OIL SEALS

NOK CORPORATION

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What Is An Oil Seal?

In this Catalog, both the International System of Units(SI) and the conventional system of units are used.

A. WHAT IS AN OIL SEAL?

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Simply stated, oil seals are components of a machine that seal lubricants.
Lubricants are used in the friction-producing areas of a machine to ensure smooth movement and long life, and oil seals are used to prevent this lubricant from leaking through "bearing clearances" of the machine. With advances in mechanical engineering, it has become necessary to prevent the leakage of not only lubricants but also water or chemicals, as well as preventing the entry of dust and dirt into the machine. Oil seals are used to perform both functions.

O rings, lip packings, gland packings, and mechanical seals function in similar ways to oil seals, as shown in **Figure 1**. Oil seals are most often used in rotating shaft applications.

The function of an oil seal is easily understood by examining a familiar example:the automobile. **Figure 2** shows oil seals used in automobile engines. In such engines, the reciprocating motion of the pistons is converted into the rotary motion of the crankshaft by the connecting rods. The crankshaft is supported by metal bearings. To lubricate these metal bearings, and other areas where metal and metal slide against each other, engine oil is filled in the oil pan. Since the oil pan is secured to the crank case, "bearing clearance" is needed between the fixed crank case and the rotating crankshaft. An oil seal is a sealing device that prevents the leakage of engine oil from the bearing clearance between the rotating crankshaft and crankcase, or the bearing clearance between a reciprocating shaft and crankcase.

Figure 3 shows oil seals typically used in a geared motor.

