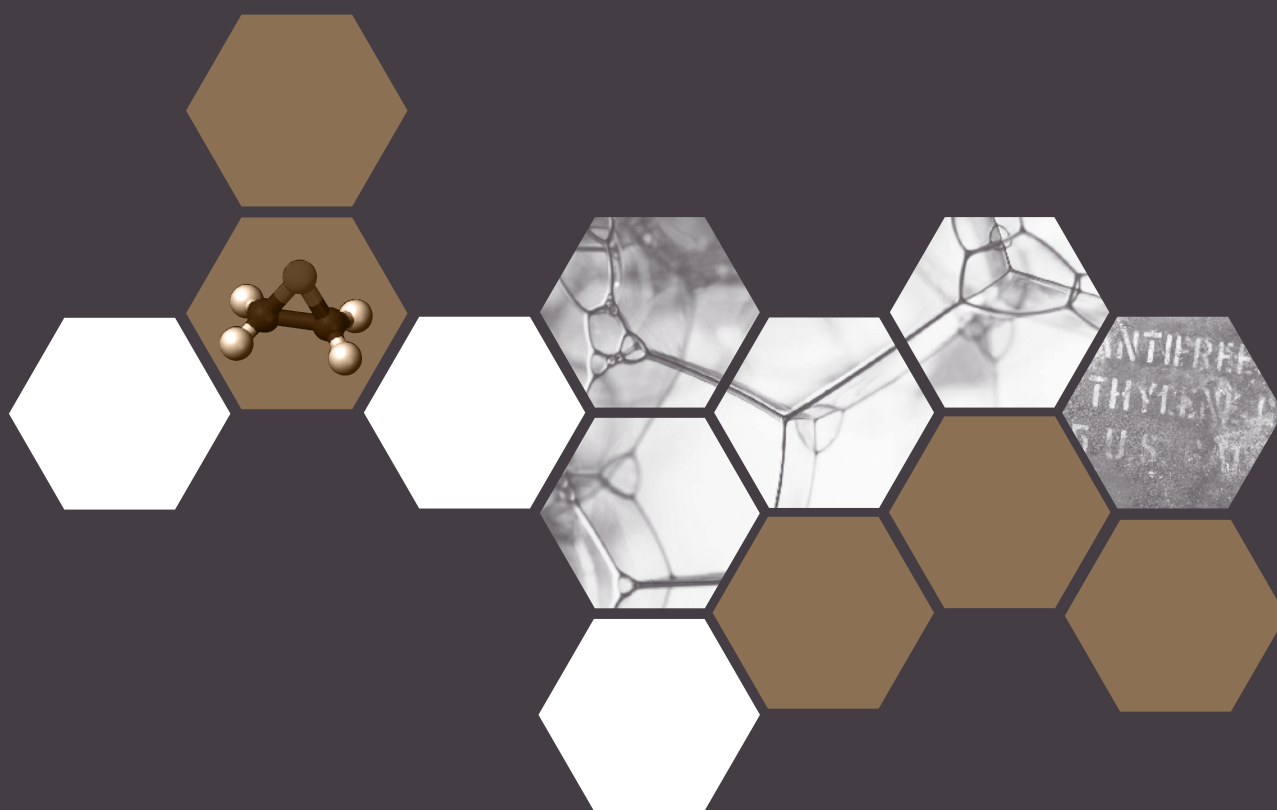


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To the Reader

Manual Preparation

As members and affiliated companies of the American Chemistry Council, we support efforts to improve the industry's responsible management of chemicals. To assist in this effort, the American Chemistry Council's Ethylene Oxide/Ethylene Glycols Panel supported the creation and publication of this manual. The Panel is comprised of the following companies:

Balchem Corporation/ARC Specialty Products

BASF Corporation

Bayer Material Science LLC

Celanese Ltd.

Champion Technologies

Croda, Inc.

The Dow Chemical Company

Eastman Chemical Company

Honeywell

Shell Chemical LP

The development of this manual was led by the Panel's Ethylene Oxide Safety Task Group (EOSTG), a group comprised of producers and users of ethylene oxide. The EOSTG functions to generate, collect, evaluate and share information to support product stewardship with regard to ethylene oxide. The EOSTG formed a manual work group, chaired by Keith Vogel of Lyondell Chemical Company, to lead the development of this document. The following work group members provided significant contributions:

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|-----------------|--|
| Tom Grumbles | Sasol North America |
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| Don Szczepanski | Huntsman Petrochemical Corporation |
| David Townsend | Celanese Chemicals Ltd. |
| Randy Viscomi | Balchem Corporation/ARC Specialty Products |
| Keith Vogel | Lyondell Chemical Company |
| Mike Wagner | Old World Industries |
| John Wincek | Croda, Inc. |
| Gerald Wise | Shell Chemical LP |

Acknowledgements

Many others contributed to the development and editing of this manual, all of whom cannot be listed here; however, the manual work group would like to thank the following individuals for their significant contributions to this publication:

| | |
|-----------------|---|
| Ralph Gingell | Shell Chemical LP |
| William Gullede | American Chemistry Council |
| Karl Loos | Shell Chemical LP |
| David McCready | The Dow Chemical Company |
| Kristy Morrison | EO STG Manager, American Chemistry Council |
| Karyn Schmidt | Assistant General Counsel, American Chemistry Council |

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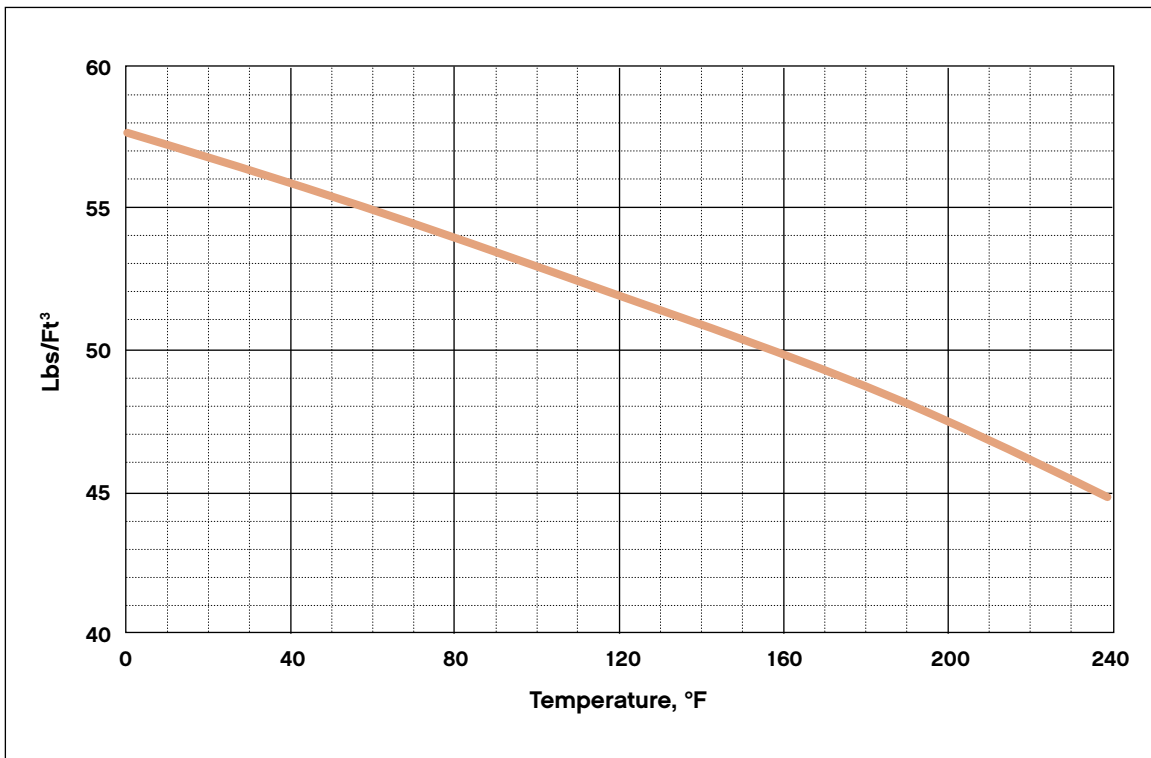


