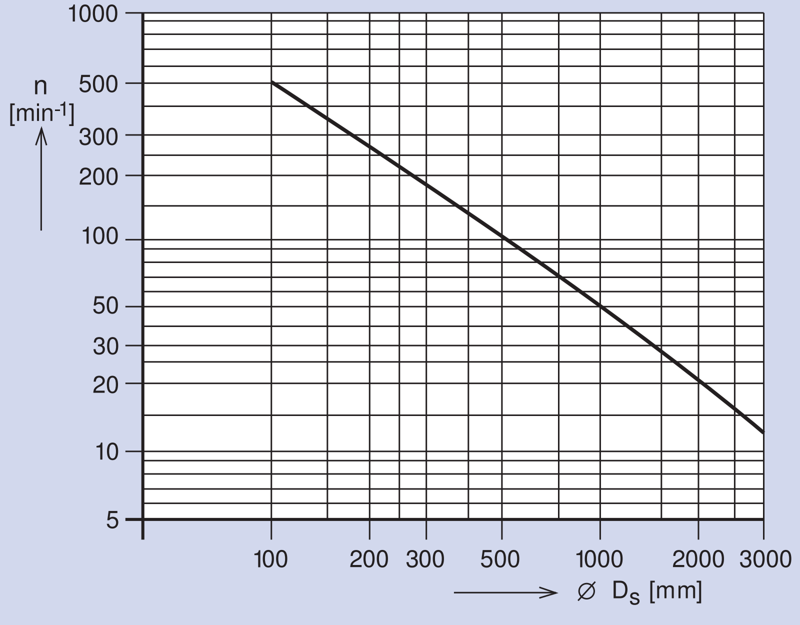
When you dimension the slewing ring life we recommend contacting the experts of the PSL Technical Consultancy Department .

Limiting Speed

In cases when the slewing ring should work at constant rotational speed (e.g. arrangement of turntables of vertical turret lathes, etc.) it is necessary to evaluate if the selected slewing ring is suitable for given rotational speed. The diagram of the limiting speed serves for this purpose - see Figure 2. This diagram is valid for slewing rings with full complement of rolling elements lubricated with oil. For grease lubrication the limiting speed values are approximately half the above mentioned value.

The limiting speed can be exceeded approximately 2.5 to 3 times, if the slewing ring is produced in a higher tolerance class, the rolling elements are seaprated by a cage and the internal clearance is optimized for given operating data. In such cases, we recommend contacting the experts of the PSL Technical Consultancy Department.

Figure 2



Slewing Ring Selection with Regard to Accuracy, Smooth Operation and Arrangement Rigidity

In some applications, e.g. arrangements of machine tool turntables, robots, manipulators, in addition to evaluating the slewing ring with regard to load, rotational speed and life, it is necessary and decisive to evaluate the suitability of the bearing with regard to accuracy, smooth operation and arrangement rigidity.

Dimension and Running Accuracy
PSL slewing rings of standard design have the following production tolerances:

Table 4

Tolerances of Functional Diameters			
Nominal Diameter [mm]		Diameter Tolerance [mm] - External (-) - Internal (+)	
over	to	centering (IT9)	head (of geared rings)
120	250	0.11	0.2
250	400	0.14	0.25
400	630	0.17	0.3
630	1000	0.23	0.4
1000	1600	0.31	0.5
1600	2500	0.44	0.7
2500	3150	0.54	0.9

Slewing rings with centering diameters according to IT8 and of higher tolerance class are delivered on the customer's demand. The centering height is usually 0.15 of the ring height.

Table 5

Tolerances of Non-Functional Diameters (ISO 2768 - m)		
Nominal Diameter [mm]		Diameter Tolerance [mm] (Ī)
over	to	
120	400	0.5
400	1000	0.8
1000	2000	1.2
2000		2.0

Table 6

Height Tolerances				
Nominal Height [mm]		Ring Height Tolerance [mm] (Ī)	Construction Height Tolerance [mm] (Ī)	
over	to			
	50	0.3	0.6	+ 0.5
50	180	0.4	0.8	of Tilting
180		0.5	1.0	Clearance

