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Huntsman’s Gas Treating business is a leading global supplier of gas treating chemicals, supplying a wide range of chemicals to the gas conditioning industry for the removal of hydrogen sulfide and carbon dioxide in refinery as well as in produced gas streams. Continuous research and development helps our customers find more effective ways to solve their gas treating requirements. In addition we provide the necessary marketing, sales, manufacturing and technical support to supply customers with the right products at the right time and at a competitive price.

DIGLYCOLAMINE® AGENT (DGA®)

Huntsman is one of the largest global producers of specialty amines, with an annual capacity exceeding 90 million pounds. The DIGLYCOLAMINE® Agent (DGA®) can be reacted with fatty acids to form amides and amine salts for foam-boosting surfactants, stabilizers, detergents, and LAS emulsifying and wetting agents in shampoos, metalworking, paper treating and textile operations.

The DIGLYCOLAMINE® (DGA®) brand of 2-(2-aminoethoxy) ethanol is a critical component in the removal of hydrogen sulfide and/or carbon dioxide from gas streams. In addition to supplying this market, Huntsman is a leader in supplying this proven technology in increasing quantities for paint strippers, photoresist strippers for electronic circuit boards, specialty surfactants, corrosion inhibitors, cutting fluids, amides, and other applications where primary amines are useful.

Physically, DIGLYCOLAMINE agent is a clear, viscous liquid at room temperature and a white crystalline solid below its freezing point of 9.5°F (-12.5°C). DIGLYCOLAMINE agent has a relatively high boiling point and low vapor pressure.

It is hygroscopic and miscible with water, most alcohols, and most polyols. Aqueous solutions of DIGLYCOLAMINE agent are alkaline. Being bifunctional, DIGLYCOLAMINE agent reacts with acids to form esters or salts. Most areas of use for DIGLYCOLAMINE agent are dependent to some degree on these features.

The use of DIGLYCOLAMINE agent solution for gas treatment purposes holds great promise, both in new plants and in the conversion of existing amine facilities to obtain either lower treatment costs or an inexpensive means of debottlenecking existing treating facilities.

This technical brochure provides the latest available data on this proven DIGLYCOLAMINE agent to ensure optimum use, giving you the advantage in your present operations and new applications. The Chemical Abstracts Service Registry number for DIGLYCOLAMINE agent is 926-06-6.
Sales Specifications

The following sales specifications are subject to change without notice. Appropriate analytical procedures for these specifications may be found to the right.

<table>
<thead>
<tr>
<th>Appearance</th>
<th>Clear liquid, substantially free from suspended matter</th>
<th>Method of Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASTM, °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBP</td>
<td>216 min.</td>
<td>ST-32.1</td>
</tr>
<tr>
<td>95%</td>
<td>226 max.</td>
<td></td>
</tr>
<tr>
<td>Color, Pt-Co scale</td>
<td>35 max.</td>
<td>ST-30.12</td>
</tr>
<tr>
<td>DIGLYCOLAMINE Agent, wt. % by titration</td>
<td>98 min.</td>
<td>ST-5.5</td>
</tr>
<tr>
<td>Water, wt. %</td>
<td>0.5 max.</td>
<td>ST-31.53</td>
</tr>
</tbody>
</table>

Analytical Procedures

Abbreviated forms of the standard methods of test for use with DGA® agent specifications are presented here. Copies of the methods in detail are available from our Technical Services Section in The Woodlands, Texas, upon request.

APPEARANCE (Method No. ST-30.1) is determined by visual inspection of DIGLYCOLAMINE agent in a 100-ml tall-form Nessler tube.

BOILING RANGE (Method No. ST-32.1) is determined by a procedure similar to ASTM D 1078-63.

COLOR (Method No. ST-30.12) is determined visually in a 40-ml tube with APHA color disc standards, or in a 100-ml tall-form Nessler tube with liquid platinum cobalt (APHA) standards.

DIGLYCOLAMINE agent (Method No. ST-5.5) is determined by titrating a solution of DIGLYCOLAMINE agent with standard hydrochloric acid using methyl purple indicator.

WATER (Method No. ST-31.53) is determined by the standard Karl Fischer method, the end point being detected electrometrically.
Gas Treating Applications

DIGLYCOLAMINE/DEA is widely used for the absorption of acid gases, such as hydrogen sulfide (H₂S) and carbon dioxide (CO₂), and has been accepted worldwide as a successful gas treating agent. The DGA agent brand of 2-(2-aminoethoxy)ethanol is also used for removal of carbonyl sulfide (COS) from aliphatic liquid hydrocarbon streams using a patented Huntsman Corporation process.

Experience obtained during the commercial application of DIGLYCOLAMINE gas treating agent has proven that its use often results in significant savings over other sweetening processes when the acid gas content of the stream to be treated is greater than 1 mole %. Natural gas sweetening units now in operation are treating gas streams with CO₂:H₂S ratios varying from over 100:1 to 0.1:1. Several plants are processing gas streams having acid gas contents in excess of 30 mole % with DIGLYCOLAMINE agent. Hydrogen sulfide recovered in DIGLYCOLAMINE agent units is being converted to bright sulfur via the Claus process.

Savings of 15 to 20% in capital investments for new plants have been made using DIGLYCOLAMINE agent as compared to monoethanolamine systems. A significant reduction in plant operating cost is also realized due to a 15 to 30% reduction in regeneration heat requirements for the treating solution. The lower circulation rate required when utilizing a 50 to 65 wt.% DIGLYCOLAMINE agent solution is the major factor in the reduction of capital and operating costs.

DIGLYCOLAMINE agent is used for the removal of CO₂ and/or H₂S from both natural and refinery gas streams. It should also be considered for synthesis gas and flue gas streams although as with all amines used for gas treating, degradation due to the presence of oxygen must be taken into consideration. DIGLYCOLAMINE agent has been successfully utilized for removal of COS, CO₂, and H₂S from liquid hydrocarbon streams. When DIGLYCOLAMINE agent is used to treat liquid hydrocarbon streams, a water wash of the treated hydrocarbon liquid is recommended to minimize entrainment losses, particularly when amine concentrations above 25 wt.% are utilized.

