CVC Specialty Chemicals, Inc.

Advantages of Higher Functionality in Formulated Epoxies for Chemical-Resistant Applications

Epoxies have long been known for providing excellent physical properties for a wide range of applications. Among the most critical of these many applications is their use in coatings for containment of, or resistance to, aggressive and/or hazardous chemicals.

Containment applications can include;

- Primary containment – as in a vessel coating or lining (or free standing filament wound vessel) designed to contain a particular reagent or reagents. Systems for primary containment are designed to withstand indefinite exposure to the reagent(s) in question.
- Secondary Containment – as a coating or lining designed for installation over concrete dikes to protect from attack of aggressive media that has spilled of leaked from its primary containment vessels. Systems for secondary containment are designed to withstand finite exposure to the reagent(s) in question, usually for a period of a few hours to a few days.
- Floor and wall coatings – to protect substrates in manufacturing environments from degradation due to incidental and/or routine exposure to aggressive chemicals.

The difference between a coating and a lining is generally dependant on the thickness of the protective system and whether or not some type of reinforcement is used as a component. Coatings are thinner, usually no more than 20 to 30 mils thick and do not utilize any type of reinforcing fabric or large quantities of fiber reinforcement. Linings, on the other hand, are much thicker (40 mils and over), and will usually utilize a fabric or fiber reinforcement. Some constructions, for particularly heavy-duty applications, are applied in layers to a thickness of 125 to 250 mils and more.

Other chemical-resistant applications for epoxies can include;

- 100% Solids Polymer Flooring
- Brick mortars and tile grouts
- Potting compounds
- Filament wound pipe

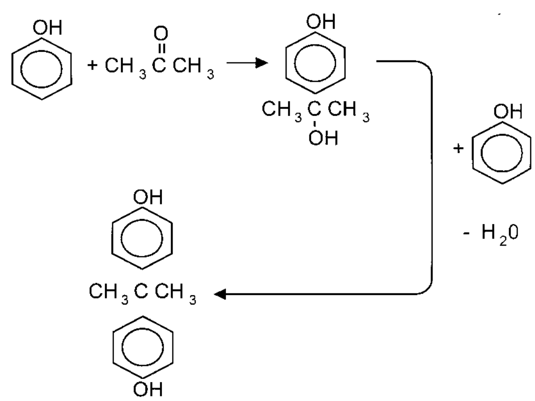
Many factors influence the degree of success a formulation achieves in protective coating and lining applications. These include the curing agent used, cure conditions, hardener stoichiometry, cure accelerators used, fillers, and additive package. Of utmost important is the resin selection.

Two basic choices are available for use in formulating epoxy based chemical-resistant systems. These would be Bisphenol A based resin (DGEBA) or Epoxy Phenol Novolac (EPN) resins. EPN's have been shown to be advantageous in chemical resistant applications. The reasons for this advantage can be traced to their structural make up.

If we compare manufacturing processes for DGEBA and EPN's, we see why EPN's have distinct advantages for chemical-resistance.

Bisphenol A is the starting phenolic for the most widely used DGEBA resin and is made via reaction of phenol with acetone. This sequence is shown in Figure 1. In current commercial processes Bisphenol A is supplied for epoxy resin production at greater than 98% difunctional content.

BISPHENOL A SYNTHESIS

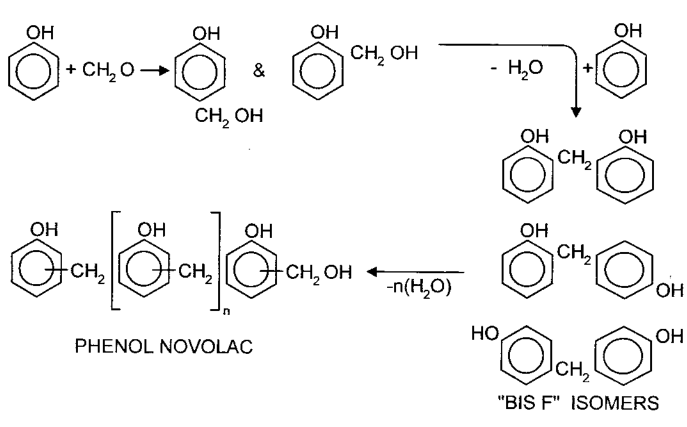


(figure 1)

