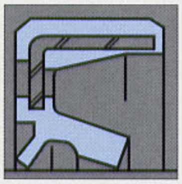
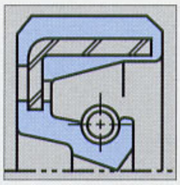
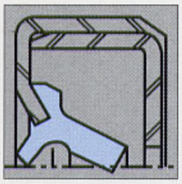
FREUDENBERG-NOK

Industrial Products Radial Shaft Seal Guide





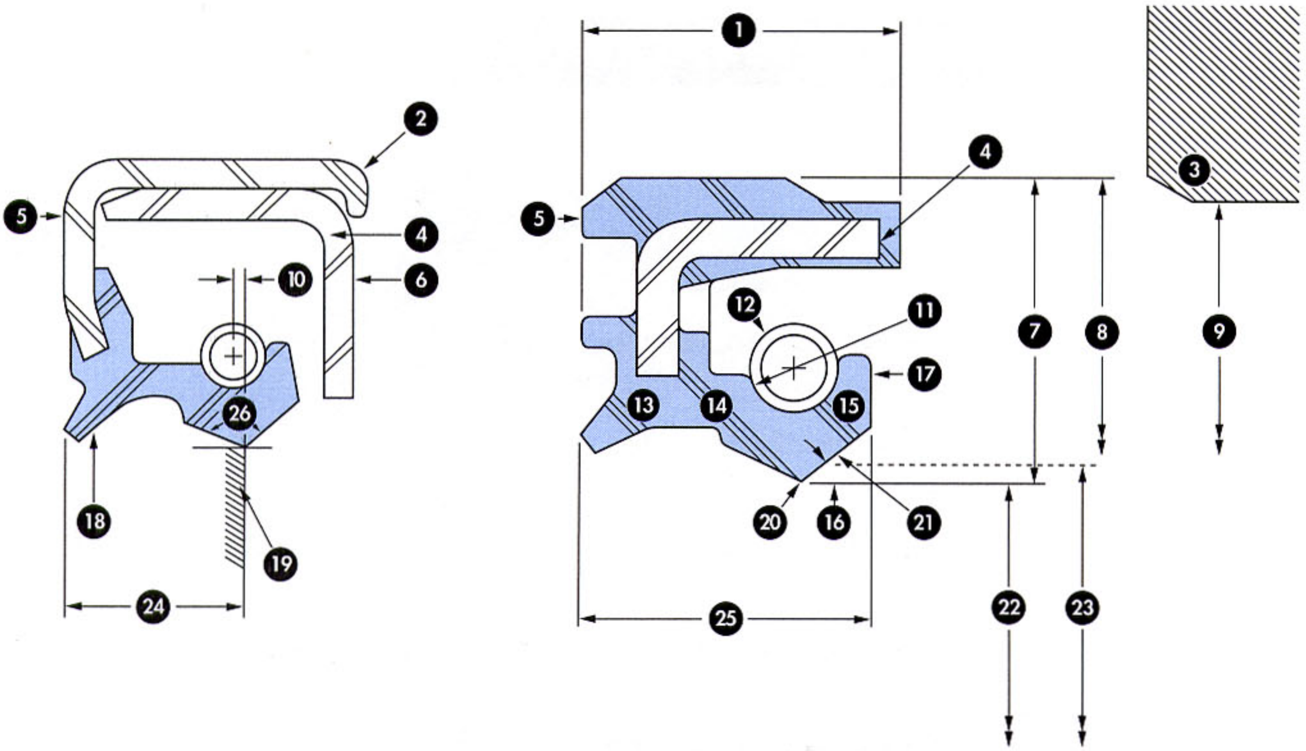


Freudenberg

NOK

TM

SEAL NOMENCLATURE



1. Seal Width
2. Metal Case (Outer)
3. Housing
4. Inner Case
5. Outside Face
6. Inside Face
7. Radial Wall Dimension
8. Seal Outer Diameter
9. Housing Bore Diameter
10. Spring Position (R-Value)
11. Spring Groove
12. Garter Spring
13. Heel Section
14. Flex Section
15. Spring Retainer Lip
16. Inside Lip Angle
17. Toe Face
18. Auxiliary (Dust) Lip
19. Rib (Helix)
20. Contact Point
21. Inside Lip Surface
22. Sprung Lip Diameter
23. Free Lip (Unsprung) Diameter
24. Contact Line Height
25. Lip Height
26. Lip Angle

OIL SEAL SELECTION

The engineering data presented here is to provide a guideline for selection of a standard seal for a general purpose application. The user needs to be aware that many design configuration of seals exist to meet specific requirements. Deviation from the standard limitations provided here should be considered as an indication to explore the possibility of using nonstandard designs (contact Freudenberg-NOK for design assistance). ISO/DIN seal designs and standards are also available, if required.

