Thermophysical Characteristics of Working Fluids and Heat Transfer Fluids

AIR1168/10

SAE Aerospace Applied Thermodynamics Manual

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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.

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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-^oF
c_v = Specific heat capacity, constant volume,Btu/lb-^oF
H = Enthalpy, Btu/lb
k = Thermal conductivity, Btu/hr-ft-^oF,cal/cm-sec-^oC
N_{Pr} = Prandtl number($\mu c_p/k$), dimensionless
P = Pressure, atm,psia, lb/ft^2
R = Universal gas constant, ft-lb/lb-^oR
S = Entropy, Btu/^oF
s = Specific entropy, Btu/lb - ^oR (or ^oF)
t = Temperature, ^oF
T = Temperature,^oR,K
V = Specific volume, ft^3/lb
Z = Compressibility factor(Z=PV/RT), dimensionless
ρg = Specific weight (density), lb/ft^3, gm/cm^3, 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

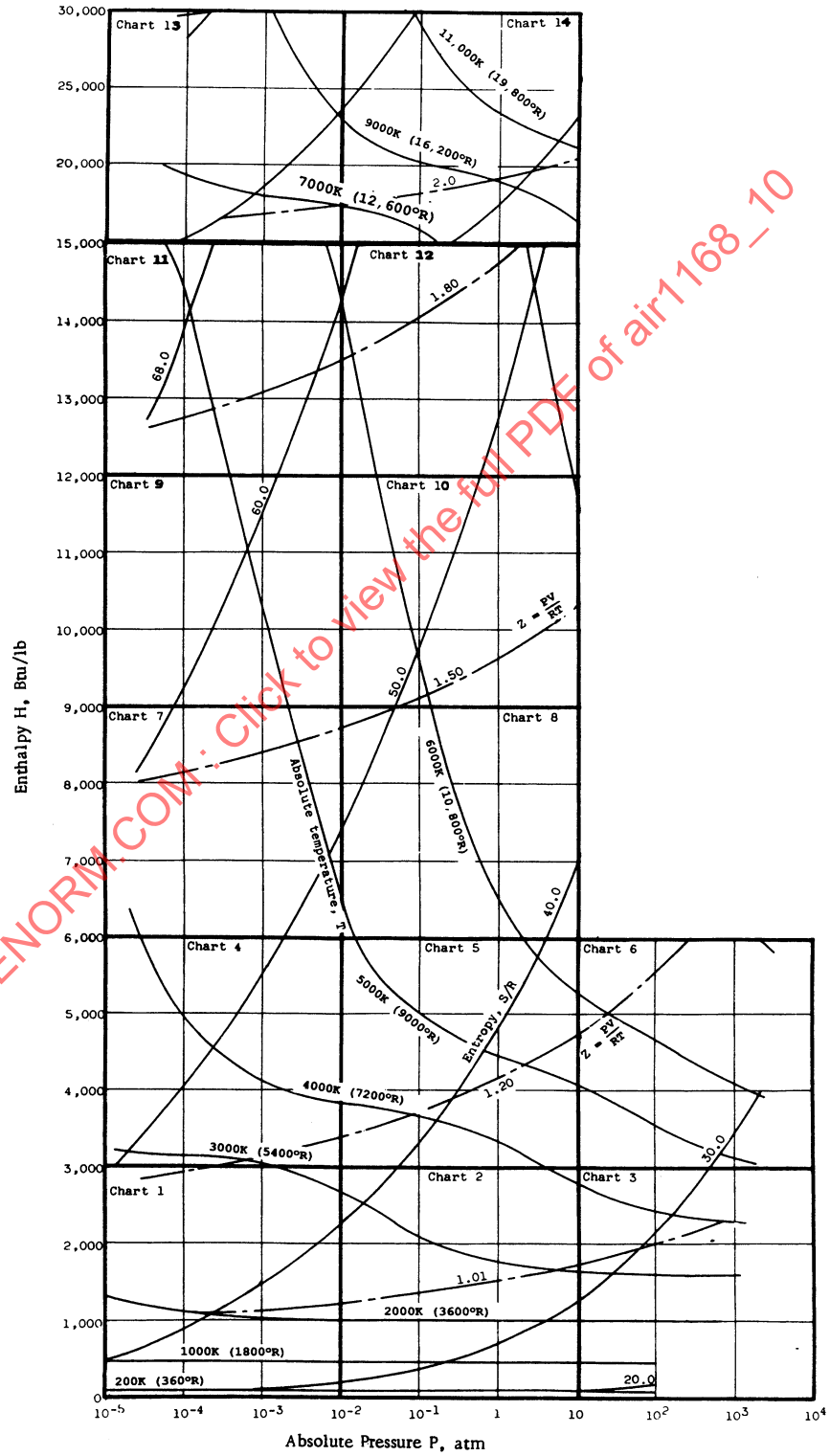


Figure 2E-1 - Pressure-Enthalpy Diagram for Air (Key to Charts); From NACA TN-4265

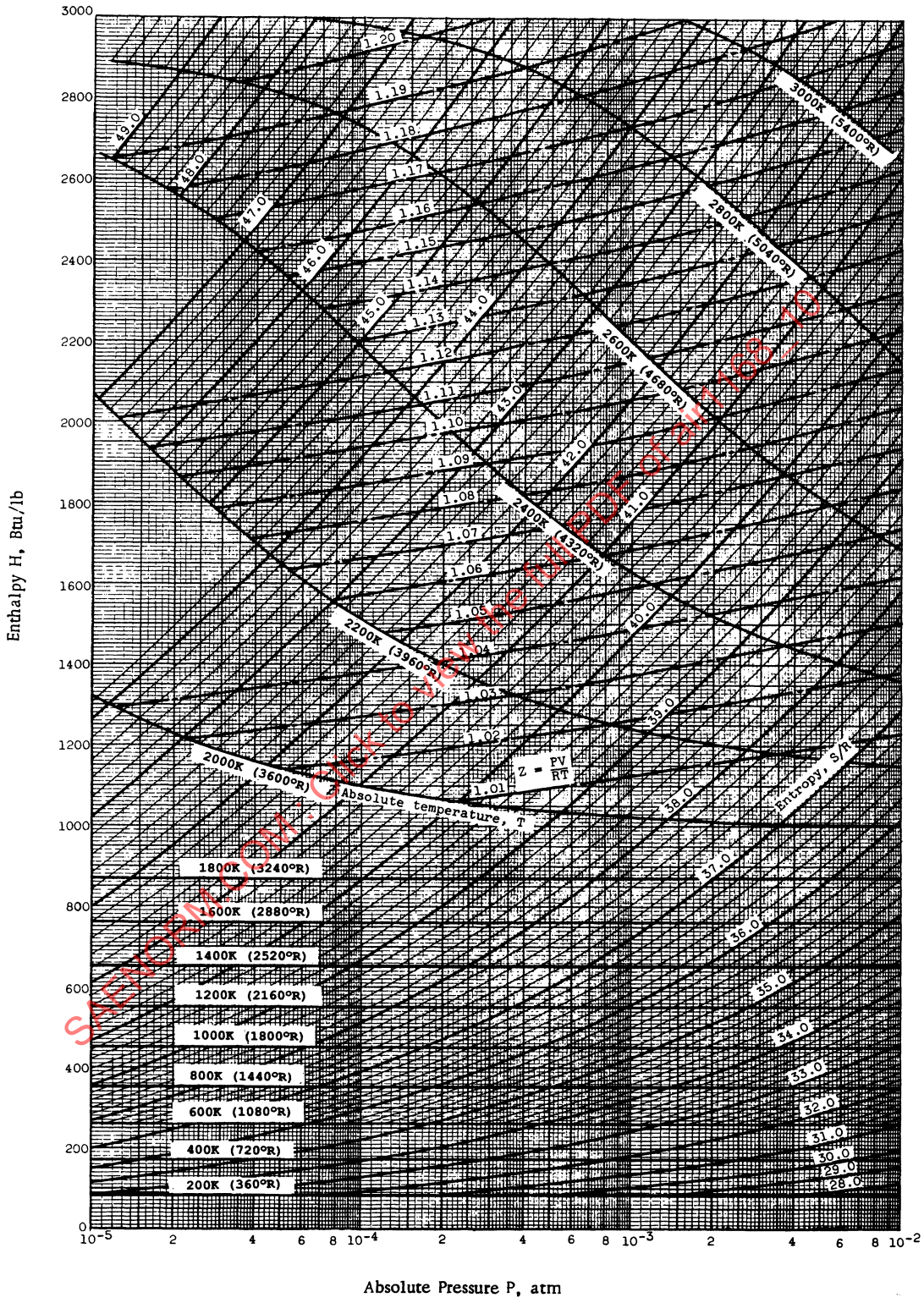


Figure 2E-2 - Chart 1 - Thermodynamic Chart For Air

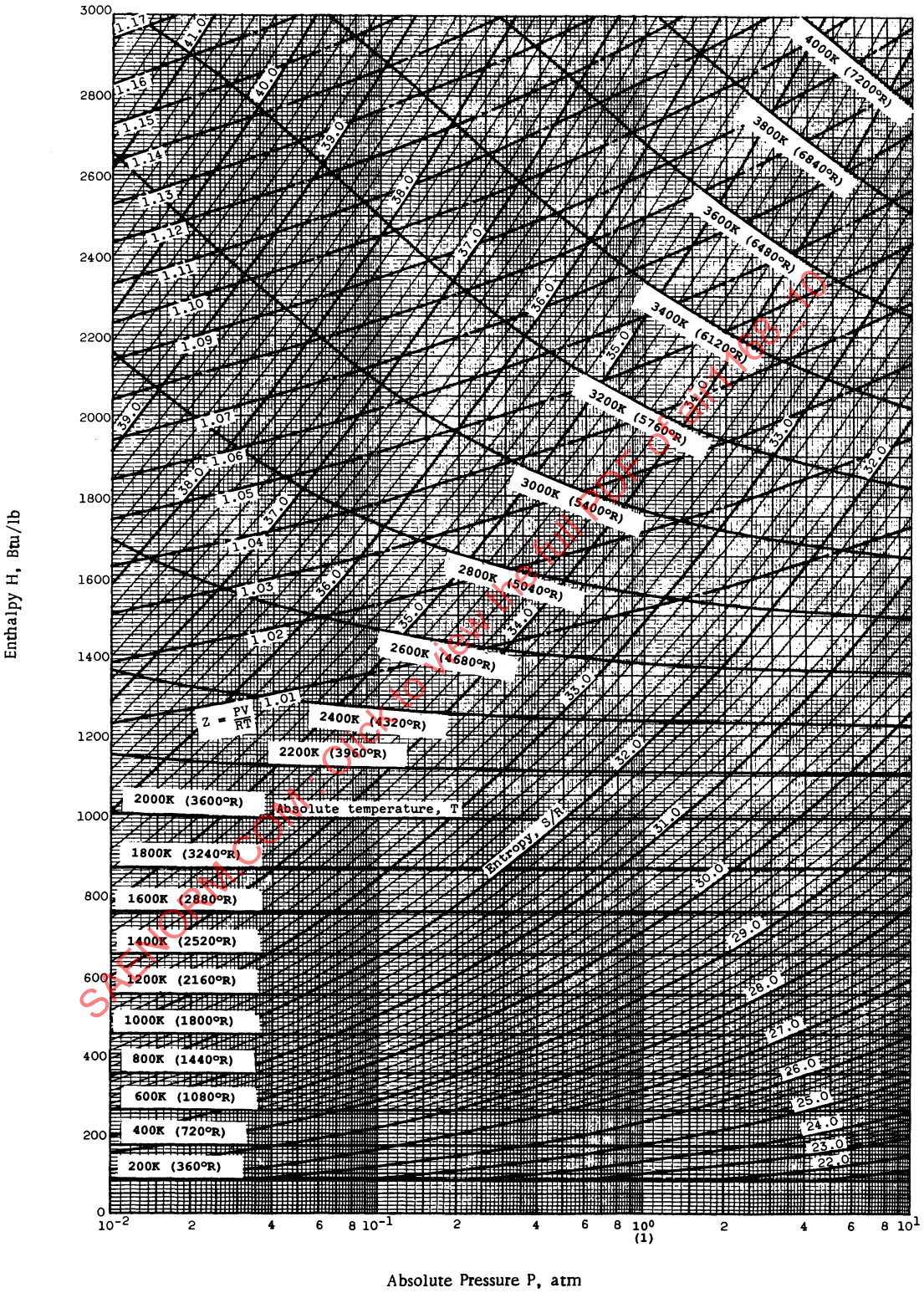


Figure 2E-3 - Chart 2 - Thermodynamic Chart For Air

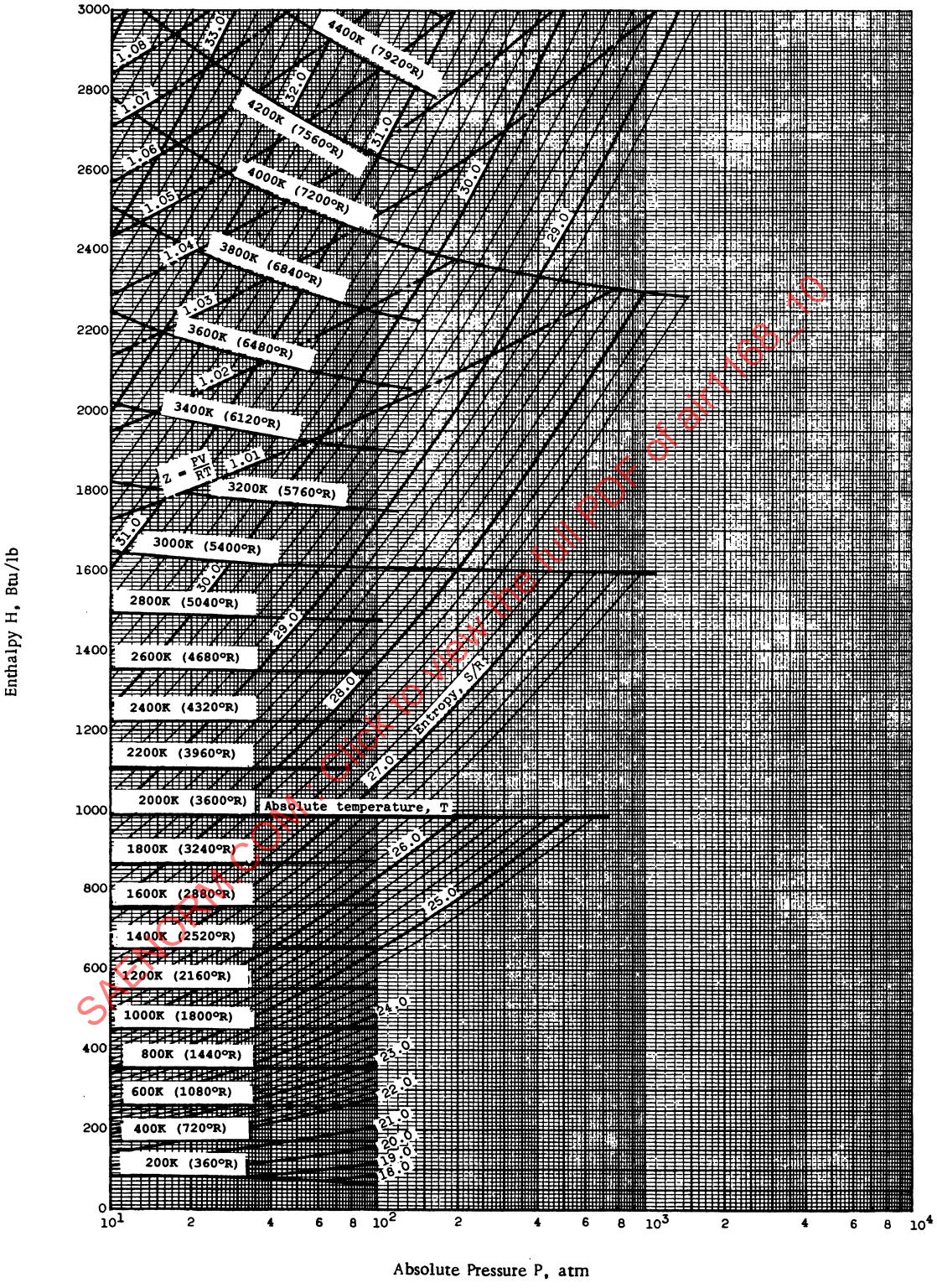
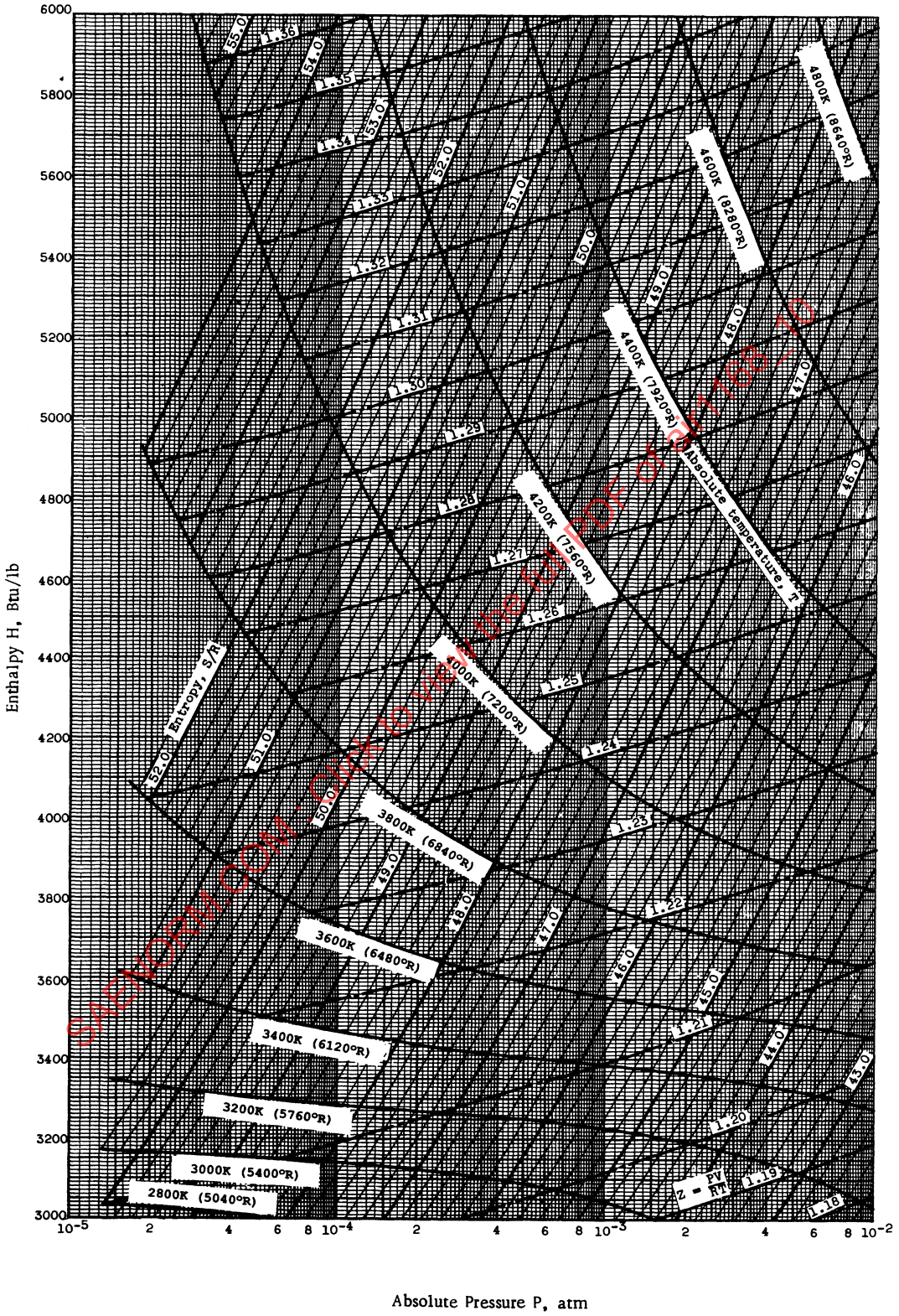