Figure 2 Ethylene Oxide Vapor Pressure

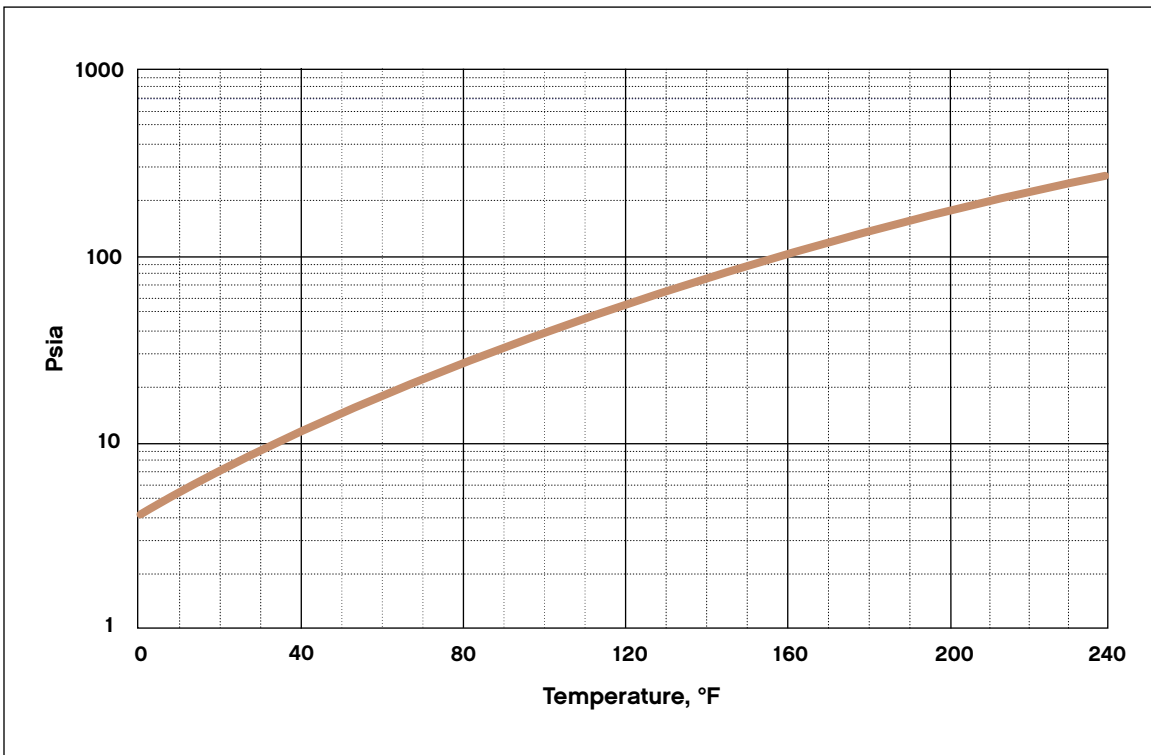


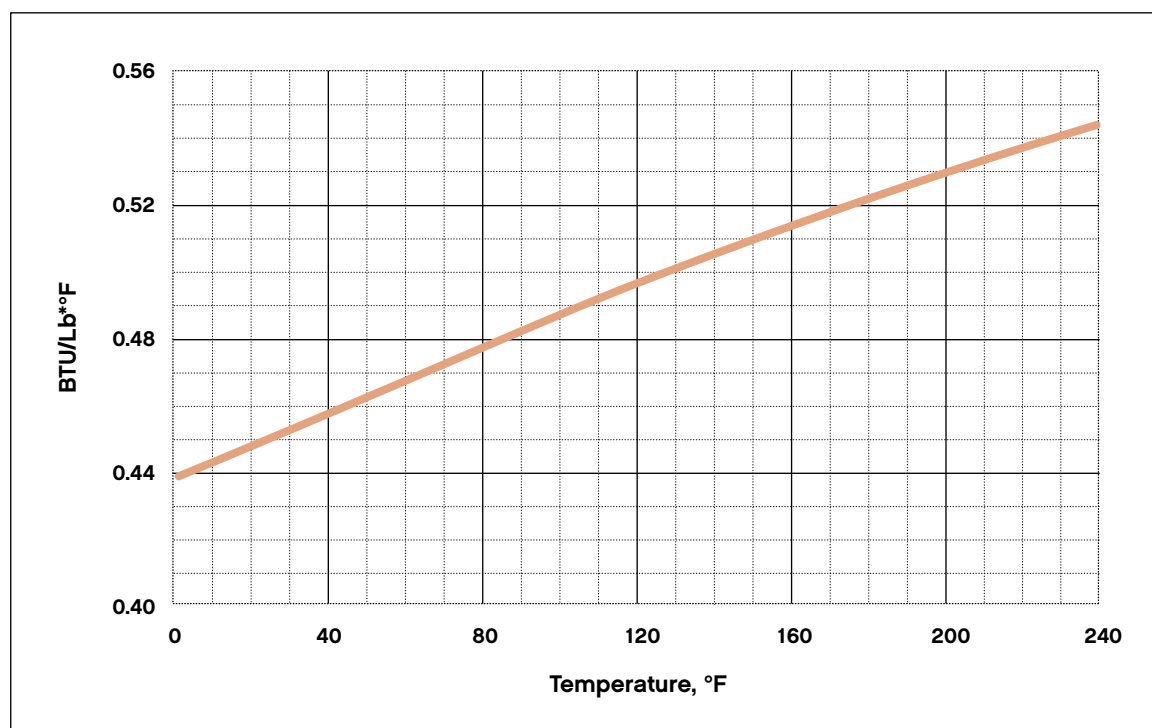
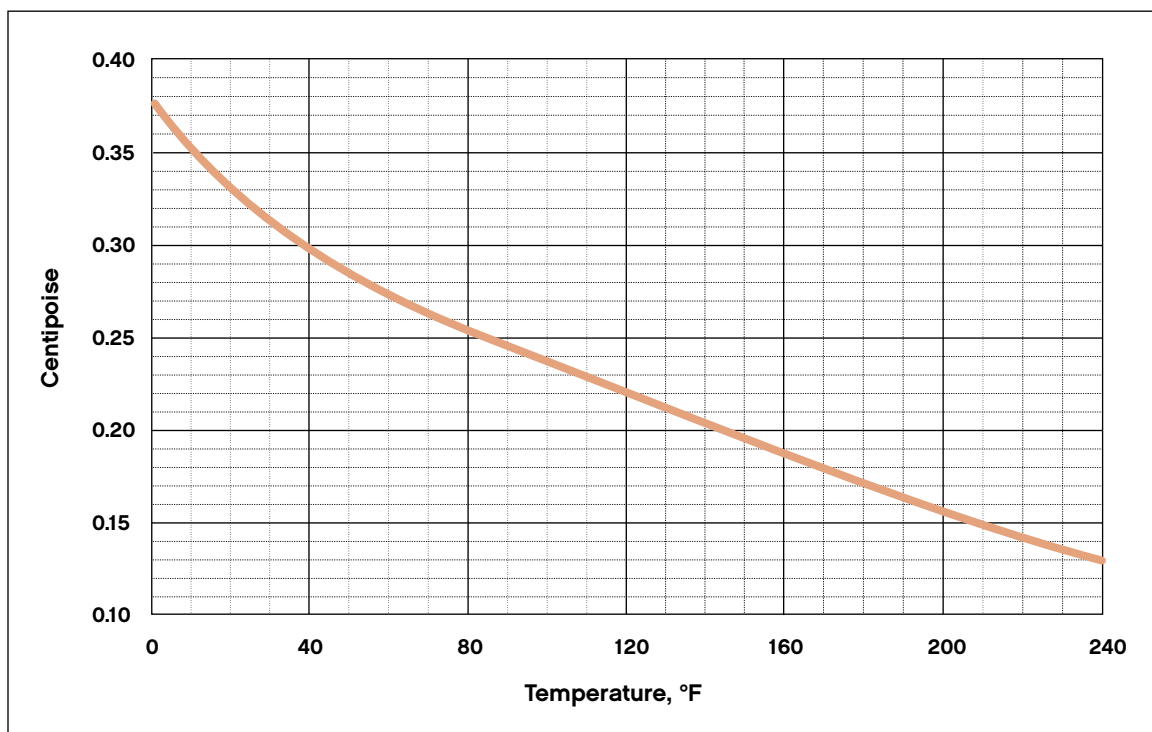
Figure 3 Ethylene Oxide Liquid Heat Capacity**Figure 4** Ethylene Oxide Liquid Viscosity

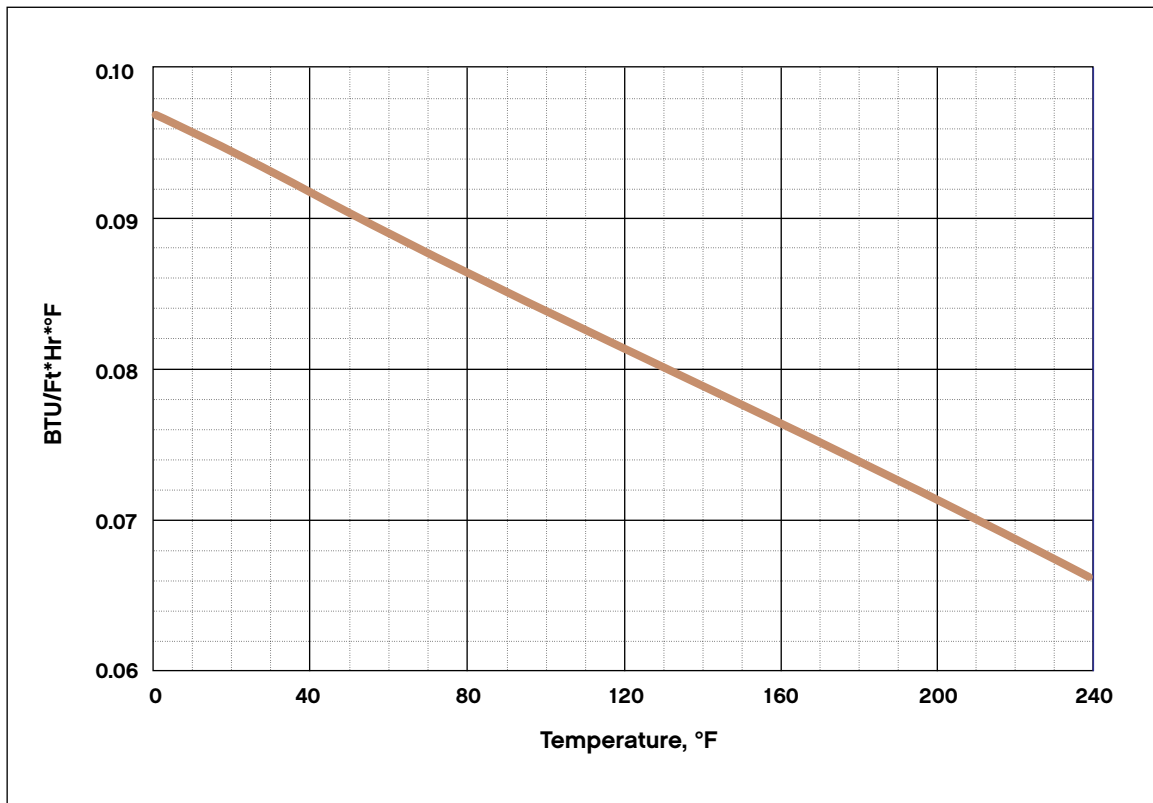
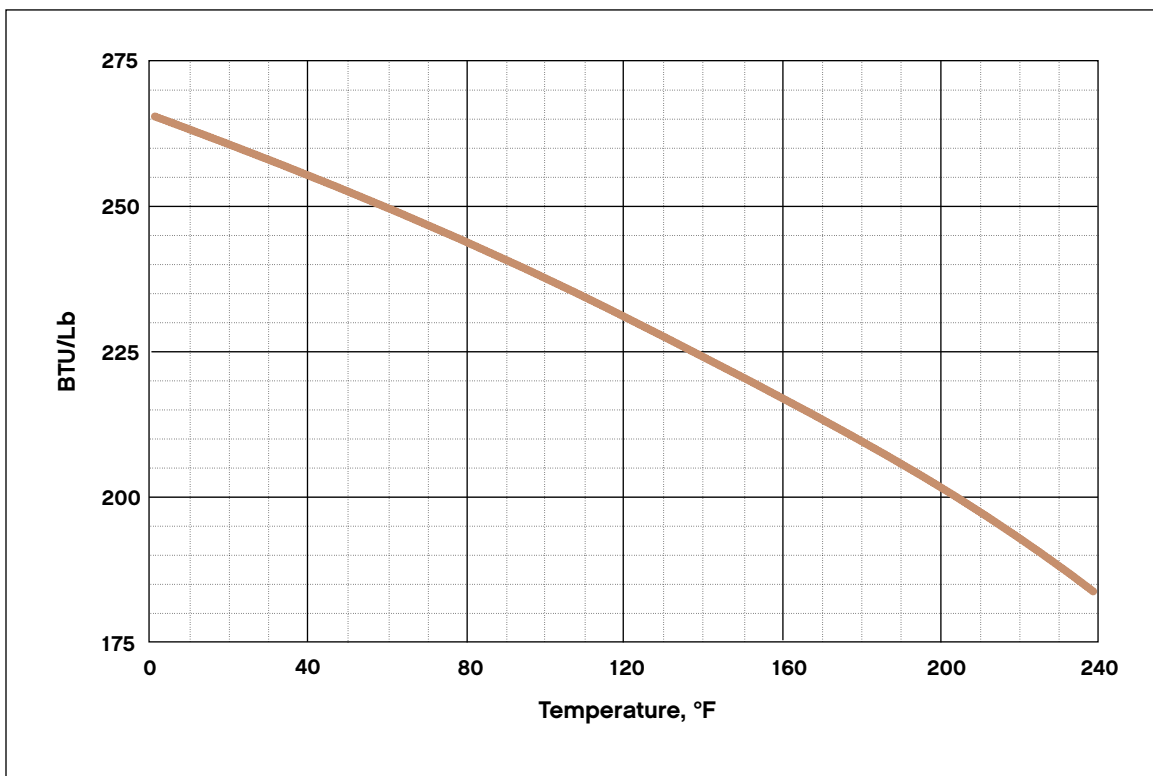
Figure 5 Ethylene Oxide Liquid Thermal Conductivity**Figure 6 Ethylene Oxide Heat of Vaporization**

