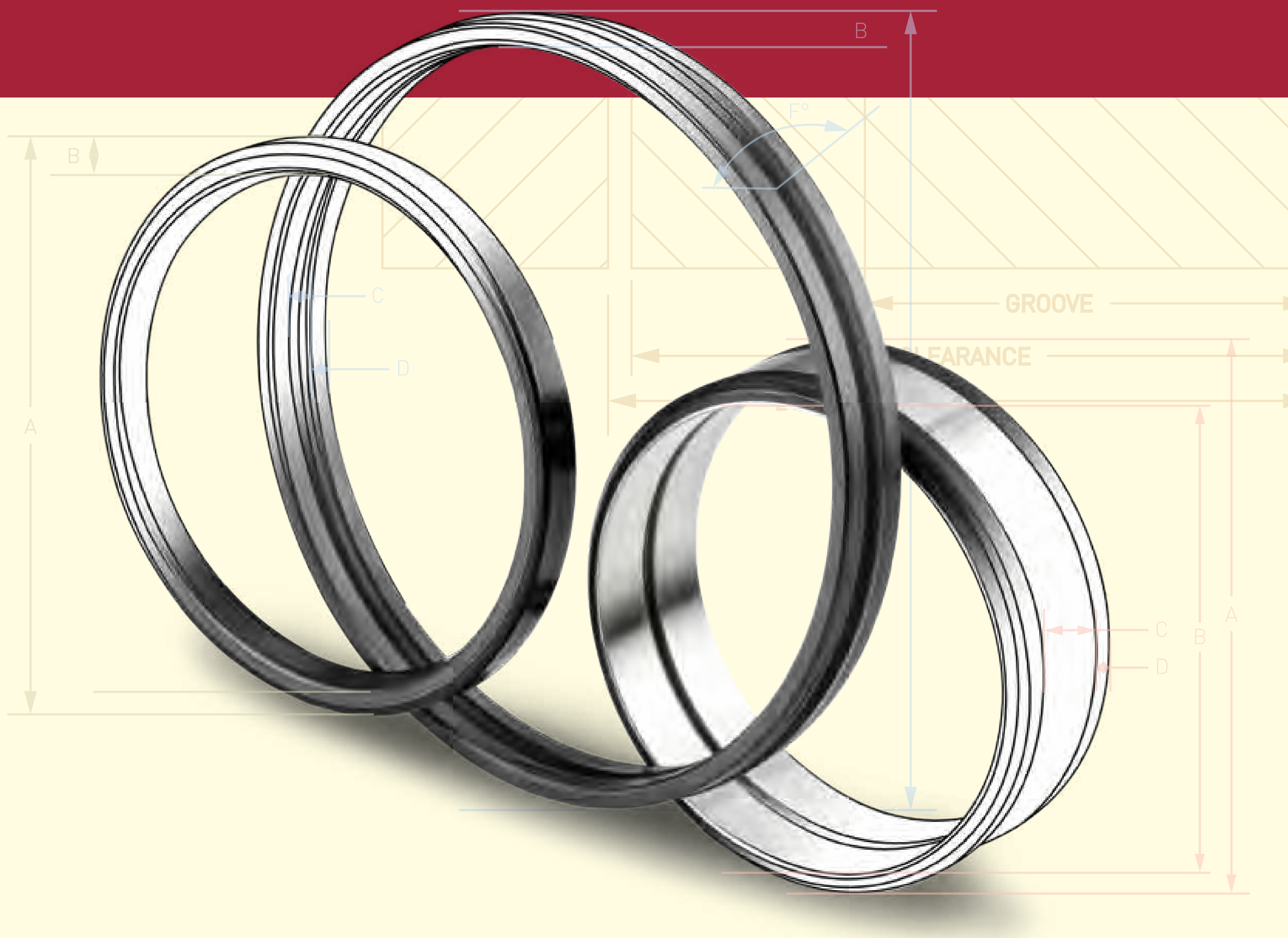
# Engineered Elastomeric Seals and Sealing Solutions




A member of the global group Fenner

CDI ENERGY PRODUCTS

# Table of Contents



To learn how CDI Energy Products can improve performance in your operations, please visit our website at CDIproducts.com or submit an inquiry at CDI-Global.Sales@CDIproducts.com

CDI ENERGY PRODUCTS

# Global Challenges. Global Capabilities.

## Engineered Products and Customized Sealing Solutions for the Energy Industry

Increasingly severe conditions associated with oil and gas exploration, drilling, completion, and production introduce unique challenges that threaten the optimal performance of critical equipment. In response to the increasing complexity of extracting hydrocarbons, energy operators and service companies alike look for innovative engineering design that will protect assets, personnel, and the environment. Whether surface and topside, downhole, or subsea, CDI Energy Products transforms specialized materials into engineered solutions that address critical performance challenges. With decades of experience in providing leading-edge, critical-service sealing solutions, we are your responsive, innovative, and collaborative partner.

| Services and Activities | Applications and Equipment |
|---|---|
| **Seismic** | Geophones and streamers |
| **Well Construction** | Top drive systems, liner hangers, pumping systems, rig equipment, cementing heads, drill bits, motors, and jars |
| **Pressure Controls** | Wellheads, trees, and BOPs |
| **Logging and Measurement** | MWD, LWD, openhole, and cased-hole |
| **Stimulation and Completions** | Packers, bridge plugs, frac plugs, and pressure pumping (including hydraulic fracturing) |
| **Downhole Tools** | Completion systems, cased-hole logging systems, wireline tools |
| **Production Optimization** | Enhanced oil recovery, artificial lift, measurement, and monitoring |
| **Intervention** | Coiled tubing systems, workover equipment |
| **Wellhead** | Surface and subsea systems |
| **Workover Equipment** | Ram and annular BOP components, seals, and blocks |

## Quality Assurance

At CDI Energy Products, we address quality at every step, from concept to completion. Using state-of-the-art manufacturing technology, robotic cells, and advanced manufacturing processes, we ensure the highest level of precision and process control. Quality is also maintained through strict adherence to detailed document review, well-defined and repeatable processes, and statistically based inspection plans.

## Quality, Health, Safety, Environment (QHSE)

Our commitment to QHSE comes from genuine concern for our people, our customers, the environment, and corporate responsibility. The health and safety culture at CDI Energy Products is based on personal empowerment, encouraging each of our employees to take personal responsibility in following the protocols and procedures that ensure QHSE compliance. Our first priority is to ensure that each of our employees returns home safely.

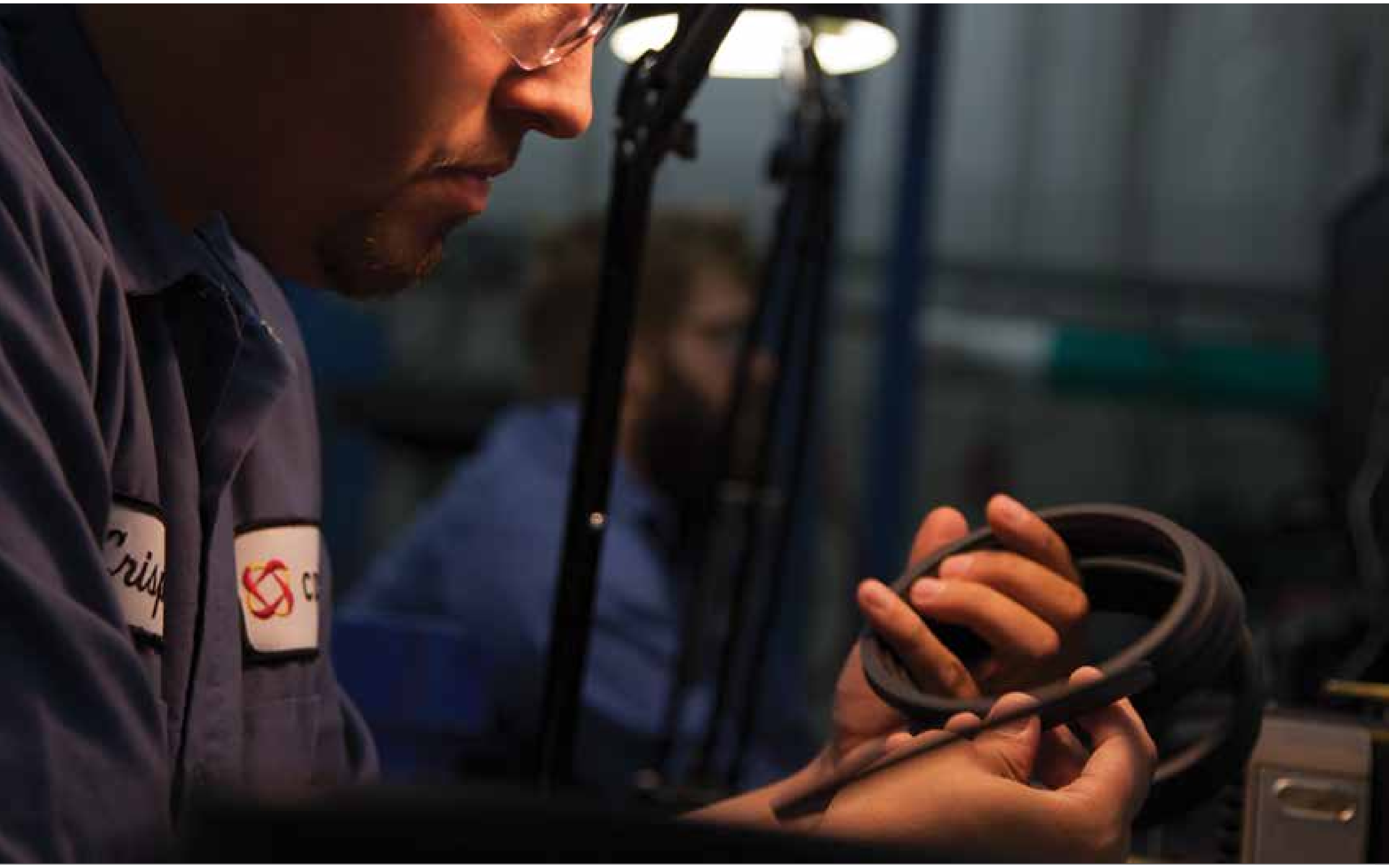
### Manufacturing Facility QHSE Certifications

**Singapore**
ISO 9001:2008
ISO 14001:2004
OHSAS 18001:2007
bizSAFE Level Star

**Hampton, UK**
ISO 9001:2008
ISO 14001:2004
OHSAS 18001:2007

**Leeds, UK**
ISO 9001:2008

**Houston, US**
ISO 9001:2008
ISO 14001:2004
OHSAS 18001:2007



# Materials Science, Engineering Design, and Advanced Manufacturing

The broad range of customized seals, engineered components, and packing assemblies offered by CDI Energy Products is backed by extensive research and some of the industry's most advanced manufacturing capabilities and high-performance material compounds. Combining our expertise in materials science, engineering design, and advanced manufacturing, we have a multidisciplinary project team capable of providing you with a versatile resource for developing unique sealing solutions for your applications.

## Materials Science Expertise

Our expertise in materials science enables us to ensure sealability across the broad pressures, temperatures, and media found in the global energy industry. Ready to implement the latest advancements in materials science, CDI Energy Products has a materials portfolio that includes advanced polymers such as API-, NACE-, ISO-, and NORSOK-approved compounds, and is continually updated by a global team of scientists on the forefront of new technology development.

**In addition to our ability to engineer and transform elastomer materials, our cross-functional team works with a portfolio of high-performance polymeric and metallic materials, including:**

### Elastomers

- NBR
- HNBR
- FKM (Viton®)
- FEPM
- FEPM (Aflas®)
- FVMQ
- PU
- EPDM
- CR
- XNBR

### Composites

- Particle-reinforced
- Fiber-reinforced
- Fabric-reinforced

### Plastics

- PTFE (Teflon®), filled and unfilled PTFE / M-PTFE
- PA (Nylon®)
- PFA
- PVDF (Kynar®)
- CTFE
- PEI (Ultem®)
- PI (Vespel®)
- PE, UHMW
- POM (Acetal, Delrin®)
- ETFE (Tefzel®)
- ECTFE (Halar®)
- Polypropylene
- PPS (Ryton®)
- PEEK®, PEK, PEKEKK

### Thermoset Plastics

- PF (phenolics)
- EP / epoxy

### Metals

- Carbon steel
- Low-alloy steel
- Aluminum bronze
- Stainless steel
- Nickel-based alloys
- Titanium
- Cobalt (Elgiloy®)

### Metal Coatings

- NOROSK M501
- PTFE (Xylan®)
- Molybdenum disulfide ($MoS_2$)
- Silver and zinc plating
- Three-coat epoxy for seawater immersion (C-157)
- System 7®
- Zinc phosphate
- Manganese phosphate
- Everlube®

## Engineering Design

Our laboratory and testing facilities are critical in the development of engineered sealing solutions and proprietary material formulations. We combine our expertise in advanced materials science with superior design capabilities, such as finite elemental analysis (FEA) and plastic flow simulation, and material and product fixture testing. From custom elastomeric seals, to plastic and metallic sealing components, our team of cross-functional experts works to ensure that each component is designed to meet your performance requirements.

### Design

- 3D modeling and drafting packages (handling formats such as .SLDDRW, .SLDASM, .SLDPT, .SLDDR, .VLM, .DXF, .DWG, .IGES, and .ProE)
- Our proprietary computerized design equations for completely automated drafting of standard CDI products

### Analysis

- Advanced FEA packages, specifically adapted for the non-linearity of polymeric materials; both plastics and elastomers
- Computational polymer melt rheology for mold optimization
- Advanced engineering calculus software packages
- Engineering library related to seals, materials, and manufacturing technology

### Experimental

- Tensile and compression experiments at different temperatures
- Dynamic mechanical analysis at different temperatures and strain rates (DMA, MA, TMA, TGA, DSC - all standard thermal analysis instruments)
- Standard thermal analysis instruments (DSC, TMA, TGA)
- Rheology
- Wear testing: dry or lubricated, with or without temperature control
- Chemical compatibility testing (liquids / gas, pressurized / non-pressurized)
- Compound development
- High-pressure testing capabilities suitable for ISO, NORSOK, and API qualification

## Advanced Manufacturing

Drawing on 40 years of experience, each customized solution benefits from our extensive machining and molding capabilities. Our skilled manufacturing specialists and programmers apply unique designs to precisely transform advanced materials into finished products that meet your specifications. With manufacturing facilities in the US, Singapore, and the UK, we employ more than 30 different molding methods and manufacturing processes, including:

### Precision Machining

**Composite Machining**

**Precision Polymer Machining**

- CNC (lathes and mills, including 5-axis machining)
- Manual (lathes and mills)
- Screw

**Precision Metal Machining**

- CNC turning
- CNC milling (vertical and horizontal)
- EDM / wire erosion

### Bonding Capabilities

- Metal to rubber
- Metal to plastic
- Rubber to rubber
- Rubber to wiremesh
- Rubber to plastic

### Large-Diameter Production

- Compression Molding
- Machining
  - CNC
  - Manual

### Molding

- Injection (rubber and plastic)
- Compression (rubber, PTFE, thermoset)
- Melt molding
- Automatic molding / automolding (thermosets and PTFE)
- Transfer molding

### Post-Processing/Post-Production Mods

**Surface Treatments**

- Friction-reducing treatment
- Plasma

**Coating**

- NOROSK M501
- PTFE (Xylan®)
- Molybdenum disulfide ($MoS_2$)
- Silver and zinc plating
- Three-coat epoxy for seawater immersion (C-157)
- System 7®
- Zinc phosphate
- Manganese phosphate
- Everlube®

**Surface modifications**

- OptiEtch™
- OptiLok™

### Custom Tool Manufacturing

| Table 1: Manufacturing Capacity | | |
|---|---|---|
| **Material** | **Molding Capability** | **Machining Capability** |
| Thermoplastics Injection | Molding to 30" | Machining to 100" |
| Elastomers Compression | Molding to 32" | Machining to 32" |
| PTFE Compression | Molding to 100" | Machining to 100" |
| Cast Polymers | Cast to 100" | Machining to 100" |

# Materials Science and Technology

## 1.1 Common Material Testing

For a seal to perform optimally, its material must possess physical and chemical properties that are compatible for the given application conditions. To verify that the material is suitable for the performance environment, laboratory testing can be conducted, resulting in a comprehensive material characterization along with considerations for part design and manufacturing processes required for producing the final product.

