

Sealing A/C systems

Choosing the right automotive tube joint seal for HFO-1234yf refrigerant compatibility.

The Parker 7637 discharge hose assembly for vehicle air-conditioning systems. For these blocks, the elastomeric seals are molded to the inside edge of a metal retaining washer. A mating piece attaches to the top to complete the block assembly or joint.

In 2011, the U.S. EPA (Environmental Protection Agency) approved HFO (hydrofluoro-olefin)-1234yf refrigerant to replace the HFC (hydrofluorocarbon)-134a refrigerant currently used in most U.S. automotive air-conditioning systems. The HFO-1234yf refrigerant has a GWP (Global Warming Potential) 335 times less than its predecessor. Japan and Europe had previously approved use of the new refrigerant for automotive

A/C systems. It appears likely that HFO-1234yf will become the new global standard for environmentally friendly refrigeration.

Invented jointly by **Honeywell** and **DuPont**, the new chemistry has undergone extensive vetting to ensure not only environmental performance but also the ability to meet critical automotive industry standards for toxicity, flammability, system performance, durability, and material compatibility.

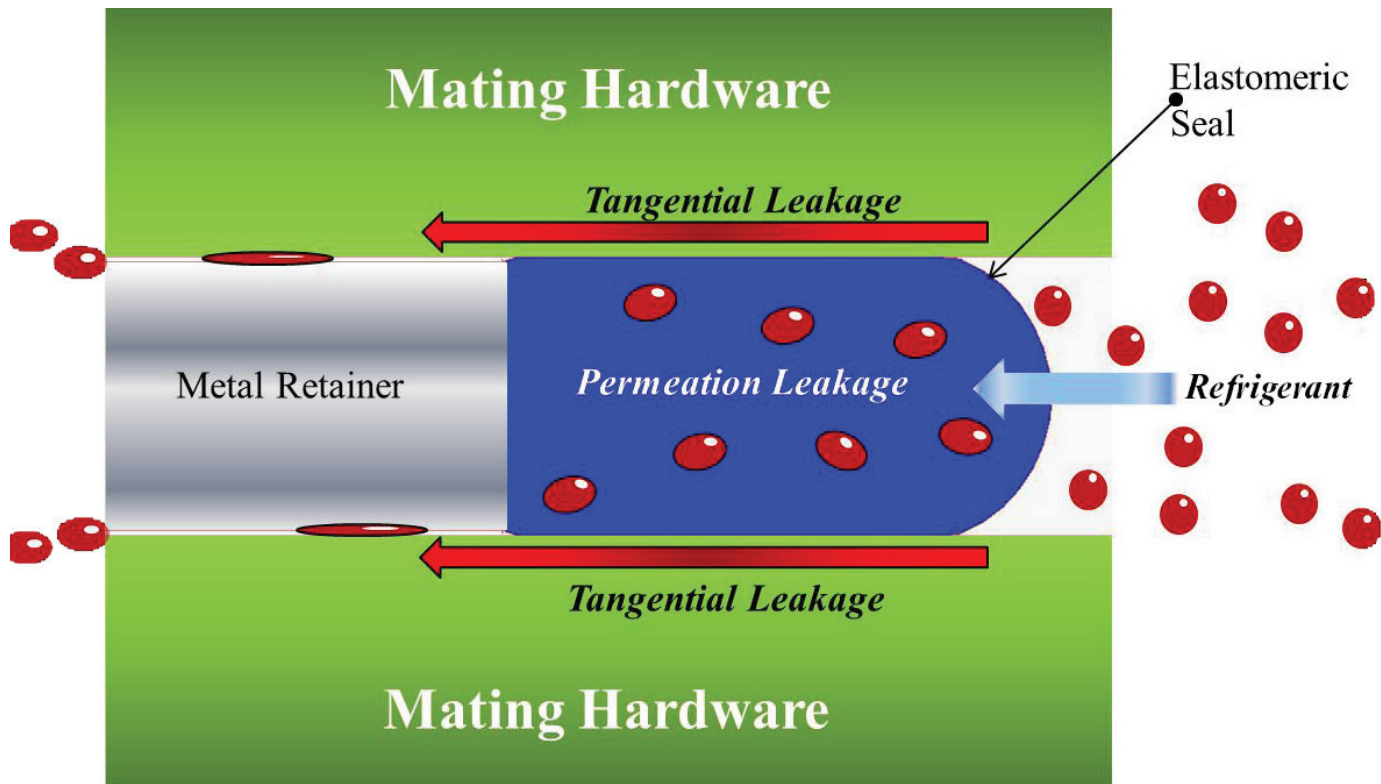
Acknowledging HFO-1234yf refrigerant's compatibility with current automotive system technologies, the EPA, nevertheless, in preparing the automotive service sector for its introduction, clearly states: "HFO-1234yf refrigerant system components should not be replaced with ones removed from a system that uses another type of refrigerant, or from a salvaged vehicle."

