

Speed Reducer Sealing and Venting

Sealed vs. Vented Speed Reducer Operation

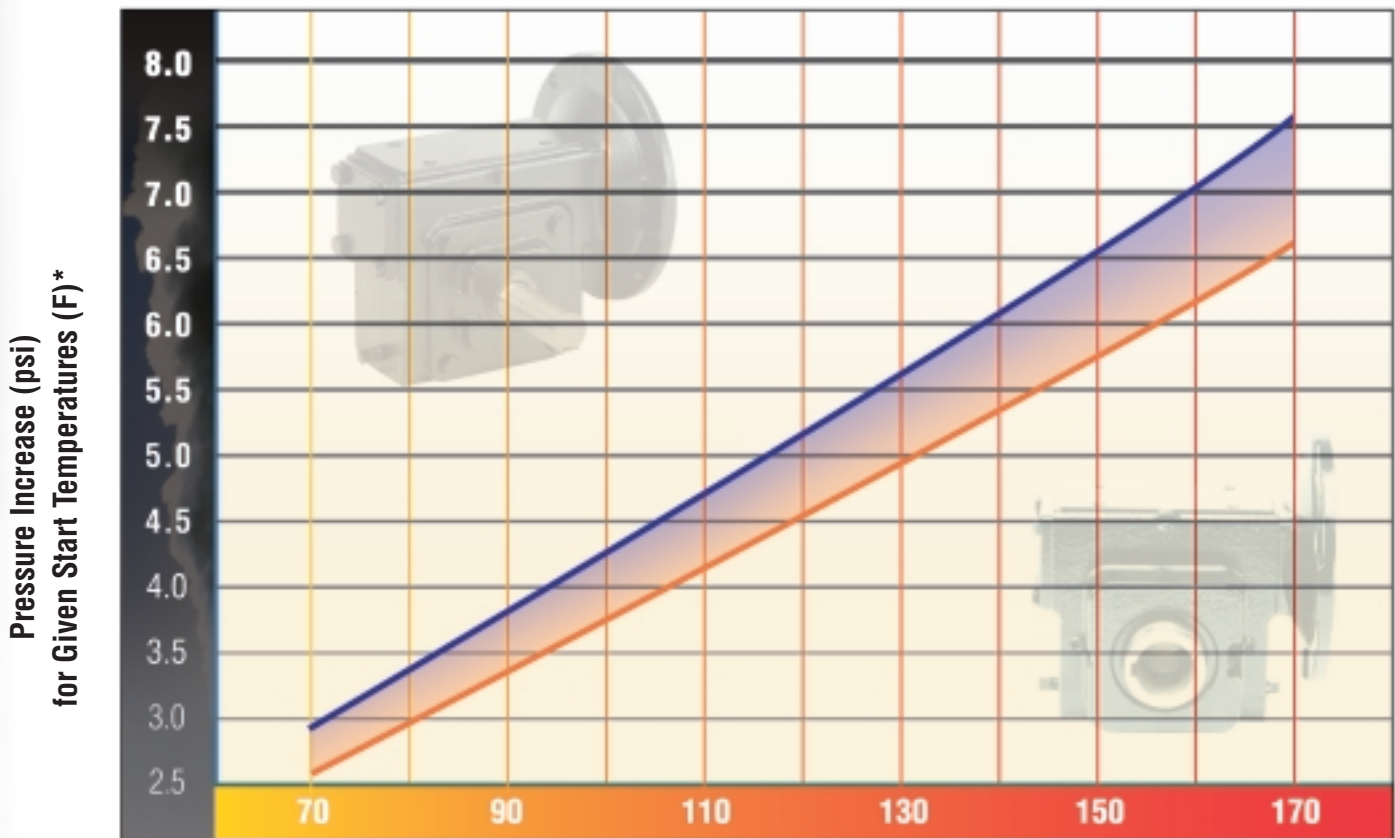
All SE Encore series speed reducers are designed to operate sealed or vented. Deciding whether a speed reducer should operate sealed or vented requires an understanding of the application, the environment, the operation of radial shaft seals, and a review of the fundamentals of thermodynamics that govern the temperature and pressure relationship in the speed reducer.

