F

Housing and Shaft Design Guide

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This section describes the design specifications for the shaft and the housing whereoil seals are installed.

Table 1 shows reference table numbers and page numbers for the design specifications for shafts and their chamfered ends, as well as for housings and their respective chamfers, arranged by oil seal type.

Table 1: Page Directory to Shaft and Housing Design Specifications by Seal Type

Item \ NOK Seal Type		S type, T type, V type, K type, TCV type, TCN type, T4 type, J type, D type, QLFY type	SBB type, Large-diameter SB type, Large-diameter TB type	MG type	OC type, OKC3 type	VR type, Z type
Shaft	Design specifications	Table 2 on page F-2			Table 11 on page F-12	Table 12 on page F-13
	Chamfer specifications	Table 3 on page F-3	Table 4 on page F-3	Table 3 on page F-3		Table 3 on page F-3
Housing	Design specifications	Table 6 on page F-8		Table 10 on page F-11	Table 11 on page F-12	Table 12 on page F-13
	Chamfer specifications	Table 7, 8 on page F-8, 9	Table 9 on page F-10			

Note : Please consult us regarding the design of the shaft and housing for W type, MO type, and MOY type oil seals.

Shaft

1. Shaft Design Specifications, Chamfer Properties

Table 2 shows shaft design specifications, and **Tables 3 and 4** show the shape and size of the required shaft chamfers.

Table 2: Shaft Design Specifications

Specification item \ NOK Seal Type	S type, T type, V type, K type, TCV type, TCN type, D type, SBB type, Large-diameter SB type, Large-diameter TB type, MG type	J type	T4 type	QLFY type
Shaft Material	Carbon steels for machine structural use			
Surface hardness	Min. 30 HRC	Min. 50 HRC	Min. 30 HRC	
Surface roughness	(0.32~0.1)μm Ra (2.5~0.8)μm Rz		(0.2~0.05)μm Ra (1.6~0.4)μm Rz	(3.2~1.6)μm Ra (12.5~6.3)μm Rz
Machining method	Plunge ground		After heat treatment, plate with hard chrome before final polishing.	Lathe cut
Dimensional tolerances	JIS h9			JIS h8

Note(1): To use oil seals with a silicone rubber lip, finish the shaft surface roughness at 1.6 to 0.6 μm Rz.
Note(2): For details on shaft machining, refer to "Proper Shaft Machining Methods" on page F-5.
Note(3): To get surface hardness min. 30 HRC, generally need heat treatment.

The notation of surface roughness on the catalog comply with JIS B 0601:2001.

F

Table 3: Shaft Chamfer Design **(for shafts up to 300 mm in diameter)** Units: mm

NOK Seal Type / Shaft diameter	**S type, T type, V type, K type, TCV type, TCN type, T4 type, D type, MG type, VR type, Z type**	**J type**	**QLFY type**
Shaft diameter d	d_1		
Up to 10	d−1.5	d−3.5	—
Over 10 to 20	d−2.0	d−4.0	
Over 20 to 30	d−2.5	d−4.5	d−1.5
Over 30 to 40	d−3.0	d−5.0	
Over 40 to 50	d−3.5	d−5.5	
Over 50 to 70	d−4.0	d−6.0	
Over 70 to 95	d−4.5	d−6.5	d−2.0
Over 95 to 130	d−5.5	d−7.5	
Over 130 to 240	d−7.0	d−9.0	—
Over 240 to 300	d−11.0	d−12.0	

The diameter d_1 in the table is less than the inside diameter of the sealing lip. Remember that a correct seal installation neither damages the sealing lip nor detaches the garter spring. Be sure to conform to the relevant size shown in the table.
The smaller roughness at shaft chamfer (less than Ra 3.2) makes your shaft inserting operation easier.

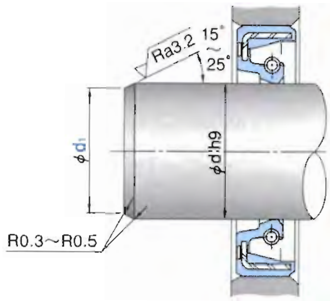
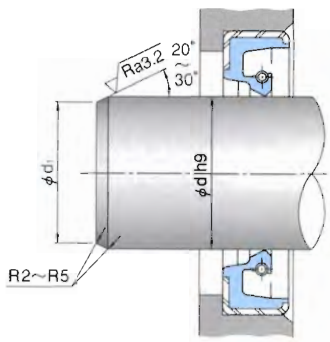


Table 4: Shaft Chamfer Design for **SBB type, large-diameter SB type and large-diameter TB type** Oil Seals**(for shafts over 300 mm in diameter)** Units:mm

NOK Seal Type / Shaft diameter	**SBB type, Large-diameter SB type, Large-diameter TB type**
Shaft diameter d	d_1
Over 300 to 400	d−12
Over 400 to 500	
Over 500 to 630	d−14
Over 630 to 800	
Over 800 to 1000	d−18
Over 1000 to 1250	
Over 1250 to 1600	d−20
Over 1600 to 2000	



The notation of surface roughness on the catalog comply with JIS B 0601:2001.

