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BASIC PSYCHOMETRICS

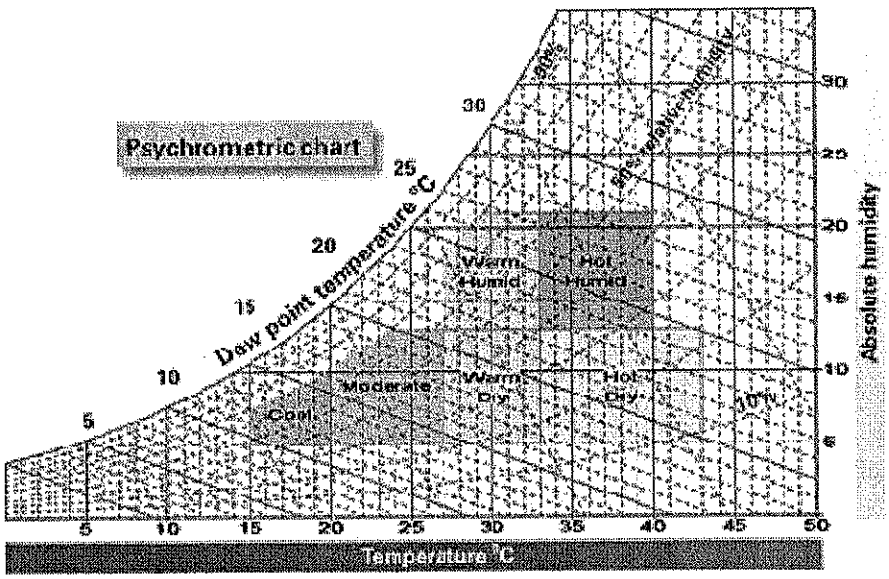
Steven Kang
Steven.kang@mnv.com.sg

Agenda

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1. Psychometrics- Seven Properties Of Air
2. Psychometric Chart
3. Formulae
4. Exercise

What is Psychometrics?



SGP - warm & humid

PSYCHOMETRICS

SEVEN PROPERTIES OF AIR

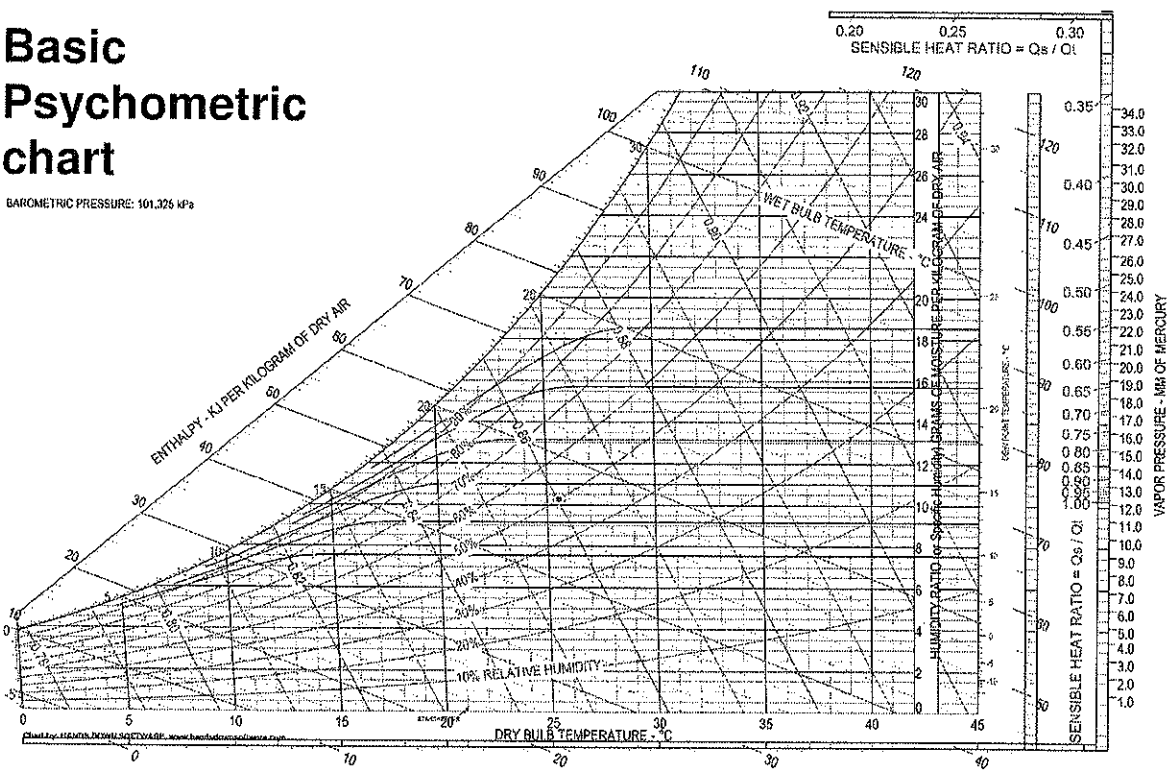
- DRY BULB TEMPERATURE
- HUMIDITY RATIO
- VOLUME
- WET BULB TEMPERATURE
- RELATIVE HUMIDITY
- ENTHALPY
- Dew Point TEMPERATURE