Any significant increase in pressure in a sealed speed reducer decreases the operational service life of the radial lip seals. A pressure change of only 5 psi may reduce the seal life by as much as one third. There are two important phenomena that cause an increase in the internal pressure of a sealed speed reducer. First, the change of internal pressure during operation is proportional to the change of internal temperature

that occurs during normal operation. The relationship follows the combined gas law expressed as $P_1V_1 / T_1 = P_2V_2 / T_2$. Secondly, radial lip seals can ingest or "pump" air into a speed reducer regardless of whether it is operating sealed or vented. While the rate of ingestion is highly variable and dependant on running time and speed, under continuous operating conditions the net effect of "pumped" air to the total pressure increase is significant. *Venting, or the use of a breather vent, is the only absolute method of eliminating the pressure increase in a speed reducer caused by the increased operating temperature.*

In some applications, the duty cycle of the speed reducer is intermittent, the run times short, and the temperature increase modest. While sealing the reducer during operation subsequently increases the pressure

Pressure Increase in a Sealed Speed Reducer (Combined Effect of Lubricant and Air Expansion)



Change in Speed Reducer Operating Temperature (F)

- * Assumes 60% lubricant and 40% air fill
- * Assumes reducer starting pressure of 14.7psi at each starting temperature
- * Uses coefficient of thermal expansion for Mobil Glygoyle 460 lubricant



Figure 1.

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in these applications, the increase may be very small and therefore have minimal impact on the seal service life. Additionally, operating a sealed speed reducer may be the best choice in applications where external airborne contamination causes a greater reduction in overall speed reducer service life than the negative impact of the internal pressure increase. The machine builder or the end equipment user should determine whether sealing or venting the speed reducer is the best choice for a specific application as this decision has a direct impact on the seal service life. The following section details the factors influencing seal life.

Internal Temperature and Pressure Increase in a Sealed Speed Reducer

A speed reducer experiences a significant internal temperature increase due to operating loads. The change in temperature of an operating speed reducer (from static ambient temperature to maximum operating temperature) often exceeds 130° Fahrenheit. In a sealed speed reducer, the increasing temperature results in a corresponding pressure increase as described by the combined gas law:

$$P_1V_1 / T_1 = P_2V_2 / T_2$$

In a closed system (e.g. sealed reducer), any change in temperature from one state of equilibrium to the next state of equilibrium results in a corresponding change in both oil volume and internal pressure. Moreover, the thermal expansion of the lubricant in the reducer can have a considerable effect on the pressure, temperature, and volume relationship. The influence of the lubricant's thermal expansion depends on the percent volume occupied by the lubricant compared to that of the air. Typically, the volume inside the reducer is about 60% lubricant and 40% air. The thermal expansion of the lubricant alone increases the internal pressure in the reducer by approximately 1.5 psi when the change in temperature is 130°F.

Figure 1 shows the total impact of the internal temperature and associated pressure increase at different ambient starting temperatures in a sealed speed reducer. Pressure increases greater than 5 psi can result from the combined effect of the lubricant's thermal expansion and the internal temperature change.

Seal "Pumping" Effects on Increased Pressure in an Operating Speed Reducer

Correctly operating radial shaft lip seals are dynamic and require the presence of a microscopically thin film

of lubricant directly under the sealing lip. The seal lip imposes shear forces on the film as the shaft rotates beneath it. This creates a seal "pumping action" that circulates the lubricant residing closest to the seal back inside the speed reducer and away from the external environment. The pumping action of the seal prevents the lubricant from seeping out and is necessary for proper operation. Unfortunately, a correctly functioning radial shaft seal also causes an unintended and unavoidable side effect. Tests confirm that microscopic air bubbles and contaminants from the external environment are entrained in the lubricant. The actively pumping seal sweeps them inward with the induced lubricant flow and once inside, they escape into the speed reducer. With continuous operation, the air bubbles accumulate inside the reducer cavity. The seal is acting as an air pump, causing air ingestion that increases the internal pressure of a sealed speed reducer. Winsmith's extensive testing has verified that the increased internal pressure of the speed reducer and the rate of pressurization are dependent on many variables including operating time, linear velocity of the shaft under the seal, temperature, seal material, and seal and shaft manufacturing tolerances.

In summary, a significantly large percentage of sealed speed reducers develop an internal pressure of 5 psi or more when operated on a continuous duty cycle. This phenomenon can occur even when there is no change in temperature because the radial lip seals ingest air into the reducer (see Figure 2). Conversely, testing indicates that when a reducer operates in an intermittent manner (e.g. 5 minutes of run time every 30 minutes of dwell), the internal pressure build-up is very small.

