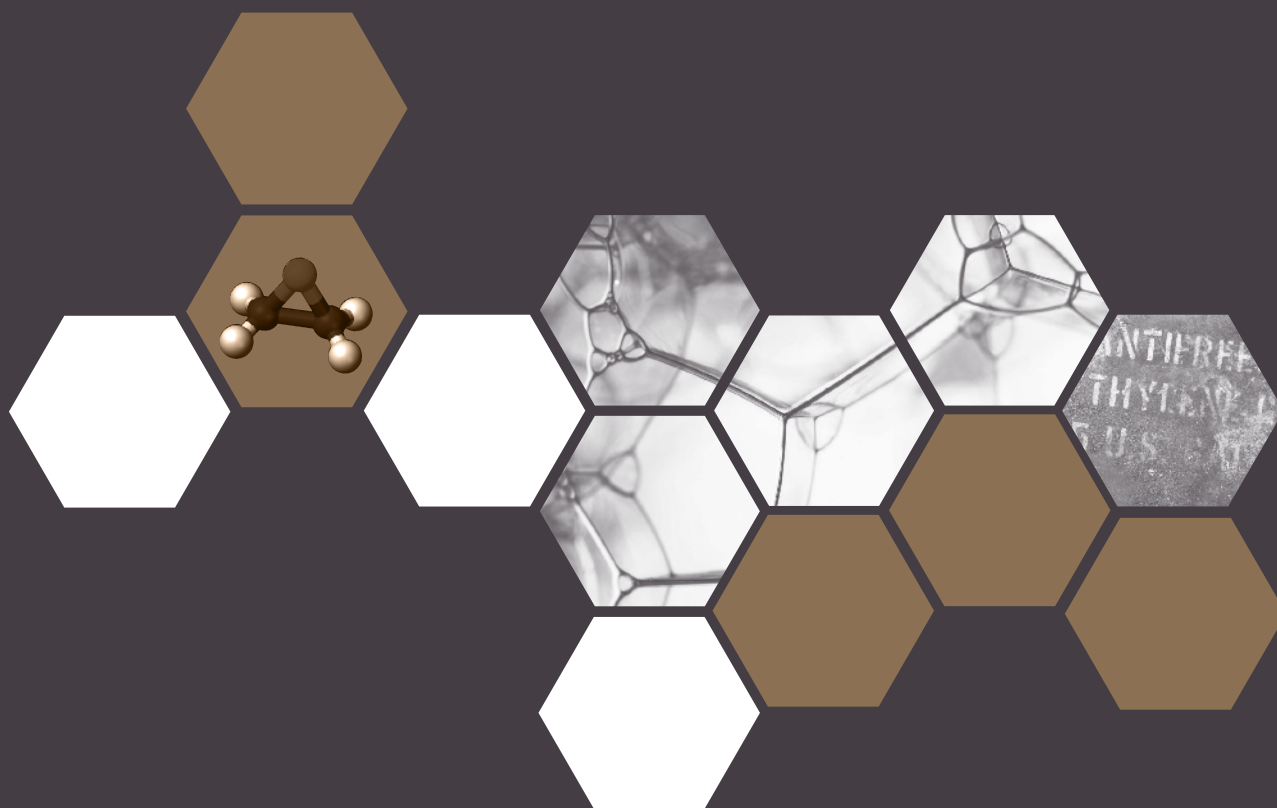


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To the Reader

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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Appendix A Figures and Tables

