Psychrometric Fundamentals

Terms, Chart, Air Mixing, and Basic Calculations

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Learning Objectives

- Understand the significance of psychrometrics to “air conditioning”
- Understand common psychrometric terms including: dry bulb and wet bulb temperature, relative humidity, specific humidity, dew point, enthalpy, flow rate, & “standard air”
- Identify all lines and units of measure on the psychrometric chart
- Given any 2 properties of air, use a psychrometric chart to determine all other other psychrometric properties
- Understand the relationship between sensible, latent, and total heat
- Understand air mixing and be able to calculate the properties of the air resulting from the mixture of two airstreams
- Use the basic psychrometric equations to calculate sensible, latent, and total cooling/heating

What is air conditioning?

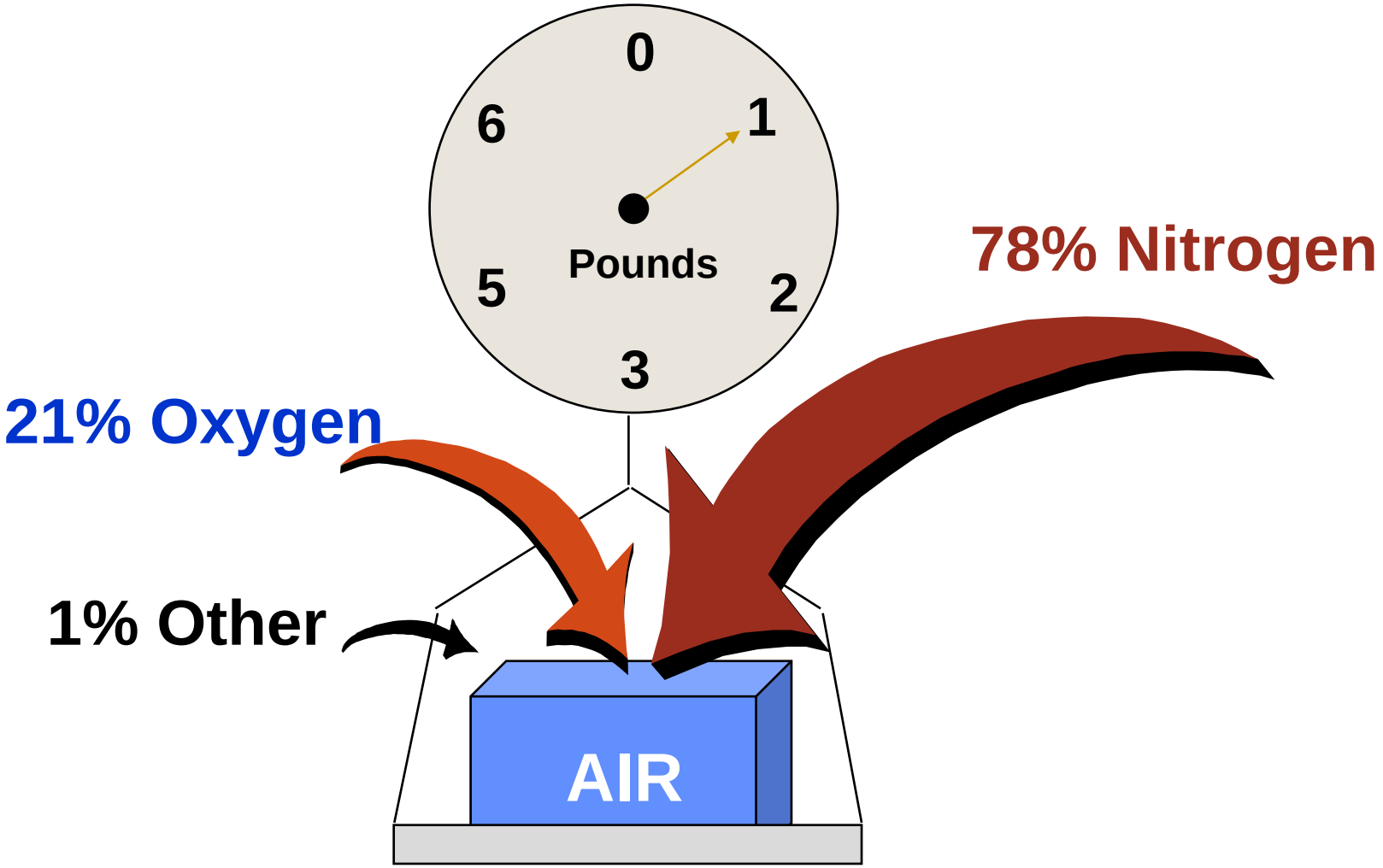
Simultaneous control
Of .....

- Temperature
- Moisture
- Cleanliness
- Ventilation
- Sound

What is Psychrometrics?

- The study of the state of the atmosphere with regard to its temperature and moisture content.

What is air?



Standard Conditions

- “Standard conditions at SL”
  - 70° F
  - 29.921 in. Hg (atmospheric pressure)
  - Dry (no water vapor)
- Spec. vol. of air at std conditions = 13.35 cu. ft. / lb
- Air flow rate expressed as: cubic feet / minute (CFM)
- Air flow rate at standard conditions expressed as (SCFM)
- Specific volume changes with temperature, moisture content, and atmospheric pressure

- At 5,000 ft atmospheric pressure is 24.896 in. Hg
- Density of dry air at 70°F at 5,000 ft is 16.04 cu. ft. / lb

Standard Conditions

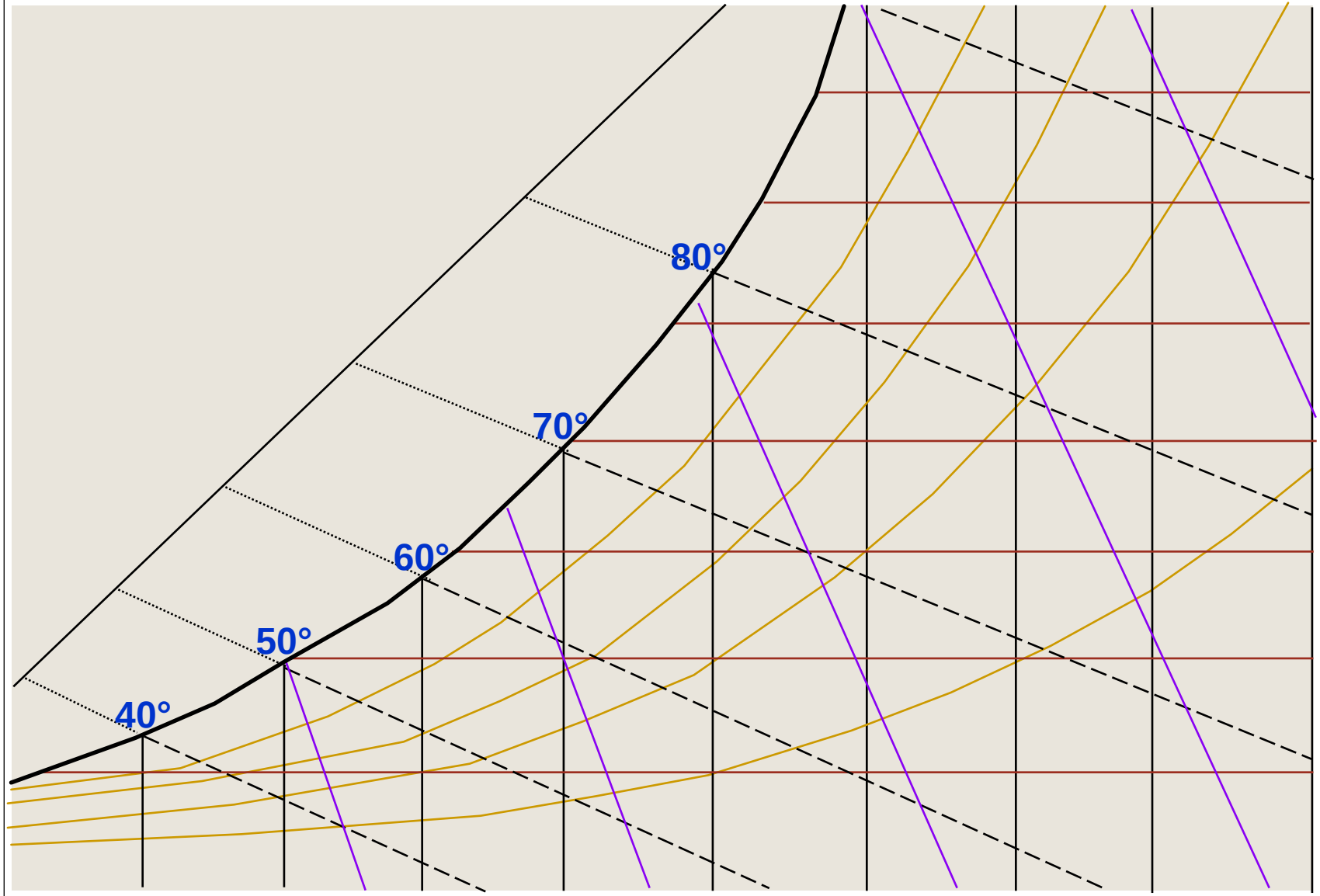
$$\text{SCFM} = \frac{13.35 \text{ cu. ft. / lb}}{\text{Actual sp. vol.}} \times \text{Actual CFM}$$