Figure 2E-4 - Chart 3 - Thermodynamic Chart For Air



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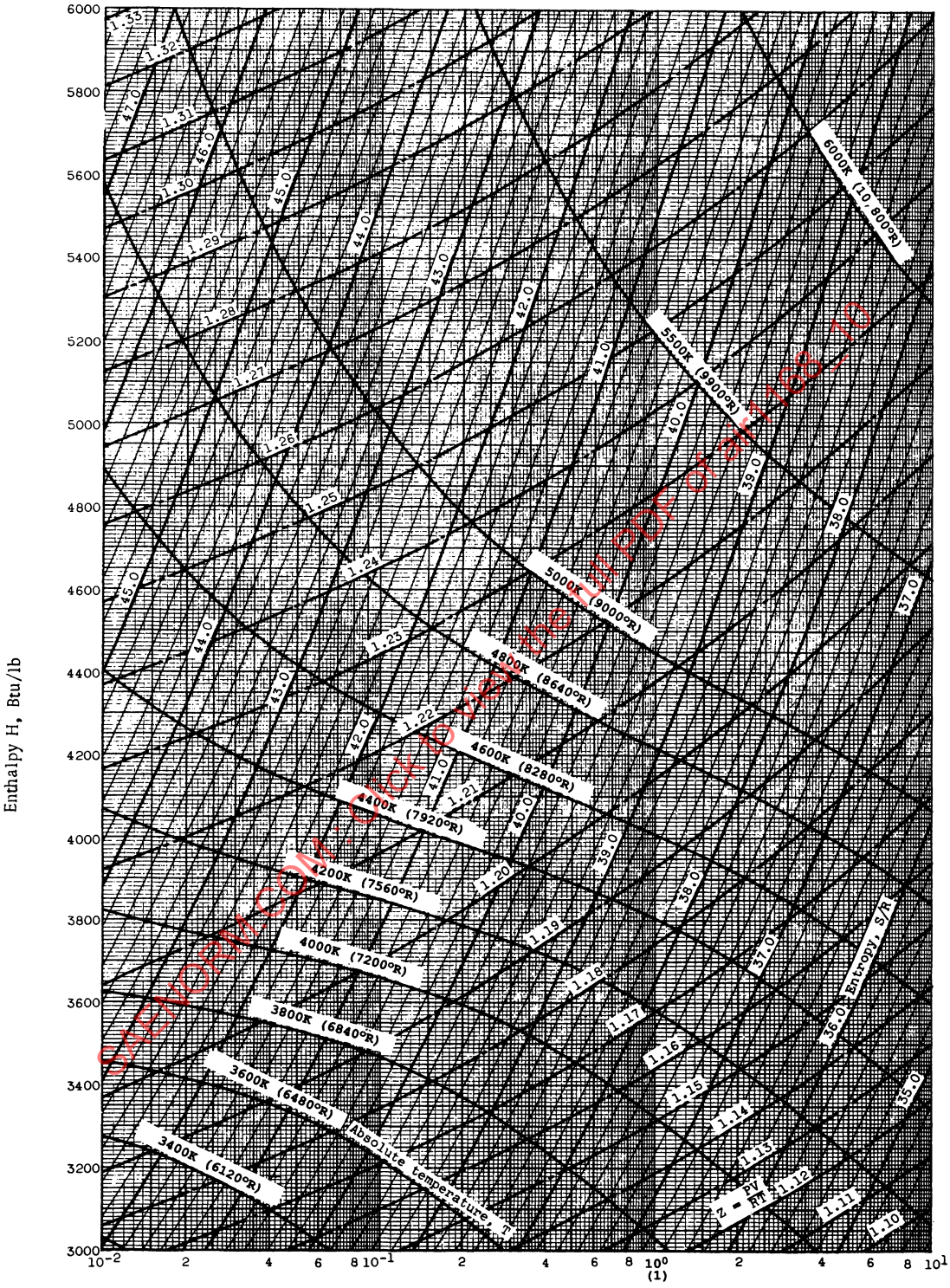

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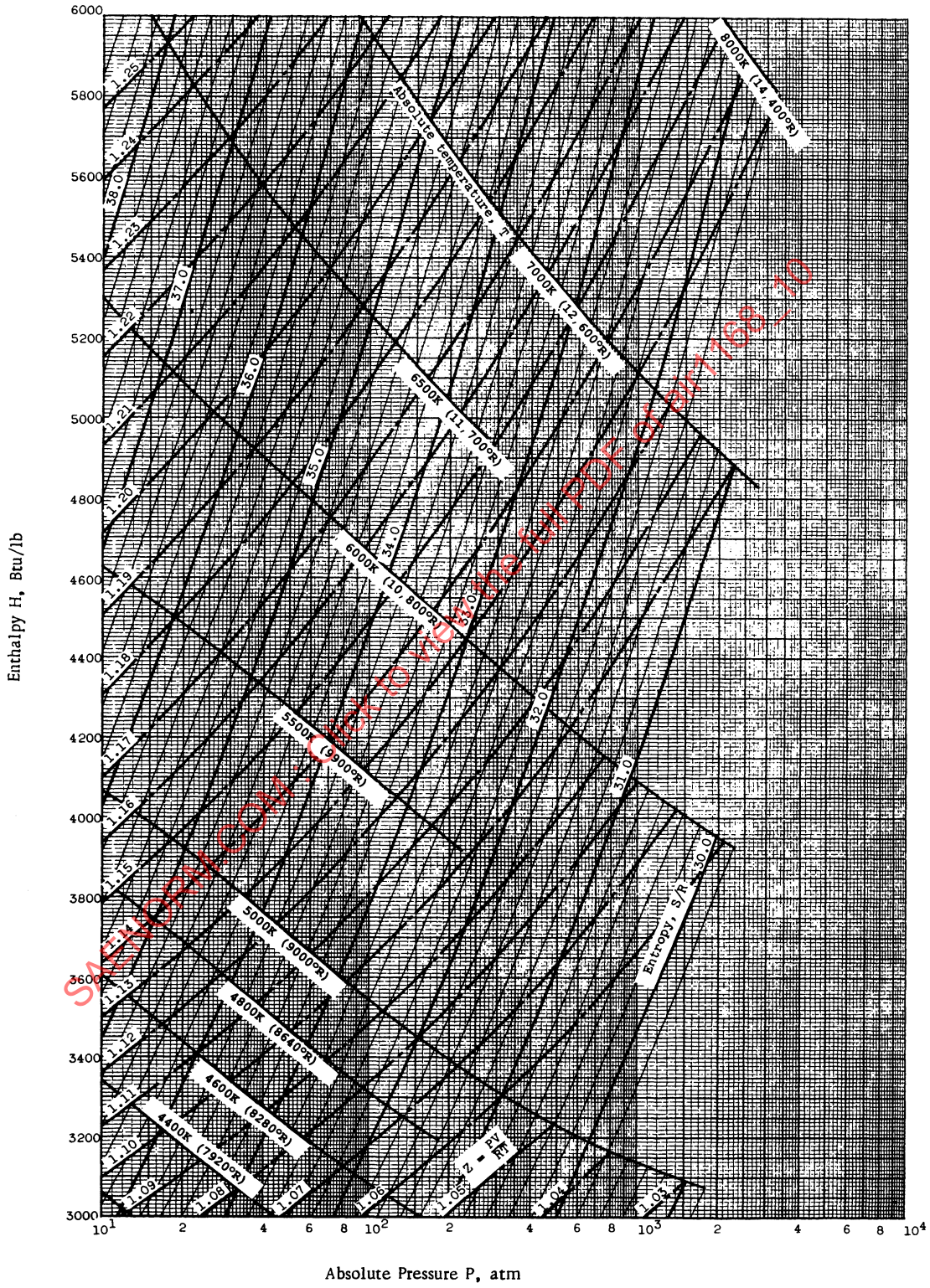
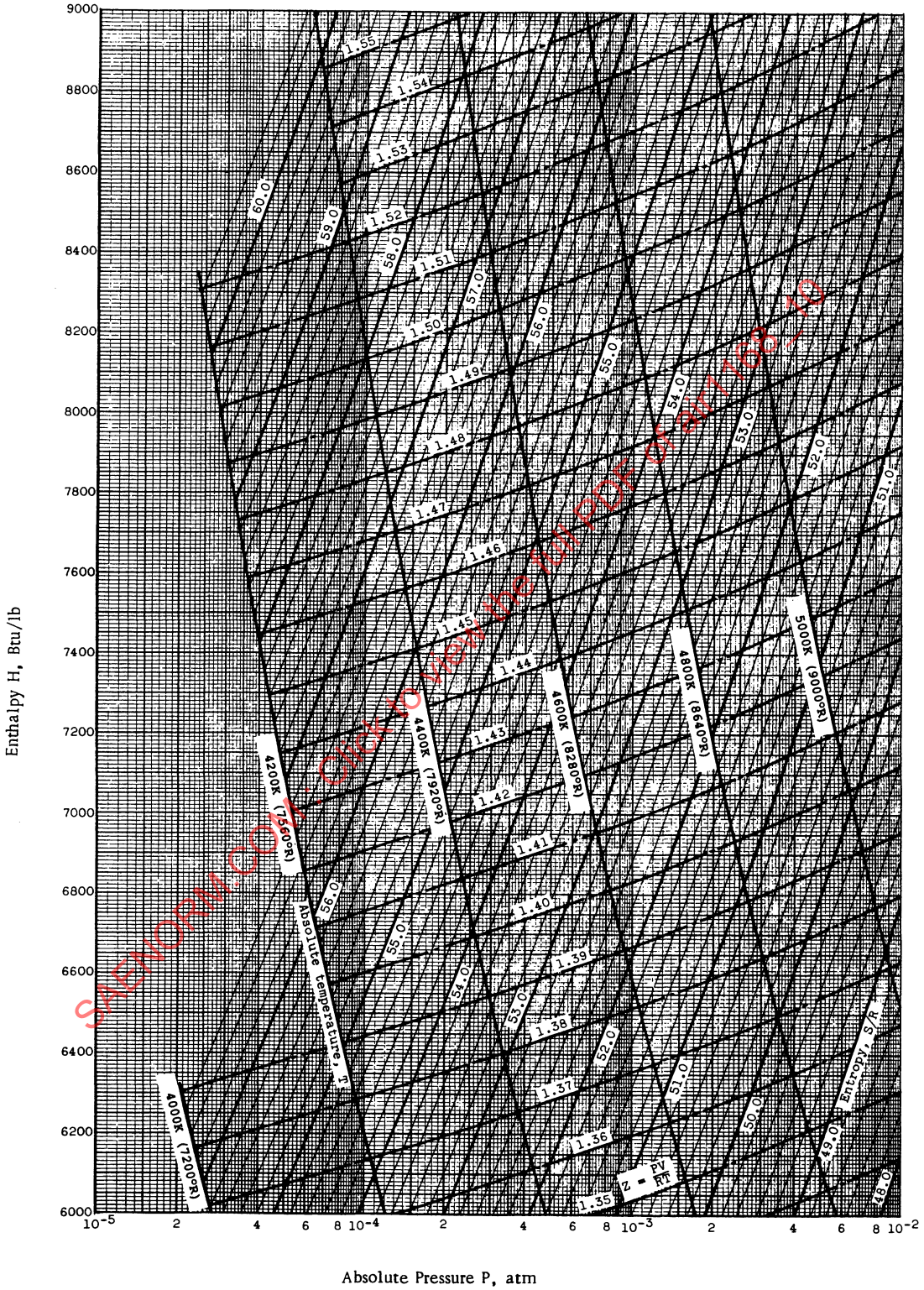


Figure 2E-7 - Chart 6 - Thermodynamic Chart For Air



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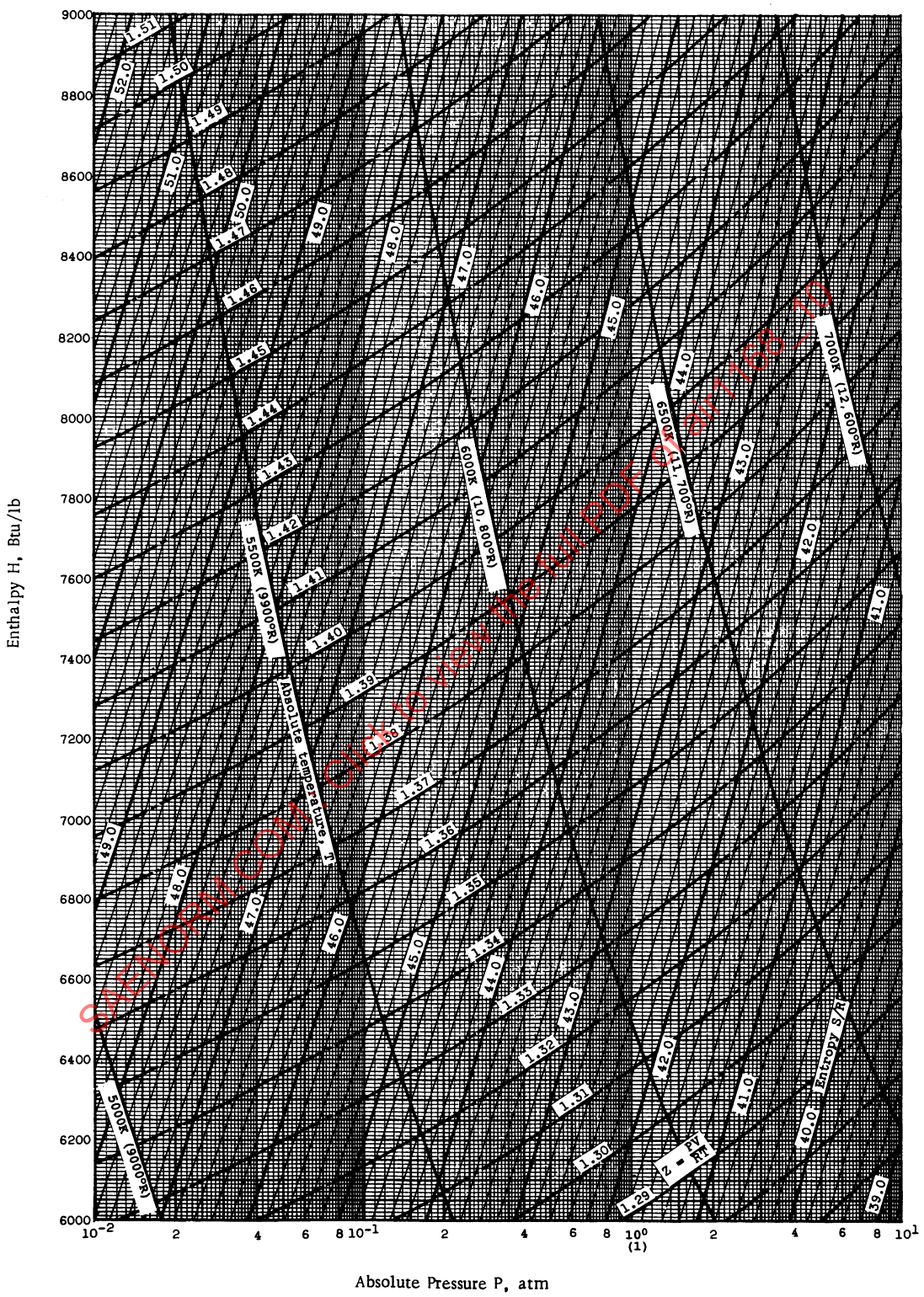

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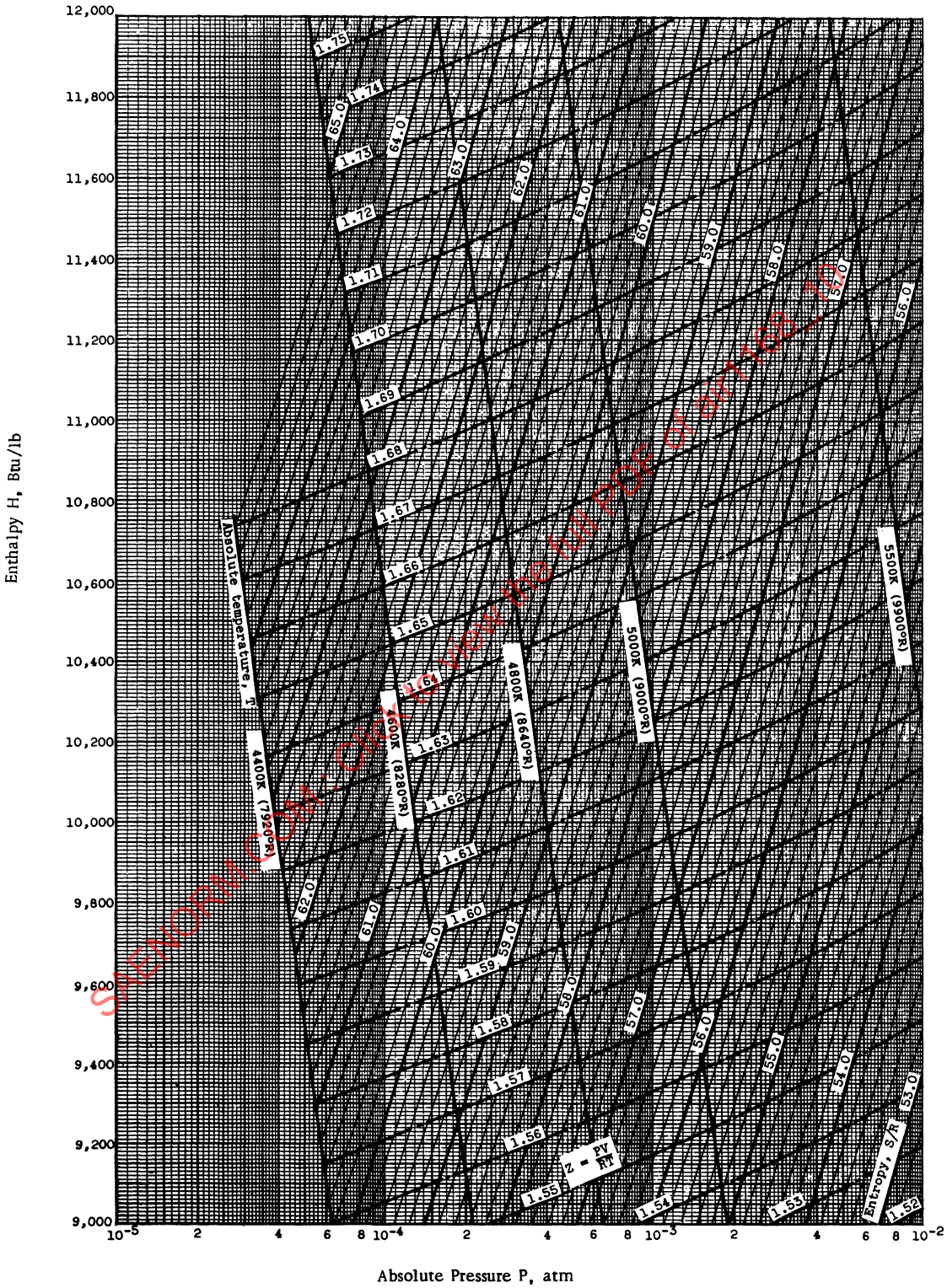

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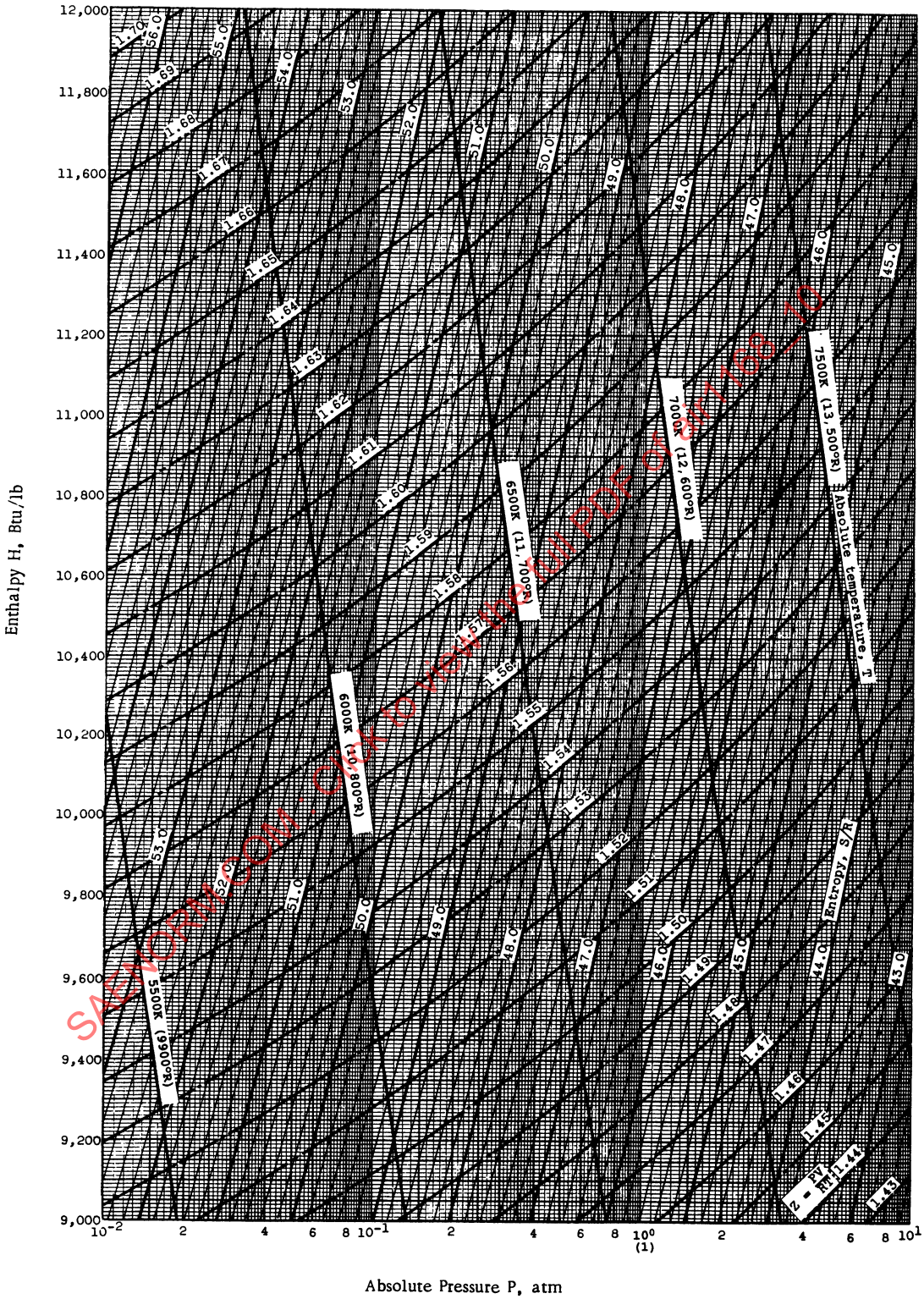

