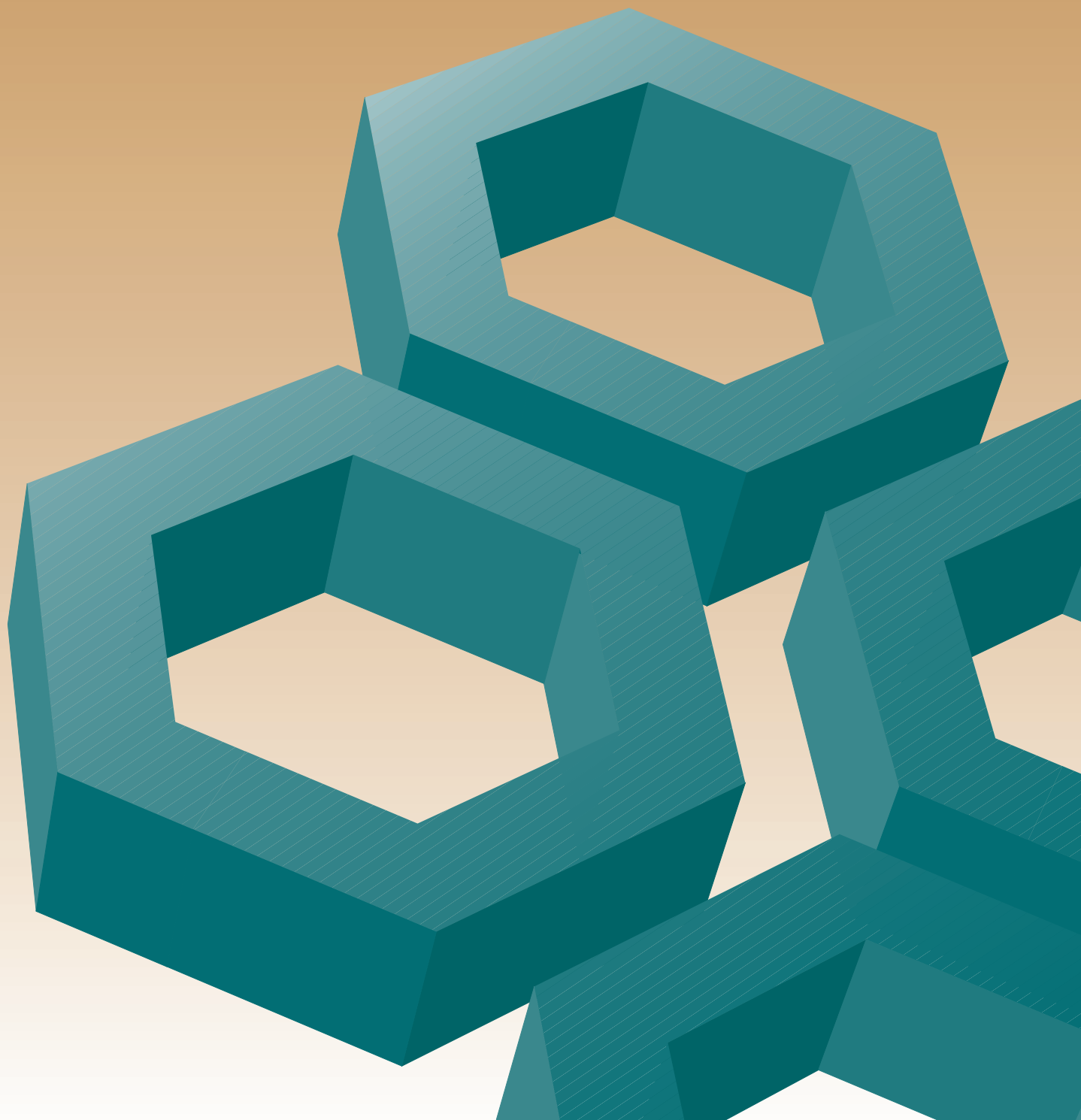




Ethyleneamines



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Introduction



The Dow Chemical Company, pioneered ethyleneamines development in 1935, when the company was the first to commercialize production, and has been the acknowledged world leader in the business ever since.

Today, Dow manufactures ethyleneamines in two world-scale facilities at its Taft, Louisiana, petrochemicals complex. We are the only producer to use both the ethylene dichloride and reductive amination catalytic processes, thus providing unparalleled flexibility in meeting customer needs.

Unexcelled quality – in product, technology, and services – is the byword of Dow's ethyleneamines business. Another first for the company was receipt of ISO 9002 registration in 1990 for the Taft quality systems. Since then, registrations have been received for raw material quality systems, including those for ethylene, ethylene oxide, and ethanolamines, as well as for domestic and international distribution systems.

In 1994, our ethyleneamines business won the Shingo Prize for Excellence in Manufacturing. The award recognizes outstanding achievements in manufacturing processes, quality enhancement, productivity improvement, and customer satisfaction.

Helping to drive these evergreen quality programs is Dow's technology leadership. Dedicated research and development focused on the ethyleneamines production processes has constantly improved product quality. Manufacturing technicians employ advanced statistical process control and zone charting for continuous improvement and reduced variability. Backing them is the in-plant laboratory with dedicated equipment for each of the ethyleneamines covered in this publication. And our applications scientists, unsurpassed in their knowledge of ethyleneamine end uses, are always ready to assist customers with their needs.

Dow's worldwide distribution network assures you of a readily available source of ethyleneamines.

Product Profiles

Ethylenediamine (EDA) (1,2-diaminoethane) is the lowest molecular weight member of the ethyleneamines family. It contains two primary amine groups and forms a maximum boiling azeotrope with water.



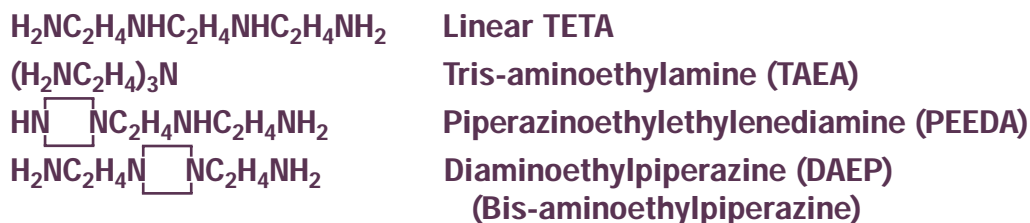
EDA is used primarily as an intermediate in the production of bleach activators, fungicides, chelating agents, plastic lubricants, textile resins, polyamides, and fuel additives.

Diethylenetriamine (DETA) is the second linear member of the ethyleneamines family. It contains two primary and one secondary amine groups. Compared to ethylenediamine, DETA exhibits a broad liquid range: 207°C (405°F) boiling point at 760 mm Hg and -39°C (-38°F) freezing point.



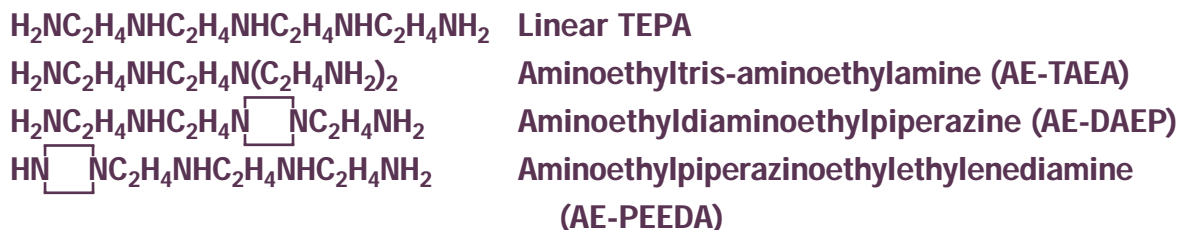
DETA is used primarily as an intermediate to manufacture wet-strength paper resins, chelating agents, ion exchange resins, ore processing aids, textile softeners, fuel additives, and corrosion inhibitors.

Triethylenetetramine (TETA) is a liquid containing linear, branched, and cyclic molecules. The principal tetramine structures are:




The major applications of TETA include epoxy curing agents, and the production of polyamides and oil and fuel additives.

Tetraethylenepentamine (TEPA) is a mixture containing linear, branched, and cyclic molecules. The structures of the major TEPA components are:



Among the major end-uses for TEPA are the preparation of oil and fuel additives, reactive polyamides, epoxy curing agents, and corrosion inhibitors.



Heavy Polyamine (HPA) is a complex mixture of linear, branched, and cyclic ethyleneamines, the structures of which can be deduced from the chemistry of manufacture and a knowledge of the structures present in TETA and TEPA. The structures of the principal components contain six or more nitrogen atoms per molecule.

The major end-use applications for HPA include oil and fuel additives, corrosion inhibitors, and asphalt additives.

Piperazine (PIP) is the simplest cyclic member of the ethyleneamines family. The product has two secondary amine groups. Anhydrous PIP has a fairly high freezing point of 110°C (230°F) and a boiling point of 146°C (295°F) at 760 mm Hg. Since this narrow liquid range makes it difficult to handle, commercial piperazine is often sold in aqueous solutions to facilitate handling and storage. In addition, an anhydrous piperazine is available in flake form.



Among the major applications for PIP are anthelmintics, pharmaceutical preparations, polyamides, and as an intermediate for the production of triethylenediamine polyurethane catalyst.

Aminoethylpiperazine (AEP) is unique among the ethyleneamines: it contains one primary, one secondary, and one tertiary nitrogen atom. AEP has a broad liquid range: boiling point of 222°C (432°F) at 760 mm Hg and a freezing point of -17°C (1.4 °F).



Major end-uses for AEP include the production of urethane catalysts, epoxy curing agents, and asphalt additives.

Aminoethylethanolamine (AEEA) is an organic base with unique properties that make it an invaluable intermediate. The primary and secondary amine groups, together with the hydroxyl group, combine the features of an ethyleneamine and an ethanolamine.



Principal end-uses include surfactants, fabric softeners, fuel additives, chelates, and coatings.

Note: "  " or "  " = -CH₂CH₂-

Typical Physical Properties

Ethyleneamine	Molecular Weight	Apparent Specific Gravity at 20/20°C	Freezing Point, °C	Vapor Pressure at 20°C, mm Hg
Ethylenediamine	60.10	0.898	11	10.40
Diethylenetriamine	103.17	0.952	- 39	0.08
Triethylenetetramine	146.24 ⁽¹⁾	0.980	- 35	<0.01
Tetraethylenepentamine UHP	189.30 ⁽¹⁾	0.994	- 46 ⁽⁶⁾	<0.01
Heavy Polyamine X	275 ⁽²⁾	1.015	- 32 ⁽⁶⁾	<0.01
Piperazine, 65%	86.14 ⁽³⁾	1.036 ⁽⁴⁾	41	6.28
Piperazine, Anhydrous	86.14	0.877 ⁽⁵⁾	110	0.10 ⁽⁷⁾
Aminoethylpiperazine	129.21	0.986	- 17	<0.01
Aminoethylethanolamine	104.15	1.030	- 45 ⁽⁶⁾	<0.01

	Electrical Conductivity at 25°C, micromhos/cm	Ionization Constant, K ₁ , at 25°C in Water	Dielectric Constant at 23°C	Solubility in Water at 20°C, % by wt
Ethylenediamine	7.52	0.73 x 10 ⁻⁴	13.29	100
Diethylenetriamine	0.86	0.65 x 10 ⁻⁴	12.22	100
Triethylenetetramine	0.24	0.63 x 10 ⁻⁴ (2)	10.24	100 ⁽¹²⁾
Tetraethylenepentamine UHP	0.091	0.72 x 10 ⁻⁴ (2)	9.32	100 ⁽¹²⁾
Heavy Polyamine X	0.092	0.95 x 10 ⁻⁴ (2)	8.72	100 ⁽¹²⁾
Piperazine, 65%	49.4 ⁽¹⁰⁾	0.43 x 10 ⁻⁴ (3)	— (9)	100 ⁽¹⁰⁾
Piperazine, Anhydrous	— (9)	0.43 x 10 ⁻⁴	— (9)	14
Aminoethylpiperazine	0.007	0.40 x 10 ⁻⁴	7.13	100
Aminoethylethanolamine	0.63	0.31 x 10 ⁻⁴	19.13	100

(1) Linear component only

(2) Typical molecular weight

(3) For Piperazine, Anhydrous

(4) At 42°C/42°C

(5) At 130°C/20°C

(6) Pour point

(7) Vapor pressure of the solid

(8) Extrapolated; with decomposition

(9) Solid at this condition

(10) At 42°C

(11) At 130°C

(12) Forms hydrate with time



	Boiling Point, °C			Δ Boiling Point/ Δp , 750-770 mm, °C per mm Hg	Absolute Viscosity at 20°C, cP
	760 mm Hg	50 mm Hg	10 mm Hg		
	117.0	47.8	19.4	0.043	1.80
	206.9	123.3	88.9	0.052	7.16
	277 ⁽⁸⁾	183	144	0.058	26.0
	288 ⁽⁸⁾	215	184	0.045	83.1
	—	279 ⁽⁸⁾	236	—	460.7
	116	54	27	0.036	22.5 ⁽¹⁰⁾
	146.1	— ⁽⁹⁾	— ⁽⁹⁾	0.037	0.73 ⁽¹¹⁾
	221.0	134.3	100.9	0.056	15.4
	242.8	161.3	127.0	0.049	140.6

