

Thermophysical Characteristics of Working Fluids and Heat Transfer Fluids

AIR1168/10

Coolanol 45
viscosity, μ , lb/hr-ft²
 ρg = Density, lb/ft³
Ethylene glycol FC-75
Thermodynamic Characteristics of
Working Fluids
 $Z = PV/RT$
Entropy, S, Btu/°F
Specific Heat, c_p , Btu/lb-°F
Enthalpy, H, Btu/lb
Freon-21

SAE Aerospace Applied Thermodynamics Manual

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INTERNATIONAL

**THERMOPHYSICAL CHARACTERISTICS OF WORKING
FLUIDS AND HEAT TRANSFER FLUIDS**

PREFACE

This document is one of 14 Aerospace Information Reports (AIR) of the Third Edition of the SAE Aerospace Applied Thermodynamics Manual. The manual provides a reference source for thermodynamics, aerodynamics, fluid dynamics, heat transfer, and properties of materials for the aerospace industry. Procedures and equations commonly used for aerospace applications of these technologies are included.

In the Third Edition, no attempt was made to update material from the Second Edition nor were SI units added. However, all identified errata were corrected and incorporated and original figure numbering was retained, insofar as possible.

The SAE AC-9B Subcommittee originally created the SAE Aerospace Applied Thermodynamics Manual and, for the Third Edition, used a new format consisting of AIR1168/1 through AIR1168/10. AIR1168/11 through AIR1168/14 were created by the SAE SC-9 Committee.

The AIRs comprising the Third Edition are shown below. Applicable sections of the Second Edition are shown parenthetically in the third column.

AIR1168/1	Thermodynamics of Incompressible and Compressible Fluid Flow	(1A,1B)
AIR1168/2	Heat and Mass Transfer and Air-Water Mixtures	(1C,1D,1E)
AIR1168/3	Aerothermodynamic Systems Engineering and Design	(3A,3B,3C,3D)
AIR1168/4	Ice, Rain, Fog, and Frost Protection	(3F)

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AIR1168/5	Aerothermodynamic Test Instrumentation and Measurement	(3G)
AIR1168/6	Characteristics of Equipment Components, Equipment Cooling System Design, and Temperature Control System Design	(3H,3J,3K)
AIR1168/7	Aerospace Pressurization System Design	(3E)
AIR1168/8	Aircraft Fuel Weight Penalty Due to Air Conditioning	(3I)
AIR1168/9	Thermophysical Properties of the Natural Environment, Gases, Liquids, and Solids	(2A,2B,2C,2D)
AIR1168/10	Thermophysical Characteristics of Working Fluids and Heat Transfer Fluids	(2E,2F)
AIR1168/11	Spacecraft Boost and Entry Heat Transfer	(4A,4B)
AIR1168/12	Spacecraft Thermal Balance	(4C)
AIR1168/13	Spacecraft Equipment Environmental Control	(4D)
AIR1168/14	Spacecraft Life Support Systems	(4E)

F.R. Weiner, formerly of Rockwell International and past chairman of the SAE AC-9B Subcommittee, is commended for his dedication and effort in preparing the errata lists that were used in creating the Third Edition.

Table of Contents

1.	INTRODUCTION	1
1.1	Scope	1
1.2	Nomenclature	1
1.3	Common Abbreviations	2
2.	SECTION 2E- THERMODYNAMIC CHARACTERISTICS OF WORKING FLUIDS	3
3.	SECTION 2F - PROPERTIES OF HEAT TRANSFER FLUIDS	29
4.	REFERENCES	68
5.	INDEX	68
5.1	Section 2E - Thermodynamic Characteristics of Working Fluids	68
5.2	Section 2F - Properties Of Heat Transfer Fluids	69

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List of Figures

Figure 2E-1 - Pressure-Enthalpy Diagram for Air (Key to Charts); From NACA TN-4265	3
Figure 2E-2 - Chart 1 - Thermodynamic Chart For Air	4
Figure 2E-3 - Chart 2 - Thermodynamic Chart For Air	5
Figure 2E-4 - Chart 3 - Thermodynamic Chart For Air	6
Figure 2E-5 - Chart 4 - Thermodynamic Chart For Air	7
Figure 2E-6 - Chart 5 - Thermodynamic Chart For Air	8
Figure 2E-7 - Chart 6 - Thermodynamic Chart For Air	9
Figure 2E-8 - Chart 7 - Thermodynamic Chart For Air	10
Figure 2E-9 - Chart 8 - Thermodynamic Chart For Air	11
Figure 2E-10 - Chart 9 - Thermodynamic Chart For Air	12
Figure 2E-11 - Chart 10 - Thermodynamic Chart For Air	13
Figure 2E-12 - Chart 11 - Thermodynamic Chart For Air	14
Figure 2E-13 - Chart 12 - Thermodynamic Chart For Air	15
Figure 2E-14 - Chart 13 - Thermodynamic Chart For Air	16
Figure 2E-15 - Chart 14 - Thermodynamic Chart For Air	17
Figure 2E-16 - Pressure-enthalpy Diagram, Freon 11	18
Figure 2E-17 - Pressure-enthalpy Diagram, Freon 12	19
Figure 2E-18 - Pressure-enthalpy Diagram, Freon 13	20
Figure 2E-19 - Pressure-enthalpy Diagram, Freon 14	21
Figure 2E-20 - Pressure-enthalpy Diagram, Freon 21	22
Figure 2E-21 - Pressure-enthalpy Diagram, Freon 22	23
Figure 2E-22 - Pressure-enthalpy Diagram, Freon 113	24
Figure 2E-23 - Pressure-enthalpy Diagram, Freon 114	25
Figure 2E-24 - Estimated Thermodynamic Properties of 1-2-Dichlorohexafluorocyclopentene-1; Estimated $P_{cr} = 480$ psia, Estimated $t_{cr} = 512^{\circ}\text{F}$	26
Figure 2E-25 - Estimated Thermodynamic Properties of Dowtherm E (Dichlorobenzene)	27
Figure 2F-1 - Coolanol 25 Property c_p (Ref.1)	29
Figure 2F-2 - Coolanol 25 Property ρg (Ref.1)	30
Figure 2F-3 - Coolanol 25 Property μ (Ref.11)	31
Figure 2F-4 - Coolanol 25 Property $(N_{Pr})^{2/3}$ (Ref.1)	32
Figure 2F-5 - Coolanol 35 Property c_p (Ref.1)	33
Figure 2F-6 - Coolanol 35 Property ρg (Ref.1)	34
Figure 2F-7 - Coolanol 35 Property μ (Ref.11)	35
Figure 2F-8 - Coolanol 35 Property $(N_{Pr})^{2/3}$ (Ref.1)	36
Figure 2F-9 - Coolanol 45 Property c_p (Ref.1)	37
Figure 2F-10 - Coolanol 45 Property ρg (Ref.1)	38
Figure 2F-11 - Coolanol 45 Property μ (Ref.11)	39
Figure 2F-12 - Coolanol 45 Property k (Ref.1)	40
Figure 2F-13 - Coolanol 45 Property $(N_{Pr})^{2/3}$ (Ref.1)	41
Figure 2F-14 - MCS-198 Property c_p (Ref.2)	41
Figure 2F-15 - MCS-198 Property ρg (Ref.2)	42
Figure 2F-16 - MCS-198 Property μ (Ref.2)	43
Figure 2F-17 - MCS-198 Property k (Ref.2)	43
Figure 2F-18 - MCS-198 Property $(N_{Pr})^{2/3}$ (Ref.2)	44
Figure 2F-19 - Aqueous Ethylene Glycol Property c_p ; % by weight (Ref.3)	45

Figure 2F-20 - Aqueous Ethylene Glycol Property $(\rho g)_t / (\rho g)_{60^\circ F}$; % by weight (Ref.3)	46
Figure 2F-21 - Aqueous Ethylene Glycol Property μ ; % by weight (Ref.3)	47
Figure 2F-22 - Aqueous Ethylene Glycol Property k ; % by weight (Ref.3)	48
Figure 2F-23 - Aqueous Ethylene Glycol, Vapor Pressure; % by weight (Ref.3)	49
Figure 2F-24 - FC-75 Property c_p (Ref.4)	50
Figure 2F-25 - FC-75 Property ρg (Ref.4)	50
Figure 2F-26 - FC-75 Property μ (Ref.4)	51
Figure 2F-27 - FC - 75 Property k (Ref.4)	52
Figure 2F-28 - FC-75 Vapor Pressure (Ref.4)	53
Figure 2F-29 - FC-43, Properties μ , ρg , c_p , k , N_{Pr} , Vapor Pressure (Ref.5)	54
Figure 2F-30 - DC-200-20 Properties (Ref.6)	55
Figure 2F-31 - DC-331 Property c_p (Ref.7)	56
Figure 2F-32 - DC-331 Property ρg (Ref.7)	56
Figure 2F-33 - DC-331 Property v (Ref.7). Note: This is not a true log scale, but is a special viscosity scale per ASTM Standard D341.	57
Figure 2F-34 - DC-331 Property k (Ref.7)	58
Figure 2F-35 - Fluid XF-1-0184 Property c_p (Ref.8)	59
Figure 2F-36 - Fluid XF-1-0184 Property ρg (Ref.8)	59
Figure 2F-37 - Fluid XF-1-0184 Vapor Pressure (Ref.8)	60
Figure 2F-38 - Fluid XF-1-0184 Property k (Ref.8)	61
Figure 2F-39 - Fluid XF-1-0184 Property μ (Ref.8)	62
Figure 2F-40 - Oronite 70 Property ρg (Ref.9)	63
Figure 2F-41 - Oronite 70 Property v (Ref.9)	64
Figure 2F-42 - Oronite 70 Property k , ρg , c_p (Ref.9)	65
Figure 2F-43 - Oronite 8200 Properties (Ref.10)	66
Figure 2F-44 - Oronite 8515 Properties (Ref.10)	67

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1. INTRODUCTION

1.1 Scope

This AIR is arranged in the following two sections:

2E - Thermodynamic Characteristics of Working Fluids, which contains thermodynamic diagrams for a number of working fluids currently in use and supplied by various industrial firms.

2F - Properties of Heat Transfer Fluids, which contains data, primarily in graphical form, on fluids that are frequently used in fluid heat transfer loops.

Other properties of the environment, gases, liquids, and solids, can be found, as follows, in AIR1168/9:

2A-Properties of the Natural Environment

2B-Properties of Gases

2C-Properties of Liquids

2D-Properties of Solids

1.2 Nomenclature

c_p = Specific heat capacity, constant pressure, Btu/lb-°F

c_v = Specific heat capacity, constant volume, Btu/lb-°F

H = Enthalpy, Btu/lb

k = Thermal conductivity, Btu/hr-ft-°F, cal/cm-sec-°C

N_{Pr} = Prandtl number ($\mu c_p/k$), dimensionless

P = Pressure, atm, psia, lb/ft²

R = Universal gas constant, ft-lb/lb-°R

S = Entropy, Btu/°F

s = Specific entropy, Btu/lb - °R (or °F)

t = Temperature, °F

T = Temperature, °R, K

V = Specific volume, ft³/lb

Z = Compressibility factor ($Z=PV/RT$), dimensionless

ρ = Specific weight (density), lb/ft³, gm/cm³, lb/gal

μ = Absolute viscosity, lb/hr-ft, lb/sec-ft, centipoise

ν = Kinematic viscosity, centistokes

Subscript

cr = Critical

1.3 Common Abbreviations

abs	— Absolute
ASME	— American Society of Mechanical Engineers
atm(ATM)	— Atmosphere
Btu(BTU)	— British Thermal Units
°C	— Degrees Centigrade
cal	— Calorie
cm	— Centimeter
const	— Constant
cu(CU.)	— Cubic
°F	— Degrees Fahrenheit
FAHR.	— Degrees Fahrenheit
Fig.(Figs.)	— Figure(s)
ft(FT)	— Feet
ft-lb	— Foot-pound
GAL	— Gallon
gm	— Gram
hr	— Hour
in.	— Inch
K	— Kelvins (Formerly Degrees Kelvin)
lb(LB)	— Pounds
lb/in. ²	— Pounds per square inch
mm/Hg	— Millimeters of Mercury
p.(pp.)	— Page(s)
psi	— Pounds per square inch
psia(PSIA)	— Pounds per square inch absolute
PRESS.	— Pressure
°R	— Degrees Rankine
Ref.(Refs.)	— Reference(s)
Rev.	— Revised
sat(SAT)	— Saturated
sec	— Seconds
Trans.	— Transactions
Vol(VOL)	— Volume
Wt	— Weight
%	— Percent

2. SECTION 2E- THERMODYNAMIC CHARACTERISTICS OF WORKING FLUIDS

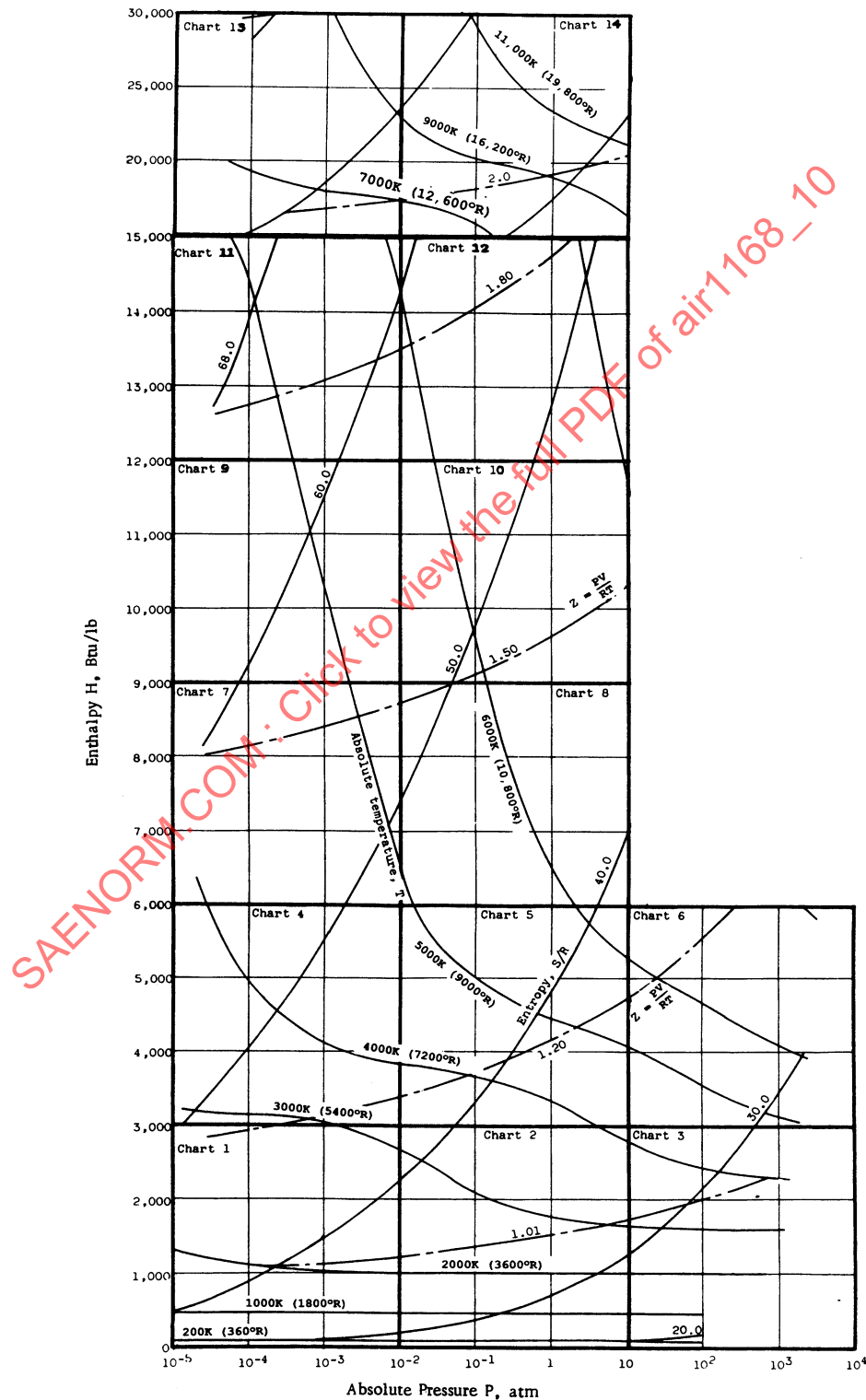


Figure 2E-1 - Pressure-Enthalpy Diagram for Air (Key to Charts); From NACA TN-4265

