Psychrometrics

- Gas-vapor mixtures (air-water vapor system)
- Dry air
- Water vapor
- Mixture
- Adiabatic saturation
- Psychrometric chart

Properties of dry air

- Air composition: Table9.1
- Specific volume: ideal gas law
- Specific heat : 0.997~1.022 kJ/kg K (-40~60^{o}C),average 1.005 kJ/kg K
- Enthalpy: Ha=1.005(T-To)
- Dry bulb temperature v.s. wet bulb temperature

Properties of water vapor

- Specific volume: ideal gas law
- Specific heat: ~1.88 kJ/kg K
- Enthalpy: $H_w=2501.4+1.88(T-T_o)$

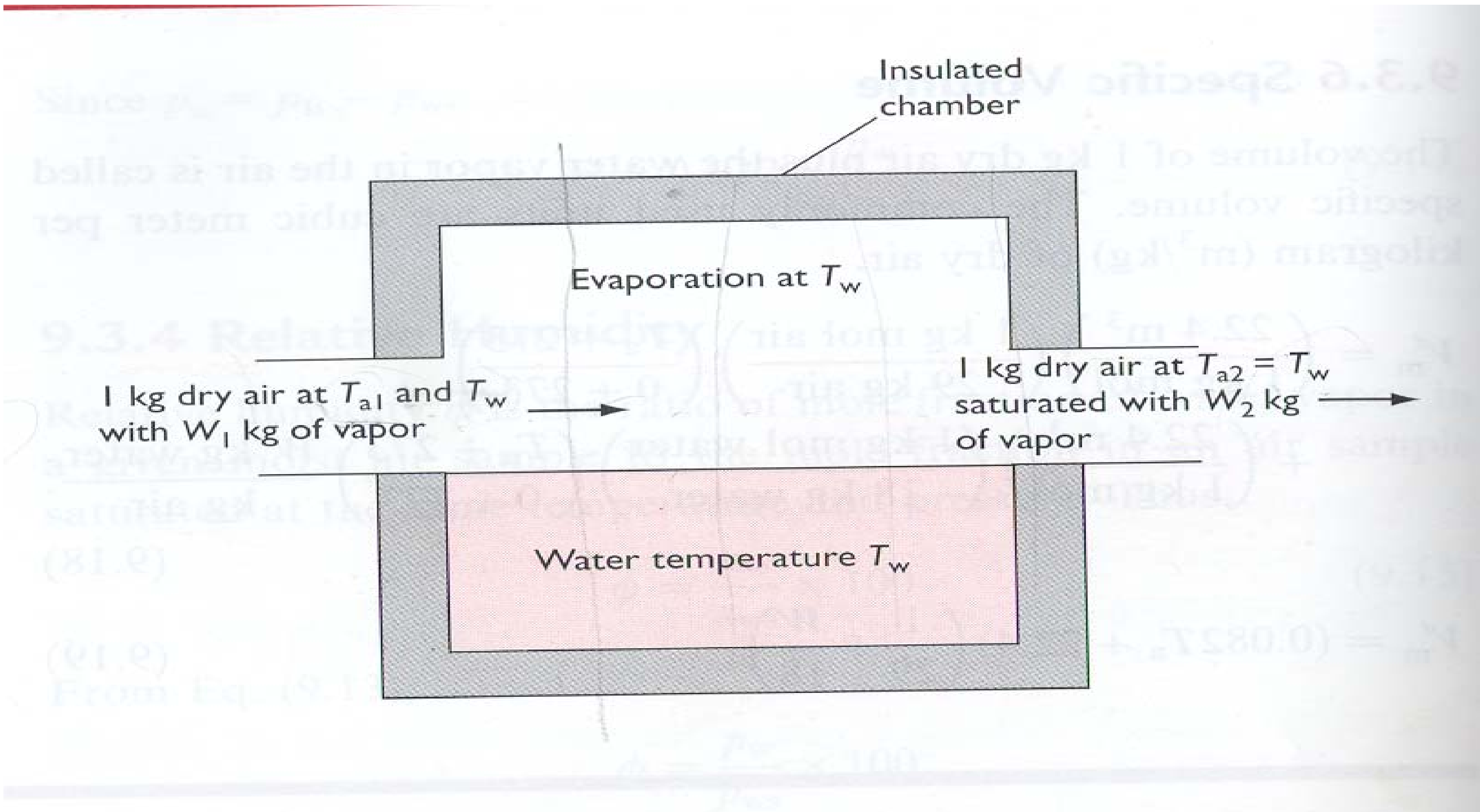
  or from steam table

Properties of air-water vapor mixtures

- Gibbs-Dalton law:
  P(total)=P(dry air)+P(water vapor)
- Dew-point temperature: cooled at constant pressure to reach saturation
- Humidity ratio (moisture content):W=(mass of water)/(mass of dry air)
- Relative humidity: RH%=(mole fraction of water vapor)/(mole fraction of water vapor at saturation)=(vapor pressure of water vapor)/(vapor pressure at saturation)