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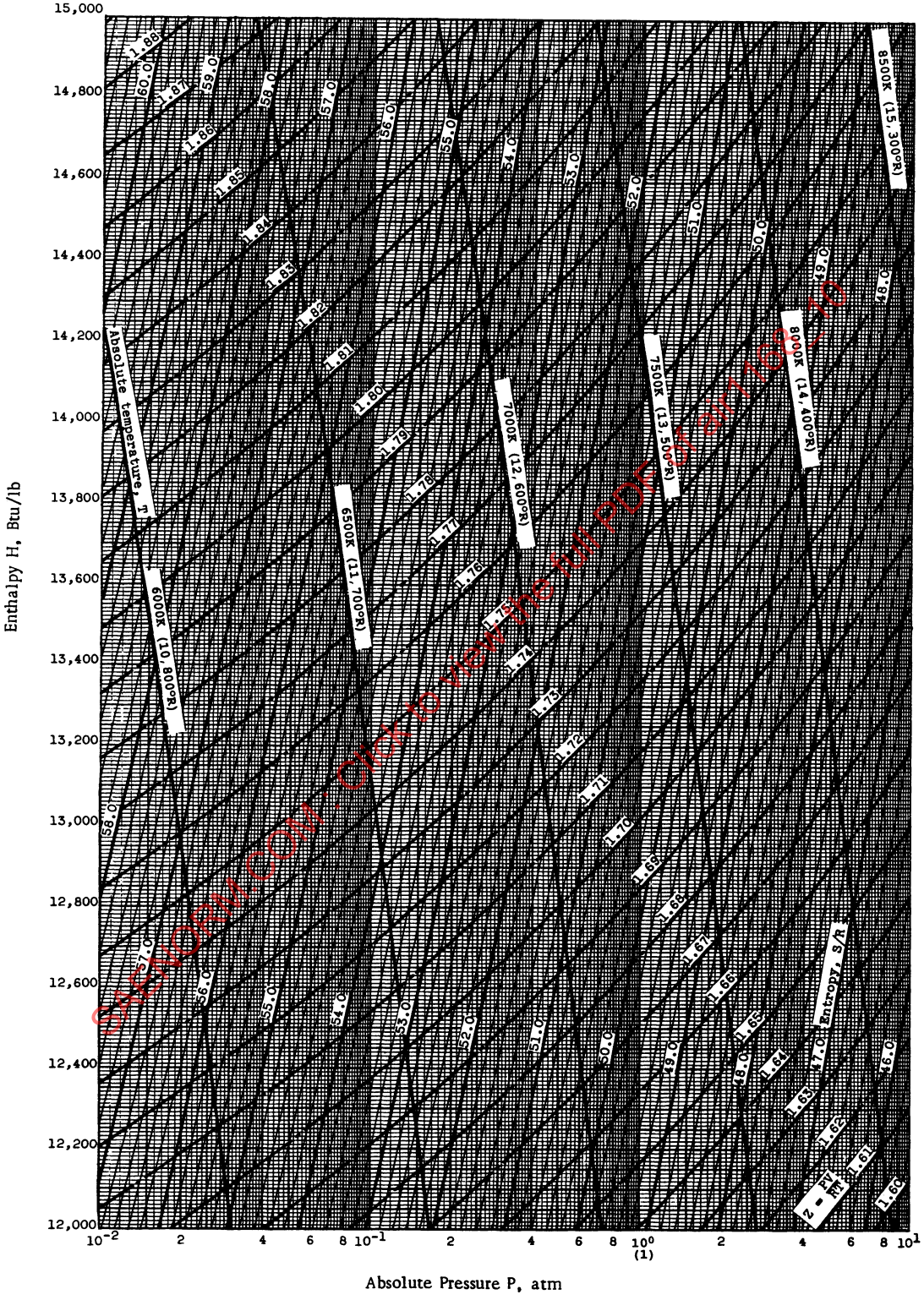

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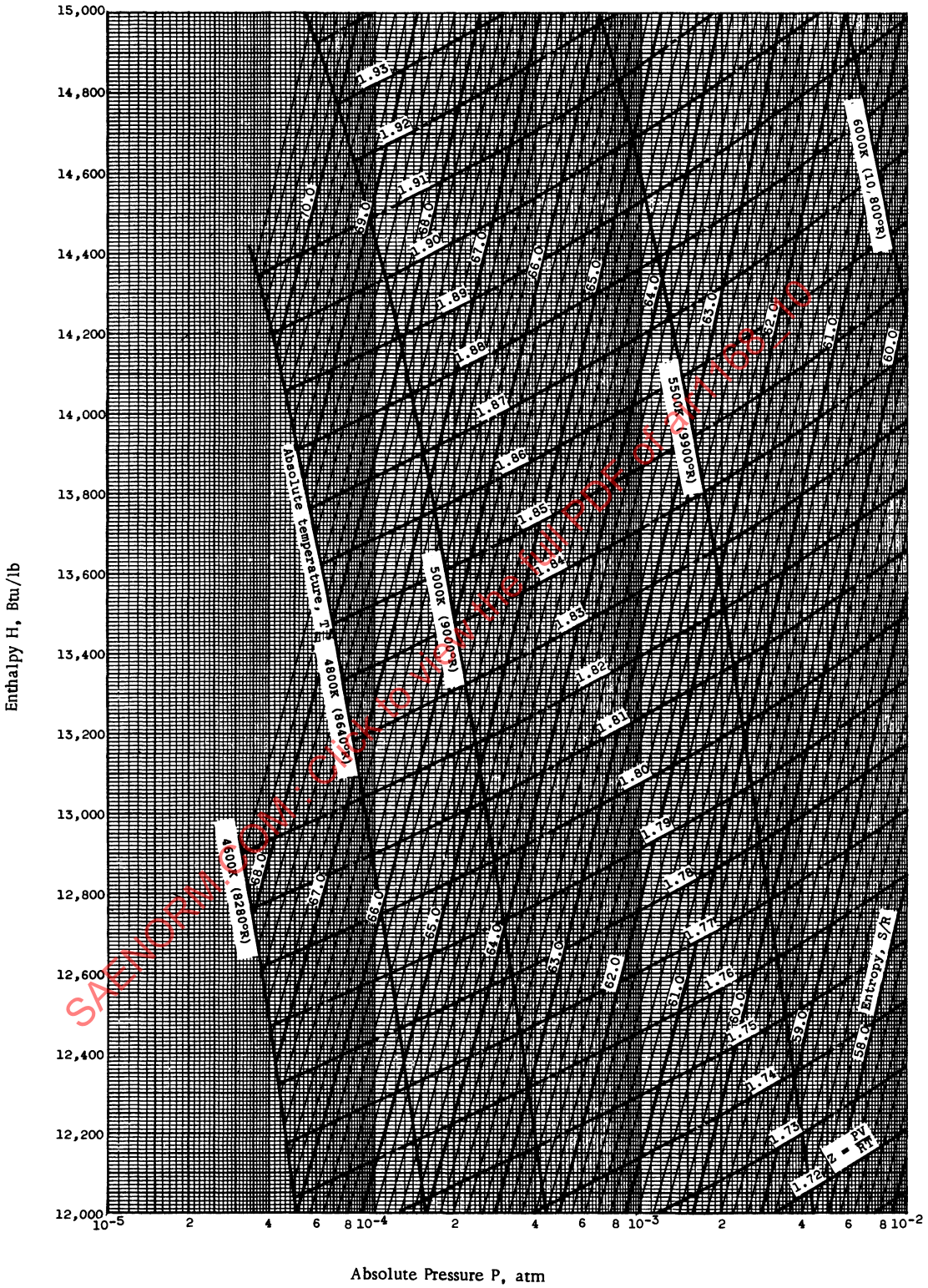

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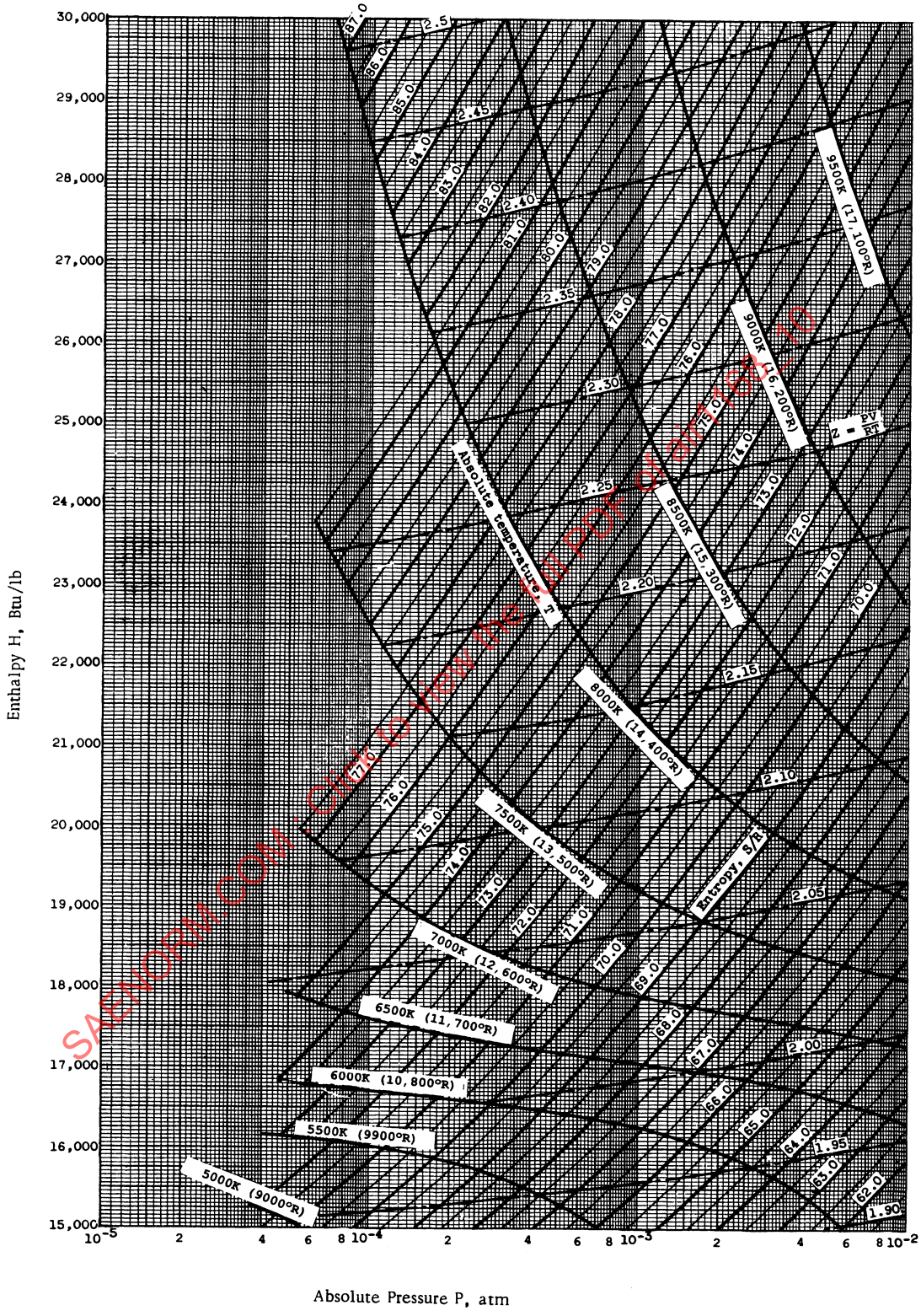

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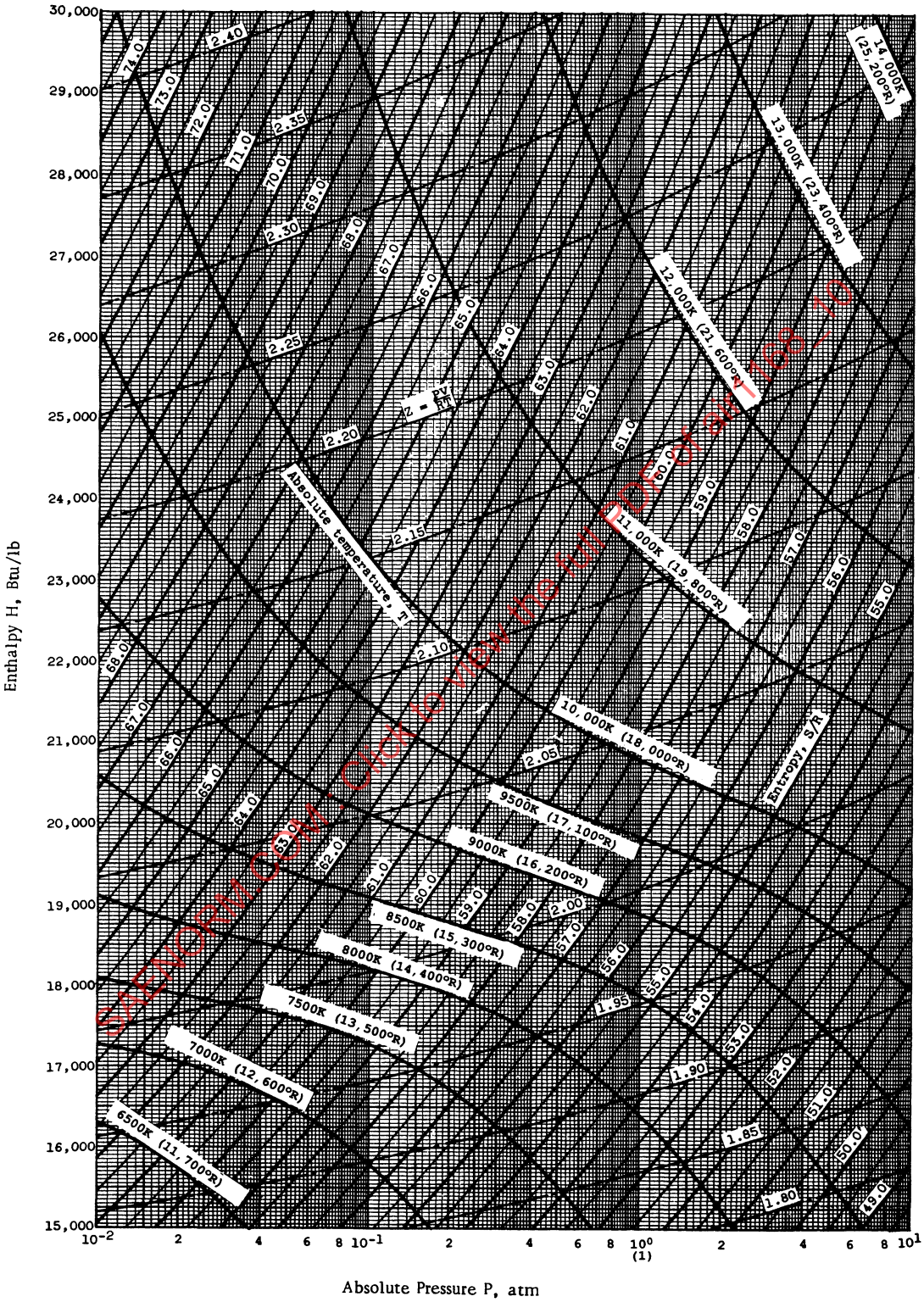