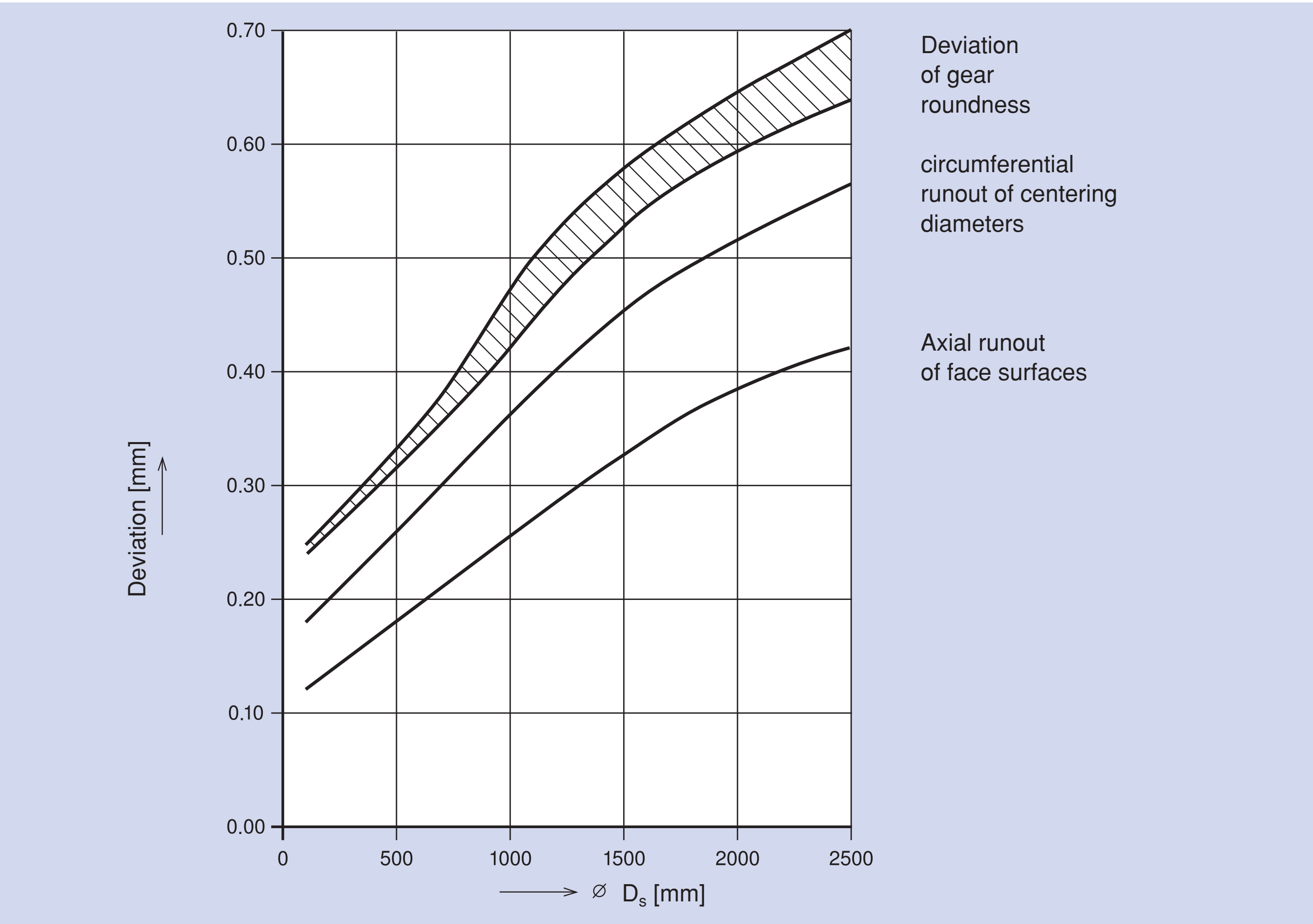
Table 7

Tolerance of Fixing Bore Position		
Pitch Diameter of Bores [mm]		Tolerance of Fixing Bore Position [mm]
over	to	+ R...
120	250	0.10
250	400	0.15
400	630	0.20
630	1000	0.25
1000	1600	0.30
1600	2500	0.35
2500	3100	0.40

Running Accuracy
The running accuracy of the slewing rings is defined by the radial runout of the centering diameters and the gear and by the axial runout of the face surfaces. The runout size depends on the diameter and cross-section of the slewing ring and on the heat treatment of the rings. Approximately, the running accuracy deviation can be read in dependence on the mean slewing ring diameter from the diagram in Figure 3.
If from the comparison of the production tolerances with required tolerances it is determined that given arrangement requires a slewing ring of higher tolerance class than standard, these cases should be solved with the experts of the PSL Technical Consultancy Department.

Deviation of Running Accuracy

Figure 3



Slewing ring internal clearance

The size of the internal clearance or preload (negative clearance) decisively influences the running of the slewing ring, the arrangement rigidity and life. Selection of the clearance or preload size depends on the requirements on the arrangement. If the arrangement is to have a high rigidity and the rotational speed is low, it is more suitable to use a slewing ring with preload. In this way there is a more uniform spacing of the load on the rolling elements and thus higher life are achieved.

If the slewing ring is to work permanently at higher rotational speed, it is more suitable to use a slewing ring with clearance. The clearance size is also stated with regard to the operating temperature of the arrangement.

If selecting the optimal clearance or preload for concrete operating conditions we recommend to consulting with the experts of the PSL Technical Consultancy Department who will also provide information with which clearance or preload the PSL slewing rings are delivered.

Slewing Ring Sealing

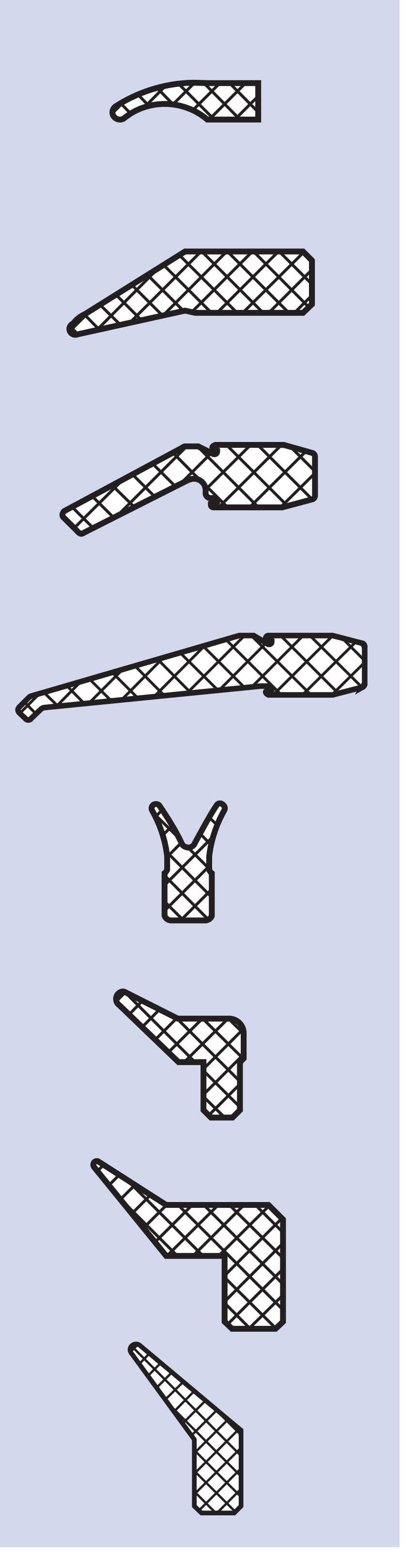
Standard PSL slewing rings for common usage are delivered sealed on both sides. Sealing is to protect from an excessive lubricant escape from the slewing ring and at the same time to protect the internal space from penetration of impurities. Profiles of commonly used sealings - see Figure 4.

The material of the standard sealing profiles is rubber NBR 70.

For special application of the slewing rings (e.g. high operating temperature, higher requirements on resistance in extreme operating conditions, etc.) it is possible to deliver these profiles also made of different materials, or to develop new special sealing suitable for the given application. In these cases contact the experts of the PSL Technical Consultancy Department.

Sealing Profiles

Figure 4



Friction Moment, Driving Motor Output Calculation

The friction moment size is influenced by following factors:

- internal design and slewing ring size
- clearance size or preload
- direction and size of the load
- machining quality and geometrical accuracy of the slewing ring raceways
- sealing method
- kind and quantity of lubricant

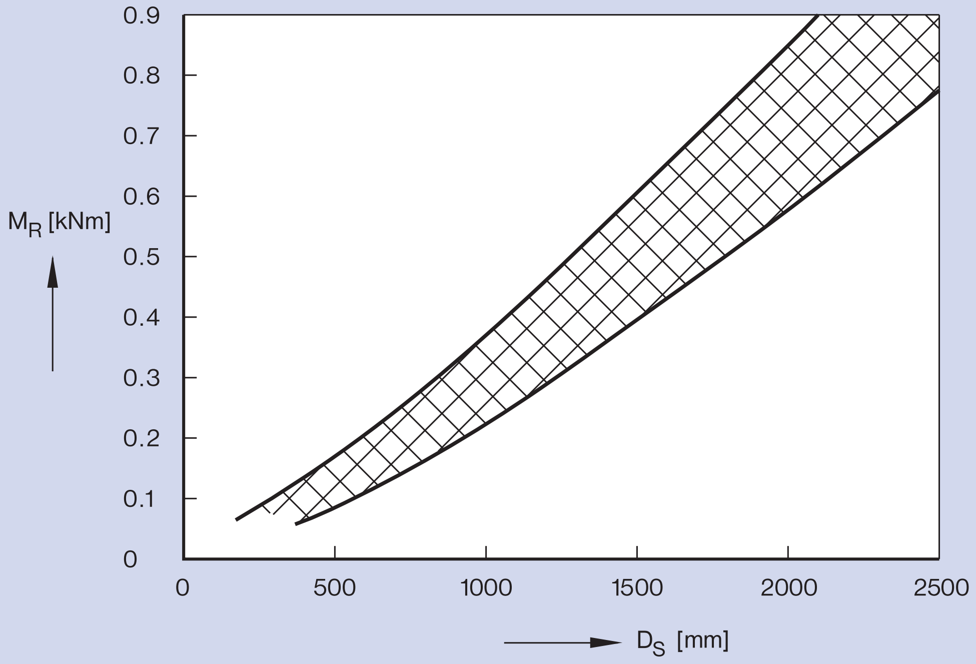
The overall torque of the slewing ring is calculated from following equation:

