Improving Equipment Uptime

COMPOSITE SEALS MEET THE CHALLENGE

Chris Tones and David C. Roberts

Management Summary

In an industrial application, equipment uptime is vital for 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. Composite seals are a significant means to protect bearings. This paper examines three methods in which composite seals meet this challenge: 1) by providing key advantages over traditional sealing devices, 2) by improving overall sealing life, and 3), by providing a quick repair option when seals have reached the end of their service life.

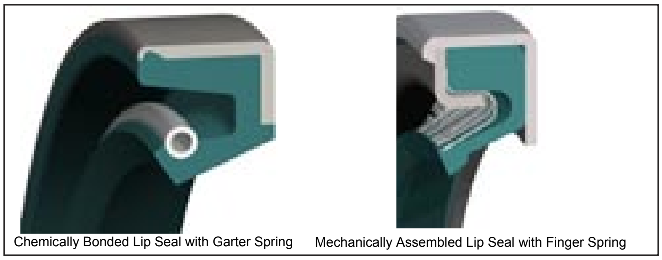


Figure 1—Bonded and assembled radial lip seals.

Advantages of Composite Seals

The concept of utilizing a bearing surface for rotating machine members dates back over 5,000 years. Evidence suggests that lubrication was used on bearings as early as 1400 B.C. (Ref. 1). By the 1800s, the Industrial Revolution created demands for more sophisticated lubrication systems (Ref. 2). In order to retain lubrication, a sealing system was needed. Originally, seals consisted of either leather straps or braided rope. By the 1920s, lip seals made of leather were being produced. The 1930s and 1940s 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 (Fig. 1). A spring— either garter- or finger-type—provides an energized lip to accommodate misalignments in the application.

A common drawback to the metal-cased seal design is 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.

An all-rubber seal is a simple way to address these issues; however, an all-rubber seal lacks the rigidity of a metal-cased

continued

seal. An effective compromise between these two options is the composite seal, which has an all-rubber exterior molded over a reinforcing media such as fabric or rubber-compressed fiber compound. While some designs reinforce seals with metal, a composite seal offers superior strength over all-rubber options while eliminating costly metal components. Furthermore, unlike metal-reinforced seals, composite seals may be split, facilitating simpler installation practices.

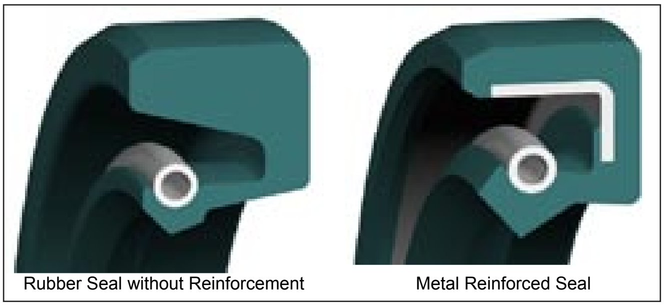

Rubber Seal without Reinforcement
Metal Reinforced Seal

Figure 2—Various rubber OD seals.

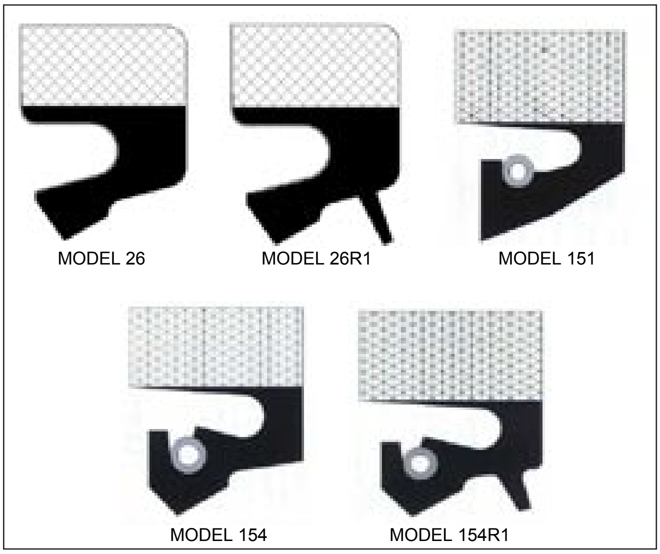


Figure 3—Garlock Klozure composite seals.