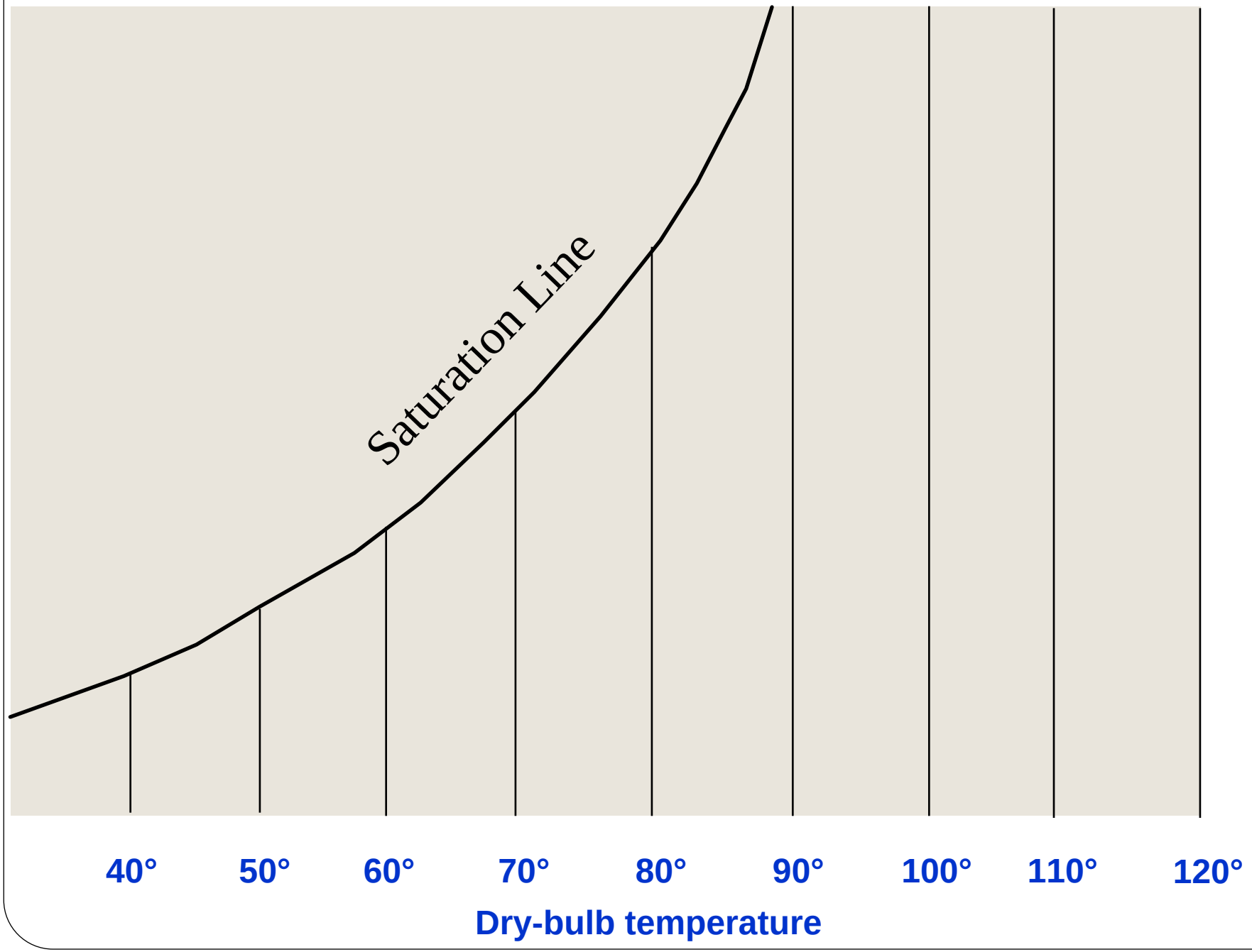
At 5,000’ Elevation

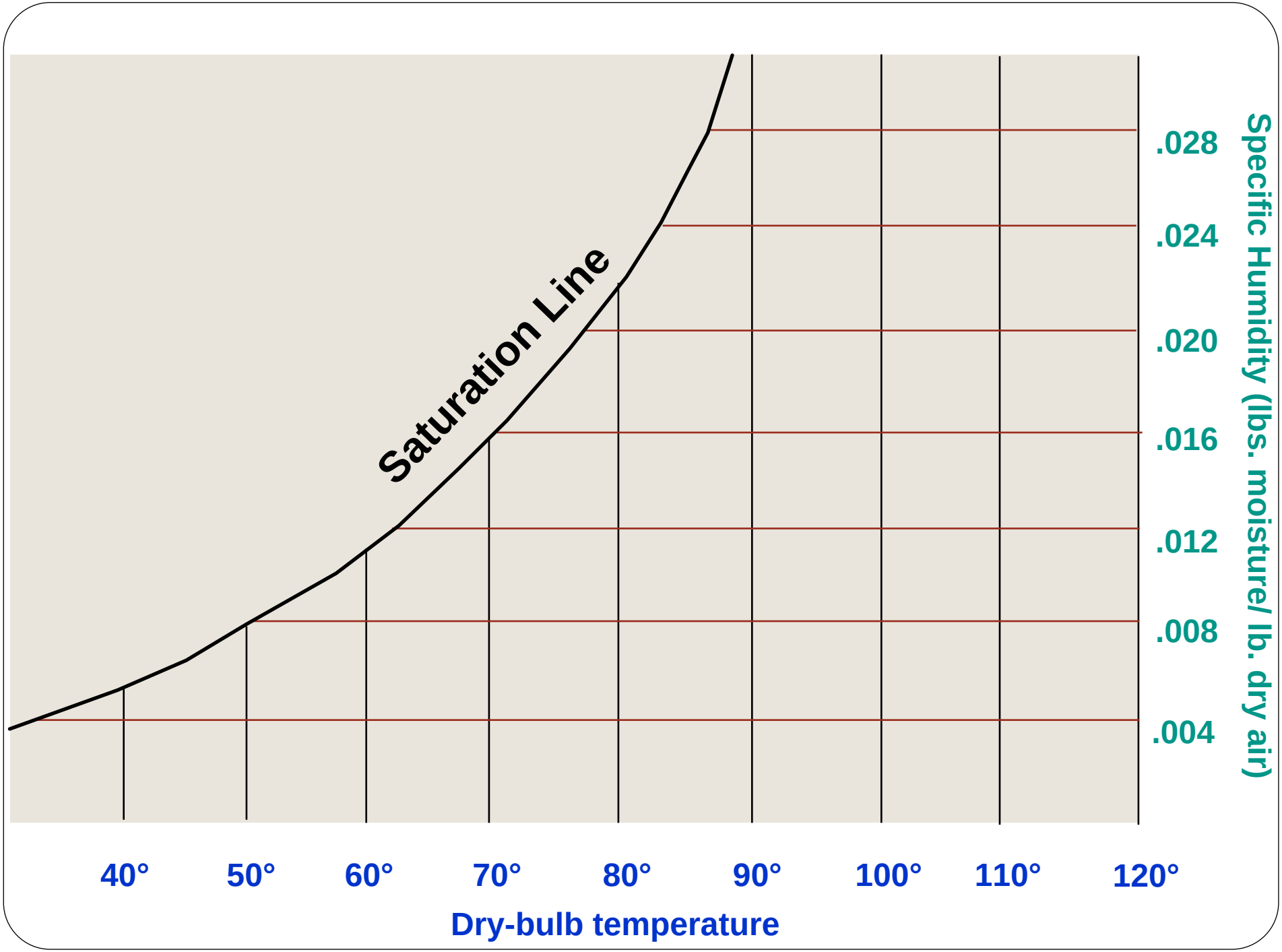
$$0.83 \text{ SCFM} = \frac{13.35 \text{ cu. ft. / lb}}{16.04 \text{ cu. ft. / lb}} \times 1 \text{ CFM}$$

Water Vapor

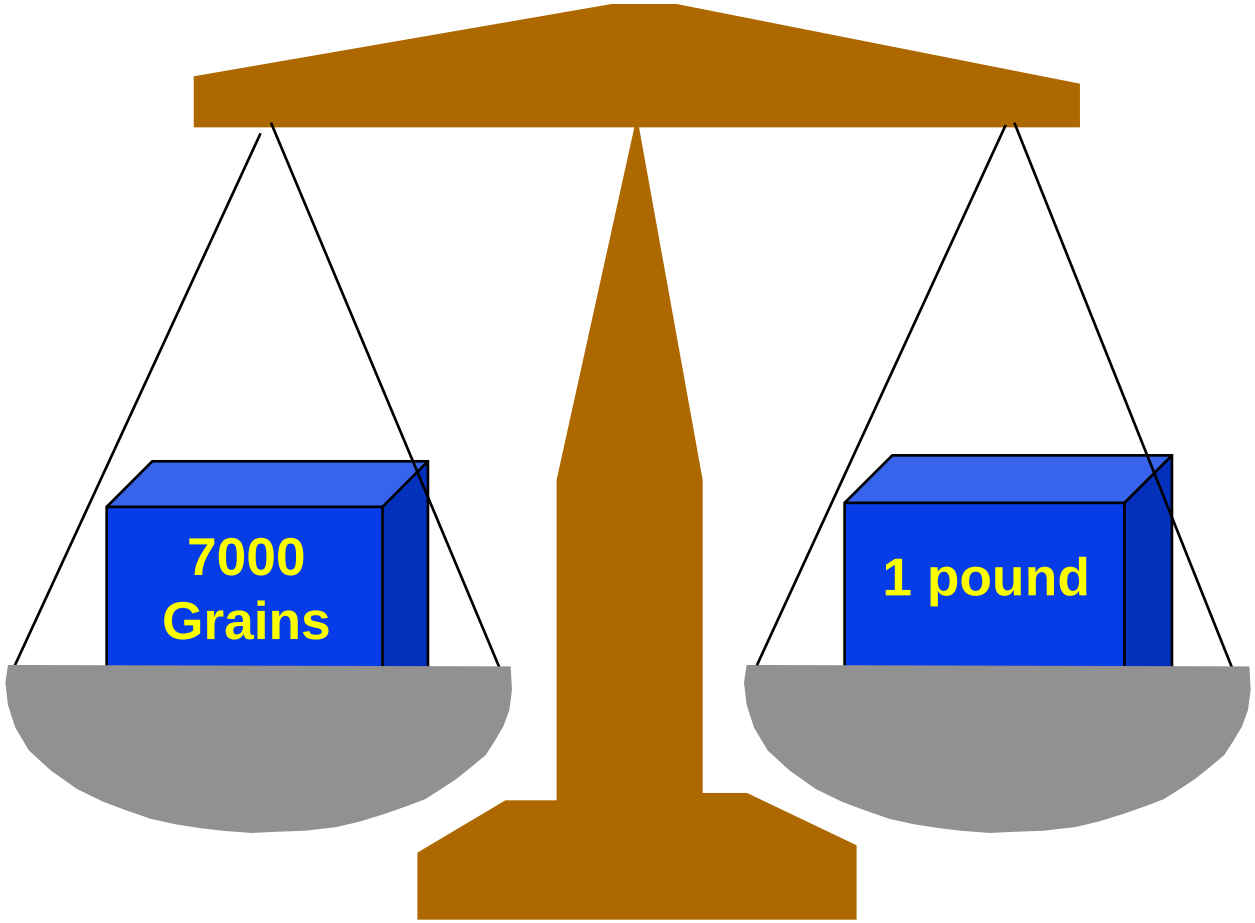
- Not present in large quantities
- Significant factor in air conditioning

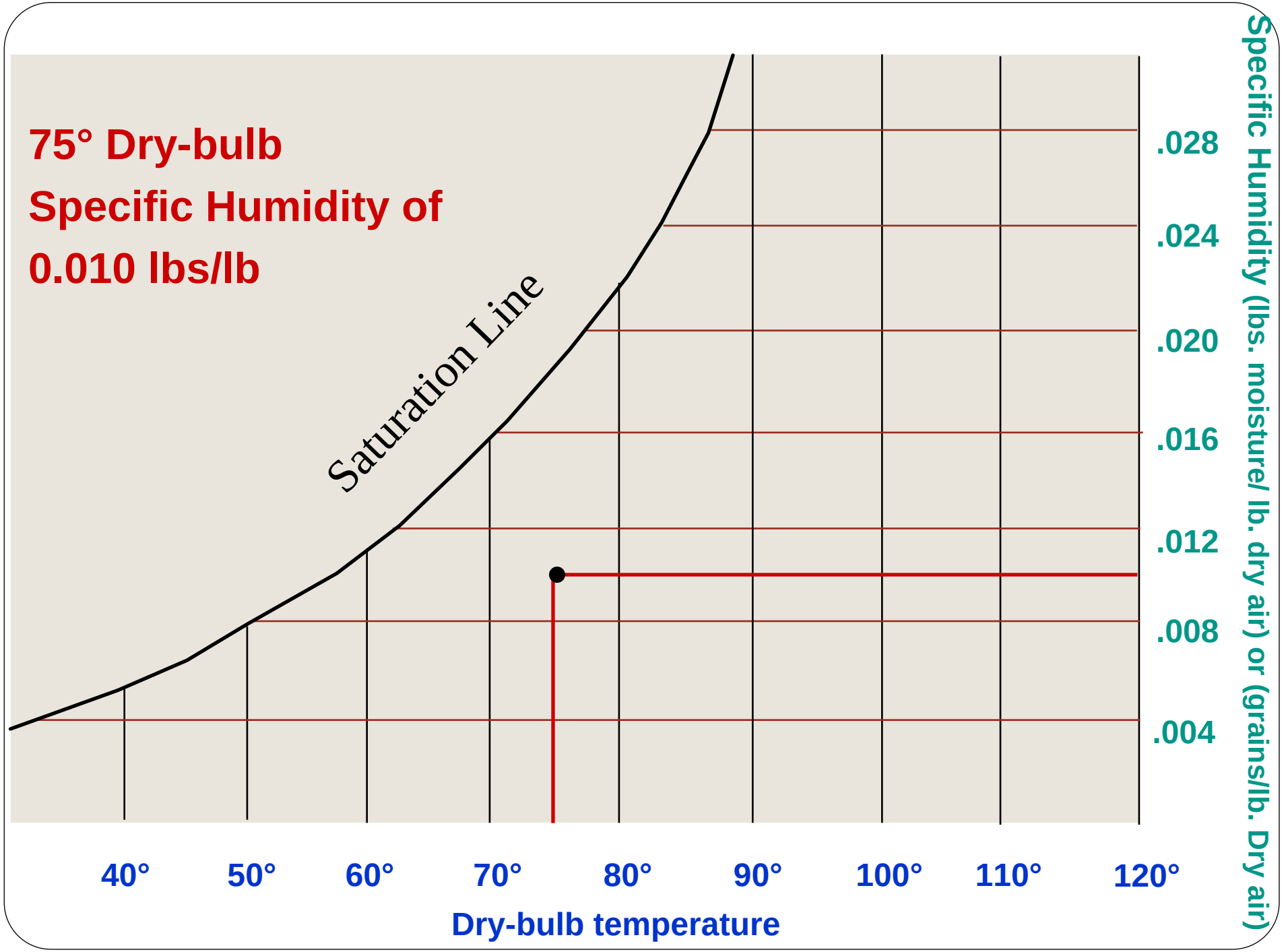

80°
70°
60°
50°
40°
.028
.024
.020
.016
.012
.008
.004
Specific Humidity (lbs. moisture/ lb. air)
40°
50°
60°
70°
80°
90°
100°
110°
120°
Dry-bulb temperature