Figure 2E-15 - Chart 14 - Thermodynamic Chart For Air

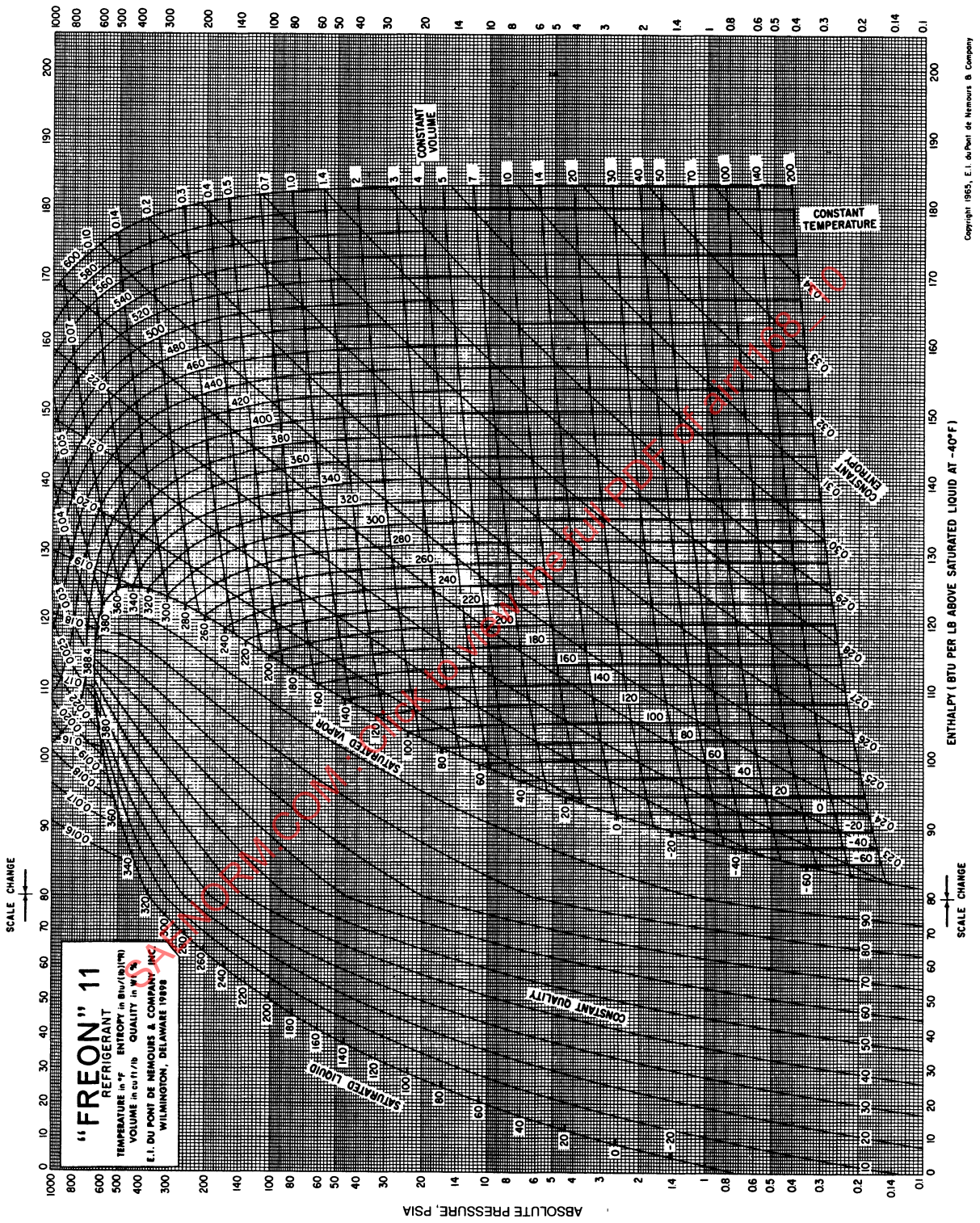

Figure 2E-16 - Pressure-enthalpy Diagram, Freon 11

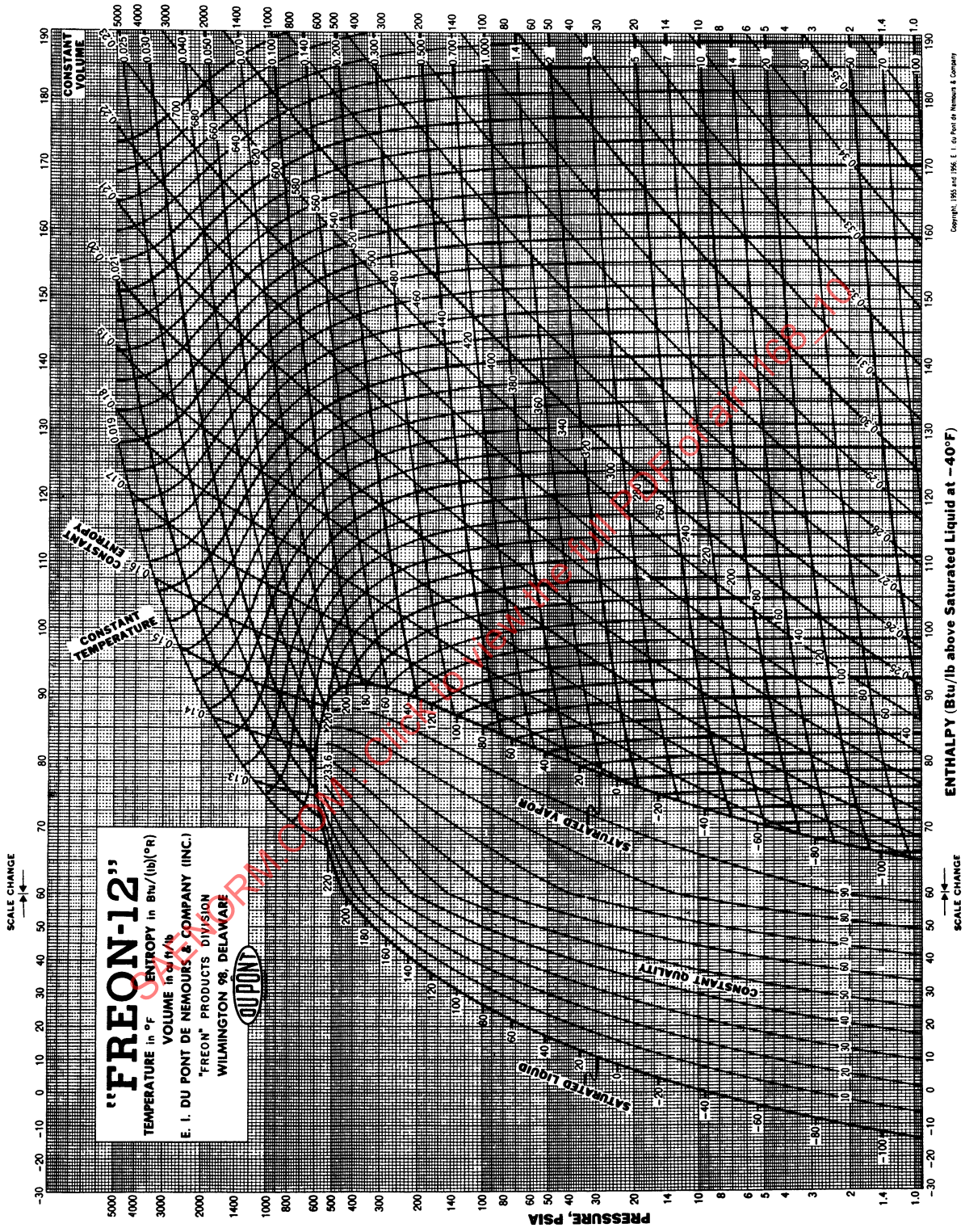

Figure 2E-17 - Pressure-enthalpy Diagram, Freon 12

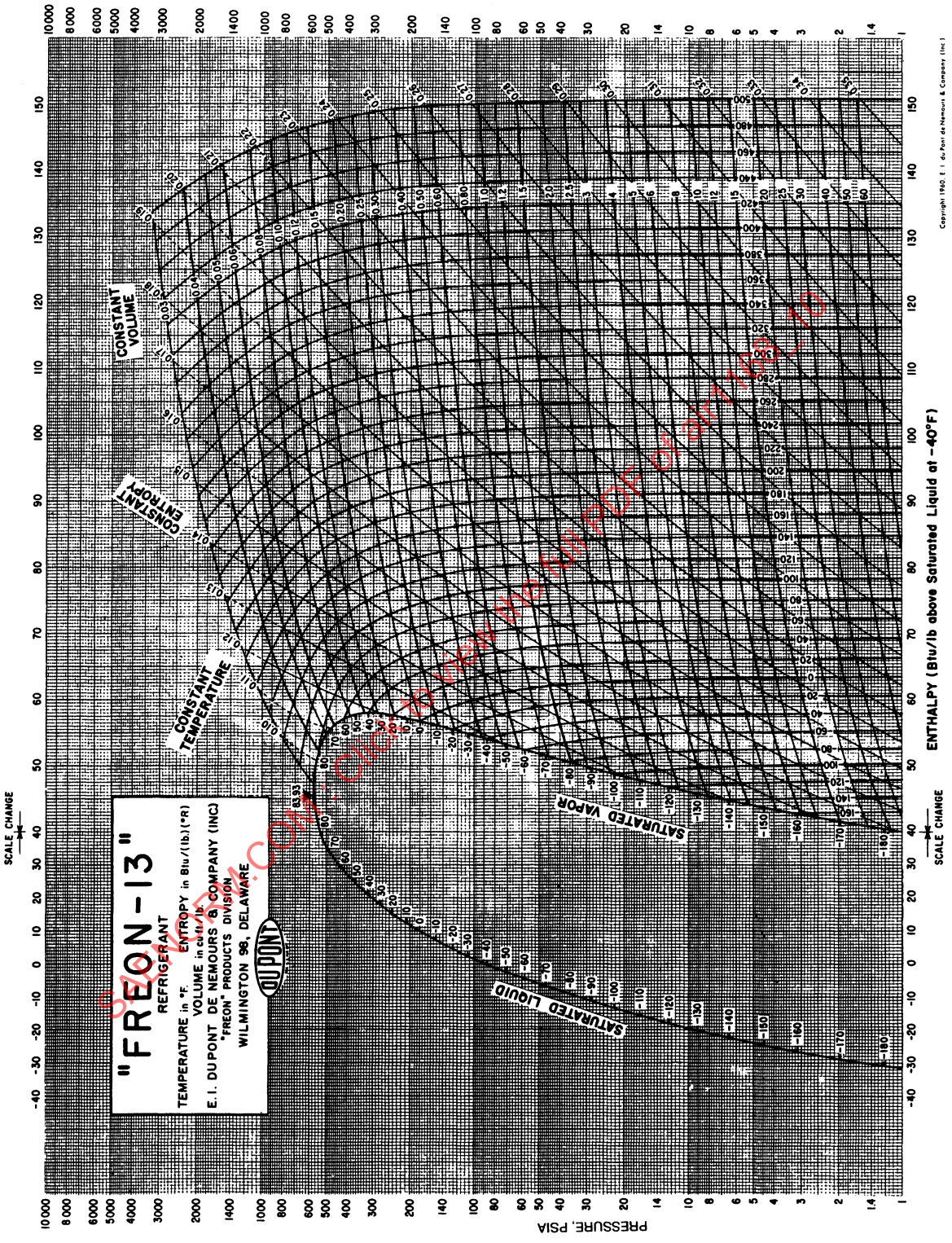

Figure 2E-18 - Pressure-enthalpy Diagram, Freon 13

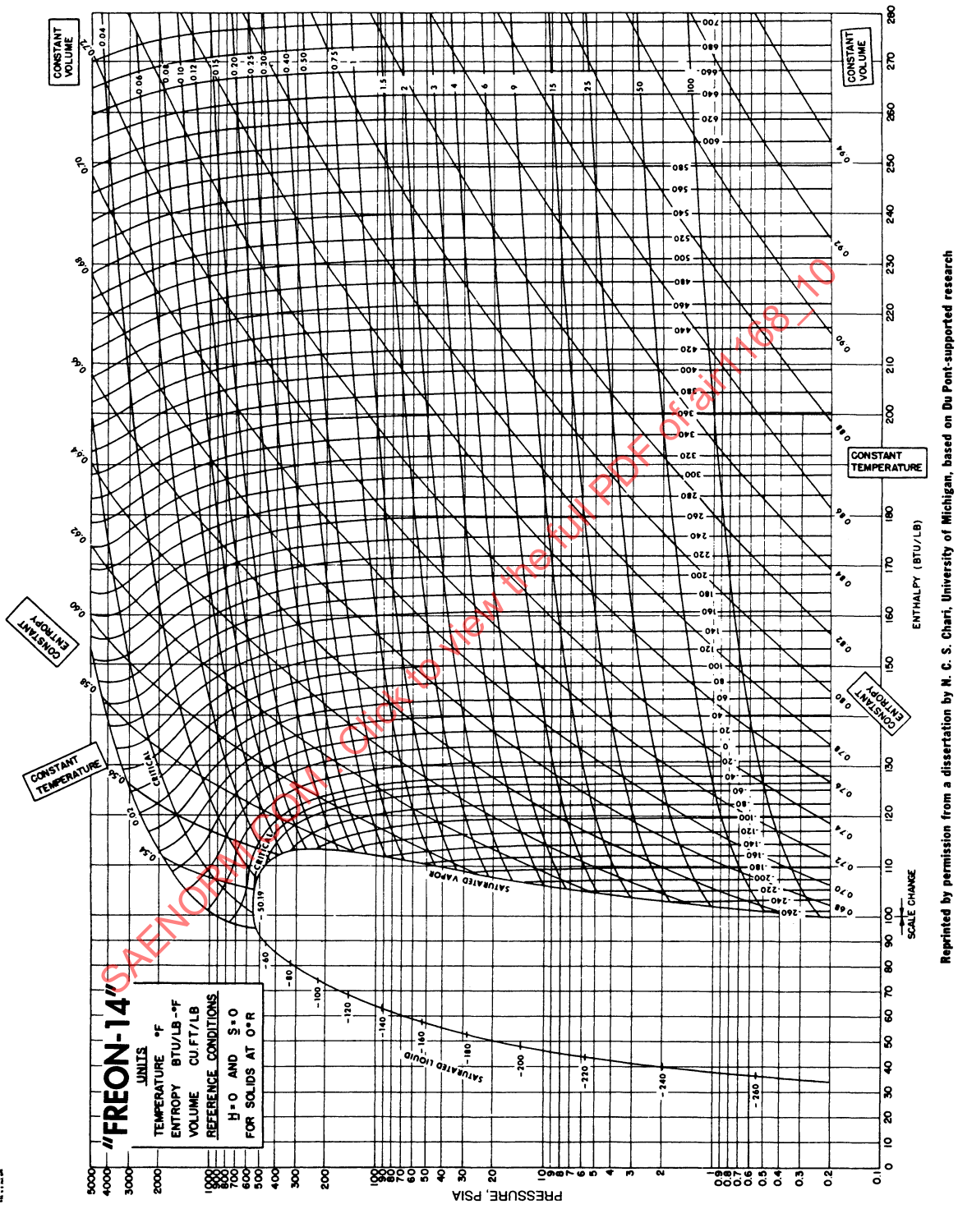

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Figure 2E-19 - Pressure-enthalpy Diagram, Freon 14

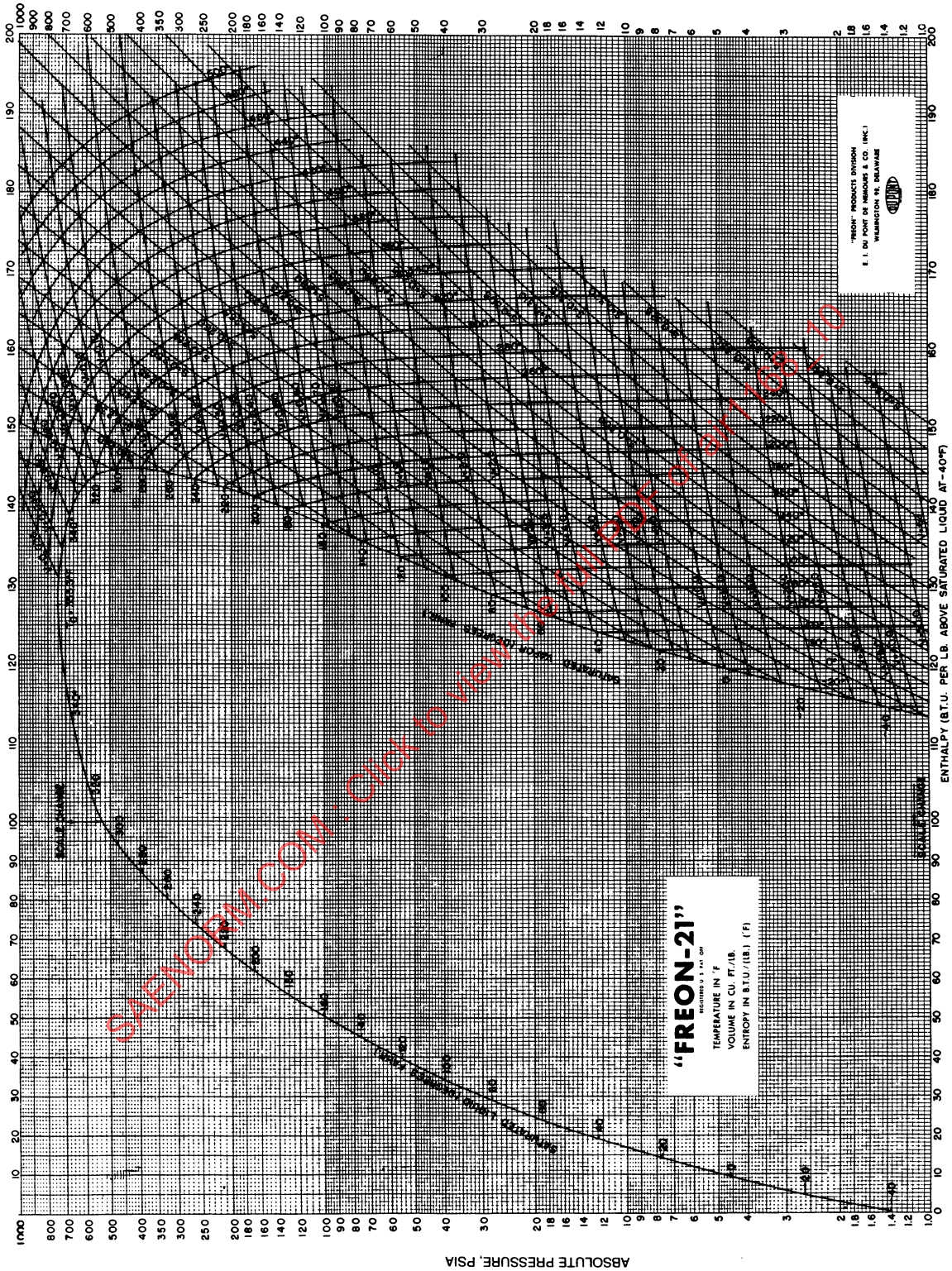
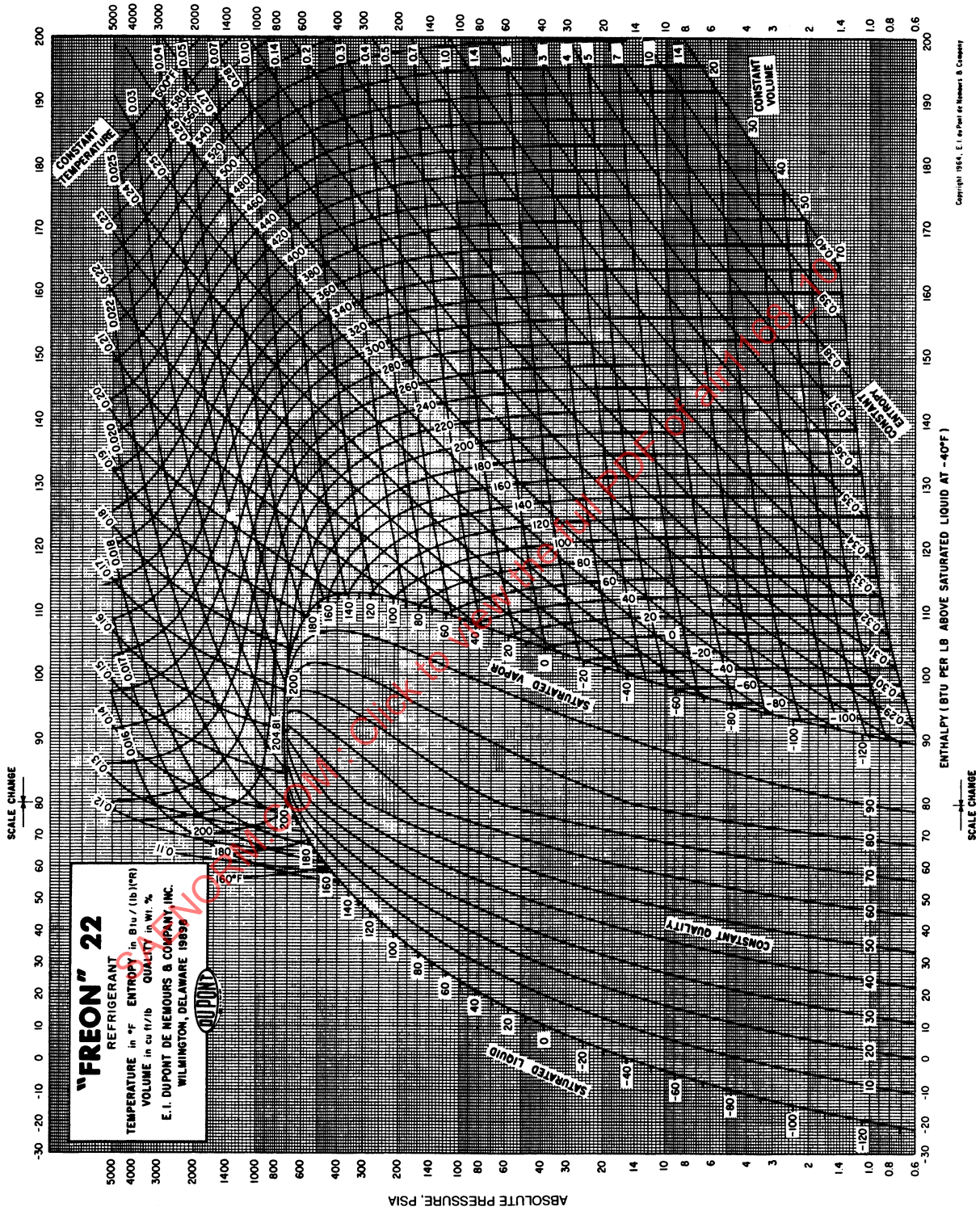


Fig. 2E-20—Pressure-enthalpy diagram, Freon 21

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



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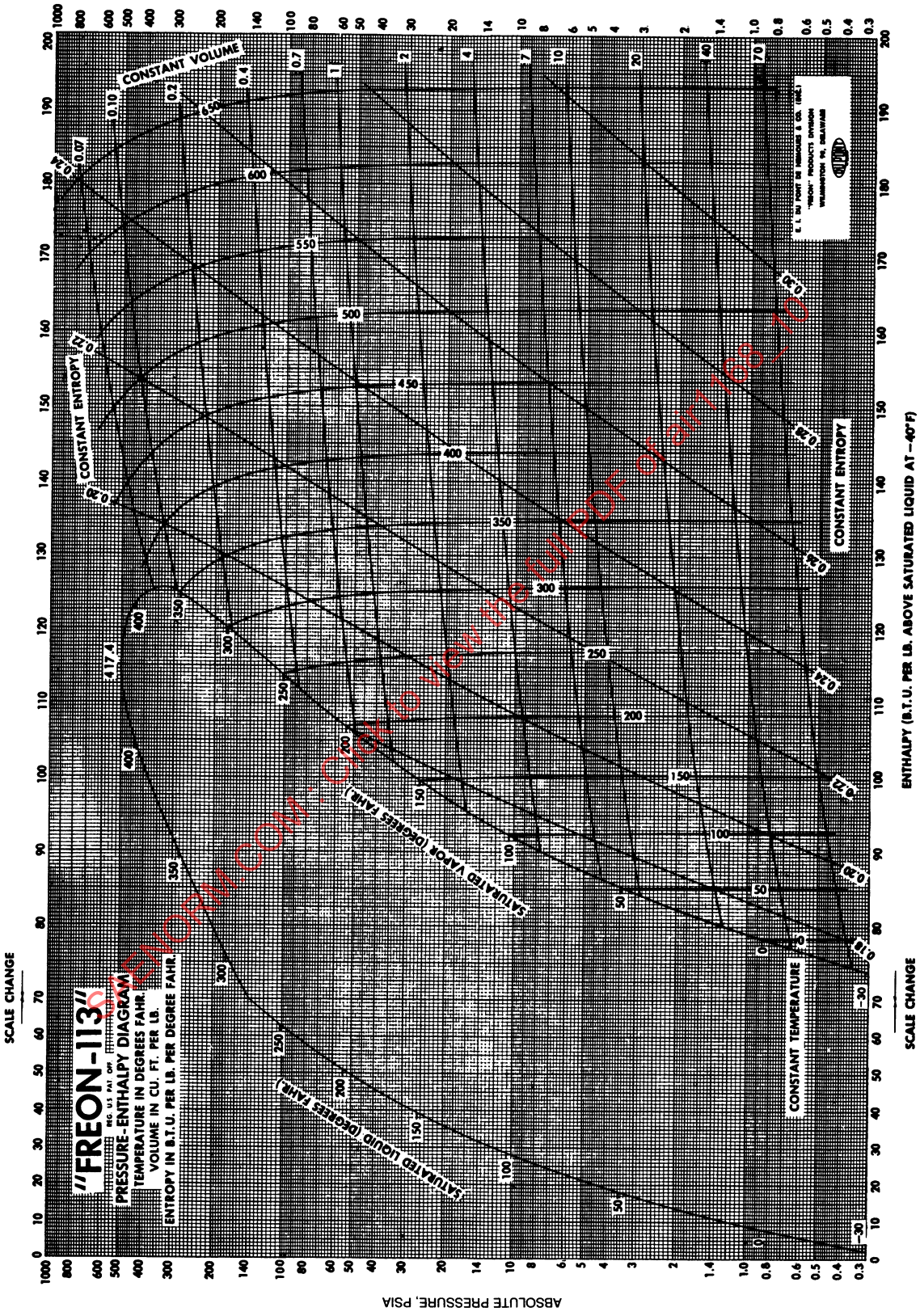

