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Psychrometric Data



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Psychrometric Data

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Keywords: Psychrometric

1 Purpose and scope

1.1 The purpose of this data is to assemble psychrometric data in chart and equation form in both SI and English units.

1.2 Psychrometric charts are presented that give Data for dry bulb temperature ranges of -35 to 600 °F in English units and -10 to 120 °C in SI units.

1.3 Many analyses of psychrometric data are made on computers. The equations given in Sections 2 and 3 enable the calculation of all psychrometric data if any two independent psychrometric properties of an air-water vapor mixture are known in addition to the atmospheric pressure. In some cases, iteration procedures are necessary. In some instances, the range of data covered by the equation has been extended beyond that given in the original source. The equations yield results that agree closely with values given by Keenan and Keyes (1936) and existing psychrometric charts.

2 Psychrometric data in SI units

2.1 Psychrometric charts; two presented. One for a temperature range of -10 to 55 °C and one for a temperature range of 20 to 120 °C.

2.2 Psychrometric equations, SI units. Symbols are defined in Table 1.

2.2.1 Saturation line. P_s as a function of T

Table 1 – Symbols

h	Enthalpy of air-vapor mixture, J/kg dry air or Btu/lb dry air
h_{fg}	Latent heat of vaporization of water at saturation, J/kg or Btu/lb
h'_{fg}	Latent heat of vaporization of water at T_{wb} , J/kg or Btu/lb
h''_{fg}	Latent heat vaporization of water at T_{dp} , J/kg or Btu/lb
h_{ig}	Heat of sublimation of ice, J/kg or Btu/lb
h'_{ig}	Heat of sublimation of ice at T_{wb} , J/kg or Btu/lb
h''_{ig}	Heat of sublimation of ice at T_{dp} , J/kg or Btu/lb
H	Humidity ratio, kg water/kg dry air or lb water/lb dry air
\ln	Natural logarithm (base e)
P_{atm}	Atmospheric pressure, Pa or psi
P_s	Saturation vapor pressure at T , Pa or psi
P_{swb}	Saturation vapor pressure at T_{wb} , Pa or psi
P_v	Vapor pressure, Pa or psi
rh	Relative humidity, decimal
T	Dry-bulb temperature, kelvin or rankine
T_{dp}	Dew-point temperature, kelvin or rankine
T_{wb}	Wet-bulb temperature, kelvin or rankine
V_{sa}	Air specific volume, m ³ /kg dry air or ft ³ /lb dry air

$$\ln P_s = 31.9602 - \frac{6270.3605}{T} - 0.46057 \ln T$$

Brooker (1967)

$$255.38 \leq T \leq 273.16$$

and

$$\ln(P_s/R) = \frac{A + BT + CT^2 + DT^3 + ET^4}{FT - GT^2}$$

Adapted from Keenan and Keyes (1936)

$$273.16 \leq T \leq 533.16$$

where

$$\begin{aligned} R &= 22,105,649.25 & D &= 0.12558 \times 10^{-3} \\ A &= -27,405.526 & E &= -0.48502 \times 10^{-7} \\ B &= 97.5413 & F &= 4.34903 \\ C &= -0.146244 & G &= 0.39381 \times 10^{-2} \end{aligned}$$

2.2.2 Saturation line. T as a function of P_s

$$T - 255.38 = \sum_{i=0}^{i=8} A_i [\ln(0.00145 P_s)]^i$$

$$620.52 < P_s < 4,688,396.00$$

Steltz and Silvestri (1958)

$$A_0 = 19.5322$$

$$A_1 = 13.6626$$

$$A_2 = 1.17678$$

$$A_3 = -0.189693$$

$$A_4 = 0.087453$$

$$A_5 = -0.0174053$$

$$A_6 = 0.00214768$$

$$A_7 = -0.138343 \times 10^{-3}$$

$$A_8 = 0.38 \times 10^{-5}$$

2.2.3 Latent heat of sublimation at saturation

$$h_{ig} = 2,839,683.144 - 212.56384 (T - 255.38)$$

$$255.38 \leq T \leq 273.16$$

Brooker (1967)

2.2.4 Latent heat of vaporization at saturation

$$h_{fg} = 2,502,535.259 - 2,385.76424 (T - 273.16)$$

$$273.16 \leq T \leq 338.72$$

Brooker (1967)

$$h_{fg} = (7,329,155,978,000 - 15,995,964.08 T^2)^{1/2}$$

$$338.72 \leq T \leq 533.16$$

Brooker (Unpublished)

