Materials and Specifications

DICHTOMATIK AMERICAS

General Elastomer Information

Dichtomatik's shaft seals are made from a wide range of materials. Depending upon a customer's application, the material color, durometer, and type can vary. Dichtomatik's standard materials and their specifications are:

Nitrile – Lip Code N (NBR)

NBR is the standard lip material for Dichtomatik's shaft seals. Dichtomatik's standard NBR compound is a 70-durometer black compound – NK701. Nitrile lip seals work well within a temperature range of -40F to 225F (-40C to 107C) and can withstand spikes of up to 250F (121C) for short periods of time. NBR seals are compatible with water and most common mineral oils and greases. NBR seals are recommended for most common applications.

Hydrogenated Nitrile – Lip Code H (HNBR)

HNBR is recommended for higher temperature applications, ranging from -40F to 302F (-40C to 150C). Compared to our standard nitrile compound, HNBR offers improved resistance to fuel, oil, heat, and chemicals. It also has good wear resistance characteristics, which make it well suited to perform in the most severe environments. Dichtomatik's standard HNBR compound is an 80-durometer black compound – HK804.

Polyacrylate – Lip Code P (ACM)

ACM compounds are recommended for higher temperature applications, ranging from -13F to 302F (-25C to 150C). ACM compounds work well with mineral oils and EP additives and greases. However, they offer poor sealing in dry running conditions and typically cost more than NBR seals. Dichtomatik's standard ACM compound is a 70-durometer black compound – PK701.

Silicone – Lip Code S (VMQ)

VMQ compounds offer the widest range of operating temperature conditions ranging from -60F to 390F (-51C to 199C). VMQ compounds do not perform well in dry running conditions and should not be used with EP based compounds and oxidized oils. The abrasion resistance of VMQ compounds is poor, so unless they are going to be used in applications that are operating in cold climates they should be avoided. Dichtomatik's standard VMQ compound is a 70-durometer black compound – SK701.

Fluorocarbon – Lip Code V (FKM)

FKM compounds are premium lip materials offering the highest temperature rating. FKM will handle temperatures ranging from -20F to 400F (-29C to 204C). FKM will resist most special lubricants and chemicals that can destroy NBR, ACM, and VMQ. FKM is extremely resistant to abrasion and provides superior wear and performance characteristics. FKM works in dry running applications, but only for intermittent periods. Dichtomatik's standard FKM compound is an 80-durometer brown compound – VN801.

Table 1: Physical Properties of the Five Major Seal Compounds

	Nitrile	**Hydrogenated Nitrile**	**Polyacrylate**	**Silicone**	**Fluorocarbon**
Compound	(Code N)	(Code H)	(Code P)	(Code S)	(Code V)
	-40F to 225F	-40F to 302F	-13F to 302F	-60F to 390F	-20F to 400F
Temperature Range	-40C to 107C	-40C to 150C	-25C to 150C	-51C to 199C	-29C to 204C
Abrasion Resistance	2	2	3	4	2
Compression Set	2	2	3	2	2
Cracking Resistance	3	2	3	1	2
Cut Growth Resistance	2	2	2	4	4
Flex Cracking Resistance	3	3	3	2	2
Impact Strength	2	1	4	3	3
Oxidation Resistance	2	1	1	1	1
Sunlight Resistance	3	2	1	1	1
Tear Resistance	2	2	4	4	3
Weather Resistance	3	2	1	1	1

Note: 1=Excellent 2=Good 3=Fair 4=Poor

For other available shaft seal materials, contact Dichtomatik Engineering. Material test reports for Dichtomatik's standard materials are on the following pages.

Metal Case and Spring Materials

One of the components of a shaft seal is the metal case. Standard shaft seals are made from a carbon steel metal case. However, if the application involves operating in a corrosive environment or extreme conditions, the metal case can be made out of stainless steel. In addition to the metal case, another component of some seals is a garter spring. A garter spring is included in the seal if it is intended to seal a media with a low viscosity – such as oil. A garter spring is not included with the seal if it is intended to seal a media with a high viscosity – such as grease. Garter springs are typically made from carbon steel, however, they too can be made out of stainless steel if the application requires. All of Dichtomatik's metal cases and springs are made from SAE grade metals as shown in the table below.