Refractive Index, n_D 20°C	Specific Heat at 20°C, cal/g•°C	Heat of Vaporization at 760 mm Hg, BTU/lb ⁽¹⁵⁾	Heat of Combustion at 25°C, BTU/lb	Heat of Formation at 25°C, BTU/lb ⁽¹⁶⁾
1.457	0.68	270	-13251	-569
1.483	0.65	197	-13910	-403
1.499	0.63	162	-14353	-162 ⁽¹⁾
1.505	0.61	162	-14487	-139 ⁽¹⁾
1.513	0.58	99	-14643	—
— ⁽⁹⁾	0.78 ⁽¹³⁾	528	-9261	—
— ⁽⁹⁾	0.63 ⁽¹⁴⁾	250	-14696	-304
1.501	0.52	152	-14744	-256
1.486	0.64	237	-12395	-1193

(13) At 42°C; melting point 36°C, heat of fusion 50.74 cal/g

(14) At 130°C; melting point 109.6°C, heat of fusion 72.83 cal/g

(15) Estimated from vapor pressure using Clausius-Clapeyron equation

(16) Calculated from gross heat of combustion



Figure 1:
Ethyleneamines,
Vapor Pressure vs. Temperature

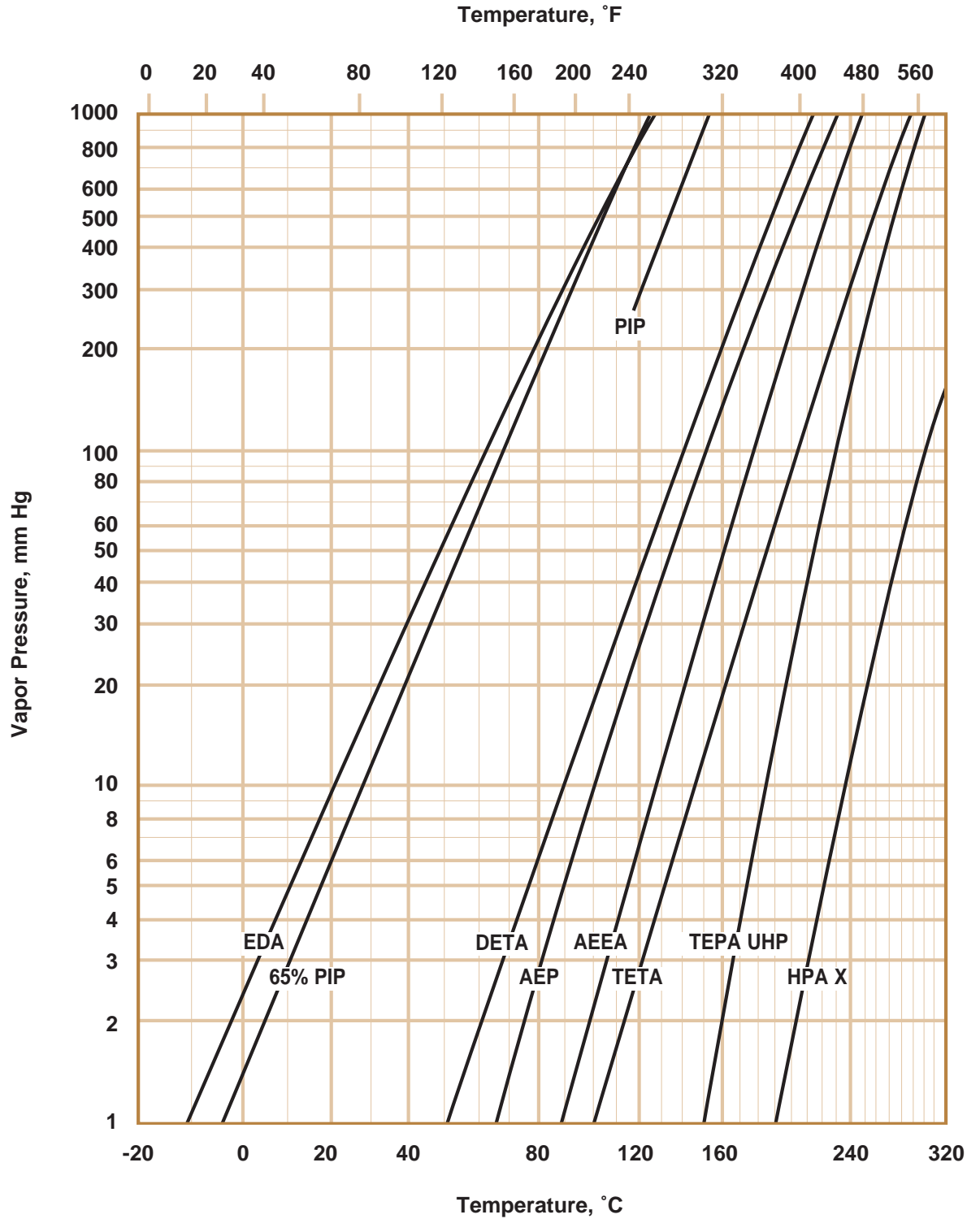




Figure 2:
Ethyleneamines,
Viscosity vs. Temperature

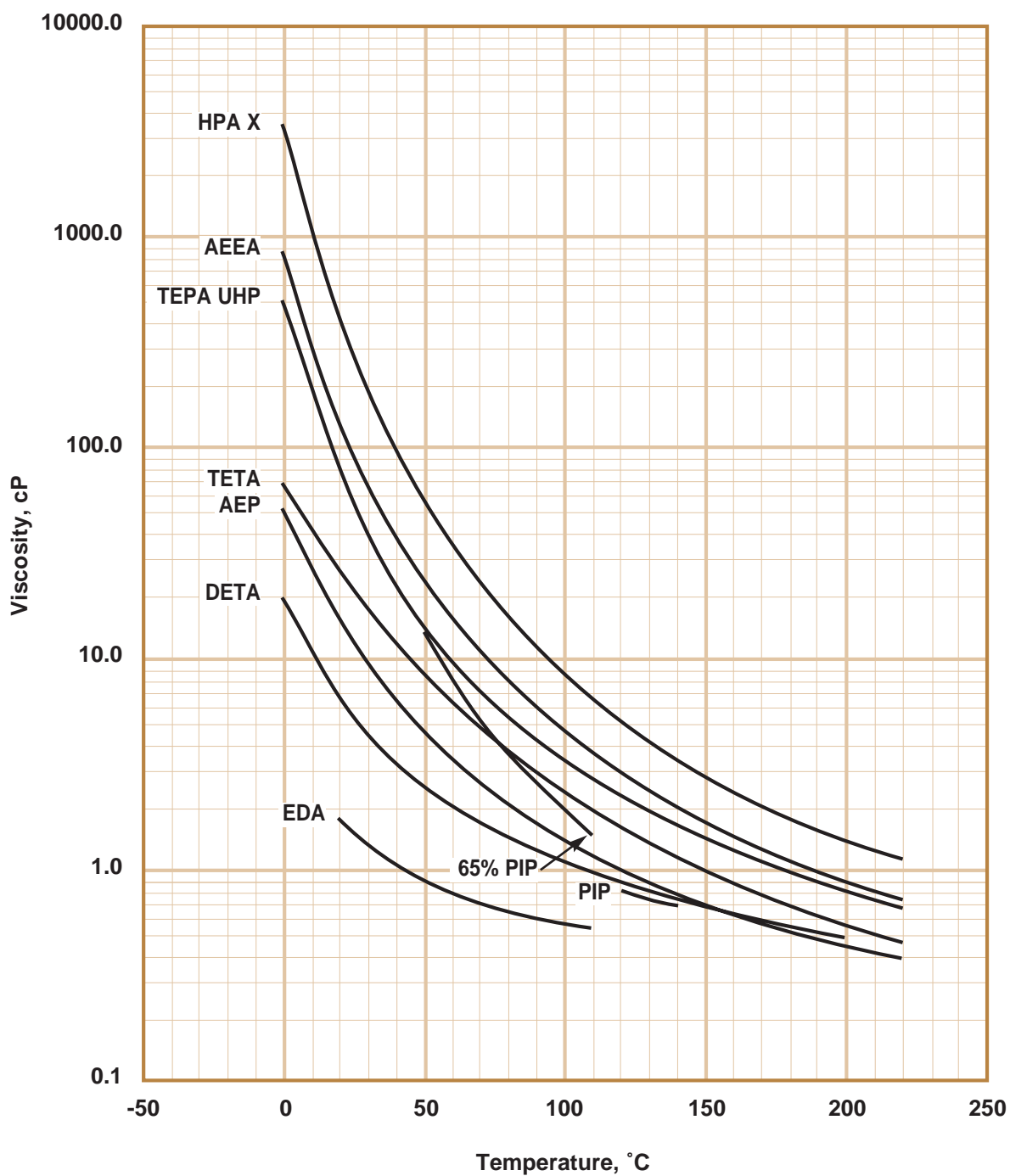


Figure 3:
Ethyleneamines,
Specific Gravity vs. Temperature

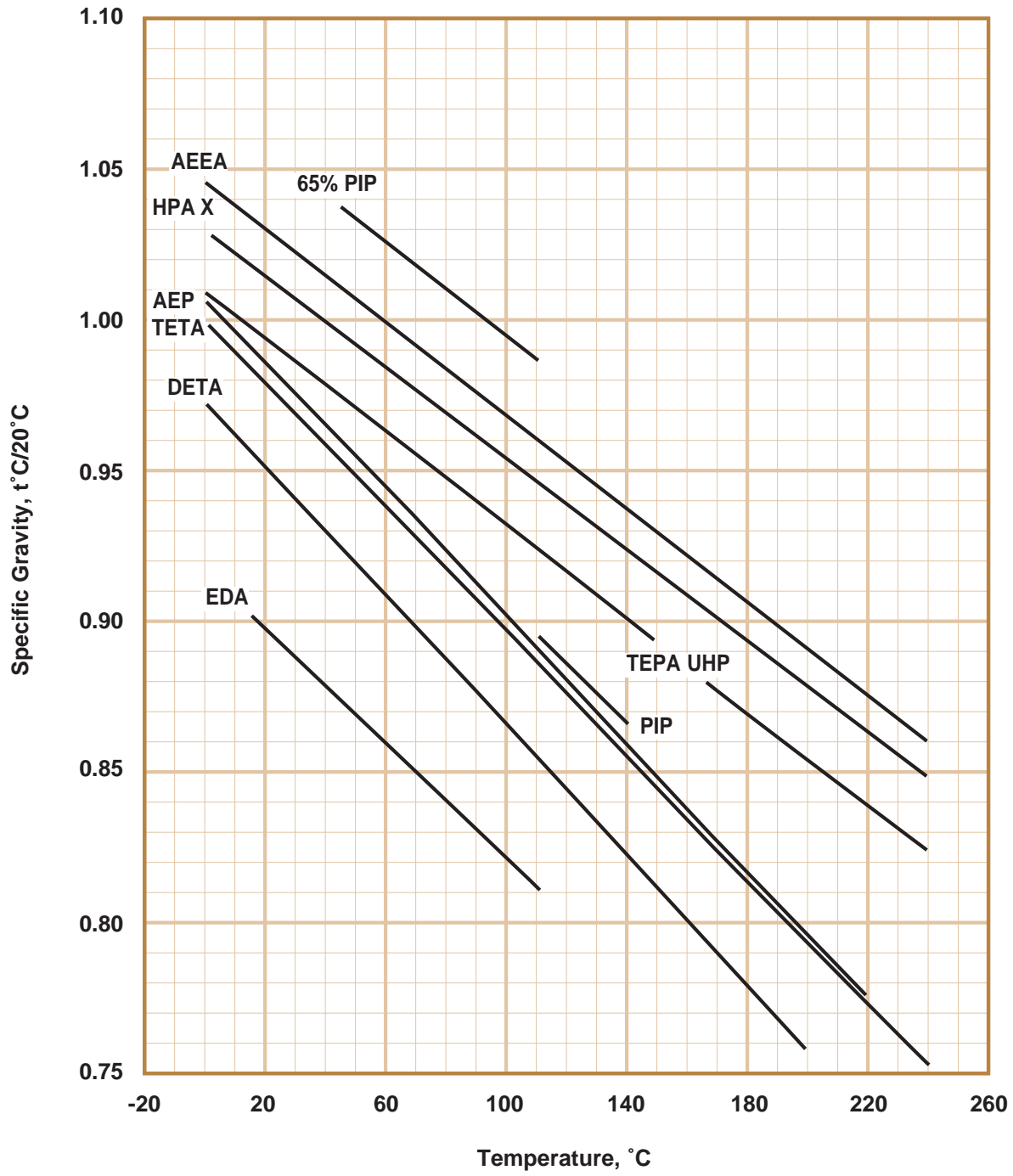




Figure 4:
Ethylenediamine Aqueous Solutions,
Freezing Point vs. Composition

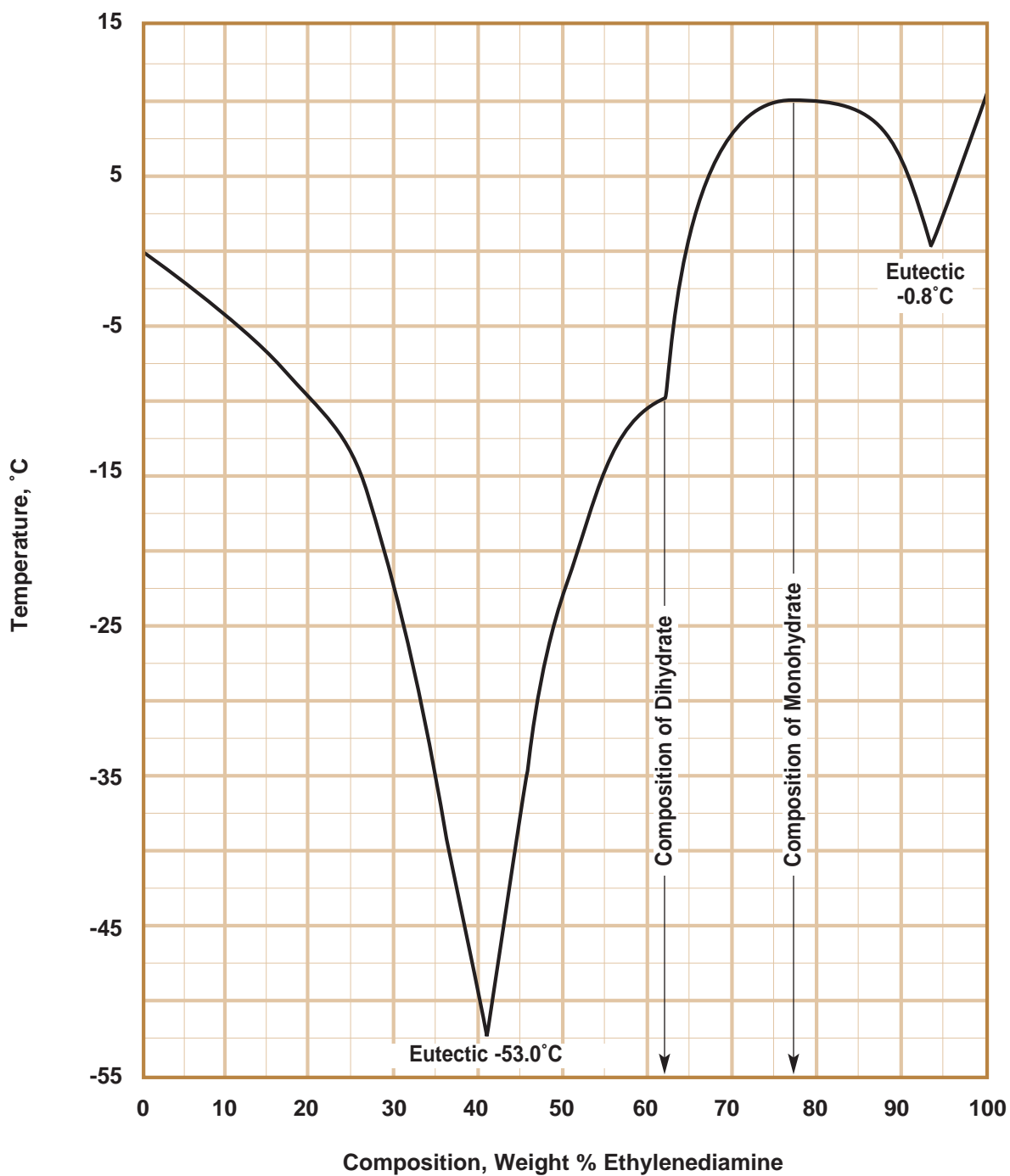


Figure 5:
Ethylenediamine Aqueous Solutions,
Vapor-Liquid Equilibria at 760 mm Hg