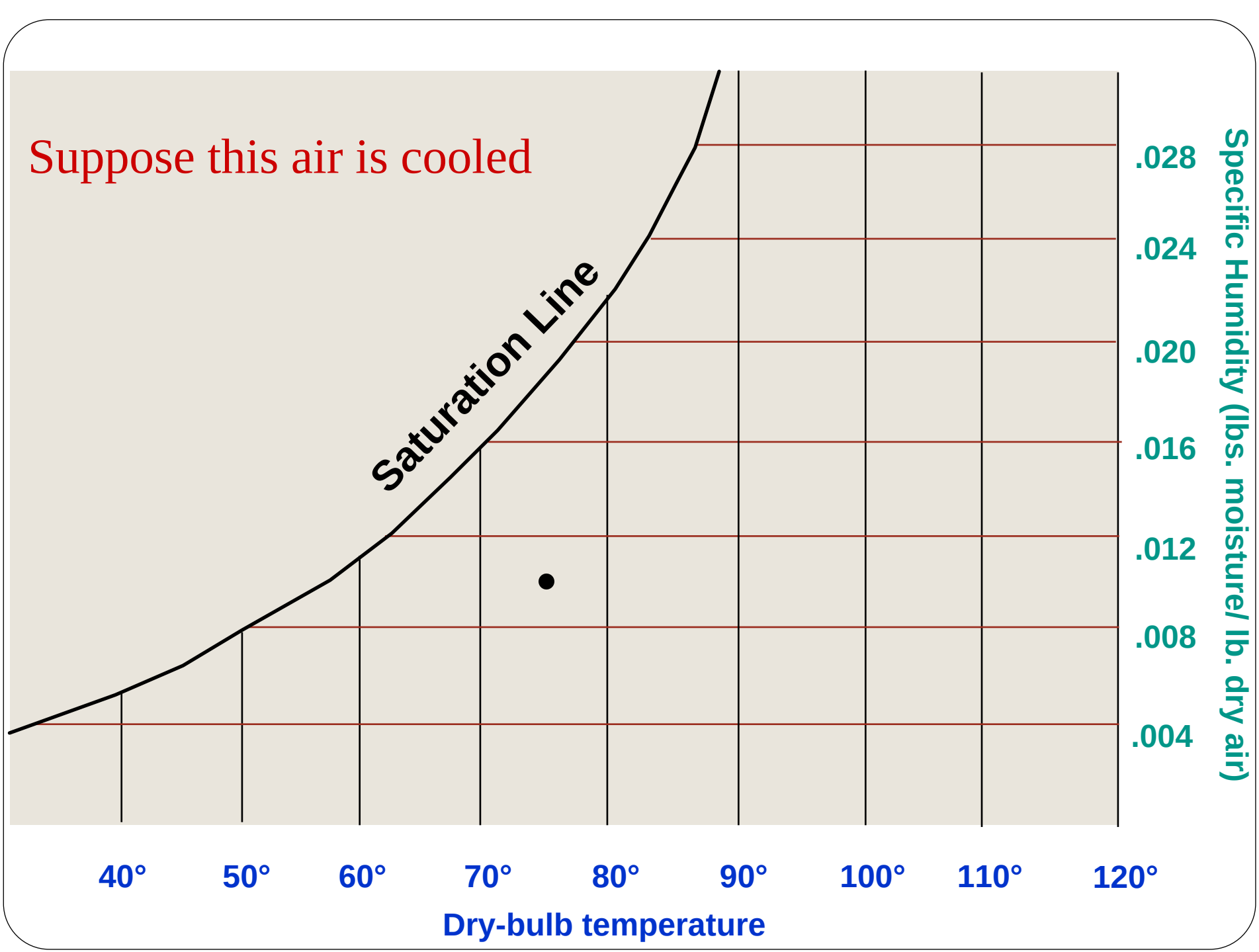

Saturation Line
40°
50°
60°
70°
80°
90°
100°
110°
120°
Dry-bulb temperature

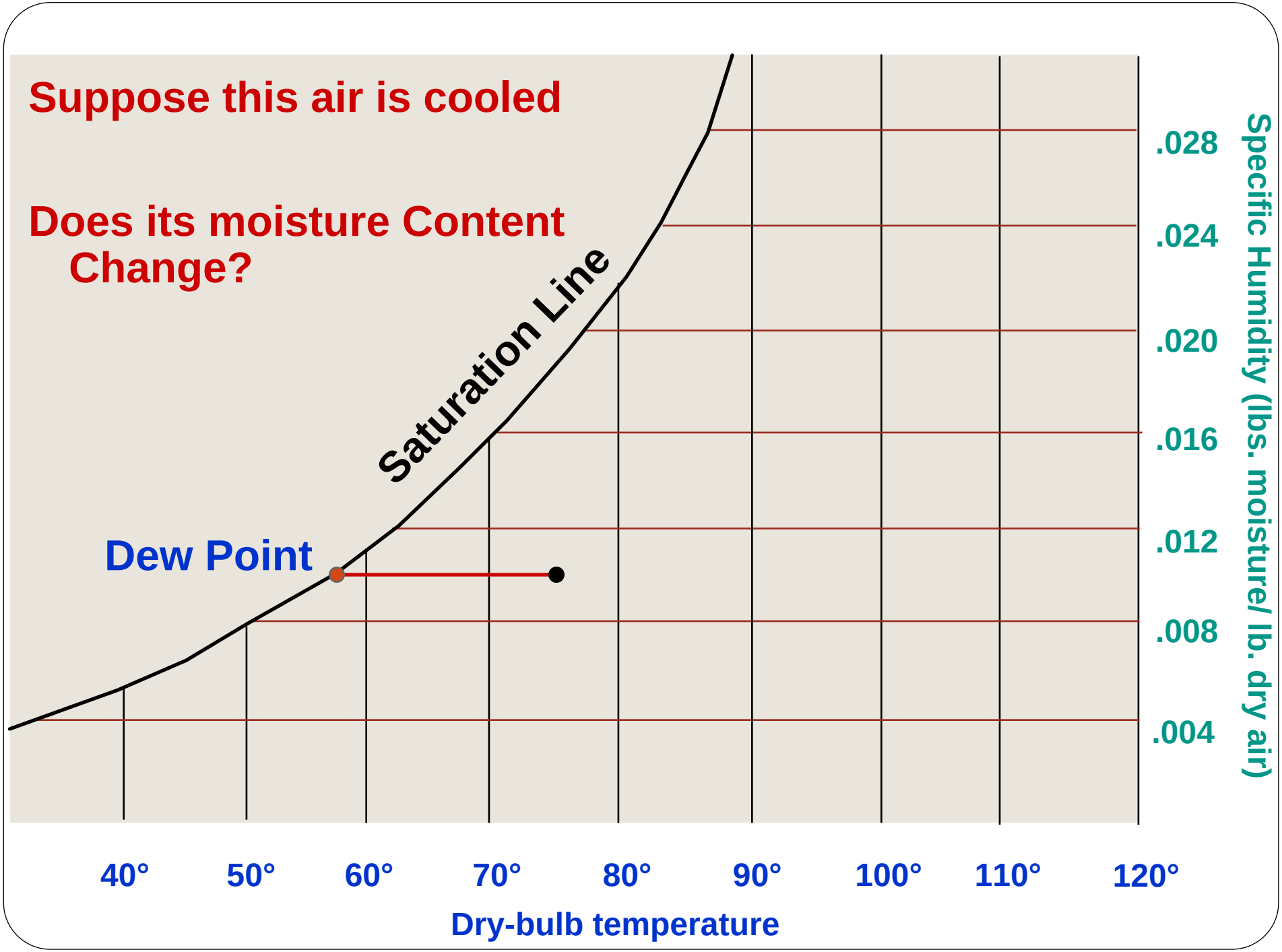

Saturation Line
.028
.024
.020
.016
.012
.008
.004
Specific Humidity (lbs. moisture/ lb. dry air)
40°
50°
60°
70°
80°
90°
100°
110°
120°
Dry-bulb temperature

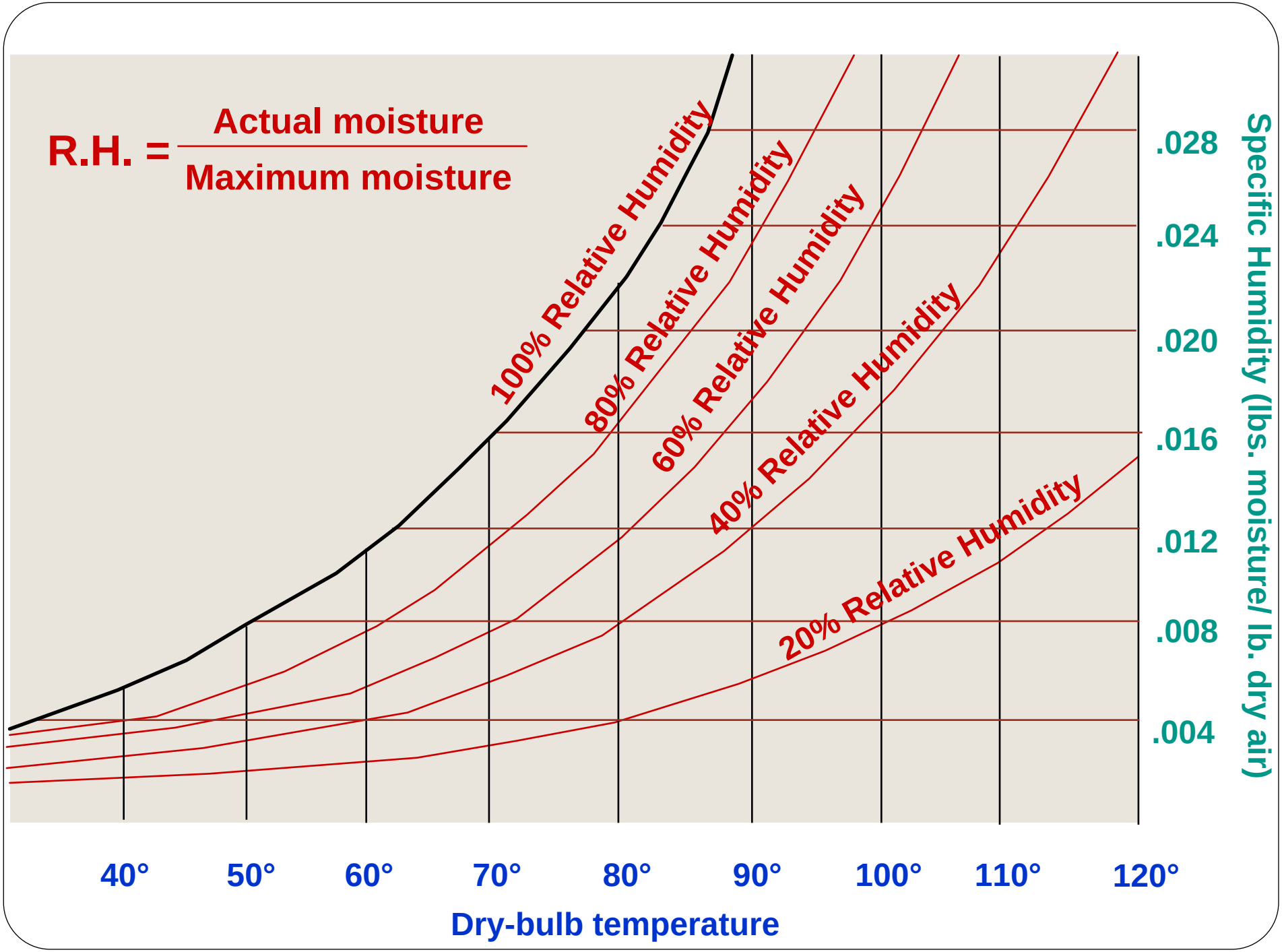
Moisture - Units of Measure




75° Dry-bulb
Specific Humidity of
0.010 lbs/lb
Saturation Line
.028
.024
.020
.016
.012
.008
.004
40°
50°
60°
70°
80°
90°
100°
110°
120°
Dry-bulb temperature
Specific Humidity (lbs. moisture/ lb. dry air) or (grains/lb. Dry air)