Table 2: Specifications of Metal Case and Garter Springs

Standard	SAE No.	Application	Material
Metal Case	1008 - 1010	General Application	Carbon Steel
	30304	Corrosive Environment	Stainless Steel
Garter Spring	1070 - 1090	General Application	Carbon Steel
	30304	Corrosive Environment	Stainless Steel

Material Code

We have now introduced the materials for each specific part of the oil seal. To allow our customers to know what the material is for each component of a seal, Dichtomatik has included a material code with each part. The material code is a 3-digit code that indicates the lip material, the case material, and the spring material in that order. The material codes are designated as shown below.

Lip Material	Case Material	Spring Material	Material Code Example	
N = NBR	C = Carbon Steel	C = Carbon Steel		NBR Lip Material
H = HNBR	S = Stainless Steel	S = Stainless Steel	NCC =	Carbon Steel Case
P = ACM		O = Without Spring		Carbon Steel Spring
S = VMQ				
V = FKM				

For information on material codes that do not appear in the list above, contact your Dichtomatik Sales representative.

Shaft Specifications

Shaft

To achieve the optimum sealing function from a shaft seal, careful consideration must be given to the design parameters of the shaft. Important criteria for the shaft include the material, hardness, finish, eccentricity, tolerance, and rotating speed.

Shaft Material

Shaft seals perform the best when the shaft is made out of a medium to high carbon steel or stainless steel material. If a softer material is used for the shaft, then it is recommended that the shaft be plated with either nickel or chrome to provide a hard sealing surface. If a nickel or chrome plating is not available, typically only seals with a sleeve included in the design will work as the sealing lip would groove the soft material too quickly.

Shaft Hardness

The hardness of the shaft is critical in the area where the sealing lip will be running. If the hardness of the shaft is too soft, the sealing lip will wear a groove into the shaft leading to seal failure and requiring that the shaft be replaced. To minimize shaft grooving, it is recommended that the shaft hardness be a minimum of 45 HRc in the area where the sealing lip(s) will be running. In applications where lubrication is doubtful, abrasive matter is present, or the shaft speed is greater than 46 ft/s (14 m/s), a minimum shaft hardness of 55 HRc is recommended. It is recommended that all shafts be heat treated or nitrided prior to assembly.

Shaft Finish

Shaft finish is a measure of how rough the surface of the shaft is. For a shaft seal to function properly, the shaft finish needs to fall within a certain range. A shaft finish can be measured using several different techniques, the most common of which is Ra and Rz. Ra is the average roughness of the shaft. For a shaft seal to function properly, it is recommended that the Ra shaft finish be 10 to 20 µin (0.2 to 0.8 µm). Rz is the average distance between the highest peak and lowest valley over a certain length. For a shaft seal to function properly, it is recommended that the Rz shaft finish be 39 to 197 µin (1 to 5 µm). To achieve the desired shaft finish, it is recommended that the shaft be centerless ground or plunge ground. After grinding it is important to check for shaft lead. The maximum permissible shaft lead angle is 0±0.05 degrees.

Shaft Eccentricity

Two types of shaft eccentricity affect seal performance. They are dynamic run-out (double dynamic eccentricity) and shaft-to-bore-misalignment (STBM or static eccentricity). Dynamic run-out is the amount in which the shaft is not rotating about its true center. Dynamic run-out is typically caused by the shaft being bent, the shaft being out of balance, or misalignment caused during assembly. STBM is the amount in which the center of the shaft is off from the center of the bore. STBM is typically caused by machining and assembly issues.

The greater that the eccentricity is in an application, the harder it is for the sealing lip to remain in contact with the shaft while it is rotating. If an application has high eccentricity, then a special seal will need to be designed to allow the sealing lip to follow the shaft during rotation. The allowable dynamic run-out and shaft-to-bore-misalignment for an application is shown in the following two figures.

