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Chemical Polarity and Its Impact on the Performance of Elastomeric Foam Insulation

By Chum Kotcha
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Closed-cell elastomeric foam is widely recognized as an effective insulator for pipes and ductwork, but ask an engineer to distinguish whether a particular elastomeric foam insulation is "NBR" or "EPDM" -based and you are likely to get a blank stare. Many engineers designing mechanical HVAC or plumbing systems today may not even realize that two distinct formulations for elastomeric foam exist. After all, both types of insulation are remarkably similar in all observable aspects, most notably the pliable, carbon-colored material and characteristically smooth skin. But despite their similarities in both application and appearance, NBR and EPDM elastomers are very different. One might even say they are polar opposites.

NBR-based elastomeric foam insulation is made of a Nitrile Butadiene Rubber/PVC polymeric blend. EPDM is made of an Ethylene Propylene Diene Methylene. Both compounds are cross-linked during a vulcanization process, which gives them their "rubbery" characteristic; however they differ significantly in their chemical structure. It's this structure that determines whether a particular polymer is considered "polar" or "non-polar," characteristics which describe the behavior of the material at a molecular level. The chemical polarity of an insulation gives us important insight into how the material will react under certain environmental stresses.

The single most pointed difference between NBR- and EPDM-based insulations is that NBR is polar and EPDM is non-polar. But what does that mean? And, more importantly, how does the polarity of the material impact its performance as an insulation? The answer is rooted in basic chemistry.

Like Oil and Water

Even those who haven't cracked a chemistry book since high school probably remember that a molecule – the smallest physical unit of an element or compound – consist of two or more atoms chemically bonded to one another. All atoms, whether they be carbon, hydrogen or any of the other 118 elements on the periodic table, have a specific electronegativity value. This value reflects an atom's ability to attract electrons. When atoms come together to form a molecule there is a certain amount of "push and pull" that takes place between them depending on the difference in electronegativity between the atoms. (Think of a tug-of-war.)

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Sometimes it's a fair fight – so fair that the electronegativity of one atom cancels the other out and a sort of equilibrium is achieved.

This "balance" of charge and/or the symmetrical distribution of shared electrons between atoms are what make certain molecules non-polar. It is why oil (non-polar) and water (polar) do not mix. Their respective electronegativity characteristics drive them apart. On the other hand, we all know how easily table salt (extremely polar!) dissolves rapidly in water. Polar molecules like to mingle – so much so that this affinity for one another can cause a change in physical state and molecular structure. Water is especially effective at creating physical change as it will eventually dissolve just about anything that happens to be the least bit polar, including highly polarized formulations of elastomeric foam.

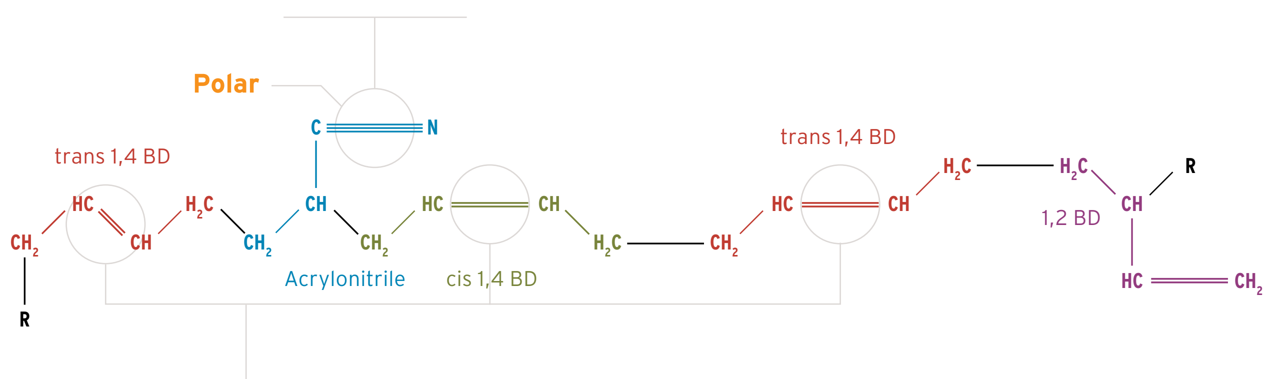
What Makes An Elastomeric Foam Polar or Non-Polar?