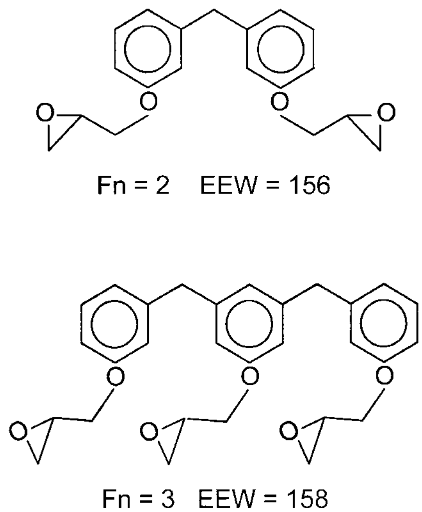
Phenol novolacs are reaction products of phenol and formaldehyde. Because formaldehyde is smaller that acetone and less hindered in its reaction with phenol, multiple formaldehyde reactions on phenol and multiple condensations with phenol can occur as illustrated in Figure 2. Conversion of Bisphenol A to the epoxy yields substantially a liner resin with a maximum

(Figure 2)

NOVOLAC SYNTHESIS



functionality of two. The epoxidation of phenol novolacs yields a mixture of di- and poly-functional resins as shown in figure 3.



(Figure 3)

As a consequence of the higher functionality inherent in EPN resins, higher crosslink density is attained. Higher crosslink density will generally result in cured products with greater resistance to chemical attack and increased thermal resistance. Also, it has been shown that higher functionality EPN resins will show increased chemical resistance over similar EPN resins with lower average functionality.

Production processes used at CVC have been shown to yield a family of EPN resins with higher functionality and lower viscosity than their competitive offsets. The reason for this is better process control at CVC, which limits the amount of advancement that occurs in epoxidation reactions. Advancement reactions produce very high molecular weight epoxies that decrease the average functionality of a product and cause higher viscosity. Table 1 shows test results comparing Epalloy 8230 and several competitive Bisphenol F type resins. The table compares difunctional and trifunctional content (with sub grouping for isomer content), average functionality (f_n), epoxide equivalent weight (EEW), and viscosity. These data clearly show the advantage of the CVC process to provide lower viscosity resin at equivalent functionality, or higher functionality resin at equivalent viscosity.

Table 1
Comparative Analysis of Bis F Epoxy Resins
% Distribution within Resin

Isomer	EPALLOY 8230	Resin A	Resin B	Resin C	Resin D	Resin E
Difunctional						
o,o'	25.8	25.8	25.1	23.4	28.1	23.1
o,p'	34.2	33.7	38.3	40.7	49.4	36.1
p,p'	11.3	17.4	14.7	18.5	17.2	12.5
Total	71.3	79.2	78.1	82.6	94.7	71.7
Trifunctional						
o,o'	5.8	2.3	2.1	1.8	0.3	4.9
o,p'	6.9	2.7	2.4	2.4	0.3	5.9
p,p'	2.2	1.2	1.2	1.3	0.2	2.8
Total	14.9	6.2	5.7	5.5	0.8	13.6
Average fn	2.16	2.06	2.07	2.06	2.01	2.14
EEW (g/eq.)	164.5	170.7	174.0	168.5	NA	172.8
Visc (cps@25°C)	3430	3550	4500	3450	~1200	5850

Comparing the performance of Epalloy 8230 (average functionality = 2.15) and Epalloy 8250 (average functionality = 2.6) with a variety of curing agents, we can see an increase in glass transition temperatures as expected.

Chart 1 compares the Tg of 8230 and 8250 cured with various curing agents, cured for 48 hours at RT followed by 2 hours at 60°C. Results show higher Tg with 8250.

Chart 2 compares Tg of 8230 and 8250 with those same curing agents after a six-month RT cure. Again, Results show higher Tg with 8250.

Chart 3 compares the Tg of the Epalloy series as we progress from the lower functionality Epalloy 8220 to higher functionality Epalloy 8330. Samples in this example were cured with PACM (para-amino cyclohexyl methane) for 2 hours at 120°C. Results clearly show how Tg increases with increasing functionality.

