

Improving Equipment Uptime: Fabric-Reinforced Seals Meet the Challenge

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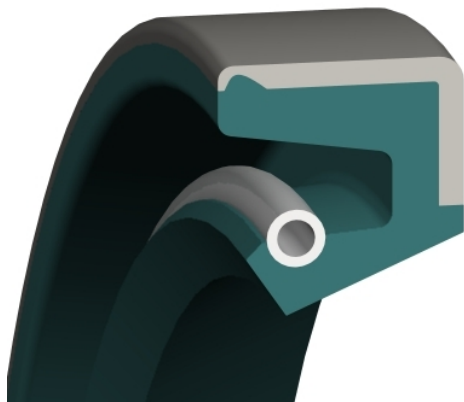
ABSTRACT: In an industrial application, equipment uptime is vital to on-time performance and profitability. The rotating members of industrial machines are subject to the highest degree of wear and are more susceptible to failure than non-moving parts. Bearing surfaces are the most critical and often the most expensive portion of the rotary assembly. It is imperative to protect these components. The primary protector of these components is the industrial seal. Fabric-reinforced rubber seals are a significant means to protect bearings. This paper looks at three methods in which fabric-reinforced seals meet this challenge: by providing key advantages over traditional sealing devices, by improving overall sealing life, and by providing a quick repair option when seals have reached the end of their service life.

Advantages of Fabric-Reinforced Rubber Seals

The concept of utilizing a bearing surface for rotating machine members dates back over 5,000 years. Evidence suggests that lubrication was being used on bearings as early as 1400 B.C.¹ By the 1800's the Industrial Revolution created demands for more sophisticated lubrication systems.² In order to retain lubrication, some type of sealing system was needed. Originally, seals consisted of either leather straps or braided rope. By the 1920's, lip seals made of leather were being produced. The 1930's and 1940's saw development of the synthetic rubber oil seal, which is still in use today.

The most common radial lip seal (or oil seal) design is the metal-cased seal. A molded rubber sealing element is captured inside of a carbon steel case. The rubber may be chemically bonded to the metal or mechanically pressed into place (see figure 1). A spring, either garter or finger type, provides an energized lip to accommodate for misalignments in the application.

A common drawback to the metal-cased seal design is the fact that the carbon steel case is exposed to the environment and therefore susceptible to corrosion. This can be resolved by using stainless steel case material; however, this significantly impacts the cost of the seal due to material expense and processing constraints. Another concern is that the metal case is press fit into the application housing. This metal-to-metal press fit can create a challenging installation, usually requiring an arbor press or other equipment. The metal case may also present problems with galling when installed in a housing made from softer materials, such as aluminum or bronze.



Chemically Bonded Lip Seal with Garter Spring



Mechanically Assembled Lip Seal with Finger Spring

Figure 1 – Bonded and Assembled Radial Lip Seals

An all-rubber seal is a simple way to address these issues; however an all-rubber seal lacks the rigidity of a metal-cased seal. An exceptional compromise between these two options is a reinforced rubber seal. While some designs reinforce seals with metal, a fabric-reinforced seal offers superior strength over all-rubber options, while eliminating costly metal components. Further, unlike metal-reinforced seals, fabric-reinforced seals may be split facilitating simpler installation practices.