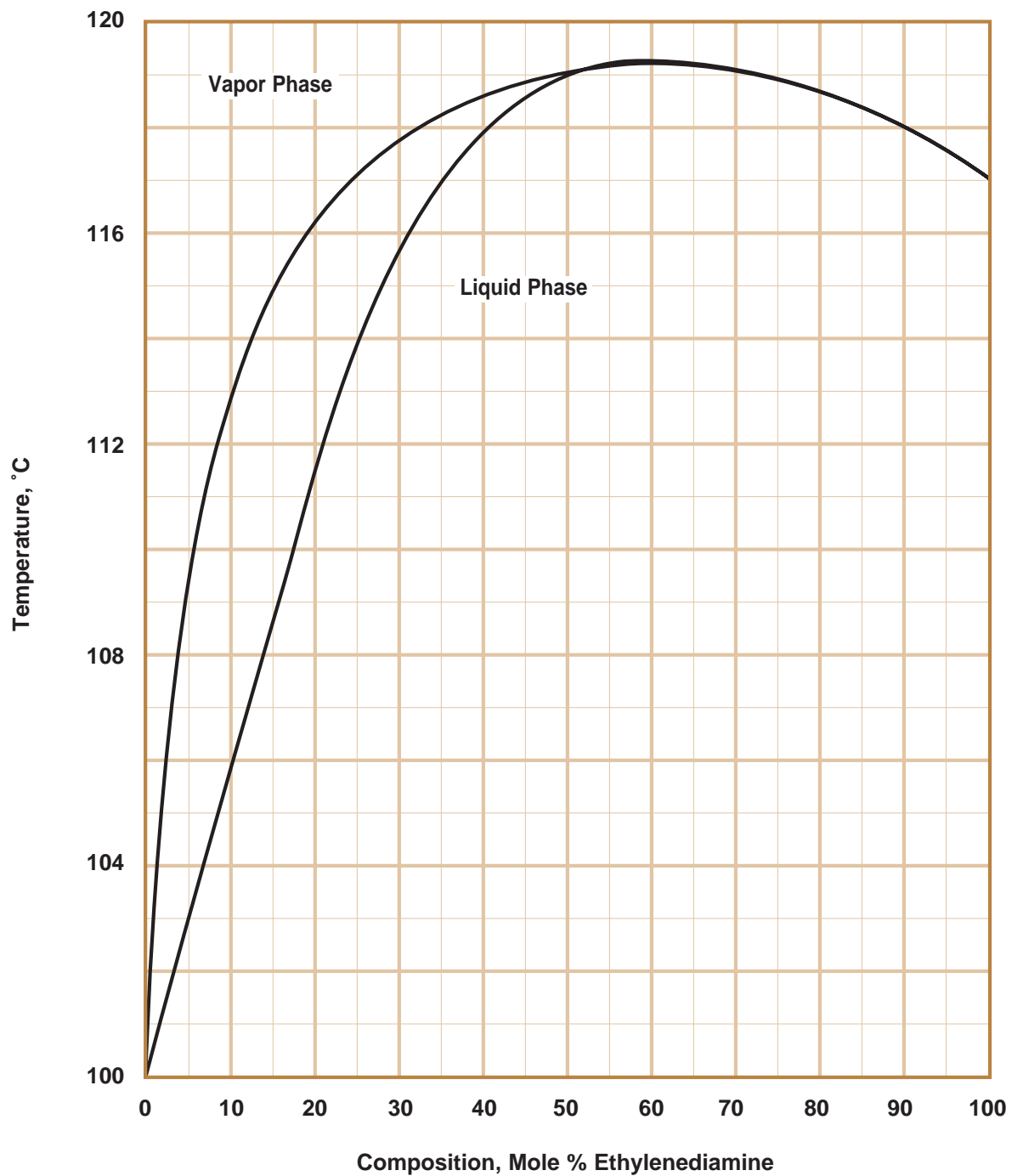




Figure 6:
Ethylenediamine Aqueous Solutions,
Heat of Solution at 22°C

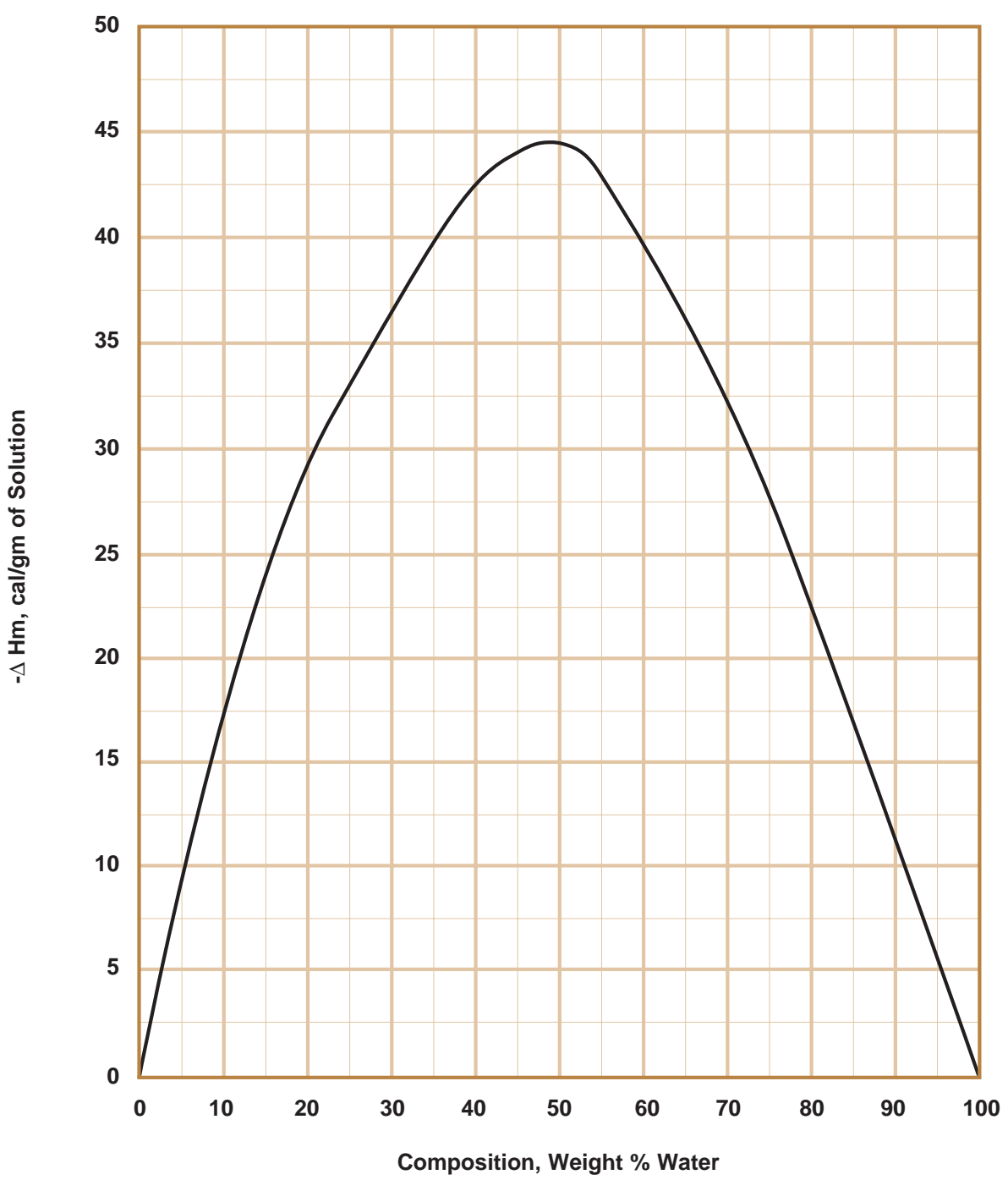




Figure 7:
Ethylenediamine Aqueous Solutions,
Specific Gravity vs. Temperature

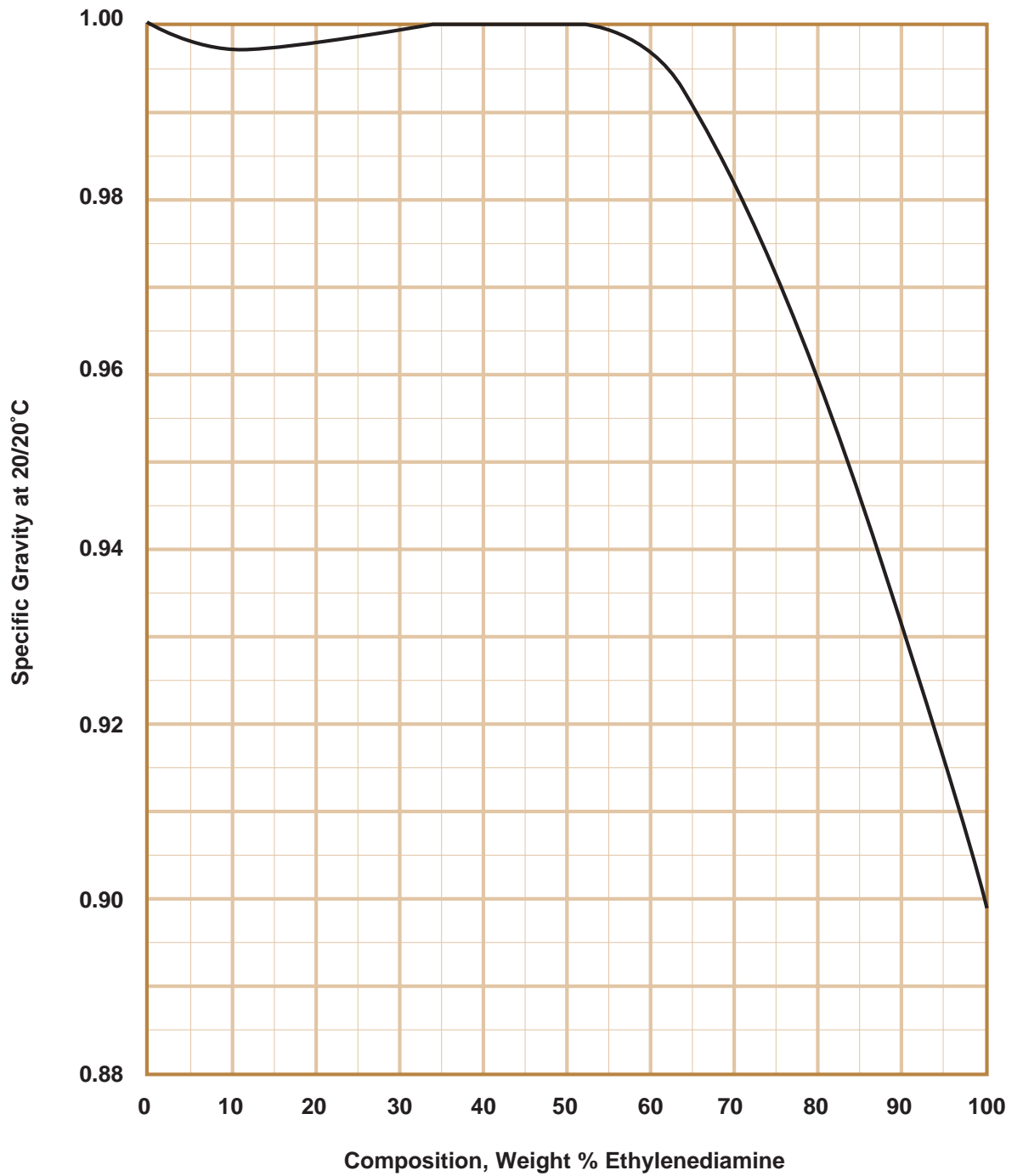
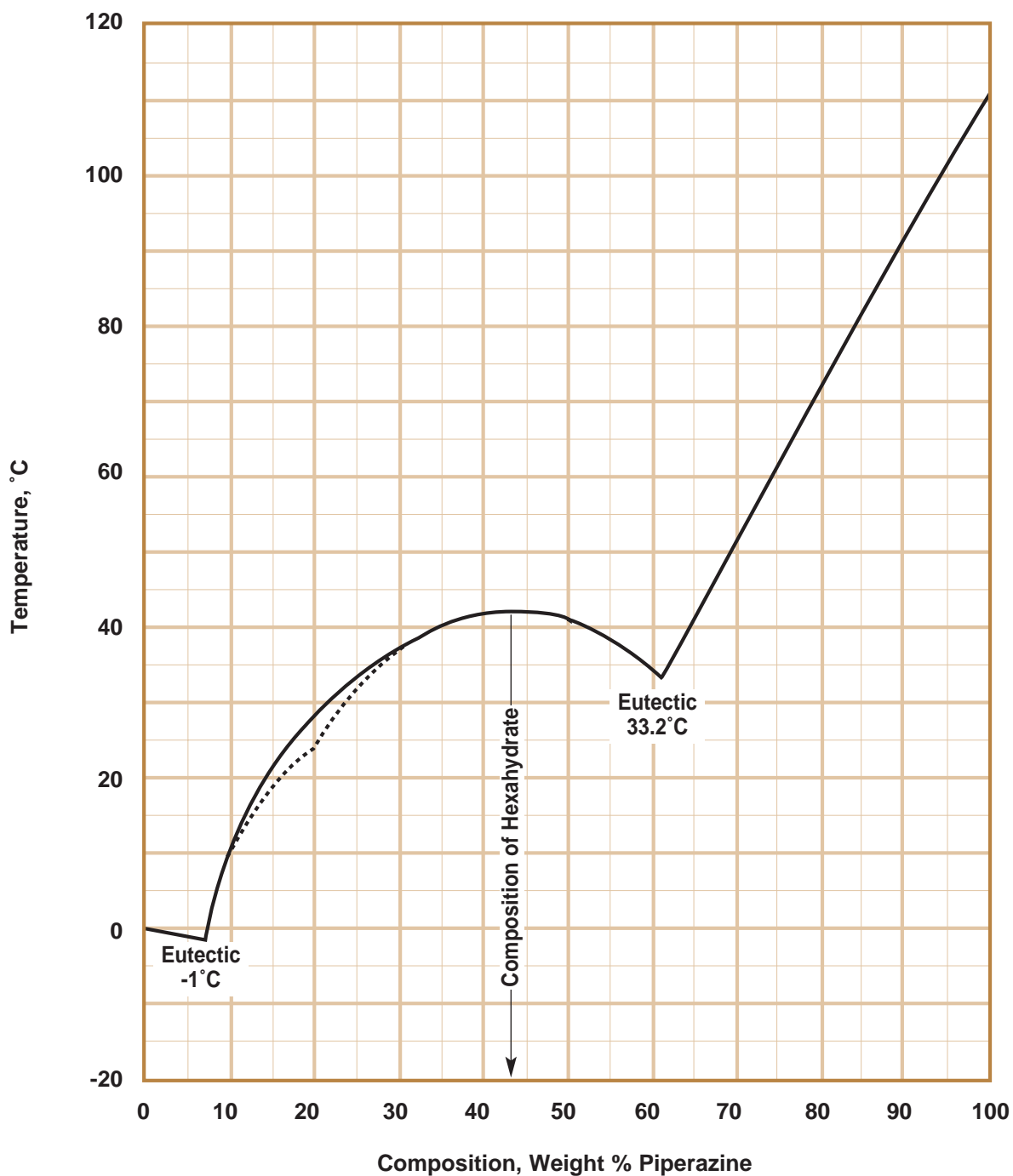


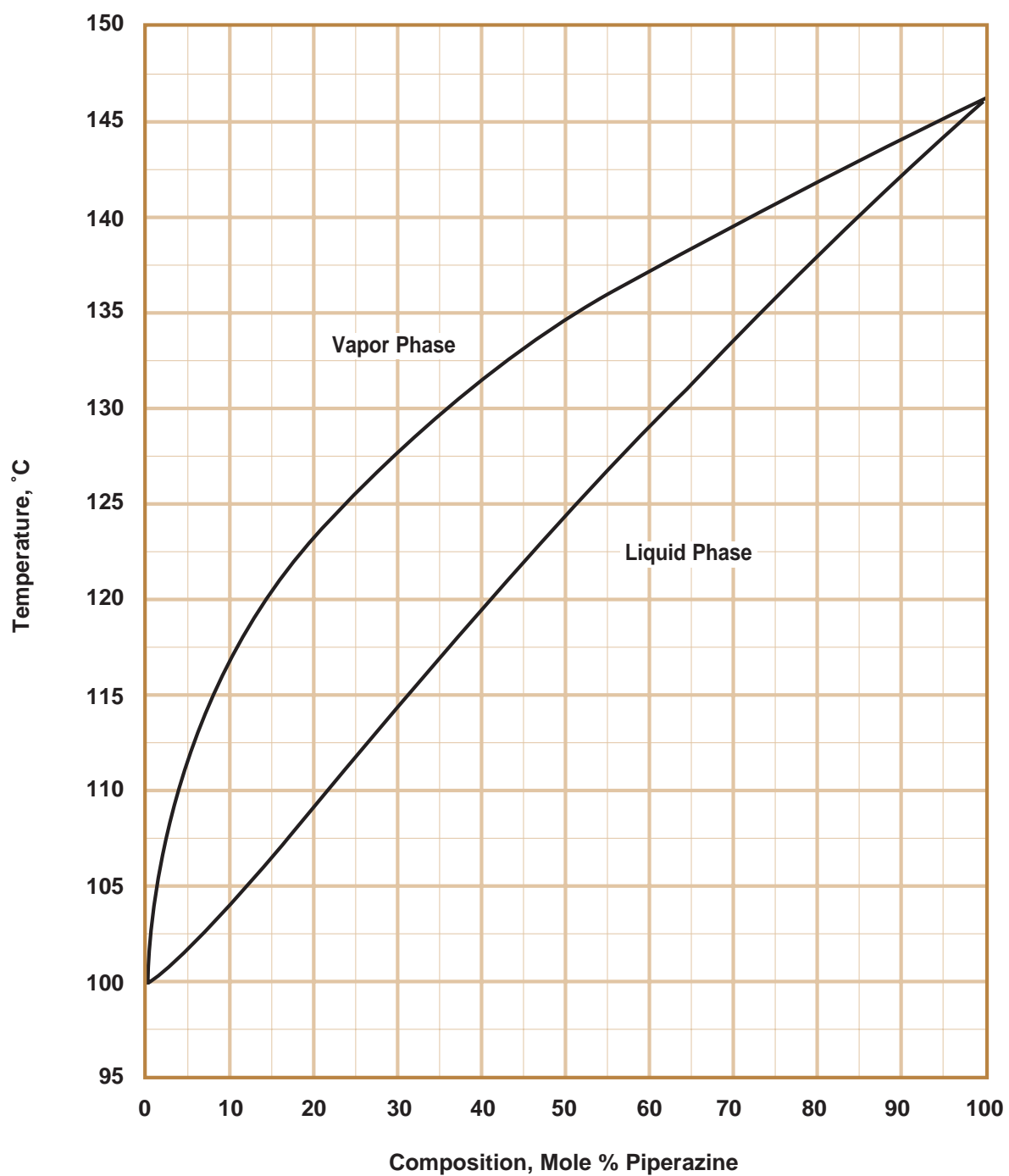


Figure 8:
Piperazine Aqueous Solutions,