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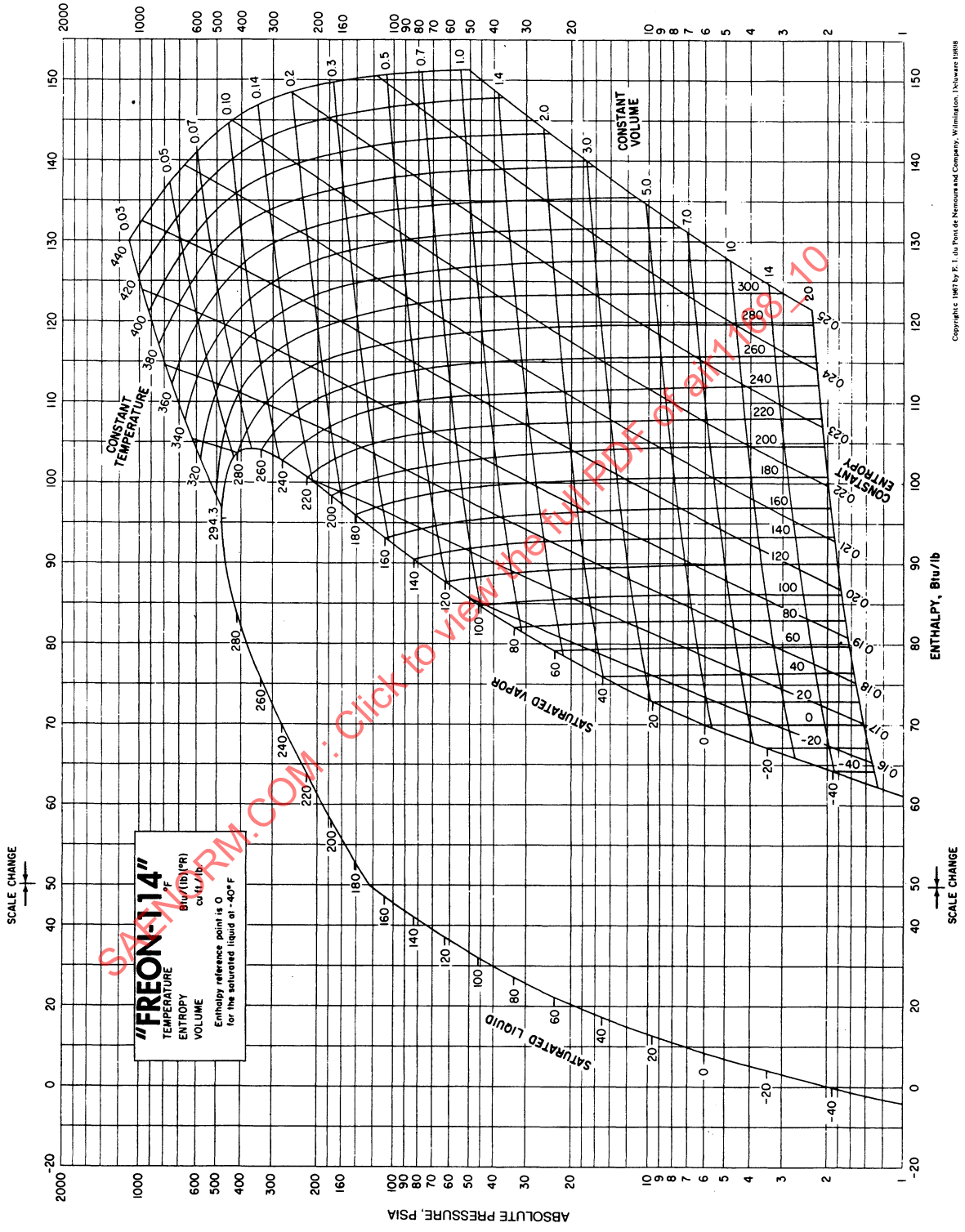

Figure 2E-23 - Pressure-enthalpy Diagram, Freon 114

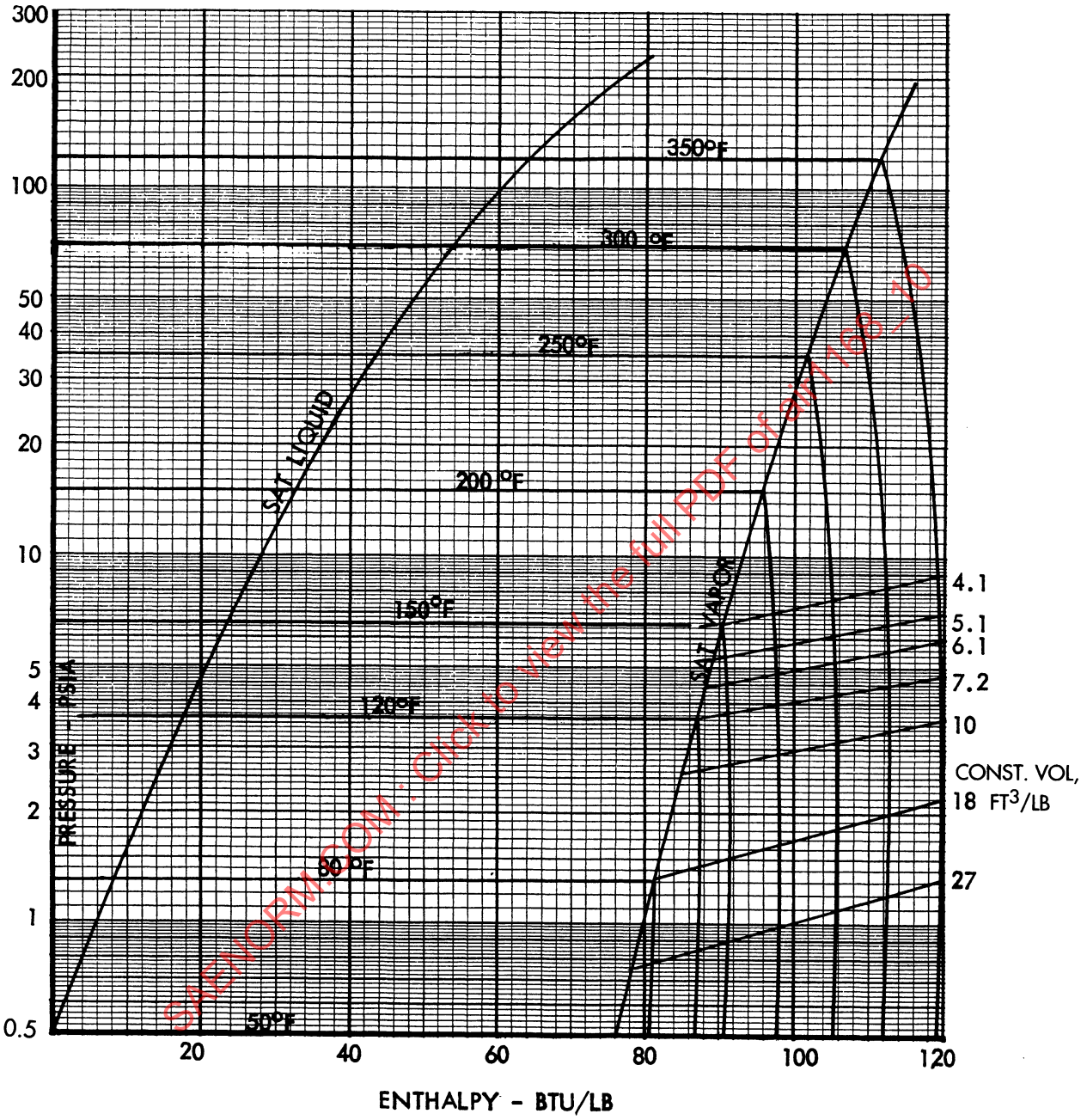

Figure 2E-24 - Estimated Thermodynamic Properties of
1-2-Dichlorohexafluorocyclopentene-1;
Estimated P_{cr} = 480 psia, Estimated t_{cr} = 512°F

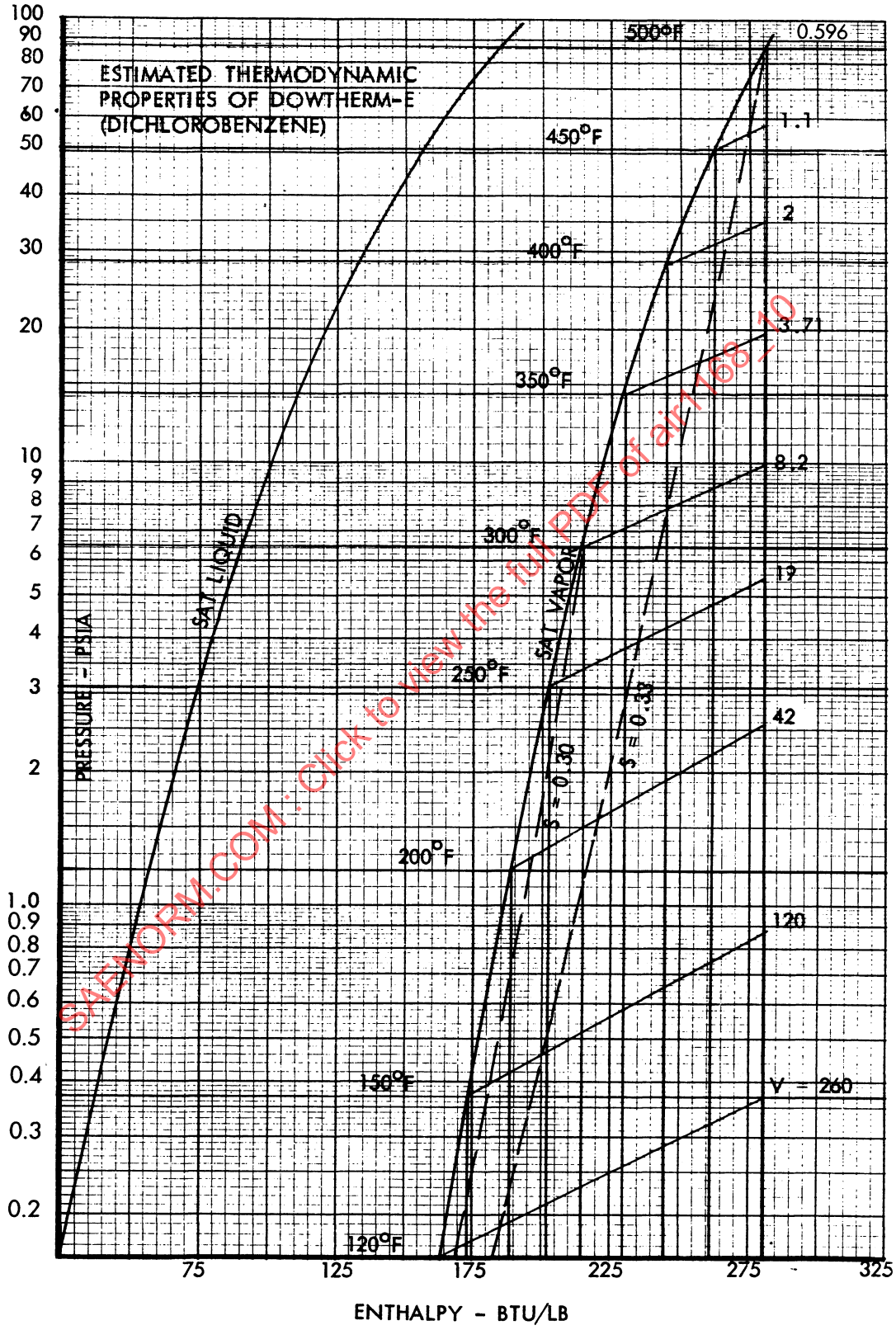

Figure 2E-25 - Estimated Thermodynamic Properties of Dowtherm E (Dichlorobenzene)

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3. SECTION 2F - PROPERTIES OF HEAT TRANSFER FLUIDS

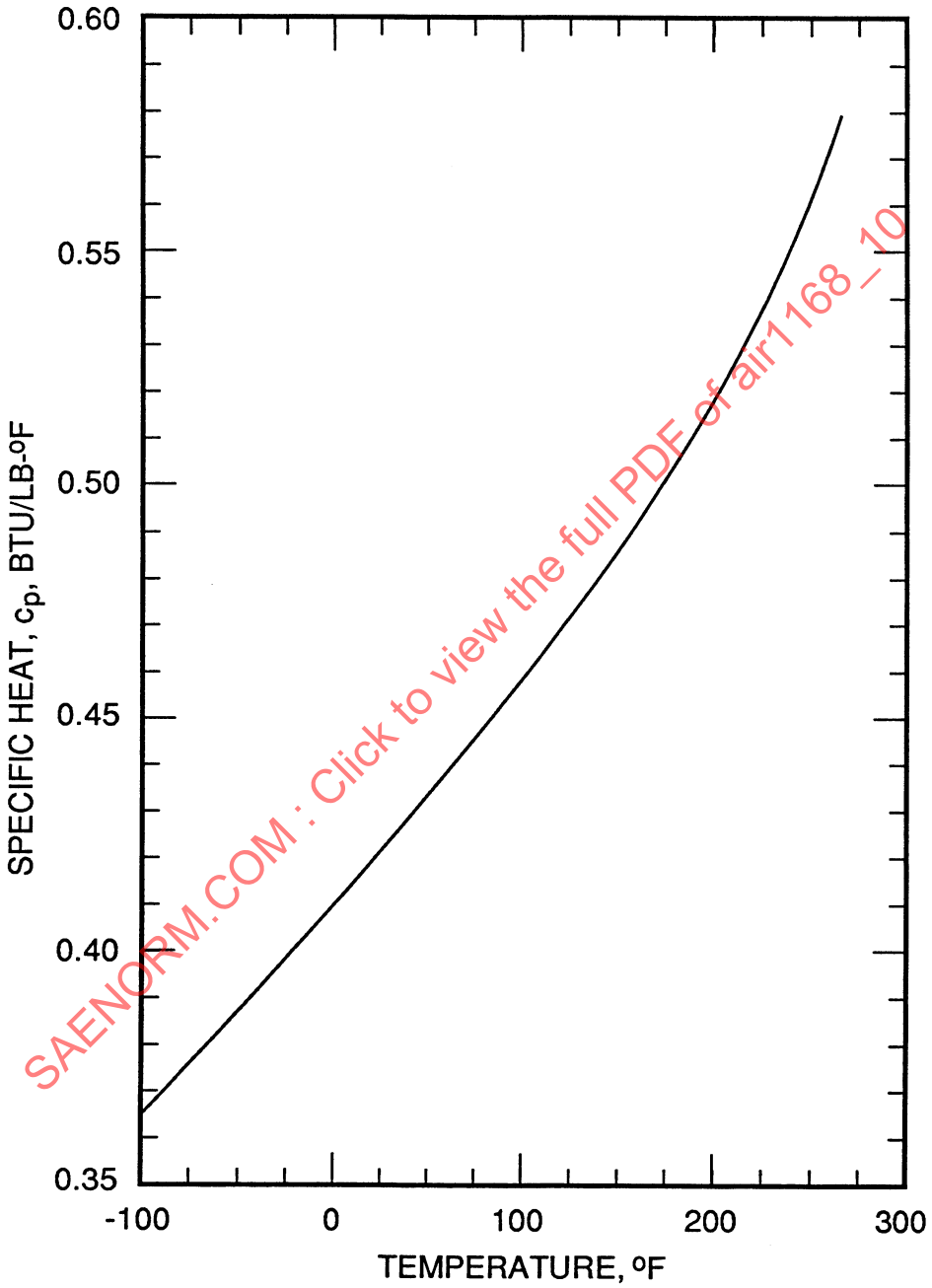

Figure 2F-1 - Coolanol 25 Property c_p (Ref.1)

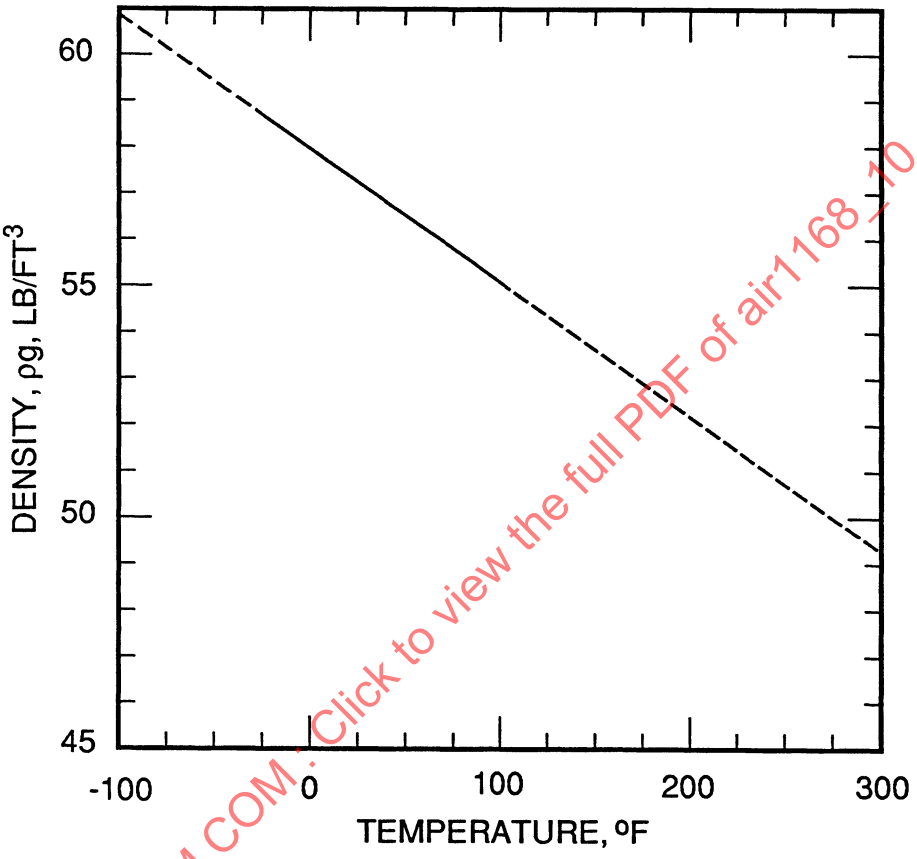

Figure 2F-2 - Coolanol 25 Property ρ*g* (Ref.1)

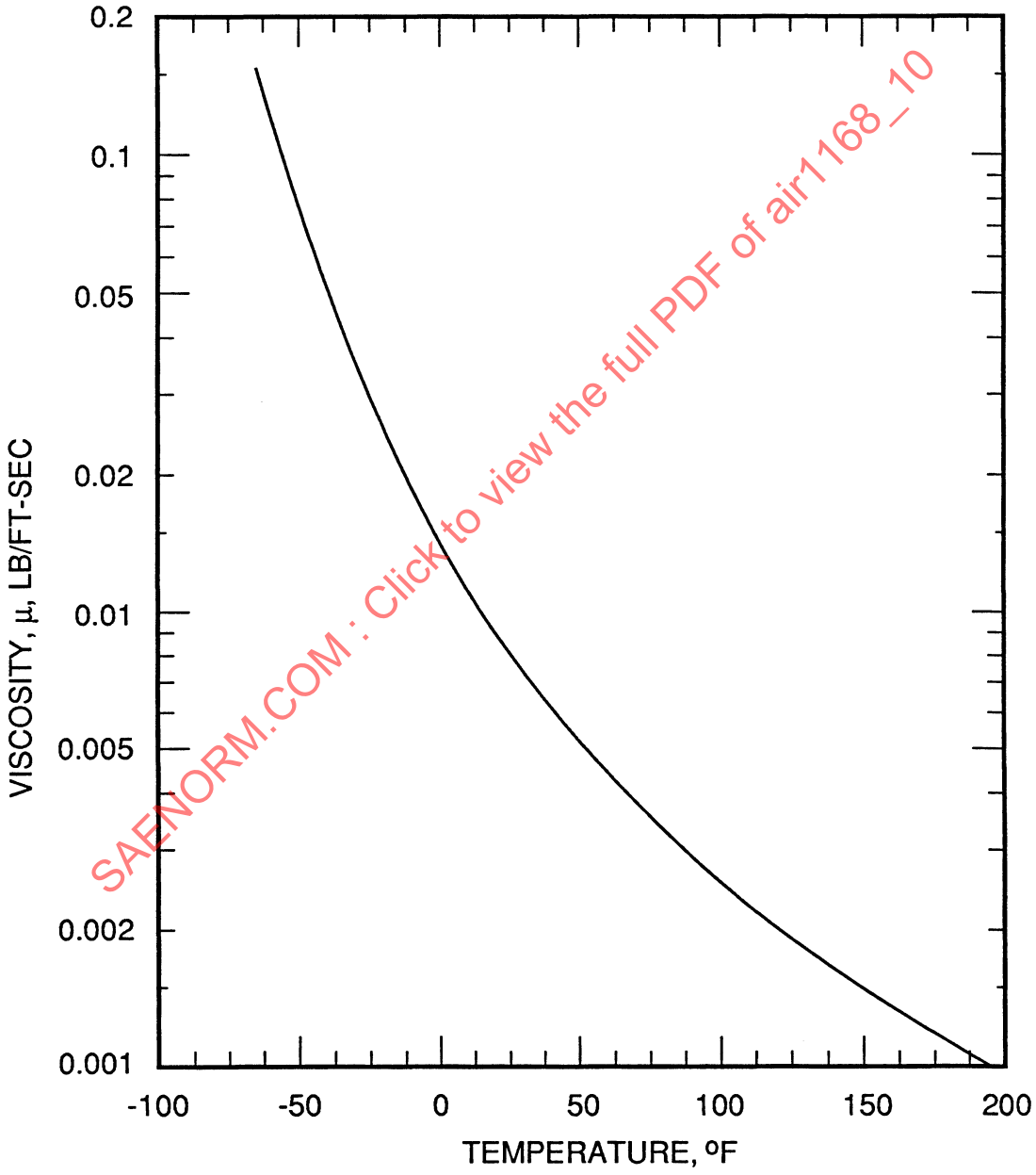

Figure 2F-3 - Coolanol 25 Property μ (Ref.11)