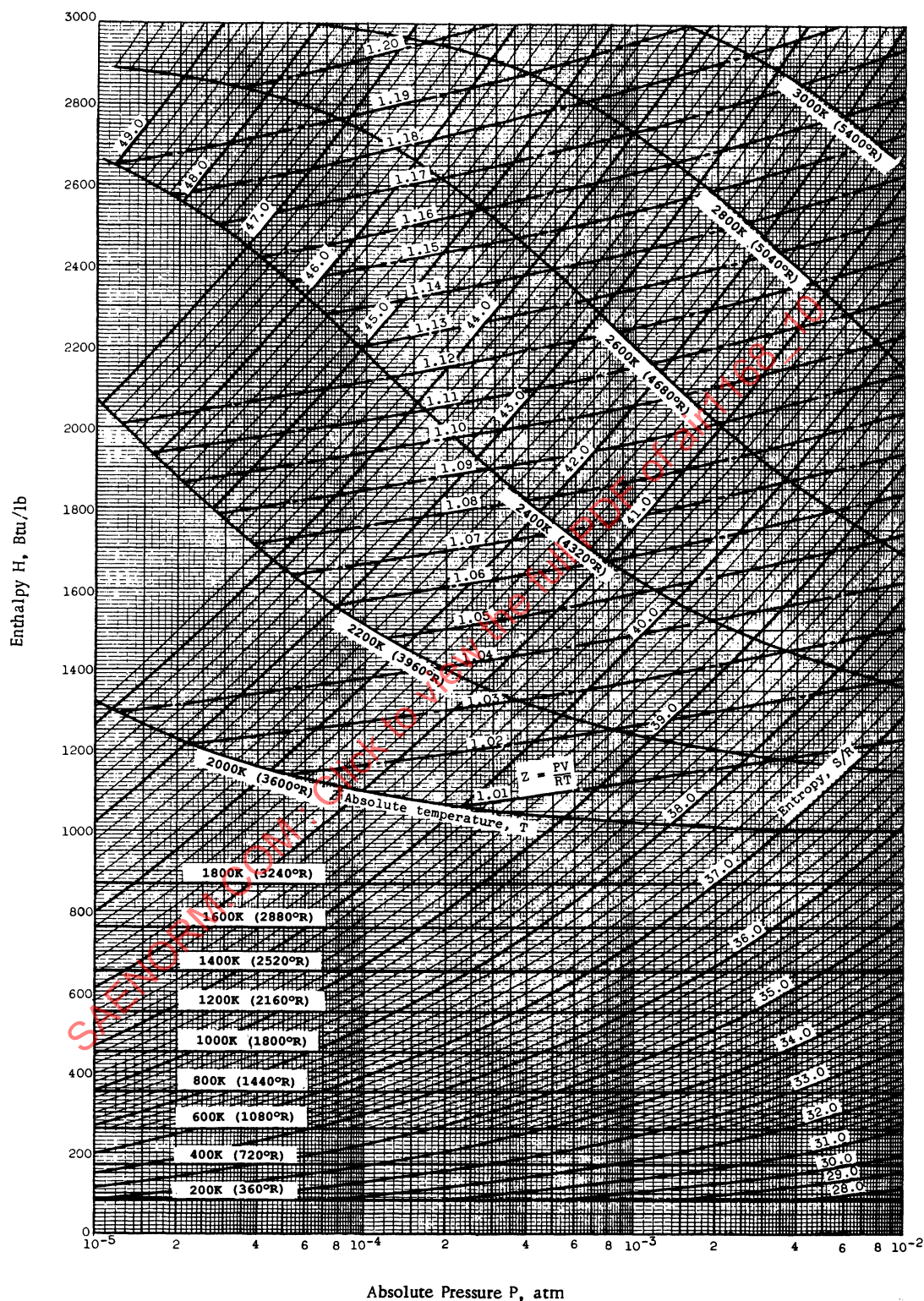


Figure 2E-2 - Chart 1 - Thermodynamic Chart For Air

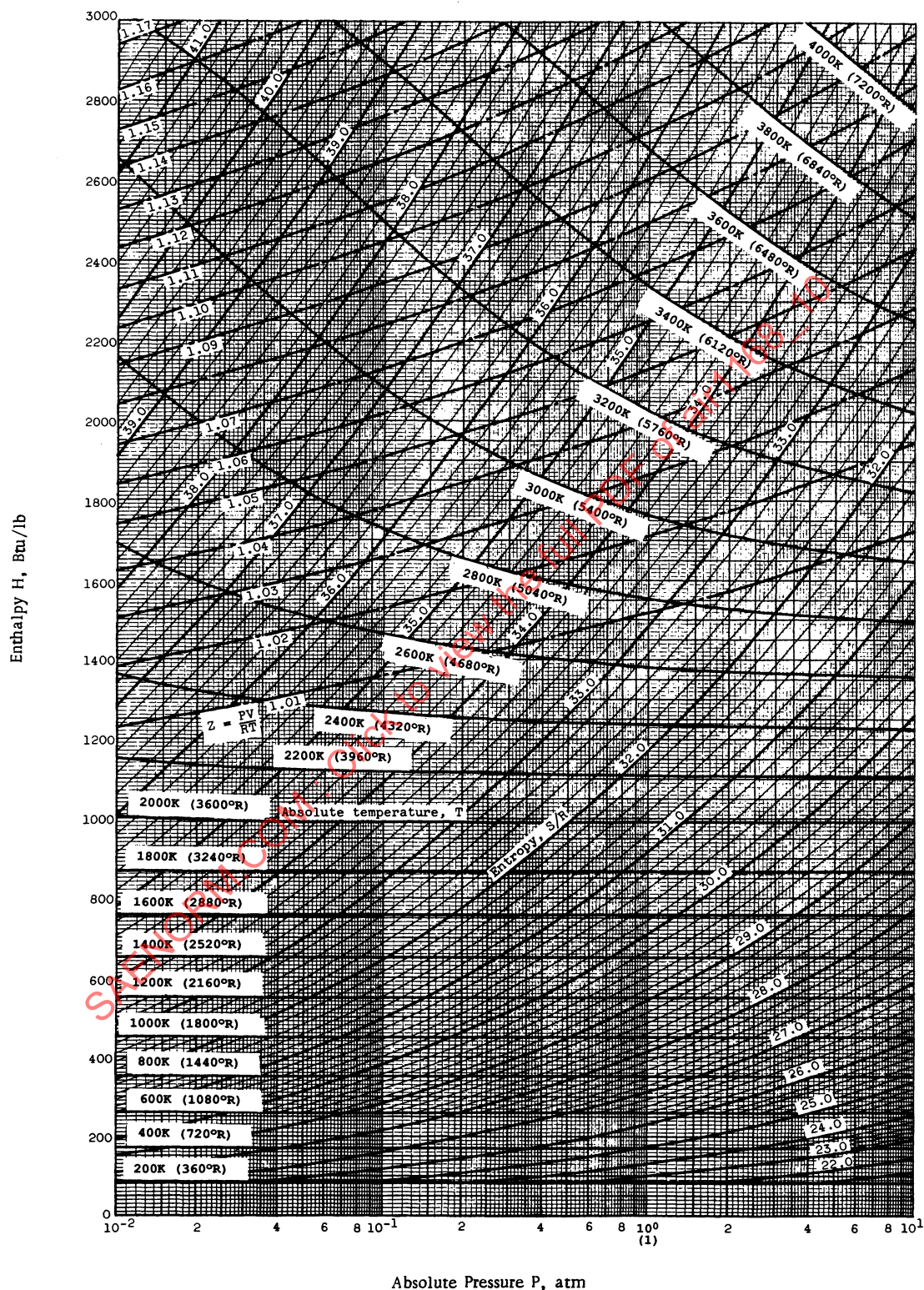


Figure 2E-3 - Chart 2 - Thermodynamic Chart For Air

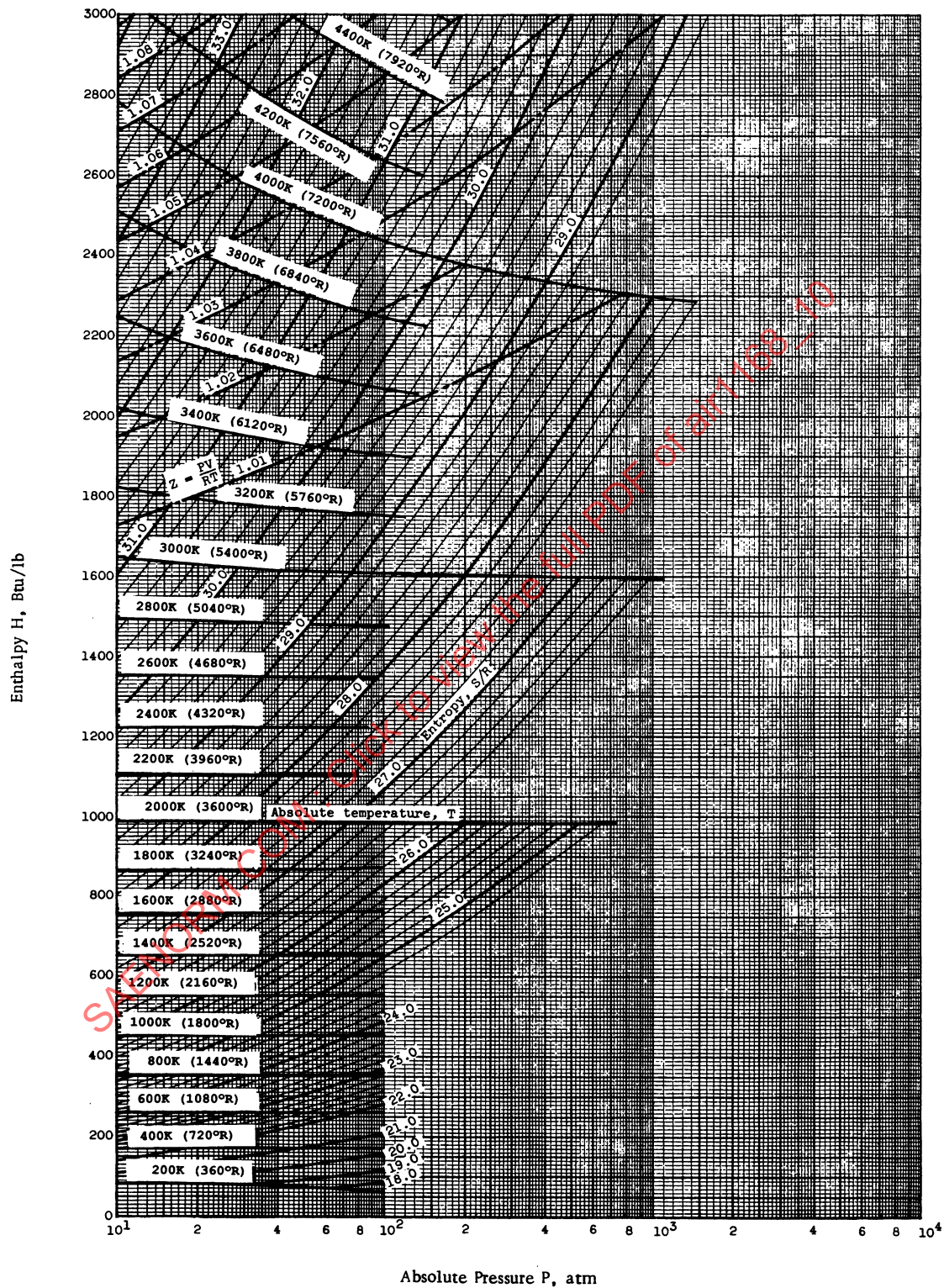
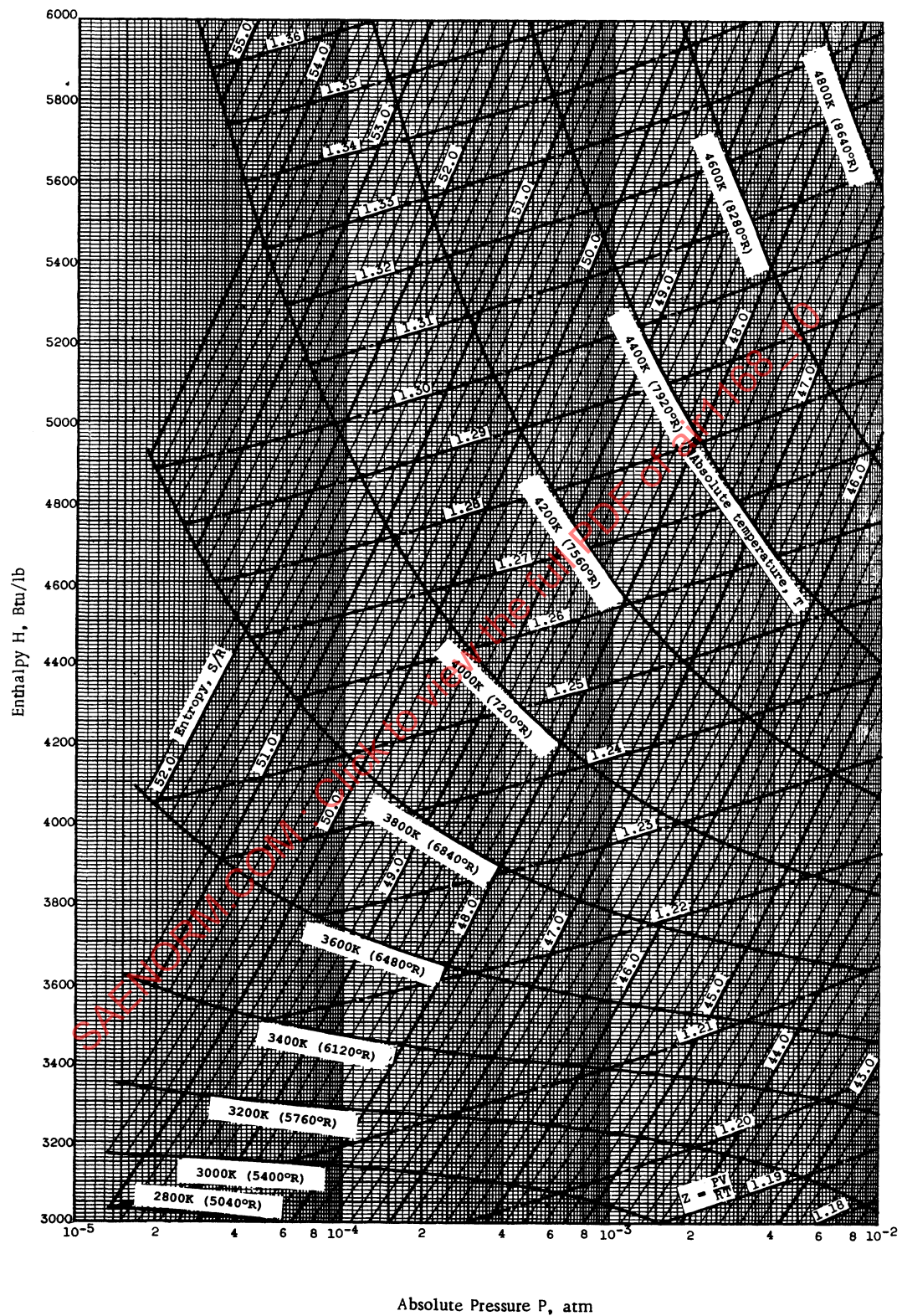
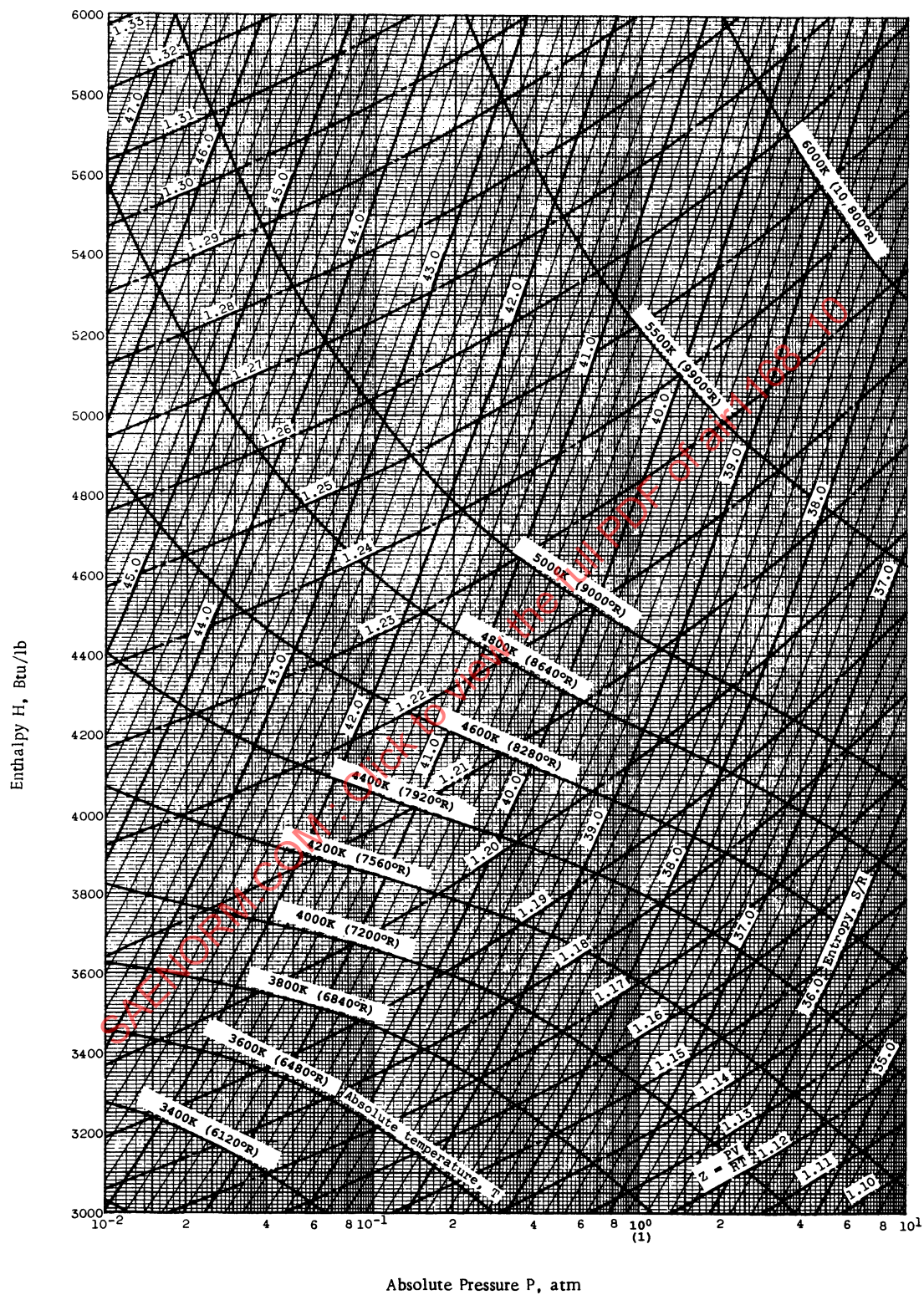