Freezing Point vs. Composition

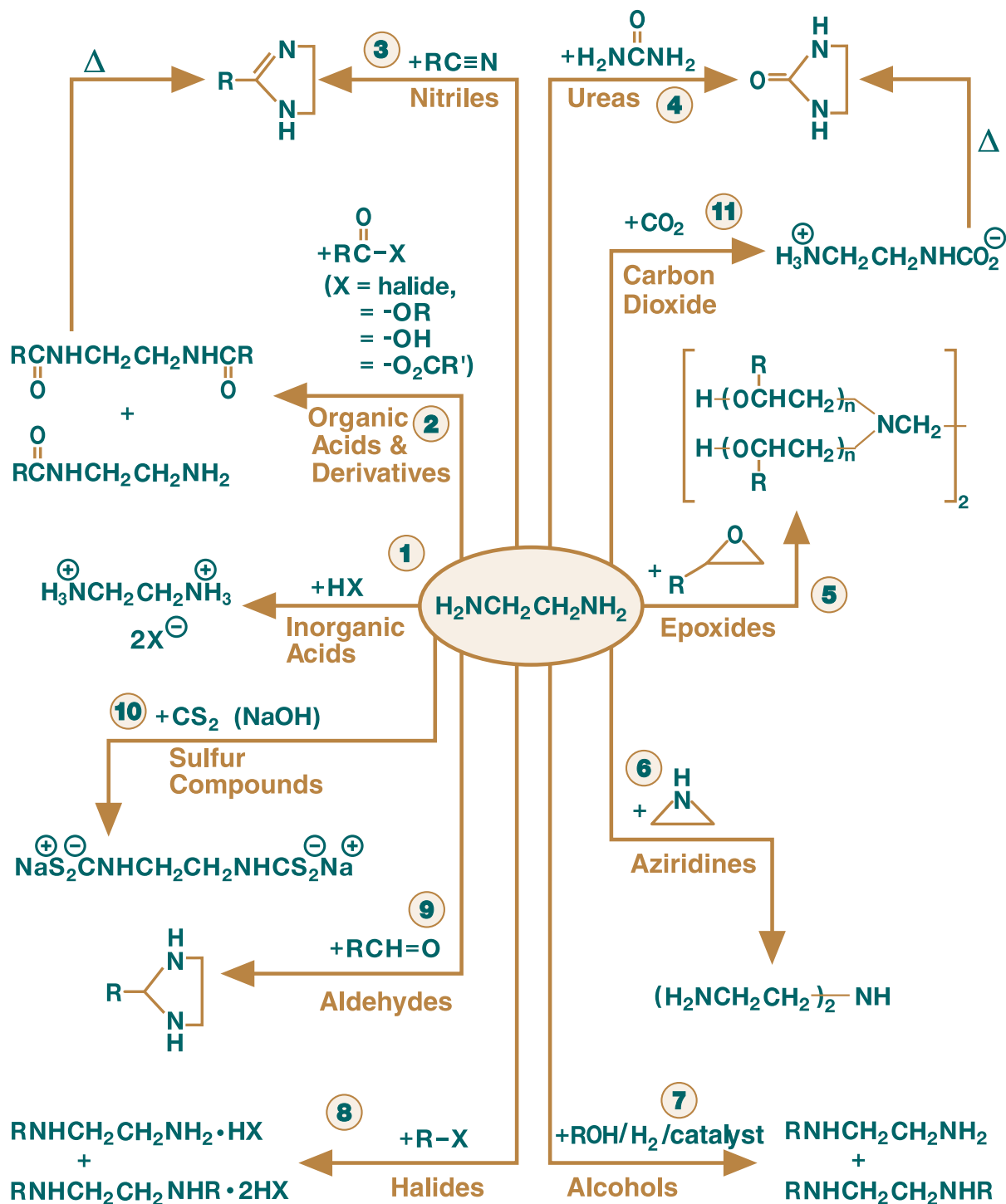


Studies show evidence of a metastable freezing point in the region of 20 wt.% piperazine

Figure 9:
Piperazine Aqueous Solutions,
Vapor-Liquid Equilibria at 760 mm Hg



Reactions of Ethyleneamines†



† Illustrated by reactions of ethylenediamine (EDA). Other ethyleneamines react similarly, depending upon structure.