Figure 1 Ethylene Oxide Liquid Density

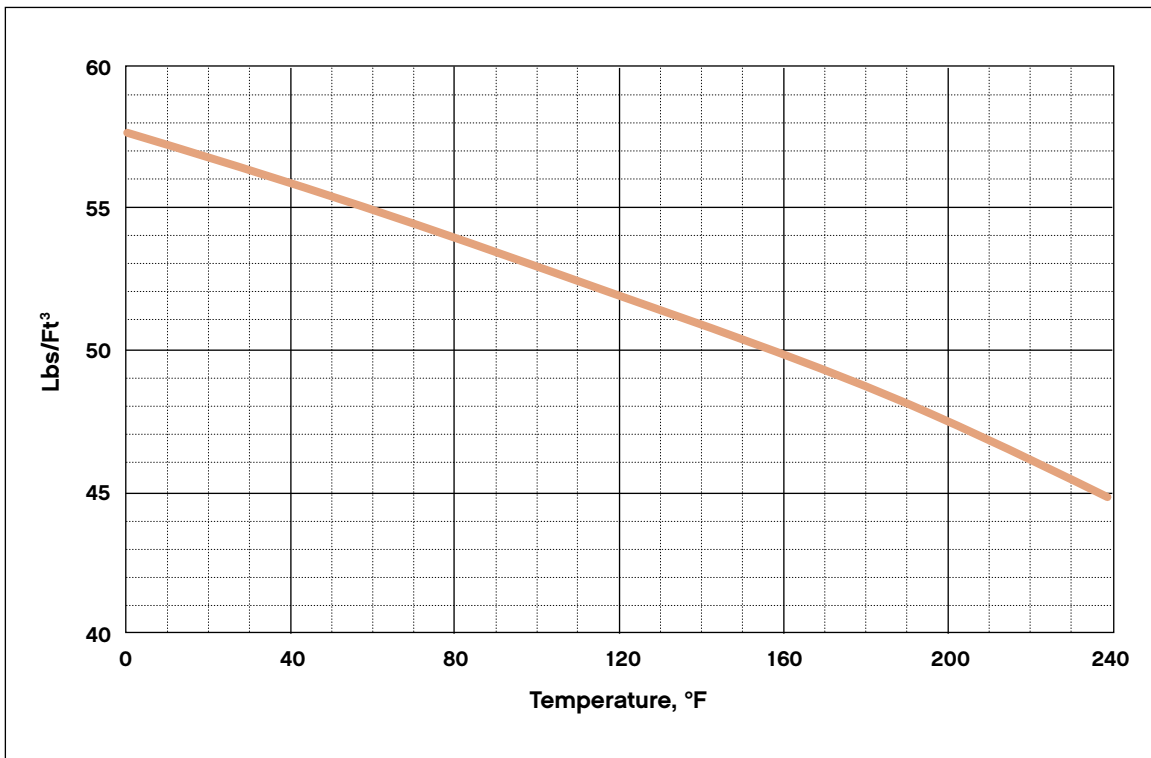


Figure 2 Ethylene Oxide Vapor Pressure

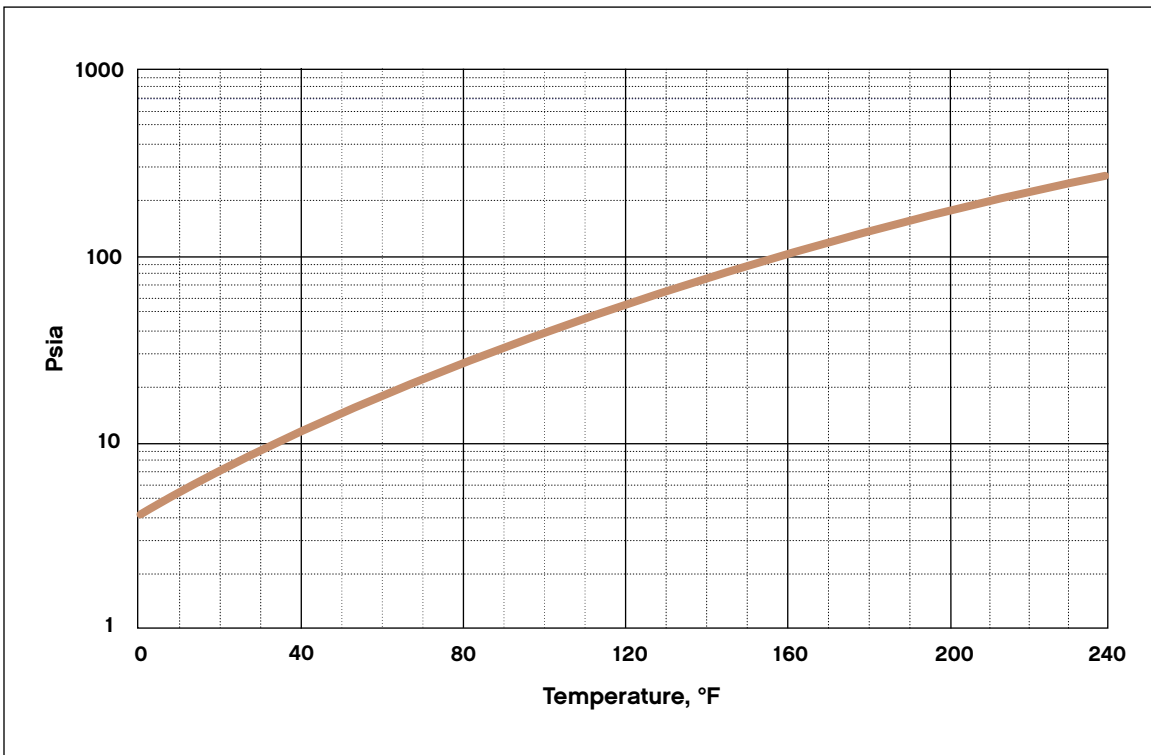


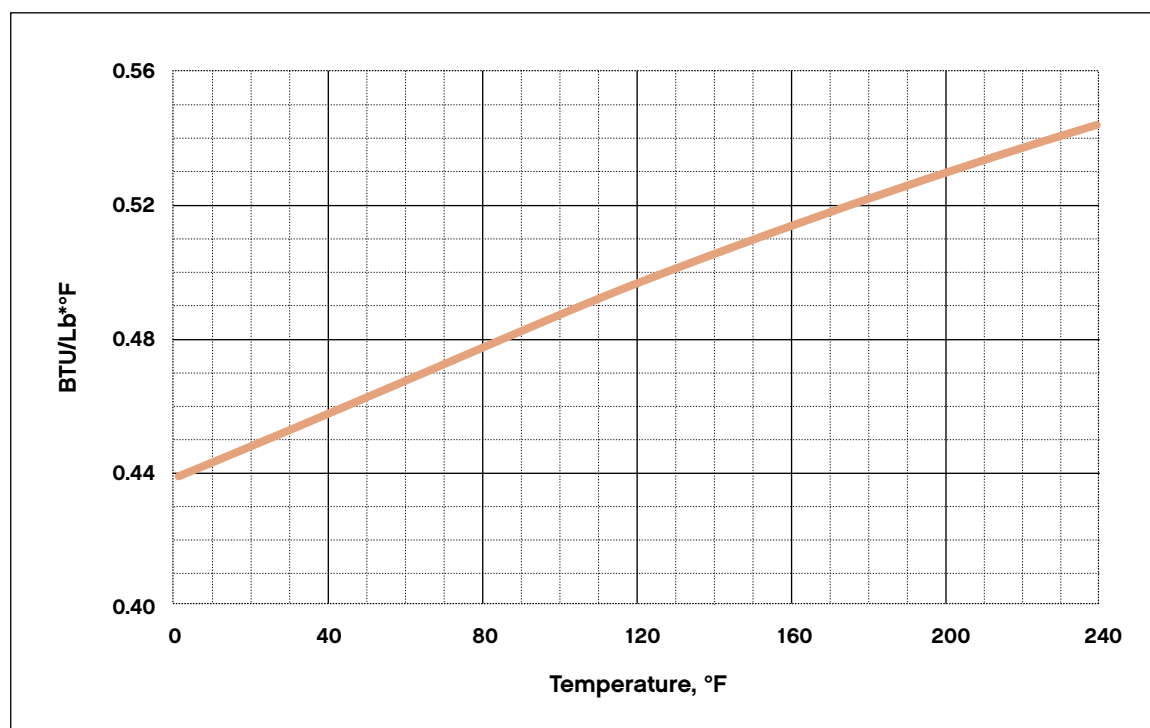
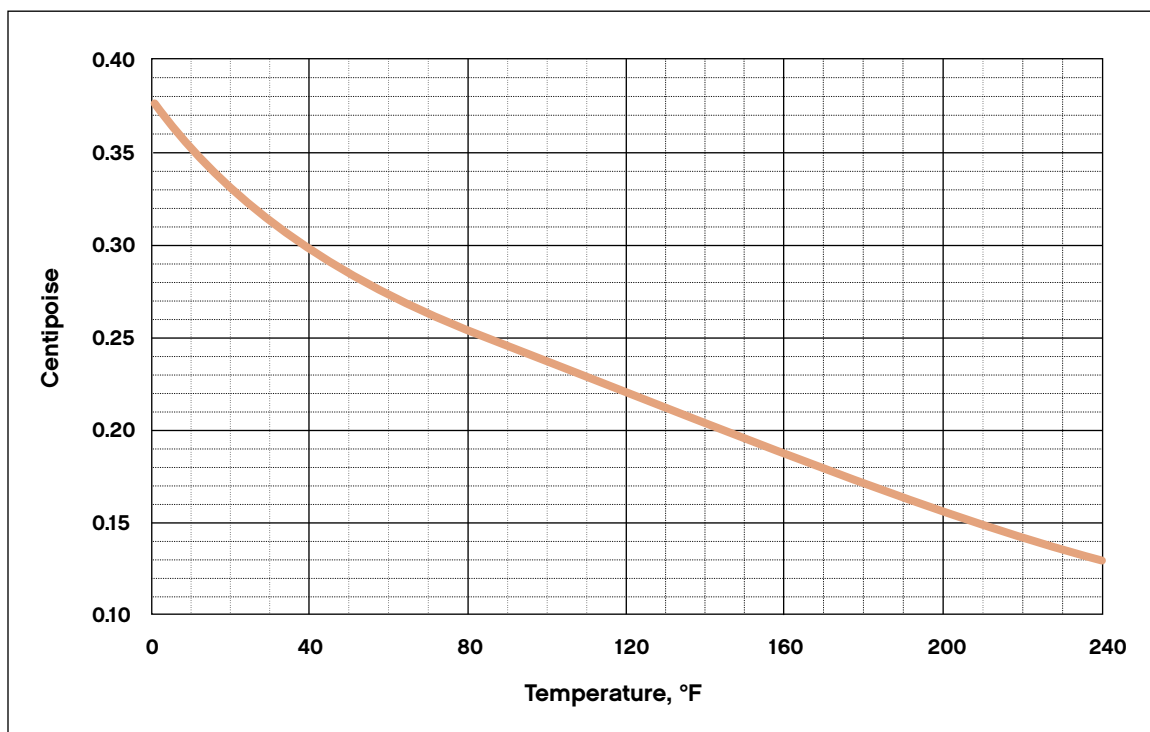
Figure 3 Ethylene Oxide Liquid Heat Capacity**Figure 4** Ethylene Oxide Liquid Viscosity