Figure 2E-4 - Chart 3 - Thermodynamic Chart For Air





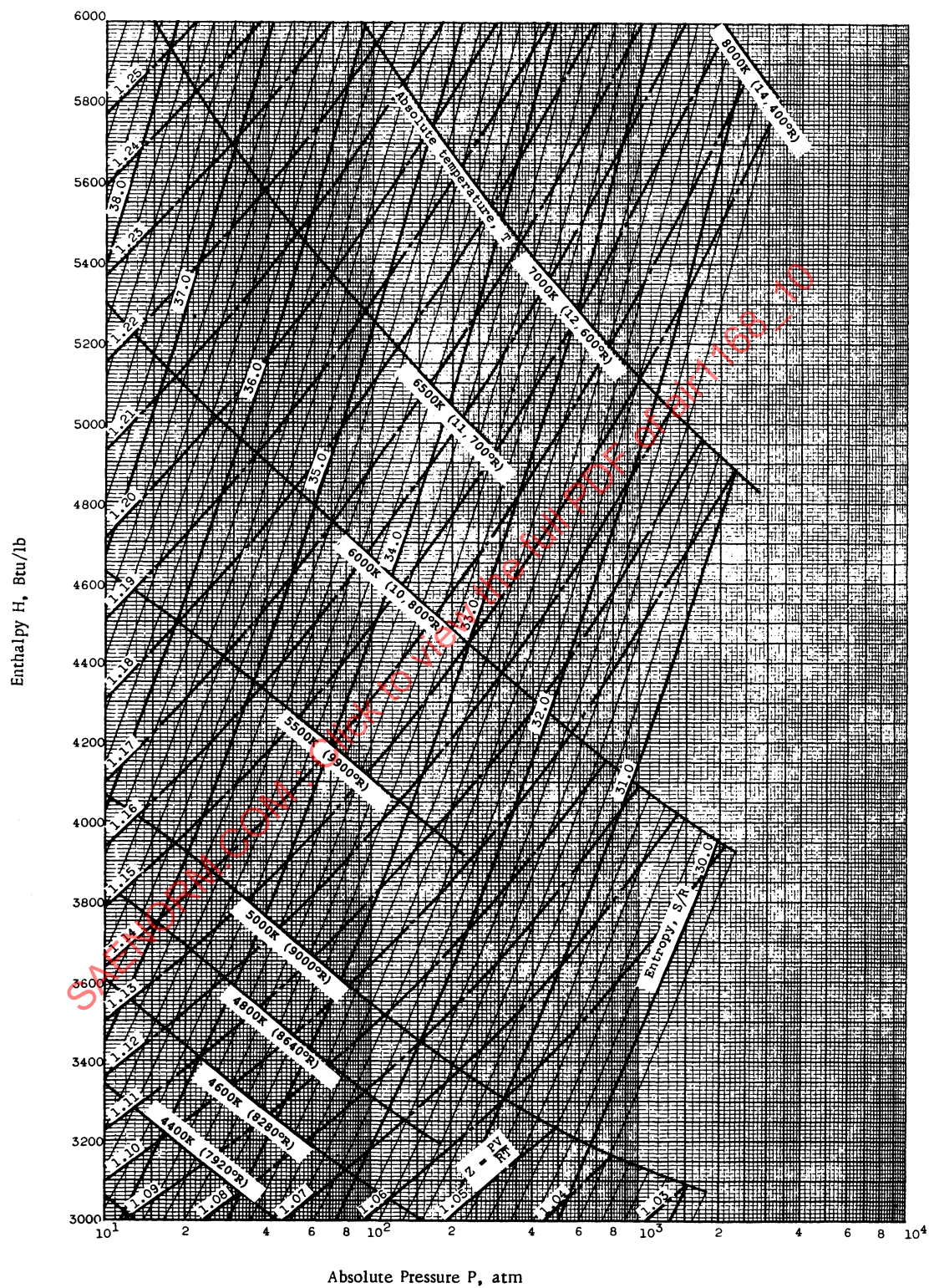


Figure 2E-7 - Chart 6 - Thermodynamic Chart For Air

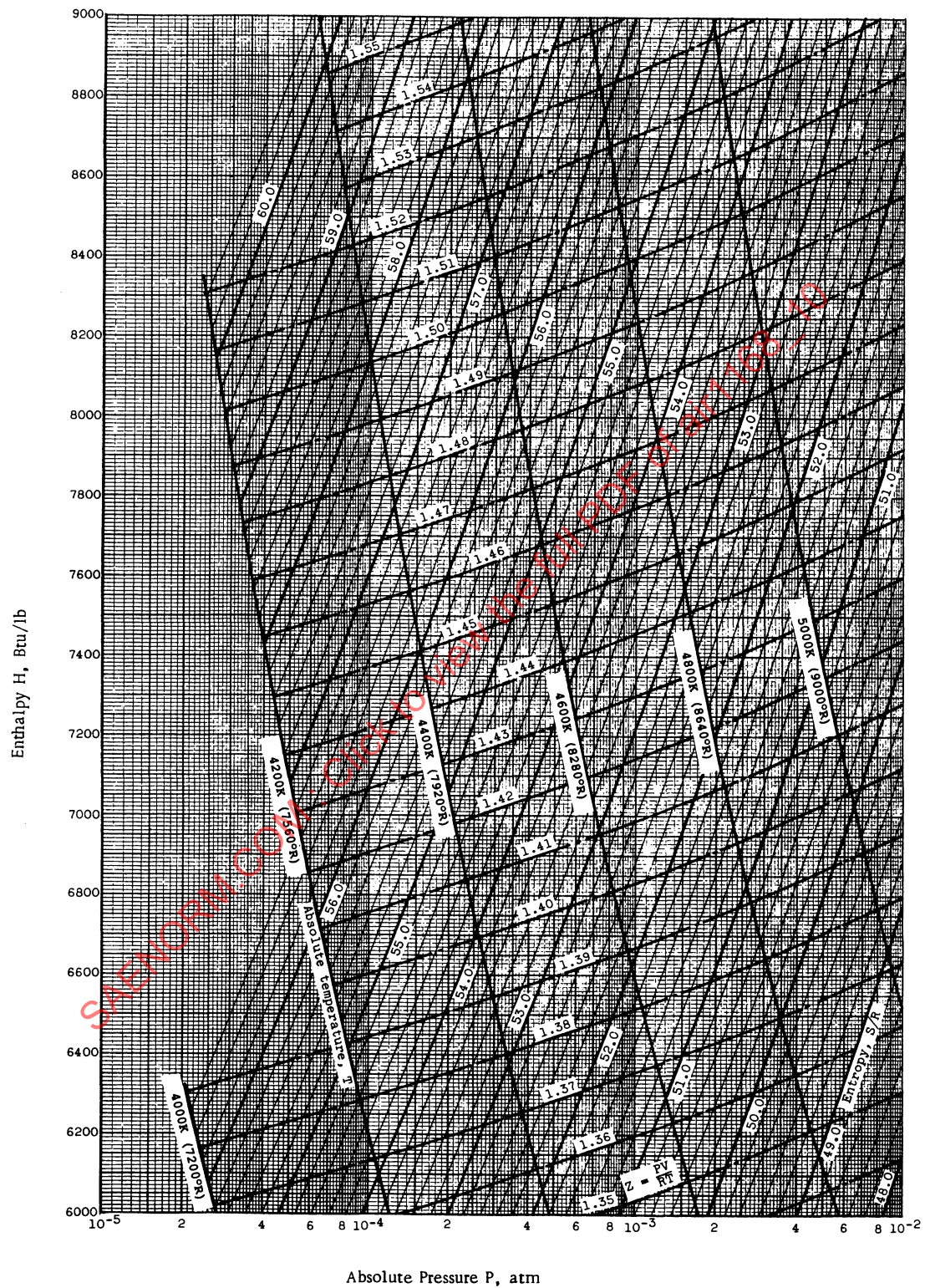


Figure 2E-8 - Chart 7 - Thermodynamic Chart For Air

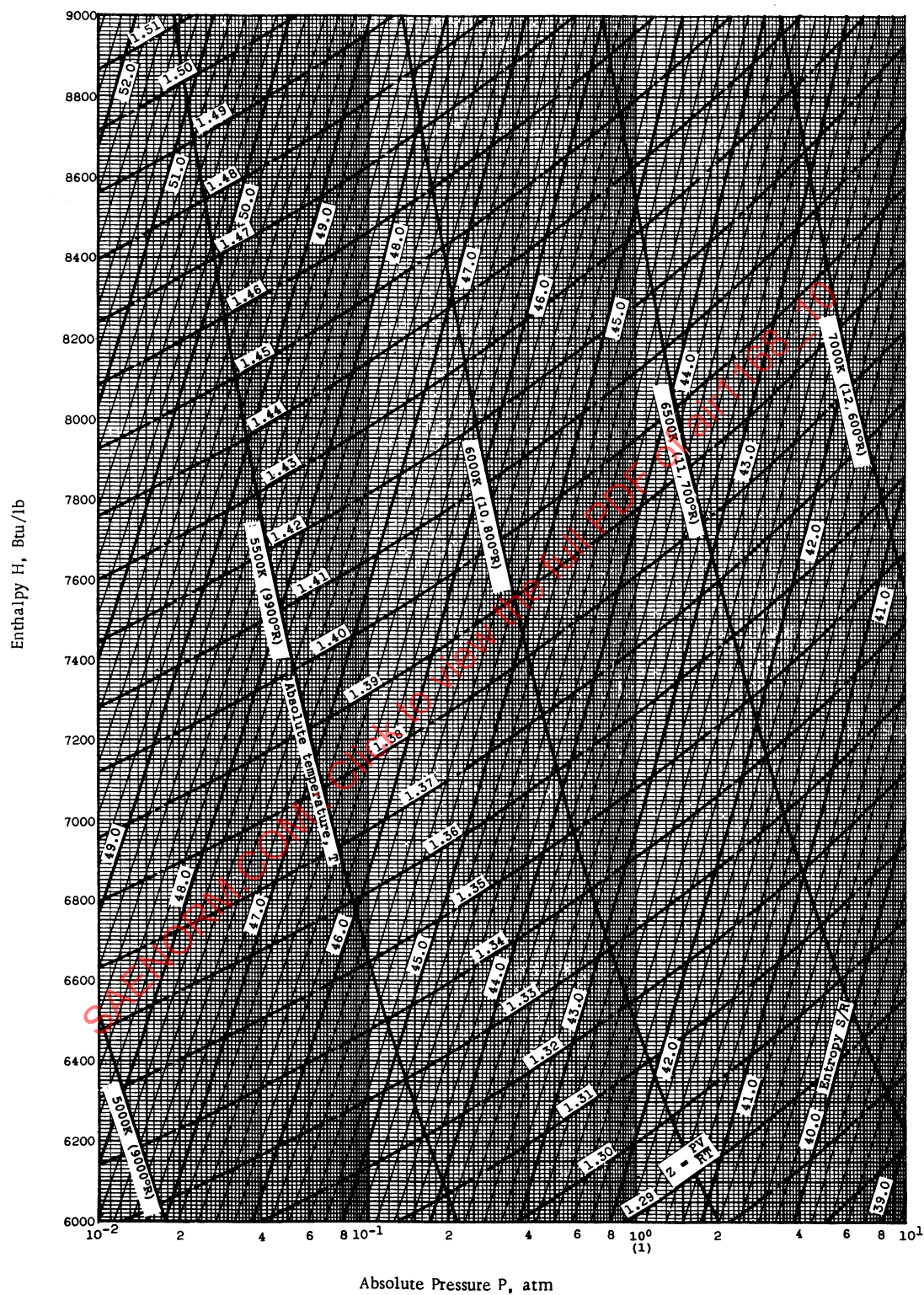


Figure 2E-9 - Chart 8 - Thermodynamic Chart For Air

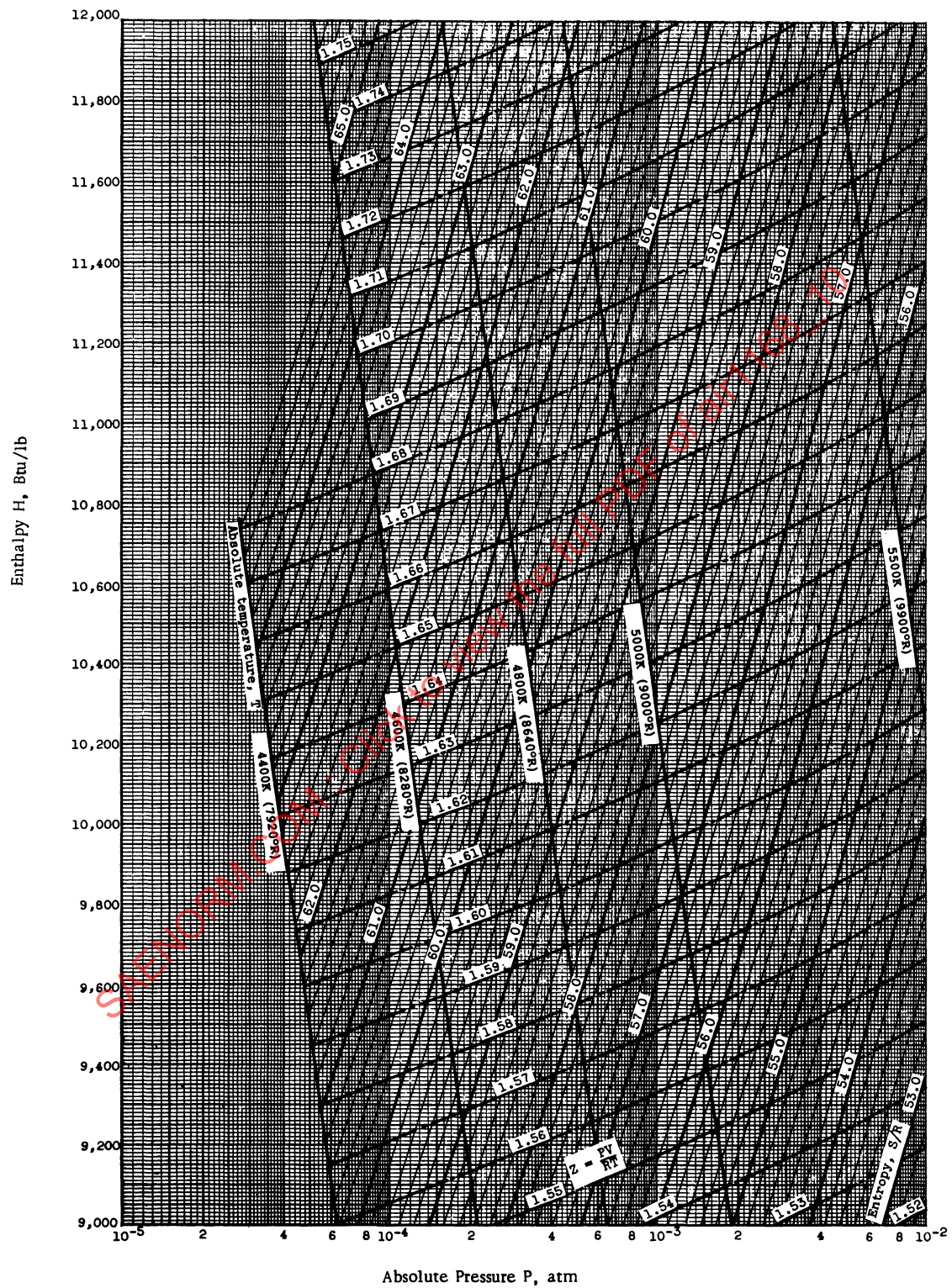


Figure 2E-10 - Chart 9 - Thermodynamic Chart For Air

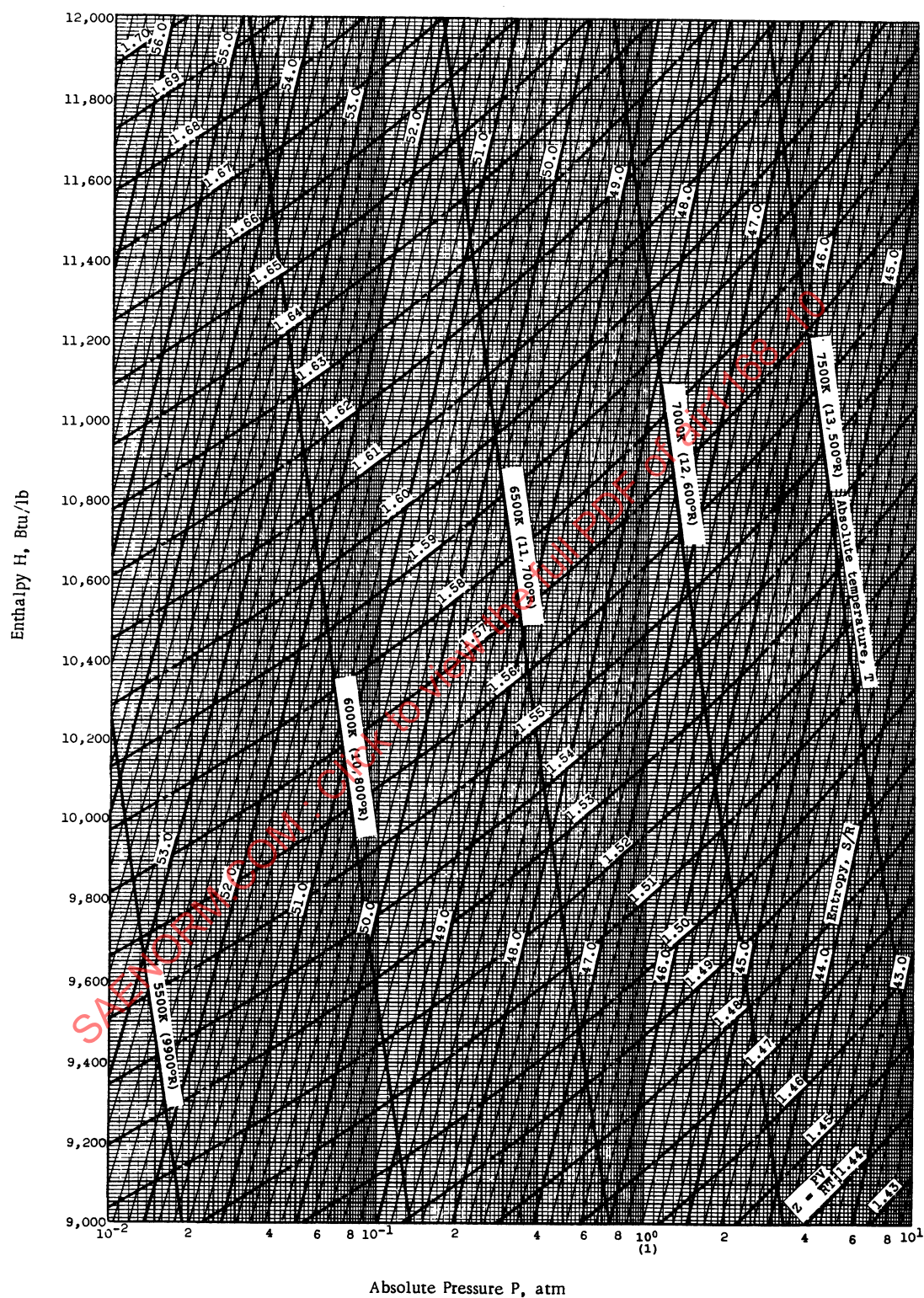


Figure 2E-11 - Chart 10 - Thermodynamic Chart For Air

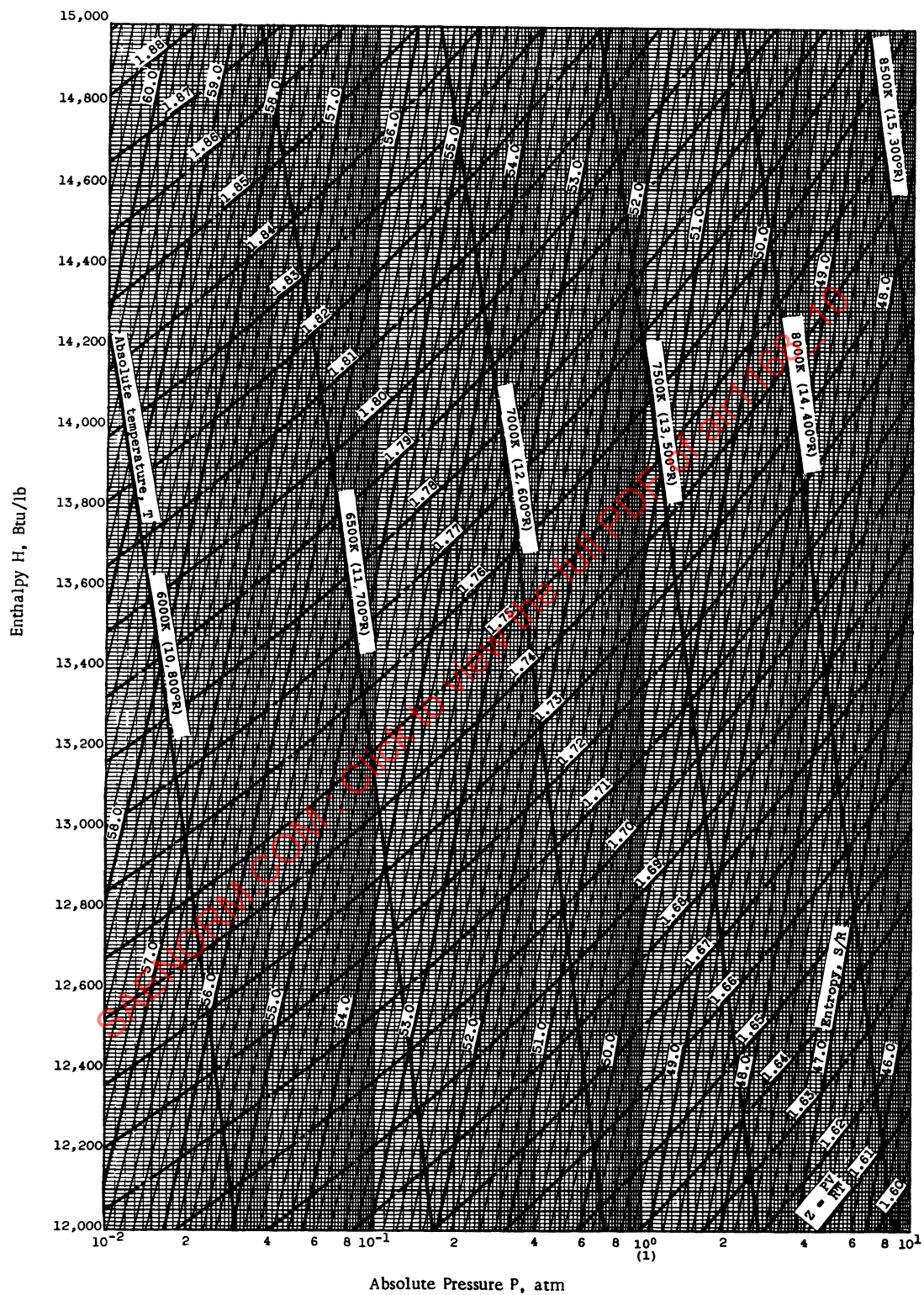


Figure 2E-12 - Chart 11 - Thermodynamic Chart For Air

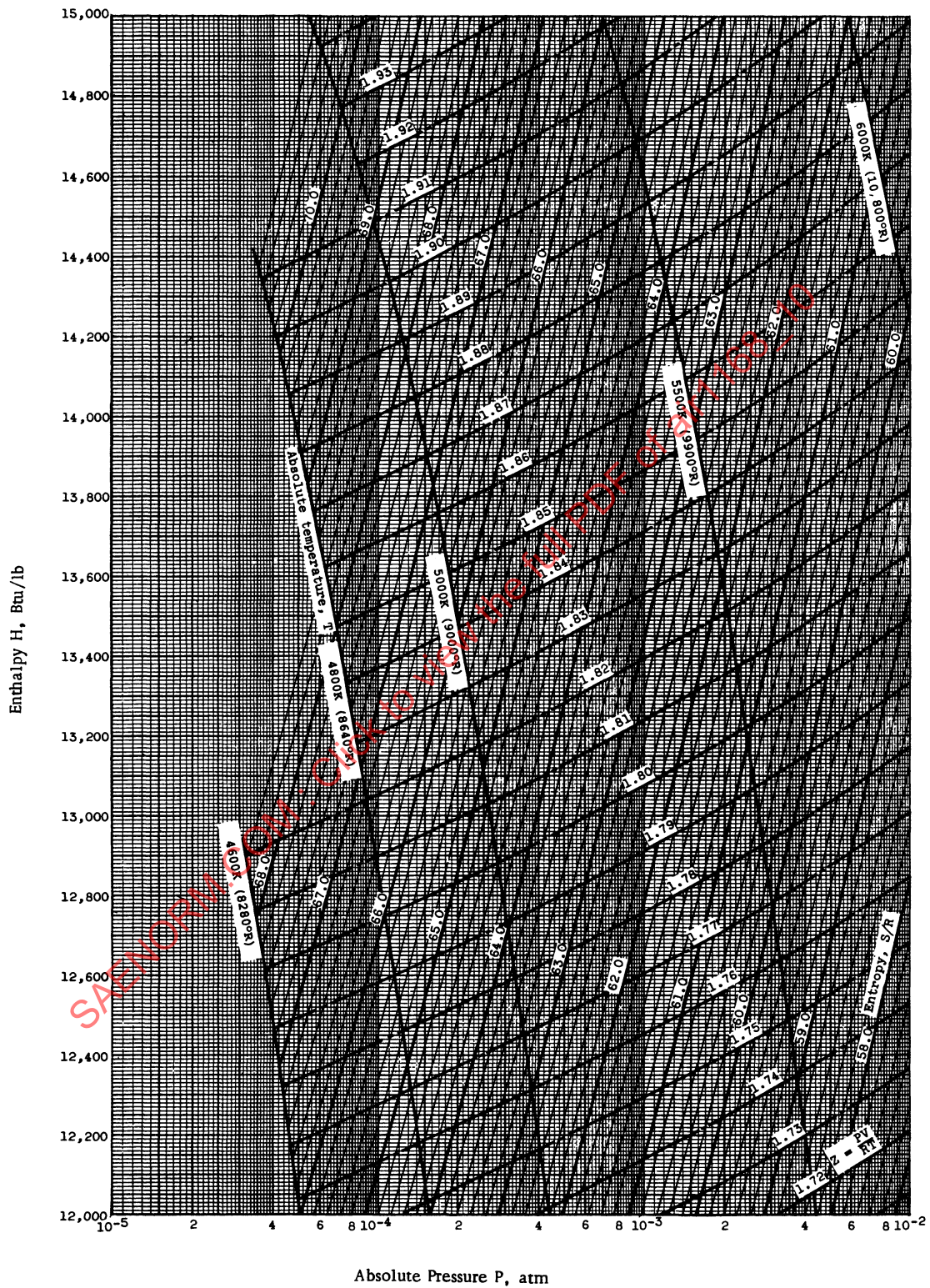