Reaction Notes

RX 1. - Inorganic Acids

Ethyleneamines react vigorously with commonly available inorganic acids, forming crystalline, water soluble salts. Ethylenedinitramine, an explosive compound, is made by reacting one mole of EDA with two moles of nitric acid and splitting two moles of water from the salt at elevated temperatures (1).

RX 2. - Organic Acids

Ethyleneamines react with acids, esters, acid anhydrides, or acyl halides to form amidoamines and polyamides. Various diamides of EDA are prepared from the appropriate methyl ester or acid at moderate temperatures (2,3). Monoamides can be cyclized to form imidazolines. This can be done without isolating the monoamide (4-8).

RX 3. - Nitriles

Hydrogen cyanide (HCN) and aliphatic nitriles (RCN) can be used to form imidazolines (9-10).

RX 4. - Ureas

Ethyleneamines react with urea to form substituted ureas and ammonia (11).

RX 5. - Epoxides

Ethyleneamines react readily with epoxides, to form mixtures of hydroxyalkyl derivatives (12-14). Product distribution is controlled by the amine-to-epoxide mole ratio.

RX 6. - Aziridines

Aziridines react with ethyleneamines in an analogous fashion to epoxides (15-16). Product distribution is controlled by the ethyleneamine-to-aziridine mole ratio.

RX 7. - Alcohols and Alkylene Glycols

Simple aliphatic alcohols can be used to alkylate ethyleneamines with hydrogen in the presence of a reductive amination catalyst (17). Either gas- or liquid-phase reactions of ethyleneamines with glycols in the presence of several different metal oxide catalysts lead to predominantly cyclic ethyleneamine products (18).



RX 8. - Halides

Alkyl halides and aryl halides, activated by electron withdrawing groups, react with ethyleneamines to form mono- or disubstituted derivatives. Product distribution is controlled by reactant ratio, metal complexation or choice of solvent. Mixing methylene chloride and EDA reportedly causes a runaway reaction (19). Aliphatic dihalides, such as ethylene dichloride, react with ethyleneamines to form various polymeric, crosslinked, water-soluble cationic products or higher ethyleneamine products, depending on the reactant ratio (20).

RX 9. - Aldehydes

Ethyleneamines react exothermically with aliphatic aldehydes. The products depend on stoichiometry, reaction conditions, and structure of the ethyleneamine. Reactions of aldehydes with such ethyleneamines as EDA or DETA give mono- and disubstituted imidazolidines via cyclization of the intermediate Schiff base (21).

RX 10. - Sulfur Compounds

EDA reacts readily with two moles of carbon disulfide (CS_2) in aqueous sodium hydroxide to form bis sodium dithiocarbamate, which can be reacted with zinc (or manganese) to give the appropriate dithiocarbamate salt. Ethylene thiourea, a suspect human carcinogen, is prepared by reacting CS_2 in aqueous EDA (22).

RX 11. - Environmental Reagents: CO_2 , NO_x , H_2O , O_2

Under normal conditions ethyleneamines are considered to be thermally stable molecules. However, they are sufficiently reactive that upon exposure to adventitious water, carbon dioxide, nitrogen oxides, and oxygen, trace levels of byproducts can form and increased color usually results. Carbon dioxide reacts readily with EDA in methanol to form crystalline N-(2-aminoethyl)carbamate (23). N-Alkyl-piperazines and piperazine can react with nitrosating agents, such as nitrogen oxides, nitrites, or nitrous acid, to form nitrosamine derivatives (24). Ethyleneamines are soluble in water. However, in concentrated aqueous solutions, amine hydrates may form, the reaction being mildly exothermic. The hydrates of linear TETA and PIP melt around 50°C (25-26).

Ethyleneamines Applications

Ethyleneamines are utilized in a wide variety of applications because of their unique combination of reactivity, basicity, and surface activity. They are predominantly used as intermediates in the production of functional products. The following table lists the major end-use applications for these versatile materials.



Major End-Uses for Ethyleneamines

Application	EDA	DETA	TETA	TEPA	HPA	PIP	AEP	AEEA
Lube Oil Additives		+	+	++	++			
Fuel Additives	++	+	+	+				+
Polyamide Resins	++	+	++	++		+		
Asphalt Chemicals				+			++	
Corrosion Inhibitors		++	+	+	++		+	
Wet-Strength Paper Resins		++	+	+				
Epoxy Curing Agents		++	++	++	+		++	
Bleach Activators	++							
Chelating Agents	++	+						+
Ore Flotation Agents		+					+	
Surfactants								++
Fabric Softeners		++	+					++
Fungicides	++							
Anthelmintics						++		
Spandex Fibers	+							
Urethanes	+					++	+	+
Military Decontamination Agents		++						
Plastic Lubricants	+							
Ion Exchange Resins		+	+					
Coatings								++

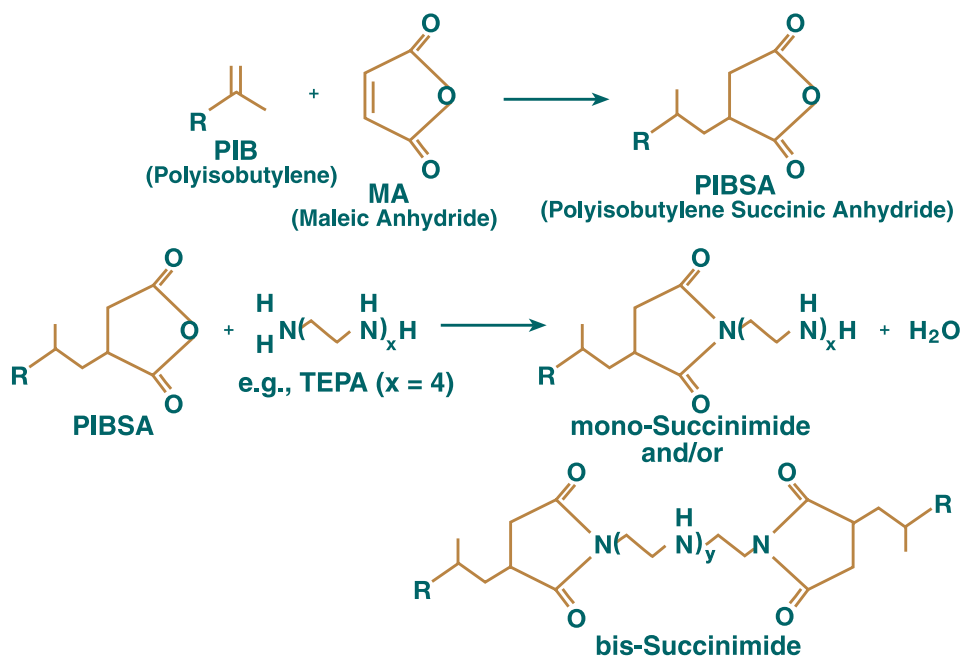
NOTE: The largest volume applications are indicated by ++

EDA	Ethylenediamine	HPA	Heavy Polyamine
DETA	Diethylenetriamine	PIP	Piperazine
TETA	Triethylenetetramine	AEP	Aminoethylpiperazine
TEPA	Tetraethylenepentamine	AEEA	Aminoethylethanolamine

Lubricant and Fuel Additives

The largest application area for ethyleneamines is in ashless dispersants for engine oils and other lubricants, and in certain dispersant-detergents for fuels. The lubricant additives function mainly to reduce the formation of

however, all the ethyleneamines have been employed for various products (45). Post-treatments of the succinimides are commonly utilized for performance improvement in engine oils (46-58). Ethyleneamines are also used in dispersant-

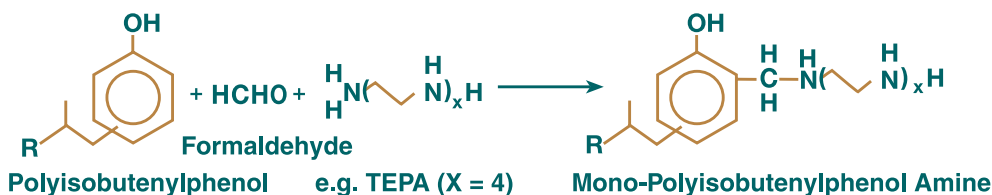


sludge and varnish deposits within internal combustion engines by inhibiting the aggregation of particles, by solubilizing oil-insoluble liquids, and by neutralizing acidic species formed in the combustion process. The ethyleneamine derivatives most commonly employed for these tasks are the mono- and bis-polyisobutenyl-succinimides, normally prepared by the condensation reaction of polyisobutenyl-succinic anhydrides (PIBSAs) (1, 2) with ethyleneamines (3-44).

The higher molecular weight ethyleneamines are most popular for these derivatives;

varnish inhibitors for lubricating oils for two-stroke engines (59).

Besides the more common means of linking long-chain hydrophobic moieties to ethyleneamines via the succinimide linkage, a different linkage is employed in another important class of ashless dispersants – the Mannich bases (60-70). They are prepared on a commercial scale by reaction of an alkylphenol with formaldehyde and an ethyleneamine (71-76). The alkyl and ethyleneamine moieties are similar to those used in the succinimide products.



Lubricant and Fuel Additives (cont'd)

Additives for lubricating oils providing a combination of viscosity index improvement (VII) and dispersancy have also been reported. These additives are prepared from ethyleneamines by reaction with various viscosity index improvement polymers that have been modified, via chlorination, for example, to provide a reaction site. Anti-rust additives for lubricating oils have also been prepared by reacting ethyleneamines with fatty acids followed by reaction with polyalkylenesuccinic anhydrides (77, 78).

Oil additives providing detergent properties have also been prepared from ethyleneamines (79, 80); and, a number of anti-wear/antiscuff additives for lube oils and greases



also use ethyleneamines. They are also used in preparing fatty acid/amine soaps and poly(urea) thickeners for lubricating greases.

Dispersant-detergent additives useful in gasoline are prepared by the direct alkylation of ethyleneamines with chlorinated polybutenes (81-86). EDA, DETA, and AEEA have found significant commercial application as dispersant detergent additives for gasoline when made by this route. Numerous similar products made generally by alkylating or acylating EDA or DETA (87-95) are also used as fuel detergent and deposit control additives. Cetane improvement

in diesel fuels has been reported for a mixture containing EDA (96).



Polyamide Resins

The main polyamide resin type, in addition to the liquid resins used as epoxy hardeners, is that prepared generally by the condensation reaction of diamines with di- and polybasic fatty acids. EDA is a principal amine reactant (1); however, tri- and tetramines are sometimes used at low levels to achieve specific performance (2). PIP and certain PIP derivatives are used with EDA in certain cases (3, 4).

These polyamides are used in hot-melt, pressure-sensitive, and heat-seal adhesives for leather, paper, plastic, and metal. They are also used to

modify alkyd resins in certain thixotropic coating systems (5), to plasticize nitrocellulose lacquers (6), and as corrosion inhibitors in alkyd paints (7).

Polyamide resins find wide use as binders in printing inks for flexogravure application on certain paper, film, and foil webs (8). Being soluble in alcohol-based solvents and exhibiting outstanding adhesion to polyolefins, polyester, cellophane, and paper, they are particularly suited to these applications. Thermoplastic polyamides are similarly used in formulating glossy, abrasion-resistant, overprint varnishes.