The use of DIGLYCOLAMINE agent in gas treating should not be confused with the much older glycolamine process, which uses a mixed ethanolamine-glycol solvent for simultaneous sweetening and dehydration. Although DIGLYCOLAMINE agent is hygroscopic at very high concentrations, it is not currently recommended for simultaneous sweetening and dehydration.

The proper choice of DIGLYCOLAMINE agent concentration and acid gas loading is affected by gas stream composition, treating conditions, and acid gas ratios in much the same manner as other amine sweetening processes involving absorption with chemical reaction. While recommended design concentrations are
between 50 - 60 wt. %, current commercial experience confirms the applicability of up to 75 wt. % DIGLYCOLAMINE agent systems.

**ACID GAS LOADING** — Recommended acid gas loadings will vary significantly in terms of SCF of acid gas/ gallon of DIGLYCOLAMINE agent, depending on CO₂:H₂S ratios, construction materials, and solution concentrations. Gases containing low CO₂:H₂S ratios are much less corrosive to amine treating systems and can be loaded to higher levels without experiencing undue corrosion, as compared to gas streams having high CO₂:H₂S ratios.

Gross acid gas loadings of 0.35 to 0.425 mole/mole of DIGLYCOLAMINE agent solution are the typical current commercial practice. Recent experience, however, indicates that higher loadings may be possible when treating gases with low CO₂:H₂S ratios. Residual acid gas loading of lean DIGLYCOLAMINE agent solutions will normally be in the range of 0.05 — 0.06 mole of acid gas per mole of DIGLYCOLAMINE agent solution for high CO₂:H₂S ratios. Lower residual acid gas loadings for lean DIGLYCOLAMINE agent solution are usually obtained with low CO₂:H₂S ratios.

**REGENERATION HEAT REQUIREMENTS** —
Regeneration heat requirements for DIGLYCOLAMINE agent solutions will be affected by the CO₂:H₂S ratio of the acid gas contained in the inlet gas stream in much the same manner as other amine solutions. For gas streams containing a high CO₂:H₂S ratio, 1.0 — 1.2 moles of water vapor per mole of total acid gas in the regenerator overhead is typically used to establish regenerator heat requirements. Gas streams containing low CO₂:H₂S ratios generally require more heat for solution regeneration.

**SECONDARY CHEMICAL REACTIONS** — Often referred to as a degradation product, there is a secondary reaction product in DIGLYCOLAMINE agent gas treating solution known as N,N’bis(hydroxyethoxyethyl)urea (BHEEU). The BHEEU product is formed by the reaction of 2 moles of DIGLYCOLAMINE agent with 1 mole of either CO₂ or COS. It is also possible to form an additional product by the reaction of 1 mole of either carbon disulfide (CS₂) or COS with 2 moles of DIGLYCOLAMINE agent to form N,N’bis(hydroxyethoxyethyl)thiourea. Experience indicates the dominant reaction with COS will be to form BHEEU. Unlike many other amines, these secondary reactions between DIGLYCOLAMINE agent and CO₂, COS, or CS₂ are not true degradation products for they are reversible at temperatures typically used in reclaiming operations (350 to 355°F). These reactions are shown below:

\[
\begin{align*}
\text{CO}_2 & \xrightarrow{\Delta} \text{H-O-H} \\
2\text{R-NH}_2 + \text{COS} & \xrightarrow{\Delta} \text{R-N-C-N-R + H}_2\text{O or H}_2\text{S} \\
\text{N,N’bis(hydroxyethoxyethyl)urea (BHEEU)} & \\
\text{COS} & \xrightarrow{\Delta} \text{H-S-H} \\
2\text{R-NH}_2 + \text{CS}_2 & \xrightarrow{\Delta} \text{R-N-C-N-R + H}_2\text{O or H}_2\text{S} \\
\text{N,N’bis(hydroxyethoxyethyl)thiourea} & \\
\end{align*}
\]

where R = HO-CH₂-CH₂-O-CH₂-CH₂
DIGLYCOLAMINE PRODUCT RECLAIMING — The reclaiming of DIGLYCOLAMINE agent is usually necessary to maintain a circulating solution free of contaminants and with low concentrations of the bis(hydroxyethoxyethyl)urea (BHEEU). Heat-stable salts can also be removed from the treating solution in the reclaiming step. Addition of a low-chloride content alkali to the reclaimer can be used to free any DIGLYCOLAMINE product tied up as a heat stable salt.

The lengths of reclaiming cycles vary and are usually determined for each individual plant. Commercial experience indicates reclaiming cycles vary from a few weeks to as long as three months or more.

Periodically, operators should visually check to make certain reclaiming operations are continuing at design conditions. A flow indicator should be installed in the DIGLYCOLAMINE agent feed and the supplemental water feed to the reclaimer. Also, instrumentation should be provided to enable plant operators to determine the quantity of heat being supplied to the DIGLYCOLAMINE agent solution reclaimer. Improper reclaimer operation can result in increases in contaminants as well as higher degradation product concentrations.

To determine DIGLYCOLAMINE agent reclaiming cycle times, samples of lean treating solution and the reclaimer liquid should be analyzed periodically for increases in contaminant levels. Increases in contaminant level will vary at each individual plant; therefore, a history of reclaiming operations must be developed. Our Technical Services team can aid customers in determining optimum reclaimer cycle times.

It is recommended that the DIGLYCOLAMINE agent reclaimer be designed utilizing the same basic design techniques as those employed for monoethanolamine reclaimers, with several additional considerations:
• The reclaimer should typically be sized to handle a minimum of 0.5% of the circulating solution. Certain types of applications might require higher reclaiming rates.

• To optimize degradation product reconversion, reclaiming temperatures should be maintained below 360°F and typically around 350 to 355°F. In order to minimize thermal degradation, supplemental water feed to the reclaimer is usually required to prevent the reclaiming temperature from exceeding the 360°F level. A portion of the regenerator reflux, steam condensate, or good quality make-up water can be used for this purpose.

• Control of the DIGLYCOLAMINE agent feed to the reclaimer is usually accomplished by setting a constant heat input to the reclaimer. With a constant reclaimer heat duty, the reclaimer feed rate is controlled by the reclaimer kettle liquid level control. If steam is utilized as the heating medium, it is recommended that a sparging steam line be installed below the reclaimer tube bundle.

