Dow Plastics

DOW LIQUID EPOXY RESINS

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Note: Safety information on the handling of novolac resins, epoxy resins, solvents, diluents, modifiers, and other common "epoxy" formulation materials is critical. However, plant conditions and environments vary so widely, no warranty of any kind can be given. Formulators-customers should contact their suppliers of each of these materials for specific safe handling recommendations. Companion bulletins, DOW Epoxy Resins Product Stewardship, Safe Handling and Storage Manual (Form No. 296-00312) and DOW Epoxy Curing Agents Product Stewardship, Safe Handling and Storage Manual (Form No. 296-01331), are available from the Dow Plastics (Thermoset Applications) Department or your Dow sales representative.

Contents

INTRODUCTION

D.E.R.* liquid epoxy resins, developed and marketed by The Dow Chemical Company, are commercially established as major raw materials in the fields of tooling, encapsulation, adhesives, laminates, and coatings.

Similar commercial success has been earned by the families of D.E.R. solid and solution epoxy resins, flexible epoxy resins, brominated epoxy resins, D.E.N.* epoxy novolac resins, and D.E.H.* epoxy curing agents … also produced and marketed by Dow. And since these products are used with various curing agents, diluents, and modifiers, an almost unlimited range and variety of properties may be obtained.

This bulletin describes the bisphenol A-based liquid epoxy resins and aliphatic glycol epoxy resins offered by Dow. Information on other DOW epoxy and epoxy-related products may be obtained from your Dow sales representative or by calling 1-800-441-4369.

The curing of a liquid epoxy resin — i.e., converting it to a thermoset solid — is fundamental to its commercial use. This is also true of epoxy, polyester, phenolic, and melamine resins. However, liquid epoxy resins, because of their structure and the method of their cure, are superior to these other resins in the following properties:

- **No volatile loss** during cure of product.
- **Dimensional stability during cure.** They exhibit little shrinkage and can be used for very accurate reproduction.
- **Chemical resistance.** Good resistance to a variety of chemicals (including solvents, acids, and bases) results with properly cured formulations.
- **Chemical inertness.** They accept a wide range of fillers and pigments; they do not affect encapsulated parts or common containers.
- **Durability**. Cured formulations exhibit good hardness, impact strength, and toughness.
- **Adhesion.** The tenacity of epoxy adhesion to almost any surface is without equal among organic coatings.
- **Versatility in curing agent choice and curing conditions.**

Typically, bisphenol A/epichlorohydrin based resins, novolac based epoxy resins, and other di- or multifunctional resins containing the aromatic ring structure will cure to hard, rigid compositions having rather low impact and elongation characteristics. There are many approaches to improving these properties and increasing flexibility in epoxy resin systems. Among them are modifications with vegetable oils, polyamide or polysulfide curing agents, or long chain polyglycols. However, such modifiers often adversely affect the physical, chemical, or solvent resistance properties of an epoxy system, or they limit the choice of curing agents and thus limit use in many applications.

D.E.R. 732 and D.E.R. 736 flexible epoxy resins are designed to overcome many of the specific disadvantages of these other flexibilizing systems. They are compatible with practically all other epoxy resins and are shelf stable after mixing. Because they are true epoxy resins, they react with all epoxy curing agents and become an integral part of the cured system.

Table 1 on page 4 lists the typical properties of DOW liquid epoxy resins; Table 2 lists the typical properties of two liquid epoxy resins that contain a reactive diluent (a C_{12}-C_{14} aliphatic glycidyl ether), which provides reduced viscosities. Each resin is briefly described in the following paragraphs. Table 3 lists the typical properties of two flexible epoxy resins.

Note: Prior to handling any of these resins, or related curing agents, diluents, catalysts, or solvents, be certain you have acquired from your supplier(s) adequate information pertaining to safe operations for your workers and your plant. Request Material Safety Data (MSD) sheets for each product from its supplier. See "Hazards" section, pages 39-42, and the bulletins mentioned in the note on the inside of the front cover.

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Products and Properties

D.E.R. 317 Epoxy Resin
A high viscosity, fast reacting (20% faster than D.E.R. 331) liquid epoxy resin designed for adhesive applications requiring quick gelling with amine curing agents.

D.E.R. 324 Epoxy Resin
A formulated blend of D.E.R. 331 and a C_{12}-C_{14} aliphatic glycidyl ether to produce a low viscosity product. The product has utility in filled formulations for flooring compounds, grouts, adhesives, decoupage coatings, and high solids coatings. Blend ratio is 83/17 D.E.R. 331 to diluent.

D.E.R. 325 Epoxy Resin
A medium viscosity resin blend of 92/8 ratio of D.E.R. 331 to C_{12}-C_{14} aliphatic glycidyl ether. Used in same applications as D.E.R. 324.

D.E.R. 330 Epoxy Resin
A low epoxide equivalent weight liquid resin processed to give very low viscosity without the use of a reactive diluent.

D.E.R. 331 Epoxy Resin
A general purpose, widely used liquid resin. It is recognized as a standard from which variations have been developed.

D.E.R. 332 Epoxy Resin
The uniqueness of D.E.R. 332 epoxy resin is reflected in its maximum epoxide equivalent weight of 178 (chemically pure diglycidyl ether of bisphenol A would have an epoxide equivalent weight of 170). Because of its high purity and lack of polymer fractions, D.E.R. 332 resin provides uniform performance and exceptionally low viscosity and color. Under some conditions of cure, as illustrated in the cure schedule and property data (pages 18-33), it gives improved elevated temperature properties.

D.E.R. 332 resin frequently crystallizes at room temperature. The pure diglycidyl ether of bisphenol A is a solid with a melting point of approximately 42°C (108°F). Crystallization may be induced by chilling, seeding by dust particles, or incorporation of filler. Warming to 50-55°C (122-131°F) restores the resin to a liquid state. Long-term warm storage may result in slight discoloration but does not affect resin performance.

D.E.R. 337 Epoxy Resin
An intermediate epoxide equivalent weight bisphenol A semi-solid epoxy resin. Used in adhesives and coatings or as a modifier for other epoxy resins to improve impact strength, extensibility, and adhesion.

D.E.R. 362 & D.E.R. 364 Epoxy Resins
Medium viscosity liquid epoxy resins based on bisphenol A which possesses the unique characteristic of crystallization resistance.† D.E.R. 362 and D.E.R. 364 contain no solvents, no diluents, and are suited for applications ranging from coatings to composites.

D.E.R. 383 Epoxy Resin
A liquid epoxy resin designed to provide reduced viscosity and extended pot life while maintaining properties essentially equivalent to those of D.E.R. 331 epoxy resin.

D.E.R. 732 & D.E.R. 736 Epoxy Resins
D.E.R. 732 and D.E.R. 736 are polyglycol di-epoxides. Dow flexible epoxy resins are principally used as additives to base epoxy systems in formulations where greater elongation, higher impact resistance, and increased flexibility are required.

†Note: Under certain conditions, liquid epoxy resins may crystallize. Crystallization may take the form of turbidity or the presence of crystals in the material or on the container. Occasionally, crystallization may continue to the point where solidification occurs. The occurrence of crystallization is in no way an indication that an epoxy resin is contaminated or out of specification. Rather, it is a phenomenon which can occasionally occur during storage at room temperature or below.

Material that shows evidence of crystallization can be returned to its original liquid state by heating it to a temperature of approximately 50°C (122°F). This temperature should be maintained until dissolution occurs. Suggestions for heating include the use of a standard vented laboratory convection oven or steam. If steam is used, it should be circulated around tightly closed containers which have been assembled under a tarpaulin. (Note: Always exercise good safety habits when working with elevated temperatures. Also, for further information and/or advice on dissolution procedures, call or write The Dow Chemical Company, Dow Plastics, Customer Information Group, P.O. Box 1206, Midland, MI 48641-1206, (1-800-441-4369), FAX 517-832-1465.

Crystallization is chiefly a result of the purity and uniformity of a liquid epoxy resin. For example, pure diglycidyl ether of bisphenol A (DGEBA) is a solid. Factors that may encourage crystallization include thermal cycling and the presence of filler, which acts as seed material for crystal formation. To discourage crystallization, store epoxy resins at room temperature or higher. Also, avoid situations where temperatures cycle from room temperature to lower temperatures, as is sometimes the case in a warehouse.

Table 1 Typical Properties† of DOW Liquid Epoxy Resins

Resin	Epoxide Equiv. Wt.	Viscosity Range (cps @ 25°C)	Color, Max (Gardner)	Flash Point, (°F) [2]	Specific Gravity, 25/25°C	Weight (Lbs/Gal) @ 25°C
D.E.R. 317	192-203	16,000-25,000	5	485	1.16	9.7
D.E.R. 330	176-185	7,000-10,000	125 [3]	485	1.16	9.7
D.E.R. 331	182-192	11,000-14,000	125 [3]	485	1.16	9.7
D.E.R. 332	172-176	4,000-6,000	75 [3]	485	1.16	9.7
D.E.R. 337	230-250	400-800 [1]	3	485	1.16	9.7
D.E.R. 362	185-205	4,500-6,500	1	480	1.14	9.5
D.E.R. 364	190-210	4,000-7,000	2	480	1.16	9.7
D.E.R. 383	176-183	9,000-10,500	125 [3]	485	1.16	9.7

[1] 70% non-volatile in DOWANOL* DB solvent.
[2] Pensky-Martens, ASTM D-93.
[3] APHA Color — ASTM method 1209.
† Typical properties; not to be construed as specifications.

Table 2 Typical Properties† of DOW Liquid Epoxy Resins Containing a Reactive Diluent

Resin	Epoxide Equiv. Wt.	Viscosity Range (cps @ 25°C)	Color, Max (Gardner)	Flash Point, (°F)[1]	Specific Gravity, 25/25°C	Weight (Lbs/Gal) @ 25°C
D.E.R. 324	197-206	600-800	3	350	1.11	9.3
D.E.R. 325	185-206	850-2,800	2	375	1.14	9.5

[1] Pensky-Martens, ASTM D-93.
† Typical properties; not to be construed as specifications.

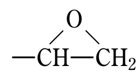
Table 3 Typical Properties† of DOW Liquid Epoxy Resins Based On Polyglycol Di-epoxides

Resin	Epoxide Equiv. Wt.	Viscosity Range (cps @ 25°C)	Color, Max (APHA)	Flash Point, (°F)[1]	Specific Gravity, 25/25°C	Weight (Lbs/Gal) @ 25°C
D.E.R. 732	305-335	55-100	125	310	1.06	8.9
D.E.R. 736	175-205	30-60	125	320	1.14	9.5

[1] Pensky-Martens Closed Cup
† Typical properties; not to be construed as specifications.

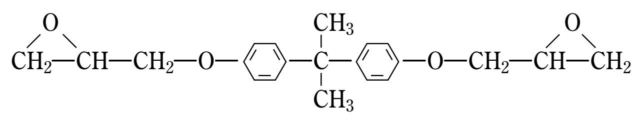
RESIN STRUCTURE

Epoxy resins contain a reactive oxirane structure

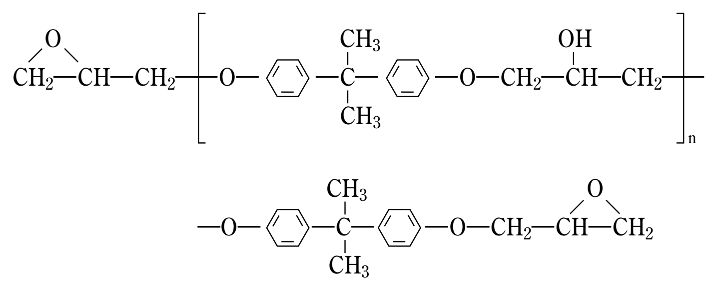


which is commonly referred to as an “epoxy” functionality. Liquid epoxy resins are converted through these reactive epoxy sites into tough, insoluble, and infusible solids.

The simplest possible epoxy resin derived from the reaction of bisphenol A and epichlorohydrin is (2,2-bis[4-(2'3' epoxy propoxy) phenyl] propane), commonly called the diglycidyl ether of bisphenol A (DGEBA).



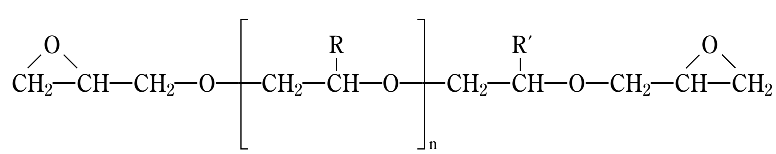
The higher molecular weight homologs are represented by the following theoretical structure:



Generic Bisphenol A Based Epoxy Resin Chemical Structure

With increasing molecular weight, another reactive site — the OH group — is introduced. This group can react at higher temperatures with anhydrides, organic acids, amino resins, and phenolic resins, or with epoxide groups (when catalyzed) to give additional cross-linking.

Typical value of “n” is about 0.15 for D.E.R. 331 epoxy resin (epoxy equivalent weight range of 182-192 and viscosity of 11,000-14,000 cps at 25°C). The low melting point solid resins begin at an “n” of about 2.5. In high melting point solid resins, “n” may be as high as 18.



Generic Aliphatic Polyglycol Diepoxide Structure

D.E.R. 736 resin has a lower value of “n,” and hence a shorter chain length than D.E.R. 732.

CURING AGENTS

Many commercial materials are suitable as reactive cross-linking agents for liquid epoxy resins. The most common types of curing agents are:

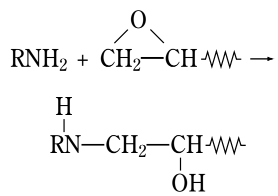
- primary and secondary polyamines and their adducts
- anhydrides
- polyamides
- catalytic types

Primary And Secondary Polyfunctional Amines

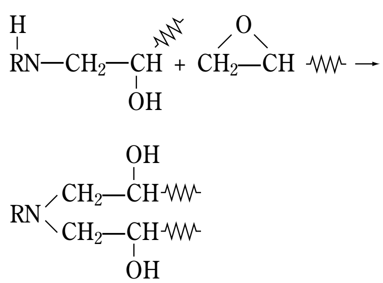
Typical of this class of curing agents are aliphatic amine compounds, such as D.E.H. 20 epoxy hardener (diethylene triamine), D.E.H. 24 epoxy hardener (triethylene tetramine), and D.E.H. 26 epoxy hardener (tetraethylene pentamine). Also used are adducts of the above amines with epoxy resins, diluents, or other amine-reactive compounds. Room temperature cures are usually employed.