Asphalt Additives and Emulsifiers

Mono- and bis-amidoamines, imidazolines, and their mixtures are used in antistripping formulations and asphalt-in-water emulsions. Antistripping additives promote adhesion between the mineral aggregate and the asphalt in mixtures for road paving, patching, and surfacing. They are typi-

cally prepared from the higher molecular weight ethyleneamines and fatty acids (1-7). Similar ethyleneamine derivatives are used to make stable asphalt-in-water emulsions (8-16). These are generally used as their HCl or acetic acid salts.

Petroleum Production and Refining

A number of ethyleneamine derivatives are also employed in petroleum production and refining operations as corrosion inhibitors, demulsifiers, neutralizers, and functional additives.

Corrosion inhibitor formulations for down-hole petroleum production applications use a significant volume of ethyleneamines. They generally utilize the condensation reaction products of higher ethyleneamines and fatty or dimer acids, i.e., mono- and bis-amidoamines, imidazolines, and polyamides. Typically, they are represented by the products made from DETA and fatty acids (1-7). They are usually applied to the petroleum well by any of several methods designed to create a film of inhibitor on the surfaces of the steel structures in the petroleum well. These films displace the corrosive production fluids and attract a film of petroleum which further isolates the steel from the fluid.

The oil-water emulsions generated at times by petroleum wells can often be broken with certain ethyleneamine derivatives (8-10) (EDA, 11; DETA, 12; and TETA, 13). In some secondary recovery operations, ethyleneamines can be used to decrease the migration of injected chemicals into the formation by adsorption and precipitation (14). TEPA and other ethyleneamines combined with thickeners help stabilize viscosity, mobility, and pH and increase resistance to hydrolysis (15). Specific ethyleneamine derivatives can also be used for water clarification (16, 17).

Ethyleneamines are also employed in petroleum refining operations, for example, as part of a system used to extract thiols from petroleum distillates (18), as part of a composition used as an antioxidant to control fouling (19), to separate alkenes from thermally-cracked petroleum products (20), to separate carbon disulfide from a pyrolysis fraction (21), and in the processing of certain catalysts (22-25).



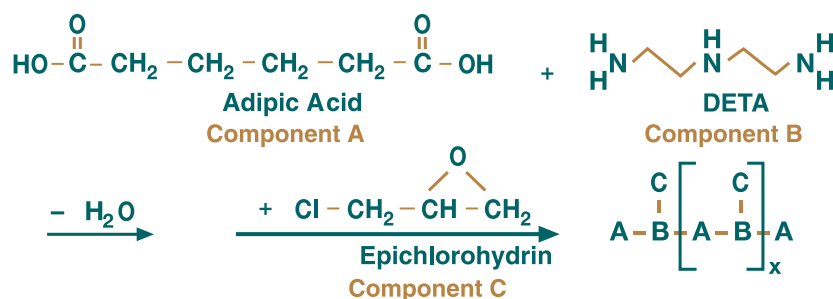
Resins and Additives for Pulp and Paper

Ethyleneamine-based chemicals are used widely in the paper industry to impart specific functional characteristics to the finished paper.

Cationic formaldehyde, polyamide, and polyamine resins, added to the beater stock to improve the wet strength of tissue, toweling, and

acidic conditions required by modified formaldehyde resins, to make nonacidic papers.

Numerous modifications of this resin type have been reported (4, 6, 8). Polyamine wet-strength resins, made by the reaction of ethyleneamines with epichlorohydrin (9), are also used.



packaging paper products, represent a major end use for ethyleneamines. The cationic formaldehyde resins, both urea- and melamine-formaldehyde types (1, 2), incorporate ethyleneamines such as DETA, TETA, and/or TEPA in the resin backbone to provide substantivity to the cellulose fibers in paper. Even though they tend to be less expensive, these types of paper wet-strength resins have been decreasing in popularity due to the adverse health effects associated with formaldehyde.

The most popular paper wet strength resins are the modified polyamides typically made with DETA, adipic acid and epichlorohydrin (3-7). These resins can be used under less corrosive neutral or alkaline conditions, rather than the

Certain pigment retention and drainage additives made with ethyleneamines include various polyamides (10, 11) and polyamines (12). Ethyleneamines are also used in the preparation of certain flocculating agents (13), waterproofing and sizing compounds (14-16), antistatic agents (17-20), and paper coatings (21). The bis-amide made by reacting EDA with stearic acid, ethylenebis(stearamide), is used as a defoamer in paper mill operations.

The sulfur-free delignification of wood chips with EDA-soda liquors has received some

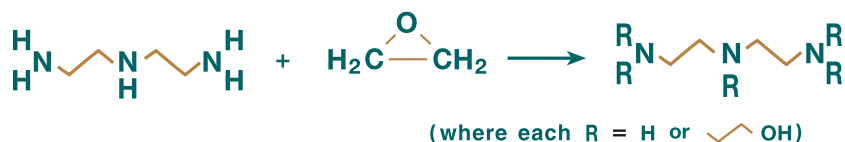
interest in the past few years (22-24). Improved rates of EDA recovery (25) have also been developed for EDA-sulfide pulping processes (26, 27).



Epoxy Curing Agents

All the commercial ethyleneamines are used either neat or as derivatives for curing epoxy resin-based coatings, adhesives, castings, laminates, grouts, etc. (1). Although the ethyleneamines themselves are often used as the curing agent or part of a curing agent package, they are commonly modified in various ways to achieve performance, handling, and safety improve-

Amidoamines and reactive polyamides prepared by condensation of TETA or higher polyamines with fatty acids (3-5) and dimer acids (6, 7), respectively, are widely used for longer pot life and better flexibility, adhesion, and solvent resistance (8). Most of the amidoamines and reactive polyamides contain significant levels of imidazoline structure, which provides improved com-



ments. The presence of different polyamino functionalities in the higher ethyleneamines allows partial reaction with various modifiers while retaining sufficient primary and secondary amino functionality for reaction with the epoxy resin portion of the system, and tertiary amino functionality to catalyze that reaction. For example, a common modification is the addition of an alkylene oxide, such as ethylene oxide, to DETA (2) as shown above.



patibility with liquid epoxy resins (9-13).

Other modifications of the ethyleneamines include partial reaction with epoxy resin to form a prepolymer; cyanoethylation, usually by reaction with acrylonitrile, to give derivatives providing longer pot life and better wetting of glass (14);

ketimines, made by the reaction of EDA with acetone; Mannich bases prepared from a phenol, formaldehyde, and a polyamine; and a variety of other ethyleneamine modifications (15-18).

Bleach Activators

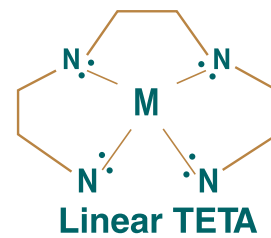
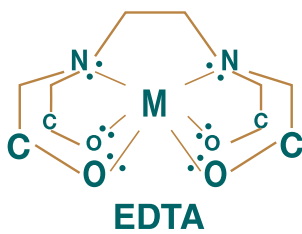
Tetraacetylenediamine (TAED) has been widely adopted for use in home laundry products as an activator for peroxygen bleaches.

It is prepared by first reacting EDA with two moles of acetic acid to form the bis-amide, which is then reacted with two moles of acetic anhydride to form the tetra-amide.

Chelates and Chelating Agents

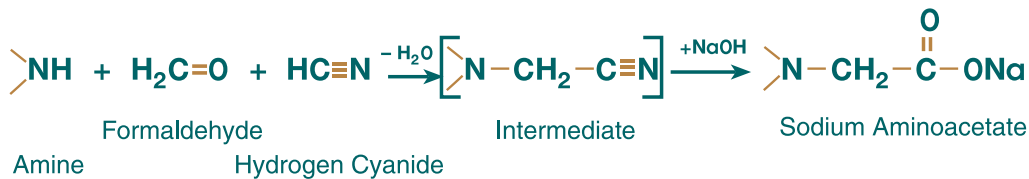
Polycarboxylic acids and their salts derived from ethyleneamines are used in a variety of applications where specific metal ions interfere with processing, or need to be buffered, concentrated, separated, or transported. They operate by forming stoichiometric complexes, called chelates, with most di- or polyvalent metals.

The most important commercial family of chelating agents is ethylenediamine tetraacetic acid (EDTA) and its various sodium salts, made from EDA.



AEAA and DETA are also used to make similar polyacetic acid or acetate products. These compounds are produced on an industrial scale primarily through the reaction of the ethyleneamine, sodium or hydrogen cyanide, and formaldehyde in the presence of sodium hydroxide (1, 2). The intermediate polynitrile may either be hydrolyzed *in situ* (3), or separated and hydrolyzed separately (4, 5).

This property makes the ethyleneamines useful in specialized applications, such as electroplating and electroless metal coating with specific metals and many alloys, where their metal complexing properties are required; and as ingredients in systems for etching and for stripping nickel and nickel alloy coatings.



Metal Ore Processing

Certain processes for enrichment of iron and phosphate ores use amidoamines and imidazolines made from ethyleneamines and fatty acids. These derivatives selectively adhere to silica particles and permit their removal by flotation procedures (1, 2). These same kinds of

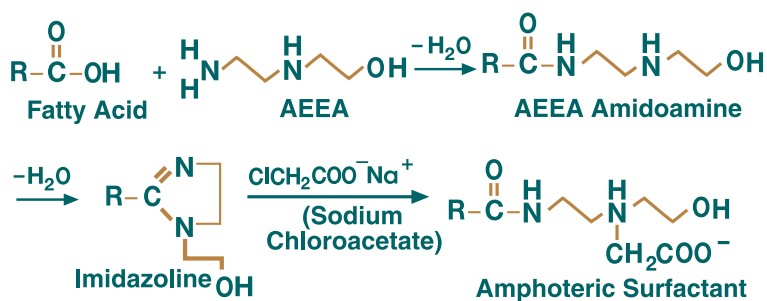
derivatives can be used for beneficiation of niobium and tantalum ores (3); and the ethyleneamines themselves aid extraction of copper, chromium, and nickel from their sulfide and oxide ores (4), and in lead ore processing and recovery operations (5-8).

Surfactants and Emulsifiers

To prepare surfactants derived from ethyleneamines, amine salts or soaps obtained by simply mixing the amine with a fatty acid (1, 2), amidoamines derived by the non-cyclicizing reaction between amine and acid, and the imidazoline formed by the reaction under vacuum at

virtue of their mildness and good foaming characteristics. The imidazolines are generally converted into amphoteric surfactants for this application by reaction with one or two moles of sodium chloroacetate (9-11).

The products of a reaction between DETA,



elevated temperature to remove two moles of water are all used. A variety of 2-alkylimidazolines and their salts prepared mainly from EDA or AEEA are reported to have good foaming properties (3-8). AEEA-based imidazolines are also important intermediates for surfactants used in shampoos by



TETA, or TEPA and fatty acids also function as water-in-oil or oil-in-water emulsifiers (12).

TEPA, ethoxylated with an average of 17 moles of ethylene oxide, improves the soil antiredeposition and clay soil removal properties of certain liquid laundry detergents (13).

Anthelmintics (Dewormers)

Piperazine is the active ingredient in certain veterinary anthelmintic preparations – primarily for combating intestinal worms in poul-

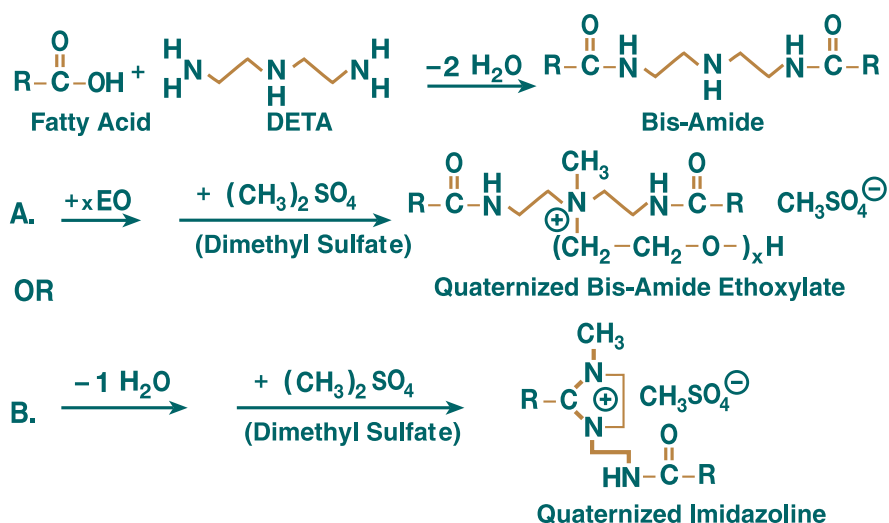
try and swine. The PIP salts have long been the agents of choice for use against roundworms and pinworms (1).