When it comes to complex chemical compounds such as those that make up elastomeric foam, it can be difficult to determine polarity. This is because the final product includes a mix of other chemicals that may include synthetic or non-synthetic rubber, fillers, curing agents, accelerators, peptizers and blowing agents. However, the molecular structure of these compounds gives us some clues.

Figure 1 below shows the molecular structure of both EPDM and NBR. Notice that there is a lack of symmetry to the NBR chain. This is indicative of an uneven sharing of electrons between the elements that make up the molecular structure. This "unevenness" destabilizes the molecular bonds under certain environmental exposures, including heat, moisture, ultraviolet light,

Figure 1

Cyanide Group > Cyanide gas **(HCN)** emitted when NBR is burned

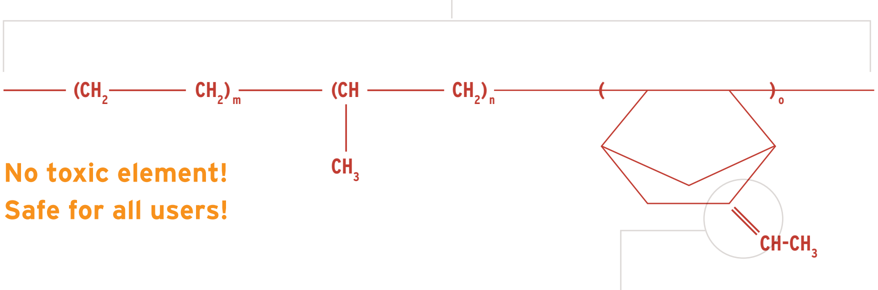


Double bonds in the main polymer chain > reactive and easily broken when attacked by HEAT, MOISTURE, UV, O3, O2, POLAR SOLVENTS, ACID AND ALKALI ozone and oxygen. It is this polarized chemical structure that makes NBR hygroscopic – meaning that it attracts water molecules from the surrounding environment. It also makes it more vulnerable to other types of environmental degradation.

The molecular structure of EPDM, shown in *Figure 2* below, is quite different. Notice that its chain is linear and much more balanced. This, among other things beyond the scope of this article, are indicative of its impressive molecular stability. It is hydrophobic, meaning that it does not induce or react with water or moisture from its surroundings. In addition, the saturated chemical structure of EPDM makes it less reactive to ultraviolet light and ozone than NBR, so it degrades at a slower rate than NBR under these exposures.

It may be months or years before these differences manifest in respective installations of EPDM and NBR insulations, but all things being equal (proper sizing, installation, environmental factors, etc.) NBR-based elastomer foam insulation will start to degrade long before insulations made of EPDM-based foams. Its cells will begin to collapse, cracking will appear and the material itself will start to lose its flexibility. As moisture infiltrates the material, its thermal properties will increasingly degrade since water is a far more effective conductor of heat than air. Extreme moisture infiltration will start to break down the material itself, the tell-tale sign being a kind of "black slime" that occurs at the surface of the product. This can be likened to the dissolution of salt in water, where water is dissolving another polar substance.

Figure 2 **Fully saturated backbone chain (no reactive double bond** > Not reactive to HEAT, MOISTURE, UV, O3, O2, POLAR SOLVENTS, ACID AND ALKALI



No toxic element!
Safe for all users!

Pendant diene: This double bond will be cured during production processes to strengthen the product only.

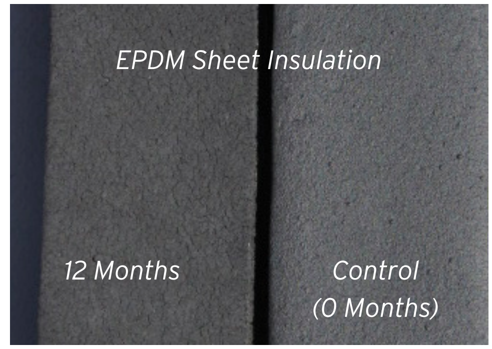
Comparatively speaking, the molecular polarity of NBR makes it markedly less stable than EPDM under environmental conditions that would be most relevant to any type of mechanical insulation application. Table 1 below compares the properties of both types of materials with respect to various exposures.

