SPIETH Hydrodynamic Radial-Slide-Bearings

Series GLM

Works Standard SN 03.01

Content

1. General

In modern and powerful machines the importance of the spindle bearing is increasing. Solutions for these tasks are offered by roller bearings as well as by slide bearings. Increasing demands for long tool life as well as for surface performance, shape accuracy, and fabrication tolerances of the work pieces has been shown in the last years, that especially at hydrodynamic sectionalised surface slide bearings – with its caused by the lubricating film high damping properties and concentric accuracy – the smoothness as well as the insusceptibility to shock together with its high durability are characteristics which can barely be featured by roller bearings.

1.1. SPIETH Hydrodynamic Radial-Slide-Bearing

SPIETH-slide bearings are hydrodynamic lubricated adjustable sectionalised-surface radial slide bearings. The main use is in the field of mechanical engineering and especially for building machine tools with its complex requirements.

1.2. Hydrodynamic lubrication

Hydrodynamic lubrication means the stream caused by a running spindle in the with lubricant filled wedged shaped gap of a slide bearing. This stream cause liquid thrusts in the lubricant with the highest level of thrust short before the smallest gap in running direction. At correct arrangement of wedged shaped gap, spindle revolutions and oil viscosity the created liquid thrust is able to lift even high loaded spindles from the bearing surface. The effect is that the spindle is >>swimming<< above the lubricant layer.

1.3. Lubricant

Used for lubrication are mineral oils, mainly spindle oils. Their viscosity has to be chosen in dependence of the working conditions. For hydrodynamic lubricated slide bearings an adequate supply of oil is required for problem free running. The function of the lubricant hereby is not only to create the hydrodynamic thrust in the wedged shaped gap, it also has to transfer the friction heat out of the region of the slide surfaces.

1.4. Lubrication system

The most used lubrication systems are:
Splash lubrication, centrifuge lubrication and external lubrication

The external lubrication by a pump is the most secure and efficient lubrication system. Especially for high sliding speeds which need a high quantity of oil for cooling the external lubrication supply by a pump is absolutely necessary. For this lubrication system any spindle position can be allowed. There is only the need for sufficient pump pressure to negotiate circuit and duct resistance to ensure an adequate quantity of oil for the temperature equation. As said before, the carrying liquid thrust will be created by itself after the rotation of the spindle has started.

1.5. Sealing

Slide bearings are provided with gaskets to avoid the escape of the lubricant out of the inner system and also to protect the bearing system against penetration of dirt and humidity. The sealing system is dependent of the working conditions.

Contact or sliding gaskets are used for low and middle velocities. The wear and friction heat limits its use. The application area is up to the peripheral speed of 12 m/s.

Higher sliding speeds require non-contact gaskets such as a pressure-tight sealing thread, labyrinth sealing or an annular gap with a loose inserted bronze sliding ring. As in the annular gap a hydrodynamic thread will be created by the spinning spindle, which is higher than the regular pressure of the lubricant, no oil can escape while the spindle is running. All non-contact sealing have a little amount of leaking oil as long as the spindle is not running. As this is known, this can be absorbed and returned to the lubricant tank.

2. Adjustable SPIETH Radial-Slide-Bearing

2.1. Use and preferences

This hydrodynamic sectionalised radial slide bearing is used wherever optimum bearing play and highest running smoothness is requested and a sufficient lubrication supply is ensured. High and low frequencies are allowed as same as both directions.

As the optimum bearing play can be set and readjusted, no longsome adaptation between bearing and spindle are necessary. It is sufficient if the seating of the spindle and the bore in the housing are machined cylindrical according to an ISO-Tolerance.

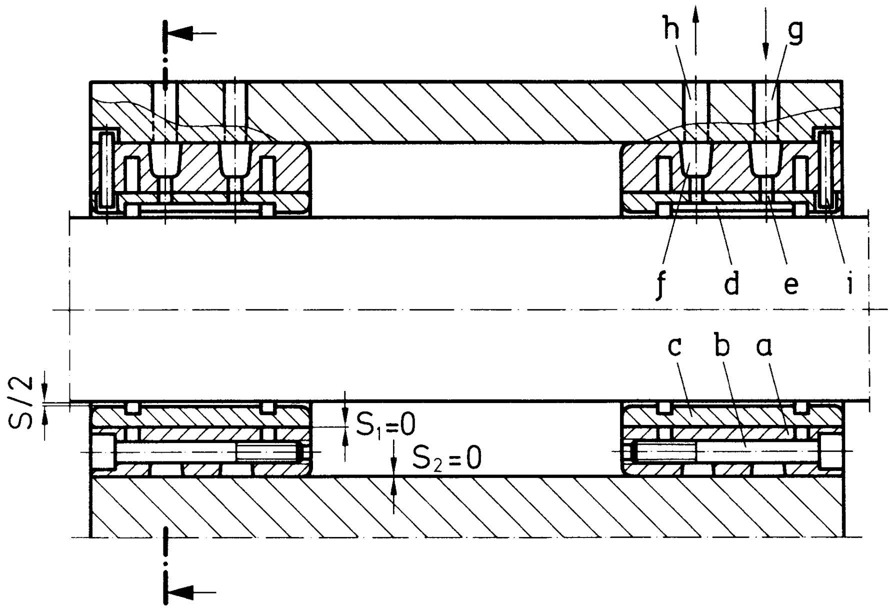
This adjustable bearing type is today successful used wherever best surface quality, and shape accuracy has to be machined. The GLM is used for spindle bearing in grinding-machines, lathes, precise drilling or as counter bearing of milling arbor and boring bars. For this machinery there are for example grind and work piece spindles with a GLM bearing in use to realize a concentricity of less than 0,4 μm.