$M_T = M_R + M_Z + M_G$ where:
- M_R - starting friction moment of a non-loaded slewing ring [kNm]
- M_Z - slewing ring friction moment caused by load [kNm]
- M_G - moment from acceleration (slowing down) of rotating mass [kNm]

The size of the starting friction moment can be read in dependence on the mean slewing ring diameter from the diagram in Figure 5. This diagram is valid for standard PSL slewing rings with two sealings.

Diagram of Starting Friction Moment

Figure 5



The friction moment caused by the load is calculated from following equation:

$$M_Z = \mu \cdot k \left(\frac{M_K \,.\, 1000}{D_S} + \frac{F_R \,.\, f_L}{2} + \frac{F_A}{k}\right) \cdot \frac{D_S}{2000}$$

where:

- μ - friction coefficient [–]
  - $\mu = 0.006$ - ball slewing rings
  - $\mu = 0.004$ - crossed ball slewing rings
- k - coefficient of load accommodation [–]
  - $k = 4.4$ - ball slewing rings
  - $k = 4.1$ - crossed ball slewing rings
- M_K - Σ of tilting moments for a slewing ring [kNm]
- F_R - Σ of radial dynamic forces for a slewing ring [kN]
- F_A - Σ of axial dynamic forces for a slewing ring [kN]
- D_S - mean slewing ring diameter [mm]
- f_L - coefficient of the raceway [–]
  - $f_L = 1.73$ - ball slewing rings - by prevailing axial and moment load
  - 1.0 - ball slewing rings by prevailing radial load
  - $f_L = 1.0$ - crossed roller slewing rings

When dimensioning the motor output necessary for the slewing ring drive also the moment of acceleration or deceleration of the rotating mass (by starting and braking), or other moments which must be overcome by the motor, e.g. the wind force, etc. must be taken into account.

Moment of acceleration (deceleration) forces is as follows:

$$M_G = I \cdot \epsilon$$

$$I = 0.01 \cdot \left(\frac{G_1}{g} \cdot r_1^2 + \frac{G_2}{g} \cdot r_2^2 + \dots + \frac{G_j}{g} \cdot r_j^2\right)$$

$$\epsilon = \frac{\pi \cdot n}{30 \cdot t_z}$$

where:

- I - moment of the rotating mass inertia [kg.m.s^2]
- ϵ - angle acceleration of the rotating mass [s^{-2}]
- $G_1,..G_j$ - weights of rotating parts [kg]
- $r_1,..\, r_j$ - center of gravity distances of the rotating mass from the rotating axis [m]
- g - acceleration of gravity [m.s^{-2}]
- t_z - acceleration (deceleration) time [s]
- n - rotational speed [min^{-1}]

The output of the driving motor is then as follows:

$$P_{KW} = \frac{M_T \cdot n}{9.55 \cdot \eta} \quad [kW]$$

where: η - gearbox efficiency [–]

Gear

Slewing rings are in many cases integrated with gears and then it is necesary to evaluate the operating ability of the slewing ring also from the point of view of the gear.

Gear Types

The types of the corrected and non-corected gears are as follows:

- spur gear - external or internal,
- helical gear - only external.

Except for standard gears it is possible to deliver the slewing rings with a special gear, as. e.g. adapted shape of the tooth profile, full radius in the dedendum, etc.
The gear of the standard slewing rings can be delivered in standard or heat treated state, or circumferentially or gap hardened.

Gear Dimensioning

For correct gear dimensioning it is necessary to know following data:

- characteristics of the operating conditions, time utilization of individual work regimes, method of lubrication, operating temperature, etc...
- nominal and maximum circumferential forces by individual working regimes,
- data about pinion (number of teeth, correction, material, heat treatment, etc.).

Calculation of the nominal and maximum circumferential force:

$$F_{Tnen} = \frac{2000 \cdot M_{Tnen}}{m \cdot (z + 2x)}$$

$$F_{Tmax} = \frac{2000 \cdot M_{Tmax}}{m \cdot (z + 2x)}$$

where:

F_{Tnen} - nominal circumferential force [kN]
F_{Tmax} - maximum circumferential force [kN]
M_{Tnen} - nominal torque [kNm]
M_{Tmax} - maximum torque [kNm]
m - gear module [mm]
z - number of teeth [–]
x - unit displacement of the basic profile (unit correction) [–]

The main criteria for evaluating of the gear suitability is the fatigue resistance of bending and max. static load transmission.

Following conditions must be fulfilled:

$F_{Tnen} \leq F_{TDov}$ - for fatigue resistance of bending

$F_{Tmax} \leq F_{TmaxDov}$ - for max. static load transmission

Permitted values of the nominal and maximum circumferential forces for the slewing ring gear PSL are shown in the publication PSL No. 9/2001-OTO-A. They were calculated for concrete materials from which the individual geared rings are produced.

If the PSL slewing ring cannot be selected according to the above mentioned criteria, contact the experts of the PSL Technical Consultancy Department.

Fastening Bolts

To secure a reliable load transmisson and operation of the slewing ring, fastening of bolts must be correctly dimensioned. The number, size and quality of the bolt material depends on the size, direction and character of the transmitted load, slewing ring and attached construction design.

Classification of Bolts and Nuts

For fastening the slewing ring bolts and nuts classified into quality classes are used - see Tables 8 and 9.
Comparison of the bolt classification classes according to individual standards - see Table 10.