• Availability of sparging steam is particularly advantageous at the end of the reclaiming cycle to prevent settling of the accumulated sludge and solids, which will reduce liquid circulation around the reclaimer tube bundle. Because relatively long reclaiming cycles can be realized, it is important that 8 to 12 inches of clearance be provided between the bottom of the reclaimer shell and the reclaimer tube bundle. This clearance will accommodate the buildup of solids and sludge.

Reclaimer overhead vapors should be returned to the stripping still via a separate line and can provide a significant portion of the regeneration heat requirements. An extra nozzle for vapor reentry should be added four or five trays from the bottom of the regenerator when sour regenerator reflux is used as the supplemental water source for the reclaimer.

CONSTRUCTION MATERIALS — The choice of construction materials for DIGLYCOLAMINE agent solution treating facilities is essentially the same as for monoethanolamine systems. Generally speaking, treating systems handling gas streams with high ratios of \( \text{CO}_2: \text{H}_2\text{S} \) are in much more corrosive service than streams with low ratios of \( \text{CO}_2: \text{H}_2\text{S} \) and similar loadings and temperatures. Where low \( \text{CO}_2: \text{H}_2\text{S} \) ratios are encountered, carbon steel is usually satisfactory.

Recommendations for construction materials should be handled on an individual basis for the specific application. Additional assistance can be obtained through our Technical Services team.

DIGLYCOLAMINE agent gas treating solution has distinct advantages over monoethanolamine and diethanolamine for plants operating in cold weather areas because heat tracing requirements are reduced. DIGLYCOLAMINE agent solutions containing 30 to 35 wt. % \( \text{H}_2\text{O} \) are within the eutectic region of the freezing curve. Freezing points as low as -40°F have been determined on actual plant samples containing 30 to 40 wt. % \( \text{H}_2\text{O} \) and various quantities of acid gas. Viscosities will, of course, be quite high at low temperatures. Normal operating solutions of 60% DIGLYCOLAMINE agent are pumpable at -10°F in many facilities.
Other Applications
DIGLYCOLAMINE agent is suggested for use in many applications where other alkanolamines, morpholine, or other amines have been utilized. It reacts with fatty acids to form amides and amine salts useful as surface-active agents, such as foam boosters and stabilizers, detergents, and emulsifying and wetting agents. The reference numbers used in the following paragraphs refer to the bibliography.

Our laboratory data demonstrate that, in certain concentration ranges, DIGLYCOLAMINE agent imparts greater viscosities than triethanolamine in amine-neutralized linear alkylbenzene sulfonic acid formulations. This effect is quite advantageous in shampoos and other specialty detergent and emulsifier applications. Aqueous solutions of sulfonic acid neutralized with DIGLYCOLAMINE agent had the following viscosities at the indicated concentrations at 25°C:

<table>
<thead>
<tr>
<th>Active Ingredients, %</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triethanolamine salt, viscosity, SUS</td>
<td>5.5</td>
<td>9.9</td>
<td>64</td>
<td>728</td>
<td>4,725</td>
</tr>
<tr>
<td>DIGLYCOLAMINE agent salt, viscosity SUS</td>
<td>5.8</td>
<td>29.3</td>
<td>619</td>
<td>4,436</td>
<td>6,910</td>
</tr>
</tbody>
</table>

DIGLYCOLAMINE agent solution use in shampoo formulations also results in reduced eye irritation.

Stanford Research Institute, under the direction of the Fats and Proteins Research Foundation, has developed a process using DIGLYCOLAMINE agent to make a tallow sulfate as a lime soap dispersant.

DIGLYCOLAMINE agent is used as an emulsifying agent to prepare metal-working lubricants that prevent carbon deposits and discoloration of the metal.

Photoresist strippers are made using DIGLYCOLAMINE agent in conjunction with N-methylpyrrolidone.

Polyurethane rubber with lower solution viscosity and higher film elongation and tensile strength is produced using DIGLYCOLAMINE agent instead of preparations using Sulfonyldiamine.

Other applications for DIGLYCOLAMINE agent include its use as a component of paint strippers, hydraulic fluids, extractive solvents, paper treating and textile treating solutions, and dyes, as detailed below.
DIGLYCOLAMINE agent is used in accelerator additives for alkaline paint stripping solutions. These products usually require much shorter contact times than more conventional alkaline paint stripping compositions.\textsuperscript{38, 45, 46, 48}

Fire-resistant polyamide ester hydraulic fluids are produced by reacting DIGLYCOLAMINE agent with a dibasic acid or one of its derivatives, such as phthalic anhydride.\textsuperscript{50}

Anhydrous mixtures of DIGLYCOLAMINE agent and other selective solvents are used to separate aromatic compounds from hydrocarbon liquids. Extraction or extractive distillation is employed. DIGLYCOLAMINE agent’s high boiling point makes it especially suitable for this application.\textsuperscript{36, 39, 42}

DIGLYCOLAMINE agent is also used in the TherMEcel\textsuperscript{®} process for protecting and stabilizing transformer insulation papers against thermal deterioration and decomposition products of transformer oil and other liquid dielectrics. The TherMEcel process was developed by the Thomas A. Edison Division of McGraw-Edison. In this process, newly formed paper is thoroughly impregnated with an aqueous solution of DIGLYCOLAMINE agent while still on the papermaking machine.\textsuperscript{37, 49}

Textile-treating solutions containing DIGLYCOLAMINE agent help cellulosic fabrics retain their original finish.\textsuperscript{43}

Liquid developers for diazo copying papers use DIGLYCOLAMINE agent to replace the NH\textsubscript{3} developers that contribute to air and water pollution problems.\textsuperscript{44, 47, 53}

DIGLYCOLAMINE agent is also employed as a stabilizer in diazo dye compounds for paper and cellulose fibers.\textsuperscript{40}

For further information on the uses of DIGLYCOLAMINE agent, consult the bibliography.
Physical Properties

The following physical properties are for DIGLYCOLAMINE agent, a product of Huntsman Corporation:

- Molecular Weight: 105.14
- Boiling point, 760 mm Hg, °C: 221
- Critical constants:
  - Critical temperature, °C: 401.4
  - Critical pressure, atm: 42.98
  - Critical density, g/cc: 0.322
- Density, g/ml, 60°F: 1.0585
  - 77°F: 1.0508
- Flash point, Pensky-Martens closed cup, °F: 255
- Freezing point, °C: -12.2
- Heat of vaporization, 760 mm Hg, Btu/lb: 219.14
- Ionization constant, 25°C, kb: 3.6 x 10^-5
- Refractive index, nD, 20°C: 1.4598
- Specific gravity, 20/20°C: 1.0560
- Specific heat of liquid, Btu/lb/ °F: 0.571
  - 180°F: 0.623
- Thermal conductivity, 68°F, Btu/hr, sq ft,*°F/ft: 0.121
- Vapor pressure, 68°F, mm Hg: <0.01
- Viscosity, 60°F, cp: 40
- Weight, 60°F, lb/gal: 8.82

* Calculated

Heats of Solution

- 20.1 wt. % water in DGA agent: 72.7 Btu per pound of water
- 20.2 wt. % DGA agent in water: 25.4 Btu per pound of DGA agent

Heats of reaction were determined on 95 wt. % DIGLYCOLAMINE agent in aqueous solution loaded to 0.2 moles of acid gas per mole of DIGLYCOLAMINE agent.

- H = -850 Btu per pound of CO₂
- H = - 674 Btu per pound of H₂S

Additional physical properties pertinent to handling and using DIGLYCOLAMINE agent are presented in the pages that follow. Properties were determined in the laboratory using DIGLYCOLAMINE agent manufactured by Huntsman Corporation. An attempt has been made to correlate values that appear in the literature. Dotted lines in the figures indicate extrapolation.
Physical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapor Pressure of Aqueous DGA Agent Solutions</td>
<td>1</td>
</tr>
<tr>
<td>Vapor-Liquid Equilibrium for Aqueous DGA Agent Solutions at Various Pressures</td>
<td>2</td>
</tr>
<tr>
<td>Vapor-Liquid Equilibrium for Aqueous DGA Agent Solutions at Various Pressures</td>
<td>3</td>
</tr>
<tr>
<td>Water Vapor Dew Points Over Aqueous DGA Agent Solutions Versus Temperature</td>
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</tr>
<tr>
<td>Viscosity of DGA Agent Versus Temperature</td>
<td>5</td>
</tr>
<tr>
<td>Viscosity of Aqueous DGA Agent Solutions Versus Temperature</td>
<td>6</td>
</tr>
<tr>
<td>Effect of Acid Gas Loading on Kinematic Viscosity of an Aqueous 25 Wt. % DGA Agent Solution Versus Temperature</td>
<td>7</td>
</tr>
<tr>
<td>Effect of Acid Gas Loading on Kinematic Viscosity of an Aqueous 50 Wt. % DGA Agent Solution Versus Temperature</td>
<td>8</td>
</tr>
<tr>
<td>Effect of Acid Gas Loading on Kinematic Viscosity of an Aqueous 65 Wt. % DGA Agent Solution Versus Temperature</td>
<td>9</td>
</tr>
<tr>
<td>Effect of Acid Gas Loading on Kinematic Viscosity of an Aqueous 80 Wt. % DGA Agent Solution Versus Temperature</td>
<td>10</td>
</tr>
<tr>
<td>Effect of Temperature on Kinematic Viscosity of Aqueous DGA Agent Solutions Loaded to 0.1 Moles CO₂/Mole DGA Agent</td>
<td>11</td>
</tr>
<tr>
<td>Effect of Temperature on Kinematic Viscosity of Aqueous DGA Agent Solutions Loaded to 0.2 Moles CO₂/Mole DGA Agent</td>
<td>12</td>
</tr>
<tr>
<td>Effect of Temperature on Kinematic Viscosity of Aqueous DGA Agent Solutions Loaded to 0.4 Moles CO₂/Mole DGA Agent</td>
<td>13</td>
</tr>
<tr>
<td>Effect of Temperature on Kinematic Viscosity of Aqueous DGA Agent Solutions Loaded to 0.2 Moles CO₂ and 0.2 Moles H₂S/Mole DGA Agent</td>
<td>14</td>
</tr>
<tr>
<td>Effect of Temperature on Kinematic Viscosity of Aqueous DGA Agent Solutions Loaded to 0.1 Moles CO₂ and 0.3 Moles H₂S/Mole DGA Agent</td>
<td>15</td>
</tr>
<tr>
<td>Density of DGA Agent Versus Temperature</td>
<td>16</td>
</tr>
<tr>
<td>Density of Aqueous DGA Agent Solution Versus Temperature</td>
<td>17</td>
</tr>
<tr>
<td>Effect of Acid Gas Loading on Density of an Aqueous 25 Wt. % DGA Agent Solution Versus Temperature</td>
<td>18</td>
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<tr>
<td>Effect of Acid Gas Loading on Density of an Aqueous 50 Wt. % DGA Agent Solution Versus Temperature</td>
<td>19</td>
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<tr>
<td>Effect of Acid Gas Loading on Density of an Aqueous 65 Wt. % DGA Agent Solution Versus Temperature</td>
<td>20</td>
</tr>
<tr>
<td>Effect of Acid Gas Loading on Density of an Aqueous 75 Wt. % DGA Agent Solution Versus Temperature</td>
<td>21</td>
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<tr>
<td>Effect of Acid Gas Loading on Density of an Aqueous 80 Wt. % DGA Agent Solution Versus Temperature</td>
<td>22</td>
</tr>
<tr>
<td>Effect of Temperature on Density of Aqueous DGA Agent Solutions Loaded to 0.2 Moles CO₂/Mole DGA Agent</td>
<td>23</td>
</tr>
<tr>
<td>Effect of Temperature on Density of Aqueous DGA Agent Solutions Loaded to 0.4 Moles CO₂/Mole DGA Agent</td>
<td>24</td>
</tr>
<tr>
<td>Effect of Temperature on Density of Aqueous DGA Agent Solutions Loaded to 0.1 Moles CO₂ and 0.1 Moles H₂S/Mole DGA Agent</td>
<td>25</td>
</tr>
<tr>
<td>Effect of Temperature on Density of Aqueous DGA Agent Solutions Loaded to 0.2 Moles CO₂ and 0.2 Moles H₂S/ Mole DGA Agent</td>
<td>26</td>
</tr>
<tr>
<td>Specific Heat of Aqueous DGA Agent Solutions Versus Temperature</td>
<td>27</td>
</tr>
<tr>
<td>Thermal Conductivity of Aqueous DGA Agent Solutions</td>
<td>28</td>
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<tr>
<td>Freezing Points of Aqueous DGA Agent Solutions</td>
<td>29</td>
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<tr>
<td>pH of Aqueous DGA Agent Solutions at 20°C</td>
<td>30</td>
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<tr>
<td>Surface Tension of Aqueous DGA Agent Solutions Versus Temperature</td>
<td>31</td>
</tr>
<tr>
<td>Hydrogen Solubility in Gas Treating Amine Solutions Versus Hydrogen Partial Pressure</td>
<td>32</td>
</tr>
<tr>
<td>Nitrogen Solubility in Aqueous 60 Wt. % DGA Agent Solution at 180°F</td>
<td>33</td>
</tr>
</tbody>
</table>
Figure 1
Vapor Pressure of Aqueous DIGLYCOLAMINE® Agent Solutions

