Psychrometric Data

Reviewed by ASAE's Structures and Environment Division and the Food Engineering Division Standards Committees; approved by the Electric Power and Processing Division Standards Committee; adopted by ASAE December 1963; reconfirmed December 1968; revised April 1974, April 1979; reconfirmed December 1983; reconfirmed by the Food and Process Engineering Institute Standards Committee December 1988, December 1989, December 1990, December 1991; reaffirmed December 1992, December 1993, December 1994.

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, m³/kg dry air or ft³/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

$R = 22{,}105{,}649.25$ $\quad D = 0.12558 \times 10^{-3}$

$A = -27{,}405.526$ $\quad E = -0.48502 \times 10^{-7}$

$B = 97.5413$ $\quad F = 4.34903$

$C = -0.146244$ $\quad G = 0.39381 \times 10^{-2}$

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)

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

$338.72 \leqslant T \leqslant 533.16$ 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'_{ig} for h'_{fg} where $T_{wb} \leqslant 273.16$

$255.38 \leqslant T \leqslant 533.16$

2.2.6 Humidity ratio

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

$255.38 \leqslant T \leqslant 533.16$

$P_v < P_{atm}$

2.2.7 Specific volume

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

$255.38 \leqslant T \leqslant 533.16$

$P_v < P_{atm}$

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.

$$h=1006.92540\ (T-273.16)$$
$$-H[333{,}432.1+2030.5980(273.16-T_{dp})]+h''_{ig}H$$
$$+1875.6864H(T-T_{dp})$$

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

and

$$h=1006.92540\ (T-273.16)$$
$$+4186.8\ H(T_{dp}-273.16)+h''_{fg}H+1875.6864\ H(T-T_{dp})$$

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

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)

$459.69 \leqslant T \leqslant 491.69$

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

Adapted from Keenan and Keyes (1936)

$491.69 \leqslant T \leqslant 959.69$

where

$R=3206.18$
$A=-27405.5$
$B=54.1896$
$C=-0.045137$
$D=0.215321\times10^{-4}$
$E=-0.462027\times10^{-8}$
$F=2.41613$
$G=0.00121547$

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)

$0.09 \leqslant P_s \leqslant 680$

where

$A_0=35.1579$
$A_1=24.5926$
$A_2=2.11821$
$A_3=-0.341447$
$A_4=0.157416$
$A_5=-0.0313296$
$A_6=0.00386583$
$A_7=-0.249018\times10^{-3}$
$A_8=0.684016\times10^{-5}$

3.2.3 Latent heat of sublimation at saturation

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

$459.69 \leqslant T \leqslant 491.69$ Brooker (1967)

3.2.4 Latent heat of vaporization at saturation

$$h_{fg}=1075.8965-0.56983\ (T-491.69)$$ Brooker (1967)

$491.69 \leqslant T \leqslant 609.69$

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

$609.69 \leqslant T \leqslant 959.69$

3.2.5 Wet bulb line

$$P_{swb} - P_v = B'(T_{wb} - T) \quad \text{Brunt (1941)}$$

where

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

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

$$459.69 \leqslant T \leqslant 959.69$$

3.2.6 Absolute humidity (humidity ratio)

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

$$459.69 \leqslant T \leqslant 959.69$$

$$P_v < P_{atm}$$

3.2.7 Specific volume

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

$$459.69 \leqslant T \leqslant 959.69$$

$$P_v < P_{atm}$$

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.

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

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

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

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

3.2.9 Relative humidity

$$rh = P_v / P_s$$

Note: Psychrometric charts are printed with permission from the American Society of Heating, Refrigerating and Airconditioning Engineers, Inc., 345 E. 47th St., New York, NY; Proctor & Schwartz, Inc., 7th St. and Tabor Rd., Philadelphia, PA; and Carrier Corp., Carrier Parkway, Syracuse, NY.