Table 8

Classification of Bolts				
Class according to ISO	Tensile Strenght [MPa] R_m	Yield Point [MPa] $R_{p0.2}$	Fatigue Limit [MPa] $\pm \sigma_A$	Prolongation [%] A_s
8.8	800	640 for $\leq$ M16 660 for $>$ M16	See VDI 2230* Blatt 1	12
10.9	1000	940		11
12.9	1200	1100		9

* VDI 2230 - Calculation system of high-stressed bolted joints - VDI guideline

Table 9

Matching of Nuts and Bolts		
Nut		Bolt - Class according to ISO With Normal Thread
Class according to ISO	Testing Stress [MPa]	
8	800	8.8
10	1000	10.9
12	1200	12.9

Table 10

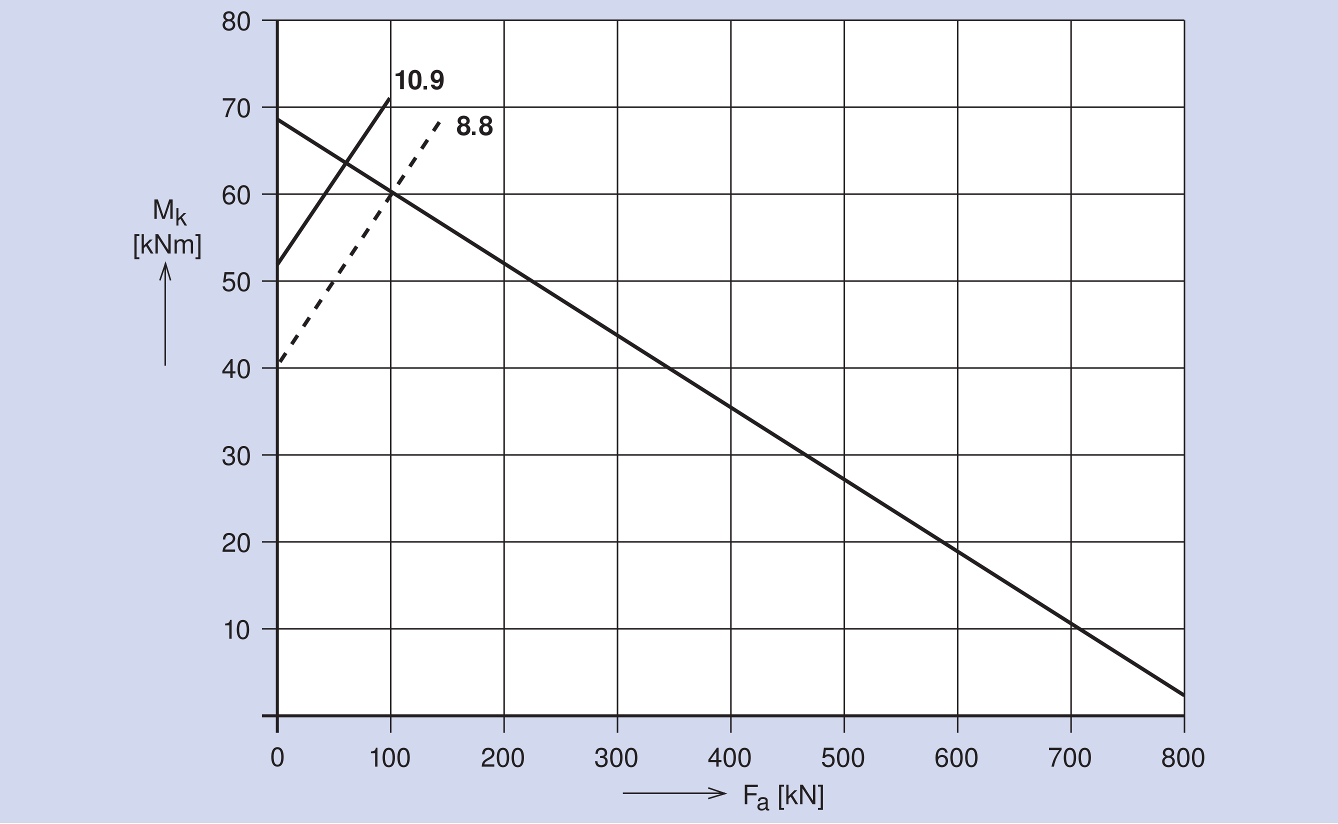
Comparison of Bolt Classes		
ISO	ASTM	SAE
8.8	A-325	Grade 5
10.9	A-490	Grade 8
12.9	A-574	

Bolt Selection by Means of Diagrams for Slewing Ring Limiting Static Load Rating

According to the maximum operating load it is possible to determine, according to the working point coordinates (coordinate calculation - see page 11) from the diagram for limiting static load rating of the slewing ring, which bolts are suitable for fastening. Example - see Figure 6. Specific cases should be consulted with the experts of the PSL Technical Consultancy Department.

Diagram for Slewing Ring Limiting Static Load Rating - Example

Figure 6



Fastening Bolts

Conditions of Diagrams for Limiting Static Load Rating of Fastening Bolts

- The bolts are uniformly spaced around the circumference on the bolt pitch circles
- The axial load acts on the slewing ring in a "seating way", i.e. the bolts are sufficiently loaded by the "hanging" load
- The size of the radial load is maximum 10% of the axial bearing load
- The design of the attached parts is rigid enough, the fitting surface are machined
- The loss of preload in the bolts due to seating is neglected
- The gradient of the bolt head or nut head seating surface to the shank axis is max.1°
- The clamping length is minimally $l_S = 5.d$
- The friction coefficient in the thread is 0.14

By great radial load the bolt diameter should be as great as possible and the slewing ring rings should be radially supported, i.e. centered.

The tolerance of the centering diameters should be as follows:

- for a bore H7,
- for a journal k6.

As the slewing rings and the bolt joint are prevailingly loaded in a cyclic way, it is necessary to use the preload so that due to loading undesirable joint loosening should not rise.

The cross-section of the classical slewing ring fastening and the diagram of the bolt linear change and connected parts in dependence on the preload is shown in Figure 7 and 8.