Figure 7 Ethylene Oxide Vapor Heat Capacity

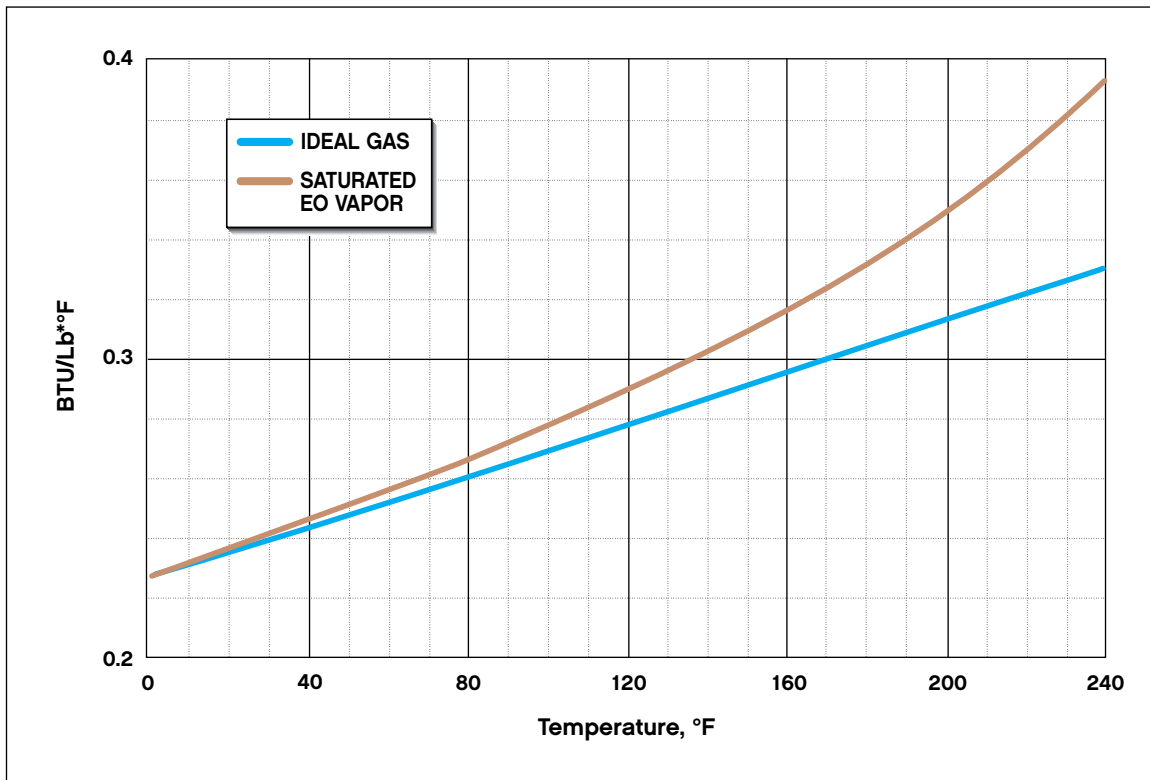


Figure 8 Ethylene Oxide Vapor Viscosity

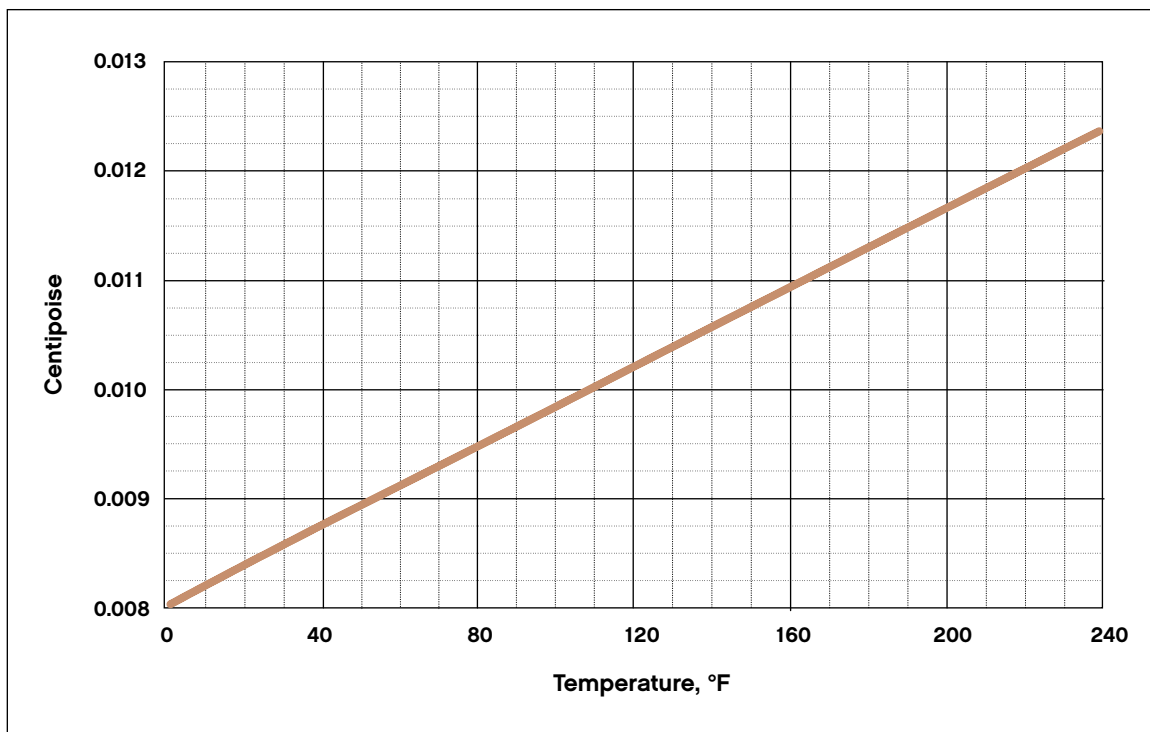


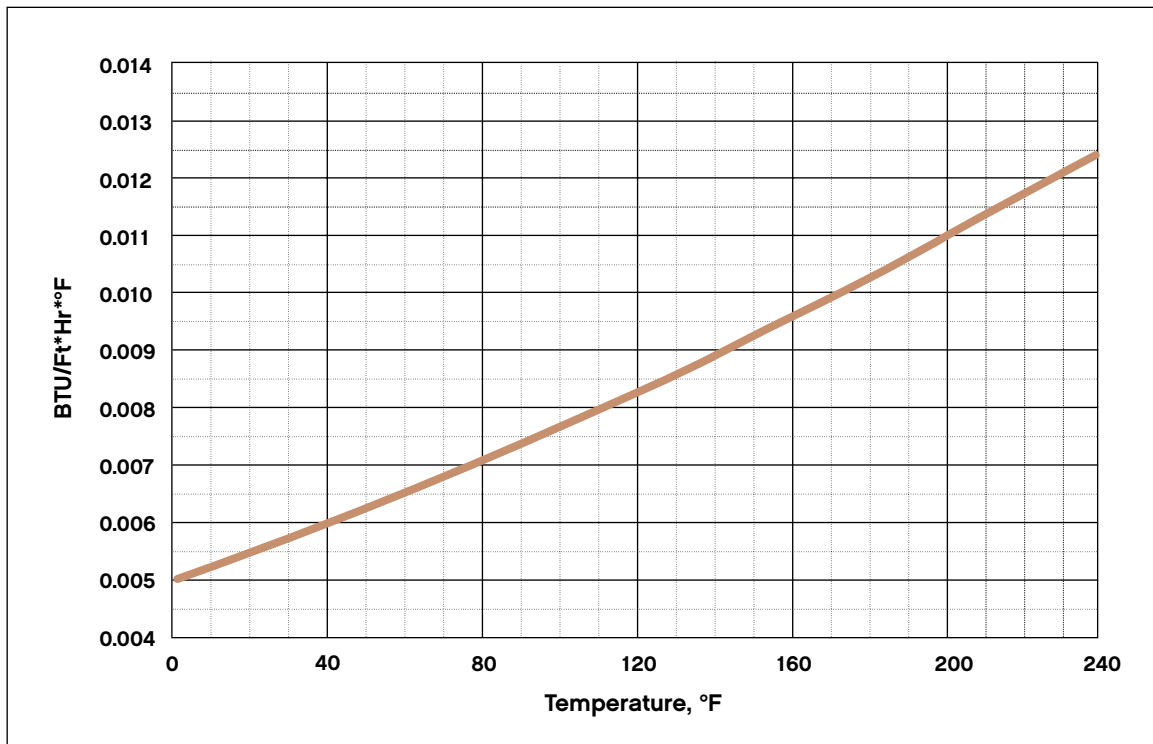
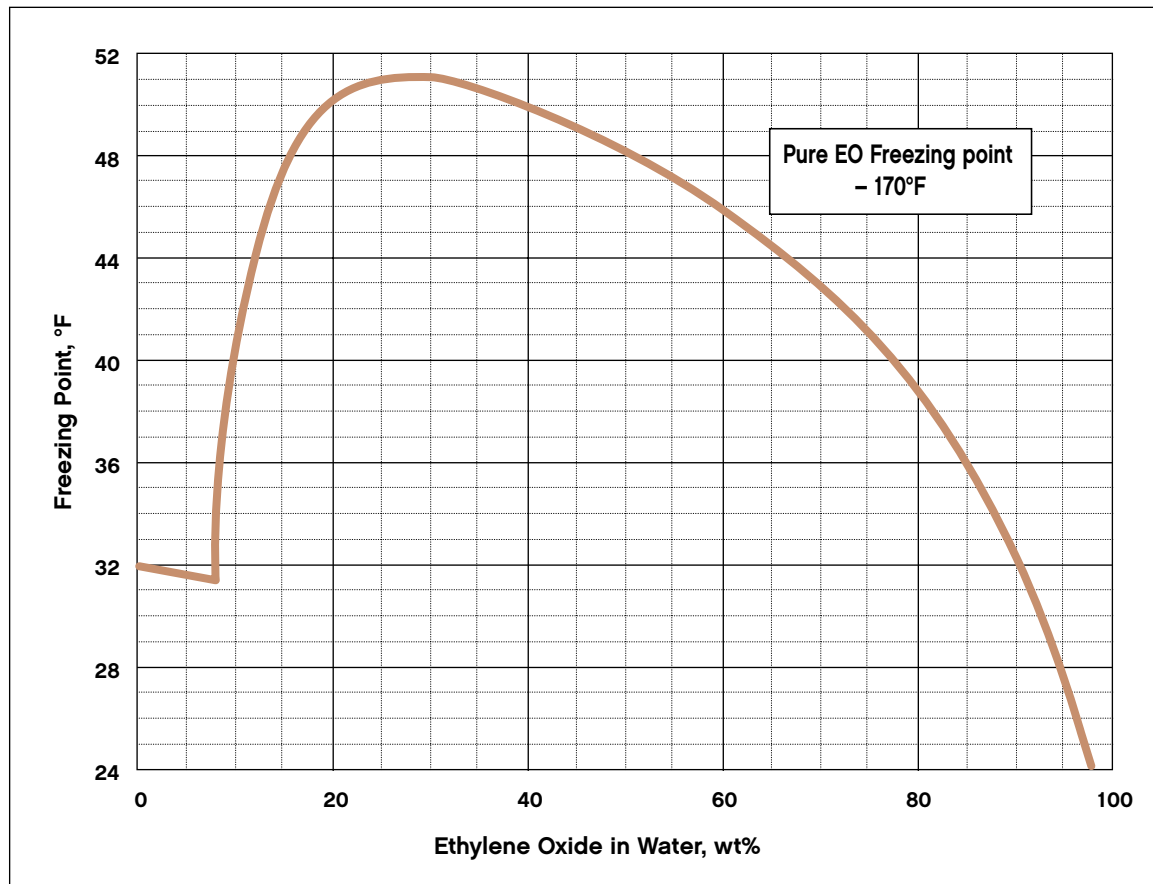
Figure 9 Ethylene Oxide Vapor Thermal Conductivity**Figure 10** Freezing Points Ethylene Oxide/Water Mixtures