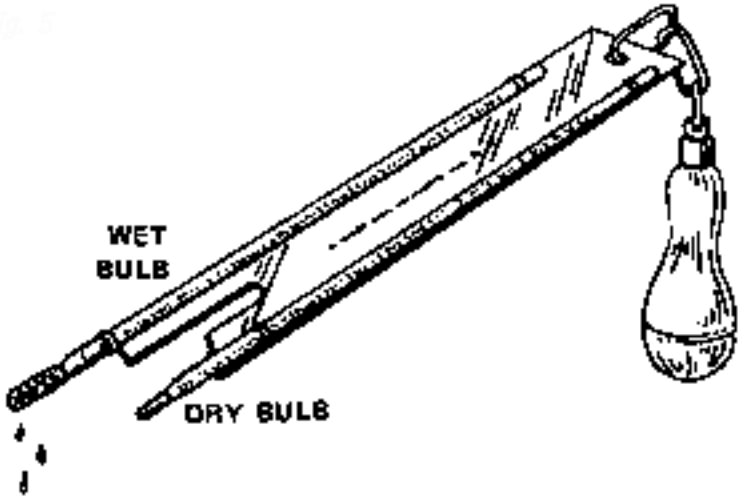

Suppose this air is cooled
Saturation Line
.028
.024
.020
.016
.012
.008
.004
Specific Humidity (lbs. moisture/ lb. dry air)
40°
50°
60°
70°
80°
90°
100°
110°
120°
Dry-bulb temperature

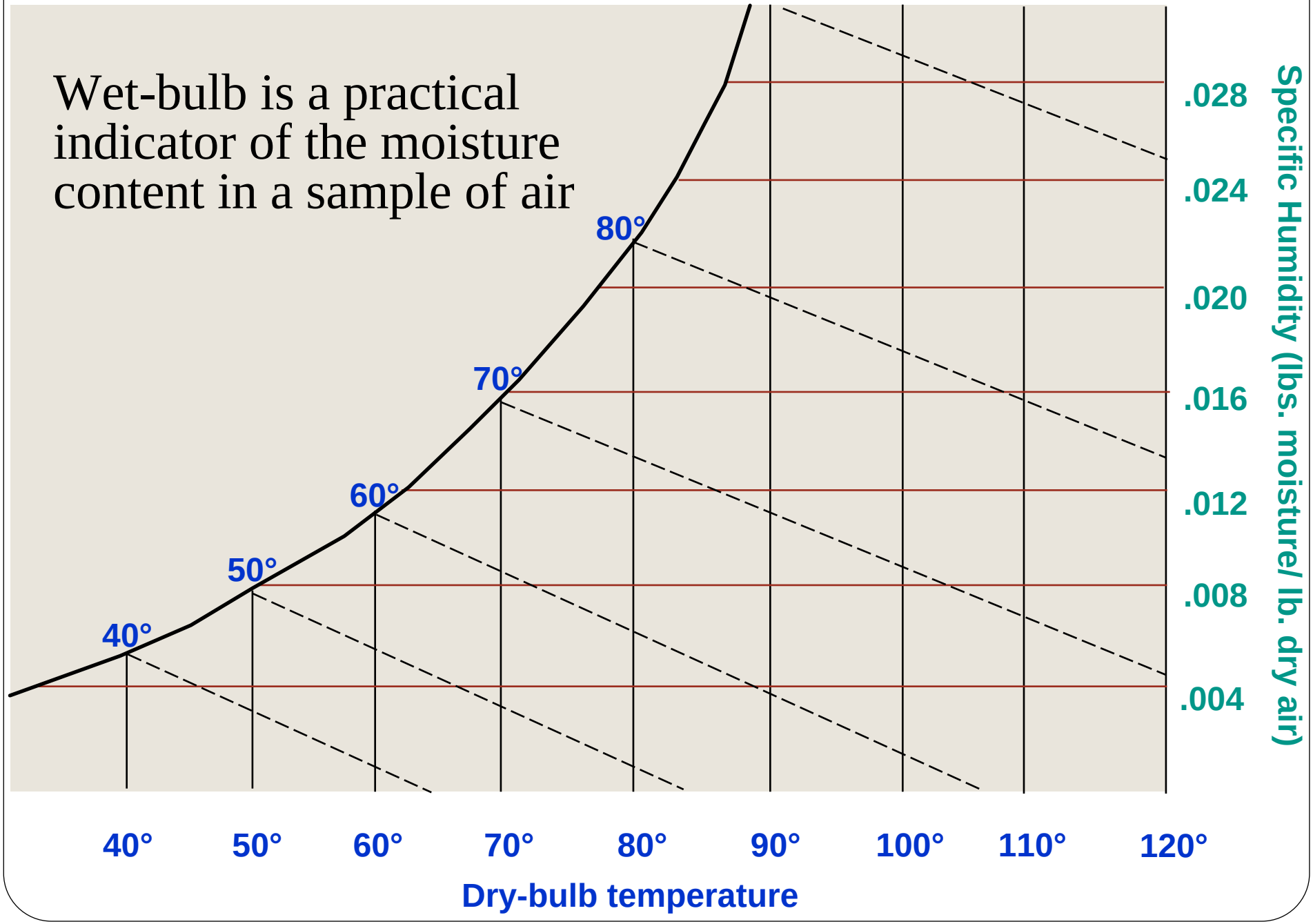

Suppose this air is cooled
Does its moisture Content Change?
Saturation Line
Dew Point
.028
.024
.020
.016
.012
.008
.004
Specific Humidity (lbs. moisture/ lb. dry air)
40°
50°
60°
70°
80°
90°
100°
110°
120°
Dry-bulb temperature

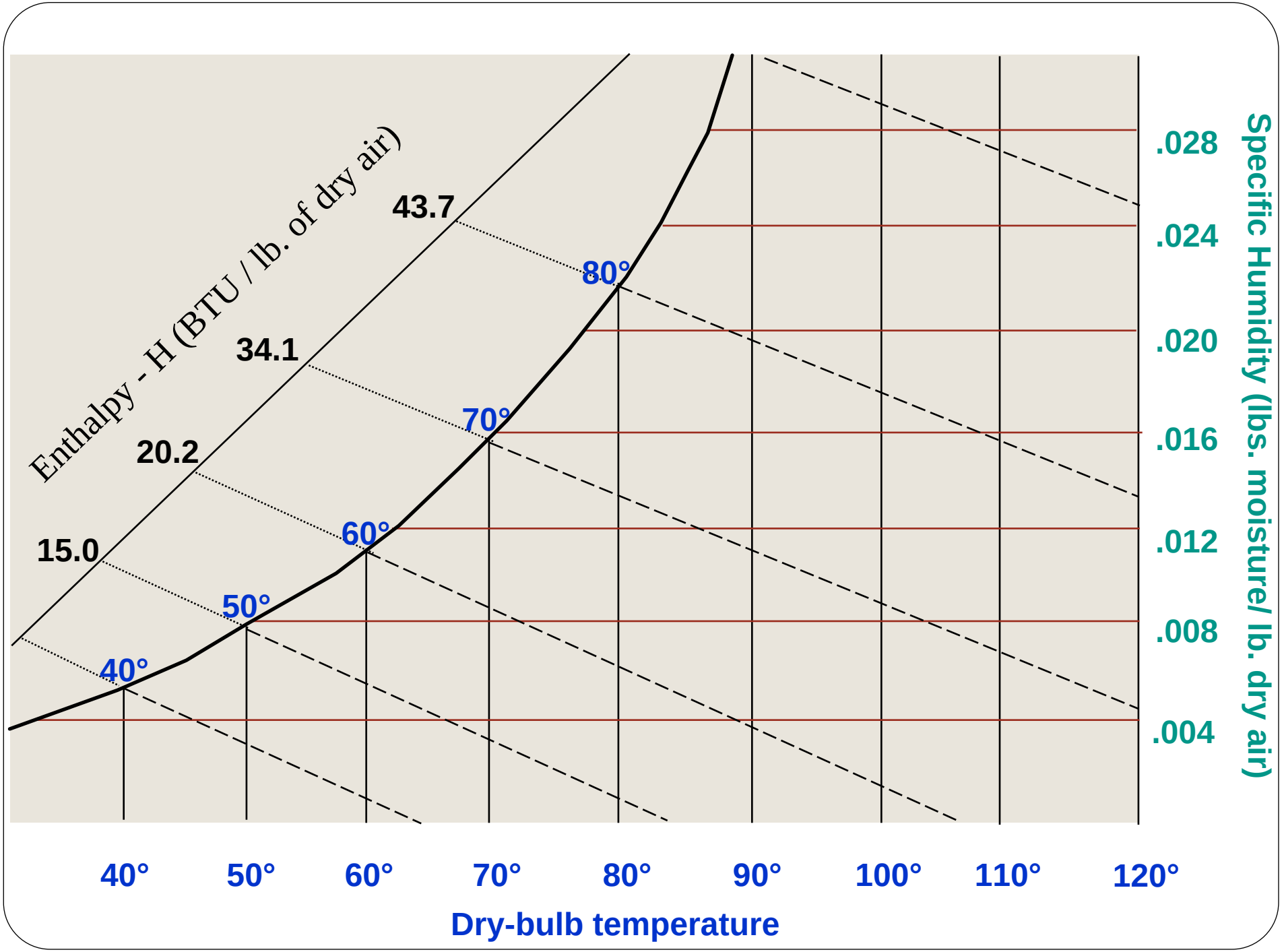

R.H. = Actual moisture / Maximum moisture
100% Relative Humidity
80% Relative Humidity
60% Relative Humidity
40% Relative Humidity
20% Relative Humidity
.028
.024
.020
.016
.012
.008
.004
Specific Humidity (lbs. moisture/ lb. dry air)
40°
50°
60°
70°
80°
90°
100°
110°
120°
Dry-bulb temperature