Figure 1: Seal Classifications

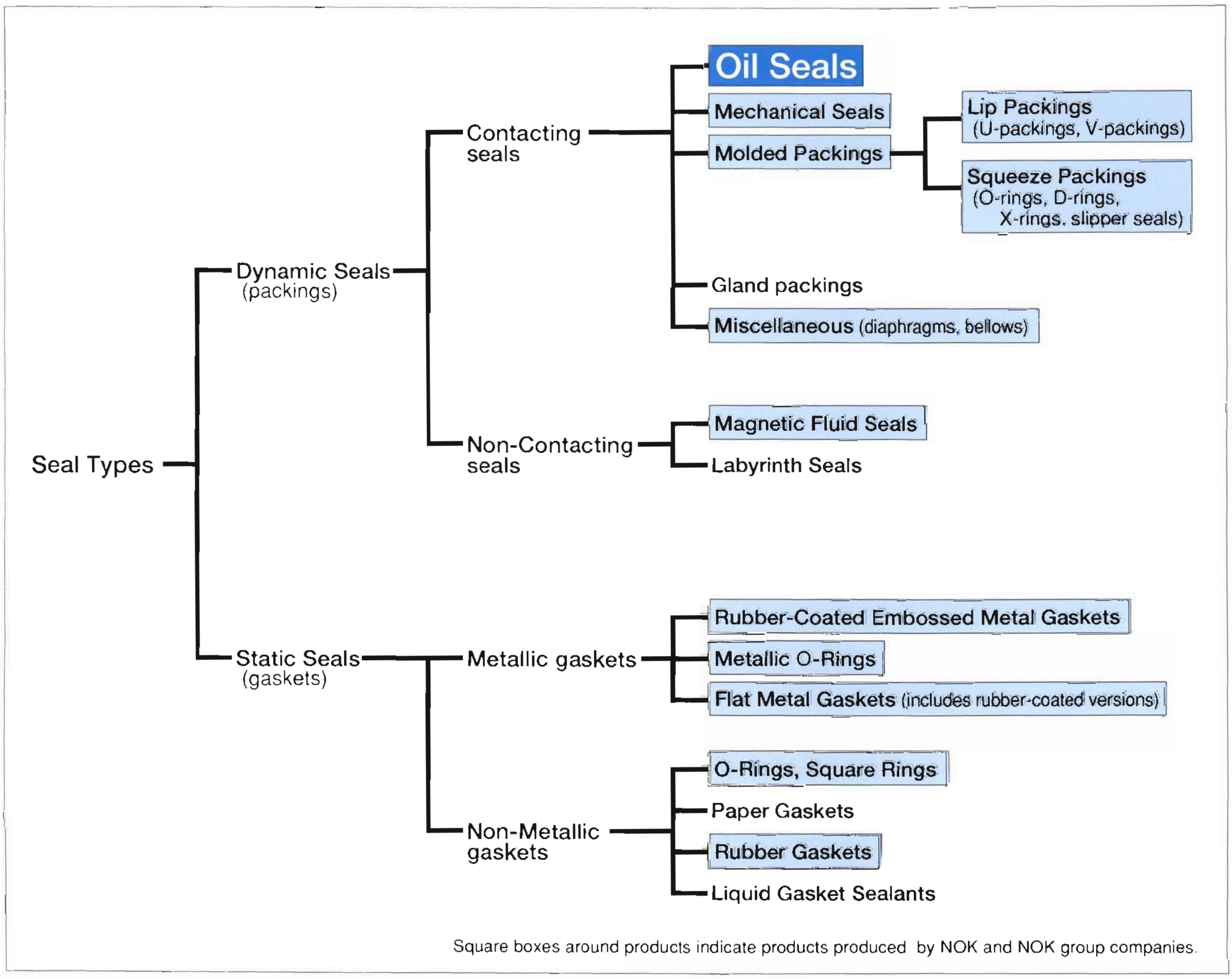


Figure 2: Oil Seals in a Typical Engine Application

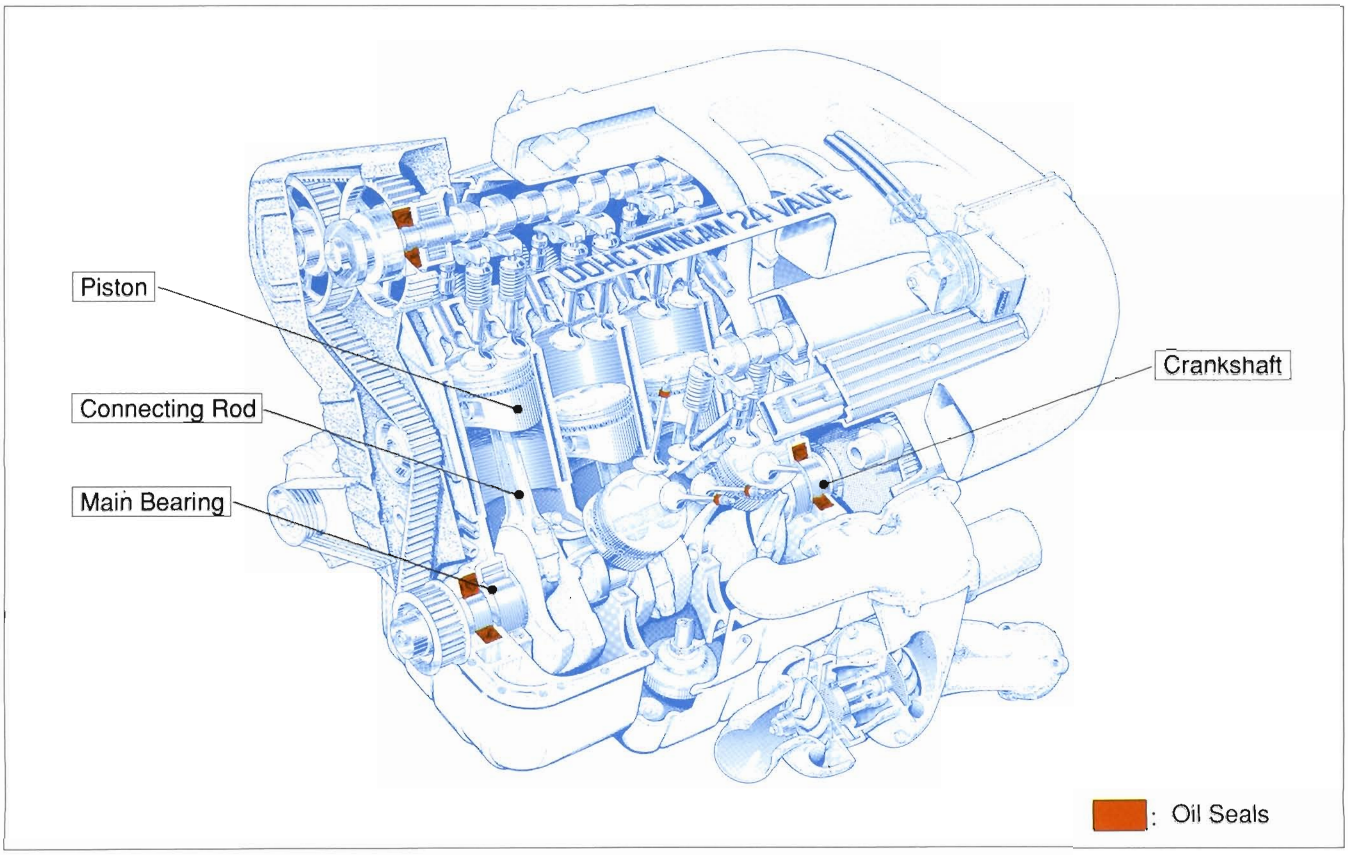
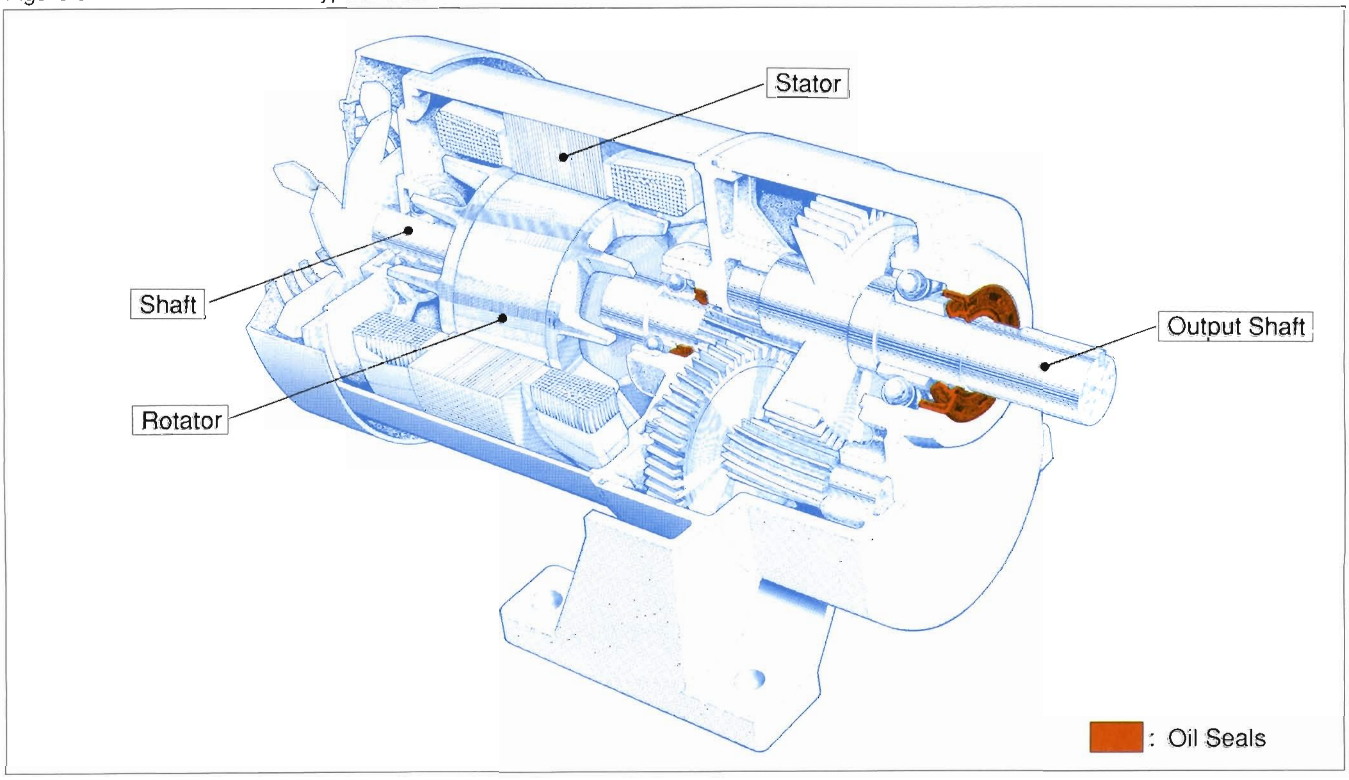


Figure 3: Oil Seals Used in a Typical Geared Motor



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Functional Components of An Oil Seal

Figure 4 shows the exterior features of a typical oil seal, and **Table 1** describes the function of each part of an oil seal.