The Effects of Temperature and Pressure on Seal Operating Life

The specific failure mechanisms of seals vary depending on the seal material. However, the normal "wear out" failure mode of an NBR rubber (Acrylonitrile-butadiene or "nitrile") dynamic radial shaft seal is related to time and temperature and often termed "embrittlement." Over time under some relative elevation of temperature, nitrile seals lose elasticity, develop micro cracks that cause an abraded sealing surface that can no longer properly contain the speed reducer lubricant. The embrittlement rate of NBR materials begins to accelerate at lip operating temperatures between 180°F and 200°F.



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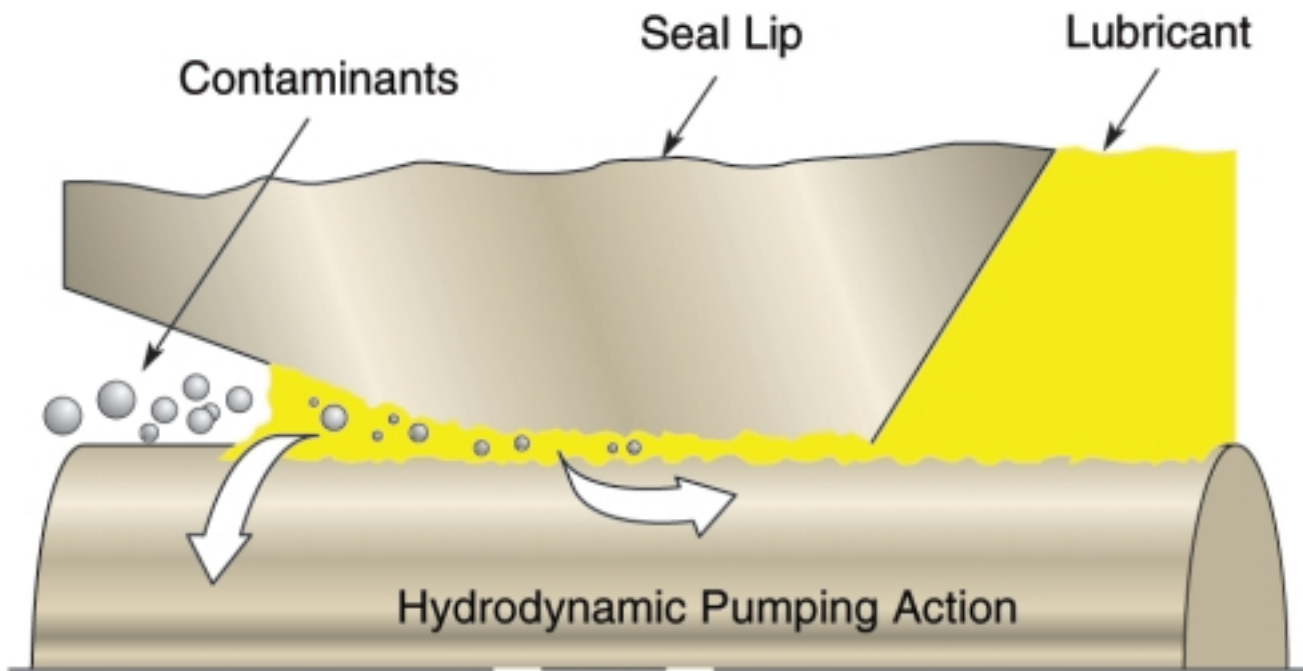


Figure 2. Ingestion of Air and Contaminant by a Radial Seal Courtesy of Parker Hannifin Corporation

The impact of increasing temperature and pressure in a sealed speed reducer on the service life of an NBR seal has been assessed by numerous seal manufacturers. While the results of these tests vary depending on variables such as the actual seal lip temperature, they indicate that a change in pressure as small as 5 psi can reduce the expected seal service life by one third. This is because a positive internal pressure differential in a speed reducer causes the shaft lip seals to exert a higher radial force on the shaft. Under dynamic conditions, this force increases the lip seal contact area on the shaft, increasing the friction, and thereby creating a correspondingly higher temperature between the shaft and the lip seal. This increase is directly proportional to the amount of radial force on the seal and to the speed of the shaft at the seal interface and causes a decrease in the seal life.