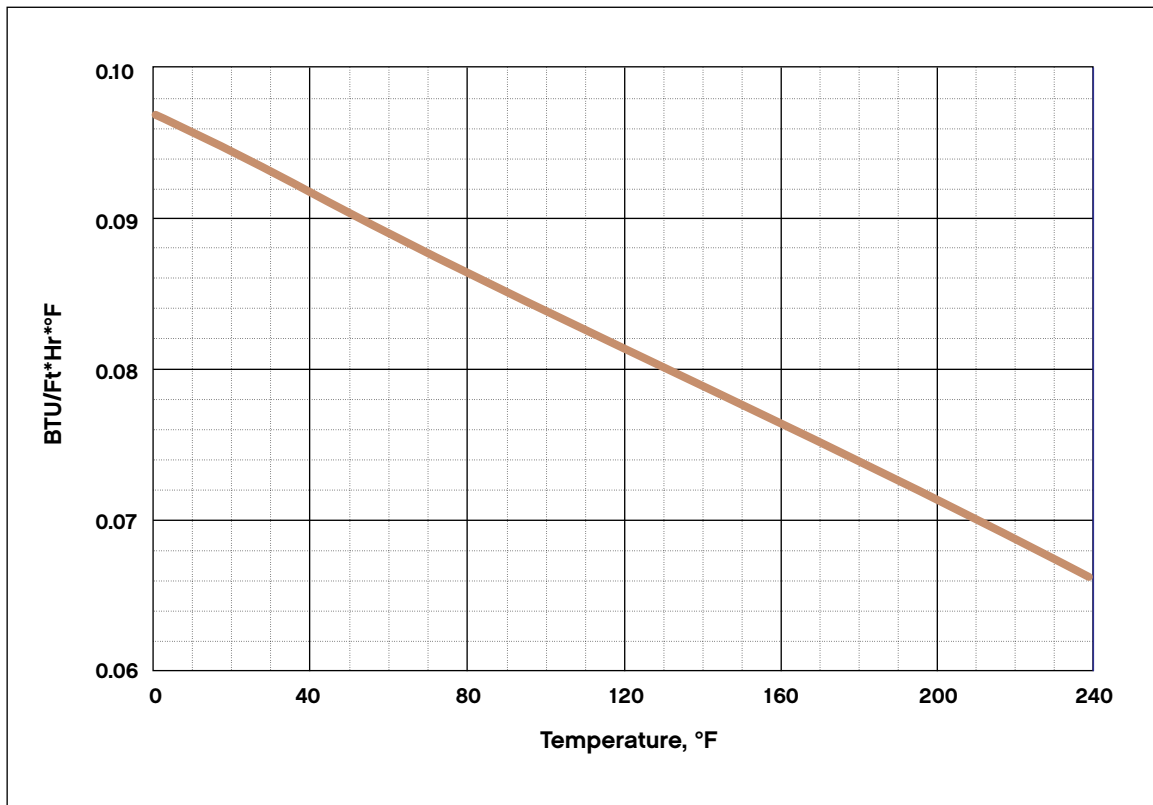
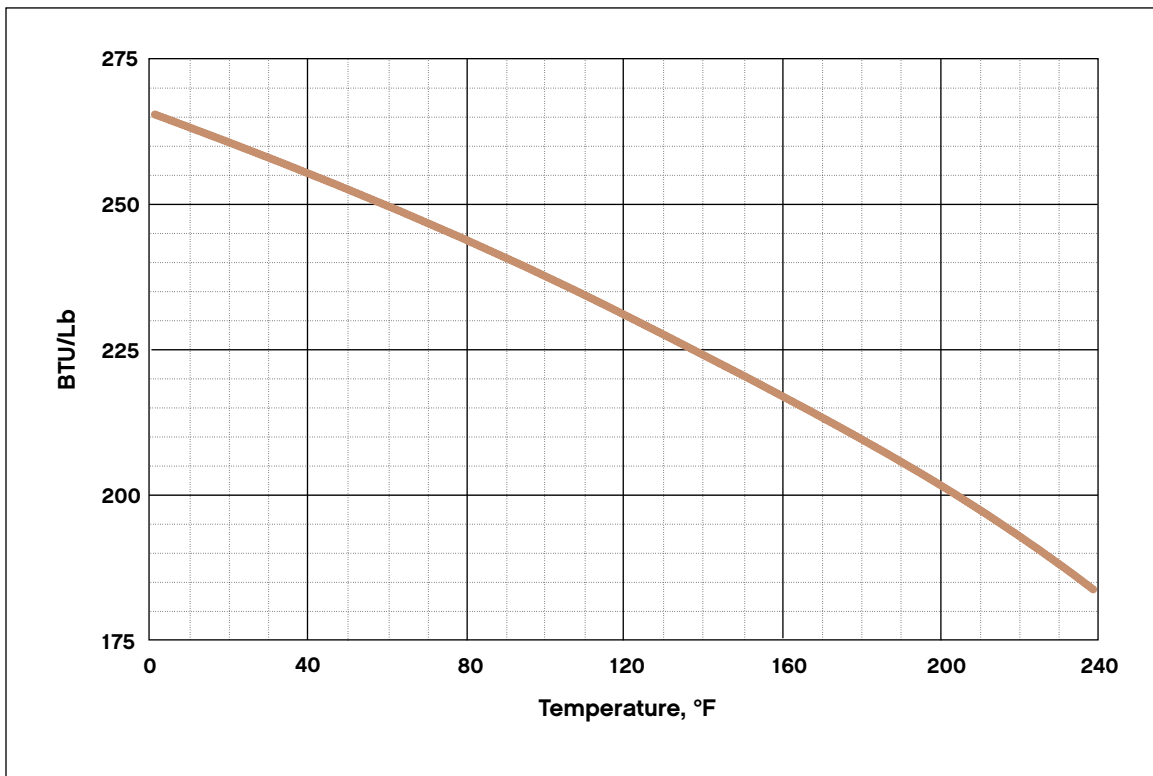
Figure 5 Ethylene Oxide Liquid Thermal Conductivity**Figure 6 Ethylene Oxide Heat of Vaporization (BTU/Lb)**