One of the most underestimated advantages of the Type GLM bearing is the damping effect of the hydrodynamic bearing system. The high absorbability of the hydrodynamic guidance is very useful for machining processes where high frequencies can occur due to the high durability of the static elements.

2.2. Layout and function

The SPIETH hydrodynamic radial slide bearings have a meander formed profiled steel hull (a) with integrated clamping screws (b) and a bearing bush made out of bearing bronze (c).

The bearings are configured in a way, that after tightening the clamping screws first the mounting play (S_1 + S_2) will be eliminated. After this the radial strangling of the inner bearing bush will start. This strangling will be in a parallel direction to the axis. It is possible to set any requested bearing play or adjustment without any scraping.



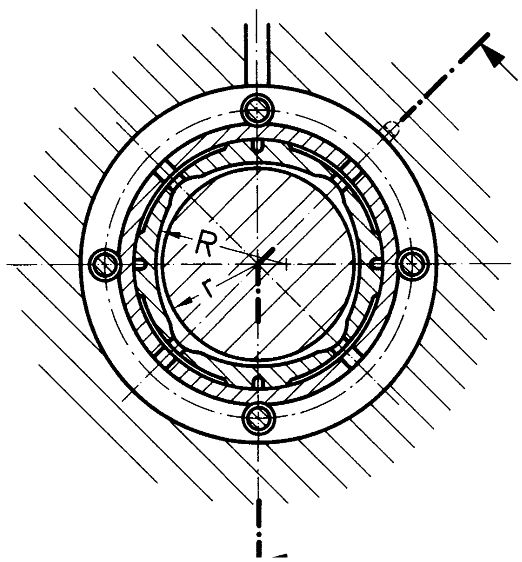


Fig. 3:

a	iron hull
b	clamping screws
c	bushing
d	lubrication flute
e	lubrication hole
f	outer cut-in
g	lubrication inlet
h	lubrication outlet
i	cylindrical pin
S	bearing play
S_1	mounting play
S_2	mounting play
r	shaft-radius
R	slide-radius

The inner bushing has some axial lubrication flutes (d) which are connected with the outer cut-in (f) in the steel hull by radial lubrication holes (e). By this arrangement the bushing is connected with the lubrication inlet (g) and outlet (h) in the housing bore.

The lubrication flutes are dividing the bushing bore in a few sliding surfaces. During the adjustment of bearing play, these sliding surfaces are changing their original radius in the way, that there will arise a wedge crack between sliding surface and spindle. The tightest point of this wedge crack will be in the middle of the sliding surface and will expand in both directions to the lubrication flutes. SPIETH hydrodynamic radial slide bearings are independent of the rotation direction of the spindle as the lubricant can flow under the developed pressure in the squeezed wedge crack and can thereby lift the spindle from the bearing sliding surface. Due to physical rules, the hydrodynamic lubrication process is all round the spindle and therefore centring the spindle unavoidable.

The radial orientation of the bearing in the housing bore will be realized by a cylindrical pin (i) which will fit in a flute to be machined in the housing.

2.3. Execution

The meander formed steel hull working as an adjustment element is made out of special steel and not hardened. The bushing is made out of high grade bearing bronze. This material was chosen for high security reasons and due to its emergency running properties as during the short period of start-up and run-out the lubrication layer may be interrupted and a metal contact between spindle and bearing sliding surface may occur.

The outer diameter of the bearing is grinded according to the tolerance h5; the bore is machined to F6. As the bearing is machined under compressed conditions, a control measurement of the bore is not possible in its untensioned delivery state.

The mounted clamping screws shall be tightened by using a wrench according to ISO 2936.

2.4. Connecting Components

2.4.1. Housing

The housing bore has to be machined cylindrically according to the tolerance H6. The radial orientation of the bearing is done by a cylindrical pin of the bearing, aligned in a flute to be machined in the housing. Normally the orientation is chosen in a way, that the direction of the bearing load is about 6° before one of the sliding surface centre out of the rotation direction.

The lubrication supply has to be done in a way, that the lubricant can be feed into the outer cut-in of the steel hull of the bearing. The lubricant return circuit will be dependent of the working conditions through the second outer cut-in and/or through outpouring side wards as leak oil. Return circuit and leak oil will be conveyed to the reservoir. For horizontal spindles it may be practical to install the supply and return from the top. At vertical spindles the supply should be beneath, the return above.

2.4.2. Spindle

For an accurate concentricity the spindle contact surface has to be done cylindrically according to tolerance g5. Recommended quality of the spindle is a surface roughness of 0,4 – 0,63 µm best realized by smooth grinding. The material of the spindle is dependent of the requirements. For high operational demands the spindle should be case hardened (≈ HRC 64) or nitrogen hardened (≈ HV 8500 N/mm^2).