When material testing is required for your application, we are able to provide a range of standard (ASTM, ISO, DIN, JIS, etc.) tests, along with custom testing specifically developed to reveal material and product behavior under certain performance conditions. This testing helps ensure that our products meet customer requirements for pressure, temperature, chemical resistance, wear resistance, extrusion, expected lifetimes, ease of installation, and operational performance.

The chart below lists some of our standard tests and testing procedures for both plastic and elastomer materials.

**Table 2: Standard Material Testing**

| Material Type | Testing Performed |
|---|---|
| **Elastomers** | **Hardness:** This test is used mostly for control purposes, as no simple relationship exists between hardness and any fundamental physical property. This testing is useful for "first approximation," for narrowing the field of potential candidate materials.<br><br>**Tensile stress-strain properties:** The fundamental mechanical properties are derived from the stress-strain curve for later use in analytical and FEA calculations for product design and for quality control of incoming batches.<br><br>**Compressive stress-strain properties:** This testing complements the tensile stress-strain curve to complete the understanding of the range of deformations. It also focuses on identifying the compressive failure of materials.<br><br>**Thermal:** Ideal room temperature scenarios are not comparable to the real world operating environment. Because of this, elasticity and viscoelasticity of materials as well as their additional thermal properties are critically important in harsh environments where temperature or thermal limits are a concern.<br><br>**Compression or permanent set:** Used to quantify relative determination of the residual seal force after subjecting a material to prolonged deflections.<br><br>**Rheology:** Used most often for rubbers, in order to optimize the vulcanization process. For plastics, rheological characterization is required for optimizing mold designs and manufacturing processes.<br><br>**Specific gravity:** Measuring the density of a material to the density of water supports quality assurance and lot-to-lot consistency.<br><br>**Chemical resistance and heat aging tests:** This testing identifies resistance and chemical compatibility of a material with various media at operational parameters such as time, temperature, pressure, and concentration.<br><br>**Wear:** These tests determine the wear resistance and abrasivity of materials under single direction sliding or in reciprocating dynamics, under specific pressures, velocities, lubrication modes, temperatures, and abrasives. Important in dynamic applications, where single direction or reciprocating dynamics is involved. We perform both dry and lubricated wear tests.<br><br>**Tear resistance:** Measures a material's resistance to crack, propagation, and tear.<br><br>**Adhesion:** This serves primarily as a quality control test for the bonding of dissimilar materials. |
| **In addition to the tests listed above, CDI Energy Products can conduct other tests to meet your specific needs and requirements.** | |

## 1.2 Information Available for Certifications

Each polymer and material compound has its own group of applicable tests, available certifications, and industry standards. When developing material specifications, OEMs and service companies may develop requirements based on the needs of their individual applications. In the evaluation of material properties and characteristics, there is a limit as to how much data can be obtained from batch certificates for raw materials. To address these concerns, our materials specialists are able to conduct standard tests for each of our materials as well as develop additional test values per your specification. The chart below shows the standard test data available for various material types:

| Table 3: List of Available Standard Certifications for Elastomer Materials | | |
|---|---|---|
| **Type of Certification** | **Properties** | **Standard** |
| Typical data available for a certificate of conformance (COC) | Batch Information | — |
| C01 Properties | Batch Data<br>Shore Hardness | ASTM Standard |
| C11 includes C01 properties along with the additional tests listed | Tensile Strength<br>Elongation<br>100% Modulus<br>Specific Gravity | D412<br>D412<br>D412<br>D792<br>D2240 |
| **Notes:** | **Other tests can be provided on a batch or qualification basis for an additional charge. Additional lead time required.** | |

# Engineered Elastomeric Materials

## 2.1 Elastomer Material Families

When proposing an oilfield sealing solution, the inherent properties of elastomers make them ideally suited to survive pressures, chemicals, abrasives, and other challenges common in the oil and gas industry. However, these material properties have to be combined with comprehensive consideration of all engineering aspects.

Some of the more common engineering aspects found in the oil and gas sector include overall assembly geometry and effect of the application constraints (gland design, extrusion gaps, etc.). Other considerations can be expanded to include things such as:

- Hydrodynamics and wettability
- Surface roughness of counter surfaces
- Dynamic or static applications
- Gases or fluids (inert or aggressive)
- Thermal fluctuations (with or without)
- Expected lifetimes

While a number of other critical elements can and should be considered alongside those referenced, proper evaluation of such factors creates the ideal scenario to design, engineer, and manufacture a sealing system that will be successful for a given application.

After evaluating service conditions to remedy any issue related to sealability, selecting a proper material is essential. The standard chemical and mechanical properties of certain elastomers make them ideal candidates for certain service conditions and less-than-ideal candidates for others. In many cases, our materials scientists can also tailor material properties, addressing specific requirements for applications with extreme operating parameters. Table 4 gives a generalized overview of the major material families, their trade names, and recommended service.

**Table 4: Classes of the Common Elastomers and Their General Chemical Compatibility**

| Families of most-common seal-grade elastomers | | | Chemical Compatibility |
|---|---|---|---|
| ASTM D-1418 | NBR | Nitrile, Buna-N | **Recommended Service:** Petroleum oils and fuels, water, glycols, silicones |
| | | | **Not Recommended:** Ketones, esters, amines, halohydrocarbons, aldehydes |
| | HNBR | Hydrogenated nitrile | **Recommended Service:** Same as NBR and XNBR but with higher heat resistance, enhanced physical properties, and increased chemical resistance. Good for harsh well service (i.e.: $H_2S$, water steam, $CO_2$, and amine corrosion inhibitors) |
| | | | **Not Recommended:** Strong acids, halohydrocarbons |
| | FKM | Fluoroelastomer | **Recommended Service:** Petroleum oils and fuels, acids, halohydrocarbons, phosphate esters |
| | | | **Not Recommended:** Ketones, amines, low-molecular-weight esters, hot water, and steam |
| | FEPM | TFE/P | **Recommended Service:** Sour petroleum oils and fuels, acids, bases, amines, steam |
| | | | **Not Recommended:** Halohydrocarbons |
| | FFKM | Perfluoroelastomer | **Recommended Service:** Sour petroleum, acids, bases, MTBE, ketones |
| | | | **Not Recommended:** Alkali metal solutions |
| | FVMQ | Fluorosilicone | **Recommended Service:** Water, steam, alcohols, phosphate esters |
| | | | **Not Recommended:** Brake fluids, ketones |
| | PU | Polyurethane | **Recommended Service:** Certain hydraulic fluids, aromatic hydrocarbons, certain greases |
| | | | **Not Recommended:** Water, strong acids, chlorinated and nitro-hydrocarbons, high temperatures |
| | EPDM | Ethylene propylene, EPR | **Recommended Service:** Water, steam, alcohols, ketones, phosphate esters |
| | | | **Not Recommended:** Petroleum oils and fuels, diester fluids, aromatic hydrocarbons |
| | CR | Polychloroprene, neoprene | **Recommended Service:** Freon®, ammonia, silicate esters, certain hydraulic fluids |
| | | | **Not Recommended:** Petroleum oil and fuels, ketones, strong acids, steam, phosphate esters, halohydrocarbons |
| | XNBR | Carboxylated nitrile | **Recommended Service:** Same as NBR, but with improved thermal properties and abrasion resistance |
| | | | **Not recommended:** Concentrated organic acids, alcohols, amines, ethers |

## 2.2 Reviewing Relative Material Test Data

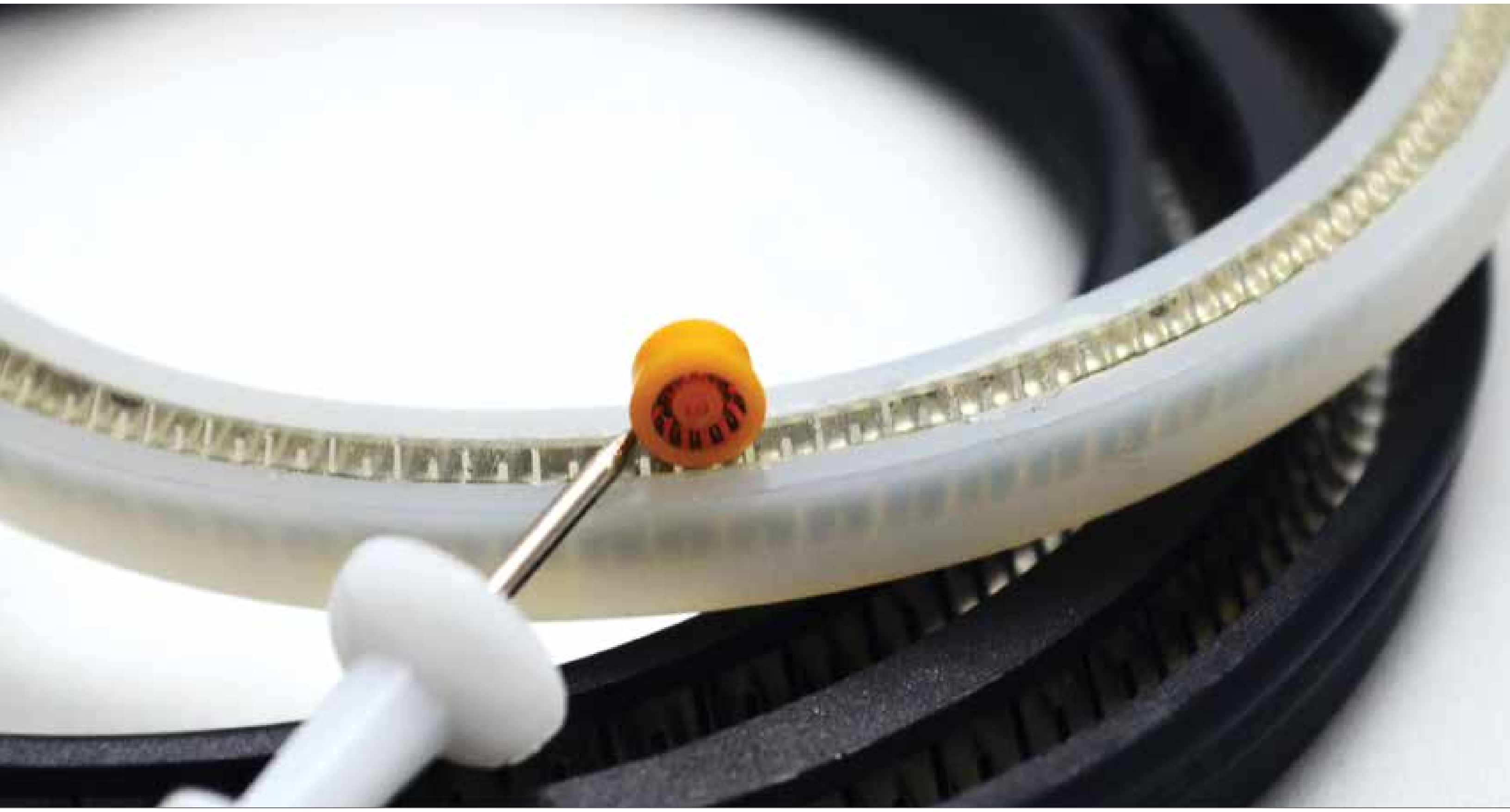
When reviewing relative material test data, it should be kept in mind that generalized compatibility of materials is a qualitative deductive process used to filter out materials that are unsuitable for relative application conditions and parameters. For many critical applications, chemical compatibility must have quantitative data allowing for more precise and nuanced material recommendations.

This requires asking difficult questions, such as:

- How bad is bad, and how good is good?
- How long does it take to drop material properties by 50% (or another relative percentage)?
- What about temperature (which has exponential influence on chemical reaction rates)?
- What about pressure (which affects saturation rates for fluids and chemical reaction rates for gases)?

These questions and many others need to have clear answers before a product can be designed, manufactured, and put to use in the field. In general, material properties are a function of many variables, including time, temperature, pressure, area of exposure, applied stress and deformations, amount of applied deformations, and chemical aggressiveness of the environment.

To ensure that a material will work in a particular application, physical and chemical properties of the material should be analyzed in conditions close to real-life scenarios, with consideration for expected lifetimes. Our materials science team routinely performs extensive chemical resistance studies in order to provide quantitative data, ensuring a confident choice of materials. We also pay close attention to the thermal performance of materials, as polymers exhibit nonlinear thermal behavior, which should be considered in stress/strain analysis.



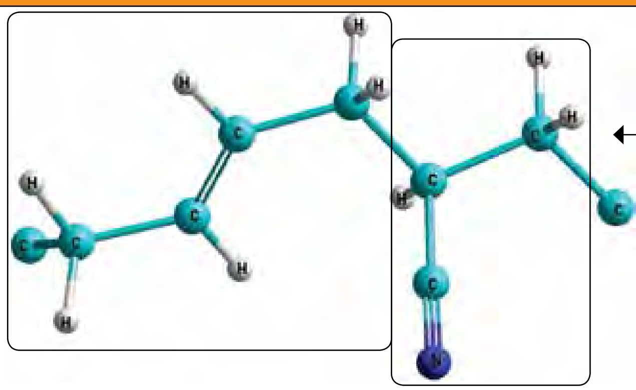
## 2.3 Material Family Reference

### NBR NITRILE (NBR)

A copolymer of acrylonitrile (ACN) and butadiene. Good oil and fuel resistance and suitable for most petroleum product applications. Due to the variety of polymer types and range of cure methods available, compounding is very diverse. Sulfur vs. peroxide cure must be evaluated based on service requirements and cost effectiveness. Resistance to high pressure $CO_2$ and methane requires high-modulus compounds to resist explosive decompression. NBR is not recommended for service in acids, bases, ketones, esters, bromides, and steam.

**NBR Structure**

Butadiene →




← Acrylonitrile

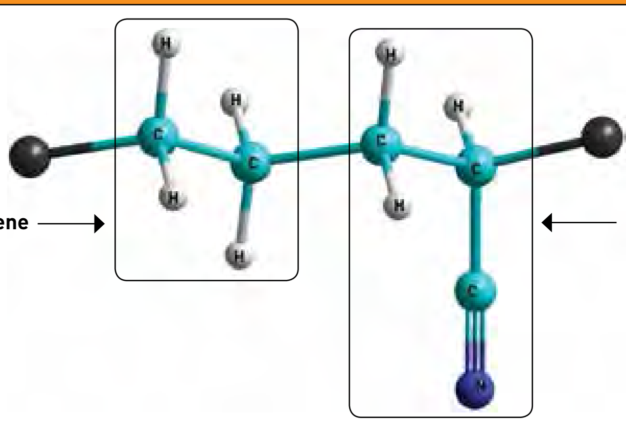
| | |
|---|---|
| **Common Names** | Nitrile, Buna, Buna-n, NBR |
| **Polymer Trade Names** | Perbunan®<br>Nipol®<br>(HYCAR®) |

### HNBR HYDROGENATED NITRILE (HNBR)

A class of nitrile polymer. HNBR compounds retain the hydrocarbon and fuel resistance of regular nitriles while exhibiting improved physical and thermal properties. These improvements are the result of reducing or eliminating unstable double bonds in the polymer backbone. This reduction of double bonds (hydrogenation) provides improved chemical resistance over regular nitrites. HNBR is not recommended for service in strong acids, ketones, esters, and halohydrocarbons.