Temperature, °F

Water
50 Wt. % DGA Agent
70 Wt. % DGA Agent
90 Wt. % DGA Agent
95 Wt. % DGA Agent
100 Wt. % DGA Agent

Vapor Pressure, mm Hg

Physical Properties
Figure 2
Vapor-Liquid Equilibrium for Aqueous DIGLYCOLAMINE® Agent Solutions at Various Pressures

Physical Properties
Physical Properties

Figure 3
Vapor-Liquid Equilibrium for Aqueous DIGLYCOLAMINE® Agent Solutions at Various Pressures

TEMPERATURE, °F

DIGLYCOLAMINE® AGENT, wt. %
Figure 4
Water Vapor Dew Points Over Aqueous DIGLYCOLAMINE® Agent Solutions Versus Temperature

<table>
<thead>
<tr>
<th>- Temperature, °F</th>
<th>Water</th>
<th>50 Wt. % DGA Agent</th>
<th>70 Wt. % DGA Agent</th>
<th>80 Wt. % DGA Agent</th>
<th>90 Wt. % DGA Agent</th>
<th>95 Wt. % DGA Agent</th>
<th>97 Wt. % DGA Agent</th>
<th>98 Wt. % DGA Agent</th>
<th>99 Wt. % DGA Agent</th>
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<tbody>
<tr>
<td>75</td>
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WATER VAPOR DEW POINT, °F

TEMPERATURE, °F
Figure 5
Viscosity of DIGLYCOLAMINE® Agent Versus Temperature
Figure 6
Viscosity of Aqueous DIGLYCOLAMINE® Agent Solutions Versus Temperature

Physical Properties
Figure 7
Effect of Acid Gas Loading on Kinematic Viscosity of an Aqueous 25 Wt. % DIGLYCOLAMINE® Agent Solution Versus Temperature

Physical Properties
Physical Properties

Figure 8
Effect of Acid Gas Loading on Kinematic Viscosity of an Aqueous 50 Wt. % DGLYCOLAMINE® Agent Solution Versus Temperature

- (44.8 Wt. % DGA Agent); 0.41 Moles CO₂/Mole DGA Agent
- (47.2 Wt. % DGA Agent); 0.19 Moles CO₂/Mole DGA Agent
- (49.6 Wt. % DGA Agent); no CO₂
- (48.6 Wt. % DGA Agent); 0.10 Moles CO₂/Mole DGA Agent
- (46.0 Wt. % DGA Agent); 0.21 Moles CO₂/Mole DGA Agent and 0.23 Moles H₂S/Mole DGA Agent
- (46.6 Wt. % DGA Agent); 0.11 Moles CO₂/Mole DGA Agent and 0.29 Moles H₂S/Mole DGA Agent
### Physical Properties

**Figure 9**

Effect of Acid Gas Loading on Kinematic Viscosity of an Aqueous 65 Wt. % DIGLYCOLAMINE® Agent Solution Versus Temperature

<table>
<thead>
<tr>
<th>Temperature, °F</th>
<th>KINEMATIC VISCOSITY, cSt</th>
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<tbody>
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<tr>
<td>250</td>
<td>5.00</td>
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(57.0 Wt. % DGA Agent); 0.42 Moles CO₂/Mole DGA Agent
(58.7 Wt. % DGA Agent); 0.20 Moles CO₂/Mole DGA Agent and 0.21 Moles H₂S/Mole DGA Agent
(60.9 Wt. % DGA Agent); 0.20 Moles CO₂/Mole DGA Agent
(59.4 Wt. % DGA Agent); 0.10 Moles CO₂/Mole DGA Agent and 0.30 Moles H₂S/Mole DGA Agent
(62.6 Wt. % DGA Agent); 0.10 Moles CO₂/Mole DGA Agent
(64.4 Wt. % DGA Agent); no CO₂
Figure 10
Effect of Acid Gas Loading on Kinematic Viscosity of an Aqueous 80 Wt. % DIGLYCOLAMINE® Agent Solution Versus Temperature

KINEMATIC VISCOSITY, cSt

TEMPERATURE, °F

(69.0 Wt. % DGA Agent); 0.42 Moles CO₂/Mole DGA Agent
(71.2 Wt. % DGA Agent); 0.20 Moles CO₂/Mole DGA Agent and 0.21 Moles H₂S/Mole DGA Agent
(72.0 Wt. % DGA Agent); 0.10 Moles CO₂/Mole DGA Agent and 0.30 Moles H₂S/Mole DGA Agent
(73.6 Wt. % DGA Agent); 0.20 Moles CO₂/Mole DGA Agent
(76.9 Wt. % DGA Agent); 0.10 Moles CO₂/Mole DGA Agent
(79.5 Wt. % DGA Agent); no CO₂
Figure 11
Effect of Temperature on Kinematic Viscosity of Aqueous DIGLYCOLAMINE® Agent Solutions Loaded to 0.1 Moles CO₂/Mole DGA Agent

Solutions of 50, 65, and 80 wt. % DGA agent were loaded to 0.1 moles CO₂/mole DGA agent to obtain this family of curves.
Figure 12
Effect of Temperature on Kinematic Viscosity of Aqueous DIGLYCOLAMINE® Agent Solutions Loaded to 0.2 Moles CO₂/Mole DGA Agent