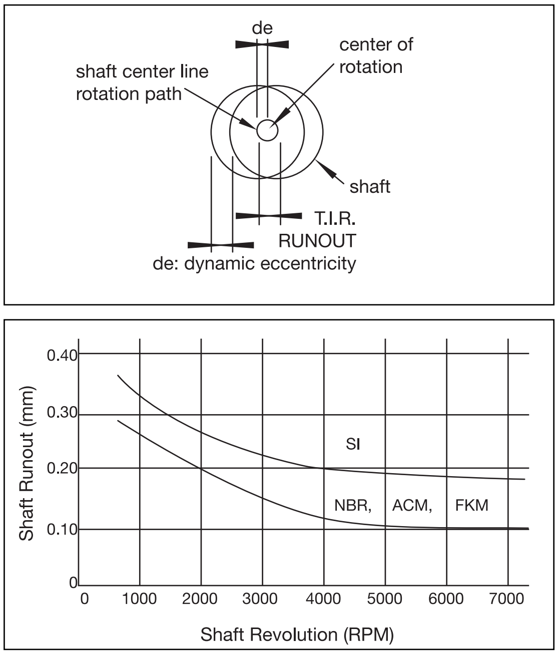

Figure 1: Dynamic Runout

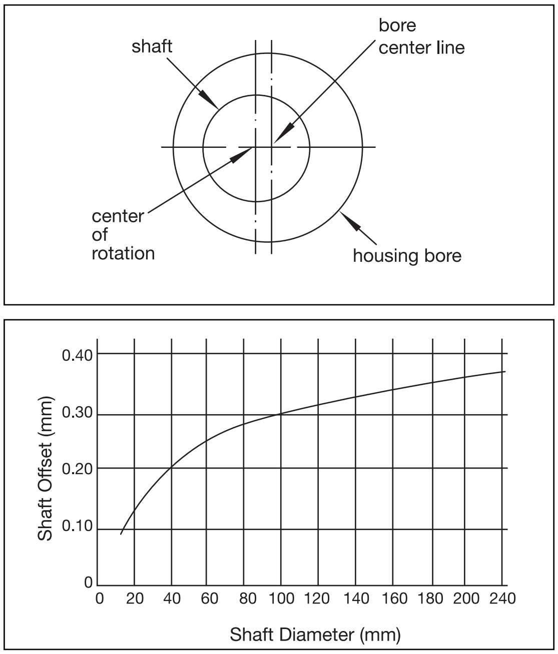

Figure 2: Shaft-To-Bore-Misalignment

Shaft Specifications

Shaft Tolerance

When creating a shaft, it is important to ensure that it is dimensioned properly. The part of the shaft where the seal will be operating should be dimensioned per the Rubber Manufacturer Association's (RMA) or the German Institute for Standardization's (DIN) standards. Dichtomatik's inch shaft seals are designed to operate on shafts that are dimensioned per RMA's standard, whereas Dichtomatik's metric seals are designed to operate on shafts that are dimensioned per DIN's standard. Tables 3 and 4 show the tolerance standards developed by RMA and DIN.

Table 3: Tolerance for Inch Shafts

Nominal Shaft Diameter (in)	Tolerance (in)
up to 4.000	+/- 0.003
4.001 to 6.000	+/- 0.004
6.001 to 10.000	+/- 0.005
over 10.000	+/- 0.006

Table 4: Tolerance for Metric Shafts

Nominal Shaft Diameter (mm)	Tolerance (mm)
up to 3.00	+0.000 / -0.060
3.01 to 6.00	+0.000 / -0.075
6.01 to 10.00	+0.000 / -0.090
10.01 to 18.00	+0.000 / -0.110
18.01 to 30.00	+0.000 / -0.130
30.01 to 50.00	+0.000 / -0.160
50.01 to 80.00	+0.000 / -0.190
80.00 to 120.00	+0.000 / -0.220
120.01 to 180.00	+0.000 / -0.250
180.01 to 250.00	+0.000 / -0.290
250.01 to 315.00	+0.000 / -0.320
315.01 to 400.00	+0.000 / -0.360
400.01 to 500.00	+0.000 / -0.400

Shaft Speed

The speed that the shaft is rotating is important when determining the appropriate lip material for the seal as each material will only function under certain operating speeds. Most often shaft speeds are given in rotations per minute (RPM). However, sometimes they may be given in feet per minute (FPM) or meters per minute (MPM). Below are conversions to convert between the standards.

FPM = Shaft Diameter in inches x RPM x 0.262
MPM = Shaft Diameter in mm x RPM x 0.001 x 3.125

To determine which material is appropriate for a given shaft speed, the following chart is to be used. This chart is only applicable in non-pressure applications. If pressure is present in an application, contact Dichtomatik Engineering to determine the appropriate material to use for the sealing lip.

For example, what would the maximum allowable shaft speed be for a shaft diameter of 60mm and a shaft seal that is made out of NBR? First, start by locating the shaft diameter along the bottom axis of the figure. Next, follow the shaft diameter line vertically to the curved line that is above the material that the seal is made out of. Then, follow the curved line to the right until the next intersection point with an angled line. Finally, follow that angled line to the shaft speed, which will be the maximum allowable shaft speed. So, for a 60mm shaft diameter and a seal made out of NBR the maximum allowable shaft speed is 2,500 RPM (1,547 FPM).