2.2.5 Wet bulb line

$$P_{swb} - P_v = B' (T_{wb} - T)$$

Brunt (1941)

where

$$B' = \frac{1006.9254(P_{swb} - P_{atm}) \left(1 + 0.15577 \frac{P_v}{P_{atm}} \right)}{0.62194 h'_{fg}}$$

Substitute h'_{fg} for h_{fg} where $T_{wb} \leq 273.16$

$$255.38 \leq T \leq 533.16$$

2.2.6 Humidity ratio

$$H = \frac{0.6219 P_v}{P_{atm} - P_v}$$

$$255.38 \leq T \leq 533.16$$

$$P_v < P_{atm}$$

2.2.7 Specific volume

$$V_{sa} = \frac{287 T}{P_{atm} - P_v}$$

$$255.38 \leq T \leq 533.16$$

$$P_v < P_{atm}$$

2.2.8 Enthalpy

Enthalpy=enthalpy of air+enthalpy of water (or ice) at dew-point temperature+enthalpy of evaporation (or sublimation) at dew-point temperature+enthalpy added to the water vapor (super-heat) after vaporization.

$$h = 1006.92540 (T - 273.16)$$

$$- H[333,432.1 + 2030.5980(273.16 - T_{dp})] + h'_{fg}H$$

$$+ 1875.6864H(T - T_{dp})$$

$$255.38 \leq T_{dp} \leq 273.16$$

and

$$h = 1006.92540 (T - 273.16)$$

$$+ 4186.8 H(T_{dp} - 273.16) + h'_{fg}H + 1875.6864 H(T - T_{dp})$$

$$273.16 \leq T_{dp} \leq 373.16$$

2.2.9 Relative humidity

$$rh = P_v / P_s$$

3 Psychrometric data in English Units

3.1 Three psychrometric charts are presented with temperature ranges of -35 to 50 °F, 32 to 120 °F and 32 to 600 °F, respectively.

3.2 Psychrometric equations, English units. Symbols are defined in Table 1.

3.2.1 Saturation line. P_s as a function of T

$$\ln P_s = 23.3924 - \frac{11286.6489}{T} - 0.46057 \ln T$$

Brooker (1967)

$$459.69 \leq T \leq 491.69$$

$$\ln(P_s/R) = \frac{A + BT + CT^2 + DT^3 + ET^4}{FT - GT^2}$$

Adapted from Keenan and Keyes (1936)

$$491.69 \leq T \leq 959.69$$

where

$$R = 3206.18$$

$$A = -27405.5$$

$$B = 54.1896$$

$$C = -0.045137$$

$$D = 0.215321 \times 10^{-4}$$

$$E = -0.462027 \times 10^{-8}$$

$$F = 2.41613$$

$$G = 0.00121547$$

3.2.2 Saturation line. T as a function of P_s

$$T - 459.69$$

$$= \sum_{i=0}^{i=8} A_i [\ln(10P_s)]^i$$

Steltz and Silvestri (1958)

$$0.09 \leq P_s \leq 680$$

where

$$A_0 = 35.1579$$

$$A_1 = 24.5926$$

$$A_2 = 2.11821$$

$$A_3 = -0.341447$$

$$A_4 = 0.157416$$

$$A_5 = -0.0313296$$

$$A_6 = 0.00386583$$

$$A_7 = -0.249018 \times 10^{-3}$$

$$A_8 = 0.684016 \times 10^{-5}$$

3.2.3 Latent heat of sublimation at saturation

$$h_{ig} = 1220.844 - 0.05077 (T - 459.69)$$

$$459.69 \leq T \leq 491.69$$

Brooker (1967)

3.2.4 Latent heat of vaporization at saturation

$$h_{fg} = 1075.8965 - 0.56983 (T - 491.69)$$

Brooker (1967)

$$491.69 \leq T \leq 609.69$$

$$h_{fg} = (1354673.214 - 0.9125275587 T^2)^{1/2}$$

Brooker (Unpublished)

$$609.69 \leq T \leq 959.69$$

3.2.5 Wet bulb line

$$P_{swb} - P_v = B' (T_{wb} - T)$$

Brunt (1941)

where

$$B' = \frac{0.2405(P_{swb} - P_{atm})(1 + 0.15577P_v/P_{atm})}{0.62194 h'_{fg}}$$