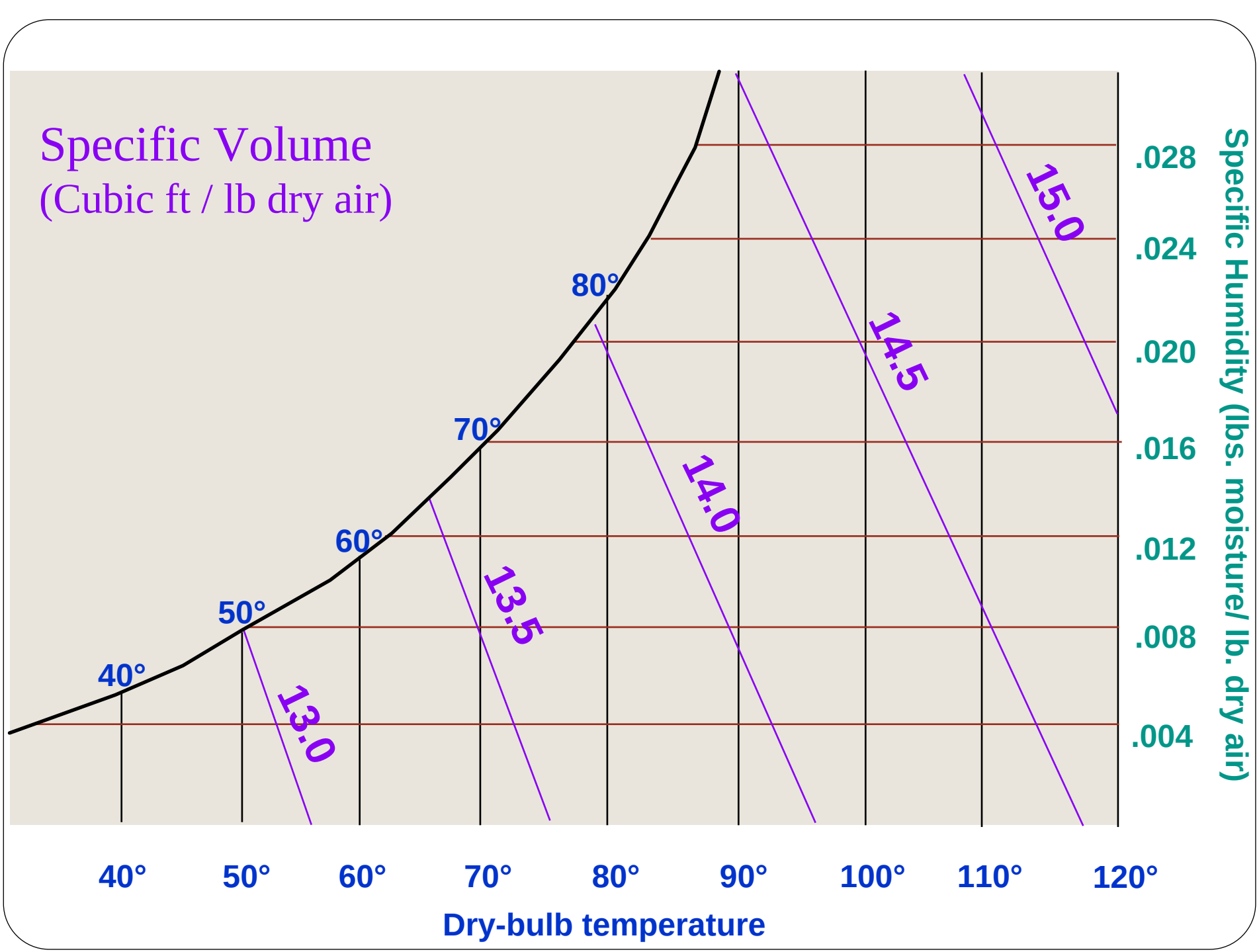
Sling Psychrometer

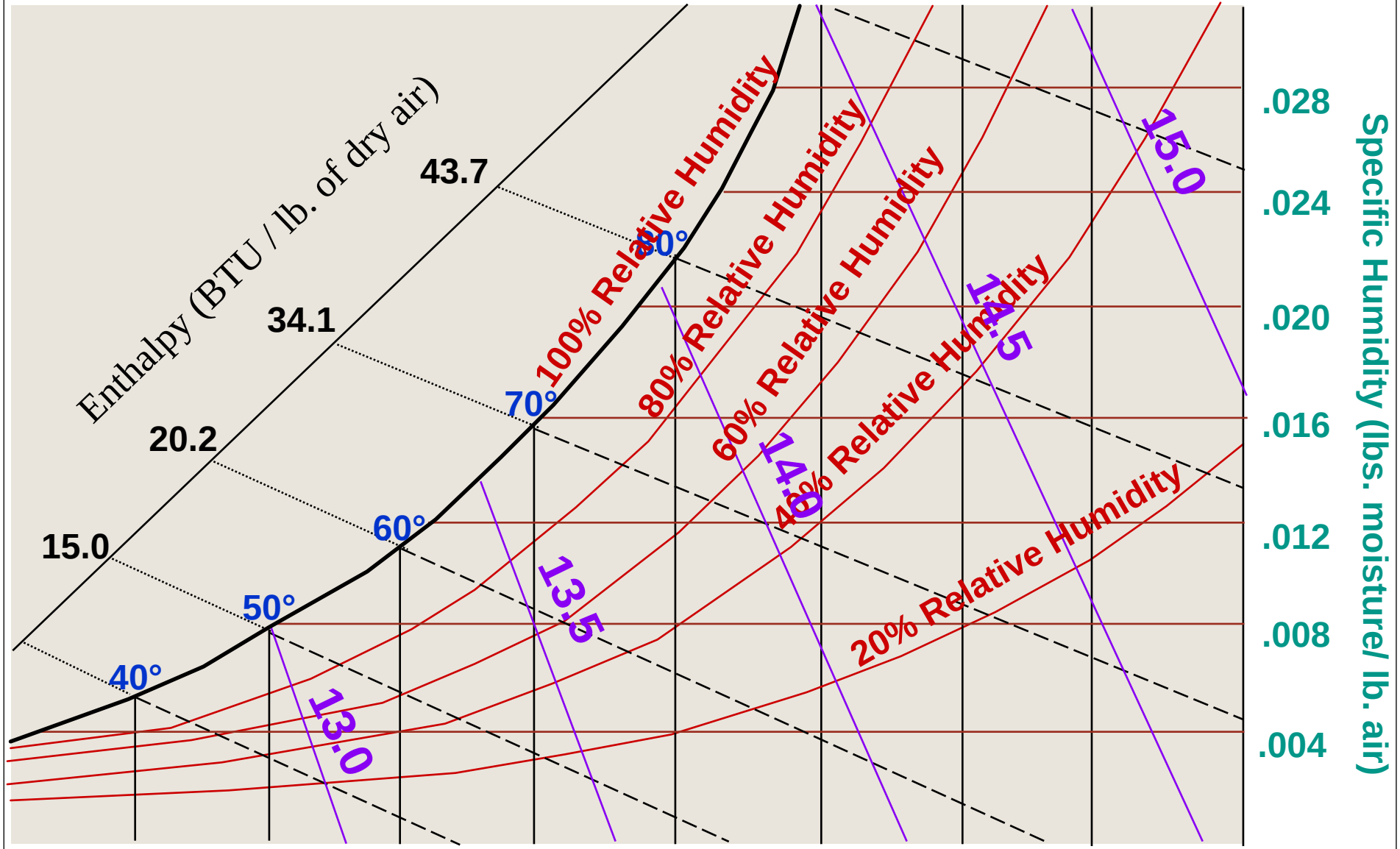
- The sling psychrometer is a simple and practical device for measuring the moisture content of air.



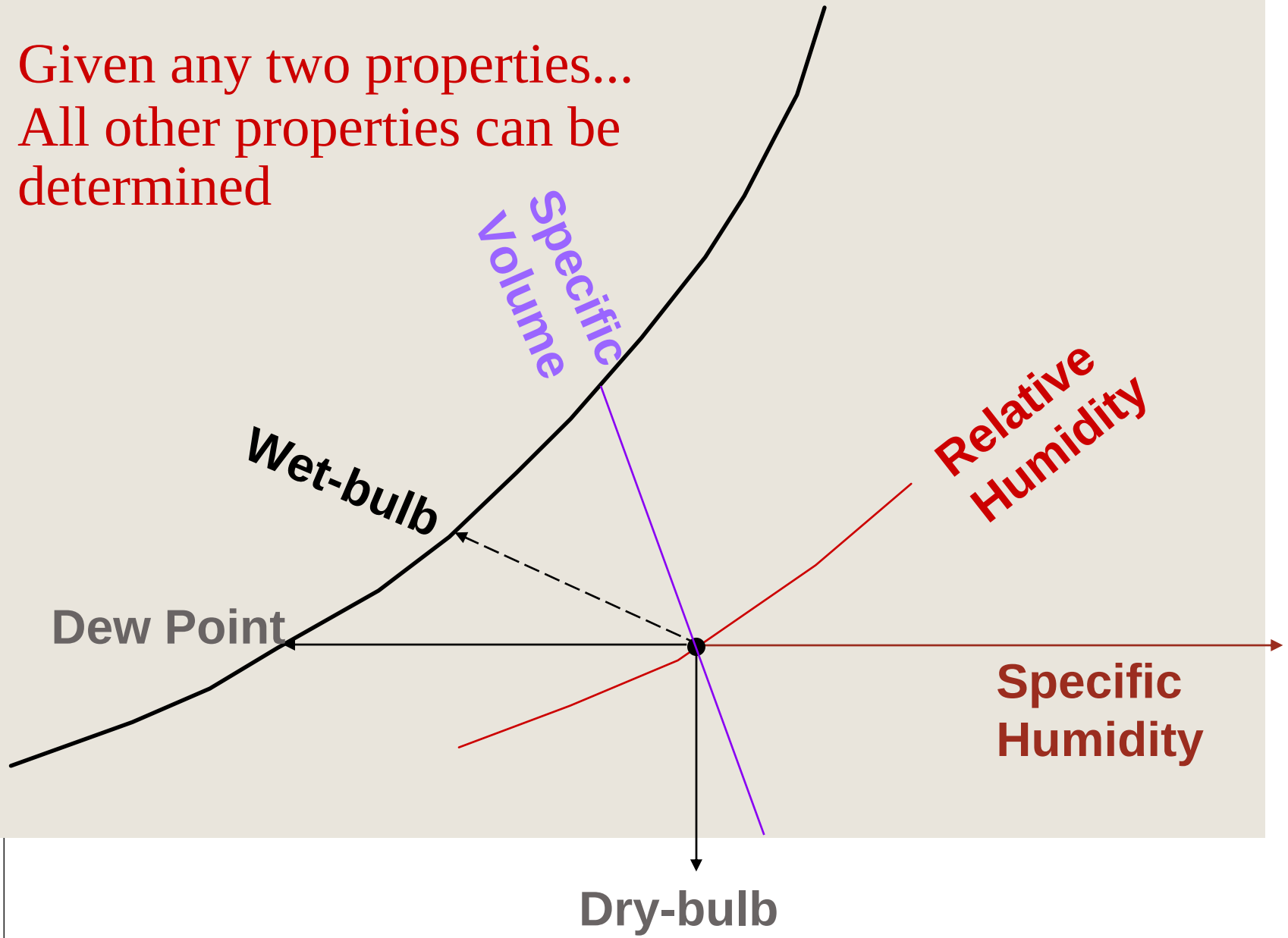

Wet-bulb is a practical indicator of the moisture content in a sample of air
80°
70°
60°
50°
40°
.028
.024
.020
.016
.012
.008
.004
Specific Humidity (lbs. moisture/ lb. dry air)
40°
50°
60°
70°
80°
90°
100°
110°
120°
Dry-bulb temperature