**HNBR Structure**

Ethylene →



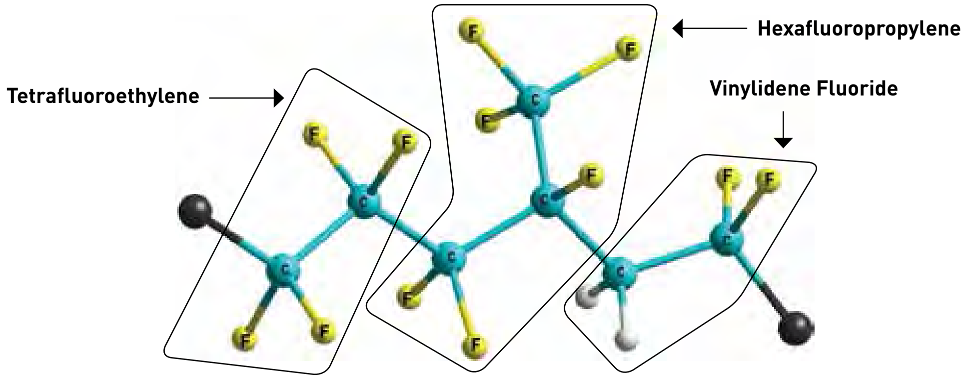

← Acrylonitrile

| | |
|---|---|
| **Common Names** | Saturated Nitrile, Hydrogenated Nitrile, HNBR, Highly Saturated Nitrile, HSN |
| **Polymer Trade Names** | Therban®<br>Zetpol® |

## FKM FLUOROCARBON (FKM)

This elastomer is widely used in oilfield and chemical applications. High-performance polymer with excellent thermal properties combined with strong resistance to hydrocarbons, $H_2S$ and $CH_4$, chemicals, and heat. Two major types of polymer exist: FKM copolymer (Type A or E) and FKM terpolymer (Type B or GF). The fluorine content present in the terpolymer increases chemical resistance but compromises low-temperature capability. The GF-type is a tetrapolymer that is suitable for peroxide curing.

**FKM Structure**

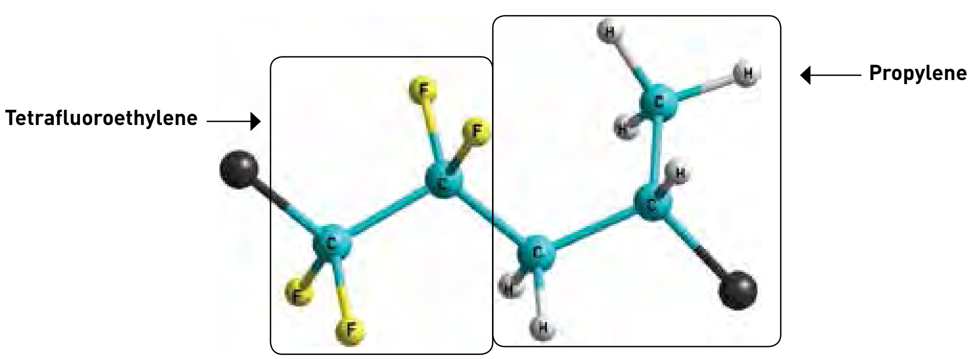



| | |
|---|---|
| **Common Names** | Fluorocarbon, Fluoroelastomer, FKM, FPM |
| **Polymer Trade Names** | Viton®<br>Fluorel®<br>Technoflon®<br>DAI-EL® |

## FEPM TETRAFLUOROETHYLENE PROPYLENE

FEPM is a high-performance class of fluorocarbon and olefin copolymer. Compounds of FEPM offer oil and chemical resistance, along with excellent thermal properties. The notable improvement over FKM polymers for oilfield applications is resistance to both acids and bases. Newer FEPM-2 polymers based on ethylene, TFE, and PMVE offer increased chemical resistance. Widely used in oilfield and chemical applications, FEPM resists oil, amines, corrosion inhibitors, $H_2S$, $CO_2$, and $CH_4$, all of which are encountered in harsh well service. FEPM is recommended for service in acids, bases, hydraulic fluids, brake fluids, steam, alcohols, ozone, and gamma radiation.

**FEPM Structure**

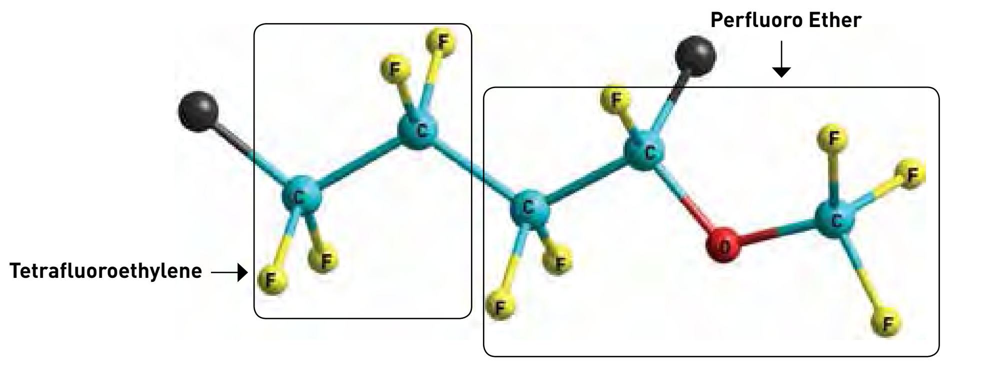



| | |
|---|---|
| **Common Names** | TFEP, Aflas®, Fluoraz®, HTCR, Viton® Extreme |
| **Polymer Trade Names** | TFEP<br>Fluoraz®<br>HTCR<br>Aflas®<br>Viton® |

## FFKM PERFLUOROELASTOMER (FFKM)

A fully fluorinated high-performance elastomer. Offers greater chemical and thermal aging resistance compared to traditional FKM and FEPM compounds. Offers the broadest chemical resistance of any elastomeric seal material due to a fully fluorinated structure. Recommended services include acids, bases, hydrocarbons, and ozone. Not recommended for service in fully halogenated fluids and molten alkali metals.

**FFKM Structure**

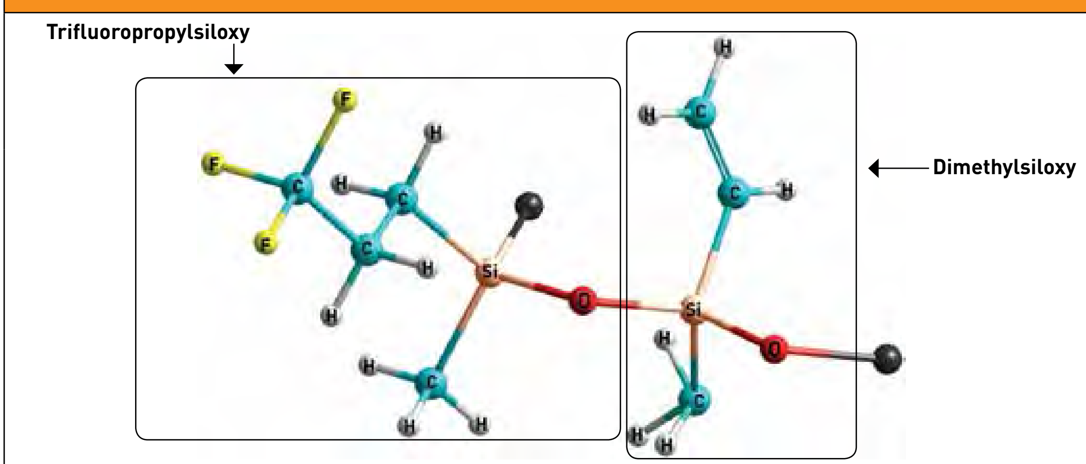



| | |
|---|---|
| **Common Names** | Perfluor, Perfluoroelastomer, FFKM |
| **Polymer Trade Names** | Kalrez®,Zalak®<br>Chemraz®<br>Parofluor®<br>DAI-EL® |

## FVMQ FLUOROSILOCONE (FVMQ)

FLUOROSILICONE (FVMQ) elastomer is an inorganic polymer, meaning that it does not have a carbon-to-carbon backbone typical of most other elastomers. This gives FVMQ compounds some unique properties related to low-temperature capability. Unlike a similar polymer—silicone (VMQ)—fluorosilicone has notable oil and fuel resistance, along with slightly lower thermal resistance. While its thermal and chemical properties are strong, its major weakness is mechanical strength and abrasion resistance, and this generally limits its use to static sealing applications. Co-molding FVMQ into PTFE and other thermoplastic jackets has broadened its usage in methanol injection pumps for low-temperature wellhead applications.

**FVMQ Structure**

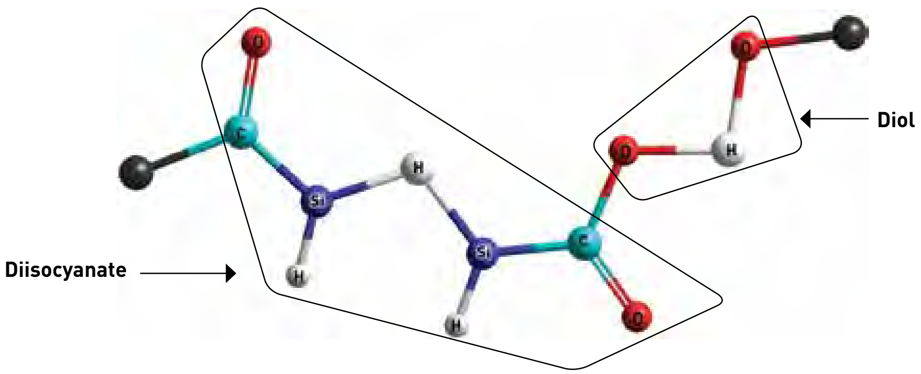



| | |
|---|---|
| **Common Names** | Fluorosilicone, FVMQ, FK |
| **Polymer Trade Names** | Silastic ®<br>FSE ®<br>FE ® |

## PU POLYURETHANE (PU)

A widely used versatile compound in the oilfield and in many other dynamic applications, polyurethanes have a urethane linkage in the repeating units. This material is made by a reaction of a polyol with diisocyanate, both of which can be different types, allowing the materials to be tailored to meet application conditions. Diisocyanates can be aromatic or aliphatic; polyols are usually classified as polyesther-, polyether-, polycarbonate-, or polycaprolactone-based. Polyurethanes are known for extremely high abrasion resistance (especially compared to conventional rubbers), notable mechanical properties, excellent fatigue resistance, and great chemical resistance. Such properties make them ideal as seal materials after thermal limits and potential for hydrolysis have been evaluated.

**PU Structure**

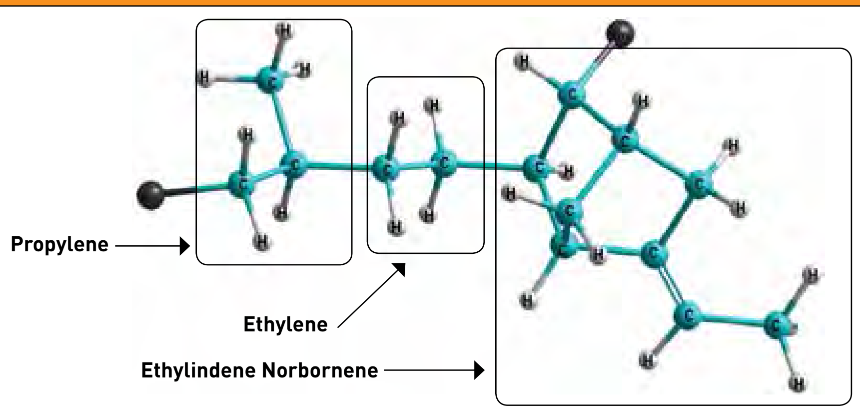



| | |
|---|---|
| **Common Names** | Polyurethane, PU |
| **Polymer Trade Names** | Hythane®<br>Pellethane®<br>Zythane®<br>Isothane® |

## EPDM ETHYLENE PROPYLENE DIENE (EPDM)

A material used in applications requiring superior aging properties. Sample applications include heater and radiator hoses, and exterior weather and water seals. Excellent resistance to water-based hydraulic fluids. Also suitable in applications involving steam, such as enhanced recovery and geothermal energy. Suitable for most water, steam, alcohols, ketones, phosphate esters. Not recommended for service in petroleum oils and fuels, diester fluids, and aromatic hydrocarbons.

**EPDM Structure**



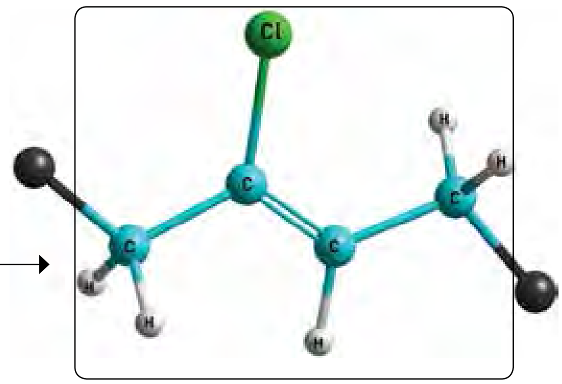

| | |
|---|---|
| **Common Names** | EP, EPR, EPDM, EPM |
| **Polymer Trade Names** | Nordel IP®<br>Buna EP®<br>Vistalon®<br>Keltan® |

## CR POLYCHLOROPRENE

Polychloroprene (CR) elastomer is a general-purpose elastomer used heavily in the fluid power industry due to a good balance of oil and ozone resistance. CR compounding is relatively simple; however, polymer choice is diverse. Differences in crystallization and viscosity have a large effect on properties and processability. The chlorine atom attached to the molecular chain provides resistance to paraffin-based lubricants while also providing good environmental resistance. CR is suitable for most non-aromatic petroleum lubricant applications. Other areas of use are in water, silicones, and weather. Strong resistance to $CO_2$ ammonia, and refrigerants. CR is not recommended for service in acids, bases, ketones, esters, aromatics, and chlorinated hydrocarbons.

### CR Structure

Chlorobutadiene →

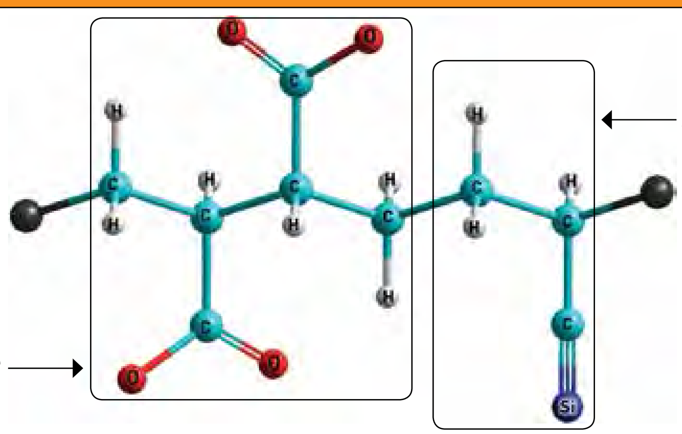


| | |
|---|---|
| **Common Names** | Chloroprene, CR |
| **Polymer Trade Names** | Neoprene® Batpren® |

## XNBR CARBOXYLATED NITRILE (XNBR)

Widely used in the fluid power and upstream oil and gas industry due to good oil resistance. A copolymer of acrylonitrile (ACN) and butadiene with a carboxylic acid appendage, it has improved abrasion resistance over standard nitrile. Faces issues with higher compression set, metal bonding, and limited process life. Aforementioned issues can be remedied by using a peroxide cure; however, XNBR's excellent abrasion resistance is sacrificed. For new applications, hydrogenated nitrile (HNBR) may be considered rather than XNBR.

