Navigating the Cooling, Heating and Reheat Process on the Psychrometric Chart

Four examples of cooling will be reviewed in the following examples. The first is an example of sensible mechanical cooling, the second is an example of sensible and latent mechanical cooling, the third example is of sensible mechanical heating, and the fourth example is of sensible and latent mechanical cooling, followed by hot gas reheat. All cooling calculations will assume the same design conditions of 90°F Dry Bulb, 75°F Wet Bulb, and 2000 cfm of outside air.

On the following psychrometric charts, different color lines represent different air properties:

Blue Line = Cooling/Heating Process
Yellow Line = EAT Dry Bulb Temperature
Red Line = EAT Wet Bulb Temperature
Green Line = EAT Enthalpy
Black Line = LAT Dry Bulb Temperature
Brown Line = LAT Enthalpy
Grey Line = EAT Humidity Ratio (Same as LAT on sensible cooling)
Purple Line = LAT Humidity Ratio

Navigating the psychrometric chart:

1. Find the design dry bulb temperature on the bottom horizontal axis and follow the yellow line up.
2. Find the design dry bulb temperature on the left curved axis and follow the red line down to the right.
3. Where those 2 lines intersect is the design EAT point.
4. Reading directly to the right from this point and following the grey line, will show the design humidity ratio on the right vertical axis.
5. Follow the green line from the design point to the upper left diagonal axis with generate the EAT enthalpy.
6. The cooling process is defined by the blue line. Sensible cooling is shown by a horizontal line and latent cooling occurs once the air reaches saturation and begins to follow the curved left axis to the lower left.
7. Determine the desired leaving air dry blub (black line) and wet bulb (brown line) temperature from what is required for the specific application.
8. Determine the LAT enthalpy (brown line), and the LAT humidity ratio (purple line) from the LAT point.
9. Use the formulas below and follow the examples to determine the cooling capacity requirement.

Listed below are common cooling formulas used for both sensible and latent cooling calculations:

Total Cooling Load (Btu/hr) = Sensible Cooling Load (Btu/hr) + Latent Cooling Load (Btu/hr)

Where:

Sensible Cooling Load (Btu/hr) = CFM x Density Factor x (T1 – T2)

Latent Cooling Load (Btu/hr) = CFM x 0.69143 x (G1 – G2)

Where:

CFM = Airflow in Cubic Feet Per Minute

$$\text{Density Factor} = 1.08 + \frac{(70\text{-Blower Temp}) \times .024}{10}$$

T1 = Entering Air Drybulb Temperature (°F)

T2 = Leaving Air Drybulb Temperature (°F)

G1 = Grains of Moisture of Entering Air = 7000 x humidity ratio (lbm moisture/lbm of dry air)

G2 = Grains of Moisture of Leaving Air = 7000 x humidity ratio (lbm moisture/lbm of dry air)

Example 1: Sensible Cooling

Design Conditions (EAT):
CFM = 2000
Dry Bulb = 90°F
Wet Bulb = 75°F

Final Conditions (LAT):
Dry Bulb = 75°F
Wet Bulb = 70.5°F

Sensible Cooling Load (Btu/hr) = CFM x Density Factor x (EAT Dry Bulb – LAT Dry Bulb)
Density Factor = 1.08 + [(70 – Blower Dry Blub) x .024)/10]
1 Ton = 12000 Btu/hr