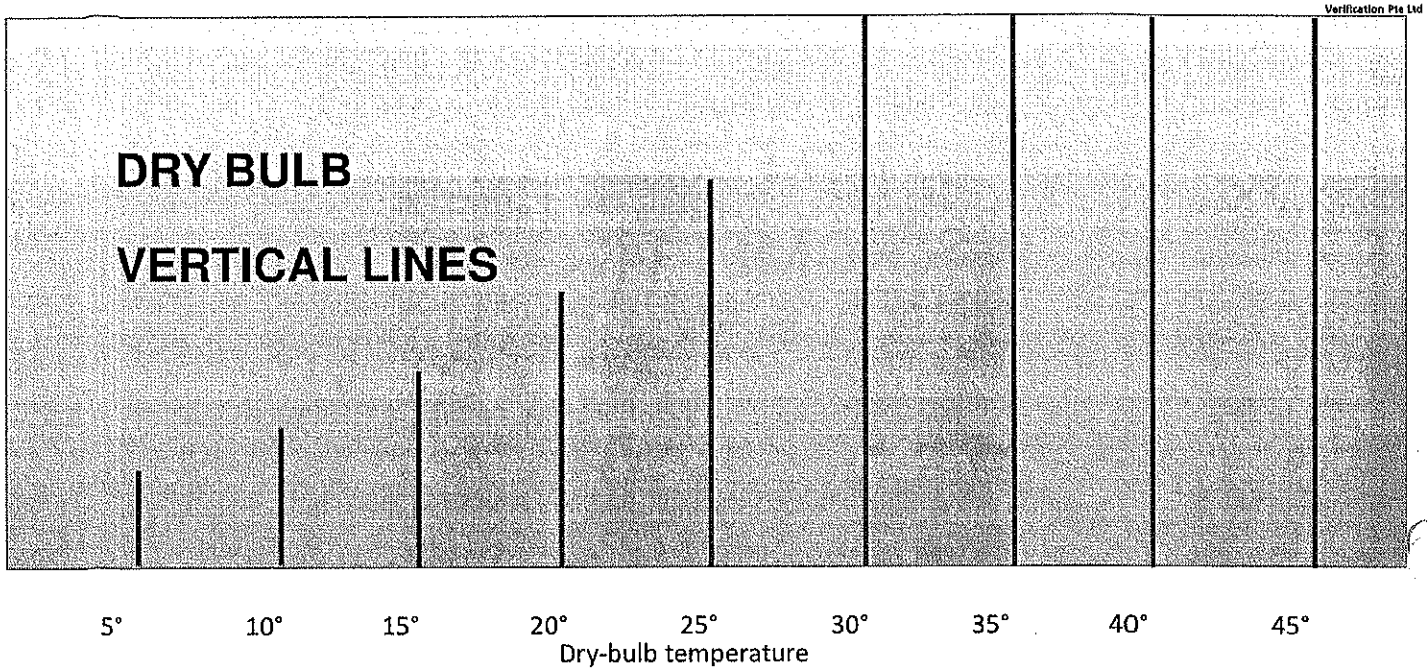
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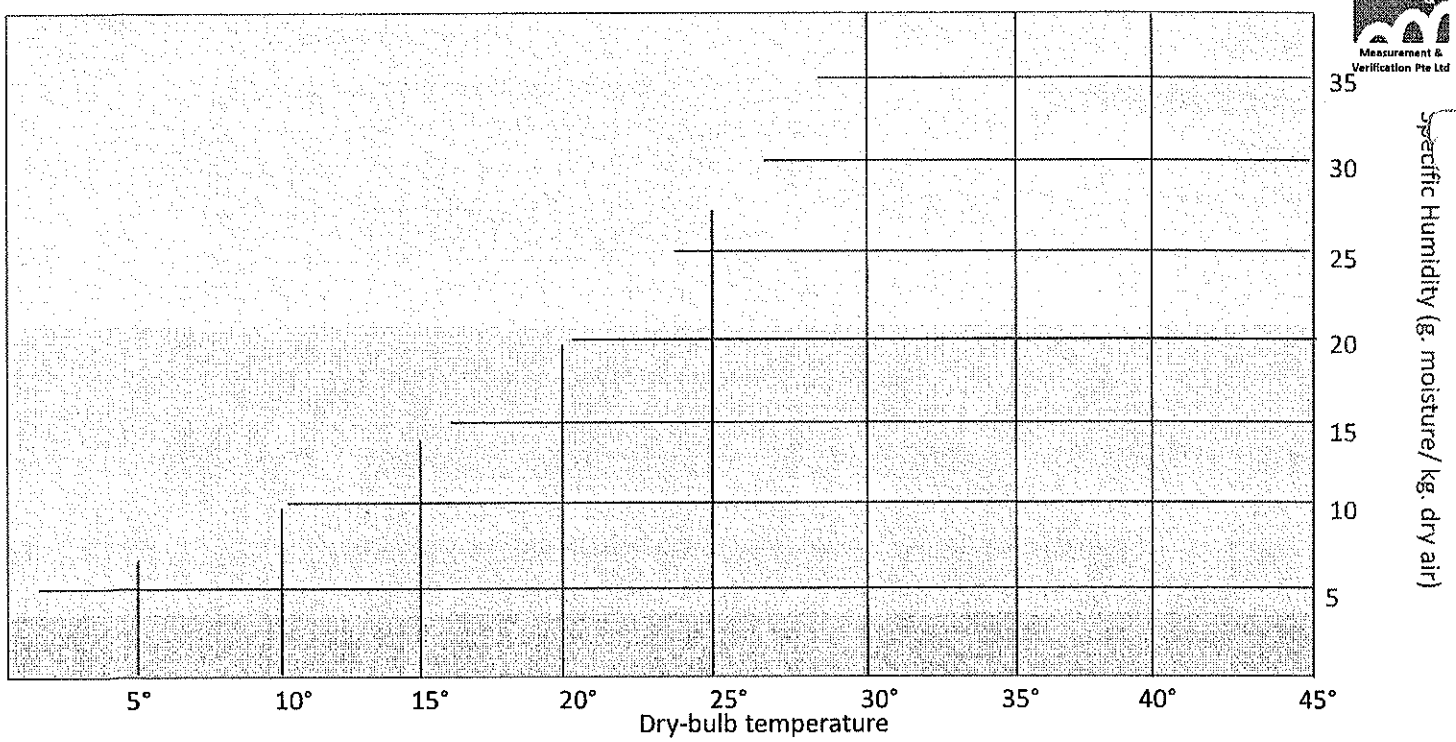
PSYCHOMETRIC CHART