Aromatic amines, such as metaphenylene diamine and diamino diphenyl sulfone, are also widely used to achieve higher heat distortion temperatures. Elevated temperature cures are usually employed.

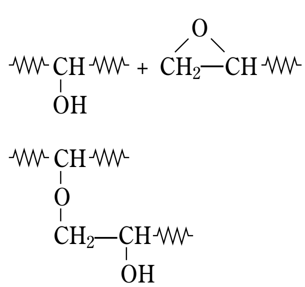
The amines react with the epoxy group through the active amine hydrogen. Each primary amine group is theoretically capable of reacting with two epoxide groups, and each secondary amine group is capable of reacting with one epoxide group. The reaction of a primary amine with an epoxy is seen as follows:



The secondary amine thus formed reacts further:



Theoretically, the hydroxyls formed should be capable of reacting with epoxy groups to form an ether linage:



This reaction is often catalyzed by tertiary amines. However, the tertiary amine formed by the epoxy-secondary amine reaction is apparently too immobile and sterically hindered to act as a catalyst.

The presence of hydroxyls, however, has an important function because they assist in opening the epoxide ring. Alcoholic or phenolic hydroxyls accelerate the primary and secondary amine cures and thus provide for the more rapid gel time of the amine adducts and the higher molecular weight resins.

Aliphatic Polyamines
The liquid aliphatic polyamines and their adducts are convenient to handle, give excellent cured resin physical characteristics, including chemical and solvent resistance, and cure at ambient or moderately elevated temperatures. Good long-term retention of properties is possible at temperatures up to 100°C. Short-term exposure at higher temperatures can be tolerated. Pot life is short and exotherm is high in thick sections and large masses. See Table 4.

Aromatic Polyamines
Most aromatic polyamines are solids and are usually incorporated in the resin by melting at elevated temperatures. Pot life is considerably longer than with aliphatic polyamines, and elevated temperature cures are required to develop optimum properties. See Table 5.

Cured systems give excellent performance up to about 150°C (302°F). They are used in adhesives, wet lay-up laminates, tooling, small pottings, and coatings. Shrinkage of aromatic polyamine cured resins, particularly with the high-molecular-weight resins, is quite low — a useful feature for encapsulation and potting.

Calculation of Stoichiometric Ratios
To obtain optimum properties with polyfunctional epoxide-reactive curing agents (particularly the amines), it is desirable to react the resin and the curing agent at approximately stoichiometric quantities. To determine the ratio required, calculations can be made as follows, using D.E.H. 20 ($NH_2 — CH_2 — CH_2 — NH — CH_2 — CH_2 — NH_2$) as an example:

1. To calculate the Amine H equivalent weight, use the following equation:

Equation (1):

$$\text{Amine H eq wt} = \frac{\text{MW of amine}}{\text{no. of active hydrogen}}$$

Example:

$$\text{Amine H eq wt D.E.H. 20} = \frac{103.2}{5} = 20.6$$

2. To calculate the stoichiometric ratio of DEH 20 to use with D.E.R. 331 epoxy resin having an epoxide equivalent weight of 189:

Equation (2):

$$\text{phr}^{\dagger}\text{ of amine} = \frac{\text{Amine H eq wt} \times 100}{\text{Epoxide eq wt of resin}}$$

Example:

phr D.E.H. 20 to be used with D.E.R. 331.

$$\text{phr} = \frac{20.6 \times 100}{189} = 10.9$$

3. Frequently, epoxy resins are blended, filled, or modified with reactive and nonreactive components. It is then necessary to adjust the concentration of the curing agent to cure only the portion of the mix that is reactive; e.g., the resins and any reactive diluent present. This may be simply done by calculating the epoxide equivalent weight (EEW) of the total mix and then applying equation (2) to determine the amount of curing agent to add to 100 parts of formulation.

Equation (3):

$$\text{EEW of mix} = \frac{\text{Total Wt}}{\frac{\text{Wt a}}{\text{EEWa}} + \frac{\text{Wt b}}{\text{EEWb}} + \frac{\text{Wt c}}{\text{EEWc}}}$$

Total weight includes all materials, both reactive and nonreactive.

a,b,c, etc., are only the materials reactive with the curing agent, and are characterized by an epoxy ring.

Example:

100 parts D.E.R. 331	Avg EEW 189
100 parts D.E.R. 337	Avg EEW 240
30 parts BGE (diluent)	Avg EEW 130
230 parts Filler	—
460 Total	

$$\text{EEW of mix} = \frac{460}{\frac{100}{189} + \frac{100}{240} + \frac{30}{130}} = \frac{460}{1.1766} = 391$$

By equation (2):

$$\text{Amount D.E.H. 20} = \frac{20.6 \times 100}{391} = 5.27$$ parts per hundred parts filled formulation

†Parts by wt per 100 parts resin

Table 4 Aliphatic Polyamines and Adducts†

Curing Agent	Wt. Per Active H	PHR D.E.R. 331	Suggested Cure Schedule	Source	Comments
D.E.H. 20 (diethylene triamine, DETA)	20.6	10.9	Gel at RT plus several days at RT or 1-2 hrs at 100°C for full cure.	The Dow Chemical Company	General purpose RT curing agent. High exotherm in large mass. May blush under humid conditions.
D.E.H. 24 (triethylene tetramine, TETA)	24.4	12.9	Gel at RT plus several days at RT or 1-2 hrs at 100°C for full cure.	Dow	General purpose RT curing agent. High exotherm in large mass. Lower vapor pressure than D.E.H. 20. May blush under humid conditions.
D.E.H. 26 (tetraethylene pentamine, TEPA)	27.1	14.3	Gel at RT plus several days at RT or 1-2 hrs at 100°C for full cure.	Dow	RT curing agent often used in 2 package protective coating systems. May blush under humid conditions.
D.E.H. 29 (amine mix)	28.8	15.2	Gel at RT plus several days at RT or 1-2 hrs at 100°C for full cure.	Dow	Amine curing agent with low vapor pressure for safer handling. Similar in properties to D.E.H. 24 but cured samples have less tendency to blush when cured under humid conditions.
D.E.H. 39 (amino ethyl piperazine, AEP)	43	22.8	Gel at RT plus several days at RT or 1-2 hrs at 100°C for full cure.	Dow	Trifunctional amine with short pot life. Imparts moderate degree of flexibility and gives improved impact.
D.E.H. 52 (amine-epoxy resin adduct)	53	28.0	Gel at RT plus several days at RT or 1-2 hrs at 100°C for full cure.	Dow	Amine adduct with D.E.R. 331. Fast cure time. Viscosity 6,000-8,000 cps. Lower vapor pressure and less critical ratios offer improved handling characteristics.
D.E.H. 58 (accelerated aliphatic amine)	30	15.9	Gel at RT plus several days at RT or 1-2 hrs at 100°C for full cure.	Dow	Amine containing an accelerator for fast reacting ambient cure systems.
XUS 19036.00 (polyethylene polyamine)	34	18.0	Gel at RT plus several days at RT or 1-2 hrs at 100°C for full cure.	Dow	Amine curing agent with low-odor, non-corrosive and excellent chemical-resistant properties, especially for secondary containment applications with reduced blush tendency under humid cure conditions.

RT = Room Temperature
†Typical properties; not to be construed as specifications.

Table 5 **Aromatic Polyamines†**

Curing Agent	Wt. Per Active H	PHR D.E.R. 331	Suggested Cure Schedule	Comments
Metaphenylene diamine (MPDA)	27	14.3	Gel at 55°C + 2 hrs at 125°C + 2 hrs at 175°C.	Aromatic diamine with a melting point of approx. 60°C. Can be used to make eutectic mix. Good elevated temp. performance. Used in laminates, castings, and filament winding.
Diamino diphenyl sulfone (DDS or DADS)	57	30.2	1 hr at 150°C 3 hrs at 220°C.	Aromatic polyamine with a melting point of approx. 175°C. Used in laminates. Has good B-stage shelf life. Cure may be accelerated with BF_3•MEA or aliphatic amines.
Diethyltoluene diamine	44.6	23.6	2 hrs at 100°C 4 hrs at 175°C.	Low viscosity liquid aromatic diamine. Gives longer pot life than other aromatic amines. Low exotherm.

†Typical formulations and cure schedules only; not to be construed as specifications.

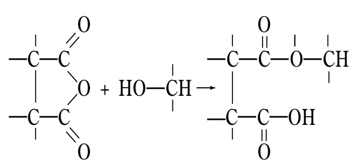
Anhydrides

Liquid and solid anhydrides are extensively used to cure epoxy resins. Products typical of this class are shown in Table 6.

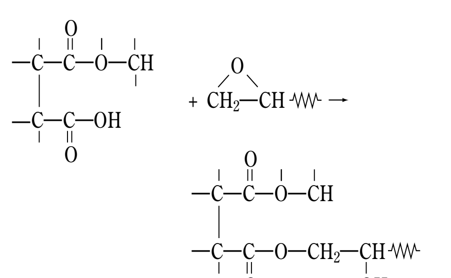
The reactivity rate of some anhydrides with epoxies is slow. An accelerator, usually a tertiary amine, is often used (0.5% to 3%) to speed gel time and cure. The optimum amount is usually critical, depending upon the anhydride and resin used and cure schedules. Amounts above or below the "correct" amount reduce high temperature performance. The "best" concentration should be determined experimentally. Eutectic mixtures to depress resin melting points may be prepared.

The reaction of anhydrides with epoxy groups is complex, with several competing reactions capable of taking place. The three most important are:

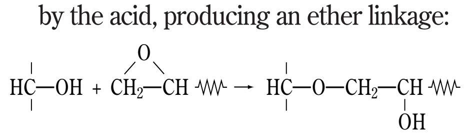
1. The opening of the anhydride ring with an alcoholic hydroxyl to form the monoester:



2. Subsequent to (1), the nascent carboxylic groups react with the epoxide to give an ester linkage:



3. The epoxide groups react with nascent or existing hydroxyl groups, catalyzed by the acid, producing an ether linkage:



At low elevated temperature cures, the ether and ester reactions take place at about the same rate. At higher temperatures, the ester linkage occurs more frequently, and this probably accounts for the reduced elevated temperature performance of systems gelled at initially high temperatures. Since reaction (3) can take place independently in the acid medium, the ratio of anhydride to epoxy is less critical than with an amine. It can vary from 0.5 to 0.9 equivalents of anhydride per equivalent of epoxy and should be determined experimentally to achieve desired properties.

Pot life of the mix is usually long; exotherm is low. Elevated temperature cures are necessary and long post cures are required to develop ultimate properties. Electrical and physical strength properties are good over a wide temperature range. Chemical resistance to some reagents is less than with amine-cured systems, but is better against aqueous acids.

Table 6 Anhydrides†

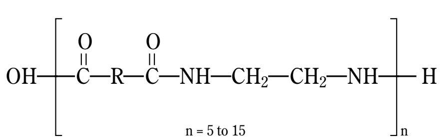
Curing Agent	PHR D.E.R. 331	Suggested Cure Schedule	Comments
Nadic methyl anhydride (NMA)	60-90[1]	2 hrs at 90°C + 4 hrs at 165°C + 16 hrs at 200°C	Liquid anhydride having long pot life at room temp. Excellent elevated temp. properties.
Hexahydrophthalic anhydride (HHPA)	60-75[1]	2 hrs at 100°C + 2-6 hrs at 150°C	Low melting point solid, approx. 35°C, soluble in liquid resin at room temp. Used in potting, filament windings, and clear castings.
Trimellitic anhydride (TMA)	60-90[1]	24 hrs at 150-180°C	Good electrical properties, good high temperature properties. Reacts rapidly at high temperatures.
Dodecenyl succinic anhydride (DDSA)	95-130[1]	2 hrs at 100°C + 4-6 hrs at 150°C	Liquid anhydride. Imparts flexibility to cured composition.
Phthalic anhydride (PA)	40-65	24 hrs at 120°C or 8 hrs at 150°C	Solid anhydride with melting point 128°C. Low exotherm and long pot life. Used in large encapsulations.
Methyl hexahydrophthalic anhydride (MHHPA)	60-75[1]	3 hrs at 100°C + 6 hrs at 140°C	Excellent light stability, fast gel time.
Tetrahydrophthalic anhydride (THPA)	60-75[1]	24 hrs at 120°C or 8 hrs at 150°C	Solid anhydride with melting point of 100°C. Similar to hexahydrophthalic anhydride in cured resin properties. Used in pottings and encapsulations.
Methyl tetrahydrophthalic anhydride (MTHPA)	70-90[1]	2 hrs at 90°C + 4 hrs at 150°C	Liquid anhydride with higher reactivity than NMA but similar cured physical properties.

[1]Plus suitable accelerator.

†Typical formulations and cure schedules only; not to be construed as specifications.

Polyamides

This class of compounds can be considered as modified polyfunctional aliphatic amines, since the polyamides most widely used are the condensation products of dimerized fatty acids and a difunctional amine such as ethylenediamine. Their theorized structure is represented as follows:



The reactivity of polyamides with epoxies is similar to that of the aliphatic amines. Since the polyamides are relatively large polymers, the ratio of polyamide to epoxy is less critical than with the low-molecular-weight amines. It is varied quite broadly to obtain properties from hard to semi-flexible. In this sense, the polyamides can be considered resin modifiers as well as curing agents.

Polyamide-cured formulations have longer pot life than formulations cured with aliphatic polyamines and their adducts. They cure at room temperature without blushing and show outstanding adhesion. Formulations are high in viscosity and are sometimes incompatible with the resin until reaction has been initiated. They are usually dark in color. Polyamide systems lose structural strength and insulation value rapidly with increasing temperatures, and are usually restricted to applications under 65˚C (149˚F). Similar products from two polyamide curing agent producers are shown in Table 7.

