Not All O-rings are Equal: How Choosing the Wrong O-Ring Material Can Bring Down your Machine

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O-rings are the unsung hero of any application. These donut-shaped engineered objects seal connections in equipment by forcing a rubber seal into a channel and applying mechanical or hydraulic pressure to prevent clearance of a less viscous material. These inexpensive and easy to replace and maintain components don't always get the credit they deserve. But, when they are not properly selected or cared for, O-rings can wreak havoc.

Because of their role in sealing machinery, O-rings are a small but critical element. In an air conditioning (AC) system, for example, the most common cause of refrigerant leak is O-ring failure. This leakage leads to loss of lubrication that can affect system performance, ice the evaporator coil or cause the compressor to overheat and eventually burn out. Compressor failure usually leads to entire system replacement, which can be extremely costly.

Item	Cost
A/C Repair	$500 - $1000
New A/C System	$1000 - $5000
O-Ring	$7.99 - $57.99
AC Recharge	$39 - $260

Figure 1. AC system repair varies by supplier and geography, but is always significantly more expensive than O-ring replacement.

There are a number of factors to consider when selecting the proper O-ring for your application. Sizing, design and installation are all important, but the basic element of choosing the proper polymer material while designing the equipment is key. Choosing the proper O-ring material when replacing in the aftermarket is equally important.

Common Causes of O-ring Failure

O-ring failure can be traced back to design, installation, production quality and material choice. Choosing the proper materials, size, compression and surface finish will make a big different in machine performance and longevity. Design related failures are particularly common, and can be avoided with certain considerations:

- Know the depth – O-rings sit in a channel known as a gland. Knowing the gland depth allows a machine designer to calculate compression and choose an O-ring that will avoid extrusion and tearing.
- Leave space – O-rings should not fill the entire gland, but leave space for O-ring swelling and possible thermal expansion of the seal.
- Avoid stretching – Stretching the O-ring past five percent of the centerline diameter should be avoided, as it can flatten the O-ring cross section. If the O-ring must be stretched past the five percent mark, the gland depth should be reduced to retain the necessary compression.
- Proper installation – As with any component, proper installation is important to successful operation. In the case of O-rings, installers should use the correct lubricant, keep both the O-ring and gland clean, and install the O-ring without stretching or pulling on the device with a screwdriver or other tools. The surface finish should also be inspected before installation, and an O-ring with scratches, nicks or imperfections should not be used.
- Choose a reputable supplier – Sourcing O-rings from a reputable supplier or manufacturer can help avoid potential production-related quality concerns. Poorly made O-rings might fail sooner than expected due to low quality materials.

Material-related O-ring Failures

Some O-ring issues can be solved by addressing the production quality, installation and design, but no number of design changes will fix the baseline issue if the correct material was not selected for your application. Choosing the wrong material can lead to abrasion, compression set, chemical compatibility issues, extrusion, spiral failure and improper thermal capabilities and weathering.

- Extrusion: Extruded O-rings are a result of both improper design and material selection. An O-ring seal is meant to plug the opening between the two connections without extruding through the opening, as seen in Figure 2. An extruded O-ring will hold the seal while a machine is running, but if the machine is turned off for repair or inspection, the O-ring will relax, causing it to crack or flatten out. When the machine is turned back on, the flattened O-ring will allow the connection to leak.

  Machine designers can address this concern by decreasing clearances, choosing an elastomer material with a higher hardness, and/or modifying the gland design to allow 25 percent void space and 75 percent gland fill.