Regarding to the for bearing play adjustment necessary control of contact pattern we recommend following for using two bearings with the same size:
The diameter of the first to insert spindle-bearing seat should be machined with a reduction of IT3. The result will be that passing the second bearing during dismounting will not smear the visible areas of a die spotting.

2.5. Mounting and adjustment of play

To inform every first time user detailed, every delivery is equipped with an extensive instruction. Further instructions are available under request.

Basic requirement for proper bearing function is an accurate cleaning of all lubrication-conveying holes, and lines. Left over from fabrication or other particles are removed best by pressure flushing with heated (warm) low viscosity machine oil.

2.5.1. Dismantling of clamping screws, greasing of thread and contact surface of screw head. Screw the screws back on place until contact of screw head contact face, but do not tighten more to avoid pretension.

2.5.2. Insert the radial-plain-bearing into the housing, pay attention that the orientation pin must not come to rest axially against the groove in the housing. Tighten the clamping screws evenly crosswise until the radial-plain-bearing is seated firmly in the housing. Even actuation of the clamping screws can be achieved by tightening in each case by a certain angular amount (e.g.30°).

2.5.3. Insert the spindle into the borehole of the radial-plain-bearing. Adjust on each spindle end a micrometer for concentricity. Pay attention that the radial play, cause by radial movements, is measured in the direction of the clamping screws and as near as possible to the radial-plain-bearing.

2.5.4. Reduce bearing play on both bearings by tightening the clamping screws crosswise until the play is 0,01 mm bigger than the wanted movement play. After each tightening sequence hit the spindle a few times lightly with a rubber mallet in the direction of the clamping screws. It could happen, that the bearing play will increase by this treatment, but this is intended.

2.5.5. As the bearing play is now 0,01 mm bigger than the wanted movement play, remove the spindle and apply a coating of inking paste. To assess the contact pattern by the left ink impression, the coating of the inking paste has to be kept real thin.

2.5.6. Reinsert the spindle into the radial-plain-bearing and generate a contact pattern by radial and axial movements of the spindle. Remove the spindle and assess the ink impressions left.

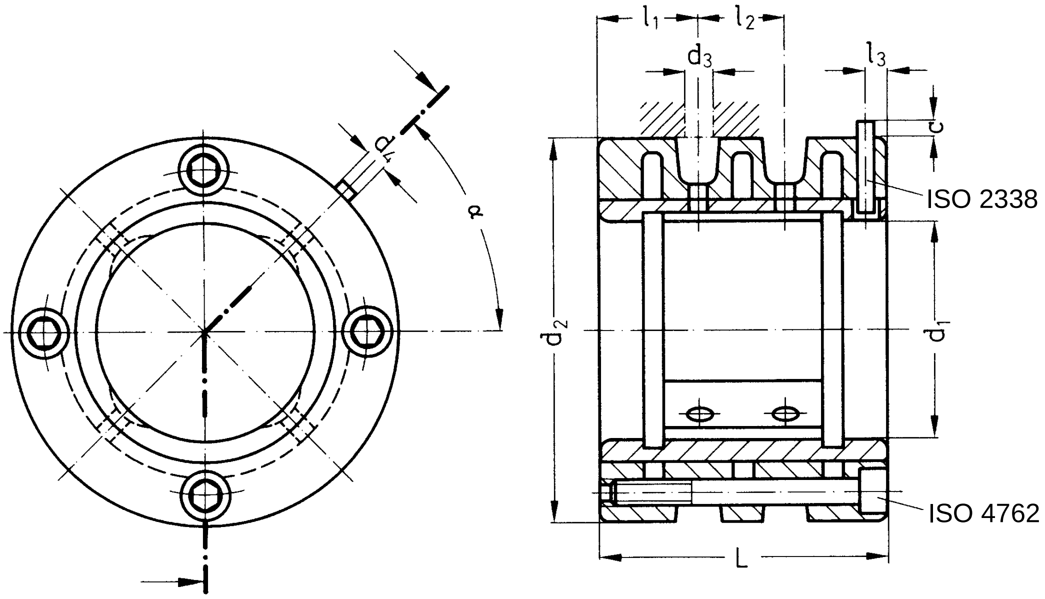
2.5.7. If the contact pattern in the radial-plain-bearing is equally at all sliding sections, the final movement play can be set by tightening the clamping screws as described above.

If the contact pattern is uneven, the clamping screws shall be tightened individually depending on the ink impressions. This could result in a one-sided adjustment.

If the movement play was set too closed, all screws have to be loosened until play is 0,01 – 0,02 mm bigger. The play has to be set again as described above.

The complete adjusting range correspond approx. the basic tolerance field IT 10 based on the spindle diameter.

