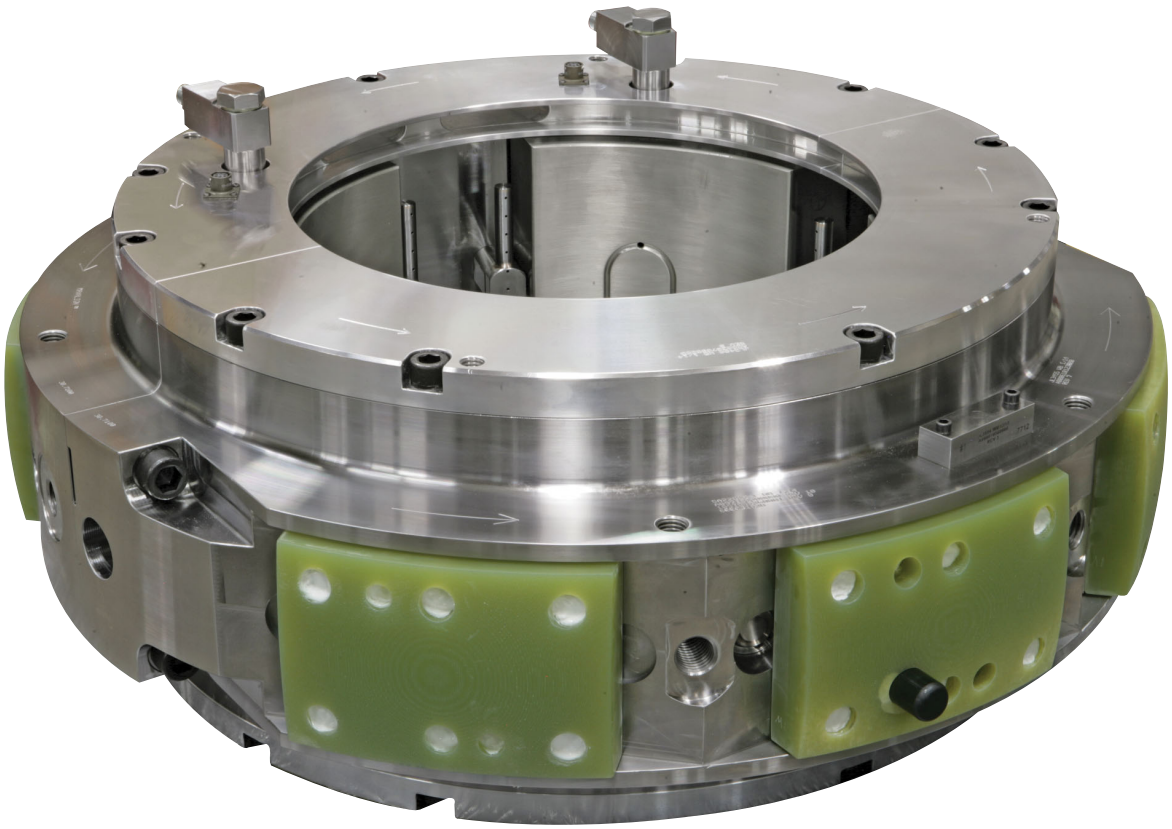
WAUKESHA BEARINGS

Tilting Pad Radial Bearings

DHB10 METRIC RANGE

DOVER PRECISION COMPONENTS

Contents



TFB series bearing featuring electrical insulation, hydrostatic jacking and 'Directed Lubrication'

Benefits

BENEFITS OF WAUKESHA BEARINGS®

- The strength of a worldwide bearing group
- Unique material options provide the widest range of hydrodynamic bearing solutions
- Engineered designs that can be customised for specific needs
- Complete design responsibility
- Full technical support – including rotordynamic analysis
- Quality assurance – ISO 9001:2015 certified quality management system
- Expertise in hydrodynamic and magnetic bearing systems
- Optimised sealing solutions for machines and bearings
- Advanced test rig validation and support

BENEFITS OF TILTING PAD RADIAL BEARINGS

- Hydrodynamically stable at high speed
- Less sensitive to load direction
- Less sensitive to shaft misalignment
- Oil flow can be minimised
- Able to use standard components
- Spares consist of pads only

BENEFITS OF WAUKESHA TILTING PAD RADIAL BEARINGS

- Simple design – no seals required
- Optimised lubrication for minimum power loss and bearing temperature
- Alignment capability to suit all requirements
- Compact designs of combined axial/radial bearings
- Provision of static and dynamic performance data as standard
- Contract drawings provided for every application

Rotordynamic Studies

Waukesha Bearings can undertake full rotating machine studies, including unbalance response analysis, undamped and damped lateral critical speed analysis, torsional critical speed analysis, eigenvalue analysis (mode shapes), stability analysis (level I and II), bearing and seal optimization, ISFD optimization and brush seal contact-induced stability and unbalance analysis. Rotordynamic analysis is carried out to meet American Petroleum Institute (API) and International Organization for Standardization (ISO) standards.

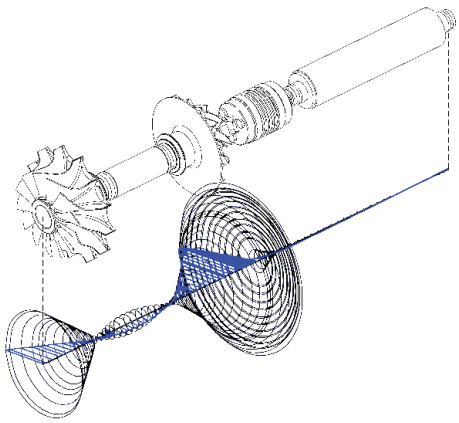


Image used by permission of Turbomachinery and Energy Systems Research Group, City University of London

General Description

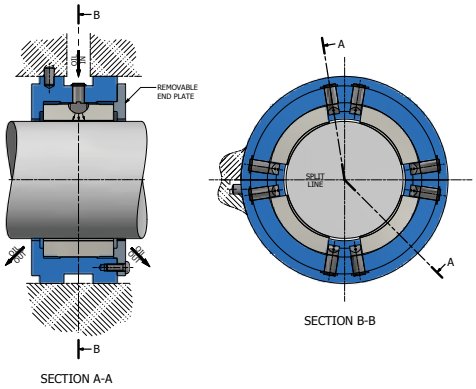


Fig 1(a) TF series bearing arrangement

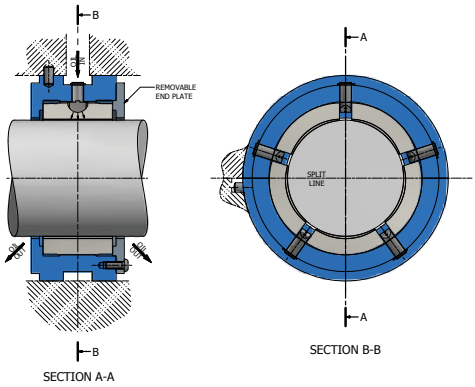


Fig 1(b) TJ series bearing arrangement

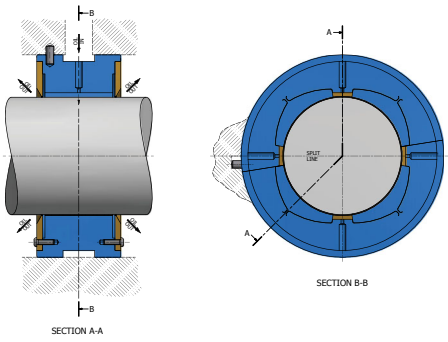


Fig 2 FP series bearing arrangement

Waukesha Tilting Pad Radial Bearings are designed to transfer radial loads from rotating shafts with minimum power loss and optimum dynamic characteristics. They are available in four main ranges:

- **TF series** – 4 pad bearings for shaft sizes 20 to 300 mm
- **TJ series** – 5 pad bearings for shaft sizes 20 to 300 mm
- **FP series** – Flexure Pivot® bearings for shaft sizes 20 to 300 mm
- **Large range (TFB & TJB series)** – 4 or 5 pad bearings for shaft sizes from 300 mm upwards

The TF (4 pad) and TJ (5 pad) series are designed on similar principles and have identical outside dimensions. The large range has some different design features which are described separately below. The dimensions of these ranges are given in the Size Tables starting on Pg. 24.

TF & TJ SERIES BEARINGS

Waukesha Tilting Pad Radial Bearings in these series consist of 4 or 5 pads located both circumferentially and radially by stop pins, and axially by end plates. See Fig 1(a) and (b). The stop pins as well as locating the pads also function as oil supply nozzles.

Standard pads are centre pivoted and are therefore suitable for either direction of rotation.

Bearings are available with one piece or split housings to comply with machine assembly requirements.

FLEXURE PIVOT® TILTING PAD BEARINGS FP SERIES

Flexure Pivot bearings achieve the same low cross-coupling and high stability associated with traditional tilting pad bearings through flexure and rotation of a central post. The design eliminates pivot wear, high contact stresses and pad flutter and is particularly suited to high-load, high-speed, small-diameter shafts.

The integral pad-pivot-retainer configuration has the added benefit of minimizing manufacturing tolerance stack-up and also allows for a low profile design, permitting upgrades of sleeve bearings with drop-in replacements that provide the performance benefits of tilting pad bearings.

Flexure Pivot bearings are typically supplied as a 4 pad design – see Fig 2 – but can also be supplied with 5 pads.

LARGE RANGE BEARINGS
TFB & TJB SERIES

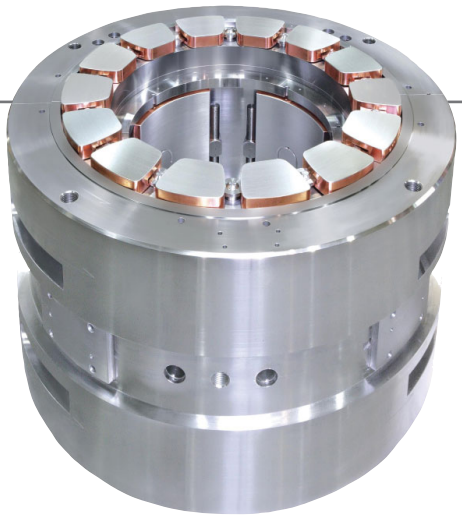
For larger shaft sizes it is usually necessary to consider improved forms of pad pivot design to ensure high stiffness combined with ability to tilt and align. Sealing requirements also can often be more onerous.

Waukesha Maxalign® bearings, also known as the TFB and TJB series, have been specially designed to meet these requirements, while reducing power loss. In particular the design features a ball and socket pivot which provides high stiffness and is highly adaptable to shaft misalignment caused by mechanical loading or thermal effects in large rotating equipment.

Patented trailing edge cooling, paired with the standard 'Directed Lubrication' (see Pg. 7), can lower Maxalign bearing temperatures to permit operating speeds in excess of 100 m/s and loads above 3 MPa, without compromising bearing life or safety margin.

Dimensions given in Table 4 (see Pg. 28) are for b/d = 0.7 bearings; other b/d ratios can be supplied if required.

Note that the various optional features available with the TF and TJ series are also available in the Large Range.



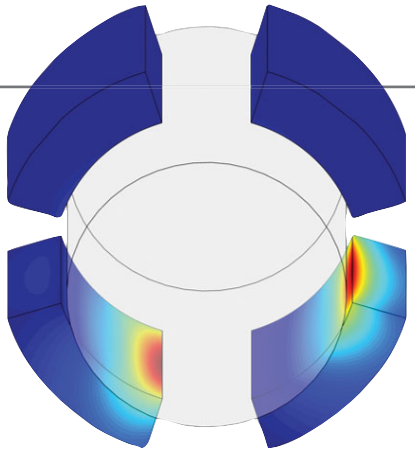
TFB610-427/0D Maxalign bearing featuring 'Directed Lubrication' and hydrostatic jacking

The Maxalign ball and socket pivot combines high stiffness and good alignment capability

Trailing edge cooling, 'Directed Lubrication' and hydrostatic jacking

Using proprietary Thermal-Elasto-Hydro-Dynamic (TEHD) models, verified by testing and decades of experience, Waukesha Bearings is able to accurately predict bearing performance.

Our models utilise advanced techniques, including a coupled thermal analysis of the fluid film and pad domain plus 3D structural analysis, that permit a comprehensive study of the bearing behavior considering physical properties of the pad lining and backing material.

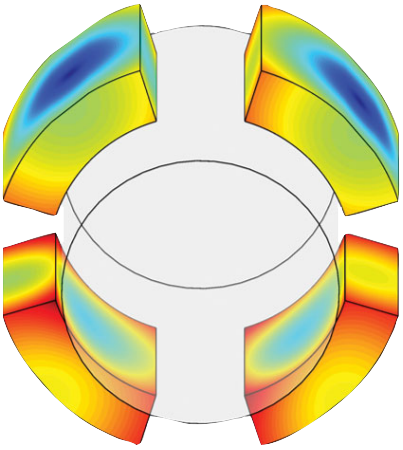


3D temperature distribution of the pads

MATERIALS

Standard pads are steel backed, lined with tin-based whitemetal (babbitt) to specification ISO SnSb8Cu4. Equivalent specification ASTM B23 Grade 2.