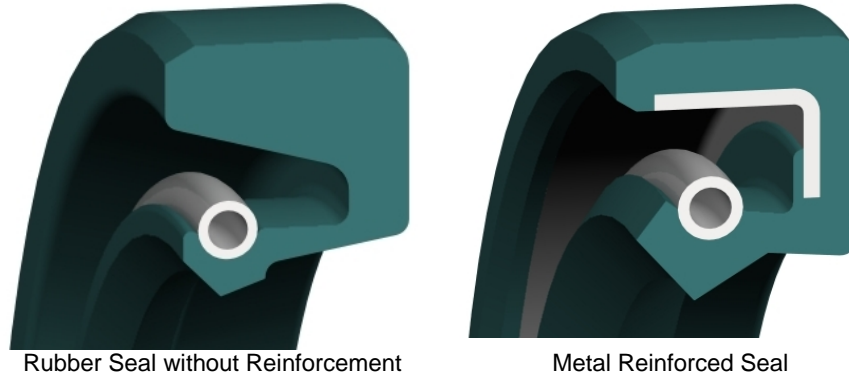


Figure 2 – Various Rubber OD Seals

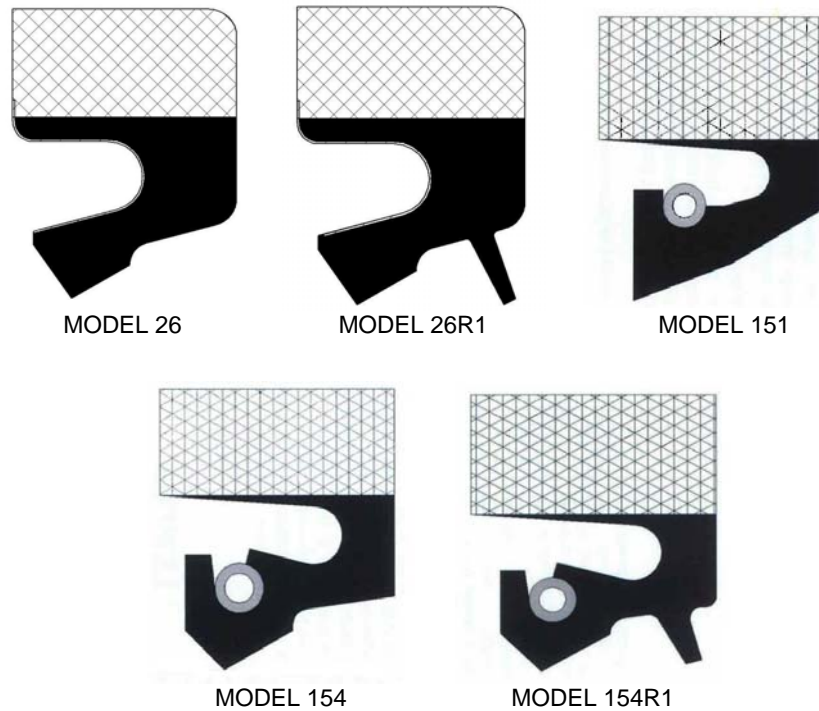


Figure 3 – Garlock Klozure® Fabric-Reinforced Seals

High-Performance Elastomers Increase Service Life

All radial lip seals are contact seals – the sealing lip is in contact with a rotating surface, usually a shaft. The hydrodynamic sealing concept shows that, when operating under normal conditions, a radial lip seal will draw lubricant under the sealing lip and recirculate it back into the system. Thus a thin layer of fluid called a meniscus is formed between the sealing lip and the sealing surface (see figure 4). Under optimum conditions, the meniscus actually creates the interface between the shaft and the sealing lip (see figure 5).³