3. Table of dimensions for Radial-Slide-Bearing Series GLM



Designation of an adjustable hydrodynamic radial slide bearing with
d_1 = 40 mm, d_2 = 65 mm, and L = 45 mm:

Radial slide bearing GLM 40 · 65

Code	dimensions in mm						cylindrical pin ISO 2338 -				clamping screws	
	d_1	d_2	L	l_1	l_2	d_3	d_4	c	l_3	α	dimensions	n
	F6 [1)]	h5				max	mm	mm	mm	°	ISO 4762 - 8.8	No.
GLM 30.55	30	55	40	13,8	12,5	4	2	2	3	45	M 4 x 35	4
GLM 35.60	35	60										
GLM 40.65	40	65	45	15	15	6					M 4 x 40	
GLM 45.70	45	70										
GLM 50.80	50	80	52	17,8	16,5	6	3	2	4	45	M 5 x 45	4
GLM 55.85	55	85	56	18,8	18,5	8					M 5 x 50	
GLM 60.90	60	90	62	20,3	21,5	10					M 5 x 55	
GLM 65.100	65	100	68	23,5	21		4	3	6		M 6 x 60	
GLM 70.105	70	105	72	24,5	23	10	4	3	6	45	M 6 x 65	4
GLM 75.110	75	110	78	26	26	15					M 6 x 70	
GLM 80.115	80	115	82	27	28						M 6 x 75	
GLM 85.120	85	120	85	27,8	29,5							
GLM 90.125	90	125	90	29,8	30,5	15	4	3	6	45	M 6 x 80	4
GLM 95.130	95	130	95	31	33	20					M 6 x 85	
GLM 100.135	100	135	100	32,3	35,5						M 6 x 90	
GLM 110.160	110	160	110	34,8	40,5						M 8 x 100	
GLM 120.170	120	170	120	38,5	43	25	4	3	7	30	M 8 x 110	6
GLM 130.180	130	180	130	41	48						M 8 x 120	
GLM 140.190	140	190	140	43,5	53						M 8 x 130	

1) see chapter 2.3.

subject to change without notice.

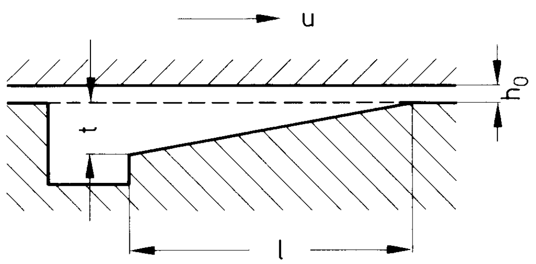
4. Calculation of Bearing

With the here presented method the designer is given the possibility to collect the for bearing definition needed but unknown values by graphic method. This method is easy and sufficient enough.

4.1. Ascertainment of load capacity (Nomogram I)

The SPIETH hydrodynamic radial slide bearing Type GLM has nearly wedge shaped retain fields in defined geometric dimensions. Therefore the load bearing capacity is according to technical literature:

$$F = C \cdot \eta \cdot u \cdot b \cdot \frac{l^2}{h_o^2}$$



b = supporting bearing width

The smallest operational lubrication gap is according to technical literature about the size of

$$h_o \approx 2\mu m$$

Due to this

$$h_o < t$$

can be ascertained and the load rating C displayed as:

$$C \approx 0{,}25 \cdot \frac{h_o}{t}$$

For the geometric of the GLM the load bearing capacity F can be calculated as:

$$\boxed{F \approx 30\eta \cdot u \cdot \frac{d^2}{h_o}}$$

and the average high loading pressure $\bar{p}$:

$$\bar{p} = \frac{F}{l \cdot b} \approx 150\eta \cdot u \cdot \frac{1}{h_o}$$

Nomogram I was compiled for the smallest lubrication gap occurring under operation $h_o \approx 2\mu m$;
η is the dynamic viscosity under working temperatures.

4.2. Ascertainment of heating of the bearing (Nomogram II)

Out of the for wedge shaped retain field named relations

$$\mu \approx (0{,}5 \ldots 1) \cdot \frac{\eta \cdot u}{\bar{p} \cdot h_o}$$

there is the outcome of the friction coefficient

$$\mu \approx \frac{1}{200}$$

and the friction loss

$$P = \frac{1}{200} \cdot F \cdot u$$

In the diagram of Nomogram II are two overlapping cases displayed:

Case 1: heat emission at the bearing surface.
At an exothermic surface

$$A \approx 10 \cdot d^2$$

and the heat transmission number

$$\alpha = 20 \left[\frac{W}{K \cdot m^2} \right]$$

the dissipation of friction loss at the bearing surface

$$P = \alpha \cdot A \cdot \Delta T_{air}$$

As a result of this, the high temperature of the bearing is

$$\Delta T_{air} \approx K_{air} \cdot \frac{P}{d^2} \;;$$

whereby $K_{air} = 0{,}005 \left[\frac{K \cdot m^2}{W} \right]$

In this case the high temperature will be ascertained with the diameter scale in the Nomogram II.

Case 2: heat emission to the coolant
At a supposed specific heat

$$c = 1900 \left[\frac{Nm}{kg \cdot K} \right]$$

and a density of the coolant

$$\rho = 0{,}9 \cdot 10^3 \left[kg / m^3 \right]$$

the dissipated friction loss by the quantity of coolant Q is

$$P = \rho \cdot c \cdot Q \cdot \Delta T_{oil}$$

As a result of this, the high temperature of the bearing is

$$\Delta T_{oil} \approx K_{oil} \cdot \frac{P}{Q} \text{ ; whereby } K_{oil} \approx 0{,}03 \left[\frac{K \cdot l}{W \cdot min} \right]$$

The high temperature will be determined by the scale of the coolant quantity in the Nomogram.

4.3. Viscosity of standard lubricants

In the Nomogram III the dynamic viscosity η of some standard lubricants in dependency of the working temperature can be ascertained.