Figure 4: Basic Features of An Oil Seal

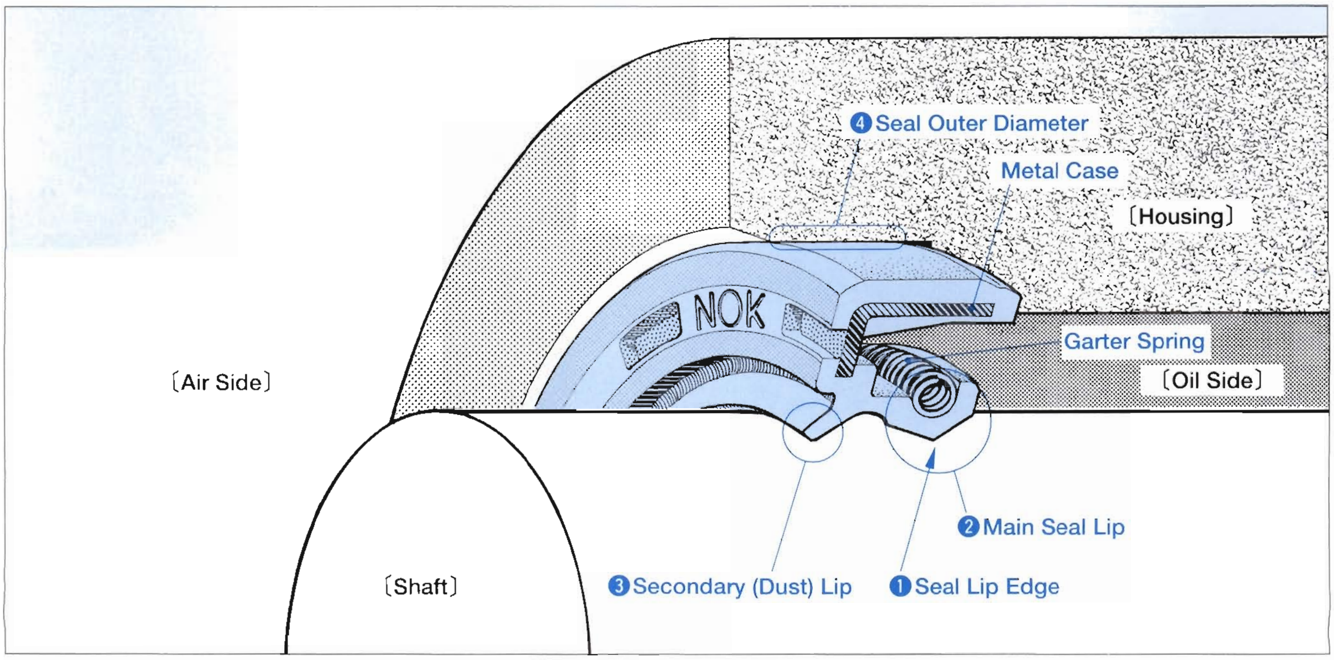


Table 1: Functions of the Various Oil Seal Components

	Part Name		Function
1	Lip Area	Sealing Edge (shaft contact)	The seal lip has the cross-sectional profile of a wedge, and it presses down onto the shaft surface to seal in fluid.
2	Lip Area	Seal Lip	The seal lip is made of a flexible elastomer and is designed to maintain stable shaft contact and sealing even with machine vibration and fluid pressure fluctuation. A garter spring adds to the radial load and helps keep the sealing edge in proper contact with the shaft.
3	Lip Area	Dust Lip	A dust lip is an auxiliary spring-less lip, and acts to prevent dirt ingestion.
4	Seal Outer Diameter		The seal OD creates a press-fit to the housing bore, thus retaining the seal and preventing fluid escape. An internal metal case provides a solid backbone for rigidity.

B

The Sealing Mechanism of An Oil Seal

B. THE SEALING MECHANISM OF AN OIL SEAL

B

How do oil seals actually seal fluid? Due to the continuing efforts of many scholars and researchers, the fundamental sealing mechanism of oil seals has been almost completely illuminated.
NOK announced a sealing theory in 1959, followed by the release of numerous technical publications to the Japan Society of Mechanical Engineers, the Japan Lubricator Makers Association, the Society of Automotive Engineers in the United States (SAE), and the British Hydrodynamics Research Association (BHRA). This theory has earned an excellent reputation among researchers and related industrial societies as being an accurate representation of seal function.
In this chapter, the lubrication factors and sealing mechanism of oil seals are briefly described based on the NOK sealing theory.

Lubrication Characteristics

Oil seals used in machines play a major role in sealing fluid, whether the machine is stopped or a shaft is in motion. The frictional force of the lip area is small, and there is little wear.
What lubrication factors of the seal lip's contact edge affect the life of an oil seal? These factors are explained in view of a seal's macroscopic phenomena.
To understand these lubrication factors, it is important to evaluate the seal's frictional properties. For this reason, we placed seals in a test machine, as shown in **Figure 1**, and measured rotational friction forces by turning the shaft under various conditions.