- Humid heat: $C=1.005+1.88W$ kJ/kg DA K
- Specific volume: for each kg of dry air (DA)

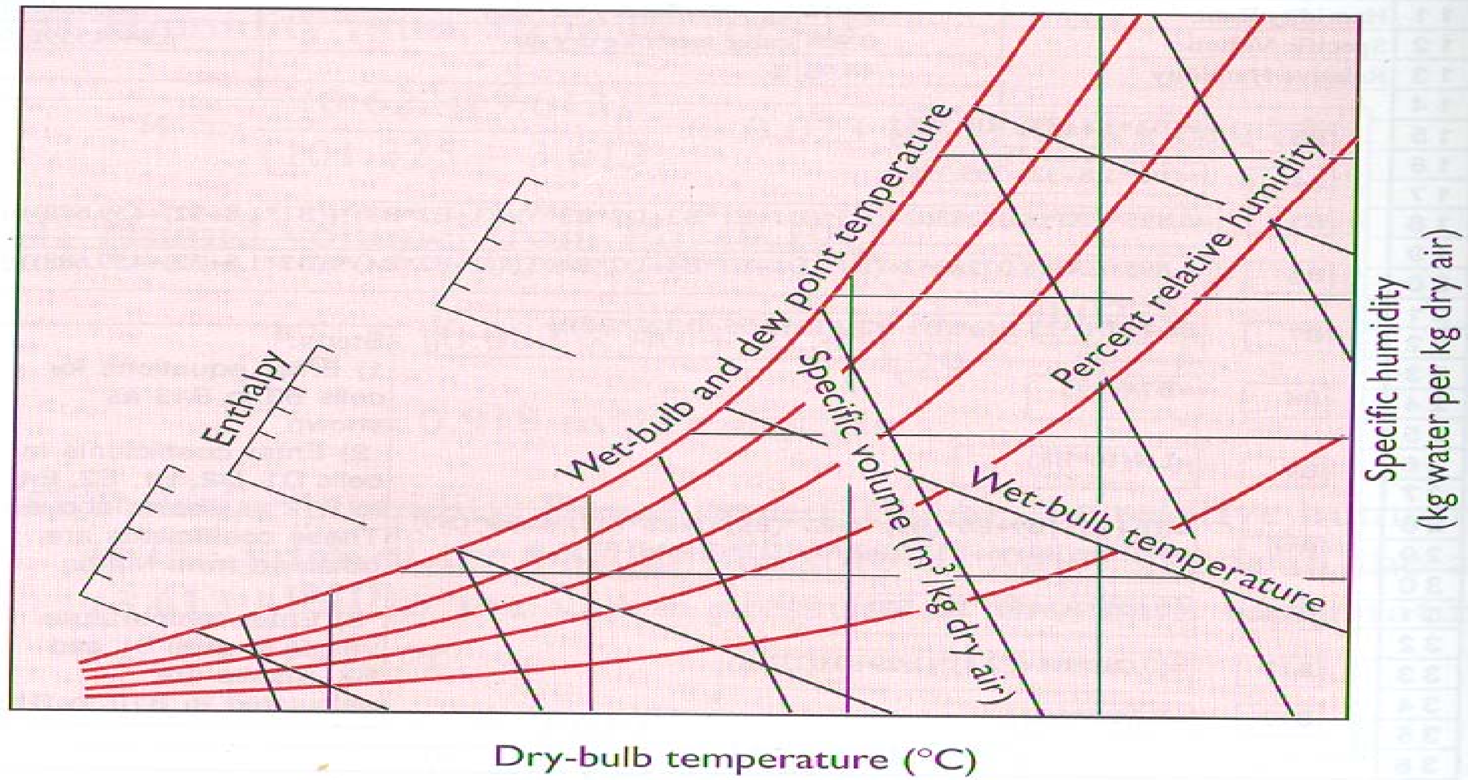
Adiabatic saturation (humidification)



Wet bulb temperature

- Psychrometric wet bulb temperature: wet wick (small amount of water) + flowing air (>1m/s, ~5m/s)
- Thermodynamic wet bulb temperature: large amount of water + flowing air (reaching saturation)
- For air-water system: psychrometric wet bulb temperature is approximately equal to the thermodynamic wet bulb temperature.