The housings and endplates are steel for the standard bearing arrangement. Floating seals when used are normally manufactured in lead bronze and knife edge end plates in aluminium alloy.



3D deformation of the pads

PRESET

Standard pads are supplied with positive preset (or preload) ratio in the range 0.35-0.55 when used with shaft diameters as recommended on Pg. 23.
The definition of preset ratio is shown in Fig 3.

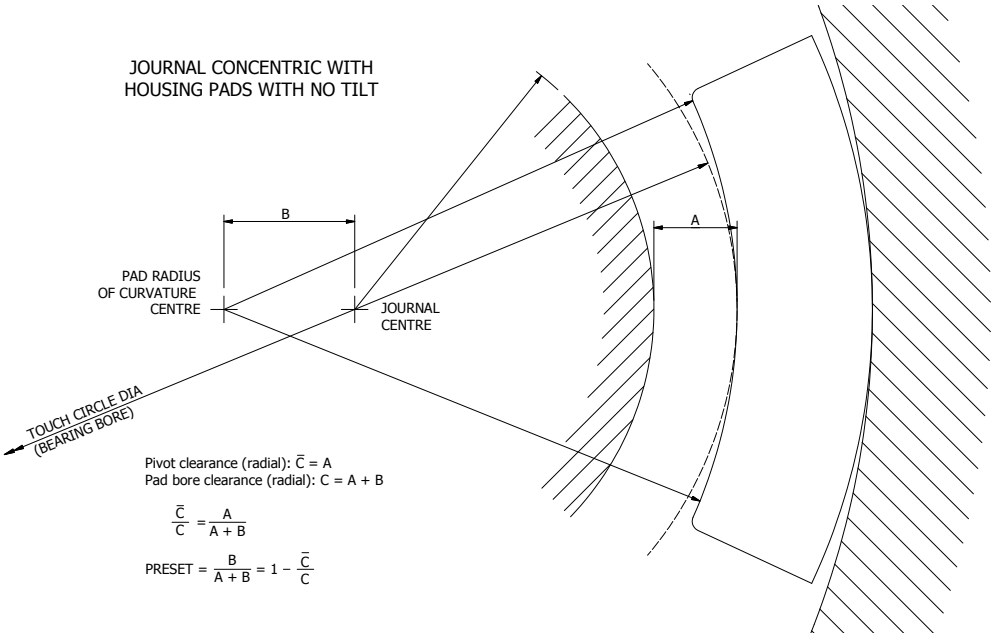


Fig 3 Definition of clearance terms (preset ratio)

Lubrication Systems and Sealing

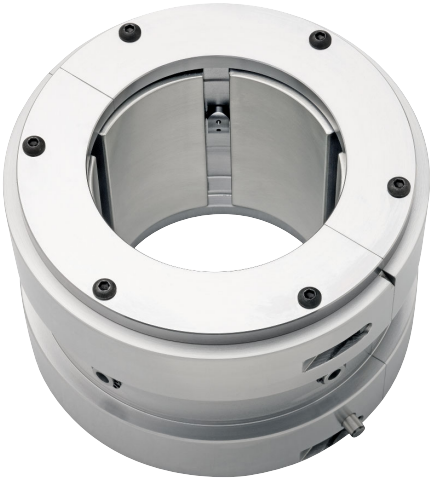
The standard Waukesha Tilting Pad Radial Bearing has the oil flow controlled by 'Directed Lubrication' nozzles between each pad with the oil exits from each end of the bearing being largely free; only large clearance baffles are provided. This arrangement minimises power loss and oil flow while keeping pad temperatures low.

While the standard system described above is ideal for the bearing itself, the machine location in which it is installed sometimes requires restriction of the end flow from the bearing, either at one or both sides.

- Floating seals reduce the flow along the shaft to a minimum; if two floating seals are used, the main flow is directed through an orifice outlet usually at the bottom of the bearing. Details of the Waukesha range of floating seals are available on request.
- Knife edge endplates, while less effective than floating seals, offer some control of end leakage.

The four most common combinations of seal/end plate are shown in Fig 4 with the identifying Style codes.

Oil supply pressure should be between 1 and 1.5 bar-g. This pressure should be available at the oil inlet annulus of the bearing; the bearing nozzles, orifices, etc., will be sized to give the correct flow at the specified supply pressure.



Small TJ050-035/2D bearing with 'Directed Lubrication' for high-speed gearbox application

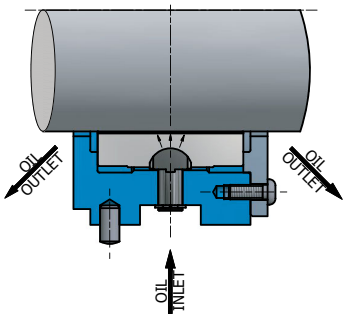


Fig 4(a) Standard

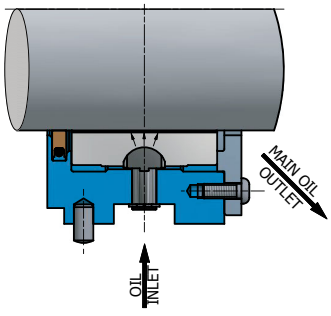


Fig 4(b) Style FL
(Minimized leakage at one end)

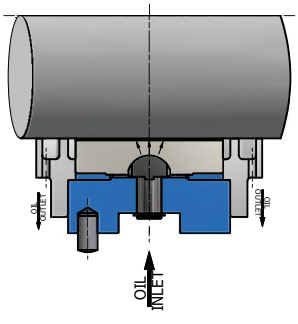


Fig 4(c) Style KN2
(Controlled leakage at both ends)

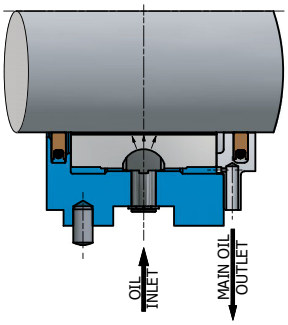


Fig 4(d) Style FL2
(Minimized leakage at both ends)

Fig 4 End plate and seal options

Alternative Pad Materials and Design

Higher speeds, loads and operating temperatures of modern machines are increasingly taking bearing design beyond the limits of whitemetal. Heat soak at standstill can also be a problem.

TJ bearing with solid bronze journal pads, combined with polymer-lined thrust pads

PAD MATERIALS

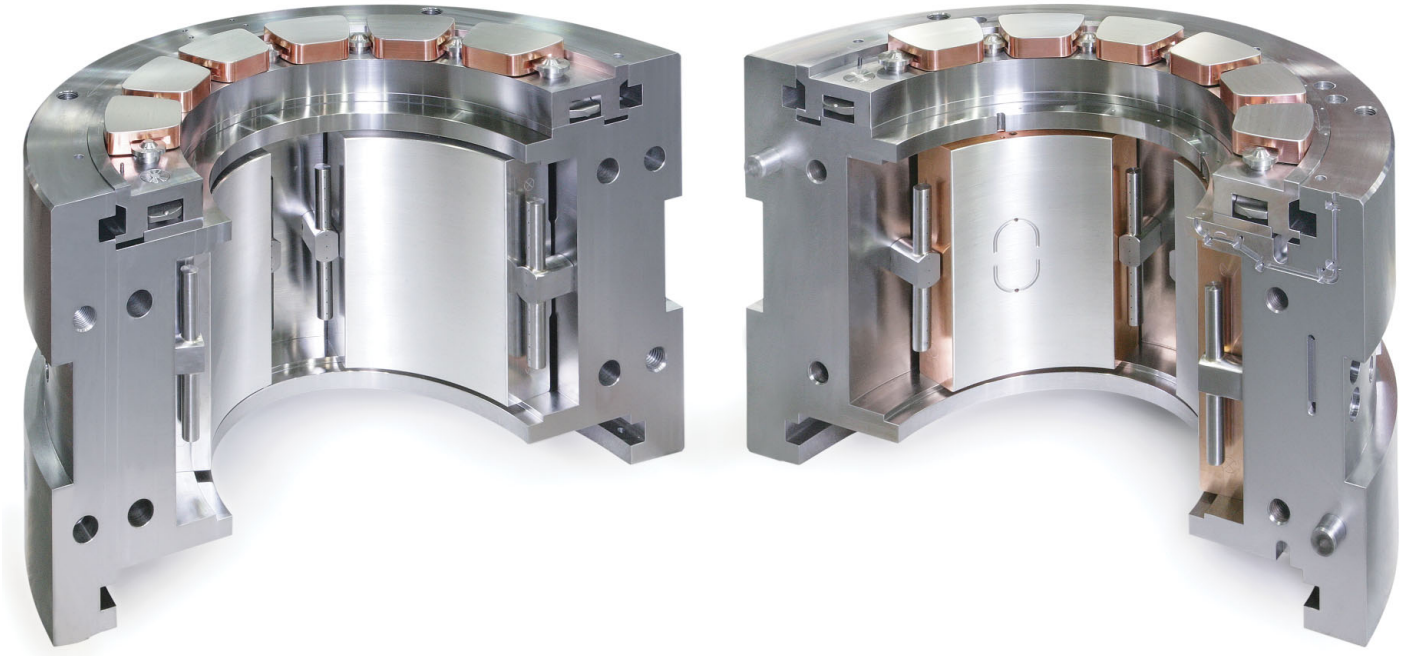
Waukesha can offer a wide choice of bearing materials where applications exceed the selection parameters indicated on Pg. 10 or lubricants other than oil are envisaged.

- RPB25P, an engineering polymer, offers outstanding potential for high ambient temperature applications and water lubrication, as well as being an electrical insulator and resistant to chemical attack. It can operate at temperatures up to 120°C higher than whitemetal.
- Copper chrome backed pads faced with whitemetal typically will reduce the pad surface temperature by 20°C at higher speeds.
- Solid bronze and steel backed pads faced with copper lead can operate at temperatures up to 40°C higher than whitemetal, but require a hardened shaft surface.
- Ceramic materials retain their load carrying capacity through extremely cold and hot environments, are compatible with thin films and low-viscosity lubricants, and are resistant to most chemicals. The hardness of ceramics will crush abrasive debris in the lubricant but also necessitates careful material selection for the shaft surface.

TJ bearing with polymer-faced pads for application with low viscosity lubricant

PIVOT POSITION

Centre pivoted pads are standard as they are preferred for bi-directional running, foolproof assembly and minimum spare stocks. At higher speeds (above 60 m/s) offset pivots can offer some bearing surface temperature reductions and the dynamic characteristics (stiffness and damping) may also be preferable for some applications; all bearings can be supplied if required with offset pivot pads (Style OP).



Maxalign bearing using a combination of standard whitemetal lined steel backed pads and whitemetal lined copper chrome backed journal pads with hydrostatic jacking; combined with copper chrome backed thrust pads

Bearing Selection

A preliminary selection of bearing size should be made using the Size Tables starting on Pg. 24, as follows:

1. Firstly for the shaft diameter required, refer to the b/d = 0.4 Size Table and check that the maximum load given is adequate.
2. If the load capacity is not adequate, refer to the b/d = 0.7 maximum loads and then, if necessary, the b/d = 1.0 loads for the required shaft size.
3. If the required load capacity is still inadequate, it will be necessary to consider using a larger diameter bearing.
4. Waukesha would normally propose 5 pad, TJ series, bearings; the characteristics of 4 pad, TF series, bearings or FP series bearings may be preferred for specific applications.

TJ bearing with 'Directed Lubrication' and a floating seal

LOAD CAPACITY

The load capacity of Tilting Pad Radial Bearings depends upon a number of different factors, principally shaft speed, lubricant viscosity and inlet temperature.

Within the speed ranges and for the oil conditions shown in Fig 5(a), 5(b) and 5(c), the load capacities given in the Size Tables can be used. At speeds above and below these ranges, the load capacity of the standard bearing will be reduced and advice should be obtained from Waukesha.