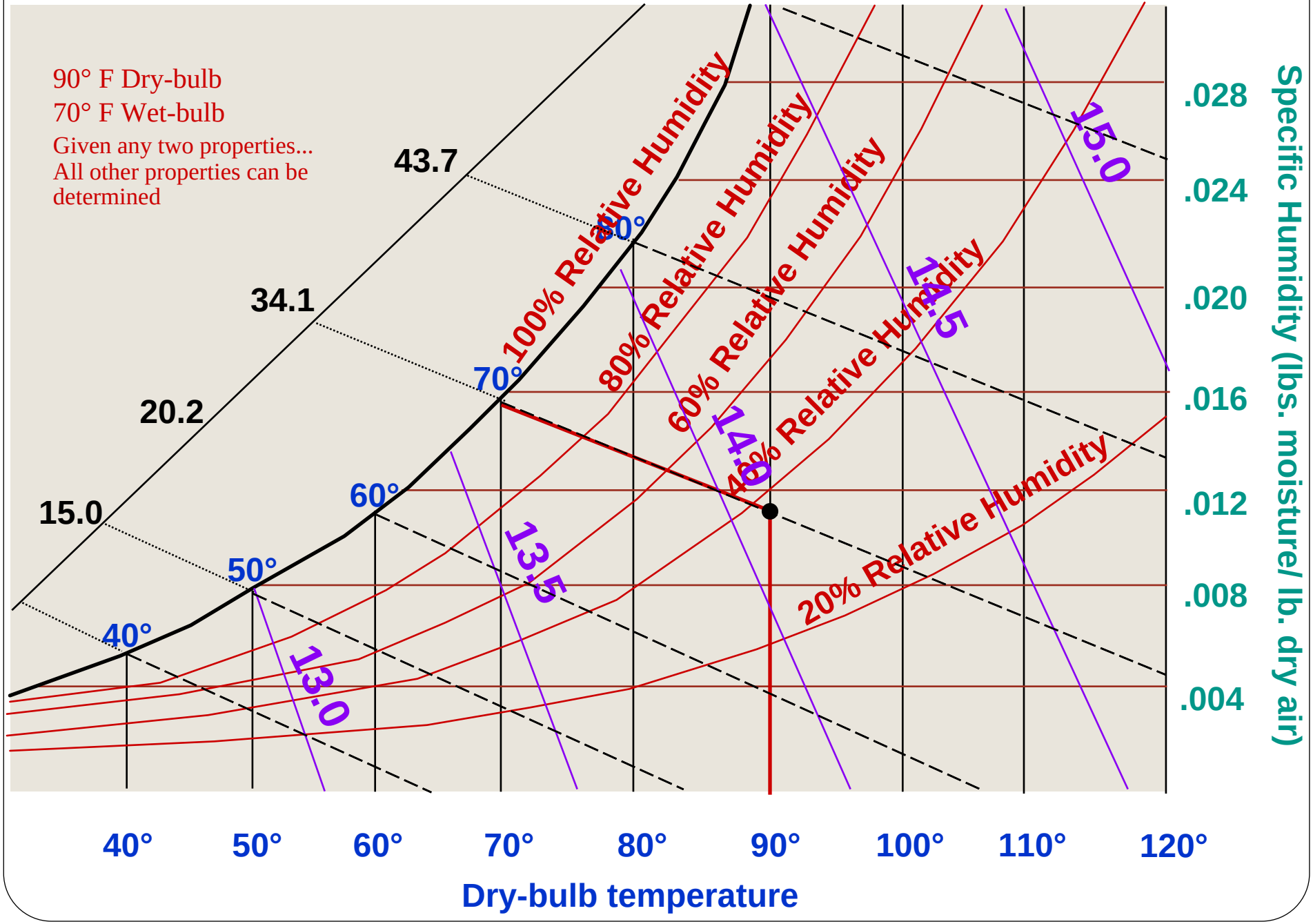

Enthalpy - H (BTU / lb. of dry air)
43.7
34.1
20.2
15.0
80°
70°
60°
50°
40°
.028
.024
.020
.016
.012
.008
.004
Specific Humidity (lbs. moisture/ lb. dry air)
40°
50°
60°
70°
80°
90°
100°
110°
120°
Dry-bulb temperature


Specific Volume
(Cubic ft / lb dry air)
40°
50°
60°
70°
80°
13.0
13.5
14.0
14.5
15.0
.028
.024
.020
.016
.012
.008
.004
Specific Humidity (lbs. moisture/ lb. dry air)
40°
50°
60°
70°
80°
90°
100°
110°
120°
Dry-bulb temperature


Enthalpy (BTU / lb. of dry air)
43.7
34.1
20.2
15.0
100% Relative Humidity
80% Relative Humidity
60% Relative Humidity
40% Relative Humidity
20% Relative Humidity
15.0
14.5
14.0
13.5
13.0
80°
70°
60°
50°
40°
.028
.024
.020
.016
.012
.008
.004
Specific Humidity (lbs. moisture/ lb. air)
40°
50°
60°
70°
80°
90°
100°
110°
120°
Dry-bulb temperature

Given any two properties...
All other properties can be determined




90° F Dry-bulb
70° F Wet-bulb
Given any two properties...
All other properties can be determined
43.7
34.1
20.2
15.0
100% Relative Humidity
80% Relative Humidity
60% Relative Humidity
40% Relative Humidity
20% Relative Humidity
80°
70°
60°
50°
40°
15.0
14.5
14.0
13.5
13.0
.028
.024
.020
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Specific Humidity (lbs. moisture/ lb. dry air)
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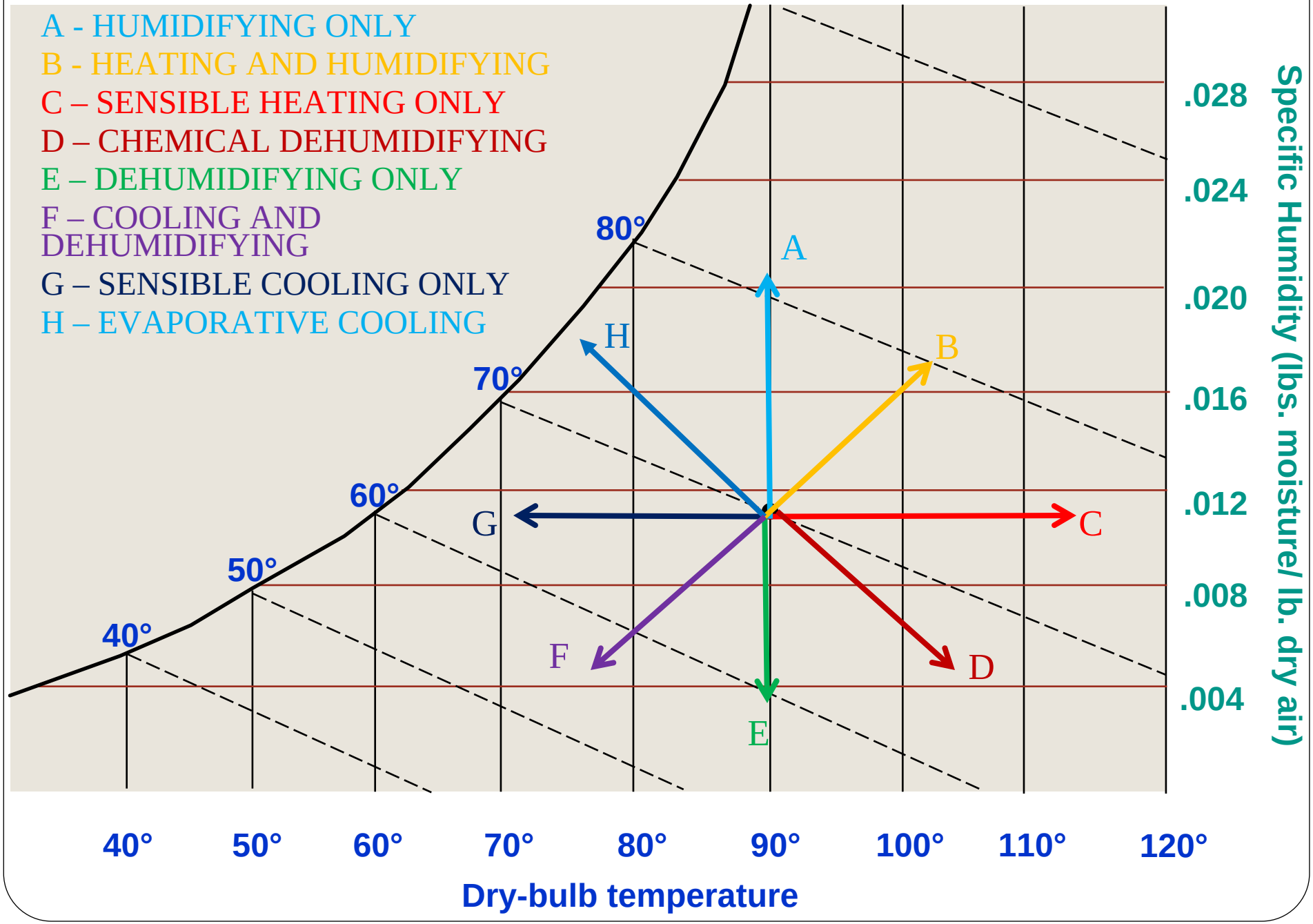
120°
Dry-bulb temperature


A - HUMIDIFYING ONLY
B - HEATING AND HUMIDIFYING
C – SENSIBLE HEATING ONLY
D – CHEMICAL DEHUMIDIFYING
E – DEHUMIDIFYING ONLY
F – COOLING AND DEHUMIDIFYING
G – SENSIBLE COOLING ONLY
H – EVAPORATIVE COOLING
A
B
C
D
E
F
G
H
40°
50°
60°
70°
80°
90°
100°
110°
120°
Dry-bulb temperature
.028
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.012
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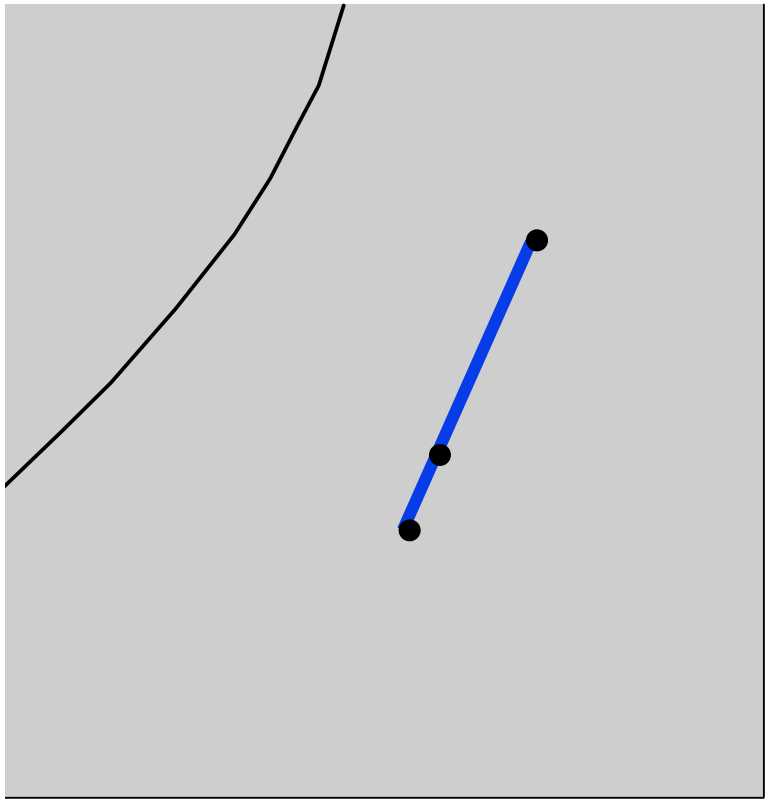
.004
Specific Humidity (lbs. moisture/ lb. dry air)

Mixing Air Streams

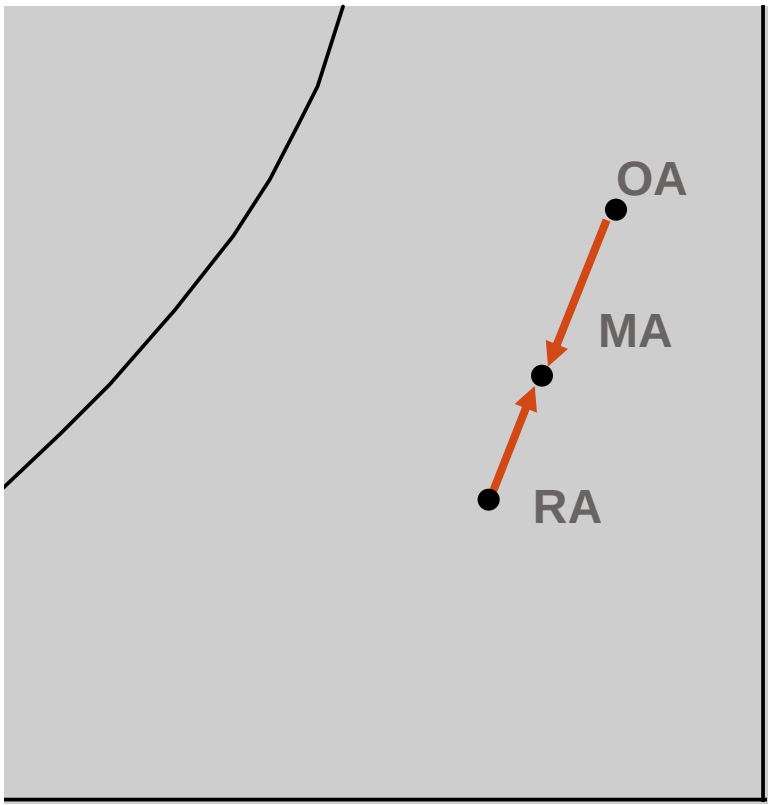


- The result of mixing two airstreams always falls on a line connecting the two points on a psychrometric chart.