GENERAL GUIDELINES

A. Determine the general category the seal application falls within (Table 1).

B. Determine if operating conditions exceed the design limits (Table 2).

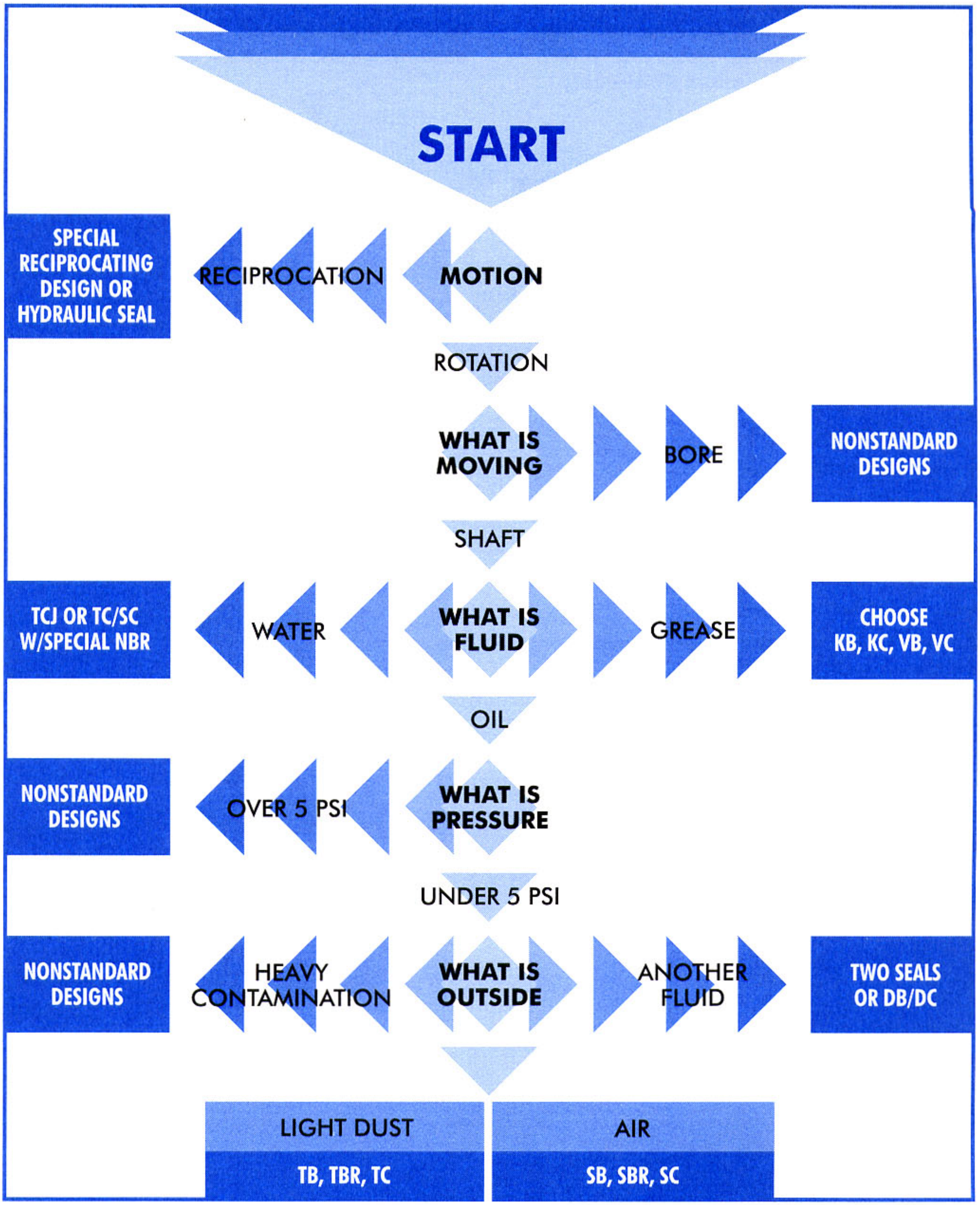
   1. **Shaft Speed**
   2. **Pressure**
   3. **Eccentricity**

C. Select appropriate lip, case and spring material (Table 3). Selection is based on temperature of application, fluid and environment to be sealed and excluded.

D. Review bore and shaft configuration (Table 4) to ensure compatibility with seal.

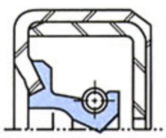
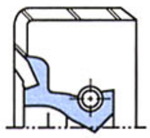
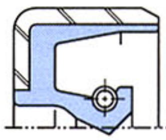
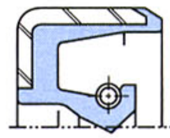
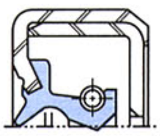
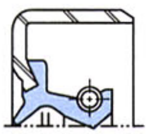
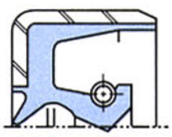
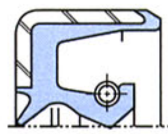
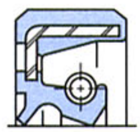
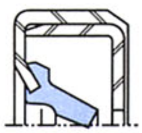
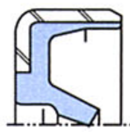
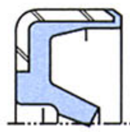
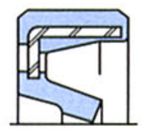
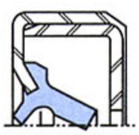
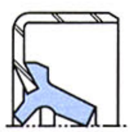
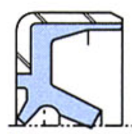
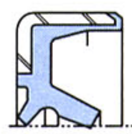
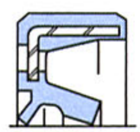
E. If design limits are exceeded, review nonstandard designs and contact Freudenberg-NOK.

SELECTION PROCESS



FREUDENBERG-NOK STANDARD SEAL TYPES

TABLE 1

LIP SYMBOLS \ BODY SYMBOLS		A2	B2	B	BR	C
		Metal O.D. design with an inner case for greater structural rigidity.	Most standardized and economical metal O.D. design.	Metal O.D. design with fluid side rubber covered.	Part rubber/part metal O.D. design for greater O.D. sealing ability.	Rubber O.D. design for excellent O.D. sealing ability.
S	General nonpressure fluid sealing applications and severe grease sealing conditions.	**SA2** 	**SB2** 	**SB** 	**SBR** 	**SC** 
T	General nonpressure fluid sealing applications and severe grease sealing conditions with light duty exclusion of foreign materials.	**TA2** 	**TB2** 	**TB** 	**TBR** 	**TC** 
V	Economical design for grease retention or sealing viscous fluid.	**VA2** 	**VB2** 	**VB** 	**VBR** 	**VC** 
K	Economical design for grease retention or sealing viscous fluid with light duty exclusion of foreign materials.	**KA2** 	**KB2** 	**KB** 	**KBR** 	**KC** 
WP	Dust wiper or scraper for hydraulic or pneumatic cylinder applications			**WPB** 		**WPC** 

NOTE:
Metal O.D. seals are most suitable for steel or cast iron housing materials.