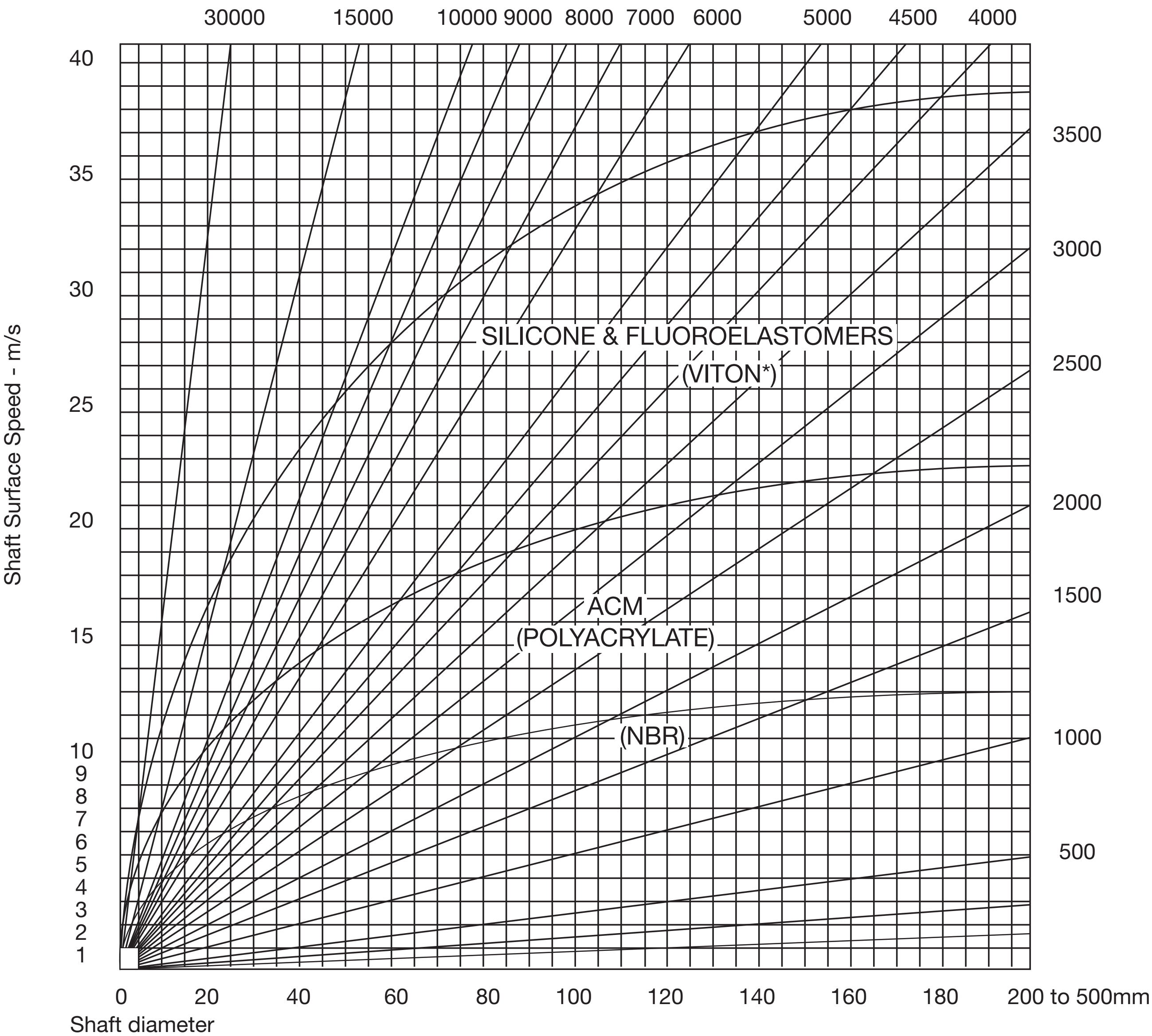

Figure 3: Shaft Speeds for Seal Materials

*Viton is a registered trademark of DuPont.

Housing Specifications

Housing

To achieve the optimum O.D. sealing function from a shaft seal, careful consideration must be given to the design parameters of the housing. Important criteria for the housing include the material, finish, and tolerance.

Housing Material

The material that the housing is made out of will determine the O.D. style of the seal. If the housing is made out of a hard material, such as steel or cast iron, then the O.D. of the seal can be either metal or rubber. However, if the housing is made out of a soft material, such as aluminum or plastic, then a rubber O.D. seal will need to be used so that the housing doesn't get scratched or gouged by the seal during installation.