Table 7 Polyamides†

Curing Agent	PHR D.E.R. 331	Suggested Cure Schedule	Comments
Versamid[1] 100 Ancamide[2] 100	70-110	RT + several days to full cure.	Semi-solid polyamide resin used primarily as a solvent cut solution to cure intermediate-molecular-weight epoxy resins in coating applications. Also available in solutions. Can be used to cure resins on wet substrates.
Versamid 115 Ancamide 220	60-100	RT gel + several days to full cure or 1-2 hrs at 100°C.	High-viscosity fluid polyamide. Can be used at 100% solids by warming to reduce viscosity. Used in laminates, adhesives, potting, sealants, and coatings. Also available in solution.
Versamid 125 Ancamide 260A	50-100	RT gel + several days to full cure or 1-2 hrs at 100°C.	Intermediate-viscosity fluid polyamide. Can be blended at RT or warmed slightly to reduce viscosity. Used in wet lay-ups, adhesives, potting, sealants, coatings, epoxy mortars, and tooling.
Versamid 140 Ancamide 350A	30-70	RT gel + several days to full cure or 1-2 hrs at 100°C.	Low-viscosity polyamide having higher heat distortion, excellent adhesion, and low shrinkage. Used in 100% solids spray applications, wet lay-ups, epoxy mortars, casting, tooling, and adhesives.

RT = Room Temperature
†Typical properties; not to be construed as specifications.

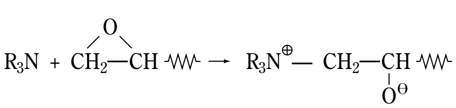
[1]Trademark of Henkel
[2]Trademark of Air Products and Chemicals, Inc.

Catalytic Curing Agents

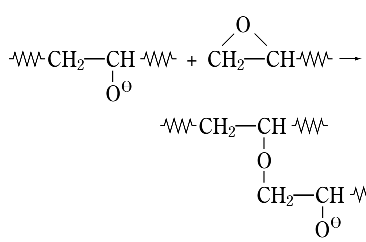
Catalytic curing agents are those compounds that promote epoxy-to-epoxy or epoxy-to-hydroxyl reactions and do not themselves serve as direct cross-linking agents. Tertiary amines, amine salts, boron trifluoride complexes, and amine borates are in this class.

The mechanism of epoxy-to-epoxy polymerization using a tertiary amine catalyst (or other catalytic curing agent) theoretically takes place as follows:

1. Opening of the epoxy group:



2. The ion thus formed is capable of opening another epoxy group:



This continues until a dense cross-linked structure containing the stable ether linkages is formed.

This oversimplified explanation does not consider the hydroxyl groups either present in the higher weight resin homologs or introduced by resin modifiers and curing agents. While the steps of the epoxy-hydroxyl reaction differ, the end structure is very similar to that postulated for the epoxy-epoxy reaction. Pot life is moderate (2 to 24 hours) for tertiary amine and amine salts, and is very long, up to several months, for the latent catalysts, such as $BF_3 \cdot MEA$ (boron trifluoride monoethylamine) complex or dicyandiamide. The latent catalysts depend on dissociation by heat with the dissociation products capable of initiating epoxy cures.

The amount of catalyst used may vary from 2 to 10 phr. The specific amount for a given system should be determined experimentally to develop the optimum in properties desired. Tertiary amine catalysts are used, for example, in small amounts to accelerate the cure of anhydride-epoxy or aromatic amine-epoxy combinations, and they are also used in conjunction with latent catalysts to attain various degrees of B-staging.

Examples of catalytic curing agents are Benzyl Dimethylamine (BDMA), BF_3 Monoethylamine ($BF_3 \bullet MEA$), Dimethyl Aminomethyl Phenol.

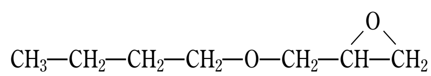
Reactive Diluents, Modifiers, Fillers

Reactive Diluents

A reactive diluent is used primarily to reduce viscosity. Adding a reactive diluent also permits higher filler loading and gives better wetting and impregnation.

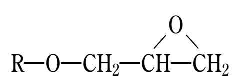
Preferably, the diluent should react with the curing agent at approximately the same rate as the resin, contribute substantial viscosity reduction at low concentrations, and be nonreactive with the resin under normal storage conditions.

Reactive diluents in common use are†:



Butyl Glycidyl Ether (BGE)

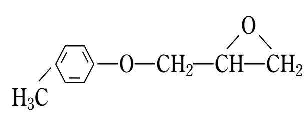
(Molecular weight — 130)



R = C_{12} to C_{14}

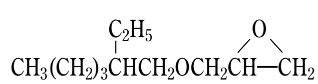
C_{12}-C_{14} Aliphatic Glycidyl Ether

(Molecular weight — 242-270)



Cresyl Glycidyl Ether (CGE)

(Molecular weight — 165)



2 — Ethylhexyl Glycidyl Ether

(Molecular weight — 186)

† Typical diluents only; not to be construed as a recommendation from Dow.

Epoxy resins may be modified for several reasons:

- to enhance physical properties, such as impact strength and adhesion,
- to alter viscosity,
- to improve pot life, lower exotherm, or reduce shrinkage, and
- to lower the cost of the formulation.

Butyl glycidyl ether produces maximum viscosity reduction. However, excessive exposure to these products may present serious health hazards. Consult product labels and current Material Safety Data (MSD) sheets before using. The higher-molecular-weight reactive diluents — like the C_{12}-C_{14} aliphatic ethers — are safer to work with, but not quite as efficient.

Figure 1 shows the viscosity-diluent concentration relationship for representative DOW epoxy resins. The amount of curing agent, when used on a stoichiometric basis, should be adjusted for the change in epoxide equivalent value of the diluent-modified resin. See "Calculation of Stoichiometric Ratios," page 7.

Figure 1:
Effect of Diluents on D.E.R. Epoxy Resins†

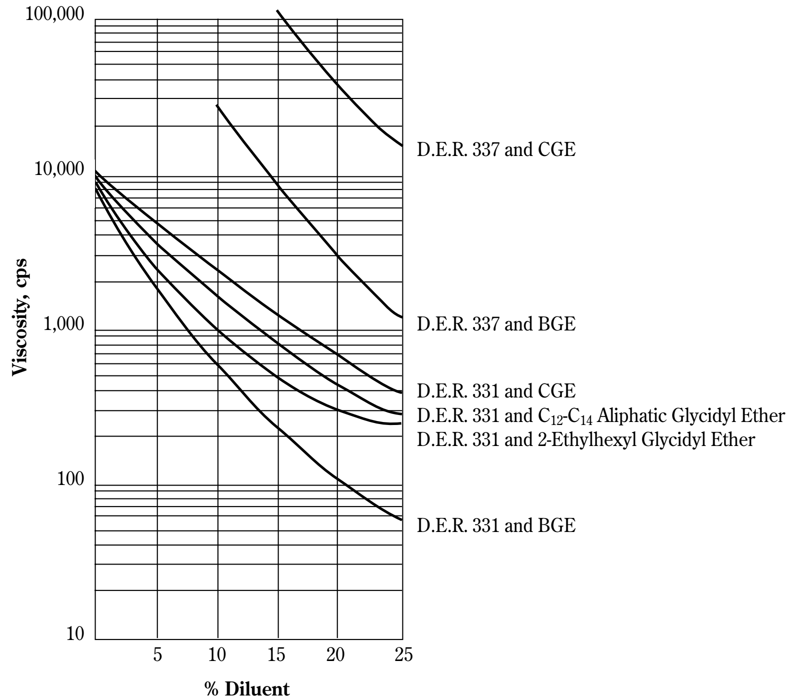
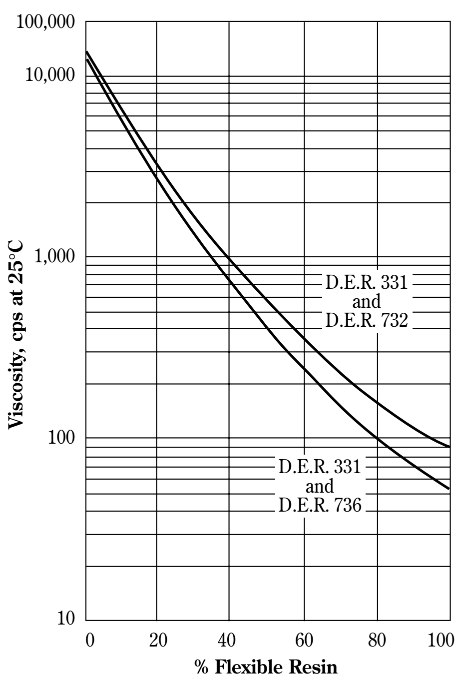


Figure 2:
Viscosity vs Flexible Resin Concentration (D.E.R. 331 with D.E.R. 732 and D.E.R. 736)



†For illustrative purposes only; not to be construed as specifications.

Resin Modifiers

Resin modifiers are used to improve mechanical and thermal shock resistance, increase elongation, and obtain higher impact strength and flexibility. Usually there is some sacrifice of physical strength, electrical properties, chemical or solvent resistance, or elevated temperature performance.

Epoxy compounds, such as the aliphatic diepoxides (D.E.R. 732 and D.E.R. 736 flexible epoxy resins), or monofunctional epoxide compounds (such as C_{12} - C_{14} Glycidyl Ether) are examples of reactive epoxide-type modifiers. Such compounds can be used at ratios up to 1:1 to obtain a flexible cured composition. They have the added advantage of being shelf stable when blended with the resin.

The low viscosity and light color of D.E.R. 732 and D.E.R. 736 resins offer viscosity reduction in epoxy formulations without affecting color of cured compositions. These advantages are not found with most other flexibilizers. Figure 2 shows the effect on viscosity of increasing amounts of flexible resin in blends with D.E.R. 331.

Modifiers which may be reactive as curing agents are often used. Common among these are polysulfide polymers, triphenyl phosphite, and various polyamides. The latter react readily with the epoxy and were discussed under "Curing Agents," page 6. The polysulfide polymers react slowly with the epoxies when used alone. One to three phr of an active catalytic amine or an amine salt, such as 2,4,6 Tri (Dimethyl Aminomethyl) Phenol, are used to accelerate cure.

Triphenyl phosphite reduces viscosity and lowers cost. Ratios up to 25 phr appear to have no gross effect on room temperature physical properties. Triphenyl phosphite, although reactive with the epoxy, is not an effective curing agent by itself. A polyfunctional curing agent is necessary to effect a cure. About 75% of the normal stoichiometric amount of amine gives optimum results when 25 phr triphenyl phosphite is used with a resin such as D.E.R. 331.

Nonreactive modifiers are not used extensively, as they cause reduction in cured resin properties. When used, their more common function is to lower cost. Materials such as dibutyl phthalate, nonylphenol, pine oil, and glycol ethers may be used. Chief requisites are that they be compatible with the resin before and after cure, not vaporize or foam during cure, and not migrate excessively from the cured composition.

Fillers†

The use of fillers in epoxy compositions can lower costs, reduce exotherm, extend pot life, and achieve improvement in one or more of the cured resin properties indicated:

- **Improved machinability**
  - powdered aluminum or copper
  - calcium carbonate
  - calcium silicate
- **Improved abrasion resistance**
  - alumina
  - flint powder
  - carborundum
  - silica
  - molybdenum disulfide
- **Improved impact strength**
  - chopped glass
  - other fibrous materials
- **Improved electrical properties**
  - mica
  - silica
  - powdered or flaked glass
- **Improved thermal conductivity**
  - metallic fillers
  - coarse sand
  - alumina
- **Improved anti-settling, flow, or thixotropic properties**
  - colloidal silicas
  - clays

Such improvements are usually achieved at the sacrifice of tensile, flexural, and impact strength (when granular fillers are used). Most fillers reduce the coefficient of thermal expansion and shrinkage in proportion to the amount of filler rather than the type of filler used.

Fibrous and flake fillers, such as chopped glass strand, glass flake, and mica, impart high viscosities at low filler loadings (10 to 25 phr). Medium-weight granular fillers, such as powdered aluminum, alumina, and silica, may be used at loadings up to 200 phr. Heavy fillers, such as powdered iron, iron oxide, and coarse sand, may be loaded at ratios up to 800 phr.

The finer particle size fillers are easier to incorporate, and have less tendency to settle. Coarse and heavy fillers tend to settle and cake on standing unless some light-weight filler or anti-settling agent is also incorporated. Fumed silica compounds are effective as anti-settling and thixotropic agents.

†Typical fillers only; not to be construed as a recommendation from Dow.

EPOXY FORMULATING TECHNIQUES

The full advantages of using epoxy resins, particularly in high volume applications, depend on the total formulation — resin, curing agent, etc.— and on the proper formulation processing techniques.

Each application has its unique performance requirements. However, some special considerations are common to many applications, and a knowledge of them is essential in determining practical solutions.

Some of these considerations are:

- Establishing and maintaining safe handling and disposal procedures to maximize worker and plant safety.
- Preparing (quickly and easily) the right amount of thoroughly mixed formulation at the correct curing agent/resin ratio.
- Avoiding excessive exotherm, premature gelling, and waste of batch mixes.
- Eliminating air entrapment in castings, laminations, and adhesive joints.
- Preventing spillage and subsequent problems of toxicity exposure and cleanup.

Equipment

Several types of automatic mixing and dispensing equipment are commercially available. Use of adequately engineered equipment makes it possible to meter, mix, and deliver automatically the right amount of formulation. The mix is uniform, and the changes in viscosity that occur when batch mixes start to react are avoided. The use of very fast curing agents is possible, since resin and curing agent are mixed and delivered almost instantaneously to the point of application. Also, heat can be applied to reduce viscosity and/or shorten cure time, or the components can be de-aired for those applications where a bubble-free mix is required. Equipment is also available to dispense product directly into evacuated molds. The use of such equipment minimizes the need for direct contact with the materials.

Batch mixing may be done in conventional paint or mortar mixing equipment. For laboratory or small batch mixes, disposable containers and portable stirring equipment are adequate. Take care to ensure thorough mixing. Uncatalyzed or over-catalyzed areas in a poor mix may result in a non-uniform cure and poor performance. Note: Batch mixing requires special care to prevent exposure of employees to resins, hardeners, etc. See "Hazards," page 36.

