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# **HUNTSMAN**

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## **EPOXY FORMULATIONS USING JEFFAMINE® POLYETHERAMINES**

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### 1. INTRODUCTION

The JEFFAMINE® Polyetheramines (PEAs) described in this brochure are the result of years of research and development carried out since the 1960's by the Texaco Chemical Company. Development of new JEFFAMINE® polyetheramine products continues to be the focus of the Huntsman Corporation today. Because of their unique structure and variety of chemical reactions, these products have found their way into many different end uses.

The purpose of this brochure is to present detailed technical formulation information primarily about four of the commercial JEFFAMINE® products: JEFFAMINE® D-230, D-400, D-2000, and T-403 amines, and to highlight their uses as curing agents for epoxy resins. Additional technical data on XTJ-504, XTJ-590, XTJ-506, HK-511 and BA-509 will also be highlighted.

We believe that the information in this brochure is correct, but no guarantee with respect to accuracy, completeness, or results is expressed or implied. The end uses mentioned are given for purposes of illustration, and the systems outlined should be viewed as "starting formulations" only. We urge you to conduct sufficient testing of any formulation before putting it into commercial use.

We hope that you will find this information both interesting and useful. For the latest information on all JEFFAMINE® polyetheramine products, both commercial materials and those under development, contact one of our service locations listed on the inside of the back cover.

### **HUNTSMAN – “Your Amine Team”™**

- Huntsman has provided over thirty years of service to the epoxy industry.
- Huntsman invented and commercialized the JEFFAMINE® PEA amine curing agents.
- Huntsman provides the most extensive range of polyetheramines – many which are unavailable anywhere else.
- Huntsman provides experienced technical support by virtue of having worked with these materials from their inception. If you have a problem, we likely have an answer.
- Huntsman's core competencies include alkoxylation and amination technologies, this means that the JEFFAMINE® amines are just part of a broad and diverse product portfolio.
- Huntsman produces the JEFFAMINE® amines in modern facilities located around the world.
- Huntsman works with our customers to develop new and unique products.

## 2. Why JEFFAMINE® Amine Curing Agents

### 2. WHY JEFFAMINE® AMINE CURING AGENTS?

The JEFFAMINE® amines, with their poly-ether containing backbone represent unique curing agents that result in properties that are often unobtainable with any other curing agents.

The unique characteristics of the JEFFAMINE® amines include:

**WATER-WHITE IN COLOR:** These make them ideal for use in decorative coatings and castings, as well as other applications requiring clarity and transparency.

**FLEXIBLE BACKBONE:** The cured epoxy will be somewhat flexible exhibiting high elongation, high impact strength and good low temperature properties. This is important in a variety of applications such as coatings that require chip resistance, coatings that are applied to materials of differing coefficient of expansion; or in composite/tooling applications where repetitive flexing or compression may be encountered.

**LOW VISCOSITY:** The low viscosities of these materials make them ideal in casting and self leveling applications. In addition, the low viscosities makes them the ideal to blend with other high-viscosity curing agents which otherwise could not be used. **LOW VISCOSITY OFTEN TRANSLATES TO LOW V.O.C.**

**CONTROLABLE REACTIVITY:** The JEFFAMINE® amines product line spans the spectrum in terms of product reactivity. For example the slower hindered products allow for a moderate pot life, important in leveling and composite applications. In addition, the low exotherm of these slower materials allows the casting of larger and thicker parts.

**GOOD HEALTH & SAFETY PROFILE:** Compared to many of the epoxy hardeners currently used, the majority of the JEFFAMINE® amines are relatively innocuous and easy to handle.

#### **JEFFAMINE® amine application advantages**

The above characteristics translate into specific advantages in a number of applications. For example, consider the following applications and the advantages of using the JEFFAMINE® amine curing agents:

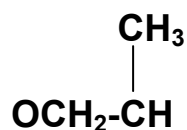
<b>Application</b>	<b>Advantage of a JEFFAMINE® amine hardener</b>
Protective coatings	-good wetting -low viscosity formulations, allow for low VOC's and are easy to apply -flexibility upon cure, resists chipping and nicking -flexibility allows good performance when substrate expands/contracts due to temperature excursions (resists delamination)
Decorative coatings	-water white -good wetting -low viscosity means good flow and leveling -flexibility upon cure means flexible substrates can be coated
Flooring	-low viscosity means good self-leveling -low viscosity allows high loading -flexibility upon cure, resists chipping and nicking -good wetting means aggregates can easily be added
Casting/Encapsulation	-low viscosity allows good mold flow -good wet-out -moderate reactivity means large parts can be processed
Composites	-moderate pot life means long working time -flexibility means reduced cyclic micro-cracking -good wet-out of fibers

### 3. Characteristics of the JEFFAMINE® Polyetheramines

#### 3. CHARACTERISTICS OF THE JEFFAMINE® POLYETHERAMINES (PEA's)

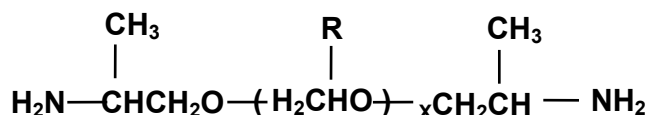
##### CHEMICAL STRUCTURE

The JEFFAMINE® PEA's make up a family of products having repeating polyether backbone structures. Four of the commercial products in the family contain repeating *oxypropylene* units.



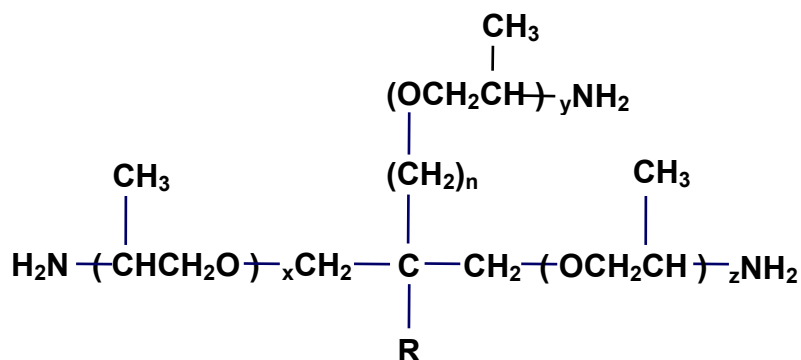
The structures are functionally terminated with primary amine groups positioned on secondary carbon atoms. The basic polyetheramine frame structure is indicated below. By varying the "X" and "R" groups the JEFFAMINE® PEA series was developed.

	X	R
D-230	1-2	CH <sub>3</sub>
D-400	4-5	CH <sub>3</sub>
D-2000	32	CH <sub>3</sub>
HK-511	2	H
XTJ-504	TEG	H
XTJ-590	EG	H



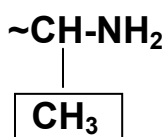
JEFFAMINE® T-403 and BA-509 are trifunctional (three amine groups per molecule) and can be represented by the following general formula.

	Initiator	Mw	x+y+z
T-403	TMP	400	5.3
BA-509	Glycerin	3000	49



The letter following the JEFFAMINE® trade name (D or T) represents the functionality (di- or tri-) of a given product, while the number designates the approximate average molecular weight. Thus, D-400 represents a diamine of about 400 molecular weight. BA-509 and HK-511 do not follow this convention. All XTJ-products indicate experimental JEFFAMINE® products, many of which have reached full commercial status.

Note that the primary amine groups in these products are attached to secondary carbon atoms. Thus, the amine nitrogen is sterically hindered in nucleophilic reactions by the pendant methyl group. The JEFFAMINE® PEA therefore exhibit "moderate" reactivity -- a desirable feature in many epoxy applications.



### 3. Characteristics of the JEFFAMINE® Polyetheramines

**Table 3.1 - Typical Physical Properties and Sales Specifications of JEFFAMINE® PEAs**

	Typical Properties									Test Method
Property	D-230	D-400	D-2000	T-403	XTJ-504	XTJ-590	XTJ-506	HK-511	BA-509	
Color, Pt-Co	30	50	100	30	10	20	12	20	10	
Brookfield viscosity, cps, 25°C (77°F)	9	21	247	70	8	9	Solid, mp ~30°C	10	398	
Specific gravity, 20/20°C	0.9480	0.9702	0.9964	0.9812	1.01	0.99	1.0694	0.984 <sup>4</sup>	1.002	
Density, lb/gal, 20°C	79	8.1	8.3	8.2	8.43	8.38	8.92	8.244	8.337	
Refractive index, n <sub>D</sub> <sup>20</sup>	1.4466	1.4482	1.4514	1.4606	1.4586	-	-	-	-	
Flash point, PMCC, °C (°F)	121(250)	163(325)	185(365)	196(385)	129(265)	105(221)	98(208)	138(280)	235(455)	
Water, wt. %	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.1	
Total acetylatables, meq/g	8.7	4.6	1.05	6.8	13.5	11.3	1.02	8.9	1.01	
Total amine, meq/g	8.4	4.4	1.0	6.4	13.4	11.26	0.96	8.4	0.97	
Primary amine, meq/g	8.2	4.3	0.97	6.1	13.4	11.26	0.95	8.4	0.97	
Vapor Pressure, mm Hg/°C	1/101	1/165	0.93/235	~1/181	~1/80	~1/80	-	1.6/100	-	
pH, 5% aqueous solution	11.7	11.6	10.5	11.6	11.7	12	11.1	11.7	10.4	
Equivalent weight with epoxies ("Amine hydrogen equivalent weight," or AHEW)	60	115	514	81	37	44	~250	62	~500	
pKa	9.46	9.51	8.65	9.23	9.62	10.3	9.75	9.67	9.36	
	Sales Specifications									
Appearance	Colorless to slight yellow with slight haze	Colorless to pale yellow with slight haze	Light yellow with slight haze	Colorless to pale yellow with slight haze	Colorless to pale yellow with slight haze	(tentative)	White, waxy low melting solid	Colorless to pale yellow with slight haze	Colorless to pale yellow with slight haze	ST-30.1
Color, Pt-Co	60 max.	75 max.	75 max.	60 max.	30 max.	50 max.	100 max.	125 max.	100 max.	ST-30.12
Total acetylatables, meq/g	8.3 min. 9.1 max.	4.2 min. 4.9 max.	0.98 min. 1.1 max.	6.5 min. 7.1 max.	--	--	0.95 min 1.15 max	8.3 min 9.3 max	0.95 min 1.05 max	<sup>1, 2</sup>
Primary amine, %	97 min.	97 min.	97 min	90 min.	--	99 min	90 min	--	97 min.	<sup>3</sup>
Total amine, meq/g	8.1 min. 8.7 max.	4.1 min. 4.7 max.	0.95 min. 1.05 max.	6.1 min. 6.6 max.	12.8 min	11.0 min	0.94 min	7.6 min 9.3 max	0.90 min 0.98 max	ST-5.35
Water, %	0.25 max.	0.25 max.	0.25 max.	0.25 max.	0.40 max	0.30 max	0.25 max	0.25 max	0.25 max	ST-31.53

The JEFFAMINE® products are completely soluble in most hydrocarbons and oxygenated solvents. The wide variety of solvents which may be used in combination with JEFFAMINE® materials is shown in Table 3.2.

1 Total acetylatables, JEFFAMINE® T-403, meq/g = uncorrected OH number by ST-31.13

56.1

2 Total acetylatables, JEFFAMINE® D-series products, meq/g = uncorrected OH number by ST-31.109

56.1

3 Primary amine, % = [(amine alkalinity, meq/g, by ST-5.35) - (secondary + tertiary amine, meq/g, by ST-5.34)] / 100  
total amine, meq/g, by ST-5.35

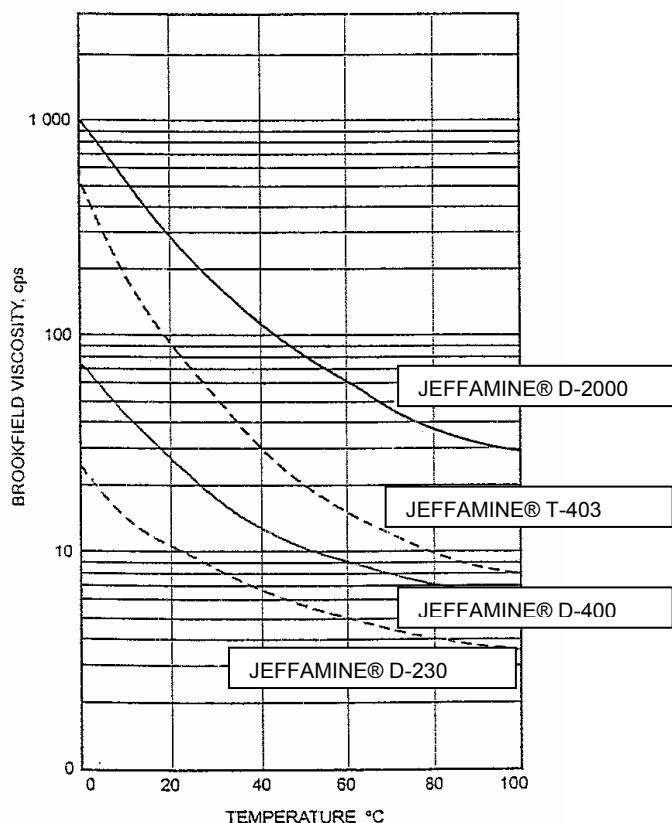
4 Specific gravity 20/4

### 3. Characterisitics of the JEFFAMINE® Polyetheramines

#### TYPICAL PHYSICAL PROPERTIES/SALES SPECIFICATIONS

Typical physical properties and sales specifications are shown in Table 3.1. One important property in high solids formulations is viscosity. The important effect of temperature on the viscosity of several JEFFAMINE® products is shown in Figure 3.1.

**Figure 3.1**  
**Effect of Temperature on the Viscosity of**  
**JEFFAMINE® Polyoxypropyleneamines**



**Table 3.2 – Solvent Miscibility of JEFFAMINE® PEA's**

Solvent *	JEFFAMINE® Products								
	D-230	D-400	D-2000	T-403	XTJ-504	XTJ-590	XTJ-506	HK-511	BA-509
Alcohols	M	M	M	M	M	M	M	M	M
Aliphatic hydrocarbons	M	M	M	M	I	I	I	M	M
Aromatic hydrocarbons	M	M	M	M	M	M	M	M	M
Esters	M	M	M	M	M	M	M	M	M
Glycol ethers	M	M	M	M	M	M	M	M	M
Ketones	M	M	M	M	M	M	M	M	M
Water	M	PM	I	M	M	M	M	M	I

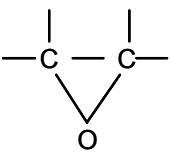
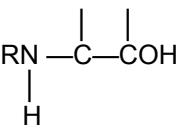
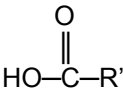
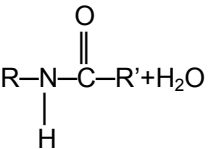
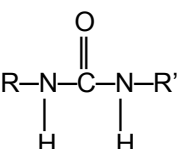
Key: M = Miscible  
PM = Partially miscible  
I = Imiscible

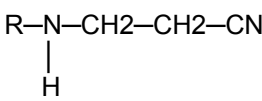
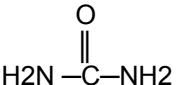
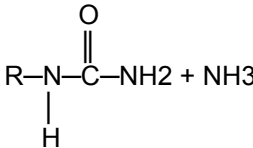

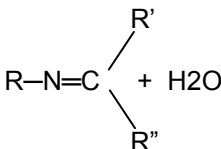
\* Miscibility data has been generalized for each type of solvent. Testing is recommended.

### 3. Characterisitcs of the JEFFAMINE® Polyetheramines

#### CHEMICAL REACTIONS

JEFFAMINE® PEA's undergo reactions typical of primary amines. General reactions which have proven to be useful include:

RNH <sub>2</sub> + Reactant	⇒	Product
 Epoxides ("epoxy resins")	⇒	 Aminoalcohols ("epoxies")
 Carboxylic acids (or esters, anhydrides, etc)	⇒	 Amides
OCN-R'  Isocyanates	⇒	 Ureas
H+X-  Acids	⇒	$\oplus$ RNH <sub>3</sub> X <sup>-</sup>  Salts

RNH <sub>2</sub> + Reactant	⇒	Products
CH <sub>2</sub> =CH-CN  Acrylonitrile	⇒	 Cyanoethylated amines
 Urea	⇒	 Substituted ureas
 Aldehydes or ketones	⇒	 Imines

For information about reactions other than involving epoxy resins and the possible utilization of those reactions, contact our Technical Department. (see inside back cover for contact information)



## 4. JEFFAMINE® PEA As Epoxy Curing Agents

### 4. JEFFAMINE® PEA AS EPOXY CURING AGENTS

#### THE JEFFAMINE® PEA AS EPOXY CURING AGENTS

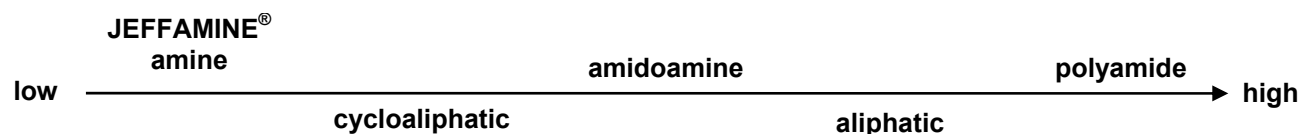
A wide range of properties may be developed through the incorporation of JEFFAMINE® products into epoxy resin formulations. Low shrinkage, good color, flexibility and tough, high gloss are characteristics of epoxy resins cured with JEFFAMINE® PEA's. For example, curing with JEFFAMINE® D-230 amine and JEFFAMINE® T-403 amine results in thermosetting products that are extremely tough and quite resistant to impact stress, and extreme thermal cycling. Room temperature curing with JEFFAMINE® T-403 amine results in composites with a high degree of strength. Formulating with the higher molecular weight products, such as JEFFAMINE® D-400 amine and JEFFAMINE® D-2000 amine can increase flexibility.

Surface imperfections (e.g., amine-blush and pinholes) of epoxy coatings cured with many unmodified aliphatic amines are largely overcome through the use of JEFFAMINE® products as curatives. Modifications used with many aliphatic amine curatives, through cyanoethylation, propoxylation, or epoxy-amine adduct preparation, necessary to reduce amine basicity, are not required for any of the JEFFAMINE® PEAs.

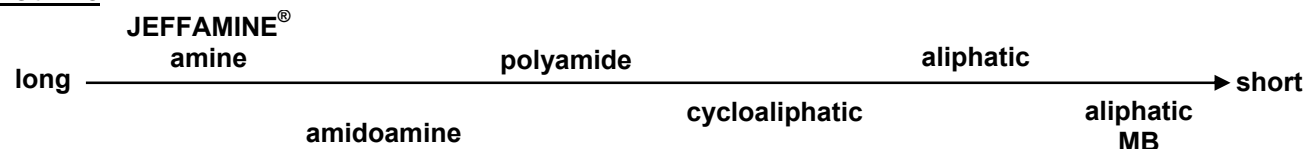
Table 4.1 compares JEFFAMINE® PEA's with other common epoxy curatives. The advantages of color, long pot life, flexibility, and low viscosity are highlighted.

**Table 4.1 –Comparison of JEFFAMINE® PEA's vs.  
Other Conventional Epoxy Curing Agents**

#### Viscosity



#### Pot Life



#### Flexibility/Impact Resistance



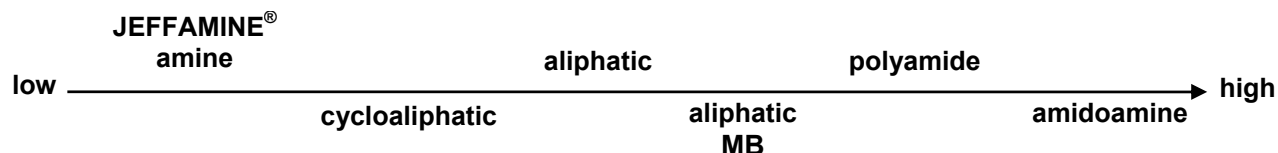
#### Water Resistance



Table 4.1 Continued  
Solvent Resistance



Color



## POLYETHERAMINE FORMULATION BASICS

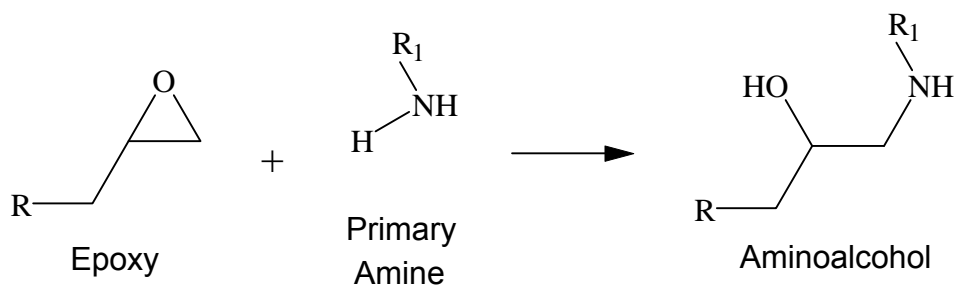
### STOICHIOMETRY

The term "stoichiometry" refers to that area of chemistry that deals with the quantities, or proportions, of substances that enter into chemical reactions.

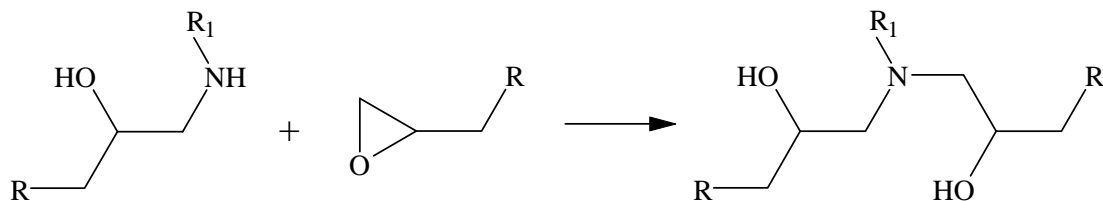
Chemicals react in definite proportions. In the simple chemical equation below, a given weight of Chemical A will always react with a given "equivalent," or "stoichiometric," amount of Chemical B to form Chemical A-B... at least as long as conditions are such that the reaction can proceed to completion.



With epoxies, when the curing agent is a "primary" amine like one of the JEFFAMINE® PEAs, two reactions take place. First, the oxirane ring in the epoxy resin is opened up.

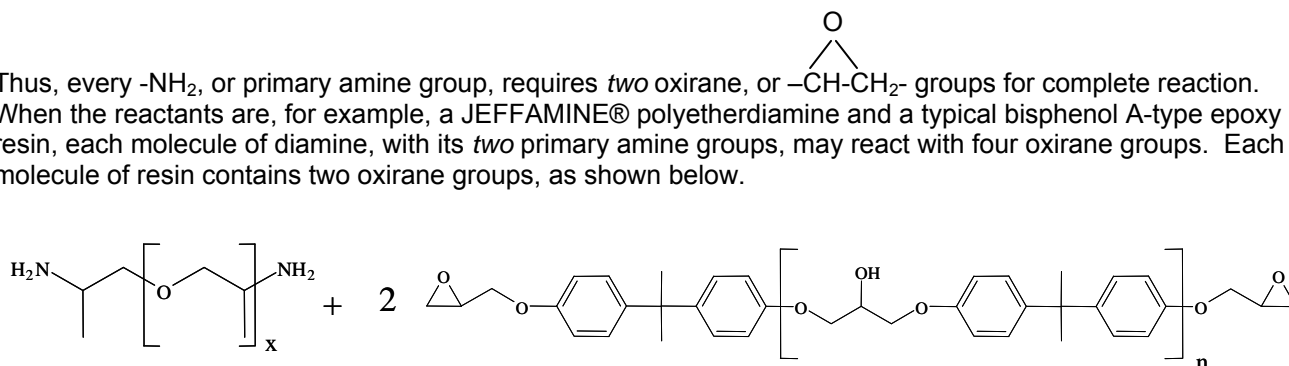


The reaction product is an aminoalcohol, and the amine nitrogen still has one hydrogen available for reaction. In a second step, this "secondary" amine can react with yet another epoxy, or oxirane, group to build molecular weight and branching.



## 4. JEFFAMINE® PEA As Epoxy Curing Agents

Thus, every -NH<sub>2</sub>, or primary amine group, requires *two* oxirane, or  $\begin{array}{c} \text{O} \\ \diagup \quad \diagdown \\ \text{CH}-\text{CH}_2 \end{array}$  groups for complete reaction. When the reactants are, for example, a JEFFAMINE® polyetherdiamine and a typical bisphenol A-type epoxy resin, each molecule of diamine, with its *two* primary amine groups, may react with four oxirane groups. Each molecule of resin contains two oxirane groups, as shown below.



Therefore, in regard to chemical balancing, *how does one arrive at the correct, or optimum, proportions of reactants with epoxy systems?* In general, there are two ways: (1) calculate the quantities involved from the chemical "equivalent" weights of all the reactants, or (2) determine the balance empirically.

Generally, the empirical, or experimental, method of chemical balancing should be the more accurate of the two procedures, since actual working conditions are used. Differences in the two calculating methods often arise from factors such as steric hindrance or catalytic effects.

### CALCULATED METHOD

How is the equivalent weight of a JEFFAMINE® product calculated? First, the equivalent weight may be approximated from the approximate molecular weight, which is the number following the letter that follows the JEFFAMINE® trade name. For example, the approximate molecular weight of JEFFAMINE® D-400 amine is 400. JEFFAMINE® D-400 amine, being a diamine, has four active hydrogens to react with epoxy groups, so the approximate equivalent weight is 400/4, or 100. This follows from the general formula:

$$\text{Amine hydrogen equivalent weight (AHEW)} = \frac{\text{Amine molecular weight}}{\text{Number of available hydrogens}}$$

and, of course, one "amine hydrogen equivalent weight" will react with one "equivalent weight" of epoxy resin.

A more accurate method for determining an amine hydrogen equivalent weight is to use the *primary amine content*, a value that is always available for each lot of product. This value, expressed in milliequivalents per gram (meq/g), is plugged into the formula

$$\text{Amine hydrogen equivalent weight (AHEW)} = \frac{1,000}{2 \times \text{primary amine content (meq/g)}}$$

For amine hardeners that contain a significant amount of secondary amine groups, as well as primary amines, the formula above should be modified as follows:

$$\text{AHEW} = \frac{1,000}{[2 \times \text{primary amine content (meq/g)}] + (\text{secondary amine content (meq/g)})}$$

These simple formulas for equivalent weight can be used for *any* JEFFAMINE® product, whatever the "functionality," or number of amine groups per molecule. Thus, if a sample of JEFFAMINE® D-230 amine has a primary amine content of 8.3 meq/g (from Table 1), the AHEW of the D-230 will be:

$$\text{AHEW} = \frac{1,000}{2 \times 8.3} = 60$$

(Note that these calculations of AHEW were designed for epoxy resin formulating. When amines are used in some other applications, such as for polyureas, the equations change because under most process conditions the isocyanate group will react only once with a primary amine group.)

## 4. JEFFAMINE® PEA As Epoxy Curing Agents

### EMPIRICAL METHOD

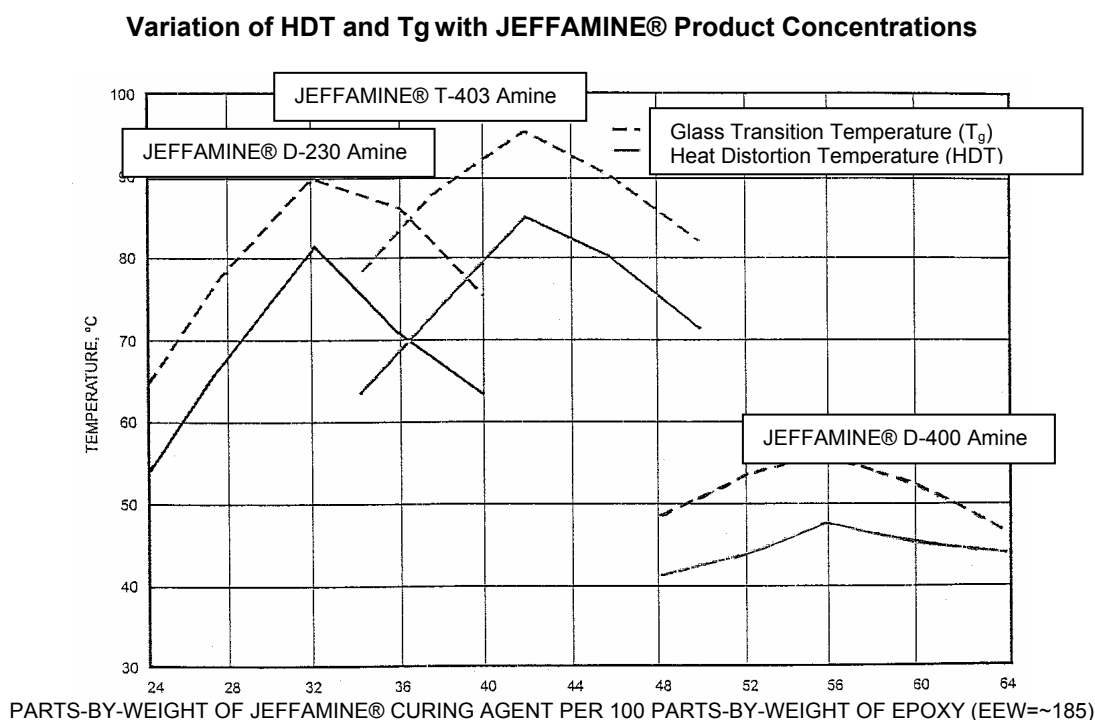
To empirically determine reactant proportions, two "indicators" may be employed: (1) heat distortion temperature (HDT) ASTM D 648, and (2) glass transition temperature ( $T_g$ ). Both are measures of the degree of epoxy cure. In practice, the method is fairly simple if only two reactants are involved, namely, a single epoxy resin and curing agent.

Procedure: Proportions of the reactants are varied, the blends are cured as completely as possible, and the HDTs or  $T_g$ s are determined and plotted against reactant concentration.

*The optimum reactant ratios are, in most cases, considered to be those at which HDTs and/or  $T_g$ s are maximized when the formulation is polymerized using the desired process conditions.* (HDT and  $T_g$  are discussed in greater detail on page 54) At such an optimum ratio, the formulation is likely to have the least amount of "leftover" amine or epoxy groups. This is good, because it minimizes changes that can be caused by further reactions.

In Figure 4.1, HDT and  $T_g$  are plotted against the amount of amine hardener for three JEFFAMINE® products---"D-230", "D-400", and "T-403". Needless to say, the empirical method is potentially cumbersome when more than two reactants are involved, which is frequently the case with epoxies. A simpler way to proportion epoxy reactants is to use calculated equivalent weights. How do the calculated AHEWs of the JEFFAMINE® polyamines compare with *empirically determined* values? First of all, AHEWs calculated from typical primary amine values have been given in Table 3.1, and are repeated below. Second, empirical equivalent weights can be derived from Figure 4.1.

Figure 4.1



$$\text{Empirical AHEW} = \frac{\text{Weight of curative at maximum HDT or } T_g \times \text{Equivalent weight of epoxy resin}^*}{100 \text{ parts by wt. of epoxy resin}}$$

\*(EEW, from the manufacturer)

For example, in the case of JEFFAMINE® D-230 amine, and an epoxy resin with EEW = 185, the numbers are:

$$\text{Empirical AHEW} = \frac{32 \times 185}{100} = 59 \text{ (60, by calculation).}$$

(compared to 60, obtained using the calculation method).

## 4. JEFFAMINE® PEA As Epoxy Curing Agents

Following this procedure, we obtain the comparative numbers for the products shown in the following table:

Product	Equivalent Weight	
	Calculated	Empirical
JEFFAMINE® D-230 amine	60	59
JEFFAMINE® D-400 amine	115	104
JEFFAMINE® T-403 amine	81	78

Thus, empirical equivalent weights for the JEFFAMINE® products are found to be within a few percent of the calculated values. *So, in working with epoxies, one can safely use amine hydrogen equivalent weights derived from the primary amine values that are available for each lot of JEFFAMINE® product.*

It is notable that in most epoxy work, formulations are based on 100 parts by weight (pbw) of epoxy resin, not on an epoxide equivalent weight (EEW) quantity (one "equivalent"). One must therefore calculate the amount of curative required to react with 100 pbw of resin.

Procedure: By definition, equivalent weights of materials react in 1:1 proportions. That is, one equivalent weight quantity of amine curative will react exactly with one equivalent weight quantity of an epoxy resin. So, a proportion may be set up where X is the parts of amine curative required to react with 100 pbw of epoxy resin (phr).

$$\frac{\text{AHEW}}{\text{EEW}} = \frac{X}{100}, \text{ or } X = \frac{\text{AHEW}}{\text{EEW}} \times 100$$

EXAMPLE: JEFFAMINE® D-230 PEA + 188 EEW Epoxy Resin.

The resin producer furnishes the epoxy equivalent weight (EEW) for his product—e.g., 188. If JEFFAMINE® D-230 amine is used as a curative, the AHEW will be 60 so 32 parts of JEFFAMINE® D-230 amine will be required to react with 100 parts of this epoxy (EEW = 188).

$$X = \frac{60}{188} \times 100 = 32 \text{ phr of JEFFAMINE® D-230 amine}$$

While discussing chemical stoichiometry, it is worth noting that considerable latitude in compounding is available to the epoxy formulator when JEFFAMINE® products are used. Deviation from chemically equivalent amounts of curative may be tolerated with minimal effect on many of the cured resin properties, a fact that is evident from the properties shown in Tables 4.2, 4.3 and 4.4. The tables show that near-optimum values for a number of properties may be obtained over a rather wide concentration variation with the JEFFAMINE® products. This is not generally the case with other amine curatives.

Thus, the epoxy formulator can use simple and precise calculated equivalent weights for JEFFAMINE® products, but at the same time enjoy rather wide compounding latitudes, deviating somewhat from the optimum stoichiometry, without serious deleterious effects on the properties of his finished products.

*Note: Although several epoxy resins have been used to develop the data in this brochure, the most commonly used resin was the industry workhorse, a diglycidyl ether of bisphenol A (DGEBA or BADGE) based material having an EEW of ~188 and viscosity of ~13,000 cP (mPa-sec) (Araldite GY-6010). Wherever "EEW ~188" is used to designate an epoxy resin, the reader should assume it is this standard, general-purpose DGEBA resin. Standard resins may be obtained from Huntsman Advanced Materials as well as a number of other suppliers. Where other types of resins were used, that fact has been noted.*

#### 4. JEFFAMINE® PEA As Epoxy Curing Agents

**Table 4.2 - Properties of an Epoxy Resin Cured with Differing Amounts of JEFFAMINE® D-230 amine**

<b>Formulation</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
Epoxy Resin (EEW 188) Araldite GY-6010	100	100	100	100	100
Curative concentration, phr <sup>1</sup>	24	28	32	36	40
<b>Properties of cured 1/8-inch castings<sup>2</sup></b>					
Izod impact strength, ft-lb/in	0.34	0.80	1.10	1.80	2.40
(J/m)	(18)	(43)	(59)	(96)	(13)
Dynatup® impact, total energy, in-lb (J)	16 (1.8)	36 (4.1)	78 (8.8)	61 (6.9)	78 (8.8)
Shore D hardness, 0-10 sec	76-73	77-75	77-74	77-74	76-73
Tensile strength, psi	10,900	10,900	9,800	9,200	9,500
(MPa)	(75.2)	(75.2)	(67.6)	(63.4)	(65.5)
Tensile modulus, psi	517,500	475,000	417,500	417,500	455,000
(GPa)	(3.57)	(3.28)	(2.88)	(2.88)	(3.14)
Elongation at break, %	2.9	5.5	9.6	4.8	6.1
Flexural strength, psi	17,000	17,600	15,700	14,700	15,600
(MPa)	(117)	(121)	(108)	(101)	(108)
Flexural modulus, psi	546,000	512,500	454,000	454,000	480,500
(GPa)	(3.76)	(3.53)	(3.13)	(3.13)	(3.31)
Glass Transition Temp., T <sub>g</sub> , °C	65	79	90	86	75
HDT, °C, 264 psi load (1.82 Mpa load)	53	67	80	69	61
% weight gain, 24-hr water boil	2.3	2.8	2.7	3.3	3.9
3-hr acetone boil	32.0	13.3	6.5	8.7	11.4
Compressive strength <sup>3</sup> psi, at yield	-	-	14,300	11,900	11,300
(Mpa), at yield	--	--	(98.6)	(82.0)	(77.9)
psi, at failure	12,800	46,700	35,000	46,900	46,200
(Mpa), at failure	(88.3)	(322)	(221)	(323)	(319)
<b>Adhesive properties<sup>4</sup></b>					
Tensile shear strength, psi	4,400	4,100	3,500	4,100	4,400
(MPa)	(30.3)	(28.3)	(24.1)	(28.3)	(30.3)
T-peel strength, pli (g/mm)	2.6 (46)	2.0 (36)	2.5 (45)	2.6 (46)	2.8 (50)

<sup>1</sup> With standard, general-purpose epoxy resin, EEW 185-192, 11,000-15,000 cP (mPa-sec) (Araldite GY-6010).

<sup>2</sup> Cured 2 hr, 80°C; 3 hr, 125°C.

