

FOR BEV SEALS, AEM COMPOUNDS OFFER EXCELLENT BALANCE OF THERMAL AND CHEMICAL RESISTANCE

BEV SEAL CHALLENGES

REQUIREMENTS FOR E-MOBILITY

Specifications for different applications in electric vehicles have been created, and engineers have clear guidelines for proper material selection for the various elements of EV technology. A first material choice is always made based on heat and fluid resistance.

LOW TEMPERATURE REQUIREMENTS

Low temperature flexibility requirements are similar to those of ICE. Typically, a low-temperature flexibility of -30 to -40°C meets every need. In rubber compounds, plasticizer typically is used to enhance low temperature properties. Some applications may allow only limited use of plasticizers in EVs, as they can be extracted by other fluids. Such extraction can change the sealing material properties and the fluid's performance.

TEMPERATURE REQUIREMENTS IN EV COMPONENTS FOR E-MOTOR AND E-TRANSMISSION

The heart of every EV is the electric motor which is very often combined with a transmission in an E-axle. Temperatures in or close to the E-motor are similar to those in ICE with up to 150°C continuous and 175°C peak temperature. Cooling of the E-motor is either made indirectly, using water/glycol blends like ICE, or — a more efficient technology — by direct cooling, using a dielectric oil inside the E-motor.

These oils would typically need to be cooled and filtered outside of the E-motor, which makes this direct cooling more complicated and more expensive. If a transmission or reducer is used, lubrication is needed. The lubricants are very often similar to automatic transmission fluids that are used in ICE. This means that the engine and transmission area of battery-powered electric vehicles (BEV) will bring requirements that can be compared to ICE, where Vamac® AEM is very often the material of choice.

BATTERY, POWER ELECTRONICS, INVERTER

Outside the motor area, temperatures are clearly lower because no significant heat radiation occurs. For batteries, optimum working temperatures are between 30 - 50°C, with peak temperatures of 90°C.

Cooling is done either indirectly with air or water/glycol blends or in high-performing cars as well with dielectric oils. Direct oil cooling (immersion cooling) is more effective, allows higher power, a longer lifetime, and longer mileage range with a single battery charge, but it is also more expensive.

FLUID RESISTANCE

The use of water/glycol is currently the most common cooling technology for batteries. It allows the use of non-oil-resistant sealing materials like ethylene propylene diene terpolymer (EPDM) or silicone rubber (liquid (LSR) or high consistency (HCR)). It must be considered that some water/glycol-based fluids contain acidic additives which may be problematic for silicone rubber.

For direct contact with oil, neither elastomer family is suitable, and oil-resistant material like AEM must be chosen.

Very often, rotating or moving parts on a car need some lubrication. Such lubricants also may cause problems if they get in contact with silicone or EPDM components.

With oil-resistant elastomer materials on the right side of the ASTM-D-2000 chart, these problems are easily solved. The lower temperatures in the battery or power electronics area would allow for lower cost sealing materials like NBR. NBR polymers, however, have an unsaturated backbone, which leads to limited heat, ozone, and UV resistance. NBR-based compounds very often contain special additives to improve ozone and UV resistance. These additives, however, can be washed out when an elastomer part comes in contact with fluids.

PROVEN BENEFITS FOR INTERNAL COMBUSTION ENGINES TRANSLATE TO BEVS

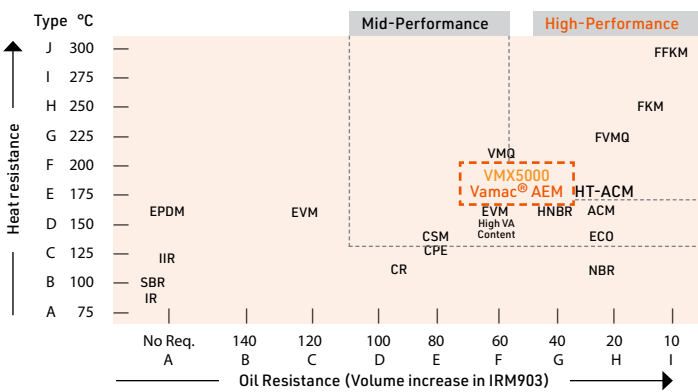
Celanese Vamac® ethylene acrylic elastomer (AEM) solves the challenges associated with internal combustion engine (ICE) sealing applications. Due to its chemical composition, Vamac® AEM offers a unique combination of properties including low-temperature flexibility and resistance to heat, oil, water/glycol, acids, and bases.