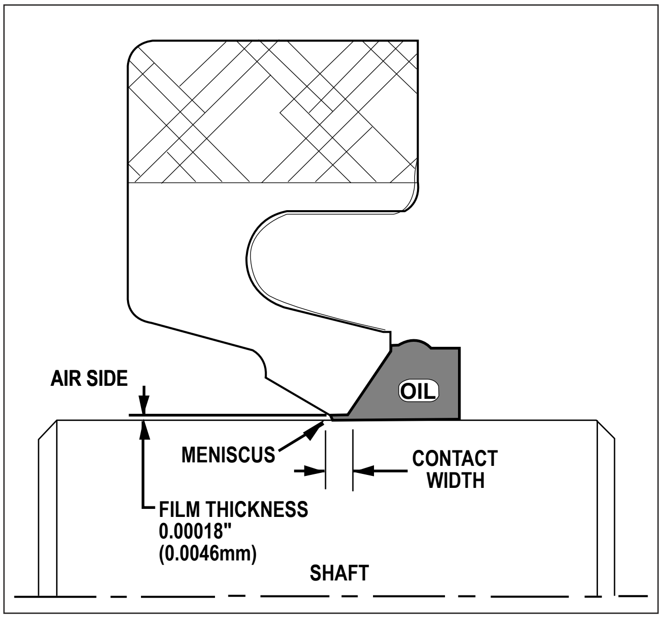


Figure 4—Hydrodynamic sealing.

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 re-circulate it back into the system. Thus a thin layer of fluid—or meniscus—is formed between the sealing lip and the sealing surface (Fig. 4). Under optimum conditions, the meniscus actually creates the interface between the shaft and the sealing lip (Fig. 5; Ref. 3).

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 (Ref. 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 fluid viscosity, rotational speed and applied pressure (Ref. 5). Seal geometry also plays an important role 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 referred to 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.

Key properties in determining elastomer performance include tensile strength, elongation, tear resistance, coefficient of friction, hardness, abrasion resistance and compression set (Ref. 6). When initially manufactured, the above properties of a radial lip seal are known for a given material. However, when subjected to a variety of operating environments, these seal properties may undergo significant changes.

Newly developed elastomer materials allow for marked improvements in properties—such as abrasion and chemical resistance—even after extended service. Garlock's Mill Right family of elastomers is an example.

These new high-performance elastomer grades offer superior performance over general service materials. A key area to consider is abrasion resistance. A material's abrasion resistance 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 (Ref. 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/1,000 cycles. Therefore, the lower the reported value, the better the abrasion resistance of the material.

Table 1 relates the improvements in abrasion resistance that the Mill-Right elastomers offer. Mill-Right N reports a Taber Wear Factor of 145.5 mg loss/1,000, compared to 548 mg loss/1,000 for general-service grade nitrile rubber—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.)

In addition to improving the physical properties themselves, the Mill-Right elastomers offer improvements in the retention of these properties in service. The radar chart in Fig. 6 demonstrates Mill-Right V's improved physical property retention over general-service grade FKM. The dotted black line represents perfection—i.e., 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.)

Split Oil Seals Improve Mean Time To Repair

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 in which this can be done will significantly impact uptime. A measurable indicator of this is the Mean Time To Repair (MTTR), which 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 off-line, disassembled and then reassembled in order to introduce a solid seal into the housing. This may involve the removal and re-installation of pillow blocks, motor housings, pump housings, etc. This is because 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 oil seal allows the user to install the sealing device without having to completely disassemble the equipment, drastically reducing maintenance time.

A split oil seal is a relatively simple concept. It involves removing a section of a solid composite 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 oil seals include a garter spring, which needs to be assembled around the shaft onto the seal during installation. Care should be exercised when selecting a split oil seal with a garter spring, as the spring may become dislodged during installation of the seal into the housing bore. Some composite split oil 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 (Fig. 7).

Most split oil 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 dis-

continued

Table 1 – Taber Wear Factor Comparison

	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/ 1,000)	548.0	145.5	113.2	39.2	481.4	49.2

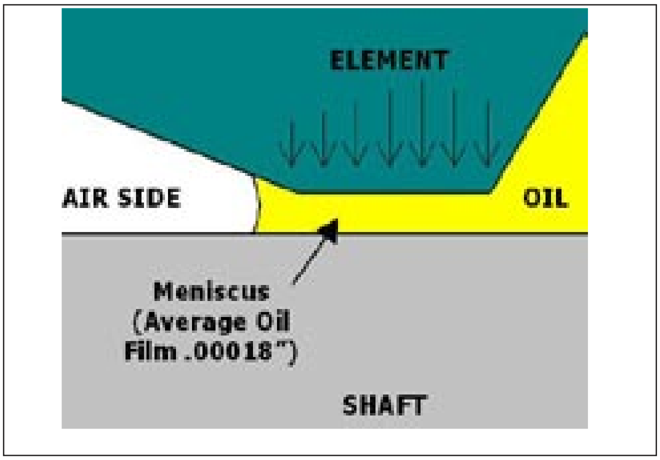


Figure 5—The sealing meniscus.