Psychrometric chart



A.5 Psychrometric Charts

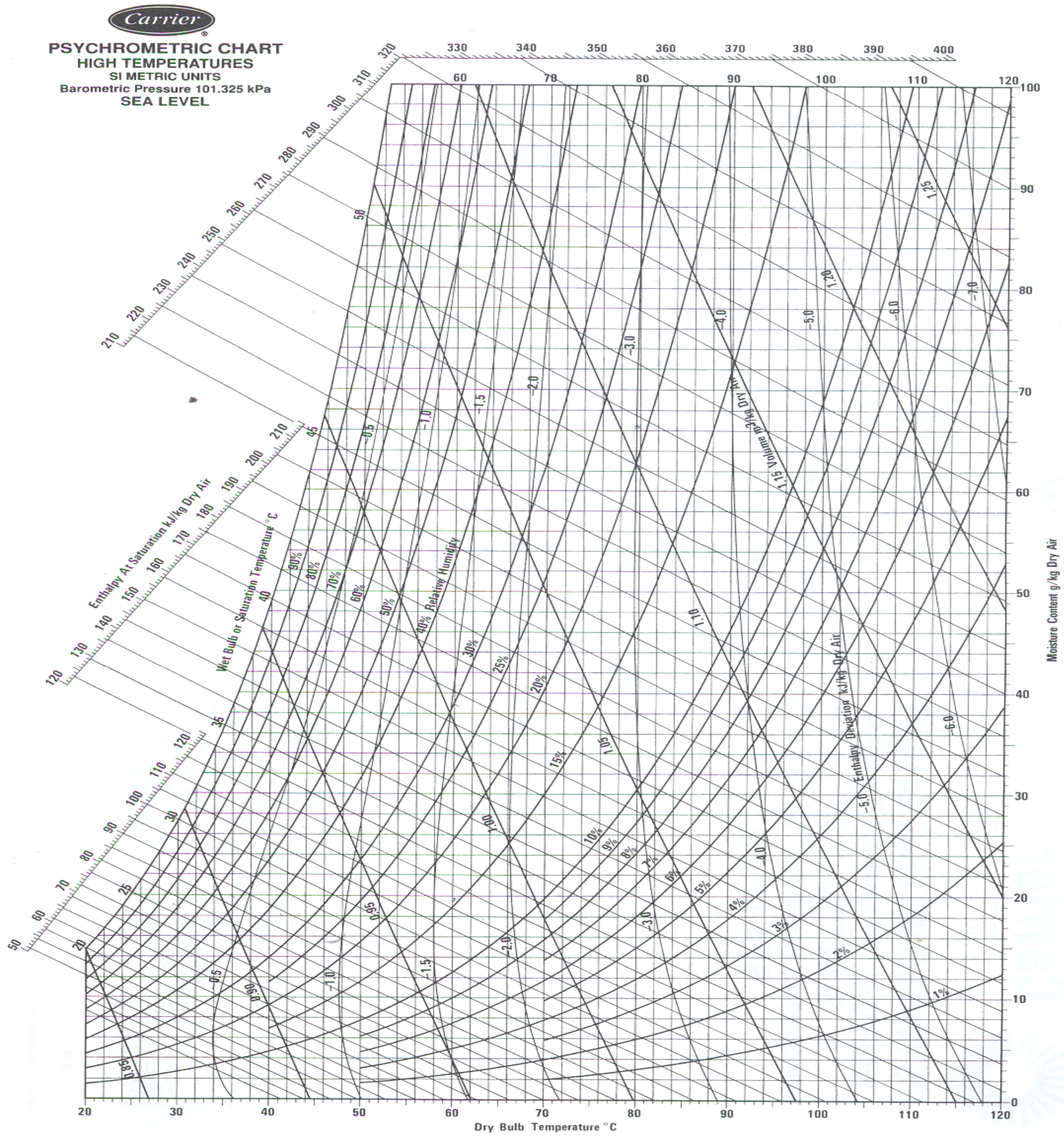


Fig. A.5.1 Psychrometric chart for high temperature range.