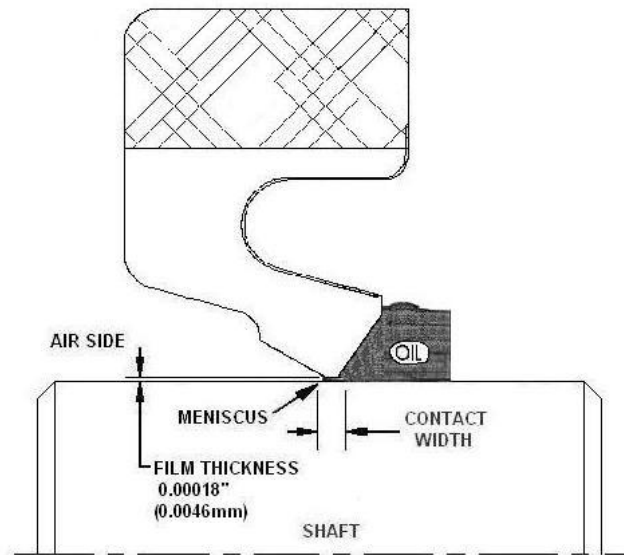


Figure 4 – Hydrodynamic Sealing

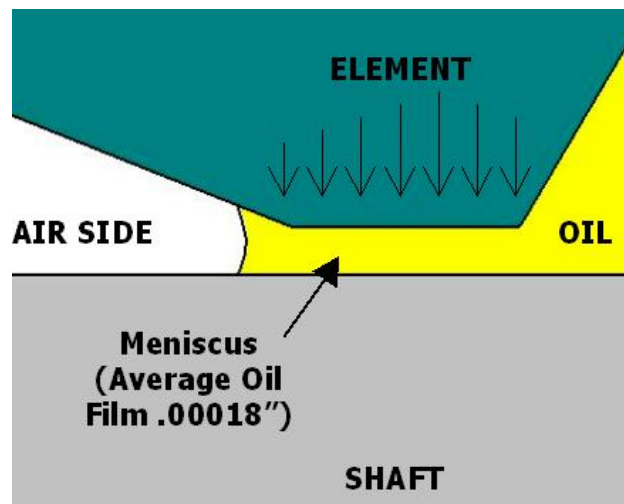


Figure 5 – The Sealing Meniscus

However, most applications do not run under optimum conditions at all times. Functional testing experiments demonstrate that at start up a radial lip seal consumes considerably more power than it does at normal operating speeds.⁴ This is due to the fact that the hydrodynamic meniscus cannot form at lower speeds. The three key variables that contribute to this phenomenon are the fluid viscosity, rotational speed, and applied pressure.⁵ Seal geometry also plays an important part in developing the hydrodynamic meniscus.

Thus, while hydrodynamic sealing is the goal, there will be times when the seal is in direct contact (dry running) against the shaft. The durability of the material plays a key role in protecting the seal geometries during these periods. Lower grade sealing materials may wear excessively during dry running periods and lose their critical geometries. The lack of these geometries will prevent the formation of a hydrodynamic meniscus leading to further seal degradation.

The most common sealing materials include acrylonitrile butadiene (nitrile, NBR), hydrogenated nitrile (HNBR), and fluoroelastomer (fluorocarbon, FKM, FPM). Fluoroelastomer is often better known by the DuPont trade name Viton[®]. The general service grades of these elastomers provide acceptable performance in many applications. However, in heavy industrial applications where uptime is critical, high performance elastomer grades can offer a significant increase in uptime. Garlock Klozure[®] offers both general service and high performance elastomer grades in its fabric-reinforced seals.

Key properties in determining elastomer performance include tensile strength, elongation, tear resistance, coefficient of friction, hardness, abrasion resistance, and compression set.⁶ At the initial molding of a radial lip seal the above properties are known for the given material. However, when subjected to harsh and varying environments, these seal properties may undergo significant changes. It was the goal of elastomer engineers at Garlock to develop a series of materials with marked improvements in properties such as abrasion and chemical resistance, that would retain these and other key physical properties in extended service. This goal was realized in the development of the Mill-Right[®] Family of Elastomers.

These new high performance elastomer grades offer superior performance over the general service materials. A key area to consider is abrasion resistance. A material's resistance to abrasion is measured by the Taber wear test (ASTM D4060). The Taber wear test starts with precisely weighed sample specimens of a particular elastomer. The specimens are "mounted to a rotating turntable and subjected to the wearing action of two abrasive wheels, which are applied at a specific pressure."⁷ When the test is completed the specimens are re-weighed to determine how much material was abraded away. Results are reported in mg loss/1000 cycles. Therefore, the lower the reported value, the better the abrasion resistance of the material.

Table 1 relates the incredible improvements in abrasion resistance that the Mill-Right[®] Family of Elastomers offers. Notice Mill-Right[®] N reports a Taber Wear Factor of 145.5 mg loss/1000 compared to 548 mg loss/1000 for general service grade nitrile rubber. That's a 73% improvement in wear resistance. Similarly, the resistance of Mill-Right ES was increased 65% over general service grade HNBR and that of Mill-Right V 90% over general service grade FKM. For charted improvements in abrasion resistance, see Appendix A.