Figure 11 C_p/C_v For Saturated Ethylene Oxide Vapor

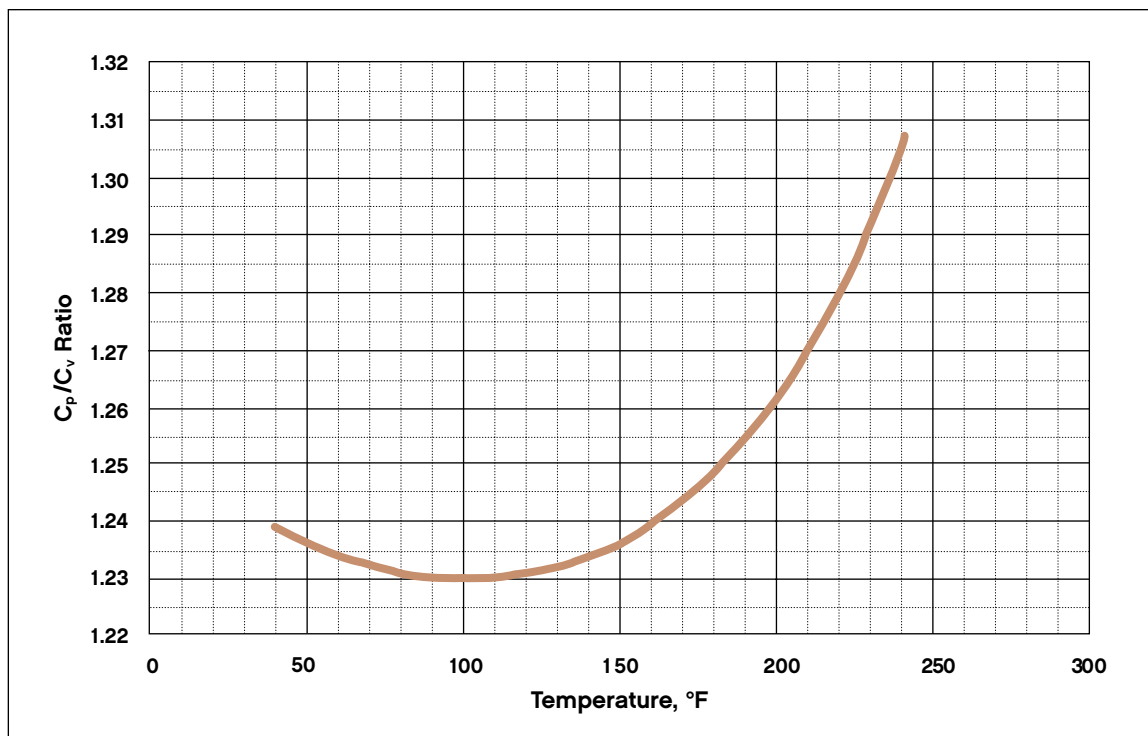


Figure 12 Ethylene Oxide Vapor Density

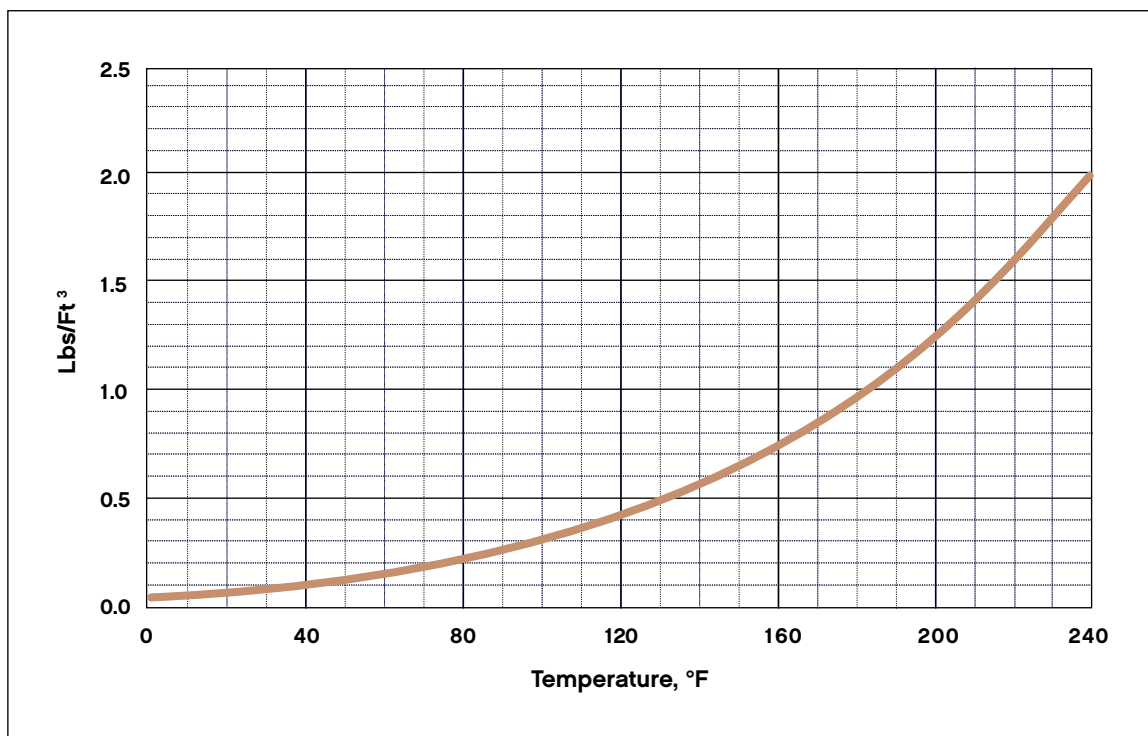
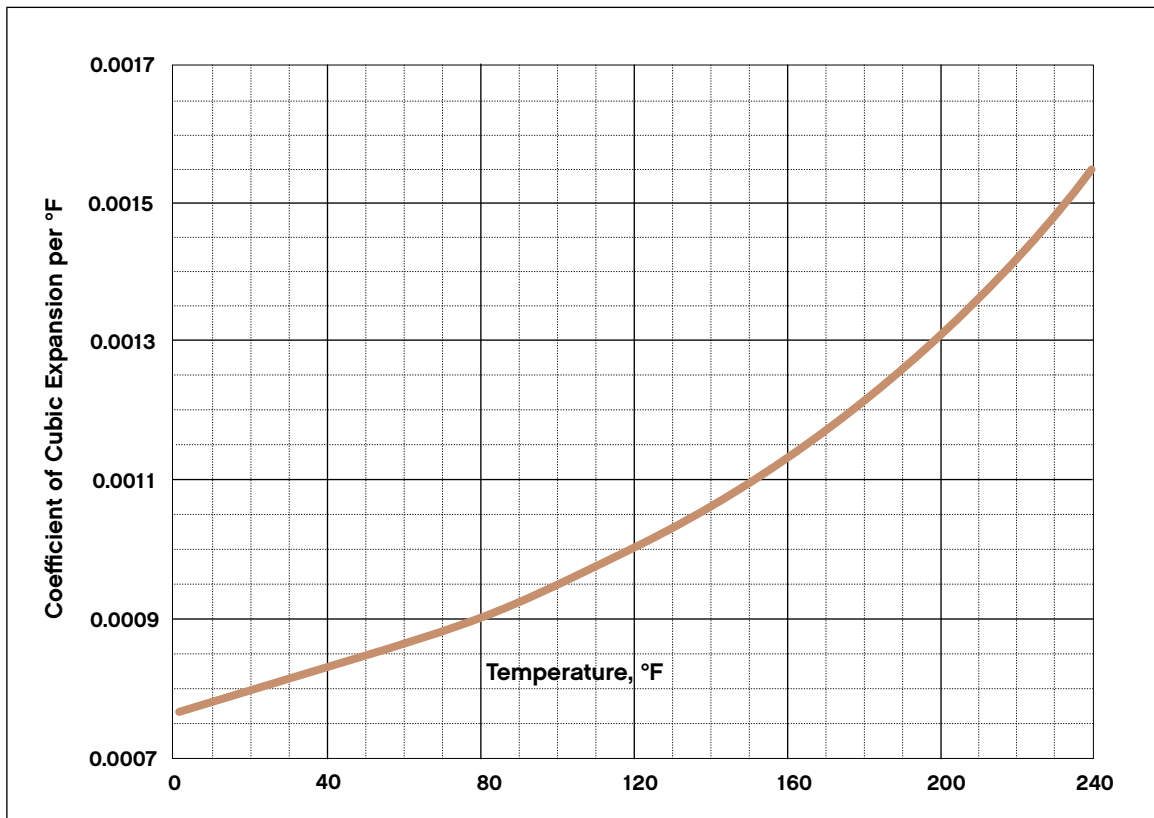


Figure 13 Ethylene Oxide Coefficient of Cubic Expansion

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Figure 14 Raoult's Law Deviation Factors for Ethylene Oxide/Water Mixtures
Terminal Regions are Expanded in the Next Figure