Outstanding compression set and compressive stress relaxation resistance also help to provide proven lifetime reliability in many different automotive sealing applications at moderate cost.

As global automotive OEMs introduce more electric vehicle (EV) platforms, Vamac® AEM has gained first applications in seals for battery packs and also offers several additional benefits that can help solve problems that arise with new technologies.

ABOUT VAMAC® AEM

To distinguish between different elastomer families, the ASTM-D-2000 classification can be used. In the chart below, the two main polymer classifications are heat resistance (y-axis) and resistance to reference oil IRM-903 (x-axis), a highly polar hydrocarbon-based fluid that causes much higher volume change for elastomers than modern engine or transmission fluids but allows for good differentiation. Vamac® AEM can be found among the polymers with good resistance to IRM-903 and with a heat (peak) resistance of 175 - 200°C.

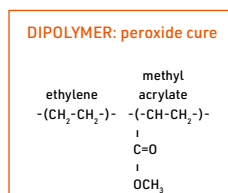
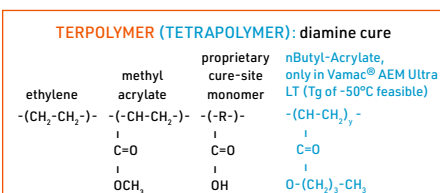


Source: Celanese

CHEMICAL COMPOSITION

Vamac® AEM polymers consist mainly of ethylene and methyl acrylate. After polymerization, all AEM grades have a fully saturated backbone, which provides excellent heat, ozone, and UV resistance. Unpolar ethylene, combined with polar methyl acrylate provides an interesting combination of excellent oil resistance and water resistance, which otherwise is only provided by significantly more expensive materials like fluoroelastomers (FKM) or hydrogenated acrylonitrilebutadiene rubber (HNBR).

All Vamac® AEM grades are free of halogens and silicone components, making AEM a good starting point for solutions where such ingredients may cause harm.



Source: Celanese

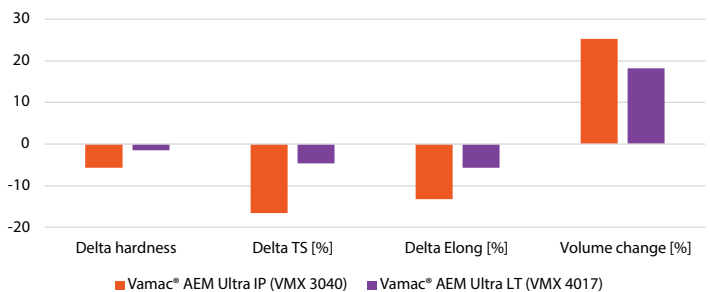
RUBBER COMPOUNDS

The final elastomer material that is used in seals, hoses, dampening parts, or cables for any kind of vehicle, is never the pure polymer alone. In the case of Vamac® AEM, the final material is a compound, where the polymer makes up only about half of the total content. Other raw materials mixed into the final compound are fillers such as carbon black or inorganic fillers, plasticizers, process aids, antioxidants, and curatives. Flame retardants can also be used whenever flame resistance is required. The combination of these additives, and the complete formulation of the mixture, determine the final properties. Vamac® AEM can be compounded with a wide variety of additives, which allow the final material properties to cover a wide hardness range of about 40 to 90 Shore A.