Figure 7 Ethylene Oxide Vapor Heat Capacity

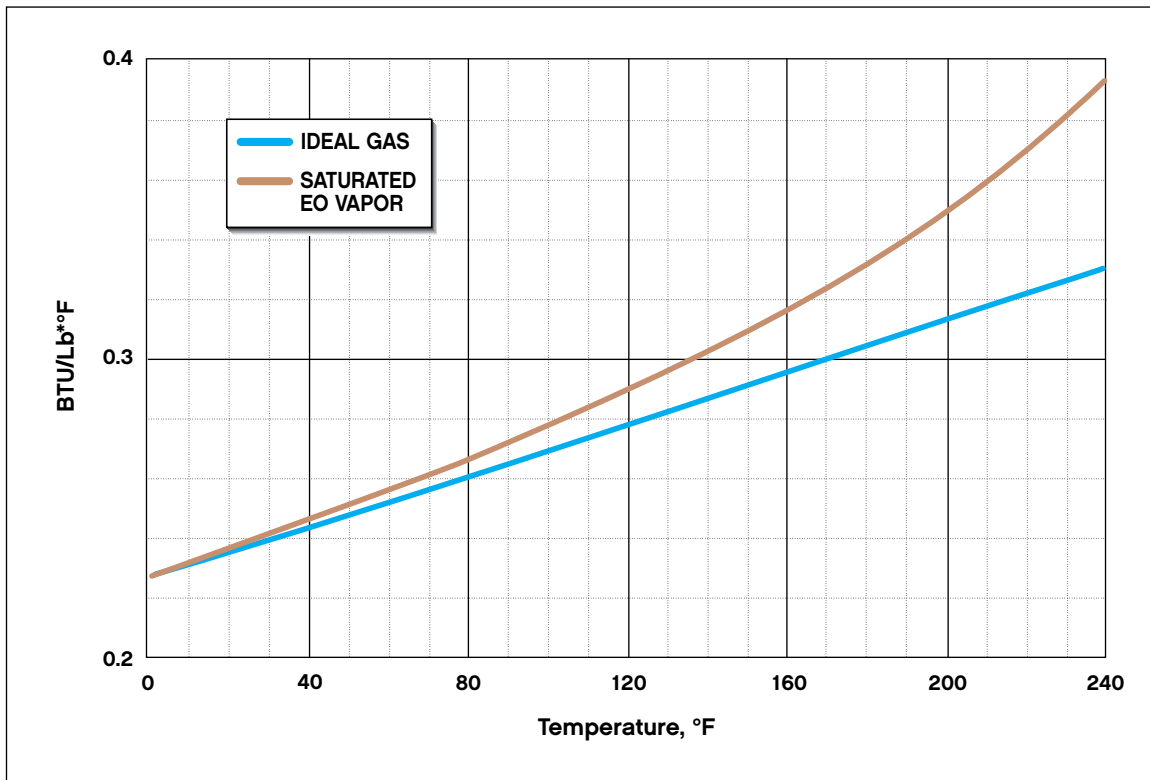


Figure 8 Ethylene Oxide Vapor Viscosity

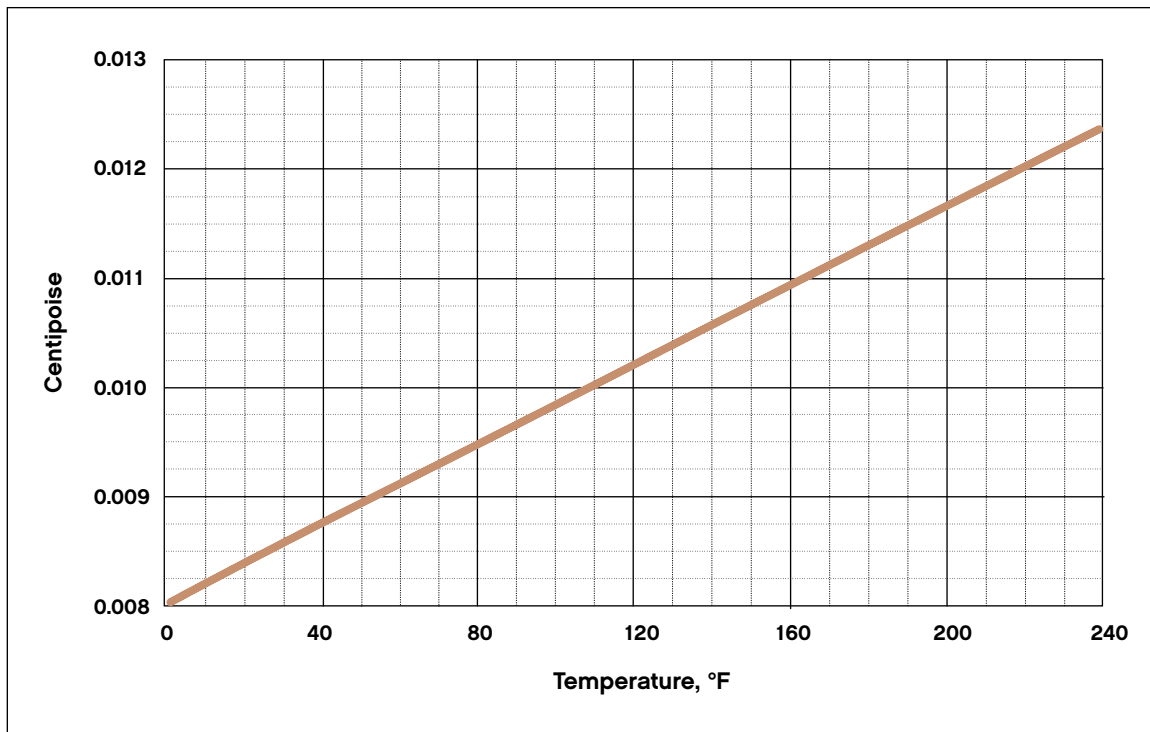


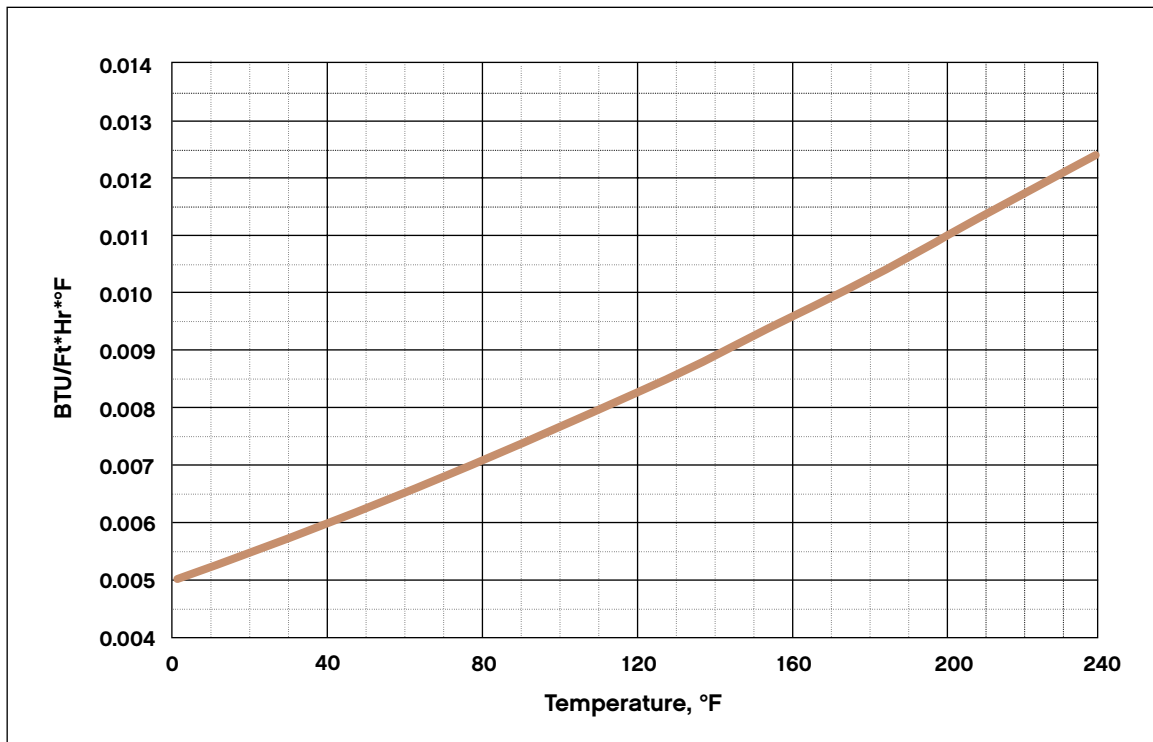
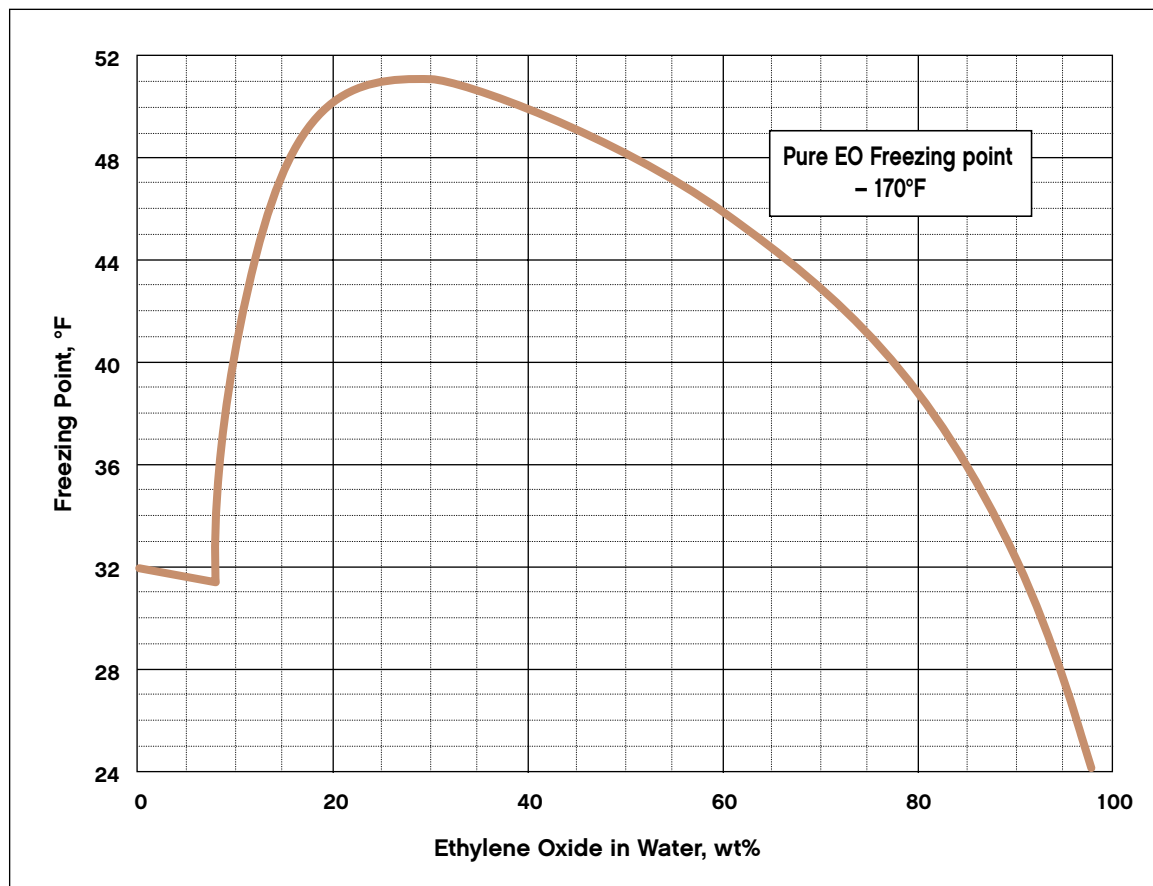
Figure 9 Ethylene Oxide Vapor Thermal Conductivity**Figure 10** Freezing Points Ethylene Oxide/Water Mixtures