One of the many system components of concern to the OEMs and aftermarket service providers is the elastomeric seals used at the different joints in



A variety of chemical compounds are utilized to construct sealing materials that are used in automotive A/C systems. Since there are thousands of compounding ingredient options available, compounds may have the same base elastomer, yet exhibit marked performance differences in the seal.

Sealing A/C systems



Tangential leakage oozes out at the points where the seal adjoins with hardware; permeation leakage bleeds through the seal itself.

automotive air-conditioning. One critical aspect of seal performance is permeation, and the material compatibility issues likely to arise in relation to it, due to the new refrigeration chemistry.

Factors for seal material selection

Currently, most tube joint seals used in automotive A/C systems are based on ethylene propylene diene monomer (EPDM) or hydrogenated nitrile (HNBR) compounds. As with most sealing systems, the seal material choice for automotive A/C applications is ultimately a compromise based on the careful evaluation of multiple performance factors. To perform their jobs effectively, automotive tube seals must demonstrate:

- Permeation resistance in conjunction with the refrigerant chemistry used
- Degradation resistance in conjunction with the system

refrigerant and lubricant

- High-temperature resistance in relation to the operating system and its surrounding environment

- Compression-set resistance within the system, as it is exposed to fluids and temperatures.

It should be noted that the same rigorous testing and evaluation of seal materials relating to permeation needs to be applied by OEMs to each of the critical factors mentioned above. This is

necessary to ascertain which seal material is ultimately the best choice for a particular automotive A/C system. Working directly with seal manufacturers who offer extensive in-house laboratory and testing capabilities, and who have a deep understanding of automotive applications, is the best way to ensure that the air-conditioning seals chosen represent the best balance of all relevant performance characteristics.

The permeation testing protocol

Two types of leakage must be considered in determining the rate of loss of refrigerant from a seal joint: tangential and permeation. Tangential leakage occurs between the seal and its mating hardware, while permeation occurs through the rubber material itself. The relevant design parameter then is a seal's ability to resist permeation through the polymer network of its compound.

To identify and compare

Seal Materials Tested for Permeation

| Identifier Tag | Material Type |
|----------------|--|
| EPDM#1 | Black 75 Durometer Type A ethylene propylene |
| EPDM#2 | Black 70 Durometer Type A ethylene propylene |
| EPDM#3 | Black 70 Durometer Type A ethylene propylene |
| EPDM#4 | Black 75 Durometer Type A ethylene propylene |
| HNBR#1 | Black 70 Durometer Type A hydrogenated nitrile |
| HNBR#2 | Black 80 Durometer Type A hydrogenated nitrile |
| HNBR#3 | Red 70 Durometer Type A hydrogenated nitrile |
| HNBR#4 | Red 70 Durometer Type A hydrogenated nitrile |

the permeation of various seal materials when exposed to the new HFO-1234yf refrigerant, the **Parker Seal Group** used a gravimetric testing method. The vapor transmission rates were measured at various temperatures using thin diaphragms made of a variety of EPDM and HNBR compounds (see table).

The materials were also tested with the addition of the lubricant Nippondenso ND-8, in order to more closely replicate actual refrigerant operating conditions. ND-8 is one of the many lubricants used in air-conditioning systems.

The Parker fixture used for this testing was originally developed for testing seal compatibility with HFC-134a refrigerant when it was adopted by the automotive market in the mid-1990s. The weight loss of the assembly was measured periodically over a number of days of exposure at a constant temperature.

The testing protocol developed by Parker was limited only by the size and strength of the assembly itself, which was not robust enough to sustain the high pressures resulting from the high-temperature environments required by the HFO-1234yf refrigerant. Interestingly, refrigerants used by the automotive industry prior to concerns about ozone depletion worked best at low temperatures, making chloroprene compounds the seal material of choice prior to the mid-1990s. The increasingly high-temperature requirements demanded by successive generations of eco-friendly

Sealing A/C systems



The seal compatibility testing fixture consists of a small reservoir of HFO-1234yf refrigerant covered with a permeation lid with holes in it that are covered by a diaphragm made of the various seal materials being compared.

refrigerants have encouraged automotive OEMs to transition to HNBR-based and EPDM-based compounds.