<sup>3</sup> 1-inch tall cylinders of 1/8 inch diameter. (2.54 cm tall cylinders of 1.27 cm diameter)

<sup>4</sup> Cured 1 hr., 125°C

**Table 4.3 - Properties of an Epoxy Resin Cured with Differing Amounts of JEFFAMINE® D-400 amine**

<b>Formulation</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
Epoxy Resin (EEW 188) Araldite GY-6010	100	100	100	100	100
Curative concentration, phr <sup>1</sup>	48	52	56	60	64
<b>Properties of cured 1/8-inch castings<sup>2</sup></b>					
Izod impact strength, ft-lb/in	0.46	0.46	0.41	0.86	1.40
(J/m)	(25)	(25)	(22)	(46)	(75)
Dynatup® impact, total energy, in-lb (J)	84	69	156	134	141
	(9.5)	(7.8)	(17.6)	(15.1)	(15.9)
Shore D hardness, 0-10 sec	74-70	74-70	74-70	74-70	73-69
Tensile strength, psi	7,900	8,400	8,000	7,400	7,400
(MPa)	(54.5)	(57.9)	(55.1)	(51.0)	(51.0)
Tensile modulus, psi	401,000	425,000	422,000	385,000	414,000
(GPa)	(2.77)	(2.93)	(2.910)	(2.654)	(2.854)
Elongation at break, %	3.7	3.8	4.7	4.5	5.5
Flexural strength, psi	12,700	13,400	13,100	11,600	12,700
(MPa)	(87.6)	(92.4)	(90.3)	(80.0)	(87.6)
Flexural modulus, psi	447,000	452,000	449,500	434,000	452,000
(GPa)	(3.082)	(3.116)	(3.099)	(2.992)	(3.116)

#### 4. JEFFAMINE® PEA As Epoxy Curing Agents

**Table 4.3 Continued**

	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
Glass Transition Temp., T <sub>g</sub> , °C	49.0	53.5	56.1	52.9	47.0
HDT, °C, 264 psi (1.82 MPa) load	41	44	47	45	44
% weight gain, 24-hr water boil	2.3	2.6	2.6	2.8	3.0
3-hr acetone boil	41.6	32.2	25.4	25.0	23.8
Compressive strength <sup>3</sup> psi, at yield	10,400	10,100	9,600	9,100	9,500
(MPa) at yield	(71.7)	(69.6)	(66.2)	(62.7)	(65.5)
psi at failure	41,000	47,100	45,300	46,400	44,300
(MPa) at failure	(283)	(325)	(312)	(320)	(305)
<b>Adhesive properties<sup>4</sup></b>					
Tensile shear strength, psi	3,900	3,800	3,800	3,800	3,600
(MPa)	(26.9)	(26.2)	(26.2)	(26.2)	(24.8)
T-peel strength, pli	3.2	3.9	4.9	5.9	5.1
(g/mm)	(57)	(70)	(88)	(105)	(91)

1 With standard, general-purpose epoxy resin, EEW 185-192, 11,000-15,000 cP (mPa-sec) (Araldite GY-6010).

2 Cured 2 hr, 80oC; 3 hr. 125oC.

3 1-inch tall cylinders of ½ inch diameter. (2.54 cm tall cylinders of 1.27 cm diameter)

4 Cured 1 hr., 125oC

**Table 4.4 - Properties of an Epoxy Resin Cured with Differing Amounts of JEFFAMINE® T-403 amine**

<b>Formulation</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
Curative concentration, phr <sup>1</sup>	34	38	42	46	50
<b>Properties of cured ½-inch castings<sup>2</sup></b>					
Izod impact strength, ft-lb/in	0.71	0.90	0.90	1.00	1.40
(J/m)	(38)	(48)	(48)	(53)	(75)
Dynatup® impact, total energy, in-lb	22	63	54	45	61
(J)	(2.5)	(7.1)	(6.1)	(51)	(6.9)
Shore D hardness, 0 -10 sec	77-75	76-74	78-75	78-75	75-72
Tensile strength, psi	11,400	10,600	9,500	9,300	8,900
(MPa)	(78.6)	(73.1)	(65.5)	(64.1)	(61.4)
Tensile modulus, psi	478,000	447,000	418,000	390,500	402,000
(GPa)	(3.30)	(3.08)	(2.88)	(2.69)	(2.77)
Elongation at break, %	5.4	7.3	6.7	11.2	12.1
Flexural strength, psi	19,100	17,000	15,500	15,100	14,700
(MPa)	(132)	(117)	(107)	(104)	(101)
Flexural modulus, psi	570,000	509,000	437,000	443,000	440,000
(GPa)	(3.93)	(3.51)	(3.01)	(3.05)	(3.03)
Glass Transition Temperature, T <sub>g</sub> , °C	77.7	89.0	95.6	89.6	82.3
HDT, °C, 264 psi (1.82 MPa) load	62	73	83	78.5	70
% weight gain, 24-hr water boil	2.0	2.1	2.0	2.2	2.5
3-hr acetone boil	14.7	9.5	5.6	5.2	6.7
Compressive strength <sup>3</sup> psi, at yield	11,400	10,500	11,700	11,500	10,100
(MPa) at yield	(78.6)	(72.4)	(80.7)	(79.3)	(69.6)
psi at failure	34,900	41,100	41,000	44,300	43,700
(MPa) at failure	(241)	(283)	(283)	(305)	(301)
<b>Adhesive properties<sup>4</sup></b>					
Tensile shear strength, psi	3,500	4,000	3,400	3,800	4,100
(MPa)	(24.1)	(27.6)	(23.4)	(26.2)	(28.3)
T-peel strength, pli	4.0	4.6	4.4	6.5	4.9
(g/mm)	(71)	(82)	(79)	(116)	(88)

1 With standard, general-purpose epoxy resin, EEW 185-192, 11,000-15,000 cP (mPa-sec) (Araldite GY-6010).

2 Cured 2 hr, 80oC; 3 hr. 125oC.

3 1-inch tall cylinders of ½ inch diameter. (2.54 cm tall cylinders of 1.27 cm diameter)

4 Cured 1 hr., 125oC

## 4. JEFFAMINE® PEA As Epoxy Curing Agents

### CURING CHARACTERISTICS

Medium-to-long pot life, low-to-moderate peak exothermic temperatures, and a relatively high hardener-to-resin ratio mark the curing of epoxy resins with JEFFAMINE® polyamines. The combination of low heat development and long pot life is beneficial for a number of applications, e.g., potting, encapsulation, and filament winding. Typical curing data are given in Table 4.5 for the JEFFAMINE® products and for four other amines commonly used for epoxy curing agents. The buildup in viscosity with time for these same systems is shown in Figure 4.2, below.

**Table 4.5 - Resin Curing Characteristics with JEFFAMINE® Polyamines and Other Typical Amine Curatives**

Curative	Curative Concentration phr <sup>1</sup>	Pot Life, minutes	Peak Exotherm °C	Drying Time, Set-to-Touch hours	6-Mil Film <sup>2</sup> Through-Dry, hours
JEFFAMINE® D-230 amine	32	280 <sup>3</sup>	64	8.9	16.2
JEFFAMINE® D-400 amine	55	480 <sup>3</sup>	35	15.0	24.8
JEFFAMINE® T-403 amine	42	280 <sup>3</sup>	38	8.6	16.3
JEFFAMINE® D-400/D-2000 amine (50:25 blend by wt.)	75	<sup>4</sup>	33	22.4	37.0
Diethylenetriamine (DETA)	11	33.8	269	1.7 <sup>5</sup>	3.4
Polyamide <sup>6</sup> (amine value 385)	52	~130	112	4.6 <sup>6</sup>	9.8
N-aminoethylpiperazine (AEP)	23	18.6	259	0.2 <sup>7</sup>	1.3
Aromatic amine <sup>8</sup>	25	180 <sup>8</sup>	27	18.2	27.6

1 General-purpose epoxy resin, EEW ~ 188. Size of curing mass: 200 g (Araldite GY-6010).

3 No definite gel; time to reach 10,000 cP (mPa-sec).

5 Versamid® 140 polyamide, Henkel Corp.

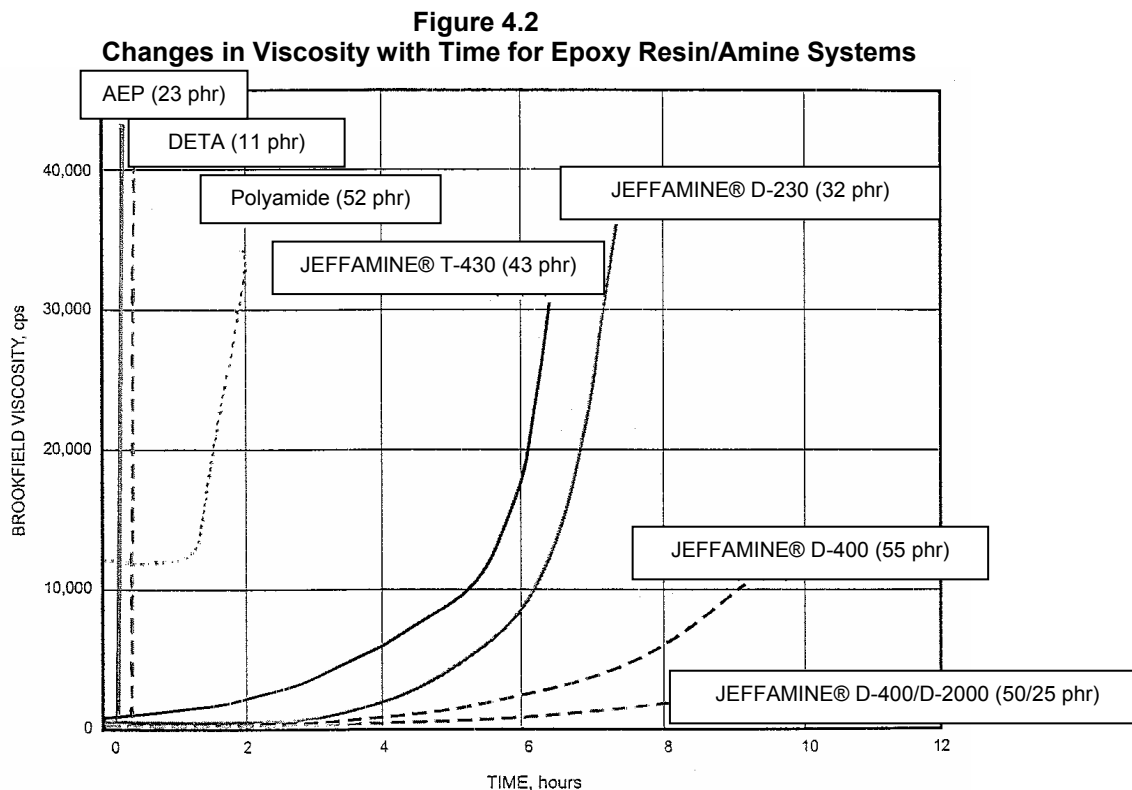
7 Surface badly mottled; heavy blush.

2 Gardner circular drying time recorder, Gardner Laboratories, Bethesda Maryland.

4 Reached 2,060 cP (mPa-sec) in ~480 minutes.

6 No induction period before applying coating: surface blush.

8 EPON CURING AGENT Y, Resolution Performance Products.





## 5. JEFFAMINE® Polyetheramine Acceleration of Cure

### 5. JEFFAMINE® PEA ACCELERATION OF CURE

#### ACCELERATOR 399

Curing epoxy with a JEFFAMINE® polyamine at temperatures near 25°C (77°F) is relatively slow. For many applications, acceleration of cure is desirable. In order to provide more rapid ambient curing of formulations containing JEFFAMINE® products, Accelerator 399 was developed. The use of small amounts of Accelerator 399 in PEA cured formulations results in considerable reduction in curing time, as shown in Tables 5.1 and 5.2. Specifically, the effect on dry time and pot life are shown graphically in Figures 5.1 and 5.2. Note that the less reactive the amine, the greater the relative effect of the accelerator. Also, note that the accelerator does not greatly affect most of the polymer properties associated with the unaccelerated systems.

Complete information concerning the use of Accelerator 399 with JEFFAMINE® curing agents is contained in the Huntsman bulletin entitled "Accelerator 399: Epoxy Curing Promoter for Use with JEFFAMINE® Curing Agents."

Other materials useful for accelerating the cure of JEFFAMINE® PEA include Accelerator 399, nonylphenol, Epoxy Curing Agent ECA-39, AEP, and various other ethylene amines. (Contact Huntsman Technical Department for details) Additional examples demonstrating the effect of these materials will be covered in the following sections.

**Table 5.1 - Effect of Accelerator 399 on Exothermic and Clear Coating Properties**

<b>Formulation, pbw</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>	<b>G</b>	<b>H</b>	<b>I</b>
Epoxy resin (EEW 188) Araldite GY-6010	100	100	100	100	100	100	100	100	100
JEFFAMINE® D-230 amine	32	32	32	-	-	-	-	-	-
JEFFAMINE® D-400 amine	-	-	-	55	55	50	50	-	-
JEFFAMINE® D-2000 amine	-	-	-	-	-	25	25	-	-
JEFFAMINE® T-403 amine	-	-	-	-	-	-	-	42	42
Accelerator 399	-	5	10	-	10	-	10	-	5
<b>Exothermic data</b>									
Brookfield viscosity (approx.), cP (mPa-sec), 25°C	600	700	700	600	600	600	600	1,600	1,600
Gel time, minutes (200-g mass)	280 <sup>1</sup>	65	25	480 <sup>1</sup>	54	<sup>2</sup>	~100	280 <sup>1</sup>	81
Peak exothermic temperature, °C	64	191	213	35	140	33	58	38	163
Time to peak temperature, minutes	396	72	30	~700	68	~960	108	450	90
<b>Coating properties, 6-mil film</b>									
Drying time, hr									
Set-to-touch	8.9	7.6	5.0	15.0	9.2	22.4	13.7	8.6	5.5
Surface-dry	12.6	9.9	8.5	18.7	10.5	26.1	15.1	13.0	7.1
Through-dry	16.2	13.6	12.5	24.8	14.5	37.0	22.6	16.3	11.7
Pencil hardness Cure:									
24 hr, ~25°C	B	HB	HB	<sup>3</sup>	<3B	<sup>3</sup>	<sup>3</sup>	2B	F
24 hr, ~25°C; 1 hr, 110°C	H	H	H	F	F	<3B	BH	H	H
7 days, ~25°C	H	H	H	F	F	3B	2B	H	H
Reverse impact, in-lb (Joules) to fail	<4	<4	16	<sup>3</sup>	>160	<sup>3</sup>	<sup>3</sup>	<4	6
Cure: 24 hr, ~25°C	(<.45)	(<.45)	(1.8)	<sup>3</sup>	(>18)	<sup>3</sup>	<sup>3</sup>	(<.45)	(0.7)
24 hr, ~25°C; 1 hr, 110°C	>160	>160	>160	>160	>160	>160	>160	>160	140
	(>18)	(>18)	(>18)	(>18)	(>18)	(>18)	(>18)	(>18)	
7 days, ~25°C	<4	<4	6	20	>160	>160	>160	6	10
	(<.45)	(<.45)	(.68)	(2.25)	(>18)	(>18)	(>18)	(.68)	(1.13)
Gloss, 60°, 7 days, ~25°C	108	107	106	104	109	106	102	110	109
	(12.2)	(12.0)	(11.9)	(11.7)	(12.3)	(11.9)	(11.5)	(12.4)	(12.3)
Crosshatch adhesion, %, 7 days, ~25°C	100	100	100	100	100	100	100	100	100

1 No definite gel; time to reach 10,000 cP (mPa-sec).

2 Reached 2,060 cps in ~480 minutes.

3 Coating too tacky to test.

## 5. JEFFAMINE® Polyetheramine Acceleration of Cure

**Table 5.2 - Effect of Accelerator 399 on Physical Properties of Unfilled Castings**

<b>Formulation, pbw</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>	<b>G</b>	<b>H</b>	<b>I</b>
Epoxy resin (EEW 188) Araldite GY-6010	100	100	100	100	100	100	100	100	100
JEFFAMINE® D-230 amine	32	32	32	-	-	-	-	-	-
JEFFAMINE® D-400 amine	-	-	-	55	55	50	50	-	-
JEFFAMINE® D-2000 amine	-	-	-	-	-	25	25	-	-
JEFFAMINE®T-403 amine	-	-	-	-	-	-	-	42	42
Accelerator 399	-	5	10	-	10	-	10	--	5
<b>Properties of cured 1/8-inch castings<sup>1</sup></b>									
Izod impact strength, ft-lb/in	0.20	0.25	0.28	1.10	1.50	9.50	8.90	0.16	0.20
J/m	(11)	(13)	(15)	(59)	(80)	(507)	(475)	(8.5)	(11)
Dynatup® impact, total energy, in-lb	8	17	27	225	200	175	199	27	23
J	(0.9)	(1.9)	(3.1)	(25.4)	(22.6)	(19.8)	(22.5)	(3.1)	(2.6)
Shore D hardness, 0 -10 sec	89-87	84-81	83-79	70-63	69-62	68-55	55-37	73-65	80-77
Tensile strength, psi	7,600	9,900	10,200	4,000	5,100	1,200	1,700	9,200	10,000
(MPa)	(52.4)	(68.3)	(70.3)	(27.6)	(35.2)	(8.27)	(11.7)	(63.4)	(68.9)
Tensile modulus, psi	476,000	532,000	500,000	300,000	300,000	-	-	470,000	510,000
(GPa)	(3.28)	(3.67)	(3.45)	(2.07)	(2.07)	-	-	(3.24)	(3.52)
Elongation at break, %	2	2	2	98	73	109	73	3	4.5
Flexural strength, psi	10,800	13,300	15,500	7,300	8,700	-	-	14,400	15,600
(MPa)	(74.5)	(91.7)	(107)	(50.3)	(60.0)	-	-	(99.3)	(108)
Flexural modulus, psi	477,000	530,000	534,000	280,000	286,000	-	-	500,000	536,000
(GPa)	(3.29)	(3.65)	(3.68)	(1.93)	(1.98)	-	-	(3.45)	(3.70)
HDT, °C, 264-psi (1.82 MPa) load,	46	45	47	28	36	-	-	44	41
% weight gain, 24-hr water boil	2.4	3.3	2.7	2.7	2.3	2.6	1.2	2.0	2.4
3-hr acetone boil	30.8	26.4	16.4	28.1	19.7	30.3	32.7	26.3	23.4
Compressive strength <sup>2</sup> , psi, at yield	12,500	13,300	12,500	6,100	5,400	-	42,800	11,500	13,400
(MPa), at yield	(86.2)	(91.7)	(86.2)	(42.1)	(37.2)	-	(295)	(79.3)	(92.4)
psi, at failure	34,000	27,000	23,000	34,000	35,000	39,000	43,300	24,000	17,000
(MPa), at failure	(234)	(186)	(159)	(234)	(241)	(269)	(299)	(165)	(117)

<sup>1</sup> Cured 7 days, ~25oC

<sup>2</sup> Cured 24 hrs, 80oC; 3 hrs, 125oC

## 5. JEFFAMINE® Polyetheramine Acceleration of Cure

**Table 5.2 – Continued**

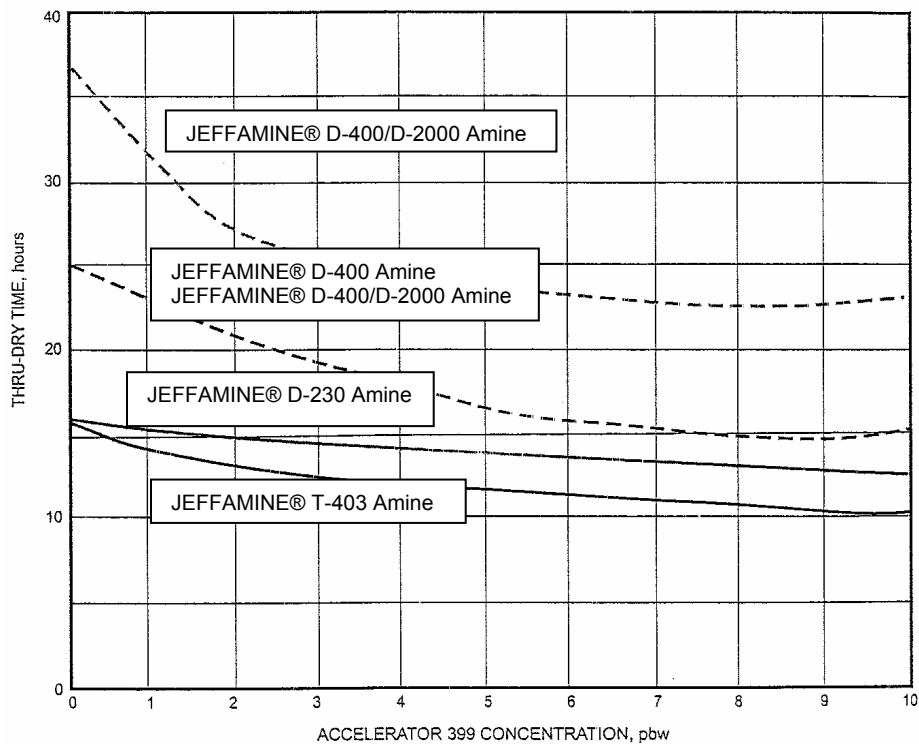
<b>Formulation, pbw</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>	<b>G</b>	<b>H</b>	<b>I</b>
<b>Properties of cured ½-inch castings<sup>1</sup></b>									
Izod impact strength, ft-lb/in	1.10	1.60	1.80	0.41	2.90	7.80	9.60	0.90	1.00
J/m	(58.7)	(85.4)	(96.1)	(21.9)	(155)	(416)	(512)	(48)	(53.4)
Dynatup® impact, total energy, in-lb	78	82	99	100	188	216	210	54	44
(J)	(8.8)	(9.3)	(11)	(11.3)	(21.2)	(24.4)	(23.7)	(6.1)	(5.0)
Shore D hardness, 0-10 sec	78-75	76-73	76-73	75-71	74-69	62-58	56-39	78-75	80-77
Tensile strength, psi	9,400	10,200	9,600	7,600	6,300	1,700	1,200	9,500	9,700
(MPa)	(64.8)	(70.3)	(66.2)	(52.4)	(43.4)	(11.7)	(8.27)	(65.5)	(66.9)
Tensile modulus, psi	392,000	460,000	441,000	390,000	360,000	30,500	9,100	418,000	420,000
(GPa)	(2.70)	(3.17)	(3.04)	(2.69)	(2.48)	(.210)	(.0627)	(2.88)	(2.90)
Elongation at break, %	8	7	8	4	4	86	75	7	8
Flexural strength, psi	14,900	17,200	16,500	12,900	10,500	970	200	15,500	15,300
(MPa)	(103)	(119)	(114)	(88.9)	(72.4)	(6.69)	(1.38)	(107)	(105)
Flexural modulus, psi	429,000	491,000	488,000	460,000	350,000	42,000	6,400	437,000	453,000
(GPa)	(2.96)	(3.39)	(3.36)	(3.17)	(2.41)	(.290)	(.0441)	(3.01)	(3.12)
HDT, °C, 264-psi (1.82 MPa) load	80	69	58	43	38	~25	24	83	72
% weight gain, 24-hr water boil	2.4	3.2	3.2	2.8	0.6	2.6	1.2	2.0	2.6
3-hr acetone boil	6.9	6.7	10.8	24.2	21.8	33.3	35.1	5.6	5.6
Compressive strength <sup>2</sup> psi, at yield	14,300	-	12,200	9,700	8,000	37,000	-	11,700	10,300
(MPa), at yield	(98.6)	-	(84.1)	(66.9)	(55.2)	(255)	-	(80.7)	(71.0)
psi, at failure	35,000	42,000	40,000	30,000	41,000	37,000	47,000	41,000	41,100
(MPa), at failure	(241)	(290)	(276)	(207)	(283)	(255)	(324)	(283)	(283)

<sup>1</sup> Cured 2 hr, 80°C, 3 hr, 125°C.

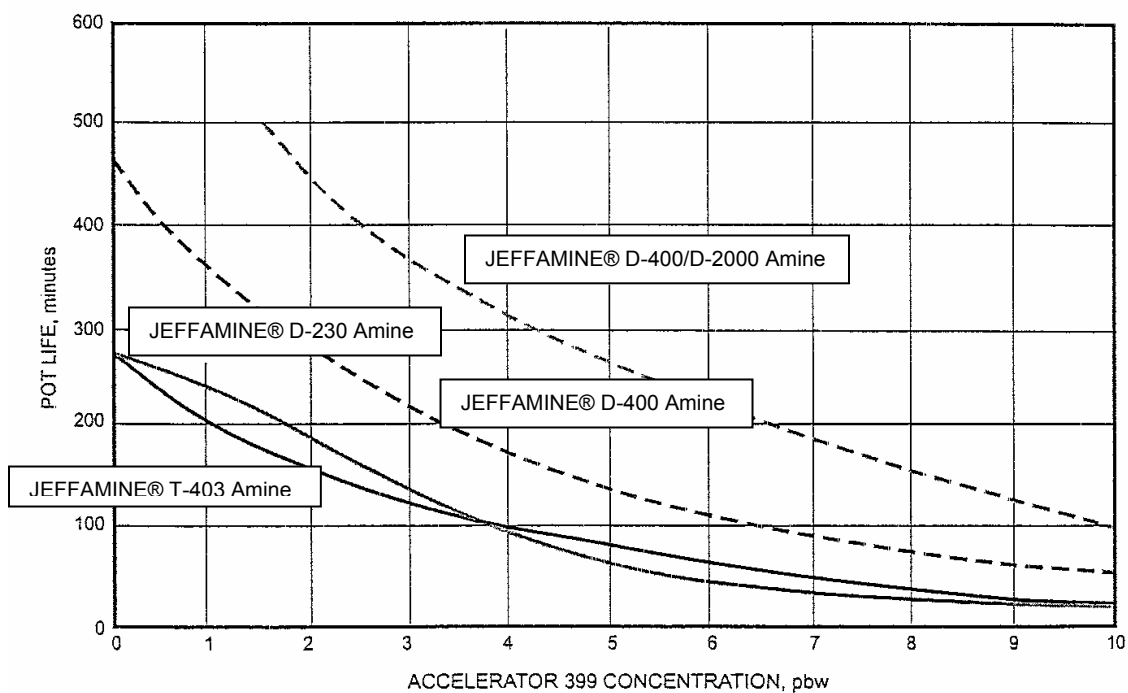
<sup>2</sup> 1-inch tall cylinders of ½ -inch diameter. (2.54 cm tall cylinders of 1.27 cm diameter.

## 5. JEFFAMINE® Polyetheramine Acceleration of Cure

**Figure 5.1**  
**Effect of Accelerator 399 on Through-Dry Time**



**Figure 5.2**  
**Effect of Accelerator 399 on Pot Life<sup>1</sup>**



<sup>1</sup> Time to reach 10,000 cps or gel, whichever occurs first.

## 5. JEFFAMINE® Polyetheramine Acceleration of Cure

### NONYLPHENOL

Alkylphenols also accelerate epoxy systems cured with JEFFAMINE® products. Nonylphenol in particular is an excellent adjunct in epoxies, accelerating cure, while maintaining good physical properties, and improved moisture resistance-not to mention lower costs.

Effects of nonylphenol on cure rates and the properties are shown in Tables 5.3, 5.4 and 5.5. The effect on cure rates is shown graphically in Figure 5.3.

The data indicates that each particular epoxy system can tolerate a certain maximum level of nonylphenol without serious deterioration of physical properties (HDT, tensile strength, etc.). Beyond that level, properties decline fairly rapidly. The maximum nonylphenol level cannot be predicted; it must be arrived at experimentally for each epoxy system.

Finally, it might be noted that other accelerating products are useful with systems cured with JEFFAMINE® products. These might include triethylenediamine and derivatives, tris(dimethylaminomethyl)phenol (a.k.a. JEFFCAT® TR-30 catalyst), JEFFCAT® TR-90 benzyldimethylamine (BDMA), triphenyl phosphite, salicylic acid and DNP dinonylphenol (supplied only by Huntsman).

**Table 5.3 - Curing with JEFFAMINE® D-230 Amine - Effect of Nonylphenol**

<b>Formulation, pbw</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
Liquid epoxy resin (EEW 188) Araldite GY-6010	100	100	100	100	100
JEFFAMINE® D-230 amine	32	32	32	32	32
Nonylphenol	-	10	20	30	40
<b>Exothermic data</b>					
Brookfield viscosity, cP (mPa·s), 250°C	600	890	1,190	1,720	2,190
Gel time, minutes (200-g mass)	280 <sup>1</sup>	127	65	49	47
Peak exothermic temperature, °C	64	132	157	164	158
Time to peak temperature, minutes	396	150	76	56	46
<b>Coating properties, 6-mil film</b>					
Gardner dry time, hr, set-to-touch	9.9	6.5	6.0	5.2	5.1
surface-dry	14.3	9.7	8.5	6.8	7.0
through-dry	20.0	17.9	13.5	11.3	10.0
<b>Properties of cured ½-inch castings<sup>2</sup></b>					
Izod impact strength, ft-lb/in	0.20	0.28	0.20	0.47	0.70
J/m	(11)	(15)	(11)	(25)	(37)
Dynatup® impact, total energy, in-lb (J)	8 (0.9)	30 (3.4)	26 (2.9)	27 (3.1)	38 (4.3)
Shore D hardness, 0-10 sec	77-70	78-75	78-74	77-72	75-69
Tensile strength, psi	8,100	9,500	9,800	8,300	6,400
(MPa)	(55.8)	(65.5)	(67.6)	(57.2)	(44.1)
Tensile modulus, psi	480,000	470,000	460,000	410,000	350,000
(GPa)	(3.31)	(3.24)	(3.17)	(2.83)	(2.41)
Ultimate elongation, %	1.8	2.3	3.8	5.0	7.8
Flexural strength, psi	11,000	12,900	14,800	14,900	10,700
(MPa)	(75.8)	(88.9)	(102)	(103)	(73.8)
Flexural modulus, psi	516,000	515,000	481,000	457,000	343,000
(GPa)	(3.56)	(3.55)	(3.32)	(3.15)	(2.36)
HDT, °C, 264 psi (1.82 MPa) load	44	44	42	40	33
% weight gain, 24-hr water boil	2.4	2.0	1.0	2.8	-0.5
3-hr acetone boil	30.8	25.4	21.4	<sup>3</sup>	<sup>3</sup>
Compressive strength <sup>4</sup> , psi, at yield	12,500	13,000	10,400	12,300	10,100
(MPa), at yield	(86.2)	(89.6)	(71.7)	(84.8)	(69.6)
psi, at failure	34,000	20,000	19,000	33,000	27,000
(MPa), at failure	(234)	(138)	(131)	(228)	(186)

<sup>1</sup> Time to reach 10,000 cP (mPa·sec)

<sup>2</sup> Cured 7 days, ~25°C

<sup>3</sup> Samples destroyed

<sup>4</sup> 1-inch tall cylinders of ½-inch diameter. (2.54 cm tall cylinders of 1.27 cm diameter)

## 5. JEFFAMINE® Polyetheramine Acceleration of Cure

**Table 5.4 - Curing with JEFFAMINE® D-400 amine - Effect of Nonylphenol**

Formulation, pbw	A	B	C	D	E
Liquid epoxy resin (EEW 188) Araldite GY-6010	100	100	100	100	100
JEFFAMINE® D-400 amine	55	55	55	55	55
Nonylphenol	-	5	10	20	30
<b>Exothermic data</b>					
Brookfield viscosity, cP (mPa·sec), 25°C	640	610	790	1,000	1,300
Gel time, minutes (200-g mass)	480 <sup>1</sup>	340 <sup>1</sup>	263 <sup>1</sup>	168 <sup>2</sup>	125 <sup>1</sup>
Peak exothermic temperature, °C	34	35	39	55	88
Time to peak temperature, minutes	960	446	344	198	148
<b>Coating properties, 6-mil film</b>					
Gardner dry time, hr, set-to-touch	15.0	14.9	13.0	12.8	10.6
surface-dry	18.7	17.7	15.4	14.1	12.2
through-dry	24.8	23.4	17.5	15.9	14.8
<b>Properties of cured ½-inch castings<sup>2</sup></b>					
Izod impact strength, ft-lb/in	1.10	1.29	2.00	8.80	9.42
J/m	(59)	(69)	(107)	(470)	(503)
Dynatup® impact, total energy, in-lb	225	223	220	217	194
J	(25.4)	(25.2)	(24.9)	(24.5)	(21.9)
Shore D hardness, 0 -10 sec	70-63	74-67	71-63	65-51	56-36
Tensile strength, psi	4,000	4,300	3,300	2,600	1,160
(MPa)	(27.6)	(29.6)	(22.8)	(17.9)	(8.00)
Tensile modulus, psi	300,000	295,000	210,000	80,000	13,000
(GPa)	(2.07)	(2.03)	(1.45)	(0.552)	(0.0896)
Ultimate elongation, %	98	101	91	98	83
Flexural strength, psi	7,300	8,100	6,300	2,200	270
(MPa)	(50.3)	(55.8)	(43.4)	(15.2)	(1.86)
Flexural modulus, psi	280,000	306,000	241,000	78,000	12,000
(GPa)	(1.93)	(2.11)	(1.66)	(0.538)	(0.0827)
HDT, °C, 264-psi (1.82 MPa) load	28.5	29	28	<24	<25
% weight gain, 24-hr water boil	2.7	2.4	1.9	1.4	0.4
3-hr acetone boil	28.1	29.4	28.0	28.3	<sup>3</sup>
Compressive strength <sup>4</sup>					
psi at yield	6,100	5,700	5,800	-	-
(MPa) at yield	(42.1)	(39.3)	(40.0)	-	-
psi, at failure	34,000	46,000	>34,000	>42,000	38,000
(MPa) at failure	(234)	(317)	(>234)	(>290)	(262)

1 Time to reach 10,000 cP (mPa-sec)

2 Cured 7 days, 25°C

3 Samples destroyed

4 1-inch tall cylinders of ½-inch diameter. (2.54 cm tall cylinders of 1.27 cm diameter)

## 5. JEFFAMINE® Polyetheramine Acceleration of Cure

### Table 5.5 - Curing with JEFFAMINE® T-403-Effect of Nonylphenol

Formulation, pbw	A	B	C	D	E
Liquid epoxy resin (EEW 188) Araldite GY-6010	100	100	100	100	100
JEFFAMINE® T-403 amine	42	42	42	42	42
Nonylphenol	-	10	20	30	40
<b>Exothermic data</b>					
Brookfield viscosity, cP (mPa-sec), 25°C	1,650	2,400	2,990	3,670	4,300
Gel time, minutes (200-g mass)	280 <sup>1</sup>	133	73	54	45
Peak exothermic temperature, °C	38	106	151	151	150
Time to peak temperature, minutes	450	177	91	65	57
<b>Coating properties, 6-mil film</b>					
Gardner dry time, hr, set-to-touch	8.6	7.4	5.5	4.1	3.7
surface-dry	13.0	9.4	7.2	5.6	5.3
through-dry	19.3	18.0	15.0	11.3	9.1
<b>Properties of cured 1/8-inch castings<sup>2</sup></b>					
Izod impact strength, ft-lb/in	0.16	0.28	0.35	0.58	0.95
J/m	(8.5)	(15)	(19)	(31)	(51)
Dynatup® impact, total energy, in-lb	27	29	28	23	32
(J)	(3.1)	(3.3)	(3.2)	(2.6)	(3.6)
Shore D hardness, 0-10 sec	73-65	79-75	79-75	77-73	75-69
Tensile strength, psi	9,200	9,000	9,000	7,900	5,800
(MPa)	(63.4)	(62.1)	(62.1)	(54.5)	(40.0)
Tensile modulus, psi	470,000	470,000	430,000	390,000	320,000
(GPa)	(3.24)	(3.24)	(2.96)	(2.69)	(2.21)
Ultimate elongation, %	2.8	2.7	4.3	5.7	9.9
Flexural strength, psi	14,400	15,600	15,500	14,500	9,500
(MPa)	(99.3)	(108)	(107)	(100)	(65.5)
Flexural modulus, psi	500,000	530,000	492,000	440,000	310,000
(GPa)	(3.45)	(3.65)	(3.39)	(3.03)	(2.14)
HDT, °C, 264 psi (1.82 MPa) load	44	44	41	41	32
% weight gain, 24-hr water boil	2.0	1.7	1.4	0.9	-0.
3-hr acetone boil	26.3	23.6	20.1	17.9	<sup>3</sup>
Compressive strength <sup>4</sup> ,               psi, at yield	11,500	13,000	12,500	10,800	3,500
(MPa), at yield	(79.3)	(89.6)	(86.2)	(74.5)	(24.1)
psi, at failure	24,000	30,000	31,000	29,000	27,600
(MPa), at failure	(165)	(207)	(214)	(200)	(190)

1 Time to reach 10,000 cP (mPa-sec)

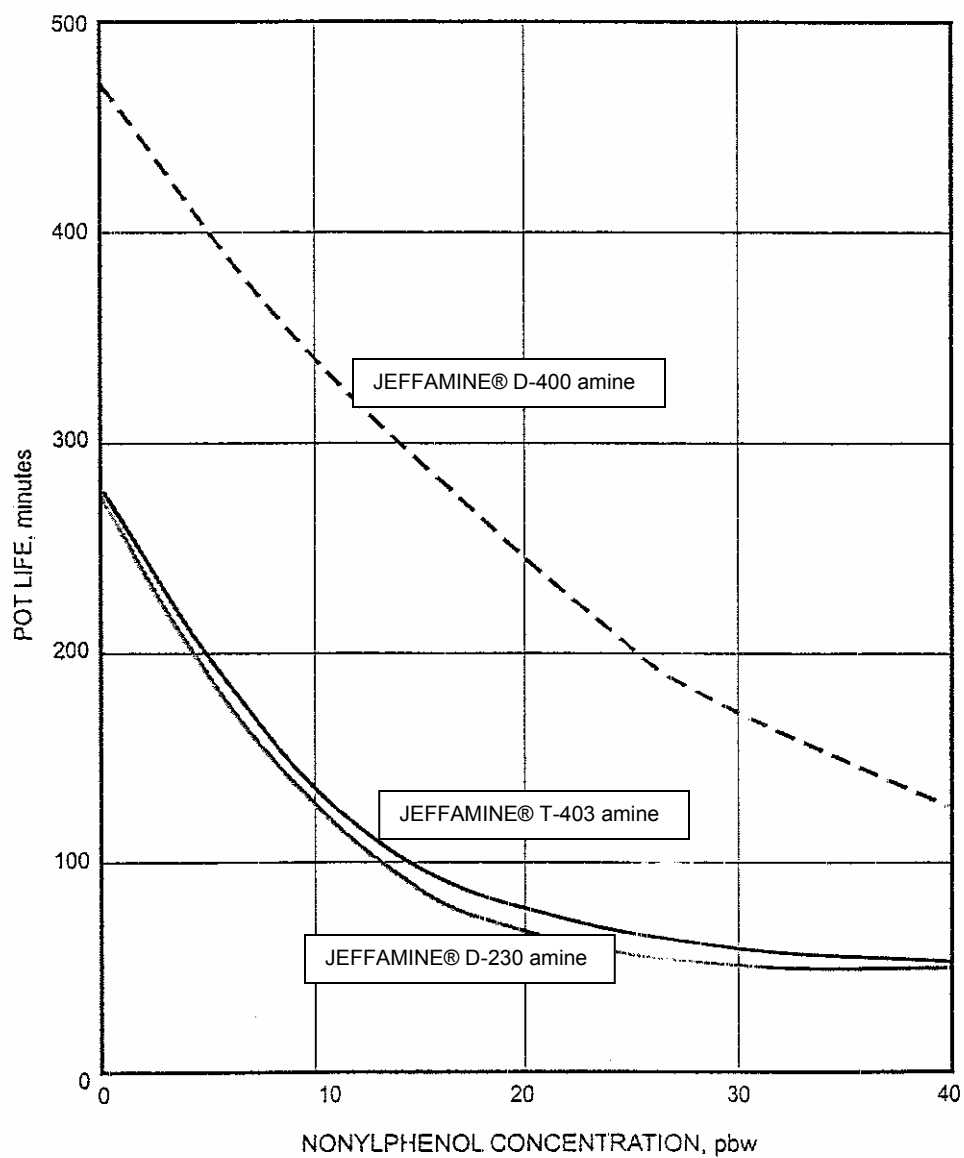
2 Cured 7 days, ~25oC

3 Samples destroyed

4 1-inch cylinders of 1.2-inch diameter. (2.54 cm tall cylinders of 1.27 cm diameter)

## 5. JEFFAMINE® Polyetheramine Acceleration of Cure

**Figure 5.3**  
**Effect of Nonylphenol on Pot Life<sup>1</sup>**



<sup>1</sup> Time to reach 10,000 cps of gel, whichever occurs first..