Temperature Control

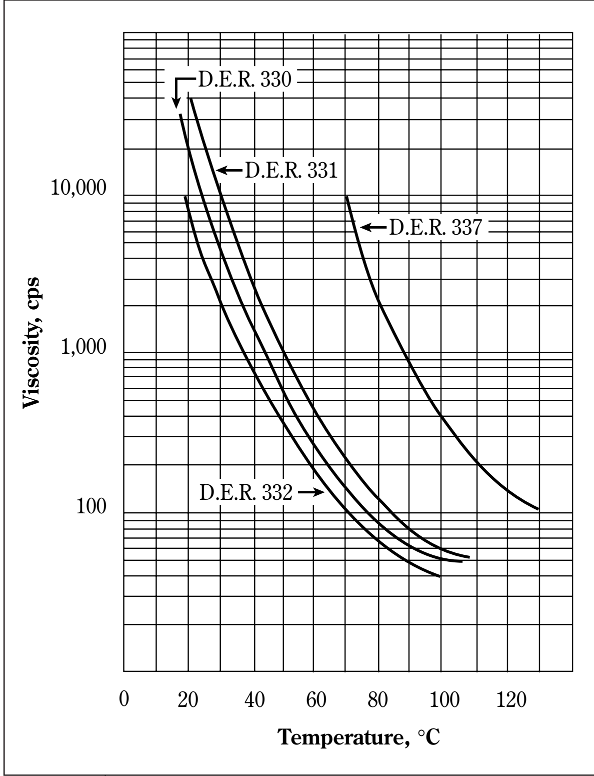
Where large batches of moderately reactive mixes (those with a pot life of several hours or days) are necessary, cooling and circulation facilities should prolong pot life. This technique is particularly adaptable to low viscosity formulations for impregnating, dipping, etc. Pot life may be further prolonged by stepwise addition of fresh mix to the resin tank. This also serves to control viscosity as the batch ages.

Viscosity vs Temperature of D.E.R. Liquid Epoxy Resins

Figure 3 shows viscosity curves of D.E.R. liquid resins over a practical range of temperatures. Reducing viscosity by elevating temperature helps incorporate higher filler loadings and aids in deaerating mixes. It also assists the dissolving and thorough mixing of solid or high viscosity curing agents.

Figure 4 is a plot of the viscosity of two concentrations of each flexible resin with D.E.R. 331 resin (a liquid bisphenol A type epoxy resin) through a temperature range of 0 to 100°C.

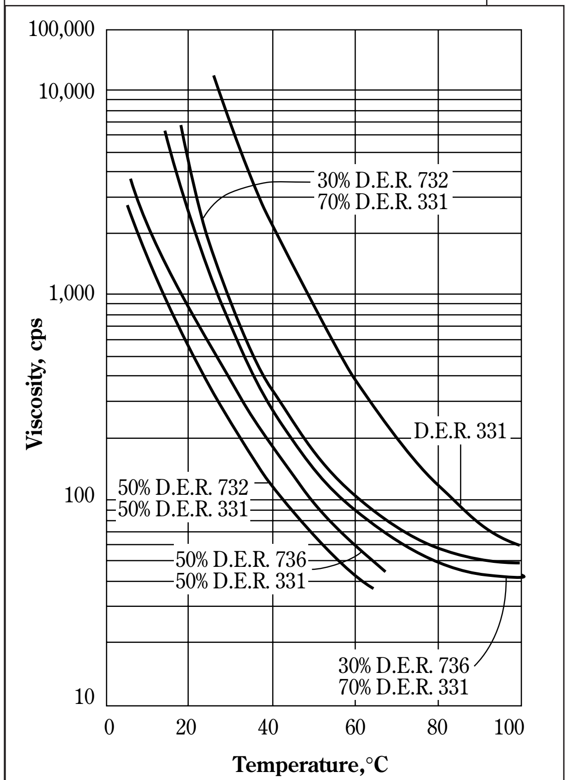
Figure 3:
Viscosity vs Temperature for D.E.R. Liquid Epoxy Resins†



†For illustrative purposes only; not to be construed as specifications.

RESIN PERFORMANCE DATA

Figure 4:
Viscosity vs Temperature (Blends of D.E.R. 732 and D.E.R. 736 with D.E.R. 331)



*Trademark of The Dow Chemical Company

Tables 10 through 30 show typical properties of unfilled castings with the Dow liquid epoxy resins cured by D.E.H. 24 (TETA), BF_3 •MEA, NMA, etc. No optimization of curing agents, phr ratios, or cure schedules was made.

The specific curing agents selected were chosen because each is typical of its class and is in common use. Curing agents of similar chemical structure can be expected to give similar performance, when recommended adjustments of ratio and cure schedule are followed.

Dow flexible epoxy resins, when used alone, develop soft cured compositions having low physical strength properties. Therefore, they are best utililtzed in blends with bisphenol A/epichlorohydrin resins such as D.E.R. 331 resin or an epoxy novolac resin such as D.E.N. 438* resin. Liquid, semi-solid, or low molecular weight solid epoxy resins also may be used. The amount of flexible resin required is dependent on the end use application and the desired properties of the formulation.

Generally, 10% to 30% of DOW flexible epoxy resin is a good starting point range to improve resilience while retaining most of the desirable properties of the unmodified system. With this level of modification, elongation, impact and sometimes tensile strength are increased while flexural and compressive strengths are decreased.

D.E.R. 732 resin or D.E.R. 736 resin are often favored at the lower levels of modification because of the viscosity reduction they provide. Heat distortion temperatures are lower with increasing amounts of flexible resin. Solvent and chemical resistance may lessen, depending on the system and type of exposure. Electrical properties are essentially unaffected at room temperatures, but are likely to fall off at elevated temperatures.

In cured systems containing 50% or more of DOW flexible epoxy resins, tensile, flexural, and compressive strengths are lowered substantially, and impact resistance and elongation are greatly increased (compared to those properties in unmodified epoxy resins). D.E.R. 736 resin, with its shorter chain length, has less effect on physical properties at a given flexible resin content than does D.E.R. 732 resin.

The cure schedules and formulating techniques used in preparing specimens for physical property testing are shown in Table 9. The cure schedules are not necessarily optimum, but are used as standard conditions to allow direct comparison with data on other Dow epoxy resins listed in other bulletins.

The test methods given in Table 8 were used in obtaining the data in Tables 10 and 12.

Test Methods

When comparing Dow data with data from other sources, consider the method of test. For example, Dow flexural strength data were obtained on coupons 1/4" thick by 1/2" wide using a span of 4". If the coupon size is reduced to 1/8" thick and the span is reduced to 2", values for flexural strengths will typically be 2,000 to 5,000 psi higher for the same formulation.

Whenever possible, all data were gathered by the ASTM procedures listed in Table 8, page 17. Procedures are given where an ASTM test was not used.

Chemical And Solvent Resistance

Because of the great number of samples involved, chemical and solvent resistance data were limited to inorganic and organic acids and bases, common solvents, oxidizing agents, and water. Amine, anhydride, and catalytic-cured systems were extensively exposed to show the effect of the type of catalyst on resistance. All formulations were exposed to a limited number of reagents to compare the effect of molecular weight change and diluents.

Table 8 **Test Methods**

Property	Test Methods	Sample Size and Comments
Heat Distortion Temperature	ASTM D 648	1/2" x 1/2" bars; span 4"
Flexural Strength and Modulus	ASTM D 790	1/2" W x 1/4" D bars; span 4"
Yield Compressive Strength and Modulus at 10% Deformation or Less	ASTM D 695	1/2" x 1/2" x 1" bars
Tensile Strength and Ultimate Elongation	ASTM D 638	Dimensions per ASTM designation: F = 2.25" T = 0.125" W = 0.500" D = 4.5" rate 0.2"/min.
Hardness, Rockwell M	ASTM D 785	1/4" thick coupons
Izod Impact Strength	ASTM D 256	1/2" x 1/2" x 2 1/2" bars
Chemical and Solvent Resistance	ASTM D 543	3" x 1" x 0.125" coupons
Thermal Degradation	—	2" dia. x 0.125" coupons exposed in air convection oven at specified temperature.
Dielectric Constant and Dissipation Factor	ASTM D 150	Cond. A: Samples conditioned 40 hrs at 23°C and 50% relative humidity. Cond. C: Samples conditioned 48 hrs at 50°C. Cond. D: Samples conditioned 96 hrs at 23°C and 96% relative humidity.
Volume and Surface Resistivity	ASTM D 257	—
Pot Life and Peak Exotherm	—	Determined on 500 gm samples. Tests initiated at elevated temperature were maintained in constant temperature bath or oven.

The following cure schedules were used in preparing test specimens for the data presented in Tables 12 through 33.

Table 9 **Cure Schedules†**

Curing Agent	Initial Gel Time Hrs	Initial Gel Temp °C	Post Cure Time Hrs	Post Cure Temp °C	Comments
D.E.H. 20 (diethylene triamine)	16	25	2	100	For high viscosity resins; both resins and molds preheated to 55°C to reduce viscosity.
D.E.H. 24 (triethylene tetramine)	16	25	3	100	For high viscosity resins; both resins and molds preheated to 55°C to reduce viscosity.
Nadic Methyl Anhydride[1]	2	90	4 +16	165 200	Resin, curing agent, and molds preheated to 90°C.
BF_3 Monoethylamine (BF_3 • MEA)	4	100	16	150	Resin preheated to 80-100°C to dissolve catalyst. Molds preheated to 100°C.
Versamid 140 [2] (polyamide)	16	25	3	100	Resins and curing agent preheated to 55°C to reduce viscosity. Molds preheated to 65°C to permit release of entrapped bubbles. Higher viscosity resins may require higher mix temperatures.
1,2-Cyclohexane Diamine (cycloaliphatic amine)	16	25	2	100	For high viscosity resins, molds preheated to 55°C to reduce viscosity. Ideal post cure includes several hours at 150°C.
D.E.H. 20 (diethylene triamine)	16	25	2	100	For high viscosity resins; both resins and molds preheated to 55°C to reduce viscosity.
D.E.H. 39 (aminoethyl piperazine)	16	25	4	60	For high viscosity resins; both resins and molds preheated to 55°C to reduce viscosity.

[1] 1.5 parts Benzyldimethylamine (BDMA) as accelerator per one hundred parts resin.
[2] Polyamide from Henkel.
†For illustrative purposes only; not to be construed as specifications.

Table 10 Physical Properties — DOW Liquid Epoxy Resins Cured with D.E.H. 24†

Resin		D.E.R. 362	D.E.R. 330	D.E.R. 331	D.E.R. 332	D.E.R. 317	D.E.R. 383	30% D.E.R. 732 70% D.E.R. 331	30% D.E.R. 736 70% D.E.R. 331
Average Epoxide Equivalent Weight		195	180	190	174	197	180	218	192
phr		13.2	13.5	13.0	14.0	12.2	13	11	13
Formulation Viscosity, cps at 25°C		1,000	1,250	2,250	900	3,200	1,650	540	400
Reactivity & Exotherm	(Min.)[1]	31	40	25	43	25	40	—	—
of a 500 Gram Mass	(°C)[2]	80	80	74	68	75	88	—	—
(@ 25°C)	(°C)[3]	270	271	266	283	270	270	—	—
	(Min.)[4]	44	55	36	55	40	55	—	—
Heat Deflection Temperature (°C)		100	104	111	107	104	100	58	76
Flexural Strength (psi)		17,000	17,700	13,900	15,590	17,000	17,000	10,825	14,400
Flexural Modulus (psi x 10^5)		5.51	4.90	4.4	4.05	4.74	5.0	3.25	4.21
Yield Compressive Strength (psi)		16,000	15,000	16,300	15,840	14,500	15,800	12,200	12,040
Compressive Modulus (psi x 10^5) at 10% deformation or less		3.50	3.40	4.4	2.63	4.06	3.37	2.99	3.51
Tensile Strength (psi)		10,300	8,950	11,400	9,620	10,700	10,900	6,600	9,225
Ultimate Elongation, %		3.4	2.8	4.4	4.4	2.7	3.1	5.53	6.00
Izod Impact Strength (ft. lb./in. notch)		—	0.40	0.50	0.50	0.50	0.50	.54	.61
Hardness (Rockwell M)		107	107	106	107	109	107	87	91

[1]Time to transition point or gel.
[2]Temperature at transition point.
[3]Temperature at peak exotherm.
[4]Time to peak exotherm.
†Typical values; not to be construed as specifications.

Table 11 Electrical Properties – DOW Liquid Epoxy Resins Cured with D.E.H. 24†

Resin	D.E.R. 330	D.E.R. 331	D.E.R. 332	D.E.R. 317	D.E.R. 383	30% D.E.R. 732 70% D.E.R. 331	30% D.E.R. 736 70% D.E.R. 331
Dielectric Constant							
Cond. A							
Frequency, Hz 60	3.97	4.02	3.98	4.02	—	3.87	3.95
10^3	3.86	3.90	3.86	3.95	4.31	3.76	3.85
10^6	3.39	3.42	3.27	3.43	—	3.27	3.32
Cond. D							
Frequency, Hz 60	4.24	4.27	4.23	4.21	—	3.92	4.58
10^3	4.13	4.17	4.07	4.12	—	4.53	4.32
10^6	3.52	3.55	3.42	3.54	—	3.69	3.58
Dissipation Factor							
Cond. A							
Frequency, Hz 60	.009	.007	.010	0.008	—	.014	.013
10^3	.020	.020	.027	0.018	0.019	.022	.023
10^6	.029	.032	.031	0.034	—	.032	.033
Cond. D							
Frequency, Hz 60	.023	.010	.013	0.010	—	.074	.043
10^3	.025	.023	.030	0.020	—	.045	.037
10^6	.033	.036	.035	0.036	—	.051	.043
Volume Resistivity (ohm—cm)							
Cond. A	1.51×10^{15}	6.1×10^{15}	1.29×10^{15}	1.18×10^{15}	1.58×10^{15}	1.97×10^{15}	1.24×10^{15}
Cond. C	1.76×10^{15}	1.7×10^{15}	1.1×10^{15}	8.5×10^{14}	—	4.43×10^{15}	1.79×10^{14}
Surface Resistivity (ohm)							
Cond. A	1.73×10^{14}	7.85×10^{15}	7.85×10^{14}	$>7.85 \times 10^{15}$	2.22×10^{15}	3.14×10^{15}	3.94×10^{15}
Cond. C	3.14×10^{14}	6.3×10^{15}	9.42×10^{14}	7.85×10^{14}	—	2.04×10^{13}	7.22×10^{13}

— = Not Determined

†Typical values; not to be construed as specifications.