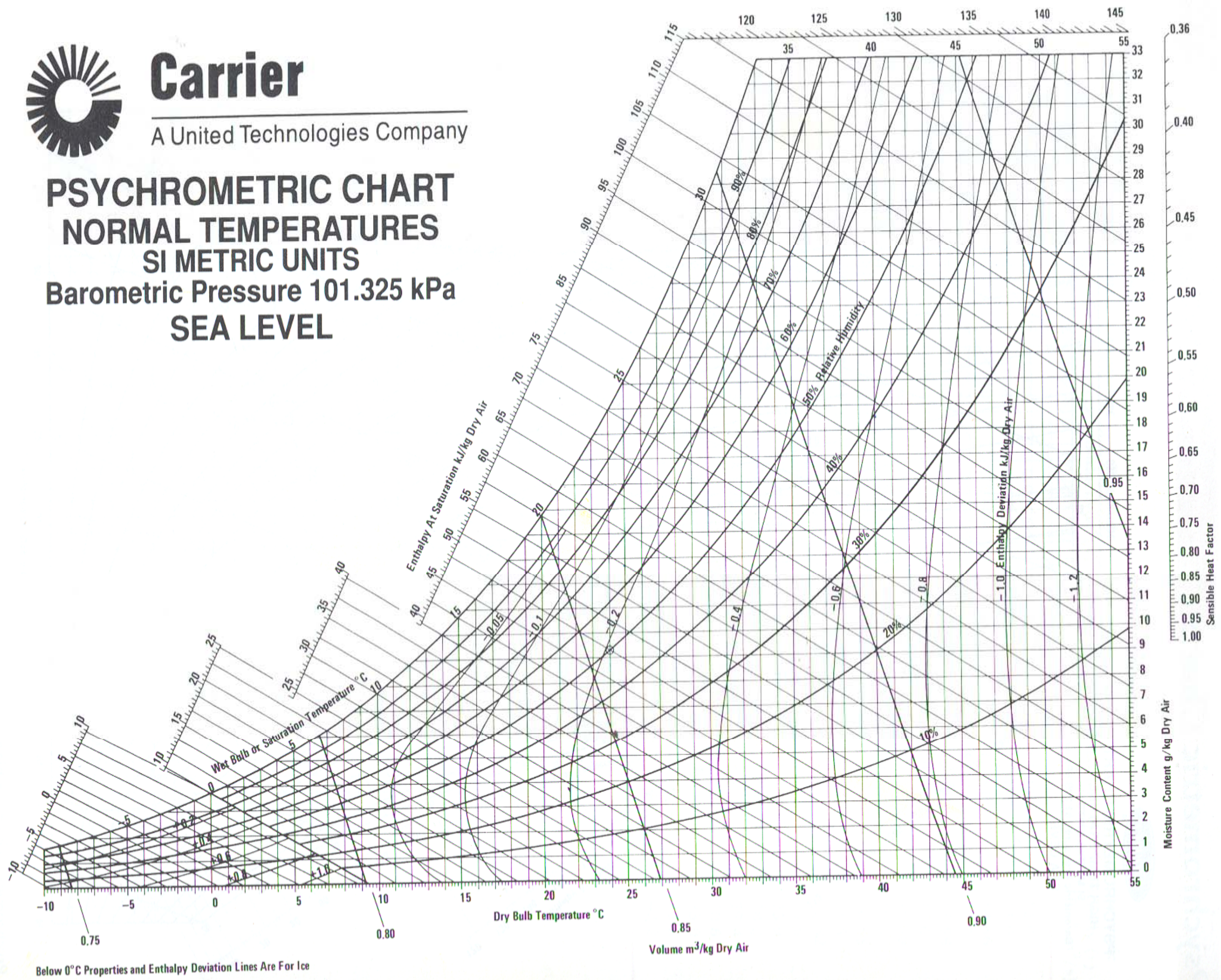


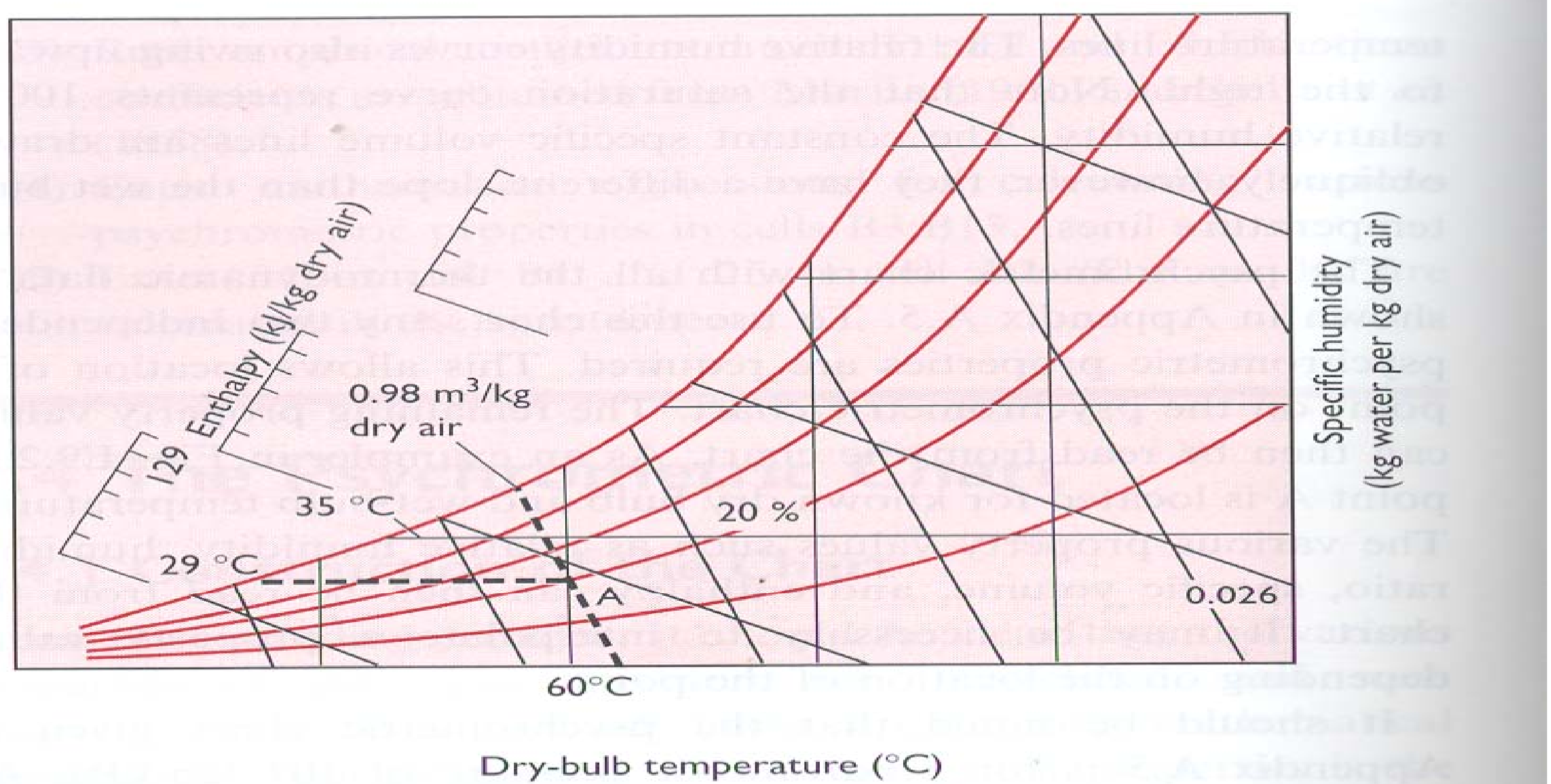
Fig. A.5.2 Psychrometric chart for low temperature range.

- Phase rule: F=C-P+2,
- C=2 (air + water vapor), P=1 (vapor)=> F=3 (degree of freedom)
- P= 1 atm. Plus another two properties

Example 9.5

- An air-vapor mixture is at 60^{o}C dry bulb temperature and 35^{o}C wet bulb temperature. Using the psychrometric chart to determine the relative humidity, humidity ratio, specific volume, enthalpy and dew-point temperature.