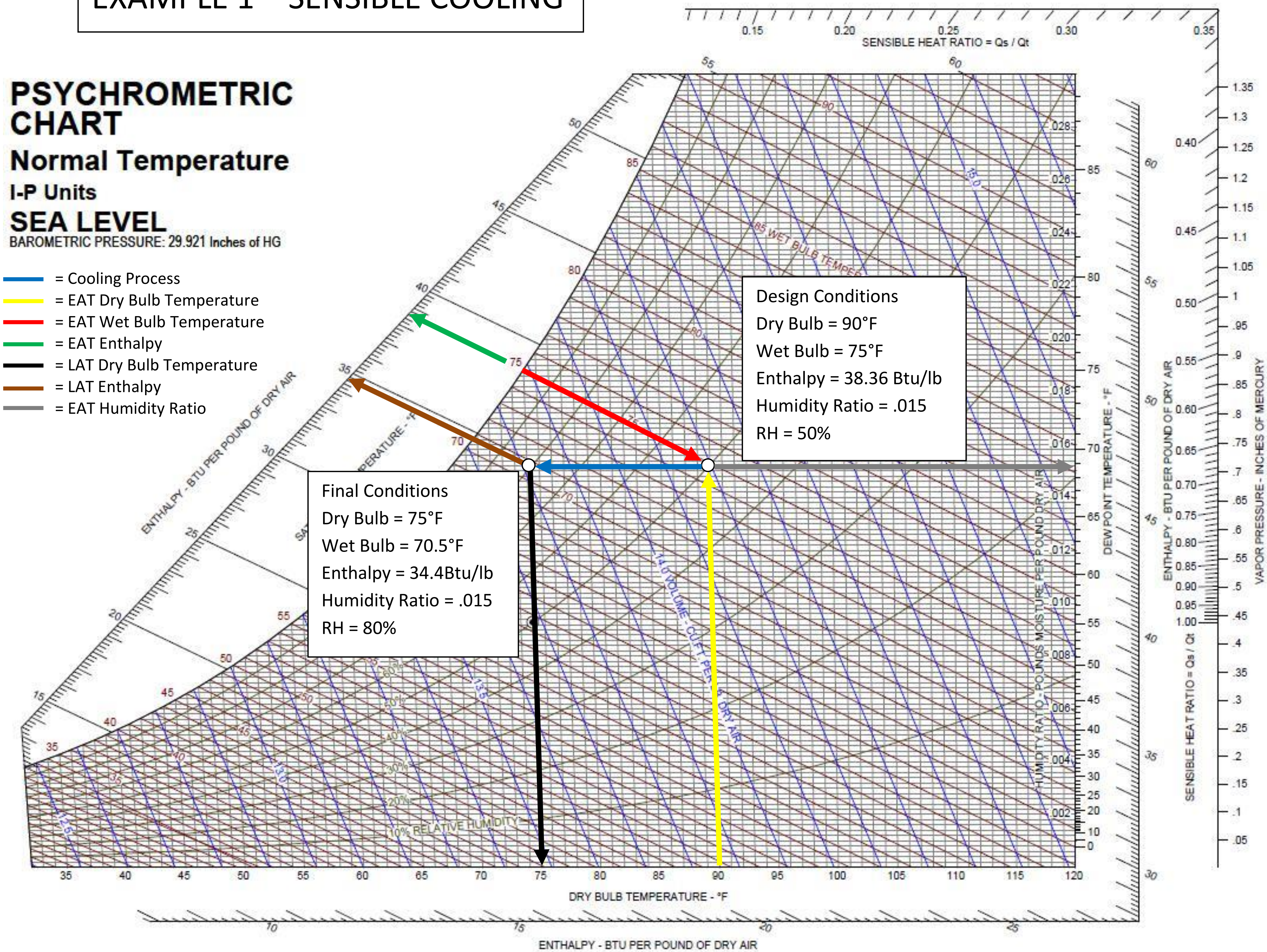
Density Factor = 1.08 + [(70 – 90) x .024)/10]
Density Factor = **1.032**

Sensible Cooling Load (Btu/hr) = 2000 x 1.032 x (90 –75)
Sensible Cooling Load = **30960 Btu/hr**

Required Cooling Tonnage = (Btu/hr)/12000
Required Cooling Tonnage = 30960/12000
Required Cooling Tonnage = 2.58 Tons

See this example on the following psychrometric chart.

EXAMPLE 1 – SENSIBLE COOLING



Example 2: Sensible and Latent Cooling

Design Conditions (EAT):
CFM = 2000
Dry Bulb = 90°F
Wet Bulb = 75°F
Enthalpy = 38.36 Btu/lb
Humidity Ratio = .015

Final Conditions (LAT):
Dry Bulb = 60°F
Wet Bulb = 60°F
Enthalpy = 26.41 Btu/lb
Humidity Ratio = .011

Sensible Cooling Load (Btu/hr) = CFM x Density Factor x (EAT Dry Bulb – LAT Dry Bulb)
Density Factor = 1.08 + [(70 – Blower Dry Blub) x .024)/10]
1 Ton = 12000 Btu/hr