Table 12

Chemical, Solvent Resistance, and Thermal Degradation — DOW Liquid Epoxy Resins Cured With D.E.H. 24†

Resin	D.E.R. 330 % WT Change, Days	D.E.R. 331 % WT Change, Days	D.E.R. 332 % WT Change, Days	D.E.R. 317 % WT Change, Days	D.E.R. 383 % WT Change, Days	30% D.E.R. 732 70% D.E.R. 331 % WT Change, Days	30% D.E.R. 736 70% D.E.R. 331 % WT Change, Days
Reagent	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**
Sulfuric Acid 30%	.56 1.24 2.85	.69 1.8 3.10	.62 1.33 3.08	0.64 1.27 2.80	.66 1.31 2.94	1.10 4.26 9.31	1.81 3.61 7.90
Sulfuric Acid 3%	— — —	.61 1.27 2.66	— — —	— — —	— — —	2.21 4.54 9.93	1.90 4.03 9.38
Hydrochloric Acid 36%	— — —	1.13 2.35 5.58	— — —	— — —	1.86 3.15 6.53	5.42 10.60 26.40	3.54 6.11 15.30
Hydrochloric Acid 10%	— — —	0.64 1.45 3.15	— — —	— — —	— — —	2.39 4.92 10.40	2.00 4.11 9.24
Nitric Acid 40%	— — —	1.9 4.1 D	— — —	— — —	4.24 D D	D[1] — —	D — —
Nitric Acid 10%	— — —	.81 1.77 3.95	— — —	— — —	— — —	3.21 6.69 15.20	2.21 4.69 10.60
Ammonium Hydroxide 28%	— — —	.35 .84 1.79	— — —	— — —	— — —	.85 1.85 3.75	.56 1.37 3.10
Ammonium Hydroxide 10%	— — —	.37 .81 1.73	— — —	— — —	— — —	— — —	— — —
Acetic Acid 25%	— — —	2.99 6.14 14.2	— — —	— — —	— — —	14.30 D —	10.86 D —
Ethyl Alcohol 95%	— — —	.14 .37 .86	— — —	— — —	— — —	4.95 9.78 20.40	1.49 3.03 6.45
Acetone	.17 .74 4.48	.45 2.1 7.7	.19 .80 4.68	0.83 3.11 7.80	.92 3.62 12.0	D — —	4.28 10.50 —
Ethylene Dichloride	— — —	.29 1.14 6.43	— — —	— — —	— — —	D — —	10.00 D —
Toluene	— — —	.04 .07 .16	— — —	— — —	.20 .21 .24	3.31 10.10 24.10	.03 .10 .81 —
Sodium Hydroxide 50%	0.00 -.06 -.11	.0 .04 .02	–.01 –.05 –.07	–0.02 –0.07 –0.11	.03 -.10 -.13	.02 .01 .02	.01 .00 .05
Sodium Hydroxide 10%	— — —	.36 .66 1.41	— — —	— — —	— — —	.68 1.39 2.67	.48 1.03 2.23
JP 4 Fuel	.03 -.01 .09	.02 -.01 .09	.02 -.02 .08	0.14 0.20 -0.21	— — —	.02 .04 .24	.03 .04 .22
Citric Acid 10%	— — —	.39 .80 1.65	— — —	— — —	— — —	1.09 2.16 4.30	.71 1.48 3.24
Chromic Acid 40%	— — —	–1.53 –5.82 –17.3	— — —	— — —	— — —	–3.17 –12.10 –34.40	–1.60 –6.43 –19.80
Distilled Water	.40 .79 1.68	.41 .88 1.7	.41 .80 1.69	0.43 0.77 1.78	.38 .76 1.40	.92 1.93 3.80	.64 1.36 3.11
HRS	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500
Thermal Degradation (% Wt. Loss) 160°C	.95 .95 1.32 1.41	.71 1.0 1.4 1.6	.92 .96 1.07 1.42	0.70 1.2 1.4 1.7	1.1 1.3 1.6 1.8	1.83 2.47 2.89 3.27	1.50 2.11 2.57 3.41
210°C	2.11 3.77 — 7.39	3.4 5.4 6.8 7.8	2.07 3.51 — 7.00	3.30 5.2 7.0 7.7	3.9 5.5 6.9 9.2	4.73 D — —	D D — —

D = Decomposed
— = Not Determined
†Typical values; not to be construed as specifications.

Table 13 — Physical Properties — DOW Liquid Epoxy Resins Cured with 1,2-Cyclohexane Diamine†

Resin	D.E.R. 331	D.E.R. 383
Average Epoxide Equivalent Weight	190	180
phr	17	16
Formulation Viscosity, cps at 25°C	1,020	700
Reactivity & Exotherm of a 500 Gram Mass (@25°C) (Min.)[1]	50	95
(°C)[2]	113	118
(°C)[3]	172	176
(Min.)[4]	56	103
Heat Deflection Temperature (°C)	110	110
Flexural Strength (psi)	15,400	15,200
Flexural Modulus (psi x 10^5)	4.2	4.1
Yield Compressive Strength (psi)	16,000	15,800
Compressive Modulus (psi x 10^5) at 10% deformation or less	3.9	4.0
Tensile Strength (psi)	10,300	12,100
Ultimate Elongation (%)	4.0	4.1
Izod Impact Strength (ft. lb./in. notch)	0.40	0.40
Hardness (Rockwell M)	106	106

[1]Time to transition point or gel.
[2]Temperature at transition point.
[3]Temperature at peak exotherm.
[4]Time to peak exotherm.
†Typical values; not to be construed as specifications.

Table 14 — Electrical Properties — DOW Liquid Epoxy Resins Cured with 1,2-Cyclohexane Diamine†

Resin	D.E.R. 331	D.E.R. 383
Dielectric Constant, Cond. A., Frequency, Hz 10^3	4.50	4.35
Dissipation Factor, Cond. A., Frequency, Hz 10^3	.016	.008
Volume Resistivity (ohm-cm), Cond. A	4.0 x 10^{15}	4.2 x 10^{15}
Surface Resistivity (ohm), Cond. A	5.6 x 10^{15}	5.9 x 10^{15}

†Typical values; not to be construed as specifications.

Table 15

Chemical, Solvent Resistance, and Thermal Degradation — DOW Liquid Epoxy Resins Cured with 1,2-Cyclohexane Diamine†

Resin	**D.E.R. 331 % WT Change, Days**				**D.E.R. 383 % WT Change, Days**			
Reagent	**7**	**28**	**120**		**7**	**28**	**120**	
Sulfuric Acid 30%	.67	1.20	2.25		.57	.98	1.85	
Nitric Acid 40%	4.11	17.1	D		3.27	9.83	D	
Acetone	1.76	5.80	21.3		2.45	10.2	25.0	
Toluene	.32	.48	.57		.66	1.70	4.64	
Sodium Hydroxide 50%	.08	-.34	-.09		-.16	.08	.02	
Hydrochloric Acid 36%	2.29	4.41	8.94		2.10	3.64	6.15	
Distilled Water	.64	.95	1.62		.47	.89	1.38	
HRS	100	200	300	500	100	200	300	500
Thermal Degradation (% Wt. Loss) 160°C	1.4	1.6	1.9	2.0	1.3	1.5	1.7	1.7
210°C	3.8	5.6	7.3	9.9	3.8	5.8	7.2	9.7

D = Decomposed

†Typical values; not to be construed as specifications.

Table 16 **Physical Properties — DOW Liquid Epoxy Resins Cured with Nadic Methyl Anhydride†**

Resin		D.E.R. 330	D.E.R. 331	D.E.R. 332	D.E.R. 337	D.E.R. 317	D.E.R. 383	30% D.E.R. 732 70% D.E.R. 331	30% D.E.R. 736 70% D.E.R. 331
Average Epoxide Equivalent Weight		180	190	174	240	197	180	218	192
phr		87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5
Formulation Viscosity, cps at 80°C		35	38	30	225	45	36	27.5	25
Reactivity & Exotherm	(Min.)[1]	158	129	97	37	80	160	—	—
of a 500 Gram Mass	(°C)[2]	113	99	93	92	100	112	—	—
(@ 80°C)	(°C)[3]	132	146	152	153	155	130	—	—
	(Min.)[4]	180	153	125	65	100	182	—	—
Heat Deflection Temperature (°C)		148	156	135	111	147	144	87	116
Flexural Strength (psi)		19,200	14,000	21,200	18,870	15,000	18,500	16,700	16,400
Flexural Modulus (psi x 10^5)		4.70	4.40	4.72	3.52	4.41	4.80	4.45	4.35
Yield Compressive Strength (psi)		16,900	18,300	20,190	18,940	15,000	17,100	17,730	16,150
Compressive Modulus (psi x 10^5) at 10% deformation or less		3.84	4.40	3.40	3.24	4.41	3.80	2.14	2.82
Tensile Strength (psi)		6,340	10,000	6,260	7,330	7,000	7,000	10,640	11,570
Ultimate Elongation, %		1.4	2.5	1.6	0.9	1.8	1.7	5.5	6.2
Izod Impact Strength (ft. lb./in. notch)		0.30	0.48	0.21	0.49	0.48	0.30	.47	.41
Hardness (Rockwell M)		111	111	114	113	1.09	112	108	106

[1]Time to transition point or gel.
[2]Temperature at transition point.
[3]Temperature at peak exotherm.
[4]Time to peak exotherm.
†Typical values; not to be construed as specifications.

Table 17 Electrical Properties — DOW Liquid Epoxy Resins Cured with Nadic Methyl Anhydride†

Resin	D.E.R. 330	D.E.R. 331	D.E.R. 332	D.E.R. 337	D.E.R. 317	D.E.R. 383	30% D.E.R. 732 70% D.E.R. 331	30% D.E.R. 736 70% D.E.R. 331
Dielectric Constant								
Cond. A								
Frequency, Hz 60	3.15	3.15	3.14	3.36	3.12	—	3.20	3.19
10^3	3.13	3.14	3.12	3.33	3.09	3.54	3.18	3.17
10^6	3.01	2.97	2.99	3.10	2.89	—	2.98	3.00
Cond. D								
Frequency, Hz 60	3.39	3.34	3.30	3.46	3.22	—	4.27	3.36
10^3	3.35	3.32	3.29	3.43	3.19	—	3.32	3.36
10^6	3.14	3.11	3.13	3.15	3.01	—	3.09	3.12
Dissipation Factor								
Cond. A								
Frequency, Hz 60	.0030	.0020	.0049	.0037	.0024	—	.0061	.0053
10^3	.0054	.0054	.0045	.0060	.0053	.0038	.0066	.0069
10^6	.016	.017	.015	.027	.018	—	.021	.020
Cond. D								
Frequency, Hz 60	.0079	.0023	.0030	.0035	.0038	—	.0060	.0061
10^3	.0063	.0059	.0044	.0067	.0059	—	.076	.0078
10^6	.020	.021	.018	.028	.020	—	.025	.026
Volume Resistivity (ohm—cm)								
Cond. A	6.11×10^{15}	6.1×10^{15}	7.2×10^{15}	7.3×10^{15}	9.0×10^{14}	6.15×10^{15}	4.71×10^{15}	1.73×10^{15}
Cond. C	3.67×10^{15}	1.17×10^{15}	1.01×10^{15}	2.9×10^{15}	4.74×10^{14}	—	4.71×10^{15}	1.24×10^{15}
Surface Resistivity (ohm)								
Cond. A	4.71×10^{15}	3.93×10^{15}	6.28×10^{15}	$>7.85 \times 10^{15}$	$>7.85 \times 10^{15}$	4.95×10^{15}	3.53×10^{15}	7.85×10^{15}
Cond. C	3.93×10^{15}	3.93×10^{16}	1.1×10^{15}	3.93×10^{15}	3.93×10^{15}	—	7.85×10^{15}	2.67×10^{14}

— = Not Determined

†Typical values; not to be construed as specifications.