Other factors which need to be considered when assessing load capacity are:

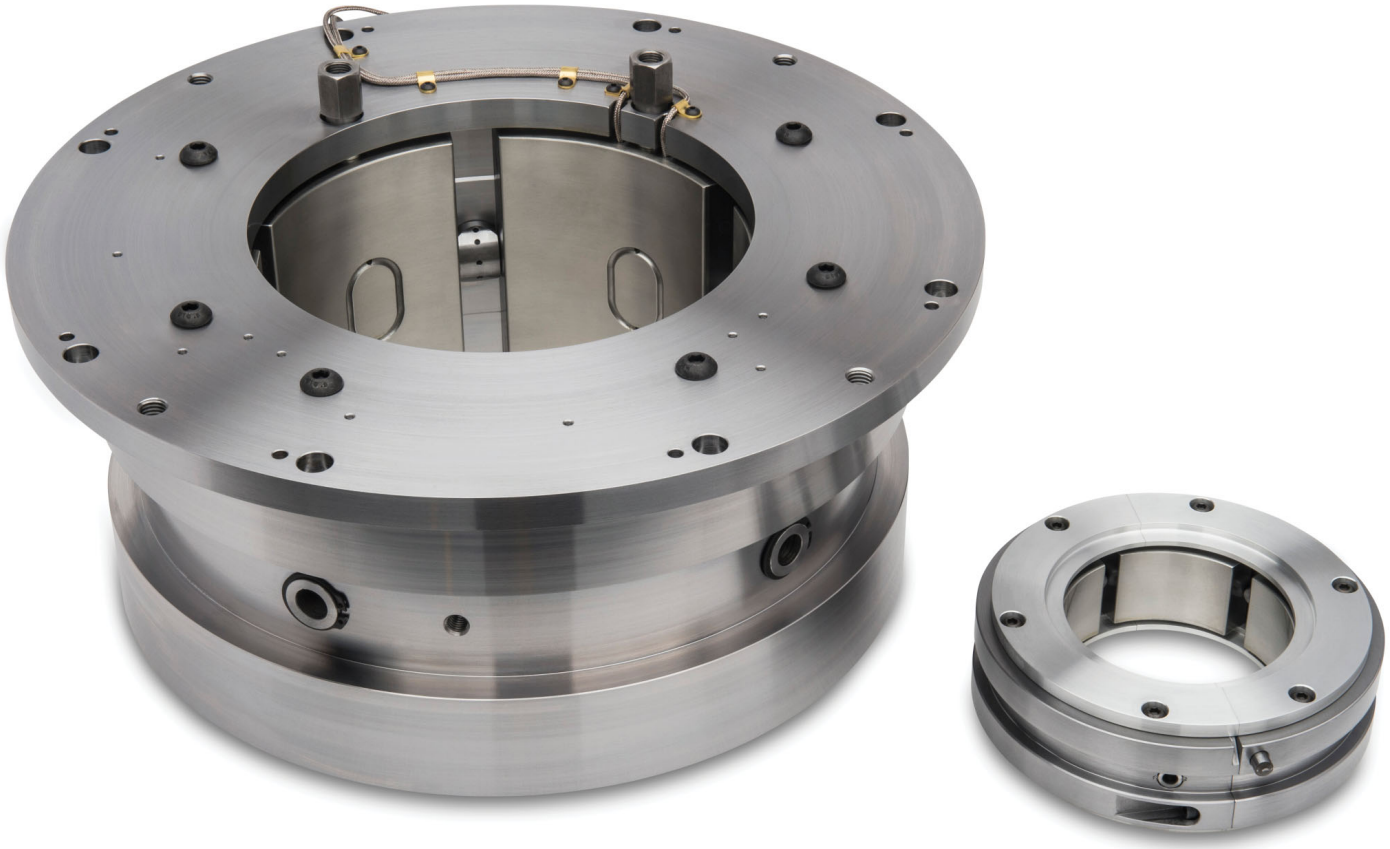
a. Direction of load – the load capacity of a tilting pad radial bearing is affected by the direction of the load relative to the pad positions. In the Size Tables the nominal load capacity is given for the two common orientations – 'load on pad' and 'load between pads'. Note that for maximum load capacity with a vertically downward load, bearings can be supplied with two pads at the bottom (Style BP) as shown in Fig 8 (see Pg. 15).

b. Load at instant of start – at this condition the specific load* for a TJ series bearing should not exceed 1.4 MPa for on pad loading or 2.2 MPa for between pad loading. For a TF series bearing the loading should not exceed 2.0 MPa for between pad loading. If these loads are exceeded the application may need either a larger bearing (to reduce the specific load) or the use of a hydrostatic ('jacking') system for use at starting and low speed: see Pg. 18 – Style J and Fig 12.

$$^{*}\text{Specific load (MPa)} = \frac{\text{Load (N)}}{\text{Pad width (mm) X shaft dia (mm)}}$$

POWER LOSS AND OIL FLOW

Power loss data for TJ series bearings is given in Fig 5(a), 5(b) and 5(c) for b/d = 0.4, 0.7 and 1.0 respectively. This is based on the oil conditions stated. Recommended oil flows are given for a 20°C temperature rise through the bearing.