Housing Finish

Housing finish is a measure of how rough the surface of the housing is. For a seal to function properly, the housing finish needs to fall within a certain range depending on the style of the seal O.D. For a metal O.D. seal, the housing finish is to be 32 to 64 μin Ra (0.8 to 1.6 μm Ra). If a rubber O.D. seal is being used, then the housing finish needs to be rougher to allow for the rubber to grip the housing better. For a rubber O.D. seal, the housing finish is to be 100 to 200 μin Ra (3 to 5 μm Ra).

Housing Tolerance

When creating a housing, it is important to ensure that it is dimensioned properly. The part of the housing where the seal will be installed should be dimensioned per the RMA or DIN standards. Dichtomatik's inch shaft seals are designed to operate in housings that are dimensioned per RMA's standard, whereas Dichtomatik's metric seals are designed to operate in housings that are dimensioned per DIN's standard. Tables 5 and 6 show the tolerance standards developed by RMA and DIN.

Table 5: Tolerance for Metric Bores

Nominal Housing Diameter (mm)	Tolerance (mm)
up to 10.00	+0.022 / -0.000
6.01 to 18.00	+0.027 / -0.000
18.01 to 30.00	+0.033 / -0.000
30.01 to 50.00	+0.039 / -0.000
50.01 to 80.00	+0.046 / -0.000
80.01 to 120.00	+0.054 / -0.000
120.01 to 180.00	+0.063 / -0.000
180.01 to 250.00	+0.072 / -0.000
250.01 to 315.00	+0.081 / -0.000
315.01 to 400.00	+0.089 / -0.000
400.01 to 500.00	+0.097 / -0.000

Table 6: Tolerance for Inch Bores

Nominal Housing Diameter (in)	Tolerance (in)
up to 3.000	+/- 0.001
3.001 to 6.000	+/- 0.0015
6.001 to 10.000	+/- 0.002
10.001 to 20.000	+0.002 / -0.004
20.001 to 40.000	+0.002 / -0.006
40.001 to 60.000	+0.002 / -0.010

Shaft and Housing Chamfer

In addition to the shaft and housing criteria previously discussed, it is also important to ensure that both the shaft and housing have a burr free chamfer or radius on the edge in which the seal will be installed past.

Housing Chamfer

The chamfer on the housing serves two purposes. First, it helps to align the seal during the installation process. Secondly, if the seal has a rubber O.D. it acts as a way to protect the rubber from being cut during installation. The housing chamfer should have an angle of 15 to 30 degrees. The depth of the housing chamfer is determined based upon the following equations and the figure below.

$$t_1 = 0.85 * b$$

$$t_2 = b + 0.03 mm$$

Shaft Chamfer

The chamfer on the shaft serves two purposes. First, it helps to reduce the risk of cutting the sealing lip during installation. Secondly, it acts as an aid to slowly stretch the sealing lip over the shaft. By slowly stretching the lip there is less of a chance that the garter spring will be dislodged during seal installation. The shaft chamfer should have an angle of 15 to 25 degrees. Another option on the shaft is to radius the edge instead of including a chamfer. If a radius is to be used on a shaft, it is recommended that the radius be a minimum of 0.024in (0.60mm) for a single lip style seal and a minimum of 0.039in (1.00mm) for a twin lip style seal. The depth of the shaft chamfer is determined by the table below.