Mixing Air Streams

OA = 95DB/78WB 1000 CFM

RA = 78DB/65WB 4000 CFM



1) Draw a line between OA & RA

2) Determine the relative percentage of OA & RA

   Total CFM = OA + RA = 5000 CFM

   OA = 1000/5000 = 20%

   RA = 4000/5000 = 80%

3) Determine the DB or WB temperature of the mixed point using ratios. Using DB:

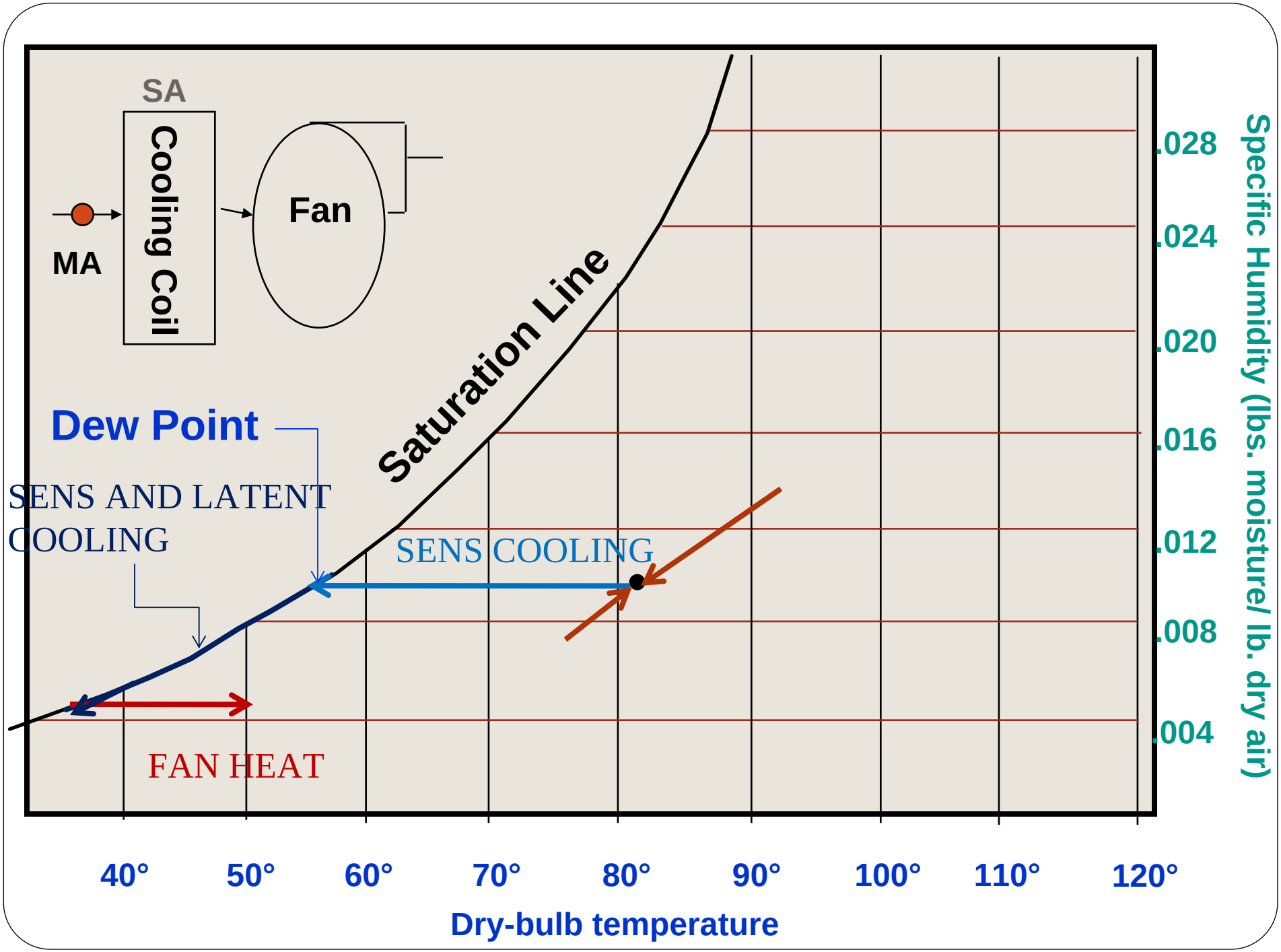
   Delta T = 95-78 = 17F

   RA Delta = 17F X 0.20 = 3.4 F

   Mixed Air DB = 78 +3.4 = 81.4 F

4) The mixed air point lies on the mixing line at the 81.4F point

   WB = 67.3 F


SA
Cooling Coil
Fan
MA
Saturation Line
Dew Point
SENS AND LATENT COOLING
SENS COOLING
FAN HEAT
.028
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Specific Humidity (lbs. moisture/ lb. dry air)
40°
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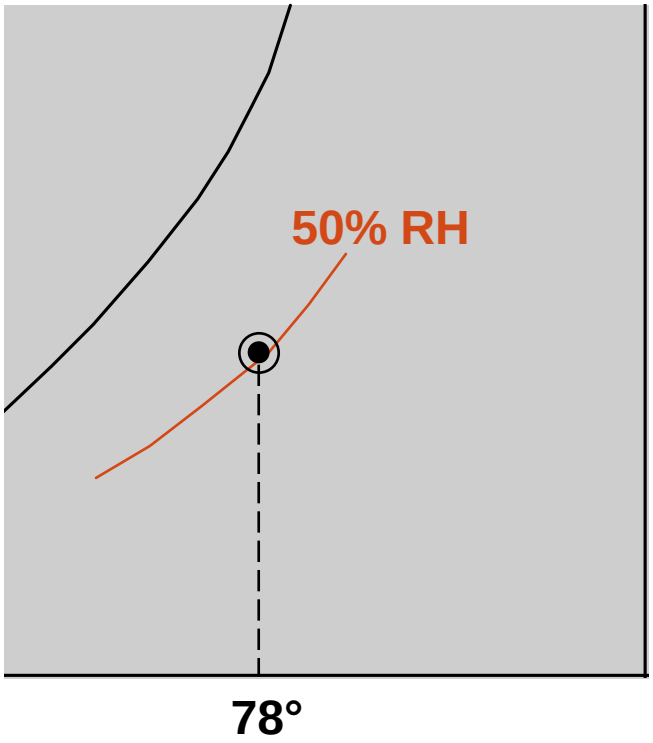
Dry-bulb temperature

Sensible Heat Ratio (SHR)

Room design for: 78° / 50% RH

Sensible heat gain = 150,000 BTUH

Latent heat gain = 30,000 BTUH



$$SHR = \frac{Q_{Sensible}}{Q_{Sensible} + Q_{Latent}} = \frac{Q_{Sensible}}{Q_{Total}}$$

$$SHR = \frac{150{,}000}{150{,}000 + 30{,}000}$$

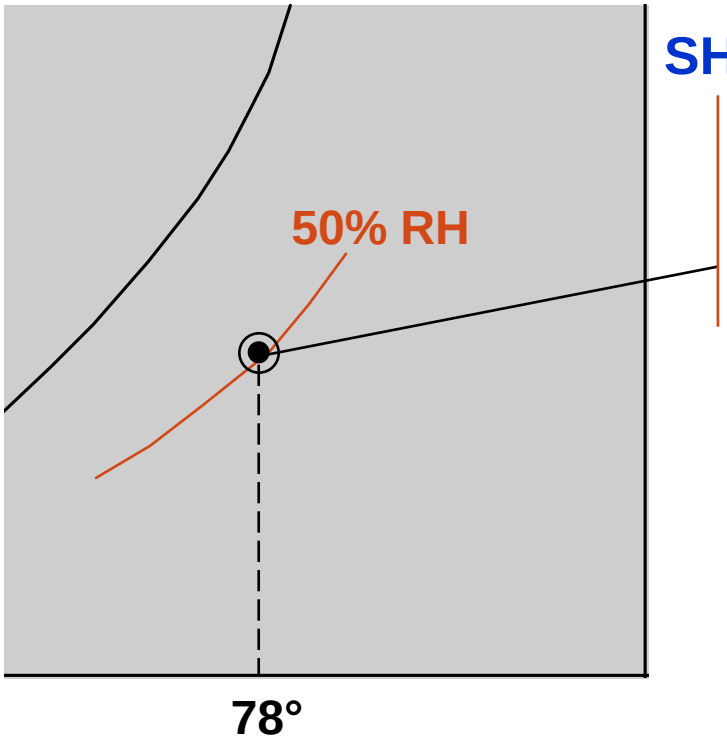
$$SHR = 0.833$$

Sensible Heat Ratio (SHR)

Room design for: 78° / 50% RH

Sensible heat gain = 150,000 BTUH

Latent heat gain = 30,000 BTUH



SHF

$$SHR = \frac{Q_{Sensible}}{Q_{Sensible} + Q_{Latent}} = \frac{Q_{Sensible}}{Q_{Total}}$$

.833

$$SHR = \frac{150{,}000}{150{,}000 + 30{,}000}$$

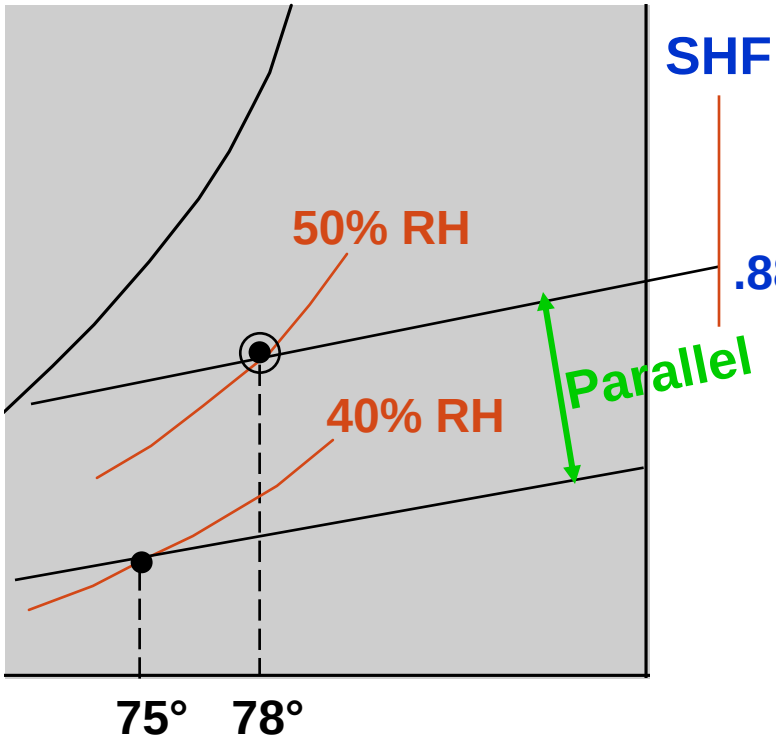
$$SHR = 0.833$$

Sensible Heat Ratio (SHR)