Solution



Enthalpy (kJ/kg dry air)
129
0.98 m³/kg
dry air
35 °C
29 °C
20 %
A
0.026
60°C
Specific humidity
(kg water per kg dry air)
Dry-bulb temperature (°C)

Heating (or cooling)

- Example 9.6:

  Calculate the rate of thermal energy required to heat 10 m^3/s of outside air at 30^oC dry bulb temperature and 80% relative humidity to a dry bulb temperature of 80^oC.

A.5 Psychrometric Charts

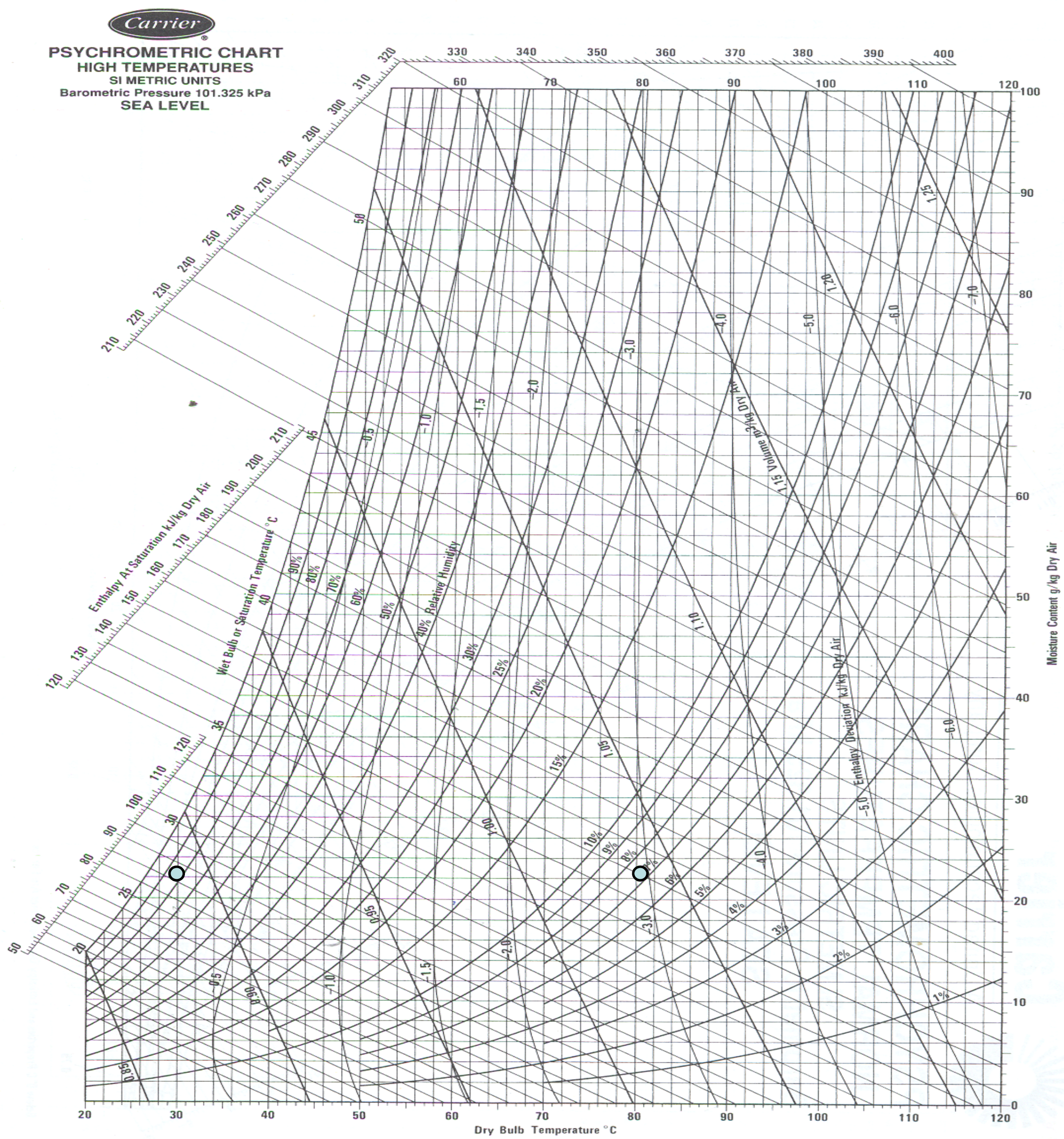


Fig. A.5.1 Psychrometric chart for high temperature range.