### XNBR Structure



← Acrylonitrile

Carboxyl Butadiene →

| | |
|---|---|
| **Common Names** | Carbox, XNBR |
| **Polymer Trade Names** | Nipol® Chemigum® Perbunan® |

# Design Criteria and Considerations

## 2.4 Material Selection for Elastomeric Seal Compatibility and Performance

Because no single seal design or material exists that is suitable for every application environment, careful attention must be paid to operating parameters and conditions that may impact seal performance. In designing the ideal sealing solution for your application, our team of experts carefully evaluates and incorporates seal design parameters based on your specific requirements.

**Questions to asking when considering seal design and material selection:**

**Media Resistance:** What materials can retain necessary physical properties in the given environment?

**Sealability:** How will the combination of materials and design effect the seal?

**Mechanical Strength:** Once the seal has been achieved, will the combination of material and design be of sufficient to perform as expected in the given application?

### Evaluating Factors and Conditions

- Temperature
- Pressure
- Velocity
- Media or chemical resistance
- Material
- Friction
- Wear resistance
- Extrusion gap
- Hardware (gland envelope)
- Service requirements
- Seal geometry
- Industry and customer specifications

**Table 5: Seal Applications, Environmental Consideration, and Service Life**

| Seal Applications | Environmental | Service Life |
|---|---|---|
| • Fluid power<br>• Pneumatic<br>• Energy or shock absorption<br>• Media separation<br>• Pressure containment | • Pressure<br>• Temperature<br>• Aggressive media<br>• Wet or dry environment<br>• Continuous or cyclical loads<br>• Dynamic or static stress | • Wear resistance<br>• Material properties<br>• Resistance to creep and cold flow<br>• Compression set<br>• Resistance to aging and embrittlement<br>• Resilience |

# Elastomer Performance in the Presence of $CO_2$ and $H_2S$

In addition to the referenced evaluating factors and conditions, careful attention must be paid to the response of elastomeric materials in supercritical applications where highly volatile gases and fluids are present. The interaction of elastomeric materials with such gases as $H_2S$ and $CO_2$ while in the presence of fluids such as water, amines, bromides, and methanol requires careful evaluation due to changing temperature and pressure scenarios.

The production environment is easily made acidic due to complex reactions between $CO_2$ and $H_2S$.

When temperature and pressure challenges are added, supercritical gases can pose extreme challenges to the success and sealability of high-performance elastomers, which can result in rapid gas decompression (RGD), explosive decompression, and even application failure.

| Table 6: Common Well Additives and Relative Effects | |
|---|---|
| Water | One of the main bases used for oilfield applications such as fracing and drilling |
| Amines | Counteract the negative effects of $H_2S$ |
| Bromides | Provides a dense, heavy material that adds weight, which helps stabilize the casing within the well |
| Alcohols (ex: methanol) | Used as antifreeze for liquids that are prone to freezing in low temperatures |

Considering these factors, current industry recommendations might discourage the use of various elastomers due to media combinations and concentrations. As additives are added to the mix, the information in the chart below is to be used as a relative guide based on field performance of elastomers when in the presence of the referenced media combinations.

The matrices found in Table 7 and Table 8 show the complex relationship between elastomer performance in the presence of $H_2S$ and varying percentages of $CO_2$ along with the referenced media.

**Table 7: Elastomeric Seal Compatibility Matrix: Low Percentages of $CO_2$ (Fahrenheit)**

| Media | Elastomer | When No $H_2S$ Is Present (°F) | When $H_2S$ Is Present (°F) |
|---|---|---|---|
| Water | NBR | 40 to 200 | -40 to 150 (Low $H_2S$ Levels) |
| Water | NBR-LT | -70 to 180 | -70 to 180 (Low $H_2S$ Levels) |
| Water | HNBR | -50 to 300 | -50 to 225 |
| Water | HNBR-LT | -60 to 250 | -60 to 225 |
| Water | FKM | -30 to 200 | -30 to 200 |
| Water | FEPM | 0 to 500 | 0 to 500 |
| Water | FFKM | -40 to 500 | -40 to 450 |
| Water | FVMQ | -75 to 200 | -75 to 150 |
| Water | PU | -75 to 200 | -75 to 200 |
| Amines | HNBR | -50 to 300 | -50 to 200 |
| Amines | HNBR-LT | -60 to 250 | -60 to 200 |
| Amines | FEPM | 0 to 500 | 0 to 500 |
| Amines | FFKM | -40 to 450 | -40 to 450 |
| Amines | FVMQ | -75 to 300 | -75 to 200 |
| Amines | PU | -75 to 200 | -75 to 200 |
| Bromides | FKM | -30 to 400 | -30 to 400 |
| Bromides | FEPM | 0 to 450 | 0 to 450 |
| Bromides | FFKM | -40 to 450 | -40 to 450 |
| Bromides | PU | -75 to 200 | -75 to 200 |
| Methanol | NBR | -40 to 250 | |
| Methanol | NBR-LT | -75 to 180 | |
| Methanol | HNBR | -50 to 300 | -50 to 200 |
| Methanol | HNBR-LT | -60 to 250 | -60 to 200 |
| Methanol | FEPM | 0 to 500 | 0 to 450 |
| Methanol | FFKM | | -40 to 450 |
| Methanol | FVMQ | -75 to 300 | -75 to 200 |
| Methanol | PU | -75 to 200 | -75 to 200 |

**Table 8: Elastomeric Seal Compatibility Matrix: High Percentages of $CO_2$ (Fahrenheit)**

| Fluid | Material | When No $H_2S$ Is Present (°F) | When $H_2S$ Is Present (°F) |
|---|---|---|---|
| Water | NBR | -40 to 200 | -40 to 150 |
| | NBR-LT | -70 to 180 | -70 to 180 |
| | HNBR | -50 to 300 | -50 to 225 |
| | HNBR-LT | -60 to 250 | -60 to 225 |
| | FKM | -30 to 200 | -30 to 200 |
| | FEPM | 0 to 500 | 0 to 500 |
| | FFKM | -40 to 500 | -40 to 450 |
| | FVMQ | -75 to 200 | -75 to 150 |
| | PU | -75 to 200 | -75 to 200 |
| Amines | HNBR | -50 to 300 | -50 to 200 |
| | HNBR-LT | -60 to 250 | -60 to 200 |
| | FEPM | 0 to 500 | 0 to 500 |
| | FFKM | -40 to 450 | -40 to 450 |
| | FVMQ | -75 to 300 | -75 to 200 |
| | PU | -75 to 200 | -75 to 200 |
| Bromides | FKM | -30 to 200 | -30 to 200 |
| | FEPM | 0 to 450 | 0 to 450 |
| | FFKM | -40 to 450 | -40 to 450 |
| | PU | -75 to 200 | -75 to 200 |
| Methanol | NBR | -40 to 250 | |
| | NBR-LT | -75 to 180 | |
| | HNBR | -50 to 300 | -50 to 200 |
| | HNBR-LT | -60 to 250 | -60 to 200 |
| | FFKM | | -40 to 450 |
| | FEPM | 0 to 500 | 0 to 450 |
| | FVMQ | -75 to 300 | -75 to 200 |
| | PU | -75 to 200 | -75 to 200 |

**Table 9: Elastomeric Seal Compatibility Matrix: Low Percentages of $CO_2$ (Celsius)**

| Fluid | Elastomer | When No $H_2S$ Is Present (°C) | When $H_2S$ Is Present (°C) |
|---|---|---|---|
| Water | NBR | -40 to 93 | -40 to 65 (Low $H_2S$ Levels) |
| Water | NBR-LT | -57 to 82 | -57 to 82 (Low $H_2S$ Levels) |
| Water | HNBR | -46 to 149 | -46 to 107 |
| Water | HNBR-LT | -60 to 250 | -51 to 107 |
| Water | FKM | -34 to 93 | -34 to 93 |
| Water | FEPM | -18 to 260 | -18 to 260 |
| Water | FFKM | -40 to 260 | -40 to 232 |
| Water | FVMQ | -59 to 93 | -59 to 65 |
| Water | PU | -59 to 93 | -59 to 93 |
| Amines | HNBR | -46 to 149 | -46 to 93 |
| Amines | HNBR-LT | -51 to 121 | -51 to 93 |
| Amines | FEPM | -18 to 260 | -18 to 260 |
| Amines | FFKM | -40 to 232 | -40 to 232 |
| Amines | FVMQ | -59 to 149 | -59 to 93 |
| Amines | PU | -59 to 93 | -59 to 93 |
| Bromides | FKM | -34 to 204 | -34 to 204 |
| Bromides | FEPM | -18 to 232 | -18 to 232 |
| Bromides | FFKM | -40 to 232 | -40 to 232 |
| Bromides | PU | -59 to 93 | -59 to 93 |
| Methanol | NBR | -40 to 121 | – |
| Methanol | NBR-LT | -59 to 82 | – |
| Methanol | HNBR | -46 to 149 | -46 to 93 |
| Methanol | HNBR-LT | -51 to 121 | -51 to 93 |
| Methanol | FEPM | -18 to 260 | -18 to 232 |
| Methanol | FFKM | – | -40 to 232 |
| Methanol | FVMQ | -59 to 149 | -59 to 93 |
| Methanol | PU | -59 to 93 | -59 to 93 |

**Table 10: Elastomeric Seal Compatibility Matrix: High Percentages of $CO_2$ (Celsius)**

| | When No $H_2S$ Is Present | | | When $H_2S$ Is Present | | |
|---|---|---|---|---|---|---|
| | Min (°C) | Material | Max (°C) | Min (°C) | Material | Max (°C) |
| **Water** | -40 | NBR | 93 | -40 | NBR | 65 |
| | -57 | NBR-LT | 82 | -70 | NBR-LT | 82 |
| | -46 | HNBR | 149 | -46 | HNBR | 107 |
| | -51 | HNBR-LT | 121 | -51 | HNBR-LT | 107 |
| | -34 | FKM | 93 | -34 | FKM | 93 |
| | -18 | FEPM | 260 | -18 | FEPM | 260 |
| | -40 | FFKM | 260 | -40 | FFKM | 232 |
| | -59 | FVMQ | 93 | -59 | FVMQ | 93 |
| | -59 | PU | 93 | -59 | PU | 93 |
| **Amines** | -46 | HNBR | 149 | -46 | HNBR | 149 |
| | -51 | HNBR-LT | 121 | -51 | HNBR-LT | 93 |
| | -18 | FEPM | 260 | -18 | FEPM | 260 |
| | -40 | FFKM | 232 | -40 | FFKM | 232 |
| | -59 | FVMQ | 149 | -59 | FVMQ | 93 |
| | -59 | PU | 93 | -59 | PU | 93 |
| **Bromides** | -34 | FKM | 93 | -34 | FKM | 93 |
| | -18 | FEPM | 232 | -18 | FEPM | 232 |
| | -40 | FFKM | 232 | -40 | FFKM | 232 |
| | -59 | PU | 93 | -59 | PU | 93 |
| **Methanol** | -40 | NBR | 121 | -46 | HNBR | 93 |
| | -59 | NBR-LT | 82 | -51 | HNBR-LT | 93 |
| | -46 | HNBR | 149 | -40 | FFKM | 232 |
| | -51 | HNBR-LT | 121 | -18 | FEPM | 232 |
| | -18 | FEPM | 260 | -59 | FVMQ | 93 |
| | -59 | FVMQ | 149 | -59 | PU | 93 |
| | -59 | PU | 93 | | | |

# Material Compatibility: Media, Performance, and Temperature—Common Engineered Materials Offered by CDI Energy Products

The ability of a material to resist an attack from aggressive media that would compromise sealability is a critical factor in seal design and material selection. Once materials that satisfactorily meet the media resistance requirements that have been selected, each material can then be evaluated for sealability in various seal configurations, with consideration of the nature of the application environment and service conditions. To perform optimally, the seal must maintain acceptable physical properties and have minimal changes of those properties during the service conditions found in the given application.

However, in some extreme applications, it's actually desirable for seals to be dissolved or degraded after some point in order to be purged or removed from service without disassembling. Considering such scenarios, it's extremely important to know how materials perform under certain environmental conditions. Temperature plays a great role, having a strong influence on chemical reaction rates. In many cases, a proper material compatibility analysis requires a quantitative rather than qualitative approach. Nevertheless, a conceptually qualitative analysis, such as shown in the table below, is useful for "first approximation" screening in choosing a material for an application.

**Table 11: Standard CDI Elastomeric Materials for Engineered Elastomeric Seals for the Oilfield**

| | Property | CR | EPDM | FKM | FFKM | HNBR | NBR | FMVQ | PU | FEPM | XNBR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature | °F | -40 to +225 | -60 to +300 | -20 to +400 | -20 to +450 | -45 to +300 | -40 to +250 | -80 to +450 | -40 to +200 | 0 to +450 | -30 to +250 |
| | °C | -40 to +107 | -51 to +148 | -28 to +204 | -28 to +232 | -42 to +148 | -40 to +121 | -62 to +232 | -40 to +93 | -17 to +232 | -34 to +121 |
| Media Resistance | Abrasion resistance | G | G | G | G | E | G | P | E | F | E |
| | Concentrated acid resistance | F | G | E | E | G | F | F | P | E | F |
| | Concentrated base resistance | F | E | P | G | G | F | G | P | E | F |
| | Oil & fuel resistance | F | P | E | E | E | E | G | G | G | G |
| | Water / Steam | F | E | F | G | G | F | F | P | E | F |
| | Aromatic solvents | G | P | E | E | G | G | G | F | G | G |
| | Ozone resistance | G | E | E | E | G | P | E | G | E | P |
| | Gas Impermeability | G | G | G | G | G | G | P | G | G | G |
| Environmental | Weather resistance | E | E | E | E | G | F | E | F | E | F |
| | Flame resistance | G | P | E | E | P | P | G | P | G | P |
| Physical | Resilience | G | G | F | F | G | F | G | F | P | F |
| | Tear strength | F | G | F | F | G | F | P | E | G | G |
| | Compression set | F | G | G | G | G | G | G | P | F | G |
| | Electrical | F | G | F | F | G | F | E | E | G | F |

**P = poor F = fair G = good E = excellent**

# CDI ENERGY PRODUCTS

## ENGINEERED ELASTOMERIC SEALS AND SEALING SOLUTIONS

FS-Seals

S-Seals

P-Seals

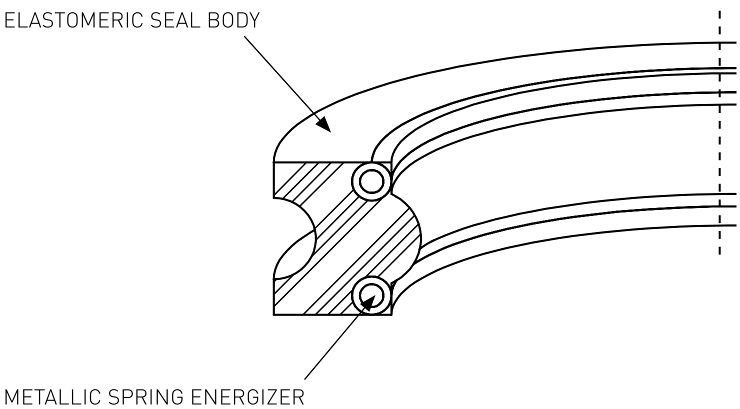
T-Seals

OL Seals

A6R Seals

PBR (Polished Bore Receptacle) Stacks and Packing Sets

# FS-Seals




## Description

FS-Seals are uniquely designed sealing elements that offer excellent sealability in areas where a high degree of seal deflection is necessary. The design features of this seal allow the component to compensate for variations in piping, casing, or large-diameter parts.