Table 18 Chemical, Solvent Resistance, and Thermal Degradation — DOW Liquid Epoxy Resins Cured with Nadic Methyl Anhydride†

Resin	D.E.R. 330 % WT Change, Days	D.E.R. 331 % WT Change, Days	D.E.R. 332 % WT Change, Days	D.E.R. 337 % WT Change, Days	D.E.R. 317 % WT Change, Days	D.E.R. 383 % WT Change, Days	30% D.E.R. 732 70% D.E.R. 331 % WT Change, Days	30% D.E.R. 736 70% D.E.R. 331 % WT Change, Days
Reagent	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**
Sulfuric Acid 30%	.33 .48 .54	.33 .83 .55	.28 .41 .51	.29 .57 1.14	0.41 0.66 1.20	.14 .22 .36	.23 .52 .77	.35 .53 .56
Sulfuric Acid 3%	— — —	.50 .81 .96	.41 .64 .85	— — —	— — —	— — —	— — —	— — —
Hydrochloric Acid 36%	— — —	.32 .56 1.36	.26 .46 1.11	— — —	— — —	.21 .38 .88	— — —	— — —
Hydrochloric Acid 10%	— — —	.42 .66 .78	.30 .53 .66	— — —	— — —	— — —	— — —	— — —
Nitric Acid 40%	— — —	.40 1.1 1.7	.36 .99 5.38	— — —	— — —	.20 .65 3.41	— — —	— — —
Nitric Acid 10%	— — —	.47 .81 .94	.40 .66 .83	— — —	— — —	— — —	— — —	— — —
Ammonium Hydroxide 28%	— — —	.67 1.24 1.84	.57 1.09 1.78	— — —	— — —	— — —	— — —	— — —
Ammonium Hydroxide 10%	— — —	.59 1.06 1.36	.60 .97 1.28	— — —	— — —	— — —	— — —	— — —
Acetic Acid 25%	— — —	.46 .73 .90	.45 .63 .84	— — —	— — —	— — —	— — —	— — —
Ethyl Alcohol 95%	— — —	.20 .37 .59	.11 .22 .37	— — —	— — —	— — —	— — —	— — —
Acetone	3.77 12.20 21.60	4.8 13.0 22.3	1.07 17.70 D	6.13 D —	6.29 17.1 D	2.33 5.62 18.8	D — —	5.74 15.3 D
Ethylene Dichloride	— — —	6.73 D —	9.81 D —	— — —	— — —	— — —	— — —	— — —
Toluene	— — —	.06 .09 .28	.02 .04 .24	— — —	— — —	.10 .14 .18	— — —	— — —
Sodium Hydroxide 50%	–.02 –.13 –.21	–.08 –.12 –.16	–.30 –.83 –1.45	–.04 –.08 –.25	0.05 0.04 0.05	–.16 –.26 –.26	–.01 –.01 –.01	–.02 –.05 –.07
Sodium Hydroxide 10%	— — —	.37 .51 .50	.34 .54 .68	— — —	— — —	— — —	— — —	— — —
JP 4 Fuel	.02 –.02 .12	.02 .02 .16	.02 .02 .13	.01 .03 .19	0.14 0.26 0.30	— — —	.02 .02 .18	.03 .02 .16
Citric Acid 10%	— — —	.50 .79 .94	.41 .64 .85	— — —	— — —	— — —	— — —	— — —
Chromic Acid 40%	— — —	.07 –.62 –2.14	.07 –.96 –3.44	— — —	— — —	— — —	— — —	— — —
Distilled Water	.47 .74 .86	.52 .82 .87	.40 .61 .84	.41 .90 1.79	0.59 0.96 1.30	.26 .54 .70	.45 .83 1.40	.48 .80 1.02
HRS	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500
Thermal Degradation (% Wt. Loss) 160°C	.21 .13 .13 .16	.12 .07 .10 .10	.27 .05 .09 .09	.36 .27 .36 .36	.35 .40 .40 .43	.17 .04 .09 .11	.61 .45 .56 .56	.28 .22 .28 .22
210°C	.28 .28 – .84	.66 1.1 1.5 1.8	.28 .31 – .76	2.38 2.59 – 3.18	.70 1.3 1.5 2.0	1.1 1.1 1.6 2.3	.77 2.58 – 2.54	1.02 1.44 – 2.81
260°C	6.26 10.50 – –	5.60 10.20 – –	5.10 9.30 – –	10.90 14.90 – –	6.10 9.80 – –	– – – –	11.80 – – –	24.90 D – –

D = Decomposed
— = Not Determined
†Typical values; not to be construed as specifications.

Table 19 **Physical Properties — DOW Liquid Epoxy Resins Cured with $BF_3 \cdot$ MEA†**

Resin		D.E.R. 330	D.E.R. 331	D.E.R. 332	D.E.R. 337	30% D.E.R. 732 70% D.E.R. 331	30% D.E.R. 736 70% D.E.R. 331
Average Epoxide Equivalent Weight		180	190	174	240	218	192
phr		3	3	3	3	3	3
Formulation Viscosity, cps at 100°C		35	40	30	900	48	45
Reactivity & Exotherm of a 500 Gram Mass (@100°C)	(Min.)[1]	260	190	125	380	—	—
	(°C)[2]	106	110	115	90	—	—
	(°C/Min.)[3]	129	160	253	93	—	—
	(Min.)[4]	325	240	140	435	—	—
Heat Deflection Temperature (°C)		121	168	130	148	59	72
Flexural Strength (psi)		12,200	14,500	13,430	11,950	12,055	14,580
Flexural Modulus (psi x 10^5)		.47	4.5	3.21	3.21	3.69	4.42
Yield Compressive Strength (psi)		16,100	16,500	16,930	14,720	10,600	11,000
Compressive Modulus (psi x 10^5) at 10% deformation or less		3.48	3.3	2.59	2.48	2.46	2.64
Tensile Strength (psi)		4,620	5,700	4,280	6,620	6,425	8,930
Ultimate Elongation (%)		.1	1.6	.80	1.7	7.8	6.45
Izod Impact Strength (ft. lb./in. notch)		0.30	0.26	0.25	0.46	.54	.49
Hardness (Rockwell M)		110	111	112	109	87	95

[1]Time to transition point or gel.
[2]Temperature at transition point.
[3]Temperature at peak exotherm.
[4]Time to peak exotherm.
†Typical values; not to be construed as specifications.

Table 20 Electrical Properties — DOW Liquid Epoxy Resins Cured with $BF_3 \cdot MEA$†

Resin		D.E.R. 330	D.E.R. 331	D.E.R. 332	D.E.R. 337	30% D.E.R. 732 70% D.E.R. 331	30% D.E.R. 736 70% D.E.R. 331
Dielectric Constant							
Cond. A							
Frequency, Hz	60	3.43	3.47	3.36	3.36	3.46	3.54
	10^3	3.40	3.45	3.34	3.33	3.40	3.48
	10^6	3.22	3.23	3.15	3.16	3.13	3.20
Cond. D							
Frequency, Hz	60	3.70	3.71	3.59	3.71	3.27	4.34
	10^3	3.66	3.70	3.58	3.68	4.08	3.82
	10^6	3.39	3.41	3.31	3.32	3.50	3.43
Dissipation Factor							
Cond. A							
Frequency, Hz	60	.0039	.0029	.0032	.0040	.0044	.0089
	10^3	.0054	.0053	.0052	.0068	.012	.0097
	10^6	.022	.023	.023	.025	.024	.031
Cond. D							
Frequency, Hz	60	.0160	.0039	.0046	.0071	.052	.013
	10^3	.0078	.0068	.0062	.0083	.031	.014
	10^6	.027	.034	.027	.035	.047	.041
Volume Resistivity (ohm-cm)							
Cond. A		4.81×10^{15}	8.6×10^{15}	1.92×10^{15}	5.1×10^{15}	7.52×10^{14}	3.77×10^{15}
Cond. C		1.68×10^{15}	1.2×10^{16}	2.64×10^{15}	1.78×10^{15}	1.10×10^{14}	1.51×10^{15}
Surface Resistivity (ohm)							
Cond. A		7.85×10^{15}	$>7.85 \times 10^{15}$	2.36×10^{15}	$>7.85 \times 10^{15}$	4.71×10^{14}	1.57×10^{15}
Cond. C		1.26×10^{15}	$>7.85 \times 10^{15}$	2.36×10^{15}	1.38×10^{15}	6.28×10^{15}	1.02×10^{15}

†Typical values; not to be construed as specifications.

Table 21 Chemical, Solvent Resistance, and Thermal Degradation — DOW Liquid Epoxy Resins Cured with $BF_3 \cdot MEA$†

Resin	D.E.R. 330 % WT Change, Days	D.E.R. 331 % WT Change, Days	D.E.R. 332 % WT Change, Days	D.E.R. 337 % WT Change, Days	30% D.E.R. 732 70% D.E.R. 331 % WT Change, Days	30% D.E.R. 736 70% D.E.R. 331 % WT Change, Days
Reagent	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**
Sulfuric Acid 30%	34 .73 1.13	.40 1.1 1.2	33 .53 1.05	.21 .60 1.02	48 .88 1.29	.36 .71 1.11
Sulfuric Acid 3%	— — —	.52 1.05 1.66	— — —	— — —	— — —	— — —
Hydrochloric Acid 36%	— — —	.26 .49 1.17	— — —	— — —	— — —	— — —
Hydrochloric Acid 10%	— — —	.44 .87 1.38	— — —	— — —	— — —	— — —
Nitric Acid 40%	— — —	.45 1.2 1.5	— — —	— — —	— — —	— — —
Nitric Acid 10%	— — —	.48 1.00 1.59	— — —	— — —	— — —	— — —
Ammonium Hydroxide 28%	— — —	.57 1.22 2.17	— — —	— — —	— — —	— — —
Ammonium Hydroxide 10%	— — —	.57 1.16 1.93	— — —	— — —	— — —	— — —
Acetic Acid 25%	— — —	.53 1.03 1.65	— — —	— — —	— — —	— — —
Ethyl Alcohol 95%	— — —	.20 .43 .80	— — —	— — —	— — —	— — —
Acetone	.27 .84 4.00	.43 1.2 3.2	.30 .93 4.67	1.12 3.16 12.6	D — —	7.71 D —
Ethylene Dichloride	— — —	.85 2.39 8.26	— — —	— — —	— — —	— — —
Toluene	— — —	.09 .17 .26	— — —	— — —	— — —	— — —
Sodium Hydroxide 50%	.01 –.04 .03	–.03 –.02 0.00	0.2 –.04 .01	–.03 –.04 –.02	.01 .05 .03	.02 .03 .04
Sodium Hydroxide 10%	— — —	.50 .94 1.46	— — —	— — —	— — —	— — —
JP 4 Fuel	.03 .08 .23	.02 .06 .23	.02 .05 .20	–.01 .00 .16	.03 .06 .27	04 .05 .28
Citric Acid 10%	— — —	.56 1.10 .169	— — —	— — —	— — —	— — —
Chromic Acid 40%	— — —	–.50 –2.42 –7.74	— — —	— — —	— — —	— — —
Distilled Water	.51 .99 1.71	.62 1.2 1.8	.53 .99 1.57	.60 1.18 1.92	.75 1.54 2.68	.56 1.12 2.04
HRS	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500
Thermal Degradation (% Wt. Loss)						
160°C	.37 .41 .41 .57	.36 .48 .11 .86	.25 .36 .41 .41	.54 .72 .80 1.07	4.44 5.72 6.63 7.8	2.40 3.32 4.09 4.84
210°C	1.42 1.87 – 3.37	2.6 4.0 4.9 5.5	.98 1.46 – 3.05	1.65 2.45 – 3.69	13.50 15.20 – 18.0	12.30 15.20 – 20.40
260°C	22.40 D – –	19.60 D – –	20.80 D – –	22.60 D – –	44.10 D – –	43.00 D – –

D = Decomposed

— = Not Determined

†Typical values; not to be construed as specifications.

Table 22 Physical Properties — DOW Liquid Epoxy Resins Cured with Polyamide[6] Curing Agent[†]

Resin	D.E.R. 330		D.E.R. 331		D.E.R. 332		D.E.R. 337		D.E.R. 317		D.E.R. 383		30% D.E.R. 732 70% D.E.R. 331		30% D.E.R. 736 70% D.E.R. 331	
Average Epoxide Equivalent Weight	180		190		174		240		197		180		218		192	
phr	43		43		43		43		43		43		43		43	
Formulation Viscosity, °C	25	50	25	50	25	50	25	50	25	50	25	50	25	50	25	50
cps	8,800	1,200	16,000	1,250	6,500	960	—	62,000	81,200	1,370	9,300	1,210	2,650	400	2,550	310
Reactivity & Exotherm of a 500 Gram Mass (°C)[1]	25	50	25	50	25	50	—	50	25	50	25	50	—	—	—	—
(Min.)[2]	169	30	94	22	160	31	—	16	114	25	169	32	—	—	—	—
(°C)[3]	53	80	56	90	70	76	—	95	70	92	54	81	—	—	—	—
(°C)[4]	89	228	118	226	153	215	—	172	250	235	89	230	—	—	—	—
(Min.)[5]	194	44	110	35	185	48	—	25	130	38	194	47	—	—	—	—
Heat Deflection Temperature (°C)	86		101		92		88		83		83		52		53	
Flexural Strength (psi)	13,100		9,700		12,170		11,330		12,300		13,000		8,350		11,250	
Flexural Modulus (psi x 10^5)	3.83		3.50		3.27		2.13		3.31		3.92		2.47		3.36	
Yield Compressive Strength (psi)	11,800		12,400		12,290		11,780		12,200		12,100		12,800		13,500	
Compressive Modulus (psi x 10^5) at 10% deformation or less	2.95		3.70		2.39		3.84		3.11		2.92		1.74		2.23	
Tensile Strength (psi)	7,600		8,300		6,810		7,290		8,900		8,000		4,830		6,850	
Ultimate Elongation (%)	3.6		3.9		2.0		–		4.6		4.0		15.3		4.73	
Izod Impact Strength (ft. lb./in. notch)	0.40		0.50		0.44		1.03		0.49		0.40		.66		.52	
Hardness (Rockwell M)	89		80		82		72		86		87		60		74	

1 Initial temperature of mix.
2 Time to transition point or gel.
3 Temperature at transition point.
4 Temperature at peak exotherm.
5 Time to peak exotherm.
6 For example Versamid 140 or Ancamide 350 A. (Curing agent is a 350-400 amine value polyamide.)
— = Not Determined
– = Not run due to high viscosity.
†Typical values; not to be construed as specifications.