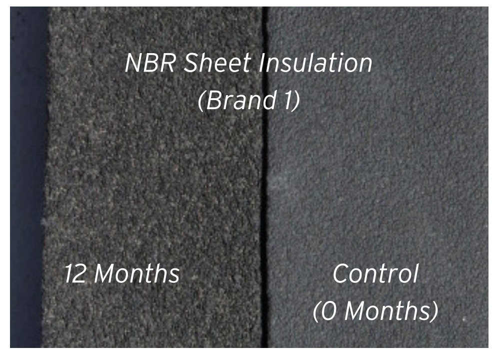
Conclusion

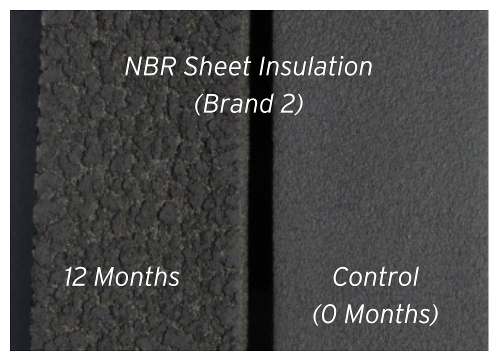
Despite their nearly identical visual characteristics and common applications in mechanical HVAC, plumbing and refrigeration systems, EPDM and NBR elastomeric closed-cell insulations are markedly different in molecular structure. The most fundamental difference is polarity. The non-polarity of EPDM makes it a more stable material when exposed to moisture, sunlight, ozone and a wide temperature range. The most notable among this is moisture. EPDM is hydrophobic (it does not dissolve in water) whereas NBR is hygroscopic (it does attract water and will eventually begin to dissolve). To the specifier this means greater precaution must be taken when opting for NBR over EPDM, especially for applications where there is high humidity and/or applications where the potential for condensation is high. Installers have far less room for error as extreme care must be taken to protect the material from environmental conditions, including moisture and sunlight. Finally, owners need to be made aware that NBR foams, though slightly less in material costs, will most likely have higher lifecycle costs due to the shorter lifespan of the product.

Typical Operating Properties

Property	EPDM	NBR
Continuous low temperature, °F	-297	-297
Continuous high temperature, °F	257	220
Ozone	Excellent	Good
UV resistance	Excellent	Good
Water vapor permeability	Excellent	Good







The above samples show one EPDM-based elastomeric foam insulation and two different brands of NBR-based insulations after undergoing identical ASTM G7 Exposure Test conditions, including exposure to rain, sunlight, wind and moisture. Samples on the right show the unexposed control sample. Samples on the left show the product after 12 months of exposure testing.

About the author

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Ms. Khotcha would like to thank Ravina Vitoorapakorn, Sales & Procurement Manager for Eastern Polymer Group, for her assistance with this article. Ms. Vitoorapakorn has a Master's degree in Polymer Science.

About Aeroflex USA

Aeroflex USA, Inc., headquartered in Sweetwater, TN, is the manufacturer of the AEROFLEX® brand of EPDM closed-cell elastomeric foam insulation for HVAC, refrigeration, and plumbing systems throughout North America. Aeroflex USA is a wholly-owned subsidiary of Aeroflex Company, Ltd., the dedicated insulation division of the Eastern Polymer Group, based in Bangkok, Thailand.

Aeroflex USA's EPDM is enriched by the vast resources and expertise of parent company, Eastern Polymer Group Public Co., Ltd. (EPG). EPG is highly regarded throughout the world for its contributions to the polymer industry. The company operates eight R&D laboratories that fuel its subsidiary companies with innovations that enhance the durability, safety and sustainability of its products.

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