2. Shaft Design Concepts

The material, hardness, and machining method of the shaft has a significant influence on the performance of the oil seal. Design specifications for the shaft need to be determined after careful examination of all relevant factors.

(1) Shaft Material

Steels for machine structural use, are suitable. However in case of cast iron or plastic, refer to **Table 5** "Notes on Usage" before selecting one of these materials.

Table 5: Notes on Usage

Shaft Material	Notes on Usage
Cast Iron	Pinhole porosity is likely to appear in cast iron shafts. If the size of the pinhole is larger than 0.05 mm, and the seal lip rides in or around this pinhole, leaks may occur. This is due to a localized and rapid loss of shaft contact to the seal lip. If cast iron shafts must be used, NOK recommends using nodular graphite cast iron shafts.
Plastics	NOK does not recommend using plastic shafts. It is difficult to insure proper hardness and surface finish, and heat dissipation is poor due to low heat transfer qualities.
Ceramics	Although ceramic shafts may be used in chemical equipment, ceramic shafts are not recommended for use with oil seals. The unique surface roughness of ceramics accelerates seal lip wear, significantly reducing the life of the oil seal. Consult us before using ceramic shafts.

(2) Shaft Hardness

The surface of the shaft with which the sealing lip of an oil seal comes into contact needs to be at least 30 HRC for the following reasons:

1. The shaft surface will not be easily scratched or dented.
2. An appropriate surface finsih can be easily machined.
3. The shaft (especially a hollow shaft) will not deform easily.
4. To minimize the shaft wear

Dents are easily overlooked, however, and it is important to take care that the shaft is not damaged by contact during shipping and assembly.

For use with J type (PTFE) seals, the shaft surface under the seal lip needs to be as hard as 50 to 60 HRC, as the J type oil seal is more likely to increase wear on the shaft compared to other oil seals. The J type oil seal is used for fluids with poor lubricity, such as chemicals or solvents, and in high temperature areas or under poor lubrication conditions. Therefore, a shaft with a hardness of only 30 to 40 HRC will quickly wear out.

(3) Shaft Finish and Machining Method

Generally, the shaft roughness directly affects the degree of seal leakage and wear (this varies according to shaft speed and oil quantity) regardless of the shaft hardness. Therefore, it is important to use shafts with the surface finish roughnesses listed in **Table 2**. For rotating shaft oil seals, special attention is needed. If machining flaws run continuously along the shaft, leaks may occur even if the surface roughness of the shaft is within a range of 2.5 to 0.8 μm Rz (excluding T4 type and QLFY type oil seals).

The following section discusses proper and improper machining methods (i.e., introducing machine lead onto the shaft through poor machining practices).

In case of shaft for reciprocating , please consult us.

The notation of surface roughness on the catalog comply with JIS B 0601:2001.

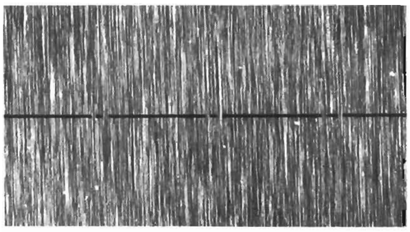
F

Proper Shaft Machining Methods

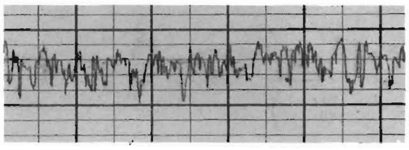
Ground Finish

Plunge grinding produces non-continuous machining striation markings that are at right angles to the shaft centerline, as shown in the photograph on the right. This is the optimum finish technique for best seal life and performance. After plating with hard chromium to improve resistance to corrosion and wear, be sure to plunge-grind the final surface.

Shaft surface
Shaft centerline



Roughness Trace



Emery Paper Finish

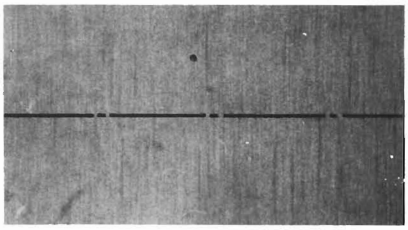
(a finishing method that does not involve moving the paper axially)

Emery paper finishing without axial movement produces non-continuous machining striation markings that are at right angles to the shaft centerline, as shown in the photograph on the right.

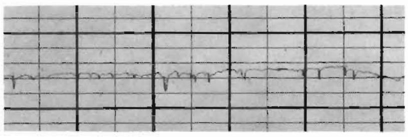
This "plunge" action surface is therefore also very suitable for oil seals.

Note that excessive force on the paper may produce deep scoring on the shaft.