## 6. SURFACE COATING FORMULATIONS

### SURFACE COATINGS

The properties of JEFFAMINE® curatives lend themselves to the preparation of excellent coatings and protective finishes. Epoxy coatings cured with JEFFAMINE® products are flexible, tough, and resistant to impact and abrasion. They have excellent resistance to blushing compared to other amine hardeners. An article entitled “Amine Blushing Problems? No Sweat!”, which describes blush and its prevention, may be found under the epoxy applications/..technical documents section of the Huntsman web site at [www.huntsmanepoxy.com](http://www.huntsmanepoxy.com).

Formulations useful in several coating application areas follow.

### DECORATIVE COATING

#### 1. Decoupage

A popular application for epoxies is in decoupage-type coatings where objects such as wooden plaques, clocks, pictures and signs are coated with a high-gloss finish. JEFFAMINE® D-230 amine and JEFFAMINE® T-403 amine are ideally suited for this application, providing clear, blush-free, glossy, solvent free, high-build coatings.

#### Decoupage Coating

Part 1—Resin	Pbw	PBvol
Epoxy resin <sup>1</sup>		100
<b>Part 2—Curative</b>		
JEFFAMINE® D-230 amine	30	} 100
Nonylphenol <sup>2</sup>	60	
Aminoethylpiperazine (AEP) <sup>3</sup>	4	

<sup>1</sup>Low viscosity resin, 4,000-6,000 cP (= mPa-sec), EEW 172-176.

<sup>2</sup>Huntsman Decoupage grade monononylphenol

<sup>3</sup>Huntsman (AEP)

#### Decoupage Coating

Coating Properties	
Drying time, hr, 6-mil film	
Set-to-touch	4.5
Surface-dry	5.5
Through-dry	7.7
Pencil hardness	
Cure: 24 hr, ~25°C	B
48 hr, ~25°C	F
7 days, ~25°C	F
Gardner impact, in-lb (J) to failure	
Cure: 24 hr, ~25°C, reverse/direct	>160/>160 (>18/>18)
48 hr, ~25°C, reverse/direct	>160/>160 (>18/>18)
7 days, ~25°C, reverse/direct	6/18 (0.68/2.0)
Taber abrasion, wt. loss, mg, 1,000 cycles,	Drying time, hr, 6-mil film
1,000 g wt. (CS-17 wheel)	Set-to-touch
Cure: 24 hr, ~25°C	116
48 hr, ~25°C	155
7 days, ~25°C	241

## 6. Surface Coating Formulations

Mix equal volumes of Part 1 and Part 2. The two parts must be thoroughly mixed together to obtain a properly cured coating. The pot life of this system is about 20 minutes.

Coatings of this type should be applied to horizontal surfaces. The object to be coated should be elevated from the work surface by a pedestal smaller in diameter than the object so the coating can flow freely off the edges. As soon as the coating is mixed, it should be poured over the object and, if necessary, spread with a brush to ensure complete coverage. The bubbles created during mixing are typically broken by brushing the coating's surface or by blowing on it using forced hot air.

This high-gloss coating of 10 to 20 mils thickness will dry in about 7 hours at room temperature (~25°C) and will achieve its full hardness in 2 to 3 days. Color and gloss (i.e., lack of blush) are outstanding.

Where a low HDT can be a problem (on tabletops, for example) a formulation containing less nonylphenol is recommended: 25/21/4 pbwt. JEFFAMINE® D-230 amine/nonylphenol/AEP, at 50 pbvol., mixed with 100 pbvol. of epoxy resin (EEW 188).

Note that clear coatings of this type should not be used on objects exposed to direct sunlight. General-purpose epoxy resins will yellow over time under such conditions.

### **2. Non-yellowing Varnish**

As indicated above, clear coatings based on standard aromatic-based epoxy resins do not hold up well in sunlight. However, solventless coatings of low viscosity having improved U.V. light stability can be formulated from hydrogenated DGEBA type resins, which are nonaromatic.

#### **Non-Yellowing Varnish**

<b>Part 1—Resin</b>	<b>pbw</b>
Hydrogenated DGEBA type epoxy, EEW 232-238	100
<b>Part 2—Curative</b>	
JEFFAMINE® T-403 amine	34
Imidazole	4

Pot life is 4 to 5 hours. The coating will dry in about 1 day.

#### **Non-Yellowing Varnish**

<b>Coating properties</b>	
Viscosity, cP (= mPa-sec)	1,050
Density, lb/gal (g/cc)	8.9 (1.07)
Drying time, hr, 6-mil film	
Set-to-touch	16.3
Surface-dry	20.6
Through-dry	30.8
Pencil hardness	
Cure: 24 hr, ~251°C	B
7 days, ~25°C	F
Yellowing index (ΔYI) After 1,000 hr Weatherometer <sup>1</sup> exposure	0.4

<sup>1</sup> Xenon bulb; continuous light, 17-minute water spray every 2 hours. Clear coating (10-12 mils) applied to white ceramic tile.

**PROTECTIVE COATINGS****1. Organic Zinc Rich Primer**

Zinc primers, developed to protect structural steel, offer excellent corrosion resistance when used either as pre-construction primers or as top-coated primers.

**Organic Zinc Rich Primer**

<b>Part 1—Resin</b>	<b>Pounds</b>	<b>Gallons</b>
Zinc Dust 44L <sup>1</sup>	1,115.0	18.9
BENTONE® 27 rheological additive <sup>2</sup>	11.0	0.6
Methanol	6.0	0.9
Solid epoxy resin, EEW 450-550	48.0	4.9
Xylene	67.0	9.3
Methyl Isobutyl ketone	16.0	2.4
n-Butanol	89.0	13.1
	1,352.0	50.1
<b>Part 2—Curative</b>		
JEFFAMINE® D-230 amine	5.3	0.67

<sup>1</sup> Zinc Corporation of America, Monaca, PA

<sup>2</sup> Elementis Specialties, Inc., Hightstown, NJ.

**Organic Zinc Rich Primer**

<b>Coating Properties</b>	
Viscosity, KU	95
Density, lb/gal (g/cc)	27.2 (3.26)
Hegman grind	1½
Drying time, hr, 4-mil wet film thickness Through-dry	1.0
Pencil hardness Cure: 48 hr, ~25°C 7 days, ~25°C	B HB
Gardner impact, in-lb (J) to fail Cure: 48 hr, ~25°C, reverse/direct 7 days, ~25°C, reverse/direct	4/30 (0.45/3.39) <4/20 (<0.45/2.26)
Taber abrasion, wt. loss, mg, 1,000 cycles, 1,000 g wt. (CS-1 7 wheel) Cure: 48 hr, ~25°C 7 days, ~25°C	165 126
Crosshatch adhesion, % Cure: 48 hr, ~25°C 7 days, ~25°C	100 100

JEFFAMINE® D-400 amine, blended on an equivalent weight basis, may be substituted for JEFFAMINE® D-230 amine to give a more flexible coating that cures more slowly.

**2. Coal Tar Epoxy**

Coal tar-modified epoxy coatings are frequently used to line water tanks and to coat bridges, decks, and pipelines. They offer corrosion protection from water, acids, alkalies, salts, and some solvents. Here is a coal tar epoxy based on JEFFAMINE® D-230 amine.

**Coal Tar Epoxy**

<b>Part 1—Epoxy Resin</b>	<b>Pounds</b>	<b>Gallons</b>
General-purpose resin, EEW-~188 (Araldite GY-6010) <sup>1</sup>	215	22.2
<b>Part 2—Curative</b>		
Coal tar pitch (70-75°C softening point)	291	28.7
JEFFAMINE® D-230 amine	66	8.4
Talc — medium oil absorption	258	11.1
Xylene	166	23.0
BENTONE® 38 <sup>2</sup>	13	.07
Ethanol (95%)	8	1.2
JEFFCAT® TR-30 accelerator (tris- (dimethylaminomethyl) phenol)	11	1.3
	813	74.4

<sup>1</sup> Huntsman Advanced Materials

<sup>2</sup> Elementis Specialties, Inc., Hightown, NJ

**Coal Tar Epoxy**

<b>Coating Properties</b>	
Viscosity, KU	105
Density, lb/gal (g/cc)	10.9 (1.31)
Hegman grind	2½-3
Drying time, hr, 6-mil wet film thickness	
Set-to-touch	~1
Surface dry	12.5
Through-dry	12.5
Pencil hardness	
Cure: 48 hr, ~25°C	F
7 days, ~25°C	F
Gardner impact, in-lb (J) to fail	
Cure: 48 hr, ~25°C, reverse/direct	4/14 (0.45/1.6)
7 days, ~25°C, reverse/direct	<4/14 (<0.45/1.6)
Taber abrasion, wt. loss, mg, 1,000 cycles, 1,000 g wt. (CS-1 7 wheel)	
Cure: 48 hr, ~25°C	44
7 days, ~25°C	89
Crosshatch adhesion, %	
Cure: 48 hr, ~25°C	100
7 days, ~25°C	100

## 6. Surface Coating Formulations

### 3. High-Solids Epoxy

Because of increasing concern for the environment and stricter governmental regulations, high-solids (i.e., low-solvent) coatings have gained importance. Formulating such coatings is complicated by the fact that liquid resins and lower-viscosity curing agents offer considerably less flexibility than the solvent borne solid resins and viscous polyamides used in the past. By using the JEFFAMINE® products in combination with the polyamides, in effect as reactive diluents, the coatings formulator may reduce solvent levels and still maintain flexibility and other necessary coating properties.

The formulations shown below for high-solids enamels demonstrate this concept. Different solvents may be substituted as needed for those listed in order to comply with current regulations.

#### High-Solids Epoxy

Part 1-Resin	A		B		C	
	Pounds	Gallons	Pounds	Gallons	Pounds	Gallons
General-purpose epoxy resin, EEW ~188	324.0	33.40	324.0	33.40	324.0	33.40
C12-C14 aliphatic glycidyl ether <sup>1</sup>	36.1	4.75	36.1	4.75	36.1	4.75
Titanium dioxide	92.0	2.60	92.0	2.60	92.0	2.60
HUBERBRITE® 7 <sup>2</sup>	220.0	6.10	220.0	6.10	220.0	6.10
MISTRON353 <sup>3</sup>	189.9	8.00	189.9	8.00	189.9	8.00
BENTONE® 27 rheological additive <sup>4</sup>	11.1	0.74	11.1	0.74	11.1	0.74
Methanol/water, 95:5	3.7	0.56	3.7	0.56	3.7	0.56
Silicone resin SR-82 <sup>5</sup>	9.0	1.00	9.0	1.00	9.0	1.00
Ethoxyethanol	41.2	5.32	41.2	5.32	41.2	5.32
	927.0	62.47	927.0	62.47	927.0	62.47
<b>Part 2-Curative</b>						
Versamid® 140 polyamide <sup>6</sup>	144.0	17.56	72.0	8.78	-	-
Ethoxyethanol	62.0	8.00	47.0	6.06	15.3	1.97
n-Butanol	33.9	5.00	23.6	3.50	8.3	1.23
Toluene	20.0	2.77	14.4	1.99	5.1	0.71
JEFFAMINE® D-230 amine	-	-	53.1	6.72	106.2	12.43
	259.9	33.33	210.1	27.05	134.9	16.34

1 Heloxy™ Modifier 8, Resolution Performance Products, Houston, TX.

2 J M Huber.

3 Luzenac

4 Elementis Specialties, Inc., Hightstown, NJ.

5 General Electric Co.

6 Henkel Corp.

The components of Part 1 should be mixed according to the following procedure:

Mix epoxy resin, glycidyl ether, and ethoxyethanol.

Add BENTONE® 27 additive and mix (high shear disperser) for about 5 minutes.

Add methanol/water and mix another 5 minutes.

Blend in silicone resin.

Add pigments and grind to a Hegman number of 3-4.

These formulations may be thinned, as needed, with an 8/5/2.8 pbv mixture of ethoxyethanol/n-butanol/toluene.

Cured properties for the above, high solids epoxies.

## 6. Surface Coating Formulations

### **High Solids Epoxy**

<b>Coating Properties</b>	<b>A</b>	<b>B</b>	<b>C</b>
Solids, wt. %	85.7	87.8	92.2
vol. %	76.4	78.6	85.4
Viscosity, KU	76	78	76
Density, lb/gal (g/cc)	12.4	12.7	13.3
Hegman grind	4-4½	4-4½	4-4½
Drying time, hr, 5-mil wet film thickness			
Set-to-touch	2.1	7.2	9.5
Surface dry	5.8	13.3	16.4
Through-dry	9.7	14.5	22.0
Pencil hardness			
Cure: 48 hr, ~25°C	H	H	H
7 days, ~25°C	H-2H	H-2H	H-2H
Gardner impact, in-lb (J) to fail			
Cure: 48 hr, ~25°C, reverse/direct	6/42	4/60	4/40
7 days, ~25°C, reverse/direct	<4/14	<4/14	<4/20
Taber abrasion, wt. loss, mg, 1,000 cycles, 1,000 g wt. (CS-1 7 wheel)			
Cure: 48 hr, ~25°C	294	132	193
7 days, ~25°C	180	137	175
Crosshatch adhesion, %			
Cure: 7 days, ~25°C	100	100	100
Gloss, 60°			
Cure: 7 days, ~25°C	78	63	97

### 7. FLOORING, TROWELING AND MORTARS

An important application area for JEFFAMINE® amines and other Huntsman products is their use in highly-filled epoxy formulations for industrial or decorative floor coatings. There are two primary types of epoxy flooring systems: self-leveling and trowel coverings. Epoxy flooring can be as simple as a thin film clear or lightly pigmented formulation or a series of built-up coating layers. However, most epoxy floors today consist of several coats, which usually include at least a base coat, mid coat and glaze or topcoat.

Self-leveling floorings have lower filler contents (less than 4:1 filler to epoxy binder), permitting the material to be spread over the substrate, usually concrete, to a thickness of about 1/8 inch. Such binder rich floorings are more chemically resistant. Skid or slip resistance may be improved by broadcasting sand or other mineral fillers over the top of the floor prior to final curing.

Trowelable floorings generally are more highly filled (6-8:1 filler to binder ratios) with a coarse mineral filler, such as quartz and/or silica sand. These higher filler loadings lead to outstanding abrasion resistance, coupled with excellent mechanical strength. Such systems are usually screeded or troweled over the substrate to a thickness of 1/4 inch or less.

A special type of synthetic epoxy surface is the pebble-finished system, where decorative river rock is used as the filler at levels of 10-15:1 over the epoxy binder. In these applications the clear epoxy is also a high-gloss coating or decorative glaze for the aggregate material. These systems are sometimes known as decorative aggregate and have been popular for interior and exterior applications in flooring, walkways and swimming pool decks.

The performance of an epoxy-based floor system depends on proper selection and formulation of components, as well as adequate substrate surface preparation. The JEFFAMINE® amine products, along with monononylphenol (MNP) have found application in all of the above flooring systems. These are often used in combination with polyamides or cycloaliphatic amine hardeners to achieve certain desired performance characteristics, which include appearance, chemical resistance, impact resistance and abrasion resistance.

Heavily-filled epoxy systems may be used for structural applications, such as concrete reinforcement. Often referred to as polymer concrete, these materials are used in applications, such as bridge overlays and other areas requiring higher compressive strengths than offered by conventional Portland cement concrete. Similar formulations are also used for tile grouting or mortars and concrete repair.

Repair of cracked concrete structures may be accomplished by injection of clear epoxy systems into the areas around the developing crack. This is done by injecting a low viscosity, slow-curing epoxy formulation using a syringe delivery into many, finely-drilled cavities in the vicinity of the crack. The JEFFAMINE® products, such as D-230, D-400 or T-403 are ideal for such systems, which have the ability to saturate deep into the concrete matrix before the epoxy matrix begins to gel and finally set or cure. This practice of crack injection has been used in the repair of concrete buildings, bridges, railroad ties, and dams.

All of the above described applications fall into the broad category of construction, or civil engineering. Aside from surface coatings and adhesives, materials included would be the "synthetic" concretes, mortars, grouts, and putties. Such materials certainly find extensive use in new construction and various civil engineering applications; and for patching and repair, they have no peer. Several specific examples follow.

**SEAMLESS FLOORS**

Epoxies are eminently suitable for seamless, poured-in-place floors. The following is an example of such a flooring system.

**Pigmented Base Coat****Part 1 – Resin**

General purpose epoxy resin, EEW - 188	<b>pbw</b> 80
Polyglycol diepoxide, EEW 320 <sup>1</sup>	20
Titanium dioxide pigment	70

**Part 2 – Curative**

JEFFAMINE® D-230	20
AEP	6.5
Nonylphenol	15

<sup>1</sup> D.E.R. 732, Dow Chemical Co

<b>Properties</b>	
Gel time, minutes (200-g mass)	36.2
Peak exothermic temperature, °C	51.9
Time to peak temperature, minutes	42.5
Drying time, hr, 8-mil film	
Set-to-touch	5.4
Surface-dry	9.0
Thru-dry	~12
Pencil hardness	
Cure: 24 hr, ~25°C	HB
7 days, ~25°C	H

A harder glaze coat is suggested.

**Part 1 – Resin**

Epoxy resin, EEW ~ 188	<b>pbw</b> 100
------------------------	-------------------

**Part 2 – Curative**

JEFFAMINE® D-230	30
Accelerator 399	5
Nonylphenol	5

Brookfield viscosity, cps, ~25°C	800
Gel time, minutes (200-g mass)	39.5
Peak exothermic temperature, °C	200
Time to peak temperature, minutes	47.0
Drying time, hr, 6-mil film	
Set-to-touch	5.8
Surface-dry	8.1
Thru-dry	11.6
Pencil hardness	
Cure: 24 hr, ~25°C	F
7 days, ~25°C	H



## 7. Flooring, Troweling and Mortars

The system may be applied to new concrete or wood surfaces. Wood surfaces must be clean and free of stains. Before the base coat is applied to wooden surfaces, seams in the surface should be filled. The base-coat formulation may serve as a filler. Old concrete should be sandblasted and thoroughly cleaned or, preferably, acid-etched. Old tile, along with mastic, should be removed and the floor thoroughly cleaned with an abrasive cleanser, washed with water, and dried before base-coat application. Application of the seamless floor system over old tile is not recommended.

The viscous, pigmented resin is thoroughly hand-mixed with the hardener component (useful working time after mixing at ~77°F is about 60 minutes). Then the base coat is applied over the thoroughly cleaned surface. A long-handled roller is normally used to apply the base coat to a thickness of ~50 mils. Sometimes a serrated trowel is used to spread the base coat evenly.

As soon as application of the base coat is completed, colored polyvinyl chloride (PVC) chips or other decorative material, such as colored quartz aggregate, ceramic chips, or sand, is sprinkled on the surface of the base coat. About 1 pound of vinyl chips per 7 square feet of floor area is required for adequate coverage. The flooring is then allowed to cure for about 24 hours before application of the first glaze coat.

A light sanding of the dry base coat is required to remove rough spots. After sweeping up loose material, a glaze coat is applied, again with a roller. This coat is allowed to dry overnight before application of the final glaze coat. Somewhat smaller amounts of the glaze coat formulation are required for the final application. The final coat will be completely tack-free and suitable for use in 24 to 48 hours.

### SAND-FILLED FLOORING

Floors of this type, where an epoxy matrix is used to bind sand and/or other pigment-like fillers into a monolithic floor surface, are very popular, especially for industrial areas. Systems can be formulated to give good abrasion resistance, high impact capacity, easy maintenance, and good chemical resistance.

Several suggested starting formulations are shown below. Two common amine curing agents have been included for comparison with the JEFFAMINE® products.

Compression strengths are excellent for all five filled systems, especially those cured with JEFFAMINE® D-230 or the polyamide. However, some processing disadvantages are apparent for the formulations containing the polyamide or TETA. The viscosity of the unfilled polyamide system is quite high and, as a result, "workability" of the filled system is poor. "Workability" of the flooring systems is also affected by the gel time of the binder; because of the short gel time of the TETA-cured binder, working time for the filled flooring system is likely to be insufficient to place and level the system before it hardens.

Formulation, pbw	A	B	C	D	E
Epoxy resin, EEW ~ 188	100	100	100	100	100
JEFFAMINE® D-230	25	-	-	-	-
JEFFAMINE® D-400	-	44	-	-	-
JEFFAMINE® T-403	-	-	35	-	-
Triethylenetetramine (TETA)	-	-	-	10.7	-
Polyamide (amine value 385)	-	-	-	-	55.8
Nonylphenol	16	16	16	16	16
N-aminoethylpiperazine (AEP)	4	4	4	4	4
#3 sand/silica flour, 3/1 pbw	1,160	1,312	1,240	1,046	1,406
Sand/binder ratio, by wt	8/1	8/1	8/1	8/1	8/1
<b>Matrix exothermic data</b>					
Brookfield viscosity, cps, 25°C	1,250	1,060	2,360	2,160	8,780
Gel time, minutes (200-g mass)	42.6	88.0	45.4	10.5	37.2
Peak exothermic temperature, °C	196.0	112.0	181.1	230.7	159.1
Time to peak temperature, minutes	50.4	114.7	55.5	15.5	50.2
Compressive strength at failure, psi <sup>1</sup>	>12,000	11,000	11,000	11,000	>12,000

<sup>1</sup>Samples: 1 -inch cylinders, 1 -inch diameter. Cure: 7 days, 250C.

**DECORATIVE AGGREGATE**

Decorative, or bonded, aggregate refers to composites made by mixing together gravel of various sizes and colors with an unpigmented epoxy system. The epoxy mix is blended with the rock at a 5 to 6 wt.% level and formed into various shapes or troweled into place much like concrete.

Decorative aggregate is attractive for several reasons. It has a deep, rich appearance which brings out the character of the rock, and it is cool to walk on because it is so porous. However, as pointed out earlier, clear epoxy coatings, as a general rule, do not hold up well in sunlight. Thus, while a decorative aggregate overlay on a patio or driveway might maintain its structural integrity for a long time, its glossy appearance would be expected to degrade in a matter of months because of exposure to the sun's ultraviolet radiation. Furthermore, "whitening" problems have been reported with bonded aggregate used outdoors for driveways, pool decks, and the like. For these reasons, we at Huntsman Corporation cannot recommend any clear epoxy system for outdoor application, whatever the curing agent might be. For indoor applications only, the formulations described below are worth investigating.

Technical bulletins are available for those wanting more information about decorative aggregate.

<b>Formulation, pbw</b>	<b>A</b>	<b>B</b>	<b>C</b>
Liquid epoxy resin, EEW ~188	100	100	100
JEFFAMINE® D-230	25	25	25
N-aminoethylpiperazine (AEP)	4	4	4
Nonylphenol	12	26	53
Resin/curing blend volume ratio	2:1	3:2	1:1
<b>Exothermic data<sup>1</sup></b>			
Brookfield viscosity, cps, ~25°C	1,380	1,660	2,740
Gel time, minutes (200-g mass)	53.5	28.0	22.5
Peak exothermic temperature, °C	187.3	186.5	159.5
Time to peak temperature, minutes	65.6	36.0	31.8
<b>Coating properties, 6-mil film</b>			
Drying time, hr			
Set-to-touch	5.7	3.0	3.2
Surface-dry	7.9	7.4	5.9
Thru-dry	13.0	12.7	10.0
Pencil hardness			
Cure: 24 hr, ~25°C	F-H	F-H	HB-F
7 days, ~25°C	H	H	H
Gardner impact, in-lb to fail			
Cure: 24 hr, ~5°C, reverse/direct.	<4/14	16/36	160/>160
7 days, ~25°C, reverse/direct	<4/18	14/30	140/>160
Crosshatch adhesion, %			
Cure: 7 days, ~25°C	100	100	100
Gloss, 60°			
Cure: 7 days, ~25°C	111	112	110

## 7. Flooring, Troweling and Mortars

<b>Properties of cured 1/8-inch castings<sup>2</sup></b>	<b>A</b>	<b>B</b>	<b>C</b>
Izod impact strength, ft-lb/in	1.62	0.30	0.79
Shore D hardness, 0-10 sec	76-74	76-75	71-67
Tensile strength, psi	9,500	9,500	5,800
Tensile modulus, psi	551,000	479,000	330,000
Elongation, %	2.1	2.5	17.1
Flexural strength, psi	13,100	14,400	10,000
Flexural modulus, psi	489,000	465,000	297,000
HDT, °C, 264-psi load	46	45.5	37
Compressive strength <sup>3</sup> , psi, at yield	14,400	14,400	9,000
at failure	20,900	29,700	29,700
<b>Aggregate properties<sup>4</sup></b>			
Compressive strength, psi			
At 77°F (25°C)	1,200	1,400	1,100
At 0°F	1,300	1,200	1,200
At 120°F	1,300	1,000	300
After 20 freeze-thaw cycles <sup>5</sup>	800	800	900
Flexural strength, psi	700	580	560

1 Curing blend components (JEFFAMINE® D-230, AEP, and nonylphenol) were mixed and allowed to cool to 25oC before the blends were used to develop exothermic data.

2 Cured 7 days, ~25oC.

3 1-inch cylinders, 1/2-inch diameter; cured 7 days, ~25oC. Tested at 25oC (77oF).

4 5.25 wt.% binder mixed with rock; cured 7 days, ~25oC

5 Samples dipped in water and chilled over dry ice for 5 hr. Blocks allowed to thaw overnight. Cycle repeated as specified.

### POLYMER CONCRETE

Polymer concretes are known for the improvements in strength, durability, and protection they offer over conventional portland cement concrete (PCC). Unlike polymer-modified PCC, which uses cement and water as a binder, polymer concrete uses an organic resin matrix as the "glue" to hold the aggregate together in place of the cementitious binder.

The polymer concrete formulation shown below may be used in repair applications, such as overlays and patching operations, in original applications where high strength to weight ratios are required, or in precast products. The low viscosity and low volatility of this binder formulation and the well-known stability and strength of epoxy systems make this an interesting polymer concrete system. Development of compressive strength is illustrated in Figure 7.1.

<b>Binder formulation</b>	<b>pbw</b>
Liquid epoxy resin (EEW 188)	100
JEFFAMINE® D-230	32
Accelerator 399	20
Graded aggregate mix	wt. %
Aggregate, 3/8-in	60
Coarse sand	30
Fly ash	10

Filler binder ratio is 11:1 pbw.

## 7. Flooring, Troweling and Mortars

<b>Properties</b>	<b>Epoxy Concrete</b>	<b>Portland Cement Concrete</b>
Compressive strength, psi	13,900	3,000-5,000
Compressive modulus, psi	$3.7 \times 10^6$	$3-4 \times 10^6$
Flexural strength, psi	2,950	410-530
Coefficient of thermal expansion, in/in $\times 10^{-6}$		
At 40°F	3.97	5.5
At 80°F	8.26	5.5
At 120°F	13.1	5.5
At 158°F	17.6	5.5
Plastic shrinkage, in/in	0.0006	0.0002-0.0006
Sandblast abrasion,		
wt. loss, g		
Dry	0.26	2.81
Wet	0.76	5.41

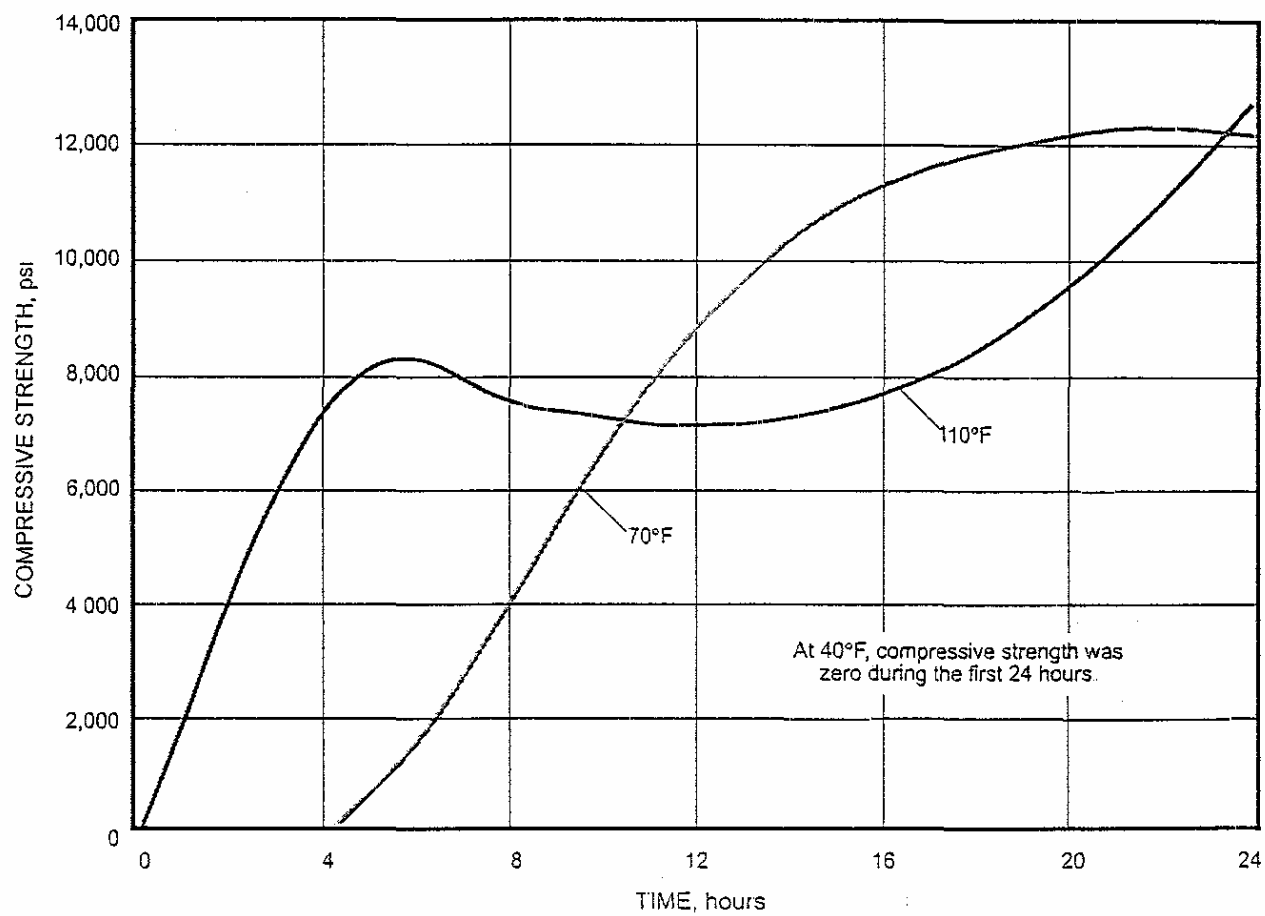
<b>Properties of Polymer Concrete Overlays on Portland Cement Concrete (PCC)</b>	
Flexural bond strength, psi	$>640^1$
Shear bond strength, psi	
Dry substrate	$790^1$
Wet substrate	$610-790^2$
After 50 freeze-thaw cycles	$490^3$

1 100% failure in PCC

2 25-100% failure in PCC.

3 50% failure in PCC.

**Figure 7.1**  
**Development of Compressive Strength in Polymer Concrete Cured at**  
**Various Temperatures with JEFFAMINE D-30**



## 7. Flooring, Troweling and Mortars

### TROWEL COATINGS

A formulation useful for coating concrete surfaces, bonding old concrete surfaces to new, topping floors subjected to heavy wear, and coating splash-zone areas of marine structures is given below. The material is thixotropic, so it can be applied to vertical surfaces where it may be used to imbed aggregate.

<b>Component 1</b>	<b>pbw</b>
Epoxy resin, EEW i88	100
Clay <sup>1</sup>	80
<b>Component 2</b>	
JEFFAMINE D-400	55
Cab-O-Sil M-5 <sup>2</sup>	17
<b>Component 3</b>	
Accelerator 399	20

1 Calcined kaolin type, e.g., Glomax LL, Georgia Kaolin Co.

2 Cabot Corp.

The clay must be dispersed thoroughly into the epoxy resin. A pigment, if required, should be dispersed along with the clay. Finely divided white sand, calcium carbonate, or other filler materials may be substituted for clay. The Cab-O-Sil should be dispersed into the JEFFAMINE® component. A high-speed Cowles mixer will be required to satisfactorily disperse these components. After proper mixing, the amine/Cab-O-Sil should be a viscous liquid. Components 1 and 2 should be mixed thoroughly. Pot life of this mixture is 6 to 10 hours. When ready to apply to a concrete surface, add component 3. A gel-like material will instantly form. The material may then be troweled onto vertical or horizontal surfaces to the thickness desired.

<b>Properties of cured 1/8-inch casting<sup>1</sup></b>	
Izod impact strength, ft-lb/in	0.31
Shore D hardness	82-76
Ultimate elongation, %	90
Flexural strength, psi	3,700
Flexural modulus, psi	207,000
Compressive strength (ultimate), psi	42,500

<sup>1</sup>Cast in open-face mold; cured 7 days at room temperature.

### WOOD CONSOLIDATION

Old and rotting wood may be "consolidated"-that is, reinforced, filled in, and preserved-by saturation with the following mixture.

<b>Part 1- Resin</b>	<b>pbw</b>
Epoxy resin <sup>1</sup>	6
1,2-Butanediol diglycidyl ether, EEW 134	3
<b>Part 2-Curative</b>	
JEFFAMINE D-230	4

1 Low-viscosity resin, 4,000-6,000 cps, EEW 172-176.

This consolidant has a pot life of ~2 hours and will hold its shape after 24 hours at 70°F. For details on the fine art of wood consolidation, see Ref. 391 in Bibliography.

## 8. REINFORCED COMPOSITES

Cured epoxy resins are ideal agents for bonding reinforcing fibers of all kinds, notably glass, graphite, and synthetics. The term “advanced” composites is sometimes used to distinguish composites in which reinforcing fibers are continuous instead of chopped. Cured epoxy resins are used as matrix resins for advanced composites in a variety of applications.

A good example of an advanced composite application is pressure vessels, used as, for example, fuel tanks in natural gas-fueled vehicles. These are commonly fabricated by winding resin-soaked fibers around a cylindrical form, or mandrel. Light weight and good impact resistance are desirable features in this use.

Certain JEFFAMINE® amines are ideally suited for use in composites. They are of low viscosity, resulting in good fiber wetting and minimum bubble retention; they cure slowly enough to allow sufficient working time; and epoxy resins cured with them bond exceptionally well to the fibers. Delamination—a problem with reinforced composites—is thus minimized.

Cured resin properties are generally suitable as well. The flexible polyether backbone gives elongation values of 10% or higher. Tensile strengths in the 8,000-10,000 psi range, and flexural modulus values of around 400,000 psi or higher are typical. These high elongations are associated with very good toughness and ductility, giving good damage tolerance and reducing the risk of catastrophic failure that might occur with more brittle systems. Cures with JEFFAMINE® amines generally give lower  $T_g$  values than some other curing agents—with T-403, for example, and a standard liquid bisphenol A resin, the  $T_g$  is around 90°C (195°F). If a higher  $T_g$  is required, other amines can be blended with the JEFFAMINE® amines. Cycloaliphatic amines, such as isophoronediamine (IPDA), have been used in blends with JEFFAMINE® D-230 and T-403 amines to increase the  $T_g$  of cured epoxies for some applications. In general, increasing the ratio of cycloaliphatic amine to polyetheramine gives higher  $T_g$ , but lower elongation and impact strength, so an appropriate balance between can be chosen (see table below).

### Composite Formulations

<b>Epoxy Resin 9000-1000 cps; EEW 176-183</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
JEFFAMINE® T-403	45	33	16		
JEFFAMINE® D-230				32	25
IPDA		7	16		5
<b>Properties of cured 1/8-inch castings<sup>1</sup></b>					
Viscosity (~25°C), cps (= MPa·s)	1,570	1,090	1,190	320	620
$T_g$ , °C (DSC)	93	107	130	90	98
Flexural Strength, psi	15,900	17,100	18,200	14,800	19,000
(MPa)	(110)	(118)	(125)	(102)	(131)
Flexural modulus, psi	404,000	404,000	402,000	455,000	490,000
(GPa)	(2.78)	(2.78)	(2.77)	(3.14)	(3.38)
Tensile strength, psi	9,100	9,800	11,000	9,700	10,700
(MPa)	(62.7)	(67.6)	(75.8)	(66.9)	(73.8)
Izod impact strength, ft-lb/in	0.90	0.58	0.45	1.3	1.5
(cm-kg/cm)	(4.90)	(3.16)	(2.45)	(7.08)	(8.17)
Elongation, %	12.0	11.5	10.0	10.0	8.0

<sup>1</sup> Cured 2 hr, 80°C; 3 hr, 125°C.

## APPLICATION EXAMPLES

## WIND TURBINE BLADES

Reinforced composites are ideal materials for replacing metals in the construction of blades that spin to propel aircrafts or generate electricity. Although the process for making such blades is complex, the epoxy matrix may be as simple or as complicated as the formulator may desire. Because of the unique properties of the JEFFAMINE® products mentioned above, a simple two-component system may suffice. The simplest system would be:

<b>Part 1- Resin</b>	<b>pbw</b>
Epoxy resin, EEW ~188	100
<b>Part 2-Curative</b>	
JEFFAMINE D-230	32

Such wind-powered electrical generators have been made with blade diameters ranging from a few feet to more than 250 feet. Top-coated with a tough urethane finish, large-diameter composite blades have turned generators continuously for years, while aluminum blades have succumbed to stress after only a few months of service.

## FILAMENT-WOUND TANKS AND PIPING

The following formulation has been suggested by workers at the Lawrence Livermore Laboratory (see numerous references in Bibliography) for the manufacture of filament-wound objects, such as tanks.

<b>Part 1- Resin</b>	<b>pbw</b>
Epoxy resin <sup>1</sup>	100
<b>Part 2-Curative</b>	
JEFFAMINE® T-403	46

<sup>1</sup> Low-viscosity resin, 4,000-6,000 cps, EEW 172-176.

For advanced fiber composites, a mismatch of thermal coefficient of expansion exists between the fiber and the matrix during a high-temperature-cure cycle, frequently resulting in delamination or fiber "microbuckling." Moderate-temperature cure is therefore desirable.

The system presented above has mechanical properties that are well-balanced for filament winding – tensile and flexural strength and modulus are good, and elongation and impact strength are higher than those seen with many other epoxy formulations. With low viscosity and a moderate pot life, it presents no processing problems in filament winding. The big advantage of this technique over metal for tanks and piping is no corrosion.