Table 23

Electrical Properties — DOW Liquid Epoxy Resins Cured with Polyamide[1] Curing Agent[†]

Resin		D.E.R. 330	D.E.R. 331	D.E.R. 332	D.E.R. 337	D.E.R. 317	D.E.R. 383	30% D.E.R. 732 70% D.E.R. 331	30% D.E.R. 736 70% D.E.R. 331
Dielectric Constant									
Cond. A									
Frequency, Hz	60	3.13	3.23	3.24	3.20	3.39	—	3.36	3.37
	10^3	3.12	3.19	3.20	3.17	3.35	3.76	3.28	3.31
	10^6	2.95	2.99	2.95	2.91	3.04	—	3.98	3.06
Cond. D									
Frequency, Hz	60	3.39	3.48	3.44	3.48	3.58	—	3.63	4.17
	10^3	3.35	3.44	3.39	3.40	3.52	—	3.90	3.74
	10^6	3.09	3.10	3.07	3.08	3.15	—	3.30	3.26
Dissipation Factor									
Cond. A									
Frequency, Hz	60	.0045	.0036	.0097	.0063	.0047	—	.011	.010
	10^3	.0065	.0070	.0097	.0091	.010	.0070	.016	.012
	10^6	.019	.019	.021	.021	.020	—	.024	.021
Cond. D									
Frequency, Hz	60	.0098	.0059	.0078	.0210	.0047	—	.058	.055
	10^3	.010	.011	.011	.014	.010	—	.036	.031
	10^6	.022	.026	.026	.027	.020	—	.044	.036
Volume Resistivity (ohm-cm)									
Cond. A		1.44×10^{15}	1.22×10^{16}	4.86×10^{15}	1.21×10^{16}	6.04×10^{15}	1.38×10^{15}	4.81×10^{15}	1.81×10^{15}
Cond. C		7.68×10^{14}	1.22×10^{16}	2.91×10^{14}	1.45×10^{15}	3.62×10^{15}	—	2.53×10^{13}	1.04×10^{13}
Surface Resistivity (ohm)									
Cond. A		1.26×10^{15}	5.5×10^{15}	7.85×10^{15}	7.85×10^{15}	$>7.85 \times 10^{15}$	2.40×10^{15}	3.93×10^{15}	7.85×10^{15}
Cond. C		1.26×10^{15}	7.85×10^{15}	2.04×10^{14}	1.33×10^{15}	1.57×10^{15}	—	9.89×10^{12}	4.0×10^{13}

[1] For example Versamid 140 or Ancamide 350 A. (Curing agent is a 350-400 amine value polyamide.)

— = Not Determined

[†] Typical values; not to be construed as specifications.

Table 24 Chemical, Solvent Resistance, and Thermal Degradation — DOW Liquid Epoxy Resins Cured with Polyamide[1] Curing Agent[†]

Resin	D.E.R. 330 % WT Change, Days	D.E.R. 331 % WT Change, Days	D.E.R. 332 % WT Change, Days	D.E.R. 337 % WT Change, Days	D.E.R. 317 % WT Change, Days	D.E.R. 383 % WT Change, Days	30% D.E.R. 732 70% D.E.R. 331 % WT Change, Days	30% D.E.R. 736 70% D.E.R. 331 % WT Change, Days
Reagent	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**
Sulfuric Acid 30%	.58 1.32 3.70	.67 1.9 3.6	.52 1.18 3.35	1.05 3.10 7.08	0.64 1.27 3.51	.40 .74 1.50	3.38 8.18 24.60	2.64 5.94 14.60
Nitric Acid 40%	— — —	1.7 3.8 6.6	— — —	— — —	— — —	2.86 0 0	— — —	— — —
Acetone	2.08 4.65 14.10	3.4 7.3 16.2	2.17 4.77 14.2	5.79 13.04 D	3.49 6.87 15.4	— — —	22.0 D —	D — —
Toluene	— — —	1.5 3.7 8.0	— — —	— — —	— — —	6.61 17.4 27.2	— — —	— — —
Sodium Hydroxide 50%	0.00 0.2 .11	–.01 .07 .20	0.00 0.00 .07	.04 .03 .15	–.02 –.07 –.10	.05 –.06 –.06	.09 .19 .34	.07 .11 .27
JP 4 Fuel	.03 .06 .34	.03 .05 .29	.02 .04 .23	.02 .06 .31	.23 .40 .59	— — —	.11 .27 .93	.07 .15 .59
Distilled Water	.47 1.03 2.36	.58 1.3 2.6	.47 .99 2.24	.47 1.18 2.61	.62 1.14 2.40	.44 .88 15.3	1.17 2.44 4.83	1.16 2.38 4.86
HRS	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500
Thermal Degradation (% Wt. Loss) 160°C	.77 1.15 1.39 1.53	.73 1.1 1.4 1.6	.50 .74 .95 1.07	1.05 1.48 1.73 1.82	1.01 1.30 1.62 1.71	.90 1.3 1.8 2.0	1.33 1.81 2.13 2.35	1.15 1.64 1.79 2.32
210°C	2.15 3.18 — 4.35	2.9 4.2 5.0 5.6	1.61 2.44 — 4.08	2.66 3.55 — 5.48	2.80 3.91 4.97 5.50	3.8 5.0 6.0 7.3	3.64 4.88 — 6.24	4.52 D — —

D = Decomposed

— = Not Determined

[1] For example Versamid 140 or Ancamide 350 A. (Curing agent is a 350-400 amine value polyamide.)

†Typical values; not to be construed as specifications.

Table 25 Physical Properties — DOW Liquid Epoxy Resins Containing a Reactive Diluent[†]

Resin Curing Agent	D.E.R. 324 —D.E.H. 24—	D.E.R. 325 —D.E.H. 24—	D.E.R. 324 —Polymide[5]—	D.E.R. 325 —Polymide[5]—	D.E.R. 324 —1,2-Cyclohexane Diamine—	D.E.R. 325 —1,2-Cyclohexane Diamine—
phr	12.2	12.5	33	33	17	17
Reactivity & Exotherm of a 500 Gram Mass (@ 25°C) (Min.)[1]	41	35	245	225	86	65
(°C)[2]	66	60	50	50	77	94
(°C)[3]	230	230	68	68	240	250
(Min.)[4]	48	39	260	250	92	75
Heat Deflection Temperature (°C)	65	88	50	63	81	99
Flexural Strength (psi)[6]	16,400	19,200	11,500	15,400	18,800	21,400
Flexural Modulus (psi x 10^5)	4.57	5.11	3.25	4.33	4.76	5.06
Yield Compressive Strength (psi)	11,800	14,300	8,400	11,700	13,900	15,900
Compressive Modulus (psi x 10^5) at 10% deformation or less	2.58	3.05	2.14	2.85	2.97	3.24
Tensile Strength (psi)	9,000	10,300	6,700	8,700	6,900	11,800
Ultimate Elongation (%)	8.70	6.37	7.32	4.53	2.03	8.95
Glass Transition Temperature (°C)	82	102	67	88	102	124

[1] Time to transition point or gel.

[2] Temperature at transition point.

[3] Temperature at peak exotherm.

[4] Time to peak exotherm.

[5] For example Versamid 140 or Ancamide 350 A. (Curing agent is a 350-400 amine value polyamide.)

[6] Sample size 1" W x 1/8" D; Span 2".

†Typical values; not to be construed as specifications.

Table 26 Electrical Properties — DOW Liquid Epoxy Resins Containing a Reactive Diluent†

Resin Curing Agent	D.E.R. 324 D.E.H. 24	D.E.R. 325 D.E.H. 24	D.E.R. 324 Polyamide[1]	D.E.R. 325 Polyamide	D.E.R. 324 1,2-Cyclohexane Diamine	D.E.R. 325 1,2-Cyclohexane Diamine
Dielectric Constant Cond. A Frequency, 1000 Hz	3.99	4.18	3.64	3.68	3.91	4.21
Dissipation Factor Cond. A Frequency, 1000 Hz	.014	.0082	.012	.0090	.0069	.016

[1] For example Versamid 140 or Ancamide 350 A. (Curing agent is a 350-400 amine value polyamide.)
†Typical values; not to be construed as specifications.

Table 27 Chemical, Solvent Resistance, and Thermal Degradation — DOW Liquid Epoxy Resins Containing a Reactive Diluent†

Resin	D.E.R. 324	D.E.R. 325	D.E.R. 324	D.E.R. 325	D.E.R. 324	D.E.R. 325
Curing Agent	D.E.H. 24 % WT Change, Days	D.E.H. 24 % WT Change, Days	Polyamide[1] % WT Change, Days	Polyamide % WT Change, Days	1,2-Cyclohexane Diamine % WT Change, Days	1,2-Cyclohexane Diamine % WT Change, Days
Reagent	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**	**7 28 120**
Sulfuric Acid 30%	.88 1.95 4.34	.70 1.56 3.57	.46 1.13 2.35	.29 .81 1.78	.52 1.18 2.23	.49 1.01 1.96
Sulfuric Acid 3%	.83 1.67 3.46	.67 1.31 2.61	.68 1.28 2.14	.53 1.09 2.06	.56 1.09 1.83	.61 1.13 1.90
Hydrochloric Acid 36%	2.70 5.38 11.2	1.80 3.77 7.98	3.45 6.48 13.6	2.16 4.22 9.13	3.62 6.99 15.2	2.55 5.17 11.1
Hydrochloric Acid 10%	.76 1.53 3.08	.80 1.58 3.29	.69 1.32 2.24	.51 1.34 1.95	.44 6.25 6.34	.41 2.18 1.86
Nitric Acid 40%	5.20 D D	9.67 D D	4.82 D D	3.13 D D	5.42 D D	4.38 D D
Nitric Acid 10%	1.01 1.96 4.07	.88 1.74 3.79	.85 1.78 3.21	.66 1.32 2.63	.77 1.58 2.87	.79 1.57 3.04
Acetic Acid 25%	6.61 12.2 26.2	4.37 8.43 18.3	7.00 12.6 25.4	4.14 7.65 15.3	7.41 13.3 27.6	5.44 9.94 20.5
Sodium Hydroxide 50%	.03 .04 .14	.03 .01 .16	.05 .03 .05	.06 .07 .06	.05 .03 .20	.03 .09 .21
Ammonium Hydroxide 28%	.67 1.27 2.61	.45 .95 2.23	.98 1.48 2.67	.67 1.33 2.36	.60 1.09 1.66	.54 .98 1.68
Ethanol 95%	2.13 4.13 8.70	.53 1.24 2.48	4.79 8.70 15.1	2.09 3.84 7.33	2.69 5.38 11.5	.41 1.56 4.13
Toluene	3.29 9.04 24.5	.08 .14 .34	24.5 D D	7.66 17.8 25.1	3.98 12.1 39.6	.15 .21 .58
Acetone	8.74 16.7 D	3.32 8.15 18.4	17.2 D D	10.2 D D	15.2 D D	4.82 D D
Ethylene Dichloride	D D D	8.23 23.3 D	D D D	D D D	D D D	15.9 D D
Distilled Water	.49 .86 1.65	.34 .77 1.58	.70 1.28 2.19	.58 1.01 1.98	.50 .87 1.18	.48 .84 1.31
HRS	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500	100 200 300 500
Thermal Degradation (% Wt. Loss) 160°C 210°C	 2.3 2.8 3.6 3.9 6.1 7.9 11.6 17.4	 1.4 1.4 2.1 2.5 4.4 6.2 7.8 10.3	 3.5 7.1 5.5 6.3 6.9 8.1 9.1 10.2	 1.4 2.0 2.6 3.0 4.3 5.5 6.4 2.4	 2.7 3.3 3.7 4.1 5.2 7.6 10.6 16.4	 1.9 2.3 2.6 2.6 4.3 6.3 8.2 10.4

D = Decomposed
[1] For example Versamid 140 or Ancamide 350 A. (Curing agent is a 350-400 amine value polyamide.)
†Typical values; not to be construed as specifications.

Additional Property Data

In Table 28, D.E.R. 332 was selected for best color; D.E.R. 331 performs similarly when blended with D.E.R. 732 and cured with amino ethyl piperazine (AEP). Systems were blended at 40°C, adding the chemical equivalent quantity of AEP. They were cured four hours at 60°C, and may also be cured at room temperature. Samples of one-eighth inch thickness were tested.

Table 28 Physical Properties of D.E.R. 332 and D.E.R. 732 Resins Cured with Amino Ethyl Piperazine

D.E.R. 332 and D.E.R. 732 (Ratio)	**100:0**	**85:15**	**70:30**	**50:50**	**35:65**
D.E.H. 39	**25.0**	**23.5**	**21.5**	**19.5**	**17.5**
Tensile Strength (psi)	7,000	8,200	6,600	2,100	300
Ultimate Elongation (%)	6.6	8.7	8.7	115	66
Color (Gardner)	2	1	<1	<1	<1
Condition	Rigid	Rigid	Flex.	Flex.	Flex.
Wt. Loss, 4 hr at 205°C (%)	0.48	0.61	0.82	1.23	1.72
Wt. Loss, 8 hr at 205°C (%)	0.87	0.85	1.20	1.94	3.00
Acetone Extraction (% – 2 hrs.)	0	0	0	0.83	2.00

Table 29 Physical Properties of D.E.R. 331 and D.E.R. 732 Resins Cured with D.E.H. 20

D.E.R. 331 and D.E.R. 732 (Ratio)	**100:0**	**90:10**	**70:30**	**50:50**
D.E.H. 20 (phr)[1]	**11.0**	**10.5**	**9.5**	**8.4**
Flexural Strength (psi)	12,200	16,000	12,400	1,700†
Flexural Modulus (x 10^5)	4.5	4.0	3.4	0.29
Compressive Strength (psi)	26,600	32,000	32,900	16,700
Compressive Modulus (x 10^5)	3.7	3.5	3.0	2.8
Tensile Strength (psi)	7,500	4,700	6,200	1,400
Tensile Modulus (x 10^5)	2.1	1.9	2.5	0.20
Izod Impact Strength (ft. lbs./in. notch)	0.43	0.48	0.76	2.00

[1]Cure Schedule: gel at room temp.; post cure 2 hrs. at 100°C. †Yielded, but did not break.

Table 30 Physical Properties of D.E.R. 331 and D.E.R. 736 Resins Cured with Nadic Methyl Anhydride

D.E.R. 331 and D.E.R. 736 (Ratio)	**100:0**	**90:10**	**70:30**	**50:50**
Nadic Methyl Anhydride	**86/5**	**82/5**	**75/5**	**69/5**
Flexural Strength (psi)	6,300	10,400	13,400	17,800
Flexural Modulus (x 10^5)	5.0	5.3	4.7	4.6
Compressive Strength (psi)	30,100	31,400	28,800	26,700
Compressive Modulus (x 10^5)	4.5	4.1	4.1	4.0
Tensile Strength (psi)	3,300	3,200	3,300	3,300
Tensile Modulus (x 10^5)	1.9	2.0	1.9	2.0
Izod Impact Strength (ft. lbs./in. notch)	0.16	0.16	0.44	0.38

[1]Cure Schedule: 4 hrs. at 80°C and 15 hrs. at 150°C.