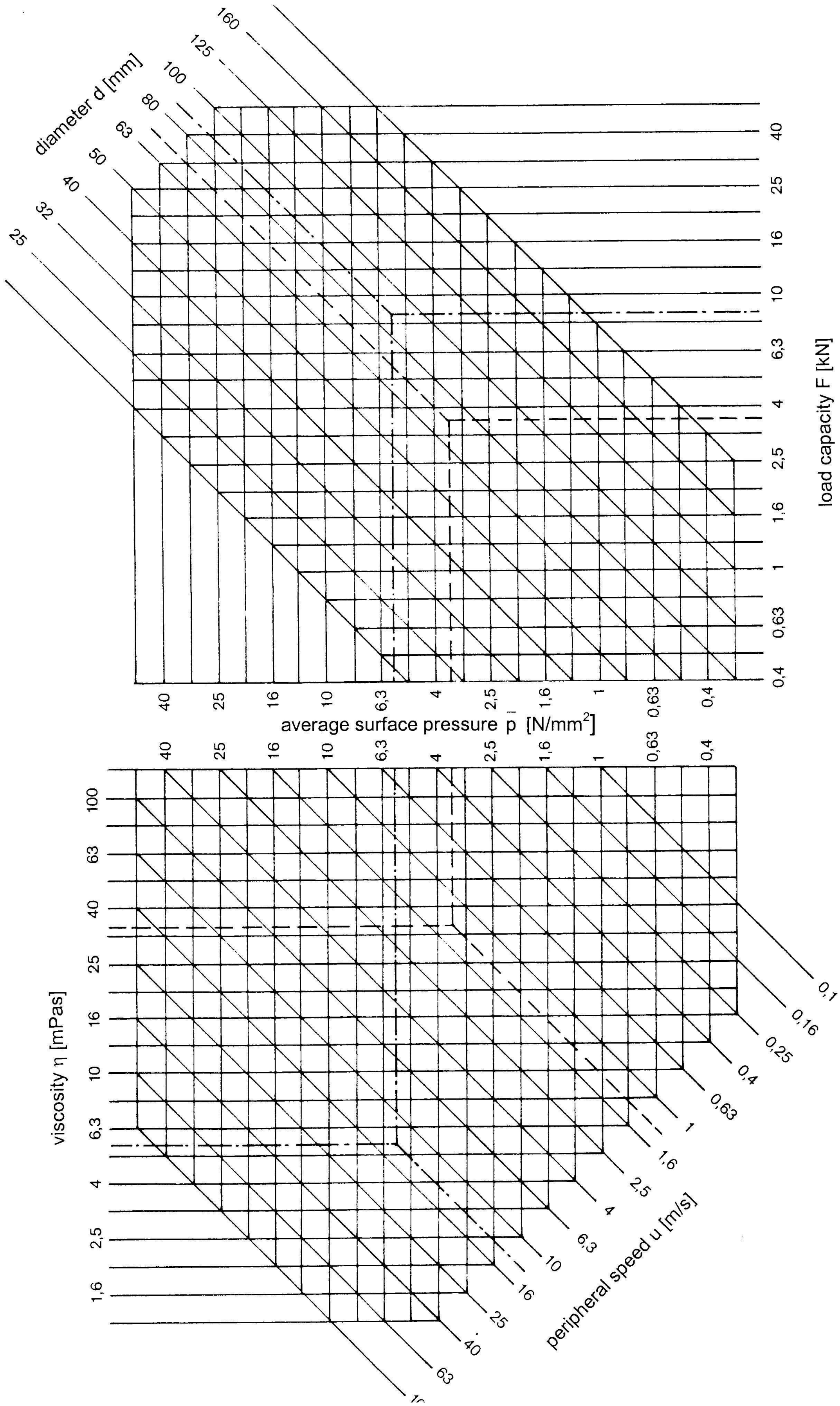
4.4. Standard values for bearing play

The bearing play is the resulting difference of the adjusted diameter of the bearing sliding surfaces and the diameter of the shaft. In the Nomogram IV there are standard values for the bearing play, graded in dependence of the bearing size and the allowed high temperature.