Rubber covered O.D. seals are preferred for soft alloy or plastic housing materials and are suitable as well for steel or cast iron housings. Also, this design category is best for rough bore finishes or for materials with a high coefficient of thermal expansion.

OPERATING CONDITIONS ("S" & "T" CONFIGURATIONS)

TABLE 2 **DESIGN LIMITATIONS**

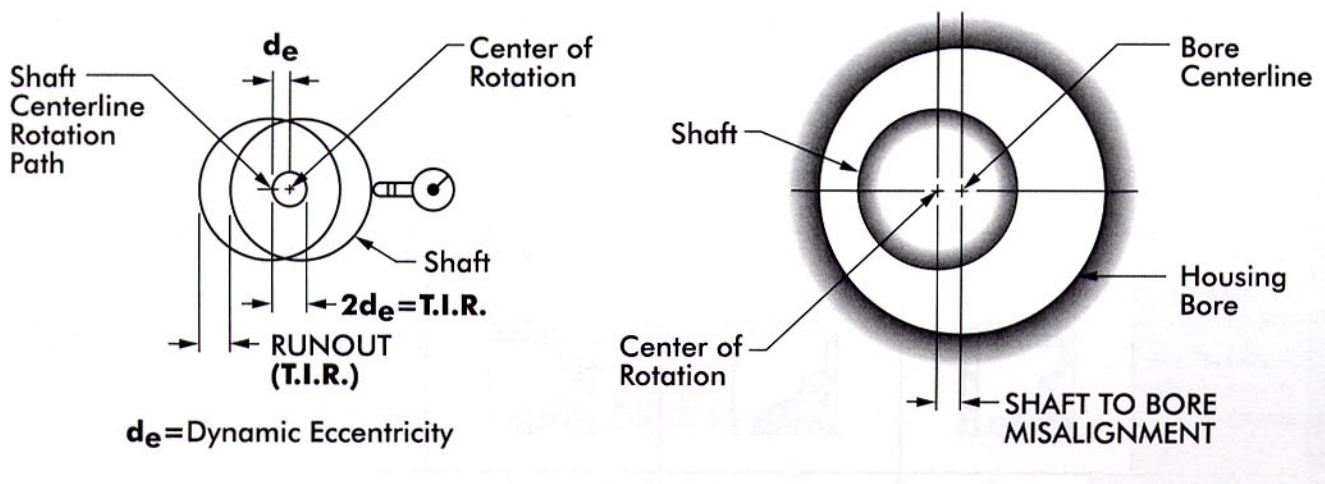
SHAFT DIAMETER	NITRILE LIP MAXIMUM CONTINUOUS SHAFT SPEED	MAXIMUM CONTINUOUS PRESSURE	MAXIMUM TOTAL ECCENTRICITY
General	3,500 rpm	5 psi	.020″
.500	8,000 rpm	5 psi	.004″
1.500	7,000 rpm	5 psi	.006″
2.500	4,500 rpm	5 psi	.010″
3.500	3,800 rpm	5 psi	.013″
4.500	2,750 rpm	5 psi	.017″

NOTE:
Higher shaft speeds possible using higher temperature materials such as polyacrylate, fluoroelastomer or silicone.

Slightly higher continuous pressure is possible for shaft speeds below 200 fpm.

Higher eccentricity is allowable if shaft speed is reduced.

ECCENTRICITY



Eccentricity is determined by measuring the shaft runout, TIR, and the shaft-to-bore misalignment. Combine the two results for the total eccentricity the seal lip must follow to function effectively. As eccentricity increases, and/or shaft speed increases, it becomes more difficult for the lip to follow the shaft.

OPERATING CONDITIONS ("V" & "K" CONFIGURATIONS)

TABLE 3 **DESIGN LIMITATIONS**

SHAFT DIAMETER	MAXIMUM SHAFT SPEED	MAXIMUM CONTINUOUS PRESSURE	MAXIMUM TOTAL ECCENTRICITY
General	2,000 rpm	4 psi	.005"
.500	4,000 rpm	4 psi	.003"
1.500	3,000 rpm	4 psi	.005"
2.500	2,300 rpm	4 psi	.006"
3.500	1,700 rpm	4 psi	.008"
4.500	1,400 rpm	4 psi	.010"

NOTE:
Higher eccentricity is allowable if maximum shaft speed is reduced.

A nonsprung seal design offers a cost effective way to seal high viscosity grease applications. Because the design does not benefit from the constant load of a garter spring, the allowable eccentricity is decreased and the fluids to be sealed are limited.

OPERATING CONDITIONS ("WP" CONFIGURATIONS)

TABLE 4 **DESIGN LIMITATIONS**

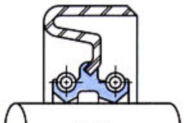
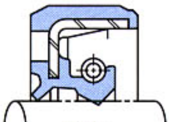
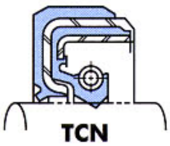
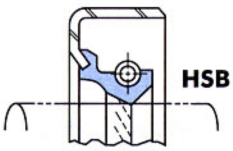
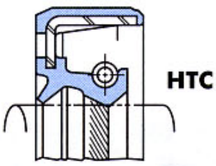
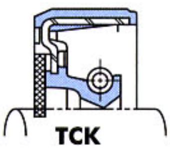
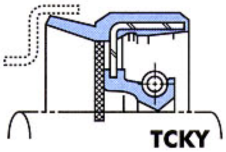
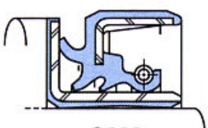
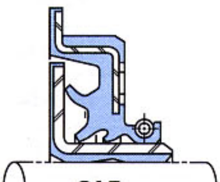
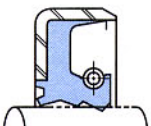
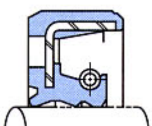
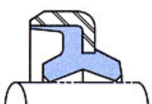
Maximum Shaft Linear Velocity	200 fpm (1 m/sec.)
Maximum Pressure Capability	4 psig (.28 kg/cm^2)
Maximum Stroke Length	78 inches (1.98 m)
Maximum Shaft-To-Bore Misalignment	0.004 inches (0.1 mm) TIR

The "WP" design was developed as a dust wiper (scraper) for reciprocating applications, such as hydraulic cylinder rods. As a result, the operating limits are different from the "V" & "K" type provided above.