Fabric Softeners

Softeners are commonly added to textile materials to make them less harsh, “softer” or more pleasing to the touch. Softeners also act as antistatic and antisoiling agents, and impart fluffiness. Softeners are added to the home washing machine during a rinse cycle or as part of a detergent/softener combination product, or to the clothes dryer. Softening agents based on DETA and TEPA are also used in industrial textile processing operations (1, 2).

generally with dimethyl sulfate, to yield compounds that can be formulated into softener products for home laundry use (4-6).

Amino esters are made from acids and an amino alcohol, such as AEEA. The amino esters, as well as their quaternized derivatives, are more subject to hydrolysis than the amidoamine and imidazoline compounds. As a result, they have gained some popularity where environmental biodegradation concerns outweigh their



The most common ethyleneamine-based fabric softeners are bis-amidoamines, made from DETA and fatty acids, that are either cyclized to the corresponding imidazoline by further dehydration, or reacted with ethylene oxide (3) to convert the central secondary amine group to a tertiary amine. These intermediates are then quaternized,

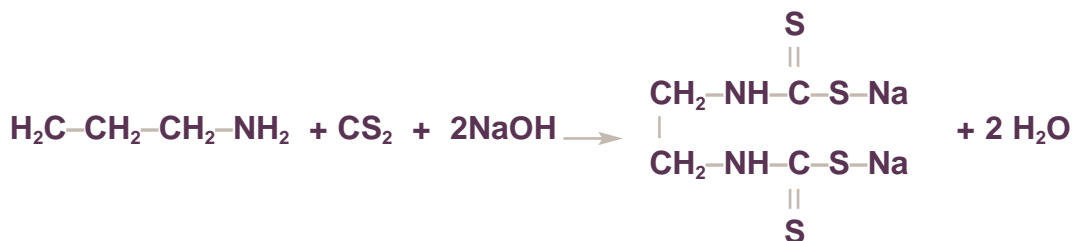


decreased storage stability and performance. Softeners based on bis-imidazoline compounds

are also prepared by condensing TETA or TEPA with fatty acids (7) or triglycerides (8), followed by quaternization with dimethyl sulfate, or sodium chloroacetate, which gives amphoteric softeners (9).

Fungicides

The ethylenebisdithiocarbamates (EBDCs) are a class of broad-spectrum, preventative, contact fungicides first used in the early 1940's. They are used on many fruit, vegetable, potato, and grain crops for prevention of mildew, scab, rust, and blight. The EBDCs are prepared by reacting EDA with carbon disulfide in the presence of an aqueous base.

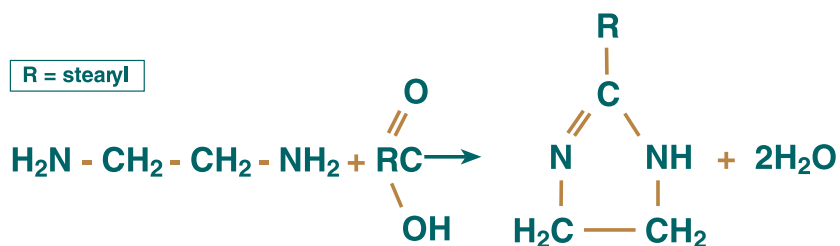


This sodium derivative, nabam, was found to be unstable. However, it is stabilized by conversion to certain other divalent metal salts. The zinc (zineb) and manganese salts (maneb) are especially effective (1-7) and are today the

primary commercial products. Zineb and maneb are normally formed by the addition of zinc or manganese salts to nabam solutions. The ammonium (amobam) and mixed zinc and manganese (mancozeb) salts are also known.

Other materials based on EDA have also been suggested as fungicides. The most important of the imidazoline type (8) is 2-heptadecyl-2-imid-

azoline (9), prepared from EDA and stearic acid. It is used as the acetate salt for control of apple scab and cherry leaf spot. A 2:1 EDA-copper sulfate complex has been suggested for control of aquatic fungi (10).



Textiles

Ethyleneamines are used in the textile-related industries for a variety of applications, including the treatment of a wide variety of natural and synthetic fibers for modification of certain properties (1, 2); as precursors for certain compounds providing durable press (3), light stabilization of spandex fibers (4), shrinkproofing wool (5), static

prevention (6), and mothproofing (7). Dye assist compounds for synthetic fibers have been derived from EDA, DETA, TETA, and TEPA (8-10). DETA is a component of Nylon 6 (11). The bis-amidoamine condensate made from TETA or TEPA and stearic acid is used as a defoamer in certain textile treatment baths.

Polymers and Elastomers

EDA is a key component of the polymer in spandex fiber. Ethyleneamines find application in vulcanization processes for certain rubbers (1-11); and they are used in styrene-butadiene latex processes to coagulate the low levels of finely-dispersed particles in the reaction medium (12-15). Urethane systems and processes employ certain ethyleneamines and their derivatives as curing agents, catalysts (TEDA [triethylenediamine] is a significant example), and polyol starters.

EDA specifically can be used as a stabilizer for certain urea resins, in phenolic resin curing, to reduce static in polystyrene foam, to inhibit isoprene polymerization,



and for etching polyimide films. EDA reacted with stearic acid makes ethylene-bis(stearamide) (EBS) that is used as an external lubricant for ABS resin and PVC, and as a parting material, viscosity regulator, preservative, and surface gloss enhancer. EDA is used in preparing silane and silanol compounds that improve the adhesion between inorganic surfaces and polymer films.

TETA has been recommended as a curing agent for furfural resin binders in foundry molds and molded graphite. Acrylate and other monomer vapors can be efficiently removed from vent streams with scrubber solvents containing TETA.

Other Applications

Ethyleneamines find application in numerous other specific industries. They include coal-oil emulsification and coal extraction, industrial corrosion inhibition, petroleum production, polymer concrete and concrete additives, stone

and concrete coatings, plaster systems, ceramics, explosives, fire retardants, functional fluids, pharmaceuticals, gas and water treating, ion exchange resins, and membranes.

Shipping Data

Since governmental regulations are subject to change, additional information on shipping data, labeling and container requirements may be obtained by contacting Dow at the numbers on the back of this booklet. We will provide a technical contact to discuss specific questions you might have.

Ethyleneamine	Average Weight per gallon, lb	
	at 20°C	at 15.56°C
Ethylenediamine	7.48	7.51
Diethylenetriamine	7.92	7.95
Triethylenetetramine	8.15	8.18
Tetraethylenepentamine UHP	8.27	8.30
Heavy Polyamine X	8.44	8.47
Piperazine, 65%	8.39 ⁽¹⁾	— ⁽²⁾
Piperazine, Anhydrous	— ⁽²⁾	— ⁽²⁾
Aminoethylpiperazine	8.21	8.24
Aminoethylethanolamine	8.57	8.60

(1) At 65°C (2) Solid at this condition (3) At 20°C to 30°C (4) At 45°C to 65°C (5) At 80 °C

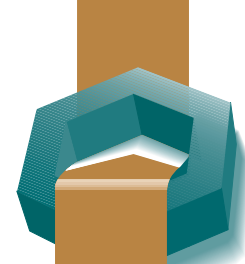
Metric Units

Ethyleneamine	Average Weight per liter, kg	
	at 20°C	at 15.56°C
Ethylenediamine	0.896	0.900
Diethylenetriamine	0.949	0.953
Triethylenetetramine	0.977	0.980
Tetraethylenepentamine UHP	0.991	0.995
Heavy Polyamine X	1.011	1.015
Piperazine, 65%	1.005 ⁽¹⁾	— ⁽²⁾
Piperazine, Anhydrous	— ⁽²⁾	— ⁽²⁾
Aminoethylpiperazine	0.984	0.987
Aminoethylethanolamine	1.027	1.031

(1) At 65°C (2) Solid at this condition (3) At 20°C to 30°C (4) At 45°C to 65°C (5) At 80 °C

Product Specifications

Product specifications and methods are available upon request. Please contact Dow at the numbers on the back of this booklet.



$\Delta\text{lb/gal}/\Delta t$ 10°C to 30°C, per °C	Coefficient of Expansion, per °C		Flash Point ⁽⁶⁾ , °F	
	at 20°C	at 55°C	Closed Cup	Open Cup
0.00794	0.00106	0.00110	110 T	103 TO
0.00703	0.00089	0.00092	208 P	225 C
0.00661	0.00081	0.00083	300 P	310 C
0.00642 ⁽³⁾	0.00081	0.00080	340 P	360 C
0.00623 ⁽³⁾	0.00076	0.00076	345 P	445 C
0.00787 ⁽⁴⁾	— (2)	0.00095 ⁽⁵⁾	None T	205 C
— (2)	— (2)	— (2)	130 P	215 C
0.00680 ⁽³⁾	0.00086	0.00085	215 P	250 C
0.00640 ⁽³⁾	0.00077	0.00077	260 P	310 C

(6) T = Tag Closed Cup, ASTM Method D 56

P = Pensky-Martens Closed Cup, ASTM Method D 93

C = Cleveland Open Cup, ASTM Method D 92

TO = Tag Open Cup, ASTM Method D 1310

$\Delta\text{kg/liter}/\Delta t$ 10°C to 30°C, per °C	Coefficient of Expansion, per °C		Flash Point ⁽⁶⁾ , °C	
	at 20°C	at 55°C	Closed Cup	Open Cup
0.000951	0.00106	0.00110	43 T	39 TO
0.000842	0.00089	0.00092	98 P	107 C
0.000792	0.00081	0.00083	149 P	154 C
0.000769 ⁽³⁾	0.00081	0.00080	171 P	182 C
0.000747 ⁽³⁾	0.00076	0.00076	174 P	229 C
0.000943 ⁽⁴⁾	— (2)	0.00095 ⁽⁵⁾	None T	96 C
— (2)	— (2)	— (2)	54 P	102 C
0.000815 ⁽³⁾	0.00086	0.00085	102 P	121 C
0.000767 ⁽³⁾	0.00077	0.00077	127 P	154 C

(6) T = Tag Closed Cup, ASTM Method D 56

P = Pensky-Martens Closed Cup, ASTM Method D 93

C = Cleveland Open Cup, ASTM Method D 92

TO = Tag Open Cup, ASTM Method D 1310

Product Availability

Products are available in bulk ocean tanker, rail car, tank truck, and nominal 55-gallon drums.



Storage and Handling

Ethyleneamines react with many other chemicals, sometimes rapidly and usually exothermically. Consequently, dedicated processing equipment is recommended. Proper selection of materials of construction for ethyleneamine service is essential to ensure the integrity of the handling system and to maintain product quality. Water, carbon dioxide, nitrogen oxides, and oxygen from the atmosphere may be absorbed by the amines. This may lead to low levels of byproducts and increase the color of the product. Storage under a dry, inert atmosphere (such as low CO₂-containing nitrogen) will minimize this sort of degradation.

Galvanized steel, copper and copper-bearing alloys are **unacceptable** for all ethyleneamine service. Carbon steel is not recommended for EDA, DETA, or AEEA storage tanks. Corrosion is not extreme (<0.001 in/yr) at typical storage temperatures, but the products will pick up iron and discolor badly. If this cannot be tolerated, then 300 series stainless steels are recommended for the storage tanks. Modest storage temperature (less than 60°C) and nitrogen blankets will allow the use of carbon steel, in dedicated service, for nonaqueous, heavier ethyleneamines without noticeable impact on product quality. Carbon steel transfer lines or agitated equipment will suffer enhanced corrosion because of erosion of the passive film by the product velocity. A 300 series stainless steel is often specified for pumps, valves, transfer lines, heating coils, and small agitated tanks.

Nonmetallic equipment is not normally used for ethyleneamine service. Ethyleneamines can permeate polyethylene and polypropylene, even at ambient temperature. However, certain grades of these materials may be acceptable in some storage applications. Carbon steel with baked phenolic lining is acceptable for storage of many pure ethyleneamines, except EDA.

Recommended gaskets for ethyleneamine service are made of GRAFOIL™ flexible graphite or polytetrafluoroethylene (TFE). No single elastomer is acceptable for the entire product line. TFE is an alternative to elastomers since it is resistant to ethyleneamines. However, since TFE is not a true elastomer, it may not always prove suitable as a replacement material.

Most commonly used industrial thermal insulating materials are acceptable for ethyleneamine service. However, porous insulation may introduce the hazard of spontaneous combustion if the insulation is saturated with ethyleneamines from a leak or external spill. Risk of insulation fires can be reduced by insisting on good housekeeping, maintenance of weather barriers, minimizing insulated flanges and fittings, and training personnel. Closed cellular glass insulation is normally resistant to insulation fires because it is difficult for the ethyleneamines to saturate these materials and also difficult for air to contact the product.

Also, like many other combustible liquids, self-heating of ethyleneamines may occur by slow oxidation in other absorbent or high-surface-area media, e.g., dumped filter cake, spill absorbents and metal wire mesh (such as that used in vapor mist eliminators). In some cases, this may lead to spontaneous combustion, and either smoldering or a flame may be observed. To avoid this situation, any of these media contaminated with ethyleneamines should be washed with water to remove the amines, or be thoroughly wetted with water and then disposed of in closed, water-saturated containers, consistent with local and federal regulations.