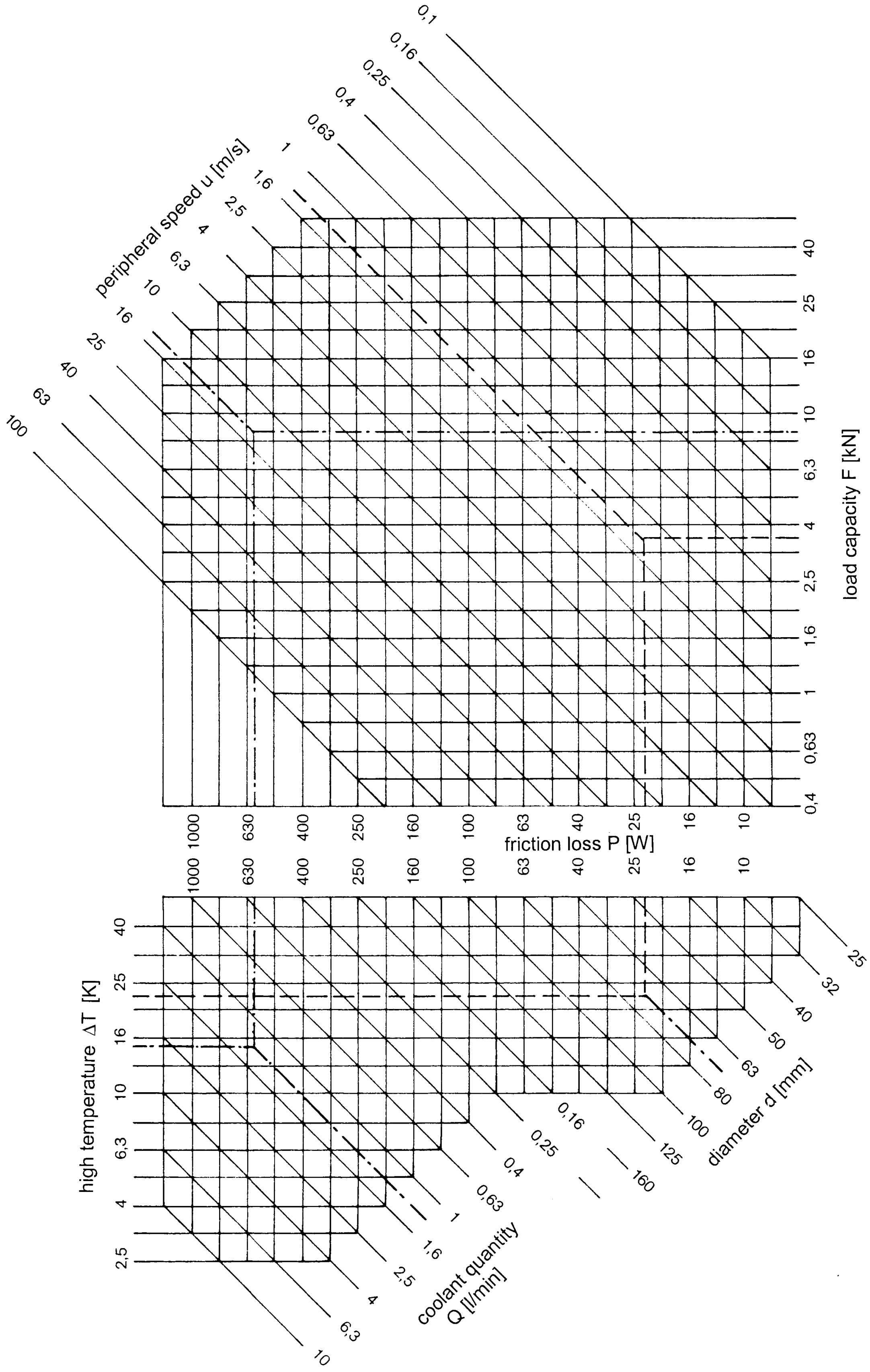
4.5. Calculation examples

Reading	description	code	dimensions	bearing case 1 heat emission at the bearing surface	 case 2 heat emission through the coolant
Nomogram I and II	diameter (spindle)	d	mm	70	90
	load capacity	F	kN	3,6	8,7
	revolutions per minute	n	1/min	355	2760
	peripheral speed	u	m/s	1,3	13
	average surface pressure	$\bar{p}$	N/mm^2	3,6	5,6
	working viscosity	η	$mPa \cdot s$	34	5,4
	high temperature	ΔT	K	22	15
	friction loss	P	W	22	590
	coolant quantity	Q	l/min	-	1,25
N'gr. III	working temperature	T	℃	42	35
	kinematical viscosity	υ	mm^2/s	134 at 20℃	10 at 20℃
N'gr. IV	bearing play standard value	S	µm	18,5	17