NONSTANDARD DESIGNS

TABLE 5

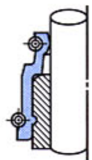
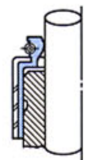
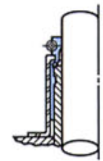
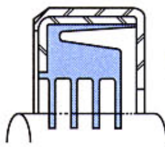
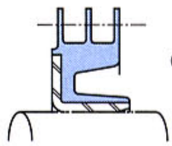
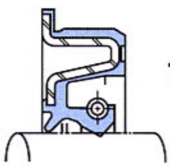
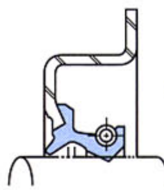
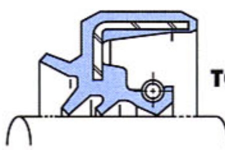
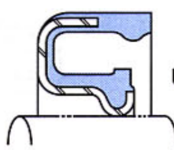
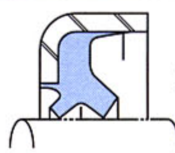
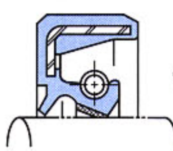
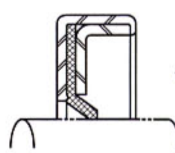
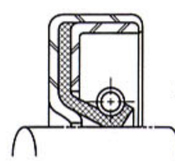
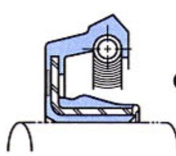
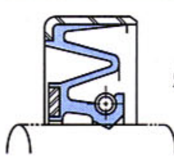
Special applications which cannot be adequately satisfied by standard designs are illustrated on the next two pages.

FREUDENBERG-NOK DESIGN			DESIGN CHARACTERISTICS
"D" Style	 **DB**	 **DC**	Applications which require separating two fluids from each other should use two garter spring loaded lips. The "D" style seal incorporates the two lips into one design. Note: The bore depth must be increased to accommodate the two seal lips.
"TCV" (Medium Pressure)	 **TCV**		For applications up to 50 psi (3.5 kg/cm²), the "TVC" design is recommended. Pressure limit is dependent on shaft speed. Available for shaft diameters less than 2.500" (65 mm).
"TCN" (High Pressure)	 **TCN**		Type "TCN" is designed for high pressure applications where continuous pressure may reach 150 psi (10.6 kg/cm²). Maximum pressure limit is dependent on shaft speed.
"H" Style	 **HSB**	 **HTC**	Hydrodynamic sealing lips are available with most designs. Both unidirectional and bidirectional helical ribs are available. The helical ribs help "pump" the fluid back under the seal lip. Basic lip design is same as standard seal.
"K" (Fabric Auxiliary Lip)	 **TCK**	 **TCKY**	Where dirt or dust ingestion is a problem, the "TCK" design provides superior exclusion. Where dust or dirt and moisture (small quantities of water) mixture are evident, combination with a slinger provides excellent results (TCKY).
"QL" (Sleeve Oil Seals)	 **QLN**	 **QLF**	The "QL" seal is specially designed for mud or very dirty applications. Maximum shaft speed is limited to 10 ft/sec. (3 m/sec.).
"T4" (Reciprocating)	 **TB4**	 **TC4**	Severe reciprocating shaft applications can be effectively sealed by the "T4" design. Pressure up to 100 psi (7 kg/cm²) can be sealed, such as in shock absorbers.
"DK" (Reciprocating)	 **DKH**	 **DKB**	Dust wiper for hydraulic cylinders. Not recommended for pressures above 5 psi (.35 kg/cm²).

NONSTANDARD DESIGNS

For oil seal designs not shown, please contact Freudenberg-NOK for recommended designs to meet your application requirements.

TABLE 5 (cont.)

DESIGN TYPE	APPLICATION	EXAMPLE		
VS	Valve Stem Seals	 VSW	 VSB	 VSB5
V	Special Mud Seals	 Y	 OY	
"5"	Flange Seals	 TC 5	 TB 5	
"9"	Side Lip Seal	 TC 9		
"UJ"	Universal Joint Seals	 UJ	 UJB	
"J"	PTFE Seals	 TCJ	 VAJ	 SA1J
"O"	Rotating Bore	 OC		
"E"	High Shaft Eccentricity	 SBE		

SHAFTS

Seal and shaft compatibility is dependent on four conditions: shaft tolerance, lead-in chamfer, finish and hardness. Proper consideration of these conditions will assist in providing optimal seal performance.

- **SHAFT HARDNESS** is an important factor to prevent excessive wear, deformation, scratches or nicks, and to allow for easy machining for proper roughness. Under normal conditions, **the seal contact area of the shaft should be Rockwell C45 minimum.**

- **SHAFT SURFACE ROUGHNESS** is very important as this greatly influences the amount of lip wear. The recommended roughness is as follows:

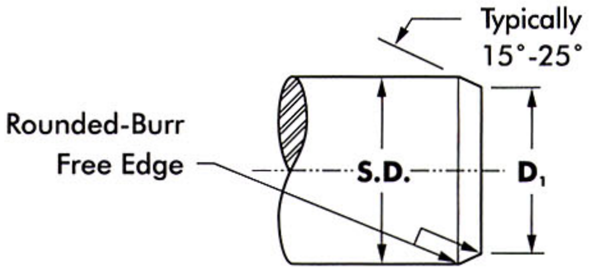
  – Rotating 10 to 20 μ inch Ra (.25 μM to .50 μM Ra): $\mathbf{R_{MAX}}$=31-126 μ inch (0.8-3.2 μM)
  – Reciprocating 5 to 10 μ inch Ra (.13 μM to .25 μM Ra) The method of achieving this finish should not be overlooked.