Solutions of 25, 50, 65, and 80 wt. % DGA agent were loaded to 0.2 moles CO₂/mole DGA agent to obtain this family of curves.
Figure 13

Effect of Temperature on Kinematic Viscosity of Aqueous DIGLYCOLAMINE® Agent Solutions Loaded to 0.4 Moles CO₂/Mole DGA Agent

Solutions of 25, 50, 65, and 80 wt. % DGA agent were loaded to 0.4 moles CO₂/mole DGA agent to obtain this family of curves.
Figure 14
Effect of Temperature on Kinematic Viscosity of Aqueous DIGLYCOLAMINE® Agent Solutions Loaded to 0.2 Moles CO₂ and 0.2 Moles H₂S/Mole DGA Agent

Solutions of 50, 65, and 80 wt. % DGA agent were loaded to 0.2 moles CO₂ and 0.2 moles H₂S/mole DGA agent to obtain this family of curves.
Figure 15
Effect of Temperature on Kinematic Viscosity of Aqueous DIGLYCOLAMINE® Agent Solutions Loaded to 0.1 Moles CO₂ and 0.3 Moles H₂S/Mole DGA Agent

Solutions of 50, 65, and 80 wt. % DGA agent were loaded to 0.1 moles CO₂ and 0.3 moles H₂S/mole DGA agent to obtain this family of curves.
Figure 16
Density of DIGLYCOLAMINE® Agent Versus Temperature

Physical Properties
Figure 17
Density of Aqueous DIGLYCOLAMINE® Agent Solution Versus Temperature

- Freezing Point Curve

DENSITY, g/cc

0 100

DIGLYCOLAMINE® AGENT, wt. %

0 10 20 30 40 50 60 70 80 90 100

-20°F
-40°F
0°F
20°F
40°F
60°F
80°F
100°F
120°F
140°F
160°F
180°F

Physical Properties
Figure 18
Effect of Acid Gas Loading on Density of an Aqueous 25 Wt. % DIGLYCOLAMINE® Agent Solution Versus Temperature

- (24 wt. % DGA Agent); 0.38 Moles CO₂/Mole DGA Agent
- (24.1 wt. % DGA Agent); 0.21 Moles CO₂/Mole DGA Agent and 0.20 Moles H₂S/Mole DGA Agent
- (24.6 wt. % DGA Agent); 0.19 Moles CO₂/Mole DGA Agent
- (24.4 wt. % DGA Agent); 0.09 Moles CO₂ and 0.11 Moles H₂S/Mole DGA Agent
- (25 wt. % DGA Agent); no CO₂
Physical Properties

Figure 19
Effect of Acid Gas Loading on Density of an Aqueous 50 Wt. % DIGLYCOLAMINE® Agent Solution Versus Temperature

DENSITY, g/cc

TEMPERATURE, °F

(44.8 wt. % DGA Agent); 0.41 Moles CO₂/Mole DGA Agent
(46.6 wt. % DGA Agent); 0.18 Moles CO₂ and 0.21 Moles H₂S/Mole DGA Agent
(47.2 wt. % DGA Agent); 0.19 Moles CO₂/Mole DGA Agent
(48.1 wt. % DGA Agent); 0.11 Moles CO₂ and 0.11 Moles H₂S/Mole DGA Agent
(49.6 wt. % DGA Agent); no CO₂
Figure 20
Effect of Acid Gas Loading on Density of an Aqueous 65 Wt. % DIGLYCOLAMINE® Agent Solution Versus Temperature

Physical Properties
Figure 21
Effect of Acid Gas Loading on Density of an Aqueous 75 Wt. % DIGLYCOLAMINE® Agent Solution Versus Temperature

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<th>Temperature, °F</th>
<th>Density, g/cc</th>
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<td>1.160</td>
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<td>160</td>
<td>1.080</td>
</tr>
<tr>
<td>180</td>
<td>1.060</td>
</tr>
</tbody>
</table>

(66.7 wt. % DGA Agent); 0.40 Moles CO₂/Mole DGA Agent
(67.8 wt. % DGA Agent); 0.20 Moles CO₂ and 0.18 Moles H₂S/Mole DGA Agent
(71.0 wt. % DGA Agent); 0.18 Moles CO₂/Mole DGA Agent
(71.1 wt. % DGA Agent); 0.09 Moles CO₂ and 0.10 Moles H₂S/Mole DGA Agent
(75 wt. % DGA Agent); no CO₂
Figure 22
Effect of Acid Gas Loading on Density of an Aqueous
80 Wt. % DIGLYCOLAMINE® Agent Solution Versus Temperature

Physical Properties
Figure 23
Effect of Temperature on Density of Aqueous DIGLYCOLAMINE® Agent Solutions Loaded to 0.2 Moles CO₂/Mole DGA Agent

Solutions of 25, 50, 65, and 80 wt. % DGA agent were loaded to 0.2 moles CO₂/mole DGA agent to obtain this family of curves.
Figure 24
Effect of Temperature on Density of Aqueous DIGLYCOLAMINE® Agent Solutions Loaded to 0.4 Moles CO₂/Mole DGA Agent

Solutions of 25, 50, 65, and 80 wt. % DGA agent were loaded to 0.4 moles CO₂/mole DGA agent to obtain this family of curves.
Effect of Temperature on Density of Aqueous DIGLYCOLAMINE® Agent Solutions Loaded to 0.1 Moles CO₂ and 0.1 Moles H₂S/Mole DGA Agent

Solutions of 25, 50, and 75 wt. % DGA agent were loaded to 0.1 moles CO₂ and 0.1 moles H₂S/mole DGA agent to obtain this family of curves.
Figure 26
Effect of Temperature on Density of Aqueous DIGLYCOLAMINE® Agent Solutions Loaded to 0.2 Moles CO₂ and 0.2 Moles H₂S/Mole DGA Agent

Solutions of 25, 50, and 75 wt. % DGA agent were loaded to 0.2 moles CO₂ and 0.2 moles H₂S/mole DGA agent to obtain this family of curves.
Physical Properties

Figure 27
Specific Heat of Aqueous DIGLYCOLAMINE® Agent Solutions Versus Temperature