References

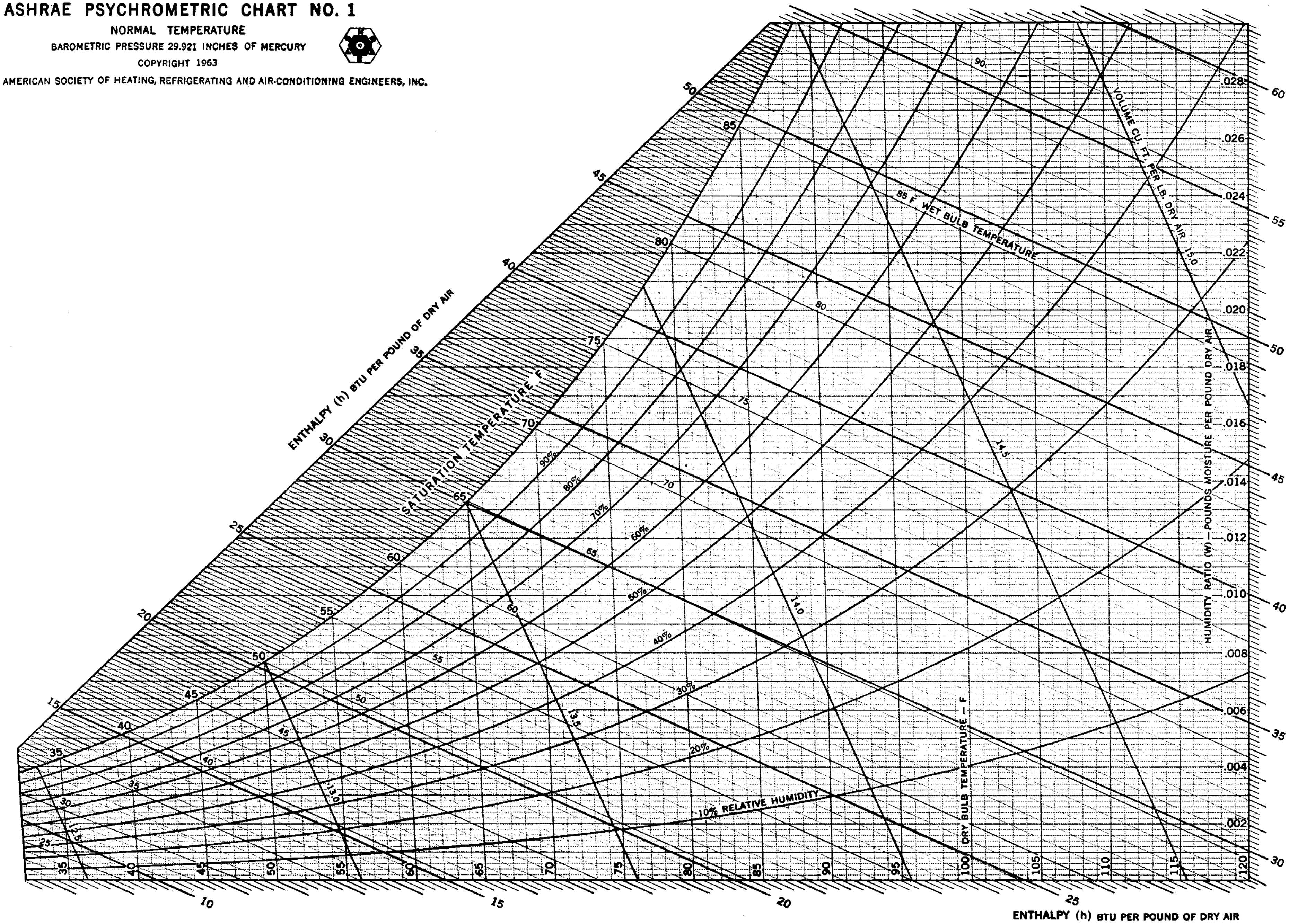
Last printed in 1981 AGRICULTURAL ENGINEERS YEARBOOK; list available from ASAE Headquarters.

ASHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE

BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.