- **PLUNGE GRINDING** is recommended for rotating shaft applications. For reciprocating applications, centerless grinding is acceptable. Rotating shaft applications require a surface with no machine lead, as machine lead may actually pump fluid from under the seal lip. Also, hard chrome plating is suggested for any cast iron or stainless steel shafts for rotating applications and for steel shafts with reciprocating applications.

- **A SHAFT CHAMFER** is suggested to assist in the installation process. Without a proper chamfer, the seal lip may be damaged or distorted resulting in a dislodged garter spring.

- **SHAFT TOLERANCE** recommendations for general applications are listed in Table 7 below. The tolerance range should be decreased for high speed or pressure applications.

TABLE 6
RECOMMENDED SHAFT CHAMFER



INCHES			
S.D.	**D_1**	**S.D.**	**D_1**
Up to 1.000	S.D. – .094	4.001 to 5.000	S.D. – .220
1.001 to 2.000	S.D. – .140	5.001 to 5.000	S.D. – .260
2.001 to 3.000	S.D. – .166	6.001 to 5.000	S.D. – .276
3.001 to 4.000	S.D. – .196	–	–

MILLIMETERS			
S.D.	**D_1**	**S.D.**	**D_1**
Up to 25.00	S.D. – 2.4	100.01 to 125.00	S.D. – 5.6
25.01 to 50.00	S.D. – 3.6	125.01 to 150.00	S.D. – 6.6
50.01 to 75.00	S.D. – 4.2	150.01 to 250.00	S.D. – 7.0
75.01 to 100.00	S.D. – 5.0	–	–

TABLE 7
RECOMMENDED SHAFT TOLERANCE

SHAFT DIAMETER (INCH)	TOLERANCE	SHAFT DIAMETER (DIN/METRIC)	TOLERANCE
Up to 4.000	±.003	Up to 100 mm	±0.08
4.001 to 6.000	±.004	100.10 to 150.00	±0.10
6.001 to 10.000	±.005	150.10 to 250.00	±0.13

HOUSING RECOMMENDATIONS

HOUSINGS

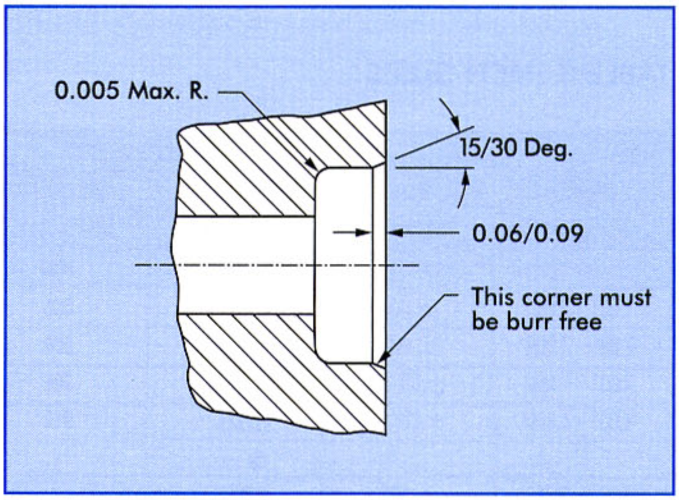
Steel and cast iron provide good surfaces for both rubber covered and metal O.D. seals. For soft alloy (aluminum) bores, rubber covered O.D. seals provide better sealing capability. In aluminum or other soft alloy bores, metal O.D. seals occasionally back out of the bore due to thermal expansion of the soft alloy. Rubber, having a higher coefficient of thermal expansion than carbon steel, will tighten in the bores as temperature rises. Plastic or nylon are not recommended because they typically expand at a high rate causing a major problem for metal O.D. seals. If plastic is to be used, rubber O.D. seals are recommended.

BORE CHAMFER

A bore chamfer is necessary to assist in installation of the seal. To the right is the recommended configuration for the chamfer.

Proper chamfer angle and depth minimizes cocking or lack of squareness of the seal to the shaft, distortion of the seal cases, and reduces assembly force.

RECOMMENDED BORE CHAMFER



SURFACE ROUGHNESS

Excessively rough bore finishes may allow paths for fluid to leak between seal O.D. and bore. Below shows the recommended maximum roughness.

	METAL O.D.	RUBBER O.D.
MAXIMUM ROUGHNESS	100 μM inch Ra	150 μM Ra
	2.50 μM Ra	3.75 μM Ra
	12.5 mm R_{MAX}	
	492 μ inch R_{MAX}	

The rubber O.D. seal is capable of functioning with a rougher finish.

	METAL O.D.	RUBBER O.D.
MAXIMUM ROUGHNESS	None	60 μinch Ra
	None	2.4 μM Ra

A minimum bore roughness is recommended for rubber O.D. seals. This improves retention.

BORE DIAMETER TOLERANCE

The recommended housing bore diameter, bore tolerance and nominal pressfit.