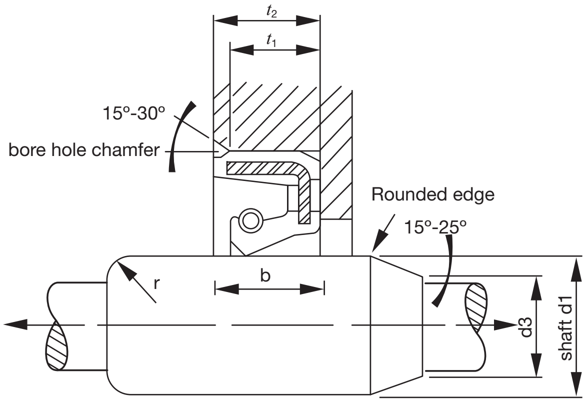

Figure 4: Shaft and Housing Chamfers

Table 7: Shaft Chamfer Dimensions

d1 (mm)	d3 (mm)	d1 (mm)	d3 (mm)	d1 (mm)	d3 (mm)	d1 (mm)	d3 (mm)	d1 (mm)	d3 (mm)
6.00	4.80	26.00	23.40	60.00	56.10	115.00	109.60	240.00	233.00
7.00	5.70	27.00	25.30	62.00	58.10	120.00	114.50	250.00	243.00
8.00	6.60	30.00	27.30	63.00	59.10	125.00	119.40	260.00	249.00
9.00	7.50	32.00	29.20	65.00	61.00	130.00	124.30	280.00	269.00
10.00	8.40	35.00	32.00	68.00	63.90	135.00	129.20	300.00	289.00
11.00	9.30	36.00	33.00	70.00	65.80	140.00	133.00	320.00	309.00
12.00	10.20	38.00	34.90	72.00	67.70	145.00	138.00	340.00	329.00
14.00	12.10	40.00	36.80	75.00	70.70	150.00	143.00	360.00	349.00
15.00	13.10	42.00	38.70	78.00	73.60	160.00	153.00	380.00	369.00
16.00	14.00	45.00	41.60	80.00	75.50	170.00	163.00	400.00	389.00
17.00	14.90	48.00	44.50	85.00	80.40	180.00	173.00	420.00	409.00
18.00	15.80	50.00	46.40	90.00	85.30	190.00	183.00	440.00	429.00
20.00	17.70	52.00	48.30	95.00	90.10	200.00	193.00	460.00	449.00
22.00	19.60	55.00	51.30	100.00	95.00	210.00	203.00	480.00	469.00
24.00	21.50	56.00	52.30	105.00	99.90	220.00	213.00	500.00	489.00
25.00	22.50	58.00	54.20	110.00	104.70	230.00	223.00		

Seal Tolerances and Press-Fits

Seal Tolerances

When designing an application for an oil seal, it is important to take into consideration the tolerances that the oil seal will be manufactured to. The table below shows the RMA standard tolerance for the width of an oil seal.

Table 8: Seal Width Tolerances

Unit	Width Range	Tolerance
in	all	+/-0.015
mm	up to 10	+/-0.20
	over 10	+/-0.30

It is important to realize that the shaft and bore dimensions that are provided in the back of this catalog with each part number are the actual shaft and bore diameters, not the I.D. and O.D. of the seal. To determine the actual O.D. of the seal the press-fit needs to be considered. When installing an oil seal into a housing, there is a pre-determined amount of press-fit that has been designed into the O.D. of the oil seal. This press-fit is what provides an interference between the O.D. of the oil seal and the housing, thus prohibiting the oil seal from slipping out of the housing. The tables below show the standard press-fit for inch and metric oil seals. Also, the tolerance of the O.D. of the seal is shown.

For example, the actual O.D. of a rubber covered seal for a 2.500" diameter bore is going to be 2.508 +/-0.003". This means that the seal will have an interference with the bore of between 0.005" to 0.011".

Table 9: Seal Press-Fits and O.D. Tolerances for Inch Seals

Bore Diameter (in)	Press-fit Recommendation (in)		Tolerance (in)	
	Metal Case	Rubber Covered Case	Metal Case	Rubber Covered Case
up to 1.000	+ 0.004	+ 0.006	+/- 0.002	+/- 0.003
1.001 to 2.000	+ 0.004	+ 0.007	+/- 0.002	+/- 0.003
2.001 to 3.000	+ 0.004	+ 0.008	+/- 0.002	+/- 0.003
3.001 to 4.000	+ 0.005	+ 0.010	+/- 0.002	+/- 0.004
4.001 to 6.000	+ 0.005	+ 0.010	+ 0.003 / - 0.002	+/- 0.004
6.001 to 8.000	+ 0.006	+ 0.010	+ 0.003 / - 0.002	+/- 0.004
8.001 to 10.000	+ 0.008	+ 0.010	+ 0.004 / - 0.002	+/- 0.004
10.001 to 20.000	+ 0.008	+ 0.010	+ 0.006 / - 0.002	+/- 0.004
20.001 to 40.000	+ 0.008	+ 0.010	+ 0.008 / - 0.002	+/- 0.004
40.001 to 60.000	+ 0.008	+ 0.010	+ 0.010 / - 0.002	+/- 0.004

Table 10: Seal Press-Fits for Metric Seals

Bore Diameter (mm)	Press-fit Recommendation (mm)	
	Metal Case	Rubber Covered Case
up to 50.00	+0.10 / +0.20	+0.15 / +0.30
50.01 to 80.00	+0.13 / +0.23	+0.20 / +0.35
80.01 to 120.00	+0.15 / +0.25	+0.20 / +0.35
120.01 to 180.00	+0.18 / +0.28	+0.25 / +0.45
180.01 to 300.00	+0.20 / +0.30	+0.25 / +0.45
300.01 to 500.00	+0.23 / +0.35	+0.30 / +0.55

Lubrication

Prior to installing an oil seal onto a shaft, lubrication must be considered. Efficient lubrication of the sealing lip will ensure minimum lip wear along with the maximum life and efficiency of the seal. For this reason, greasing or oiling of both the seal and shaft must be done prior to installation of the seal. By greasing or oiling the seal and shaft you ensure that the sealing lip will not be running dry.