VERSATILITY FOR COMPONENTS IN CONTACT WITH MULTIPLE EV FLUIDS

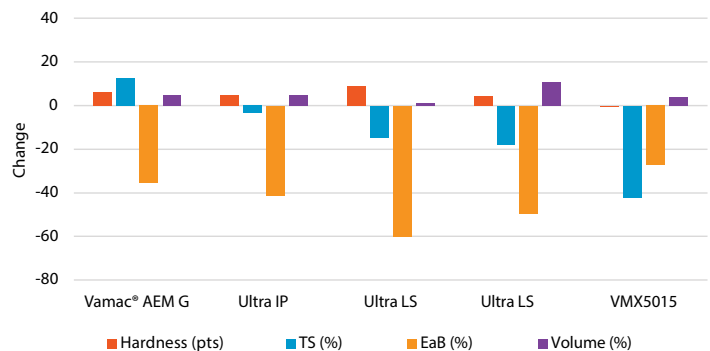
Vamac® AEM provides resistance to oil and water/glycol blends at the same time. Thus, it can be used also for components where oil and water contact may happen simultaneously. This can be the case for a seal which is in contact with a water coolant on one side and a lubricating EV fluid on the other. The next two charts show resistance of some standard Vamac® AEM compounds to a modern coolant and EV fluid used by a leading German OEM for E-motor lubrication.

FLUID AGING, 1008 H AT 108°C IN COOLANT / WATER (50/50)



Resistance of two Vamac® AEM compounds to a water/coolant mixture

FLUID AGING IN EV FLUID, 1008 H / 150°C

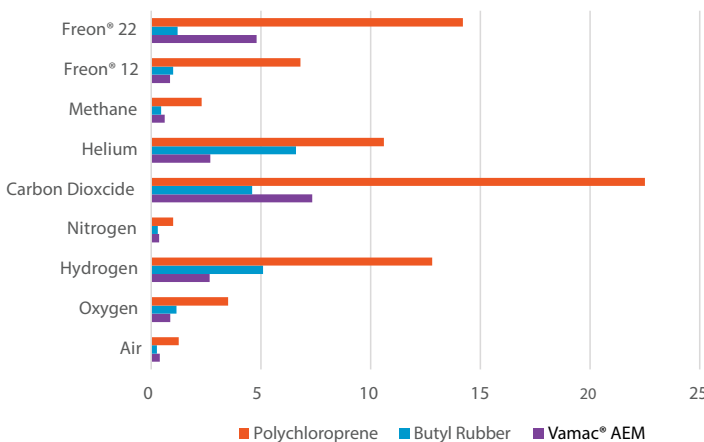


Resistance of five Vamac® AEM compounds to EV fluid

Source: Celanese

GAS PERMEATION

Thanks to its major components, ethylene without any side chains and methyl acrylate with very short side chains, and good polymer linearity, Vamac® AEM also provides very low gas permeation levels. The following slide compares a standard Vamac® AEM G-based compound with other polymers that are known for low gas permeation.