Figure 2E-13 - Chart 12 - Thermodynamic Chart For Air

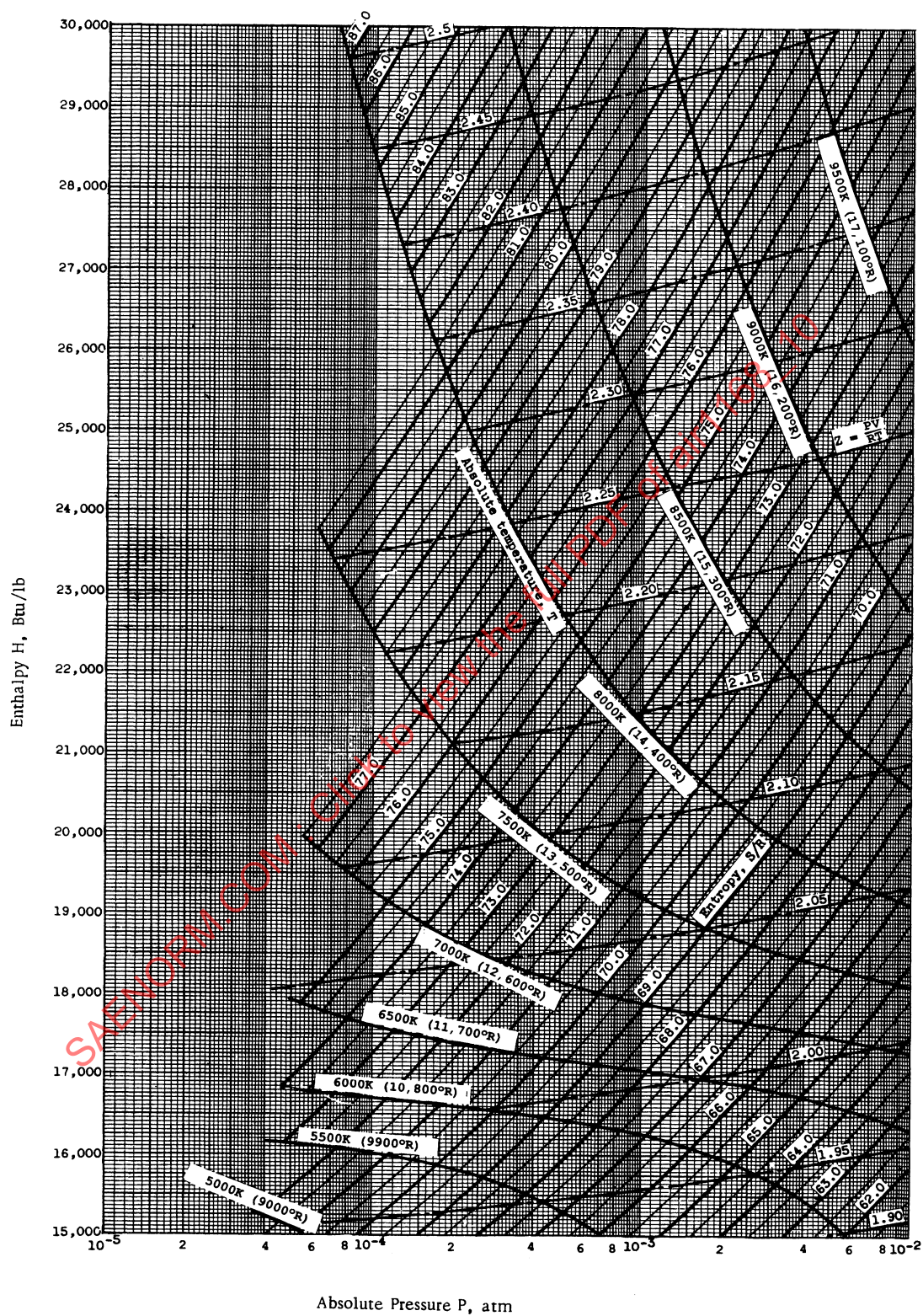


Figure 2E-14 - Chart 13 - Thermodynamic Chart For Air

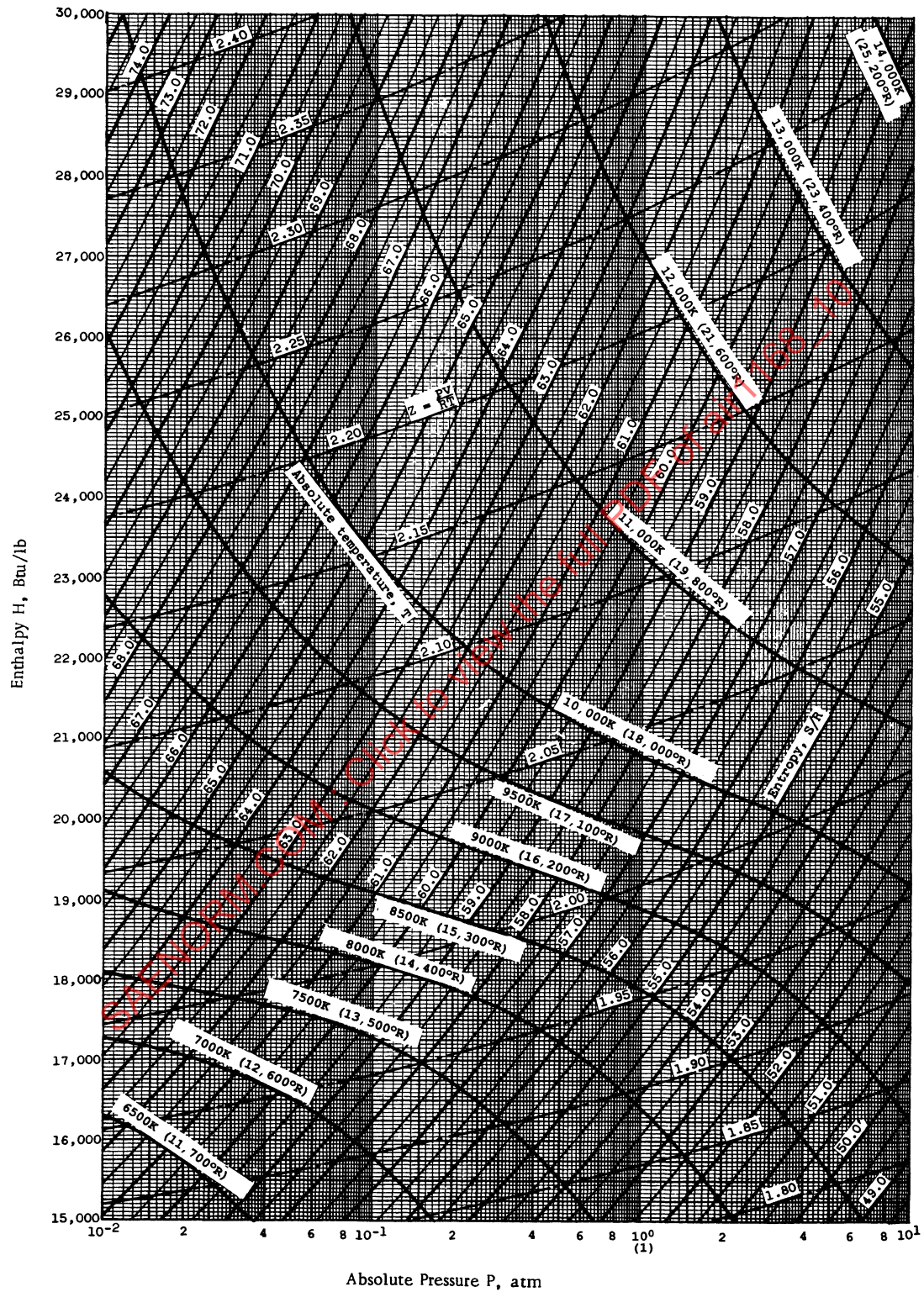


Figure 2E-15 - Chart 14 - Thermodynamic Chart For Air

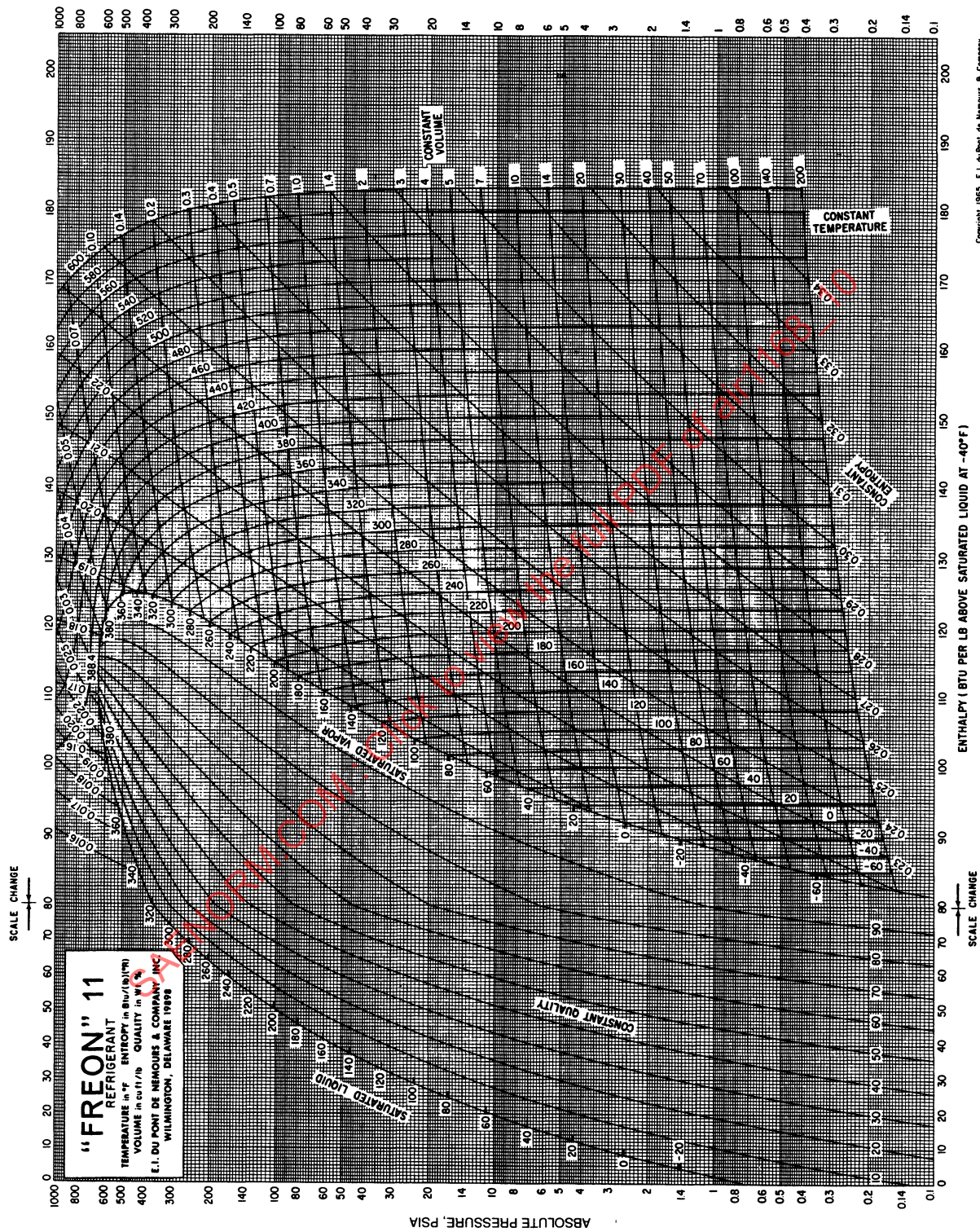


Figure 2E-16 - Pressure-enthalpy Diagram, Freon 11

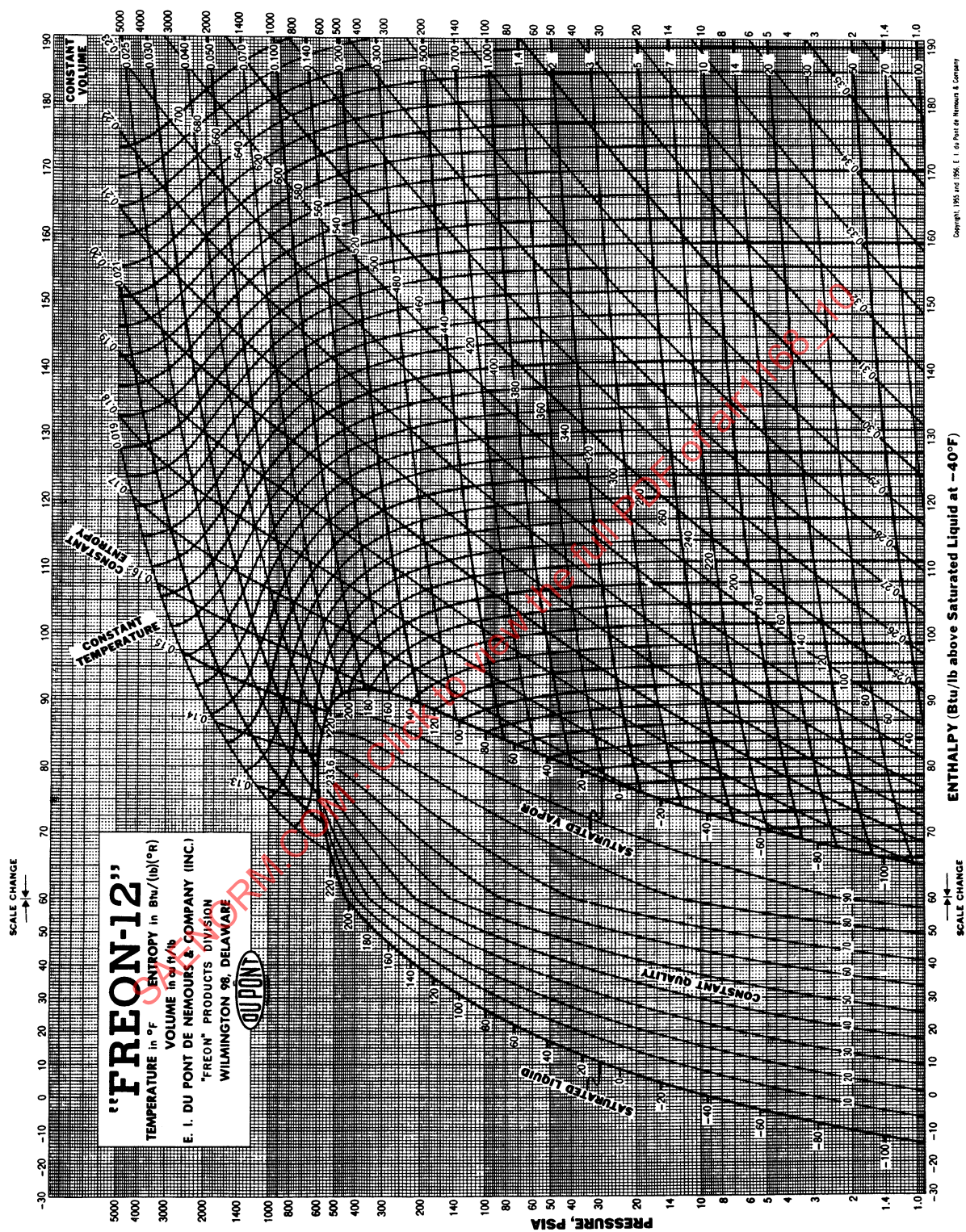


Figure 2E-17 - Pressure-enthalpy Diagram, Freon 12

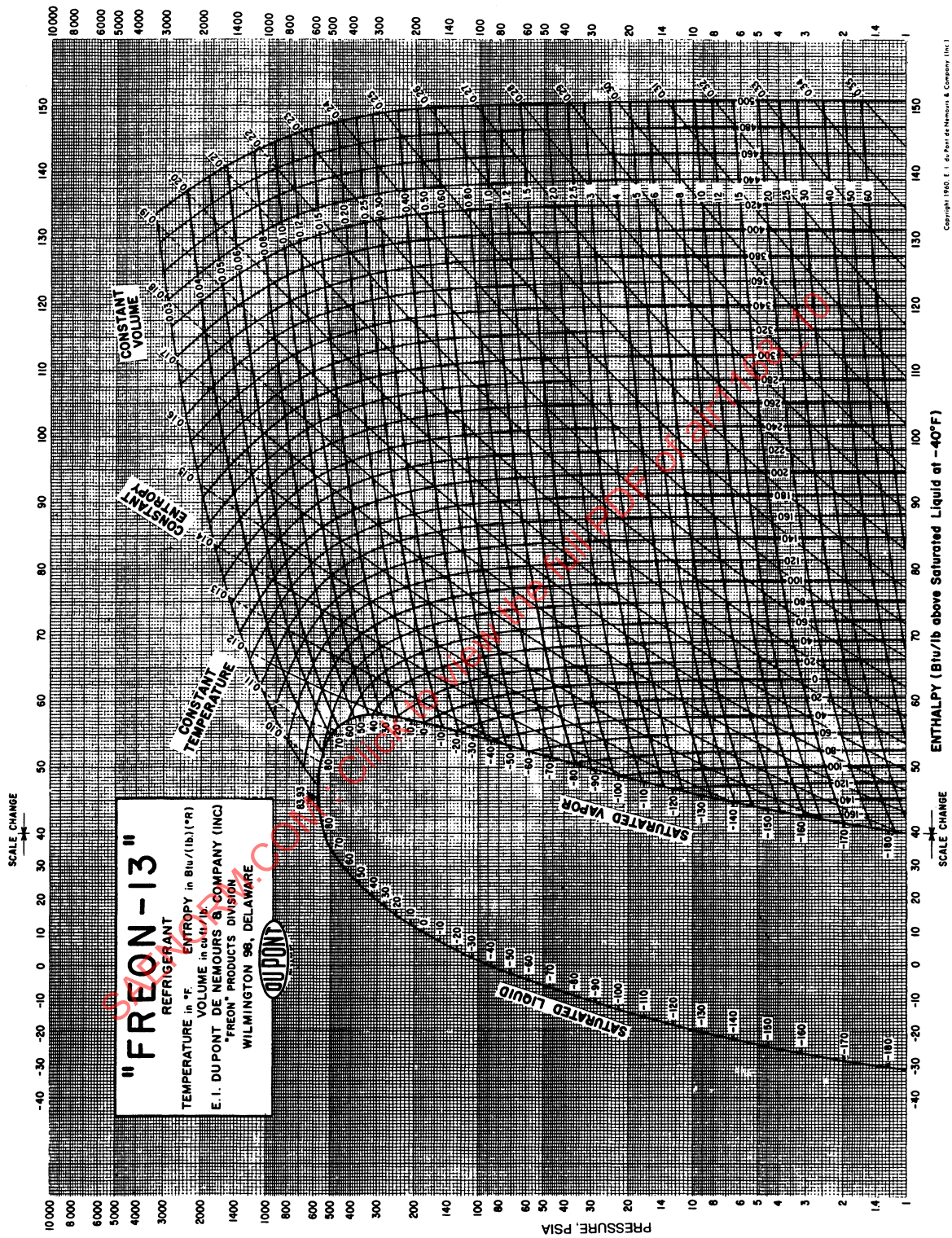


Figure 2E-18 - Pressure-enthalpy Diagram, Freon 13

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Figure 2E-19 - Pressure-enthalpy Diagram, Freon 14