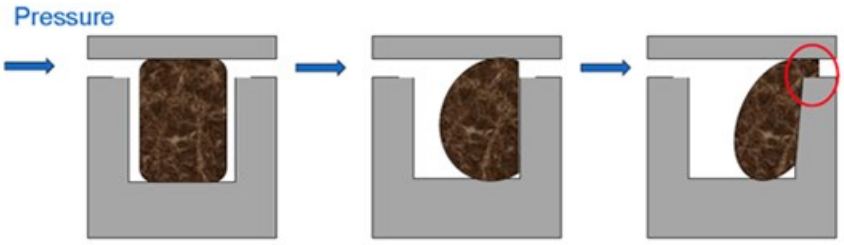

Figure 2. This cross section depicts the gland (gray channel) and O-ring (brown). With improper design and/or material selection, pressure applied to the connection may cause the O-ring to extrude through the opening.

- Compression Set: Rubber compounds can permanently deform under strain, and compression set refers to the percentage of deflection that the elastomer fails to recover after a fixed period of time under specific squeeze and temperature, as seen in Figure 3. Once the O-ring has compressed, if pressure or temperature is changed – again, using the example of turning the machine off and then back on – the seal will no longer hold. Selecting the correct polymer for the pressure and temperature your application will face is key to avoiding O-ring compression set. Also key to avoiding compression set is chemical compatibility of the O-ring and the fluid in the system. Different fluids will interact with each polymer type differently, and chemical incompatibility leads to degradation, which accelerates compression set and can lead to failure in as few as 70 hours.

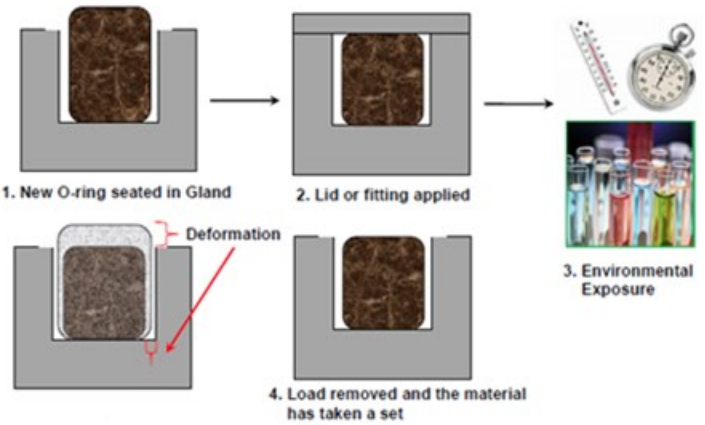

Figure 3. The O-ring (brown) seated in the gland (gray) will permanently deform after time, pressure and temperature are applied.

- Thermal Degeneration and Weathering: The chemical structure of the base polymer will dictate the thermal, ultra-violet (UV) and ozone compatibility of the O-ring. If you choose a polymer without the correct temperature compatibility, the O-ring can form radial cracks on the highest temperature surfaces.

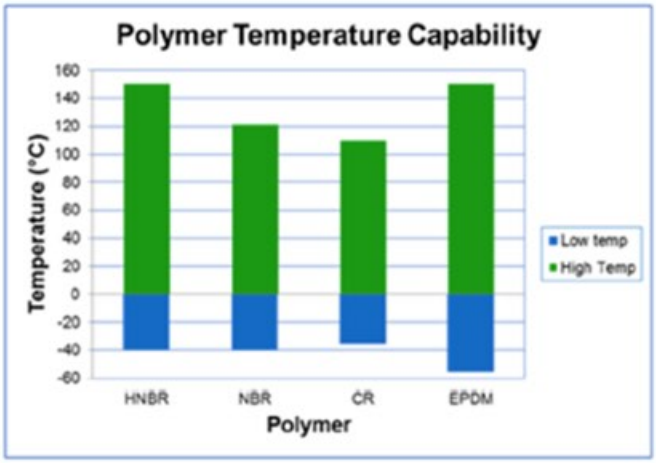

Figure 4. Polymers are not all equal when it comes to withstanding heat and cold.