	General Service Grade NBR	Garlock Klozure [®] Mill-Right [®] N	General Service Grade HNBR	Garlock Klozure [®] Mill-Right [®] ES	General Service Grade FKM	Garlock Klozure [®] Mill-Right [®] V
Taber Wear Factor (mg loss/1000)	548.0	145.5	113.2	39.2	481.4	49.2

Table 1 – Taber Wear Factor Comparison

In addition to improving the physical properties themselves, the Mill-Right[®] Family of Elastomers also offers drastic improvements in the retention of these properties in service. The radar chart below demonstrates Mill-Right V's improved physical property retention over general service grade FKM. The dotted black line represents perfection – no change in physical properties at all; while the red and green lines represent general service grade FKM and Mill-Right V, respectively. While perfection is the obvious goal, it is understood by elastomer engineers that it is quite unlikely that it will be achieved. But notice how much closer Mill-Right V gets to this goal than its general service counterpart. For radar charts on all three Mill-Right[®] grades see Appendix B.

Garlock Klozure[®] Mill-Right[®] V Vs. Fluoroelastomer

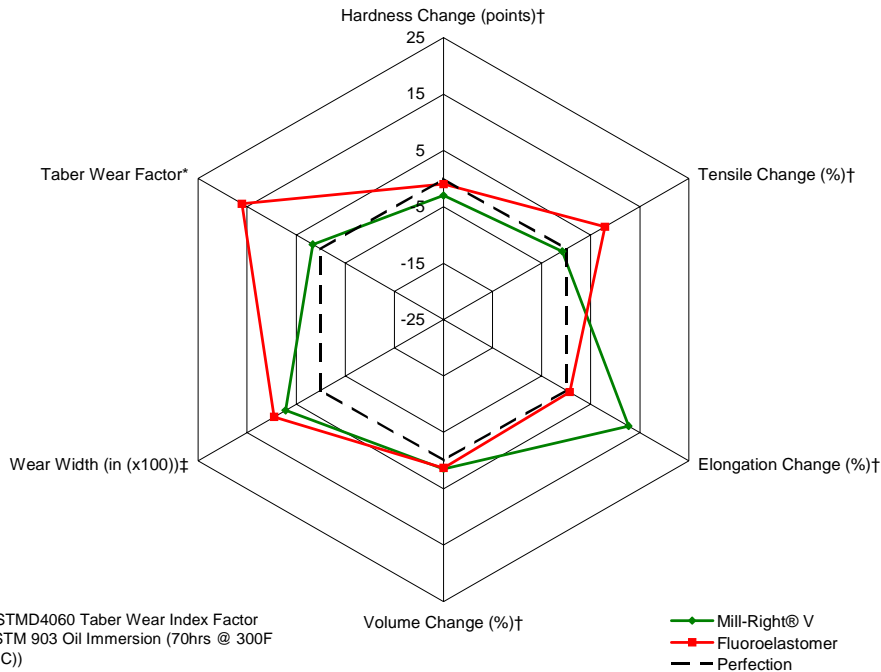


Figure 6 – Mill-Right V Radar Chart

Split Seals Improve Mean Time To Repair (MTTR)

Inevitably, no matter how well-engineered the material is, all contact seals will have a finite service life. Service life is affected by a variety of factors, including: equipment condition, environmental condition, thermal factors, and surface velocity. When a seal has reached the end of its service life, it must be replaced. The ease to which this can be done will significantly impact uptime. A measurable indicator of this is the Mean Time To Repair (MTTR) and is simply a ratio of the total repair time to the number of repairs completed.

Replacing solid oil seals in the field can have a significant negative impact on MTTR. This is because the entire system must be taken offline, disassembled, and then reassembled in order to introduce a solid seal into the housing. This may involve the removal and reinstallation of pillow blocks, motor housings, pump housings, etc. This is due to the fact that solid seals must be installed over the free end of a shaft with all attached components removed from the assembly. The innovation of a split seal allows the user to install the sealing device without having to completely disassemble the equipment, drastically reducing maintenance time.