The metal garter spring in this design provides pressure-energized anti-extrusion capabilities. During operation, the activated features provide an ID-type seal that has proven effective in pressures up to 10,000 psi.

The FS-Seal technology is especially suited for applications where there are large extrusion gaps relative to diameter. The shape of the FS-Seal design allows for a high level of deflection across the full range of operating temperatures, without the risk of gland overfill. Similar to the S-Seal, the FS-Seal construction eliminates the installation problems that can occur when using multiple component seals. FS-Seals are inherently flexible, enabling positive installation in practically any large-diameter gland.

## Design Features and Benefits

- Range of elastomeric and spring material combinations
- Pressure-energized
- Can be retrofitted to existing groove
- Ability to seal large or inconsistent extrusion gaps
- Flexible seal for easy installation or field repair
- Handles aggressive chemicals and abrasive oilfield applications
- Large cross-section / diameter ID version of S-Seal
- Standard and custom sizes

### Common Applications and Services

- Casing and tubing hanger
- Stab-in operations
- High-pressure pipelines
- Hydraulic cylinders
- Fluid and gas applications
- Wide ranges of temperature and pressure

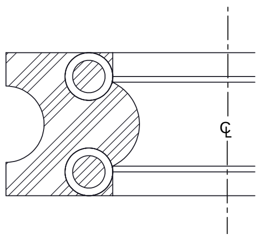
### Manufacturing and Production Processes

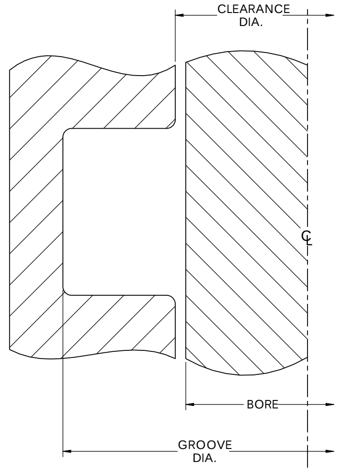
- Molding

### Sizing

- API standard casing sizes
- Custom sizing options

## Engineering and Design Considerations



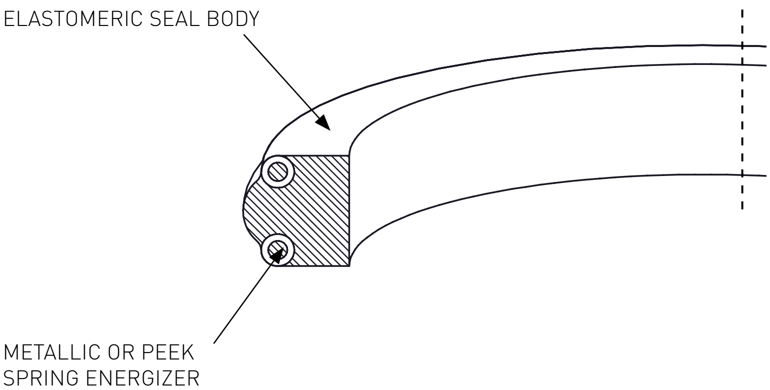



## Material Selection

| Commonly Used Elastomeric Jacket Material | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| HNBR | -45 to +300 | -42 to +148 | Same as NBR and XNBR but with higher heat resistance, enhanced physical properties, and increased chemical resistance. Good for harsh well service (i.e.: $H_2S$, water steam, $CO_2$, and amine corrosion inhibitors) |
| NBR | -25 to +250 | -31 to +121 | Petroleum oils and fuels, water, glycols, silicones |
| FEPM (Aflas®) | 0 to +450 | -17 to +232 | Sour petroleum oils and fuels, acids, bases, amines, steam |
| **Custom Compounds** | **Custom compounds and blends can be offered upon request. Please contact your CDI Energy Products representative for additional information.** | | |

| Commonly Used Metallic Spring Material | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| 316 Stainless Steel | -300 to +550 | -184 to +287 | General service, hydraulics |
| Nickel-Based Alloy (Inconel®) | -300 to +800 | -184 to +427 | Harsh service, NACE MR-01-75 |
| PEEK Spring | -56 to +260 | -48 to +126 | Dynamic motion, non-galling, gland friendly |

# S-Seals




## Description

The S-Seal design incorporates garter springs with an elastomeric sealing element, enabling it to withstand large extrusion gaps and high pressures when energized. This integral "phantom" O-Ring design combines the stability of a rectangular cross section with the proven sealability of the O-Ring. The one-piece design found in this version of the S-Seal offers a technically advanced alternative to traditional three-piece seal configurations such as T-Seals or O-Rings with back-ups.

This seal configuration streamlines installation, allowing for convenient field repair and maintenance. Additionally, the S-Seal can easily be stretched into place without splitting or compromising the anti-extrusion elements of the seal.

Our S-Seal seal design has successfully been used in applications with extrusion gaps up to .125" (3.175 mm). A range of material choices are available for a variety of services and temperatures, making this sealing solution ideal for static and HPHT sealing applications.

## Design Features and Benefits.

- Replaces common three-piece seal assemblies
- Ease of installation
- Can bridge large extrusion gaps
- Broad range of spec-grade elastomeric materials
- Large selection of available sizes
- Multiple material options for spring elements
- Metallic anti-extrusion spring option provides maximum extrusion resistance in static applications
- Thermoplastic anti-extrusion spring option available for dynamic applications

## Common Applications and Services

- Static HPHT applications
- Stab-in operations
- Manifolds
- Connectors
- Perforation
- Risers
- BOPs
- Compressors
- Directional drilling
- Wellheads

## Manufacturing and Production Processes

- Molding

## Sizing

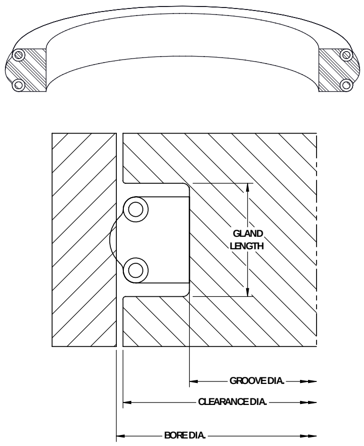
- Standard AS568B housing sizes
- Custom sizing options

To learn how CDI Energy Products can improve performance in your operations, please visit our website at CDIproducts.com or submit an inquiry at CDI-Global.Sales@CDIproducts.com

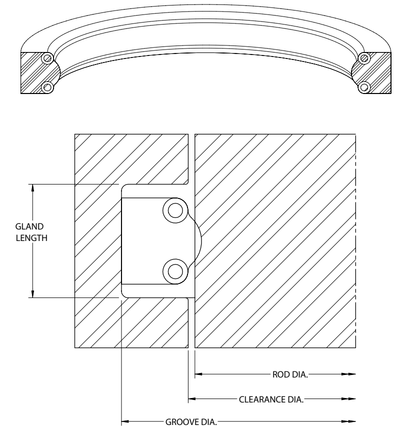
CDI ENERGY PRODUCTS

# Engineering and Design Considerations

## Piston Configuration




## Rod Configuration




# Material Selection

| Commonly Used Elastomer Materials | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| HNBR | -45 to +300 | -42 to +148 | Same as NBR and XNBR but with higher heat resistance, enhanced physical properties, and increased chemical resistance. Good for harsh well service (i.e.: $H_2S$, water steam, $CO_2$, and amine corrosion inhibitors) |
| FKM (Viton®) | -20 to +400 | -28 to +204 | Petroleum oils and fuels, acids, halohydrocarbons, phosphate esters |
| FEPM (Aflas®) | 0 to +450 | -17 to +232 | Sour petroleum oils and fuels, acids, bases, amines, steam |
| NBR | -40 to +250 | -40 to +121 | Petroleum oils and fuels, water, glycols, silicones |
| **Custom Elastomer Compounds** | **Custom compounds and blends can be offered upon request. Please contact your CDI Energy Products representative for additional information.** | | |

| Spring Option 1: Commonly Used Metallic Materials for Spring | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| 316 Stainless Steel | -300 to +550 | -184 to +287 | General service, hydraulics |
| Nickel-Based Alloy (Inconel®) | -300 to +800 | -184 to +427 | Harsh service, NACE MR-01-75 |
| Phosphorus Bronze | -300 to +500 | -184 to +260 | Non-galling for slightly dynamic capability (ex: stab in) |

| Spring Option 2: Available Specialty Polymeric Material for Spring | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| PEEK | -56 to +260 | -48 to +126 | Dynamic motion, non-galling, gland friendly |
| **Custom Plastic Compounds** | **Custom compounds and blends can be offered upon request. Please contact your CDI Energy Products representative for additional information.** | | |

# P-Seals

## Description

The P-Seal is a one-piece seal design that typically uses molded-in garter spring elements as anti-extrusion devices. The inside diameter is the primary sealing face and uses injected plastic packing in the outer groove to energize the seal. By incorporating anti-extrusion spring elements into the design, anti-extrusion devices are eliminated, reducing the risk of application performance interruption by loose components. Molded-in mesh anti-extrusion rings can be utilized, as per the needs of your application.

## Design Features and Benefits

- Bidirectional sealing capabilities
- Extremes of pressure and temperature
- Ability to seal large extrusion gaps
- Designed to seal large tolerances found in standard oilfield casing
- Ease of installation due to singular component
- Material selection available for a wide range of wellhead applications
- Available in standard and custom sizes
- Adjustable sealability achieved by use of plastic packing or grease

## Common Applications and Services

- Casing and tubing hangers
- Wellheads
- Stab-in operations
- High-pressure pipelines
- Hydraulic cylinders
- Fluid and gas applications
- Wide ranges of temperature and pressure

## Manufacturing and Production Processes

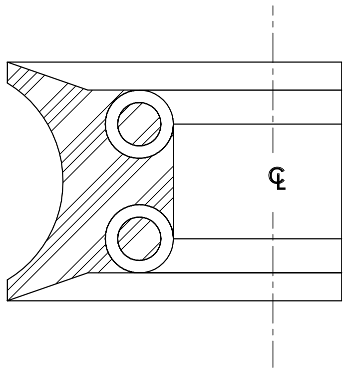
- Machining
- Molding

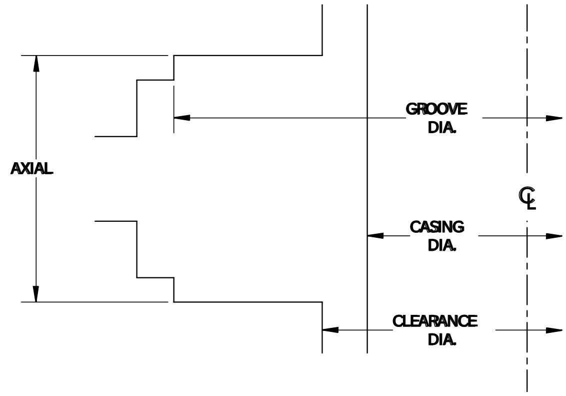
## Sizing

- API standard casing sizes
- Custom sizing options

# Engineering and Design Considerations

## Standard P-Seals Rod Configuration



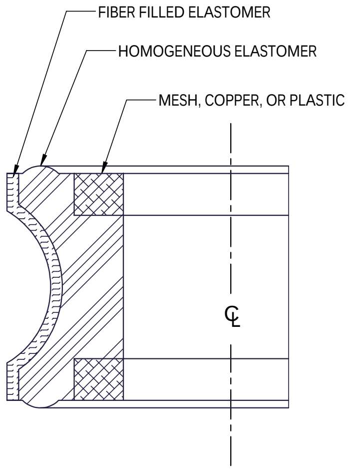

The standard P-Seal is a one-piece molded design utilizing molded-in garter springs as anti-extrusion devices. This design enhances assembly by eliminating the loose anti-extrusion devices found in other designs. Tooled for common sizes between 4-1/2" and 9-5/8".

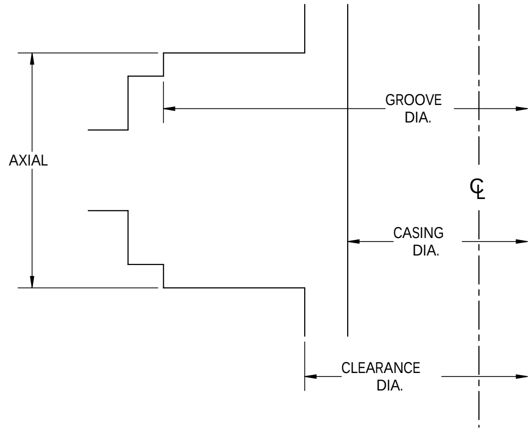
## Material Selection

| Commonly Used Elastomer Materials | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| NBR | -40 to +250 | -31 to +121 | Petroleum oils and fuels, water, glycols, silicones |
| HNBR | -45 to +300 | -42 to +148 | Petroleum oils and fuels, water, glycols, silicones |
| FKM (Viton®) | -25 to +450 | -31 to +232 | Petroleum oils and fuels, acids, halohydrocarbons, phosphate esters |
| EPDM | -60 to +300 | -51 to +111 | Water, steam, alcohols, ketones, phosphate esters |
| **Custom Elastomer Compounds** | **Custom compounds and blends can be offered upon request. Please contact your CDI Energy Products representative for additional information.** | | |

# Engineering and Design Considerations

## Enhanced P-Seals Rod Configuration



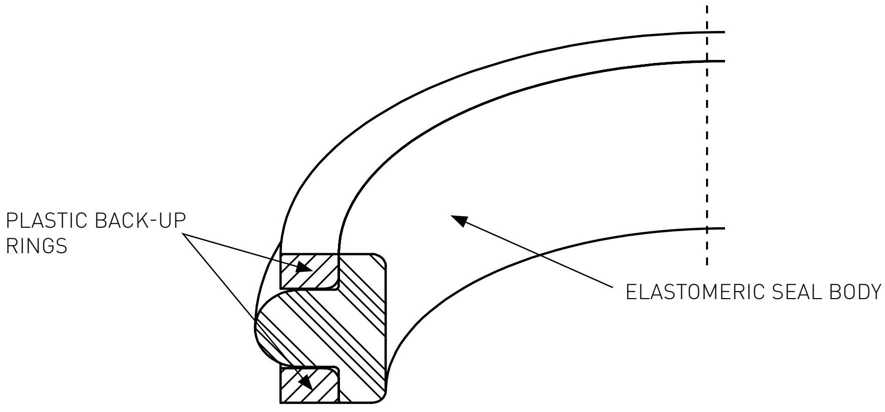




The EPS style is a three-piece design utilizing a wiremesh or plastic anti-extrusion system along with a buckle-resistant elastomer body. In some applications, a fabric reinforced rubber may be used. This reduces the chance of buckling or breaking the seal when injecting plastic packing around the circumference of the seal.

| **Commonly Used Fiber Reinforced Elastomer Materials** | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| HNBR | -45 to +300 | -42 to 148 | Petroleum oils and fuels, water, glycols, silicones |
| FKM (Viton®) | -20 to +400 | -31 to +232 | Petroleum oils and fuels, acids, halohydrocarbons, phosphate esters |
| FEPM (Aflas®) | 0 to +450 | -17 to +232 | Sour petroleum oils and fuels, acids, bases, amines, steam |
| NBR | -40 to +250 | -31 to +121 | Petroleum oils and fuels, water, glycols, silicones |
| **Custom Elastomer Compounds** | **Custom compounds and blends can be offered upon request. Please contact your CDI Energy Products representative for additional information.** | | |

| **Commonly Used Anti-Extrusion Material** | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| Stainless Steel Wiremesh | -300 to +800 | -184 to +427 | Harsh service, NACE MR-01-75 |
| Bronze Wiremesh | -300 to +500 | -184 to +260 | Non-galling for slightly dynamic capability (ex: stab-in) |
| PA (Nylon®) | -90 to +265 | -67 to +129 | -90°F to +265°F |

# T-Seals




## Description

T-Seals are characterized by a T-shaped elastomeric cross section with two thermoplastic back-up rings. This seal design offers sealing capable of handling extreme pressures, temperatures, and large extrusion gaps. With dual back-up rings surrounding both sides of the flanged, elastomeric cross section, this distinctive design aids in mitigating extrusion in applications where sealing against bidirectional pressure is a key concern.