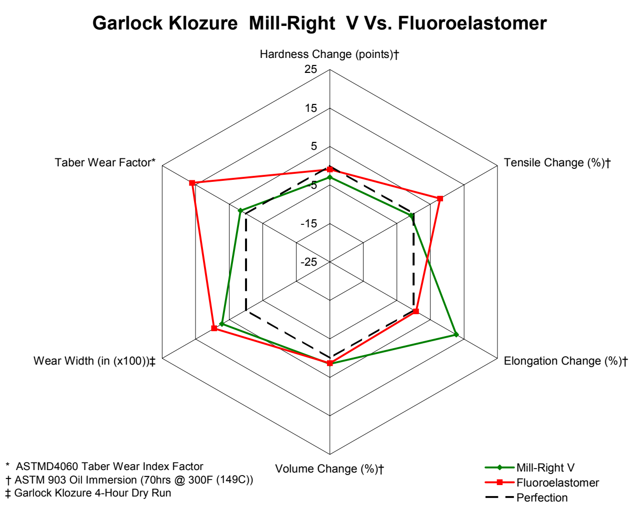


Figure 6—Mill-Right V radar chart.

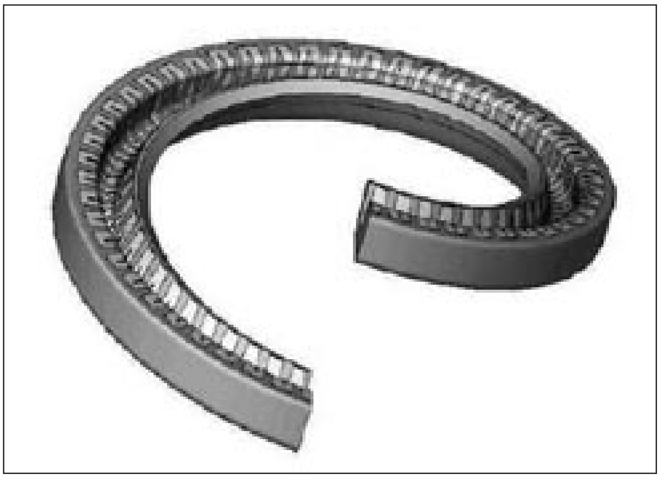


Figure 7—Garlock Klozure composite split oil seal with finger spring.

engaged 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 (Fig. 8).

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, to the extent 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 (Fig. 9).

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. Composite seals are a primary method for 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 specific needs. Utilizing timesaving designs such as split seals serves to dramatically reduce downtime. Good use of all these innovations will positively impact uptime and ultimately improve profitability.

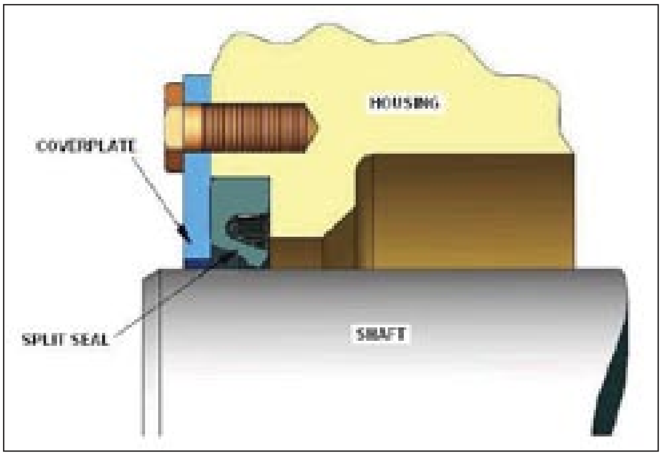


Figure 8—Split oil seal with cover plate.

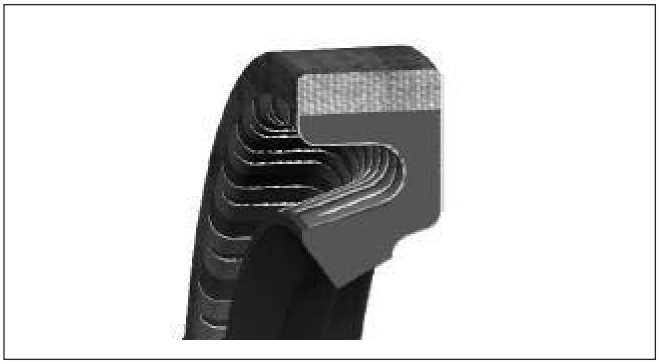


Figure 9—Garlock Klozure Model 26 composite split oil seal.