Substitute h'_{ig} for h'_{fg} when $T_{wb} \leq 491.69$

$$459.69 \leq T \leq 959.69$$

3.2.6 Absolute humidity (humidity ratio)

$$H = \frac{0.6219 P_v}{P_{atm} - P_v}$$

$$459.69 \leq T \leq 959.69$$

$$P_v < P_{atm}$$

3.2.7 Specific volume

$$V_{sa} = \frac{53.35 \times T}{144(P_{atm} - P_v)}$$

$$459.69 \leq T \leq 959.69$$

$$P_v < P_{atm}$$

3.2.8 Enthalpy

Enthalpy=enthalpy of air+enthalpy of water (or ice) at dew-point temperature+enthalpy of evaporation (or sublimation) at dew-point temperature+enthalpy added to the water vapor (super-heat) after vaporization.

$$h = 0.2405(T - 459.69) - H[143.35 + 0.485(491.69 - T_{dp})] + h'_{ig}H + 0.448H(T - T_{dp})$$

$$459.69 \leq T_{dp} \leq 491.69$$

$$h = 0.2405(T - 459.69) + H(T_{dp} - 491.69) + h'_{ig}H + 0.448H(T - T_{dp})$$

$$491.69 \leq T_{dp} \leq 671.69$$

3.2.9 Relative humidity

$$rh = P_v/P_s$$

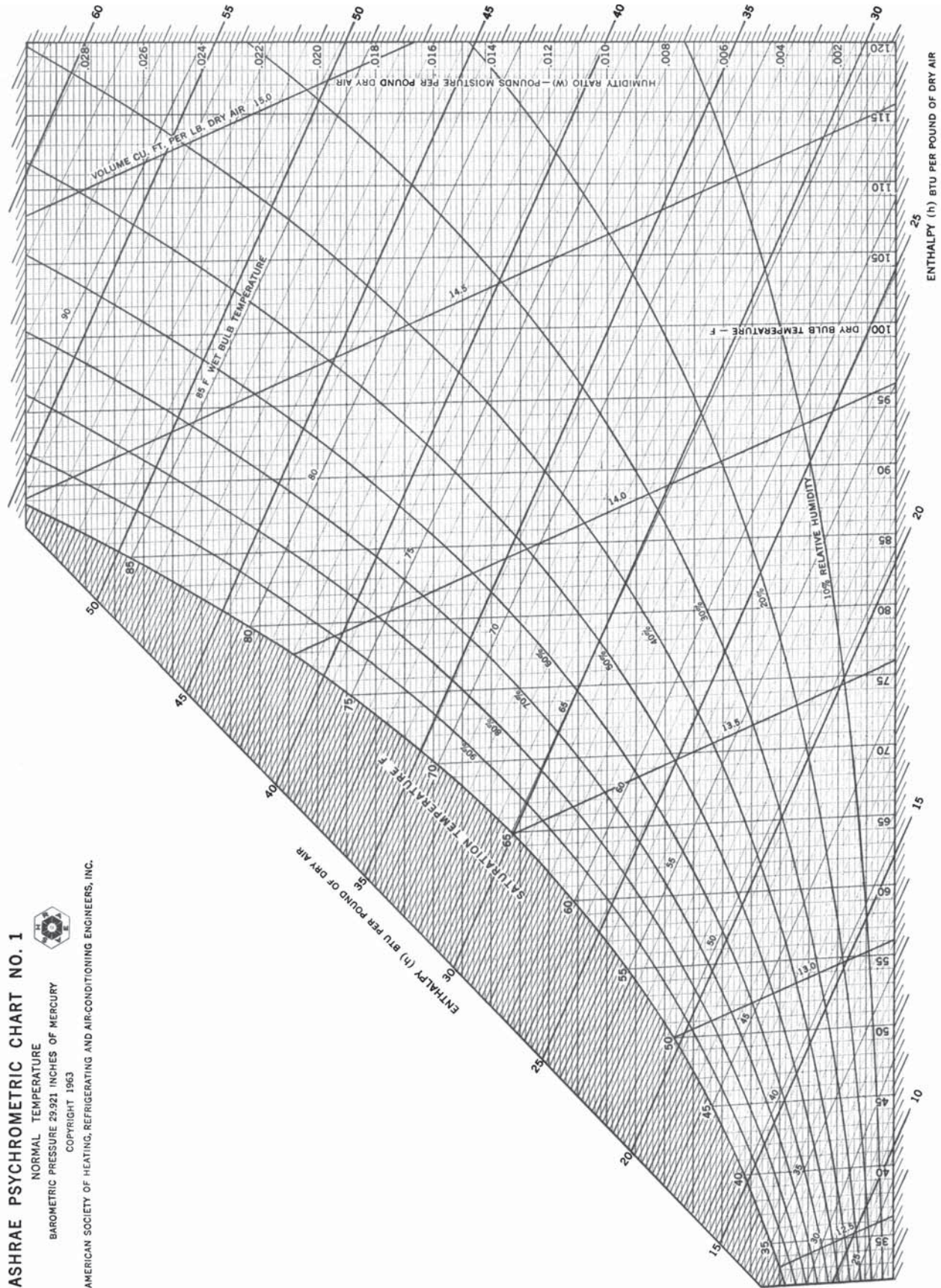
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References