A split radial lip seal is a relatively simple concept. It involves removing a section of a solid fabric-reinforced seal, to create a seal with a single split point. The seal can be opened along the axis of rotation to allow easy assembly over the diameter of the shaft. Some split seals include a garter spring which needs to be assembled around the shaft onto the seal during installation. Care should be exercised in selecting a split seal with a garter spring, as the spring may become dislodged during installation of the seal into the housing bore. Many Garlock Klozure® split seals include a molded-in finger spring which eliminates the need for a garter spring and contributes to even load distribution at the contact point on the shaft. Others are available with the traditional garter spring.

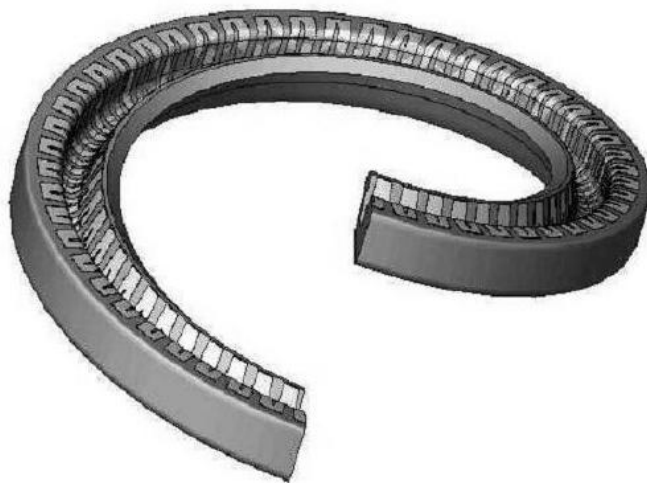


Figure 7 – Garlock Klozure® Split Seal with Finger Spring

Most split seals require a cover plate in order to be fully retained within the housing bore (some solid models also have this requirement). Otherwise, the seal may become disengaged from the application during operation. A cover plate is simply a flat metal plate (either whole or split) that can be bolted against the housing to provide proper compression of the seal (see figure 8).

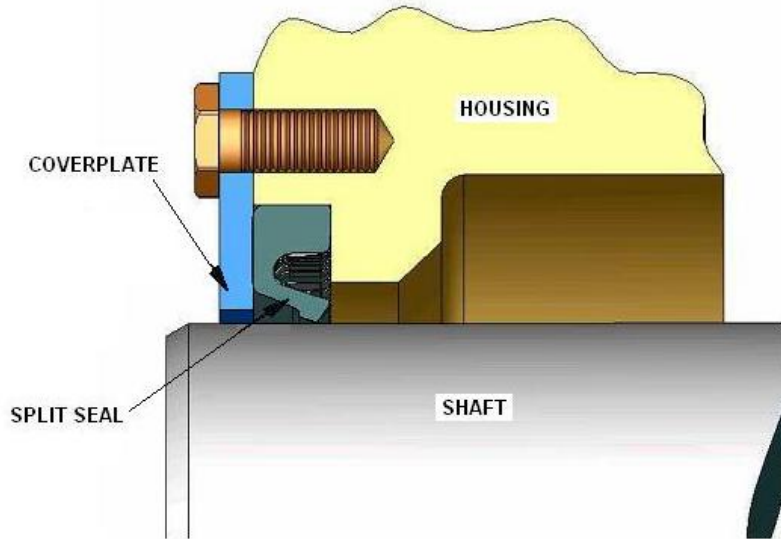


Figure 8 – Split Seal with Cover Plate

It is vital that the seal width and bore depth be properly fitted so that there is appropriate axial retention of the split seal. Some high-performance split seals include significant OD interference, such that a cover plate is not necessary within a particular size range. For example, the Garlock Klozure[®] model 26 split seal does not require a cover plate for housing bores under 10.000 inches (254mm) in diameter (see figure 9).