TJ220-154/0D and TJ100-042/2D bearings

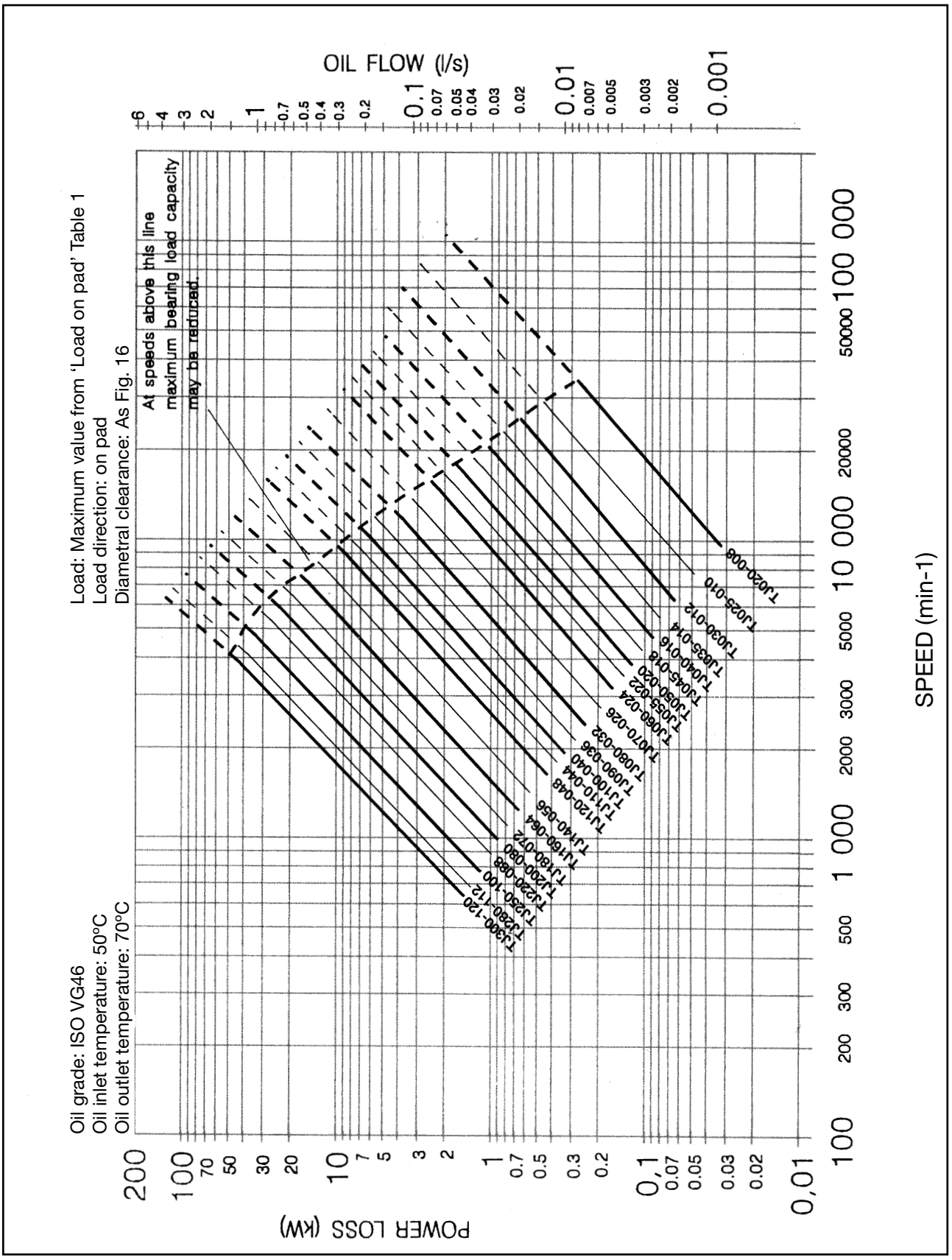


Fig 5(a) Power loss and oil flow – TJ series, b/d = 0.4

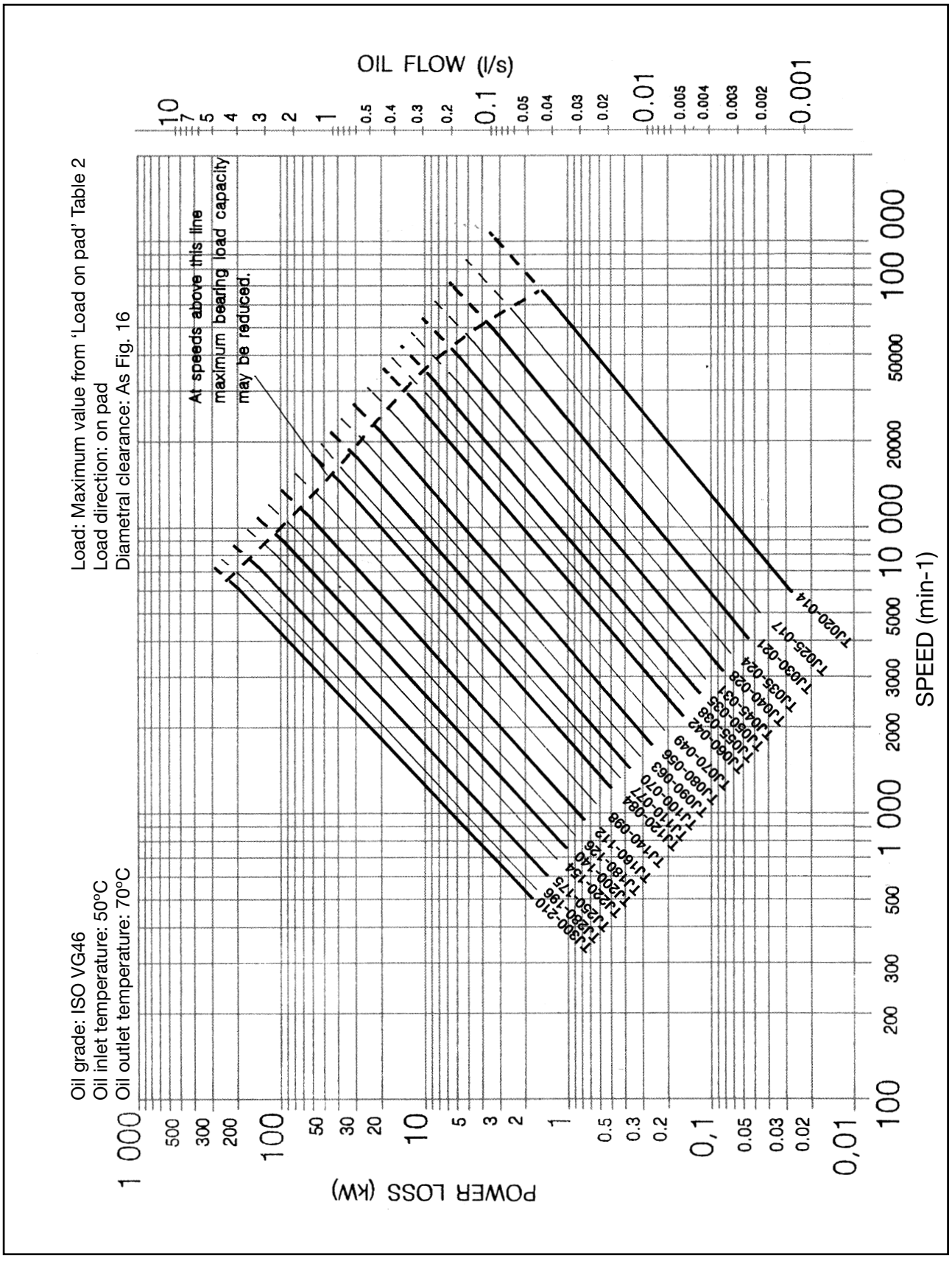


Fig 5(b) Power loss and oil flow – TJ series, b/d = 0.7

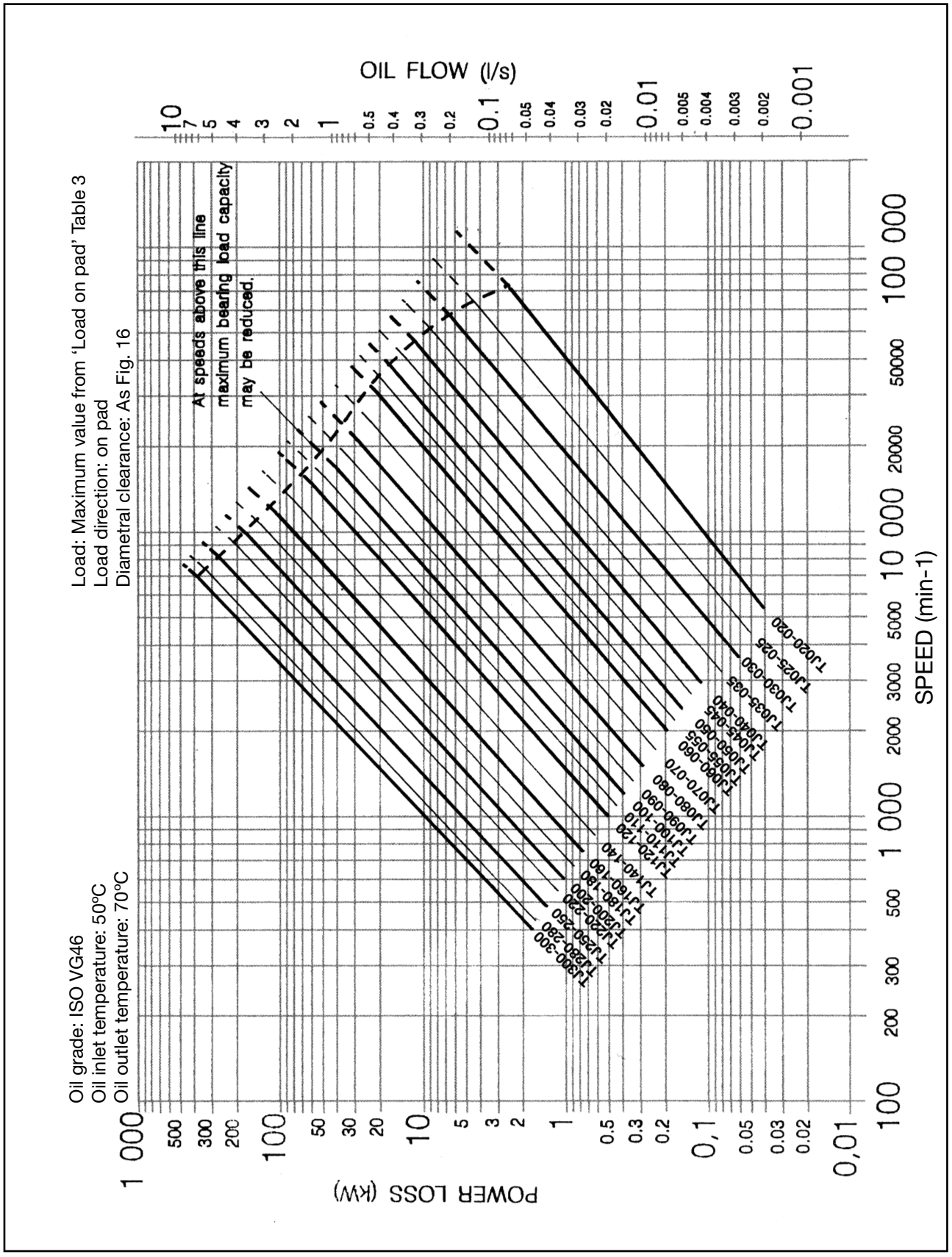


Fig 5(c) Power loss and oil flow – TJ series, b/d = 1.0

Optional Features

Standard bearings are available with a number of optional features identified by Style Codes as follows.

AXIAL ALIGNMENT
STYLE AA

Standard Waukesha pads have a line pivot over half the pad length. While this offers significant ability to deal with misalignment, in some cases increased ability to deal with misalignment is required and Style AA can be used. Style AA – see Fig 6 – includes a large axial radius on the pad pivot that mates with a straight seat in the bearing housing to permit self-alignment. The pad pivot and bearing housing are hardened to accommodate the load in the contact area. Bearing housing dimensions are the same as those for standard line contact pads.

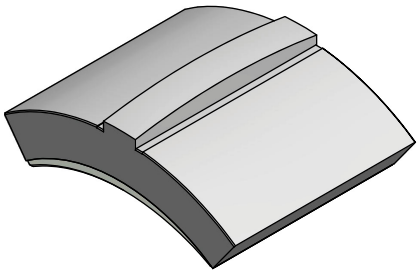


Fig 6 Axial alignment pivot – Style AA

ADJUSTABLE PIVOTS
STYLE AP

In some cases, especially on prototype units, it is desirable to have the ability to alter the bearing clearance: this can be achieved within standard dimensions by having pads with adjustable pivots – see Fig 7.

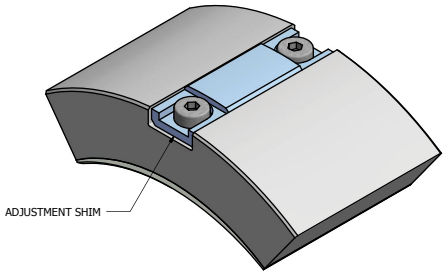


Fig 7 Adjustable pad pivot – Style AP

PAD ARC LENGTH
STYLE AR

Four pad bearings (TF series) and 5 pad bearings (TJ series) are normally supplied with 60° arc pads. Series TF bearings can also be supplied with 75° arc pads by specifying Style AR75.

TWO PAD ORIENTATION
STYLE BP

This style – see Fig 8 – may be required either for maximum load capacity with a vertically downward load (see Pg. 10) and/or for its particular stiffness and damping characteristics.

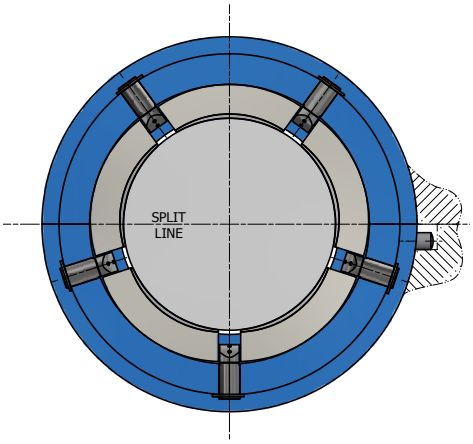


Fig 8 Two-pad orientation – Style BP

INTEGRAL SQUEEZE FILM DAMPER
STYLE D

The patented ISFD® design – see Fig 9 – is a leading solution for the control of vibration. Highly engineered damping and stiffness are used to shift critical speeds and increase the dynamic stability of the rotor/bearing system.

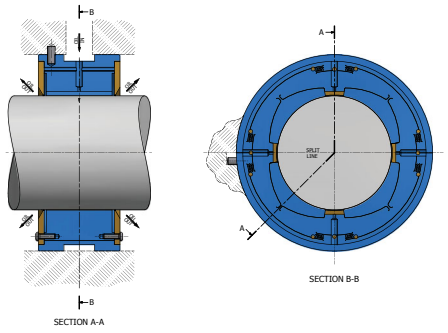


Fig 9 Integral squeeze film damper – Style D

FLOATING SEALS
STYLE FL

Where oil leakage along the shaft from one or both ends of the bearing must be kept to a minimum, floating seals are recommended – see Pg. 7.

TEMPERATURE SENSORS
STYLE IT1 & IT2

Bearings can be supplied either with provision for fitting temperature sensors (Style IT1) or already fitted with sensors of Waukesha supply (Style IT2).
A typical installation is shown in Fig 10.

Information required when specifying Style IT1 is:

- Sensor hole size required
- Number of sensor holes and in which pads (or Waukesha choice)
- Position in pad and at which end (or Waukesha choice)

When specifying Style IT2, information required is similar. In addition we need to know:

- Type of sensor – RTD or thermocouple, single or duplex
- Electrical characteristics – for example 2 or 3 wire circuit for RTDs, material pair for thermocouples
- Cable length and termination – for example whether a terminal head is required and if so what specification it must meet
- Alternatively, use the thermocouple or RTD specification codes on the next page

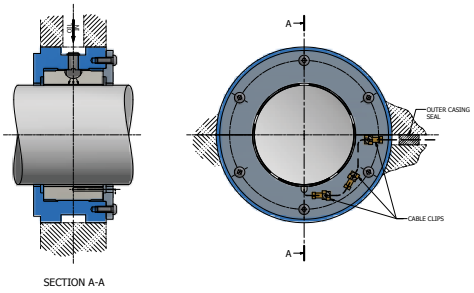
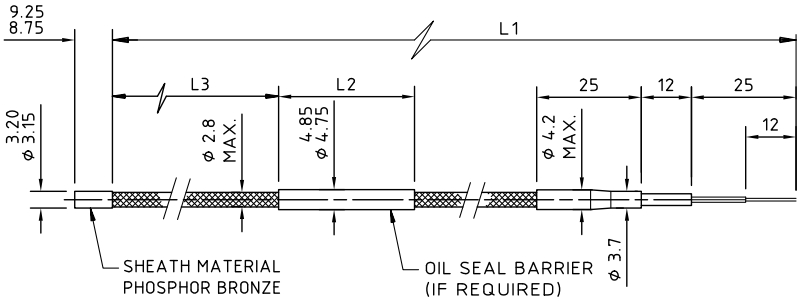
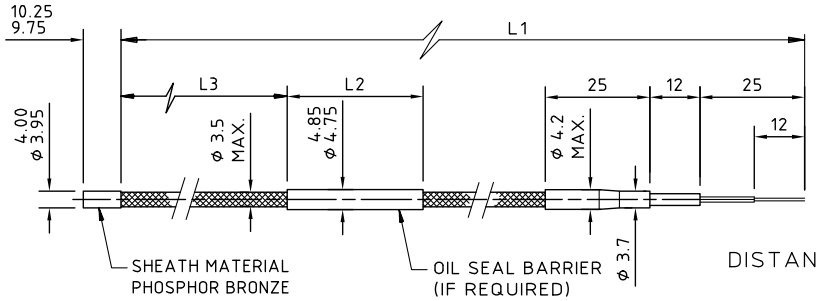


Fig 10 Temperature sensor installation — Style IT2

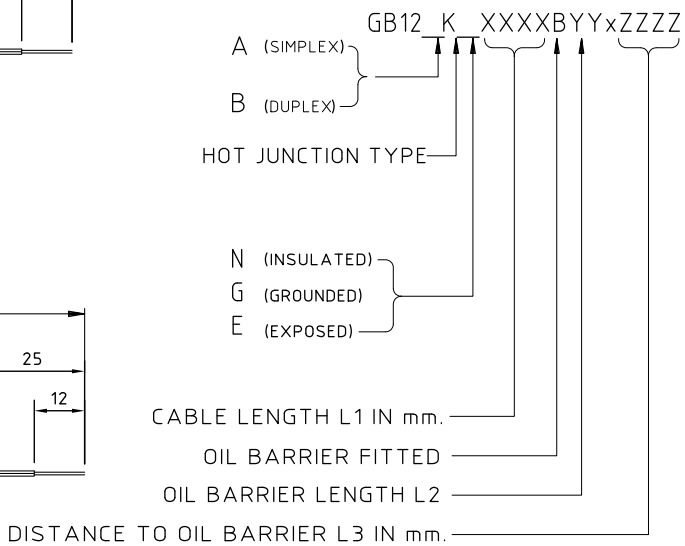
THERMOCOUPLE SPECIFICATION CODES



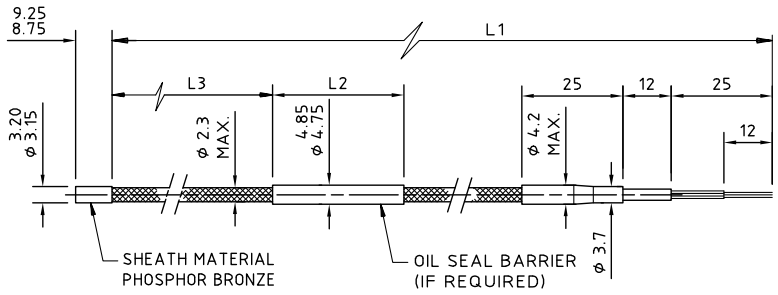
SIMPLEX THERMOCOUPLE GB12A



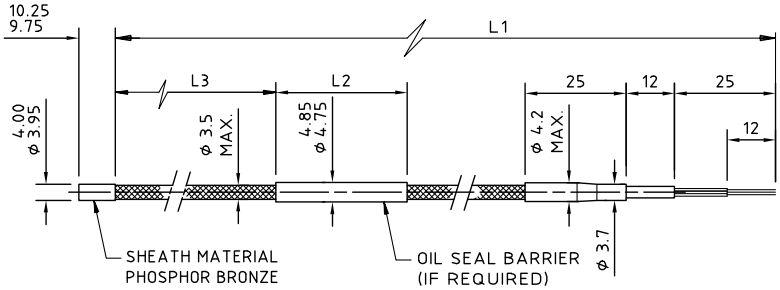
DUPLEX THERMOCOUPLE GB12B



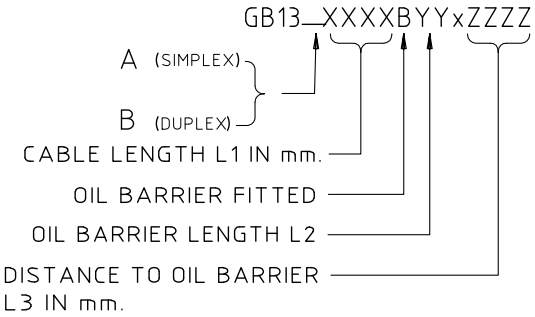
RTD SPECIFICATION CODES



SIMPLEX RESISTANCE TEMPERATURE DETECTOR GB13A



DUPLEX RESISTANCE TEMPERATURE DETECTOR GB13B



PROXIMITY PROBES
STYLE IR

Bearings can be supplied with provision for mounting proximity probes on the end plates – see Fig 11. Information required when specifying this option is:

- Sensor size – details of fastening required
- Number and position of probes

HYDROSTATIC JACKING
STYLE J

Bearings can be supplied with hydrostatic jacking in cases where there is a high load at the instant of start (see Pg. 10 – Load Capacity). Waukesha will specify the required oil supply quantity and pressure for the hydrostatic system when given the starting load conditions. See Fig 12 for a typical installation arrangement.