Suitable for static and dynamic applications, T-Seals are designed to resolve issues in seal extrusion and to prevent the rolling of the seal when operating in reciprocating applications. For applications that previously used an O-Ring and back-up ring combination, the T-Seal can be retrofitted into the existing groove for both piston and rod orientation—optimizing this versatile design to meet your specific application requirements. Offers improved RGD resistance and lower temperature sealing performance due to higher levels of squeeze and gland fill when compared to standard O-Ring designs.

## Design Features and Benefits

- Flexible seal and split back-up rings for easy installation and field repair
- Eliminates seal rolling / spiraling
- Bidirectional sealing capabilities
- Compact, condensed design
- Can be retrofitted to existing groove
- RGD resistance
- Extremes of pressure and temperature
- Ability to seal large extrusion gaps
- A broad range of elastomeric and thermoplastic back-up ring combinations
- Handles aggressive chemicals in oilfield applications
- Available in standard and custom sizes

## Common Applications and Services

- Surface equipment
- Downhole
- Wellhead
- Valves
- High-pressure pipelines
- Riser systems
- Reciprocating pumps
- Hydraulic cylinders

## Manufacturing and Production Processes

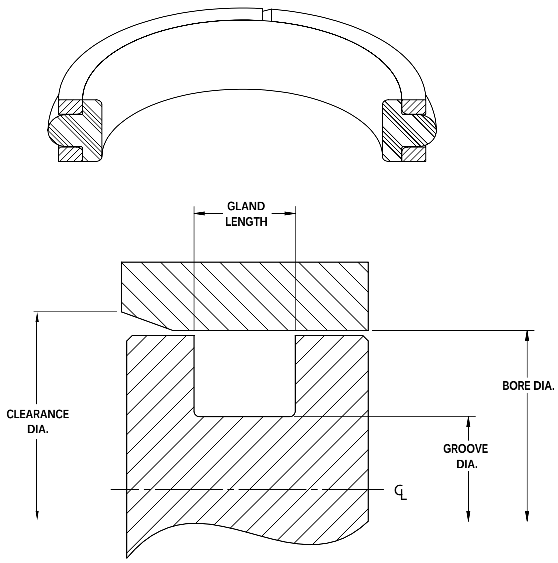
- Machining
- Molding

## Sizing

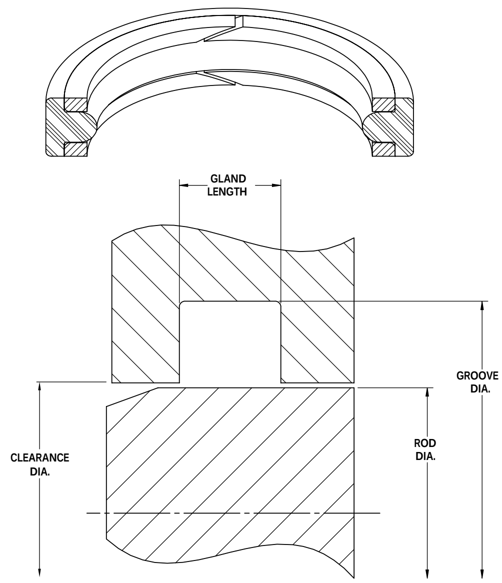
- Standard AS568B housing sizes
- Custom sizing options

# Engineering and Design Considerations

## Piston Configuration



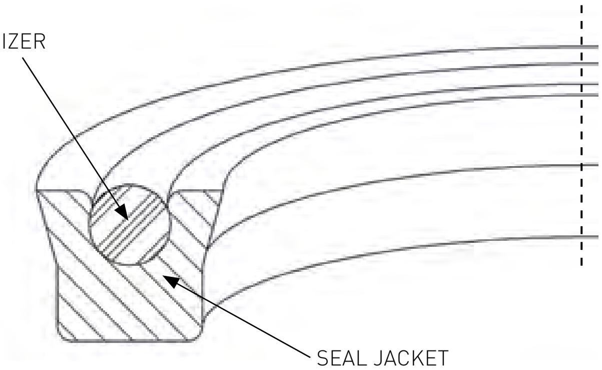

## Rod Configuration




## Material Selection

| Commonly Used Plastic Materials | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| PTFE (Teflon®) | -300 to +400 | -185 to +204 | Hydrocarbon oils, pneumatic and gases, chemical processes, aggressive chemicals |
| PA | -90 to +265 | -67 to +129 | Limited acid-base resistance, hydrocarbons, broad temperature ranges |
| PEEK | -70 to +500 | -56 to +260 | Aggressive chemicals, broad media, HPTHT environments |
| **Custom Plastic Compounds** | **Custom compounds and blends can be offered upon request. Please contact your CDI Energy Products representative for additional information.** | | |

# OL-Seals




## Description

The OL-Seal combines a flexible elastomeric lip-type seal jacket with an O-Ring energizer, offering a solution capable of sealing at high and low pressures. The versatility provided by this symmetrical seal design allows for successful use in both rod and piston applications. The use of an elastomeric jacket and energizer makes the OL-Seal a flexible sealing solution that eases installation, even when stretching may be required.

By filling the seal cavity with an O-Ring energizer, this sealing system becomes a dynamic solution more than able to compensate for fluctuations in system pressures, while increasing sealability. At extremely low pressures the O-Ring acts by increasing the sealing force and enhancing sealability. With increases in system pressure, additional force is applied throughout the sealing mechanism, actuating the seal lips. Once this actuation occurs, the lips of the seal profile mate with the gland surface, creating a positive seal and ensuring sealability.

## Design Features and Benefits

- High or low pressures
- Suitable for vacuum
- Suitable for oversized bores and undersized rods
- Good wear characteristics and resistance to abrasion
- Flexibility and ease of installation
- Positive lip actuation
- Wide range of sizes
- Varied material options
- Compact housing
- Can be retrofitted
- Contamination resistance

## Common Applications and Services

- Downhole tools
- Actuators
- Static and dynamic applications
- Subsea and surface applications

## Manufacturing and Production Processes

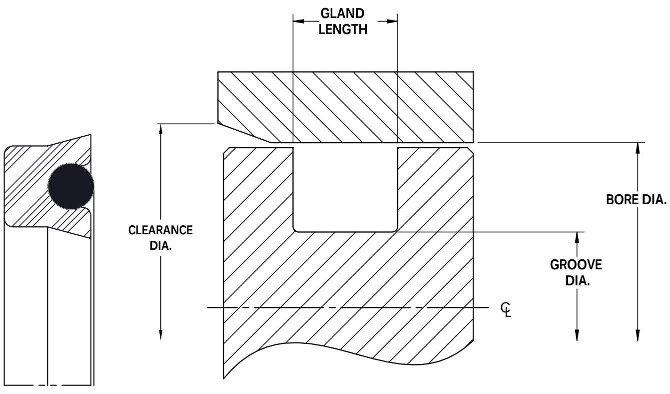
- Machining
- Molding

## Sizing

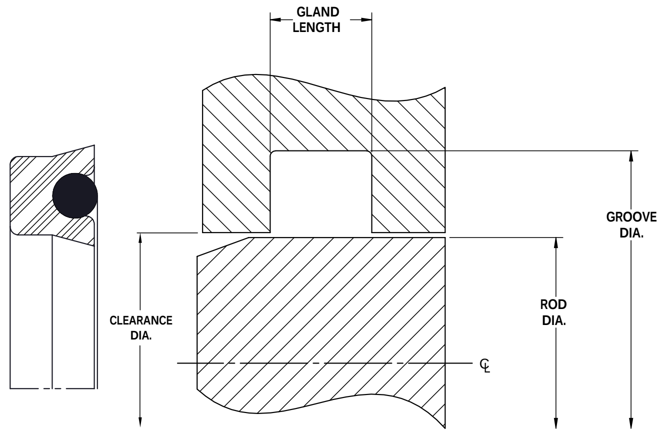
- Standard sizing available from .125" ID to 32" OD
- Custom sizing

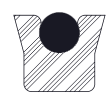
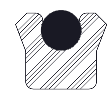
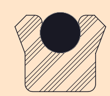
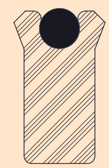
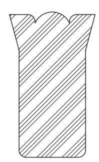
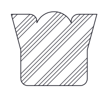
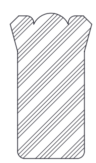
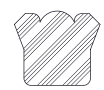
# Engineering and Design Considerations

## Piston Configuration




## Rod Configuration



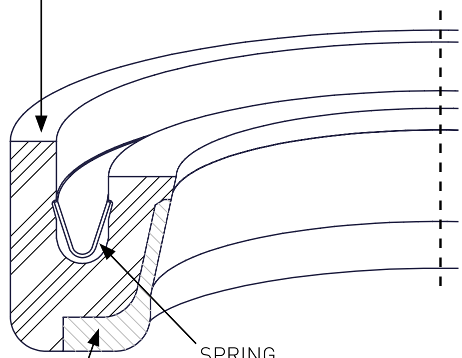

| Design Profiles | |
|---|---|
| **Standard Lip Profile**<br><br>The standard OL Seal profile ensures positive lip contact and sealability when low pressure sealing is required. A square-shaped lip profile gives this design a scraper-styled edge that quickly scrapes away fluids and film that may accumulate during normal operation cycles.<br><br>The standard profile can be further customized to feature a deep heel. |  Standard Lip  Square Lip |
| **B-Lip Profile**<br><br>This profile produces the high unit loading on the lip profile. After installation, stability within the gland is ensured by the rectangular shape of this cross section. The beveled lip of this seal design creates a sharp, wiper-like effect that can easily cut through dense, viscous fluids or film. Stability within the gland is ensured by the rectangular shape of this cross section.<br><br>The beveled profile can be further customized to feature a deep heel. |  Square Lip (Bevel)  B-Lip Deep |
| **Integral**<br><br>The integral OL-Seal design combines the benefits of any of the profile designs into a single-piece assembly. By integrating the energizing element with the seal jacket and profile, the number of components is reduced, easing installation and decreasing the likelihood that the energizer will be dislodged during operation.<br><br>The integral OL-Seal can be designed with all of the previously mentioned configurations, including the deep heel.<br><br>Thermoset elastomers are the preferred material family for this configuration. |  Integral Deep Standard-Lip  Integral Standard-Lip  Integral Deep B-Lip  Integral B-Lip |

## Material Selection

| Commonly Used Elastomer Materials for Seal Jacket | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| HNBR | -45 to +300 | -42 to +148 | Same as NBR and XNBR but with higher heat resistance, enhanced physical properties, and increased chemical resistance. Good for harsh well service (i.e.: $H_2S$, water steam, $CO_2$, and amine corrosion inhibitors) |
| FKM (Viton®) | -20 to +400 | -31 to +232 | Petroleum oils and fuels, acids, halohydrocarbons, phosphate esters |
| FEPM (Aflas®) | 0 to +450 | -17 to +232 | Sour petroleum oils and fuels, acids, bases, amines, steam |
| Polyurethane | -40 to +200 | -40 to +93 | Certain hydraulic fluids, aromatic hydrocarbons, certain greases |
| Polyester-Based TPE | -40 to +250 | -40 to +120 | Oil and hydrocarbons, where abrasion resistance is needed, solvent resistance |
| **Custom Compounds** | **Custom compounds and blends can be offered upon request. Please contact your CDI Energy Products representative for additional information.** | | |

| Commonly Used Elastomer Materials for O-Ring Energizer | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| NBR | -25 to +250 | -31 to +121 | Petroleum oils and fuels, water, glycols, silicones |
| HNBR | -45 to +300 | -42 to 148 | Same as NBR and XNBR but with higher heat resistance, enhanced physical properties, and increased chemical resistance. Good for harsh well service (i.e.: $H_2S$, water steam, $CO_2$, and amine corrosion inhibitors) |
| FKM (Viton®) | -20 to +400 | -31 to +232 | Petroleum oils and fuels, acids, halohydrocarbons, phosphate esters |
| FEPM (Aflas®) | 0 to +450 | -17 to +232 | Sour petroleum oils and fuels, acids, bases, amines, steam |

# A6R Seals




## Description

The A6R rod and piston seals are enhanced lip seals that are designed to solve the problem of high friction, wear, and damage of lip seals in rotary and reciprocating applications.

When used in rotary applications, the broad elastomeric contact area prevents the seal from spinning on the static gland surface. Combining this elastomeric design element with the low-friction PTFE wear surface provides integral anti-extrusion capabilities, enhancing overall sealbility compared to an all elastomer or all PTFE seal.

Lip seal designs made entirely from elastomers are sometimes susceptible to higher compression set related failures due to the full elastomeric cross section. The A6R seal incorporates a V-shaped metal energizer which provides a flexible seal while maintaining lower permanent set. This along with the asymmetrical design prevents the seal from rolling in reciprocating applications, making the A6R seal an ideal choice in challenging applications where extrusion, compression set, friction, and high seal wear are key concerns.

## Design Features and Benefits

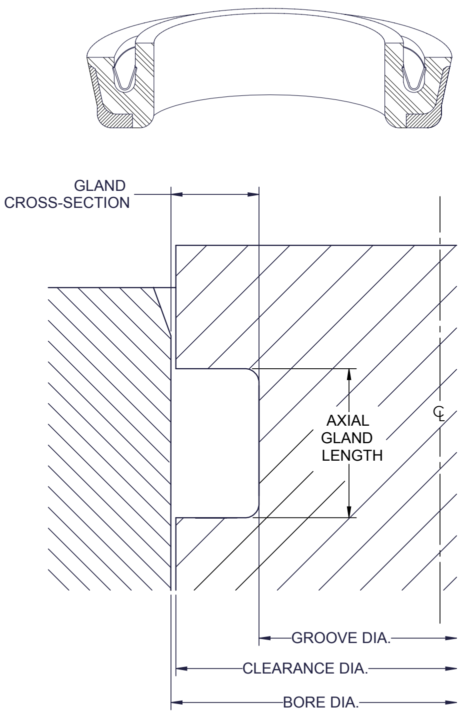
- High or low pressures
- Good wear characteristics and resistance to abrasion
- Flexibility and ease of installation
- Notable anti-extrusion capabilities
- Wide range of sizes
- Varied material options
- Can be retrofitted
- Contamination resistance
- Low friction characteristics

## Common Applications and Services

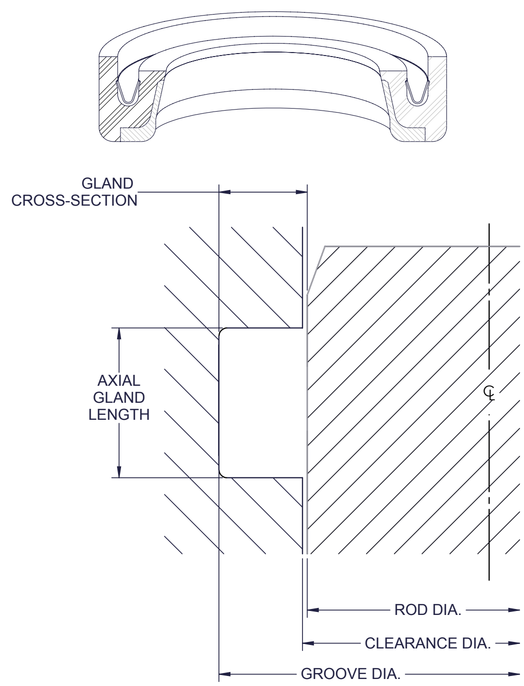
- Riser systems
- Mud motor
- ESP (electrical submersible pumps)
- Valve stems
- Hammer drills
- Jar and fishing tools

# Engineering and Design Considerations

## Piston Configuration




## Rod Configuration




# Material Selection

| Standard Elastomer Materials for Seal Jacket | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| HNBR | -45 to +300 | -42 to +148 | Same as NBR and XNBR but with higher heat resistance, enhanced physical properties, and increased chemical resistance. Good for harsh well service (i.e.:$H_2S$, water steam, $CO_2$, and amine corrosion inhibitors) |
| FKM (Viton®) | -20 to +400 | -31 to +232 | Petroleum oils and fuels, acids, halohydrocarbons, phosphate esters |
| FEPM (Aflas®) | 0 to +450 | -17 to +232 | Sour petroleum oils and fuels, acids, bases, amines, steam |
| **Custom Compounds** | **Custom compounds and blends can be offered upon request. Please contact your CDI Energy Products representative for additional information.** | | |

| Standard Plastic Materials for Seal Jacket | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| PTFE (Teflon®) | -300 to +400 | -185 to +204 | High capabilities, lower friction, and notable chemical resistance |
| **Custom Compounds** | **Custom compounds and blends can be offered upon request. Please contact your CDI Energy Products representative for additional information.** | | |

| Metal Spring Material | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| Stainless Steel | 300 to +550 | -184 to +287 | General service hydraulics |
| Cobalt-Based Alloy | -300 to +800 | -184 to +427 | Harsh service, NACE MR-01-75 |

# PBR (Polished Bore Receptacle) Stacks and Packing Sets

## Description

Due to fluctuating temperatures during operation, a typical downhole scenario results in the expansion and contraction of metallic production casing and tubing during naturally occurring thermal cycling. As this process takes place, the casing and tubing increases and decreases axially, resulting in continuous contrary motion and movement of critical sealing elements as they glide throughout the changing annular space.