- Chemical Compatibility: In its role as connection seal, an O-ring will regularly come in contact with the material that is being sealed into the system. In the AC system example, that material is likely a refrigerant, such as R-1234yf, the latest AC refrigerant on the market. The differing properties of each polymer mean that an O-ring built for an AC system may not function as well in a system where it is sealing in oil instead of refrigerant – and vice versa.

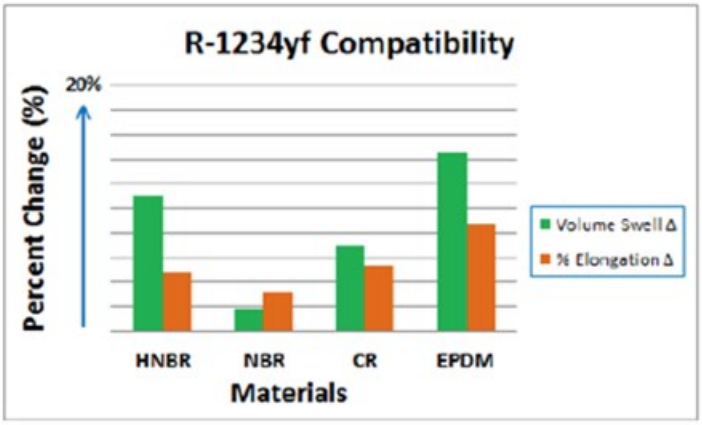

Figure 5. Test results demonstrate the variations in polymer compatibility with new R-1234yf refrigerant. Chemical incompatibility can lead to excessive elastomeric material swelling and loss of properties, which can make the O-rings more susceptible to degradation and failure during use. Poor chemical compatibility can lead to failure very quickly, some studies show failure in as little as 70 hours. By understanding the application's temperature and fluid requirements, a designer can select an O-ring with the appropriate chemical composition for the machine.

Comparing Cost vs. Quality

A standard rubber formulation includes a polymer (which can vary), carbon black, mineral fillers, antioxidant, plasticizer, curative and process aid. To reduce costs, some manufacturers replace some of the carbon black or reinforcing mineral fillers with cheaper fillers such as talc and kaolin (Dixie Clay). These materials can provide the rubber with the same hardness as a typical formulation, but at a lower cost as compared to rubber formulated with more expensive carbon black or mineral filler. While hardness is one important factor, there are many other factors to consider, so it is important to choose a reputable manufacturer that can meet requirements for hardness, tensile strength, chemical compatibility, and more.

Selecting the Right Material for your Application

Choosing the right O-ring size, design and material might seem like a small decision, but it can have huge implications for your machine and your bottom line.

There are many, many combinations of thermoplastic and rubber that can be used when manufacturing an O-ring. Companies like Eaton test these different materials to help customers and machine designers understand which will work best in any given application.

To select the best O-ring, machine designers must first understand the application.

- What is the critical temperature? A machine operating in South America may need O-rings made with a different polymer than a machine working in Northern Canada.
- What type fluid is the O-ring sealing? An O-ring compatible with oil may not also be compatible with refrigerant.

When specifying an O-ring, designers must consider all of the factors. Frequently, only the required hardness is indicated, which can lead to a poor quality O-ring being chosen for the application. By using an ATSM D2000 "call out," along with necessary morphology and dimensions, a designer can specify not only the hardness but all required properties and temperatures that your O-ring requires, including tensile strength, compression set, temperature resistance and more. O-ring manufacturers and suppliers can match the ASTM D2000 parameters to the right component for your application, helping extend machine life and prevent unexpected downtime.

Once you have selected and installed the right O-ring for your application, equipment owners should plan to replace O-rings each time the system needs to be opened. Recalling the significant costs of repairing or replacing a leaky system, correct O-ring material selection, design, installation and maintenance serves as a low cost insurance against leakage.

O-rings, the common components that help keep equipment running, might not seem critical at first glance. Using the correct, high quality O-ring for your application will require a small investment up front but pay dividends in reduced downtime and equipment maintenance costs.

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