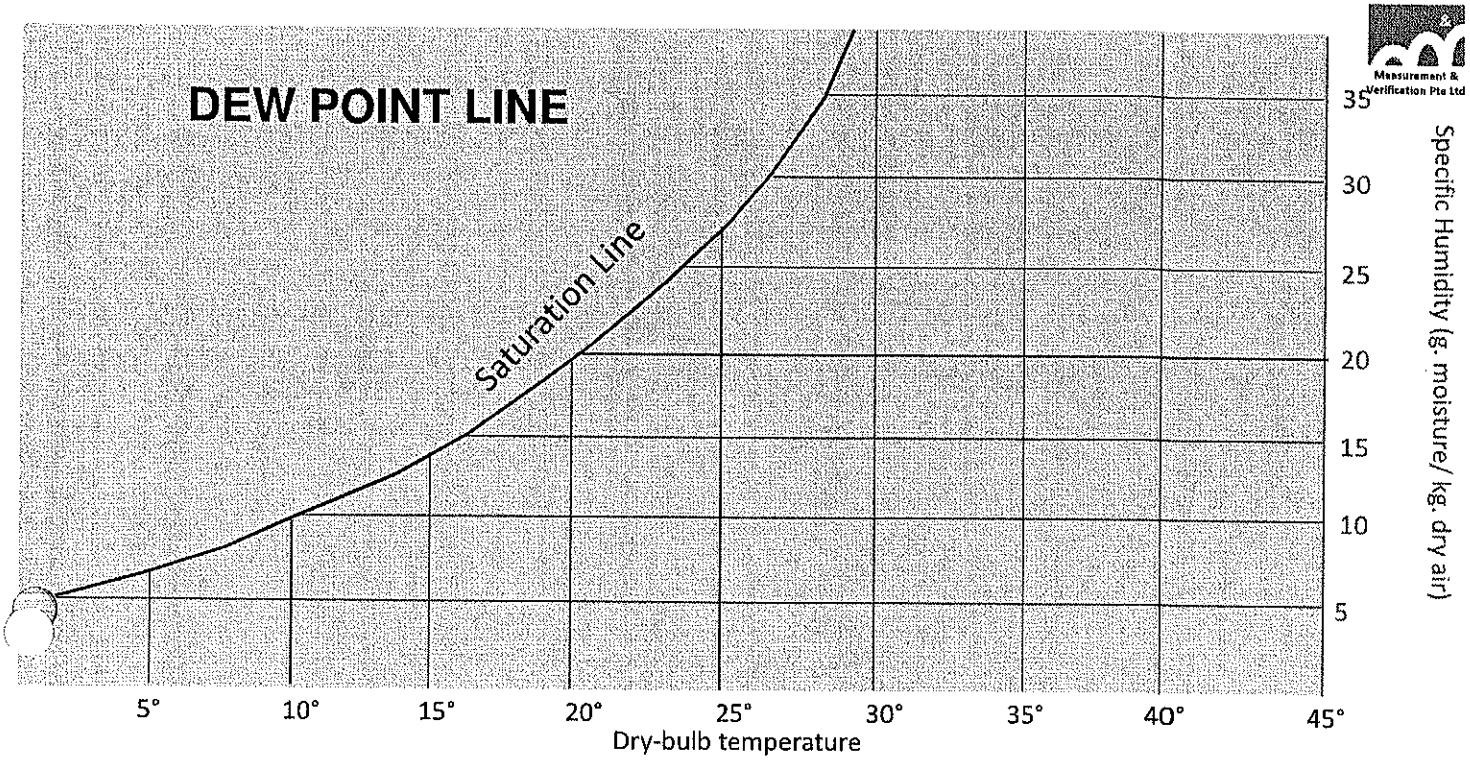
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Basic Psychometric chart