The amines do not present any unusual flammability problem at ordinary temperatures. EDA has the lowest flash point (Tag Closed Cup): 43°C (110°F). As commercially pure materials, ethyleneamines exhibit good temperature stability. At elevated temperatures some product breakdown may be observed in the form of ammonia and the formation of lower and higher molecular weight species. This degradation increases in rate as the temperature and/or time increases. Additionally, contaminants can lower the onset of rapid exothermic thermal decomposition (for example, mineral acids contamination). Testing for thermal stability is suggested whenever ethyleneamines are mixed with other materials.

Ethyleneamines are typically maintained above their freezing points which may require storage above ambient temperatures (particularly EDA and PIP). In addition, heavier ethyleneamines may be stored at elevated temperatures (40-60°C) to ease in-plant handling by lowering the viscosity. Storage at elevated temperatures can cause vapors “breathing” from the tank to contain significant concentrations of product. All amine vents should be routed to a safe location and “smoking vents” routed to water scrubbers to capture the vapors.

Tank vents and safety devices are also susceptible to fouling by solid amine carbamates formed by the reaction of the amines with carbon dioxide. Vent fouling can be reduced by using nitrogen blankets on storage tanks to exclude atmospheric CO₂. Also, vent units and relief devices may be steam-traced to maintain 160°C, which causes the carbamates to decompose. Vent units require periodic inspection to verify that fouling is not occurring and to ensure that seals are functioning properly to exclude air from the tank.

Additionally, although the amines are water-soluble, in certain concentrations, solid amine hydrates may form, which can be a nuisance in handling. Hydrates can plug processing equipment, vent lines and safety devices. Hydrate problems are usually avoided by insulating and heat tracing equipment to maintain a temperature of at least 50°C. Water cleanup of ethyleneamine equipment can result in hydrate problems, even in areas where routine processing is nonaqueous. Warm water cleanup can reduce the extent of the problem.

This information is of a general nature. For additional information, contact Dow at the numbers on the back of this booklet and request our **Ethyleneamines Storage and Handling Brochure** and/or a technical contact who will discuss specific questions about acceptable materials of construction and storage practices.

Health Effects

Information on health effects and their management, as well as recommended safety procedures, may be found in the Material Safety Data Sheets, which are updated as new information becomes available. For the latest Material Safety Data Sheets on ethyleneamines, contact Dow at the numbers on the back of this booklet.

Ecological Fate and Effects

Dow has conducted a series of laboratory studies on the biodegradation and ecological effects of these amines. Biodegradation was measured by the river-simulating 20-day biochemical oxygen demand (BOD) test using nonacclimated microorganisms, with the exception of EDA/DETA studies which used acclimated seed. The data presented in the following table show that the amines biodegrade slowly, except for EDA and AEEA, which rapidly biodegraded.

The impact of acclimation on the rate and extent of biodegradation is shown by the EDA and DETA acclimated seed data. Natural acclimation in a wastewater treatment plant or in the general environment would be expected to increase the rate and extent of biodegradation for the related compounds.

Bacterial inhibition tests indicate that none of these amines tested should be inhibitory to conventional wastewater treatment processes at expected discharge levels of less than 500 mg/L.

Aquatic toxicity measurements showed only moderate toxicity for most of the tested amines. Several amines, EDA, DETA, TETA, and AEP, showed more toxicity to *Daphnia magna* with LC₅₀ values ranging from 5 to 40 mg/L.

These studies were conducted by procedures which follow the EPA, ASTM, and Standard Methods techniques.

Ecological Fate and Effects of Ethyleneamines

Product Evaluated	Theoretical Oxygen Demand, (ThOD) mg/mg ⁽¹⁾		
	Carbonaceous Meas. (COD)	Carbonaceous Calc.	Nitrogenous Calc.
Ethylenediamine	1.28	1.33	2.13
Diethylenetriamine	1.68	1.55	1.86
Triethylenetetramine	1.94	1.64	1.75
Tetraethylenepentamine UHP	1.88	1.69	—
Heavy Polyamine X	1.93	—	—
Piperazine, 65%	1.48	1.86	1.49
Aminoethylpiperazine	1.84	1.86	1.50
Aminoethylethanolamine	1.63	1.54	1.23

- (1) Measured by Chemical Oxygen Demand (COD) procedure published in *Standard Methods for the Examination of Water and Wastewater*, 17th ed., Public Health Assoc. (1989). Calculated value based on oxygen required to oxidize the chemical to carbon dioxide and water, while the nitrogen converts to and remains as ammonia. The nitrogenous oxygen demand is calculated based on nitrogen being oxidized to nitrate by nitrifying bacteria.
- (2) Measured in dilution bottle biochemical oxygen demand test published in *Standard Methods*. The biooxidation values are calculated as percentage ratio of BOD and ThOD (BOD/ThOD x 100). Nonacclimated domestic sewage microorganisms used as seed.
- (3) The measured biooxidation as a percent of the total carbonaceous and nitrogenous oxygen demand (sum of calculated carbonaceous and nitrogenous ThOD values) is presented for Days 5, 10, and 20.

Product Safety



When considering the use of any Dow products in a particular application, you should review our latest Material Safety Data Sheets and ensure that the use you intend can be accomplished safely. For Material Safety Data Sheets and other product safety information, contact Dow at the numbers on the back of this booklet. Before handling any other products mentioned in the text, you should obtain available product safety information and take necessary steps to ensure safety of use.

No chemical should be used as or in a food, drug, medical device, or cosmetic, or in a product or process in which it may contact a food, drug, medical device, or cosmetic until the user has determined the suitability and legality of the use. Since government regulations and use conditions are subject to change, it is the user's responsibility to determine that this information is appropriate and suitable under current, applicable laws and regulations.

Dow requests that the customer read, understand, and comply with the information contained in this publication and the current Material Safety Data Sheet(s). The customer should furnish the information in these publications to its employees, contractors, and customers, or any other users of the product(s), and request that they do the same.

Biochemical Oxygen Demand ⁽²⁾ , % biooxidation			Aquatic Toxicity ⁽⁵⁾ LC50, mg/L	
Total Carbonaceous ⁽²⁾ Days 5/10/20	Nitrogenous ⁽³⁾ Days 5/10/20	Bacterial ⁽⁴⁾ Inhibition IC50, mg/L	48-hour <i>Daphnia magna</i>	96-hour Fathead Minnow
68/100/100				
A36 ⁽⁶⁾ /A45 ⁽⁶⁾ /A70 ⁽⁶⁾	25/37/78	1000	5 (4-6)	210 (190-230)
<5/<5/<5				
A23 ⁽⁶⁾ /A46 ⁽⁶⁾ /A70 ⁽⁶⁾	—/—/—	>5000	17 (15-19)	260 (220-310)
3/4/9	—/—/—	680	40 (35-50)	330 (280-400)
4/7/12	—/—/—	—	—	310
<5/<5/<5	—/—/—	—	—	—
<10/<10/<10	—/—/—	4600	90 (80-110)	720 (640-800)
2/4/7	—/—/—	1400	36 (25-50)	560 (500-620)
2/64/90	1/37/53	>5000	110 (90-130)	515 (470-560)

(4) Determined by turbidity/growth procedures where the median inhibition concentration (IC50) is measured after 16 hours of incubation with sewage microorganisms.

(5) Fathead minnows and *Daphnia magna* bioassays were conducted using procedures published by EPA and ASTM. The 95% confidence limits (95% CL) are shown in parentheses.

(6) Biooxidation values for EDA and DETA are taken from tests with acclimated microorganisms. No nitrification was measured in the acclimated systems.

FDA Status

Dow provides the following FDA Status Summary for the convenience of our customers. However, it is the responsibility of the user of an ethyleneamine as a Direct or Indirect Food Additive to read and understand any applicable FDA regulations in Title 21 of the Code of

FDA Regulation 21 CFR	Ethylenediamine Permitted Uses
173.20	Preparation of ion-exchange membranes used in the processing of grapefruit juice.
173.25	Crosslinker with epichlorohydrin to make ion-exchange resins used in the processing of food.
173.320	Component in an antimicrobial formulation used in cane sugar mills, applied to the sugar mill grinding, crusher, and/or diffusor systems at a maximum level of 1.0 ppm based on the weight of raw cane processed.
173.320	Component in an antimicrobial formulation used in cane sugar and beet sugar mills, applied to the sugar mill grinding, crusher, and/or diffusor systems at a maximum level of 2.0 ppm based on the weight of raw cane or beets processed.
175.105	Polyamides formed by reaction with dimerized vegetable oil acids for use as components of food-packaging adhesives .
175.105	Component of adhesives used in articles intended for packaging, transporting, or holding food.
175.300	Catalyst and crosslinking agent for epoxy resins used in resinous and polymeric coatings applied as a continuous film or enamel over a metal substrate or applied as a continuous film or enamel to any suitable substrate provided that the coating serves as a functional barrier between the food and the substrate and is intended for repeated food-contact use.
175.300	Polyamides from dimerized vegetable oils for use as adjuncts for epoxy resins .
175.300	Polyamides from vegetable oil acids and sebacic acid for use in side seam and can-end cements .
175.300	Modifier for urea-formaldehyde and melamine-formaldehyde resins used as the basic polymer in resinous and polymeric coatings on a metal substrate.
175.380	Catalyst for epoxy resins and component of polyamides for use in xylene-formaldehyde resins condensed with 4,4'-iso-propylidenediphenol epichlorohydrin epoxy resins .
175.390	Catalyst for epoxy resins and component of polyamides for use in zinc-silicon dioxide matrix coatings .
176.170 176.180	Catalyst for epoxy resins used as the food contact surface of paper and paperboard in contact with fatty, aqueous, and dry food.
176.170 176.180	Modifier for amino resins used as a component of the coated and uncoated food-contact surface of paper and paperboard in contact with fatty, aqueous, and dry food.
176.170 176.180	Modifier for urea-formaldehyde and melamine-formaldehyde resins for use as a component of the coated or uncoated food-contact surface of paper and paperboard in contact with fatty, aqueous, and dry food.
176.170 176.180	Polyamide-epichlorohydrin resins prepared by reacting adipic acid or other acids with diethylenetriamine to form a basic polyamide and further reaction of the polyamide with other materials to form water-soluble thermosetting resins for use in the manufacture of paper and paperboard .
176.180	Urea-formaldehyde resins chemically modified with polyamines made by reacting ethylenediamine with dichloroethane or dichloropropane for use as a component of the coated or uncoated food-contact surface of paper and paperboard in contact with dry food .
176.180	Component of the coated or uncoated food-contact surface of paper and paperboard in contact with dry food (as a crosslinking agent in polymerization).
176.210	Formulation of defoaming agents used in the manufacture of paper and paperboard prior to and during the sheet forming operation.
176.300	Adjuvant in the preparation of slimicides used as antimicrobial agents to control slime in the manufacture of paper and paperboard.
177.1010	Catalyst activator in semirigid and rigid acrylic and modified acrylic plastics ; at a level not to exceed 0.5 wt% based on the monomers.
177.1200	Modifier for melamine-formaldehyde resins for use as the basic polymer in cellophane, and as a resin to anchor coatings to substrate.
177.1200	Polyamines made by reacting ethylenediamine with dichloroethane or dichloropropane, sulfanilic acid, and other listed amines, as a modifier for melamine-formaldehyde resins used in cellophane.
177.1200	Modifier for urea-formaldehyde resins for use as the basic polymer in cellophane and as a resin to anchor coatings to substrate.
177.1200	Polyamines made by reacting ethylenediamine with dichloroethane or dichloropropane for modifying urea-formaldehyde resins used as the basic polymer and as a resin to anchor coatings to the substrate in the manufacture of food-packaging cellophane.
177.1210	Catalyst for epoxy resins and component of polyamides for use in making closures with sealing gaskets .
177.2600	Accelerator in vulcanization of rubber articles intended for repeated use ; not to exceed 1.5 wt% of the rubber product.
178.3120	Additive in the production of animal glue .



Federal Regulations (21 CFR) to determine any limitations or restrictions on the proposed use. Furthermore, it is the responsibility of the user to determine that any such use is suitable, safe, and FDA-compliant.

Diethylenetriamine (EDA)	Triethylenetetramine (DETA)	Tetraethylenepentamine (TETA)	Aminoethylethanolamine (TEPA)	(AEEA)
	✓			
	✓	✓	✓	
✓				
✓				
✓	✓	✓	✓	
✓			✓	✓
✓	✓	✓	✓	
✓	✓	✓	✓	
✓	✓	✓	✓	
✓	✓	✓	✓	
✓	✓	✓	✓	
✓	✓	✓	✓	
✓	✓	✓	✓	
✓	✓	✓	✓	
	✓	✓	✓	
	✓			
✓				
	✓	✓	✓	
	✓			
✓			✓	
	✓			
✓		✓	✓	
	✓	✓	✓	
✓				
✓	✓	✓	✓	
		✓		
✓	✓			

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Published August 2001.