Shaft surface
Shaft centerline



Roughness Trace



How to Minimize Shaft Wear

A shaft may experience wear even if it is treated via induction or carburizing hardening processes. This is primarily due to dust, earth and sand, or silica (SiO_2) or alumina (Al_2O_3) contained in deteriorated oil. These minute foreign particles can enter into the contact area of the sealing lip either from the air or oil side. To protect the shaft from wear caused by particles from the air side, NOK recommends using a dust seal together with an oil seal, or selecting an oil seal with higher dust resistance.

When the oil contains high levels of silica or alumina, shaft wear can be reduced by changing the oil at appropriate intervals. In addition, hard chromium plating of the shaft or using hard chromium plated sleeve shafts is recommended.

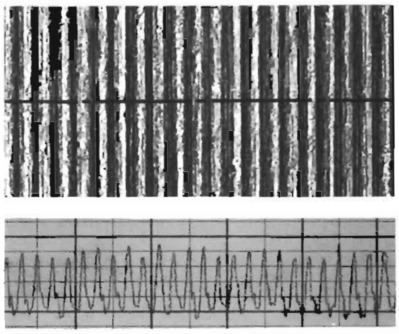
Grindstone Dressing

Take care when dressing the grindstone for plunge ground finishing. If the grindstone incurs directional lead during the dressing, the lead will transfer to the shaft. NOK recommends roller dressing. If single-point dressing is unavoidable, use a slow feed rate and be sure to spark-out during grinding.

Improper Shaft Machining Methods

Lathe Cut Finish

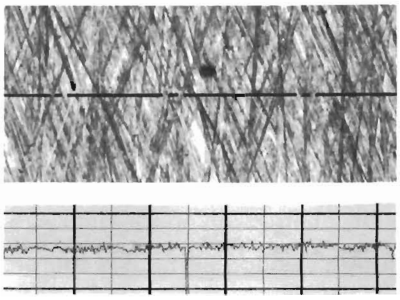
Lathe finishing is very distinctive: a roughness curve shows continuous rows of well-shaped triangular peaks and valleys spiralling around the shaft. These spiral valleys can continue from the inner side of the oil seal, through the sealing lip contact area, and to the air side, causing sealed fluid to leak through the valleys via a "screw-pump" action.



Super-finishing

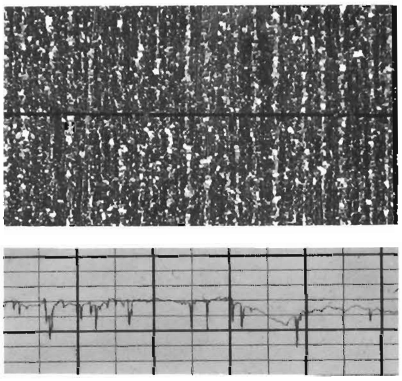
Super-finishing creates a herringbone-like texture, and reduces roughness compared to other finishing methods. However, this texture also causes seal leakage through the presence of machine lead, which can overpower a seal and pump oil to the air side.

In some cases, this herringbone-like texture can cause premature wear on the seal lip.



Roller Burnishing

Roller burnishing is generally performed after a lathe cutting operation. The burnishing will not remove the substrate machine lead produced by the lathe, which could cause leakage. Roller burnishing is also prone to producing a too-smooth finish, causing the oil film to become too thin, resulting in increased friction and premature seal wear.



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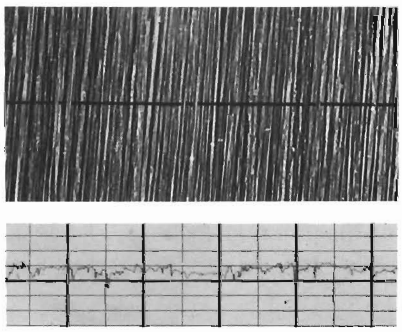
Emery Paper Finishing

(With axial oscillation)

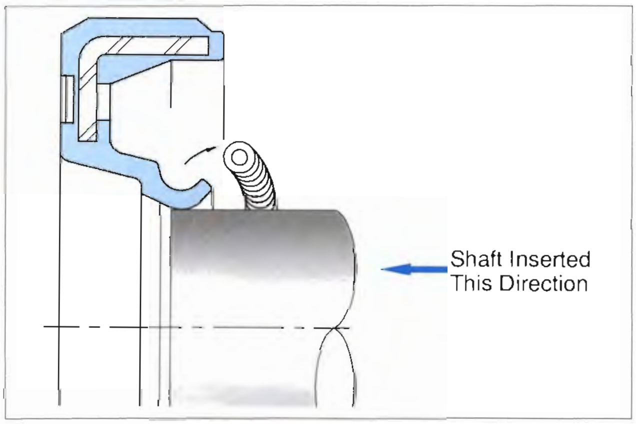
After lathe machining, finishing the surface with emery paper is the easiest and most widely accepted method. However, finishing by moving the emery paper axially produces a herringbone lead texture, causing leaks to occur (similar to super finishing).



(4) Shaft Chamfer

If there is a sharp corner at the shaft's end, the seal lip will be damaged when the oil seal is installed over the shaft, thus causing a leak. Also, if the shaft is not properly chamfered, the sealing lip might get caught on the corner as shown in **Fig. 4**, causing lip "turn-under" and possible garter spring ejection. Therefore, the shaft should be properly chamfered as shown in **Tables 3 and 4**.