A unique composite application for the above formulation has been reported to be in stainless steel fiber/ organic matrix composites for cryogenic use (Ref. 502). This system has the distinct advantage that its thermal expansion characteristics are quite close to those of copper.

## BOATS

Quality boats-racing sailboats, kayaks, canoes-are ideal subjects for epoxy systems cured with JEFFAMINE® PEA. Canoes, for example, have been made from this system.

<b>Part 1- Resin</b>	<b>pbw</b>
Epoxy resin, EEW ~188	100
<b>Part 2-Curative</b>	
JEFFAMINE® D-230	30
Accelerator 399	10



## 8. Reinforced Composites

The amount of the Accelerator 399 can be adjusted to obtain the desired pot life. Of course, for longest pot life, no accelerator is used at all, and the system below may be useful for fabrication techniques such as vacuum bagging where longer working time is desirable.

<b>Part 1- Resin</b>	<b>pbw</b>
Epoxy resin <sup>1</sup>	100
<b>Part 2-Curative</b>	
JEFFAMINE® T-403	44

1 Medium-viscosity resin, 7,000-10,000 cps, EEW 177-188.

This simple system is of low viscosity and wets the fiber network well. Working time should be adequate to meet most demands.

Cure time would be 16 hours at 60°C, or only 1 hour at 120°C. (Oven curing is common with composites.)

## 9. CASTING AND ENCAPSULATION

The terms "encapsulation," "casting," and "potting" differ slightly in meaning but are frequently used interchangeably in practice. An encapsulated object is totally enclosed in some medium. Potting usually refers to a system in which there is a container around an encapsulated part. A casting has no container, but may be poured into a void, such as a mold, and then removed after complete curing.

Casting or potting systems require low exothermic reactions of the epoxy system to avoid overheating. Clarity, minimum shrinkage and good thermal shock resistance are the result of controlling exotherm. These criteria may be met with many of the JEFFAMINE® amine curing agents, such as JEFFAMINE® D-230, D-400 or T-403 amines.

<b>Part 1-Resin</b>	<b>Pbw</b>
Epoxy resin <sup>1</sup>	100
<b>Part 2-Curative</b>	
JEFFAMINE® D-230	32
Accelerator 399	0-5

<sup>1</sup> Low-viscosity resin, 4,000-6,000 cps, EEW 172-176.

The use of accelerators should be minimized in order to optimize properties, but small amounts may be added to adjust curing schedules, depending on the size of the casting or potted part. A simple kind of formulation, like the one above, will exhibit very little of the shrinkage, which is a problem with many amine curing agents.

An important use for epoxies is in the potting of electrical and electronic components. These parts are protected from moisture, as well as thermal and mechanical shock, such as those experienced in airplane or automobile motors. The versatility of the JEFFAMINE® curing agents in this application is evident from the formulations shown in Table XX and shown briefly below:

	Pbw			
General-purpose epoxy resin, EEW -188 (Araldite GY-6010)	100	100	100	100
JEFFAMINE® D-230	32	-	-	-
JEFFAMINE® D-400	-	55	-	50
JEFFAMINE® T-403	-	-	42	-
JEFFAMINE® D-2000	-	-	-	25

Thus, the formulator can vary hardness, curing time, impact strength, etc., over a wide range, without sacrificing electrical properties.

*Suggestion:* Include JEFFAMINE® T-5000 to improve thermal and mechanical shock resistance in the first and third formulation in the table.

Note: "Anhydride" curing agents have traditionally been used for electrical potting. Their advantages are mild exothermic reactions, usefulness over a wide range of concentrations, and outstanding electrical properties; their disadvantages are that they are solids or viscous liquids, formulations require a high-temperature cure, and they tend to be brittle.

For larger mass castings, the use of accelerators is not recommended, but the addition of large amounts of fillers, which serve as heat sinks and also reduce costs, are usually added. These types of castings may be used as stamping molds for automotive parts. One formulation used a mixture of JEFFAMINE® D-400 and T-403 amines as the only curing agent, along with a standard epoxy resin and 65% by weight of fillers, consisting of various sizes of minerals, such that they would pack well into the composite matrix. Such castings have good impact strength, abrasion resistance and may be used several times for stamping out prototype automotive parts.

## 9. Casting and Encapsulation

Another popular type of potting system is the encapsulation of artificial flowers in a glass vase with a clear epoxy formulation, which resembles the presence of water. These products may be used for long periods of time as decorations for tables in restaurants, hotels and private homes. In such formulations the JEFFAMINE® amine products, such as D-230, D-400 and T-403 are used with a very clear and low-color epoxy resin. These un-accelerated systems are ideal for keeping the exothermic heat of cure to a minimum, and avoiding shrinkage, which may cause the glass vase to fracture. Some formulations may be prepared by going off ratio 10-15% in the direction of excess epoxy or curing agent to prevent these problems. Most of these systems have good color stability for long periods, but those using JEFFAMINE® T-403 amines are superior.

## 10. ADHESIVES

In general, epoxies are outstanding adhesives. Most of the formulations presented in this manual up to this point could be looked upon as "adhesive" because their adhesion to a substrate is a necessary requirement for success in any particular application. For example, bonding (adhesion) is all-important with decorative aggregate, encapsulation, and advanced fiber composites.

An adhesives formulator who wishes to try a JEFFAMINE® PEA in a formulation should first consult the appropriate basic data presented in previous sections to arrive at appropriate gel times, viscosities, mix ratios, etc. Once a basic recipe is selected, it may be modified in a myriad of ways to meet the formulator's needs. Thus, a formulation may be thickened with fumed silica, metallized with metal powders, made conductive with graphite, extended with fillers, or colored with pigments or dyes.

But no discussion of epoxy adhesives would be complete without pointing out that adhesion can be greatly enhanced by inclusion of several JEFFAMINE® PEAs, the most notable being JEFFAMINE® T-5000 amine. The latter is a trifunctional primary amine of ~5000 molecular weight with a viscosity of ~900 cps (MPa's) at 25°C. The value of this material as an adhesion promoter is evident from this comparison.

Formulation, pbw	A	B
Epoxy resin, EEW ~188	100	100
JEFFAMINE® D-230 amine	32	30.6
Accelerator 399	10	10
JEFFAMINE® T-5000 amine	-	13.2

Adhesive Properties <sup>1</sup>		
Tensile shear strength, psi (MPa)	1,100 (7.58)	4,000 (27.6)
T-peel strength, pli (N/M)	3.2 (559)	16.7 (2,930)

<sup>1</sup> Cure: 7 days, ~25°C.

JEFFAMINE® T-5000 amine may function as an adhesion promoter equally well in epoxy systems cured with amines other than the JEFFAMINE® products. Improvements in adhesion and *thermal shock* properties can be expected, *if* the additive becomes insoluble in the system as it cures, resulting in phase separation and the formation of "microvoids." The importance of microvoids in such systems has been discussed at length (Ref. 66, 340, 445). More extensive data for epoxy formulations modified with JEFFAMINE® T-5000 amine are available in our brochure "Adhesion Properties of Epoxy Formulations," available at [www.jeffamine.com](http://www.jeffamine.com) (select "epoxy applications," then "epoxy related technical documents").

XTJ-504 and XTJ-590 can be used to make ultra fast curing adhesives without compromising flexibility or adhesion. Cure rates are generally 3-4 times as fast as using JEFFAMINE® D-230 alone.

## 11. CURED PROPERTIES REFERENCE GUIDE

### PROPERTIES OF EPOXY RESINS CURED WITH JEFFAMINE® PEA

A review of properties obtained by curing epoxy resins with JEFFAMINE® products under a variety of conditions follows. A few other common amine curing agents have been included for comparison. Results are typical of data obtained from laboratory testing and demonstrate certain properties that may be obtained with polyetheramine-cured formulations. The curing systems chosen for inclusion in this section are not intended for specific applications, but indicate that values obtained with JEFFAMINE® curatives compare favorably with, and in many cases exceed, those obtained with other curatives.

### FLEXURAL STRENGTH AND MODULUS

ASTM D 790 (ERF 5-82)-"Flexural strength" is a measure of the ability of a material to withstand failure due to bending. Values obtained for flexural strength and modulus (stress/strain in the initial, elastic region) for formulations cured with JEFFAMINE® PEA, shown in Table 11.1, are equivalent to those obtained with other curatives when curing is carried out at an elevated temperature. Formulations based on JEFFAMINE® curatives do not develop the brittleness found with many formulations cured at ambient temperatures.

A complete range of modulus values may be obtained by use of the JEFFAMINE® products alone or in blends with several of the more flexibilizing JEFFAMINE® products.

**Table 11.1 - Flexural Strength and Modulus<sup>1</sup>**

Curative	Curative Concentration phr <sup>2</sup>	Conditions of Cure	Flexural Strength, psi (kg/cm <sup>2</sup> )		Flexural Modulus, psi (kg/cm <sup>2</sup> )	
JEFFAMINE® D-230 amine	32	3	14,900	(1,040)	429,000	(29,900)
	32 <sup>5</sup>	4	15,500	(1,090)	534,000	(37,400)
JEFFAMINE® D-400 amine	55	3	12,900	(900)	460,000	(32,100)
	55 <sup>5</sup>	4	8,700	(610)	286,000	(20,000)
JEFFAMINE® T-403 amine	42	3	15,500	(1,080)	437,000	(30,500)
	42 <sup>5</sup>	4	16,400	(1,150)	520,000	(36,400)
JEFFAMINE® D-400/D-2000 amine	50/25	3	970	(66)	42,000	(3,000)
Diethylenetriamine (DETA)	11	3	14,200	(990)	380,000	(26,600)
	11	6	17,000	(1,190)	523,000	(36,600)
Polyamide (amine value 385)	52	3	13,400	(940)	380,000	(23,300)
	52	4	13,600	(950)	376,000	(26,300)
N-aminoethylpiperazine (AEP)	23	3	13,000	(910)	342,000	(23,900)

<sup>1</sup> Sample size: 1/8 x 1/2 x 5 in. Instron crosshead speed: 0.1 in/min (2.54 mm/min) or 0.5 in/min (12.7 mm/min).

<sup>2</sup> General purpose epoxy resin e.g. ARALDITE® GY 6010 epoxy, EEW~188.

<sup>3</sup> Cured 2 hr, 80oC; 3 hr, 125oC.

<sup>4</sup> Cured 7 days, ~25oC.

<sup>5</sup> With 10 phr Accelerator 399.

<sup>6</sup> Cured 28 days, ~25oC. Sample was brittle when tested at 7 and 21 days.

## TENSILE STRENGTH AND MODULUS

ASTM D 638 (ERF 6-82)-Tensile strength (nominal) is the highest load achievable, divided by the original cross-sectional area of the sample, when it is pulled apart. Excellent values of tensile strength and modulus (stress/strain in the initial, elastic region) may be obtained with JEFFAMINE® curatives (Table 11.2). Results obtained with JEFFAMINE® amine-containing formulations cured at ambient temperature with accelerators are near those obtained with elevated-temperature curing. Values obtained with competitive curing agents vary widely, depending on the method of cure. The extreme brittleness encountered with DETA at ambient temperature is the result of "B-staging," or incomplete cure, a common occurrence with curing agents of low molecular weight.

**Table 11.2 - Tensile Strength and Modulus<sup>1</sup>**

Curative	Curative Concentration phr <sup>2</sup>	Conditions of Cure	Tensile Strength, psi (MPa)		Tensile Modulus, psi (GPa)	
JEFFAMINE® D-230 amine	32	3	9,400	(64.8)	392,000	(2.70)
	32 <sup>5</sup>	4	10,200	(70.3)	500,000	(3.45)
JEFFAMINE® D-400 amine	55	3	7,600	(52.4)	390,000	(2.69)
	55 <sup>5</sup>	4	5,100	(35.2)	300,000	(2.07)
JEFFAMINE® T-403 amine	42	3	9,500	(65.5)	418,000	(2.88)
	42 <sup>5</sup>	4	10,200	(70.3)	510,000	(3.52)
JEFFAMINE® D-400 amine	50/25	3	1,700	(11.7)	30,500	(0.21)
JEFFAMINE® D-2000 amine	50/25 <sup>5</sup>	4	1,700	(11.7)	-	-
Diethylenetriamine (DETA)	11	3	7,600	(52.4)	391,000	(2.70)
	11	6	8,800	(60.7)	560,000	(3.86)
Polyamide (amine value 385)	52	3	7,800	(53.8)	370,000	(2.55)
	52	4	7,900	(54.5)	311,000	(2.14)
N-aminoethylpiperazine (AEP)	23	3	9,200	(63.4)	342,000	(2.36)

1 Sample size: Type 1 dimensions. Instron crosshead speed: 0.2 in/min. (5.08 mm/min.)

2 General-purpose epoxy resin, EEW ~188, i.e. Araldite GY-6010.

3 Cured 2 hr, 80oC; 3 hr, 125oC.

4 Cured 7 days, ~25oC.

5 With 10 phr Accelerator 399.

6 Cured 28 days, ~25oC. Sample was brittle when tested at 7 and 21 days.

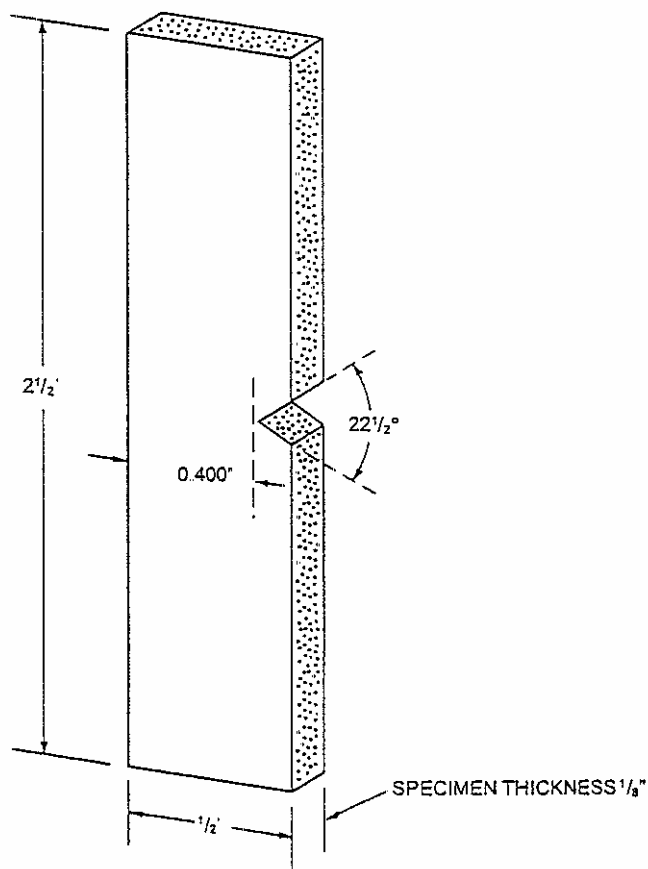
## IMPACT RESISTANCE

Two very different approaches were used. One is the Izod method and the other uses the Dynatup® drop weight impact tester.<sup>1</sup>

In the *Izod method*, ASTM D-256 (ERF 33-82), impact testing is carried out with a pendulum-type device where the test specimen (Figure 11.1) is positioned as a cantilever beam with the notched side facing the striker. Five samples of each formulation are tested, with the average value being recorded as the notched Izod impact strength.

1 Instron Corporation, Canton, Massachusetts.

**Figure 11.1**  
**Izod Test Specimen**



Results, shown in Table 11.3, indicate that curing with the JEFFAMINE® products at an elevated temperature is required to develop ultimate impact values. Izod impact resistance is low for DETA and the polyamide selected for testing. Moderate impact values are obtained for samples cured with JEFFAMINE® D-400, D-230, or T-403 amines. Incorporating JEFFAMINE® D-2000 amine for a more flexible formulation can result in cured systems with higher impact values.

## 11. Cured Properties Reference Guide

**Table 11.3 - Izod Impact Resistance (Notched)**

Curative	Curative Concentration, phr <sup>1</sup>	Conditions of Cure	Izod Impact Strength, ft-lb/in (cm-kg/cm)	
JEFFAMINE® D-230 amine	32	2	1.10	(5.99)
	32 <sup>4</sup>	3	0.28	(1.53)
JEFFAMINE® D-400 amine	55	2	0.41	(2.23)
	55 <sup>4</sup>	3	1.50	(8.17)
JEFFAMINE® T-403 amine	42	2	0.90	(4.90)
	42 <sup>4</sup>	3	0.35	(1.91)
JEFFAMINE® D-400/D-2000 amines	50/25	2	7.80	(42.57)
Diethylenetriamine (DETA)	11	2	0.42	(2.29)
	11	5	0.40	(2.18)
Polyamide (amine value 385)	52	2	0.51	(2.78)
	52	3	0.58	(3.16)
N-aminoethylpiperazine (AEP)	23	2	1.65	(8.99)

1 General-purpose epoxy resin, EEW ~188.

2 Cured 2 hr, 80oC; 3 hr, 125oC.

3 Cured 7 days, ~25oC.

4 With 10 phr Accelerator 399.

5 Cured 28 days, ~25oC. Sample brittle when tested at 7 and 21 days.

The test method utilized in the USA is ASTM D256. The result of the Izod test is reported in energy lost (ft-lb or J) per unit of specimen thickness (cm or in) at the notch in Figure 11.1

Additionally, the results may be reported as energy lost per unit cross-sectional area at the notch (J/m<sup>2</sup> or ft-lb/in<sup>2</sup>).

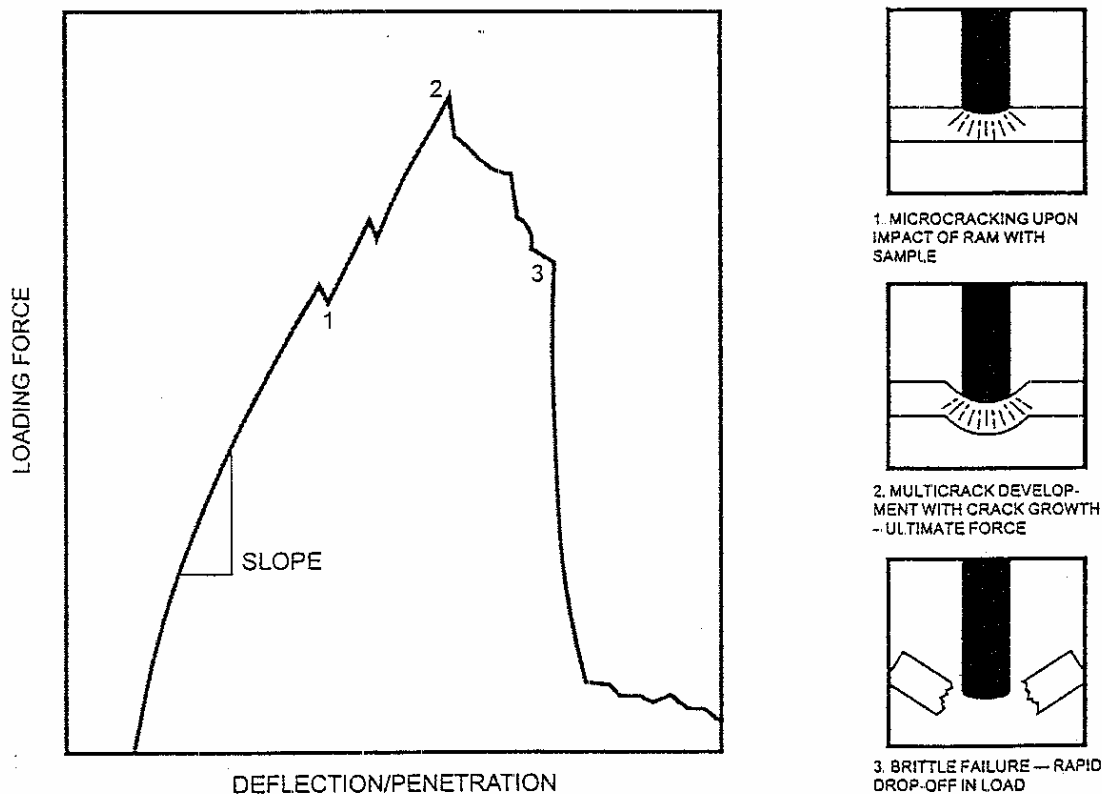
In Europe, ISO 180 methods are used and results reported based only on the cross-sectional area at the notch (J/m<sup>2</sup>).

The second method for measuring impact resistance involves a Dynatup® instrumented impact tester, an instrument capable of providing considerable insight into the nature of impact fracturing of plastic materials. This device may be used to test a wide variety of samples of differing geometry, size, and orientation. A "tup," which is dropped onto the test sample, can be adjusted to provide impact velocities from 30 to 32,000 inches per minute. An environmental chamber is available for performing tests over a range of temperatures.

The instrument develops a graphic picture of the impact process. Information concerning energy, loading force, and displacement at yield and at break is presented in a force/displacement curve such as the typical graph shown in Figure 11.2. The slope of the force/displacement curve indicates impact modulus. As the drawing illustrates, with initial impact of the tup with the test sample, there is application of an increasing load. If the material is brittle, as many thermosetting polymers are, the load will increase rapidly. As the force applied begins to exceed the strength of the test part, cracks will develop, causing a decrease in load. Conditions may stabilize with further tup penetration, allowing further loading to occur before multi-crack development, crack growth, and ultimate failure of the impacted test sample occur.



**Figure 11.2**  
**Typical Force/Displacement Curve – Impact Tester**

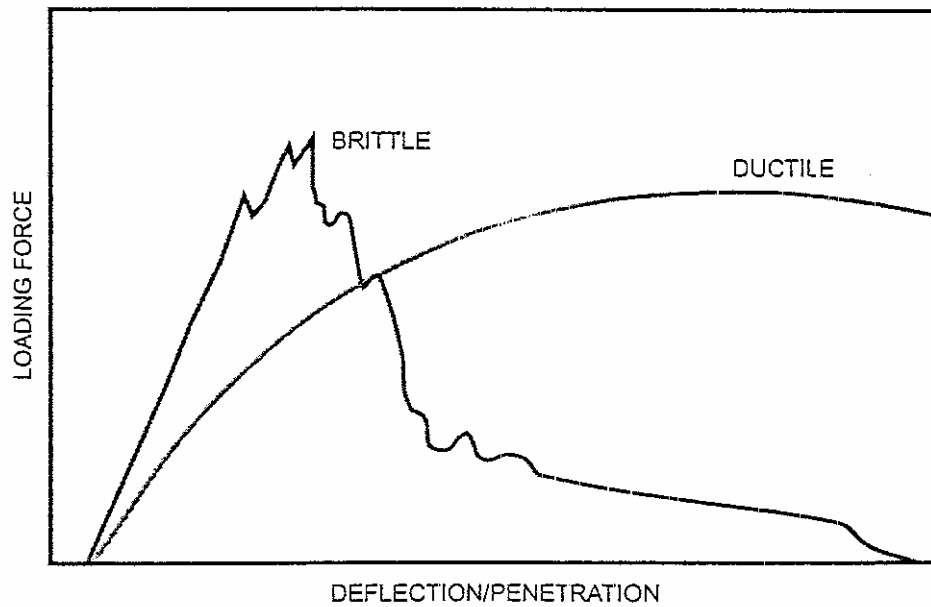


Impact on plastic materials or composites can produce either brittle or ductile failure, with most materials falling somewhere in between the two extremes. Two typical load/deflection curves are shown in Figure 11.3.

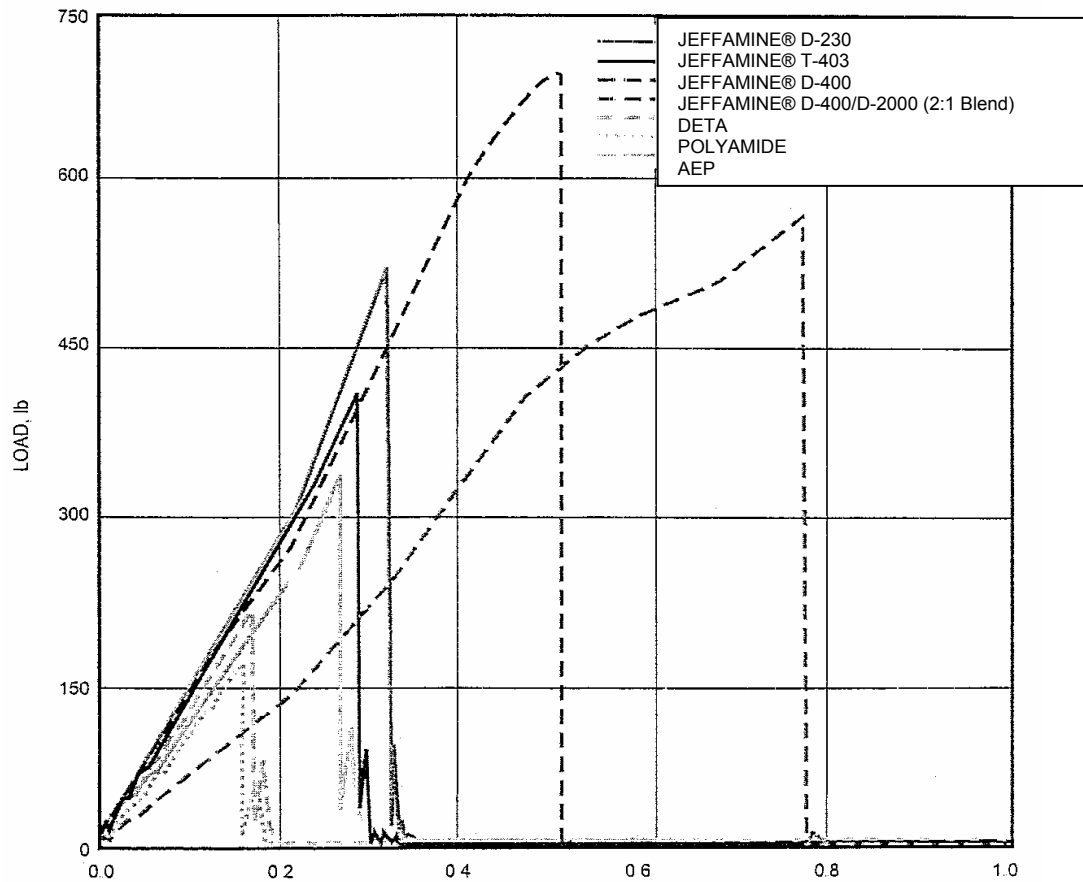
Brittle failure may occur at deflections before maximum load and at relatively low deflections, as when a glass-like material shatters. In contrast, ductile failure occurs at relatively high deflections that may be beyond maximum load, as when a piece of vinyl is impacted. The area under the stress-strain curve typically increases when a material begins to exhibit ductile failure and may be taken as a measure of the material's "toughness".

The Dynatup® impact tester may be used for many types of evaluations, i.e., design characteristics, quality control, or material behavior. With epoxy curing agents, comparisons may be made as to the ability of cured resin systems to withstand impact stresses. Such comparisons are graphically illustrated in Figure 11.4 for a number of widely used epoxy curatives. (The graphs are from simple formulations consisting of a standard resin and stoichiometric amounts of the amine curatives. Cure conditions: 2 hr, 80°C; 3 hr, 125°C.) Impact testing of the non-reinforced epoxy panels indicates large differences in impact behavior. For example, a formulation cured with an amine known to provide a rather brittle epoxy system --diethylenetriamine (DETA)--fails under minimal impact loading. A polyamide-cured system also fails at a low loading. Offering large improvements in impact resistance over DETA and the polyamide are the JEFFAMINE® PEA's with the shortest polyether backbone chains ("D-230" and "T-403") and N-aminoethylpiperazine (AEP). All three provide a moderate degree of impact resistance. Use of the higher molecular weight JEFFAMINE® amines results in considerably higher impact resistance because of the greater flexibility of polymers made using these amines. In general, epoxy systems cured with the JEFFAMINE® PEA's offer *outstanding resistance to impact*.

**Figure 11.3**  
Types of Fracture-Dynatup® Impact Tester



**Figure 11.4**  
Impact Behavior of an Epoxy Resin Cured with Various Amines-Dynatup® Impact tester



### THERMAL SHOCK RESISTANCE

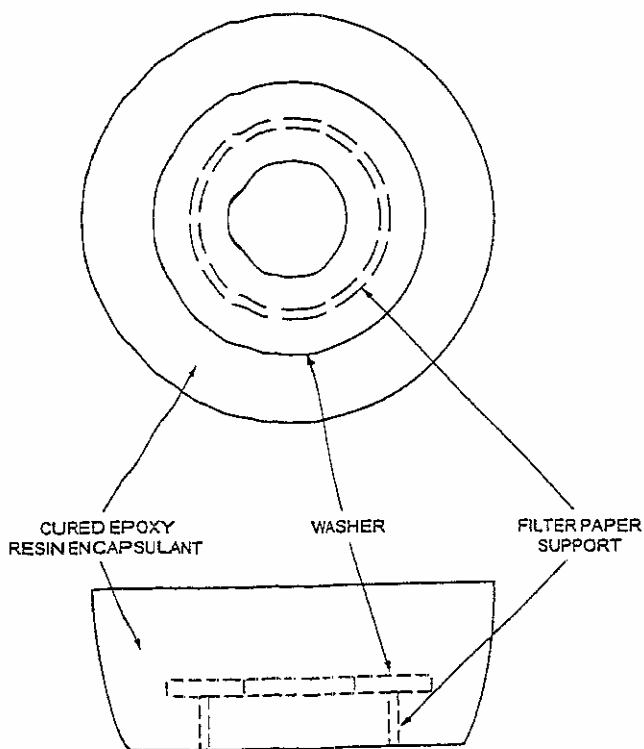
The resistance of a material to fracture upon exposure to large, quick temperature changes is an important attribute of that material in certain applications. For example, an epoxy used to encapsulate an electrical part for a jet airplane must withstand repeated thermal cycling. One of the outstanding features of the JEFFAMINE® polyoxypropyleneamine is the thermal shock resistance they bring to epoxy systems, as demonstrated by the simple "washer test" described below.

Test samples (Figure 11.5) are prepared by encapsulating a steel washer (outside diameter 1 inch, inside diameter 3/8-inch, thickness  $\frac{1}{16}$ -inch, zinc coated, weight 6-7 grams) resting on a  $\frac{1}{4}$ -inch ring of filter paper cut from a 19 x 19-cm cellulose extraction thimble centered inside an aluminum evaporating dish. Ten test samples of each formulation are cured under specified conditions and then removed from the aluminum dishes. These samples are subjected to the following thermal cycle:

1. Specimens are placed in a mechanical convection oven at 140°C for 1/2 hour.
2. Samples are removed from the oven and immediately plunged into a dry ice-acetone bath maintained at -40°C. Residence time in the bath is fifteen minutes.
3. After removal from the bath, samples are conditioned at ambient temperature for fifteen minutes. Each specimen is examined for internal cracking and, if no cracks have formed, samples are recycled. Results are reported after 10 cycles.

Other thermal cycles, more or less severe, may be used to indicate performance characteristics of various formulations.

**Figure 11.5**  
**Thermal Shock Test Sample**



## 11. Cured Properties Reference Guide

Some washer test results are shown in Table 11.4. They indicate *superior thermal shock* resistance for samples cured with any of the JEFFAMINE® amine products. With only one exception, samples prepared with other curatives shatter severely after only *one* cycle.

Of significance is the fact that inclusion of Accelerator 399 at a 10-phr level has only a minor effect on thermal shock properties of the polyetheramine-based systems in Table 11.4.

Inclusion of another JEFFAMINE® amine, designated "T-5000", in formulations like those in Table 11.4, often results in improved thermal shock resistance due to the phase separation, or micro-void formation, related to its high molecular weight. With this additive, cracking may be prevented under conditions more severe than those described on page 49. For more details about JEFFAMINE® T-5000, contact our technical service representative or any of the sales offices listed on the inside of the back cover.

**Table 11.4 - Thermal Shock Properties**

Curative	Curative Concentration, phr <sup>1</sup>	Conditions of Cure	Number of Samples Cracked During Each Cycle										Total Samples Cracked
			Cycle: 1	2	3	4	5	6	7	8	9	10	
JEFFAMINE® D-230 amine	32	2	0	2	1	0	0	0	0	1	0	0	4
	32	3	0	1	0	0	0	0	0	0	0	1	2
	32 <sup>4</sup>	2	0	0	0	1	3	0	1	1	1	0	7
JEFFAMINE® D-400 amine	55	2	0	0	0	2	1	0	1	1	1	0	6
	55	3	0	0	1	2	1	0	0	0	0	2	6
	55 <sup>4</sup>	2	2	0	1	1	0	2	1	0	0	0	7
JEFFAMINE® T-403 amine	42	2	0	0	1	1	0	0	0	0	0	1	3
	42	3	1	0	0	0	0	2	0	0	0	0	3
	42 <sup>4</sup>	2	0	0	1	0	0	0	0	1	0	0	2
JEFFAMINE®	50/25	2	0	0	0	0	3	1	0	0	0	3	7
D-400/D-2000 amines	50/25	3	0	0	2	0	2	1	0	1	0	0	6
	50/25 <sup>4</sup>	2	0	0	1	3	0	1	0	1	0	0	6
Diethylenetriamine (DETA)	11	2	10	-	-	-	-	-	-	-	-	-	10
	11	3	10	-	-	-	-	-	-	-	-	-	10
Polyamide (amine value 385)	52	2	6	2	0	1	1	-	-	-	-	-	10
	52	3	10	-	-	-	-	-	-	-	-	-	10
N-aminoethylpiperazine (AEP)	23	2	10	-	-	-	-	-	-	-	-	-	10
	23	3	10	-	-	-	-	-	-	-	-	-	10

<sup>1</sup> General-purpose epoxy resin, EEW ~188.

<sup>2</sup> Cured 7 days, ~25°C.

<sup>3</sup> Cured 2 hr, 80°C; 3 hr, 125°C.

<sup>4</sup> With 10 phr Accelerator 399.

**HEAT DISTORTION TEMPERATURE (HDT)**

ASTM D 648 (ERF 17-82)-The temperature at which a polymer sample distorts or deflects under load upon heating under specified conditions is called the *heat distortion temperature*. This property, HDT, may be important if a manufactured part is to be subjected to elevated temperatures.

Low-to-moderate HDT values are developed upon curing epoxy resins with JEFFAMINE® PEA at an elevated temperature. Rather low values can be expected with ambient curing. Typical results are shown in Table 11.5. JEFFAMINE® amines may be blended with other amine curing agents to obtain cured systems with higher HDT and  $T_g$  (glass transition temperature) values (Tables 5.3 through 5.5). Curing multifunctional epoxy resins, rather than di-functional resins, with JEFFAMINE® products also increases the HDT values of the final polymer.

**Table 11.5 - Heat Distortion Temperature**

Curative	Curative Concentration, phr <sup>1</sup>	Conditions of Cure	Heat Distortion Temperature, 264-psi load	
			°C	°F
JEFFAMINE® D-230 amine	32	2	80	176
	32 <sup>4</sup>	3	58	136
JEFFAMINE® D-400 amine	55	2	43	109
	55 <sup>4</sup>	3	36	97
JEFFAMINE® T-403 amine	42	2	83	181
	42 <sup>4</sup>	3	47	117
JEFFAMINE® D-400/ D-2000 amines	50/25	2	25	77
Diethylenetriamine (DETA)	11	2	128	262
	11	5	55	131
Polyamide (amine value 385)	52	2	67	152
	52	3	48	118
N-aminoethylpiperazine (AEP)	23	2	106	223

1 General-purpose epoxy resin, EEW ~188.

2 Cured 2 hr, 80°C; 3 hr, 125°C.

3 Cured 7 days, ~25°C.

4 With 10 phr Accelerator 399.

5 Cured 28 days, ~25°C. Sample brittle at 7 days.

**GLASS TRANSITION TEMPERATURE ( $T_g$ )**

In addition to HDT, a related property that can be used to assess the extent of cure or cross-linking is the *glass transition temperature* ( $T_g$ ). The  $T_g$  of a polymer may be defined as the mid-point of the temperature range over which an amorphous (glassy, non-crystalline) plastic goes from being relatively hard and rigid to being relatively flexible (i.e., from glassy to rubbery). Much formulation of epoxy systems involves varying combinations of different amine hardeners to change the  $T_g$  of the plastic, thus modifying its properties. Although some formulators may not actually use or think in terms of  $T_g$  directly, understanding the relationship between a polymer's  $T_g$  and its mechanical properties can aid in solving formulation problems.

During the past thirty years, a variety of instruments have become widely available that allow one to measure the  $T_g$  of a polymer using several different methods. Among the most commonly used instruments are the Differential Scanning Calorimeter (DSC), the Thermomechanical Analyzer (TMA), the Dynamic Mechanical Analyzer (DMA), and the Dynamic Mechanical Spectrometer (DMS). The  $T_g$  value obtained for a given polymer is somewhat method and rate dependent. Generally speaking,  $T_g$ 's will "track" HDT.

## COMPRESSIVE STRENGTH

ASTM D 695 (ERF 8-82)-*Compressive strength* is the force required to crush a material. Test samples are cylindrical in shape, ½ inch in diameter, and 1 inch in length. Both compressive yield strength (the stress at yield point or at the point at which an increase in strain first occurs without a corresponding increase in stress) and ultimate compressive strength (the maximum compressive stress applied during testing) may be measured by this test method.

It is evident from the series of ultimate compressive strength values given in Table 11.6 that compressive values for an epoxy resin cured with the JEFFAMINE® products are high. As expected, slightly higher values are obtained for those systems cured at an elevated temperature. Values obtained by curing with JEFFAMINE® products are equivalent to or higher than those obtained with other curing agents. Interestingly, use of an amine blend ("D-400" & "D-2000") results in cured samples that can be compressed to <10% of their original length without rupture and which return to their original length upon release of stress.

**Table 11.6 - Compressive Strength**

Curative	Curative Concentration, phr <sup>1</sup>	Conditions of Cure	Compression Yield, Psi (MPa)	Ultimate Compressive Strength, psi (MPa)
JEFFAMINE® D-230 amine	32	<sup>2</sup>	14,300 (98.6)	35,000 (241)
	32 <sup>4</sup>	<sup>3</sup>	12,500 (86.2)	23,500 (162)
JEFFAMINE® D-400 amine	55	<sup>2</sup>	9,700 (66.9)	30,000 (207)
	55 <sup>4</sup>	<sup>3</sup>	5,400 (37.2)	35,000 (241)
JEFFAMINE® T-403 amine	42	<sup>2</sup>	11,700 (80.7)	41,000 (283)
	42 <sup>4</sup>	<sup>3</sup>	11,200 (77.2)	23,000 (1,600)
JEFFAMINE® D-400/D-2000 amines	50/25	<sup>2</sup>	37,000 (255)	37,000 (255)
	50/25 <sup>4</sup>	<sup>3</sup>	42,800 (295)	43,300 (159)
Diethylenetriamine (DETA)	11	<sup>2</sup>	14,700 (101)	35,800 (247)
	11	<sup>5</sup>	15,100 (104)	19,000 (131)
Polyamide (amine value 385)	52	<sup>2</sup>	10,000 (68.9)	36,000 (248)
	52	<sup>3</sup>	10,600 (73.1)	19,000 (131)
N-aminoethylpiperazine (AEP)	23	<sup>2</sup>	12,300 (84.8)	36,000 (248)
	23	<sup>6</sup>	8,000 (55.2)	8,000 (55.2)

<sup>1</sup> General-purpose epoxy resin, EEW ~188.