Solution

- 30^oC, 80% => H=85.2 kJ/kg DA

  W=0.0215 kg H_2O/kg DA,
  V=0.89 m^3/kg DA
- 80^oC, W=0.0215 kg H_2O/kg DA =>H=140 kJ/kg DA
- Mass flow rate of DA=10/0.89
- Energy requirement = (mass flow rate of DA)(ΔH)=(10/0.89)(140-85.2) kJ/s =615.7 kW

Mixing

- Example 9.7:

  In efforts to conserve energy, a food dryer is being modified to reuse part of the exhaust air along with ambient air. The exhaust airflow of 10 m^3/s at 70^oC and 30% relative humidity is mixed with 20 m^3/s of ambient air at 30^oC and 60% relative humidity. Using the psychrometric chart to determine the dry bulb temperature and humidity ration of the mixed air.

A.5 Psychrometric Charts

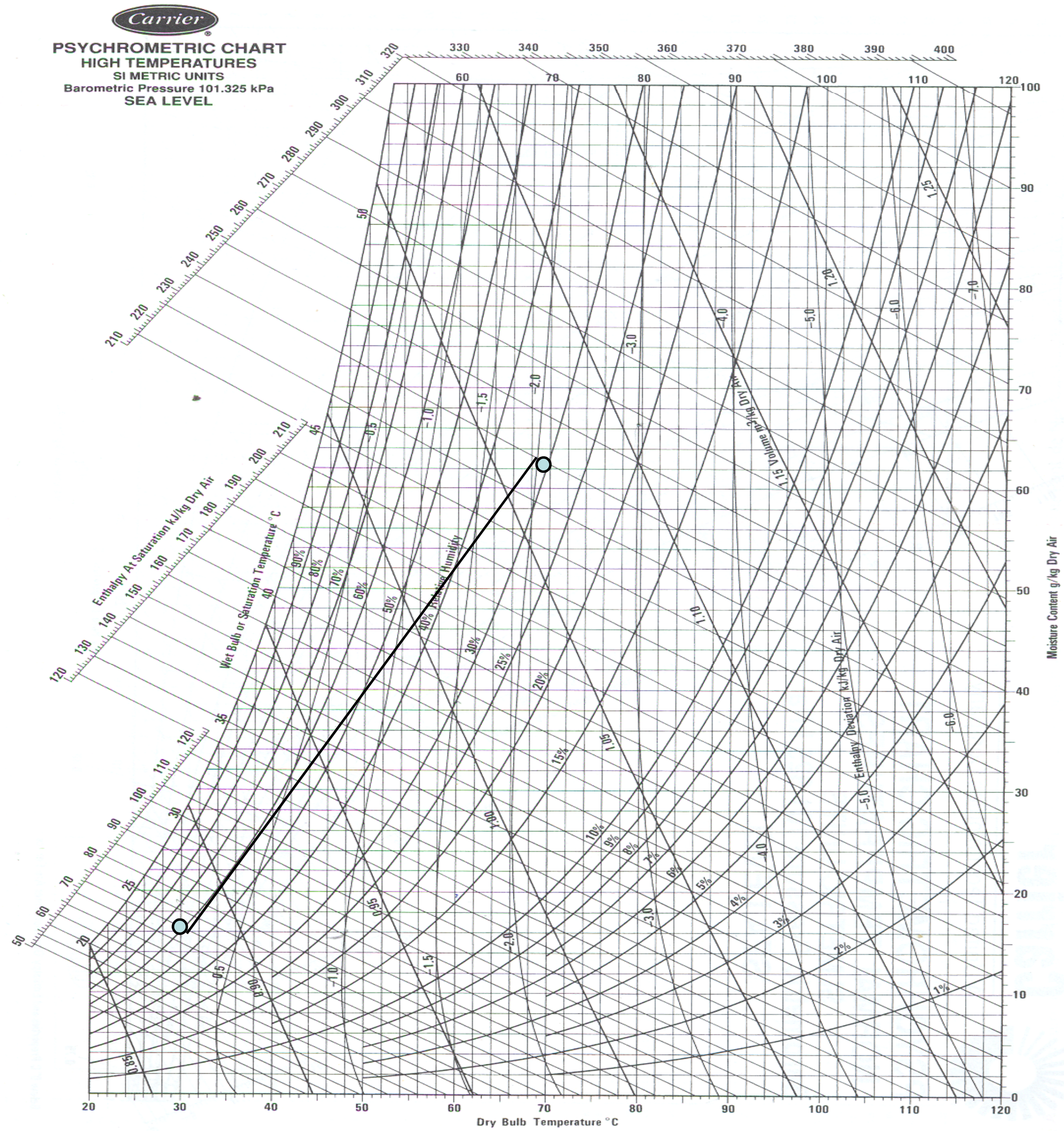


Fig. A.5.1 Psychrometric chart for high temperature range.