SPECIFIC HEAT, Btu/lb/°F

TEMPERATURE, °F

Water
50 Wt. % DGA Agent
60 Wt. % DGA Agent
70 Wt. % DGA Agent
80 Wt. % DGA Agent
90 Wt. % DGA Agent
DGA Agent
Figure 28
Thermal Conductivity of Aqueous DIGLYCOLAMINE® Agent Solutions
Physical Properties

Figure 29
Freezing Points of Aqueous DIGLYCOLAMINE® Agent Solutions

FREEZING POINT, °F

DIGLYCOLAMINE® AGENT, wt. %
Physical Properties

Figure 30
pH of Aqueous DIGLYCOLAMINE® Agent Solutions at 20°C
Surface Tension of Aqueous DIGLYCOLAMINE® Agent Solutions Versus Temperature

Figure 31

- Surface Tension, dynes/cm
- Temperature, °F

- Water
- 50 Wt. % DGA Agent
- 75 Wt. % DGA Agent
- DGA Agent
Figure 32
Hydrogen Solubility in Gas Treating Amine Solutions
Versus Hydrogen Partial Pressure

Hydrogen solubility in 20 wt. % MEA-water solution at 144°F
Hydrogen solubility in 60 wt. % DGA agent-water solution at 180°F

HYDROGEN SOLUBILITY, cu ft/gal DGA agent

HYDROGEN PARTIAL PRESSURE, psia

Physical Properties
Figure 33
Nitrogen Solubility in Aqueous 60 Wt. % DIGLYCOLAMINE® Agent Solution at 180°F

Physical Properties
DIGLYCOLAMINE agent undergoes reactions typical of alcohols and amines. It is isomeric with diethanolamine; however, it has certain structural differences that are advantageous in some applications. For example, DIGLYCOLAMINE agent is a primary amine, whereas diethanolamine is a secondary amine.

The primary NH$_2$ group makes DIGLYCOLAMINE agent more reactive than diethanolamine. In certain reactions, such as those involving CO$_2$, DIGLYCOLAMINE agent will have an advantage over the primary amine, monoethanolamine, in avoiding cyclic structures.
Handling and Storage

General
The handling and storage of DIGLYCOLAMINE agent presents no unusual problems. Our Technical Service staff is available to assist those persons desiring additional information. See the Toxicity and Safety section for related additional information.

Maintaining Specifications
DIGLYCOLAMINE agent is hygroscopic and will absorb water vapor when exposed to a moist atmosphere. If water content is to be minimized, a dry inert gas pad under a few ounces of pressure should be used on the storage tanks. A gas pad should also be used if low color is important, since absorbed atmospheric oxygen and carbon dioxide will cause DIGLYCOLAMINE agent to develop color. Since DIGLYCOLAMINE agent is basic, it will react with acidic gases, hence carbon dioxide and natural gas containing acidic sulfur compounds cannot be used. Nitrogen is quite suitable.

The solvent properties and alkaline nature of DIGLYCOLAMINE agent should also be considered when installing handling and storage facilities. DIGLYCOLAMINE agent will react with copper to form complex salts. The use of copper and alloys containing copper should be avoided in equipment that will contact DIGLYCOLAMINE agent or its aqueous solutions. Carbon steel storage tanks constructed according to a recognized code are generally satisfactory. In cases where low color is important, stainless steel is preferred.

DIGLYCOLAMINE agent is not compatible with phenolic resin linings.

Steam coils with sufficient surface area to heat the tank contents using low-pressure steam should be built into the tank about six inches above the floor. The coils should be constructed in such a manner as to allow the condensate to drain. Stainless steel coils are preferred, particularly when low color DIGLYCOLAMINE agent solution is important. If steam heat is to be used continuously to prevent high viscosities or freezing, a temperature regulator that throttles either the steam or condensate should be installed.

In situations where the ambient temperature is low, tank insulation is desirable. Asphalt-cork or urethane foam insulation sprayed onto the outer wall is satisfactory. If a nitrogen pad is used, pressure relief and vacuum relief valves of a suitable capacity should be installed. The system may consist of a cylinder of nitrogen, a pressure reducing valve, a pressure relief valve, and a line to the top of the storage tank. Tankage should be diked and electrically bonded and grounded.

In cold climates, when DIGLYCOLAMINE agent is utilized for gas treating applications, it can be diluted with water to approximately 80% concentration. An 80 wt. % DIGLYCOLAMINE agent:water solution has a freezing point below -40°F.

Transfer Lines
Carbon steel transfer lines at least two inches in diameter and joined by welds or flanges are suitable. Screwed joints are subject to failure unless back-welded because DIGLYCOLAMINE agent will leach conventional pipe dopes. U.S. Rubber 899 gasket material or its equivalent is satisfactory for use with flanged connections in DIGLYCOLAMINE agent service.
If the ambient temperature is below 20°F, the transfer line for the pure product should be steam traced and insulated. Steam tracing can be accomplished by affixing copper tubing of approximately 3/8-inch diameter to the underside of the line, insulating the tube to the line, and using low-pressure steam in the tubing. For flexible connections, stainless steel hose is preferred to rubber, since rubber will generally deteriorate in DIGLYCOLAMINE agent service and increase the color of the product with time and temperature. Systems that are insulated and steam-traced should be preheated in cool weather before being put into service. Normally, 15 to 30 minutes of applying steam to the tubing will adequately warm, but not overheat, the system. Transfer piping and pumps may be equipped with a nitrogen padding system so the DIGLYCOLAMINE agent can be pressured out of the lines when an extended idle period is contemplated. This practice will help reduce losses and color increases that would result if the DIGLYCOLAMINE agent were allowed to remain in the lines.

**Pumps**

Carbon steel rotary pumps can be used with DIGLYCOLAMINE agent, although a centrifugal pump is preferred. Rotary pumps should be equipped with externally lubricated bearings. A Durametallic Type RO-TT mechanical seal is suitable. Where pump packing is required, Garlock 234, Garlock 239, or equivalent is satisfactory.

Because DIGLYCOLAMINE agent has high viscosities at low temperatures, provision should be made for preheating pumps exposed to the cold. To preheat pumps, install steam tracing and apply low-pressure steam to the tubing.