Figure 1: An Oil Seal Installed in a Friction Testl

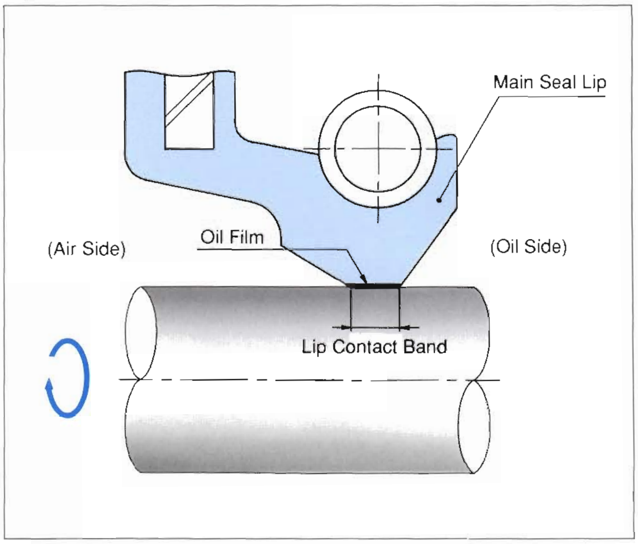
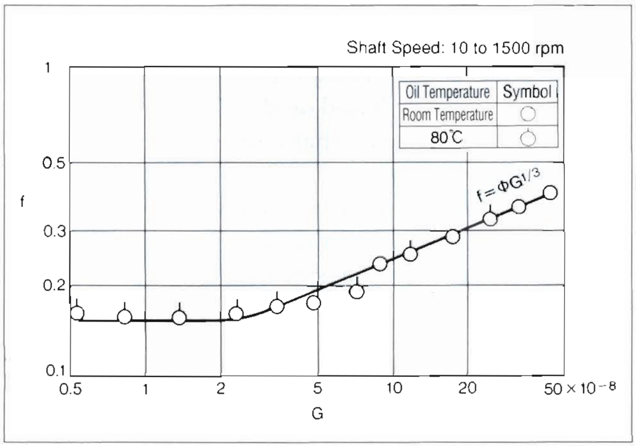


Figure 2 shows the relationship between the non-dimensional duty parameter, G (which is determined by the shape of the oil seal and conditions of use), and the coefficient of friction, f.

Figure 2: Friction Characteristics of Rotating Shaft Oil Seals (f vs. G plot)



Here, the relationship between the coefficient of friction, f, and the non-dimensional duty parameter, G, is given by Expression (1).

$$f=\Phi G^{1/3}\cdots\cdots(1)$$

Where
f =Coefficient of Friction
Φ =An Oil Film Condition Constant
G =Non-Dimensional Duty Parameter ($=\mu \cdot u \cdot b/Pr$)

Pr =Radial Lip Load on Shaft (N{kgf})
μ =Oil Viscosity (N·s/cm²{kgf·s/cm²})
u =Linear Shaft Velocity (cm/s)
b =Lip-to-Shaft Contact Band Width (cm)

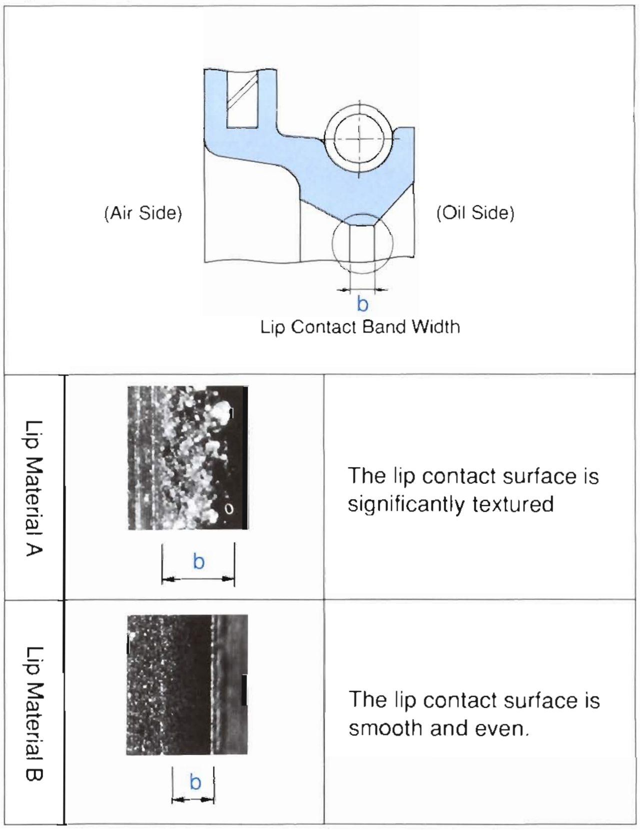
In **Figure 2**, the positive slope area of the frictional properties has been explained by the lubrication theory. Under such lubrication conditions, the frictional property of seals is governed by the viscosity of the fluid and the shaft's linear velocity (and is also identical to the frictional property of the bearing), and the resultant oil film present underneath the lip edge. In other words, the oil seal's lip and the shaft slide against each other with an intervening film of oil, thus reducing wear.