Figure 11 C_p/C_v For Saturated Ethylene Oxide Vapor

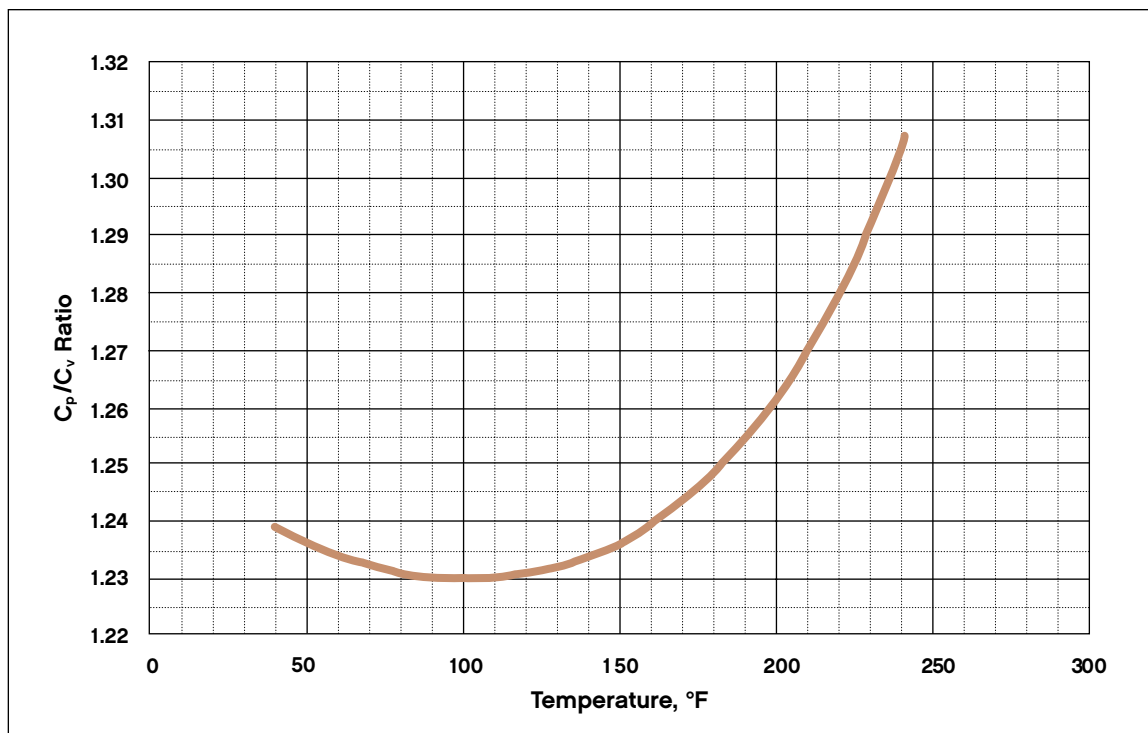


Figure 12 Ethylene Oxide Vapor Density

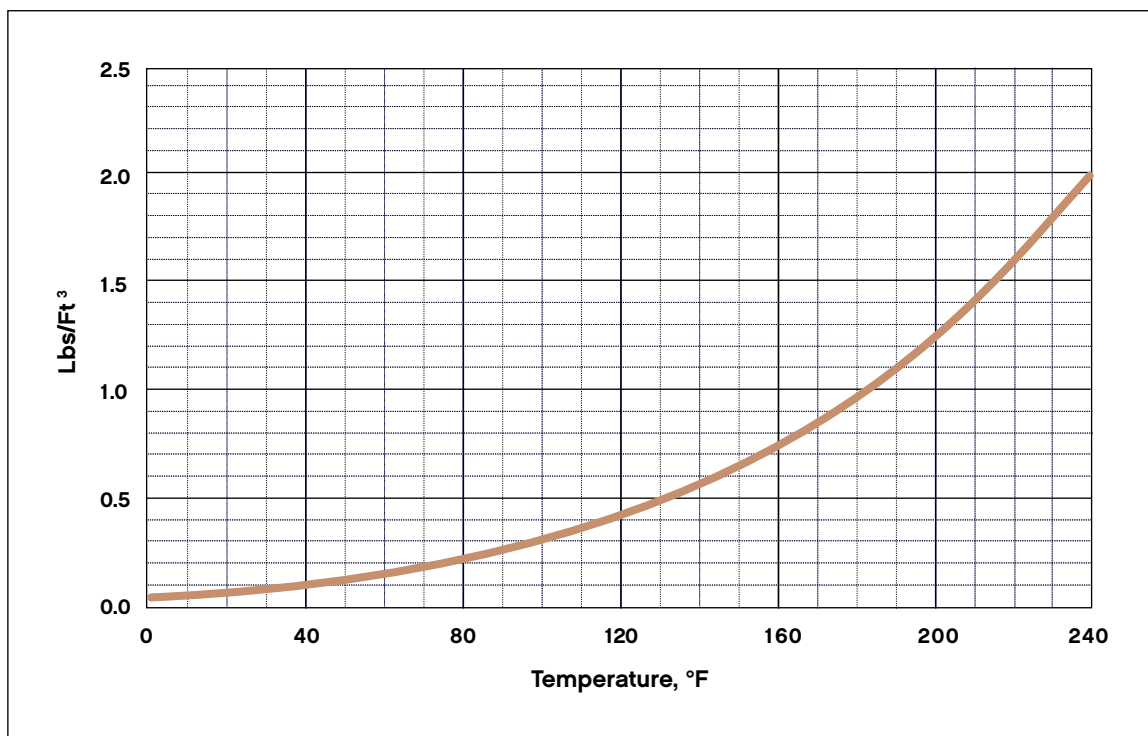
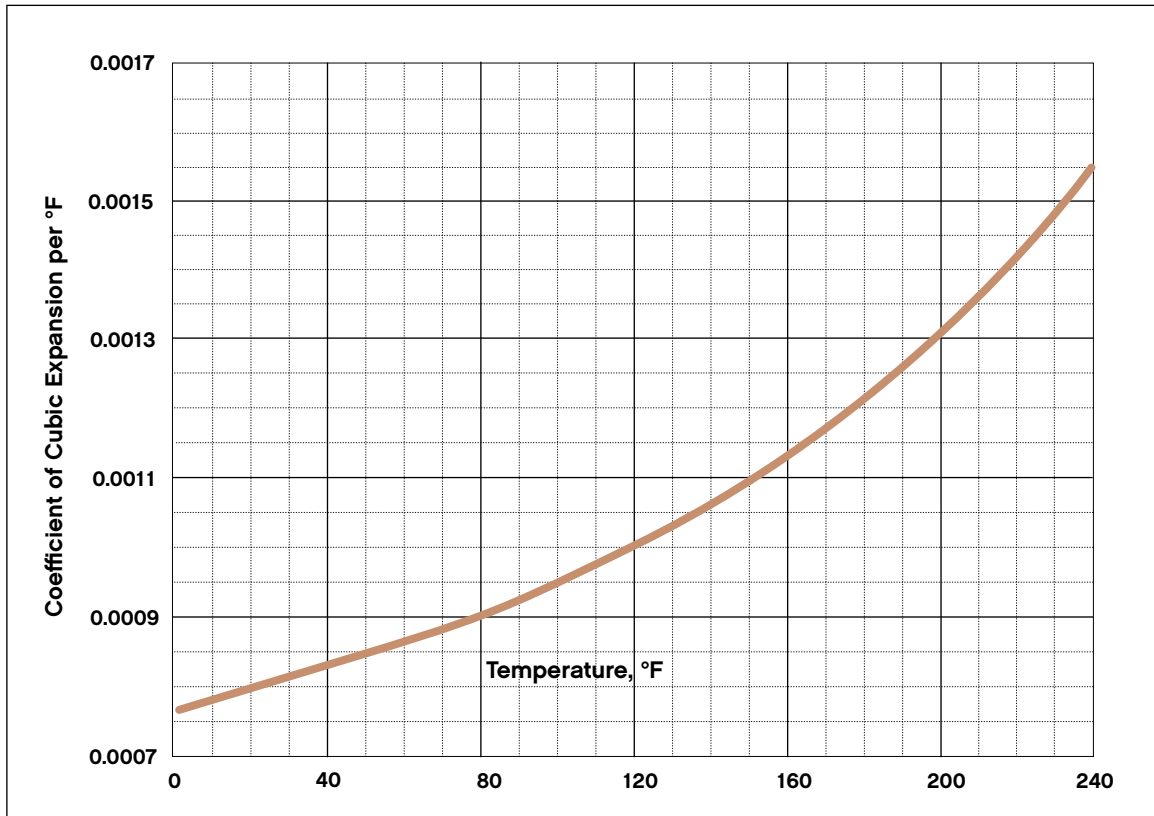