Figure 4: Lip "Turn-Under" and Garter Spring Ejection



(5) Shaft Key Ways and Splines

Even if the shaft is properly chamfered per **Tables 3 and 4**, the seal lip may be damaged if there is a key way or spline on the shaft surface which the lip contacts during installation.

If a key way or spline must be used on the shaft surface that will pass under the seal's lip during installation, make the nominal diameter of the key way or spline 5 to 15mm smaller than the diameter of the shaft's seal journal so that a cover may be used, as shown in **Figure 5**.

(6) Miscellaneous

If a shaft's bearing journal is the same diameter as the shaft's seal journal, the shaft will be scratched from bearing installation, and thus cause a leak path under the seal lip. Instead, design the shaft's bearing journal to be larger than that of the seal journal, thus avoiding shaft damage in the critical seal lip area of the shaft.

Housing

The housing is the area where a bore recess can receive and retain a seal.

Table 6 shows the most desirable design characteristics for housing bores, and **Tables 7 and 8** show the shapes and sizes of various housing bores.

1. Housing Design Specifications

Design specifications for housings are shown in **Table 6**. Refer to **Table 10** for MG type, **Table 11** for O type, and **Table 12** for VR and Z type oil seals.

2. Housing Bore Configuration

The shape and size of a housing bore needs to be determined according to the type and size of the oil seal to be used. Design a housing bore based on the following:

(1) Standard Oil seals

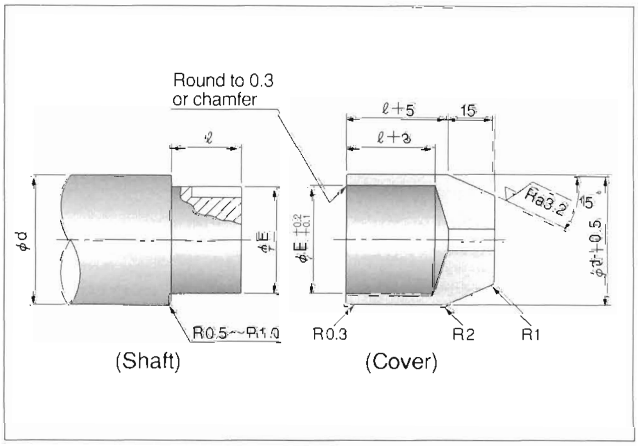
For standard oil seals (with shafts up to 300 mm in diameter), the shape and size of the housing hole varies depending on the pressure in the application.

Non-Pressurized Applications

(Max. 0.03 MPa (0.3 kgf/cm^2)

The shapes and sizes of housing bores in non-pressurized applications are shown in **Table 7**.

Figure 5: Cover Design for Key Ways or Splines

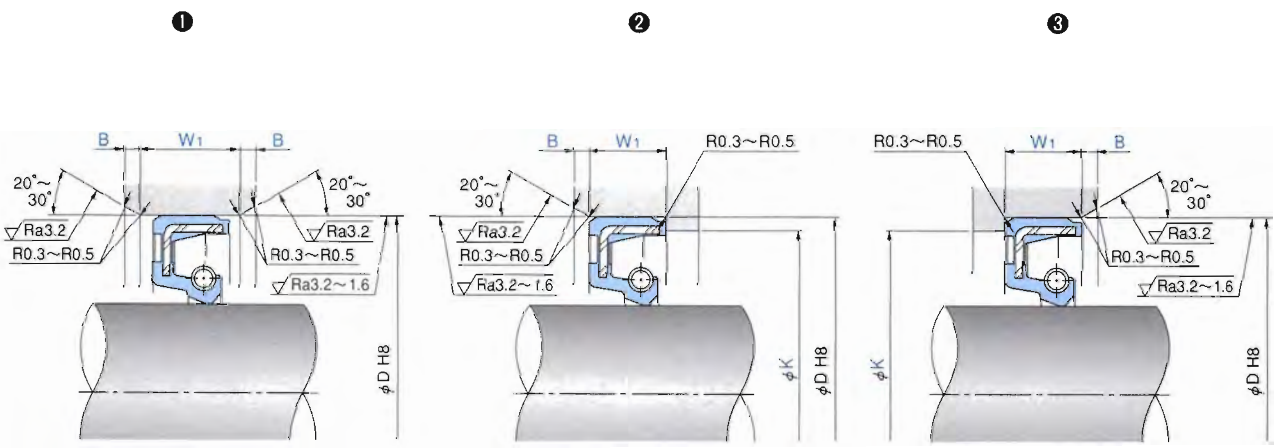


The notation of surface roughness on the catalog comply with JIS B 0601:2001.