<sup>2</sup> Cured 2 hr, 80oC; 3 hr, 125oC.

<sup>3</sup> Cured 7 days, ~25oC.

<sup>4</sup> With 10 phr Accelerator 399.

<sup>5</sup> Cured 14 days, ~25oC.

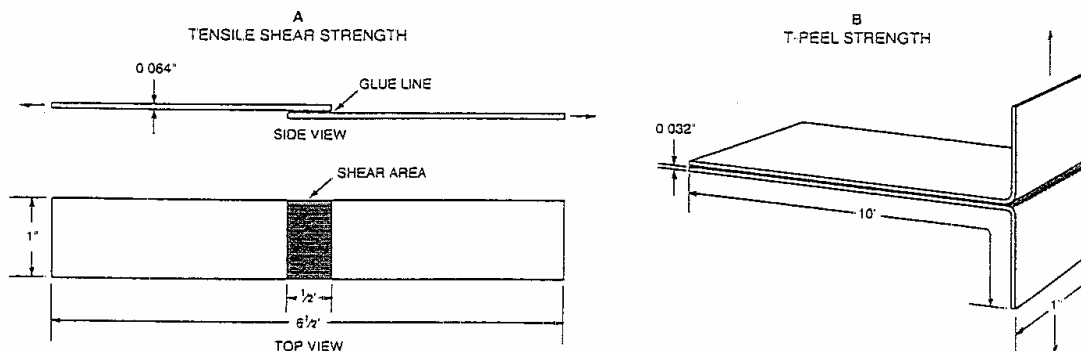
<sup>6</sup> Cured 28 days, ~25oC.

## ADHESIVE PROPERTIES

To test adhesion properties of epoxy systems, we prefer two procedures: *tensile shear strength* (lap shear), conducted according to ASTM D 1002 (ERF 15-82); and *peel strength* (T-peel), measured by ASTM D 1876. Tensile shear measures the degree of adhesion to a substrate and the rigidity of the bond. The strength required to pull the specimen apart in the direction shown in Figure 11.6A is measured. On the other hand, in the T-peel test (specimen shown in Figure 11.6B), strips of flexible aluminum are joined and peeled apart in a tensile tester. The force needed to separate the strips is a measure of the peel strength.

## 11. Cured Properties Reference Guide

**Figure 11.6 A & B**  
Adhesion Test Specimens



Tensile shear values obtained by curing with JEFFAMINE® PEA are quite high when samples are cured at an elevated temperature, while values are considerably reduced for bonds cured under ambient conditions (Table 11.7). This is also the case for other amine curatives. More-elastomeric formulations, e.g., one cured with a blend of JEFFAMINE® D-400 and D-2000 amines, result in moderate values of tensile shear regardless of the method of cure.

Peel strength values are generally low for the more rigid systems. However, a flexible formulation cured with a blend of JEFFAMINE® D-400 and D-2000 amines exhibits peel strength values that are quite high.

Over what range of temperatures might adhesives based on the PEA be useful? Tensile shear testing throws light on this question; test results for systems cured with neat PEA are shown graphically in Figure 11.7. Note that systems based on JEFFAMINE® D-230 amine and JEFFAMINE® T-403 amine maintain their strength well up to at least 60°C. With JEFFAMINE® D-400 amine, shear strength drops off sharply above about 40°C. With the inclusion of JEFFAMINE® D-2000 amine, shear strengths are outstanding below room temperature, but not above.

**Table 11.7 - Adhesion Properties**

Curative	Curative Concentration, phr <sup>1</sup>	Conditions of Cure	Tensile Shear Strength, Psi (MPa)		Peel Strength, pli (GPa)	
JEFFAMINE® D-230 amine	32	2	4,000	(280)	2.0	(0.36)
	32 <sup>4</sup>	3	970	(68)	3.5	(0.62)
JEFFAMINE® D-400 amine	55	2	3,900	(274)	4.7	(0.84)
	55 <sup>4</sup>	3	3,100	(217)	2.5	(0.45)
JEFFAMINE® T-403 amine	42	2	3,500	(245)	2.0	(0.36)
	42 <sup>4</sup>	3	1,100	(77)	3.6	(0.64)
JEFFAMINE® D-400/D-2000 amines	50/15	2	1,600	(112)	15.9	(2.84)
	50/25 <sup>4</sup>	3	1,100	(77)	21.1	(3.77)
Diethylenetriamine (DETA)	11	2	1,600	(112)	—	
	11	5	900	(63)	0.6	(0.11)
Polyamide (amine value 385)	52	2	2,700	(190)	3.9	(0.70)
	52	3	2,400	(170)	2.3	(0.40)
N-aminoethylpiperazine (AEP)	23	2	2,700	(190)	2.6	(0.47)
	23	5	600	(42)	0.8	(0.14)

<sup>1</sup> General-purpose epoxy resin, EEW ~188.

<sup>2</sup> Cured 2 hr, 80°C; 3 hr, 125°C.

<sup>3</sup> Cured 7 days, ~25°C.

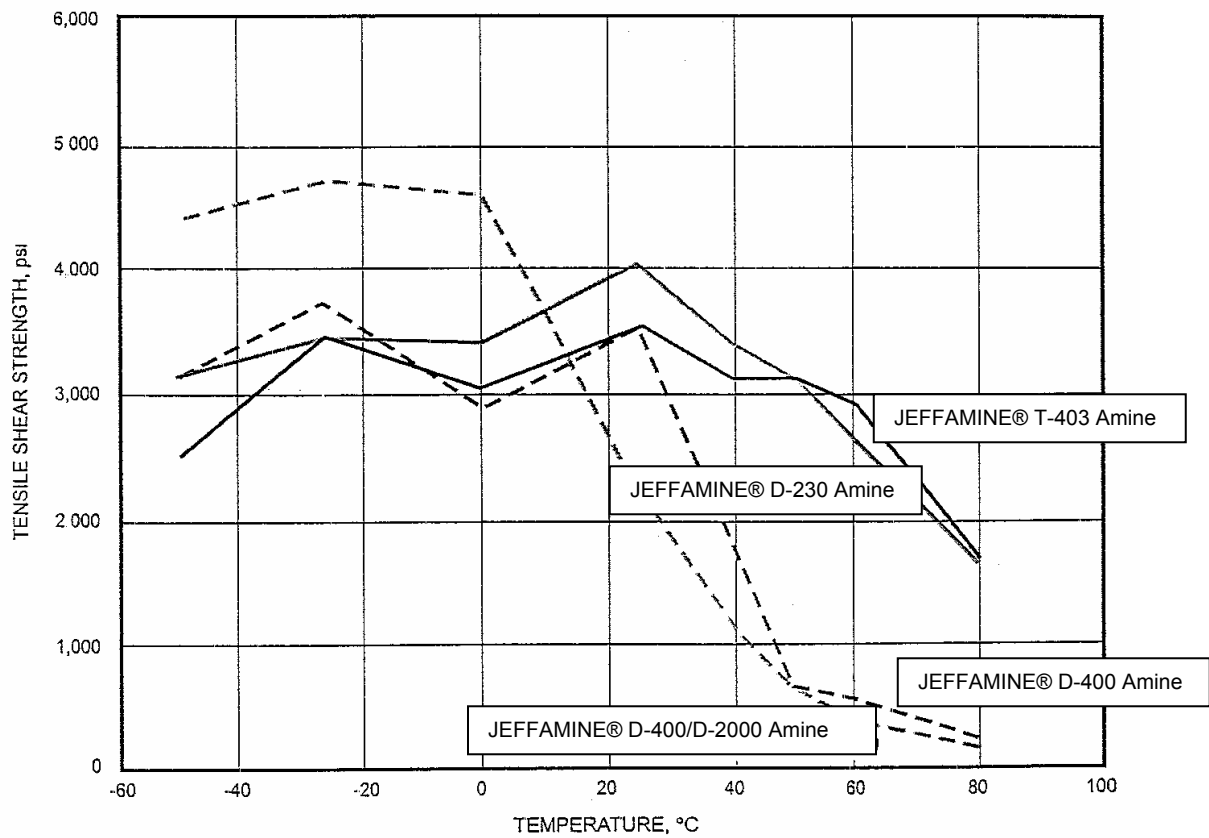
<sup>4</sup> With 10 phr Accelerator 399.

<sup>5</sup> Cured 28 days, ~25°C. Sample brittle when tested at 7 and 21 days.

## 11. Cured Properties Reference Guide

Adhesion can be greatly enhanced by inclusion of small amounts of phase-separating or microvoid-forming additives such as JEFFAMINE® T-5000 amine. For more detailed information about this adhesion promoter, contact our technical service representative or any of the sales offices listed in this brochure.

**Figure 11.7**  
**Effect of Temperature on the Tensile Shear Strength of JEFFAMINE®**  
**Polyoxypropyleneamine-Based Adhesives**





**RESISTANCE TO CHEMICALS: IMMERSION TESTING**

Immersion testing is carried out on cured epoxy samples 3 x 1 x 1/8 inch in size. Weight gain is calculated for each of the samples after submersion for 28 days in a variety of chemicals and solvents. Results of such tests are shown in Table 11.8.

Generally speaking, the JEFFAMINE® products offer good alkali and water resistance, and fair acid resistance. Solvent resistance is poor in most cases. Elevated curing temperatures will improve chemical resistance.

**Table 11.8 - Immersion Weight Gain of Epoxy Castings**

Curative	Curative Concentration, phr <sup>1</sup>	Conditions of Cure	% Weight Gain After 28 Days Immersion in:					
			10% NaOH	Distilled Water, 40°C	30% H <sub>2</sub> SO <sub>4</sub>	5% Acetic Acid	Methanol	Toluene
JEFFAMINE® D-230 amine	32	<sup>2</sup>	1.1	2.4	1.9	4.8	20.1	1.5
	32	<sup>3</sup>	0.4	2.5	10.4	<sup>5</sup>	22.8	<sup>5</sup>
JEFFAMINE® D-400 amine	55	<sup>2</sup>	1.4	2.8	6.9	9.2	26.6	<sup>5</sup>
	55	<sup>3</sup>	1.7	2.7	11.2	18.3	27.1	<sup>5</sup>
JEFFAMINE® T-403 amine	42	<sup>2</sup>	0.9	1.8	1.1	1.5	11.8	1.1
	42	<sup>3</sup>	1.1	2.0	3.3	40.2	20.0	<sup>5</sup>
Diethylenetriamine (DETA)	11	<sup>2</sup>	0.6	1.4	1.1	0.9	1.6	0.1
	11	<sup>3</sup>	0.8	2.0	2.8	12.0	5.3	8.8
Polyamide (amine value 385)	52	<sup>2</sup>	1.1	3.4	2.7	3.1	10.6	7.2
	52	<sup>3</sup>	1.4	3.3	3.0	10.6	23.9	<sup>5</sup>
N-aminoethylpiperazine (AEP)	23	<sup>4</sup>	2.2	5.5	59.9	<sup>5</sup>	<sup>5</sup>	9.1

1 General-purpose epoxy resin, EEW -188.

2 Cured 2 hr, 80oC; 3 hr, 125oC.

3 Cured 7 days at room temperature.

4 Cured 28 days at room temperature.

5 Sample disintegrated during test.

**ELECTRICAL PROPERTIES**

The electrical properties of epoxy resins cured with JEFFAMINE® PEA are good. Values obtained with JEFFAMINE® polyoxypropyleneamine-cured epoxy systems (Table 11.9) are typical of those expected with epoxy/amine formulations. No deficiencies in electrical properties are noted upon curing with any of the JEFFAMINE® polyamines. Higher values would undoubtedly result from more specialized formulating. Special resins are available for electrical potting, for example.

**Table 11.9 - Electrical Properties of Epoxy Systems Cured with JEFFAMINE® Products**

<b>Formulation,<sup>1</sup> pbw</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
Epoxy resin <sup>2</sup>	100	100	100	100
JEFFAMINE® D-230 amine	32	—	—	—
JEFFAMINE® D-400 amine	—	55	—	50
JEFFAMINE® T-403 amine	—	—	42	—
JEFFAMINE® D-2000 amine	—	—	—	25
<b>Electrical properties</b>				
Dielectric constant, 100 Hz (ASTM D 150), 23°C	4.7	4.6	4.8	6.0
40°C	4.7	4.6	4.7	7.0
60°C	4.7	5.2	4.8	7.6
100°C	5.4	7.4	5.1	7.2
1,000 Hz (ASTM D 150), 23°C	3.6	3.5	3.5	3.9
Dissipation factor, 100 Hz, 23°C	$3.4 \times 10^{-3}$	$4.3 \times 10^{-3}$	$5.3 \times 10^{-3}$	$8.2 \times 10^{-3}$
40°C	$3.1 \times 10^{-3}$	$4.2 \times 10^{-3}$	$5.0 \times 10^{-3}$	$8.3 \times 10^{-3}$
60°C	$3.5 \times 10^{-3}$	$7.4 \times 10^{-3}$	$5.3 \times 10^{-3}$	$8.5 \times 10^{-3}$
100°C	$6.9 \times 10^{-3}$	$23.5 \times 10^{-3}$	$14.6 \times 10^{-3}$	$94.7 \times 10^{-3}$
1,000 Hz, 23°C	$31.1 \times 10^{-3}$	$31.6 \times 10^{-3}$	$32.5 \times 10^{-3}$	$50.9 \times 10^{-3}$
Volume resistivity, ohm-cm, DC (ASTM D 257), 23°C	$5.0 \times 10^{15}$	$4.3 \times 10^{15}$	$3.1 \times 10^{15}$	$5.9 \times 10^{13}$
40°C	$3.4 \times 10^{15}$	$5.2 \times 10^{14}$	$6.0 \times 10^{14}$	$3.2 \times 10^{13}$
60°C	$2.6 \times 10^{14}$	$2.8 \times 10^{13}$	$2.7 \times 10^{14}$	$1.7 \times 10^{12}$
80°C	$3.0 \times 10^{14}$	$2.4 \times 10^{13}$	$1.8 \times 10^{14}$	$1.6 \times 10^{11}$
Arc resistance, sec, 25°C (ASTM D 495), stainless electrode	88	108	103	91
tungsten electrode	104	118	109	122
Dielectric strength, v/mil, 25°C, 1/8-inch thickness (ASTM D 149)	558	597	647	576

<sup>1</sup> Cured 2 hr, 80°C; 3 hr, 125°C.

<sup>2</sup> General-purpose epoxy resin, EEW ~188.

**12. HANDLING AND STORAGE****MATERIALS OF CONSTRUCTION****At temperatures of 75 to 100°F**

Tanks	Carbon Steel
Lines, valves	Carbon Steel
Pumps	Carbon Steel
Heat exchanger surfaces	Stainless Steel
Hoses	Stainless Steel, Polyethylene, Polypropylene, TEFLON® fluoropolymer
Gaskets, Packing	TEFLON® fluoropolymer or polypropylene – avoid materials such as neoprene, Buna N and VITON® fluoroelastomer
Atmosphere	Nitrogen

**At temperatures above 100°F**

Tanks	Stainless Steel or Aluminum
Lines, valves	Stainless Steel
Pumps	Stainless Steel or Carpenter 20 alloy or equivalent
Atmosphere	Nitrogen

Because amines can react with the humidity and carbon dioxide in the air, it is recommended that the head space of containers used to store any amines be purged with dry nitrogen prior to closure, in order to maintain maximum shelf-life. Repeated air exposure can lead to formation of ammonium carbamates, which in some applications may cause process problems, though JEFFAMINE® amines are less likely than most other amines to have such problems.

A nitrogen blanket is suggested for all storage in case of accidental high temperatures. It should be noted that pronounced discoloration is likely to occur at temperatures above 140°F, whatever the gaseous pad.

Clean-out of lines and equipment containing the JEFFAMINE® PEA's is easy; warm water or steam is all that is required.

In the event of spillage of this product, the area may be flushed with water. The proper method of disposal of waste material is by incineration with strict observance of all federal, state, and local regulations.

TEFLON® is a registered trademark of the DuPont Company.

VITON® is a registered trademark of DuPont Dow Elastomers.

### 13. TOXICITY AND SAFETY

MSDS should be reviewed thoroughly prior to use of each product.

The JEFFAMINE® PEAs should be considered hazardous, having the potential to cause burns to the skin and eyes and toxic effects by absorption through the skin or by swallowing. Impervious gloves and chemical-type goggles with face shield must be worn when handling these products. When handling large quantities subject to splashes and spills, impervious suits and rubber boots must also be worn.

Should accidental contact occur, flush the eyes thoroughly with water for at least 15 minutes and get immediate medical attention. Do not attempt to neutralize with chemical agents. Continue flushing for an additional 15 minutes if medical attention is not immediately available.

In case of skin contact, immediately wash the exposed area with plenty of water for at least 15 minutes. Do not attempt to neutralize with chemical agents. If drenched, immediately remove contaminated clothing under the safety shower. Discard or decontaminate clothing and shoes before reuse.

In case of ingestion, immediately give two glasses of water (16 oz), but do not induce vomiting and get immediate medical attention. These materials are corrosive. If vomiting occurs, give fluids again. Have a physician determine if condition of patient will permit induction of vomiting or evacuation of stomach. Do not give anything by mouth to an unconscious or convulsing person.

JEFFAMINE® D-230 amine is considered slightly toxic if swallowed or absorbed through the skin. JEFFAMINE® D-400 amine is considered moderately toxic if swallowed and slightly toxic if absorbed through the skin. JEFFAMINE® D-2000 amine is considered toxic if swallowed, and slightly toxic if absorbed through the skin. JEFFAMINE® T-403 amine is considered toxic if absorbed through the skin or swallowed. All of these JEFFAMINE® products are corrosive to the skin, and are severely to extremely irritating to the eyes. In acute toxicity testing, the results shown below were obtained.

Test	JEFFAMINE® Product			
	D-230	D-400	D-2000	T-403
Single oral dose LD50 value in rats, g/kg	2.88	1.10	0.48	0.22
Single dermal LD50 value in rabbits, g/kg	2.98	1.56	2.09	0.61
Draize score for skin irritation in rabbits	>6.5-8.0/8.0	3.08/8.0	>6.5-8.0/8.0	8.0/8.0
DOT 4-hour test, corrosiveness to the skin	Corrosive	Corrosive	Corrosive	Corrosive
Draize score for eye irritation in rabbits	>80-110/110	60.70/110	>80/110	80-110/110
Delayed contact hypersensitivity	Negative	Negative	Not Determined	Negative

All four JEFFAMINE® products have been found to be non-mutagenic in the Ames Salmonella/microsome plate test. Additional tests on D-230 and D-400 showed these products to be inactive in the Balb/3T3 in vitro Cell Transformation Assay and the Mouse Lymphoma Assay. Tests on D-2000 and T-403 showed these products to be inactive with respect to genetic toxicity in the Mouse Micronucleus Test and Unscheduled DNA Synthesis (UDS) Assays.

## **14. SHIPPING INFORMATION**

### **AVAILABILITY**

The JEFFAMINE® products described in this brochure are available in tank cars, tank wagons, and 55-gallon drums through customer service. Sizes of 5-gallon cans are available through the sample department. Some products may need additional lead time. Samples can be obtained by contacting the Huntsman Corporation offices listed on the inside of the back cover. Orders can be placed by contacting the customer service advisers listed on the inside of the back cover.

### **TRANSPORTATION INFORMATION**

See MSDS for individual JEFFAMINE® products for transportation information.

## 15. HUNTSMAN CORPORATION PUBLICATIONS RELATING TO EPOXIES

### PRODUCT DATA SHEETS AND APPLICATION BULLETINS

Accelerator 399

Adhesive Properties of JEFFAMINE Polyetheramine Epoxy Curing Agents

Application Guide for JEFFAMINE Products

Curing Epoxy Resins with Blends of JEFFAMINE Products and Imidazoles

Epoxy Curing Agents and Accelerators

Epoxy Polymer Concrete Using JEFFAMINE EDR-148 (XTJ-504)

Epoxy Resin Curing-Comparison of a Polyetheramine, JEFFAMINE® D-230, with Three Commonly Used Polyamides

Flexible Epoxy Adhesive Formulations Prepared from High Molecular Weight Polyoxyalkyleneamines

JEFFAMINE® D-230 Polyoxypropylenediamine

JEFFAMINE® D-400 Polyoxypropylenediamine

JEFFAMINE® D-2000 Polyoxypropylenediamine

JEFFAMINE® EDR Series of Polyetheramines

JEFFAMINE® EDR-148 (XTJ-504) JEFFAMINE® M Series JEFFAMINE® M-600 JEFFAMINE® M-1000

JEFFAMINE® M-2005 and M-2070 JEFFAMINE® Polyetheramines in Syntactic Foams JEFFAMINE®

Poly(oxyethylene)diamines-JEFFAMINE® ED Compounds

JEFFAMINE® T-403 Polyoxypropylenetriamine

JEFFAMINE® T-3000

JEFFAMINE® T-5000

Monononyphenol (MNP) Additive for Epoxy Applications Polyamides from JEFFAMINE Polyetheramines:

Preparation and Use in Hot Melt Adhesives

Reactive Diluents for Polyamide Curing Agents

TEXACURE™ EA-20 Epoxy Curing Agent

TEXACURE™ EA-24 Epoxy Curing Agent

TEXACURE™ EA-43 Epoxy Curing Agent

TEXACURE™ SPA-51 Epoxy Curing Agent

The JEFFAMINE® Polyoxyalkyleneamines

Use of JEFFAMINE® Polyoxyalkyleneamines in Decoupage-Type Decorative Coatings

Use of JEFFAMINE® T-5000 as a Component of Epoxy Adhesive Systems Water-Reducible Coatings via Epoxy

Resin Modification with JEFFAMINE® M-1000

### BIBLIOGRAPHIES

Coatings Applications

Elastomeric Applications

Encapsulation and Molding Applications

Epoxy Accelerator Applications

Laminate and Composite Applications

Latent Curing Applications

Textile and Fiber Applications

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

### 16. BIBLIOGRAPHY-JEFFAMINE® PEA APPLICATIONS

Ref	Patent #	Country	Author/Company or Publication/Date	Description
<b>Adhesives</b>				
1	39,322	AU	Shenkel (to Teroson GmbH), August 4, 1989.	Product of reaction between 2000 mol. wt. etherdiamine and excess epoxy is cured with dicyandiamide for a hot melt adhesive.
2	310,706	EP	H. G. Waddill, J. J. Lin, and G. P. Speranza (to Texaco Development Corp.), February 1, 1989.	Amidoamine curing agents prepared by reaction of JEFFAMINE® polyetheramines with aromatic di- or tricarboxylic acids provide rapid cure of epoxy resins at ambient temperatures.
3	432,923	EP	Henry S. Y. Hsich (to Lord Corp.), June 19, 1991.	Epoxy resin-rubber blends with reduced phase separation are formed using a reactive liquid rubber and JEFFAMINE® D-230 with an epoxy resin.
4	432,943	EP	G. P. Speranza and W. Y. Su (to Texaco Chemical Company), June 19, 1991.	Amine-terminated polyoxyalkylenepolyamides compatible with polyols used in adhesives are prepared from JEFFAMINE® D-2000, D-400, and adipic acid.
5	1,004,859	CAN	Minnesota Mining Co., February 8, 1977.	A tough, elastomeric epoxy binder containing a water-insoluble polyetherpolyamine is used to adhere hard particles to resilient surfaces.
6	1,484,797	GB	Anthony V. Cunliffe, Norman C. Paul, Peter J. Pearce, and David Hugh Richards (to U. K. Secretary of State for Defense, London), September 8, 1977.	A room-temperature-curable adhesive with high bond strength was produced by reaction of a diepoxide with a carboxy-terminated nitrile rubber which was hardened by a primary amine-terminated polyether.
7	2,748,705	GR	Heinz Schulze and H. G. Waddill (to Texaco Development Corp.), May 24, 1978.	A poly(oxypropylene)diamine was condensed with urea or with maleic anhydride to form products useful in improving metal-to-metal adhesion of hardened epoxy resins.
8	2,828,152	GR	H. G. Waddill (to Texaco Development Corp.), January 11, 1979,	A ureide group-terminated reaction product of JEFFAMINE® D-2000 and urea was added to amine-hardener epoxy resins to improve adhesion. Added to anhydride-cured epoxy systems, thermal shock properties were improved.
9	2,940,912	GR	H. G. Waddill (to Texaco Inc.), April 30, 1980.	The adhesion of a hardened epoxy resin was improved through use of mixtures of a polyoxyalkylenepolyamine of 900-4000 mol. wt. with a low mol. wt. polyamine such as JEFFAMINE® D-230 or bis(3-aminopropyl)ethylenediamine.
10	3,432,370	US	Charles W. Bash and George A. Lane (to Dow Chemical Co.), March 11, 1969.	Binders for illuminating flares are prepared from salts of amino-terminated polypropylene glycol and an epoxy resin.
11	3,511,725	US	Don L. Stevens and Harold E. Filter (to Dow Chemical Co.), May 12, 1970.	Binders for solid rocket propellants were prepared by cross-linking amine-terminated polyglycols with various resins.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
12	4,070,225	US	Vernon H. Batdorf (to H. B. Fuller Co.), November 17, 1976.	A latent or slow-curing adhesive system was formulated from an epoxy resin and a primary amine-terminated polyamide. The polyamide was prepared from a polymeric tall oil fatty acid, a polyoxypropyleneamine, 1,4-bis(aminopropyl)piperazine, and ethylenediamine.
13	4,082,708	US	Mehta; Ramesh ( for HB Fuller Co), April 4, 1978	Adhesive systems comprising a bisamino piperazine-containing polyamide
14	4,119,615	US	Schulze; Heinz (for Texaco Development Corp), October 10, 1978	Thermoplastic adhesive polyoxamide from polyoxypropylene polyamine
15	4,141,885	US	Texaco Development Corp., February 27, 1979.	High molecular weight polyoxyalkyleneamine bisureides are used as additives in anhydride-cured or amine-cured epoxy compositions to improve adhesion properties and thermal impact strength.
16	4,146,700	US	H. G. Waddill and Heinz Schulze (to Texaco Development Corp.), March 27, 1979.	The diamide prepared from a polyoxyalkylenepolyamine urea condensate increases adhesive strength of an amine-cured epoxy composition.
17	4,147,857	US	H. G. Waddill and Heinz Schulze (to Texaco Development Corp.), April 3, 1979.	Polyoxyalkylenepolyamine succinimide derivatives, when added to amine-cured epoxy systems, resulted in enhanced adhesion properties.
18	4,178,426	US	H. G. Waddill (to Texaco Development Corp.), December 11, 1979.	Polyetheramines with urea termination are used to enhance adhesive properties of epoxy resins cured with aminopropyl derivatives of ethyleneamines.
19	4,187,367	US	H. G. Waddill (to Texaco Development Corp.), February 5, 1980.	Epoxy resins cured with a polyoxyalkylenepolyamine aminoalkylene derivative and containing a polyether diureide had high adhesion and peel strength properties.
20	4,423,170	US	H. G. Waddill (to Texaco Development Corp.), December 27, 1983.	Water-dilutable epoxy adhesive systems are produced with epoxy resins modified with polyoxyalkylene poly- or monoamines.
21	4,485,229	US	H. G. Waddill and R. J. G. Dominguez (to Texaco Inc.), November 27, 1984.	Epoxy adhesive systems containing JEFFAMINE® T-5000 as an adhesion promoter give high peel strength and good shear strength.
22	4,605,605	US	Cannone (to AT&T Bell Labs), August 12, 1986.	An epoxy sealant cured with a polyoxypropylenetriamine was used to prevent electrolyte leakage in standby batteries.
23	4,728,737	US	A. B. Goel (to Ashland Oil, Inc.), March 1, 1988.	High performance epoxy structural adhesives with chemical thixotropy contain JEFFAMINE® D-400.
24	4,740,536	US	Chao; Yen-Yau H., (for Rohm & Haas Co.), April 26, 1988	Water-based binder, coating and adhesive compositions from alkaline-curable latex polymers, epoxies and amines
25	4,740,539	US	A. B. Goel (to Ashland Oil, Inc.), April 26, 1988.	Flexible, two-component structural adhesives are prepared from epoxy resin, reactive liquid rubber, isocyanates, JEFFAMINE® T-3000 or T-5000, bisphenol A, and a tertiary amine catalyst.
26	4,760,125	US	N. Wiemers (to Henkel), July 26, 1988.	Use of polyoxypropyleneamines in hot melt adhesives gives improved flexibility.



## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
27	4,766,186	US	Kathy B. Sellstrom and H. G. Waddill (to Texaco Chemical Company), August 23, 1988.	Epoxy adhesive systems cured with JEFFAMINE® EDR-series amines provide high shear strength and relatively high peel strength.
28	4,798,879	US	Hannah; Steven L.; Williams; Maureen R.; Greenlee; Thomas W, (for The BF Goodrich Co), January 17, 1989	Catalyzed fast cure polyurethane sealant composition
29	4,814,415	US	Kathy B. Sellstrom and D. C. Alexander (to Texaco Chemical Company), March 21, 1989.	Adhesives cured with blends of JEFFAMINE® polyoxyalkyleneamines and oxamidoamine derivatives of the JEFFAMINE® products offer high peel strength in addition to good shear strength.
30	4,822,683	US	Schappert; Raymond F.; Piccirilli; Robert M. (for PPG Industries), April 18, 1989	Method for preparing an adhesive bond with a curable composition having reduced shrinkage during cure
31	4,837,295	US	K. F. Drain and K. Kadziela (to Loctite Corp.), June 6, 1989.	Epoxy/bismaleimide mixtures cured with JEFFAMINE® D-230 offer improved initial adhesion and thermal shock resistance for use with engineering plastics for electrical/electronic components.
32	4,847,319	US	Bandlish; Baldev K. (for The BF Goodrich Corp Company), July 11, 1989	Sealant compositions or coating mixtures containing functional silane or siloxane adhesion promoters nonreactive with blocked isocyanates
33	4,853,456	US	Kathy B. Sellstrom and T. L. Renken (to Texaco Chemical Company), August 1, 1989.	Adhesives cured with blends of JEFFAMINE® polyoxyalkyleneamines and iso- or terephthalamidoamine derivatives offer excellent shear strength and peel strength.
34	4,952,621	US	Bandlish; Baldev K. (for The BF Goodrich Corp Company), August 28, 1990	Urethane sealants or coating admixtures having improved shelf stability
35	4,952,659	US	Hannah; Steven L.; Williams; Maureen R. (for The BF Goodrich Corp Co), August 28, 1990	Catalyzed fast cure polyurethane sealant composition
36	5,077,360	US	DePompei; Michael F.; Hernandez; Pamela K. (for Tremco, Inc.) December 31, 1991	Acrylic sealant composition and methods relating thereto
37	5,120,817	US	G. P. Speranza, H. G. Waddill, and J. J. Lin (to Texaco Chemical Company), June 9, 1992.	Rapid curing epoxy hardeners are produced by the condensation reaction of phenol, formaldehyde, and polyoxyethylenediamines.
38	5,198,524	US	Bush; Richard W.; Carney; Eugene E (for WR Grace & Co), March 30, 1993	Moisture-curing acrylate/epoxy hybrid adhesives
39	5,241,016	US	Waddill; Harold G.; Grigsby, Jr.; Robert A.; Cuscurida; Michael; Zimmerman; Robert L. (for Texaco Chemical Co), August 31, 1993	Epoxy adhesives containing aminated, long chain monoepoxide capped polyols
40	5,712,039	US	Marhevka; Virginia C.; Griggs; Allen L.; Tarbutton; Kent S. (for 3M) January 27, 1998	Epoxy adhesives with dithiooxamide adhesion promoters
41	5,891,367	US	Basheer; Rafil Abdulkadir; Zwolinski; Michael Stephen (for General Motors Corp) April 6, 1999	Conductive epoxy adhesive

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
42	5,929,141	US	Lau; Steven E.; Huff; Deborah S.; Hermansen; Ralph D.; Johnston; E. Dean (for Raytheon Co) July 27, 1999	Adhesive of epoxy resin, amine-terminated ban and conductive filler
43	5,955,199	US	Johnson; Randy Allen; Tufts; Timothy Allen (for Ashland Inc) September 21, 1999	Imine-containing curative for two component polyurethane structural adhesives
44	6,015,865	US	Blank; Norman E.; Schenkel; Hubert K. (for Henkel-Teroson GmbH) January 18, 2000	Hot melt adhesive from epoxy resin/amine-terminated polyalkylene glycol adduct
45	6,528,595	US	Ikawa; Masahiro; Okuhira; Hiroyuki; Chino; Keisuke (for Yokohama Rubber Co Ltd) March 23, 2003	Adhesive of thiirane and oxirane-containing compound and oxirane-containing compound
46	6,645,341	US	Gordon; Terry (for National Starch & Chemical Investment Holding Corp) November 11, 2003	Two part epoxide adhesive with improved strength
47	6,727,320	US	Attarwala; Shabbir; Qinyan; Zhu; Burdzy; Matthew P. (for Henkel Loctite Corp) April 27, 2004	Polymerizable compositions in non-flowable forms
48	57,034,648	JP	Toshiba Battery Co., Ltd., February 25, 1982.	Leakage-resistant alkaline cells use epoxy resin, polyoxypropylene-amine, and polyamide composition between gasket and sealing plate.
49	57,185,370	JP	Canon, November 15, 1982.	Epoxy adhesives with good efficiency and durability are cured with ethyleneamines and aminopropyl ethylene glycols and used for optical materials.
50	59,147,014	JP	Nitto Electric Industries, August 23, 1984.	Epoxy adhesive compositions containing polyetherdiamines, liquid acrylonitrile-butadiene copolymers, and inorganic fibers offer improved strength and adhesion properties at lower temperatures.
51	60,069,127	JP	Nitto Electric Industries, April 19, 1985.	A composition comprised of epoxy resin, polyetherpolyamine, and a urea derivative offers improved heat resistance and adhesion properties.
52	60,069,128	JP	Nitto Electric Industries, April 19, 1985.	An epoxy composition cured with a mixture of dicyandiamide, an amine-terminated liquid rubber, a polyetherpolyamine, and a urea derivative mixes easily, cures rapidly, and offers improved heat resistance and adhesion properties.
53	61,207,425	JP	Nitto Electric Industries, September 13, 1986.	An adhesive prepared from rubber-modified epoxy resins, polyether-polyamines, and guanidine or cyanoguanidine products cures rapidly and offers excellent heat resistance and adhesion properties.
54	62,243,616	JP	Nitto Electric Industries, October 24, 1987.	An epoxy composition useful for adhering materials with different coefficients of thermal expansion contains polyetherpolyamines and an inorganic fibrous material.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
55	2,552,518 76,125,429	GR JP	H. P. Klein (to Texaco Development Corp.), August 12, 1976, November 1, 1976.	Polyamide adhesives were prepared from a mixture of a poly-oxypropylenepolyamine, a C4-20 aliphatic or aromatic clicarboxylic acid, and, optionally, epoxy resins or other additives.
56	2,741,268 4,082,708	GR US	Ramesh Mehta (to H. B. Fuller Co.), March 23, 1978, and April 4, 1978.	Quick-setting epoxy adhesive formulations containing polyamide hardener prepared from clicarboxylic acid and dialkylpiperazine or polyoxypropylenediamine offer high peel strength.
57	2,748,656,	GR	Heinz Schulze and H. G. Waddill (to Texaco Development Corp.), May 24, 1978.	Polyether diamines and polyether diureides were prepared by the reaction of poly(oxypropylene)diamine with formic acid, urea, phenyl isocyanate, or benzyl alcohol and added to epoxy resins containing amine hardeners to improve adhesion of the hardened resins.
58	3,847,726 2,217,331	US GR	Wilhelm Becker, et al. (to Reichhold-Albert Chemie Aktiengesellschaft), November 12, 1974; November 2, 1972.	Vibration-damping sheet metal laminates were prepared with an adhesive composed of an epoxy resin cured with the condensation product of a polyoxypropyleneamine, phenol, and an aldehyde.
59	4,122,069,	US	Lee G. Meyer (to Texaco Development Corp.), October 24, 1978.	The adhesion of amine-cured epoxy resins was improved by addition of dihydroxyalkyl carbamate-terminated polyether additives. These additives were prepared by reaction of a polyoxypropylenepolyamine (JEFFAMINE® D-2000) with ethylene carbonate.
60	4,179,552 2,910,110	US GR	H. G. Waddill (to Texaco Development Corp.), December 18, 1979.	Rapid-hardening epoxy resin systems are cured with epoxy adducts of aminopropyl derivatives of JEFFAMINE® amines. Systems also contain an accelerator and an adhesion promoter.
61	4,420,606 3,368,656 88,011,362	USGRJP	K G. Waddill (to Texaco Inc.), December 13, 1983.	A flexible adhesive is prepared from a polyepoxide modified with a polyoxyalkylenemonoamine and a modified imidazole catalyst.
62	4,500,604 87,075 3,368,654	US EP GR	J. Herold, W. Gruber, and G. Henke (to Henkel), August 25, 1983.	An adhesive from the polyetheramine or polyamide cure of an epoxy resin prepared by a glycidol/isocyanate reaction is used in the production of laminated polyolefin films.
63	57,167,370 88,058,197	JP JP	Mitsui Petrochemical Industries, October 15, 1982. and November 15, 1988.	Isocyanate oxime accelerators are used in epoxy adhesives cured with 33 polyoxypropyleneamines and acid hydrazides.
64	EP0329266	EP	Alexander, DC; Renken, TL; Sellstrom, KB (for Texaco Development Corp) August 23, 1989	Amidoamine and oxamidoamine co-curatives in epoxy thermoset adhesive.
65			Stephen G. Seger, Jr. and Louis H. Sharpe, <i>Polym. Sci. Technol.</i> 1975, 9B (Adhes. Sci. Technol.), 577-95.	Adhesives for bonding ferrite transformer core components comprised an epoxy resin and JEFFAMINE® T-403.
66			H. G. Waddill, "Epoxy Adhesive Formulations with Enhanced Properties," presented at the 13th National S.A. M.P. E. Technical Conference, Boston, Mass., November 13-15, 1979.	Property enhancement through the creation of a "microvoid" system throughout a cured epoxy matrix is discussed.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
67			H. N. Vazirani, <i>Adhes. Age</i> 1980,23 (10) 31-5.	Flexible epoxy resins were prepared having a wide variety of mechanical properties. One- and two-part systems are prepared using epoxy resin adducts of polyoxyalkylenepolyamines.
68			Kathy B. Sellstrom, "Polyethylene Glycol Diamines: New Curing Agents for Epoxy Adhesives," presented at the Adhesive and Sealant Council conference, Cincinnati, Ohio, October 25-28, 1987.	A new JEFFAMINE® epoxy curing agent is introduced. Adhesive properties obtained with the curing agent are discussed.
69			A. T. Hu, R. S. Tsai, and R. D. Lee, <i>J. Appl. Polymer Sci.</i> 1989,37, 1863-76.	Use of JEFFAMINE® D-2000 in hot melt adhesives is described; improvement in impact strength is shown.
70			Kathy B. Sellstrom and H. G. Waddill, "Modifiers for Enhanced Adhesion Property Development," presented at SPI/Epoxy Resin Formulators Division spring conference, Costa Mesa, Calif., March 15-17, 1989.	Effects of molecular weight, terminal group, backbone structure, and functionality of modifiers on microvoid-forming ability in amine-cured epoxy adhesives are discussed.
71			D. C. Alexander, Kathy B. Sellstrom, and T. L. Renken, "Polyamidoamines from JEFFAMINE Amines: Preparation and Use in Epoxy Adhesives," presented at the Adhesive and Sealant Council Conference, Los Angeles, Calif., March 19-3, 1989.	A variety of polyamidoamines prepared from JEFFAMINE® polyoxyalkyleneamines are used in epoxy adhesives to give enhanced properties.
72			D. C. Alexander, Kathy B. Sellstrom, and T. L. Renken, "Derivatives of JEFFAMINE Amines: Preparation and Use in Adhesives," presented at the SPI/Epoxy Resin Formulators Conference, Charleston, S. Car., September 23-25, 1992.	Polyamidoamines and urea condensates of some of the JEFFAMINE® polyetheramines are prepared and used in epoxy adhesives to give enhanced properties.
<b>Coatings</b>				
73	245,559	EP	L. A. Nativi and P. L. Kropp (to Loctite), November 19, 1987.	Coating compositions for electronic circuit boards are comprised of epoxy resin, 200-6500 mol. wt. polyoxypropyleneamine, and UV-reactive ester. Coatings are immobilized with UV light, then allowed to cure completely under ambient conditions.
74	293,088	EP	R. P. Redman (to ICI), November 30, 1988.	A nonyellowing electrodeposition coating system contains an amine-epoxy adduct optionally prepared with polyoxyalkyleneamines.
75	324,950	EP	G. Off, U. Reiter, W. Jouck, D. Santure, and D. Ruhl (to BASF), July 26, 1989.	Electrically conductive substrates (motor vehicle bodies) are coated by electrodeposit into bath containing cationic amine-modified epoxy resin and a polyoxyalkyleneamine.
76	405,464	EP	Yasuhiro Kimura, et al. (to Ajinomoto Co., Inc.; Nippon Paint Co., Ltd.), June 28, 1989.	Acrylamide derivatives of JEFFAMINE® M-600 are used in radio-curable coating compositions.