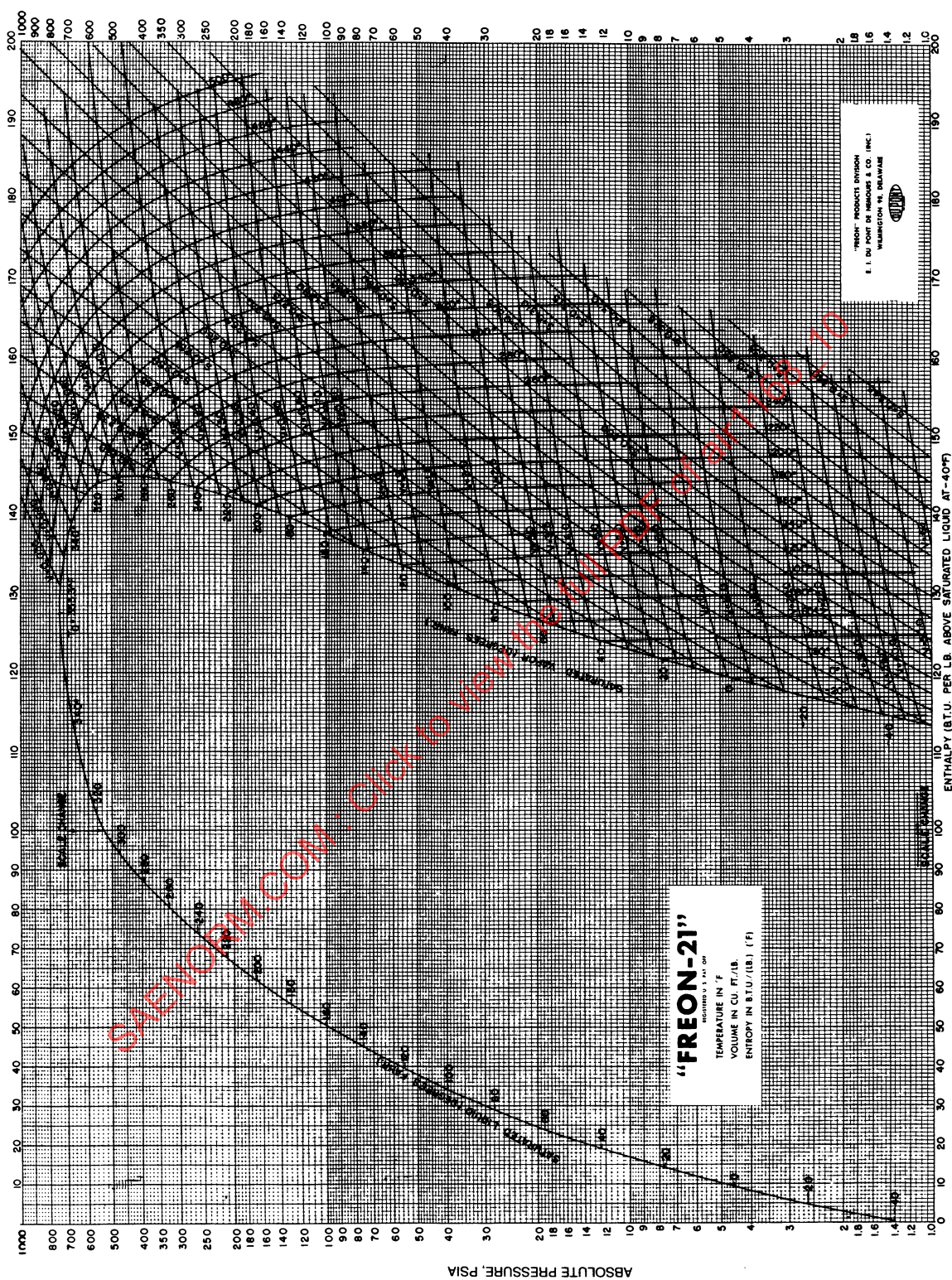


Fig. 2E-20—Pressure-enthalpy diagram, Freon 21

Figure 2E-20 - Pressure-enthalpy Diagram, Freon 21

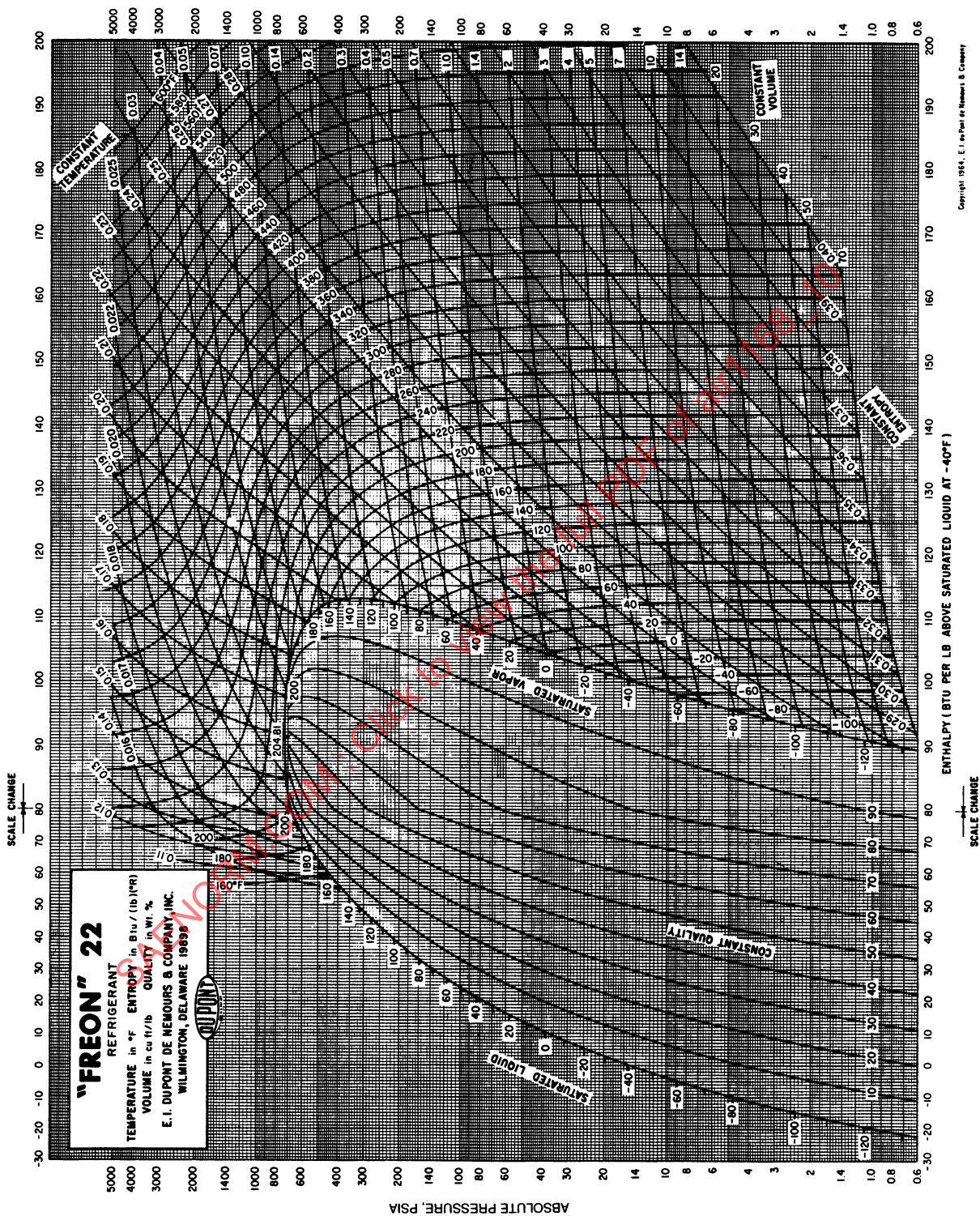


Figure 2E-21 - Pressure-enthalpy Diagram, Freon 22

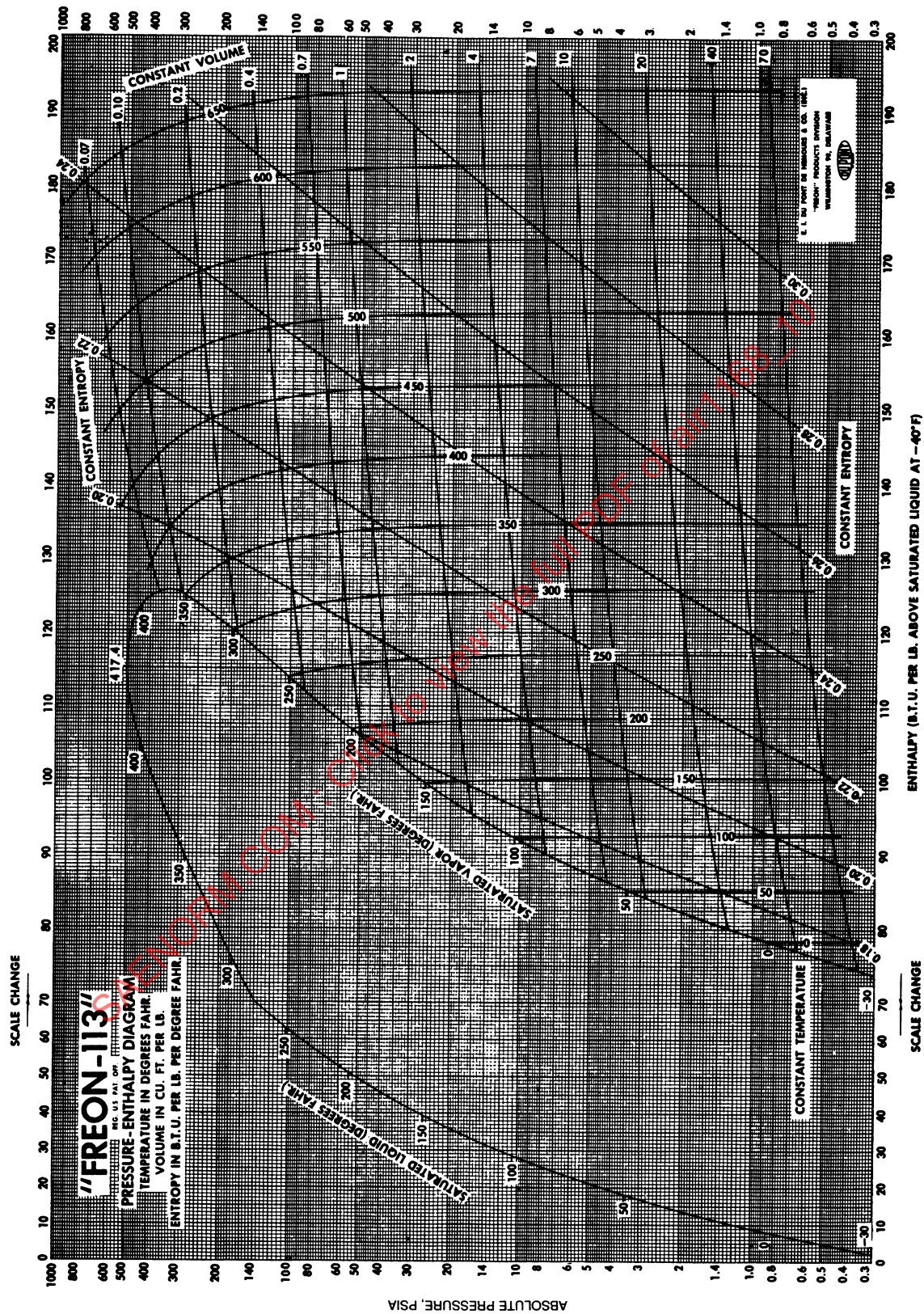


Figure 2E-22 - Pressure-enthalpy Diagram, Freon 113

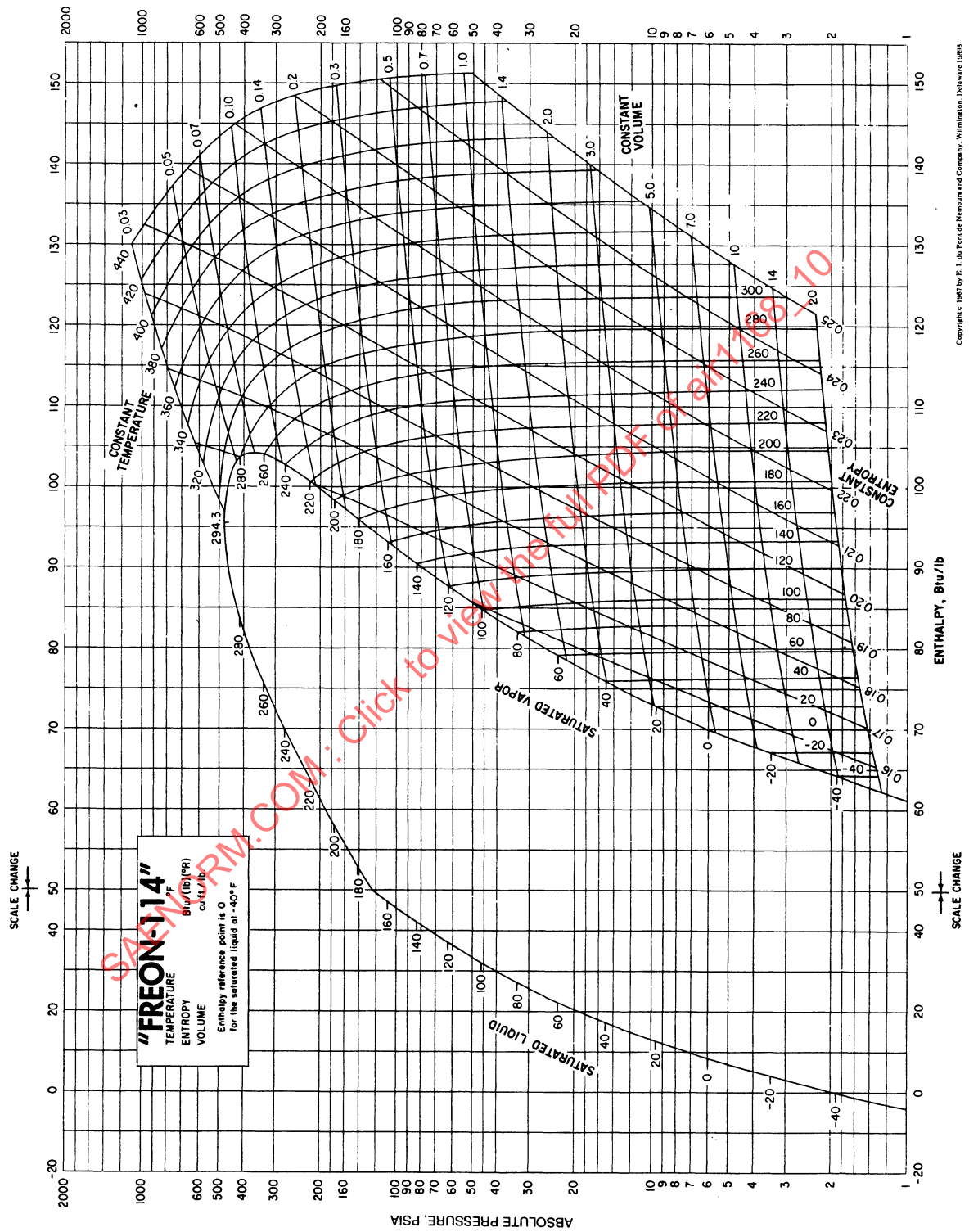


Figure 2E-23 - Pressure-enthalpy Diagram, Freon 114

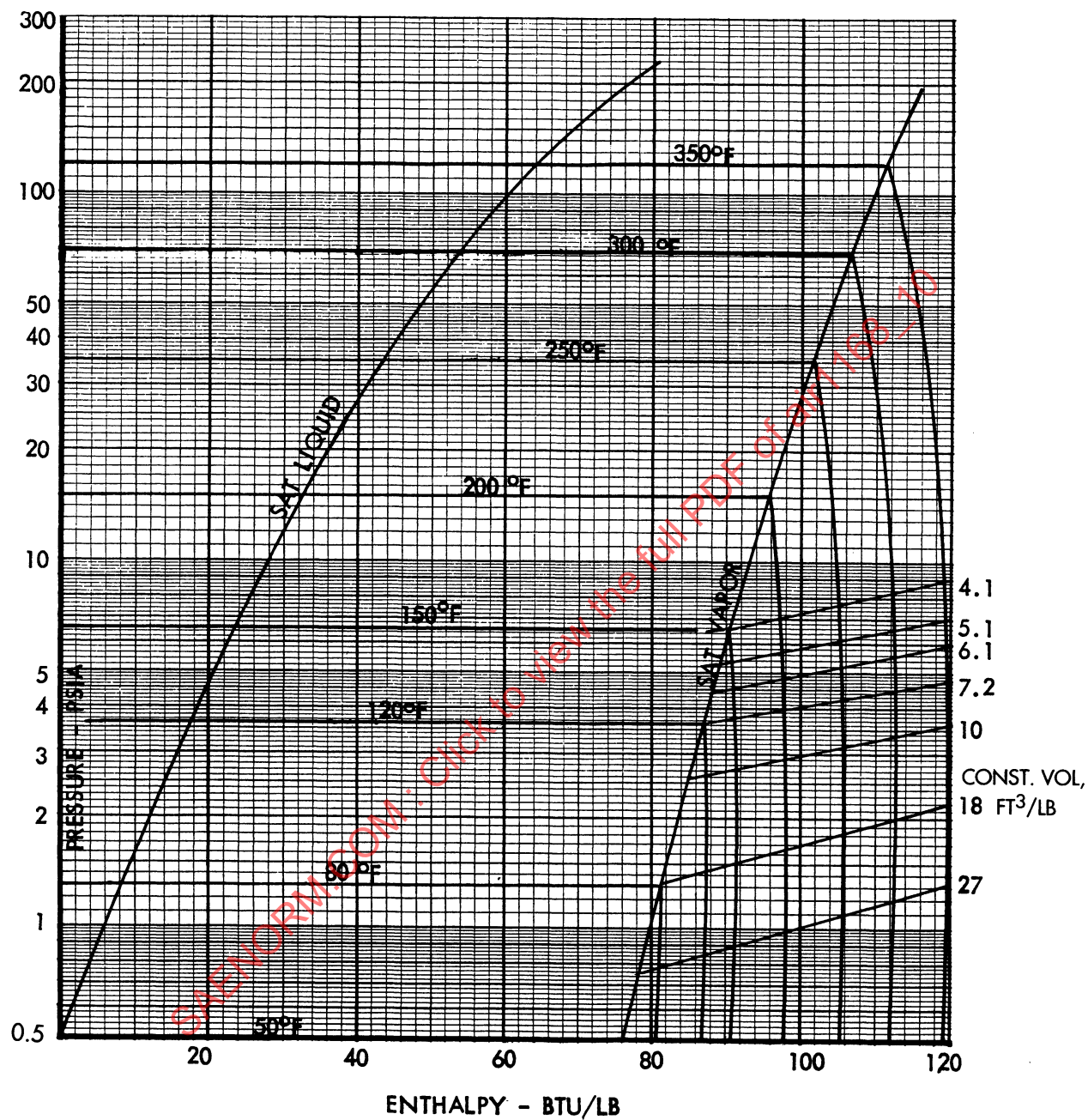


Figure 2E-24 - Estimated Thermodynamic Properties of
 1-2-Dichlorohexafluorocyclopentene-1;
 Estimated $P_{cr} = 480$ psia, Estimated $t_{cr} = 512^{\circ}\text{F}$

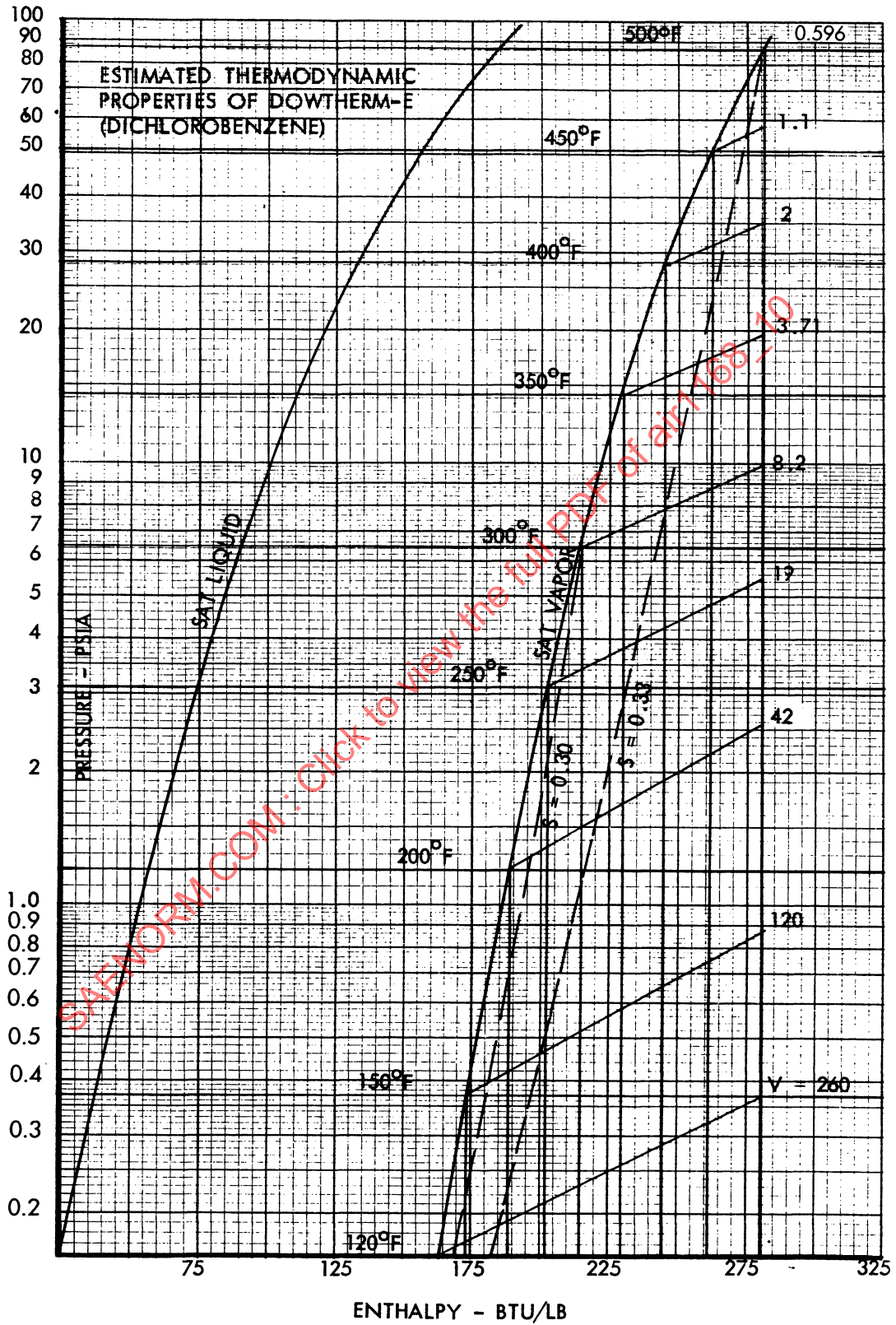


Figure 2E-25 - Estimated Thermodynamic Properties of Dowtherm E (Dichlorobenzene)

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3. SECTION 2F - PROPERTIES OF HEAT TRANSFER FLUIDS

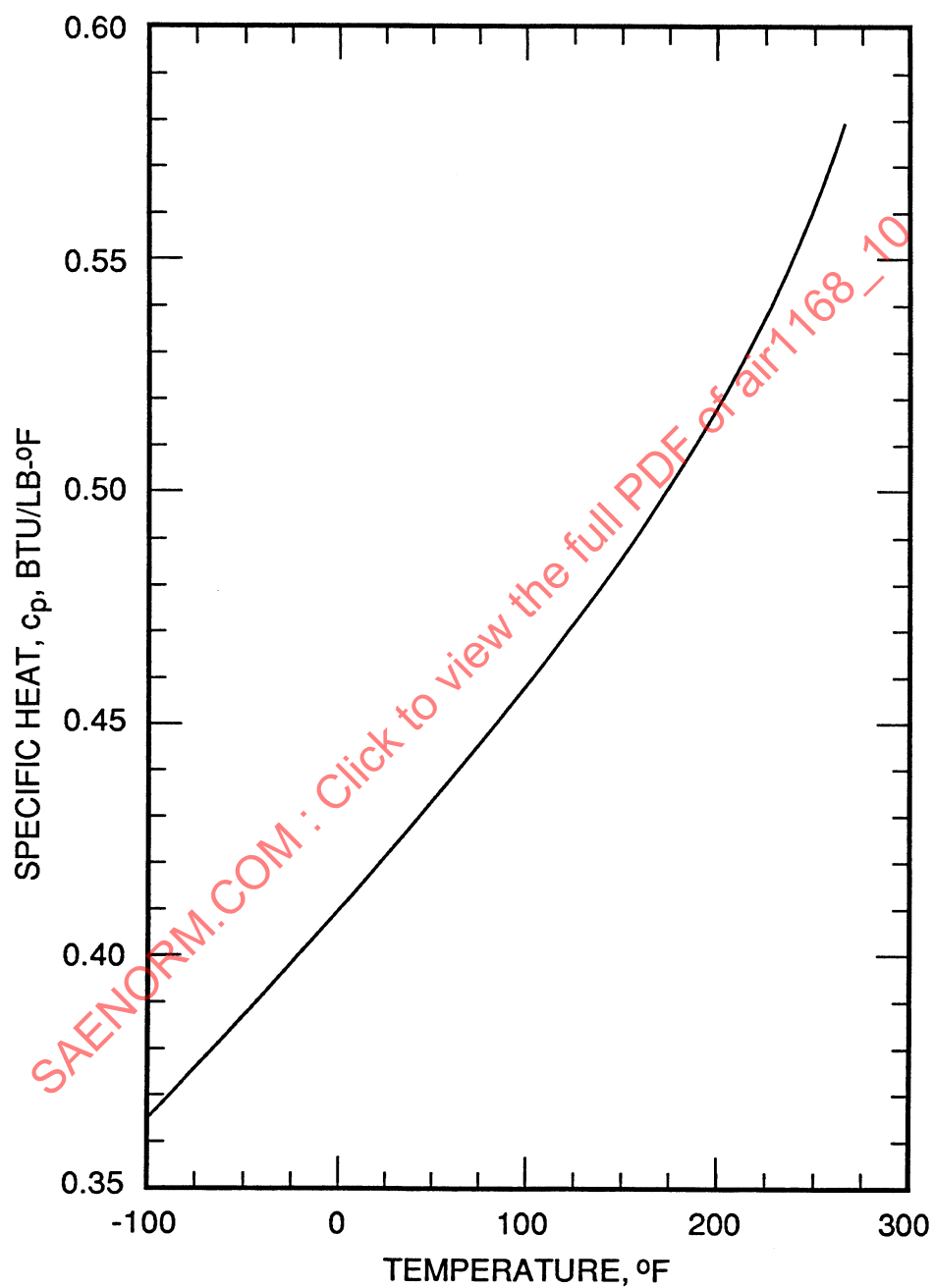


Figure 2F-1 - Coolanol 25 Property c_p (Ref.1)

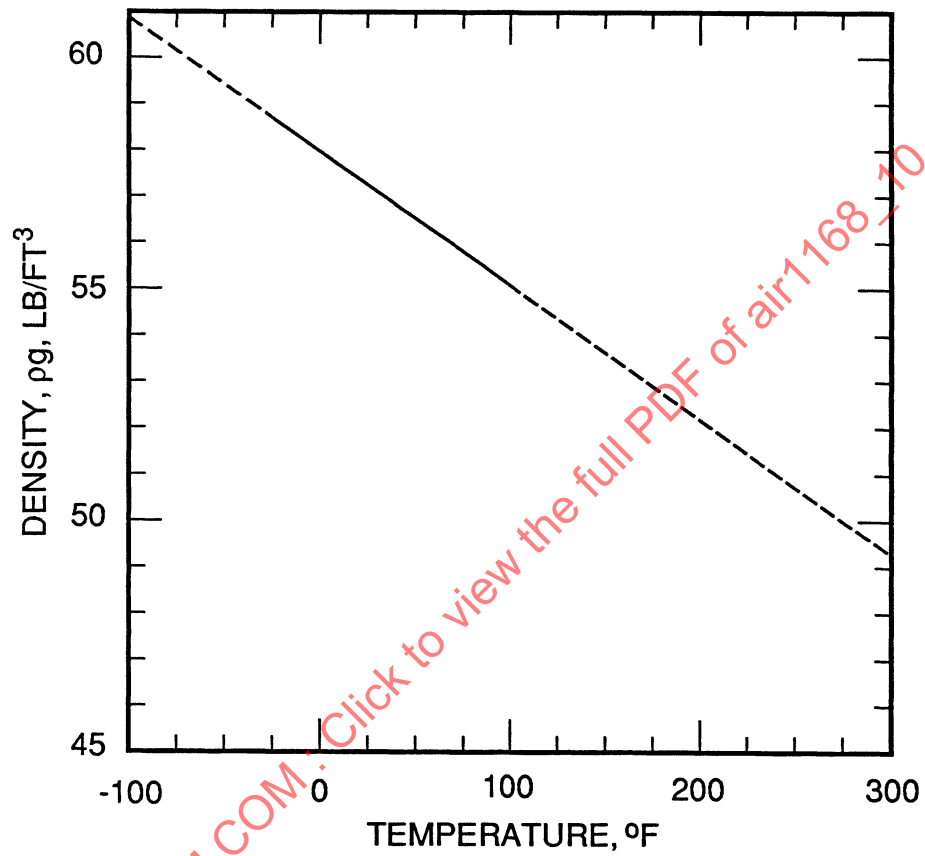


Figure 2F-2 - Coolanol 25 Property ρ_g (Ref.1)