Room design for: 78° / 50% RH

Sensible heat gain = 150,000 BTUH

Latent heat gain = 30,000 BTUH

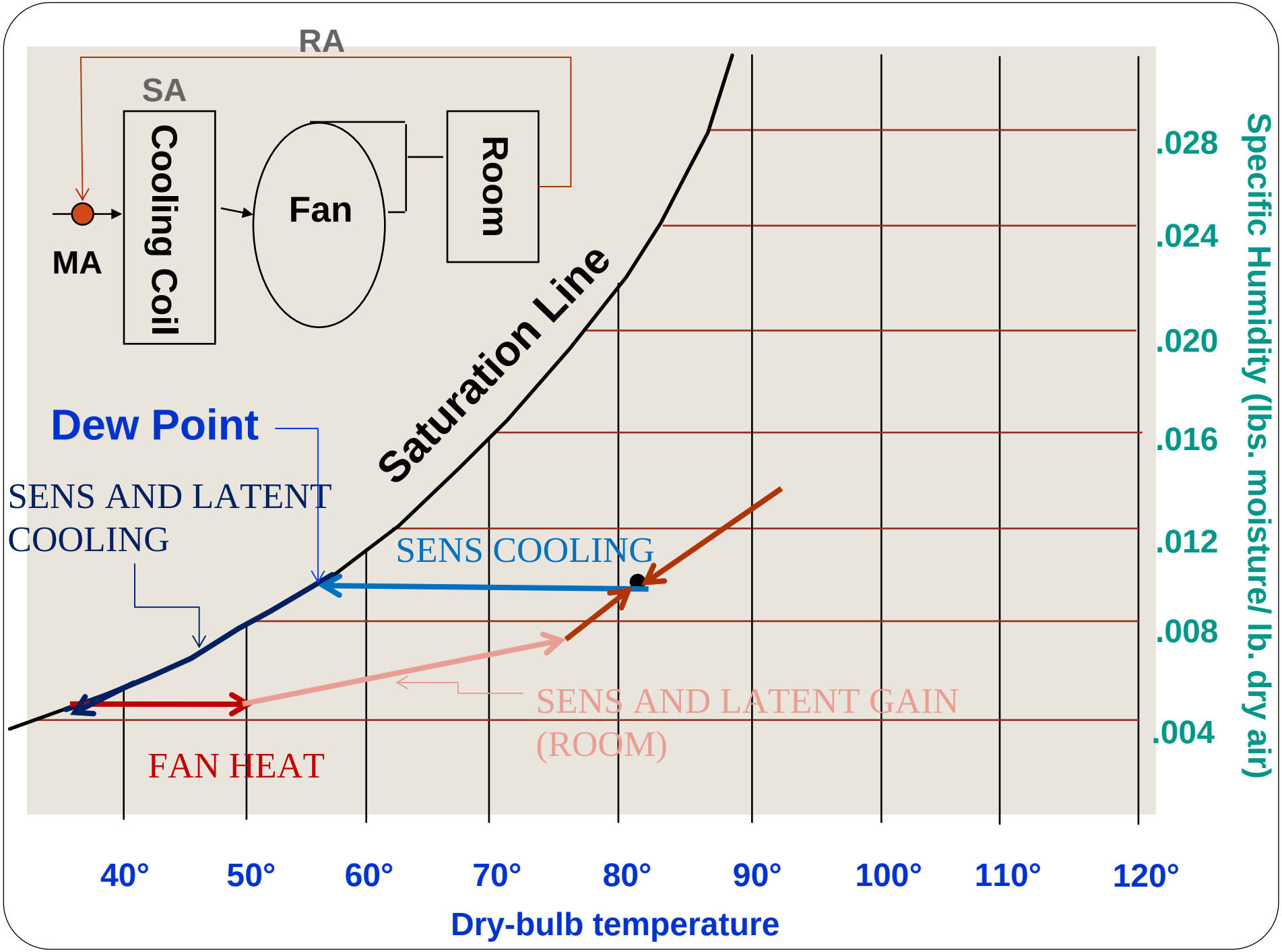


SHF .889

$$SHR = \frac{Q_{Sensible}}{Q_{Sensible} + Q_{Latent}} = \frac{Q_{Sensible}}{Q_{Total}}$$

$$SHR = \frac{150{,}000}{150{,}000 + 30{,}000}$$

$$SHR = 0.833$$


RA
SA
Cooling Coil
Fan
Room
MA
Saturation Line
Dew Point
SENS AND LATENT COOLING
SENS COOLING
SENS AND LATENT GAIN (ROOM)
FAN HEAT
.028
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Specific Humidity (lbs. moisture/ lb. dry air)
40°
50°
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120°
Dry-bulb temperature

Formulas

$Q_{sensible}$ = SCFM (ft^3/Min) x Δ T (°F) x 1.085 (BTU*Min)/(ft^3*Hr * °F)

(Sometimes also see 1.1, 1.09, or 1.08)

$Q_{sensible\ (5000\ ft)}$ = CFM (ft^3/Min) x Δ T (°F) x 0.90 (BTU*Min)/(ft^3*Hr * °F)

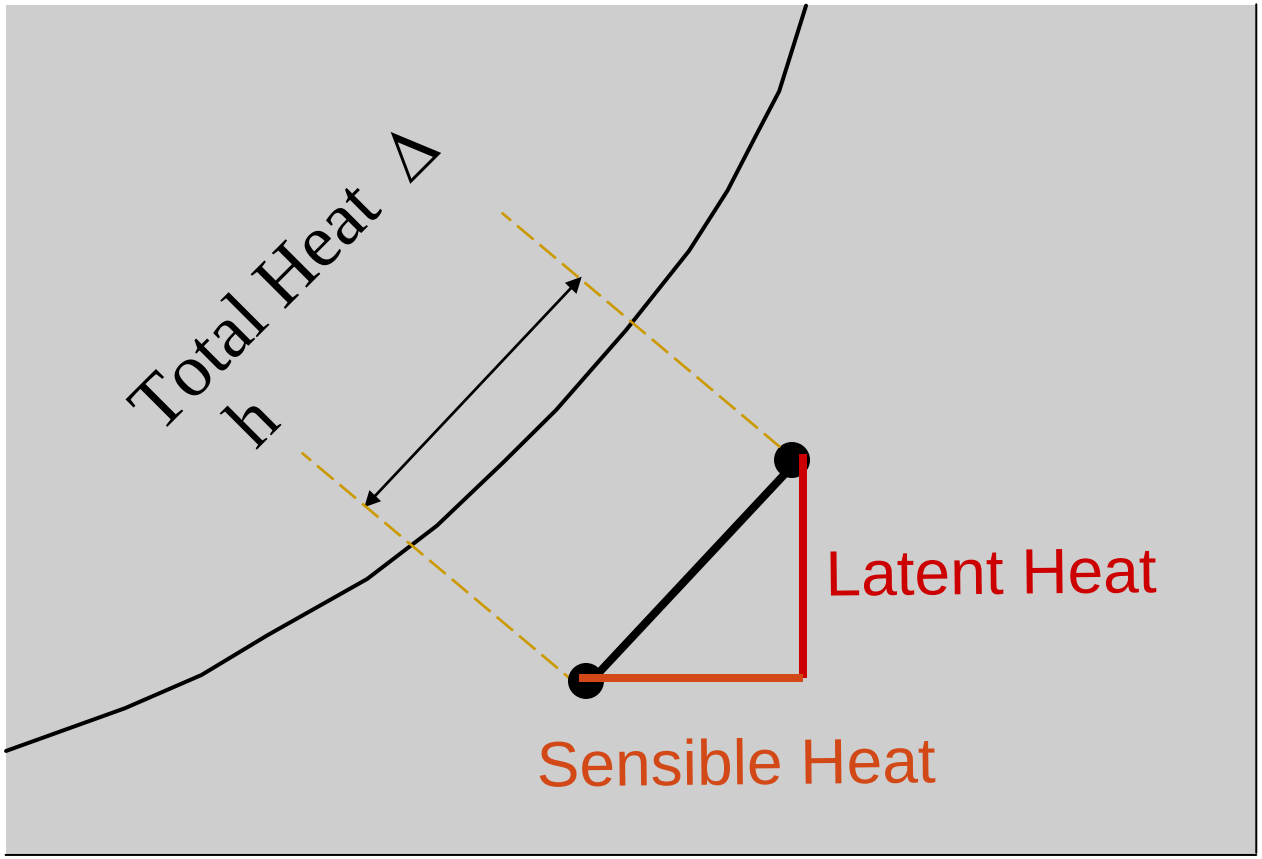
Q_{Total} = $Q_{Sensible}$ + Q_{Latent}

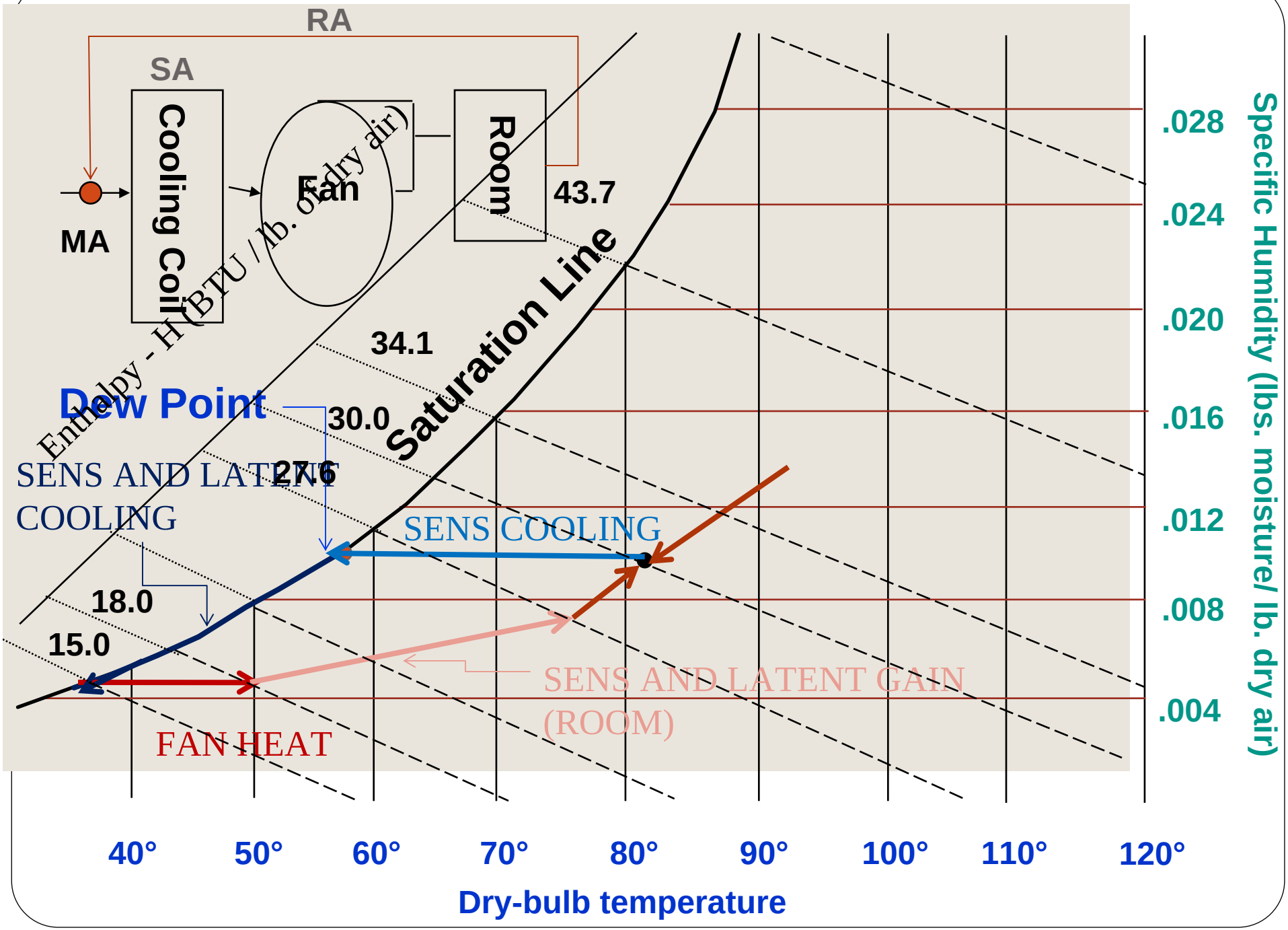
Q_{Total} = SCFM (ft^3/Min) x Δ h (BTU/lb) x 4.5 (Min * lb/ ft^3)

$Q_{Total\ (5000\ ft)}$ = CFM (ft^3/Min) x Δ h (BTU/lb) x 3.74 (Min * lb/ ft^3*Hr)

Q is in BTU/h

Total Heat




RA
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SENS COOLING
SENS AND LATENT GAIN (ROOM)
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Specific Humidity (lbs. moisture/ lb. dry air)
40°
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120°
Dry-bulb temperature

Formulas

- Qroom = 5,000 (ft^3/Min) *(27.6 BTU/LB-18.0BTU/LB)*3.74 (Min * lb/ ft^3*Hr)
- Qroom =179,600 BTU/h

- Qcoil = 5,000 (ft^3/Min) *(30.0 BTU/LB-15.0BTU/LB)*3.74 (Min * lb/ ft^3*Hr)
- Qcoil =280,500 BTU/h

Questions?

Thank You