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Ref	Patent #	Country	Author/Company or Publication/Date	Description
77	451,814	EP	Klaus, Cibura, John A. Gilbert, Yali F. Hallock, and John D. McGee (to BASF Corp.), October 16, 1991.	A phenol/epoxy adduct is reacted with formaldehyde and JEFFAMINE® D-2000 to produce a plasticizing resin useful in cathodic electrodeposition coatings.
78	972,096	CA	Jefferson Chemical Inc., July 29, 1975.	Epoxy compositions containing carbon disulfide and a polyoxyalkylenepolyamine are used as coatings on a variety of materials.
79	1,027,182	RU	G. R. Malkina, Z. N. Safina, and R. A. Dmitrieva (to All-Union Scientific Research Institute of Pump Engineering Technology), July 7, 1983.	A composition for coating floors, with increased light resistance, derives from an acrylate rubber latex containing glycidyl methacrylate units and a polyoxypropylenediamine hardener, along with a filler.
80	1,568,989	FR	Farbwerke Hoechst A.-G., May 30, 1967.	A hardened epoxide resin with increased resilience, useful for preparing coatings, lacquers, and varnishes, was prepared from linear, amine-terminated poly(propylene oxide) and glycidyl ethers.
81	2,462,453	GR	Dianippon, March 3, 1977.	Polyamides prepared from dimer acid and polyetherdiamines are used in aqueous epoxy coatings to provide good corrosion and chemical resistance.
82	2,519,390	GR	Henry Ashjian, Henry A. Gawel, and Archie K. Blakely (to Mobil Oil Corp.), November 13, 1975.	A polyamide was prepared from linoleic acid dimer, a polyoxypropylenetriamine (JEFFAMINE® T-403), and diethylenetriamine. Heated with epoxy resins, the polyamides gave water-based paints.
83	2,849,123	GR	H. G. Waddill (to Texaco Development Corp.), June 28, 1979.	Water-compatible polyamide hardeners of epoxy resins were prepared from aminopropyl derivatives of polyoxyalkylenepolyamines. Aqueous resin coating systems were prepared using the polyamide curatives.
84	3,203,974	JP	T. Matsunaga, M. Koseki, and H. Akiyama (to Sanyo Chemical Industries, Ltd.), September 5, 1991.	Urethane coatings exhibiting excellent chip and yellowing resistance contain polyoxyalkylenepolyamines or derivatives of the amines.
85	3,316,185	US	Norman H. Reinking (to Union Carbide Corp.), April 25, 1967.	Liquid glycol diamines were used to cure epoxy resins and form tough, impact-resistant coatings.
86	3,645,969	US	James R. Harvey (to Union Carbide Corp.), February 29, 1972.	Flexible, tough, clear coatings were prepared from bisphenol A diglycidyl ether resin and a polyglycol polyamine.
87	3,730,908	US	James R. Harvey (to Union Carbide Corp.), May 1, 1973.	A mixture of a polyglycol polyamine and an alkylene polyamine cured an epoxy resin to form coatings that were without haze and free of an oily surface blush.
88	3,943,104	US	H.G. Wadill (to Jefferson Chemical Co), March 9, 1976	Method of accelerating epoxy curing
89	3,947,339	US	Jerabek; Robert D.; Marchetti; Joseph R.; Zwack; Robert R. (for PPG, Ind.) March 9, 1976	Method of electrodepositing primary amine group-containing cationic resins
90	3,963,680	US	O'Keefe; Donald R.; Gasper; A. Joseph (for Minnesota Mining), June 15, 1976	One-part, room-temperature latent, curable isocyanate compositions

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Ref	Patent #	Country	Author/Company or Publication/Date	Description
91	3,998,771	US	Feneis, Jr.; Thomas John; Bryant; Miles Talmadge (for Mobil Oil), December 21, 1976	Water-based epoxy resin zinc-rich coating compositions
92	4,011,281	US	Waddill; Harold George; Schulze; Heinz (for Texaco Development Corporation), March 8, 1977	Polyether thiourea epoxy curing agents
93	4,017,438	US	Jerabek; Robert D.; Marchetti; Joseph R.; Zwack; Robert R. (for PPG Industries, Inc.) April 12, 1977	Ketimine-blocked primary amine group-containing cationic electrodepositable resins
94	4,102,866	US	Speranza; George P.; Waddill; Harold G. (for Texaco Development Corp), July 25, 1978	Method of making glycidyl ethers of novolak resins
95	4,110,310	US	Schulze; Heinz; Waddill; Harold G. (for Texaco Development Corp.), August 29, 1978	Polyether diamide epoxy additives
96	4,115,226	US	Zwack; Robert R.; Jerabek; Robert D.; (for PPG Ind), September 19, 1978	Cataphoretic electrodeposition baths containing water-soluble lead salts
97	4,136,092	US	Jackle; William A.; Mazzeo; Michael P; Gillis, Marina N. (for Thiokol Corp), January 23, 1979	Polyurethane curing agents
98	4,139,524	US	Waddill; Harold G. (for Texaco Development Corp), February 13, 1979	Bis ureide of a polyoxyalkylene polyamine as an epoxy additive
99	4,164,520	US	H. G. Waddill and H. P. Klein (to Texaco Development Corp.), August 14, 1979.	An epoxy resin cured with the reaction product from phenol, formaldehyde, and aminopropyl derivative of JEFFAMINE® amines offers relatively fast cure for coatings, adhesives, etc.
100	4,167,498	US	H. G. Waddill (to Texaco Development Corp.), September 11, 1979.	Epoxy curing agents useful in water-based coatings are prepared by reacting aminopropyl derivatives of JEFFAMINE® amines with acids in water.
101	4,179,418	US	H. G. Waddill (to Texaco Development Corp.), December 18, 1979.	A water-based epoxy coating is cured with a polyamide prepared from a carboxylic acid or derivative and an aminopropyl derivative of a polyoxypropylenepolyamine.
102	4,189,564	US	Waddill; Harold G. (for Texaco Development Corp), February 19, 1980	Non-crystallizing epoxy resin accelerator
103	4,260,720	US	Bosso; Joseph F.; Nugent; Richard M.; Plasynski; Joseph E. (for PPG Ind), April 7, 1981	Novel mercapto chain extended products and their use in cationic electrodeposition
104	4,269,879	US	Murray L. Davis (to the Dampney Co.), May 26, 1981.	Low-viscosity, solvent-free coatings were prepared. The curing system consisted of coal tar, cycloaliphatic amines, polyoxyalkylene- amines, and an accelerator.
105	4,292,155	US	Bosso; Joseph F.; Nugent; Richard M.; Plasynski; Joseph E. (for PPG Ind), September 29, 1981	Cationic electrodeposition employing novel mercapto chain extended products
106	4,304,889	US	H. G. Waddill and Heinz Schulze (to Texaco Inc.), December 8, 1981.	Chemically resistant epoxy coatings are prepared with an aromatic amine and the condensation product of maleic anhydride with JEFFAMINE® amines.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
107	4,316,003	US	Mark F. Dante and Roy A. Allen (to Shell Oil Co.), February 16, 1982.	An adduct suitable for curing waterborne epoxy systems comprises the reaction product of an epoxy resin with a monoamine which is reacted with a polyfunctional amine. Suitable polyfunctional amines are polyoxypropyleneamines (JEFFAMINE® products).
108	4,393,237	US	Yeakey; Ernest L.; Watts, Jr.; Lewis W. (for Texaco, Inc.) , July 12, 1983	Polyoxyalkylenepolyacrylamides
109	4,419,467	US	Wismer; Marco; Bosso; Joseph F. (for PPG Industries), December 6, 1983	Process for the preparation of cationic resins, aqueous, dispersions, thereof, and electrodeposition using the aqueous dispersions
110	4,420,574	US	Moriarity; Thomas C; Geiger; William J.( for PPG Industries), December 13, 1983	Ungelled polyepoxide-polyoxyalkylenepolyamine resins, aqueous dispersions thereof, and their use in cationic electrodeposition
111	4,421,906	US	H. G. Waddill and Kathy B. Sellstrom (to Texaco Inc.), December 20, 1983.	Epoxy resins modified with JEFFAMINE® M- or ED-series amines are used in water-based coating formulations.
112	4,423,166	US	Moriarity; Thomas C; Geiger; William J.( for PPG Industries), December 27, 1983	Ungelled polyepoxide-polyoxyalkylenepolyamine resins, aqueous dispersions thereof, and their use in cationic electrodeposition
113	4,436,890	US	Kaufman; Marvin L. (for Mobil Oil), March 18, 1984	Aromatic urea-based curing agent system for epoxy resin coating compositions
114	4,468,307	US	Wismer; Marco; Bosso; Joseph F. (for PPG Industries), August 28, 1994	Method of cationic electrodeposition
115	4,480,082	US	McLean; Paul D.; Garton; Andrew; Scott; Robert F.; Gransden; Susan E., (for Canadian Patents & Development Ltd), October 30, 1984	Epoxy resin fortifiers based on aromatic amides
116	4,528,345	US	H. G. Waddill (to Texaco Development Corp.), July 9, 1985.	Epoxy coatings are prepared by pre-reacting a polyoxyalkylenepolyamine or N-aminoethylpiperazine with a cycloaliphatic diepoxy resin and then curing with an accelerator.
117	4,532,299	US	Seneker; James A. (for Ameron, Inc), July 30, 1985	Flexibilized chemically resistant epoxy resin
118	4,536,600	US	Yeakey; Ernest L.; Watts, Jr.; Lewis W. (for Texaco, Inc.) , August 20, 1985	Polyoxyalkylenepolyacrylamides and the preparation thereof
119	4,576,980	US	Dai; Shenghong A.; Sherwood; Philip W. (for The Dow Chemical Co.), March 18, 1986	Azetidinedione compounds as crosslinkers for electrodeposited coatings
120	4,612,098	US	Dai; Shenghong A.; Sherwood; Philip W. (for The Dow Chemical Co.), March 18, 1987	
121	4,629,769	US	Waddill; Harold G.; Speranza; George P. (for Texaco, Inc.), December 16, 1986	4,4,6-trimethylhexahydropyrimidine as an epoxy curing agent
122	4,639,286	US	Rasmussen; Jerald K.; Heilmann; Steven M.; Palensky; Frederick J., (for 3M), January 27, 1987	Curable compositions containing azlactone-functional compounds

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Ref	Patent #	Country	Author/Company or Publication/Date	Description
123	4,647,646	US	Hardy; Alan; Agger; Reginald T.; Crabtree; Andrew, (for USM Corp), March 13, 1987	Heat curable compositions
124	4,659,787	US	Cummings; Lowell O. (for Chemcrete International Partnership), April 21, 1987	Method for making epoxy curing agents
125	4,665,191	US	Waddill; Harold G.; Speranza; George P. (for Texaco, Inc.), May 12, 1987	Mannich condensates
126	4,666,970	US	Zwack; Robert R.; Jerabek; Robert D. (for PPG Industries, Inc), May 19, 1987	Cataphoretic electrodeposition baths containing water-soluble lead salts
127	4,683,302	US	Dai; Shenghong A.; Sherwood; Philip W. (for The Dow Chemical Co), July 28, 1987	Azetidinedione compounds as crosslinkers for electrodeposited coat
128	4,690,980	US	Singer; Debra L.; Birkmeyer; William J.; Dowbenko; Rostyslaw; Kania; Charles M. (for PPG Industries, Inc.) , September 1, 1987	Acrylic modified polymers
129	4,695,618	US	Mowrer; Norman R. (for Ameron, Inc.), September 22, 1987	Solventless polyurethane spray compositions and method for applying them
130	4,716,209	US	Schmid, Ansel, and Murray (to DeSoto), December 29, 1987.	Electron beam-curable coatings are prepared from the reaction product of diols and JEFFAMINE® D-230 with excess isocyanate.
131	4,761,465	US	Speranza; George P.; Lin; Jiang-Jen; Cuscurida; Michael (for Texaco Inc.), August 2, 1988	Difunctional isocyanate-terminated polyoxyalkylene diamine prepolymers and polymer coatings applications
132	4,767,836	US	Cuscurida; Michael (for Texaco), August 30, 1988	Storage stable polyurethane coating
133	4,786,682	US	Perez; Leon A.; Crum, III; H. Hayne (for PPG Industries), November 22, 1988	Coating compositions prepared from Michael adducts
134	4,800,222	US	Waddill; Harold G. (for Texaco, Inc.) , January 24, 1989	Accelerator for curing epoxy resins comprising piperazine, triethanolamine and tris(dimethylaminomethyl)phenol
135	4,812,493	US	Cummings; Lowell O., (for Adhesive Coatings), March 14, 1989	Dual cure rate water-based coating compositions
136	4,816,533	US	Hisgen; Bernd; Kock; Hans-Jakob (for BASF), March 29, 1989	Wholly aromatic mesomorphic polyester amides and preparation thereof
137	4,824,925	US	Kamarchik, Jr.; Peter; McCollum; Gregory J.; Mauer; George W. (for PPG Industries), April 25, 1989	Novel blocked isocyanates and curable compositions containing the same
138	4,870,150	US	Bandlish; Baldev K.; Barron; Larry R. (for Tremco Inc.), September 26, 1989	Polyurethanes made from blends of polypropyleneoxide polyol and polybutyleneoxide polyol intermediates
139	4,880,872	US	Thomas; Arthur K, (for ICI Americas, Inc.), November 14, 1989	Heat resistant high modulus reaction injection molding (RIM) polymers, blends used in the production thereof and a process for producing the same
140	4,886,842	US	Drain; Kieran F; Kadziela; Kris (for Loctite Corp), December 12, 1989	Epoxy-amine compositions employing unsaturated imides



## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
141	4,886,867	US	Lin; Jiang-Jen; Speranza; George P. (for Texaco Inc.), December 12, 1989	Novel compositions from polyoxyalkylene amines and epoxides
142	4,891,111	US	McCollum; Gregory J.; Zwack; Robert R.; Scriven; Roger L. (for PPG Industries Inc), January 2, 1990	Cationic electrocoating compositions
143	4,904,751	US	Speranza; George P.; Lin; Jiang-Jen; Cuscurida; Michael (for Texaco Chemical Co), February 27, 1990	N,N'-dialkyl substituted polyoxyalkylene amines as curing agents for blocked isocyanates
144	4,906,726	US	Cummings; Lowell, (Adhesive Coatings Co), March 6, 1990	Water-based coating compositions containing hydroxides and oxides of calcium, strontium and barium
145	4,906,774	US	Speranza; George P.; Lin; Jiang-Jen; Cuscurida; Michael, (Texaco, Inc), March 6, 1990	Process for preparing diamines
146	4,910,269	US	Waddill; Harold G., (Texaco Chemical Co), March 20, 1990	Polyether polyamine-piperazine cured cycloaliphatic epoxy resin compositions
147	4,916,199	US	Bandlish; Baldev K. Barron; Larry R. (for The BF Goodrich Corp Co), April 10, 1990	Polyurethanes made from blends of polypropyleneoxide polyol and organic-silicone block copolymer based polyol intermediates
148	4,929,661	US	Noomen; Arie; Peters; Petrus J., (for Akzo NV), May 29, 1990	Aqueous coating composition containing a functional organic compound, a curing agent, and a dispersing agent
149	4,931,157	US	Valko; Joseph T.; Plasynski; Joseph E. ; Miller; Robert D. (for PPG Industries), June 5, 1990	Epoxy resin advancement using urethane polyols and method for use thereof
150	4,933,056	US	Corrigan; Victor G.; Zawacky; Steven R. (for PPG Industries), June 12, 1990	Cationic electrodepositable compositions through the use of sulfamic acid and derivatives thereof
151	4,937,318	US	Yamaguchi; Keizaburo; Tanabe; Yoshimitsu; Urakami; Tatsuhiro; Yamaguchi; Akihiro; Yamaya; Norimasa; Ohta; Masahiro (for Mitsui Toatsu Chemicals), June 26, 1990	Aromatic amine resins
152	4,940,770	US	Speranza; George P.; Lin; Jiang-Jen, (for Texaco Chemical Co), July 10, 1990	Novel compositions from polyoxyalkylene amines and epoxides
153	4,946,924	US	Speranza; George P.; Lin; Jiang-Jen; Templeton; James H. (for Texaco Chemical Co), August 7, 1990	Secondary isopropyl amine derivatives of polyoxyalkylene diamines and triamines
154	4,981,944	US	Bartels; Tamme; Maters; Gerardus J. W. M., (for Akzo NL), January 1, 1991	Liquid coating composition curable at ambient temperatures
155	4,996,282	US	Noren; Gerry K.; Krajewski; John J.; Murphy; Edward J. (for DeSoto, Inc), February 26, 1991	Cationically curable polyurethane compositions having vinyl ether functionality
156	5,017,632	US	Charles W. Bredow, Frederick J. Schindler, and Charles E. Warburton, Jr. (to Rohm & Haas Co.), May 21, 1991.	Filled water-based coating compositions for concrete and metal are prepared using epoxy resin, acrylic polymer latex, and JEFFAMINE EDR-148.
157	5,017,676	US	Cuscurida; Michael (for Texaco), May 21, 1991	Acetoacetoxyethyl methacrylate in the cure of epoxy resins

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
158	5,051,494	US	Yamaguchi; Keizaburo; Tanabe; Yoshimitsu; Urakami; Tatsuihiro; Yamaguchi; Akihiro; Yamaya; Norimasa; Ohta; Masahiro (for Mitsui Toatsu Chemicals), September 24, 1991	Thermosetting resin composition comprising an aromatic amine
159	5,070,119	US	R. M. Nugent, Jr., T. A. Ward, P. D. Greigger, and J. A. Seiner (to PPG Industries, Inc.), December 3, 1991.	A flexible intumescent coating composition cured in part with JEFFAMINE® D-2000 did not crack in 27 cold test cycles.
160	5,075,503	US	Lin; Jiang-Jen; Speranza; George P. (for Texaco Inc.), December 24, 1991	Hydrazine terminated polyoxyalkylene amines
161	5,081,168	US	Granville D. Edwards and Bonita S. Wilson (to Shell Oil Co.), January 14, 1992.	A polyoxyalkylenediamine, a polyamide, and 2-ethyl-4-methyl-imidazole are used to cure an epoxy system for in situ rehabilitation of fractured and/or corroded pipes.
162	5,086,162	US	Speranza, GP; Su, W-Y (for Texaco Chemical) February 4, 1992	Polyether amide from polyalkylene glycol diamine and diacid mixture
163	5,087,661	US	Aoki; Masaaki; Kamiyama; Masay GBi; Honda; Hiroshi, (for Mitsui Toatsu Chemicals), February 11, 1992	Moisture curable polyurethane composition comprising polyaldimine
164	5,091,574	US	Lin; Jiang-Jen; Speranza; George P. (for Texaco Chemical Corp), February 25, 1992	Polyoxyethylene diamine derivatives of diglycidyl ethers
165	5,093,455	US	Cuscurida; Michael; Speranza; George P.; Su; Wei-Yang, (for Texaco Chemical Corp), March 3, 1992	N,N-dialkylenediamines as curing agents for blocked isocyanate coatings
166	5,096,556	US	Corrigan; Victor G.; Zawacky; Steven R.(for PPG Industries) , March 17, 1992	Cationic microgels and their use in electrodeposition
167	5,098,947	US	Metzger; Carl W.; Hauefler; Hartmut; Munch; Jurgen; Freese; Karl-Heinz; Orth; Ulrich (for Akzo NV), March 24, 1992	Waterborne coatings and binder systems for use therein
168	5,106,945	US	Hare; Clive H. (FOR Monsanto Co), April 21, 1992	Polyglycidamide-poly(meth)-acryloyl-polyamine compositions
169	5,108,832	US	Nugent, Jr.; Richard M.; Ward; Thomas A.; Greigger; Paul P; Seiner; Jerome A. (for PPG Industries Inc), April 28, 1992	Flexible intumescent coating composition
170	5,151,470	US	Sanders; Joseph; Mafoti; Robson; Markusch; Peter H. (for Miles Inc), September 29, 1992	Aminocrotonates as curing agents for epoxy resins
171	5,178,646	US	Barber, Jr.; Loren L.; Christianson; Todd J.; Preston; Jay B. (For 3M), January 12, 1993	Coatable thermally curable binder precursor solutions modified with a reactive diluent, abrasive articles incorporating same, and methods of making said abrasive articles
172	5,189,073	US	Klockemann Werner; Humbert Heiko; Primeaux; Dudley J (for Texaco Chemical) February 23, 1993	Process For The Production Of Expanded Materials Based On Polyurea Elastomers

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
173	5,191,033	US	Cuscurida; Michael; Speranza; George P.; Sellstrom; Kathy B. (for Texaco Chemical Corp), March 2, 1993	Epoxy resin composition containing aminated epoxy resin-alkylene oxide polyols
174	5,202,383	US	Moriarty; Thomas C.; McCollum; Gregory J.; Zwack; Robert R.; Scott; Matthew S.; Zawacky; Steven R.; Corrigan; Victor G. (for PPG Industries), April 13, 1993	High throw power electrodeposition system
175	5,204,385	US	Naderhoff; Bryan A. (for Reichhold Chemicals Inc), April 20, 1993	Water reducible epoxy resin curing agent
176	5,206,200	US	Bush; Richard W.; Carney; Eugene E (for WR Grace & Co), April 27, 1993	Tin catalysts for hydrolysis of latent amine curing agents
177	5,213,897	US	Baron; Arthur L.; MacLeay; Ronald E.; Kmiec; Jennifer P. (for Elf Atochem North America, Inc), May 25, 1993	Epoxy resins containing bound light stabilizing groups
178	5,221,707	US	Chihara; Kohji Y.; Goewey; James R. (for GenCorp, Inc.) , June 22, 1993	Coating blend compositions
179	5,227,198	US	Laura; Alger E.; Easton; Ronald J.; Frisch; Kurt C.; Xiao; Han X. (for A-Line Products), July 13, 1993	Aqueous coating composition and method of use
180	5,233,009	US	Madan; Sanjeev; Kogelnik; Hans-Joachim; Daneshvar; Majid; Pantone; Richard S.; Clatty; Jan L. R. (for Miles, Inc.) August 3, 1993	Polyurethanes comprising the reaction of an isocyanate terminated prepolymer and a polyol mixture comprising triols and an organic diamine
181	5,235,007	US	Alexander; David C.; Crawford; Wheeler C.; Klein; Howard P. (for Texaco Chemical Co), August 10, 1993	Epoxy curing agents
182	5,246,984	US	Darwen; Stuart P.; Cornforth; Daniel A. (for Air Products & Chemicals Inc), September 21, 1993	Water dispersible polyamine-epoxy adduct and epoxy coating composition
183	5,300,363	US	Laura; Alger E.; Easton; Ronald J.; Frisch; Kurt C.; Xiao; Han X. (for A-Line Products Corp), April 5, 1994	Aqueous coating composition
184	5,300,584	US	Farkas; Julius, (for The BF Goodrich Corp), April 5, 1994	Low viscosity diprimary amine reactive modifiers for epoxy resins
185	5,312,886	US	House; David W.; Scott, Jr.; Ray V. ; Gattuso; Mark J. (for UOP), May 17, 1994	Bis(N-alkylaminocyclohexyl)methanes as curing agents for polyurethanes and polyureas
186	5,318,851	US	Baron; Arthur L.; MacLeay; Ronald E.; Kmiec; Jennifer P. (for Elf Atochem North America, Inc), June 7, 1994	Epoxy resins containing bound light stabilizing groups
187	5,320,716	US	Akhtar Masud, June 14, 1994	Electroactive, insulative and protective thin films
188	5,320,738	US	Kaufman; Marvin L. (for PPG Industries), June 14, 1994	Reduced yellowing electrodepositable coating composition
189	5,338,568	US	Lohnes; Steven A.; Crowne; Francis R. (for Cappas Ltd), August 16, 1994	Additive for two component epoxy resin compositions
190	5,342,918	US	Howelton Richele T; Speranza George P (for Texaco Chemical Corp) August 30, 1994	Carboxyl-terminated polyetheramines

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
191	5,359,123	US	Ohshima; Toshiyuki; Ishibashi; Hideo; Tamura; Rie; Yamamoto; Satoshi; Izumo; Takaharu (for Nippon Paint Co Ltd) October 25, 1994	Polyoxyalkylene polyamines having secondary amino groups
192	5,382,606	US	Butikofer; Pierre-Andre (for Sika AG, vorm. Kaspar Winkler & Co) January 17, 1995	Curing agent for aqueous epoxy resin dispersions, process for its preparation and its use
193	5,391,596	US	Muto; Kiyoshi; Suzuki; Hiroshi (for Asahi Denka Kogyo KK; A.C.R. Co. Ltd.) February 21, 1995	Emulsifying epoxy resin composition and curable composition
194	5,422,042	US	Waddill; Harold G.; Su; Wei-Yang; Cuscurida; Michael; Renken; Terry L. (for Huntsman Corp) June 6, 1995	Imidazolidone polyetheramine strength enhancing additives of epoxy resin systems
195	5,427,856	US	Laura; Alger E.; Easton; Ronald J.; Frisch; Kurt C.; Xiao; Han X. (for A-Line Products Corp) June 27, 1995	Aqueous coating composition
196	5,430,107	US	Bederke; Klaus; Kerber; Hermann; Schubert; Walter; Brock; Thomas; Löffler; Helmut (for Hreberts GmbH), July 4, 1995	Binding-agent composition, coating agent containing said binding agent, and the use thereof
197	5,461,122	US	Yilgor; Iskender; Yilgor; Emel O. (for Th. Goldschmidt AG), October 24, 1995	Waterproof, moisture vapor permeable polyurethane urea polymer comprising polycaprolactone and polydimethyl siloxane soft segments
198	5,475,039	US	Butikofer; Pierre-Andre (for Sika AG, vorm. Kaspar Winkler & Co) December 12, 1995	Curing agent for aqueous epoxy resin dispersions, process for its preparation and its use
199	5,488,092	US	Kausch; Charles M.; Melby; Earl G.; Sharma; Satish C. (for GenCorp, Inc.) January 30, 1996	Low VOC, primerless, polyurethane compositions
200	5,489,630	US	Walker; Frederick H. (for Air Products and Chemical Inc.) February 6, 1996	Self-emulsifying epoxy curing agent
201	5,508,324	US	Cook; Michael I. (for Air Products and Chemicals Inc.) April 16, 1996	Advanced polyamine adduct epoxy resin curing agent for use in two component waterborne coating systems
202	5,508,326	US	Muto; Kiyoshi; Suzuki; Hiroshi (for Asahi Denka Kogyo KK; A.C.R. Co. Ltd.) April 16, 1996	Emulsifying epoxy resin composition and curable composition
203	5,508,373	US	Shah; Shailesh; Moon; Robert M. (for Henkel Corp) April 16, 1996	Curing agents for epoxy resins based on 1,2-diaminocyclohexane
204	5,510,432	US	Schmalstieg; Lutz; Rettig; Rainer; Konig; Eberhard (for Bayer Aktiengesellschaft) April 23, 1996	Mixed blocked isocyanate prepolymers, a process for their production and their use for the production of flexible epoxy resin systems
205	5,521,273	US	Yilgor; Iskender; Yilgor; Emel O. (for Th. Goldschmidt AG), May 28, 1996	Waterproof, moisture vapor permeable polymers, films and coated textiles and other materials
206	5,527,839	US	Walker; Frederick H. (for Air Products and Chemical Inc.) June 18, 1996	Self-emulsifying epoxy curing agent based on the reaction product of epoxy resin and polyether polyol
207	5,536,775	US	Curatolo; Benedict S.; Apicella, Jr.; Frank V.; Richardson, Sr.; Thomas W. (for Sandoz, Ltd) July 16, 1996	Amine curable compositions

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Ref	Patent #	Country	Author/Company or Publication/Date	Description
208	5,539,042	US	Birch; D'Arcie W. (for 3M) July 23, 1996	Aqueous, coatable, thermally condensable composition
209	5,565,505	US	Papalos; John G.; Grinstein; Reuben H.; Shah; Shailesh; Mulvey; Joseph L.; Jewell; Brian G. (for Henkel Corp) October 15, 1996	Self-dispersing curable epoxy resins, dispersions made therewith, and coating compositions made there from.
210	5,565,506	US	Papalos; John G.; Grinstein; Reuben H.; Shah; Shailesh; Mulvey; Joseph L.; Jewell; Brian G. (for Henkel Corp) October 15, 1997	Self-dispersing curable epoxy resins, dispersions made therewith, and coating compositions made therefrom
211	5,567,480	US	Johnson; John R.; Roder; William R.; Henegar; C. Sherill (for Reily Industries Inc) October 22, 1996	Coal tar enamel coated steel pipe and process for producing same
212	5,567,748	US	Klein; Dieter H.; Wessely; Hans J. (for The Dow Chemical Co) October 22, 1996	Water compatible amine terminated resin useful for curing epoxy resins
213	5,569,687	US	Sanborn; Timothy P.; Beno, Jr.; Joseph M.; Flynn; Roy W. (for Rohm & Haas Co) October 29, 1996	Waterborne zinc-rich primer compositions
214	5,576,416	US	Walker; Frederick H. (for Air Products & Chemicals Inc) November 19, 1996	Amide-containing self-emulsifying epoxy curing agent
215	5,582,704	US	Valko; Joseph T.; Faucher; Philippe; Karabin; Richard F.; Moriarity; Thomas C.; Eswarakrishnan; V.; Van Buskirk; Ellor J.; McCollum; Gregory J.; Kollah; Raphael O. (for PPG Industries Inc) December 10, 1996	Cationic resin and capped polyisocyanate curing agent suitable for use in electrodeposition
216	5,583,167	US	Chou; Jason L.; Shah; Shailesh; Jewell; Brian G.; Moon; Robert M. (for Henkel Corp) December 10, 1996	Curing agents for aqueous epoxy resins
217	5,587,409	US	Dreischhoff; Dieter; Geisler; Joerg-Peter; Godau, Claus; Hoenel, Michael; Stengel-Rutkowski, Bernhard (for Hoechst Aktiengesellschaft) December 24, 1996	Curing agents for aqueous epoxy resin dispersions
218	5,589,534	US	Metzger; Carl W.; Feith; Bernhard H.; Gruber; Ute; Zedler; Angelika A.; van Wingerde; Mario M. M. (for Akzo Nobel NV) December 31, 1996	Aqueous coating compositions including a reactive emulsifier
219	5,596,030	US	Walker; Frederick H. (for Air Products & Chemicals Inc) January 21, 1997	Amide-containing self-emulsifying epoxy curing agent
220	5,599,855	US	Walker; Frederick H. (for Air Products & Chemicals Inc) February 4, 1997	Self-emulsifying epoxy curing agent
221	5,604,269	US	Papalos; John G.; Shah; Shailesh; Grinstein; Reuben H.; Mulvey; Joseph L.; Jewell; Brian G. (for Henkel Corp) February 18, 1997	Self-dispersing curable epoxy resins, dispersions made therewith, and coating compositions made there from
222	5,606,010	US	Erhan; Semih; Nithianandam; Varabelambedu S. (for Erham, Semih) February 25, 1997	Methods for the preparation of inherently metal binding poly-amine-quinone polymers

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
223	5,620,747	US	Laura; Alger E.; Easton; Ronald J.; Frisch; Kurt C.; Xiao; Han X (A-line Products Corp) April 15, 1997	Aqueous coating composition
224	5,623,046	US	Papalos; John G.; Shah; Shailesh; Grinstein; Reuben H.; Mulvey; Joseph L.; Jewell; Brian G. (for Henkel Corp) April 22, 1997	Self-dispersing curable epoxy resins, dispersions made therewith, and coating compositions made there from
225	5,626,915	US	Laura; Alger E.; Easton; Ronald J.; Frisch; Kurt C.; Xiao; Han X. (for A-Line Products Corp) May 6, 1997	Aqueous coating composition
226	5,629,046	US	Laura; Alger E.; Easton; Ronald J.; Frisch; Kurt C.; Xiao; Han X. (for A-Line Products Corp) May 13, 1997	Aqueous coating composition
227	5,630,922	US	Eswarakrishnan; Venkatachalam; Zwack; Robert R.; McCollum; Gregory J.; Kollah; Raphael O. ; Zawacky; Steven R. (for PPG Industries Inc) May 20, 1997	Electrodepositable coating composition containing diorganotin dicarboxylates
228	5,643,976	US	Arora; Kartar S.; Wiggins; Michael S. (for Henkel Corp) July 1, 1997	Self-dispersing curable epoxy resin dispersions and coating compositions made there from
229	5,648,409	US	Arora; Kartar S.; Devore; David I.; Grinstein; Reuben H.; Johnson; Grannis S.; Papalos; John G.; Shah; Shailesh (for Henkel Corp) July 15, 1997	Aqueous self-dispersible epoxy resin based on epoxy-amine adducts containing aromatic polyepoxide
230	5,652,024	US	Sanborn; Timothy Parker; Beno, Jr.; Joseph Michael; Flynn; Roy Wesley (for Rohm & Haas Co) July 29, 1997	Waterborne zinc-rich primer compositions
231	5,652,323	US	Papalos; John G.; Grinstein; Reuben H.; Shah; Shailesh; Mulvey; Joseph L.; Jewell; Brian G. (for Henkel Corp) July 29, 1997	Self-dispersing curable epoxy resins, dispersions made therewith, and coating compositions made there from
232	5,656,712	US	Mirossay; Thomas C., August 12, 1997	Polyurethane compositions and method
233	5,674,567	US	Kausch; Charles M.; Melby; Earl G; Sharma; Satish C. (for GenCorp Inc) October 7, 1997	Low VOC, primerless, polyurethane compositions
234	5,674,951	US	Hargis; I. Glen; Kausch; Charles M.; Livigni; Russell A.; Malik; Aslam A.; Melby; Earl G.; Vitus; Francis Jerome (for GenCorp Inc) October 7, 1997	Abrasion-resistant and low friction coating compositions
235	5,684,080	US	van der Heide; Evert; Vietje; Gerrit; Wang; Pen-Chung (for Shell Oil Co) November 4, 1997	Aqueous polymer emulsion
236	5,688,877	US	Koenig; Raymond A.; Gan; Joseph; Hayman; Richard J. (for The Dow Chemical Co) November 18, 1997	Kinetically controlled in-situ generation of catalytic species for the curing of epoxy/amine compositions
237	5,688,905	US	Walker; Frederick Herbert (for Air Products & Chemicals Inc) November 18, 1997	Primary-tertiary diamines mixed with polyamines as epoxy resin hardeners