The Sealing Mechanism

NOK was the first to actually view the sealing mechanism of an oil seal using state-of-the-art image processing technology. Underneath the very narrow lip edge, oil is continually circulated from the air side to the oil side, and then from the oil side to the air side, thus lubricating the sliding surfaces and limiting wear. Theoretical studies have revealed that the sealing mechanism is determined by minor "irregularities" in the sliding surface, and by how the pressure is distributed at the contact area. Here, the sealing mechanism of oil seal is briefly described through macroscopic phenomena.

Lip materials are an important factor in the formation of these special irregularities on the sliding surface of oil seals. **Figure 3** shows the textures of the lip surface of two different materials. Lip material A produces a more significant texture on the sliding surface than lip material B.

Figure 3: Lip Surface Textures of Two Materials



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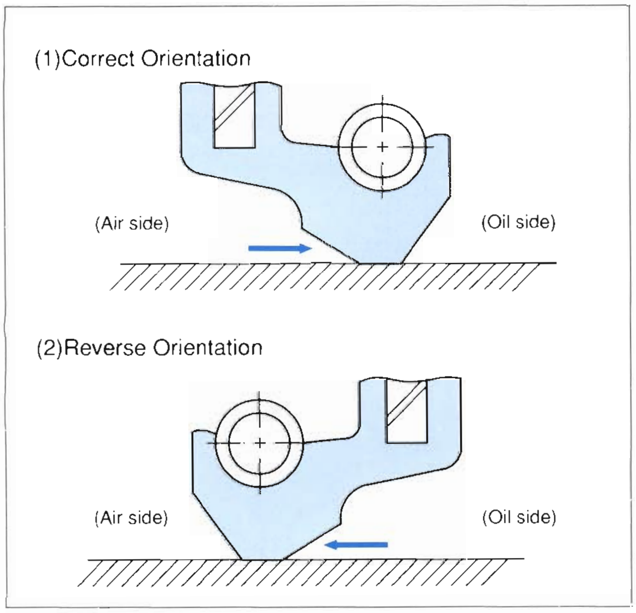
Two oil seals having identical contact pressure distributions were produced using these two lip materials. Since it is generally difficult to measure an air intake rate on an oil seal, the fluid transfer rate is measured using a reversed seal orientation. Thus, oil is now on the "air-side" of the seal, and is transferred under the seal lip via the seal's pumping action.

Scenario (a) in **Figure 4** shows a normal seal installation, i.e., when air is forced toward the oil side. Scenario (b) shows that oil is transferred toward the air side because the oil seal is installed in the reverse direction.

Figure 4: Normal and Reversed Oil Seal Orientation



Through the reverse installation (b), the seal's ability to pump oil was quantified by running the shaft and measuring the resultant oil flow rate.

As a result, lip material A was easily identified as more effective in pumping fluid from the air side toward the oil side than lip material B. This was true only when the shape of the lip is not considered (or the same). Even when the lip materials were identical, the pumping ability changes according to the profile of contact pressure distribution; for instance, by changing the shape of the lip.

The two critical elements described above that exert control over the seal's performance, the lubrication characteristics and sealing mechanism, are in a delicately controlled balance through two design factors: the material and shape of the lip. Therefore, in view of these material science considerations, it is necessary to keep in mind that the circulating oil flow must be restricted to within the lip contact area, and that the average film thickness under the seal lip must be controlled.

NOK has put considerable effort into developing lip materials specifically based on the above concepts, and has developed oil seals that can respond to various demanding conditions.

NOK will continue to concentrate on providing products of unsurpassed performance and quality through our ongoing development activities.