KNIFE-EDGE END PLATES
STYLE KN

Where some control of the oil leakage from one or both ends of the bearing is required, knife-edge end plates may be used — see Pg. 7.

OFFSET PIVOT PADS
STYLE OP

Offset pivot pads, instead of the standard centre pivot pads, can be supplied as outlined on Pg. 9.

TFB series bearing with hydrostatic jacking in two lower pads

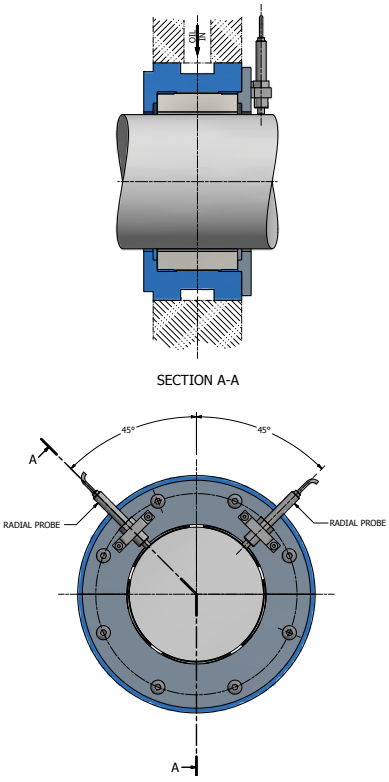


Fig 11 Proximity probe installation — Style IR

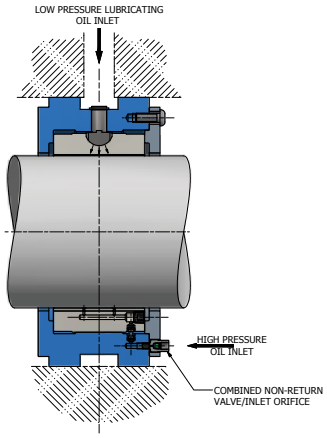


Fig 12 Hydrostatic jacking – Style J

AXIAL LOADS
STYLES TL & TP

Bearings can be supplied with either single or double axial faces to accommodate axial loads – see Figs 13 and 14 on the following pages.

The most compact arrangement is Style TL with either uni- or bi-directional taper land faces or plain grooved faces. Load capacities of these alternatives are given in Fig 13.

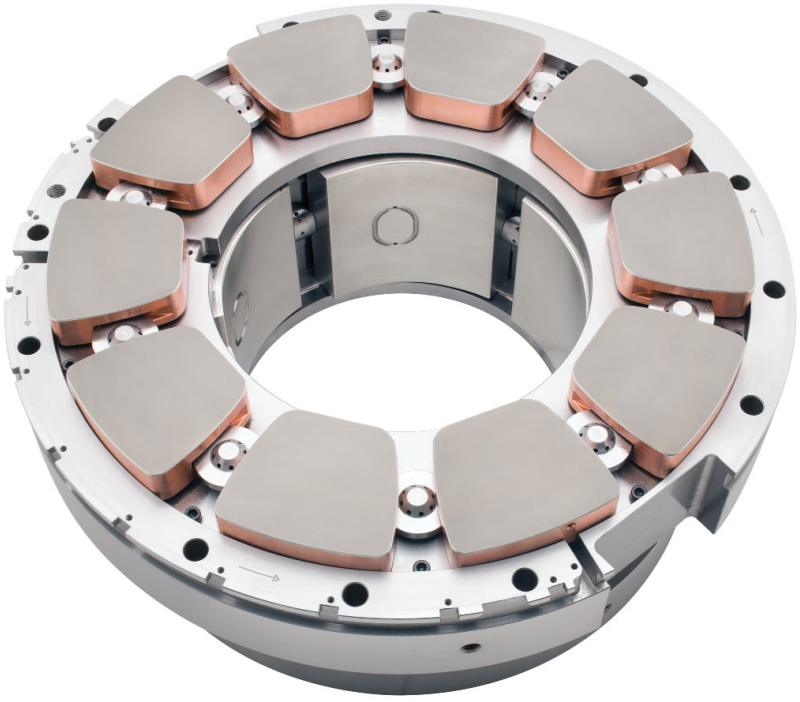
To specify these, the following Style Codes should be used:

- Style TLG – plain grooved face
- Style TLU – taper land face (uni-directional)
- Style TLB – taper land face (bi-directional)

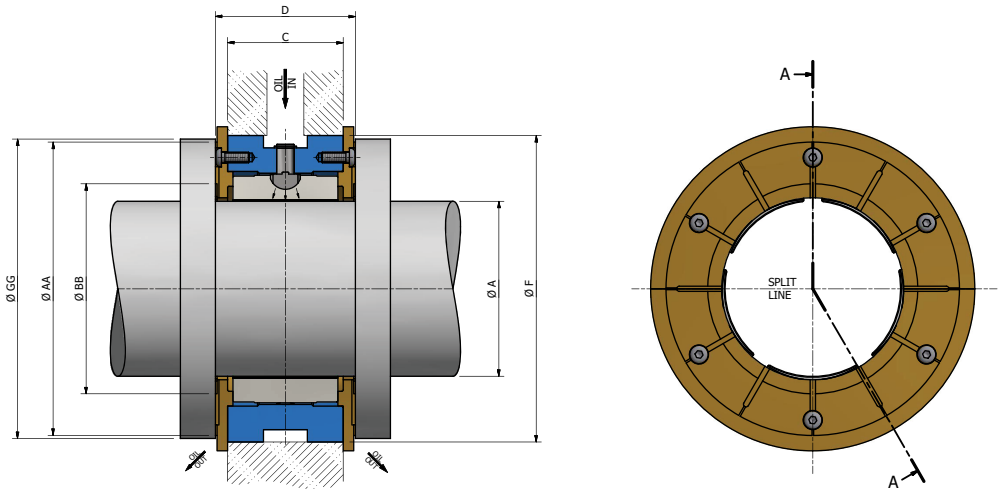
For higher axial loads Style TP should be used. Style TP incorporates tilting pad faces from the Waukesha MS range as described in Designers Handbook 5A. The unique system of 'Directed Lubrication' with centre pivot pads will normally be used for Style TP axial faces.

The codes TLG, TLU, TLB and TP specify a single axial face. If a double axial face is required, a 2 suffix should be added (i.e., TLG2, etc.).

If these features are required, the value of the axial load at the instant of start up as well as during running should be stated in the enquiry.



TJ250-140/0D bearing combined with high performance thrust bearing using copper chrome backed thrust pads



SECTION A-A

NOTE: STYLE TLG2 IS SHOWN.
STYLE TLU2 & TLB2 ASSEMBLIES
HAVE SAME EXTERNAL DIMENSIONS

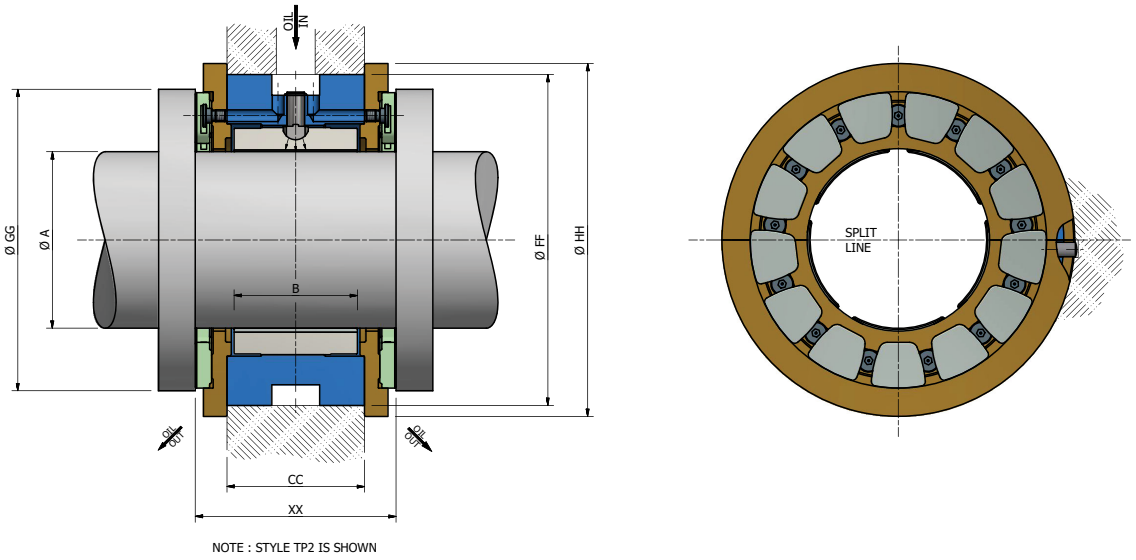
SIZES AND AXIAL LOAD CAPACITY FOR STYLE TL

(For single letter dimensions see main dimension tables – Pgs. 25-27.)

TILTING PAD RADIAL BRG SIZE		AXIAL FACE O. DIA	AXIAL FACE I. DIA	AXIAL COLLAR O. DIA	NOMINAL LOAD CAPACITY (N)		
					PLAIN GROOVED FACE	TAPERLAND FACE (SEE NOTE)	
		AA	BB	GG		UNIDIRECTIONAL	BIDIRECTIONAL
TF TJ	020	55	30	57	600	6100	3200
TF TJ	025	60	35	62	650	6800	3800
TF TJ	030	65	40	67	700	7300	4250
TF TJ	035	75	45	77	1000	10 100	5800
TF TJ	040	80	50	82	1100	10 500	6200
TF TJ	045	85	55	87	1200	11 000	6600
TF TJ	050	95	60	98	1500	14 500	8850
TF TJ	055	100	70	103	1400	12 400	7500
TF TJ	060	105	75	108	1500	12 700	7700
TF TJ	070	120	85	123	2000	16 600	10 200
TF TJ	080	130	95	133	2200	17 000	10 450
TF TJ	090	155	105	158	3500	33 300	20 000
TF TJ	100	165	120	168	3500	29 000	17 600
TF TJ	110	175	130	178	3800	29 300	17 800
TF TJ	120	190	140	193	4500	36 000	22 000
TF TJ	140	215	160	218	5700	43 000	26 200
TF TJ	160	245	185	248	7100	52 500	32 000
TF TJ	180	280	210	283	9400	71 500	43 900
TF TJ	200	305	230	309	11 000	80 000	49 000
TF TJ	220	325	250	329	11 900	80 000	49 000
TF TJ	250	370	285	374	15 300	102 500	62 200
TF TJ	280	410	320	415	18 000	113 000	69 000
TF TJ	300	430	340	435	19 000	113 000	69 200

Note: Load capacities for taper land faces are for preliminary guidance only; they are based on the high speed dotted line in Fig 5(a) with the same oil conditions.

Fig 13 Plain/taper land axial faces – Style TL (assemblies with low/medium axial load capacity)



NOTE : STYLE TP2 IS SHOWN

SIZES AND AXIAL LOAD CAPACITY FOR STYLE TP

(For single letter dimensions see main dimension tables – Pgs. 25-27.)

TILTING PAD RADIAL SIZE	TILTING PAD AXIAL BRG SIZE (SEE NOTE)	HOUSING WIDTH			HOUSING O. DIA	COLLAR O. DIA	FLANGE O. DIA	AXIAL LENGTH			MAXIMUM LOAD CAPACITY (N) (SEE NOTE)
		b/d = 0.4	b/d = 0/7	b/d = 1.0				b/d = 0.4	b/d = 0/7	b/d = 1.0	
		CC			FF	GG	HH	XX			
TF TJ 040	M1347	26	33	55	82	79	90	48	55	67	3980
TF TJ 045	M1256	28	36	50	89	88	98	51	59	73	5860
TF TJ 050	M1356	31	40	55	95	94	104	54	63	78	6350
TF TJ 055	M1456	35	43	60	111	100	120	58	66	83	6816
TF TJ 060	M1367	35	47	65	120	113	130	61	73	91	9910
TF TJ 070	M1379	39	54	75	134	133	145	68	83	104	15 280
TF TJ 080	M1479	46	61	85	146	141	157	75	90	114	16 530
TF TJ 090	M1394	50	69	96	165	158	177	82	101	128	24 220
TF TJ 100	M13103	53	76	106	177	172	190	89	112	142	29 450
TF TJ 110	M13112	59	83	116	190	188	204	97	121	154	35 860
TF TJ 120	M13123	62	90	126	215	204	230	105	133	169	43 390
TF TJ 140	M13146	71	105	147	240	243	256	118	152	194	64 100
TF TJ 160	M14146	85	119	167	266	260	284	132	166	214	69 120
TF TJ 180	M12190	88	134	188	298	294	317	146	192	246	102 560
TF TJ 200	M14190	102	148	208	336	335	357	160	220	280	120 250
TF TJ 220	M14207	108	162	228	374	365	397	174	228	294	143 190
TF TJ 250	M14225	127	202	277	406	400	431	196	253	328	172 550
TF TJ 280	M13269	138	206	290	450	448	477	217	285	369	229 640
TF TJ 300	M14269	152	220	310	482	476	511	231	299	389	247 000

Note: Tilting pad axial bearings are from the MS range as described in Designers Handbook 5A; see bearing selection comments for restrictions in use of maximum load capacity.