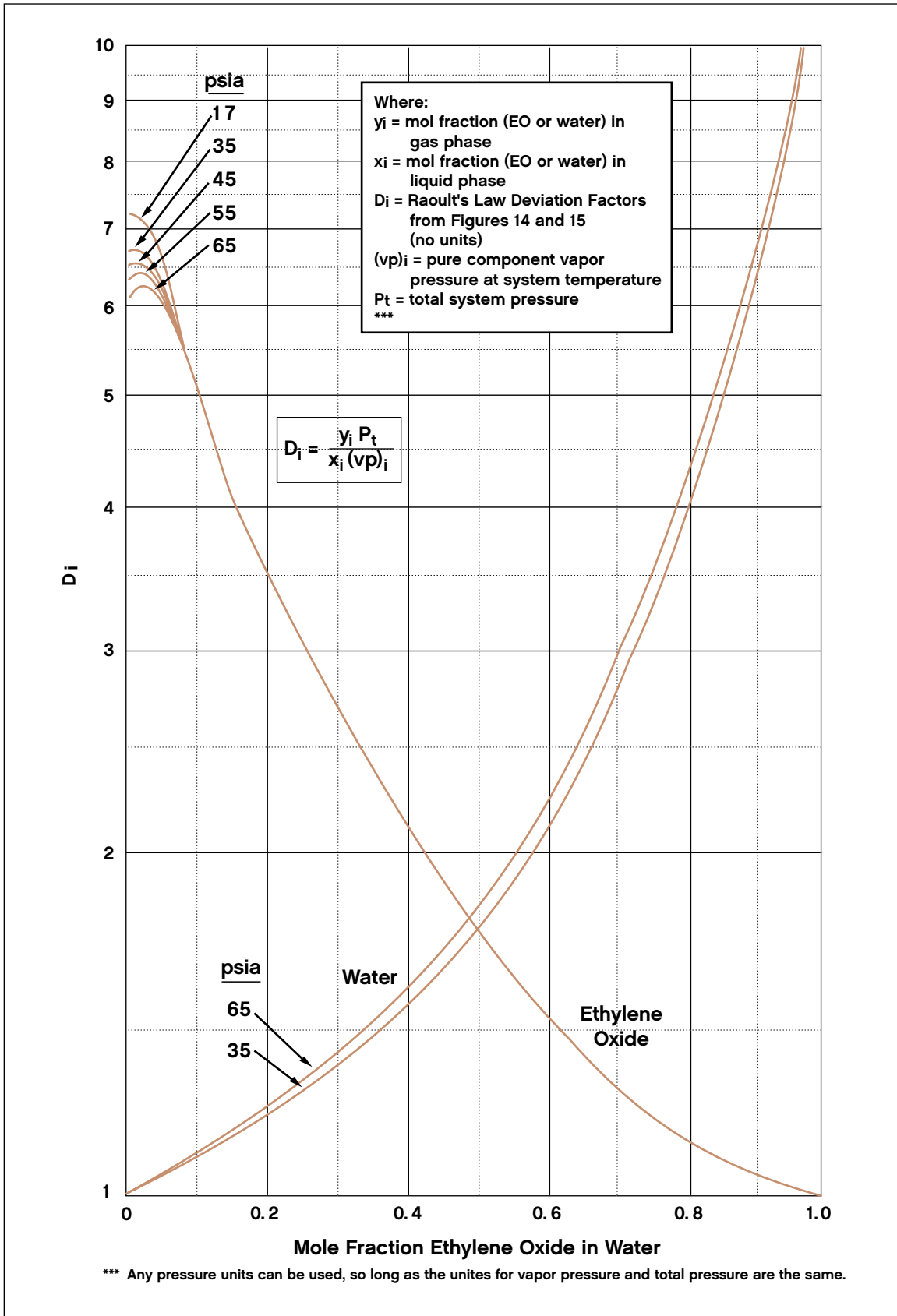


Figure 15 Raoult's Law Deviation Factors for Ethylene Oxide/Water Mixtures

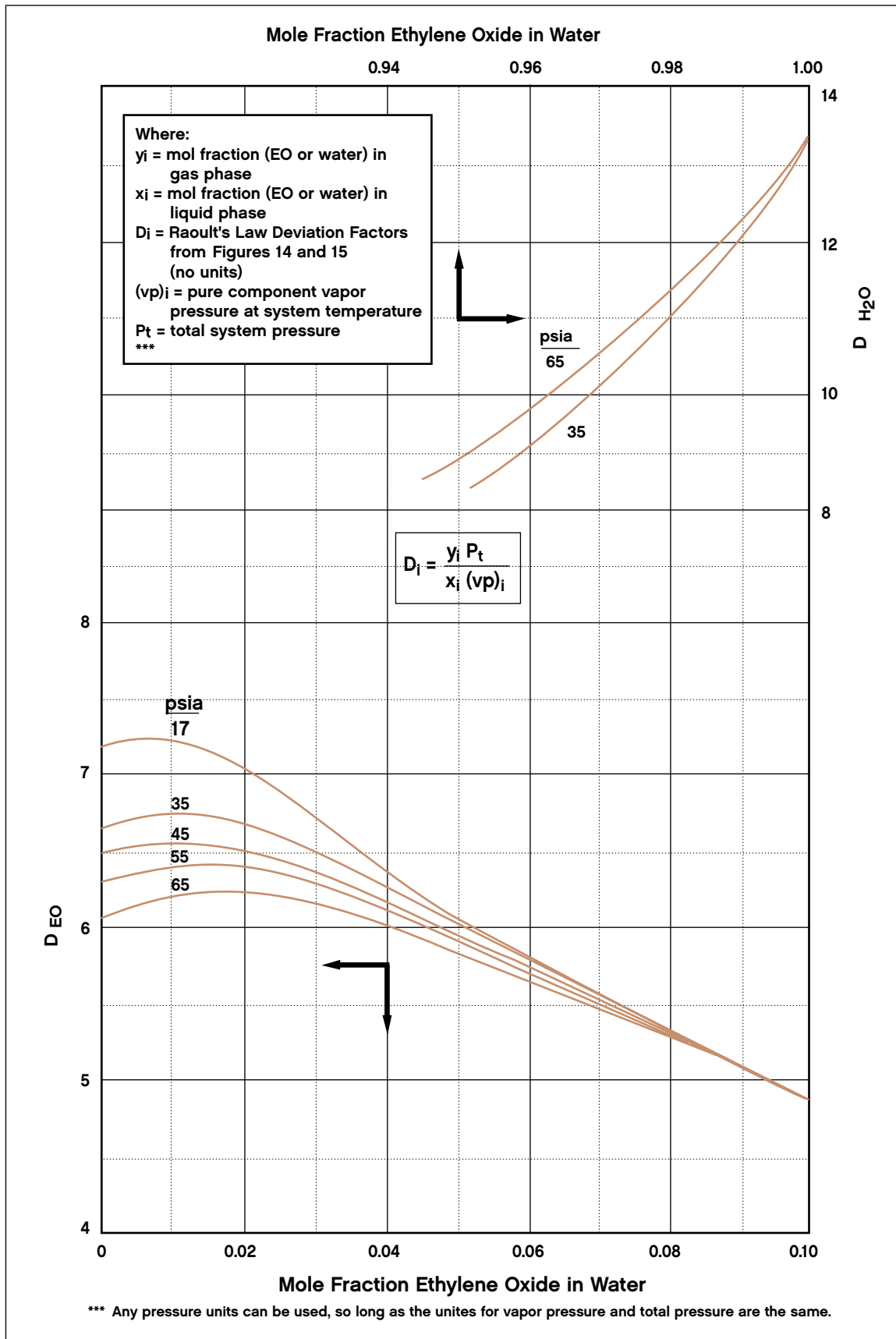


Figure 16 Flammability Data on