TABLE 8 **INCH SIZES**

BORE DIAMETER	BORE TOLERANCE	NORMAL PRESSFIT		O.D. TOLERANCE (1)		OUT OF ROUND (2)	
		SEALS WITH METAL O.D.	SEALS WITH RUBBER O.D.	SEALS WITH METAL O.D.	SEALS WITH RUBBER O.D.	SEALS WITH METAL O.D.	SEALS WITH RUBBER O.D.
Up to 1.000	±.001	.004	.006	±.002	±.003	.005	.010
1.001 - 2.000	±.001	.004	.006	±.002	±.003	.006	.012
2.001 - 3.000	±.001	.004	.006	±.002	±.003	.006	.014
3.001 - 4.000	±.0015	.005	.008	±.002	±.004	.007	.018
4.001 - 6.000	±.0015	.005	.010	+.003 –.002	±.004	.009	.023
6.001 - 8.000	±.002	.006		+.003 –.002		.012	
8.001 - 9.000	±.002	.007		+.004 –.002		.015	
9.001 - 10.000	±.002	.008		+.004 –.002		.015	

TABLE 9 **EQUIVALENT METRIC SIZES**

BORE DIAMETER	BORE TOLERANCE	NORMAL PRESSFIT		O.D. TOLERANCE (1)		OUT OF ROUND (2)	
		SEALS WITH METAL O.D.	SEALS WITH RUBBER O.D.	SEALS WITH METAL O.D.	SEALS WITH RUBBER O.D.	SEALS WITH METAL O.D.	SEALS WITH RUBBER O.D.
Up to 25.00	±0.025	0.10	0.15	±0.05	±0.08	0.13	0.25
25.01 - 50.00	±0.025	0.10	0.15	±0.05	±0.08	0.15	0.30
50.01 - 75.00	±0.025	0.10	0.15	±0.05	±0.08	0.15	0.36
75.01 - 100.00	±0.038	0.13	0.20	±0.05	±0.10	0.18	0.46
100.01 - 150.00	±0.038	0.13	0.25	+0.08 –0.05	±0.10	0.23	0.58
150.01 - 200.00	±0.051	0.15		+0.08 –0.05		0.30	
200.01 - 225.00	±0.051	0.18		+0.10 –0.05		0.38	
225.01 - 250.00	±0.051	0.20		+0.10 –0.05		0.38	

(1) **Seal O.D.** - The average of a minimum three measurements to be taken at equally spaced positions.

(2) **Out of Round (OOR)** - The maximum variance between any of the readings used in determining seal O.D.

LIP MATERIAL

One of the most important components of the seal is the elastomer material. Freudenberg-NOK has specially developed elastomer blends to meet a wide variety of sealing requirements. Available are many classes of materials with over 100 individual formulas to satisfy various sealing conditions. Table 10 and Table 11 provide general information and fluid compatibility ratings.

TABLE 10 **GENERAL ELASTOMER INFORMATION**

BASE POLYMER	NITRILE	POLYACRYLATE	SILICONE	FLUOROELASTOMER
TEMPERATURE* RANGE	-50°F ~ 250°F -45°C ~ 125°C	-20°F ~ 300°F -30°C ~ 150°C	-80°F ~ 400°F -60°C ~ 200°C	-30°F ~ 400°F -35°C ~ 200°C
Oil Resistance	●	●	■	●
Acid Resistance	■	▲	▲	▲
Alkali Resistance	■	❖	❖	▲
Water Resistance	■	▲	■	■
Heat Resistance	■	●	●	●
Cold Resistance	■	▲	■	▲
Wear Resistance	●	●	■	●
Ozone Resistance	■	●	●	●

	ADVANTAGES	DISADVANTAGES
NITRILE	• Commonly referred to as Buna-N and is Copolymer of Butadiene and Acryonitrile • Low cost • Good resistance to petroleum oils, water, silicone oils, greases, glycol base fluids • Good abrasion resistance, cold flow, tear resistance	• Poor resistance to ozone and weather aging
POLYACRYLATE	• Polymerised acrylic acidesters • Good resistance to mineral oils, hypoid gear oils, E.P. additives, greases, aging and flex cracking • Higher temperature limit than Nitrile	• Fair cold temperature limit • Lower mechanical strength • Costs slightly higher than Nitrile • Poor dry running ability, water resistant
SILICONE	• Broad temperature range • Good ozone resistance • Resistant to compression set	• Low resistance to hydrocarbon fluids like gasoline or paraffin fluids or steam above 50 psi • Cost is higher than Polyacrylate
FLUOROELASTOMER	• Good temperature resistance • Compatible with wide range of fluids • Commonly chosen as high temperature replacement for Nitrile or Polyacrylate	• Fair resistance to water, dry running • Low temperature resistance is fair • Cost is high

* Maximum temperature limits dependent on other operating conditions.

1. ● Very good.
   ■ Good for most applications.
   ▲ Fair, can be used if no other materials available but otherwise not recommended.
   ❖ Not recommended
2. Phosphate Ester and Water Glycol hydraulic fluids are not included in the Table.
3. Water resistance includes steam. No material is ideally compatible as lubricity of water is very poor.
4. PTFE, Ethylene Acrylate, and other elastomers are available.

TABLE 11 **FLUID COMPATIBILITY**

TYPE OF FLUID TO BE SEALED		LIP MATERIAL			
		NITRILE	POLYACRYLATE	SILICONE	FLUOROELASTOMER
Engine Oil	SAE 30 Wt.	●	●	●	●
	SAE 10 Wt.	●	●	■	●
Gear Oil	Super Gear	●	●	▲	●
	Hypoid Gear	■	■	❖	●
Turbine Oil No. 2		■	■	■	●
Machine Oil No. 2		■	■	▲	●
Automatic Transmission Fluid		●	●	▲	●
Petroleum Base Lubricating Oil		●	●	▲	●
Gasoline		▲*	❖	❖	●
Light Oil/Kerosene		▲	❖	❖	■
Cutting Oil		●	■	▲	●
Grease		●	●	●	●
E.P. Lubricants		■	●	❖	●
Water-Glycol		●	❖	■	▲
Alcohol		●	❖	■	▲
20% Hydrochloric Acid Solution		▲	▲	▲	●
30% Sulfuric Acid Solution		▲	▲	❖	●

* Special compound available.

1. ● Very good.
   ■ Good for most applications.
   ▲ Fair, can be used if no other materials available but otherwise not recommended.
   ❖ Not recommended

METAL CASE AND SPRING

The other major components of a seal are the metal case and garter spring. Table 12 lists the material specification Freudenberg-NOK uses for its components.