1. Brooker, D. B. 1967. Mathematical model of the psychrometric chart. TRANS-ACTIONS of the ASAE 10(4):558-560, 563.
2. Brunt, David. 1941. Physical and dynamical meteorology. Cambridge University Press, 85-87.
3. Keenan, J. H. and F. G. Keyes. 1936. Thermodynamic properties of steam. John Wiley and Sons, Inc.
4. Steltz, W. G. and G. J. Silvestri. 1958. The formulation of steam properties for digital computer application. TRANSACTIONS of the ASME 80:967.

ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
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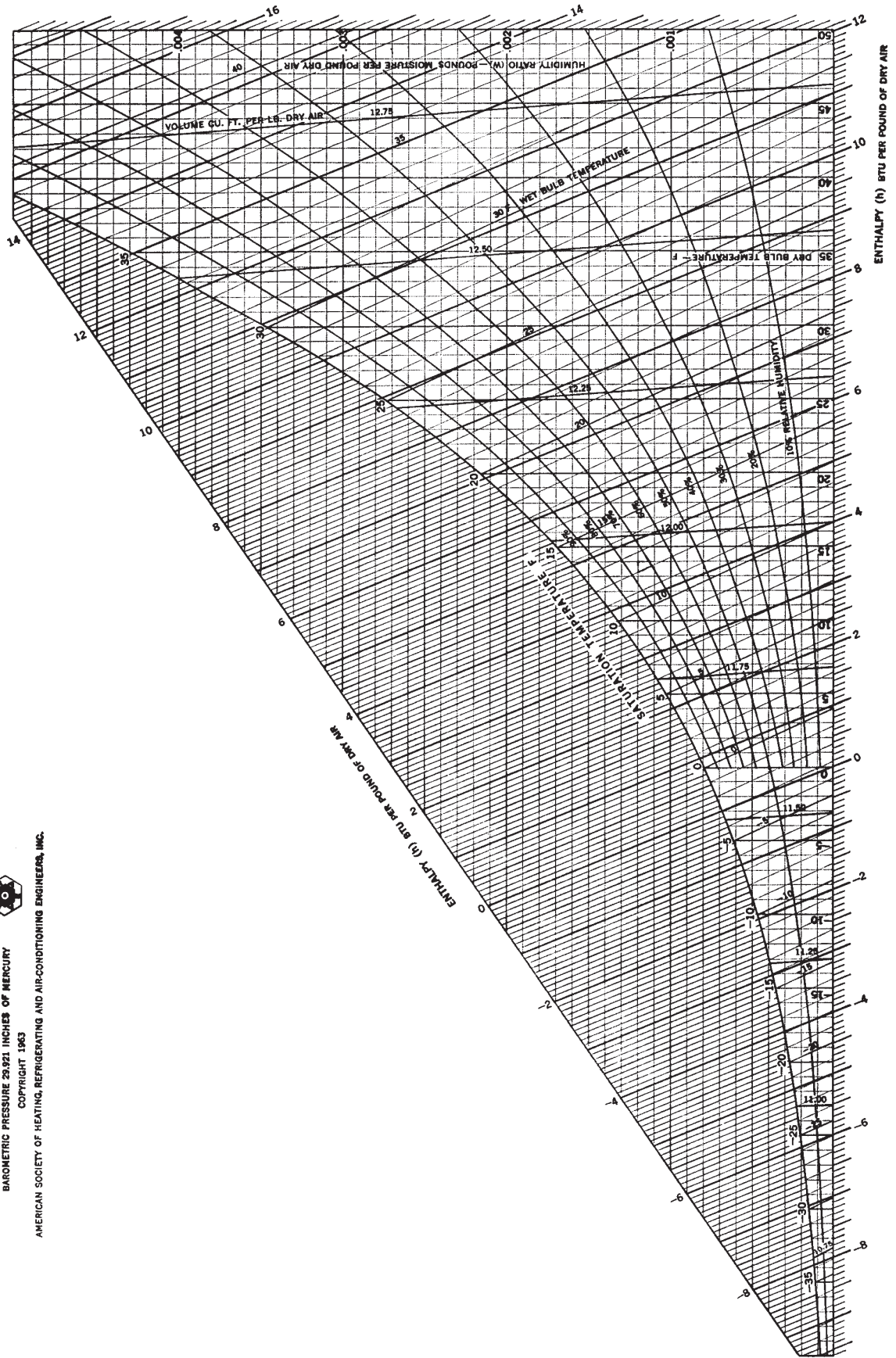