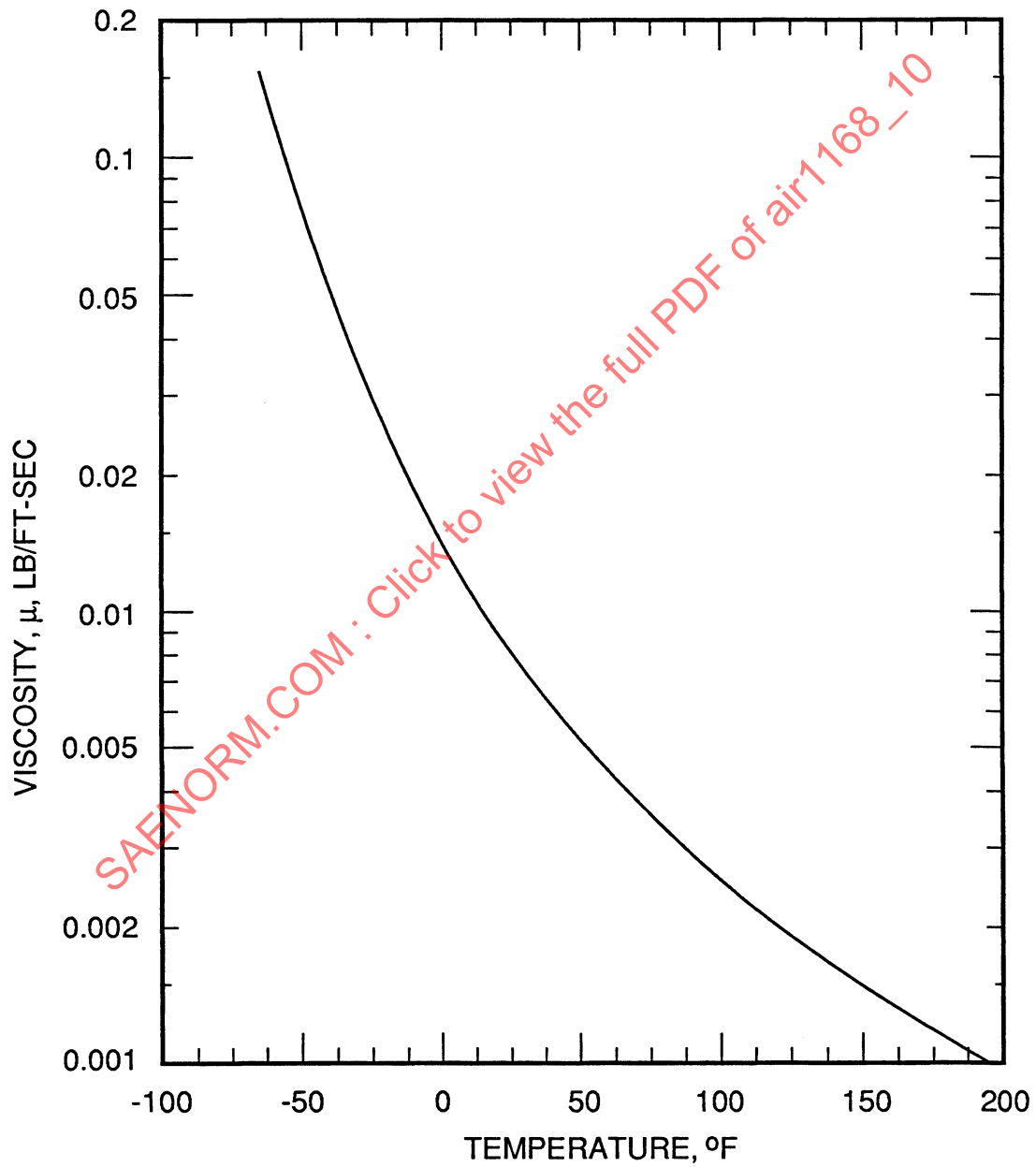


Figure 2F-3 - Coolanol 25 Property μ (Ref.11)

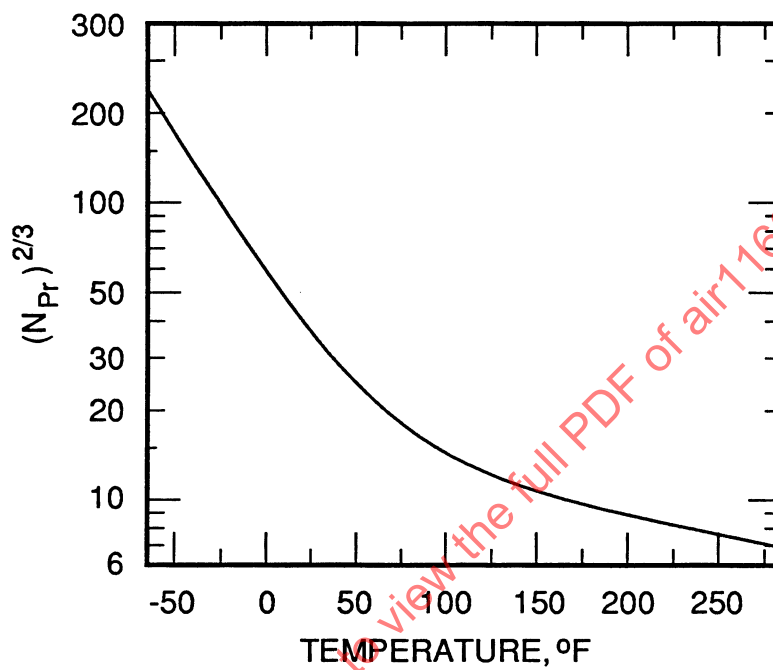


Figure 2F-4 - Coolanol 25 Property $(N_{Pr})^{2/3}$ (Ref.1)

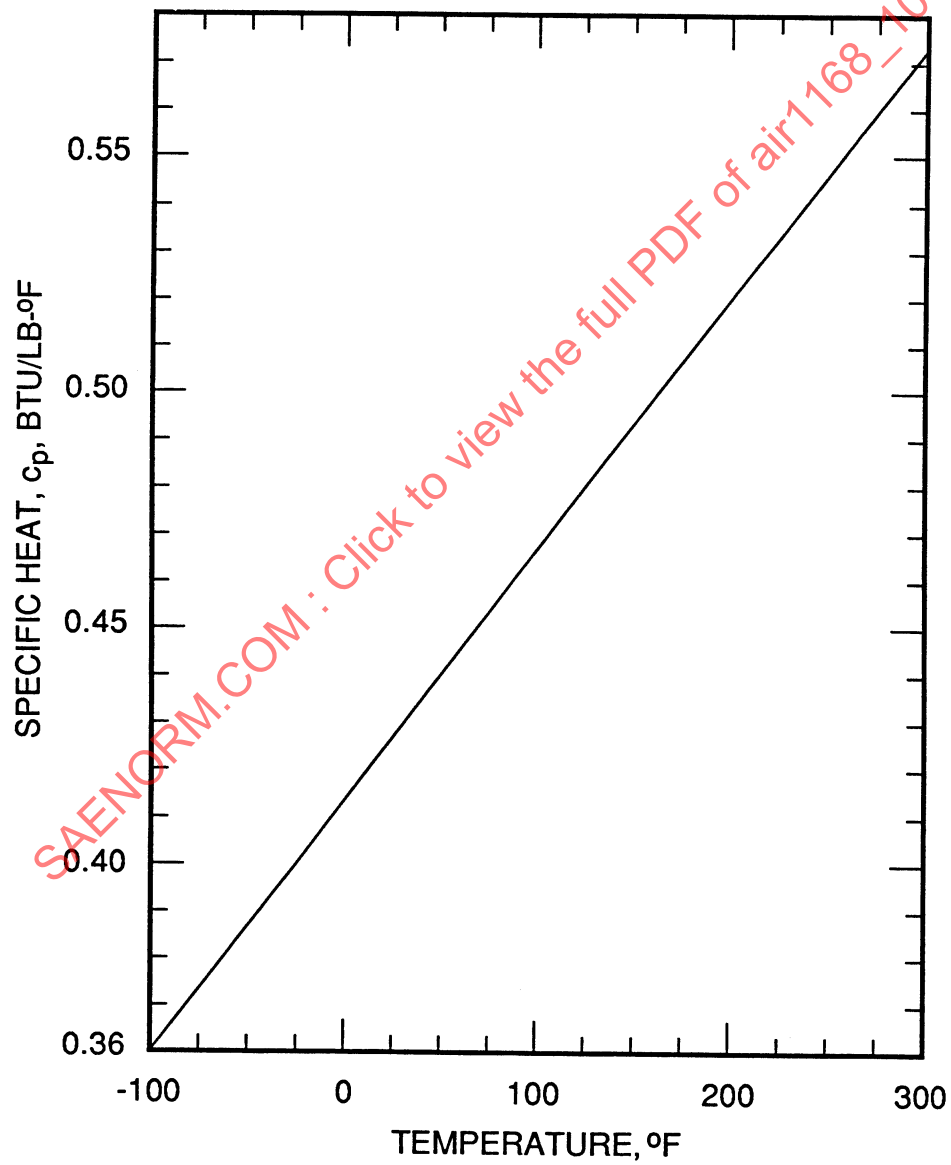


Figure 2F-5 - Coolanol 35 Property c_p (Ref.1)

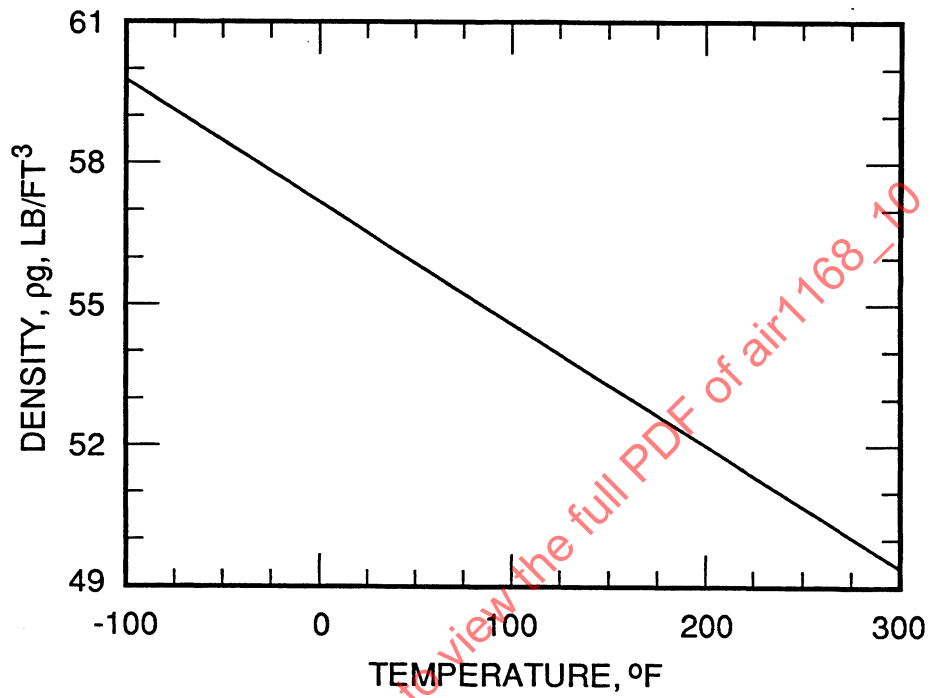


Figure 2F-6 - Coolanol 35 Property ρ_g (Ref.1)

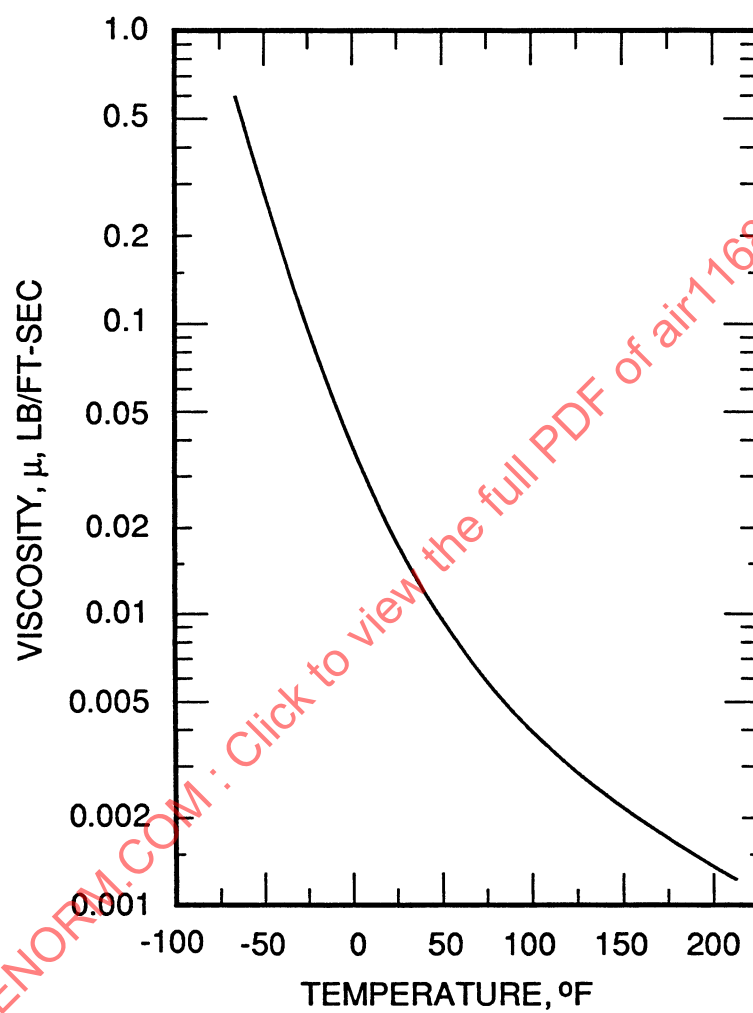


Figure 2F-7 - Coolanol 35 Property μ (Ref. 11)

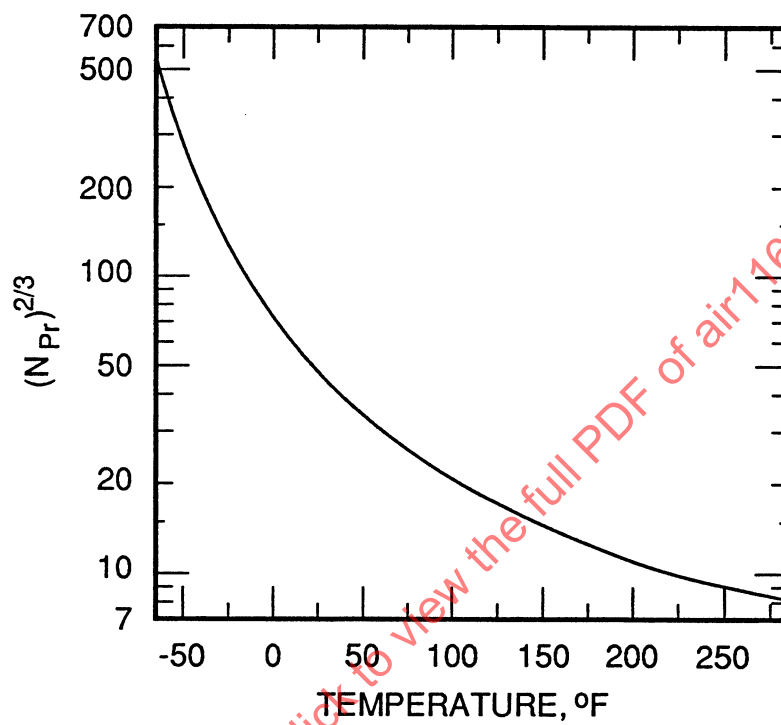


Figure 2F-8 - Coolanol 35 Property $(N_{Pr})^{2/3}$ (Ref.1)

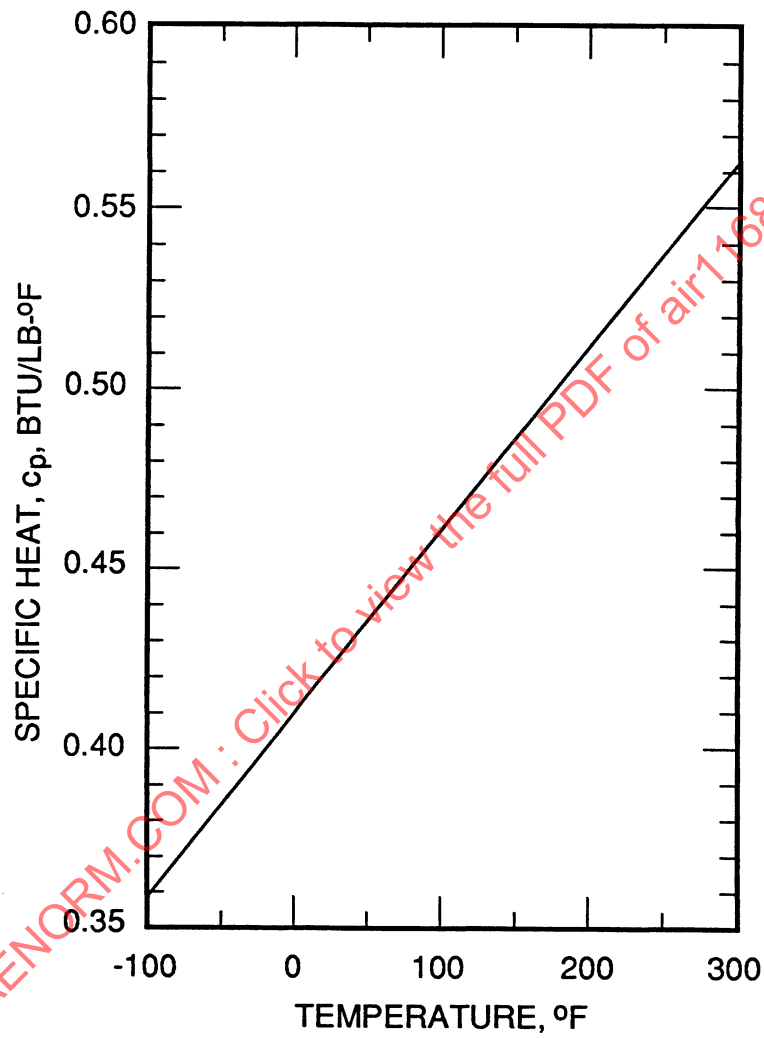


Figure 2F-9 - Coolanol 45 Property c_p (Ref.1)

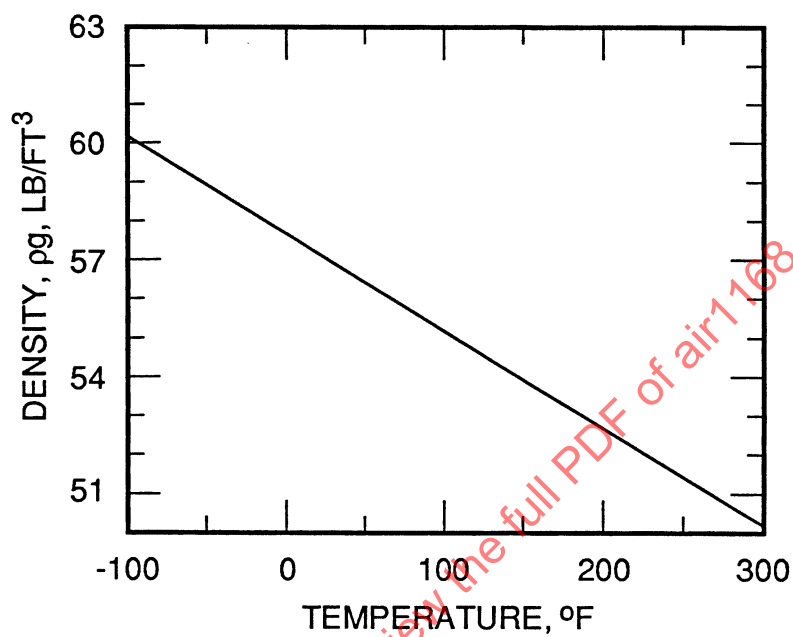


Figure 2F-10 - Coolanol 45 Property ρ_g (Ref.1)

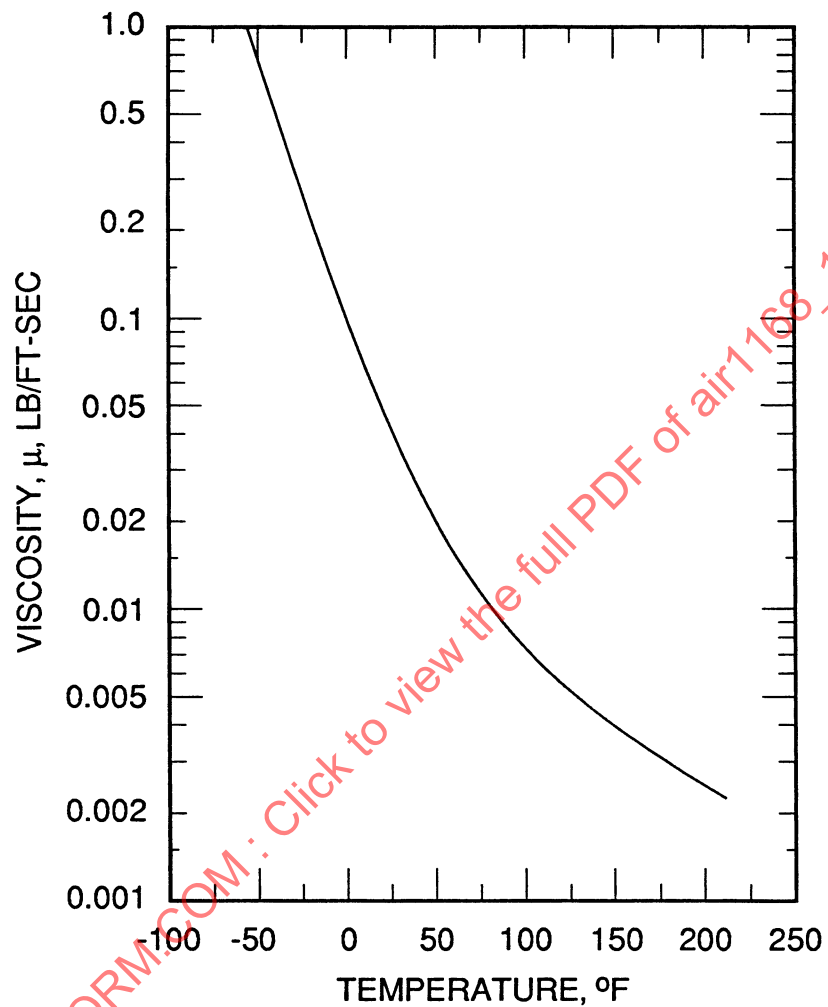


Figure 2F-11 - Coolanol 45 Property μ (Ref.11)