**Unloading in Cold Weather**

Thawing a tank or tank car of DIGLYCOLAMINE agent is accomplished by applying steam at 50 pounds pressure maximum to the coils of the tank or tank car. Product temperature should be kept below 150°F.

Thawing may be accelerated by using a liquid circulating pump. In the case of unloading tank cars, or if steam is being discontinued to tanks, the coils should be blown free of condensate with dry air to prevent freezing of the condensate and coil rupture. For further information on handling frozen product in tanks, it is recommended that reference be made to Association of American Railroads' Pamphlet No. 34, and General American Transportation Corporation's "Care of Heater Coils in Tank Cars."

DIGLYCOLAMINE agent that has frozen in drums may be thawed in a hot room at about 100°F. Thawing should be expected to require approximately two to three days.
New Facilities and Cleaning
Prior to putting storage vessels into service, it is desirable to purge with nitrogen to remove oxygen from the tank atmosphere. Although frequent cleaning of tanks and transfer lines is not recommended, it may be necessary due to contamination or accumulation of foreign material in the system. For such cleaning, a water wash is generally satisfactory.

Tank cleaning is normally accomplished by thoroughly sluicing the interior of the tank with a water jet, followed by cloth or chamois drying. Unless excessive rust scale makes it necessary, the interior of the tank should not be wire brushed or sandblasted because the oxides of iron are relatively inert to DIGLYCOLAMINE agent. Once clean and dry, the tank should be sealed and purged with dry nitrogen to avoid undue condensation and rust formation. Most of what has been described so far is concerned with commercial, essentially anhydrous, DIGLYCOLAMINE agent. Aqueous DIGLYCOLAMINE agent solutions have lower freezing points and lower viscosities, so storage and handling may be simplified considerably by dilution in storage if the DIGLYCOLAMINE agent is to be used as an aqueous solution (see Physical Properties section).
Toxicity Studies
Results of acute toxicity testing using DIGLYCOLAMINE agent indicate that this product is slightly toxic by single oral exposure, and practically nontoxic by single dermal exposure. The oral LD$_{50}$ in rats has been determined to be 2.6 g/kg, and the dermal LD$_{50}$ in rabbits is in excess of the 3.0 g/kg maximum concentration employed in our limit test.

Acute irritation studies have shown this product to be extremely irritating/corrosive to the skin of rabbits, with a Draize score of 8.0 (maximum score 8.0). Due to its corrosive properties to the skin, rabbit eye irritation studies using DIGLYCOLAMINE agent have not been performed, but it is expected that this product would be extremely irritating/corrosive to the eyes. A dermal sensitization study (Beuhler method) has shown DIGLYCOLAMINE agent to be nonsensitizing to guinea pigs induced and challenged at concentrations of 10% in acetone.

A battery of in vitro genetic toxicity studies, employing an Ames assay, a cell transformation assay, and an Unscheduled DNA Synthesis (UDS) assay, did not demonstrate any evidence of DNA damage or cell growth transformation in the test systems.

Human Health Effects and First Aid
On the basis of the above toxicity studies, the principal health hazard from accidental exposures to DIGLYCOLAMINE agent is a moderate-to-severe irritation/corrosion of the eyes, skin, and mucous membranes. Chemical-type goggles with face shield must be worn during handling or use of the undiluted product or concentrated solutions. Contact lenses should not be worn. Protective clothing and gloves resistant to chemicals and petroleum distillates must be worn.

Should accidental eye contact occur, flush eyes with large amounts of water for at least 15 minutes, after which a physician should be consulted. During flushing of the eyes, eyelids should be held apart to permit rinsing of entire surface of eyes and lids.

For skin contact, immediately flush skin with large amounts of water for at least 15 minutes. Clothing wet with the product must be removed immediately and laundered before reuse.

If DIGLYCOLAMINE agent is accidentally ingested, and the individual is conscious and can swallow, he or she should be given two large glasses of water, after which a physician should be consulted. Since this product is expected to produce severe irritation/corrosion of mucous membranes, vomiting should not be induced, due to the possibility of lung damage from aspiration of the product into the lungs during vomiting.

The vapor pressure of DIGLYCOLAMINE agent is quite low, and exposure to harmful quantities of vapor should not be a health problem under usual circumstances. However, adequate ventilation should be provided where a large quantity of product is exposed, or where mists or vapors are generated. Spills in confined areas should be cleaned up promptly.

Spill Containment and Disposal
Spilled DIGLYCOLAMINE agent can be absorbed using a solid absorbent and placed into drums for disposal. Larger amounts of material may be disposed of by incineration or placement in a properly controlled landfill site. In all instances, disposal of this product should be performed in compliance with all local, state, provincial, and federal regulations.
Shipping Information

Delivery of DIGLYCOLAMINE agent can be made in 10,000 and 20,000-gallon tank cars. These cars are constructed of welded carbon steel and have bottom unloading fittings and steam coils.

Deliveries can also be made in insulated, stainless steel, full or compartmented tank wagons with steam coils. If requested, tank wagons can be equipped with unloading pumps and hoses.

Drums of DIGLYCOLAMINE agent can be shipped in truckload or less-than-truckload quantities. The net weight of a drum is 480 pounds; the gross weight is approximately 501 pounds per drum. Drums are UN1A1 or UN1H1, nonreturnable.

Under U.S. Department of Transportation (DOT) and Canadian Transportation of Dangerous Goods (TDG) regulations, the proper shipping name for DIGLYCOLAMINE agent is “2-(2-aminoethoxy)ethanol,” identification number UN 3055. This product is considered a corrosive material (TDG hazard class 8) and requires a “CORROSIVE” label for shipping.

For further information, please refer to the Material Safety Data Sheet (MSDS) for this product.
Gas Treating Applications


Physical Properties


Other Applications


45. Murphy, Donald P.; Oxy Metal Ind. Corp.: “Amine Stripping Compounds,” U.S. 3,972,839, August 3, 1976; C.A. 85 144882S.


51. Standard Oil Co.: “Lubricants for Metal Machining,” Neth. 65 03,934, September 28, 1965; C.A. 64 7957g. Corresponds to U.S. 3,298,954 and British 1,109,304.


Toxicity

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For all other emergencies, call 409-722-8381, our 24-hour emergency number in Port Neches, Texas.
Huntsman Corporation

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