Comparison of Tg, 8230 v. 8250

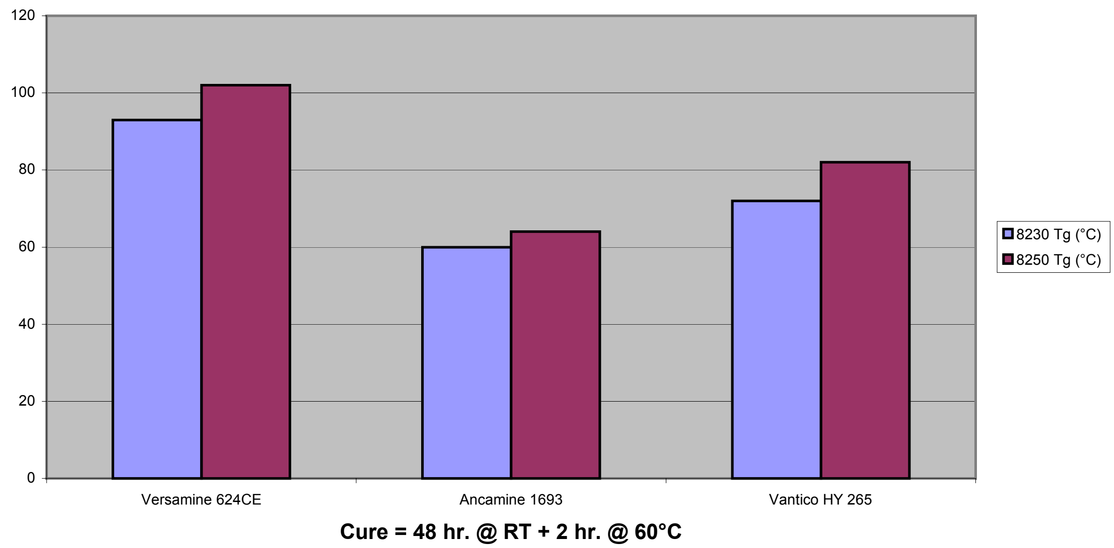


Chart 1

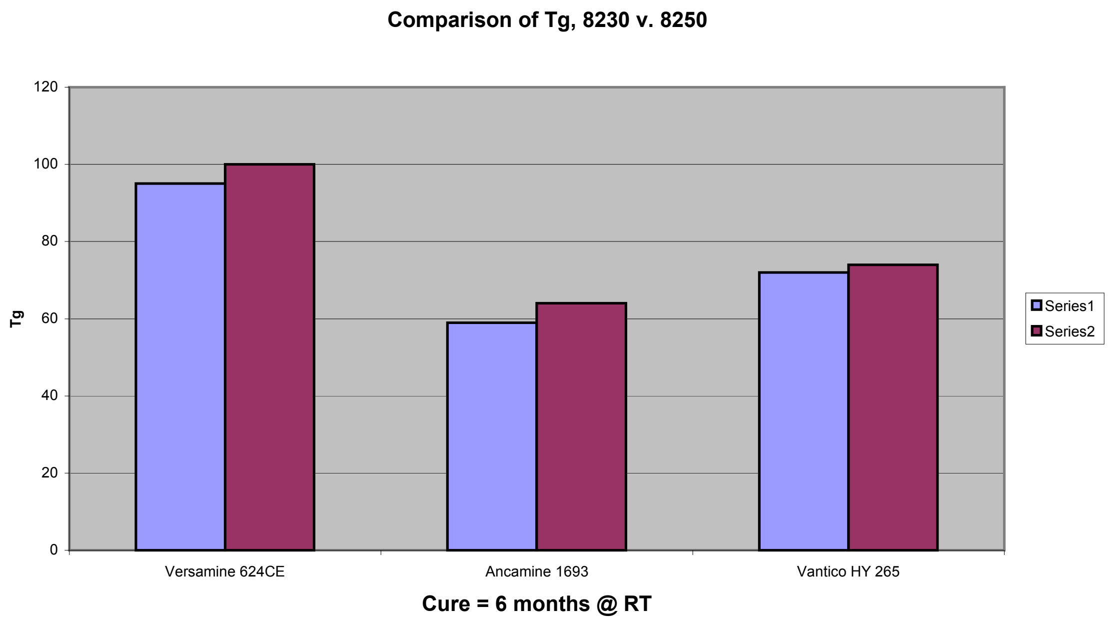


Chart 2

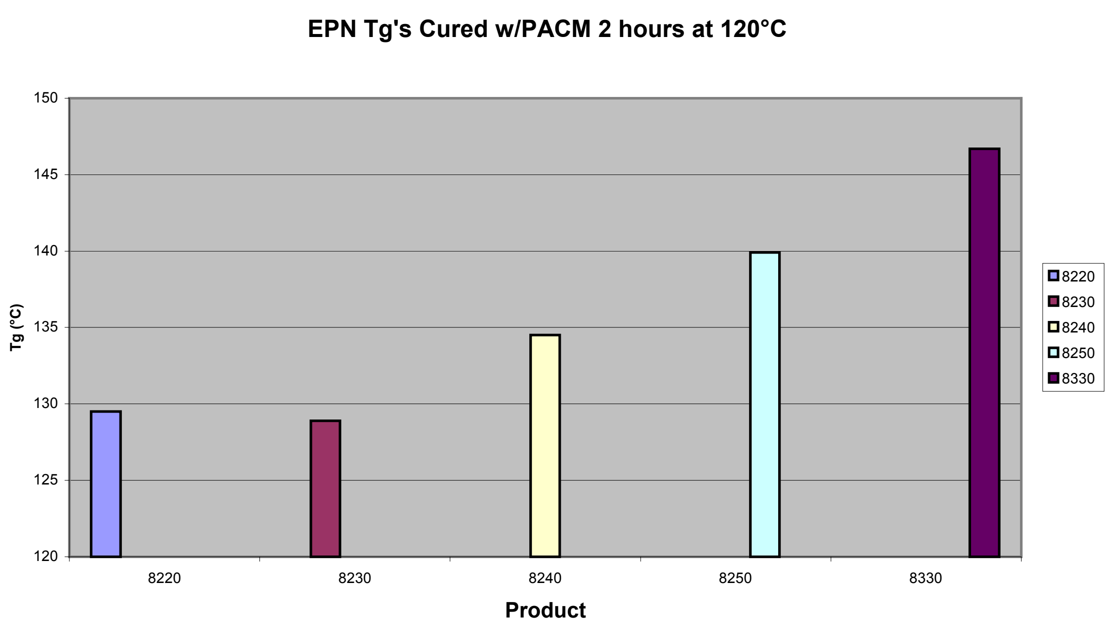


Chart 3

Chemical resistance testing was performed comparing the performance of 2.15 functional resin (Epalloy 8230) and 2.60 functional resin (Epalloy 8250). Several different curing agents were used. The cure schedule was 7 days at room temperature and samples were immersed in reagent for 28 days, also at room temperature. Testing was carried out in concentrated H_2SO_4, Glacial Acetic Acid, MEK, Toluene, and Methanol. The following table compares the performance of the lower and higher functionality EPN resins. In each case the higher functionality resin shows significant advantage over the lower functionality resin in terms of weight change.

Curing Agent	Reagent	2.15 func. EPN	2.60 func. EPN
Versamine 676CE	98% H_2SO_4	-24.0%	-9.5 %
Araldite HY 265	98% H_2SO_4	-11.9	+1.0
Ancamine 1693	Glacial Acetic	-12.7	-3.8
Versamine 624CE	Glacial Acetic	D*	-2.6
Versamine 624CE	MEK	D*	1.0
Ancamine 1693	Toluene	1.8	0.5
Versamine 670CE	Methanol	D*	2.0
Versamine 676CE	Methanol	D*	8.0

By building in higher functionality where possible, formulators will provide advantages to their products in terms of higher thermal properties and increased chemical resistance. Use of EPN resins in place of bisphenol A resins will provide higher functionality, resulting in better chemical and thermal resistance.

CVC is dedicated is dedicated to the epoxy industry. Our staff is always ready to discuss your application requirements.

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