During these production scenarios, polished bore receptacle seal assemblies (PBR stacks) are used to compensate for the thermal expansion and contraction of the tubing, thus preventing buckling, tool separation, or the damage of metallic elements. Combining contrasting materials in the packing configurations enables this packing assembly to balance dynamic, high pressure sealing in conditions requiring the highest levels of sealabiliy along with excellent anti-extrusion capabilities.

The self-lubricating and high-pressure extrusion-resistant plastic components are complemented by the softer, conformable elastomeric elements offering high sealability in both uphole and downhole pressures. The performance ability of this seal assembly is the result of combining elastomer and plastic components that offer inherent lubricating properties, enabling the sealing elements to survive broad temperature fluctuations and range of motion while providing bidirectional sealing from both directions with redundant seal components for maximum reliability.

## Design Features and Benefits

- Wide range of tooling and sizes
- Varied material options—both machined and molded
- Friction characteristics and extrusion resistance can be tailored through material selection
- High or low pressures
- Redundant seal lips
- Bidirectional sealing
- Stab-in capabilities

### Common Applications and Services

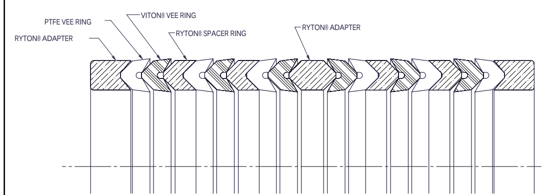
- PBR (polished / packer bore receptacles)
- Jars and fishing tools
- Stem packing
- Subsurface safety valves
- Reciprocating pump packing

## Engineering and Design Considerations

**Common Packing and Polished Bore Receptacle (PBR) Seal Assemblies**

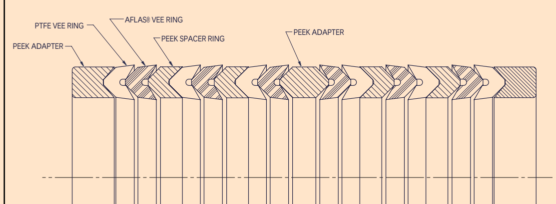
### VTR

To achieve an optimal seal set, the VTR downhole oilfield seal assembly uses higher strength, harder plastic materials along with lower strength, softer elastomer materials. The high-strength Ryton® adapters provide anti-extrusion resistance, while the softer PTFE and Viton® V-Rings optimize sealability and provide solid anti-extrusion resistances. As a cost-effective configuration, this assembly is typically provided as a bidirectional assembly, but is ideally suited for lower temperatures ranges, stab-in applications, and environments where exposure to hydrocarbons are a concern.



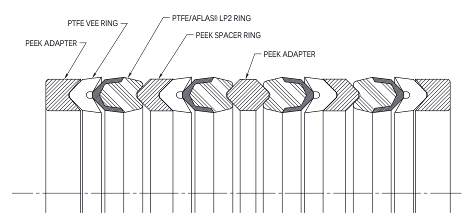

### ATP

The ATP seal assembly is an ideal seal assembly that offers a broader chemical and temperature upgrade for downhole completion activities. Similar to the VTR seal assembly,the higher strength, harder plastic materials are combined with the lower strength, softer elastomer materials to provide dynamic sealability and solid anti-extrusion capabilities. High-strength PEEK adapters provide anti-extrusion resistance, while softer PTFE and Aflas® V-Rings optimize sealability and extrusion resistance. This assembly is suitable for a higher range of temperatures, offers improved checmical resistance, and is also suitable applications that involve steam exposure.




### LP2

The beveled edges of the LP2 PBR stack allow for multiple stab-in connections while preventing damage to the seal lips. This assembly features the LP2 composite ring, which bonds a PTFE to an elastomeric body featuring an axial length that is greater than the cross section. Incorporating the composite LP2 ring within the overall design combines the strength and low friction of PTFE with the high sealability of elastomers in a singular component design. This unique design feature prevents rolling during operation and secures the assembly safely in the bore. As the assembly moves up and down in the bore due to changes in the application environment, the broad material combinations allow for ease of motion, reistance to broad media, and high sealability. This design was developed specifically for polished bore receptacles.

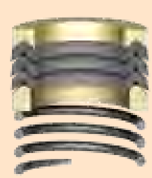



### Additional Packing Sets, Configurations, and Assemblies

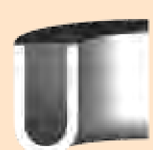
In addition to the packing configurations mentioned in this section, CDI also offers a number of enhanced packing sets that can be customized to meet specific applications needs. Whether valves, chokes, or pumps, these components can be molded or machined for a broad range of sizes and design requirements. They come in a variety of materials options that make them suitable and ideal for HPHT environments, FiresSafe and geothermal usage, and low emissions requirements.

**Some of our common configurations**

**J Packing**



**Pump Packing**



**U Packing**

**VS Packing**

## Material Selection

| Standard Elastomer and Plastic Materials for V-Ring Components | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| HNBR | 45 to +300 | -42 to +148 | Same as NBR and XNBR but with higher heat resistance, enhanced physical properties, and increased chemical resistance. Good for harsh well service (i.e.:$H_2S$, water steam, $CO_2$, and amine corrosion inhibitors) |
| FKM (Viton®) | -20 to +400 | -31 to +232 | Petroleum oils and fuels, acids, halohydrocarbons, phosphate esters |
| FEPM (Aflas®) | 0 to +450 | -17 to +232 | Sour petroleum oils and fuels, acids, bases, amines, steam |
| FFKM | -20 to +450 | -28 to +232 | Sour petroleum, acids, bases, MTBE, ketones |
| Rubber Coated Fabrics | -60 to +500 | -51 to +260 | Stronger, more dimensionally stable compared to homogenous elastomer materials |
| Fiber-Filled Elastomers | 0 to +500 | -17 to +260 | Stronger, more dimensionally stable compared to homogenous elastomer materials, and can achieve tighter tolerances |
| PTFE (Teflon®) | -300 to +400 | -185 to +204 | High capabilities, lower friction, and notable chemical resistance |
| **Custom Compounds** | **Custom compounds and blends can be offered upon request. Please contact your CDI Energy Products representative for additional information.** | | |

| Standard Plastic Materials for Adapters | | | |
|---|---|---|---|
| **Base Material** | **Temperature Range** | | **Service Recommendation** |
| | °F | °C | |
| PTFE (Teflon®) | -300 to +400 | -185 to +204 | High capabilities, lower friction, and notable chemical resistance |
| PEEK | -56 to +260 | -48 to +126 | Dynamic motion, non-galling, gland friendly |
| **Custom Compounds** | **Custom compounds and blends can be offered upon request. Please contact your CDI Energy Products representative for additional information.** | | |

| Metal Spring Material | | | | |
|---|---|---|---|---|
| **Base Material** | **CDI Compound #** | **Temperature Range** | | **Service Recommendation** |
| | | °F | °C | |
| Stainless Steel | 316 SS | 300 to +800 | -184 to +427 | General service hydraulics |
| Cobalt-Based Alloy | Elgiloy | -300 to +400 | -184 to +204 | Harsh service, NACE MR-01-75 |

# Custom Engineered Elastomer Products and Product Manufacturing Capabilities

In addition to the common engineered elastomeric seals and sealing solutions presented in the previous sections of this guide, our global engineering team and technical specialists are able to work with you to address specific application and performance needs.

Made from high-performance elastomeric, composite, and metal materials that will more than adequately address your application challenges, our sealing solutions leverage advanced manufacturing capabilities to produce critical components for your existing prints and designs. For a custom solution to solve your application challenges, our global team of specialists will partner with you to design, engineer, and manufacture a fully customized, comprehensive solution.

## Bonded Seals and Bonded Sealing Solutions

- Metal-to-rubber seals
- Rubber-to-rubber seals
- Plastic-to-rubber seals
- Rubber-to-wiremesh
- Logging pads
- Sliding sleeves
- Closing sleeves

## Packing (Fabric Reinforced and Homogenous Rubber)

- Hydraulic V-packing
- Pump packing
- Heavy duty V-packing
- Valve stem packing

## Lip Seals (Fabric Reinforced and Homogenous Rubber)

- Block vees
- U-cups
- Piston cups

## BOP Components

- Outer seals
- Inner seals
- Ram blocks

## Plugs

- Bridge plugs
- Wiper plugs
- Cement plugs

## Packers

- Casing
- Hanger
- Geothermal
- Rubber packer

## Spring-Energized Seals

- Optiseal® spring energized seals
- A6R composite spring-energized seals

For specific sizes, and capabilities of any of these components, contact your account manager or send an inquiry to CDI-Sales.Global@CDIproducts.com

# Compound List

## Homogeneous Elastomers

| **NBR** Nitrile | **Recommended Service:** Petroleum oils and fuels, water, glycols, silicones<br><br>**Not Recommended:** Ketones, esters, amines, halohydrocarbons | |
|---|---|---|
| **Comp#** | **Hardness +/-5** | **Features** |
| 405<br>406<br>407<br>9001001<br>408<br>9001541<br>9002191<br>409XR<br>9000931 | 45a<br>60a<br>70a<br>70a<br>80a<br>80a<br>80a<br>90a<br>90a | General service, high quality, medium-high ACN, sulfur cure compounds |
| 408P | 80a | Harsh service, medium ACN peroxide cure |
| 407HAP<br>409HAP<br>9000241 | 70a<br>90a<br>90a | Harsh service, high ACN peroxide cure |
| 408NB<br>409NB | 80a<br>92a | Non-black, high ACN, peroxide cure compounds |
| 407LT | 68a | Low-temperature service, low ACN, peroxide cure compound |

| **HNBR** Hydrogenated Nitrile | **Recommended Service:** Same as NBR and XNBR but with higher heat resistance, enhanced physical properties, and chemical resistance. Good for harsh well service (i.e.: $H_2S$, steam, $CO_2$, and amine corrosion inhibitors)<br><br>**Not Recommended:** Strong acids, halohydrocarbons | |
|---|---|---|
| **Comp#** | **Hardness +/-5** | **Features** |
| 806 | 65a | Highly saturated, medium ACN, peroxide cure compound |
| 801-85 | 85a | Explosive-decompression-resistant HNBR compound for gas service |
| 9140061<br>803-80<br>9002271 | 70a<br>80a<br>80a | Fully saturated, medium ACN, peroxide cure compounds |
| 804-75<br>804-85 | 75a<br>85a | Highly saturated, high ACN, peroxide cure compounds |
| 807<br>808<br>809<br>9002301 | 70a<br>80a<br>90a<br>90a | Fully saturated, medium-high ACN, peroxide cure compounds |
| 808LT | 78a | Low-temperature, medium ACN, peroxide cure compound |
| 886 | 86a | Tough, internally lubricated for low friction and wear. Ideal for reciprocating pumps |
| 887<br>888 | 89a<br>95a | High-strength HNBR, excellent high-temperature replacement for urethane and Hytrel® lip seals |

| **FKM** Fluoroelastomer | **Recommended Service:** Petroleum oils and fuels, acids, halohydrocarbons, phosphate esters<br>**Not Recommended:** Ketones, amines, strong bases | |
|---|---|---|
| **Comp#** | **Hardness +/-5** | **Features** |
| 906 | 65a | General purpose copolymer compound |
| 9020111<br>907SP<br>908SP<br>9020481<br>9025121<br>909SP<br>909-95 | 70a<br>72a<br>80a<br>80a<br>90a<br>92a<br>96a | High quality, specification grade, incorporated cure copolymer for low compression set |
| 907LS<br>908LS<br>909LS | 70a<br>80a<br>92a | High quality, low-shrink compounds that allow the use of NBR tooling on small and medium C/S parts (i.e.: V-rings, U-cups) |
| 909HV<br>9021251 | 90a<br>90a | High-molecular-weight polymer for improved explosive decompression resistance |
| 907B<br>909B | 75a | High quality, incorporated cure terpolymer with higher fluorine content |
| 901-75<br>9020271<br>901-90<br>9021631 | 75a<br>80a<br>90a<br>90a | Harsh service tetrapolymer with higher fluorine content, peroxide cure |
| 901LT<br>9021441 | 75a<br>75a | Low-temperature, peroxide cure |
| FHP-1 | 65a | High-purity fluoroelastomer for semiconductor applications – cream color |

| **FEPM** Fluoro-olefin elastomer | **Recommended Service:** Sour petroleum oils and fuels, acids, bases, amines, steam<br>**Not Recommended:** Halohydrocarbons | |
|---|---|---|
| **Comp#** | **Hardness +/-5** | **Features** |
| 904-80<br>9020311<br>904-90<br>904-95 | 80a<br>80a<br>90a<br>96a | Harsh-service Aflas® 100H polymer |
| 900-75<br>900-90 | 75a<br>90a | Broad chemical resistance, Viton Extreme® Perfluoro-olefin |
| 902-75<br>902-90 | 75a<br>90a | Enhanced processing base-resistant fluoroelastomer for amine-containing lubricants. Improved bondability over Aflas 100H polymer |

| **FFKM** Perfluoroelastomer | **Recommended Service:** Sour petroleum, acids, bases, MTBE, ketones<br>**Not Recommended:** Alkali metal solutions | |
|---|---|---|
| **Comp#** | **Hardness +/-5** | **Features** |
| PES-75<br>PES-90 | 75a<br>90a | Extreme chemical resistance, fully fluorinated |
| PSS-75<br>PSS-90 | 75a<br>90a | Extreme chemical resistance, fully fluorinated |

| **Perfluoroether-Silicone** | **Recommended Service:** High heat and extreme chemical resistance. Good for static seals with proper anti-extrusion devices for high pressure<br><br>**Not Recommended:** MTBE, dynamic sealing applications | |
|---|---|---|
| **Comp#** | **Hardness +/-5** | **Features** |
| 623 | 70a | General service, black color |

| **XNBR**<br>Carboxylated Nitrile | **Recommended Service:** Same as NBR but with improved thermal physical properties and abrasion resistance<br><br>**Not recommended** for new applications, as HNBRs offer better overall properties | |
|---|---|---|
| **Comp#** | **Hardness +/-5** | **Features** |
| 509LX | 90a | General service, sulfur cure compound with good abrasion resistance |
| 507P<br>509P | 75a<br>92a | Harsh service, peroxide cure compounds |

| **VMQ**<br>Silicone | **Recommended Service:** Hot air, alcohols, $CO_2$, vegetable oils, electrical<br><br>**Not Recommended:** Ketones, silicones, most petroleum oils and fuels | |
|---|---|---|
| **Comp#** | **Hardness +/-5** | **Features** |
| 623 | 70a | General service, black color |

| **FVMQ**<br>Fluorosilicone | **Recommended Service:** Hydrocarbons, alcohols, hot air, ozone, chlorinated hydrocarbons<br><br>**Not Recommended:** Brake fluids, ketones | |
|---|---|---|
| **Comp#** | **Hardness +/-5** | **Features** |
| 607 | 80a | General service compound |

| **EPM-EPDM**<br>Ethylene-propylene | **Recommended Service:** Water, steam, alcohols, ketones, phosphate esters<br><br>**Not Recommended:** Petroleum oils and fuels, diester fluids, aromatic hydrocarbons | |
|---|---|---|
| **Comp#** | **Hardness +/-5** | **Features** |
| 104 | 88a | "Y267" type geothermal steam compound |
| 107<br>108 | 70a<br>80a | General service, sulfur cure compounds |
| 107P<br>108P | 70a<br>80a | Harsh service, peroxide cure compounds |

| **CR**<br>Polychloroprene | **Recommended Service:** Freon®, ammonia, silicate esters, hydraulic fluid<br><br>**Not Recommended:** Petroleum oil and fuels, ketones, acids, steam, phosphate esters, halohydrocarbons | |
|---|---|---|
| **Comp#** | **Hardness +/-5** | **Features** |
| 207<br>208 | 70a<br>80a | General service compounds |