Fig 14 Tilting pad axial faces – Style TP (assemblies with high axial load capacity)

Installation

METHODS OF LOCATION

Bearings are available with alternative methods of location – see Fig 15.

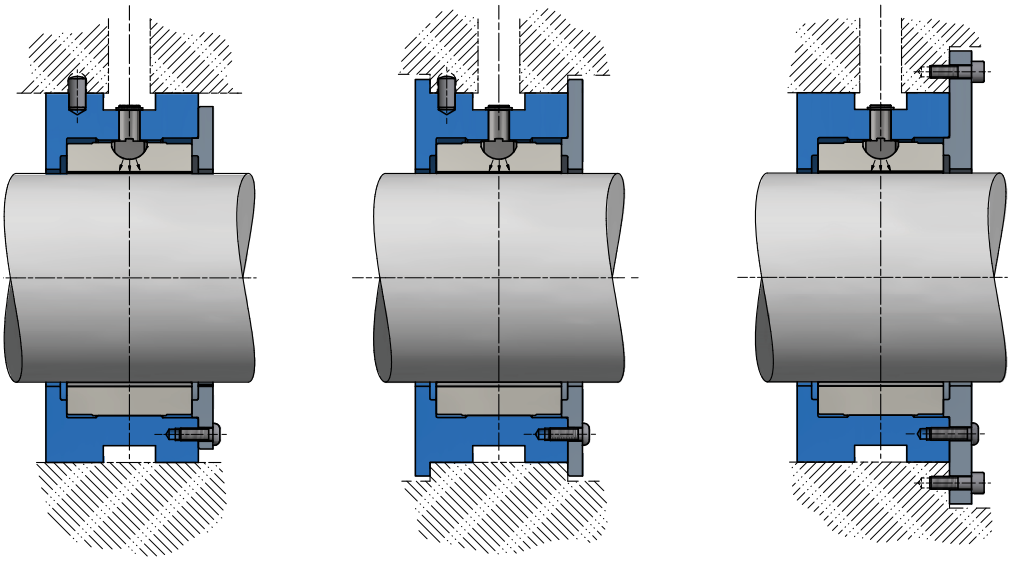


Fig 15 Alternative bearing location methods

DIAMETRAL CLEARANCE AND SHAFT DIAMETER

This range of Tilting Pad Radial Bearings is based on a standard bearing 'bore' for all operating conditions; the necessary change in diametral clearance for various shaft speeds is obtained by varying the shaft diameter. This enables standard pads for each size to be used which simplifies customer records and minimises inventory.

Waukesha's recommended minimum diametral clearance at the pivots for normal usage is shown in Fig 16. In some circumstances clearances obtained from this figure can be reduced, but it is recommended that Waukesha be consulted before reductions are made.

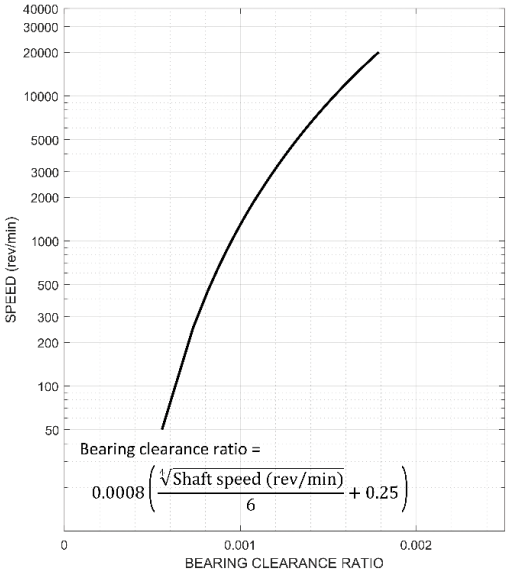


Fig 16 Minimum diametral clearance

$$\text{Bearing clearance ratio} = \frac{\text{Diametral clearance over pivots}}{\text{Nominal bearing bore}}$$

The example below will show how maximum/minimum figures can be established for both diametral clearance and shaft diameter when standard Waukesha Tilting Pad Radial Bearings are used.

EXAMPLE

It is desired to establish the clearances and shaft diameter for a TJ050-020/2DF which has to run at 17 385 rev/min maximum speed.

1. From Fig 16 bearing clearance ratio for 17 385 min-1 = 0.00173
   therefore minimum diametral clearance =
   0.00173 X 50 = 0.087 mm
2. From Fig 17 tolerance on diametral clearance for 50 = 0.051 mm
   therefore maximum diametral clearance =
   0.087 + 0.051 = 0.138 mm
3. Maximum shaft dia = nominal size – minimum dia clearance =
   50.000 – 0.087 = 49.913 mm
4. Tolerance on shaft dia from Fig 17 for 50 mm = 0.016 mm
   therefore minimum shaft dia =
   49.913 – 0.016 = 49.897 mm

Shaft surface finish varies with size. A typical figure is 0.4 micron Ra (approx. 16 microinch CLA) for a diameter of 100 mm. A hardened shaft is not usually required.

SHAFT DIAMETER		TOLERANCES (0.001mm)	
OVER	UP TO AND INCLUDING	DIAMETRAL CLEARANCE	SHAFT DIA (IT6)
20	30	41	13
30	40	47	16
40	50	51	16
50	55	54	19
55	80	57	19
80	90	60	22
90	120	63	22
120	140	68	25
140	180	72	25
180	220	79	29
220	250	83	29
250	300	90	32

Fig 17 Bearing and shaft tolerances

LOAD DIRECTION RELATIVE TO PADS

The load capacity of a Tilting Pad Radial Bearing is affected by the direction of the load as mentioned on Pg. 10. When the load vector falls on the centre of a pad, the maximum specific load recommended is approximately 2.1 MPa, and when it falls between the pads it is approximately 2.8 MPa. These values are used for the maximum loads given in the Size Tables starting on Pg. 24.

Size Tables

The tables on the following pages show the sizes of the bearings which have been selected as described on Pg. 10.

Table 1: b/d = 0.4 bearings TF, TJ and FP series 20-300 mm shaft dia

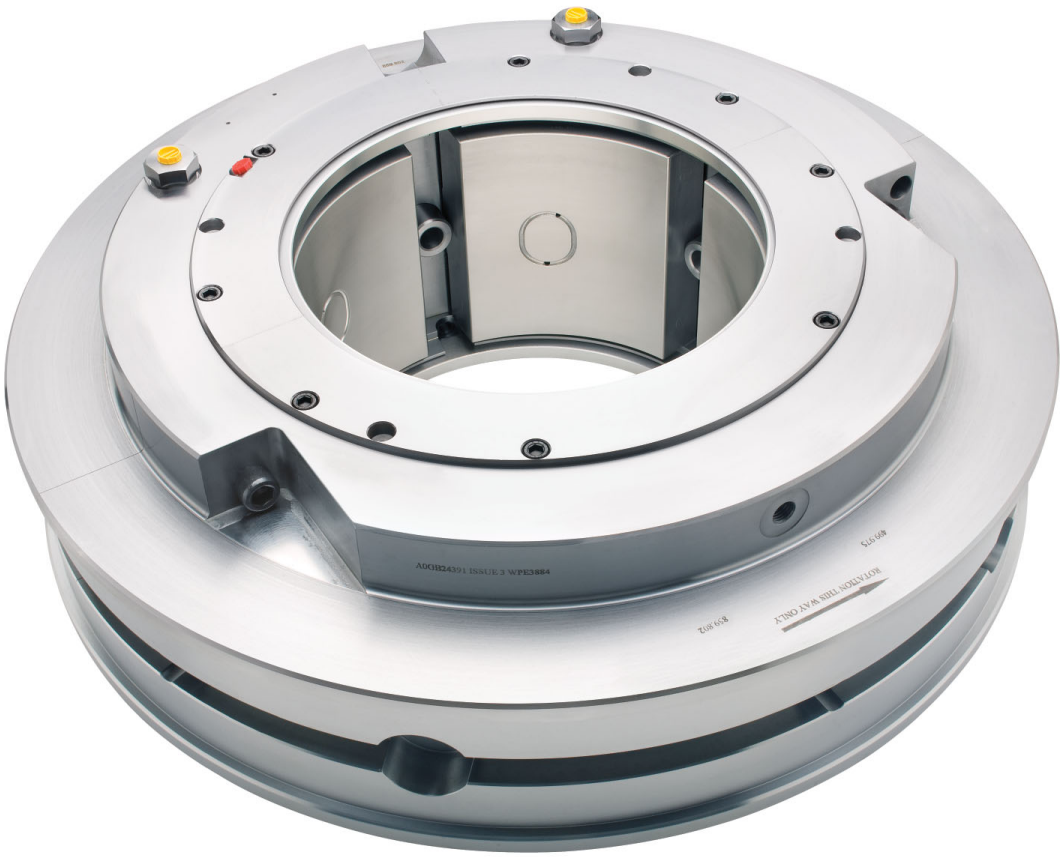
Table 2: b/d = 0.7 bearings TF, TJ and FP series 20-300 mm shaft dia

Table 3: b/d = 1.0 bearings TF, TJ and FP series 20-300 mm shaft dia

Table 4: b/d = 0.7 bearings TFB and TJB (Maxalign) series 300-700 mm shaft dia

When the sizes have been confirmed from these tables, refer to Pg. 29 which shows how the full size code is produced by adding suffixes.

All dimensions in these tables are in millimetres unless otherwise stated.