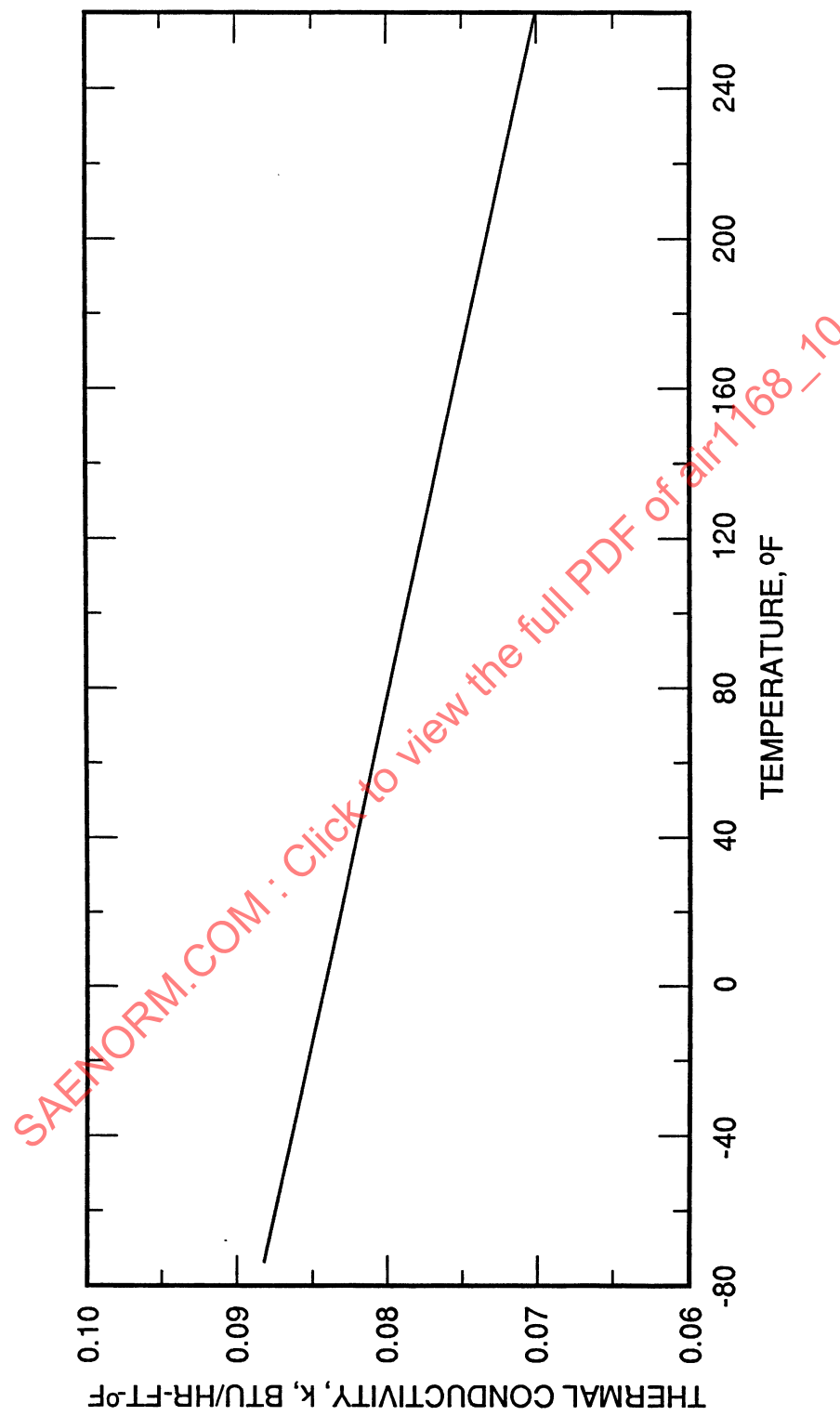
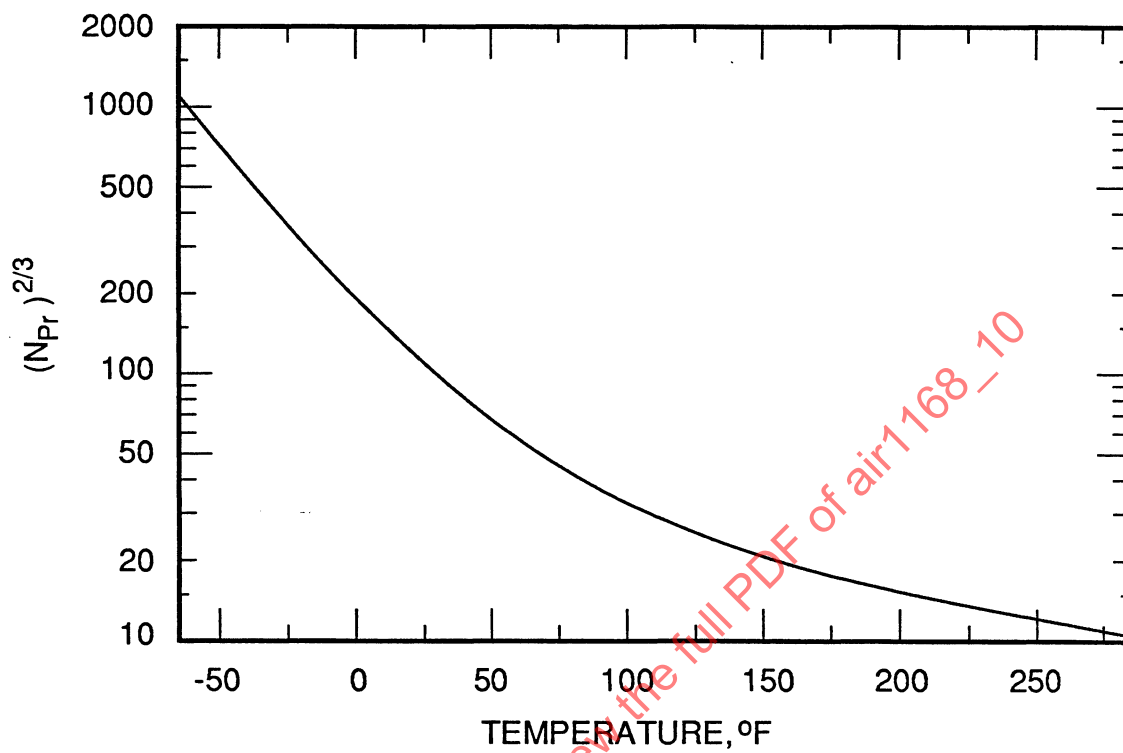
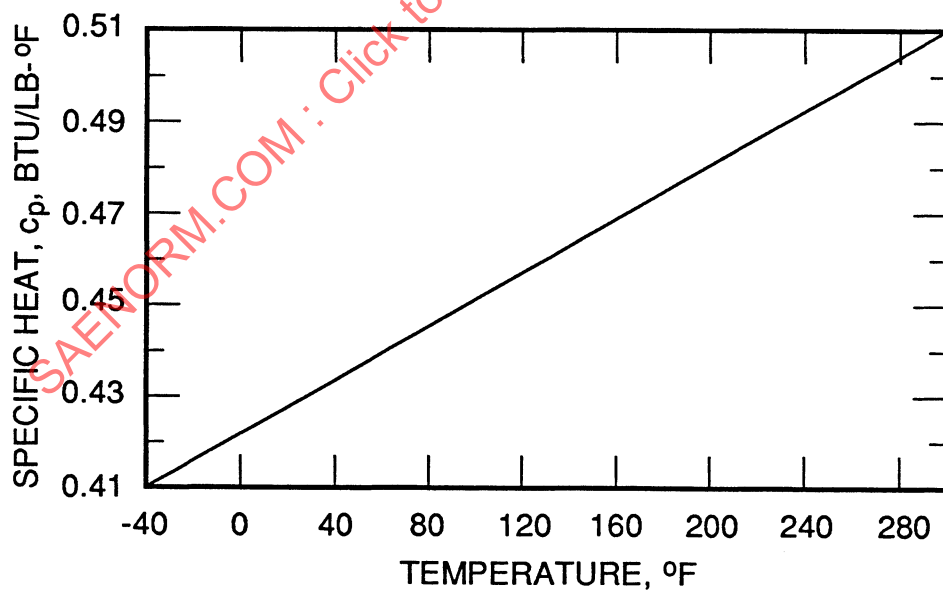


Figure 2F-12 - Coolanol 45 Property k (Ref.1)

Figure 2F-13 - Coolanol 45 Property $(N_{Pr})^{2/3}$ (Ref.1)Figure 2F-14 - MCS-198 Property c_p (Ref.2)

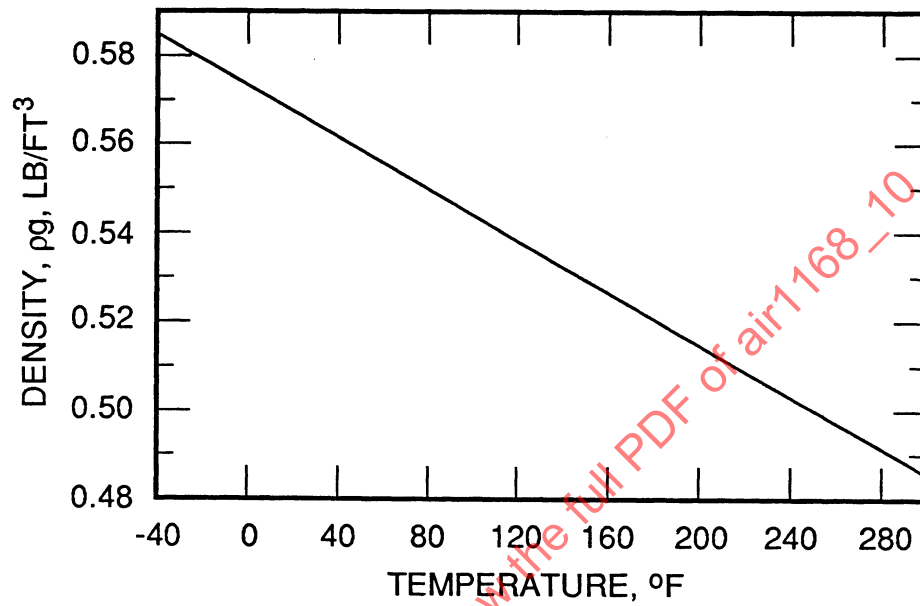


Figure 2F-15 - MCS-198 Property ρ_g (Ref.2)

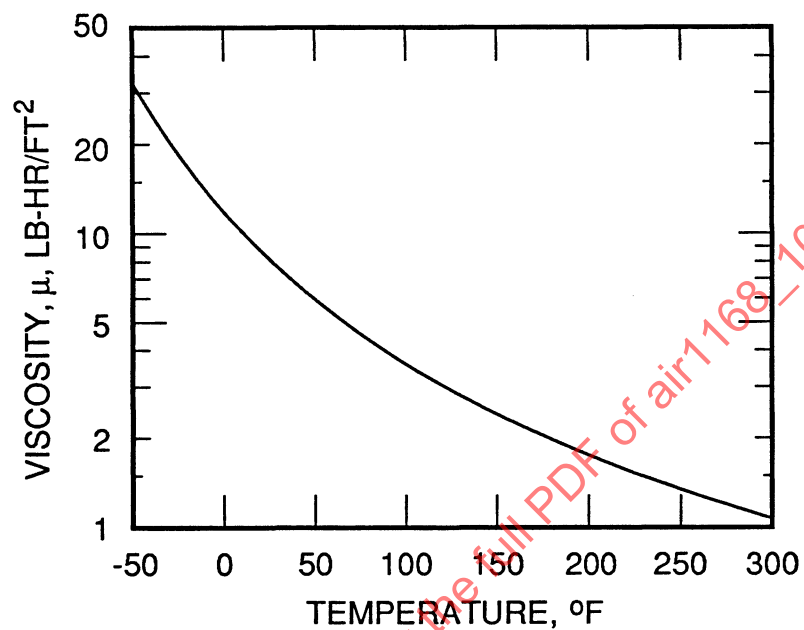


Figure 2F-16 - MCS-198 Property μ (Ref.2)

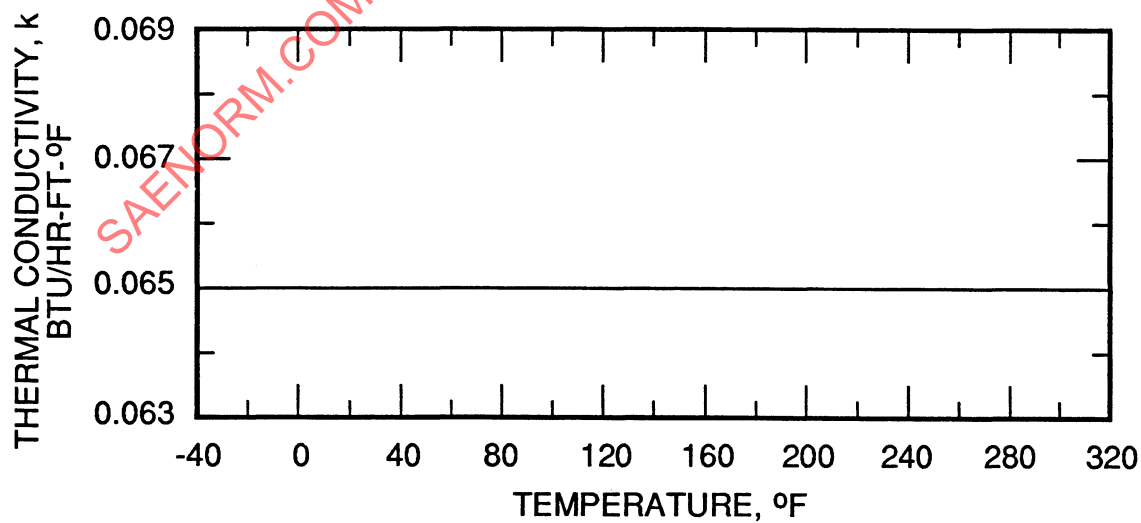


Figure 2F-17 - MCS-198 Property k (Ref.2)

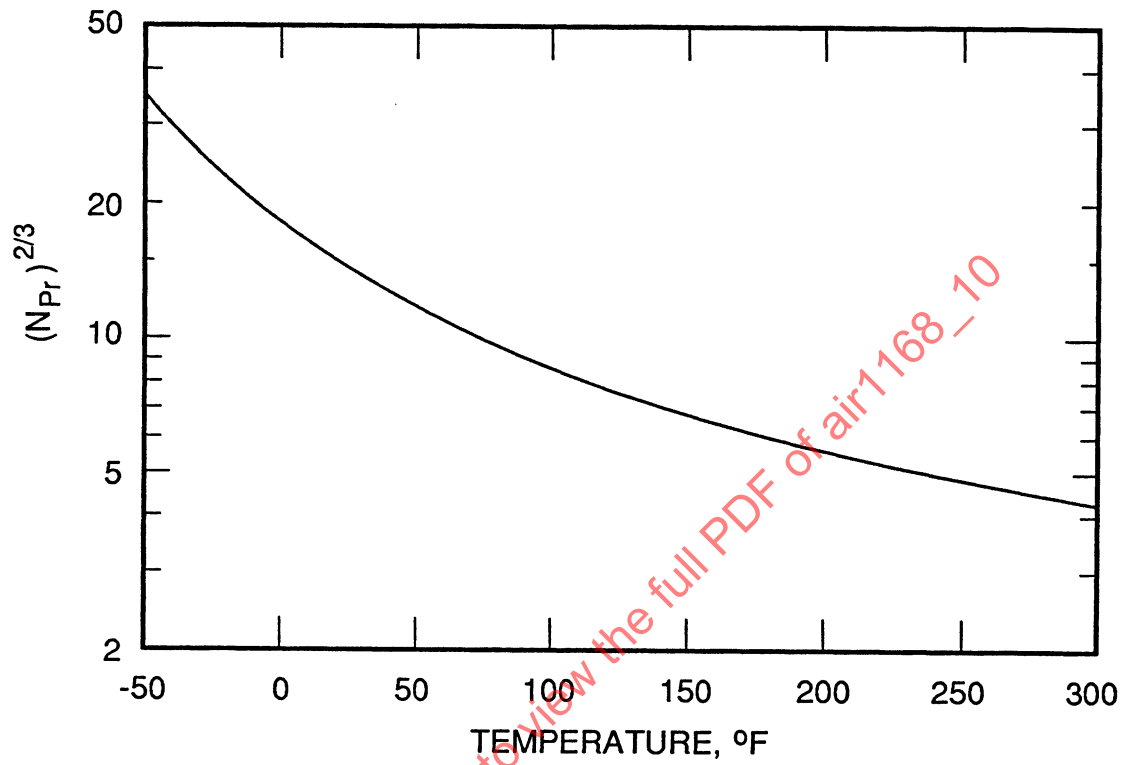


Figure 2F-18 - MCS-198 Property $(N_{Pr})^{2/3}$ (Ref.2)

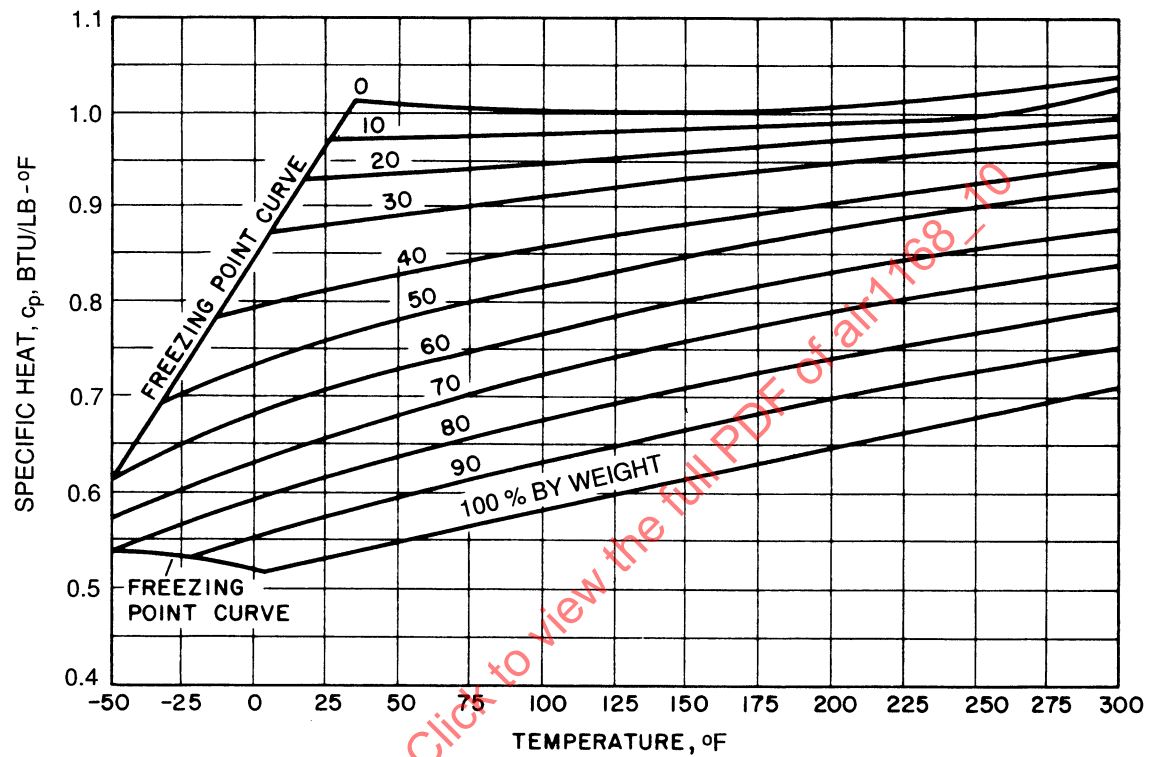


Figure 2F-19 Aqueous Ethylene Glycol Property c_p ; % by weight (Ref.3)

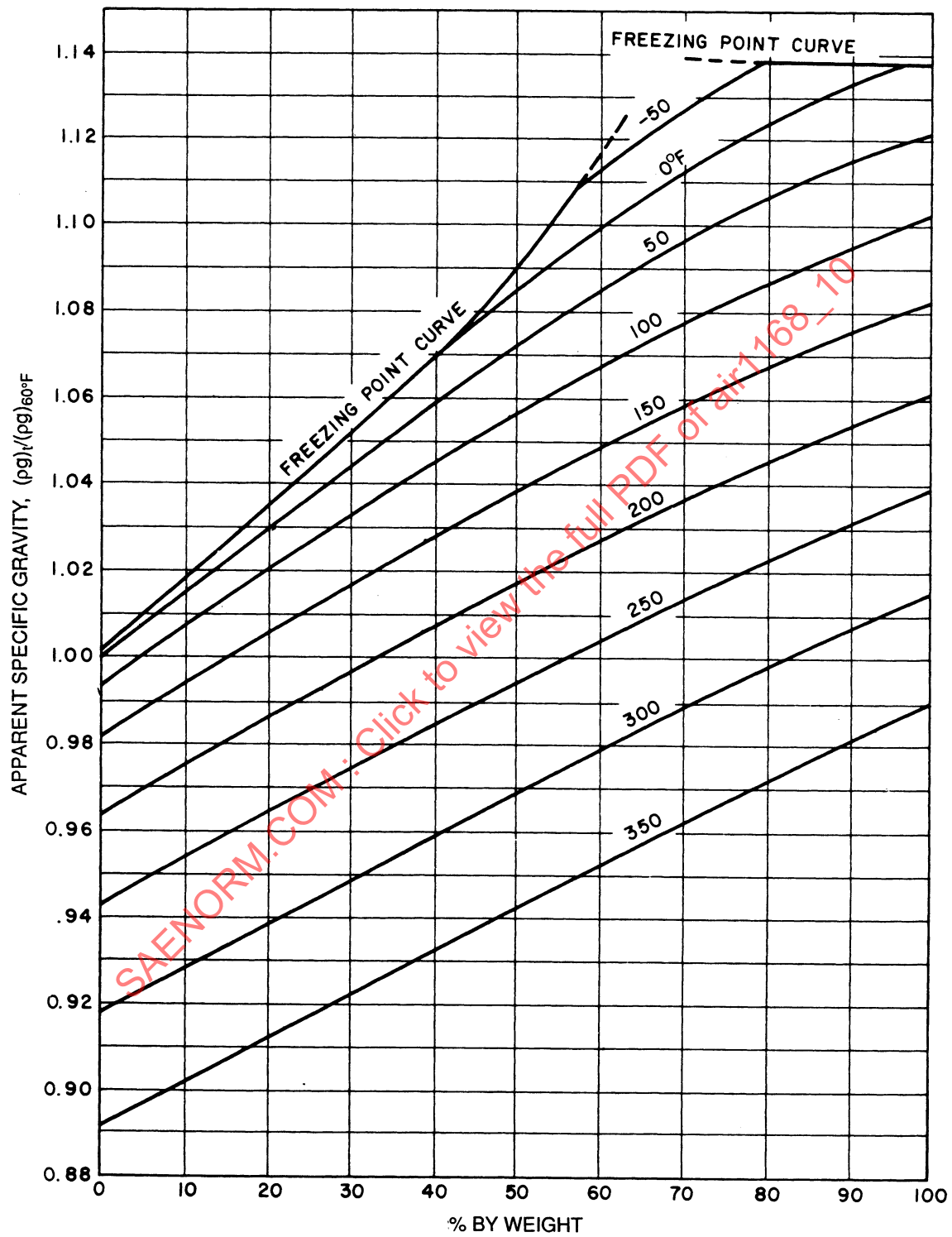


Figure 2F-20 - Aqueous Ethylene Glycol Property $(\rho g)_t / (\rho g)_{60^\circ F}$; % by weight (Ref.3)