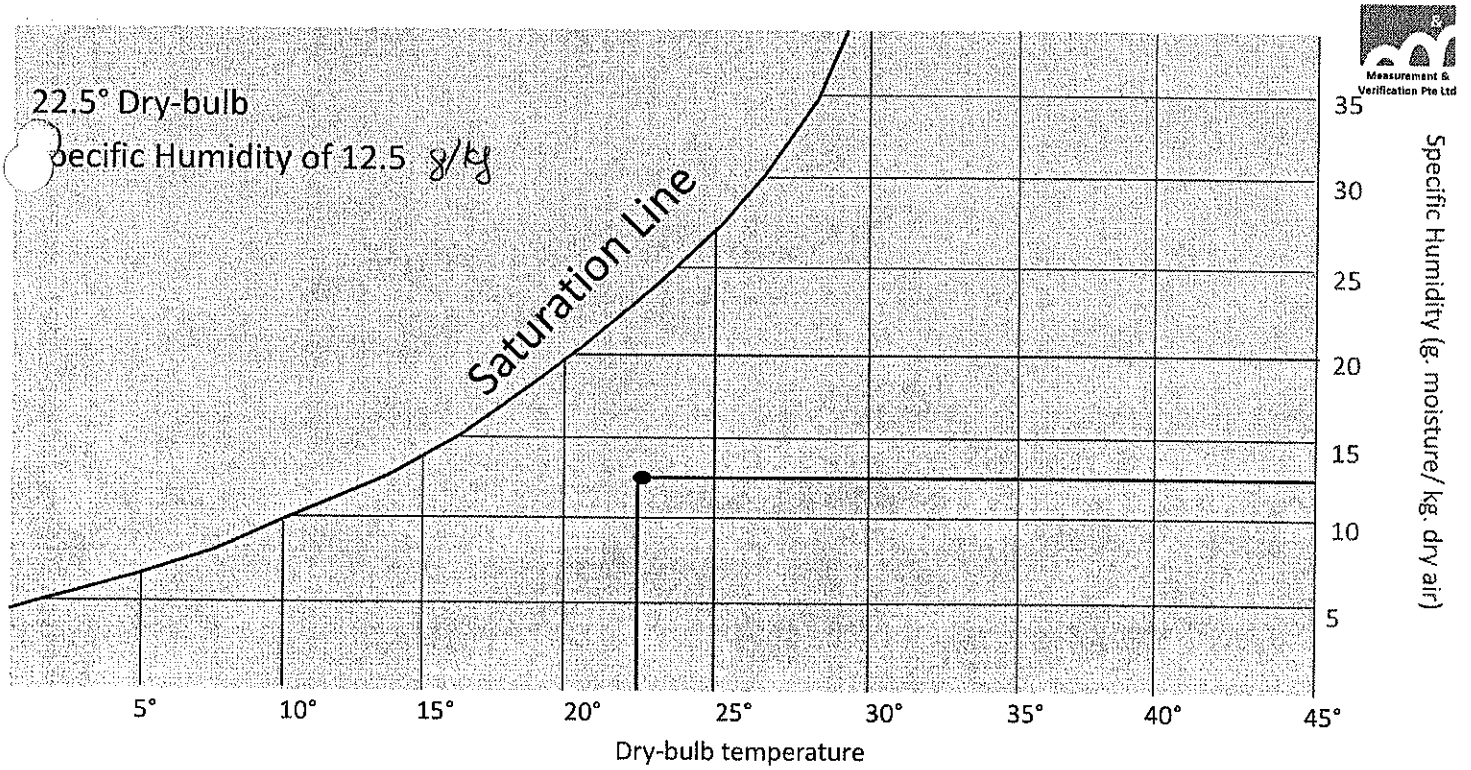



DRY BULB
VERTICAL LINES
5°
10°
15°
20°
25°
30°
35°
40°
45°
Dry-bulb temperature