Performing the test

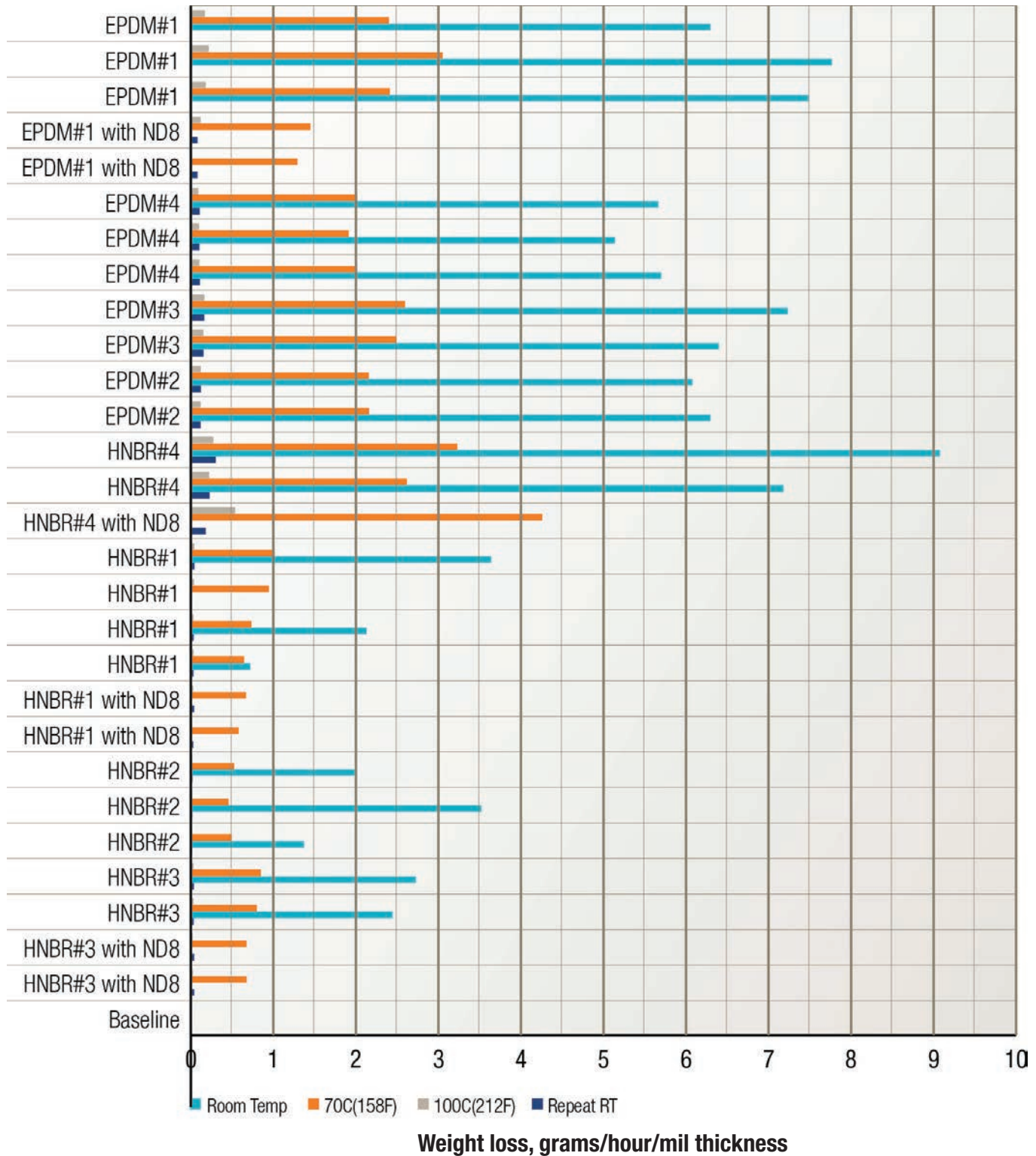
The test fixture was developed with a total weight restriction of about 200 g (7.0 oz). The fixture consists of a small reservoir of refrigerant covered with a permeation lid. The permeation lid is made from aluminum with about 50 through holes covered by a stainless steel screen in the recessed area of the lid. Flat, circular diaphragms of the seal materials are used to cover the holes in the lid. An O-ring is used as a seal between the container and the diaphragm.