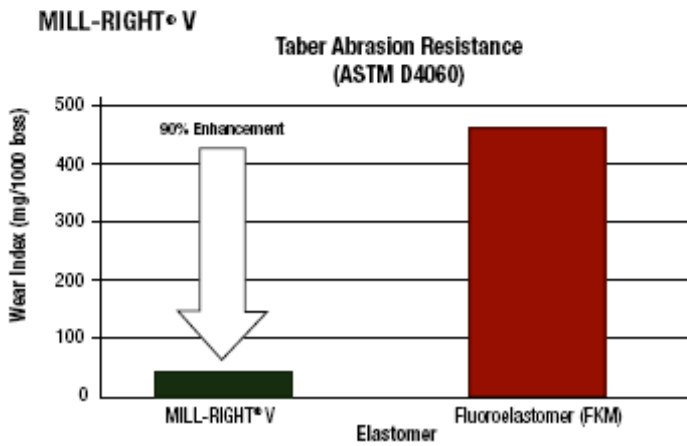
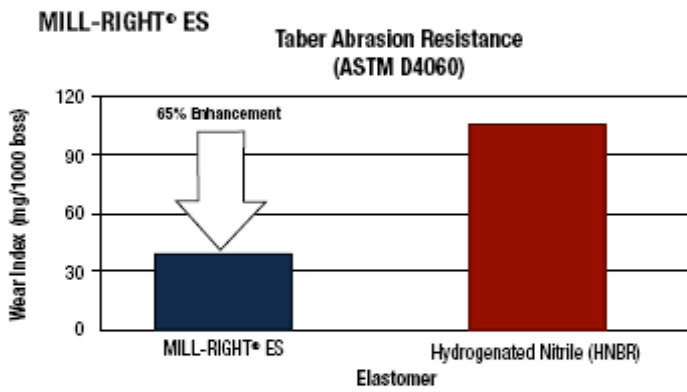
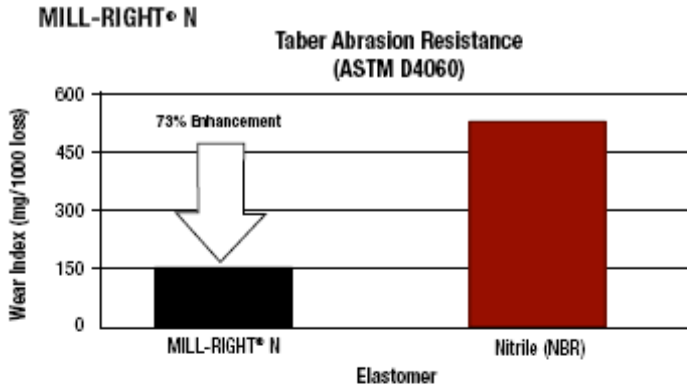


Figure 9 – Garlock Klozure[®] Model 26 Split Seal

Conclusion

Improving uptime is not a simple task. Equipment needs to be broken down into systems, systems into sub-systems, and sub-systems into components. Identifying critical components that will significantly impact uptime is vital. Since rotating components are so critical to function, protecting these systems will positively impact uptime. Fabric-reinforced seals are a primary method of protecting these systems. These seals offer significant advantages over standard designs. The options of both general service and high-performance grade elastomers provide the end user with the ability to select the grade to meet their specific needs. Utilizing time saving designs such as split seals serves to dramatically reduce downtime. Good use of all these innovations will positively impact uptime and ultimately improve profitability.