## Reinforced Elastomers

| Coating Polymer | Comp# | Description |
|---|---|---|
| NBR<br>XNBR<br>HNBR | 416<br>417<br>419<br>410<br>429<br>447<br>449<br>548<br>550<br>828<br>847<br>848<br>850 | Soft NBR / Cotton fabric – black<br>Medium NBR / Cotton fabric – black<br>Hard NBR / Cotton fabric – green<br>Hard NBR / Cotton fabric – black<br>Hard NBR / Aramid fabric – green<br>Medium NBR / Polycotton – black<br>Hard NBR / Polycotton – black<br>Medium XNBR / Polycotton – brown<br>XNBR / Aramid fiber – black<br>Medium HNBR / Aramid fabric – black<br>Medium NBR / PTFE / Polycotton – gray<br>Medium HNBR / Polycotton – black<br>HNBR / Aramid fiber - black |
| FKM | 918<br>928<br>951<br>959 | Medium FKM / Cotton fabric – black<br>Medium FKM / Aramid fabric - black<br>FKM / Mineral / Aramid fiber - black<br>FKM / Aramid fiber - black |
| FEPM | 923<br>950 | Medium Aflas® / Aramid fabric - black<br>Aflas® / Aramid fiber - black |
| EPDM | 117 | Medium EPDM / Cotton fabric – olive |

**Note:**

All media recommendations are merely guidelines and can be affected by operating temperature. Unless specified, the service temperature is based on a medium-durometer compound of that series in an air environment. Part geometry can have an effect on the actual service temperature rating. The CDI Energy Products compound list is an outline of compounds used by CDI Energy Products to fabricate parts; many other materials are available. For more information on availability of these or any other materials, please contact your distributor or customer service.

# Technical Report

## ISO / NORSOK Certified Elastomer Materials

To better serve our customers manufacturing high performance valves and wellhead equipment for the oil and gas industry, CDI Energy Products has evaluated several CDI elastomeric seal compounds to ISO 23936-2.

ISO 23936:2011, Non-Metallic Materials in Contact With Media Related to Oil and Gas Production, Part 2: Elastomers has replaced the un-balloted NORSOK M-710, Annex–B, R3 draft. Testing was conducted to Annex A: Ageing of Elastomeric Materials and to Annex B: Rapid Gas Decompression (RGD). The compounds selected are extensively used in sealing solutions provided by CDI Energy Products.

The testing was contracted with an independent laboratory, Akron Rubber Development Laboratory Inc. (ARDL), located in Ohio, USA.

### Annex A:

This procedure is used to qualify elastomer compounds for service in liquids and gases representative of the intended application environment. The test parameters that can be selected are the composition of the hydrocarbon liquid phase, the gas phase, and three test temperatures. The test temperatures used are intended to be above the recommended service temperature of the polymer used to compound the material. These are selected based on API 6A or ISO 10423 temperature classifications in table A.6. Based on changes in physical properties in the elastomer at different intervals, an Arrhenius plot of estimated service life can be generated.

AS568-222 O-Rings are aged in the test chamber at the specified temperature and media at 10 MPa (1450 psi). At specified intervals the chamber is depressurized and test samples are removed and then the chamber is repressurized with media, and aging is continued until the specimens no longer meet the standard acceptance criteria or time is expired.

| Phase | Composition |
|---|---|
| Liquid | 60% As Specified (Aromatic or Non-Aromatic) |
| Gas | 30% As Specified (Sweet or Sour) |
| Water | 10% Deionized |

| Test Temperature | Test Pressure | Duration |
|---|---|---|
| 3 Intervals Specified, All Above Maximum Service Temperature For The Polymer | 10 MPa (1450 psi) | As Specified For Each Temperature |

### Annex B:

This procedure is used to qualify elastomeric materials for service in gas environments that could subject elastomeric materials to rapid gas decompression (RGD) or explosive decompression (ED). AS568-325 O-Rings were molded from standard compounds; the specimens were saturated in a pressurized methane/carbon dioxide environment, and then subjected to 8 decompression cycles over a period of 7 days. The O-Rings were then evaluated to the rating system outlined in the ISO 23936-2, Annex-B standard.

| Mol % | Composition |
|---|---|
| 10 | $CO_2$ |
| 90 | $CH_4$ |

| Test Temperature | Test Pressure | Duration |
|---|---|---|
| 100°C (212°F) | 15 MPa (2176 psi) | 7 days |

The performance of the compounds is summarized in the grid below.

| CDI Compound | Description | Annex A: Chemical Aging | |
|---|---|---|---|
| | | Test Parameters | Acceptance Criteria |
| 803-80 | 80a HNBR – Resilient | A.5 Sour Multiphase<br>A.6 Non-ISO / API | Tested |
| 809 | 90a HNBR – Oilfield Service | A.5 Sour Multiphase<br>A.6 Non-ISO / API | Tested |
| 809LT | 90a HNBR – Low Temp | A.5 Sour Multiphase<br>A.6 | Scheduled |
| 801-85 | 85a HNBR – ED Resistant | A.5 Sour Multiphase<br>A.6 Non-ISO / API | Tested |
| 900-92 | 92a FEPM | A.5 Sour Multiphase<br>A.6 API-X | Scheduled |
| 904-92 | 92a FEPM | A.5 Sour Multiphase<br>A.6 API-X | Scheduled |
| 901-90 | 90a FKM-2 – Peroxide Cure | A.5 Sour Multiphase<br>A.6 API-X | Tested |
| 909HV | 90a FKM-1 – Bisphenol Cure | A.5 Sour Multiphase<br>A.6 API-X | Tested |
| 909LT | 90a FKM-3 – Low Temp | A.5 Sour Multiphase<br>A.6 API-X | Tested |
| 9021581 | 92a FKM | A.5 Sour Multiphase<br>A.6 API-X | Scheduled |
| 9021602 | 92a FKM – Low Temp | A.5 Sour Multiphase<br>A.6 API-X | Scheduled |
| 408 | 80a NBR – Sulfur Cure | A.4 Sweet Multiphase<br>A.6 API – U,V | Tested |
| 408LT | 80a NBR – Low Temp | A.4 Sweet Multiphase<br>A.6 API – U,V | Tested |
| 409XR | 90a NBR – Sulfur Cure | A.4 Sweet Multiphase<br>A.6 API – U,V | Tested |
| 9003010 | 90a NBR – ED Resistant | A.4 Sweet Multiphase<br>A.6 API – U,V | Scheduled |
| PES-90 | 90a FFKM – High Temp | A.5 Sour Multiphase<br>A.6 API-X | Scheduled |
| PLT-90 | 90a FFKM – Low Temp | A.5 Sour Multiphase<br>A.6 API-X | Scheduled |

*Per ARDL Test Reports PN102808, PN103020, PN103335, PN1034363, PN104363, PN105110, certification according to ISO 23936-2:2011, Annex-B applies to CDI grades listed above. More detailed test information is available upon request from CDI Energy Products.*

*CDI-TR002GL-1214-R03-US*

# Technical Report

## API 6A, Appendix-F Immersions

To better serve our customers manufacturing high performance downhole and wellhead equipment for the oil and gas industry, CDI Energy Products has evaluated several CDI elastomeric and thermoplastic seal compounds using the immersion testing procedure specified in **API 6A, Appendix F** (also known as ISO 10423:2009).

The compounds selected are extensively used in sealing solutions provided by CDI Energy Products.

The testing was contracted with independent laboratories, including MERL in the UK and Akron Rubber Development Laboratory Inc. (ARDL) located in Ohio, USA.

### Appendix F1.13.5.2:

This procedure is used to evaluate polymer compounds for service in liquids and gases representative of the intended application environment. The test parameters that can be selected are the composition of the gas/liquid phase and the test temperature. The test media is determined by the appropriate API 6A Material Class. The test temperature used corresponds to the API 6A Temperature Classes. However, API allows a bespoke media, temperature, pressure, and/or duration to be specified by the end user.

Dog-bone or dumbbell specimens per ASTM D412 (elastomer) D-638 (thermoplastics) or D-1708 (PTFE) are aged in the liquid phase of the test chamber at the specified temperature at 6.9 MPa (1000 psi) for a standard exposure period of 160 hours. The percent change of the physical properties of the aged and un-aged specimens are reported. Acceptance criteria will be specified by the end user or the seal manufacturer based on the intended application.

| Test Temperature | Standard Test Pressure | Standard Duration |
|---|---|---|
| Typically the Upper Operating Temperature or Bespoke | 6.9 MPa (1000 psi) | 160 hours |

| API 6A Material Class | | Gas Phase | Liquid Phase |
|---|---|---|---|
| AA/BB | General Service | 5% $CO_2$ / 95% $CH_4$ | Kerosene + 5% De-ionized $H_2O$ |
| CC | General Service | 80% $CO_2$ / 20% $CH_4$ | |
| DD/EE | Sour Service | 10% $H_2S$ / 5% $CO_2$ / 85% $CH_4$ | |
| FF/HH | Sour Service | 10% $H_2S$ / 80% $CO_2$ / 10% $CH_4$ | |
| Bespoke | | As Specified by User | |

| API 6A Temperature Classification | Operating Range °F | | | Operating Range °C | | |
|---|---|---|---|---|---|---|
| K | -75 | To | +180 | +60 | To | +82 |
| L | -50 | To | +180 | -46 | To | +82 |
| P | -20 | To | +180 | -29 | To | +82 |
| R | +74 | To | +74 | +23 | To | +23 |
| S | 0 | To | +150 | -18 | To | +66 |
| T | 0 | To | +180 | -18 | To | +82 |
| U | 0 | To | +250 | -18 | To | +121 |
| V | +35 | To | +250 | +2 | To | +121 |
| X | 0 | To | +350 | -18 | To | +177 |
| Y | 0 | To | +650 | -18 | To | +343 |
| Bespoke | As Specified by User | | | | | |

| CDI Compound | | Media | Temp | Δ H Pts | Δ M % | Δ V % | Δ T % | Δ E % | Δ M50 % | Δ M100 % | Visual |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 803-80 | 80a HNBR | DD/EE | 155°C | -11.8 i | +12.2 | +16.6 | -28.4 | -16.9 | -17.8 | -12.8 | no damage |
| 809 | 90a HNBR | DD/EE | 155°C | -6.2 i | +8.7 | +10.7 | -9.8 | -12.7 | -10.8 | +4.1 | no damage |
| 809 | 90a HNBR | FF/HH | 150°C | -5.6 a | +12.1 | +13.8 | -9 | -21 | -11 | +14 | no damage |
| 901-75 | 75a FKM | DD/EE | 155°C | -5.4 i | +2.9 | +6.6 | -26.8 | -12.1 | -9.8 | -3.7 | no damage |
| 901-90 | 90a FKM | DD/EE | 155°C | -5.6 i | +2.4 | +5.1 | -15.1 | -4.8 | -6.2 | -8.1 | no damage |
| 703 | PPS Filled PTFE | FF/HH | 202°C | -10.2 d | +4.0 | +4.4 | -8.6 | -18.1 | -8.9 | -3.2 | no damage |
| 711 | Carbon Filled PTFE | FF/HH | 202°C | -8.2 d | +2.1 | +3.0 | -22.3 | 0 | -20.7 | -17.6 | no damage |
| 716 | Graphite Filled PTFE | FF/HH | 202°C | -6.8 d | +1.2 | +2.2 | -8.7 | -12.4 | -4.3 | +1.5 | no damage |
| 754 | Carbon Filled PEEK | FF/HH | 202°C | -4.0 d | +3.0 | +2.8 | -44.8 | +2 | -- | -- | no damage |

**H**ardness (a=Type-A,d=Type-D,i=IRHD), **M**ass, **V**olume, **T**ensile, **E**longation, **M**odulus @ **50%, M**odulus @ **100%** and visual are evaluated.
More detailed test information is available upon request from CDI Energy Products.

CDI-TR00xxxxxx-1014-R01-US

CDI ENERGY PRODUCTS

To learn how CDI Energy Products can improve performance in your operations, please visit our website at: CDIproducts.com; or talk with our experts at your regional office.

**In-depth Global Solutions**
CDI Energy Products is a designer and manufacturer of custom plastic and elastomeric products, seals, and ancillary metal components. As part of the global group Fenner, our multiple locations enable us to partner with clients worldwide to produce unique, high-performance solutions for the energy industry.

**United Kingdom**
CDI Energy Products
Unit 6b Astra Park, Parkside Lane
Leeds, West Yorkshire LS11 5TD
Phone: +44 (0) 113.2709.674
CDI-UK.Sales@CDIproducts.com

CDI Energy Products
130 Oldfield Road
Hampton, Middlesex TW12 2HT
Phone: +44 (0) 20.8481.8300
CDI-UK.Sales@CDIproducts.com

**United States**
CDI Energy Products
8103 Rankin Road
Humble, Texas 77396
Phone: +1 281.446.6662
CDI-US.Sales@CDIproducts.com

**Norway**
CDI Energy Products
Kjøpmannsbrotet 7
Kleppe, 4352
Phone: +47 51.78.60.30
CDI-Norway.Sales@CDIproducts.com

**Germany**
CDI Energy Products
Billwerder Ring 17
Hamburg, 21035
Phone: +49 (0) 40.73.47.48.0
CDI-Germany.Sales@CDIproducts.com

**Singapore**
CDI Multiseals
10 Tuas South Street 5
Singapore, 637792
Phone: +65 6861.6811
CDI-Multiseals.Sales@CDIproducts.com



CDI-PG001GL-0215-R01-US