# **ARCOR®** ® High-Performance Novolac Epoxy Coatings & Rebuilding Materials

## Technical Review - Product Design

There are many categories of Novolac epoxy resins based upon the average # of epoxy functional groups (epoxide rings) per chain.

The most widely used by formulators such as ARCOR® fall into 3 groupings (the variances within the group depend on the manufacturing source). They are 2.2-2.4 functionality; 2.6-2.8 functionality; 3.2-3.6 functionality.

There are also several classes of amines and subgroups that have different reactivity (amine hydrogen reacts with epoxide group to form the cross-link, curing the epoxy). The main classes are Aliphatic, Cycloaliphatic & Aromatic. Most have 3 or more reactive sites which will give a high density 3 dimensional cross-linked structure.

Aromatics provided the best heat & chemical resistance (benzene ring like toluene, naphthalene) but can be hazardous. The main component is methylenedianiline (MDA) which is a known carcinogen. These amines have not been used in ARCOR® formulations since 1992.

The main classes of amines used by ARCOR® are aliphatic & cycloaliphatic. The aliphatics are long branched chains with multiple reactive sites allowing for a high density 3-D crosslink. The cycloaliphatics are based on a carbon ring but unlike the aromatics they are a class of alicyclic compounds that are aliphatic in nature so are not harmful or hazardous. The active amine groups branching off the ring allows for even better 3-D cross-link densities but also tends to allow for more resiliency in the final cured product (less brittleness).

Pairing of epoxy & amine and blends alters both chemical, heat and physical characteristics. All of the above epoxy & amine classes can be mixed and matched to achieve different aspects to the final product.

Amines designed for room temperature applications typically employ plasticizers to insure complete reaction. We utilize additional reactive plasticizers to minimize loss of heat & chemical resistance often associated with lack of heat cure (reactive in that they participate in the polymerization process). Amines designed for heat-cured reactions use little or no plasticizers and typically give higher chemical and thermal performance particularly in aggressive acids.

Additionally ARCOR® uses many other types of reactive additives that can be used to alter cure speed, extent of cure at ambient, adhesion, flexural, compressive, wear and other characteristics.

For example adhesion of an epoxy (organic) to steel (inorganic) will have both a physical and a chemical attribute. On its own the chemical portion will be a simple weak hydrogen bond and to some extent the stronger ionic bond. The addition of a dual reactive molecule will promote a much stronger covalent bond. It works much like soap. One side of the molecule has a reactive group that will for a bond with the steel (inorganics). The other side offers up an organic reactive group which will bond with the epoxide group (much like the amine hydrogen) giving a much stronger covalent bond.

Other non-reactive additives aid in air release (air is entrapped during manufacturing, dispensing/packaging, mixing and application in the field). Different additives are used to minimize the airs ability to become entrapped and others to facilitate release after entrapment. Failure to use the right combination of these will result in entrapped air in the final applied film. This is true even with vacuumed products. Much air is added during dispensing then again during field mixing and again when applied.

Other additives are used to facilitate wetting, flow & film formation. The surface tension of a viscous epoxy in its liquid state, the result of cohesive forces, wants it to resist flow evidenced by a balling up & fish-eyes during application an during the cure process. Additives are utilized to reduce the surface tension to improve flow. This improves application and helps the applicator better control coating thickness.

Additionally components are used to reduce the internal tension & stress of the epoxy to allow for optimal wet-out throughout the curing process. As the epoxy cures internal forces can increase which creates a stress within the curing system which can act to 'pull' the epoxy from the surface inhibiting adhesion and can ultimately crack the coating.

Finally additives are used to enhance the final film formation during cure. These are used in conjunction with the air release agents and surface tension reducers as discussed above to promote a smooth error free film throughout the cure process facilitating a pin-hole free coating.

ARCOR® also uses many types of fillers. Although non-reactive they can impart many modifications in physical performance and also temperature and chemical performance.

Often fillers are regarded as 'extenders' which allow for lower cost formulation. This is true in the commodities sector of epoxy formulation which rely heavily on talcs & bicarbonate fillers. In the higher end, higher performance, specialized formulation field (which we consider most of our products part of), fillers are used for their ability to impart a specific characteristic to the resultant formulation.

For example needle shaped filler is excellent at reducing a Novolacs tendency to chip or scallop (similar to what's seen in porcelain) and aids in internal stress mitigation in conjunction with surface tension modifiers as discussed above.

Various minerals aid in abrasion resistance. Specialty mineral fillers are surface treated to allow them to form a superior bond within the epoxy (same family of additives referred to earlier to promote adhesion).

Fibers are excellent ways to address flexural, tensile, compressive issues.
Asbestos was commonly used by formulators in the 50's, 60's, 70's, and 80's.
It has since been replaced by more benign milled glass fibers.

ARCOR® has worked with DuPont since 2000 to incorporate raw Kevlar pulp into our formulations and modify manufacturing techniques to maximize the results in tensile, thermal, flexural and compressive improvement. Most of our rebuilds utilize it and now many of our coatings. We have been able to spray apply Kevlar coatings since 2001.

> ***Flexural Strength***: The network of fibers and fibers rapidly disperses forces applied to the coating system thus improving flexural strength. In a laboratory test additions of Kevlar nearly tripled the flexural strength changing a sample from brittle epoxy to a flexible sheet which could be bent backwards and forwards.
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> ***Chip Resistance:*** Because of the improvement in impact resistance and cohesive strength Kevlar reinforcement has a pronounced beneficial effect on resistance to chipping damage.
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> ***Tensile Strength:*** Additions of Kevlar fibers have been shown to increase tensile and tear strengths by factors of up to five times. Wear resistance, which is related to toughness and tensile strength is also improved severalfold.

***Thermal Resistance:*** Kevlar retains its impressive properties from cryogenic temperatures up to 750°F (399°C). This unique property assures continued high performance under all foreseeable service conditions.

By careful use & balancing of the myriad of components discussed above ARCOR® has greatly minimized the negative tendencies often associated with Hi-Functionality Epoxy Novolacs. This has allowed us to mainstream the highest 3.6 functional resins for use in larger applications with the improved chemical and heat performance such a high cross-linked system generates.