Table 6: Housing Design Specifications

Specification item \ NOK Seal Type		**S type, T type, V type, K type, TCV type, TCN type, T4 type, J type, SBB type, Large-diameter SB type, Large-diameter TB type, D type, QLFY type**
Housing Material		Metals with Low Thermal Expansion Coefficients (Example: Carbon steels for machine structural use)
Bore ID surface roughness	Metal OD oil seal	(3.2 ~ 0.4)μm Ra (12.5 ~ 1.6)μm Rz
	Rubber OD oil seal	(3.2 ~ 1.6)μm Ra (12.5 ~ 6.3)μm Rz
Dimensional tolerance	Nominal size: 400 mm or smaller	JIS H8
	Nominal size: 400 mm or larger	JIS H7

Table 7: Housing Bores for Non-Pressurized Applications



Housing bore size

Units: mm

Nominal width of oil seal (b)	Minimum size of W1	B	Minimum size of W2
Up to 6	b+0.5	1.0	b+1.0
Over 6 to 10		1.5	
Over 10 to 14		2.0	
Over 14 to 18		2.5	
Over 18 to 30	b+1.0	3.0	b+2.0

Units: mm

Nominal outside diameter of oil seal (D)	K
Up to 50	D-4
Over 50 to 150	D-6
Over 150 to 300	D-8

The notation of surface roughness on the catalog comply with JIS B 0601:2001.

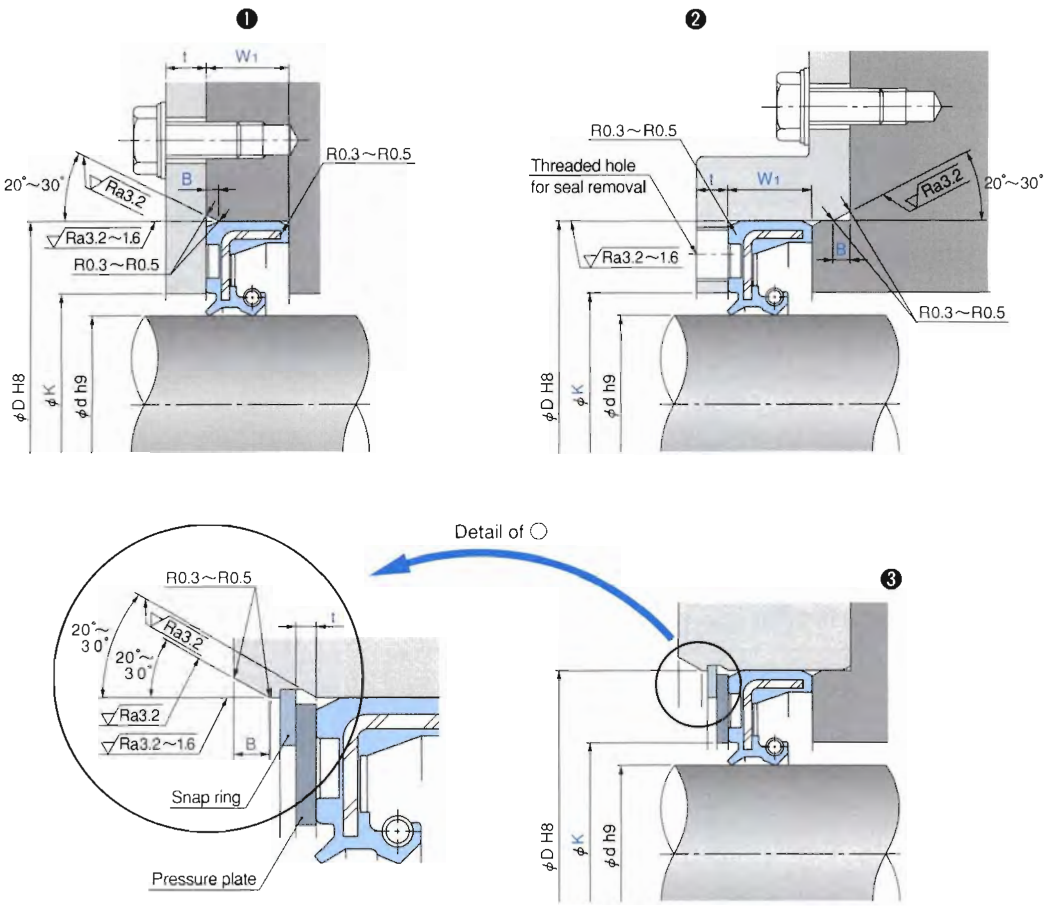
F

Pressurized Applications

(0.03 MPa (0.3 kgf/cm^2) or higher)

The housing bore designs to be used in the presence of internal pressure are shown in **Table 8**.

Table 8: Housing Bore Design for Pressurized Applications



If a snap ring must be used, round (blend) the housing grooves.

