

HyPox™ RA840 Modified Anhydride Cured Epoxy Resins

Scope: A project was initiated with the intent of comparing CTBN liquid polymers to a flexible anhydride. The specific application was an epoxy over wrap composite for compressed natural gas (CNG) aluminum cylinders. Therefore recipe 1 is the non-elastomer modified resin serving as the control. It was provided by the fabricator of the composite.

Initially, Hypro™ 1300X8 CTBN and 1300X13 CTBN in the form of respective epoxy adducts, HyPox RA840 and HyPox RA1340 were examined at a rubber concentration of 10 phr (parts per hundred resin). Recipes 2 and 3 represent these elastomer modified epoxy compositions. HyPox's RA840 and RA1340 have 40% rubber concentrations.

In each case 10 parts of the flexible anhydride (HY 920) were replaced with 10 parts of CTBN. Mechanical, toughness and thermal properties were measured with an emphasis on fracture surface energy represented by  $G_{Ic}$ . It is the energy required to propagate a crack in a material.

Recipe 2 containing HyPox RA840 was appreciably tougher than recipe 3 containing HyPox RA1340 based on its higher  $G_{Ic}$  value. Thus additional formulating work was done with HyPox RA840. Recipe 4 contains 15 parts of flexible anhydride and 15 parts of Hypro 1300X8 CTBN. As expected it was even tougher than recipe 2. Finally, HyPox RA840 as the sole modifier was examined in recipe 5 at a rubber concentration of 15 phr.

These data indicate that 1300X8 CTBN adduct as HyPox RA840 is significantly more effective than HY 920 regarding enhancing toughness and maintaining  $T_g$ .

Formulations for HyPox Modified Anhydride Cured Epoxy Resins

	1	2	3	4	5
HY 920	30	20	20	15	0
HyPox RA840	-	25	-	37.5	37.5
HyPox RA1340	-	-	25	-	-
Araldite 6005	150	135	135	128.5	128.5
MTHPA	90	97	97	101	113
BDMA	2.0	2.2	2.2	2.3	2.5
A/E (Molar)	0.85	0.85	0.85	0.85	0.85

Cure: 30 minutes at 80° plus four (4) hours at 150°C

Mechanical Properties of CTBN Modified Anhydride Cured Epoxies

	1	2	3	4	5
Tensile Strength, psi (MPa)	11,000 (75.9)	11,100 (76.5)	11,000 (75.9)	10,280 (70.8)	11,200 (77.2)
Tensile elongation, %	6.79	5.20	6.87	5.65	4.86
Tensile modulus, kpsi (GPa)	483 (3.3)	427 (2.94)	434 (2.99)	420 (2.89)	402 (2.77)
Flexural strength, psi (MPa)	17,000 (117)	16,300 (112.4)	16,900 (116.6)	16,000 (110.3)	15,500 (106.9)
Flexural elongation, %	6.0	6.2	6.1	5.7	5.8
Flexural modulus, kpsi (GPa)	416 (2.86)	394 (2.72)	403 (2.78)	387 (2.67)	380 (2.62)
G <sub>ic</sub> , J/m <sup>2</sup>	154	471	169	880	792
Tg, °C	101	110	108	112	121

NOTE: Recipes not gelled after 30 minutes at 80°C

REMARKS: Casting associated with recipe 3 was appreciably more transparent than any of formulations containing RA840. Morphology has not been examined but we suspect rubber particles to be very small in RA1340 containing system and not as effective as morphology in RA840 modified formulations.

PRODUCT	DESCRIPTION	VISCOSITY @25°C, cps	EQUIVALENT WEIGHT
Hy 920*	Flexible anhydride; non-aromatic carboxyl acid anhydride	4,500-6,500	225
Araldite 6005	Medium viscosity bisphenol A resin	7,500-9,500	189
MTHPA	Methyltetrahydrophthalic anhydride	80	166
BDMA	Benzyl dimethyl amine	-	-
HyPox RA840	60/40 adduct of DGEBA liquid epoxy and CTBN (1300X8)	-	340
HyPox RA1340	60/40 adduct of DGEBA liquid epoxy and CTBN (1300X13)	-	340

\*Dimerized fatty acid pre-reacted with epoxy diluent