Density Factor = 1.08 + [(70 – 90) x .024)/10]
Density Factor = **1.032**

Sensible Cooling Load (Btu/hr) = 2000 x 1.032 x (90 –60)
Sensible Cooling Load = **61920 Btu/hr**

Latent Cooling Load (Btu/hr) = CFM x 0.69143 x (G1 – G2)
G1 = Grains of Moisture of Entering Air = 7000 x humidity ratio (lbm moisture/lbm of dry air)
G2 = Grains of Moisture of Leaving Air = 7000 x humidity ratio (lbm moisture/lbm of dry air)

G1 = 7000 x .015
G1 = 105

G2 = 7000 x .011
G2 = 77

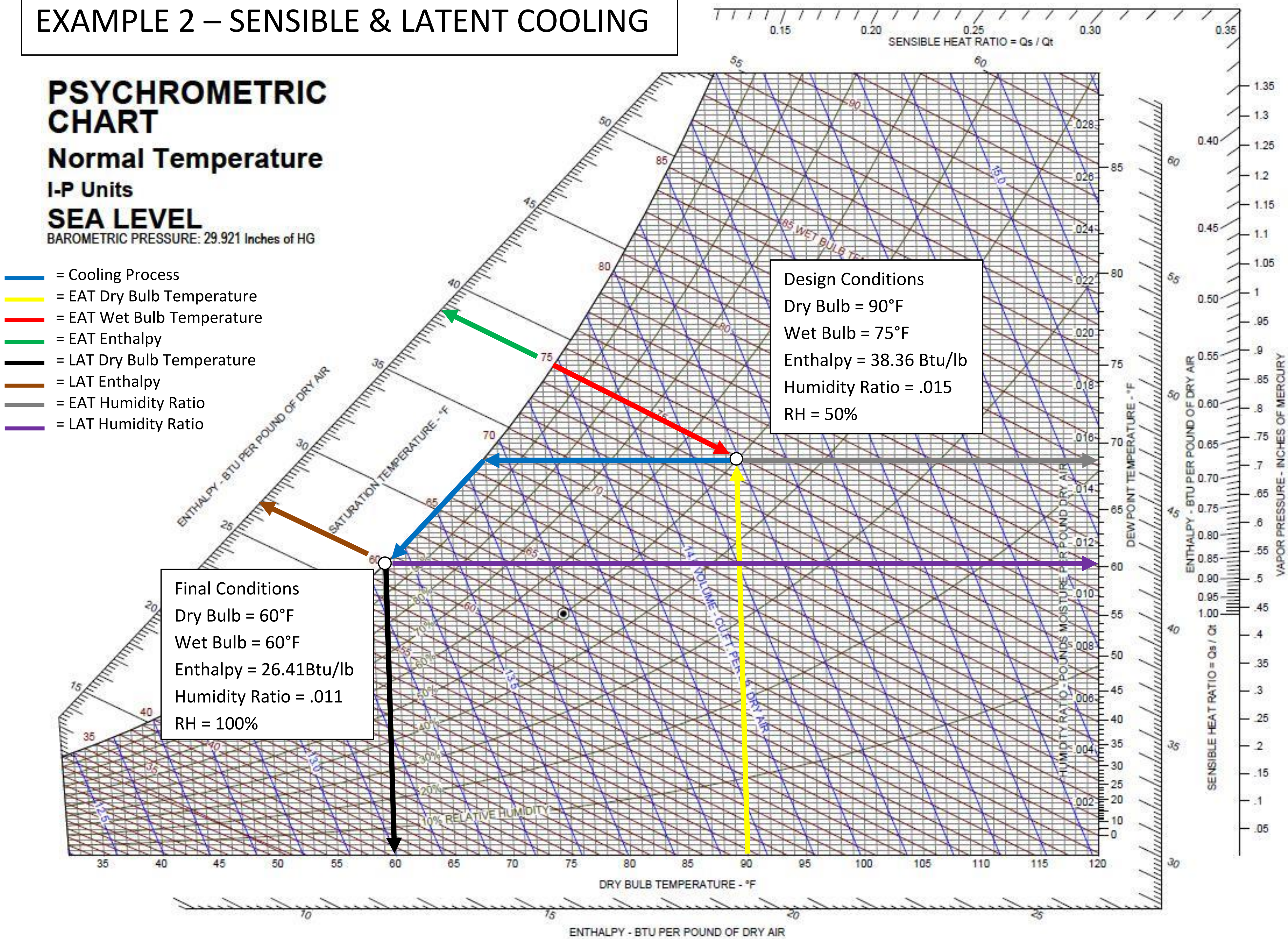
Latent Cooling Load = 2000 x 0.69143 x (105 – 77)
Latent Cooling Load = **38720 Btu/hr**