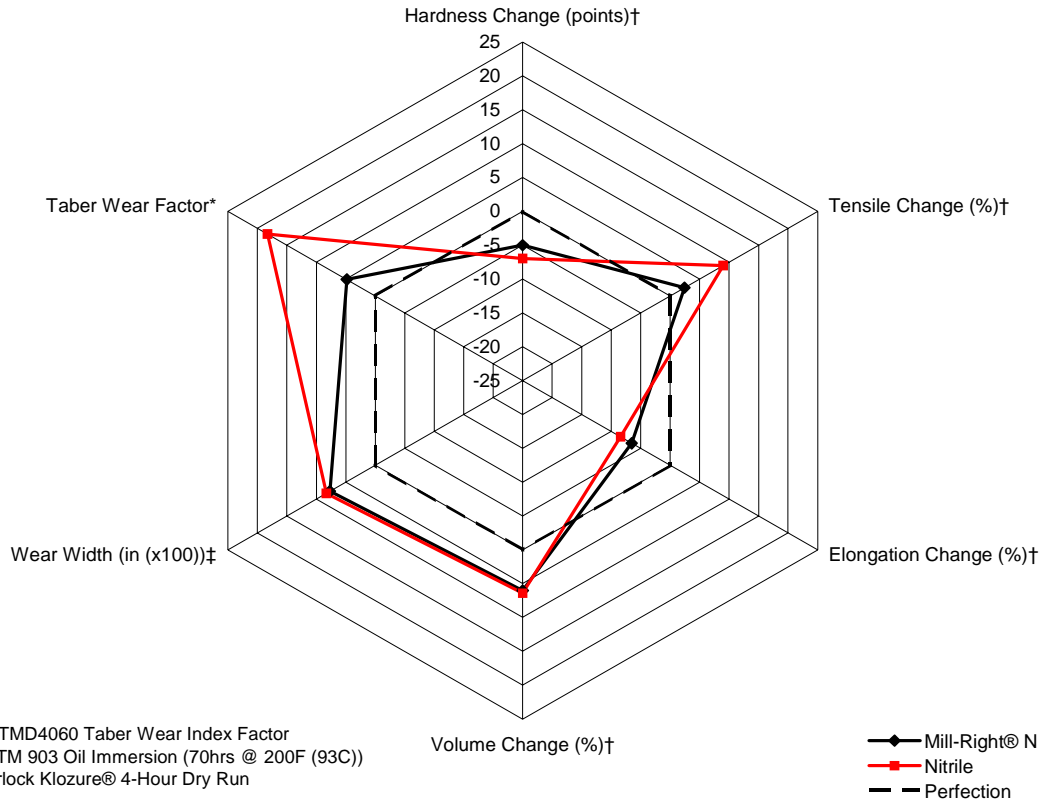
Appendix A – Abrasion Resistance Improvements