TJB series bearing with flooded lubrication for large turbo generator

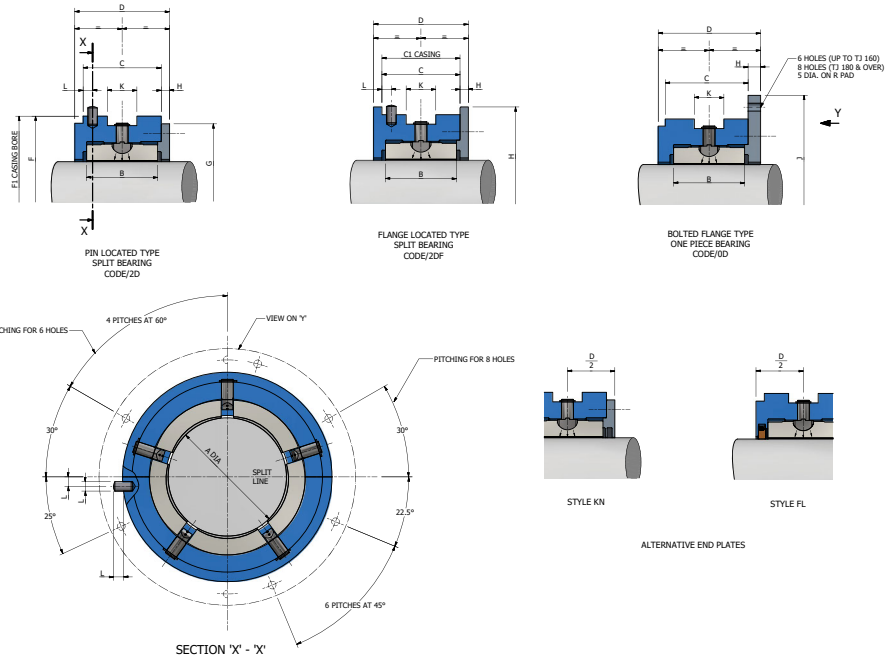


TABLE 1: b/d = 0.4

SIZE	NOM SHAFT DIA	PAD WIDTH		RECOMMENDED CASING	WIDTH		RECOMMENDED CASING BORE	DIA	DIA	DIA				PC DIA	DIA	MAXIMUM LOAD (N)		WEIGHT (KG)
	A	B	C	C1	D	F	F1 DIA*	G	H	J	K	L	M	R	S	LOAD ON PAD	LOAD BETWEEN PADS	
TF TJ 020-008	20	8	13	12.994 12.976	21	58	58.019 58.000	54	65	86	6	4	4	72	5.5	335	445	0.3
TF TJ 025-010	25	10	15	14.994 14.976	23	62	62.019 62.000	60	69	90	6	4	4	76	5.5	520	700	0.4
TF TJ 030-012	30	12	17	16.994 16.976	25	69	69.019 69.000	66	76	97	6	4	4	83	5.5	750	1000	0.5
TF TJ 035-014	35	14	19	18.993 18.972	27	76	76.019 76.000	72	80	100	6	4	4	86	5.5	1025	1370	0.7
TF TJ 040-016	40	16	21	20.993 20.972	31	82	82.022 82.000	78	90	110	6	4	5	96	5.5	1340	1790	0.8
TF TJ 045-018	45	18	23	22.993 22.972	33	89	89.022 89.000	85	98	117	6	4	5	103	5.5	1700	2270	0.9
TF TJ 050-020	50	20	25	24.993 24.972	35	95	95.022 95.000	92	104	127	7.5	4	5	111	6.6	2100	2800	1
TF TJ 055-022	55	22	27	26.993 26.972	37	111	111.022 111.000	100	120	143	7.5	5	5	127	6.6	2540	3390	1.6
TF TJ 060-024	60	24	29	28.993 28.972	39	120	120.022 120.000	106	130	152	9	5	5	136	6.6	3020	4030	2
TF TJ 070-028	70	28	33	32.991 32.966	45	130	130.025 130.000	118	141	162	11	5	6	146	6.6	4120	5490	2.6
TF TJ 080-032	80	32	37	36.991 36.966	49	139	139.025 139.000	130	150	171	11	6	6	155	6.6	5400	7170	3
TF TJ 090-036	90	36	42	41.991 41.966	56	165	165.025 165.000	152	177	197	14	6	7	181	6.6	6800	9070	5
TF TJ 100-040	100	40	46	45.991 45.966	60	177	177.025 177.000	164	190	217	14	8	7	197	9	8400	11 200	6
TF TJ 110-044	110	44	50	49.991 49.966	68	190	190.029 190.000	176	204	230	16	8	9	210	9	10 200	13 600	8
TF TJ 120-048	120	48	54	53.990 53.960	72	215	215.029 215.000	188	230	255	17	10	9	235	9	12 100	16 100	11
TF TJ 140-056	140	56	63	62.990 62.960	83	228	228.029 228.000	212	244	268	21	10	10	248	9	16 500	22 000	13
TF TJ 160-064	160	64	71	70.990 70.960	95	266	266.032 266.000	245	284	314	22	12	12	290	11	21 500	28 700	20
TF TJ 180-072	180	72	80	79.990 79.960	104	298	298.032 298.000	278	317	354	25	12	12	326	14	27 200	36 300	27
TF TJ 200-080	200	80	88	87.988 87.953	114	336	336.036 336.000	302	357	392	28	16	13	364	14	33 600	44 800	38
TF TJ 220-088	220	88	96	95.988 95.953	128	374	374.036 374.000	326	397	430	31	16	16	402	14	40 700	54 200	53
TF TJ 250-100	250	100	109	108.988 108.953	145	406	406.040 406.000	371	431	478	35	20	18	442	18	52 500	70 000	65
TF TJ 280-112	280	112	122	121.986 121.946	160	450	450.040 450.000	407	477	522	39	20	19	486	18	65 900	87 800	86
TF TJ 300-120	300	120	130	129.986 129.946	172	482	482.040 482.000	431	511	554	42	20	21	518	18	75 600	101 000	110

** Gives H6-h6 fit for /2D and /2DF bearings and H6-g6 fit for /OD bearings*

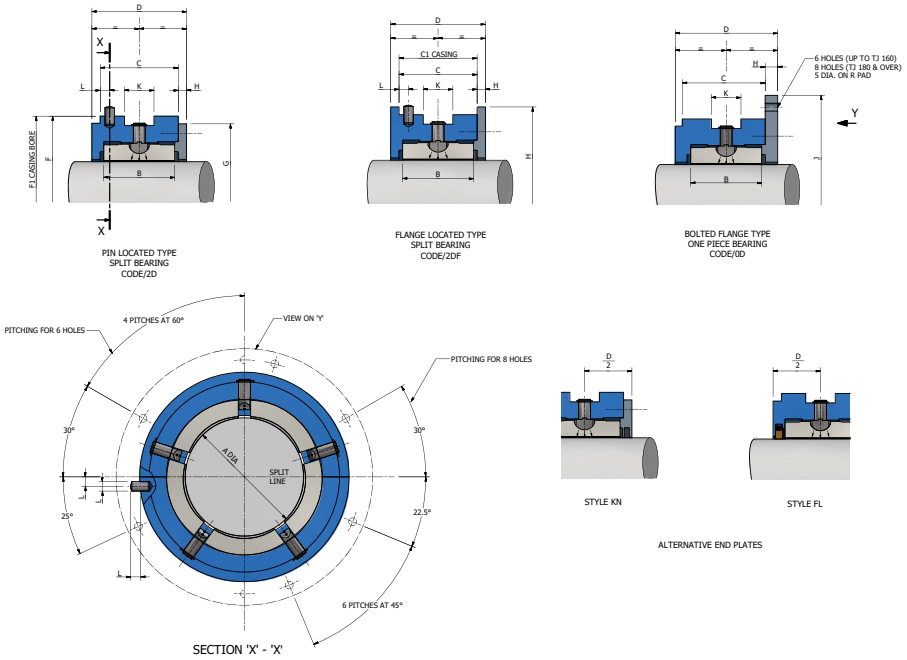


TABLE 2: b/d = 0.7

SIZE	NOM SHAFT DIA	PAD WIDTH		RECOMMENDED CASING	WIDTH		RECOMMENDED CASING BORE	DIA	DIA	DIA				PC DIA	DIA	MAXIMUM LOAD (N)		WEIGHT (KG)
	A	B	C	C1	D	F	F1 DIA*	G	H	J	K	L	M	R	S	LOAD ON PAD	LOAD BETWEEN PADS	
TF TJ 020-014	20	14	19	18.993 18.972	27	58	58.019 58.000	54	65	86	6	4	4	72	5.5	590	785	0.4
TF TJ 025-017	25	17	22	21.993 21.972	30	62	62.019 62.000	60	69	90	6	4	4	76	5.5	920	1225	0.5
TF TJ 030-021	30	21	26	25.993 25.972	34	69	69.019 69.000	66	76	97	8	4	4	83	5.5	1320	1760	0.7
TF TJ 035-024	35	24	29	28.993 28.972	37	76	76.019 76.000	72	80	100	9	4	4	86	5.5	1800	2400	0.9
TF TJ 040-028	40	28	33	32.991 32.966	43	82	82.022 82.000	78	90	110	10	4	5	96	5.5	2350	3140	1.2
TF TJ 045-031	45	31	36	35.991 35.966	46	89	89.022 89.000	85	98	117	11	4	5	103	5.5	3020	4030	1.4
TF TJ 050-035	50	35	40	39.991 39.966	50	95	95.022 95.000	92	104	127	12	4	5	111	6.6	3670	4900	1.6
TF TJ 055-038	55	38	43	42.991 42.966	53	111	111.022 111.000	100	120	143	13	5	5	127	6.6	4500	5930	2.4
TF TJ 060-042	60	42	47	46.991 46.066	57	120	120.022 120.000	106	130	152	15	5	5	136	6.6	5290	7060	3.3
TF TJ 070-049	70	49	54	53.990 53.960	66	130	130.025 130.000	118	141	162	17	5	6	146	6.6	7200	9600	4
TF TJ 080-056	80	56	61	60.990 60.960	73	139	139.025 139.000	130	150	171	20	6	6	155	6.6	9410	12 500	5
TF TJ 090-063	90	63	69	68.990 68.960	83	165	165.025 165.000	152	177	197	22	6	7	181	6.6	11 900	15 900	8
TF TJ 100-070	100	70	76	75.990 75.960	90	177	177.025 177.000	164	190	217	25	8	7	197	9	14 700	19 600	10
TF TJ 110-077	110	77	83	82.988 82.953	101	190	190.029 190.000	176	204	230	27	8	9	210	9	17 800	23 700	12
TF TJ 120-084	120	84	90	89.988 89.953	108	215	215.029 215.000	188	230	255	29	10	9	235	9	21 200	28 200	17
TF TJ 140-098	140	98	105	104.988 104.953	125	228	228.029 228.000	212	244	268	34	10	10	248	9	28 800	38 400	21
TF TJ 160-112	160	112	119	118.988 118.953	143	266	266.032 266.000	245	284	314	39	12	12	290	11	37 600	50 200	31
TF TJ 180-126	180	126	134	133.986 133.946	160	298	298.032 298.000	278	317	354	44	12	12	326	14	47 600	63 500	43
TF TJ 200-140	200	140	148	147.986 147.946	174	336	336.036 336.000	302	357	392	49	16	13	364	14	58 800	78 400	61
TF TJ 220-154	220	154	162	161.986 161.946	194	374	374.036 374.000	326	397	430	54	16	16	402	14	71 100	94 900	85
TF TJ 250-175	250	175	184	183.985 183.939	220	406	406.040 406.000	371	431	478	61	20	18	442	18	91 900	122 000	102
TF TJ 280-196	280	196	206	205.985 205.939	244	450	450.040 450.000	407	477	522	69	20	19	486	18	115 000	154 000	142
TF TJ 300-210	300	210	220	219.985 219.939	262	482	482.040 482.000	431	511	554	74	20	21	518	18	132 000	176 000	175

** Gives H6-h6 fit for /2D and /2DF bearings and H6-g6 fit for /OD bearings*

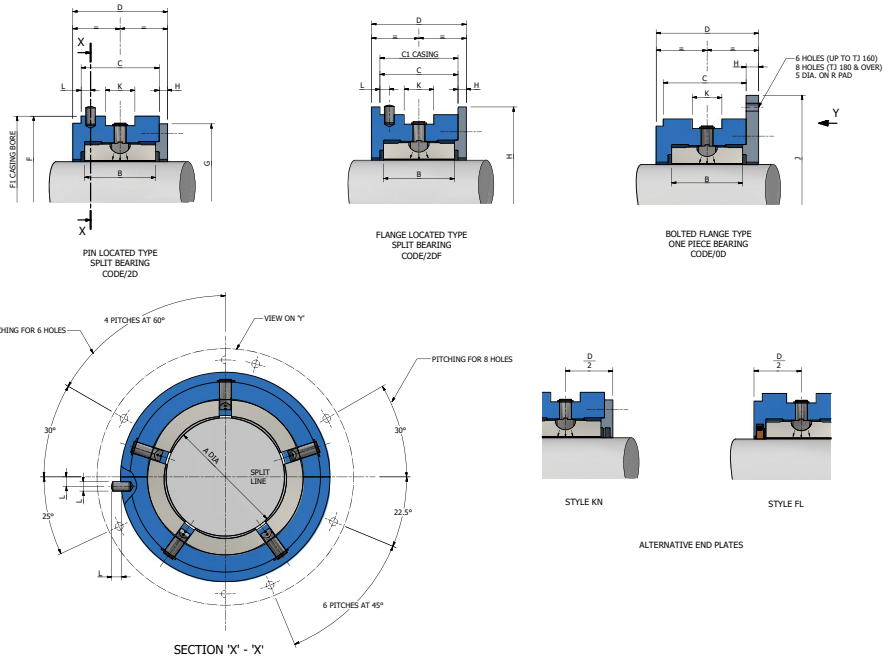


TABLE 3 : b/d = 1.0

SIZE	NOM SHAFT DIA	PAD WIDTH		RECOMMENDED CASING	WIDTH		RECOMMENDED CASING BORE	DIA	DIA	DIA				PC DIA	DIA	MAXIMUM LOAD (N)		WEIGHT (KG)
	A	B	C	C1	D	F	F1 DIA*	G	H	J	K	L	M	R	S	LOAD ON PAD	LOAD BETWEEN PADS	
TF TJ 020-020	20	20	25	24.993 24.972	33	58	58.019 58.000	54	65	86	7	4	4	72	5.5	840	1120	0.5
TF TJ 025-025	25	25	30	29.993 29.972	38	62	62.019 62.000	60	69	90	9	4	4	76	5.5	1310	1750	0.7
TF TJ 030-030	30	30	35	34.991 34.966	43	69	69.019 69.000	66	76	97	11	4	4	83	5.5	1890	2520	0.9
TF TJ 035-035	35	35	40	39.991 39.966	48	76	76.019 76.000	72	80	100	13	4	4	86	5.5	2570	3430	1.2
TF TJ 040-040	40	40	45	44.991 44.966	55	82	82.022 82.000	78	90	110	14	4	5	96	5.5	3360	4480	1.4
TF TJ 045-045	45	45	50	49.991 49.966	60	89	89.022 89.000	85	98	117	16	4	5	103	5.5	4250	5670	1.8
TF TJ 050-050	50	50	55	54.990 54.960	65	95	95.022 95.000	92	104	127	18	4	5	111	6.6	5250	7000	2.3
TF TJ 055-055	55	55	60	59.990 59.960	70	111	111.022 111.000	100	120	143	19	5	5	127	6.6	6350	8470	3.3
TF TJ 060-060	60	60	65	64.990 64.960	75	120	120.022 120.000	106	130	152	21	5	5	136	6.6	7560	10 100	4.2
TF TJ 070-070	70	70	75	74.990 74.960	87	130	130.025 130.000	118	141	162	25	5	6	146	6.6	10 300	13 700	5
TF TJ 080-080	80	80	85	84.988 84.953	97	139	139.025 139.000	130	150	171	28	6	6	155	6.6	13 400	17 900	6
TF TJ 090-090	90	90	96	95.988 95.953	110	165	165.025 165.000	152	177	197	32	6	7	181	6.6	17 000	22 700	10
TF TJ 100-100	100	100	106	105.988 105.953	120	177	177.025 177.000	164	190	217	35	8	7	197	9	21 000	28 000	13
TF TJ 110-110	110	110	116	115.988 115.953	134	190	190.029 190.000	176	204	230	39	8	9	210	9	25 400	33 900	16
TF TJ 120-120	120	120	126	125.986 125.946	144	215	215.029 215.000	188	230	255	42	10	9	235	9	30 200	40 300	22
TF TJ 140-140	140	140	147	146.986 146.946	167	228	228.029 228.000	212	244	268	49	10	10	248	9	41 200	54 900	26
TF TJ 160-160	160	160	167	166.986 166.946	191	266	266.032 266.000	245	284	314	56	12	12	290	11	53 800	71 700	41
TF TJ 180-180	180	180	188	187.985 187.939	212	298	298.032 298.000	278	317	354	63	12	12	326	14	68 000	90 700	58
TF TJ 200-200	200	200	208	207.985 207.939	234	336	336.036 336.000	302	357	392	70	16	13	364	14	84 000	112 000	84
TF TJ 220-220	220	220	228	227.985 227.939	260	374	374.036 374.000	326	397	430	77	16	16	402	14	102 000	136 000	115
TF TJ 250-250	250	250	259	258.983 258.938	295	406	406.040 406.000	371	431	478	88	20	18	442	18	131 000	175 000	144
TF TJ 280-280	280	280	290	289.983 289.938	328	450	450.040 450.000	407	477	522	98	20	19	486	18	165 000	220 000	194
TF TJ 300-300	300	300	310	309.983 309.938	352	482	482.040 482.000	431	511	554	105	20	21	518	18	189 000	252 000	239