Total Cooling Load (Btu/hr) = Sensible Cooling Load (Btu/hr) + Latent Cooling Load (Btu/hr)
Total Cooling Load = 61920 Btu/hr + 38720 Btu/hr
Total Cooling Load = 100,640 Btu/hr

Required Cooling Tonnage = (Btu/hr)/12000
Required Cooling Tonnage = 100,640/12000
Required Cooling Tonnage = 8.38 Tons

See this example on the following psychrometric chart.

EXAMPLE 2 – SENSIBLE & LATENT COOLING



Example 3: Sensible Heating (Heat Pump)

Design Conditions (EAT):
CFM = 2000
Dry Bulb = 40°F
Wet Bulb = 32°F

Final Conditions (LAT):
Dry Bulb = 55°F
Wet Bulb = 40°F

Sensible Heating Load (Btu/hr) = CFM x Density Factor x (LAT Dry Bulb – EAT Dry Bulb)
Density Factor = 1.08 + [(70 – Blower Dry Blub) x .024)/10]
1 Ton = 12000 Btu/hr

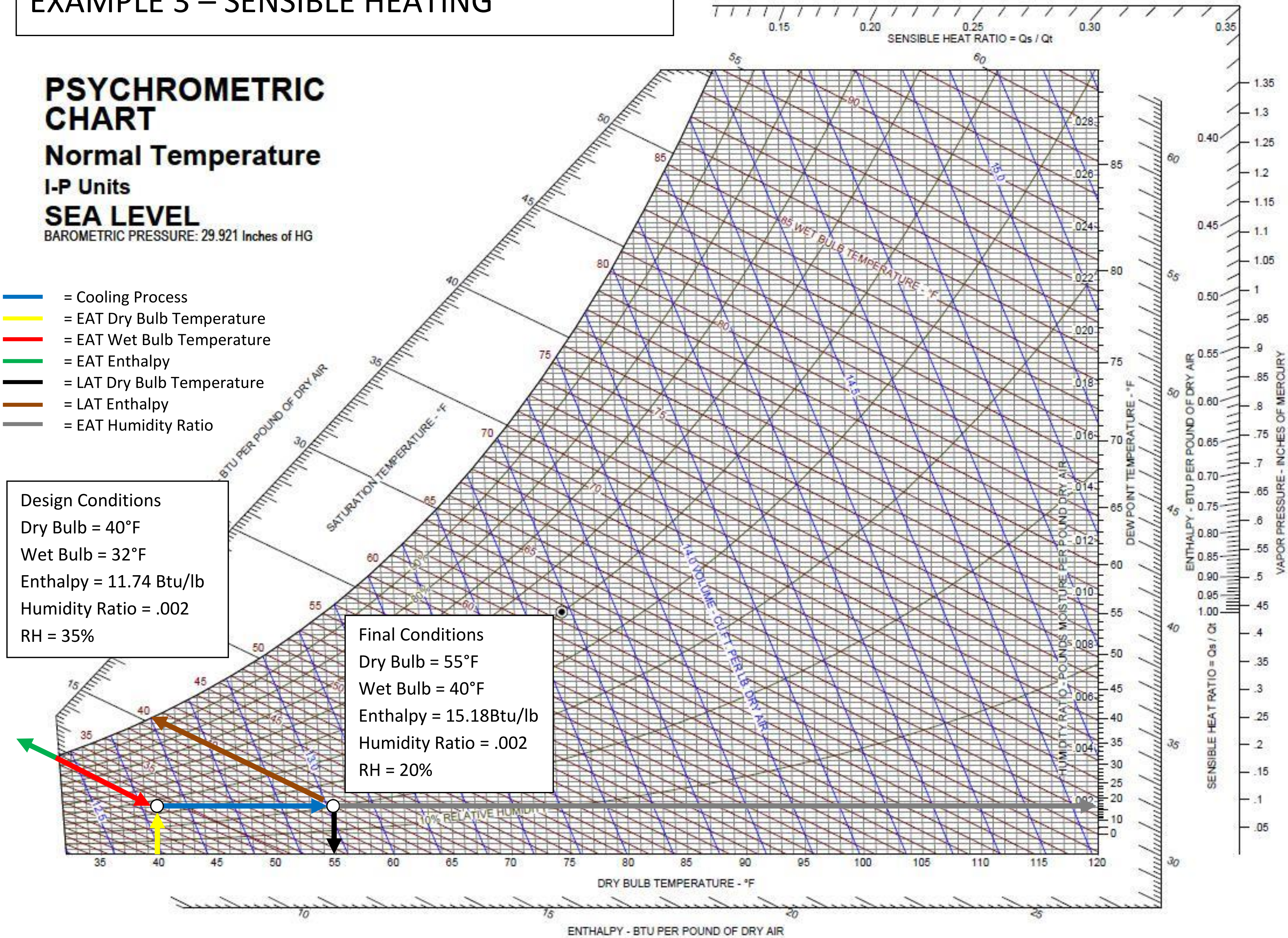
Density Factor = 1.08 + [(70 – 55) x .024)/10]
Density Factor = **1.116**

