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.

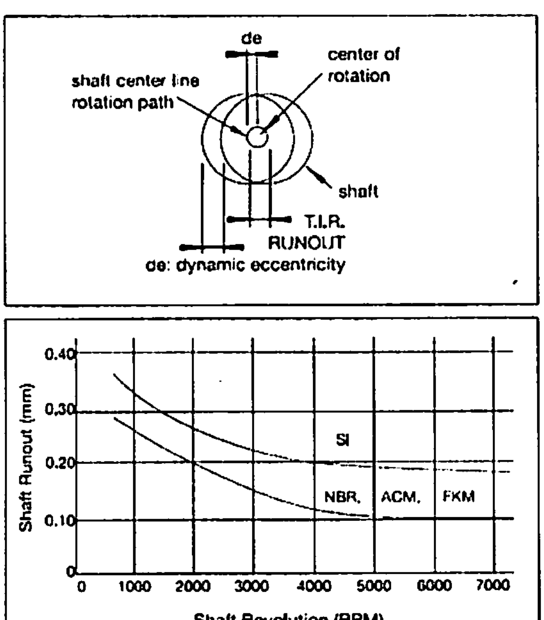

Figure 1: Dynamic Runout

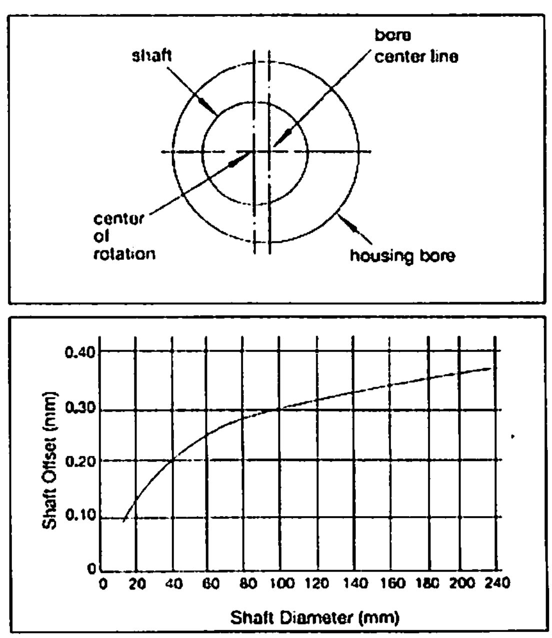

Figure 2: Shaft-To-Bore-Misalignment

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.

Shaft Specifications

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).

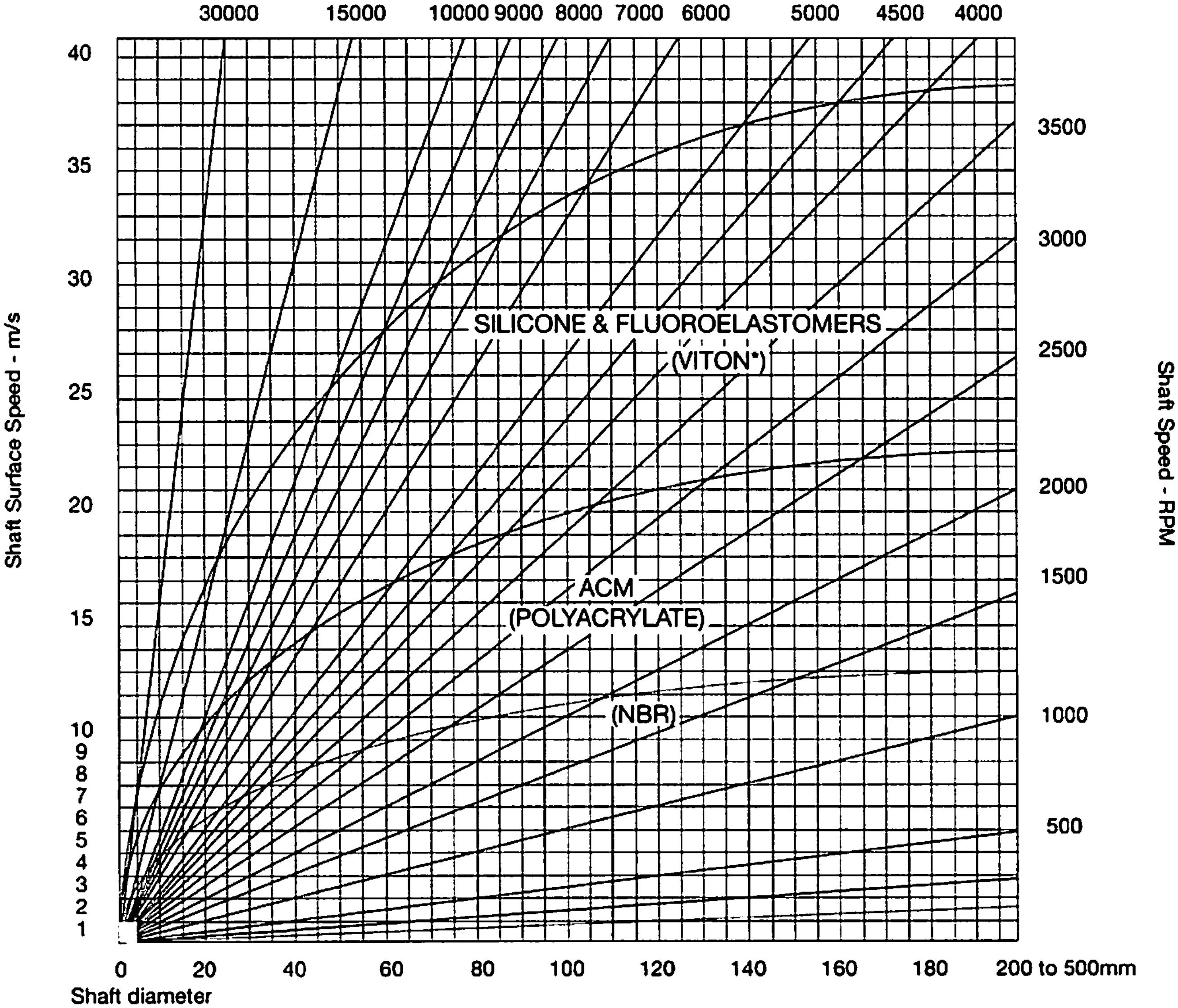

Figure 3: Shaft Speeds for Seal Materials

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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

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.

$$t_1 = 0.85^* b$$
$$t_2 = b + 0.03mm$$

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.