Housing bore size Units: mm

Nominal width of oil seal (b)	W_1	B
Over 6 to 10	b $^{+0.3}_{+0.5}$	1.5
Over 10 to 14	b $^{+0.4}_{+0.6}$	2.0
Over 14 to 18	b $^{+0.5}_{+0.8}$	2.5
Over 18 to 30	b $^{+0.6}_{+0.9}$	3.0

Pressure plate size Units: mm

Nominal outside diameter of oil seal (D)	K	Minimum plate thickness t
Up to 50	d+3	3
Over 50 to 120	d+4	5
Over 120 to 250	d+5	8
Over 250	d+6	10

The notation of surface roughness on the catalog comply with JIS B 0601:2001.

(2) General Oil Seals

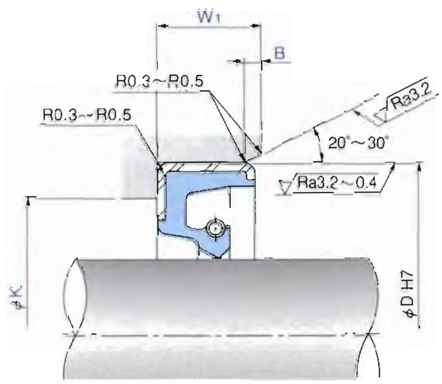
For general oil seals, design the housing bore based on the following.

The shape and size of housing holes for SBB type, large-diameter SB type, and large-diameter TB type oil seals are shown in **Table 9**.

Table 9: Bore Design for **SBB type, large-diameter SB type, and large-diameter TB type** (shaft over 300 in diameter) oil seals

Housing design specifications Units: mm

Nominal outside diameter of oil seal (D)	K
Over 300 to 400	D-10
Over 400 to 500	
Over 500 to 630	D-12
Over 630 to 800	
Over 800 to 1000	
Over 1000 to 1250	
Over 1250 to 1600	D-14
Over 1600 to 2000	



Housing bore size Units: mm

Nominal width of oil seal (b)	W_1	B
Up to 6	b+0.5	1.0
Over 6 to 10		1.5
Over 10 to 14		2.0
Over 14 to 18		2.5
Over 18 to 30	b+1.0	3.0

The notation of surface roughness on the catalog comply with JIS B 0601:2001.

F

MG Type Oil Seal

Design specifications of the housing bores for MG type oil seals are shown in **Table 10**. Since no reinforcing metal case is used in an MG type oil seal, the seal is installed by cutting the seal at one point and butt-jointing the cut ends, which makes it difficult to obtain the proper retention strength. Therefore, the housing bore must be designed so that the oil seal sits at the correct position and is secured by pressure from both sides.

Table 10: Housing Bore Design Specifications for MG Type Oil Seals

Housing design specifications

Item		Specifications
Housing Material		Metals with low thermal expansion coefficients (Example: Carbon steels for machine structural use)
Bore Inner Diameter Surface Roughness		(3.2 ~ 1.6)μm Ra (12.5 ~ 6.3)μm Rz
Method		Machining
Dimensional tolerances	400mm or smaller nominal outside diameter	JIS H8
	400mm or larger nominal outside diameter	JIS H7

Housing bore size

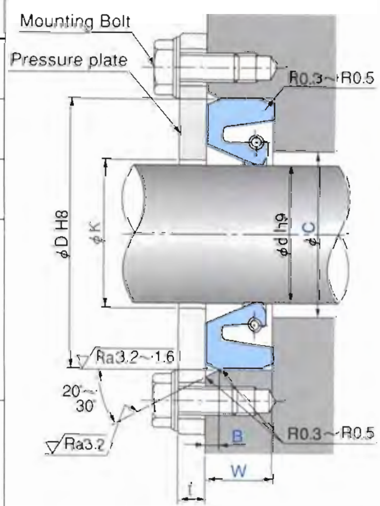
Units: mm

Nominal width of oil seal (b)	W	B
Up to 6	$b^{-0.1}_{-0.2}$	1.0
Over 6 to 10	$b^{-0.1}_{-0.3}$	2.0
Over 10 to 14	$b^{-0.1}_{-0.4}$	3.0
Over 14 to 18	$b^{-0.1}_{-0.5}$	4.0
Over 18 to 30	$b^{-0.1}_{-0.6}$	5.0
Over 30	$b^{-0.1}_{-0.7}$	6.0

Housing bore, pressure plate, and mounting bolt

Units: mm

Nominal outside diameter of oil seal (D)	C	Pressure plate		Mounting bolt	
		Minimum plate thickness t	K	Size	Quantity
Up to 50	d+8	3	d+3	M6	4 (equally spaced)
Over 50 to 125	d+10	5	d+5	M8	4 (equally spaced)
Over 125 to 315	d+18	10	d+8	M10	6 (equally spaced)
Over 315 to 400					
Over 400 to 500	d+25	15			8 (equally spaced)
Over 500 to 630			d+12	M12	
Over 630 to 800	d+28	18			12 (equally spaced)
Over 800 to 1000					
Over 1000 to 1250					
Over 1250 to 1600	d+30	20	d+15	M16	16 (equally spaced)
Over 1600 to 2000					



The notation of surface roughness on the catalog comply with JIS B 0601:2001.