Sensible Heating Load (Btu/hr) = 2000 x 1.116 x (55 –40)
Sensible Heating Load = **33480 Btu/hr**

Required Heating Tonnage = (Btu/hr)/12000
Required Heating Tonnage = 33480/12000
Required Heating Tonnage = 2.79 Tons

See this example on the following psychrometric chart.

EXAMPLE 3 – SENSIBLE HEATING



Design Conditions
Dry Bulb = 40°F
Wet Bulb = 32°F
Enthalpy = 11.74 Btu/lb
Humidity Ratio = .002
RH = 35%

Final Conditions
Dry Bulb = 55°F
Wet Bulb = 40°F
Enthalpy = 15.18Btu/lb
Humidity Ratio = .002
RH = 20%

Example 4: Sensible and Latent Cooling with Reheat

Design Conditions (EAT):
CFM = 2000
Dry Bulb = 90°F
Wet Bulb = 75°F
Enthalpy = 38.36 Btu/lb
Humidity Ratio = .015

Final Conditions (LAT):
Dry Bulb = 60°F
Wet Bulb = 60°F
Enthalpy = 26.41 Btu/lb
Humidity Ratio = .011

Sensible Cooling Load (Btu/hr) = CFM x Density Factor x (EAT Dry Bulb – LAT Dry Bulb)
Density Factor = 1.08 + [(70 – Blower Dry Blub) x .024)/10]
1 Ton = 12000 Btu/hr

Density Factor = 1.08 + [(70 – 90) x .024)/10]
Density Factor = **1.032**

Sensible Cooling Load (Btu/hr) = 2000 x 1.032 x (90 –60)
Sensible Cooling Load = **61920 Btu/hr**

Latent Cooling Load (Btu/hr) = CFM x 0.69143 x (G1 – G2)
G1 = Grains of Moisture of Entering Air = 7000 x humidity ratio (lbm moisture/lbm of dry air)
G2 = Grains of Moisture of Leaving Air = 7000 x humidity ratio (lbm moisture/lbm of dry air)