Comparative gas permeation rate at 23°C, different elastomers

Source: Celanese

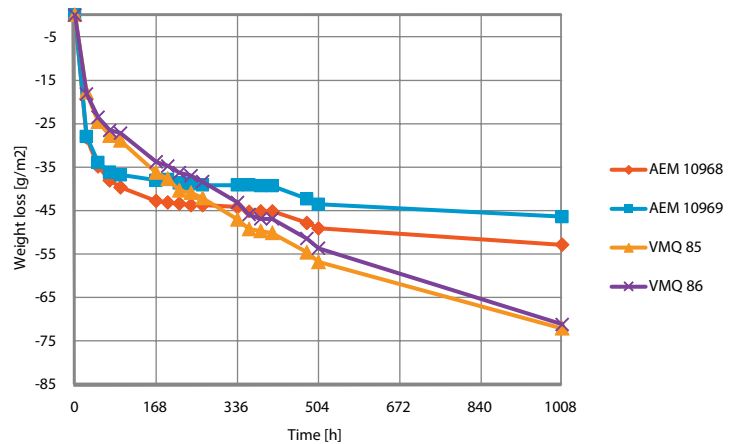
OIL PERMEATION

Permeability to oils is mainly determined by the polarity of an elastomer, and less by the linearity. A modern EV fluid was used for comparative oil permeation tests between two liquid silicone rubber compounds and two Vamac® AEM compounds based on Vamac® AEM Ultra IP and Ultra LS; the second with higher MA content and therefore better oil resistance. The oil was filled into Thwing-Albert cups for fuel permeation tests, covered with two mm thick membranes made from the four different elastomer compounds, and placed upside-down in an oven at 80°C. After some time, the outer surface of the LSR membranes were becoming wet, whereas the Vamac® AEM-based membranes stayed dry. Additionally, weight-loss of the cups over time was recorded.



The outer surface of a Vamac® AEM membrane (left) vs. an LSR membrane (right)

WEIGHT LOSS OF EV FLUID BY M2 @ 80°C



Source: Celanese

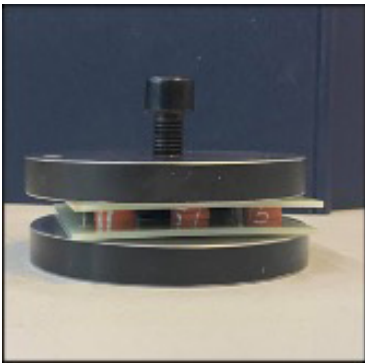
FLAME-RESISTANCE REQUIREMENTS, HALOGEN-FREE FLAME RETARDANTS

Thermal runaways of batteries used in EVs have caused several BEVs to catch fire. To minimize the risk of toxic fumes and extend the time that passengers could use to get out of the danger zone, leading OEMs have established strict requirements for flame retardance. Vamac® AEM can be compounded in several ways to reach good flame retardance like V0 according to UL94.

PROBLEMS OF SILICONE RUBBER SEALS IN CONTACT WITH FLAME-RETARDANT PLASTICS

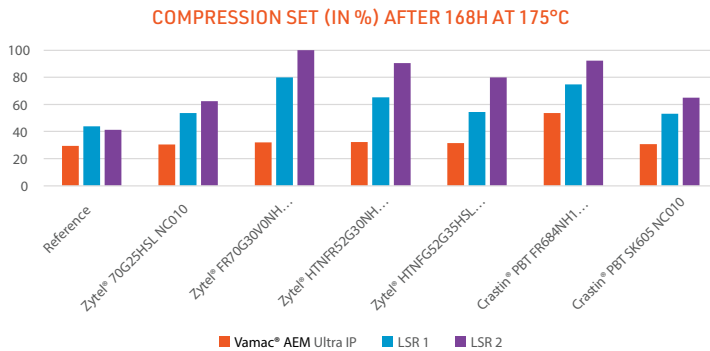
To meet these FR requirements, plastic materials that are used for parts in BEVs, such as connectors, housings, or busbars, have to be flame retardant as well. Additional requirements for low toxicity of fumes in the case of fire have led to a clear trend that standard FR plastics with halogenated flame retardants are replaced by new FR grades with halogen-free flame retardants. These do not cause toxic components like HBr in the case of a burning part that contains brominated flame retardants. These halogen-free flame retardants are usually based on phosphorous.

Liquid silicone rubber (LSR), and high consistency silicone rubber (HCR) have been used successfully for many years in applications such as connector seals. Both materials are also considered for many sealing applications in BEVs. However, it was recently found that seals made from both types of silicone rubber showed strong deformation and high compression set after exposure to temperatures above 100°C for longer periods. These problems occurred mainly when the silicone seals were in direct contact with non-halogen flame retardant (NH-FR) plastic parts.



TEST SET-UP

To simulate these conditions, and verify the compression set performance of LSR in comparison to Vamac® AEM, Celanese technical experts chose a simple test set-up, using standard CSet fixtures, and compressed rubber slabs sandwiched between two sheets of different Celanese engineered plastic materials based on PA66, PPA, and PBT.