Figure 7

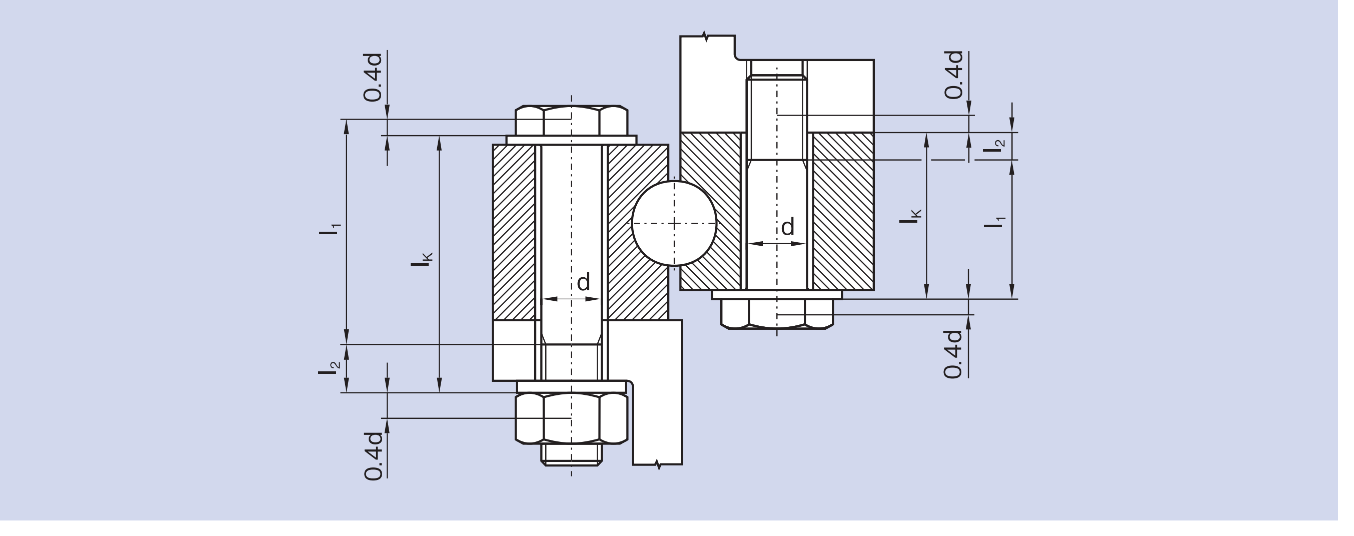


Figure 8

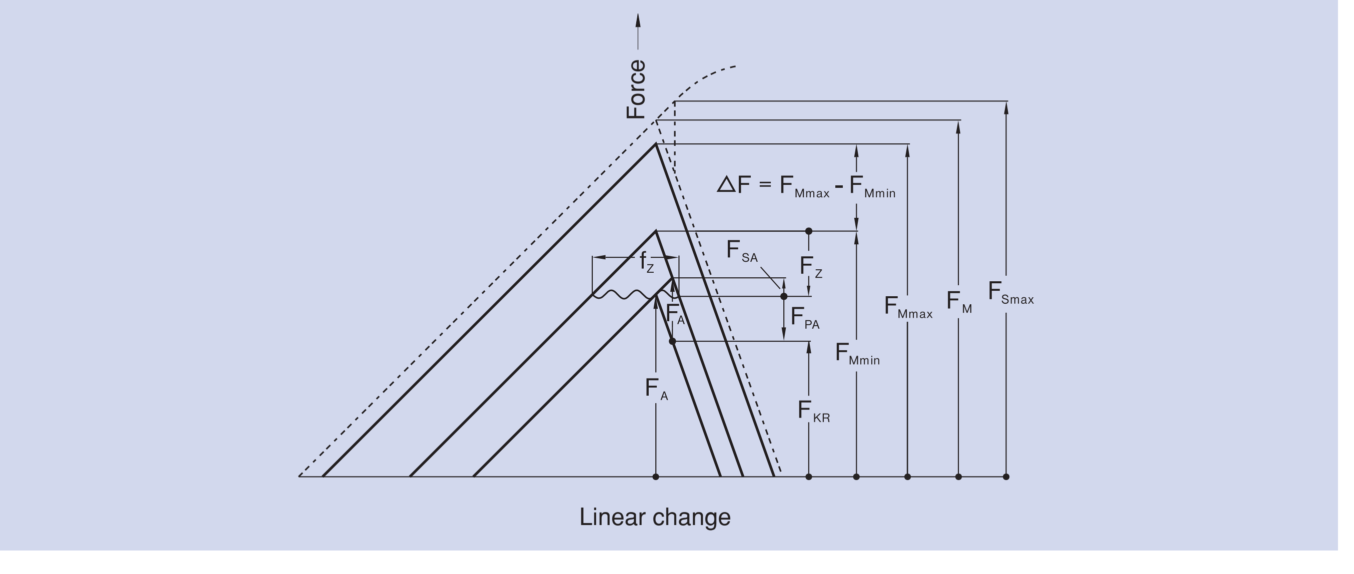


Table 11

Preloads and Tightening Torques for metric Bolts (Friction Coefficient μ = 0.14)								
Strength Class of the Bolt according to DIN/ISO 898			8.8		10.9		12.9	
Sliding threshold $R_{p0.2}$ [MPa]			640 for ≤ M 16 660 for > M 16		940		1100	
Bolt Size according to DIN 13	Stressed Cross-Section A_S [mm²]	Thread Cross-Section Ad_3 [mm²]	Preload F_M [N]	Tightening Torque M_U [Nm]	Preload F_M [N]	Tightening Torque M_U [Nm]	Preload F_M [N]	Tightening Torque M_U [Nm]
M 5	14.2	12.7	6400	5.5	9300	8.0	10900	9.3
M 6	20.1	17.9	9000	9.3	13200	13.9	15400	16.2
M 8	36.6	32.8	16500	22.5	24200	33	28500	38
M 10	58	52.3	26000	45	38500	67	45000	78
M 12	84.3	76.2	38500	78	56000	117	66000	135
M 14	115	105	53000	126	77000	184	90000	216
M 16	157	144	72000	193	106000	279	124000	333
M 18	193	175	91000	270	129000	387	151000	459
M 20	245	225	117000	387	166000	558	194000	648
M 22	303	282	146000	522	208000	747	243000	873
M 24	353	324	168000	666	239000	954	280000	1116
M 27	459	427	221000	990	315000	1395	370000	1665
M 30	561	519	270000	1350	385000	1890	450000	2250
M 33	694	647	335000	See note	480000	See note	560000	See note
M 36	817	759	395000		560000		660000	
M 39	976	913	475000		670000		790000	
M 42	1120	1045	542000		772000		904000	
M 45	1300	1224	635000		905000		1059000	
M 48	1470	1377	714000		1018000		1191000	
M 52	1760	1652	857000		1221000		1429000	
M 56	2030	1905	989000		1408000		1648000	
M 60	2360	2227	1156000		1647000		1927000	

Note:
Tightening torques shown in the Table 11 and 12 are valid for tightening with a torque spanner, the permissible variance is ±10% of values shown in the table.

When using bolts with thread greater than M30, the friction size is substantially different, it is not recommended to create the required preload by a torque spanner, but by means of a hydraulic tensioning device and the preload should be adjusted by means of measuring of the whole bolt prolongation. The overall bolt prolongation is:
$\Delta l = F_M.\delta_s$ [mm].

Where: δ_s - Resilience of bolt and nut

Table 12

Preloads and Tightening Torques for Bolts with UNC Standard Thread (Friction Coefficient μ = 0.14)							
Strength Class of the Bolt according to ASTM			A-325 (Grade 5)		A-490 (Grade 8)		
Bolt Size according to ANSI B 1.1	Stressed Cross-Section A_S [sq.inch]	Thread Cross-Section Ad_3 [sq.inch]	Preload F_M [lbs]	Tightening Torque M_U [ft.lbs]	Preload F_M [lbs]	Tightening Torque M_U [ft.lbs]	
1/4 – 20	0.0318	0.0269	1893	7	2896	10	
5/16 – 18	0.0524	0.0453	3120	14	4771	21	
3/8 – 16	0.0775	0.0678	4611	25	7052	38	
7/16 – 14	0.1063	0.0933	6325	39	9674	60	
1/2 – 13	0.1419	0.1257	8443	60	12913	92	
9/16 – 12	0.1819	0.1620	10826	87	16557	133	
5/8 – 11	0.2260	0.2017	13447	120	20566	183	
3/4 – 10	0.3345	0.3019	19900	213	30436	325	
7/8 – 9	0.4617	0.4192	25211	314	42018	524	
1 – 8	0.6057	0.5509	33074	471	55123	786	
1 1/8 – 7	0.7633	0.6929	41675	668	69458	1113	
1 1/4 – 7	0.9691	0.8896	50200	894	88189	1571	
1 3/8 – 6	1.1511	1.0502	59626	See note	104748	See note	
1 1/2 – 6	1.4053	1.2935	72792		127878		
1 3/4 – 5	1.8995	1.7437	98392		172851		
2 – 4 1/2	2.4982	2.2996	129408		227339		
2 1/4 – 4 1/2	3.2477	3.0206	168230		295540		
2 1/2 – 4	3.9988	3.7154	207139		363893		

1 sq.in. = 645,16 mm^2
1 mm^2 = 1.5500031 · 10^{-3} sq.in.