All SE Encore speed reducers with a quill input adaptor use special HNBR (hydrogenated nitrile butadiene rubber) or fluoroelastomer (aka Viton®) materials on all input shafts because these materials are tolerant of higher lip operating temperatures. The typical failure mode of HNBR material is blistering at the seal surface.

Performance Issues with Bladders and Expansion Chambers

Various speed reducer design approaches aimed at eliminating the internal pressure increase have incorporated internal collapsible diaphragms or bladders. Eliminating the pressure increase requires that the bladder or diaphragm collapse at very low pressures and have a volume that sufficiently accommodates the expansion of the air and the lubricant. In a reducer with a two inch center distance, the internal volume is between 30 in³ and 40 in³. Assuming the volume is 60% lubricant and 40% air and applying the previously discussed combined gas law over a temperature change of 130°F (70°F start, 200°F final), the size of an internal diaphragm or bladder required to prevent a pressure increase must be between 3.9 in³ and 5.2 in³. In most typical speed reducers, there is insufficient internal space for such a large bladder. Moreover, while some internal expansion chambers are effective in limiting or reducing internal pressure rise due to temperature changes, *none are completely effective in avoiding the pressure build up related to seal air pumping action associated with continuous duty cycle applications.*

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Applications Determine When Sealing a Speed Reducer is Preferred to Venting

As covered in the preceding discussion, sealing a reducer can increase the internal pressure which results in decreased seal service life. This is especially prevalent when operating under continuous duty conditions. However, there are certain applications where the speed reducer duty cycle is highly intermittent, and run times are short with light average duty loads. Testing and field experience indicate that small internal pressure increases (1 – 2 psi) have a minimal effect on the seal service life.

Another application dependent situation where sealed reducer operation is preferred occurs when the external air environment is extremely contaminated with material that, if drawn into the reducer through a vent, can rapidly reduce seal, bearing, or worm gear life. In these applications, the increased pressure resulting from operating a sealed reducer can still have a significantly negative effect on seal life and, in these cases, require more frequent seal replacement. However, the reducer life may be lengthened by operating sealed rather than operating with an open vent in these types of harsh environments. Further, the machine builder or equipment operator might determine that the convenience of operating a sealed speed reducer outweighs the negative result of reduced seal service life. *The Winsmith two (2) year warranty on defect in parts and workmanship remains unaffected whether an SE Encore worm gear speed reducer operates with or without a vent since the vent/sealed decision only affects the service life of the speed reducer wear components.*

In conclusion, there are three fundamental factors that govern the speed reducer seal/vent decision. First, as the temperature increases in a sealed reducer, so will the pressure. Second, the radial shaft seals are designed to “pump” lubricant back into the speed reducer. This pumping action also causes an ingestion of air that increases the internal pressure. Any increase of pressure causes decreased dynamic radial seal life. Venting is the most cost effective method of eliminating the pressure. Finally, when extreme environmental conditions cause component or seal wear in excess of that caused by an increased internal pressure, sealing a speed reducer is the best likely alternative. However, under these conditions, seal wear is apt to take place at higher than predicted rates.

SE Encore Venting Solution is a Standard Feature

The SE Encore worm gear speed reducer series can satisfactorily operate sealed or vented. Each reducer is supplied with an optional “open-closed vent” that can be installed by the equipment builder or the equipment user. This exclusive Winsmith vent is made from black DuPont™ Zytel® Nylon with UV protection. The vent’s design incorporates a labyrinth with a dust/splash cap that minimizes contaminate and water incursion from the external environment created by general, harsh, and outdoor applications. The reducer housing offers multiple locations for vent installation depending on the final reducer mounting position on the equipment. Turning the top cap to the closed position ensures that no oil drains while the equipment is in transit to the operating location. Turning the top cap counter clockwise, by hand, opens the vent prior to running the speed reducer. A special screw driver slot molded into the cap allows easy actuation when access is limited. The vent should be installed in the highest pipe plug location available based on the actual mounting orientation of the speed reducer on the operating equipment. Additionally, a bright yellow plastic tag is provided with the vent that reads:

“IMPORTANT – VENT REQUIRES ACTIVATION THIS UNIT HAS BEEN SHIPPED TO YOU WITH THE VENT IN THE CLOSED POSITION – IT IS IMPORTANT TO OPEN THE VENT BY MAKING A ONE QUARTER TURN COUNTER CLOCKWISE”

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