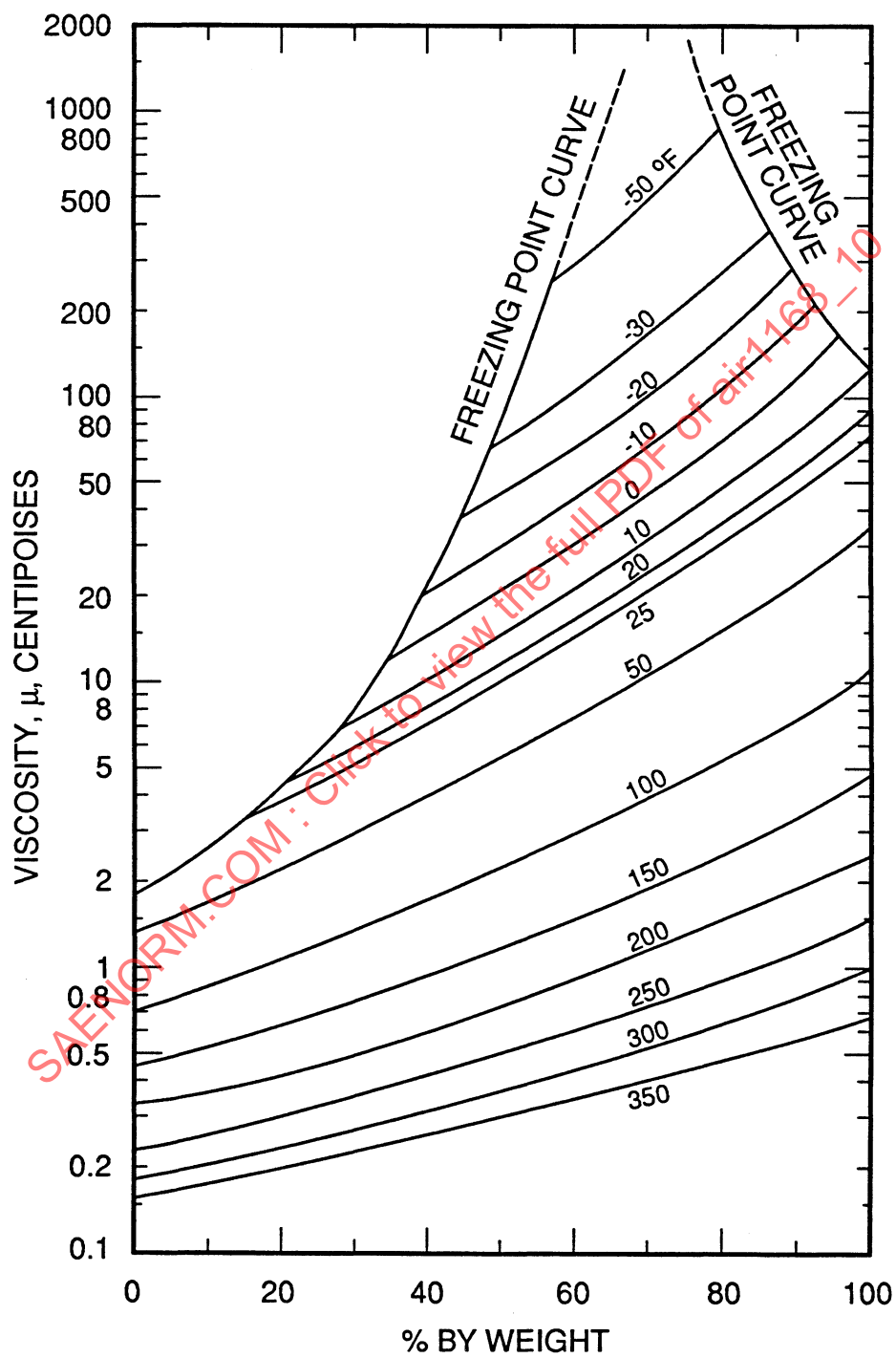


Figure 2F-21 - Aqueous Ethylene Glycol Property μ ; % by weight (Ref.3)

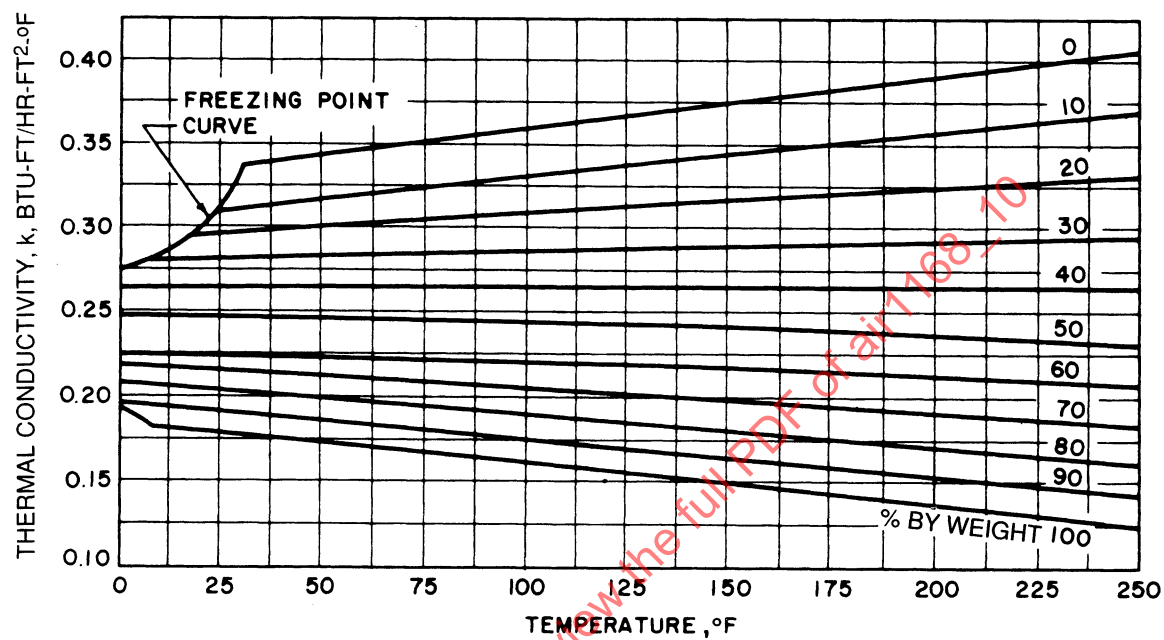


Figure 2F-22 - Aqueous Ethylene Glycol Property k ; % by weight (Ref.3)

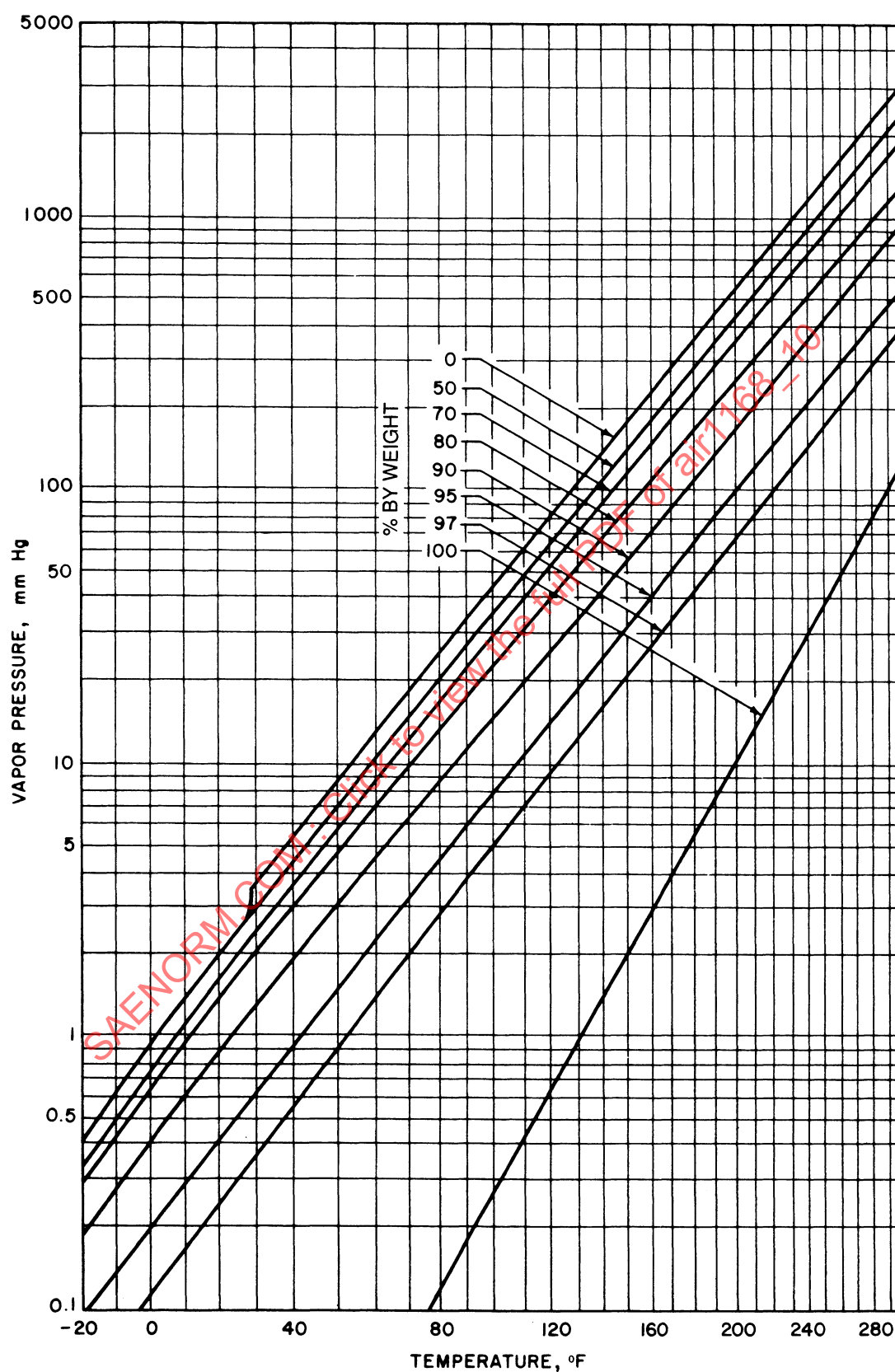
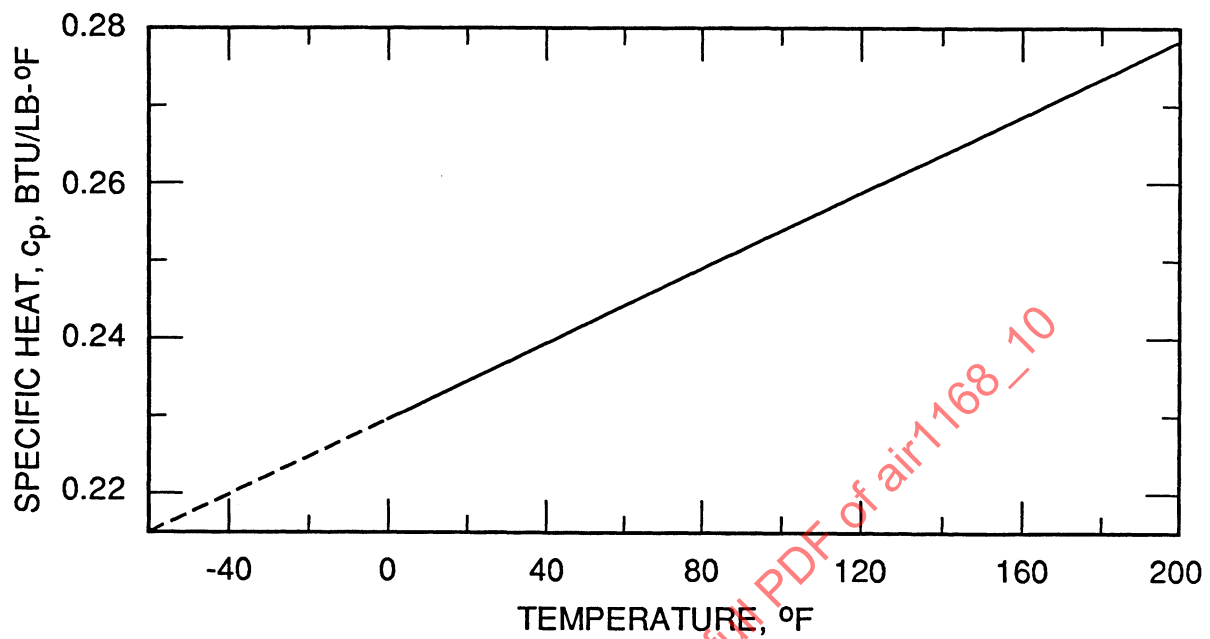
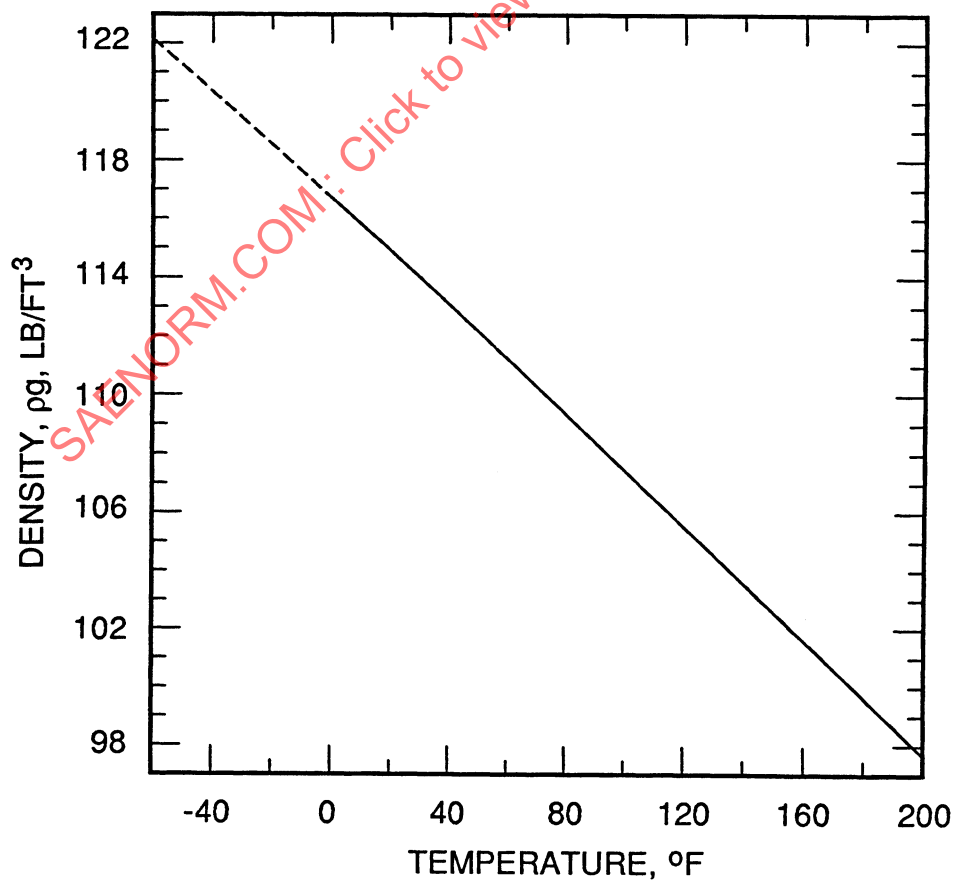


Figure 2F-23 - Aqueous Ethylene Glycol, Vapor Pressure; % by weight (Ref.3)

Figure 2F-24 - FC-75 Property c_p (Ref.4)Figure 2F-25 - FC-75 Property ρ_g (Ref.4)

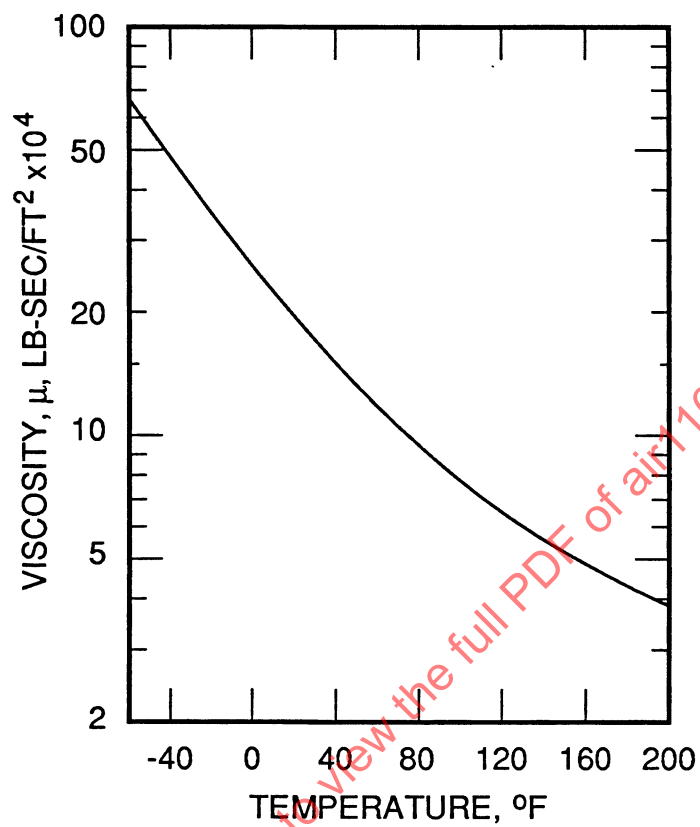


Figure 2F-26 - FC-75 Property μ (Ref.4)

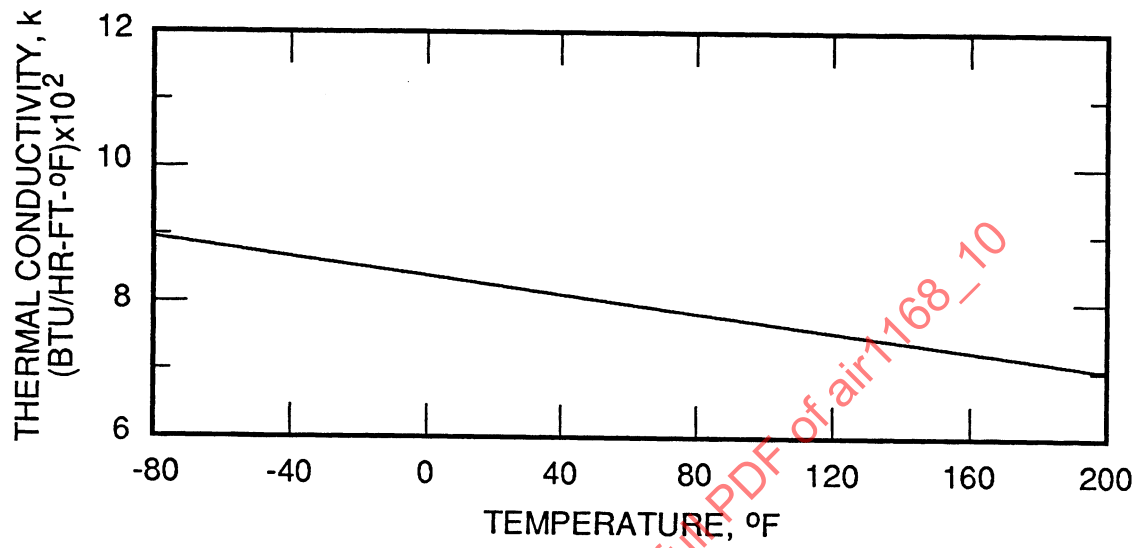


Figure 2F-27 - FC - 75 Property k (Ref.4)

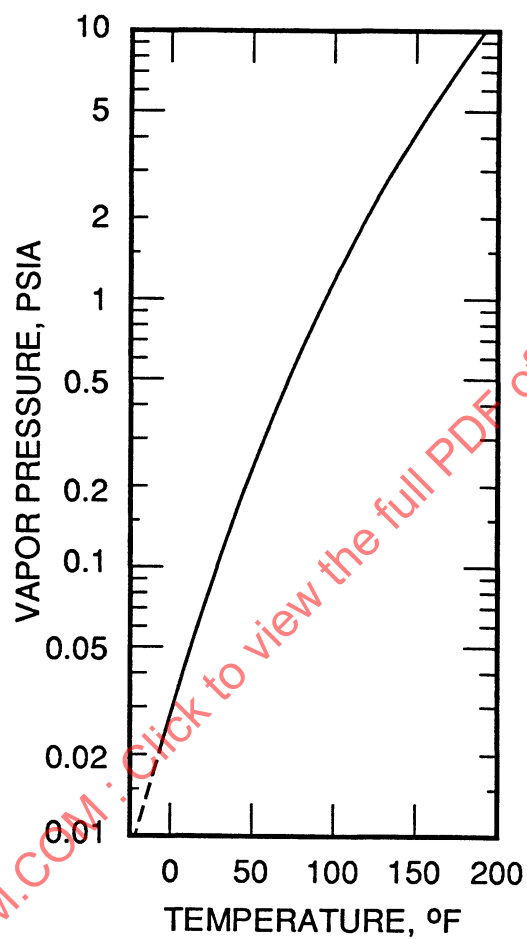


Figure 2F-28 - FC-75 Vapor Pressure (Ref.4)