** Gives H6-h6 fit for /2D and /2DF bearings and H6-g6 fit for /OD bearings*

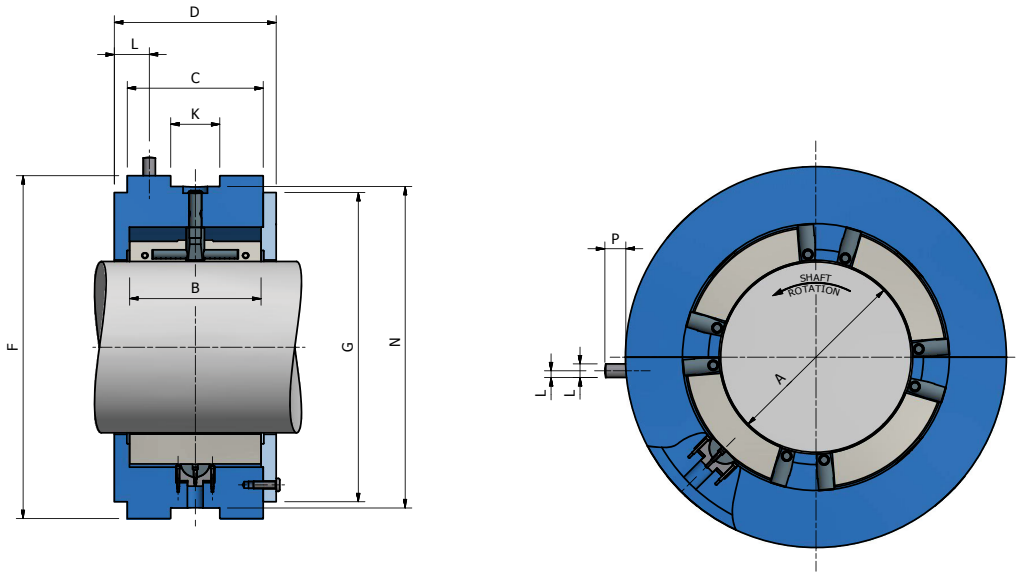


TABLE 4 : b/d = 0.7

SIZE		NOM SHAFT DIA	PAD WIDTH		WIDTH	DIA	DIA			DIA	
		A	B	C	D	F	G	K	L	N	P
TJB TFB	300-210	300	210	220	264	525	450	74	20	489	14
TJB TFB	350-245	350	245	256	304	593	512	86	25	551	18
TJB TFB	400-280	400	280	291	345	684	577	98	25	636	18
TJB TFB	450-315	450	315	327	385	752	640	110	30	698	21
TJB TFB	500-350	500	350	362	425	838	713	123	30	778	21
TJB TFB	550-385	550	385	398	467	904	776	135	35	838	25
TJB TFB	600-420	600	420	433	506	997	841	147	40	925	28
TJB TFB	650-455	650	455	469	546	1065	905	159	40	987	28
TJB TFB	700-490	700	490	504	586	1159	971	172	45	1075	32
TJB TFB	750-525	750	525	540	627	1225	1033	184	50	1135	35

Size Codes

Waukesha Tilting Pad Radial Bearings are identified by a two part code which consists of the bearing size followed by a suffix indicating the type of construction.

The size designation is shown in the left-hand column of the Size Tables on Pgs. 25-28 while the suffix options are shown below.

In addition to the basic two part code, various additional features can be specified by referencing an appropriate Style option from Pgs. 15-19. Note than in many cases the use of the Style designation does not completely describe the feature required and additional information is required.

CODE NOMENCLATURE

TJ 050 020 / 2D Style J

Style Options:

AA	=	Axial alignment
AP	=	Adjustable pivots
AR75	=	75° arc pads on Series TF Bearings
BP	=	Two pad orientation
D	=	Integral squeeze film damper
FL or FL2	=	Single or double floating seal
IT1	=	Provision for customer supply temperature sensors
IT2	=	Temperature sensors (Waukesha supply)
IR	=	Provision for customer supply proximity probes
J	=	Hydrostatic jacking
KN or KN2	=	Single or double knife edge end plate
OP	=	Offset pivot pads
TLG or TLG2	=	Single or double plain grooved axial face
TLU or TLU2	=	Single or double taper land axial face (uni-directional)
TLB or TLB2	=	Single or double taper land axial face
TP or TP2	=	Single or double tilting pad axial face

Type of Housing:

(see Fig 15)
/2D = Split brg, pin located
/2DF = Split brg, flange located
/0D = One piece brg, flange located

Pad width (mm)

Nominal shaft dia (mm)

Range Prefix:

FP = Flexure Pivot bearing
TF = 4 pad bearing
TFB = Large range 4 pad bearing
TJ = 5 pad bearing
TJB = Large range 5 pad bearing

Example of complete bearing reference codes which should be used for orders or enquiries are as follows:

CODE	DESCRIPTION
TJ050-020/2D	50 mm 5 pad bearing, b/d = 0.4, split, pin located
TJ100-100/0D	100 mm 5 pad bearing, b/d = 1.0, one piece, flange located
TF120-084/2DF Style J	120 mm 4 pad bearing, b/d = 0.7, split, flange located with jacking
TJ200-080/2DF Style BP, FL, IR	200 mm 5 pad bearing, b/d = 0.4, split, flange located with two pad orientation, single floating seal and provision for radial proximity probes
TJ250-250/2DF Style TP2	250 mm 5 pad bearing, b/d = 1.0, split, flange located with tilting pad axial faces on both ends

Orders and Enquiries

When enquiring for Waukesha Tilting Pad Radial Bearings from this handbook, we recommend that the anticipated operating conditions are given so that confirmation can be given for the bearing selection.

Please use the **Journal Bearing Inquiry Sheet** available online at www.waukeshabearings.com or state the following:

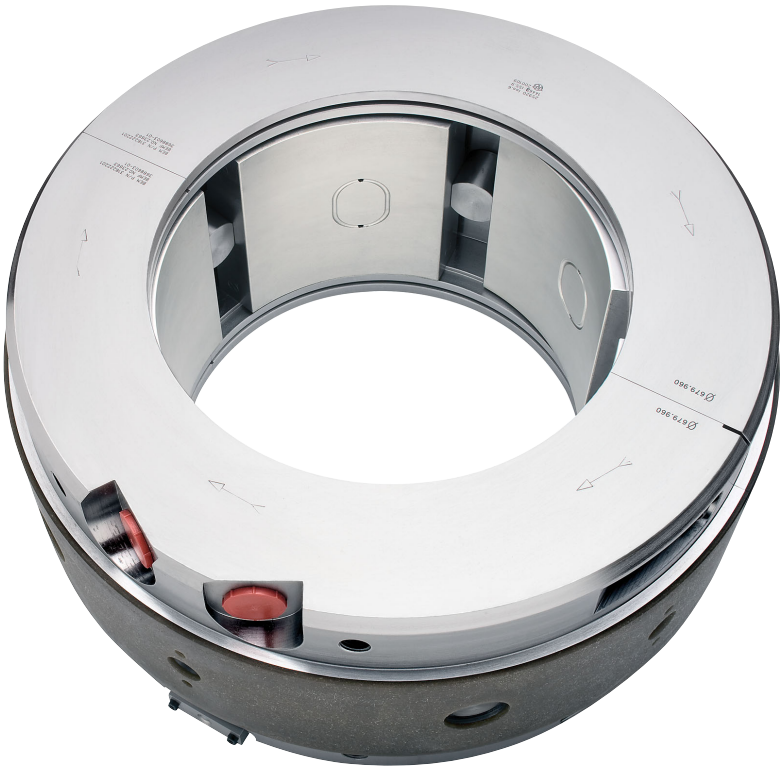
- Application
- Shaft diameter – with tolerance if non-standard shaft to be used
- Shaft speed – normal and maximum
- Load – normal, maximum and at start-up; also angle and whether steady or rotating
- Oil grade to be used – also inlet temperature and pressure at entry to the bearing
- Optional features — if these are required, additional information may be needed as indicated in the appropriate Style description

Engineered Bearing Solutions

The type of bearing described in this handbook is one of a complete range of shaft support products which Waukesha Bearings manufactures for rotating machinery (turbines, compressors, pumps, gearboxes, motors, generators, couplings, etc.).

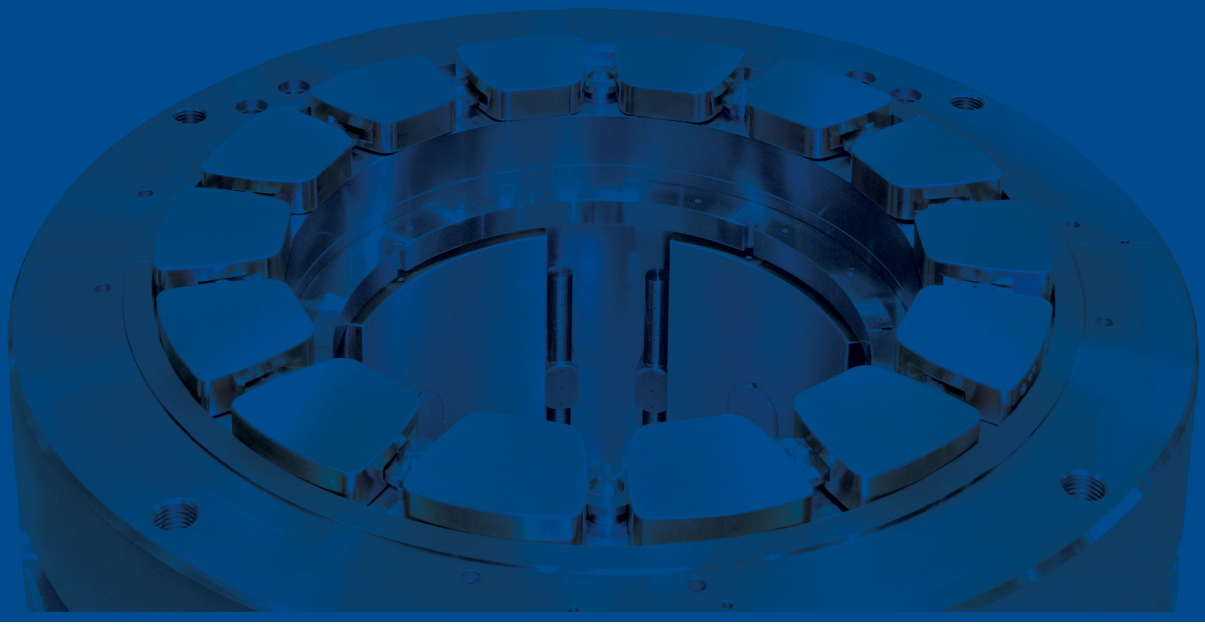
Some other products in the Waukesha Bearings range:

- Equalised and unequalised tilting pad thrust bearings
- Horizontal bearing assemblies, self contained and force lubricated
- Vertical bearing assemblies, self contained and force lubricated
- Medium and heavywall fixed profile journal bearings
- Fixed profile thrust washers
- Marine thrust and line shaft units
- Bearings for water and product lubrication
- Active magnetic bearing systems
- Spares, repairs and bearings to customer drawings



TJB400-240/2 bearing with insulation for a 400 mm diameter shaft at 3000 rev/min

Note: The information in this handbook is given in good faith but no guarantee is given or implied in respect of such information. Waukesha products are subject to continued development and Waukesha reserves the right to make changes in the specification and design of their products without prior notice.



WAUKESHA BEARINGS

DOVER PRECISION COMPONENTS

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