STORAGE

These comments are necessarily general and abbreviated. More complete details are available in the technical brochures, DOW Epoxy Resins-Product Stewardship, Safe Handling and Storage Manual (Form No. 296-00312) and DOW Epoxy Curing Agents-Product Stewardship, Safe Handling and Storage Manual (Form No. 296-01331), available from your Dow sales representative.

Liquid epoxy resins are stable for long periods of time at room temperature. Diluent or solvent cut resins should be stored in tight containers to prevent loss of the volatiles. A good practice is to store all resins and curing agents in tight containers, because some are susceptible to moisture absorption, which may affect rate of cure and other properties. Moderate elevated temperature storage (50-55°C; 122-131°F) to reduce viscosity or prevent resin crystallization has little effect on most DOW resins, even after several months time. Storage at temperatures above 55°C is satisfactory for periods of two or three days for processing purposes. At these higher temperatures, some color and viscosity increase occurs. The rate of increase depends upon the temperature and varies for different resins.

Each anticipated condition of elevated temperature storage should be checked to determine its effect on the resin.

Bulk Storage

For large consumers of epoxy resins, bulk storage of liquid resins is entirely feasible. Dow personnel, experienced in bulk storage and handling, are available to assist you by making suggestions regarding the design of storage and handling facilities.[1]

[1]Many bulk storage and handling details are discussed in the two aforementioned technical brochures.

Hazards & Handling Precautions

Material Safety Data sheets on D.E.R. and D.E.H. product types are available from Dow Plastics† to help customers meet their handling and disposal needs and applicable OSHA requirements.

Because of the wide variety of materials used in epoxy resin systems, the following discussion is only a general guide. Also, because of the many plant environments involved, no warranty of any kind can be given. For more detailed information, formulators should contact the manufacturer of each material used. The Dow technical brochures, DOW Epoxy Resins Product Stewardship Safe Handling and Storage Manual, Form No. 296-00312 and DOW Epoxy Curing Agents Product Stewardship Safe Handling and Storage Manual, Form No. 296-01331 can be helpful.

Ask your Dow sales representative for copies, or call the Dow Customer Information Group at 1-800-441-4369 to request these brochures.

Note: Dow recommends that its customers conduct a continuing training program for all personnel involved in epoxy handling, formulating, disposal, etc. Planning for employee and plant safety has value only when it is interpreted and practiced by the people involved.

† Dow Plastics, a business group of The Dow Chemical Company and its subsidiaries.

Health Hazards

Consult the Specific Manufacturers Material Safety Data Sheet before handling any chemical.

Liquid Epoxy Resins

Skin

D.E.R. 317, D.E.R. 324, D.E.R. 325, D.E.R. 330, D.E.R. 331, D.E.R. 332, D.E.R. 337, D.E.R. 362, D.E.R. 364, and D.E.R. 383 epoxy resins are not acutely irritating to the skin. However, they are capable of causing skin sensitization. Susceptibility to skin irritation and sensitization varies from person to person. These epoxy resins, however, are considered to be milder skin sensitizers than amine-type curing agents or epoxy functional reactive diluents.

Inhalation

Vapor inhalation with most liquid resins is not considered a problem unless the resins are heated. D.E.R. 333, D.E.R. 343, and D.E.R. 345 resins are exceptions: they contain xylene solvent with a TLV of 100 ppm (1997).

Ingestion and Eye Contact

All of the liquid resins are low in acute oral toxicity. Eye contact should result in only slight, transient irritation. (Note: In the event of skin contact, thoroughly wash the affected area with copious amounts of soap and water. Remove contaminated clothing and launder before reuse. In the event of eye contact, the eyes should be flushed with plenty of water. If eye or skin irritation persists, seek qualified medical attention.)

Curing Agents

Curing agents can be hazardous to health. For example, aliphatic amine-type materials are capable of causing serious irritation, even burns, depending upon the degree of contact. In addition, they may cause a serious rash or an asthmatic-type response in sensitized persons. This response may develop after several weeks or months of contact with the liquid or vapors that cause no immediate apparent effects, or it may result from a single massive exposure.

The aromatic amine curing agents discussed in this bulletin are considered to present a less acute hazard from skin contact than the aliphatic amine curing agents. For example, they are considerably less irritating to the skin, and although they may cause skin sensitization responses, they are less likely to than the aliphatic amines. And because the aromatic amine curing agents are usually solids, they are considered to present no significant acute vapor inhalation hazard, unless handled at elevated temperatures.

Anhydride curing agents are considered to be capable of causing severe eye and skin irritation, even burns, depending upon the severity of contact. In addition, some of them may cause sensitization responses.

Continued next page

Hazards & Handling Precautions

Polyamide-type curing agents are distinctly less hazardous to handle than the other curing agents. They are considered to present a low degree of health hazard.

Because of the differences in the catalytic-type curing agents suggested for use, no general statement can be made as to the hazards involved in their handling and use.

Note: Specific information should be requested from the manufacturer of each curing agent prior to its use.

Reactive Diluents

Because of their toxicological properties, the reactive diluents proposed for use are considered to present a high degree of hazard. For example, they are capable of causing skin and eye irritation. They are also capable of causing sensitization responses in a significant number of people who contact them. They may also present a significant hazard from inhalation. In short, they may be considered more hazardous than the liquid epoxy resins. **Consult your supplier(s) prior to use.**

Resin Modifiers

These materials vary greatly in their chemical structure. Therefore, a general statement concerning their degree of hazard cannot be made. The epoxy-type compounds may be considered to present the same degree of hazard as do the liquid epoxy resins. However, other reactive modifiers may be more or less hazardous depending upon the product. **Consult your supplier(s) prior to use.**

Fillers

Fillers vary in their degree of hazard from handling. Some, such as the clays, may be considered essentially nonhazardous. However, dusts of glass, silica bearing powders, and powdered metals may present a serious hazard from inhalation and/or explosion. **Consult your supplier(s) prior to use.**

Cured Resins

Resins that are completely polymerized (cured) are considered to be toxicologically inert. Therefore, they present no health problems from handling.
However, dusts from machining cast or molded parts may be an inhalation or explosion hazard.

HANDLING PRECAUTIONS

Each of these materials, *when handled alone*, may require special precautions for their safe handling. **Consult with the manufacturer of each product concerning proper handling procedures prior to use.**
Resins systems, comprised of epoxy resins, curing agents, and other modifiers, require special precautions for their safe handling. Specific recommendations can only be made when specific conditions of handling are known.
However, in general, resin systems should be handled so that all human contact is prevented.
This can best be done by handling the materials in an enclosed system. If that is not feasible, the following guidelines and precautions can be helpful in avoiding health problems.

1. All personnel concerned with the handling of these materials must maintain strict cleanliness of both their person and the area in which they work. There is no substitute for strict cleanliness and housekeeping.

2. Continued instruction of all employees must be given concerning the consequences of contact, as well as the precautions necessary for safe operations. Remember:
   - liquid epoxy resins may cause allergic sensitization and/or irritation.
   - avoid contact with eyes and skin.
   - avoid breathing vapors (especially of solvent containing systems).
   - do not take internally.

3. Suitable protective clothing to prevent contact should be worn; the particular type of clothing depends on the operation. (Caution: Impervious clothing can increase the hazard if contamination occurs on the inside. Do not wear or use contaminated articles unless they have been thoroughly decontaminated.)

4. Contamination of the work area should be minimized by placing clean disposable paper on tables and benches. The paper should be renewed twice daily or immediately following gross contamination. (Note: Proper disposal of "disposables" is necessary or they can be a source of contamination to other workers.)

5. Contact with the material can be reduced by the use of disposable utensils, such as paper dippers, containers, etc. See note in "4."

6. Contact with vapors should be prevented. Ventilation sufficient to remove all vapor at the point of use, and to assure fresh air supply, should be provided.

7. Isolate epoxy resin work areas from other work areas to limit the direct exposure of untrained workers and their exposure to contaminated tools and equipment.

Continued next page

Handling Precautions

The preceding comments are based on extensive experience and are expressed in good faith. We will work with customers-users to assist them in the proper use and handling of these materials. However, The Dow Chemical Company can accept no liability for operations not under its direct control. Responsibility for proper use, storage, and handling of these materials is that of the customer-user.

Flammability

All D.E.R. epoxy resins are organic materials and will burn when sufficient heat and oxygen are supplied.

A common measure of flammability is flash-point temperature (e.g., see Table 1, page 4). This value indicates the minimum temperature at which flammable conditions are produced in controlled laboratory experiments at atmospheric pressure.

Note: Solvents, diluents, and other materials used with epoxy resins commonly increase the hazard of flammability and/or explosion. **Consult your supplier(s) prior to use.**

Fires involving D.E.R. epoxy resins can be extinguished with foam, dry powder, or carbon dioxide. Water is not normally an effective extinguishing agent with these resins.

When burning, these resins give off toxic byproducts, such as carbon monoxide gas. Therefore, avoid breathing fumes, gases, or smoke resulting from a fire. Fire fighters should use an organic vapor respirator or self-contained breathing apparatus.

Spill Containment and Cleanup

Persons engaged in spill cleanup should be protected from vapors and from skin contact by wearing appropriate protective clothing and equipment.

The immediate concern in any spill is to protect personnel and to prevent a possible fire hazard. Also, personnel engaged in spill cleanup should know proper disposal techniques in advance.

For small spills of liquid or solution epoxy resin (less than 5 gallons), apply an absorbent material or a high surface-area material such as sand to the spill, then shovel the mass into a suitable container. The residue on the floor or dock should be removed with steam or hot soapy water. (Note: Use of methylene chloride, acetone or aromatic solvents in cleanup poses a distinct hazard and should be avoided.) For solution resins, keep spark-producing equipment away from the spill site. Also, if possible, shut off or remove all potential sources of ignition.

In the event of a larger spill (55 gallons or more), employees should stay up wind. Evacuate and rope off the spill area. Shut off leaks and all potential sources of ignition. The spill should be contained with a dike, and excess resin should be collected in suitable containers for final disposal. Hot soapy water or steam may be required for final cleanup. (Note: The use of solvents during cleanup is hazardous and should be avoided.)

Epoxy resins are often heated when handled in bulk. In spills of hot resin, care should be taken to avoid thermal burns.

Liquid and solution resins should be prevented from entering sewers or drains, or any body of water, including rivers, streams or lakes. If spilled material does enter drains or waterways, notify local authorities at once.

For Chemical Emergency (Spill, Leak, Fire, Exposure or Accident), call CHEMTREC, day or night, at 1-800-424-9300 in the U.S.

In Canada, call CANUTEC at 613-996-6666

In Mexico, call SETIQ at 91-800-97-619

Appendix— Abbreviations

AEP	—	Amino Ethyl Piperazine
BDMA	—	Benzyldimethylamine
BGE	—	Butyl Glycidyl Ether
CGE	—	Cresyl Glycidyl Ether
CPS	—	Centipoise (viscosity); Cycles per Second (electrical)
DDS or DADS	—	Diamino Diphenyl Sulfone
DDSA	—	Dodecenyl Succinic Anhydride
DEAPA	—	Diethylaminopropylamine
DETA	—	Diethylene Triamine
DGE	—	Diglycidyl Ether
DICY	—	Dicyandiamide
EEW	—	Epoxide Equivalent Weight
HDT	—	Heat Distortion Temperature
HHPA	—	Hexahydrophthalic Anhydride
MEA	—	Monoethylamine
MEK	—	Methyl Ethyl Ketone
MIBK	—	Methyl Isobutyl Ketone
MPDA	—	Metaphenylene Diamine
MSDS	—	Material Safety Data Sheet
MTHPA	—	Methyltetrahydrophthalic Anhydride
MW	—	Molecular Weight
NMA	—	Nadic Methyl Anhydride
PA	—	Phthalic Anhydride
PGE	—	Phenyl Glycidyl Ether
PHR	—	Parts per Hundred Parts Resin (by weight)
TEPA	—	Tetraethylene Pentamine
TETA	—	Triethylene Tetramine
THPA	—	Tetrahydrophthalic Anhydride

Product Stewardship

Dow encourages its customers and potential users of Dow products to review their applications of such products from the standpoint of human health and environmental quality. When requested, Dow personnel will assist customers in dealing with ecological and product safety considerations. Your Dow sales representative can arrange the proper contacts. Dow product literature, including Material Safety Data sheets, should be consulted prior to the use of Dow products. These may be obtained from your Dow sales representative or sales office.

The Dow Chemical Company has a fundamental concern for all who make, distribute, and use its products, and for the environment in which we live. The success of this Product Stewardship program rests with each and every individual involved with Dow products — from the initial concept and research to the manufacture, sale, distribution, use, and disposal of each product.

Internally, Dow's Product Stewardship program encompasses the education of its employees in safe handling procedures, protective clothing and equipment, and the use of safety devices, such as eye wash fountains, and emergency showers. It involves monitoring of personnel for potential vapor exposure, continuous measurement of area and effluent water for organic contaminants, and periodic medical surveillance.

Externally, the Product Stewardship program means helping in the education of those who transport, unload, use, and dispose of a product. This is accomplished through bulletins, pamphlets, product literature, correspondence, telephone contacts, seminars, and training programs. In these and other programs, agendas may include discussion of the product hazards, suggested industrial hygiene practices, and suggested product handling practices.

More detailed product stewardship information is available in two product safe handling and storage manuals: DOW Epoxy Resins Product Stewardship, Safe Handling and Storage Manual, Form No. 296-00312 and DOW Epoxy Curing Agents Product Stewardship, Safe Handling and Storage Manual, Form No. 296-01331.

For additional information
in the U.S. and Canada, call the
Dow Customer Information Group at
1-800-441-4369 or 1-517-832-1426 or cig@dow.com.

In Mexico,
call 95-800-441-4369.

In Europe, contact the Dow Information Centre
in The Netherlands at ++31-20-6916268 (phone),
++31-20-6916418 (fax) or dicinfo@euronet.nl (e-mail).

In the Pacific area, call
the Dow Customer Service Center at
81-120-024394 (toll-free in Japan) or
81-3-5460-2114 (outside Japan).

In Brazil, call
the Dow Chemical Service Center at 55 11 51889367.

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