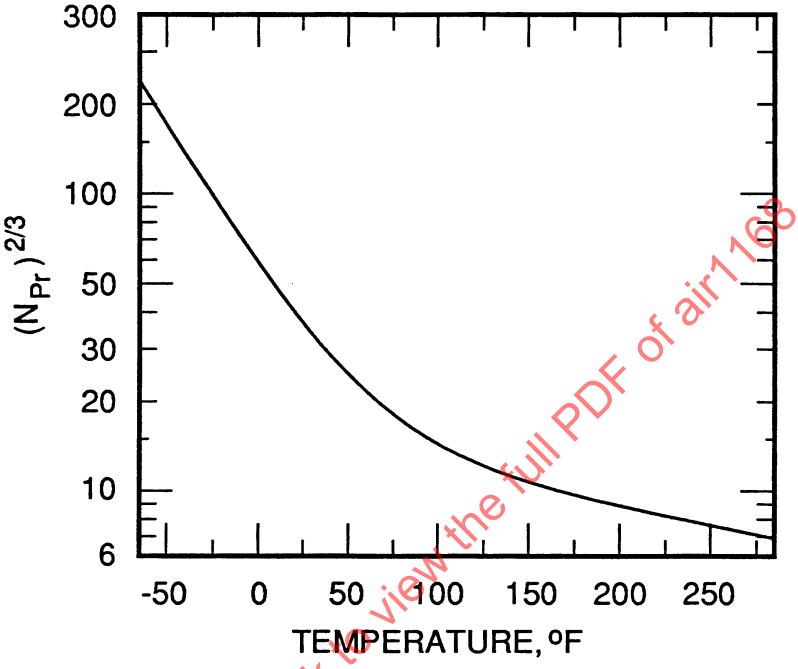

Figure 2F-4 - Coolanol 25 Property $(N_{Pr})^{2/3}$ (Ref.1)

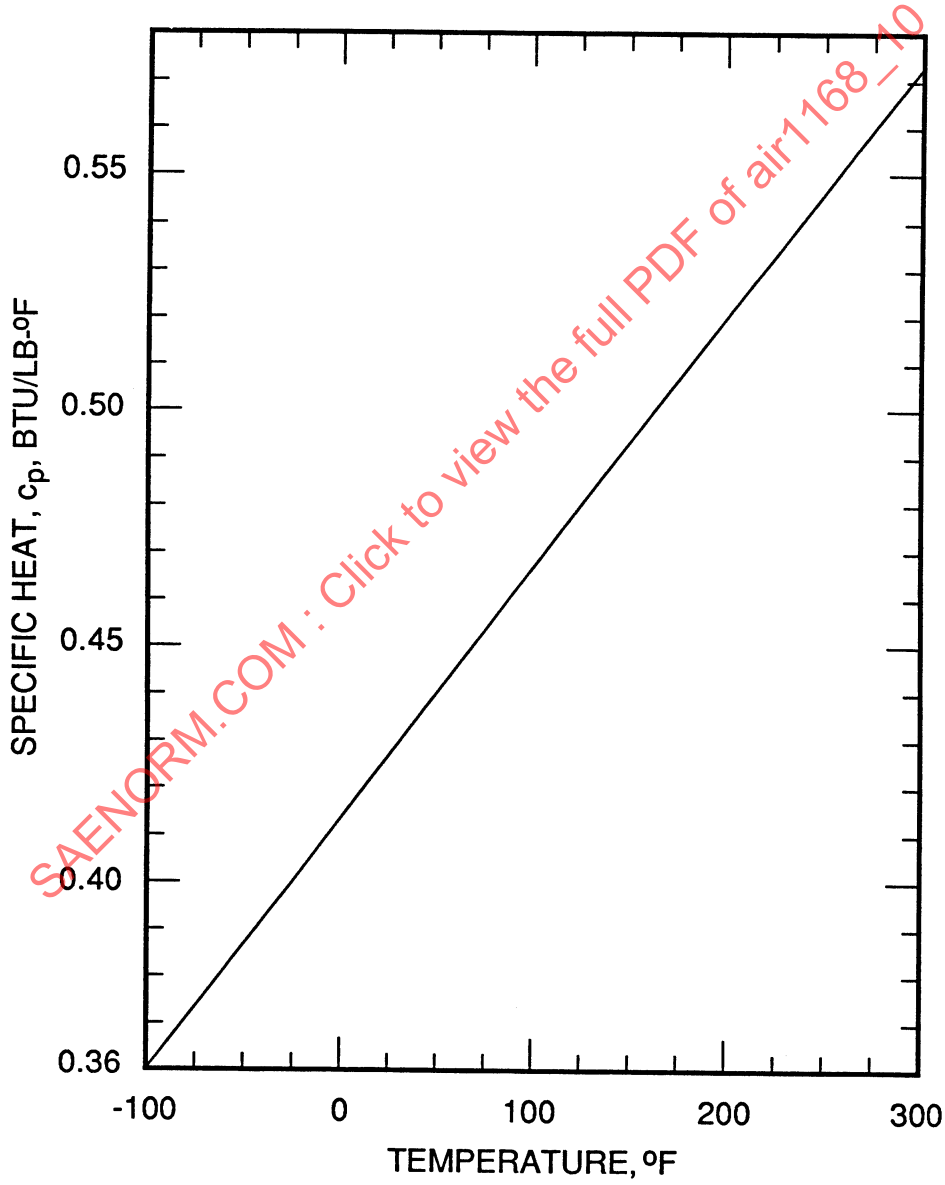

Figure 2F-5 - Coolanol 35 Property c_p (Ref.1)

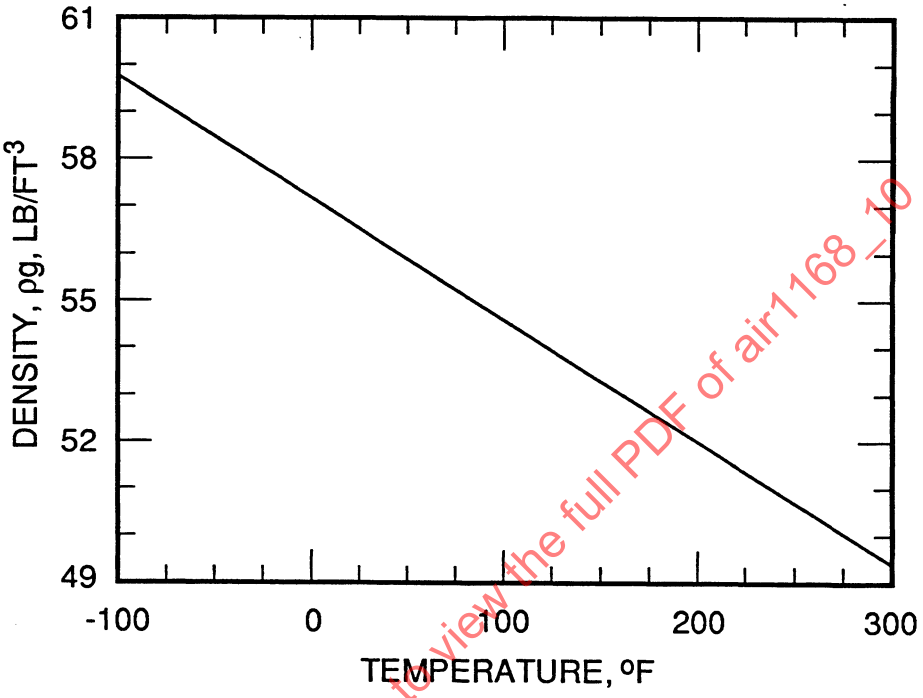

Figure 2F-6 - Coolanol 35 Property ρg (Ref.1)

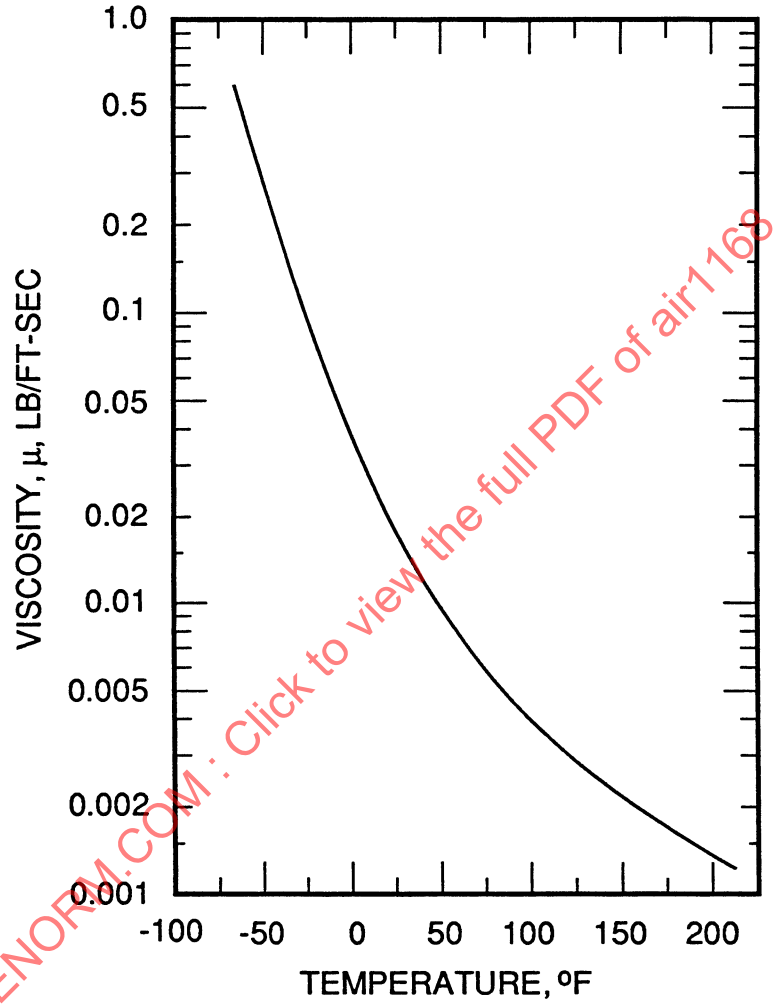

Figure 2F-7 - Coolanol 35 Property μ (Ref. 11)

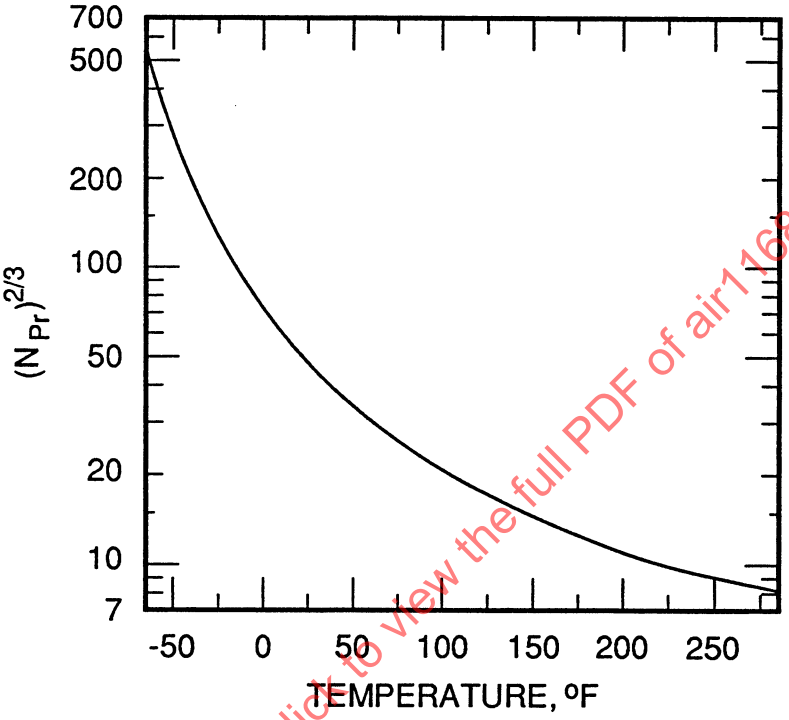

Figure 2F-8 - Coolanol 35 Property $(N_{Pr})^{2/3}$ (Ref.1)

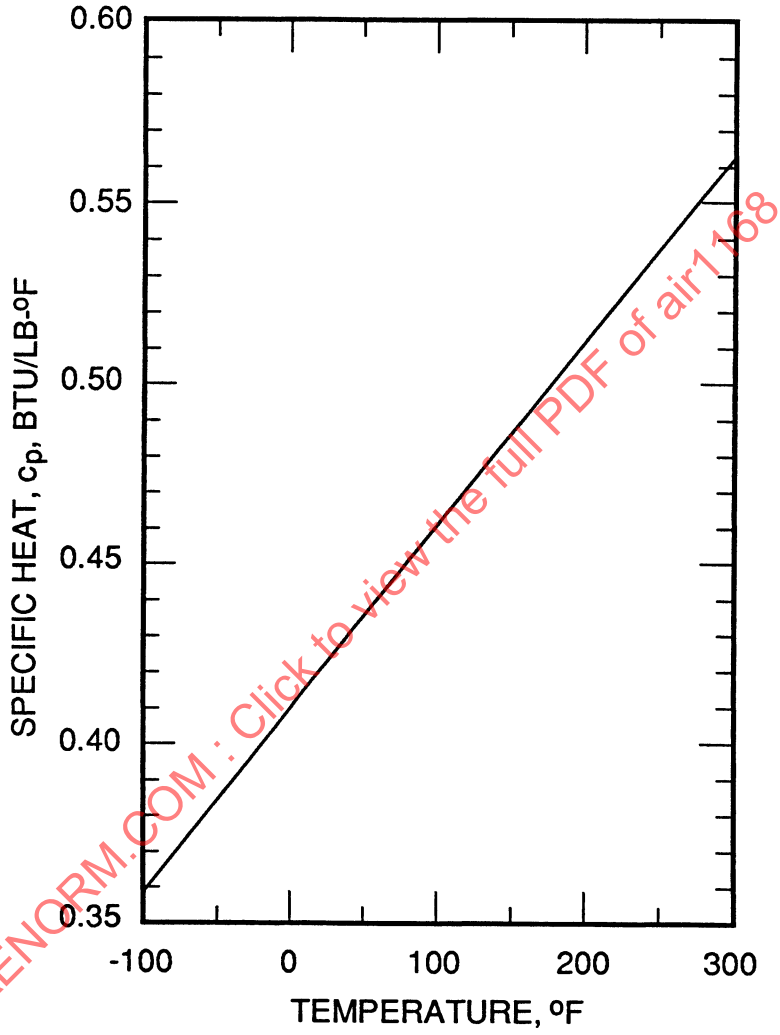

Figure 2F-9 - Coolanol 45 Property c_p (Ref.1)

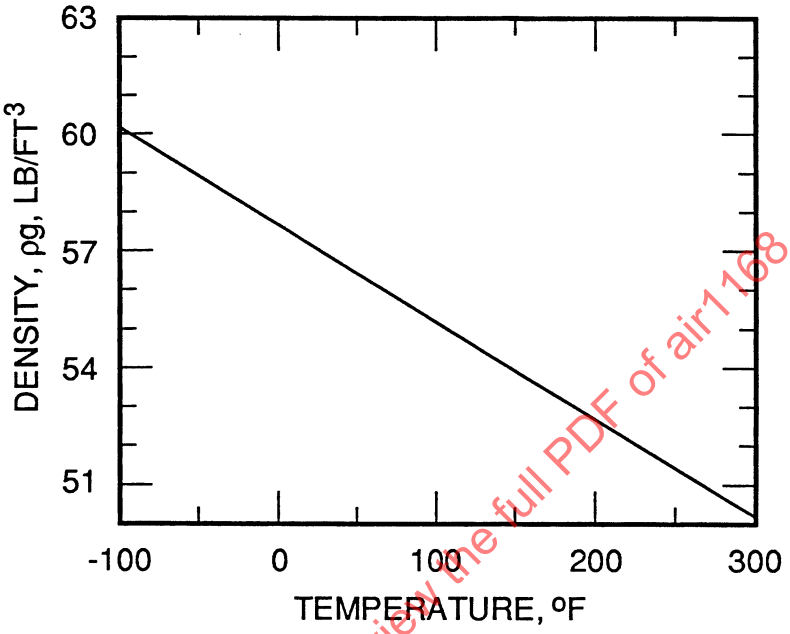

Figure 2F-10 - Coolanol 45 Property ρ*g* (Ref.1)

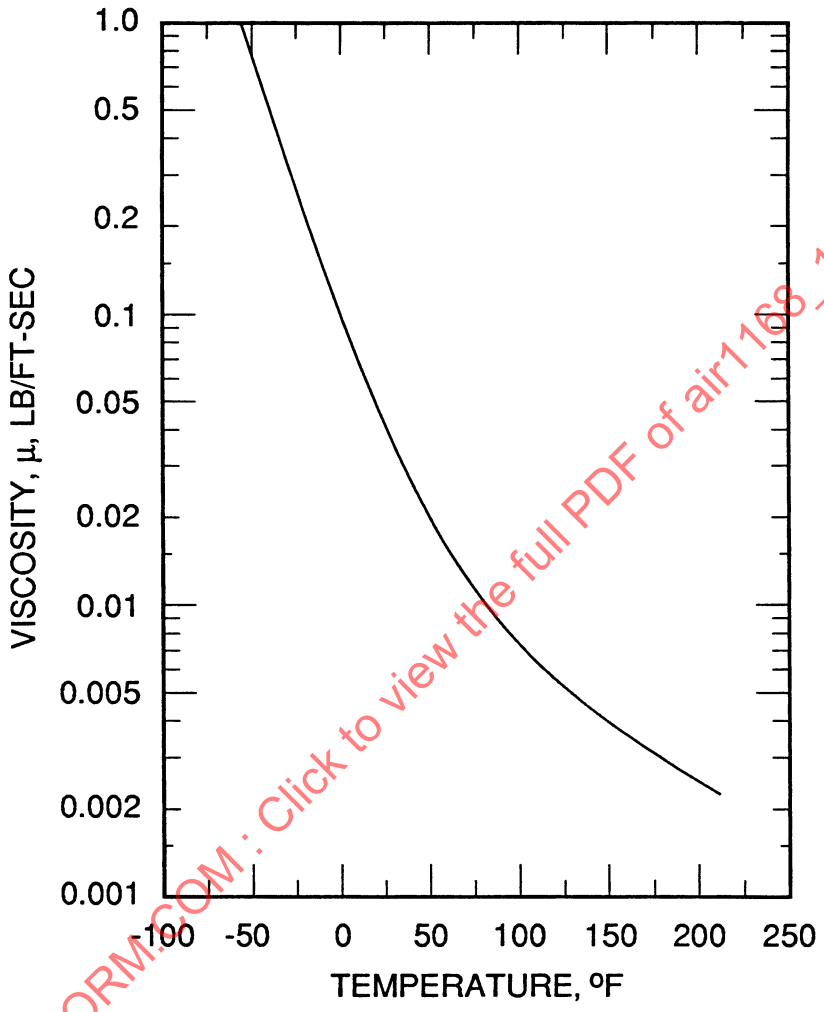

Figure 2F-11 - Coolanol 45 Property μ (Ref.11)

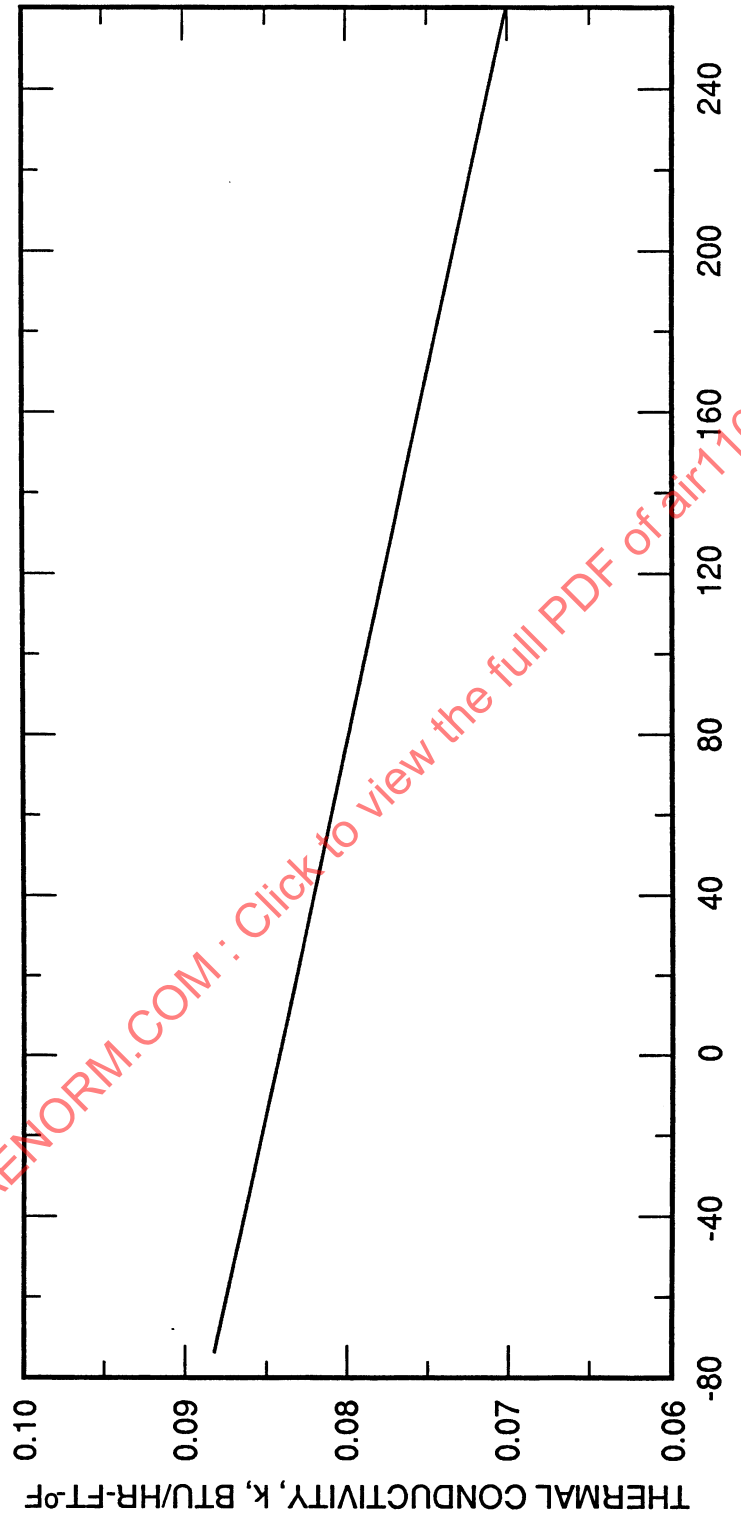

Figure 2F-12 - Coolanol 45 Property *k* (Ref.1)