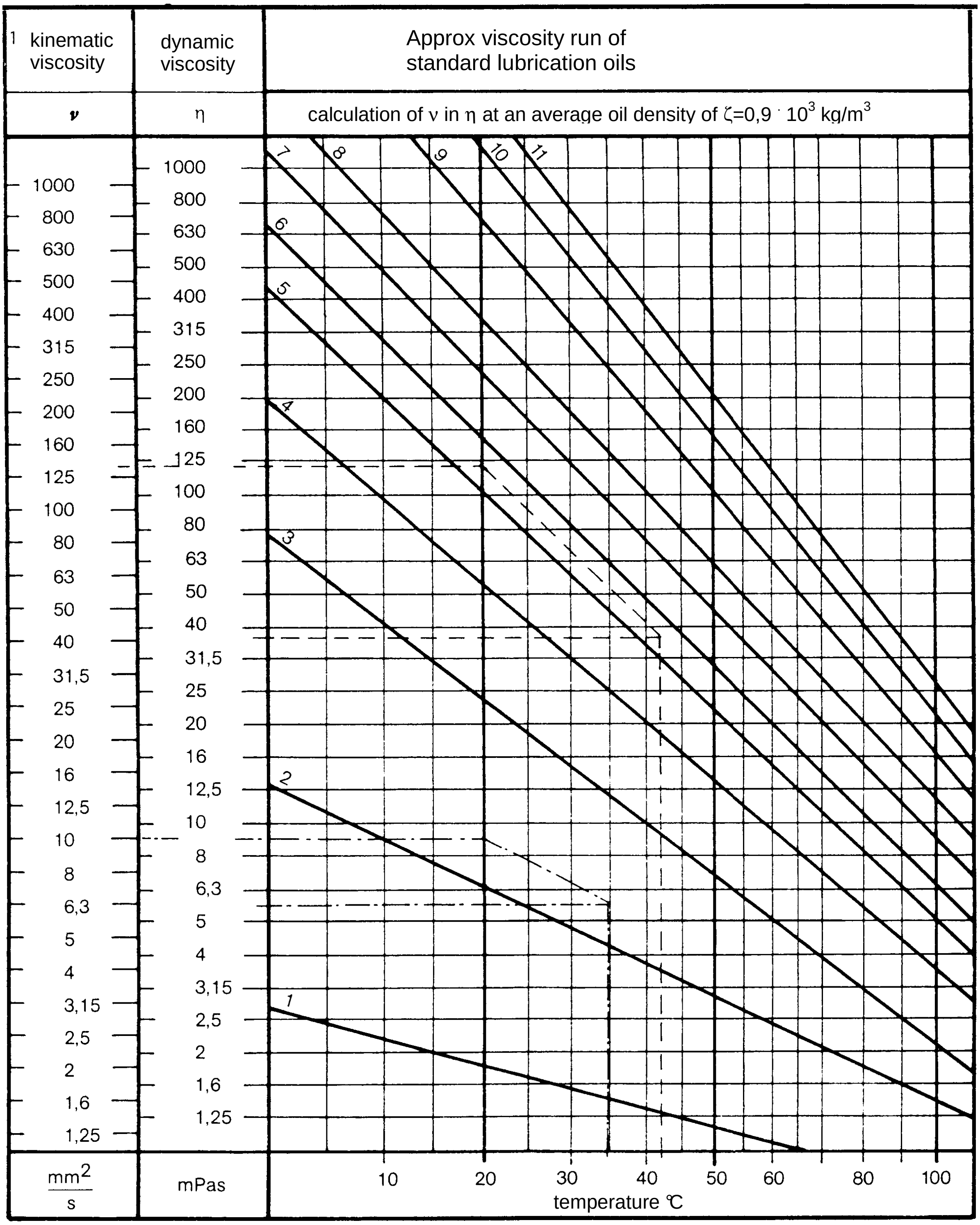
4.1.1. Nomogram I



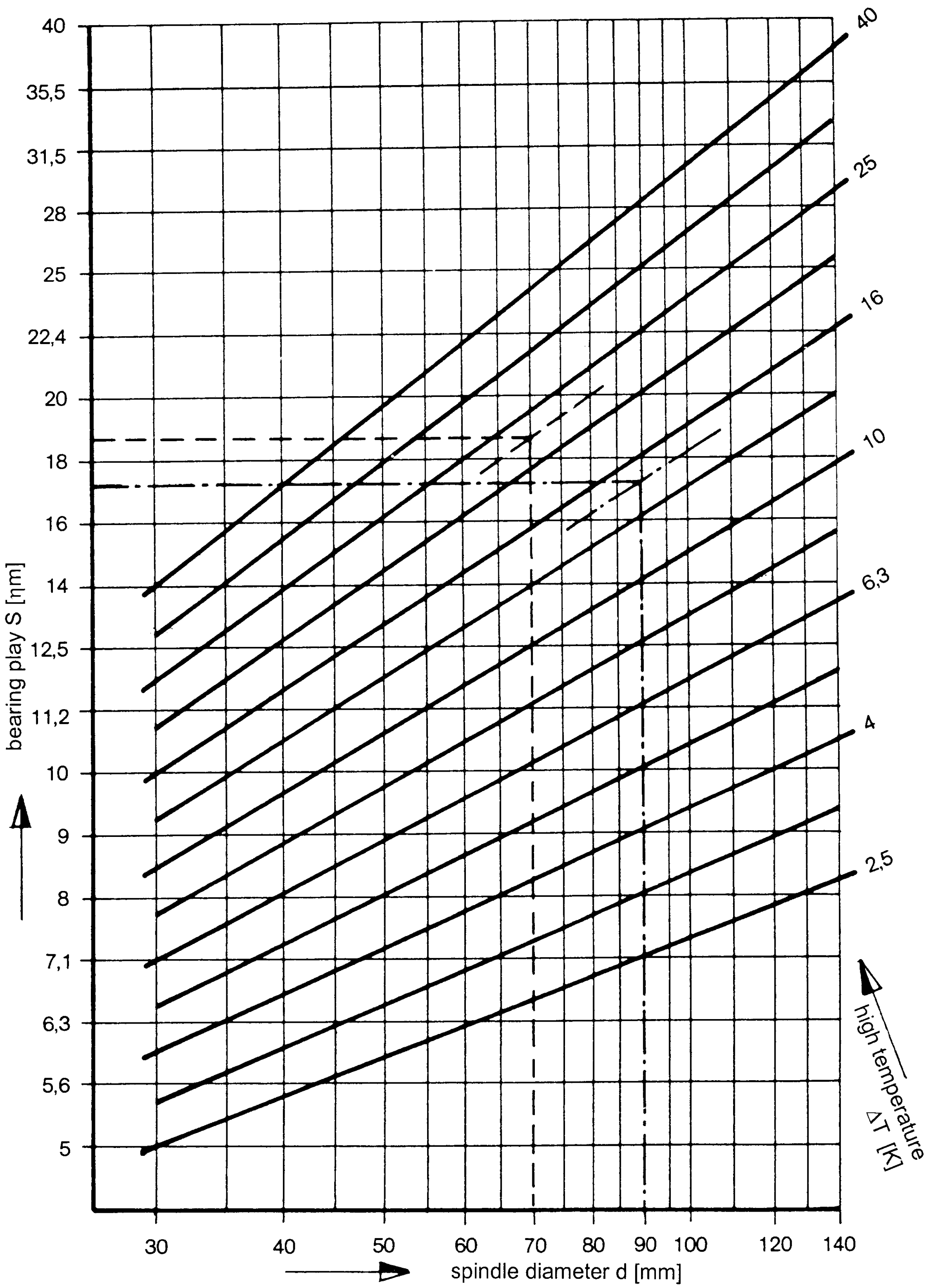
4.2.1. Nomogram II



4.3.1. Nomogram III



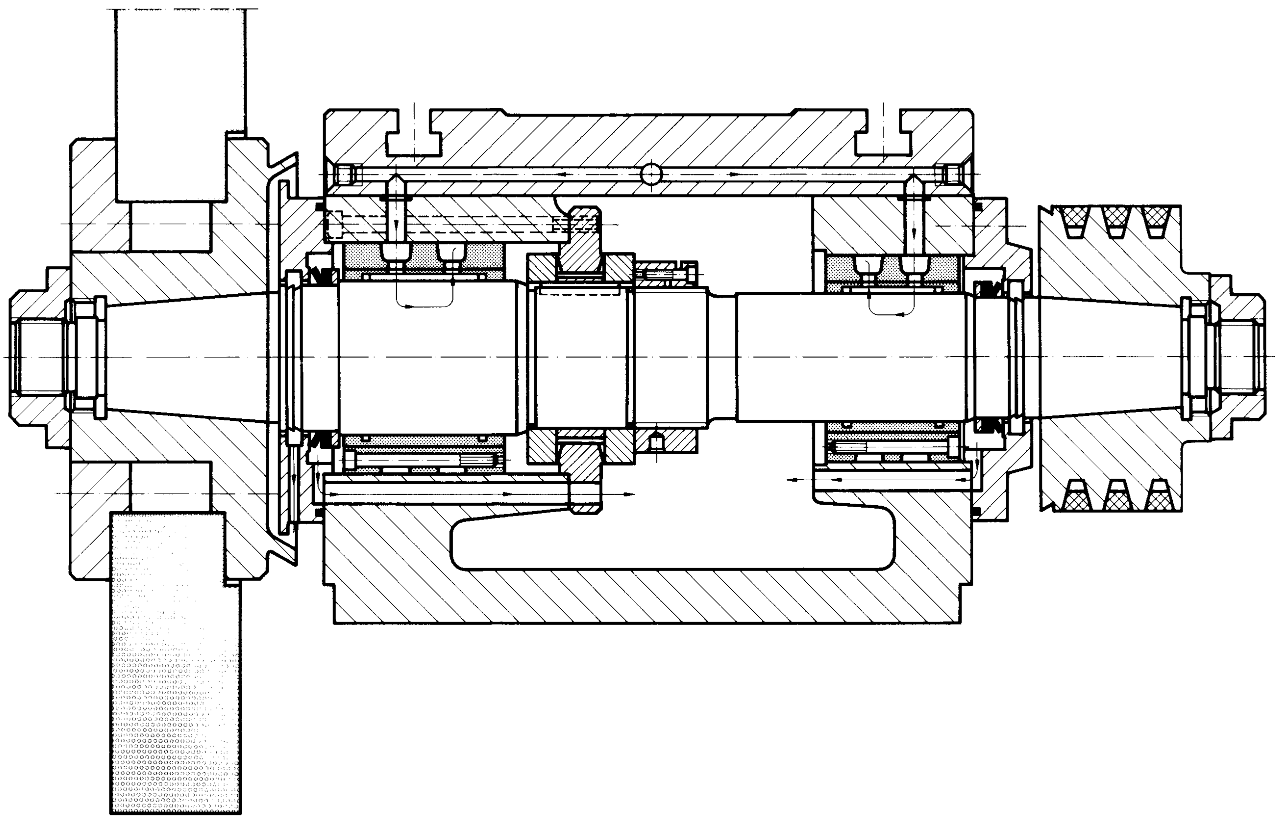
4.4.1. Nomogram IV



4.6. Legend

F	=	load capacity
η	=	dynamic viscosity at working temperature
u	=	peripheral speed
d	=	diameter (shaft)
$\bar{p}$	=	average surface pressure
P	=	friction loss
Q	=	coolant quantity
ΔT	=	high temperature (difference between working- and coolant supply temperature)
T	=	working temperature
ν	=	kinematical viscosity
s	=	bearing play

5. Assembly example



Headstock with open housing

The adjustable hydrodynamic sectionalised radial slide bearings GLM are mounted directly in the bores of the headstock. The axial guiding is placed between the GLM, adjusted for correct play and tightened with a SPIETH-Locknut against the spindle accretion. V-rings are used for sealing against oil loss.

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