1 lbs = 4.448222 N
1 N = 0.22480892 lbs

1 ft.lbs = 1.355818 Nm
1 Nm = 0.73756209 ft.lbs.

Table 13

Permissible Specific Pressure Beneath Bolt or Nut Head		
Material of Clamped Parts	P_G [Nmm^{-2}]	
St 37	260	If the permissible specific pressure is over than hardened washers for the friction connections should be used beneath the bolt heads.
St 50, C 45 N, 46 Cr 2 N, 46 Cr 4 N	420	
C 45 V, 46 Cr 4 V, 42 CrMo 4 V	700	
GG 25	800	

Minimum Screwing Depth

The screwing depth of the studs is selected with regard to material into which the studs will be screwed. Recommended values are shown in Table 14 and are valid for the thread tolerance 6 H.

Table 14

Minimum Screwing Depht						
Bolt Strenght Class Thread Fineness d/p	**8.8 < 9**	**8.8 ≥ 9**	**10.9 < 9**	**10.9 ≥ 9**	**12.9 < 9**	**12.9 ≥ 9**
St 37	1.0 . d	1.25 . d				
St 50, C 45 N, 46 Cr 2 N, 46 Cr 4 N	0.9 . d	1.0 . d		1.2 . d		1.4 . d
C 45 V, 46 Cr 4 V, 42 CrMo 4 V	0.8 . d	0.9 . d		1.0 . d		1.1 . d

In the Table: d - nominal (outside) thread diameter [mm]

p - thread lead [mm]

$\frac{d}{p}$ - thread fineness - is valid: $\leq$ M 30 ⋯ $\frac{d}{p} < 9$

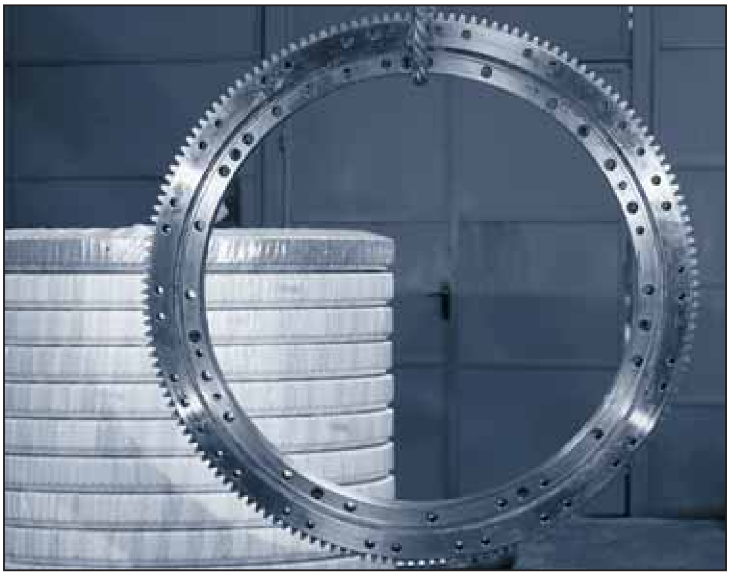
$>$ M 30 ⋯ $\frac{d}{p} \geq 9$

Preservation, Packaging, Transport and Storing of Slewing Rings

Before packaging, the slewing rings are preserved with a liquid preservation agent providing protection against corrosion for approximately 12 months in a tempered store. The store temperature should be 20 ± 5°C with relative humidity max. 60%.

After preservation the slewing rings are wrapped with PE foil band, then packed on pallets or boxes. The form of packaging should be discussed in advance with PSL, a.s.

Slewing rings should always be transported horizontally, if possible on a pallet, sufficiently secured to prevent movement.



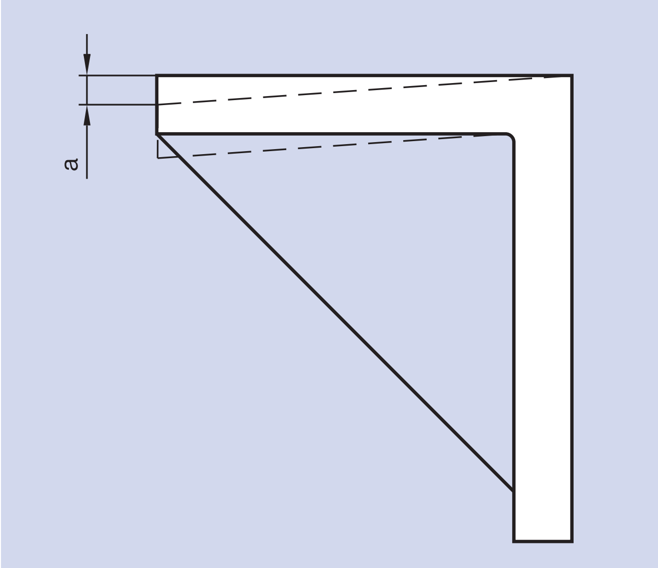
Mounting and Maintenance of Slewing Rings

Requirements on Seating Surfaces

Seating surfaces of the connecting structure for slewing rings up to diameter 3 000 mm must meet following conditions:

a) machining roughness
   max. R_a = 12.6 (usually R_a = 6.3),
b) maximum permissible flatness deviation
   a = 0.1 . D_s [mm],
c) maximum deflection of connecting structure under maximum operating load should not exceed value
   y = 0.5 . D_s [mm],
   where: D_s - bearing mean diameter [m].

The variation of flatness can occur only once within the 180° section. To prevent local bearing overloading due to seating surface out of flatness or deflection of the connecting structure, any possible variation within the section 0° - 90° - 180° should increase or decrease gradually.



Mounting Procedure

Before assembling it is necessary to clean all surfaces thoroughly of burrs, paint residues, etc. Seating surfaces should be dry, without lubricant. Furthermore, it is necessary to inspect flatness of the seating surfaces. Feeler gauges are used to check slewing ring adaptation.