There are two important things to note about lubricating a seal. First, it is important that a rubber oil seal never be allowed to run dry. Second, it is important to note that during the bedding-in period of an oil seal, it is possible for minor oil weeping to occur.

Another recommended practice is to apply a coating of the application media to be retained by the oil seal to the lip(s) on the oil seal prior to installing the seal. This will help to reduce the friction when sliding the seal onto the shaft and to keep the lip(s) lubricated during the bedding-in period.

The figure below shows an example of where to pack grease on a dual lip seal prior to installing the seal on the shaft. By packing the void between the two lips with grease you are ensuring sufficient lubrication for the seal.

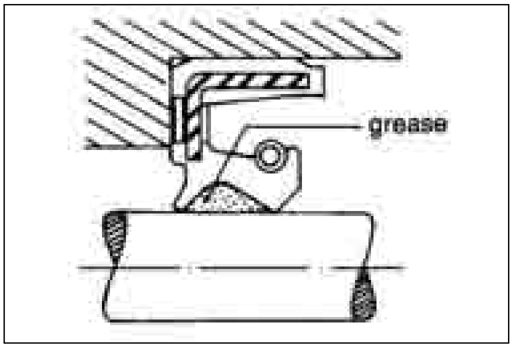

Figure 5: Lubricating a Dual Lip Seal

The figure below shows an example of where grease should be packed if redundant seals are being installed into an application. When redundant seals are being used, typically only the seal nearest to the bearing will be lubricated, meaning that the outside seal will be running dry. To prohibit the outside seal from running dry and increase its sealing efficiency, it is recommended that grease be packed between the two seals.

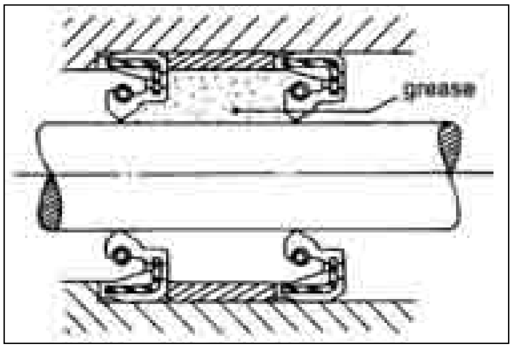

Figure 6: Lubricating Redundant Seals

Recommended Installation Methods

When installing a shaft seal onto a shaft and into a housing there are proper and improper techniques to use. When installing a seal onto a shaft with a key-way or spline, the recommended practice is to place an installation bullet over the shaft. By placing a bullet over the shaft, the sealing lip(s) won't get cut on the edges of the key-way or spline during installation. Another technique is to us an oil seal installation tool. By using an installation tool you reduce the odds of deforming the seal during installation.

Prior to installing the oil seal, be sure that the seal has been properly lubricated. For proper lubrication techniques see Lubrication section.

Below are several illustrations showing the recommended methods for installing shaft seals.