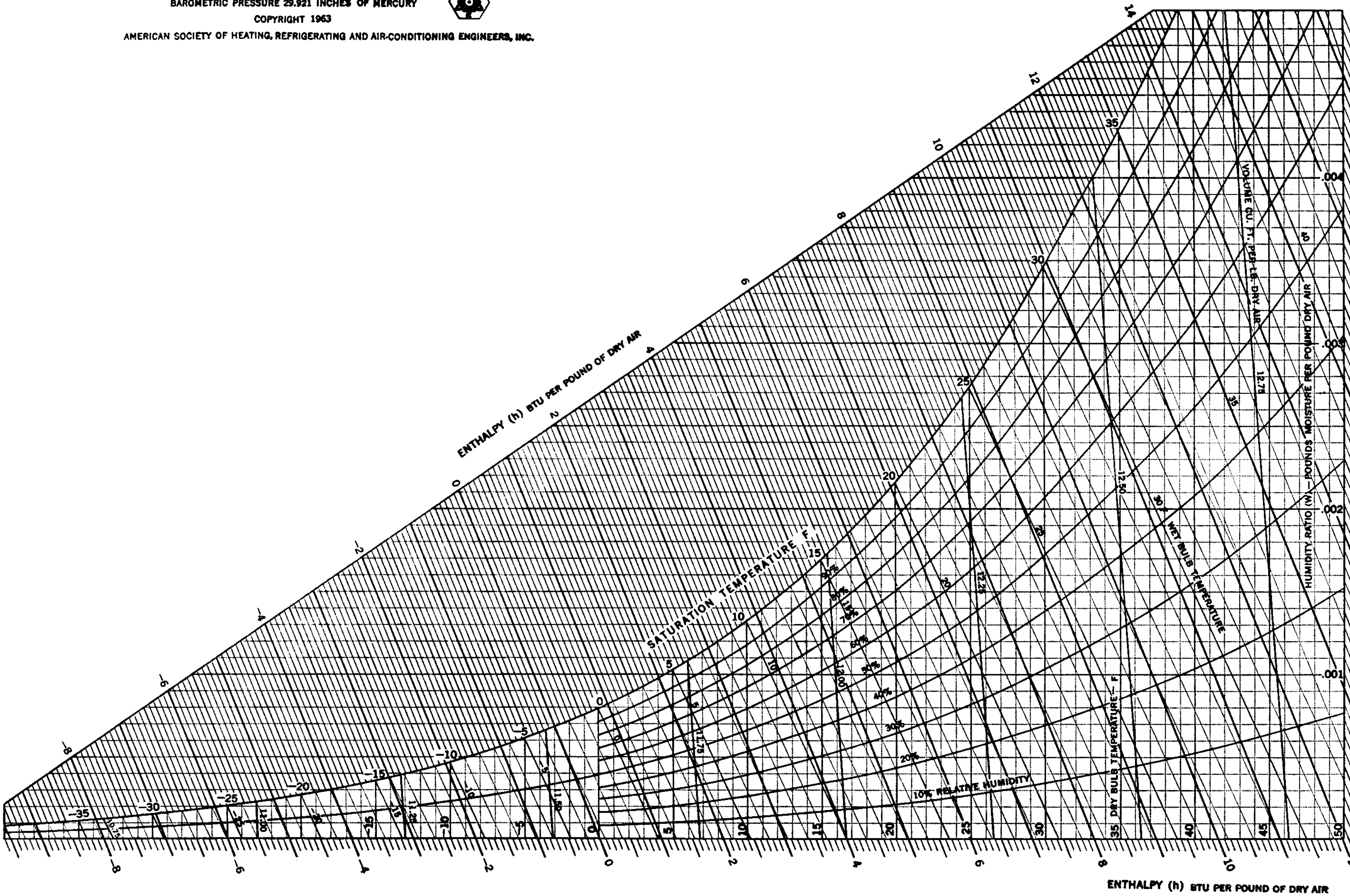


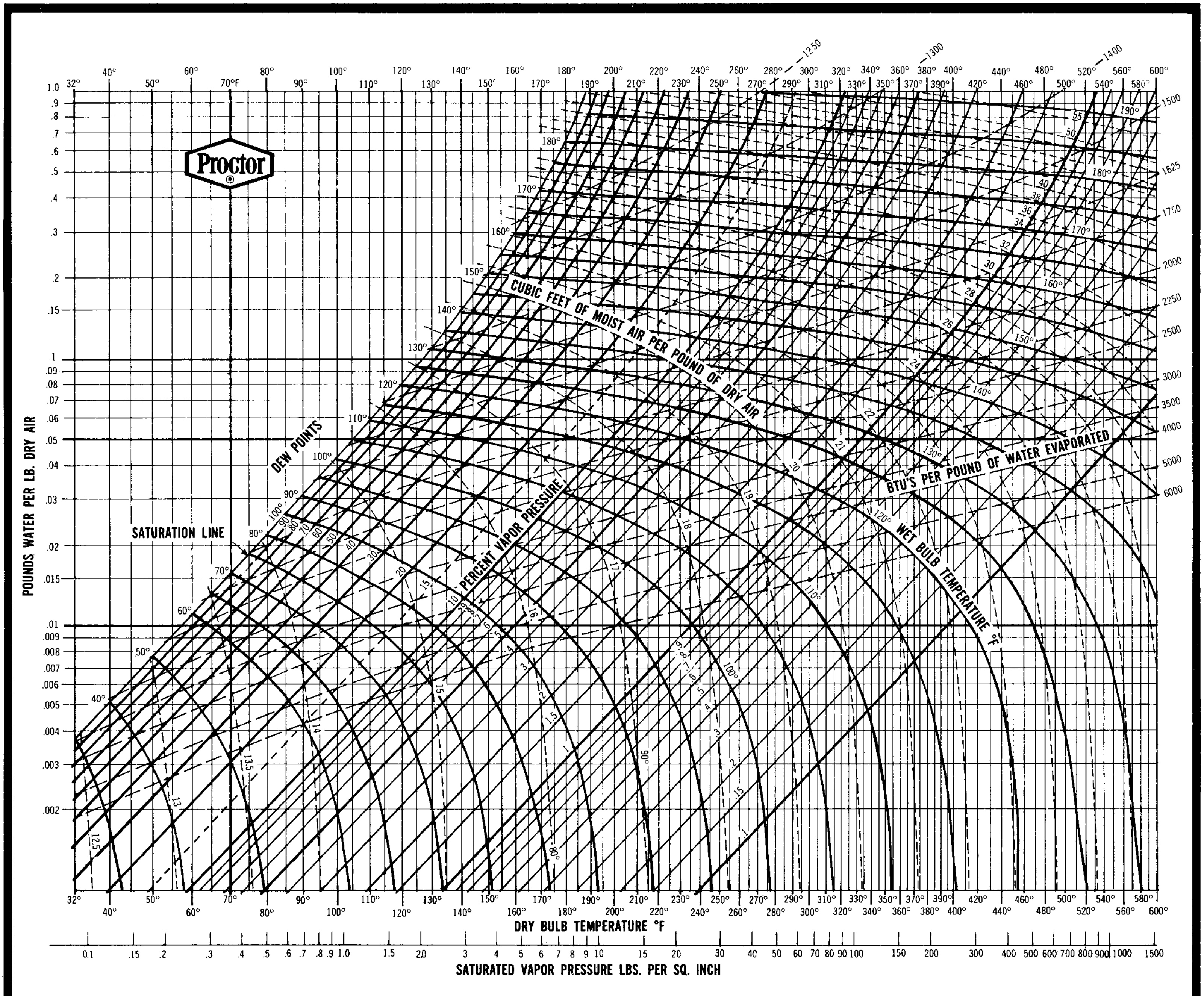
ASHRAE PSYCHROMETRIC CHART NO. 2

LOW TEMPERATURE

BAROMETRIC PRESSURE 29.921 INCHES OF MERCURY

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.




Proctor
POUNDS WATER PER LB. DRY AIR
SATURATION LINE
DEW POINTS
PERCENT VAPOR PRESSURE
CUBIC FEET OF MOIST AIR PER POUND OF DRY AIR
BTU'S PER POUND OF WATER EVAPORATED
WET BULB TEMPERATURE °F
DRY BULB TEMPERATURE °F
SATURATED VAPOR PRESSURE LBS. PER SQ. INCH