As a baseline, one fixture is tested with a solid lid to restrict the permeation to the O-ring and edge of the diaphragm. This limits the exposed area of the diaphragm to approximately the same diameter as the

inside diameter of the O-ring. The fixture, which has a capacity of roughly 1.0 oz (30 mL) of liquid, is only partially filled with the HFO-1234yf refrigerant.

The fixtures are placed into an oven with a temperature that is slightly elevated from room temperature. At completion, the test fixtures are removed from the oven and the weight of the container is measured immediately using an analytical balance. The weight is recorded to the

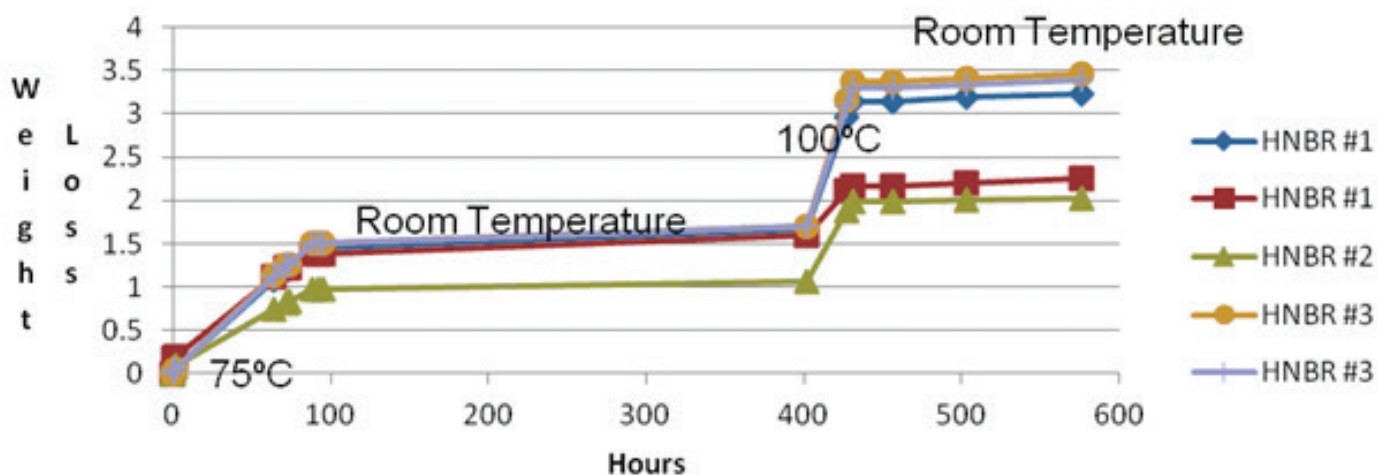
Permeation Resistance



Each of the eight materials was tested with the HFO-1234yf refrigerant, some with lubricant. Aside from the correlation between high operating temperatures and permeation, the critical finding, as demonstrated here, is the dramatic variation of all the materials.

Sealing A/C systems

Example of Cycle



The average permeation losses are based upon these test results.

nearest 0.0001 gram. The containers are then returned to the oven and removed once again at various intervals for

weighing. After several measurements at the temperature that is slightly elevated from room temperature, the fixtures are measured at room temperature for up to 26 weeks. Select fixtures are also tested at higher temperatures using the same procedures.

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The results

As the world community moves toward hybrid and electric-powered vehicles, A/C performance has become more critical than ever, with OEMs relying on these systems not only for driver comfort but also for maintaining safe vehicle operating temperatures.

When the Parker testing protocol was rigorously applied to the eight tested materials, the permeation rates for all materials increased dramatically with increasing temperature, presumably

due to increasing vapor pressure. Given the higher operating temperatures required for HFO-1234yf refrigerant, it is reasonable to assume that seal permeation performance will become increasingly critical to automotive A/C systems designed for this new, environmentally responsible refrigerant.

While the permeation performance of EPDM compounds improved with the addition of ND-8 lubricant, more testing is required to confirm to what extent EPDM seal performance might be improved with what specific levels of lubricant. Both the HNBR and EPDM compounds exhibit properties that are beneficial to air-conditioning systems. The seal material choice for automotive applications is ultimately a compromise based on the careful evaluation of multiple performance factors, including permeation resistance. **AEI**

Don Bowman, Manager of Materials Development for the Composite Sealing System Division of Parker Hannifin, wrote this article for AEI.



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