Figure 13 Ethylene Oxide Coefficient of Cubic Expansion

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

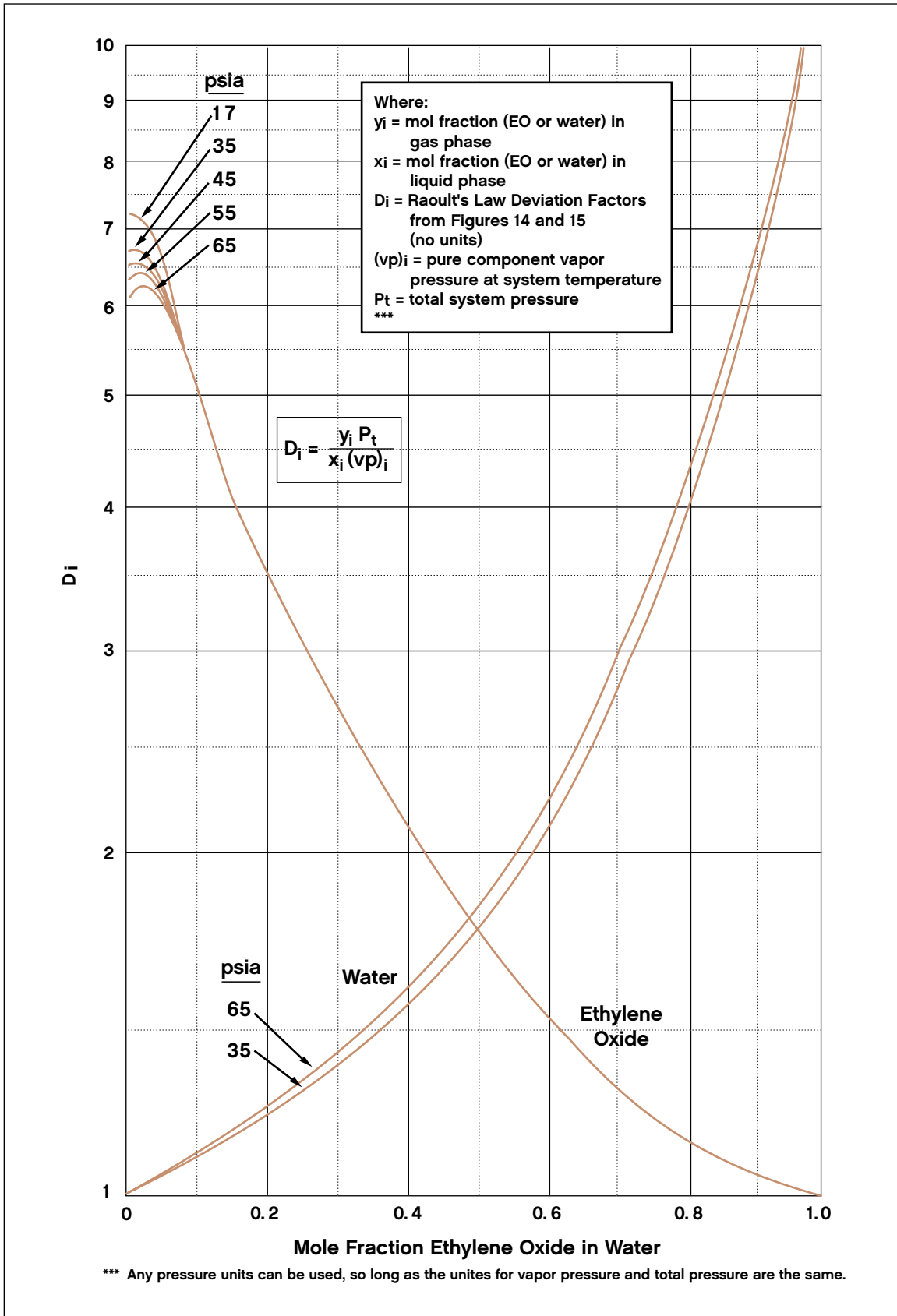


Figure 15 Raoult's Law Deviation Factors for Ethylene Oxide/Water Mixtures

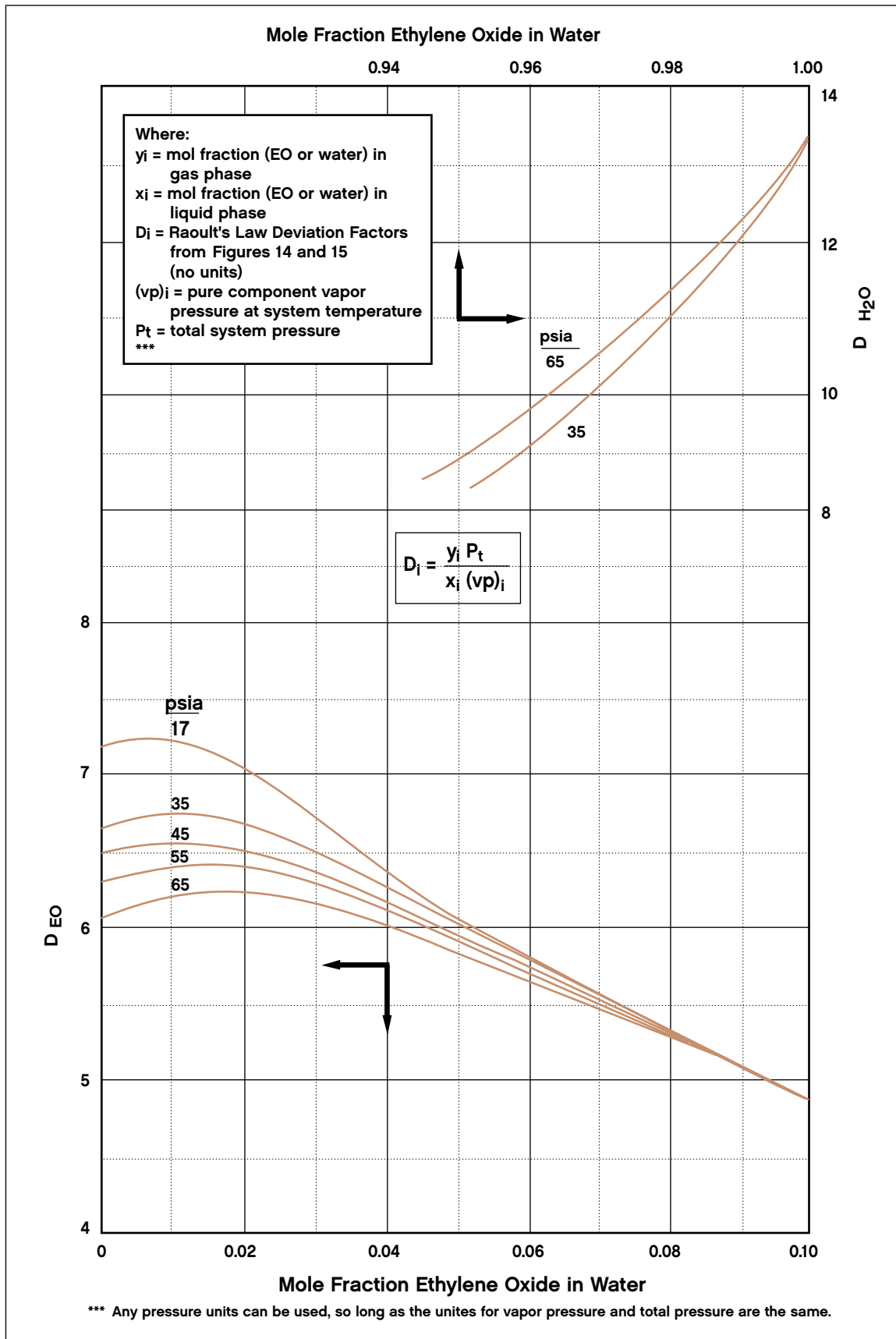