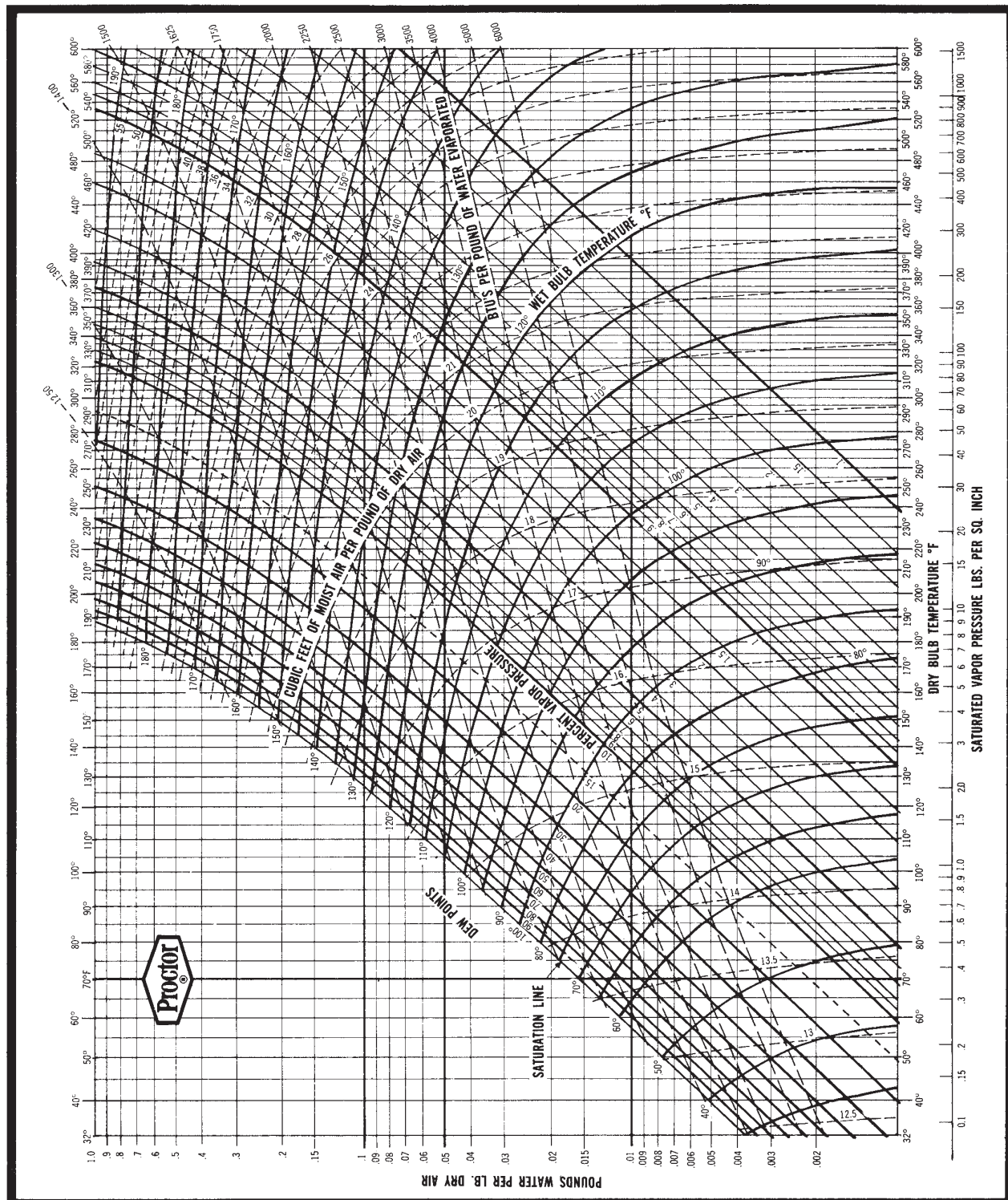
ASHRAE PSYCHROMETRIC CHART NO. 2

LOW TEMPERATURE
BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY
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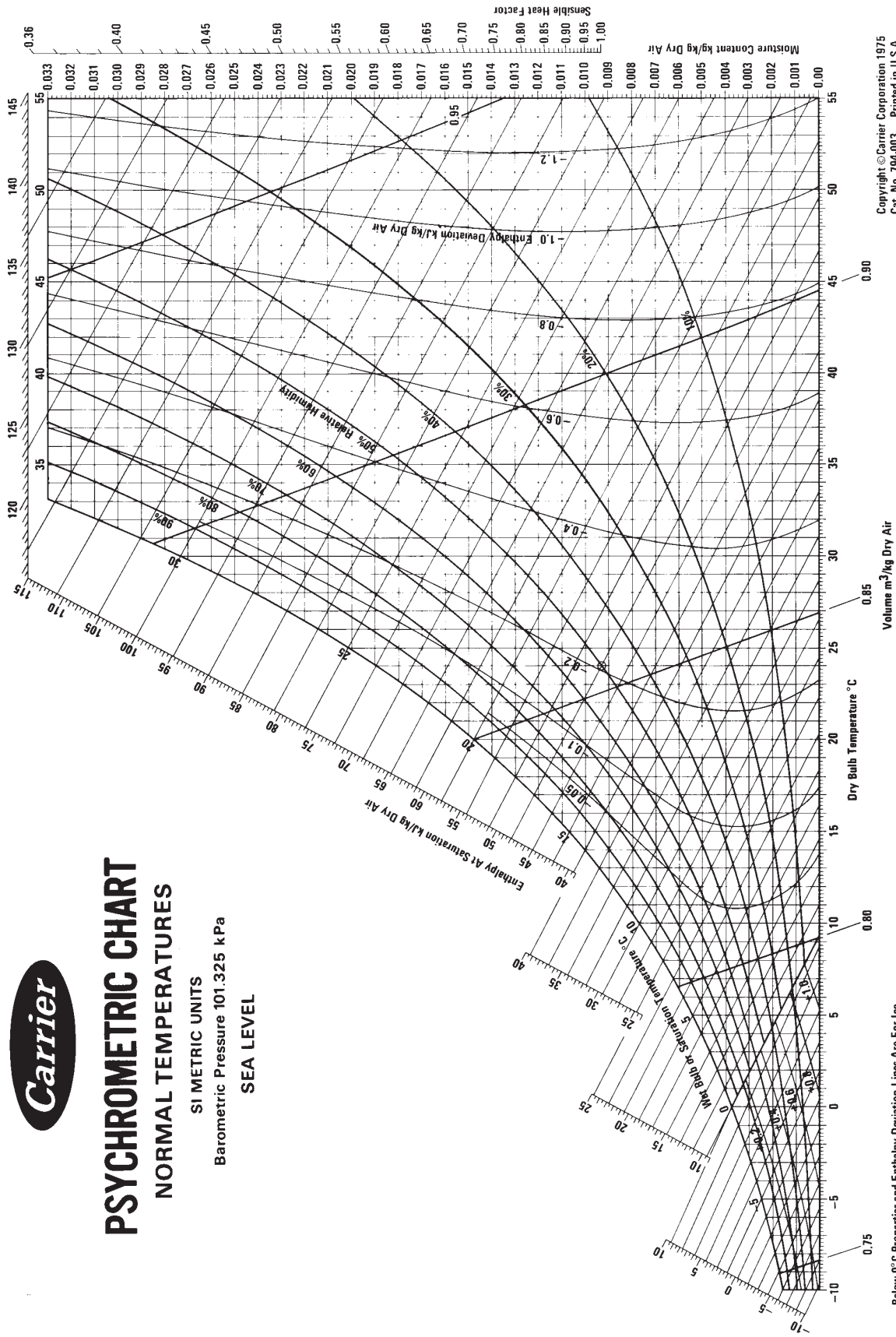