G1 = 7000 x .015
G1 = 105

G2 = 7000 x .011
G2 = 77

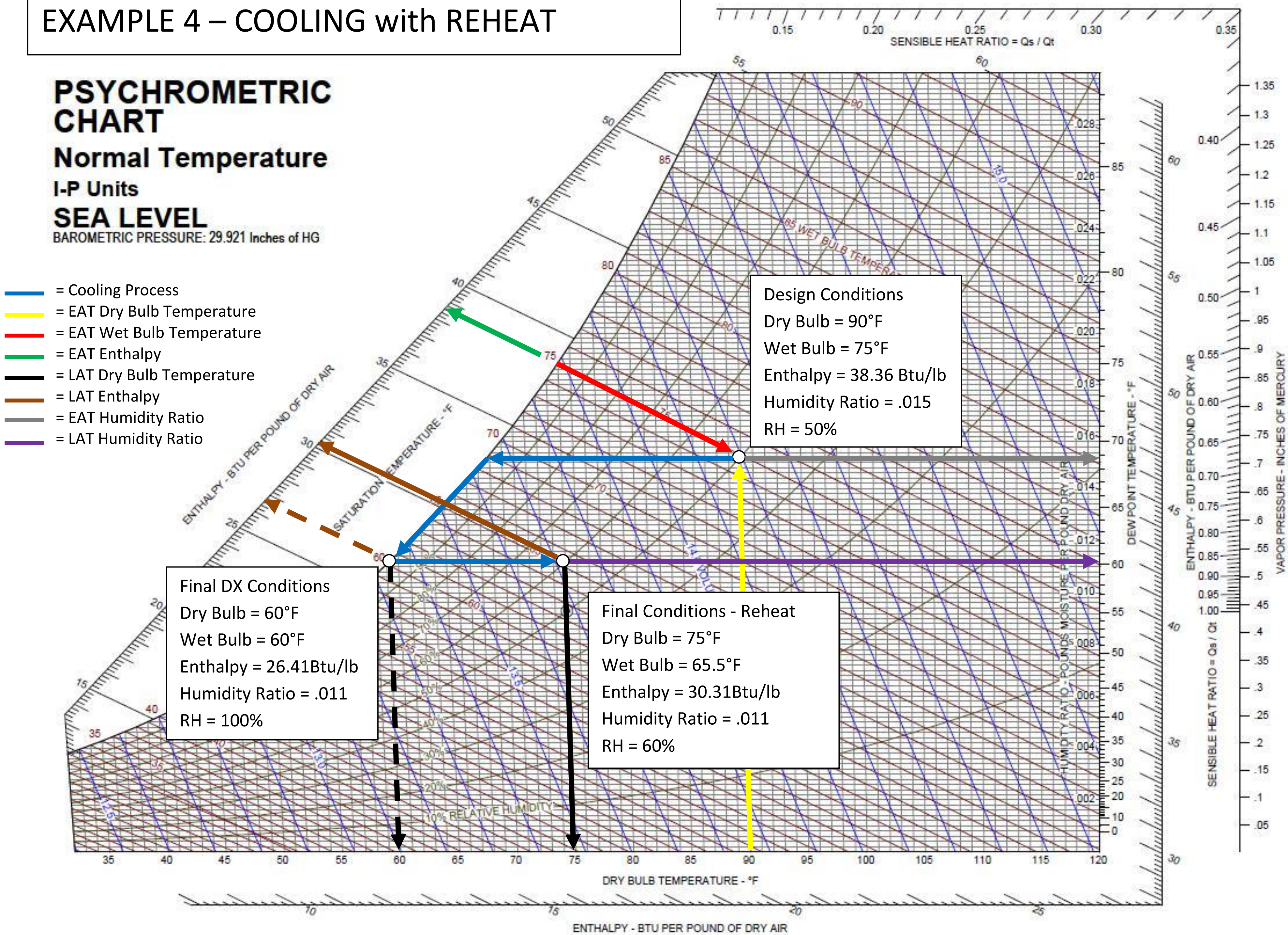
Latent Cooling Load = 2000 x 0.69143 x (105 – 77)
Latent Cooling Load = **38720 Btu/hr**

Total Cooling Load (Btu/hr) = Sensible Cooling Load (Btu/hr) + Latent Cooling Load (Btu/hr)
Total Cooling Load = 61920 Btu/hr + 38720 Btu/hr
Total Cooling Load = 100,640 Btu/hr