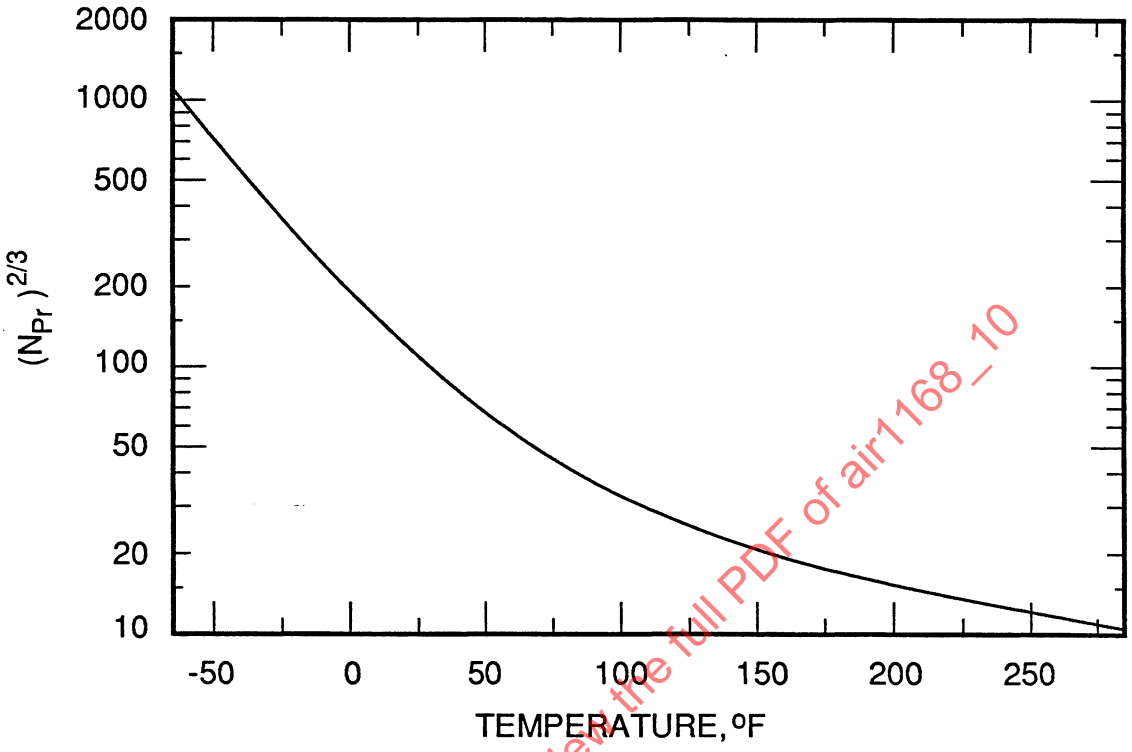

Figure 2F-13 - Coolanol 45 Property $(N_{Pr})^{2/3}$ (Ref.1)

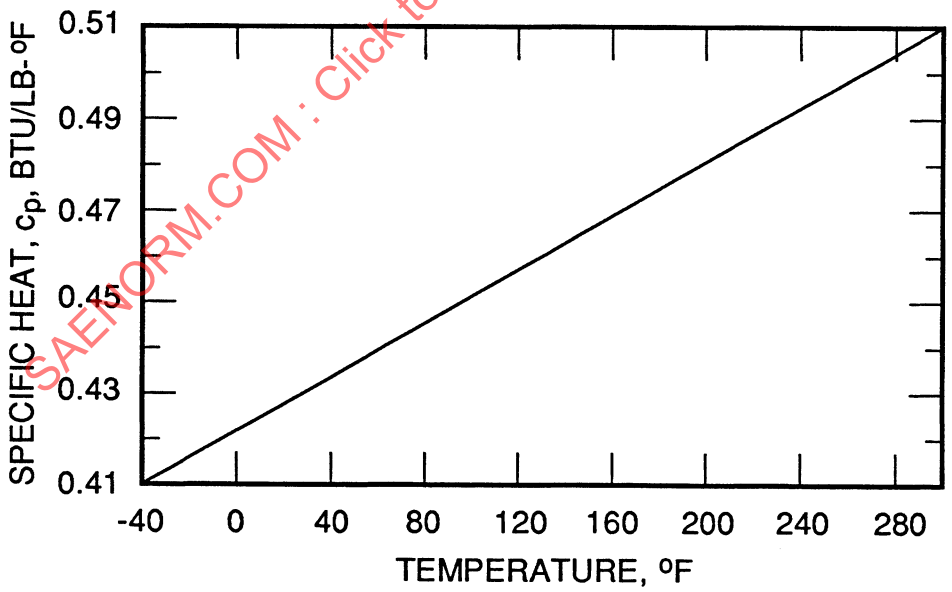

Figure 2F-14 - MCS-198 Property c_p (Ref.2)

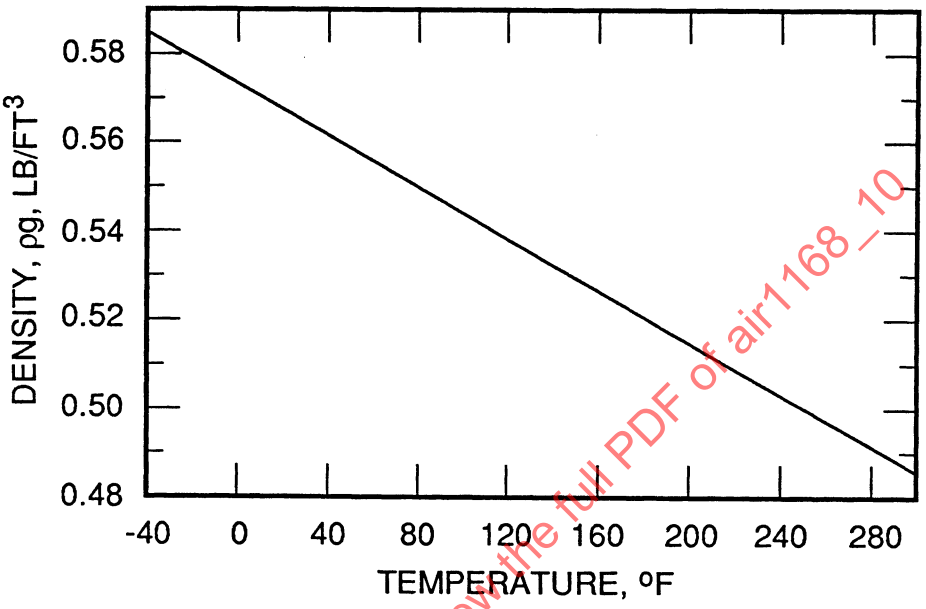

Figure 2F-15 - MCS-198 Property ρg (Ref.2)

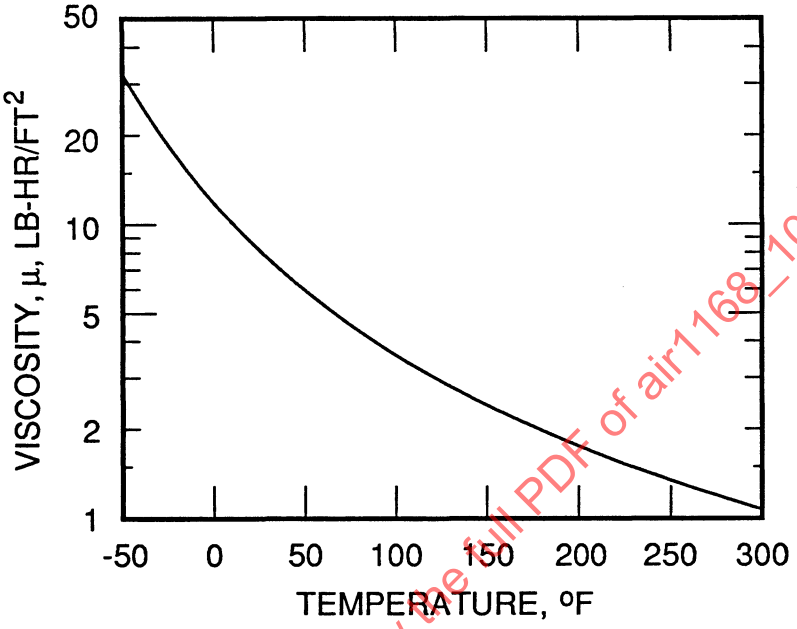

Figure 2F-16 - MCS-198 Property μ (Ref.2)

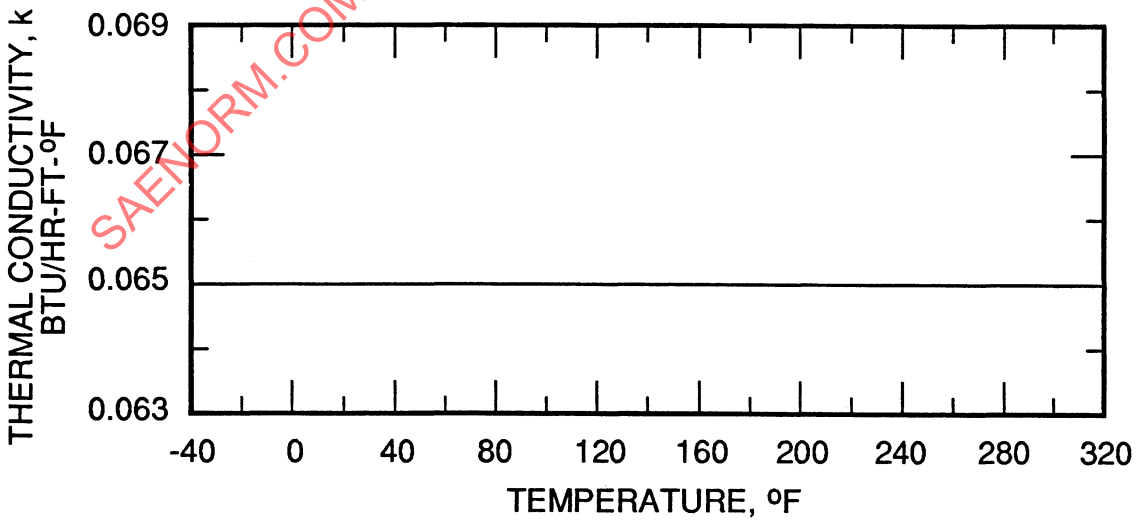

Figure 2F-17 - MCS-198 Property *k* (Ref.2)

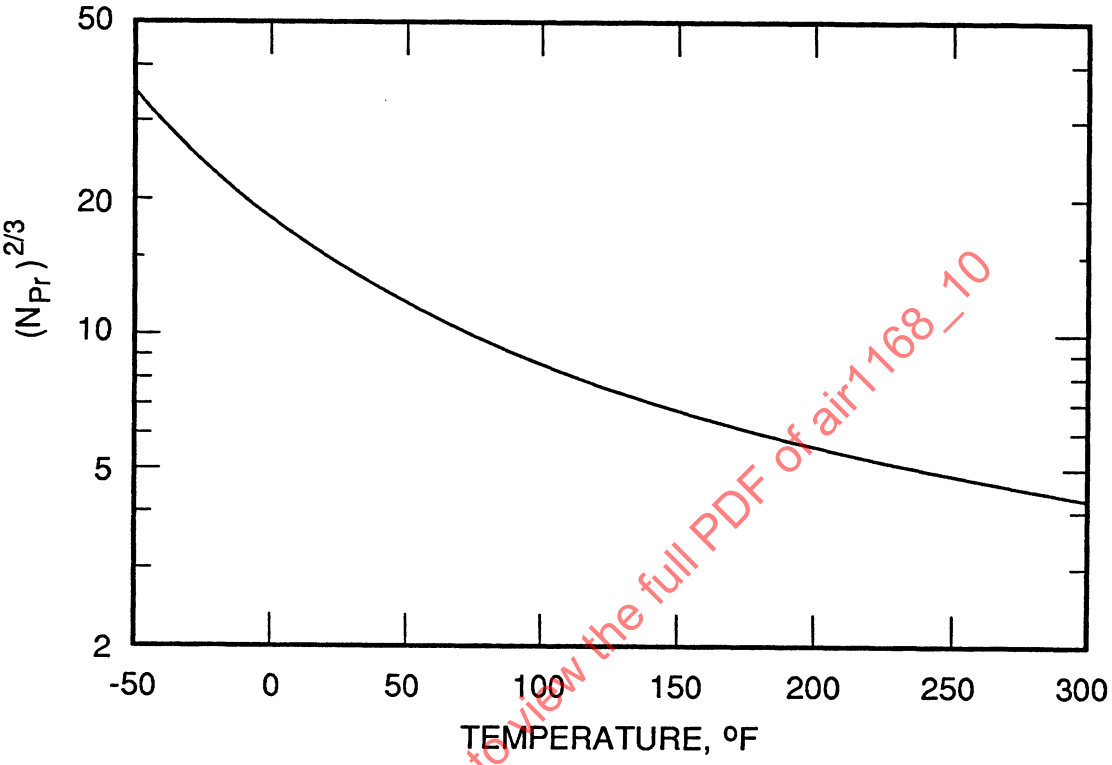

Figure 2F-18 - MCS-198 Property $(N_{Pr})^{2/3}$ (Ref.2)

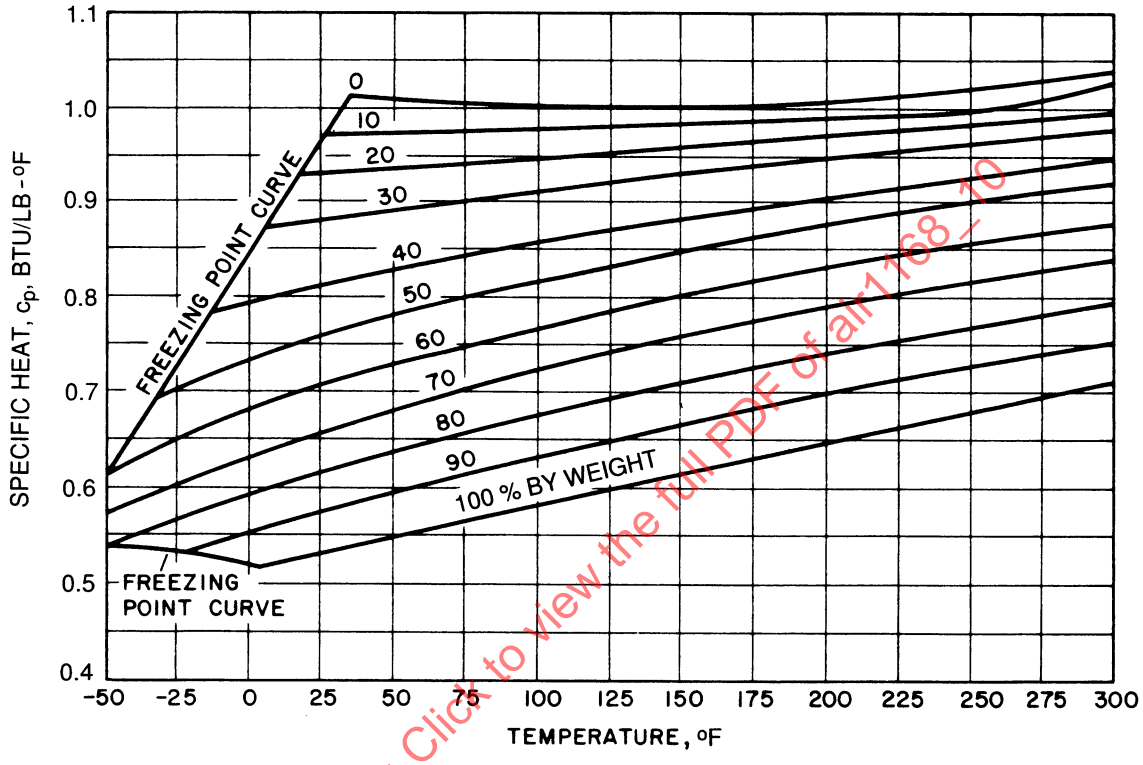

Figure 2F-19 - Aqueous Ethylene Glycol Property c_p; % by weight (Ref.3)

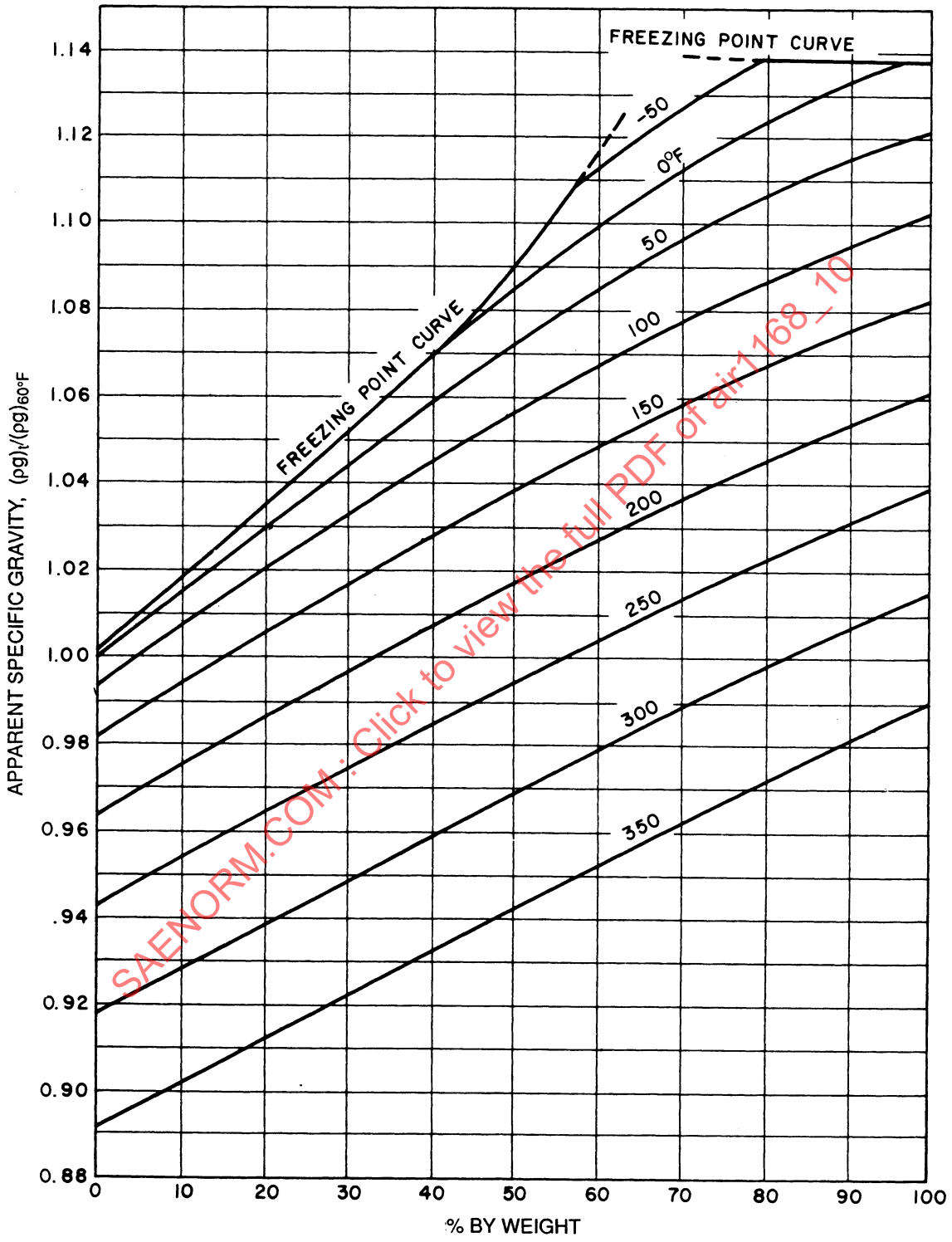

Figure 2F-20 - Aqueous Ethylene Glycol Property $(\rho g)_t/(\rho g)_{60°F}$; % by weight (Ref.3)