Figure 16 Flammability Data on EO-Air Mixtures at Subatmospheric Pressures

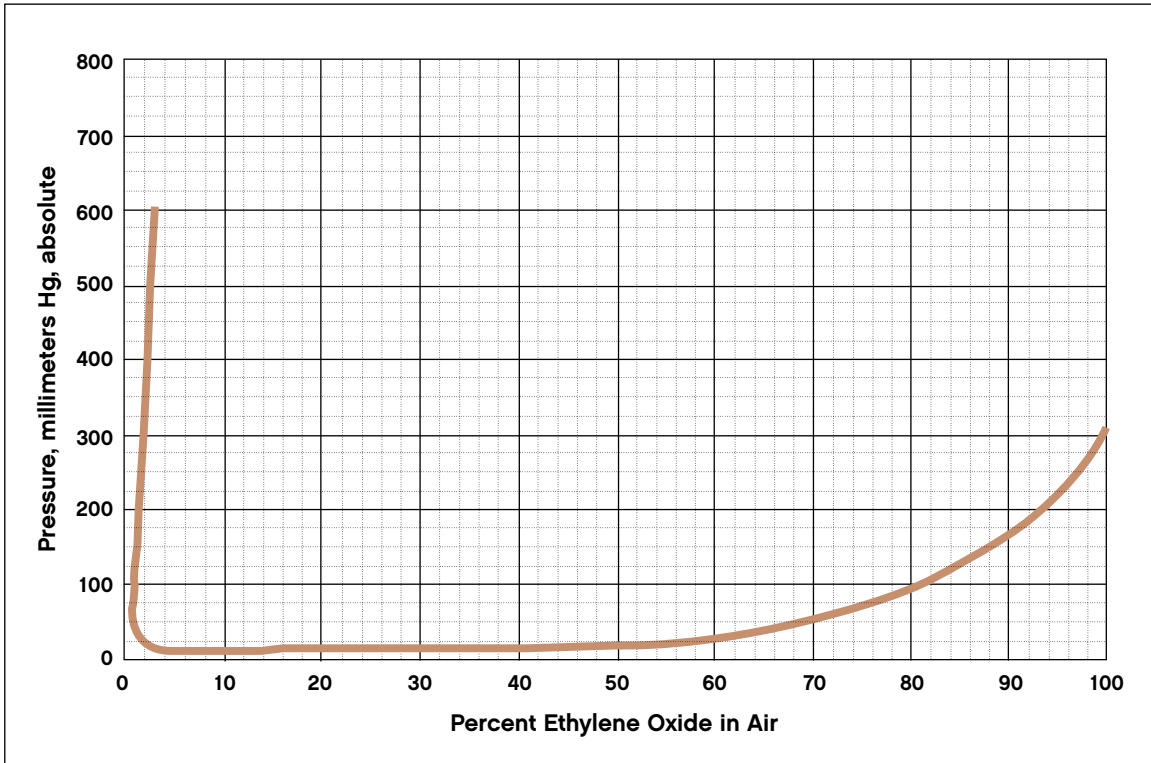


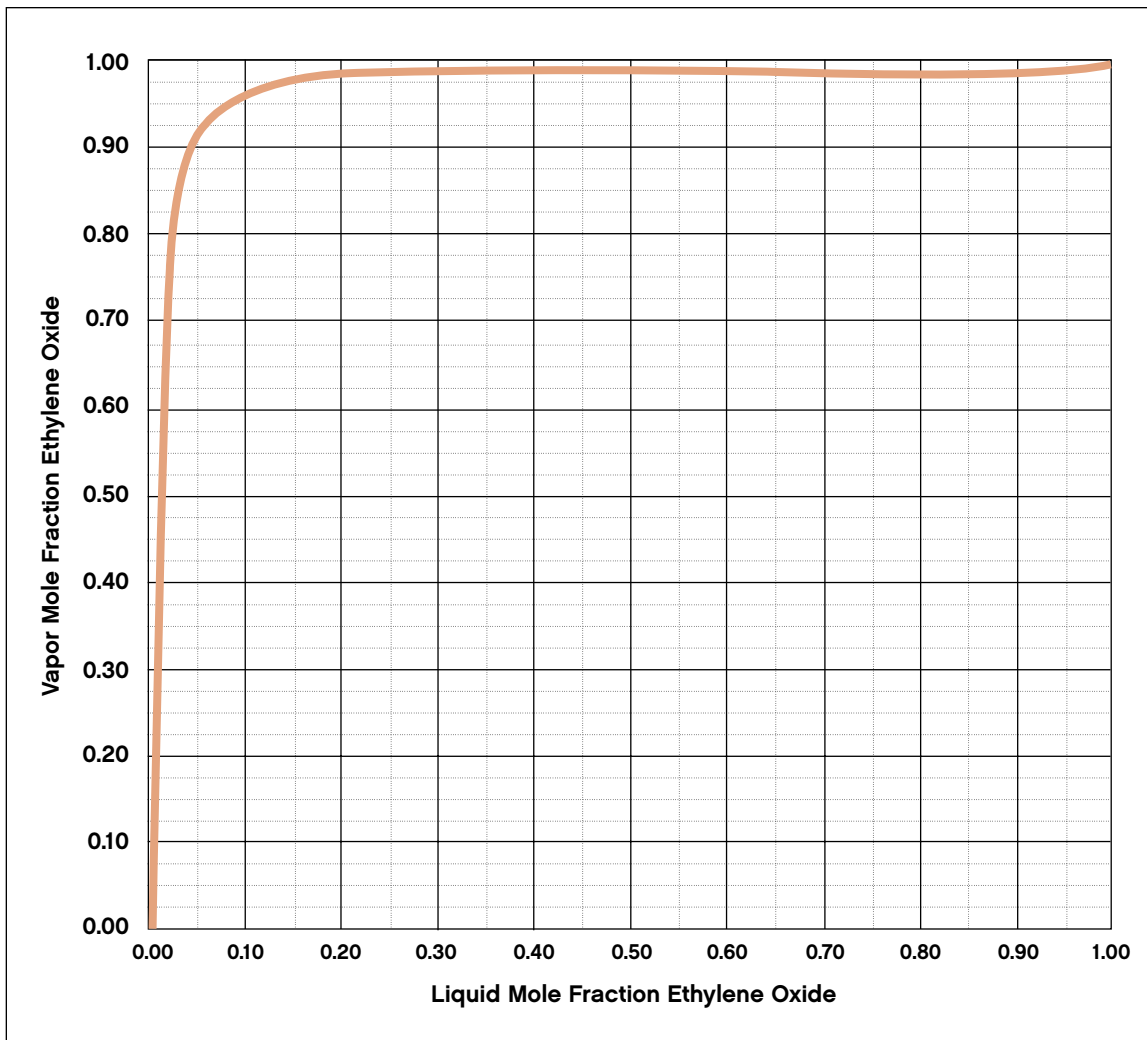
Figure 17 Vapor/Liquid Equilibria of Ethylene Oxide/Water Systems

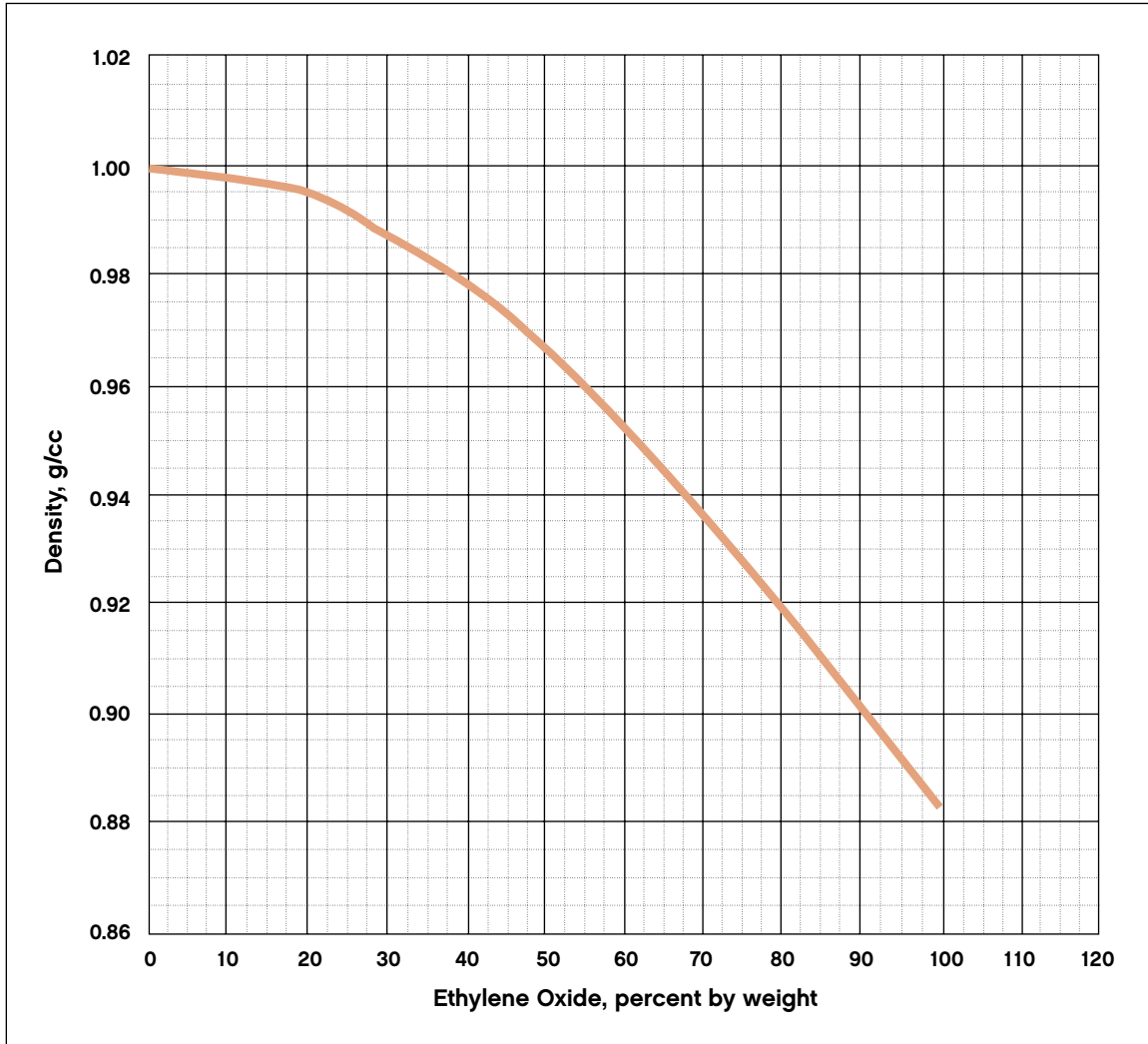
Figure 18 Density vs. Composition of Ethylene Oxide/Water Systems