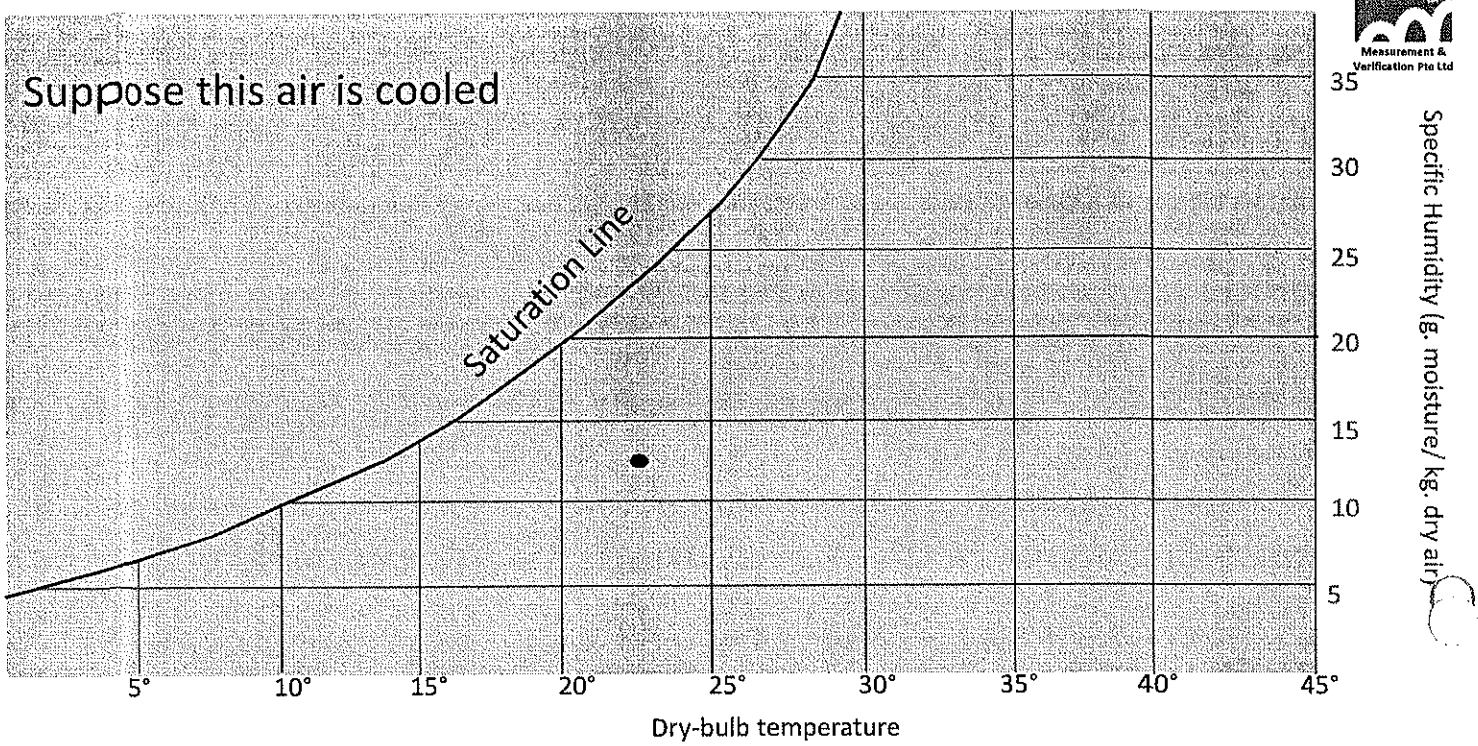

35
30
25
20
15
10
5
Specific Humidity (g. moisture/ kg. dry air)
5°
10°
15°
20°
25°
30°
35°
40°
45°
Dry-bulb temperature