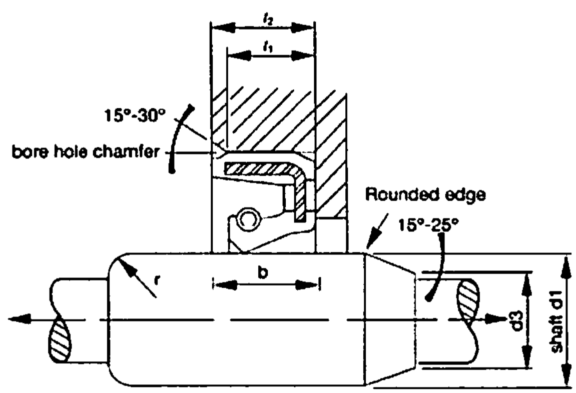

Figure 4: Shaft and Housing Chamfers

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		

Shaft Specifications

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).

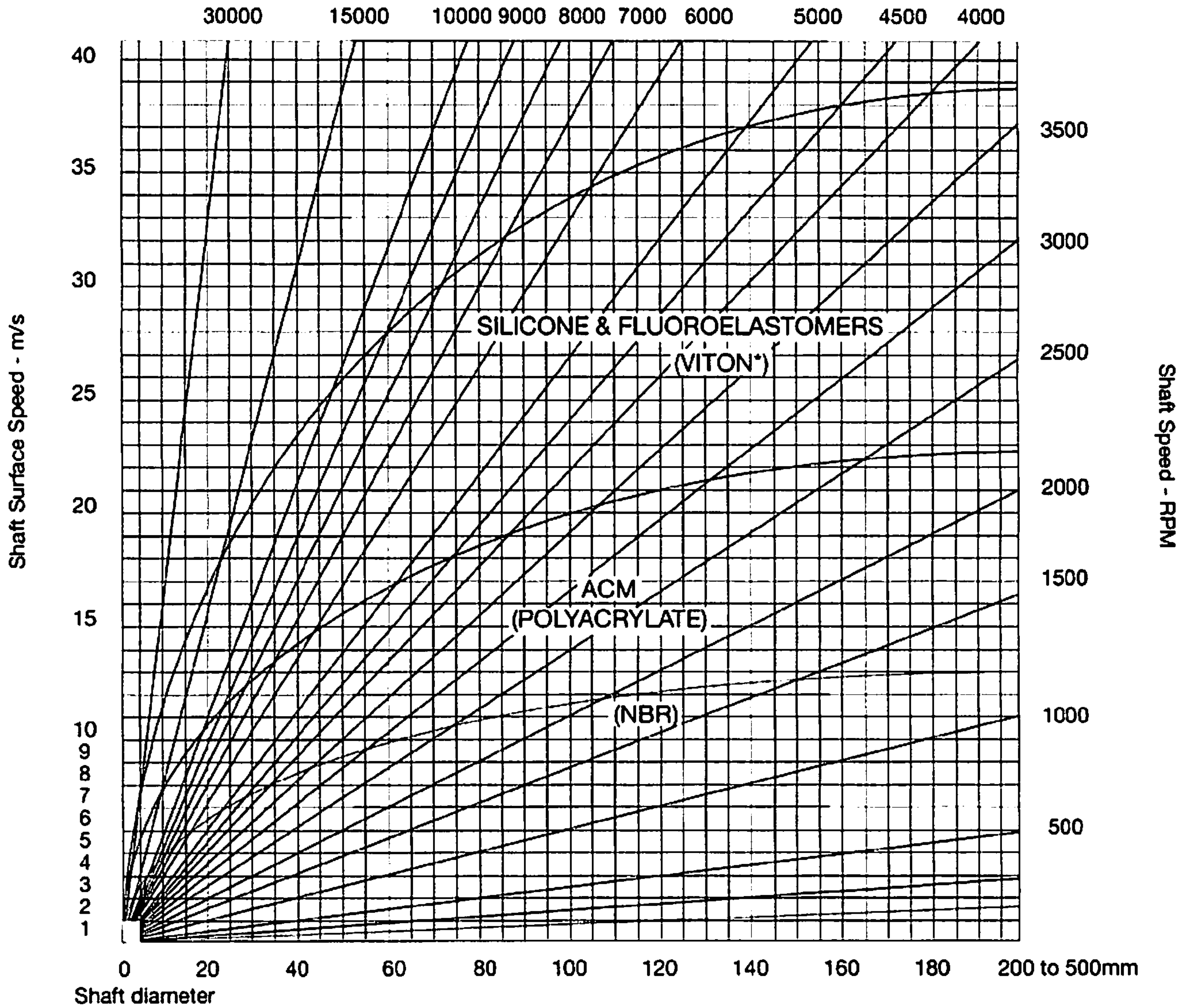

Figure 3: Shaft Speeds for Seal Materials

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