Source: Celanese

SHORT-TERM TESTS AT PEAK TEMPERATURE

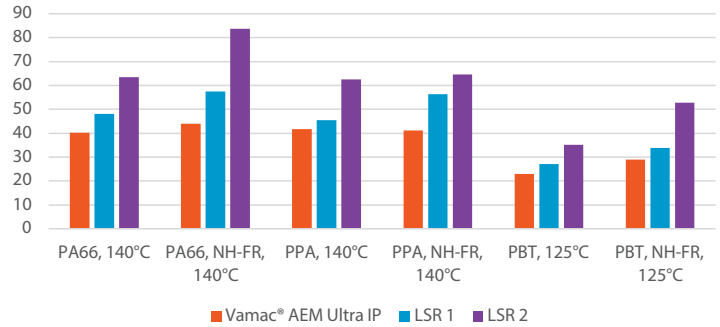
Two standard LSR types were tested according to ISO-815-B for one week at 175°C and compared with a standard Vamac® AEM Ultra IP-based compound.

The reference CSet without contact to plastic sheets already showed significantly lower CSet results for Vamac® AEM compared to the two LSR grades under these conditions. Contact to standard PA66 and PPA increases CSet for both LSRs significantly. The CSet gets significantly worse for PA66 or PPA with NH-FR additives. No negative impact on Vamac®'s AEM CSet is seen when in contact with NH-FR or standard PA66 or PPA. Standard PBT already increases CSet of LSR significantly; the NH-FR additives lead to the worst CSet. These additives also cause a chemical reaction between Vamac® AEM and PBT, as seen from the CSet of Vamac® AEM in contact with Crastin® PBT FR684NH1.

LONGER-TERM TESTS AT LOWER TEST TEMPERATURES

In order to check impact of lower temperatures, tests with polyamides at 140°C and PBT at 125°C were conducted over six weeks. Also at lower temperatures, Vamac® AEM Ultra IP showed superior compression set resistance over silicone rubber, independent of test conditions and plastic type. Both LSR types did reveal significant increase in CSet when the samples were compressed between NH-FR plastic sheets.

CSET (IN %) IN CONTACT WITH DIFFERENT PLASTICS, 6 WEEKS

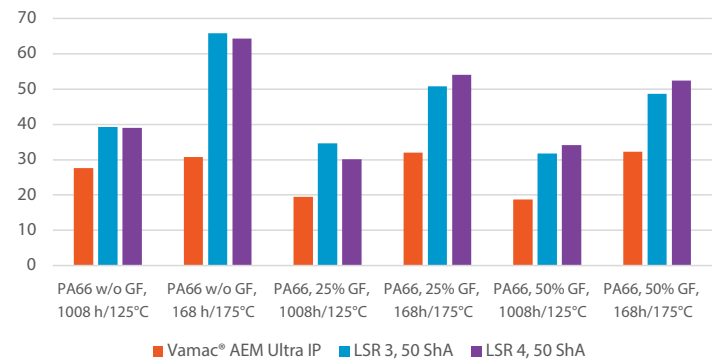


Source: Celanese

IMPACT OF GLASS FIBER CONTENT IN PA66 ON COMPRESSION SET OF LSR AND VAMAC® AEM

As the compression set of LSR already suffers when in contact with standard plastics without the halogen-free flame retardants, a third study was conducted to examine the impact of glass fiber content in PA66 on the compression set. Tests were carried out for one week at 175°C and six weeks at 125°C. Two other standard LSR types were used for this study, along with the standard Vamac® AEM Ultra IP-based compound.

CSET (IN %), PA66 WITH DIFFERENT GF LEVELS



Source: Celanese

Under both test conditions, Vamac® AEM clearly performs better than both LSR grades. Vamac®'s AEM CSet also does not show strong variation related to glass fiber content, whereas LSR's compression set gets worse as the glass fiber content decreases, or as PA66 content increases. A chemical reaction between silicone and polyamide called aminolysis is suspected to be the reason. This effect may have a significant impact on sealing properties for any LSR seal in contact with polyamide.

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