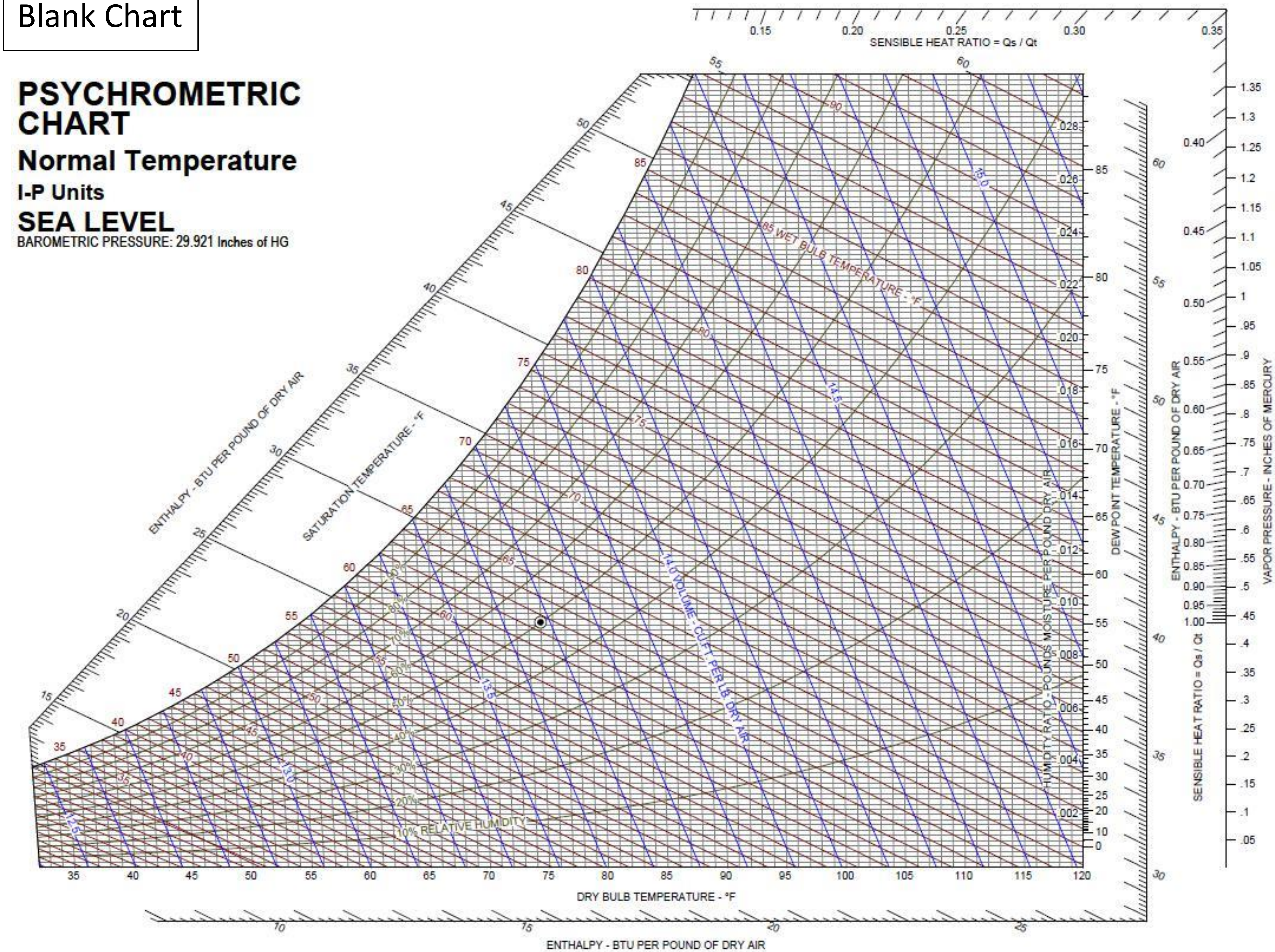
Required Cooling Tonnage = (Btu/hr)/12000
Required Cooling Tonnage = 100,640/12000
<u>Required Cooling Tonnage = 8.38 Tons</u>

See this example on the following psychrometric chart.

EXAMPLE 4 – COOLING with REHEAT



Blank Chart


PSYCHROMETRIC CHART
Normal Temperature
I-P Units
SEA LEVEL
BAROMETRIC PRESSURE: 29.921 Inches of HG
SENSIBLE HEAT RATIO = Qs / Qt
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
WET BULB TEMPERATURE - °F
VOLUME - CU.FT. PER LB. DRY AIR
RELATIVE HUMIDITY
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
DEW POINT TEMPERATURE - °F
ENTHALPY - BTU PER POUND OF DRY AIR
SENSIBLE HEAT RATIO = Qs / Qt
VAPOR PRESSURE - INCHES OF MERCURY
DRY BULB TEMPERATURE - °F
ENTHALPY - BTU PER POUND OF DRY AIR