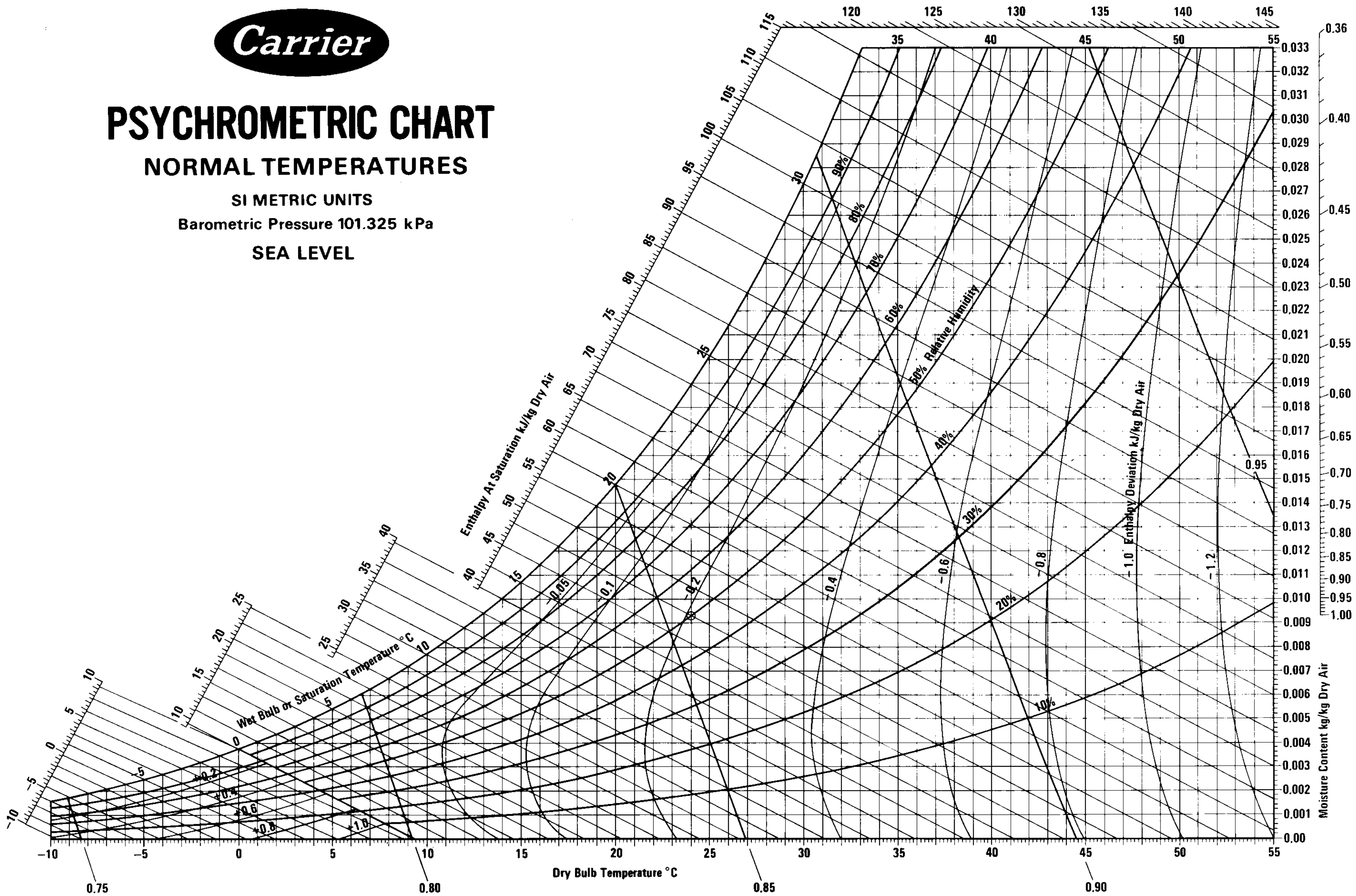
PSYCHROMETRIC CHART

NORMAL TEMPERATURES

SI METRIC UNITS

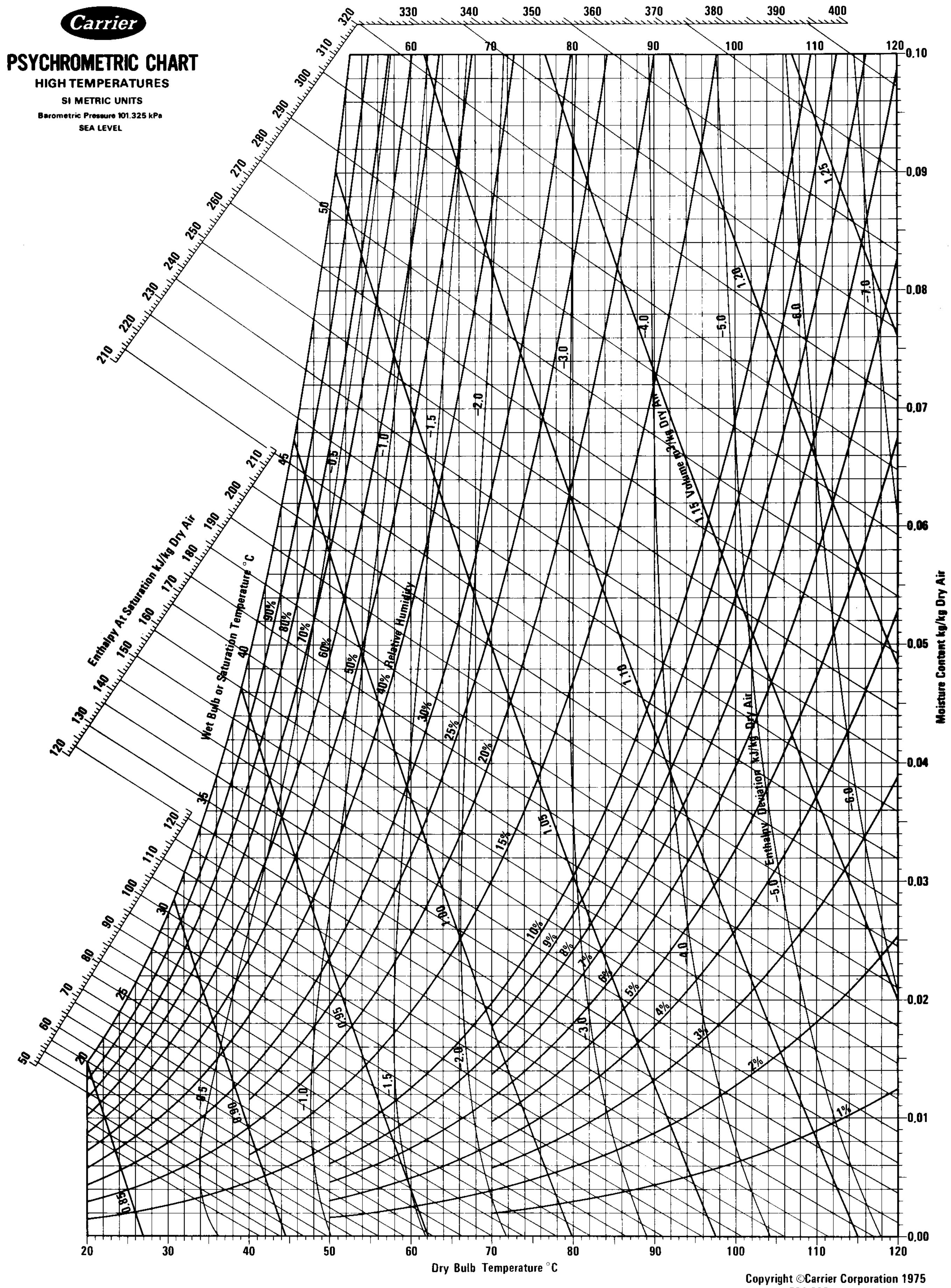
Barometric Pressure 101.325 kPa

SEA LEVEL



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

Cat. No. 794-003 Printed in U.S.A.


Carrier
PSYCHROMETRIC CHART
HIGH TEMPERATURES
SI METRIC UNITS
Barometric Pressure 101.325 kPa
SEA LEVEL
Enthalpy At Saturation kJ/kg Dry Air
Wet Bulb or Saturation Temperature °C
Relative Humidity
Volume m3/kg Dry Air
Enthalpy Deviation kJ/kg Dry Air
Dry Bulb Temperature °C
Moisture Content kg/kg Dry Air
20 30 40 50 60 70 80 90 100 110 120
0.00 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.10
90% 80% 70% 60% 50% 40% 30% 25% 20% 15% 10% 9% 8% 7% 6% 5% 4% 3% 2% 1%
0.85 0.90 0.95 1.00 1.05 1.10 1.15 1.20 1.25