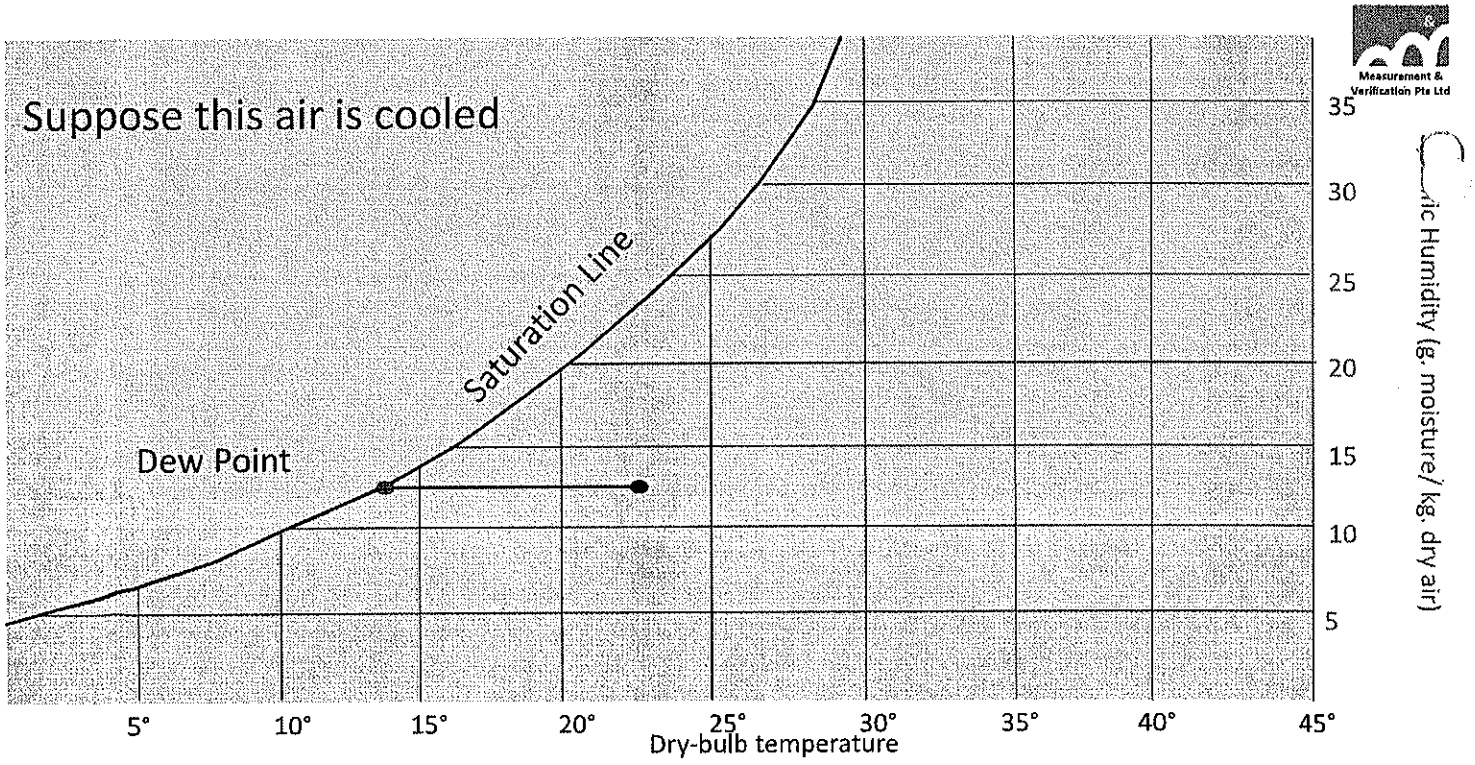
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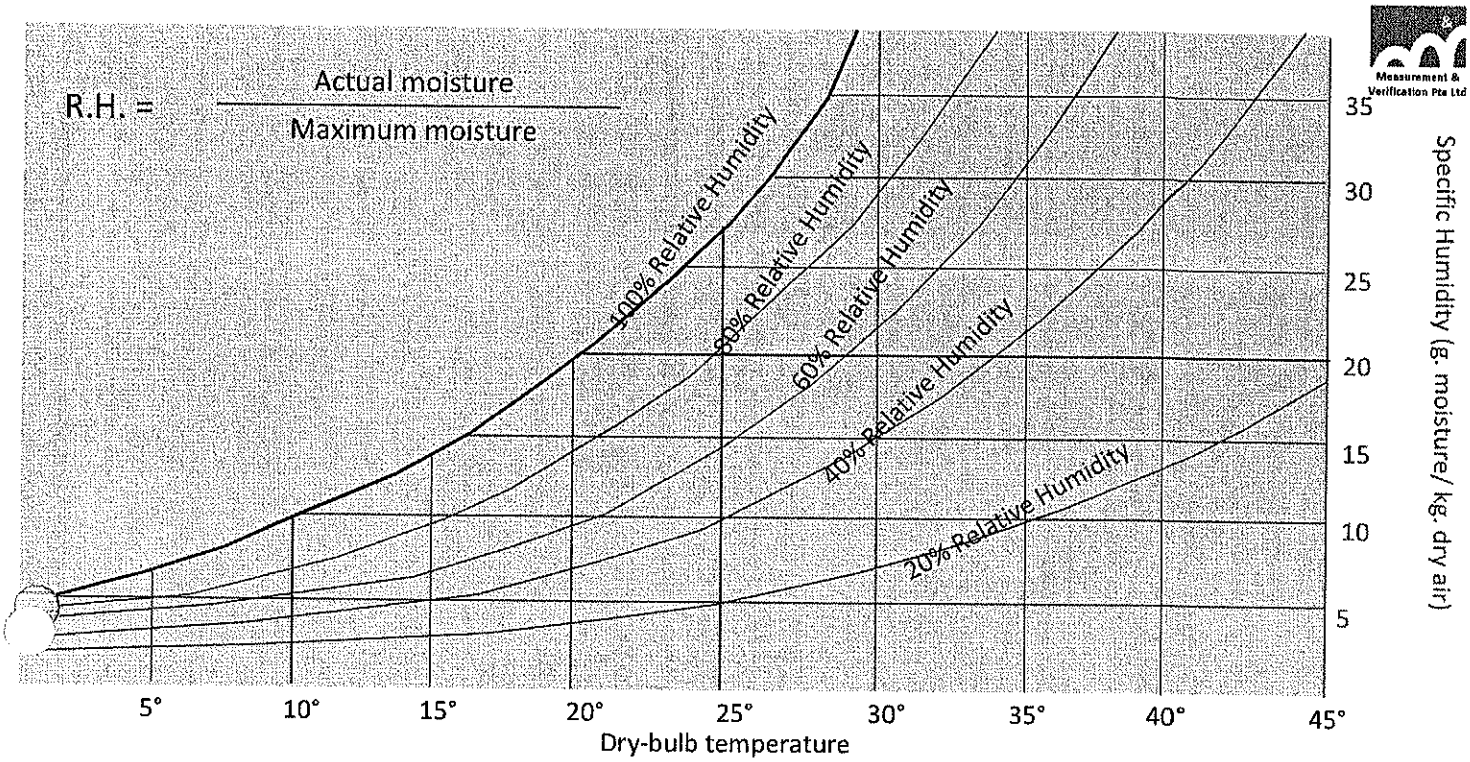