References

1. Haycock, Roger. F., Arthur J. Caines and John E. Hillier, *Automotive Lubricants Reference Book*, 2nd Edition, Warrendale, PA : Society of Automotive Engineers., 2004.
2. Brink, Robert V., Editor, Daniel E. Czernik and Leslie A. Horve. *Handbook of Fluid Sealing*, New York, McGraw-Hill, Inc., 1993.
3. Rogalski, Earl. "Dynamic Sealing Technology," *Society of Tribologists & Lubrication Engineers Conference Proceedings*, October 2004.
4. Chitren, Elizabeth and Jim Drago. "Improved Life for Dynamic Seals in Wind Turbine Applications," WindPower 2005 Conference and Exhibition, May 15–18, 2005.
5. The University of Tennessee at Martin. "Hydrodynamic Bearings— Theory, Engineering 473," *Machine Design*, Lecture 25.
6. Chris Tones and Earl Rogalski. "Recent Advances in Elastomer Technology," Iron & Steel Technology Conference, May 2005, pg. 1025–1032.
7. Taber Industries, 2007, *http://www.taberindustries.com/Products/abraser/taber_abraser_description.asp?ct=1&sc=1*.

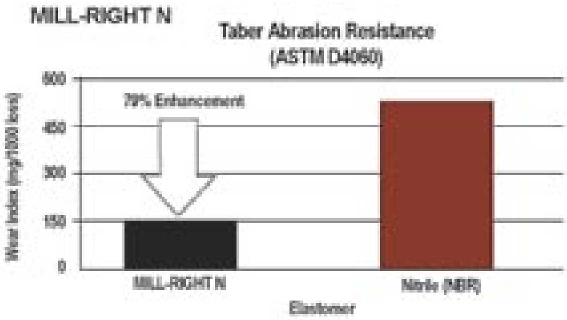
For more information:
Garlock Sealing Technologies, Inc.
An Enpro Industries Company
1666 Division Street
Palmyra, NY 14522
Phone: (315) 597-4811
Fax: (866) 645-7325
www.garlock.com

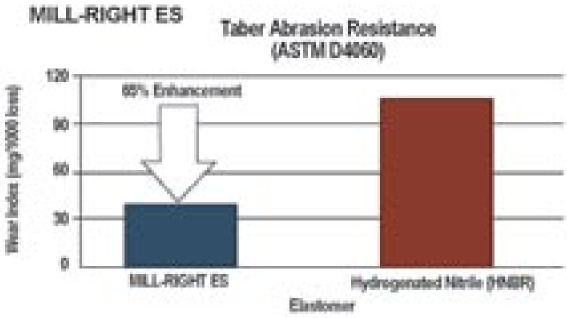
David C. Roberts *currently holds the position of product engineer at Garlock Sealing Products, an EnPro Industries company. In this position, Roberts is responsible for the design, development and testing of sealing devices for dynamic applications. Principal product lines supported include radial lip seals, bearing isolators and mechanical seals. Prior to his role as a product engineer, Roberts held the position of applications engineer for radial lip seal and bearing isolator products. Roberts' published works include "Extending Equipment Life through Improved Sealing Technology," published at the Power-Gen Conference, 2007, and "Improving Equipment Uptime: Composite Seals Meet the Challenge," published at the AIST Conference, 2009. Roberts holds a bachelor's degree in mechanical engineering technology from the College of Applied Science and Technology at Rochester Institute of Technology and is licensed as a professional engineer in New York state.*

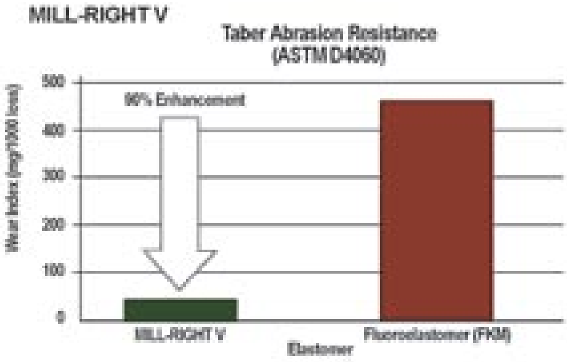
Chris Tones *currently holds the position of product engineer at Garlock Sealing Products, an EnPro Industries company. In this position, he is responsible for the design, development and testing of sealing devices for dynamic applications. Principal product lines supported include radial lip seals, bearing isolators, and mechanical seals. Prior to his role as a product engineer, Tones has held positions including process engineer, materials engineer and test lab technician. He holds a bachelor's degree in organizational management, associate's degree in mechanical engineering and four U.S. patents on bearing isolator and radial lip seal technologies.*