EO-Air Mixtures at Subatmospheric Pressures

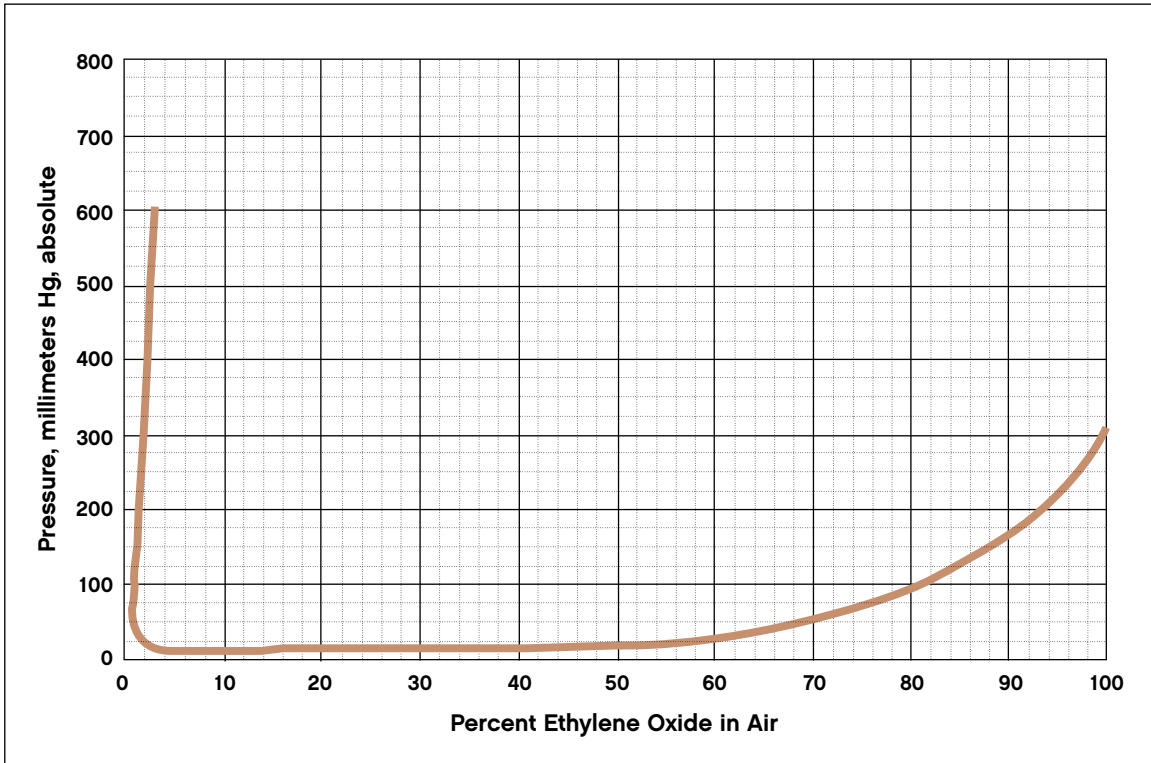


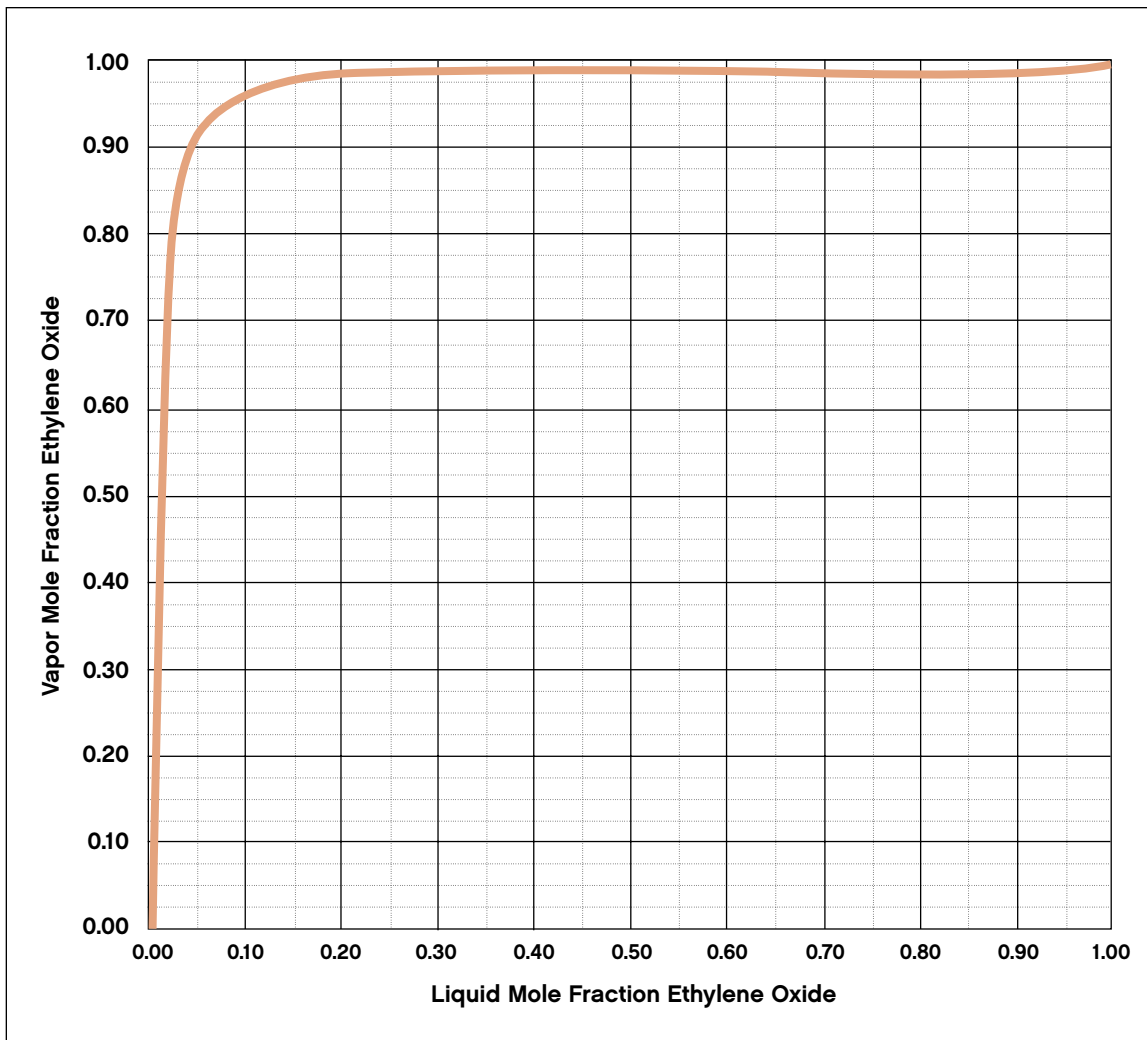
Figure 17 Vapor/Liquid Equilibria of Ethylene Oxide/Water Systems