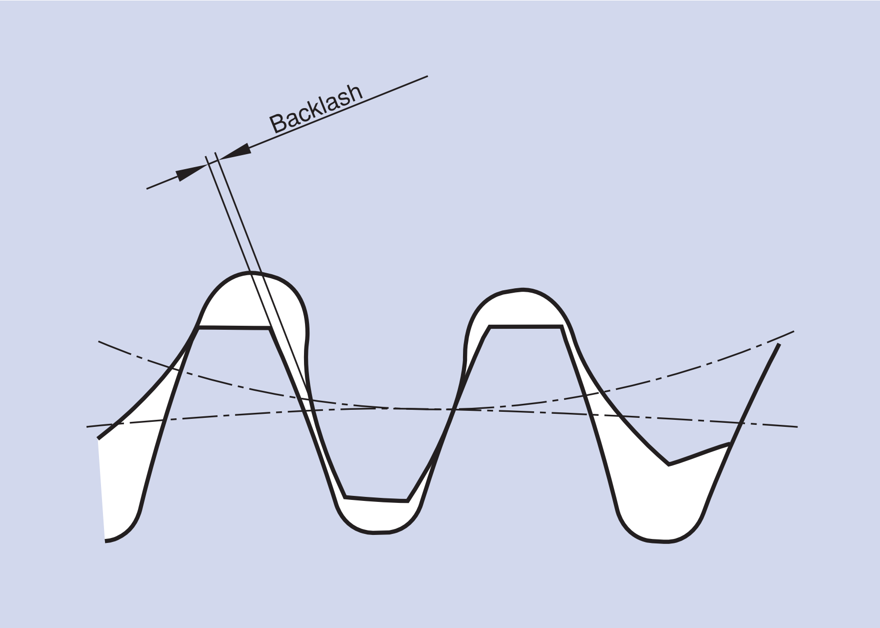
The unhardened area of the non rotating ring should be mounted so that it is positioned in the least loaded zone - i.e. in the plane perpendicular to the main load plane.

The unhardened area is marked on the respective ring non-functional surface with symbol"X" by stamping or with a red line.

When assembling a geared slewing ring it is important to adjust the backlash in the gear correctly.

It is adjusted with a feeler gauge or with another suitable method in the zone of maximum radial gear runout.

The extent of the backlash should be in the range of (0.035-0.04).m, where "m" means the gear module. The backlash should be inspected again after the slewing ring is finally fixed on the machine. The zone of the maximum radial gear runout is marked with blue line in the gap between teeth. According to the customer's requirement it is possible to use a different method of designation.



Slewing rings are fixed on the machine with pre-stressed bolts. Before assembly the mounting bolts should be coated slightly with oil. The necessary tightening torque for corresponding bolt size and material is indicated in Table 11 and 12.

Slewing Ring Maintenance

Maintenance involves regular relubrication of raceways and gear together with inspection of fastening and wear of the bearing.

Types of Lubricants
PSL slewing rings are filled with grease "LV 2 EP" (producer - Mogul). Further recommended lubricants are shown in Table 15.

Lubricant Quantity and Relubrication Interval
Relubrication interval and lubricant quantity primarily depends upon operating conditions, i.e. load, rotational speed, operational environment properties, etc. For low-speed applications (mobile cranes, construction cranes, etc.) the relubrication interval is about 200 operating hours. For machines with a higher rotational speed or for equipment operating under permanent rotational speed or in tropical conditions (excavators, universal finishing machines, magnetic separators, etc.), the relubrication interval is shorter - it is about 70 to 100 operating hours. Quantity of the lubricant for each relubrication can be approximately calculated using the following formula:

$$Q_m = 0.3 \cdot D_s^2 \text{ [kg]}$$

where: D_s - slewing ring mean diameter [m]

When relubricating, the lubricant should be uniformly distributed in the inner space of the slewing ring. The most suitable way of achieving this is to apply the lubricant whilst the bearing rotates or by application from several positions around the circumference.

Table 15

Recommended Lubricants		
Producer	Recommended Lubricant for Raceway	Gear
ARAL	Aralub HLP 2 248 K to 403 K (-25 °C to +130 °C)	Aralub LFZ 1 235 K to 523 K (-20 °C to +250 °C)
BP	Energrease LS-EP 2 248 K to 403 K (-25 °C to +130 °C)	Energrease LC 3 243 K to 433 K (-30 °C to +160 °C)
Castrol	Spheerol EPL 2 253 K to 393 K (-20 °C to +120 °C)	Viscogen 0 238 K to 398 K (-35 °C to +125 °C)
elf	EPEXA 2 243 K to 393 K (-30 °C to +120 °C)	CARDREXA DC 1 253 K to 393 K (-20 °C to +120 °C)
Esso	BEACON EP 2 248 K to 403 K (-25 °C to +130 °C)	EP GREASE 350 253 K to 393 K (-20 °C to +120 °C)
KLÜBER LUBRICATION	CENTOPLEX 2 EP 253 K to 403 K (-20 °C to +130 °C)	GRAFLOSCON C-SG 0 plus 243 K to 473 K (-30 °C to +200 °C)
Mobil	Mobilux EP 2 253 K to 393 K (-20 °C to +120 °C)	Mobitac 81 243 K to 393 K (-30 °C to +120 °C)
	Stabyl LEP 2 253 K to 393 K (-20 °C to +120 °C)	Ceplattyn KG 10 243 K to 523 K (-30 °C to +250 °C)
	Calithia EP Fett T 2 248 K to 403 K (-25 °C to +130 °C)	GREASE S. 8327 253 K to 503 K (-20 °C to +230 °C)
DEA	Multifak EP 2 243 K to 403 K (-30 °C to +130 °C)	Spectron ZKF-EP 0 253 K to 423 K (-20 °C to +150 °C)

Slewing Ring Inspection in Operation

During service it is necessary to regularly recheck the mounting bolt torque at recommended intervals. Individual inspection intervals vary according to machine operation conditions.
When inspecting, the following method can be used (approximately valid for crane operation):

Note: Specified inspection intervals must be shortened by 1/2 up to 1/3 for machines loaded more heavily by vibrations or dynamically.

In addition to the mounting bolt check, raceway wear checking is also carried out in operation (mainly at significant important rotary connections) using the measurement method "tilting clearance". The tilting clearance is the difference of the mutual ring displacement in axial direction measured under load by minimum and maximum tilting moment.

In the operation register of the equipment the initial tilting clearance is recorded (in the jib position 1 to 8) and its enlargement is then followed in certain time intervals. The principle of the tilting clearance measurement and an example of the measuring record are shown in Figure 9 and 10.

More detailed technical information concerning slewing ring checking can be provided by the experts of PSL, Bearing Development Department.