TABLE 12 **CASE AND SPRING SPECIFICATION**

CASE	
SAE NO.	APPLICATION
1008 ~ 1010	General
30302 ~ 30304	Special Corrosion Resistance Condition

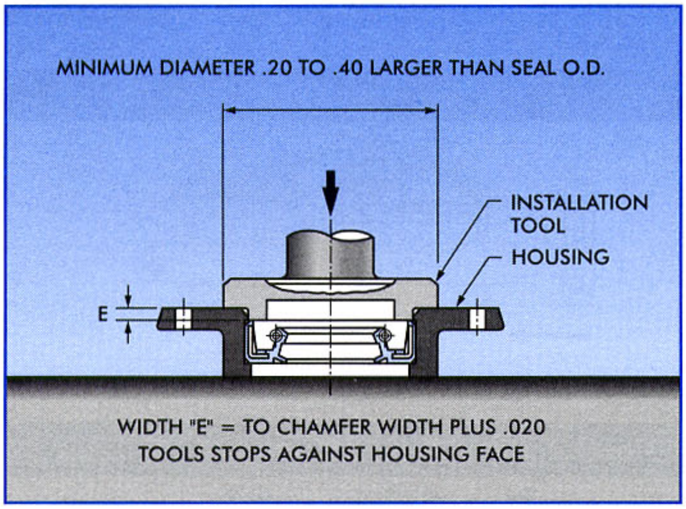
SPRING	
ASTM OR SAE NO.	APPLICATION
A228 ~ A227	General
30302 ~ 30304	Special Corrosion Resistance Condition

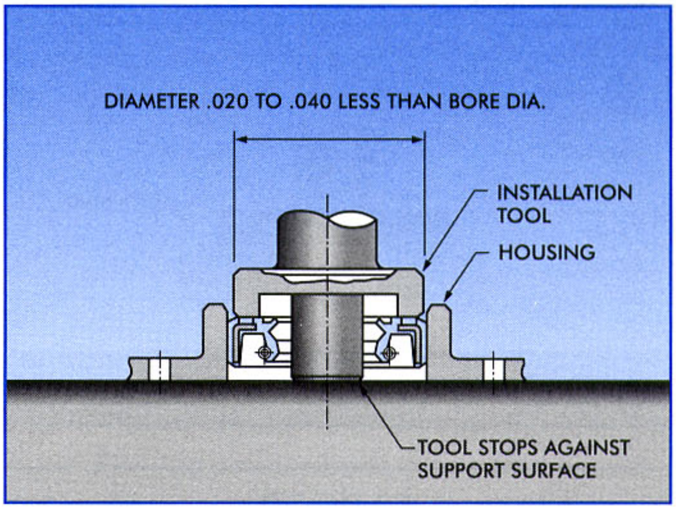
The metal case is produced from carbon steel for general applications in oil or grease. For special applications when sealing sea water or corrosive fluids or gasses, stainless steel can be applied at an increase in price. With water applications, cost may be reduced by using a rubber covered design with carbon steel case. For the garter spring, piano wire is used for general applications. Where corrosion resistance or extreme heat resistance is required, stainless steel is available.

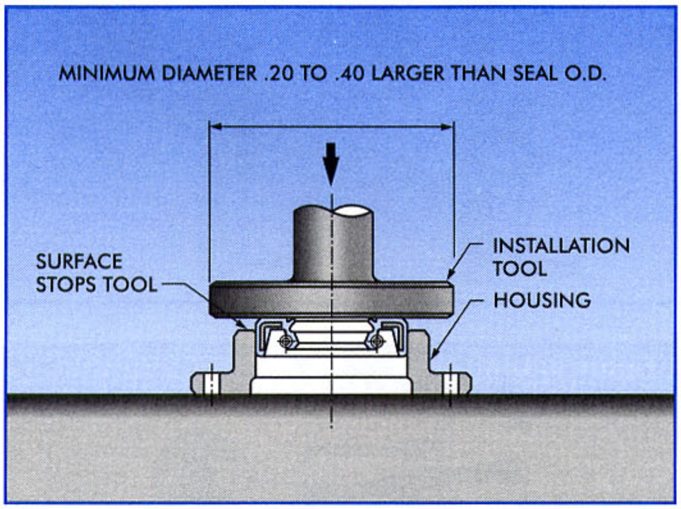
OIL SEAL INSTALLATION PROCEDURES

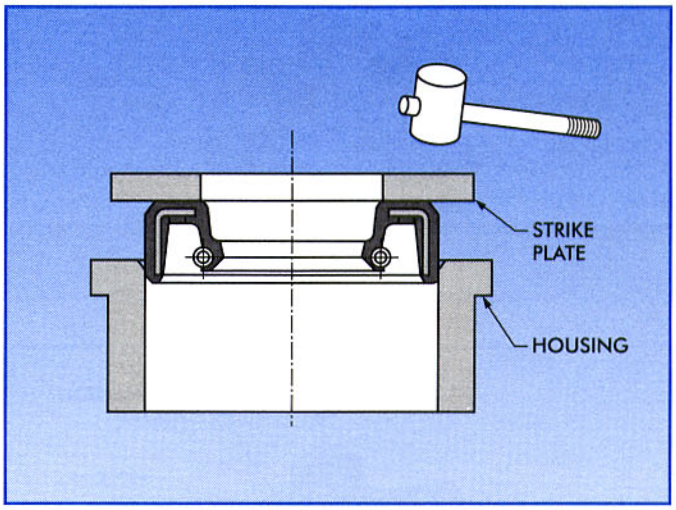
The subject of installation represents an area commonly overlooked when selecting an oil seal for an application. Studies have shown this area to be one of the major causes of premature seal failure. To assist the installation, the seal should be prelubricated with grease or oil to reduce sliding friction of contact surfaces. This will also help protect the seal lips during initial run-in. An installation tool should always be used when installing an oil seal. The use of a tool improves ease of installation and reduces the possibility of seal cocking (non-perpendicular to shaft). A hydraulic or pneumatic press is advised to supply necessary force to install the seal. Following are examples of both recommended and improper installation methods.