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
238	5,693,423	US	Laura; Alger E.; Easton; Ronald J.; Frisch; Kurt C.; Xiao; Han X (for A-Line Products Corp) December 2, 1997	Aqueous coating composition
239	5,713,393	US	Johnson; John R.; Roder; William R.; Henegar; C. Sherill (for Reily Industries Inc) February 3, 1998	Coal tar enamel coated steel pipe and process for same
240	5,719,210	US	Arora; Kartar S.; Shah; Shailesh (for Henkel Corp) February 17, 1998	Self-dispersing curable epoxy resins, dispersions made therewith, and coating compositions made there from
241	5,723,565	US	Cuscurida; Michael; Sellstrom; Kathy Beth (for Huntsman Petrochemical Corp) March 3, 1998	Epoxy curing agents
242	5,726,251	US	Wilkinson; Steven Paul; DePinto; Jeffrey Thomas (for Air Products and Chemicals Inc) March 10, 1998	Powder coatings of amine-reactive resins and amine carbamate salts
243	5,750,595	US	Arora; Kartar S.; Wiggins; Michael S. (for Henkel Corp) May 12, 1998	Self-dispersing curable epoxy resin dispersions and coating compositions made there from
244	5,756,566	US	Laura; Alger E. (for A-Line Products Corp) May 26, 1998	Aqueous coating composition
245	5,760,107	US	Valko; Joseph T.; Faucher; Philippe; Karabin; Richard F.; Moriarity; Thomas C.; Eswarakrishnan; V. ; Van Buskirk; Ellor J.; McCollum; Gregory J.; Kollah; Raphael O. (for PPG Industries Inc) June 2, 1998	Cationic resin and capped polyisocyanate curing agent suitable for use in electrodeposition
246	5,760,108	US	Arora; Kartar S.; Johnson; Grannis S.; Aloye; James (for Henkel Corp) June 2, 1998	Self-dispersing curable epoxy resin esters, dispersions thereof and coating compositions made there from
247	5,763,506	US	Papalos; John G.; Grinstein; Reuben H.; Shah; Shailesh; Mulvey; Joseph L.; Jewell; Brian G. (for Henkel Corp) June 9, 1998	Self-dispersing curable epoxy resins, dispersions made therewith, and coating compositions made there from
248	5,767,191	US	Zawacky; Steven R.; Zwack; Robert R.; McCollum; Gregory J.; Eswarakrishnan; Venkatachalam; Coleridge; Edward R. (for PPG Industries Inc) June 16, 1998	Electrodepositable coating compositions and method for improved cure response
249	5,770,657	US	Chou; Jason L.; Shah; Shailesh; Jewell; Brian G.; Moon; Robert M. (for Henkel Corp) June 23, 1998	Curing agents for aqueous epoxy resins
250	5,798,398	US	Shah; Shailesh; Cash; Ronald J.; LaFreed; Ronald; Aloye; James; Mulvey; Joseph L. (for Henkel Corp) August 25, 1998	Epoxy curing agent comprising a metaxylylenediamine-epichlorohydrin adduct
251	5,804,051	US	Boyd; Donald W.; Zwack; Robert R.; Kollah; Raphael O.; McCollum; Gregory J. (for PPG Industries Inc) September 8, 1998	Electrodepositable coating compositions containing hydroxamic acid and derivatives thereof, and their use in a method of electrodeposition

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<b>Ref</b>	<b>Patent #</b>	<b>Country</b>	<b>Author/Company or Publication/Date</b>	<b>Description</b>
252	5,804,640	US	Laura; Alger E.; Easton; Ronald J.; Frisch; Kurt C.; Xiao; Han X. (for A-Line Products Corp) September 8, 1998	Aqueous coating composition
253	5,820,987	US	Kaufman; Marvin L.; O'Neill; Patrick; Karabin; Richard F.; McCollum; Gregory J. (for PPG Industries Inc) October 13, 1998	Cationic electrocoating compositions, method of making, and use
254	5,843,580	US	van der Heide; Evert; Vietje; Gerrit; Wang; Pen-Chung (for Shell Oil Co) December 1, 1998	Aqueous polymer emulsion
255	5,851,618	US	Liddell; Kimm Alan; Marzouk; Mohsen Mohamed (for Illinois Tool Works Inc) December 2, 1998	Peelable floor coating systems
256	5,859,125	US	van der Heide; Evert; Vietje; Gerrit; Wang; Chung (for Shell Oil Co) January 22, 1999	Aqueous polymer emulsion
257	5,859,135	US	Doomen; Willy Frans Anna; van Wingerde; Mario Martinus Maria (for Akzo Nobel NV) January 12, 1999	Aqueous coating compositions comprising functional group-containing crosslinkable resins
258	5,869,571	US	van der Heide; Evert; Vietje; Gerrit; Wang; Chung (for Shell Oil Co) February 9, 1999	Aqueous polymer emulsion
259	5,874,490	US	Arora; Kartar S.; Papalos; John G.; Johnson; Grannis S. (for Henkel Corp) February 23, 1999	Aqueous self-dispersible epoxy resin based on epoxy-amine adducts
260	5,880,190	US	Laura; Alger E (for A-Line Products Corp) March 9, 1999	Aqueous coating composition
261	5,936,012	US	Kaufman; Marvin L.; O'Neill; Patrick; Karabin; Richard F.; McCollum; Gregory J. (for PPG Industries Inc) August 10, 1999	Cationic electrocoating compositions, method of making, and use
262	5,948,229	US	Zwack; Robert R.; Eswarakrishnan; V.; Coleridge; Edward R.; McCollum; Gregory J. (for PPG Industries Ohio Inc) September 7, 1999	Electrodepositable coating compositions having improved cure response
263	5,965,673	US	Hermansen; Ralph D.; Lau; Steven E (for Raytheon Co) October 12, 1999	Epoxy-terminated prepolymer of polyepoxide and diamine with curing agent
264	5,972,189	US	McMurdie; Neil D.; Zwack; Robert R.; Scott; Matthew S.; White; Michael L. (for PPG Industries Ohio Inc) October 26, 1999	Electrodepositable coating composition containing bismuth diorganodithiocarbamates and method of electrodeposition
265	5,993,972	US	Reich; Murray H.; Teffenhart; John; Kuzma; Jirina (for Tyndale Plains-Hunter, Ltd) November 30, 1999	Hydrophilic and hydrophobic polyether polyurethanes and uses therefore
266	6,008,313	US	Walker; Frederick Herbert; Starnier; William Edward; Smith; Andrea Kare (for Air Products & Chemicals) December 28, 1999	Polyamide curing agents based on mixtures of polyethyleneamines and piperazine derivatives



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Ref	Patent #	Country	Author/Company or Publication/Date	Description
267	6,017,432	US	Boyd; Donald W.; Eswarakrishnan; Venkatachalam; McCollum; Gregory J.; Zwack; Robert R. (for PPG Industries Ohio Inc) January 25, 2000	Electrodepositable coating compositions and their use in a method of cationic electrodeposition
268	6,037,444	US	Rannard; Steven Paul; Davis; Nicola Jane (for Courtaulds Coatings Ltd) March 14, 2000	Selective chemical reactions and polymers of controlled architecture produced thereby
269	6,110,341	US	McMurdie; Neil D.; Zwack; Robert R.(for PPG Industries Ohio Inc) August 29, 2000	Electrodeposition baths containing organic phosphorous-based compounds
270	6,127,459	US	Stark, deceased; Charles J.; Back; Gayle Edward; Elmore; Jimmy D.; Ghosh; Kalyan; Wang; Pen-Chung; Dangayach; Kailash (for Shell Oil Co) October 3, 2000	Epoxy resin curing agent-reacting acid-terminated polyalkylene glycol with excess amine-terminated polyamine-epoxy resin adduct
271	6,136,894	US	Stark, deceased; Charles J.; Back; Gayle Edward; Elmore; Jimmy D.; Ghosh; Kalyan; Wang; Pen-Chung; Dangayach; Kailash (for Shell Oil Co) October 24, 2000	Aqueous epoxy resin system with curing agent from reacting acid-terminated polyalkylene glycol with epoxy-amine adduct
272	6,153,709	US	Xiao; Hong; Hsu; Gloria (for Essex Specialty Products Inc) November 28, 2000	Chip resistant, vibration damping coatings for vehicles
273	6,174,977	US	Ariyoshi; Yasushi; Suzuki; Takehiro (for Toyo Ink Mfg Co, Ltd) January 16, 2001	Cold curable resin composition and base material coated with the same
274	6,190,525	US	Karabin; Richard F.; Kaylo; Alan J. (for PPG Industries Ohio Inc) February 20, 2001	Electrodeposition baths containing yttrium
275	6,220,305	US	Johnson; John R.; Roder; William R.; Henegar; C. Sherill (for Reilly Industries Inc) April 24, 2001	Coal tar enamel coated steel pipe and process for same
276	6,221,934	US	Stark; (deceased) Charles J.; Elmore; Jimmy D.; Back; Gayle Edward; Wang; Pen-Chung; Galgoci, Jr.; Ernest Charles (for Shell Oil Co) April 24, 2001	Aqueous dispersions of epoxy resins
277	6,221,998	US	Okuhira; Hiroyuki; Adachi; Naoya (for The Yokohama Rubber Co Ltd) April 24, 2001	One-pack type moisture-curable composition
278	6,225,376	US	Klein; Dieter H.; Joerg; Karin C. (for The Dow Chemical Co) May 1, 2001	In-situ emulsified reactive epoxy polymer compositions
279	6,235,811	US	Robeson; Lloyd Mahlon; Dubowik; David Alan (for Air Products & Chemicals Inc) May 22, 2001	Epoxy resin-vinyl acetate polymer blends
280	6,245,835	US	Klein; Dieter H.; Wessely; Hans Juergen; Joerg; Karin C. (for The Doe Chemical Co) June 12, 2001	Polymeric amines and reactive epoxy polymer compositions

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Ref	Patent #	Country	Author/Company or Publication/Date	Description
281	6,248,225	US	Palaika; Thomas; Van Buskirk; Ellor J.; Corrigan; Victor G.; Eswarakrishnan; Venkatachalam; McCollum; Gregory J.; Zwack; Robert R.; Faucher; Philippe; Wilson; Craig A.; Szymanski; Chester J.; Poole; James E.; Ritter; Keith S.; Syput; Richard F. (for PPG Industries Ohio Inc) June 19, 2001	Process for forming a two-coat electrodeposited composite coating the composite coating and chip resistant electrodeposited coating composition
282	6,258,919	US	Vogel; Thomas; Wegmann; Alex (for Vantico Inc) July 10, 2001	Curable epoxy resin compositions containing water-processable polyamine hardeners
283	6,258,920	US	Starnier; William Edward; Dubowik; David Alan; Walker; Frederick Herbert (for Air Products & Chemicals Inc.) July 10, 2001	Polyamidoamine curing agents based on mixtures of fatty and aromatic carboxylic acids
284	6,265,519	US	Krebaum; Paul (for Molex Inc) July 24, 2001	Thiolamide curing agents
285	6,271,333	US	Okuhira; Hiroyuki (for The Yokohama Rubber Co Ltd) August 7, 2001	One-part moisture curable composition
286	6,277,903	US	Sophiea; Daniel P.; Hoffman; Dwight K.; Hong; Xiao; Hsu; Gloria (for The Dow Chemical Co. Essex Specialty Products) August 21, 2001	Sound damping coating of flexible and rigid epoxy resins
287	6,277,928	US	Stark; (deceased) Charles J.; Back; Gayle Edward; Elmore; Jimmy D.; Ghosh; Kalyan; Wang; Pen-Chung; Dangayach; Kailash , August 21, 2001	Epoxy-functional amidoamine reacted with excess polyamine and monoepoxy as epoxy curative
288	6,281,321	US	Kelly; Sarah Anne Mackie; Birkert; Christopher Robin; Andrews; Adrian Ferguson (for Akzo Nobel NV) August 28, 2001	Coating compositions
289	6,294,596	US	Papalos; John G.; Shah; Shailesh; Grinstein; Reuben H.; Mulvey; Joseph L.; Jewell; Brian G. (for Henkel Corp) September 25, 2001	Self-dispersing curable epoxy resins, dispersions made therewith, and coating compositions made there from
290	6,297,320	US	Tang; Weilin; Ding; Hong; D'Errico; Michael J.; Leonard; David P. (for The Sherwin-Williams Co) October 2, 2001	Curable compositions comprising acetoacetoxy and imine functionality
291	6,303,672	US	Papalos; John G.; Shah; Shailesh; Grinstein; Reuben H.; Mulvey; Joseph L.; Jewell; Brian G. (for Henkel Corp) October 16, 2001	Self-dispersing curable epoxy resins, dispersions made therewith, and coating compositions made there from
292	6,359,037	US	Stark; (deceased) Charles J.; Back; Gayle Edward; Elmore; Jimmy D.; Ghosh; Kalyan; Wang; Pen-Chung ; Dangayach; Kailash , March 19, 2002	Polyamine/epoxy-functional amidoamine product with epoxy resin
293	6,417,292	US	Moriarty; Thomas C.; Eswarakrishnan; Venkatachalam; Ritter; Keith S. (for PPG Industries Ohio Inc) July 9, 2002	Electrodepositable coating compositions including ungelled reaction products of epoxy functional polyesters and amines coated substrates and methods of electrocoating using the same

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Ref	Patent #	Country	Author/Company or Publication/Date	Description
294	6,423,425	US	Faucher; Philippe; McCollum; Gregory J.; Zwack; Robert R.; Pawlik; Michael J.; Van Buskirk; Ellor James; Corrigan; Victor G (for PPG Industries Ohio Inc) July 23, 2002	Article having a chip-resistant electrodeposited coating and a process for forming an electrodeposited coating
295	6,437,055	US	Moriarty; Thomas C.; Webster, Jr.; Geoffrey R. (for PPG Industries Ohio Inc) August 20, 2002	Electrodepositable coating from gelled epoxy-polyester and amine
296	6,479,103	US	Wichelhaus; Winfried; Lorenz; Wolfgang; Kunz; Andreas; Krey; Wolfgang (for Henkel Kommanditgesellschaft auf Aktien) November 12, 2002	Conductive organic coatings
297	6,489,396	US	Nakamura; Kazuhiko; Yokota; Yoshiyuki; Takahashi; Kunio; Yoshida; Masaya (for Nippon Shokubai Co Ltd) December 3, 2002	(Meth)acrylate ester-based resin composition
298	6,525,159	US	Okuhira; Hiroyuki; Adachi; Naoya; Ishikawa; Kazunori; Takeda; Toshimitsu; Kotani; Yo (for Yokohama Rubber Co Ltd) February 25, 2003	One-pack cold moisture curable resin compositions
299	6,538,060	US	Rajalingam; Ponswamy; Rajalingam; Umarani (for Urecoats International Inc) March 23, 2003	Bituminous polyurethane interpenetrating elastomeric network compositions as coatings and sealants for roofing and other applications
300	6,596,519	US	Takayanagi; Masaaki; Iguchi; Akiko; Gotou; Naoki; Tsuchiya; Kinya (for The Nisshin Oil Mills Ltd) July 22, 2003	Paint or ink composition
301	6,605,668	US	Buter; Roelof; Roelofs; Andreas Henricus Johannes (for Akzo Nobel NV) August 12, 2003	Water-dissipatable polymers and their use in aqueous systems
302	6,624,276	US	Lamers; Paul H.; Martz; Jonathan T.; Meyers; Lawrence D.; Novak; Carolyn A.; Olson; Kurt G.; Rowley; James P.; Verardi; Christopher A. (for PPG Industries Ohio Inc) September 23, 2003	Curable polyurethanes, coatings prepared there from, and method of making the same
303	6,734,263	US	Eadara; Rajan; Jacob; Roy P.; Ahn; Yushin; Philip; Biju; Joseff; Jori (for Diversified Chemical Technologies Inc) May 11, 2004	Non-polyvinyl chloride, interpenetrating network epoxy/urethane acrylates
304	6,756,466	US	Okuhira; Hiroyuki; Adachi; Naoya; Ishikawa; Kazunori; Takeda; Toshimitsu; Kotani; Yo (for Yokohama Rubber Co Ltd) June 29, 2004	One-part, room temperature moisture curable resin composition
305	6,794,479	US	Okuhira; Hiroyuki; Ishikawa; Kazunori (for Yokohama Rubber Co Ltd) September 21, 2004	Composition of polyepoxide and oxazolidine latent curing agent
306	58,059,220	JP	Toto Kasei, April 8, 1983.	A coating resin prepared from piperazine or an amine containing a piperazine ring and a diepoxy compound is used in lacquer-type paint and in metal primers and wire coatings.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
307	60,170,621	JP	Nianippon Ink, September 4, 1985.	An epoxy coating composition containing a urethane-modified epoxy resin and a polyoxypropyleneamine offers improved flexibility and toughness and good weather and chemical resistance.
308	1,951,524 1,951,525	GR GR	Wilhelm Becker (to Reichhold-Albert-Chemie A.-G.), June 11, 1970 and August 6, 1970.	The condensation product of phenol, poly(oxypropylene)diamine, and formaldehyde was reacted with glycidyl ethers to form luminous, elastic, thin coatings.
309	193,685 4,689,131	EP US	Y. Ledisert, P. Faucher, J. Roue, and R. L. Scriven (to PPG France), October 9, 1986, and August 25, 1987.	The reaction product of a polyoxyalkyleneamine and a monoepoxide is used as an additive in a cathodic electrodeposition coating. The additive provides improved surface appearance without affecting adhesion of topcoats.
310	215,005 3,562,263	EP GR	F. Augustin, K. Comehl, W. Lindner, and H. Wassong (to BASF, Farber & Faser), April 20, 1988 and May 26, 1988.	Hollow fillers are used in an amine-cured epoxy coating to provide transport of liquids away from underground walls.
311	297,696 01,006,063	EP JP	H. G. Waddill (to Texaco Development Corp.), January 4, 1989	A composition containing cycloaliphatic resin, acrylate ester, polyetherpolyamine, and aminoethylpiperazine cures rapidly to give nonyellowing, weather-resistant, high gloss coatings.
312	4,432,850 4,420,574 70,550	US US EP	T. C. Moriarity and W. J. Geiger (to PPG Industries), February 21, 1984, December 13, 1983	A non-gelled polyepoxide-polyoxyalkyleneamine-polyamine resin is partially neutralized and used in an aqueous dispersion for electro-deposition coating to provide a good surface, a good flexibility, and water resistance.
313	4,507,363 166,906	US EP	S. W. Chow and D. F. Smith (to Union Carbide), March 26, 1985	Epoxy compositions containing polyetheramines and polyamidoamines used as coatings for corroded metal surfaces require little pretreatment or cleaning of the metal to provide excellent protection and corrosion resistance.
314	4,748,167 172,460	USEP	S. K. Das, K. O. Olson, and J. A. Claar (to PPG Industries), February 26, 1986	Water-based coating compositions with improved pot life contain acrylic polymers and a polyoxyalkyleneamine.
315	4,810,535 326,937	US EP	McCollum and Zwack (to PPG), July 3, 1989 and August 9, 1989.	The ungelled product from reaction of glycidol with an amine-functional adduct of monoepoxide and polyoxyalkyleneamine is used in electro-deposition coatings to reduce surface defects and improve topcoat adhesion.
316	434,098 A2	EP	R. M. Gerkin, A. D. Beckett, and J. V. Koleske (to Union Carbide Chemicals and Plastics Company, Inc.), June 26, 1991.	JEFFAMINE® T-5000 is used in a photocurable composition to improve adhesion, flexibility, gloss, and other properties of coatings and adhesives.
317	5,034,434 200,397	US EP	M. P. Beresford and R. P. Redman (to ICI), July 23, 1991.	Non-gelled reaction products from JEFFAMINE® amines, secondary amines, polyepoxides, and monoepoxides are cross-linked in aqueous coatings applied by cathodic electrodeposition. The composition offers improved emulsion stability, throwing power, and corrosion resistance.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
318	5,266,630 2,075,022	US GB	Noomen; Arie; Peters; Petrus J. (for Akzo NV), November 30, 1993	Aqueous coating composition containing a functional organic compound, a curing agent, and a dispersing agent
319	5,272,189 2,038,786	US CA	Kaufman; Marvin L. (for PPG Industries), December 21, 1993	Reduced yellowing electrodepositable coating composition
320	AU8388101	AU	Evsoukov Serguei; Hohn Arthur; Nouwen Jan; Schornick Gunnar (for BASF AG) January 2, 2002	Polymeric aldehyde/polyetheramine networks
321	CA2003678	CA	Speranza, GP; Su, W-Y (for Texaco Development Corp) August 27, 1990	Elastomeric Polyamide Hot Melt Adhesives
322	CA2038632	CA	Speranza, GP; Su, W-Y (for Texaco Development Corp) October 11, 1990	Polyether Amides and Methods Therefore
323	CA2038668	CA	Champion, Donald H.; Speranza, George P; Su, Wei-Yang (for Texaco Chemical) October 11, 1991	Polyether Amides from Mixed Amines
324	CA2057632	CA	Champion Donald H; Speranza George P (for Texaco Chemical) June 15, 1992	Polyamides From Polyetheramines, Hexamethylene Diamine And Adipic Acid
325	CA2086719	CA	Cuscurida, M; Su, WY; Renken, TL; Waddill, HG (for Texaco Chemical) February 14, 1994	Heimd-Containing Polyetheramine Curative For Flexible, Toughened Products
326	EP0301706	EP	Speranza, GP; Waddill, HG; Lin, JJ (for Texaco Development Corp) February 1, 1989	Aromatic amidoamines.
327	EP0490482	EP	Speranza, GP; Champion, DH (for Texaco Chemical) June 17, 1992	Polyamides from polyetheramines, hexamethylene diamine and adipic acid.
328	EP0511620	EP	Ferrara Matteo (for Sir Ind SPA) November 4, 1992	Aqueous emulsions of epoxyphenolic resins.
329	EP0517167	EP	Chen Shuh-Chung; Schoenberg Jules (for National Starch Chem Invest) December 9, 1992	Flexible polyetheramines useful in epoxy compositions.
330	EP0688796	EP	Krull Matthias Dr; Mielcke Erdmann; Feustel Michael Dr (for Hoechst AG) December 27, 1995	Reaction products of polyetheramines with polymers of alpha, beta- unsaturated dicarboxylic acids
331	GB1260966		Becker, Wilhelm (Reichhold-Albert Chmie Aktiengesellschaft) January 19, 1972	Curing of Epoxy Resins
332	KR8101536	KR	Waddill, H (for Texaco Development Co) October 27, 1981	Method of Improving Properties of Curable Epoxy Resin Composition
333	KR8101793	KR	Waddill, H; (for Texaco Development Co) November 14, 1981	Process For Accelerated Cure Of Epoxy Resins
334	KR9506724	KR	Im Yong; Cha Jong-Won; Park Song-Kwang (for Kolon Inc) June 21, 1995	Method For Producing Polyamid
335	TW520382	TW	Schmidt, Dale C (for Dow Chemical Co) February 11, 2003	A composition comprising a stable aqueous dispersion of an acid salt of a polyetheramine having structural units and a method of preparing a stable aqueous dispersion of an acid salt of a polyetheramine
336	WO9730103	WO	Chang Dane; Wilson David A (for Dow Chemical Co) August 21, 1997	Preparation Of Polyetheramines And Polyetheramine Derivatives

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
337			S. V. Urs and S. A. Puglia, "Development of Flexible Epoxy Resins and Coatings," AD-645,798, December 1966; U.S. Govt. Res. Develop. Dept., July 25, 1967.	A flexible epoxy coating system suitable for use on naval aircraft was prepared by curing an epoxy resin with a polyoxypropylene diamine of ~500 mol. wt.
338			R. G. Young and W. R. Howell, <i>Modern Paint and Coatings</i> 65, No. 3, p. 43 (1975).	Polyoxypropylenediamines, e.g., JEFFAMINE® D-230 and D-400, are regarded as "the best known long-chain aliphatic amines for decorative coatings." Coating formulations are included.
339			V. S. Nithianandam, F. Chertok, and S. Erhan, <i>Journal of Coatings Technology</i> 1991, 63(796), 47-9.	Studies of JEFFAMINE® D-400-p-benzoquinone polymers show that addition of polyamines and epoxides to the polymer can cause improved adhesion.
340			Y. Huang and A. J. Kinloch, <i>Polymer</i> 1992, 33(6), 1331-2.	Toughness of a cured epoxy system is increased through microvoid formation caused by the addition of JEFFAMINE® BuD-2000 to the system.
<b>Curing Accelerated</b>				
341	972,096	CA	Norman B. Godfrey and Heinz Schulze (to Jefferson Chemical Co.), July 29, 1975.	Fast-curing epoxy resin compositions were prepared by addition of carbon disulfide to polyoxyalkylenepolyamines or other polyamines prior to mixing with a bisphenol A-epichlorohydrin polymer.
342	2,854,827	GR	H. G. Waddill and H. P. Klein (to Texaco Development Corp.), June 28, 1979.	Products of the reaction of the hydrogenated adduct of acrylonitrile and JEFFAMINE® D-400 with formaldehyde and phenol were rapidly reacting hardeners with epoxy resins.
343	3,591,556	US	Norman B. Godfrey and Heinz Schulze (to Jefferson Chemical Co.), July 6, 1971.	Fast, efficient, low-temperature cures of epoxy resins were achieved through use of a combination of a sulfonamide and a polyoxyalkylenepolyamine.
344	3,639,928	US	Floyd E. Bentley and Norman B. Godfrey (to Jefferson Chemical Co.), February 8, 1972.	Curing of epoxy resins with polyoxypropylenepolyamines was accelerated in the presence of a mixture of N-(3-aminopropyl)piperazine and salicylic acid.
345	3,666,721	US	Norman B. Godfrey (to Jefferson Chemical Co.), May 30, 1972.	A mixture of a polyamine and an organic sulfonic acid was synergistic for accelerating the cure of epoxy resins with polyoxypropylenediamines.
346	3,703,497	US	Donald D. Carlos and David A. Shimp (to Celanese Coating Co.), November 21, 1972.	Oximes (e.g., benzaldoxime) accelerated the cure of epoxy resins and a polyoxypropylenediamine.
347	3,740,373	US	Floyd E. Bentley and Norman B. Godfrey (to Jefferson Chemical Co.), June 19, 1973.	A synergistic mixture of polyoxyalkylenepolyamine, N-(3-aminopropyl)piperazine, salicylic acid, and a phenol cured epoxy resins rapidly.
348	3,785,997	US	Norman B. Godfrey (to Jefferson Chemical Co.), January 15, 1974.	Epoxy resins were cured rapidly with polyoxypropylenepolyamines in the presence of synergistic accelerator mixtures of organic sulfonic acids, e.g., methanesulfonic acid, and polyamines, e.g., N-(2-aminoethyl)piperazine.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
349	4,110,313	US	Heinz Schulze and H. G. Waddill (to Texaco Development Corp.), August 29, 1978.	Epoxy resins cured rapidly in the presence of dithiocarbamate salts of polyoxyalkylenepolyamines.
350	4,127,514	US	H. G. Waddill (to Texaco Development Corp.), November 28, 1978.	An accelerator for curing epoxy resins with polyoxyalkylene polyamines consisted of a mixture of iminobispropylamine and salicylic acid.
351	4,195,153	US	H. G. Waddill (to Texaco Development Corp.), March 25, 1980.	Noncrystallizing accelerators of epoxy resin curing with polyoxyalkylenepolyamines consist of mixtures of N-(aminoethyl)piperazine, piperazine, and triethanolamine.
352	4,226,971	US	H. G. Waddill and H. P. Klein (to Texaco Development Corp.), October 7, 1980.	Mannich bases prepared from aminopropyl derivatives of JEFFAMINE® amines act as fast curing agents for epoxy resins.
353	4,332,720	US	Heinz Schulze, R. L. Zimmerman, and H. G. Waddill (to Texaco Development Corp.), June 1, 1982.	N,N1-polyoxyalkylene bis(lactam carboxylic acids) prepared from polyoxyalkylenepolyamines and unsaturated carboxylic acids were used as accelerators in curing epoxy resins.
354	4,436,891	US	Umeda and Y Iwase (to Texaco Inc.), March 13, 1984.	Alkyleneimine-modified polyoxyalkylenepolyamines cure epoxy resins at a high rate.
355	4,683,282	US	A. B. Goel (to Ashland Oil, Inc.), July 28, 1987.	JEFFAMINE® amine/boron trifluoride complexes act as accelerators for cure of epoxy resins.
356	4,683,284	US	A. B. Goel (to Ashland Oil, Inc.), July 28, 1987.	Oxime carbonates are used as accelerators for amine-cured epoxy systems.
357	4,714,750	US	R. A. Grigsby and G. P. Speranza (to Texaco Inc.), December 22, 1987.	New epoxy curing agents and/or accelerators are Mannich condensates prepared from 2,6-di-tert-butylphenol and polyoxyalkyleneamines.
358	4,761,466	US	A. B. Goel (to Ashland Oil, Inc.), August 2, 1988.	Thiocyanate complexes of imidazolines are used to accelerate Cure of epoxy resins by JEFFAMINE® T-403 or ethyleneamines.
359	4,775,734	US	A. B. Goel (to Ashland Oil, Inc.), October 10, 1988.	Non-nucleophilic acid/amine salts are used as catalysts for amine-cured epoxy compositions in coatings, adhesives, RIM, composites, and other applications.
360	4,835,241	US	H. G. Waddill (to Texaco Chemical Company), May 30, 1989.	Equivalent reacting amounts of an acrylate ester and piperazine are added to a resin system cured with a JEFFAMINE® polyetheramine in order to speed cure rate.
361	86,036,855	JP	Mitsui Petrochemical Industries, August 20, 1986.	A dimethylaminomethylated polyalkenylphenol is used to accelerate cure of an epoxy resin with an amine hardener.
362	86,047,161	JP	Nitto Electric Ind., October 17, 1986.	Low viscosity epoxy systems containing amine-terminated liquid rubber copolymers and cured with polyoxyalkyleneamines use catalysts such as dicyandiamide or boron trifluoride complexes.
363	3,875,072 2,411,284	US GR	H. G. Waddill (to Jefferson Chemical Co.), April 1, 1975; and September 26, 1974.	An accelerator combination of piperazine and an alkanolamine was used to cure epoxy resins with a polyoxyalkylenepolyamine.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
364	4,326,050 2,721,626	US GR	Heinz Schulze, R. L. Zimmerman, and H. G. Waddill (to Texaco Development Corp.), April 20, 1982 and December 15, 1977.	An aromatic polyamine-cured epoxy composition containing an accelerator prepared from JEFFAMINE® amines and a lactam offers high strength and good solvent resistance.
<b>Curing Latent</b>				
365	2,143,845	GR	Don L. Stevens and Harold E. Filter (to Dow Chemical Co.), March 2, 1972.	Salts of polyoxypropylenediamine and several acids were useful epoxy resin curing agents.
366	2,145,833	GR	Ronald L. DeHoff (to R. T. Vanderbilt Co., Inc.), March 23, 1972.	Liquid mixtures of an aniline/formaldehyde condensate with 2-methylimidazole and, in some cases, a polyoxypropylenediamine have good shelf life and are useful as epoxy resin hardeners.
367	2,847,363	GR	Friedrich Stockinger, Sameer H. Eldin, and Friedrich Lohse (to Ciba-Geigy A.-G.), May 10, 1979.	Complexes of amine-terminated polyoxyalkylenes with divalent metal salts of sulfonic, phosphonic, or carboxyl-containing N heterocyclic carboxylic acids were used as cross-linking agents for epoxy resins. Epoxy/complex mixtures had a shelf life of ~70 days.
368	4,218,377	US	Sameer H. Eldin, Friedrich Lohse, and Friedrich Stockinger (to Ciba-Geigy Corp.), August 19, 1980.	Metal salt/amine complexes in which the amine was a polyoxyalkylenepolyamine (JEFFAMINE® D-2000) cured readily when mixed with an epoxy resin and heated to ~160°C. Such mixtures were stable at 40°C for ~70 days.
369	4,403,078	US	D. R. McCoy and H. G. Waddill (to Texaco Inc.), September 6, 1983.	Latent-cure adhesives are made from epoxy resins and polyoxyalkylenediamine biguanide salts as curing agents.
370	4,683,283	US	A. B. Goel (to Ashland Oil, Inc.), July 28, 1987.	Epoxy systems cured with JEFFAMINE® D-400 use phenol carbonates as latent accelerators.
371	53,034,896	JP	Hitachi Chemical, March 31, 1978.	An epoxy composition uses carboxylic acids and imidazolyltriazine compounds to give waterproof and chemical-resistant compositions with rapid cure at elevated temperatures.
372	53,034,897	JP	Hitachi Chemical, March 31, 1978.	Azine derivatives of imidazoles and carboxylic anhydrides are used as latent accelerators in amine-cured epoxy compositions.
373	57,167,370	JP	Mitsui Petrochemical Industries, Ltd., October 15, 1982.	Storage-stable adhesives are made from epoxy resin-polyoxypropylenediamine adducts, dicyandiamide, and a dimethylurea.
374			Sameer H. Eldin, Friedrich Stockinger, Friedrich Lohse, and Greta Rihs, <i>J. Appl. Poly. Sci.</i> 26,3609-3622 (1981).	A zinc-pyrrolidone-carboxylate complex with a long-chain polyoxypropylenediamine (JEFFAMINE® D-2000) was found to give variable processing and properties over a broad range.
<b>Construction</b>				
375	1,250,568	RU	E. V. Grigorev, T. P. Fornicheva, and E. G. KutGBhtin (to Ind. Bldgs. Struc. Res.), August 15, 1986.	A floor covering coating system which provides increased working life and reduced air entrapment is formulated using a polyoxypropyleneamine.
376	4,383,054	US	Heinz Schulze and H. G. Waddill (to Texaco Inc.), May 10, 1983.	Hydrophilic polymers prepared from aqueous solutions or dispersions of polyoxypropylenepolyamine N,N'1polymethylene sulfonates are described which are useful for earth injection where consolidation is needed.



## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
377	4,487,805	US	Kathy B. Sellstrom (to Texaco Inc.,) November 12, 1984.	A decorative epoxy resin aggregate binder formulation is described in which the curing system is composed of a polyoxypropylenediamine, N-aminoethylpiperazine, nonylphenol, and a UV absorber.
378	4,487,806	US	Kathy B. Sellstrom and H. G. Waddill (to Texaco Inc.), November 12, 1984.	A decorative aggregate binder system is described, the curing system of which is composed of a polyoxypropylenediamine, nonylphenol, and m-xylenediamine.
379	4,490,485	US	Peterson; Bruce W.; Speranza; George P; Grigsby, Jr.; Robert A., (for Texaco, Inc.), December 25, 1984	Manufacture of flexible polyurethane foam containing a condensation product of polyethylene terephthalate
380	4,501,830	US	Miller; Richard; Rizer; Janine M., (for Research One Limited Partnership), February 26, 1985	Rapid set lightweight cement product
381	4,574,145	US	Cummings; Lowell O., (for Chemcrete International), March 4, 1986	Epoxy curing agents and method for making them
382	4,754,590	US	Gordon; James R., July 5, 1988	Method and apparatus for waterproofing concrete
383	4,808,476	US	Mikus; John P.; Robert W.; Ward; Thomas A.; Seiner; Jerome A. (for PPG Industries), February 29, 1989	Method for protecting heat sensitive substrates from fire and excessive heat and resulting article
384	4,828,879	US	Kathy B. Sellstrom and H. G. Waddill (to Texaco Inc.), May 9, 1989.	JEFFAMINE polyoxyethyleneamine is used in a formulation for epoxy polymer concrete useful for road and bridge deck overlays.
385	4,904,711	US	Kathy B. Sellstrom and H. G. Waddill (to Texaco Chemical Company), February 27, 1990.	A rapid-cure epoxy polymer concrete formulation useful in large scale repair of cementitious road and bridge surfaces is disclosed.
386	5,049,411	US	Kathy B. Sellstrom and H. G. Waddill (to Texaco Chemical Company), September 17, 1991.	Polymer concrete compositions that bond well to wet or dry cementitious surfaces are presented.
387	5,162,060	US	Bredow; Charles W.; Schindler; Frederick J, (for Rohm & Haas Co), November 10, 1992	Polymer-modified cements with improved chemical resistance
388	5,350,784	US	Darwen; Stuart P.; Cornforth; David A. (for Air Products and Chemical Inc), September 27, 1994	Water dispersible polyamine-epoxy adduct and epoxy coating composition
389	6,160,041	US	Neuner; John D. (for Hexcel Corp) December 12, 2000	Non-cementitious concrete-like material
390	6,271,305	US	Rajalingam; Ponswamy; Rajalingam; Umarani (for Urecoats Technologies Inc) August 7 ,2001	Bituminous polyurethane interpenetrating elastomeric network compositions as coatings and sealants for roofing and other applications
391			M. W. Phillips and J. E. Selwyn, "Epoxyes for Wood Repairs in Historic Buildings," U.S. Department of the Interior, Washington, D.C., 1978.	
392			Kathy B. Sellstrom, "Curing Agents for Epoxy Polymer Concrete," presented at the SPI/Epoxy Resin Formulators Conference, Nashville, Tenn., October 10-12, 1990.	Properties of epoxy polymer concrete systems cured with the JEFFAMINE® polyetheramines are discussed.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
<b>Elastomers</b>				
393	451,951	EP	G. P. Speranza and W. Y. Su (to Texaco Chemical Company), October 16, 1991.	JEFFAMINE® EDR-192 and aromatic dicarboxylic acids are used to produce polymers having good water absorbency.
394	463,717	EP	F. C. Onwumere (to Becton, Dickinson, and Co.), January 2, 1992.	Melt-processable polyurea-polyurethane elastomers containing JEFFAMINE® D-4000 are used in the manufacture of biocompatible medical goods.
395	2,245,896	GB	M. A. Cannon, R. Ruelle, and D. L. Dufour (to Monsanto Company), January 15, 1992.	Polyurethane-containing polymer blends modified with JEFFAMINE® ED-600 offer improved low temperature flexibility and reduced plasticizer migration in high temperature molding operations.
396	3,299,169	US	John C. Smith (to Dow Chemical Co.), January 17, 1967.	A diglycidyl ether mixture was cured with a polyoxypropylenediamine and ethanolamine to form a soft elastomer with high elongation, tensile strength, and clarity.
397	3,607,792	US	G. P. Speranza and H. G. Waddill (to Jefferson Chemical Co.), September 21, 1971.	A carbon-black-filled epichlorohydrin-ethylene oxide copolymer was vulcanized with a polyoxypropylenepolyamine to give ozone-resistant rubbers.
398	3,829,354	US	James L. Bertram, et al. (to Dow Chemical Co.), August 13, 1974.	Epoxy resins were modified with hydrogen sulfide and cured with an aminated polyglycol to produce flexible laminates.
399	4,321,342	US	John E. Davis and Moses Cenker (to BASF-Wyandotte Corp.), February 27, 1982.	A graft polymer dispersion prepared through reaction of a primary amine-terminated polyoxypropylene polyether polymer (JEFFAMINE® product) with styrene and acrylonitrile was used to cure a polyepoxide compound. The reactants formed an elastomeric material after heat curing.
400	5,025,100	US	J. J. Lin and G. P. Speranza (to Texaco Chemical Company), June 18, 1991	Epoxy-terminated adducts prepared with JEFFAMINE® D-2000 and a liquid epoxy resin were reacted with JEFFAMINE® EDR-148 to give a flexible cured polymer.
401	5,053,465	US	H. G. Waddill (to Texaco Chemical Company), October 1, 1991.	Polyoxyalkylenepolyamines are reacted with blocked isocyanate prepolymers to yield cured elastomeric products with exceptional elongation, impact strength, and peel strength.
402	5,059,672	US	Engebretson; Preston J. (for Thare Coat Inc.), October 22, 1991	Elastomeric reaction products of aromatic isocyanate, aliphatic isocyanate and aromatic diamine components
<b>Encapsulation &amp; Mouldings</b>				
403	301,706	EP	H. G. Waddill, J. J. Lin, and G. P. Speranza (to Texaco Development Corp.), February 1, 1989.	Amidoamines prepared from a mixture of di- and tricarboxylic acids/ esters/anhydrides and a mixture of polyoxyalkylene di- and triamines allow rapid cure of epoxy resins at ambient temperatures.
404	301,716	EP	J. J. Lin and G. P. Speranza (to Texaco Development Corp.), February 1, 1989.	Polyamido diprimary amines prepared by reacting JEFFAMINE® amines with dicarboxylic acids and then reacting the resulting diacids with lower molecular weight diprimary amines are used to cure epoxy resins.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
405	435,497	EP	G. P. Speranza and J. J. Lin (to Texaco Chemical Company), July 3, 1991.	Polyamidoamines useful as epoxy curing agents are prepared from JEFFAMINE® EDR-1 92 and maleic or fumaric acids or derivatives of the acids.
406	01,165,619	JP	Toshiba Chem., June 29, 1989.	Polyetherdiamines used as curing agents in a low color epoxy formulation offer improved processability and good mechanical strength, heat resistance, and toughness.
407	1,565,585	FR	Farbwerke Hoechst A.-G., May 2, 1969.	A propylene glycol amine was used to cure a glycidyl ether to form a heat-stable, impact-resistant composition useful in soundproofing applications.
408	1,567,293	FR	Farbwerke Hoechst A.-G., May 16, 1969.	Hard epoxy resins with improved impact strength were prepared by treating glycidyl ethers with oxypropylated trimethylolpropane-ammonia reaction products.
409	2,052,334	FR	John L. Evans and Anthony G. Rubino (to Singer-General Precision, Inc.), May 14, 1971.	Gas gyroscope bearing envelopes with improved shrinkage resistance were prepared comprising a matrix and a coated hemispheric cavity. The cavity was coated with an epoxy resin hardened with a polyoxypropyleneamine.
410	2,611,019	GR	Peter R. Ramirez (to American Optical Corp.), September 15, 1977.	Compositions suitable for injection molding of eyeglass frames contained bisphenol A epoxy resin, polyether diamine, and the trimethyl derivative of hexamethylenediamine. Fast curing time permitted large-scale production and low softening temperature made lens insertion easy.
411	2,748,603	GR	Heinz Schulze and H. G. Waddill (to Texaco Development Corp.), May 24, 1978.	Polyoxypropylenediamines, treated with urea, phenyl isocyanate, formic acid, or benzyl alcohol to prepare diureides or diamides, were used as additives to improve thermal shock resistance of epoxy resins hardened with methyl-5-norbornene-2,3-dicarboxylic anhydride.
412	2,827,269	GR	L. Kamlander (to Optique du Monde), August 30, 1979.	Isophoronediamine and a polypropylene glycol triamine are used with an epoxy resin to produce eyeglass frames.
413	03,275,714	JP	Kazumasa Kobayashi, et al. (to Nippon Steel Chemical Co., Ltd.; Dainippon Ink and Chemicals, Inc.), December 6, 1991.	JEFFAMINE® D-400 is a component of a liquid epoxy hardener system also containing epoxy adducts or Michael adducts of imidazoles and other aliphatic or alicyclic primary amines. The hardener blend provides longer pot life and improved strength.
414	3,929,717	US	S. Yen Lee (to U.S. Government, Secretary of Army), December 30, 1975.	A composition useful for potting electronic components but easily removable for repair of components was formulated from a dihydroxyphenol; the diglycidyl ether of a polyoxyalkylene glycol; a polyoxyalkylenediamine (JEFFAMINE D-230); a primary or secondary alkyl-, alkanol-, or arylamine; and polyvinylpyrrolidone.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
415	4,002,598	US	Texaco Development Corp., January 11, 1977.	Improved epoxy properties are obtained with a curing agent prepared from a polyoxyalkyleneamine and urea, a urea-forming compound, or a difunctional isocyanate.
416	4,122,068	US	Lee G. Meyer (to Texaco Development Corp.), October 24, 1978.	Epoxy resin compositions containing bis(hydroxyalkyl)poly(oxyalkylene)dicarbamates and cured with bicyclic anhydrides have high resistance to thermal shock and are useful in encapsulating or potting compounds.
417	4,146,701	US	H. G. Waddill and Heinz Schulze (to Texaco Development Corp.), March 27, 1979.	Thermal shock properties of epoxy resin castings cured with aromatic or alicyclic anhydrides were improved by addition of a polyoxypropylenediamine succinimide bisurea.
418	4,169,177	US	H. G. Waddill and Heinz Schulze (to Texaco Development Corp.), September 25, 1979.	Resistance to thermal shock of certain anhydride-cured epoxy resins was enhanced without compromising heat deflection properties by addition of a diamide of a polyoxyalkylenepolyamine-urea condensate with a 400-4500 mol. Wt.
419	4,178,427	US	H. G. Waddill and Heinz Schulze (to Texaco Development Corp.), December 11, 1979.	Polyether-ureas, prepared by treating a polyoxyalkylenepolyamine with urea, were good curing agents for epoxy resins, imparting improved tensile shear strength, flexural strength, and elongation.
420	4,267,044	US	Kroplinski; Thaddues F.; Case; Barton C. (for NL Industries), May 12, 1981	Thixotropic polyurethane compositions as sealants for membrane separatory devices
421	4,436,891	US	A. Umeda and Y lwase (to Mitsui-Texaco Chemical), March 13, 1984.	An epoxy curing agent prepared from an alkyleneimine and a polyoxyalkylenepolyamine provides reduced cure time and improved epoxy properties.
422	4,514,530	US	Kathy B. Sellstrom and G. P. Speranza (to Texaco Inc.), April 30, 1985.	Recycled polyethylene terephthalate is reacted with an excess of various amines, including JEFFAMINE® D- and T-series polyetheramines, to give modified curing agents with faster cure rate than the unmodified amines.
423	4,518,749	US	H. G. Waddill and Heinz Schulze (to Texaco Development Corp.), May 21, 1985.	Bis(hydrogen maleates) of polyoxyalkylenepolyamines cure epoxy resins to provide improved flexibility and reduced brittleness.
424	4,522,933	US	Kathy B. Sellstrom and H. G. Waddill (to Texaco Inc.), November 12, 1985.	Recycled polyurethane elastomers are reacted with excess amines, including JEFFAMINE® D- and T-series amines, to give extended amine curing agents.
425	4,533,719	US	H. G. Waddill (to Texaco Development Corp.), August 6, 1985.	Monoamides are prepared from fatty monocarboxylic acids and polyoxyalkylenepolyamines for use as epoxy curing agents for adhesives and thermal shock-resistant encapsulations.
426	4,578,412	US	Kathy B. Sellstrom and H. G. Waddill (to Texaco Inc.), March 25, 1986.	Amine curing agents containing recycled polyurethane elastomeric materials or Mannich condensates of the extended amines are useful as epoxy curing agents.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
427	4,581,422	US	G. P. Speranza and H. G. Waddill (to Texaco Inc.), April 6, 1986.	A new epoxy curing agent is prepared from dicyandiamide, formaldehyde, and JEFFAMINE® amines; the viscous liquid product is easily dispersed uniformly into epoxy resins.
428	4,581,423	US	G. P. Speranza and H. G. Waddill (to Texaco Chemical Company), April 8, 1986.	Epoxy resins are cured with Mannich condensates prepared from hydantoin, formaldehyde, and JEFFAMINE® polyetheramines.
429	4,736,011	US	H. G. Waddill and G. P. Speranza (to Texaco Chemical Company), April 5, 1988.	Mannich condensates from imidazole, formaldehyde, and a JEFFAMINE® polyetheramine are used as epoxy curing agents.
430	4,769,438	US	R. L. Zimmerman, H. G. Waddill, and Kathy B. Sellstrom (to Texaco Chemical Company), September 6, 1988.	A variety of polyetheramines prepared from aminated, propoxylated 1,4-butanediol are used to cure epoxy resins.
431	4,789,721	US	H. G. Waddill, J. J. Lin, and G. P. Speranza (to Texaco Chemical Company), December 6, 1988.	JEFFAMINE® products are condensed with phenyl indane carboxylic acid to form an amidoamine useful as an epoxy curative.
432	4,825,000	US	J. M. Larkin, R. L. Zimmerman, M. Cuscurida, and H. G. Waddill (to Texaco Chemical Company), April 25, 1989.	Polyether glycols modified with phenyl glycidyl ether and then aminated are used as epoxy curing agents.
433	5,098,986	US	G. P. Speranza and J. J. Lin (to Texaco Chemical Company), March 24, 1992.	Mannich condensates prepared from JEFFAMINE® EDR-148, nonylphenol, and formaldehyde are light-colored liquid products useful as epoxy curing agents.
434	5,101,060	US	G. P. Speranza and J. J. Lin (to Texaco Chemical Company), March 31, 1992.	Paired Mannich condensates prepared from alkylphenols, formaldehyde, and two polyoxyalkylenepolyamines are used as epoxy curing agents.
435	5,109,098	US	Harris, Haberman, and Joseph (to Dow Chemical), April 28, 1992.	Imines and secondary amines prepared from JEFFAMINE® DU-700 or other polyetheramines with hydrogen bonding moieties in the backbone are used in epoxy curing.
436	5,472,532	US	Wallace, II; Ingvar A. (for Thiokol Corp.) December 5, 1995	Ambient temperature mix, cast, and cure composite propellant formulations
437	8,400,376	WO	L. O. Cummings, February 2, 1984.	Products of the reaction of polyetheramine with urea-formaldehyde resins offer improved toughness and strength when used to cure epoxy resins.
438	61,069,819	JP	Kanegafuchi Chem., April 10, 1986.	A reactive epoxy resin composition for molding, coating, or potting materials is modified with a carboxyl-terminated butadiene nitrile rubber and cured with amines, including polyetherdiamines. Improvements in mechanical strength and resistance to heat and impact are noted.
439	88,004,563	JP	Mitsubishi Gas Chem. Ind., January 29, 1988.	An unsaturated epoxy ester composition containing polyetherpolyamines or other amines has viscosity suitable for preparing prepregs and has high hot compression moldability.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
440	4,574,143 131,401 60,036,526	US EP JP	Kathy B. Sellstrom and H. G. Waddill (to Texaco, Inc.), March 4, 1986	Extended amine-type curing agents are prepared from scrap polyethylene terephthalate and polyoxypropyleneamines.
441	8,702,686 224,422 62,502,346	WO EP JP	S. Druelle, J. Galy, F. Micldans, J. Pascault, S. Montranal, and H. Sautereau (to Dow), May 7, 1987, June 3, 1987, and September 10, 1987.	Epoxy prepolymers prepared from butadiene/acrylonitrile copolymers are cured with polyetherdiamines.
442	87,003,169 2,854,827	JP GR	H. G. Waddill and H. P. Klein (to Texaco Development Corp.), January 23, 1987	The Mannich condensate prepared from phenol, formaldehyde, and an aminopropylene derivative of a polyoxyalkyleneamine provides rapid cure of epoxy resins at ambient temperatures.
443	91/13,109	WO	J. A. Rinde, F. W. Mercer, K. Dawes, and R. B.G. Bownik (to Raychem Corporation), September 5, 1991.	Cross-linked polyurea compositions prepared from JEFFAMINE® D-400 and blocked isocyanates are used in potting applications,
444			David Evans, John T. Morgan, et al., "Epoxy Resins for Superconducting Magnet Encapsulation." Report, 1972, RHEPR-251, 27 pp. (Avail. Dept. NTIS [U.S. sales only] GBAEA).	Epoxy resin systems were evaluated for use at liquid helium temperatures. The more shock-resistant resins tested contained chains of polyether bonds. JEFFAMINE® products produced satisfactory systems.
445			H. G. Waddill, <i>Soc. Adv. of Mat and Process Eng. 11th Nat Technical Conf</i> , 182-194 (1979).	The use of polyoxyalkylenediamine bis(carbamoyl)ether to enhance properties of adhesion and thermal shock was described. Evidence for development of "microvoid" systems was shown to explain the effectiveness of the additive.
446			H. G. Waddill, <i>Reinf. Plastics/Compos. Inst., SPI ANTEC</i> , 22b, 1 5 (1980).	Several epoxy resin systems were evaluated for use with the reaction injection molding (RIM) process. Polyoxyalkylenepolyamines were found to have limited use in RIM applications because of their low reactivity.

### Laminates and Composites

447	3,819,474	US	James L. Bertram, Ross C. Whiteside, and Preston H. Franke, Jr. (to Dow Chemical Co.), June 25, 1974.	Composites with good flexibility, tear resistance, and peel strength were prepared by reaction of a hydrogen sulfide-modified epoxy resin with an aminated polypropylene glycol. The resin curative system was applied to spun Mylar to form a flexible laminate.
448	4,294,792	US	Arons; Irving J.; Merrill; Richard E.; Drennan; Arthur P., (for Universal Optical Co), October 13, 1981	Molded plastic parts, particularly spin-cast plastic parts for eyeglass frames
449	4,389,515	US	De La Mare; Harold E.; Brownscombe; Thomas F. (for Shell Oil), June 21, 1983	Curable polyepoxide-unsaturated monomer compositions suitable for use in rim processes
450	4,397,998	US	De La Mare; Harold E.; Brownscombe; Thomas F. (for Shell Oil), August 9, 1983	Curable epoxy compositions suitable for use in RIM processes
451	4,528,308	US	H. G. Waddill (to Texaco Development Corp.), July 9, 1985.	Epoxy resins are cured with blends of imidazole or substituted imidazoles and JEFFAMINE® polyetheramines.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
452	4,605,688	US	Kathy B. Sellstrom and H. G. Waddill (to Texaco Inc.), August 12, 1986.	Syntactic foam is prepared from an epoxy resin cured with JEFFAMINE® D-230, glass microballoons, and amine-functional surfactants and modifiers.
453	4,608,403	US	Kathy B. Sellstrom (to Texaco Inc.), August 26, 1986.	Syntactic foam formulations with improved processing characteristics use an epoxy resin binder cured with JEFFAMINE® D-230.
454	4,739,019	US	Schappert; Raymond F. (Pittsburgh, PA); Piccirilli; Robert M., (for PPG Industries, Inc.), April 19, 1988	Curable epoxy based compositions having reduced shrinkage during cure
455	4,746,381	US	Parker; Delbert R.; Clark; Daren A. (for AB Chance Co), May 24, 1988	Method of making an end cap connection for a fluid-resistance electrical device
456	4,746,541	US	Marikar; Yusuf M. F.; Besso; Michael M. (for Hoechst Celanese Corp) , May 24, 1988	Electrically conductive thermally stabilized acrylic fibrous material and process for preparing same
457	4,781,971	US	Marikar; Yusuf M. F.; Besso; Michael M. (for Hoechst Celanese Corp) , November 1, 1988	Electrically conductive thermally stabilized acrylic fibrous material and process for preparing same
458	4,920,161	US	Wang, Atkins, Esebi, and Dearlove (to General Motors Corp.), April 24, 1990.	High strength epoxy tooling compositions curable at room temperature are cured with JEFFAMINE® amines and contain interstitially-matched filler systems.
459	5,007,418	US	Bartizal; Dennis C.; Campagna; Anthony J. (for 3M), April 16, 1991	Resilient semi-rigid orthopedic support devices
460	5,104,691	US	Edwards; Granville D.; Wilson; Bonita S. (for Shell Oil Co), April 14, 1992	Epoxy resin system for insitu rehabilitation of pipes
461	5,106,953	US	Yamaguchi; Keizaburo; Tanabe; Yoshimitsu; Urakami; Tatsuhiro; Yamaguchi; Akihiro; Yamaya; Norimasa; Ohta; Masahiro (for Mitsui Toatsu Chemical Inc), April 21, 1992	Aromatic amine resins, processes for producing the same and a thermosetting resin composition containing the same
462	5,192,594	US	Madan; Sanjeev; Kogelnik; Hans-Joachim; Daneshvar; Majid, (for Miles Inc), March 9, 1993	Process for the preparation of a polyurethane structural support
463	5,210,169	US	Muhlebach; Andreas; Gruber; Erich, (for Ciba-Geigy, Corp), May 11, 1993	Thermosetting composition
464	5,250,632	US	Waddill; Harold G.; Su; Wei-Yang; Cuscurida; Michael; Renken; Terry L. (for Texaco Chemical Co), October 5, 1993	Heimd-containing polyetheramine curative for flexible, toughened products
465	5,275,888	US	Madan; Sanjeev; Kogelnik; Hans-Joachim; Daneshvar; Majid; Pantone; Richard S.; Clatty; Jan L. R. (for Miles, Inc.) January 4, 1994	Process for the preparation of a composite structure comprising a ceramic enamel layer and polyurethane layers
466	5,334,441	US	McGarry; Frederick J.; McBain; Douglas S. (for GenCorp, Inc), August 2, 1994	Composite comprising unsaturated polyester-flexible polymer block copolymer coated fiber structures in a polyester or vinyl ester resin matrix
467	5,498,763	US	McGarry; Frederick J.; McBain; Douglas S. (for GenCorp, Inc), March 12, 1996	Polyester-flexible polymer block copolymer coated fiber structures

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
468	5,565,499	US	Klemarczyk; Philip T.; Okamoto; Yoshihisa; Moran, Jr.; James P. (for Loctite Corp) October 15, 1996	Filament-winding compositions for fiber/resin composites
469	5,585,414	US	Klemarczyk; Philip T.; Okamoto; Yoshihisa; Moran, Jr.; James P. (for Loctite Corp) December 17, 1996	Filament winding compositions for fiber/resin composites
470	5,652,299	US	Nakajima; Masayuki; Coalson; Richard L.; Olson; Kurt G.; Desai; Umesh C. (for PPG Industries Inc) July 29, 1997	Water-based vacuum forming laminating adhesive
471	5,679,719	US	Klemarczyk; Philip T.; Okamoto; Yoshihisa; Moran, Jr.; James P.; Levandoski; Susan; Hanlon; Veronica (for Loctite Corp) October 21, 1997	Method of preparing fiber/resin composites
472	5,879,810	US	Ellwood; Michael; Leeming; Stephen William (for Zeneca Limited) March 9, 1999	Composite articles
473	5,952,446	US	Krebaum; Paul (for Molex Inc) September 14, 1999	Elastomeric epoxy composition
474	6,031,046	US	Smith; Stuart B. (for Hebr International Inc) February 29, 2000	Unsaturated polyester resin composition
475	6,093,496	US	Cummings Gerald W; Clark Richard J; Evans Randall K; Hess Kevin J; Crawford Wheeler C; Dominguez Richard Joseph Gilbert; Henkee Christopher S (for Huntsman Specialty Chemical Corp) July 25, 2000	Polyolefin containing polyetheramine modified functionalized polyolefin
476	6,100,206	US	Scholz; Matthew T.; Edgar; Jason L.; Callinan; Andrew J.; Ersfeld; Dean A.; Mindaye; Worku A. (for 3M Innovative Properties Co) August 8, 2000	Light-weight orthopedic casting article
477	6,121,398	US	Wool; Richard; Kusefoglu; Selim; Palmese; Giuseppe; Khot; Shrikant; Zhao; Ralph (for University of Delaware) September 19, 2000	High modulus polymers and composites from plant oils
478	6,140,416	US	Dominguez Richard J G; Evans Randall Keith; Clark Richard J (for Huntsman Specialty Chemical Corp) October 31, 2000	Polyether amine modification of polypropylene
479	6,146,574	US	Clark Richard J; Crawford Wheeler C; Henkee Christopher S (for Huntsman Specialty Chemical Corp) November 14, 2000	Article manufacture using polyolefin containing polyetheramine modified functionalized polyolefin
480	6,306,964	US	Dominguez Richard J G; Evans Randall Keith; Clark Richard J (for Huntsman Specialty Chemical Corp) October 23, 2001	Polyether amine modification of polypropylene
481	6,410,127	US	Kamae; Toshiya; Oosedo; Hiroki; Noda; Shunsaku; Kouchi; Shinji; Sawaoka; Ryuji (for Toray Industries Inc) June 25, 2002	Epoxy resin compositions, epoxy resin compositions for fiber-reinforced composite materials, and fiber-reinforced composite materials comprising the same



## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
482	6,573,309	US	Reitenbach; Dirk; Muenz; Xaver (for Henkel Teroson GmbH) June 3, 2003	Heat-curable, thermally expandable moulded part
483	6,649,707	US	Rhodes; Larry F.; Goodall; Brian L.; Mulhaupt; Rolf; Shick; Robert A.; Benedikt; George M.; Jayaraman; Sai Kumar; Soby; Lynn M.; McIntosh, III; Lester H. (for Sumitomo Bakelite Co Ltd) November 18, 2003	Blends and alloys of polycyclic polymers
484	5,250,132	US	Lapp; Christy K.; Grund; Paul D. (for Westinghouse Electric Corp), October 5, 1993	Method of making a composite laminate having an internally damped constraining layer
485	AU7477798	AU	Cummings Gerald W; Dominguez Richard J G; Clark Richard J; Evans Randall K; Hess Kevin J; Crawford Wheeler C; Henkee Christopher S (for Huntsman Specialty Chemical Corp) December 8, 1998	Polyolefin containing polyetheramine modified functionalized polyolefin
486	CA1339907	CA	Gerkin Richard Michael; Kirchner David Lee (for Huntsman Corp) June 9, 1998	Process for the Manufacturing of N-(Polyoxyalkyl)-N-(Alkyl)Amines
487	CA2377553	CA	Esneault Calvin P; Maugans Rexford A; Ho Thoi H; Patel Rajen M; Bensason Selim; Chum Pak-Wing S; Hahn Stephen F; Walsh Leonie K (for Dow Chemical Co) February 8, 2001	Hydrogenated Block Polymers Having Elasticity And Articles Made There from
488	CN1255151T	CN	Crawford W C; Dominguez R J G; Henkee C S (for Huntsman Specialty Chemical Corp) May 31, 2000	Polyolefin containing polyetheramine modified functionalized polyolefin
489	KR2000023697	KR	Richard J Clark; Joseph Gilbert Richard Dominguez; Randall Keith Evans (for Huntsman Specialty Chemical Corp) April 25, 2000	Polyetheramine Modified Compositions From Polypropylene And Production Process Thereof
490	TW382021	TW	Glass Terry W; Sanford Joe T; White Jerry E (for Dow Chemical Co) February 11, 2000	A thermoplastic hydroxy-functionalized polyetheramine, the process for preparing the same, a laminate structure comprising the same, and a solvent or waterborne coating composition
491			T. T. Chiao, A. D. Cummins, and R. L. Moore, <i>Composites, Vol 3</i> , p. 10 (1972).	JEFFAMINE® products were used to cure epoxy tensile specimens.
492			T. T. Chiao and R. L. Moore, <i>S.A.M.P.E. Quarterly, Vol. 3</i> , No. 3 (1972).	JEFFAMINE® T-403 was used to cure epoxy resins forming a matrix for S-glass fiber strength study.
493			T. T. Chiao and R. L. Moore (Lawrence Livermore Lab., Univ. of Calif., 201 Livermore, Calif.), <i>Report 1973, UCRL-74751</i> ,	An epoxy resin curable at room temperature with a polyethertriamine was used as a binder for filament winding for advanced fiber composites. The structures did not delaminate under stress.
494			T. T. Chiao, R. L. Moore, and C. M. Walkup, <i>S.A.M.P.E. Quarterly, Vol. 4</i> , No. 4 (1973).	JEFFAMINE® T-403 was used to cure epoxy resin matrix in study of graphite fiber as reinforcement.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
495			T. T. Chiao and R. L. Moore, <i>Proc. Annu. Conf. Reinf. Plast. Compos. Inst., Soc. Plast. Ind.</i> 1974, 29,16B.	Advanced fiber composites prepared from bisphenol A diglycidyl ether cured with a polyethertriamine, JEFFAMINE® T-403, had good mechanical properties with neither delamination nor fiber microbuckling.
496			C. C. Chiao, <i>Proc. -Flywheel Technol. Symp.</i> 1975,160-3.	Several years of stress-rupture data for S-glass-reinforced epoxy resins with a number of curing systems showed an apparent exponential dependence of time-to-failure on the applied stress. Among the systems evaluated was a D.E.R. 332 resin/JEFFAMINE® T-403 combination.
497			T. T. Chiao, E. S. Jessup, and H. A. Newey, <i>S.A.M.P.E. Quarterly</i> 1975, 6(3), 38-42.	A bisphenol A-based epoxy resin cured with a polyethertriamine, JEFFAMINE® T-403, was recommended for filament winding application or lay-up processes.
498			P. Ciriscioli and A. MGBherjee, <i>Failure Modes Compos.</i> 1976, 3,170-81.	The creep behavior of bisphenol A diglycidyl ether cross-linked with JEFFAMINE® T-403 was studied between 23°C and 156°C. Specimens deformed in creep only at ~80°C.
499			J. A. Rinde and H. A. Newey (Lawrence Livermore Lab., Univ. of Calif., Livermore, Calif.), <i>Report 1976, UCID-17219. See ERDA Energy Res. Abstr.</i> , 1977, 2(6), Abstr. No. 14260.	Data on properties of epoxy resin systems studied at Lawrence Livermore Laboratory were collected and reported. Curing agents described include several JEFFAMINE® products.
500			T. T. Chiao, C. C. Chiao, and R. J. Sherry, <i>Proc. Int. Conf. Fract. Mech. Technol.</i> 1977, 1, 257-69.	Accelerated tests for prediction of long-term durability by substitution of time with temperature and stress gave good results in polyamide fiber composite testing. A D.E.R. 332/JEFFAMINE® T-403 composite reinforced with glass fiber showed a slight decrease in strength in 4-year tests.
501			Linda L. Clements and R. L. Moore, <i>S.A.M.P.E. Quarterly</i> 1977, 9(1),6-12.	Longitudinal tensile properties of a Kevlar 49 fiber composite with a room-temperature-cured D.E.R. 332/JEFFAMINE® T-403 matrix were quite good and improved over a moderate-temperature-curable epoxy system.
502			R. L. Kolek and R. D. Blaugher, <i>Advances in Cryogenic Engineering</i> , 24, 256 (1978).	This paper describes an advanced metal-fiber reinforced composite with thermal expansion characteristics quite close to those of copper. JEFFAMINE® T-403 is the curing agent.
503			Roger J. Morgan, E. T. Montes, and Wayne J. Steele, <i>Polymer</i> 1982, 23, 295-304.	A number of epoxy resin systems were tested for tensile deformation and various failure processes were studied. One of the curing agents used was an aliphatic polyetheramine, JEFFAMINE® T-403.
504			Morgan and Walkup, <i>J. App. Polymer Sci.</i> 1987, 34, 37-46.	Epoxy systems cured with various amines, including JEFFAMINE® T-403, were evaluated for suitability in filament-wound carbon fiber composites.

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
<b>Miscellaneous</b>				
505	122,810	EP	S. Dabi (to Personal Products Co.), October 24, 1984.	An absorbent, flexible, resilient cellular product that absorbs body fluids is derived from epoxy resins and polyoxyalkylenepolyamines.
506	1,793,655	GR	Texaco Development Corp., July 27, 1978.	Preparation of polyoxyalkylenepolyamines for use as epoxy curing agents is disclosed.
507	3,472,771	US	Pierce Leonard Jr; Grimm Donald C (for Union Carbide Corp) October 14, 1969	Lubricating Compositions Including A Polymer Which Contains A Salt Or Amide Of A Polyetheramine And An Acid
508	4,129,416		Heinz Schulze (to Texaco Development Corp.), December 12, 1978.	Reaction of urea-terminated polyetheramines with formaldehyde produces resin that does not shrink on storage.
509	4,181,682	US	L. W. Watts and H. G. Waddill (to Texaco Development Corp.), January 1, 1980.	Preparation of an aminated, propoxylated polybutanediol useful as an epoxy curing agent is disclosed.
510	4,189,002	US	Martin; Robert C. (for The Dow Chemical Co), February 19, 1980	Method for rigless zone abandonment using internally catalyzed resin system
511	4,255,311	US	S. H. Eldin and H. Gysin (to Ciba-Geigy Corp.), March 10, 1981.	A storage-stable, formaldehyde-free composition useful as a textile-treating agent for crease resistance derives from a water-soluble epoxy resin, an acrylic copolymer, and a polyoxypropylenepolyamine.
512	4,362,856	US	Kluger; Edward W. (for Milliken Research Corporation ), December 7, 1982	Poly-(-2-aminoalkyl)polyamines
513	4,485,236	US	Rasmussen; Jerald K.; Heilmann; Steven M.; Palensky; Frederick J., (for 3M), November 27, 1984	Azlactone-functional compounds
514	4,487,987	US	J. H. Paslean and C. S. Steele (to Texaco Inc.), November 12, 1984.	Described is a method of decolorizing mixtures of N-aminoethylpiperazine, polyoxypropylenediamines, and nonylphenol with N,N1-diethylhydroxylamine.
515	4,490,510	US	L. O. Cummings, December 25, 1984.	A new class of epoxy curing agents is revealed that utilizes the monomer of urea-formaldehyde and amines which include the polyoxypropylenepolyamines.
516	4,508,854	US	S. Dabi (to Personal Products Co.), May 2, 1985.	Adsorbent epoxy foams cured with JEFFAMINE® amines are produced by addition of a blowing agent at gelation.
517	4,533,713	US	Howells; Richard D., (for 3M), August 6, 1985	Fluoroaliphaticsulfonamides containing oxirane groups and/or N-.beta.-hydroxyalkylene groups
518	4,675,374	US	G. Nichols, June 23, 1987.	A copolymer from an amine or amine derivative with a mixture of epoxies and di- or polyacrylates sets at room temperature and can be used as an adhesive or for coating, sealing, or molding.
519	4,684,710	US	Schimmel; Karl F.; Ward; Thomas A. ; Seiner; Jerome A (for PPG Industries, Inc.), August 4, 1987	Half-amide reaction products of dioxalates and amino group containing materials

## 16. Bibliography – JEFFAMINE® Polyetheramine Applications

Ref	Patent #	Country	Author/Company or Publication/Date	Description
520	4,826,930	US	R. L. Zimmerman, H. G. Waddill, and G. P. Speranza (to Texaco Chemical Company), May 2, 1989.	New epoxy curatives were produced by condensing JEFFAMINE® amines with 1,3,5-triaminotriazine in the presence of supported acid catalysts.
521	4,847,395	US	Deguchi; Yoshikuni; Iwakiri; Hiroshi; Iwamoto; Kazunari; Yonezawa; Kazuya (for Kanegafuchi Kagaku Kogyo Kabushiki Kaisha), July 11, 1989	Glycidyl compounds
522	4,847,417	US	J. Larkin (to Texaco Inc.), July 11, 1989.	Bis(diaminopolyalkoxy)-N-alkylamines prepared by aminating an alkoxyated tertiary amine are useful as reactants with epoxy resins, isocyanates, and dimer acids.
523	4,927,912	US	Speranza; George P.; Lin; Jiang-Jen; Templeton; James H. (for Texaco Chemical Co), May 22, 1990	Secondary isopropyl amines derived from oxyalkylene triamines
524	4,992,590	US	Michael Cuscurida, John M. Larkin, Kathy B. Sellstrom, and Robert A. Grigsby, Jr. (to Texaco Chemical Company), February 12, 1991.	High molecular weight polyoxyalkyleneamines prepared by aminating oxyalkylated polyetheramines are used as additives in epoxy resin formulations and as co-reactants with isocyanates in polyurea systems.
525	4,996,294	US	Cuscurida; Michael; Su; Wei-Yang; Speranza; George P. (for Texaco Chemical Co), February 26, 1991	Preparation of aminotetramines
526	5,010,161	US	Speranza, Michael; Lin, Jiang-Jen ; Cuscurida; Michael (for Texaco Inc), April 23, 1991	Process for preparing novel diamines
527	5,024,698	US	R. J. Schwartz and M. Z. Gregorio (to Sun Chemical Corporation), June 18, 1991.	Monoazo pigments with improved properties are produced using azomethine couplers prepared from JEFFAMINE® M-series polyethermonoamines and acetoacetanilide.
528	5,049,281	US	Robert C. Schucker (to Exxon Research and Engineering Co.), September 17, 1991.	An epoxy-terminated prepolymer prepared with JEFFAMINE® DU-700 is used in a multiblock polymer membrane which exhibits good selectivity to aromatics from a hydrocarbon feed.
529	5,062,894	US	R. J. Schwartz, A. C. Zwirgzdas, and T. R. Chamberlain (to Sun Chemical Corporation), November 5, 1991.	Storage-stable printing inks containing pigments prepared with JEFFAMINE® M-2070 offer lower viscosity than those containing pigments prepared with other amines.
530	5,068,306	US	R. F. Harris and M. D. Joseph (to Dow Chemical Company), November 26, 1991.	A process for preparing aminophenyl derivatives of polyetheramines under conditions to minimize formation of urea carboxylates is disclosed. JEFFAMINE® D-2000 is used as an example,
531	5,093,528	US	Dobson; Ian D.; Froom; Simon F. T. (for BP Chemicals Ltd), March 3, 1992	Process for the production of secondary amine terminated polyethers and their use
532	5,097,070	US	Lin; Jiang-Jen; Speranza; George P. (for Texaco Chemical Co), March 17, 1992	High molecular weight trifunctional polyoxyethylene amines

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534	5,140,068	US	Siebert; Alan R.; Bertsch; Robert J. (for The BF Goodrich Corp Co), August 18, 1992	Epoxy resin systems modified with low viscosity statistical monofunctional reactive polymers
535	5,145,949	US	Yamaguchi; Keizaburo; Tanabe; Yoshimitsu; Urakami; Tatsuhiko; Yamaguchi; Akihiro; Yamaya; Norimasa; Ohta; Masahiro (for Mitsui Toatsu Chemical Inc), September 8, 1992	Production process for making aromatic amine resins
536	5,153,232	US	Primeaux, II; Dudley J. (for Texaco, Inc), October 6, 1992	Foamed polyurea elastomer-rigid and close-celled
537	5,157,077	US	Siebert; Alan R.; Bertsch; Robert J.; Guiley; C. Dale (for The BF Goodrich Corp), October 20, 1992	Epoxy resin systems modified with statistical monofunctional reactive polymers
538	5,171,769	US	Bull; Christopher H.; Martin; Richard J., (for Ciba-Geigy Corp), December 15, 1992	Filled thixotropic resin compositions comprising epoxy resin, curing agent, sugar-aldehyde and filler
539	5,204,208	US	Paine; Anthony J.; Martin; Trevor I.; Martins; Lurdes M.; Moffat; Karen A; Mychajlowskij; Walter, (for Xerox Corp), April 20, 1993	Processes for custom color encapsulated toner compositions
540	5,280,068	US	Siebert; Alan R.; Bertsch; Robert J. (for The BF Goodrich Corp), January 18, 1994	Epoxy resin systems modified with low viscosity statistical monofunctional reactive polymers
541	5,298,618	US	Speranza; George P.; Champion; Donald H.; Plishka; Martin J. (for Texaco Chemical Co), March 29, 1994	Macrocyclic oxamides
542	5,310,789	US	Furihata; Toshikazu; Tomoshige; Toru (for Mitsui Petrochemical Industries Inc), May 10, 1994	Vinyl halide resin with epoxy resin and polyamine
543	5,344,852	US	Brooks; Gary T.; Edwards, Jr.; Harold R.; Thrash; Kathy J.; Rubis; Donald E.; Sinclair; David P. (for Aristech Chemical Corp), September 6, 1994	Unsaturated polyester-polyurethane hybrid resin foam compositions
544	5,389,430	US	Yilgor; Iskender; Yilgor; Eme (for Th. Goldschmidt AG) February 14, 1995	Textiles coated with waterproof, moisture vapor permeable polymers
545	5,414,123	US	Hamilton; R. Scott; Lund; Gary K.; Hajik; Robert M. (for Thiokol Corp) May 9, 1995	Polyether compounds having both imine and hydroxyl functionality and methods of synthesis
546	5,470,605	US	Lundeen; Richard H. (for 3M), November 28, 1995	Universal adhesion promoting composition for plastics repair, kit including same, and method of use
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549	5,660,601	US	Guenther Wolfgang; Oppenlaender Knut; Becker Rainer; Henkes Erhard; Henne Andreas; Reif Wolfgang; Menger Volkmar; Schwahn Harald; Thomas Juergen (for BASF AG) August 26, 1997	Polyetheramine-containing fuels for gasoline engines
550	5,744,574	US	Ezzell; Stephen A.; Hansen; Richard G.; Anderson; Gregory J. (for 3M) April 28, 1998	Isomaleimides and polymers derived there from
551	5,777,033	US	Venkataswamy; Krishna; Abdou-Sabet; Sabet; Patel; Raman; Horron; Jacques (for Advanced Elastomer Systems LP) July 7, 1998	Co-cured rubber-thermoplastic elastomer compositions
552	5,853,886	US	Pinnavaia; Thomas J.; Lan; Tie (for Claytec Inc) December 29, 1998	Hybrid nanocomposites comprising layered inorganic material and methods of preparation
553	5,869,581	US	Tysak; Theodore (for Rohm and Haas Co) February 9, 1999	Aqueous polish compositions containing acid-amine latexes
554	6,005,052	US	Venkataswamy; Krishna; Chmielewski; Craig Allen (for Advanced Elastomer Systems LP) December 21, 1999	Staged condensation, dynamic vulcanization process for making a substantially unplasticized plastic/rubber blend
555	6,017,632	US	Pinnavaia; Thomas J.; Lan; Tie (for Claytec Inc) January 25, 2000	Hybrid organic-inorganic nanocomposites and methods of preparation
556	6,060,625	US	Lambert Timothy L; Su Wei-Yang; McKinney Mike W; Marquis Edward T (for Huntsman Specialty Chemical Corp) May 9, 2000	Process for the production of etheramine alkoxylates
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564	CA2372226	CA	Berry Tricia S; Winkler Marie S; Kirkpatrick Donald E (for Dow Chemical Co) November 23, 2000	Process For Preparing Starch And Epoxy-Based Thermoplastic Polymer Compositions
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568	JP2174750	JP	Haiko Funberuto; Deetorefu, Heru (for RWE DEA AG) July 6, 1990	Secondary Polyetheramine, Preparation Thereof And Preparation of Polyurethane There from In The Absence Of Catalyst
569	JP8081563	JP	Matsutohiasu, Kururu; Mitsuhiyaeru, Fuoisteru (for Hoechst AG) March 26, 1996	Reaction Product Of Alpha, Beta-Unsaturated Dicarboxylic Acidpolymer With Polyetheramine
570	MXP0200098 1	MXP	Hahn, Stephen F (for Dow Chemical Co) July 30, 2002	Hydrogenated Block Copolymers having Elasticity and Articles Made There from
571	MXP0200231 2	MXP	Schmidt, Dale C (for Dow Chemical Co) July 30, 2002	Aqueous Solution or Dispersion on an Acid Salt of a Polyetheramine
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573	WO0069960	WO	Berry Tricia S; Winkler Marie S; Kirkpatrick Donald E (for Dow Chemical) November 23, 2000	Process For Preparing Starch And Epoxy-Based Thermoplastic Polymer Compositions
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## Additional Literature

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