Appendix B – Radar Charts

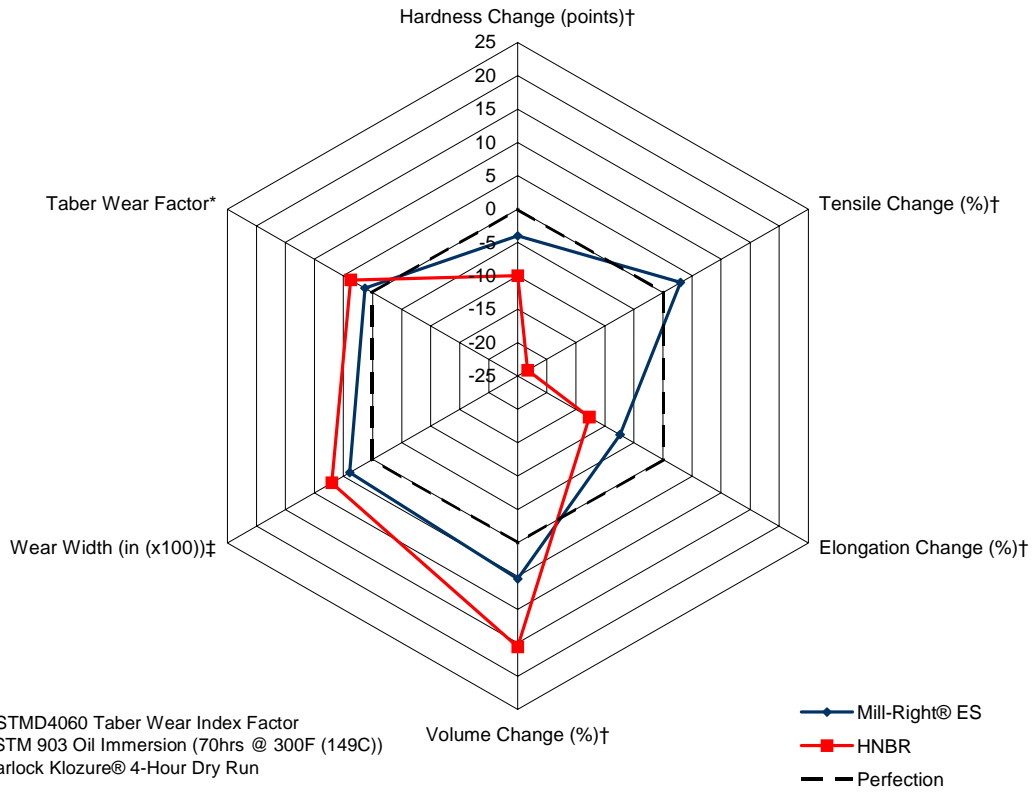
Mill-Right N Radar Chart

Garlock Klozure® Mill-Right® N Vs. Nitrile



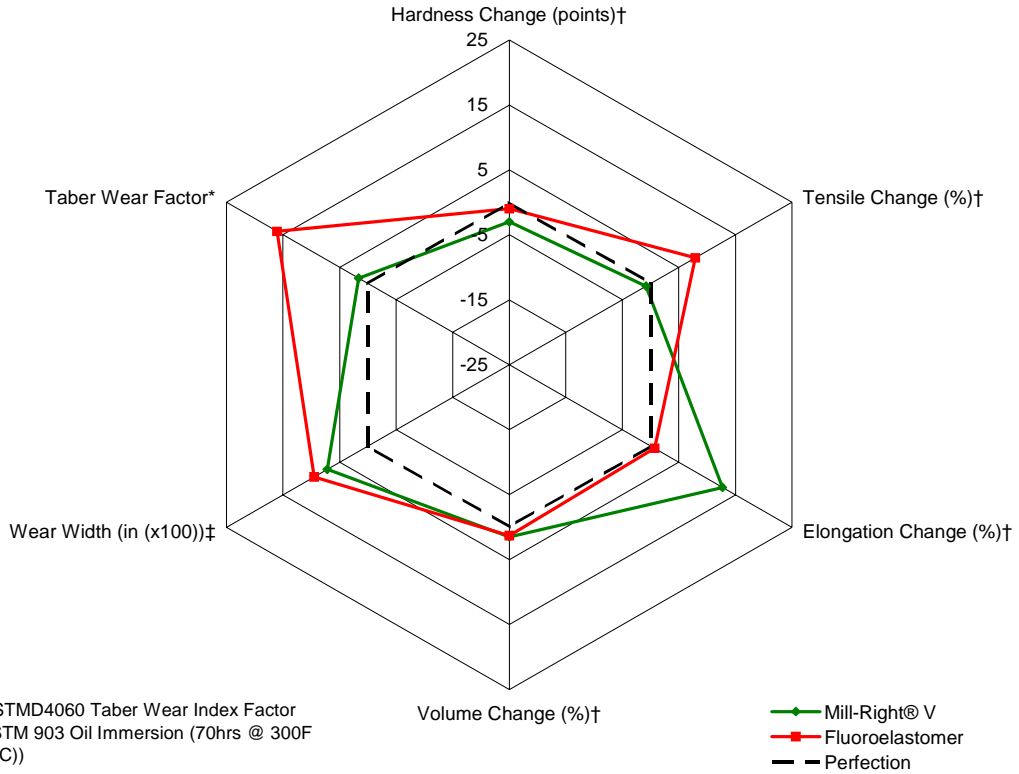
Mill-Right ES Radar Chart

Garlock Klozure® Mill-Right® ES Vs. HNBR



Mill-Right V Radar Chart

Garlock Klozure® Mill-Right® V Vs. Fluoroelastomer



Appendix C – References

- ¹ Haycock, Roger F., Arthur J. Caines, John E. Hillier, *Automotive Lubricants Reference Book*, 2nd edition, Warrendale, PA : Society of Automotive Engineers., 2004.
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- ⁶ Tones, Chris, Earl Rogalski, *Recent Advances in Elastomer Technology*, Iron & Steel Technology Conference, May 2005: p1025-1032.
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