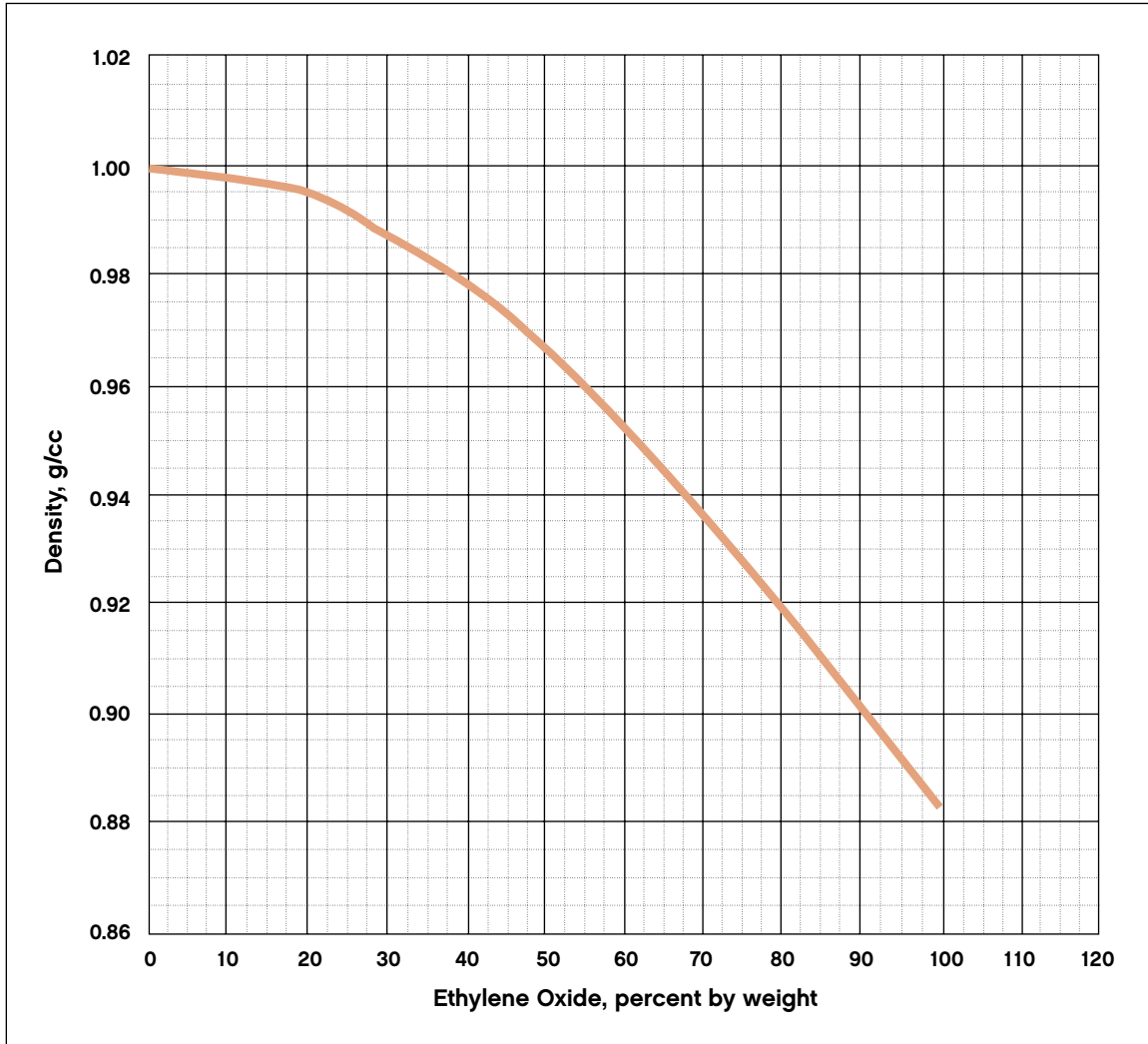
Figure 18 Density vs. Composition of Ethylene Oxide/Water Systems

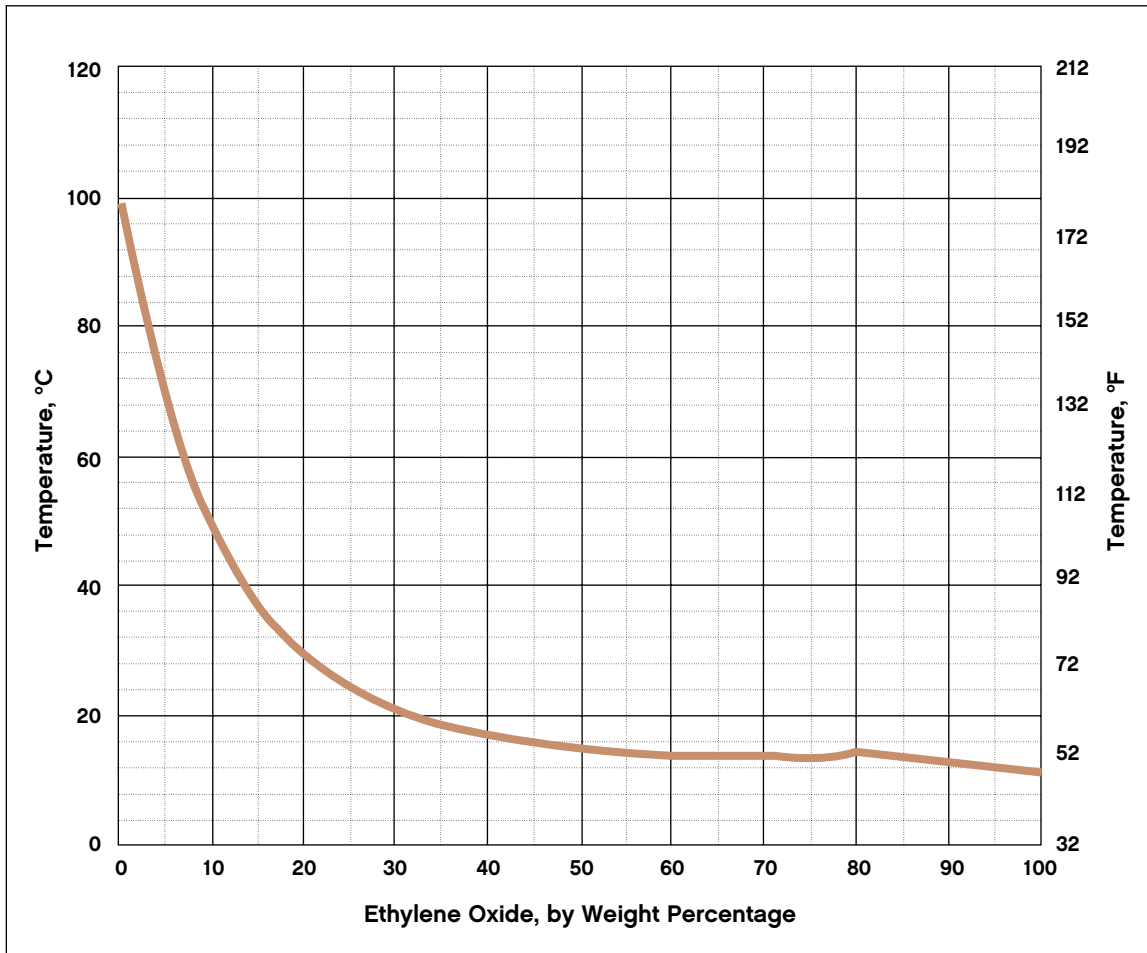
Figure 19 Boiling points of aqueous EO concentrations