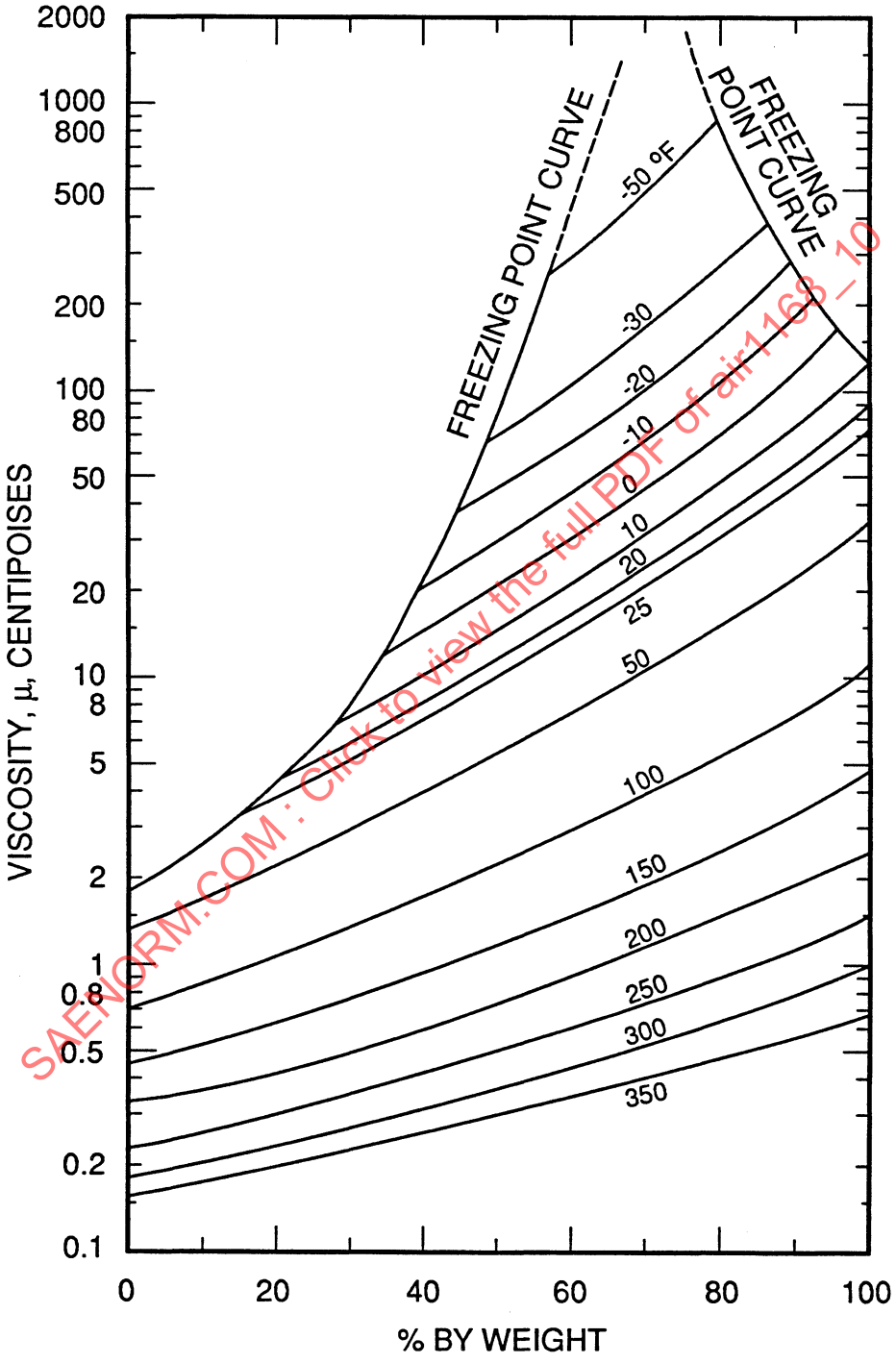

Figure 2F-21 - Aqueous Ethylene Glycol Property μ; % by weight (Ref.3)

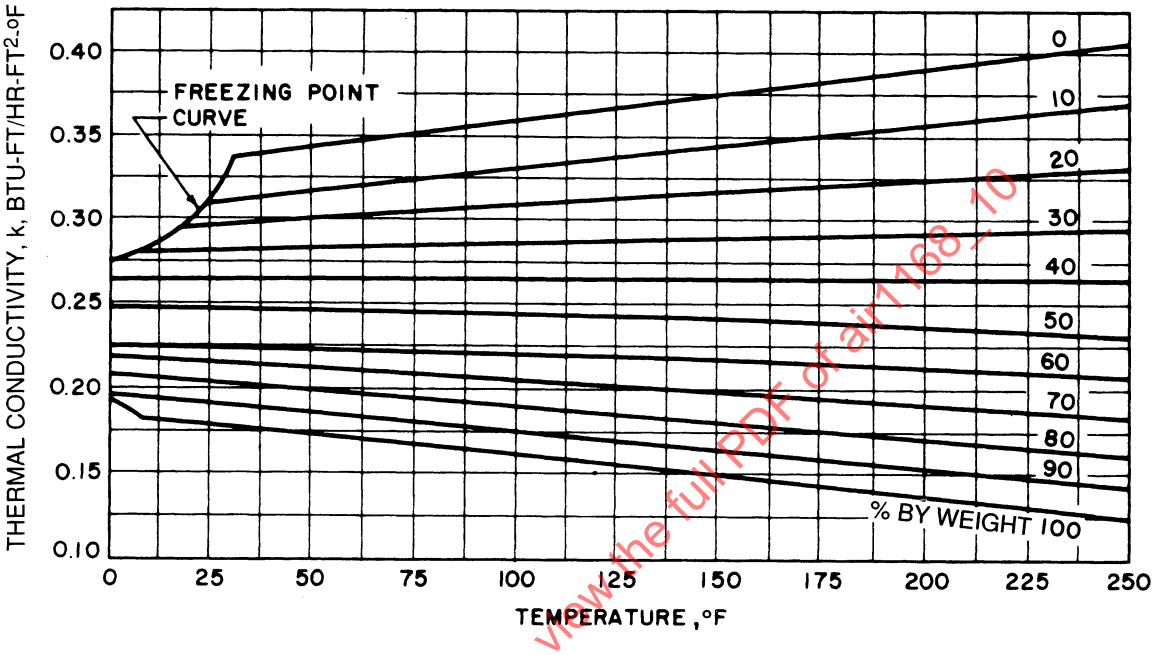

Figure 2F-22 - Aqueous Ethylene Glycol Property *k*; % by weight (Ref.3)

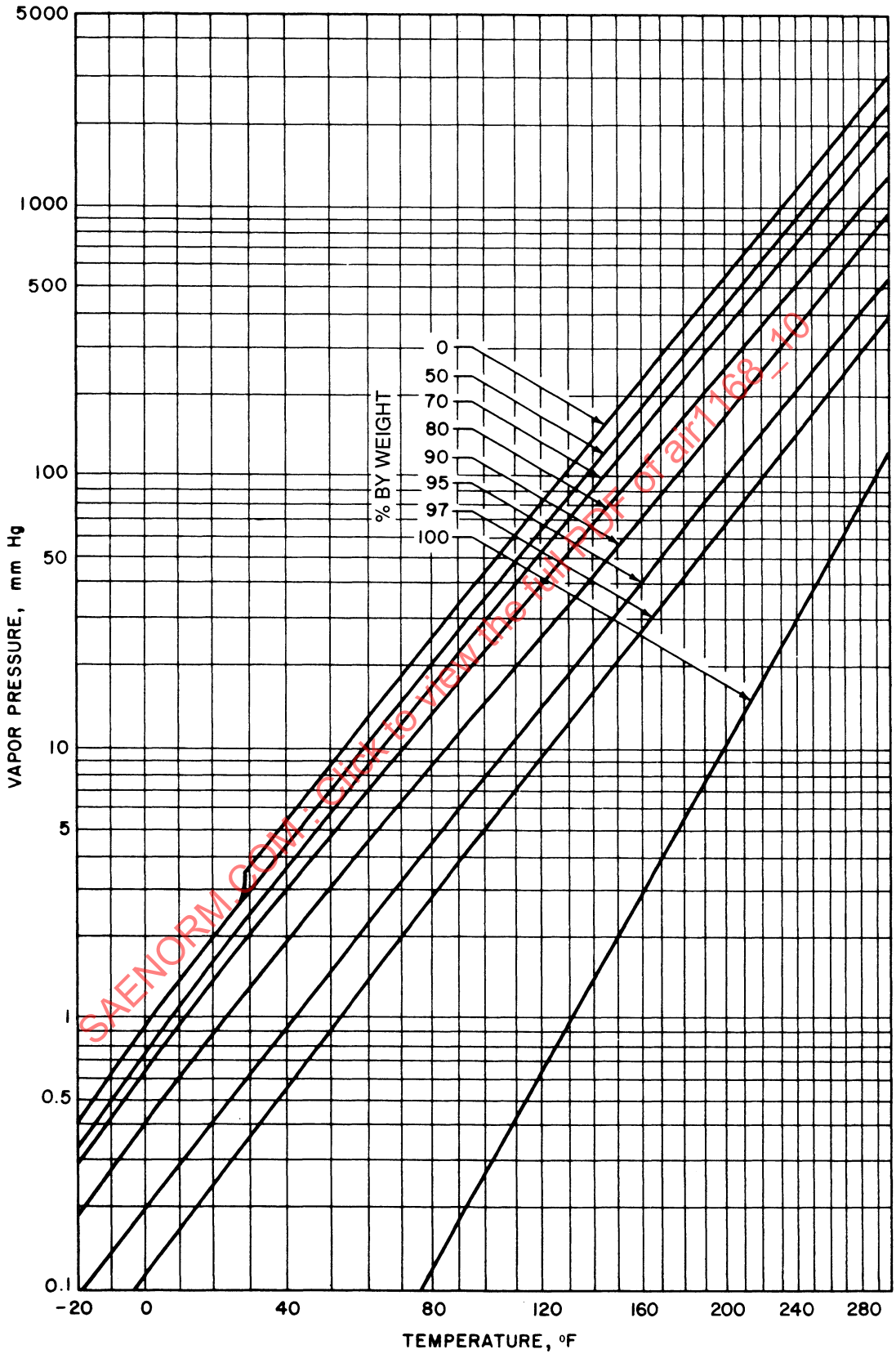

Figure 2F-23 - Aqueous Ethylene Glycol, Vapor Pressure; % by weight (Ref.3)

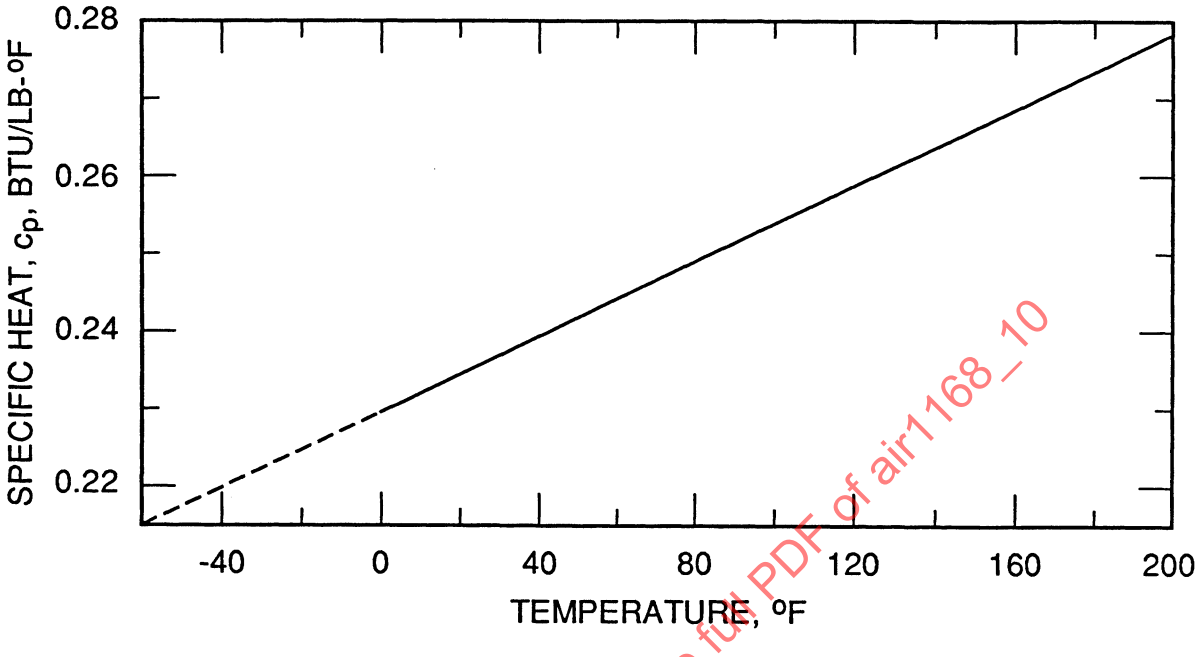

Figure 2F-24 - FC-75 Property c_p (Ref.4)

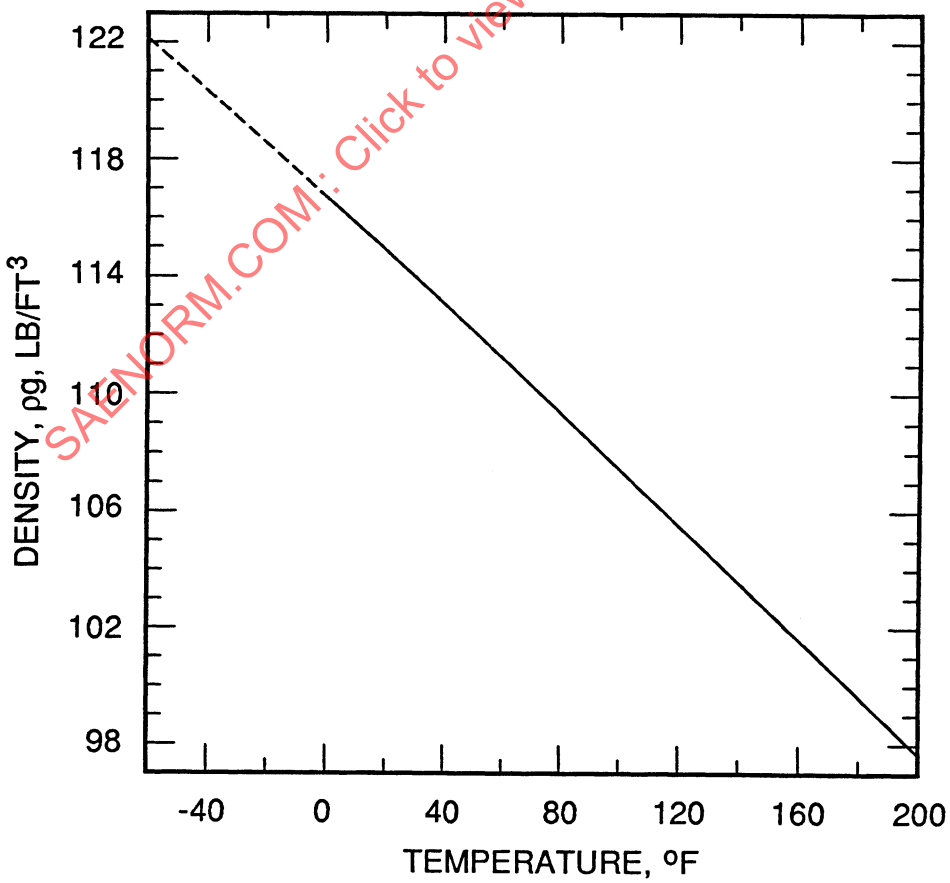

Figure 2F-25 - FC-75 Property ρg (Ref.4)

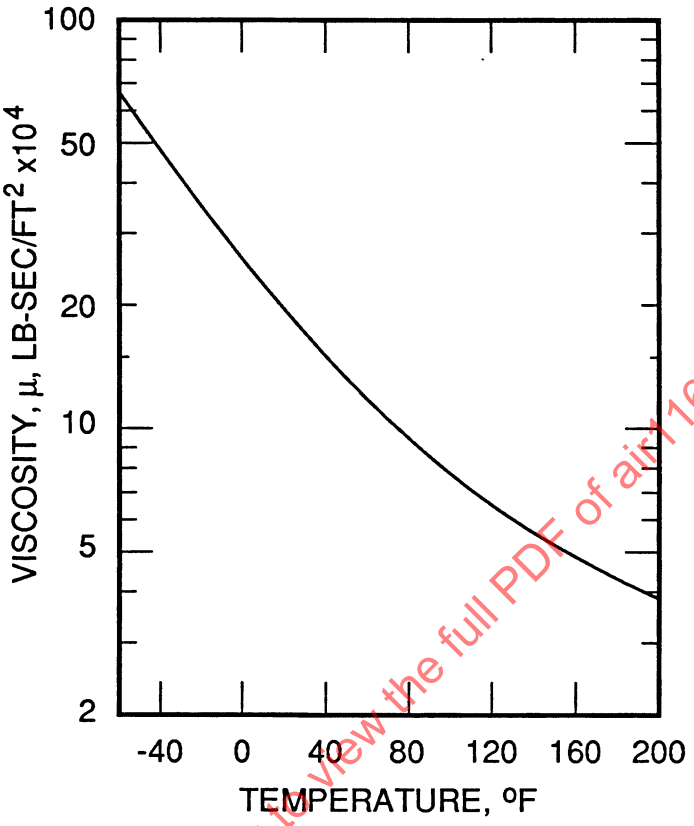

Figure 2F-26 - FC-75 Property μ (Ref.4)

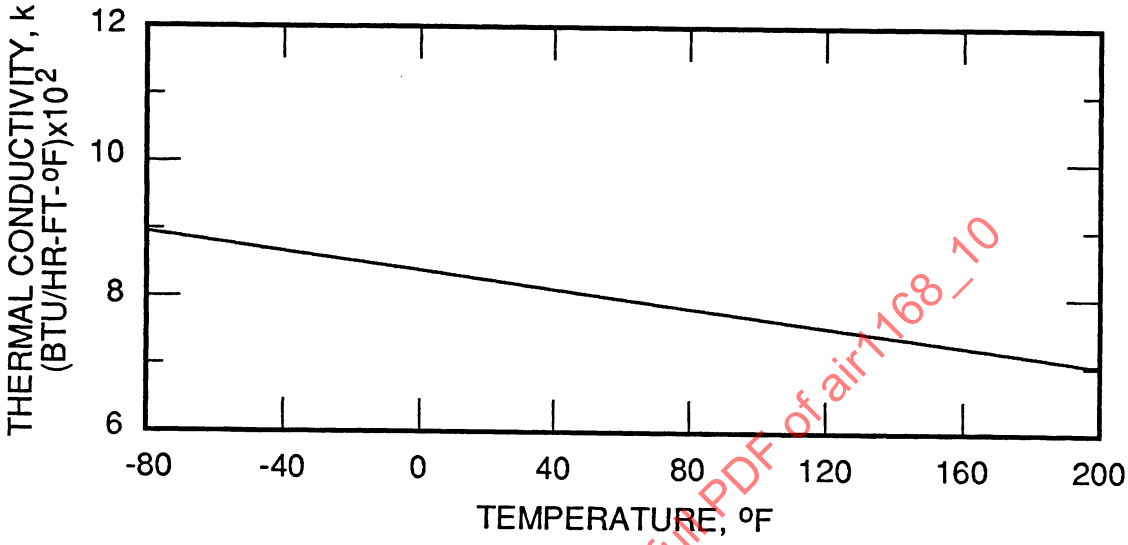

Figure 2F-27 - FC - 75 Property k (Ref.4)

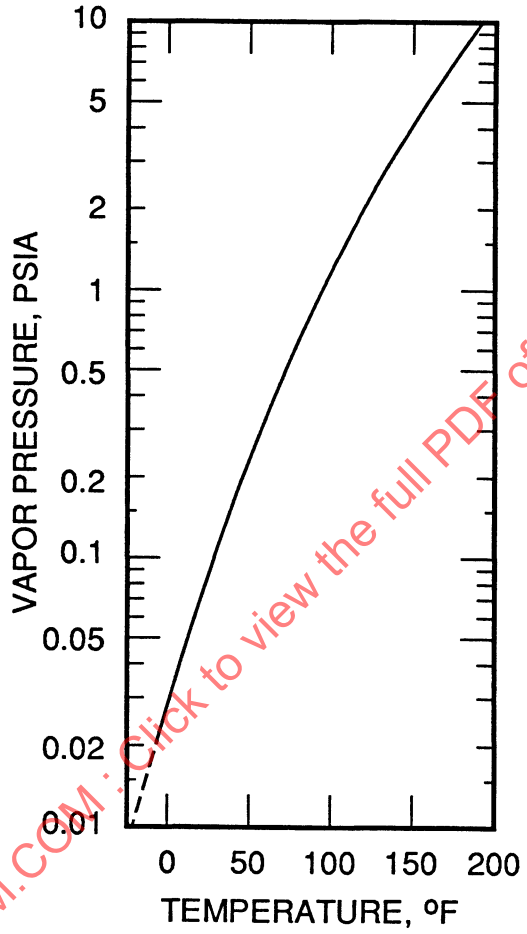

Figure 2F-28 - FC-75 Vapor Pressure (Ref.4)