F

OC and OKC3 Type Oil Seals

The sealing lip of an OC type oil seal comes into contact with the inner surface diameter of the housing bore, while the sealing lip of an OKC3 type oil seal comes into contact with the inner diameter surface of the shaft flange. The machining methods for these inner diameter surfaces and the surface roughnesses are shown in **Table 11**.

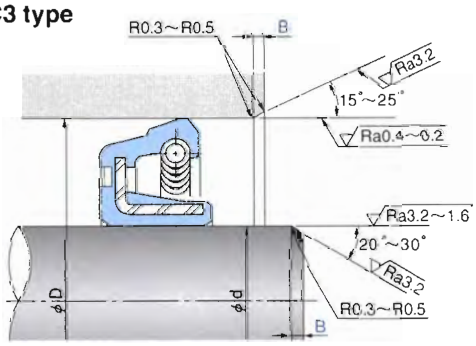
Table 11: Housing and Shaft Design Specifications for OC and OKC3 Type Oil Seals

Units: mm

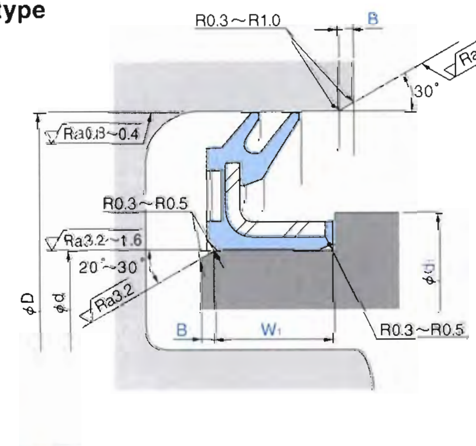
Item \ Classification / Seal Type		Shaft design specifications		Housing(inner diameter surface) design specifications	
		OC type	**OKC3 type**	**OC type**	**OKC3 type**
Housing Material		Carbon steels for machine structural use			
Surface hardness		Min. 30 HRC			
Surface roughness		(3.2～1.6)μm Ra (12.5～6.3)μm Rz		(0.4～0.2)μm Ra (3.2～1.6)μm Rz	(0.8～0.4)μm Ra (6.3～3.2)μm Rz
Method		Machining		Plunge ground Machining	Machining
Dimensional tolerances	Nominal size: 400 mm or smaller	JIS h8		JIS H9	
	Nominal size: 400 mm or larger	JIS h7			

Shape and size of housing bore (inner diameter surface)

OKC3 type



OC type



Nominal width of oil seal (b)	W_1	B	d_1
Up to 6	b+0.5	1.0	d+10
Over 6 to 10		1.5	
Over 10 to 14		2.0	
Over 14 to 18		2.5	
Over 18 to 30	b+1.0	3.0	

The notation of surface roughness on the catalog comply with JIS B 0601:2001.

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VR and Z Type Oil Seals

Design specifications for the shafts and housings of VR and Z type oil seals are shown in **Table 12**.

Table 12: Shaft and Housing Designs for VR and Z Type Oil Seals

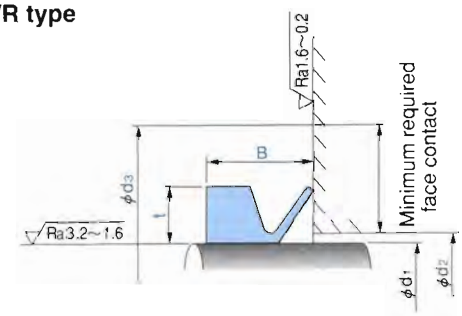
Units: mm

Item \ Classification / Seal Type	Shaft design specifications		Housing design specifications	
	VR type	**Z type**	**VR type** ※	**Z type**
Housing Material	Carbon steels for machine structural use			
Surface hardness	Min. 30 HRC			No requirement
Surface roughness	(3.2 ~ 1.6)μm Ra (12.5 ~ 6.3)μm Rz	(0.4 ~ 0.2)μm Ra (3.2 ~ 1.6)μm Rz	(1.6 ~ 0.2)μm Ra (6.3 ~ 0.8)μm Rz	(0.8 ~ 0.2)μm Ra (6.3 ~ 1.6)μm Rz
Method	Machining			

※ The housing roughness specification for the VR type seal is only required where the seal lip contacts the housing axially.