PSYCHROMETRIC CHART

NORMAL TEMPERATURES

SI METRIC UNITS
Barometric Pressure 101.325 kPa
SEA LEVEL



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Below 0°C Properties and Enthalpy Deviation Lines Are For Ice

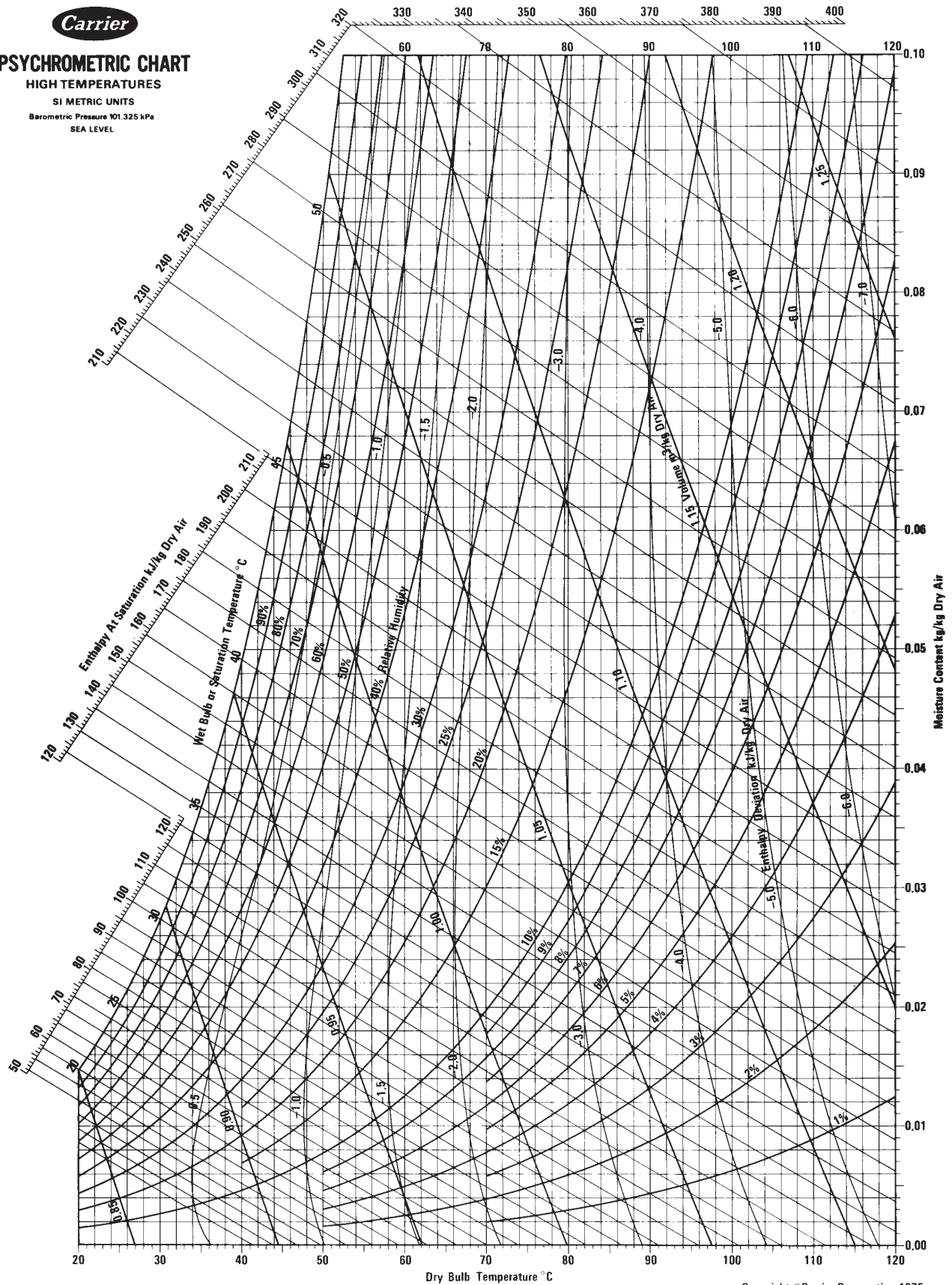


PSYCHROMETRIC CHART

HIGH TEMPERATURES

SI METRIC UNITS

Barometric Pressure 101.325 kPa
SEA LEVEL



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