Figure 20 Decomposition Data

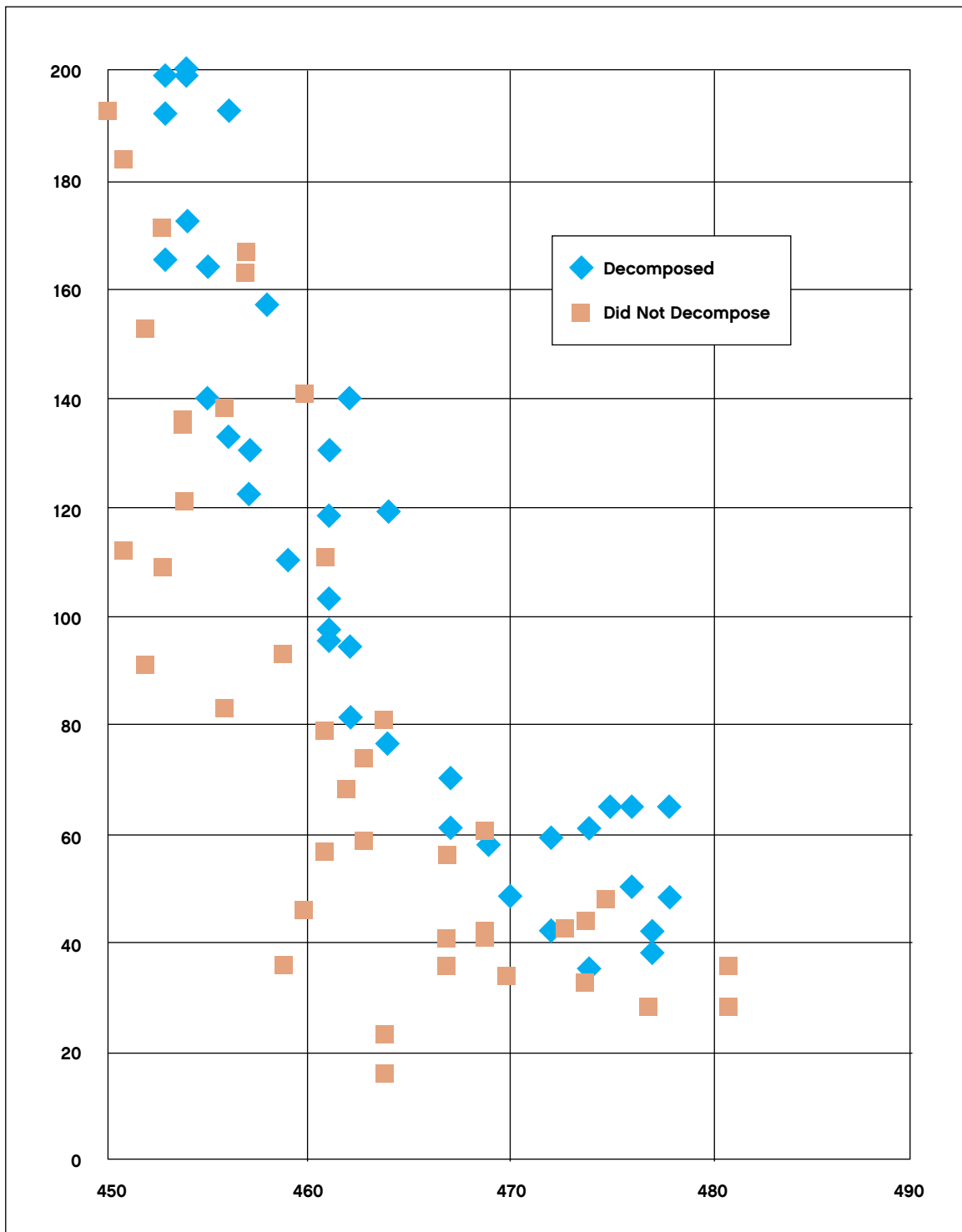


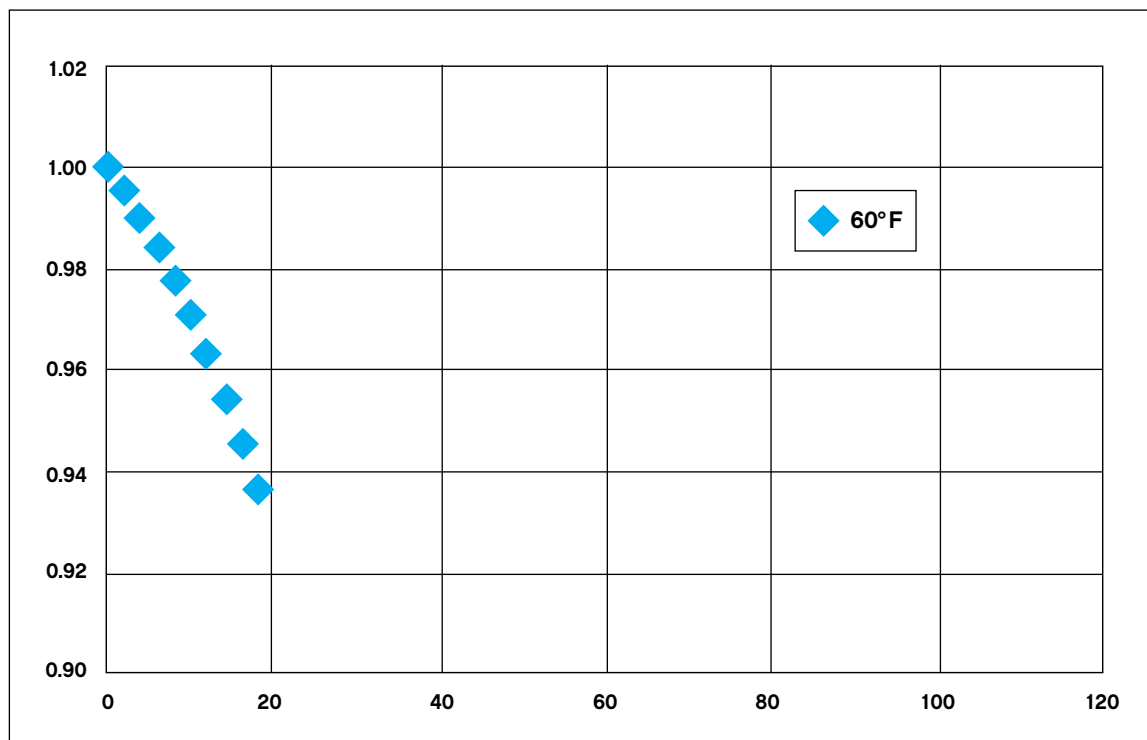
Figure 21 Vapor Compressibility vs. Pressure as a Function of Temperature

Table A1 Physical Property Equations

| EQUATION COEFFICIENTS (ALL PROPERTIES IN SI UNITS) | | | | | |
|--|----------------------|-------------|-------------|-------------|-------------|
| PROPERTY | UNITS | A | B | C | D |
| Solid Density | KgMOL/M ³ | 2.75E+01 | | | |
| Liquid Density | KgMOL/M ³ | 1.8360E+00 | 2.6024E-01 | 4.6915E+02 | 2.6960E-01 |
| Coeff of Expansion | per°K | | 2.6024E-01 | 4.6915E+02 | 2.6960E-01 |
| Vapor Density | KgMOL/M ³ | 3.3904E+00 | -5.0556E-02 | 2.9019E-04 | -7.6743E-07 |
| Vapor Pressure | Pa | 9.1944E+01 | -5.2934E+03 | -1.1682E+01 | 1.4902E-02 |
| Heat of Vaporization | J/KgMOL | 3.6652E+07 | 3.7878E-01 | | |
| Solid Heat Capacity | J/KgMOL*°K | -2.1143E+04 | 1.4903E+03 | -1.1881E+01 | 3.8745E-02 |
| Liquid Heat Capacity | J/KgMOL*°K | 1.4471E+05 | -7.5887E+02 | 2.8261E+00 | -3.0640E-03 |
| Ideal Gas Heat Capacity | J/KgMOL*°K | 3.3460E+04 | 1.2116E+05 | 1.6084E+03 | 8.2410E+04 |
| Second Virial Coefficient | M ³ KgMOL | 6.0016E-02 | -5.2057E+01 | -1.8056E+07 | 6.9368E+19 |
| Liquid Viscosity | Kg/M*S | -8.5210E+00 | 6.3502E+02 | -3.3140E-01 | |
| Vapor Viscosity | Kg/M*S | 2.9540E-06 | 4.7120E-01 | 7.874E0+02 | -2.3580E+04 |
| Liquid Thermal Conductivity | W/M*°K | 2.6957E-01 | -3.9840E-04 | | |
| Vapor Thermal Conductivity | W/M*°K | -3.7880E+04 | 1.1150E+00 | -5.6410E+03 | |
| Surface Tension | N/M | 7.4730E-02 | 1.1410E+00 | | |

Note: The symbol * denotes multiplication. The symbol ^ denotes exponentiation.
T is temperature, deg Kelvin. *Tr* is reduced temperature, *T/T* critical

Table A2 Conversion Factors

| To Convert From | To | Multiply By | Notes |
|----------------------|------------------------|-------------|-------|
| KgMOL/M ³ | Lb/Gal | 0.3676 | 1 |
| Pascals | Lb _f /sq in | .445E-04 | |
| J/KgMOL | BTU/Lb | 9.785E-06 | 1 |
| J/KgMOL*°K | BTU/Lb*°F | 5.422E-06 | 1 |
| KgM*S | Centipoise | 1E+03 | |
| W/M*°K | BTU/Ft*Hr*°F | 0.578 | |
| N/M | Lb _f /ft | 6.852E-02 | |

Notes: 1. Only valid for Ethylene Oxide

| E | USABLE RANGE | | EQUATIONS |
|-------------|--------------|-------|---|
| | MIN°K | MAX°K | |
| | | 161 | $Y = A + (B \cdot T) + (C \cdot T^2) + (D \cdot T^3) + (E \cdot T^4)$ |
| | 161 | 469 | $Y = A / (B \cdot (1 + (1 - T/C)^D))$ |
| | 161 | 469 | $Y = (-D/C) \cdot \ln(B) \cdot ((1 - T/C)^{D-1})$ |
| 7.9840E-10 | 233 | 383 | $Y = A + (B \cdot T) + (C \cdot T^2) + (D \cdot T^3) + (E \cdot T^4)$ |
| 1.0000E+00 | 161 | 469 | $Y = \exp(A + (B/T) + (C \cdot \ln T) + (D \cdot T^E))$ |
| | 161 | 469 | $Y = A \cdot ((1 - Tr)^B + (C \cdot Tr) + (D \cdot Tr^2) + (E \cdot Tr^3))$ |
| | 25 | 161 | $Y = A + (B \cdot T) + (C \cdot T^2) + (D \cdot T^3) + (E \cdot T^4)$ |
| | 161 | 284 | $Y = A + (B \cdot T) + (C \cdot T^2) + (D \cdot T^3) + (E \cdot T^4)$ |
| 7.3730E+02 | 50 | 1500 | $Y = A + B \cdot ((C/T) / \sinh(C/T))^2 + D \cdot ((E/T) / \cosh(E/T))^2$ |
| -1.7212E+00 | 235 | 1500 | $Y = A + (B/T) + (C/T^3) + (D/T^8) + (E/T^9)$ |
| | 161 | 284 | $Y = \exp(A + (B/T) + (C \cdot \ln T) + (D \cdot T^E))$ |
| | 161 | 1000 | $Y = (A \cdot T^B) / (1 + (C/T) + (D/T^2))$ |
| | 161 | 284 | $Y = A + (B \cdot T) + (C \cdot T^2) + (D \cdot T^3) + (E \cdot T^4)$ |
| | 273 | 1000 | $Y = (A \cdot T^B) / (1 + (C/T) + (D/T^2))$ |
| | 161 | 469 | $Y = A \cdot ((1 - Tr)^B + (C \cdot Tr) + (D \cdot Tr^2) + (E \cdot Tr^3))$ |

Table A3 Henry's Law Constants (Atm/mole fraction)

| T (°C) | Nitrogen | Argon | Methane | Ethane |
|--------|----------|-------|---------|--------|
| 32 | 2800 | 1671 | 613 | 84.3 |
| 77 | 2180 | 1420 | 614 | 109 |
| 122 | 1820 | 1270 | 595 | 129 |

Henry's Law Constants can be used with the following equation to determine solubility of these gases:

$$X_i = \frac{Y_i P_t}{H_i}$$

Table A4 Henry's Law Constants (MPa/mole fraction)

| T (°C) | Nitrogen | Argon | Methane | Ethane |
|--------|----------|-------|---------|--------|
| 0 | 284 | 169 | 62.1 | 8.5 |
| 25 | 221 | 144 | 62.2 | 11.0 |
| 50 | 184 | 129 | 60.3 | 13.1 |

Where:

X_i = mol fraction of gas (N₂, Ar, Methane, or Ethane) in liquid EO

Y_i = mol fraction of gas in vapor space above liquid EO

P_t = total pressure, Atm

H_i = Henry's Law Constants for gas, Atm

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