Mating Face Design

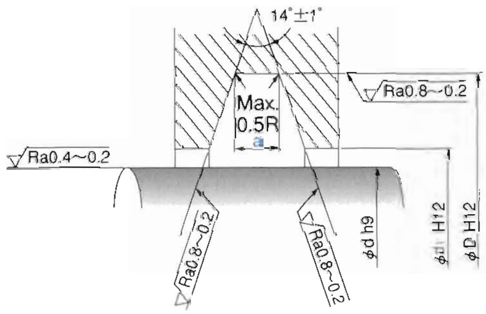
VR type



Recommended shaft diameter d_1	B	d_2	d_3	t
Up to 4	$2.5^{\pm0.3}$	d+1	d+4	1.5
Over 4 to 10	$3.0^{\pm0.4}$		d+6	2.0
Over 10 to 20	$4.5^{\pm0.6}$	d+2	d+9	3.0
Over 20 to 40	$6.0^{\pm0.8}$	d+3	d+12	4.0
Over 40 to 70	$7.0^{\pm1}$		d+15	5.0
Over 70 to 110	$9.0^{\pm1.2}$	d+4	d+18	6.0
Over 110 to 160	$10.5^{\pm1.5}$		d+21	7.0
Over 160 to 200	$12.0^{\pm1.8}$	d+5	d+24	8.0
Over 200	$20.0^{\pm3.0}$	d+10	d+45	15.0

Housing Bore (inner surface diameter)

Z type



Shaft diameter d	d_1
Up to 20	d+1.0
Over 20 to 60	d+1.5
Over 60 to 110	d+2.0
Over 110	d+3.0

Groove width a	Dimensional tolerance
Up to 3	+0.14 0
Over 3 to 6	+0.18 0
Over 6 to 10	+0.22 0
Over 10 to 18	+0.27 0

The notation of surface roughness on the catalog comply with JIS B 0601:2001.

F

3. Housing Design Concepts

The material, roughness, size, and shape of the housing bore will affect the performance of the oil seal. Determine the design specifications after careful consideration of these factors.

(1) Housing Material

For steel or cast iron housings, use either rubber OD or *metal OD* seals. Since light alloys or resins generally have high coefficients of thermal expansion, the size of the housing hole increases as the temperature increases. For metal OD oil seals, leakage may occur in the press-fit area, or the seal itself may become dislodged. If light alloy or plastic housings must be used, use rubber OD seals.

(2) Surface Roughness of Housing Bore (inner diameter surface)

Oil seals prevent leakage by maintaining contact between the sealing edge and shaft and also by obtaining a proper fit to the bore. Thus, care is needed when machining the housing hole. A very rough inner housing surface will create a leak path past the seal. Refer to **Table 6** on page F-8 for proper roughness levels.

(3) Dimensional Tolerances of Housing Bores

At NOK, we define outside diameter tolerances for oil seals based on JIS H8 for oil seals with 400 mm or smaller nominal outside diameters and JIS H 7 for oil seals with 400 mm or larger nominal outside diameters.

If JIS H8 or JIS H7 standards are not used, seal installation may be difficult, cause damage, or even fail to be retained during operation.

(4) Housing Bore Design

If excessive weight or pressure is placed on the oil seal, it may become dislodged. No special care is needed if there is no inner pressure on the oil seal (max. 0.03 MPa (0.3 kgf/cm^2). In applications where the pressure is 0.03 MPa (0.3 kgf/cm^2) or larger, design the housing so that it secures the oil seal axially. The shape and size of the housing bores are shown in **Table 8** on page F-9. You can select either configuration ❶ or ❷ in the table. Configuration ❷ allows easy installation and removal of the oil seal. If a snap ring must be used, round (blend) the snap ring groove edges of the bore as shown in ❸.

(5) Split-Type Housing

Avoid using a split-type housing for the following reasons:

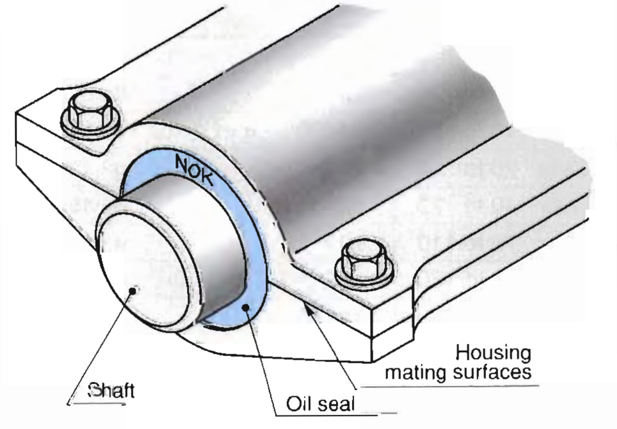
① Leakage may occur from the split line area.
② Seal displacement may occur at the split line area.
③ It may be difficult to ensure proper roundness of the housing bore.
④ Misalignment may occur between the shaft and housing hole.

Items ② and ③ result in leaks at the split line area, and item ④ results in leaks at the sealing lip.

If a split-type housing must be used, machine the housing so that it does not misalign and become oval-shaped, and then use a rubber OD seal in the pre-assembled housing.

Figure 2: Split-Type Housing

Align and secure split sections, then insert oil seal.



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(6) Improper Housing Bore Designs

Figure 3 illustrates two improper housing designs. For case ❶, since stamped steel is used, the hole surface is apt to be tapered and the inside diameter or roundness will vary, causing the oil seal to leak or even become dislodged.

For the housing design in ❷, the housing may be installed off-center, as it uses a combination of screws. Do not use a screwed-in housing.

Figure 3: Improper Housing Bore Designs