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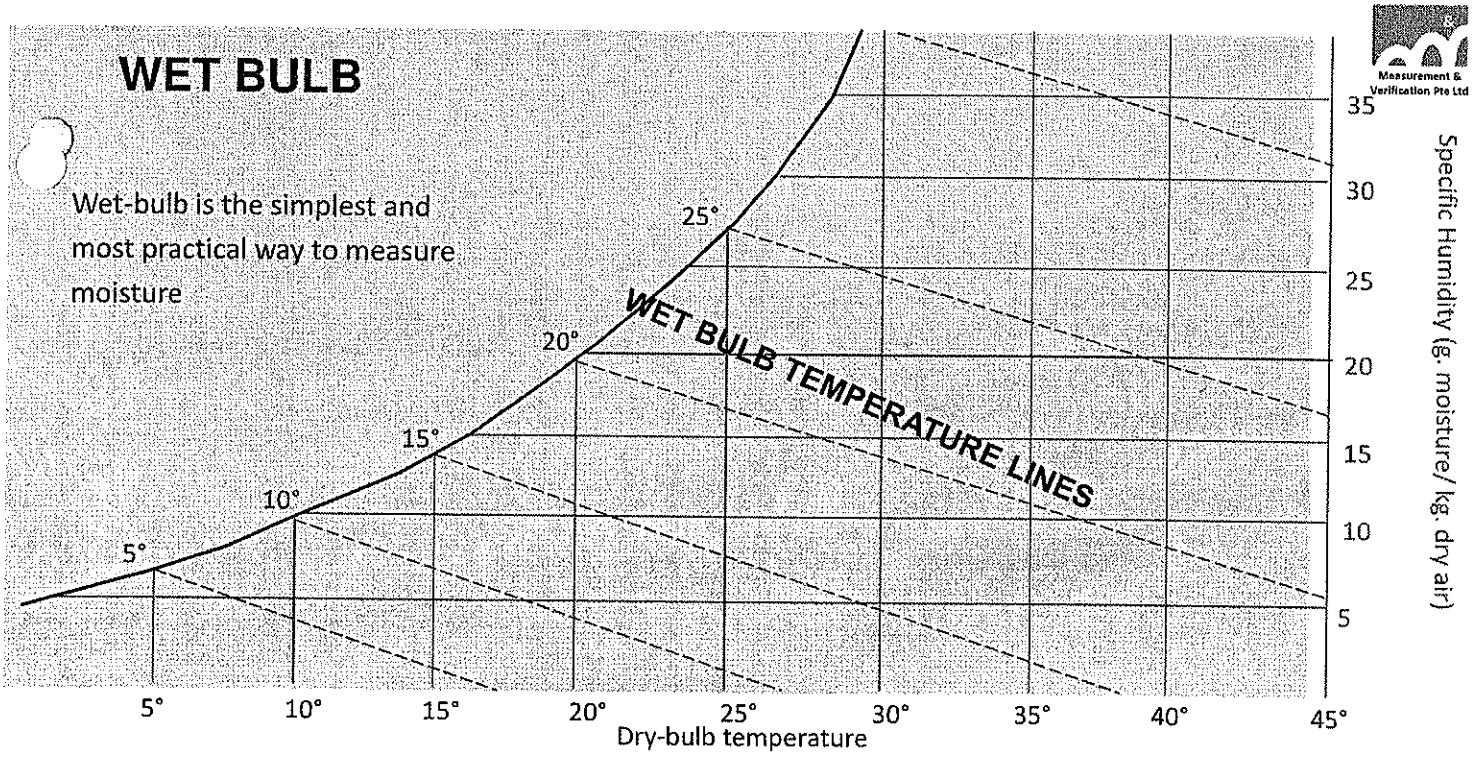