Appendix A

Abrasion Resistance Improvements



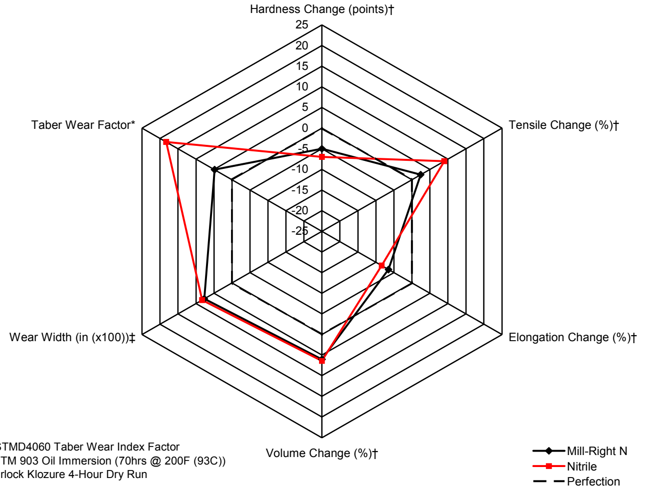




Appendix B – Radar Charts

Mill-Right N Radar Chart

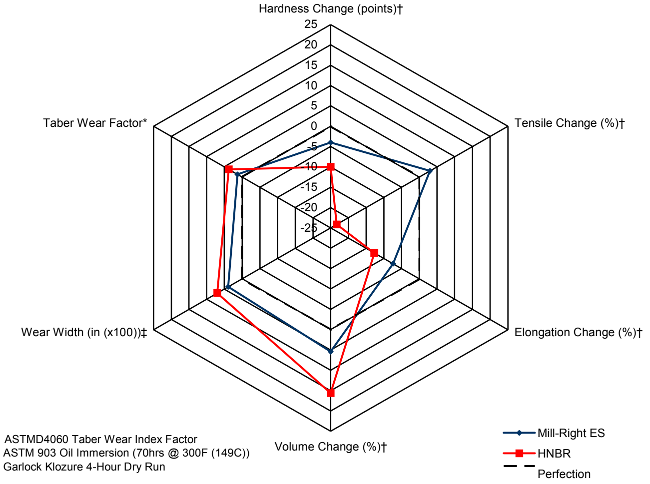
Mill-Right N Vs. Nitrile



* ASTMD4060 Taber Wear Index Factor
† ASTM 903 Oil Immersion (70hrs @ 200F (93C))
‡ Garlock Klozure 4-Hour Dry Run

Mill-Right ES Radar Chart

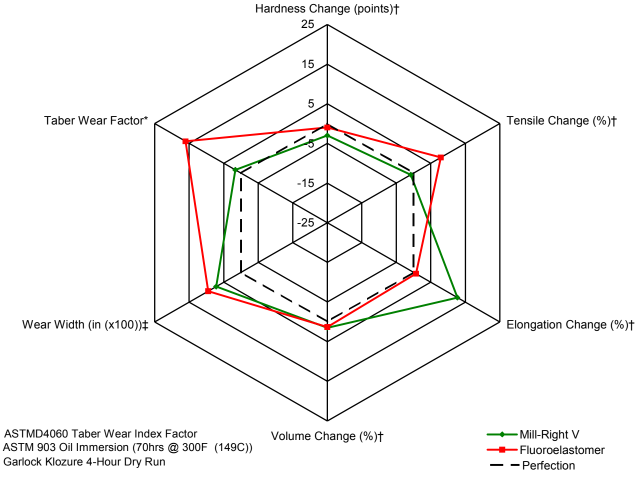
Mill-Right ES Vs. HNBR



* ASTMD4060 Taber Wear Index Factor
† ASTM 903 Oil Immersion (70hrs @ 300F (149C))
‡ Garlock Klozure 4-Hour Dry Run

Mill-Right V Radar Chart

Mill-Right V Vs. Fluoroelastomer



* ASTMD4060 Taber Wear Index Factor
† ASTM 903 Oil Immersion (70hrs @ 300F (149C))
‡ Garlock Klozure 4-Hour Dry Run