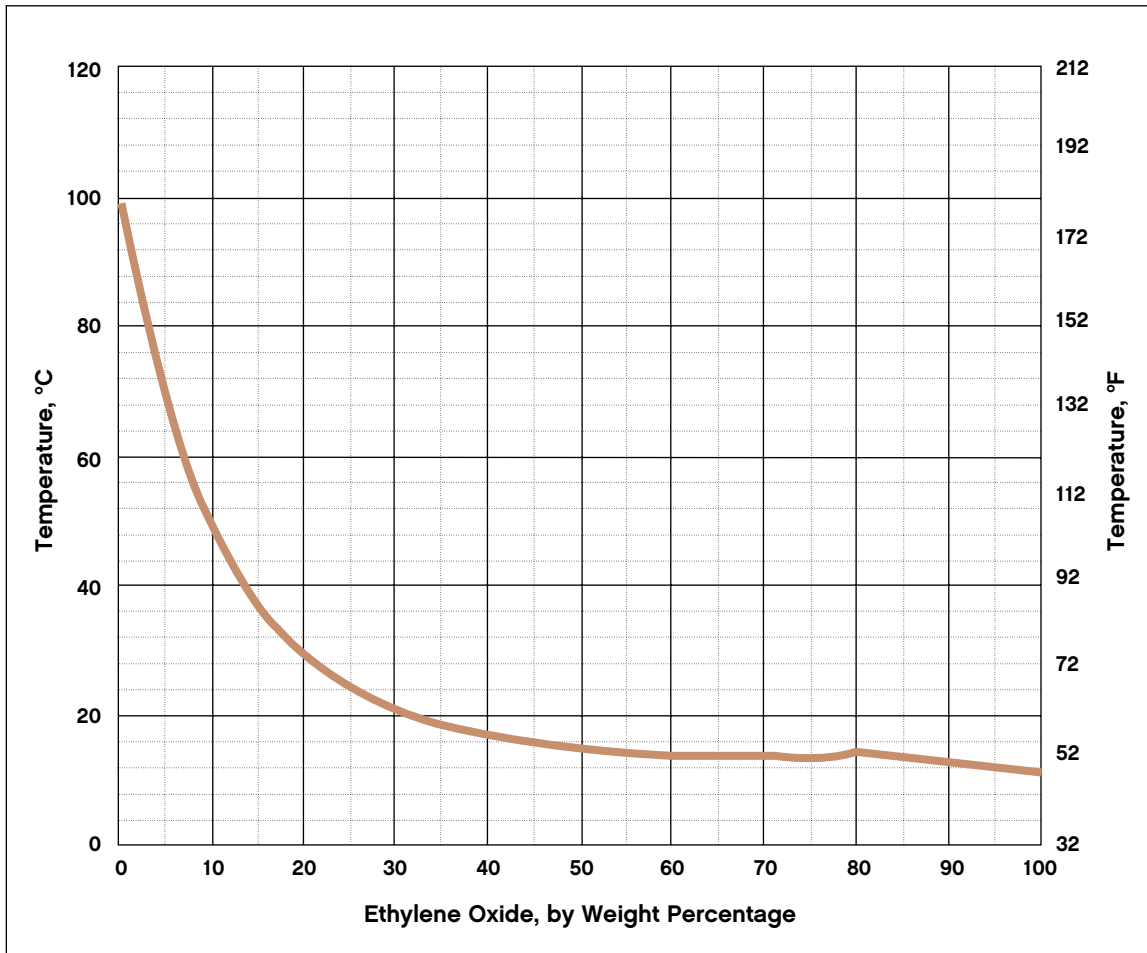
Figure 19 Boiling points of aqueous EO concentrations

Figure 20 Decomposition Data

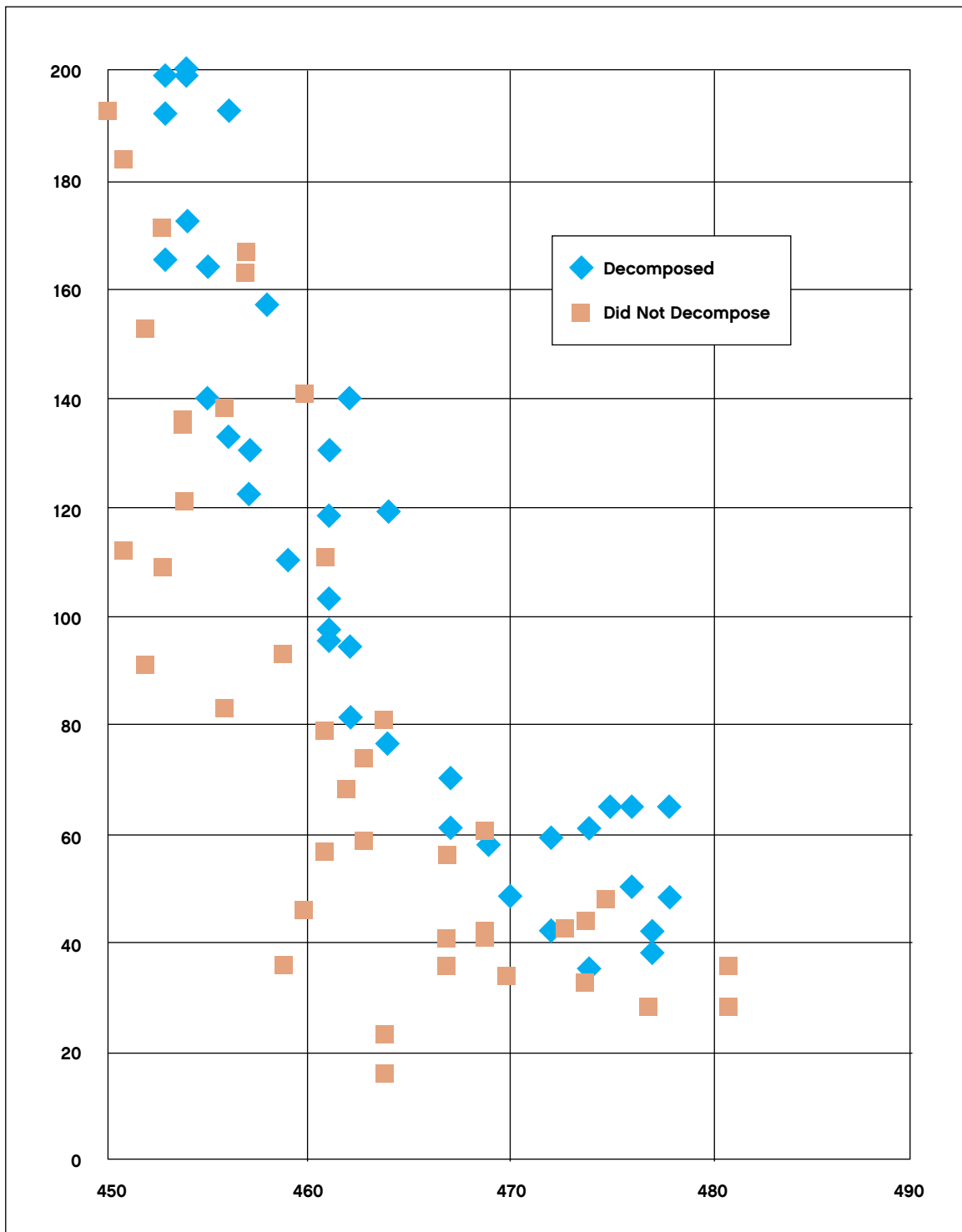


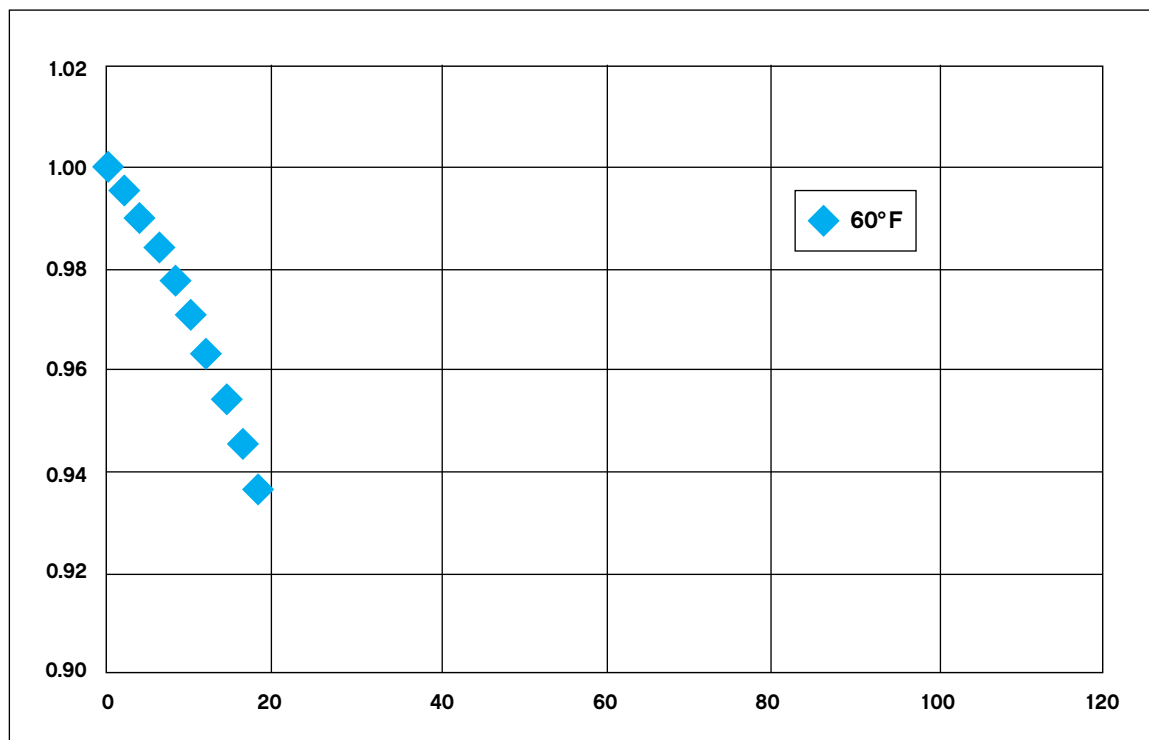
Figure 21 Vapor Compressibility vs. Pressure as a Function of Temperature

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	$Y = A / (B^{(1+(1-T/C)^D)})$
	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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