Table 16

Inspection No.	Number of Operating Hours	Inspecting Action
1.	About 200 Hours	• inspection of all bolts torque • if more than 10% of bolts are loose, another inspection is necessary after about 200 operating hours
2.	About 600 Hours	• inspection of all bolts torque
3. and further	After about 2000 Hours	• if one or more bolts are loose to less than 80% of the prescribed torque, these and both adjoining bolts must be replaced by new ones • if 20% of all bolts have less than 80% of prescribed torque, all bolts must be replaced by new ones
	Each 12000 Hours	• replace all bolts by new ones

Measuring of Tilting Clearance Size and Example of Measuring Record

Figure 9

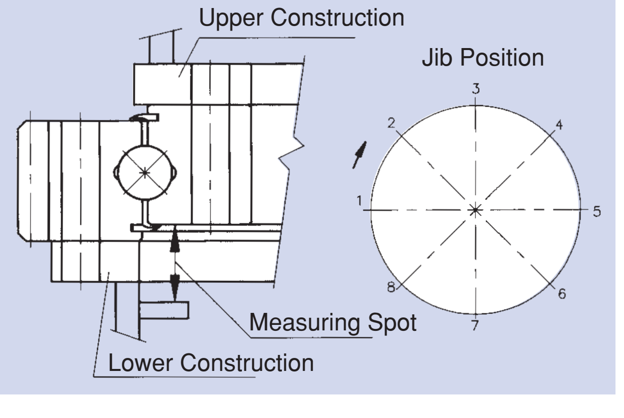


Figure 10

Measuring Spot	Basic	Checking I.	II.	III.	IV.	V.	VI.
1							
2							
3							
4							
5							
6							
7							
8							
Inspector							
Signature							
Date							

PSL, a. s.
Robotnícka
017 01 Považská Bystrica
Slovakia

Quality For Heavy Duty

Customer Requirements on PSL Product – Slewing Ring

1. Customer

Company name:
Address:
Town: | ZIP: | State:
Contact person: | Depart.:
Phone: | Fax: | E-mail:

2. Application

Description of application, machine:

Machine type: Info also available at web:
Bearing will be used for: ☐ New application ☐ Replacement, spare parts

3. Operation/Speed

Rotating ring: ☐ Outer race ☐ Inner race

Axis of rotation: ☐ Vertical axis *(Bearing installed horizontal)* ☐ Horizontal axis *(Bearing installed vertical)*

☐ Angular *(Please specify in Remarks)* ☐ Variable *(Please specify in Remarks)*

Direction of rotation: ☐ Mainly one-direction ☐ Cyclic (Oscillating)

Way of rotation: ☐ Continuous ☐ Interrupted/Intermmitent

Maximal speed: rpm Maximal angle of rotation

Required life: hours or cycles

4. Dimensions

	Most suitable		Acceptable range	
Outside diameter	mm	inch	mm (max)	inch (max)
Inside diameter	mm	inch	mm (min)	inch (min)
Overall height	mm	inch	mm (max)	inch (max)
Raceway diameter	mm	inch	mm (max)	inch (min)
	Outer race (most suitable)		Inner race (most suitable)	
Bolts circle diameter:	mm	inch	mm	inch

5. Bearing loads

Load cases	Loads			Gear**		Rotational speed		Time of rot. %
	Axial*	Radial	Moment	Tooth load	Gear torque	Max	Average	
1								
2								
3								
4								

Unit of measurement ☐ kN, kNm ☐ lbs, lbs.ft

**Axial loads are positive if compression, negative if tensile*
***Please, fill one data only, either tooth load or torque ring gear*

6. Gear requirements

☐ External gear — Tooth form:
☐ Internal gear — Modul/DP:
☐ No gearing — Contact angle – α:

	Pinion	Geared ring
Number of teeth – z		
Profile correction – xm		
Gear width – b		

Other requirements (precision, quality):

Please, include the drawing of the pinion if possible

7. Bolts

☐ Metric only
☐ SAE only
☐ Metric or SAE

Bolt diameter

Bolt material

Outer race boltholes:

☐ Thru without thread
☐ Thru and counterbored
☐ Thru tapped
☐ Tapped and counterbored
☐ Tapped and dead hole
☐ Without special request

Inner race bolt holes:

☐ Thru without thread
☐ Thru and counterbored
☐ Thru tapped
☐ Tapped and counterbored
☐ Tapped and dead hole
☐ Without special request

8. Special requirements (check where applicable)

☐ Seals are required
☐ Extremely dirty
☐ No grease lubrication
☐ Oil lubrication

Location specification of grease holes:

Outer race
☐ Outer diameter
☐ Mounting site
☐ Other (specify in Remarks)

Inner race
☐ Inner diameter
☐ Mounting site
☐ Other (specify in Remarks)

☐ High temperature (> 50 °C) — Max. temperature °C
☐ Low temperature (< -25 °C) — Min. temperature °C
☐ Precision/preload bearing (Please, provide details below)
☐ Rolling elements must be caged. No spacers

Remarks:

For the most precise and economically, please attach applicable drawings or sketches.

9. Offer

Required date of offer:
Required date of delivery:
Quotation quantity: pcs
Annual requirements: pcs/year:

Individual consultation required. Please call for appointment: ☐

Please send the filled questionnaire to one of the following address:

Thank you very much for your cooperation

PSL, a. s.; Slovakia	PSL Wälzlager GmbH; Germany	PSL of America; USA	PSL OOO; Russia
tel: +421/42/4371 506	tel: +49/6074/828 98 30	tel: +1/330/405-1888	tel.: +7-495-925-6187
fax: +421/42/7326 644	fax: +49/6074/828 98 331	fax: +1/330/405-1398	fax: +7-495-925-6188
e-mail: pslpb@pslas.com	e-mail: info@psl-gmbh.de	e-mail: sales@pslamerica.com	e-mail: pslopora@yandex.ru

Conversion Equivalents for U.S. and Metric Measurements			
Measurement	**When you Know**	**Multiply by**	**To get an equivalent in**
Lenght	[inch]	25,4	[mm]
	[mm]	0,03937	[inch]
	[ft]	0,3048	[m]
	[m]	3,2808399	[ft]
	[mile]	1,609	[km]
	[km]	0,6214	[mile]
Area	[sq. inch]	645,16	[mm^2]
	[mm^2]	0,001550003	[sq. inch]
	[sq. ft]	92903,04	[mm^2]
	[mm^2]	0,00001076391	[sq. ft]
Volume	[c. inch]	16387,064	[mm^3]
	[mm^3]	0,000061023744	[c. inch]
Weight	[lb]	0,4536	[kg]
	[kg]	2,2046	[lb]
	[lb]	0,0004536	[t]
	[t]	2204,6	[lb]
Force	[lbf]	4,448222	[N]
	[N]	0,22480892	[lbf]
	[lbf]	0,004448222	[kN]
	[kN]	224,80892	[lbf]
Torque	[lbf.inch]	0,1129848	[Nm]
	[Nm]	8,850748	[lbf.inch]
	[lbf.ft]	1,3558182	[Nm]
	[Nm]	0,73756207	[lbf.ft]
	[lbf.ft]	0,0013558182	[kNm]
	[kNm]	737,56207	[lbf.ft]
Temperature	[°F]	(°F-32)/1,8	[°C]
	[°C]	1,8.°C+32	[°F]
Presure, Stress	[psi]	0,006894757	[MPa]
	[MPa]	145,03774	[psi]
Power	[hp]	0,7457	[kW]
	[kW]	1,341	[hp]
Velocity	[ft.s^{-1}]	0,3048	[m.s^{-1}]
	[m.s^{-1}]	3,2808399	[ft.s^{-1}]
	[mph]	1,609	[km.h^{-1}]
	[km.h^{-1}]	0,621	[mph]
Acceleraction	[ft.s^{-2}]	0,3048	[m.s^{-2}]
	[m.s^{-2}]	3,2808399	[ft.s^{-2}]

Notes:

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