ACCEPTABLE METHOD



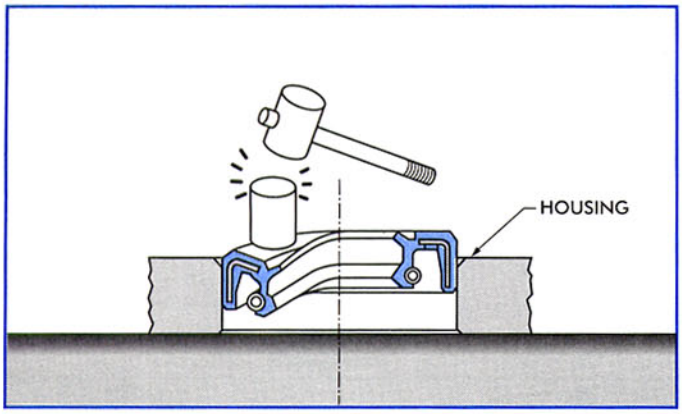


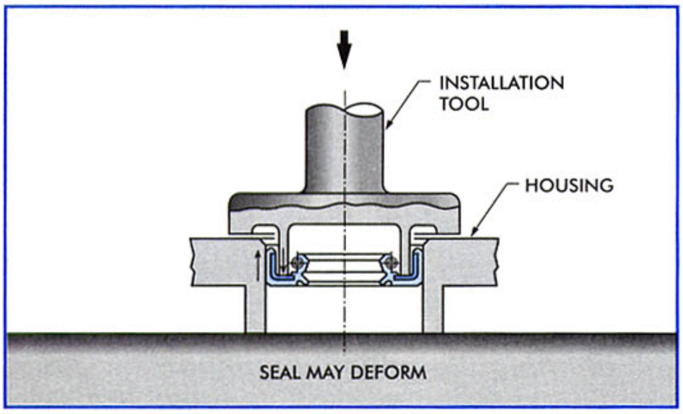


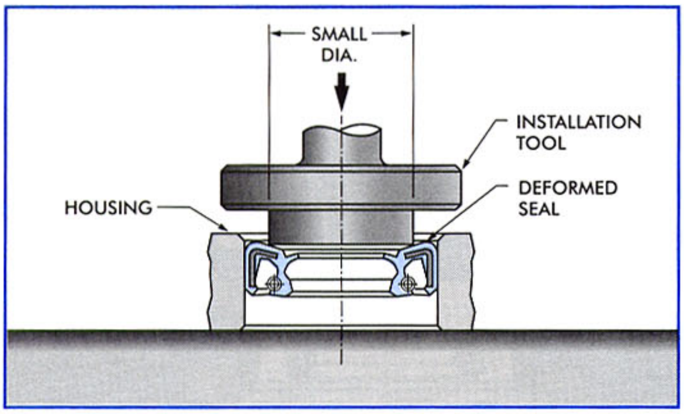


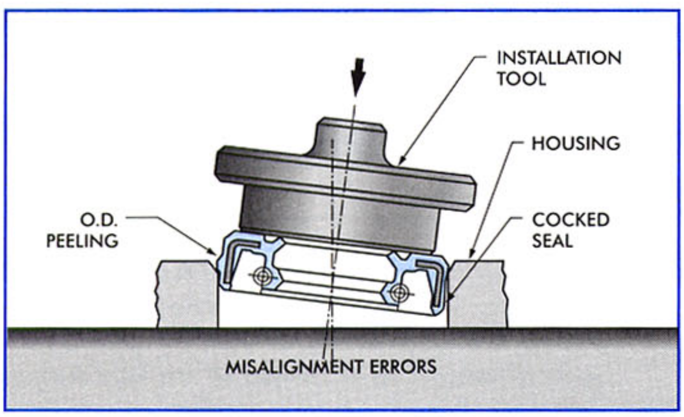
In each preferred method, installation load is absorbed by either housing or bottom plate to prevent seal damage and to assist in locating the seal properly within the bore.

IMPROPER METHOD









SHAFT INSTALLATION

The advisable sequence of installation is to install the seal over the shaft and then into the housing bore. Care should be exercised not to damage or deform the seal lip. The proper chamfer angle will minimize this problem. When installing over a keyway or spine, a sleeve or bullet should be employed to protect the seal lip from cuts (reference figure 6).

Where the shaft must be installed through the seal, centering guides for the shaft will prevent lip deformation and dislodging of the spring. When possible, the shaft should be rotated as it passes through the seal to reduce sliding friction.

Figure 6. Seal Installation Over Shaft Splines

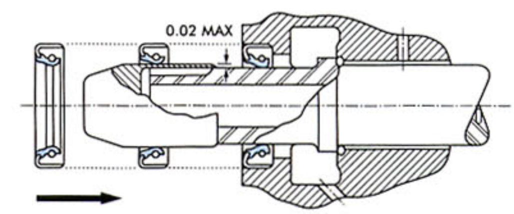


Figure 7. Heavy Weight Housing

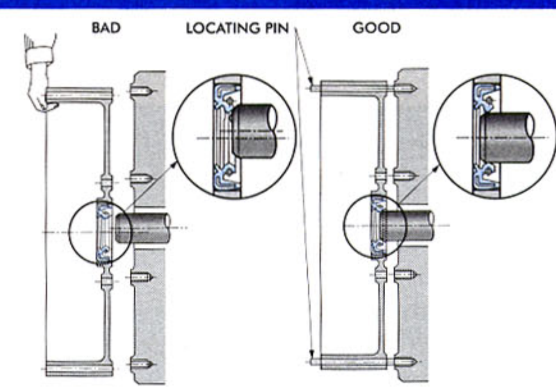


Figure 8. Long Shaft