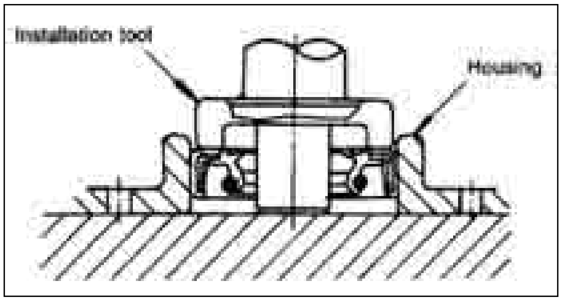

Figure 7: Tool Stops Against Support

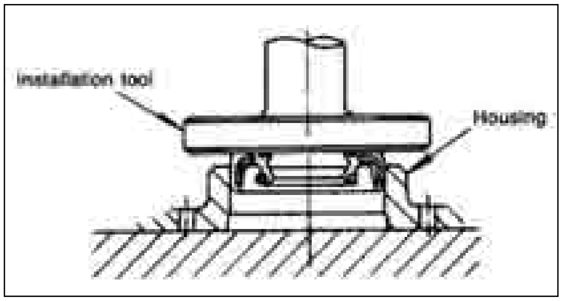

Figure 8: Tool Stops Against Housing Face

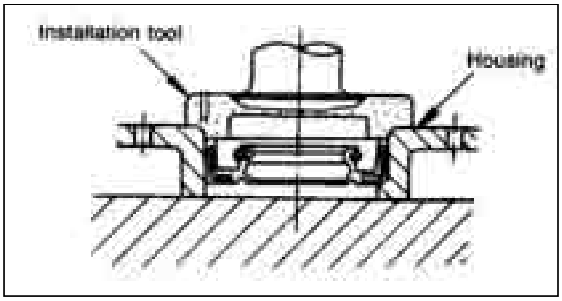

Figure 9: Tool Stops Against Housing Face

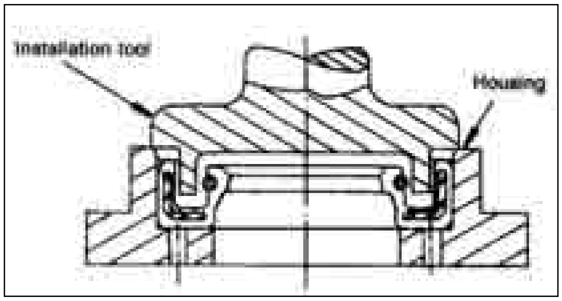

Figure 10: Tool Stops Against Housing

Improper Installation Methods

When installing a shaft seal it is important to make sure it is installed properly. Improper installation can cause the seal to become damaged or cocked, both of which will cause the seal to either leak immediately or have a decreased sealing life.

Below are several illustrations showing improper techniques to use when installing a shaft seal.

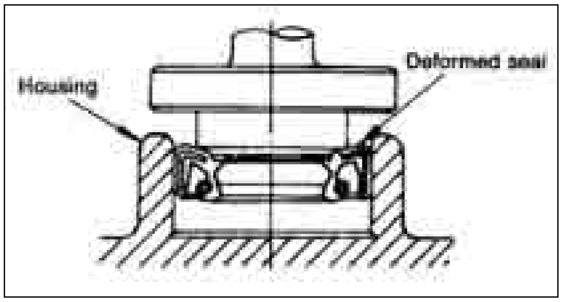

Figure 11: Deformed Seal

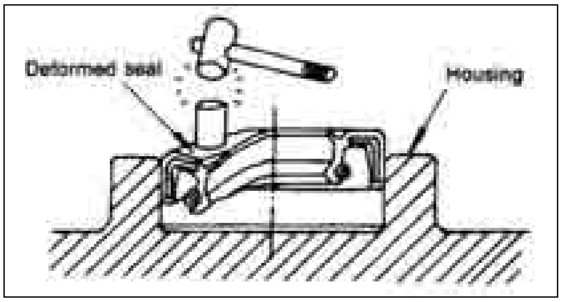

Figure 12: Deformed Seal

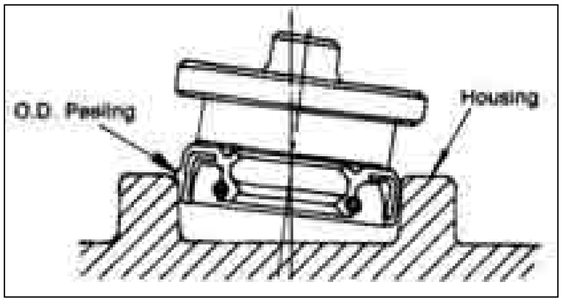

Figure 13: Misalignment Error

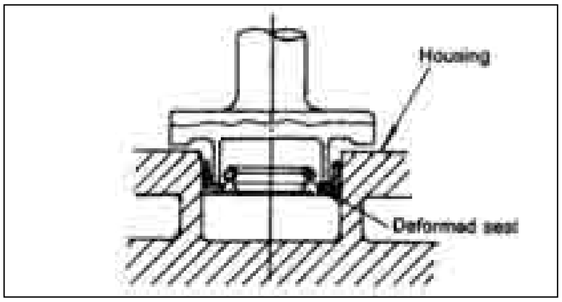

Figure 14: Deformed Seal

If you are not sure of the correct method to use when installing a shaft seal, contact Dichtomatik Engineering. The engineering department can recommend correct practices, as well as create installation tool drawings for your application.