Drying

- Example 9.8:
- Heated air at 50^{o}C and 10% relative humidity is used to dry rice in a bin dryer. The air exits the bin under saturated conditions. Determine the amount of water removed per kg of dry air.

Solution

- Adiabatic saturation: wet bulb temperature remains constant.

A.5 Psychrometric Charts

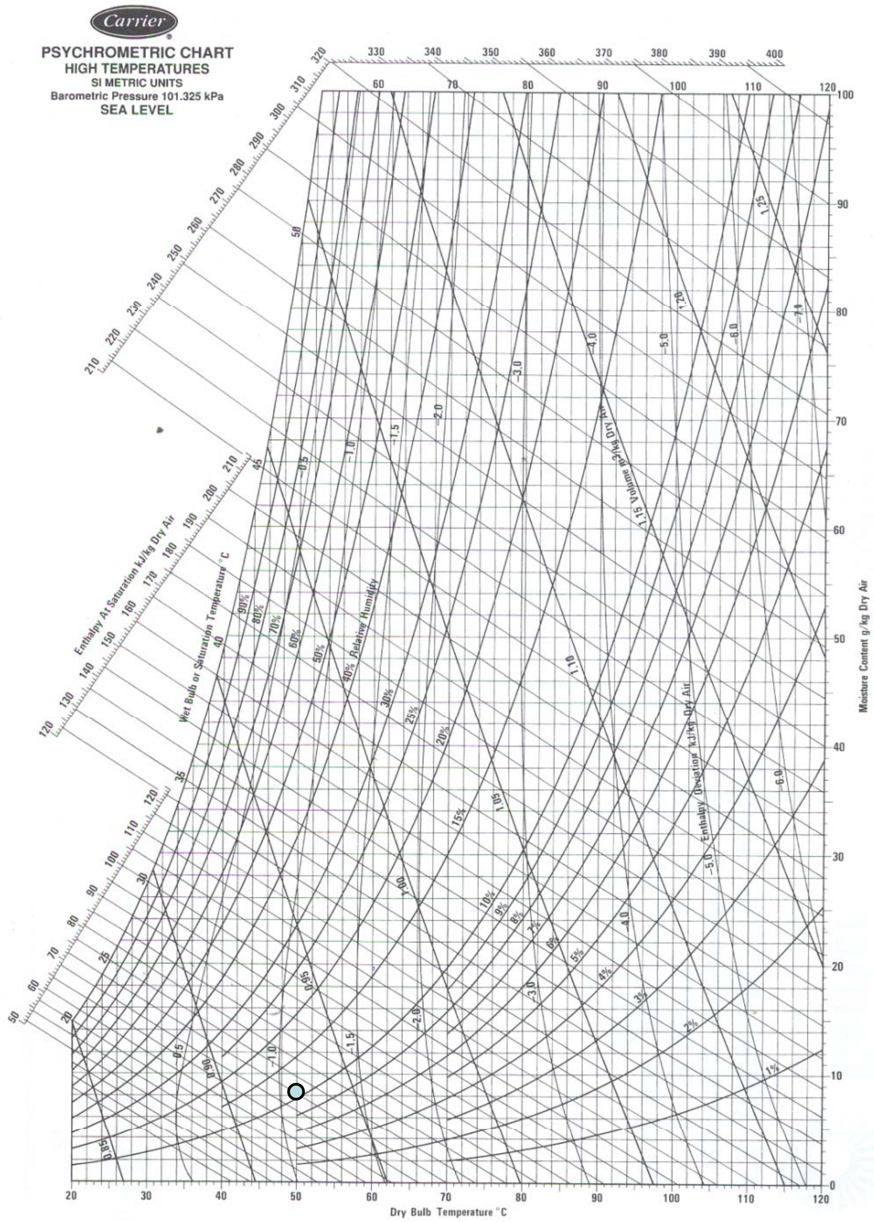


Fig. A.5.1 Psychrometric chart for high temperature range.