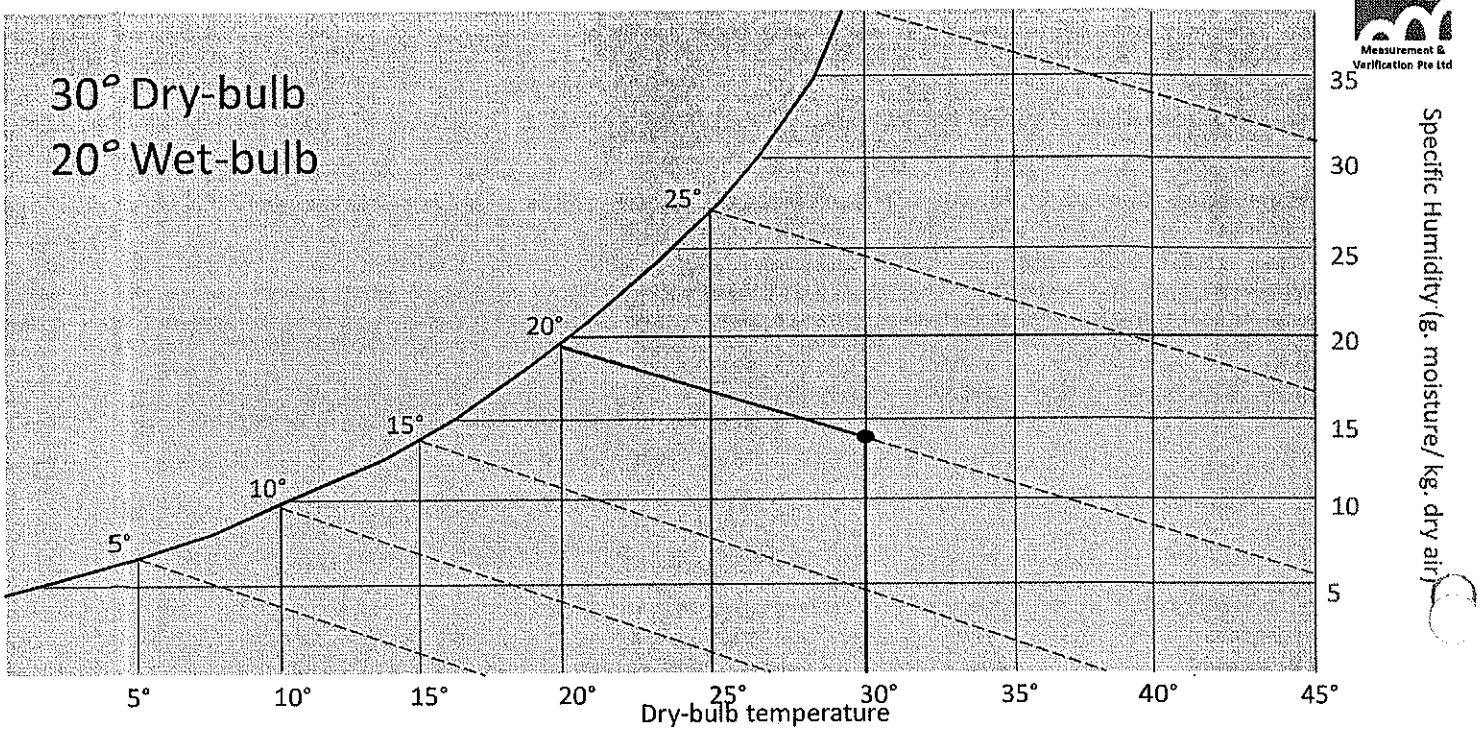
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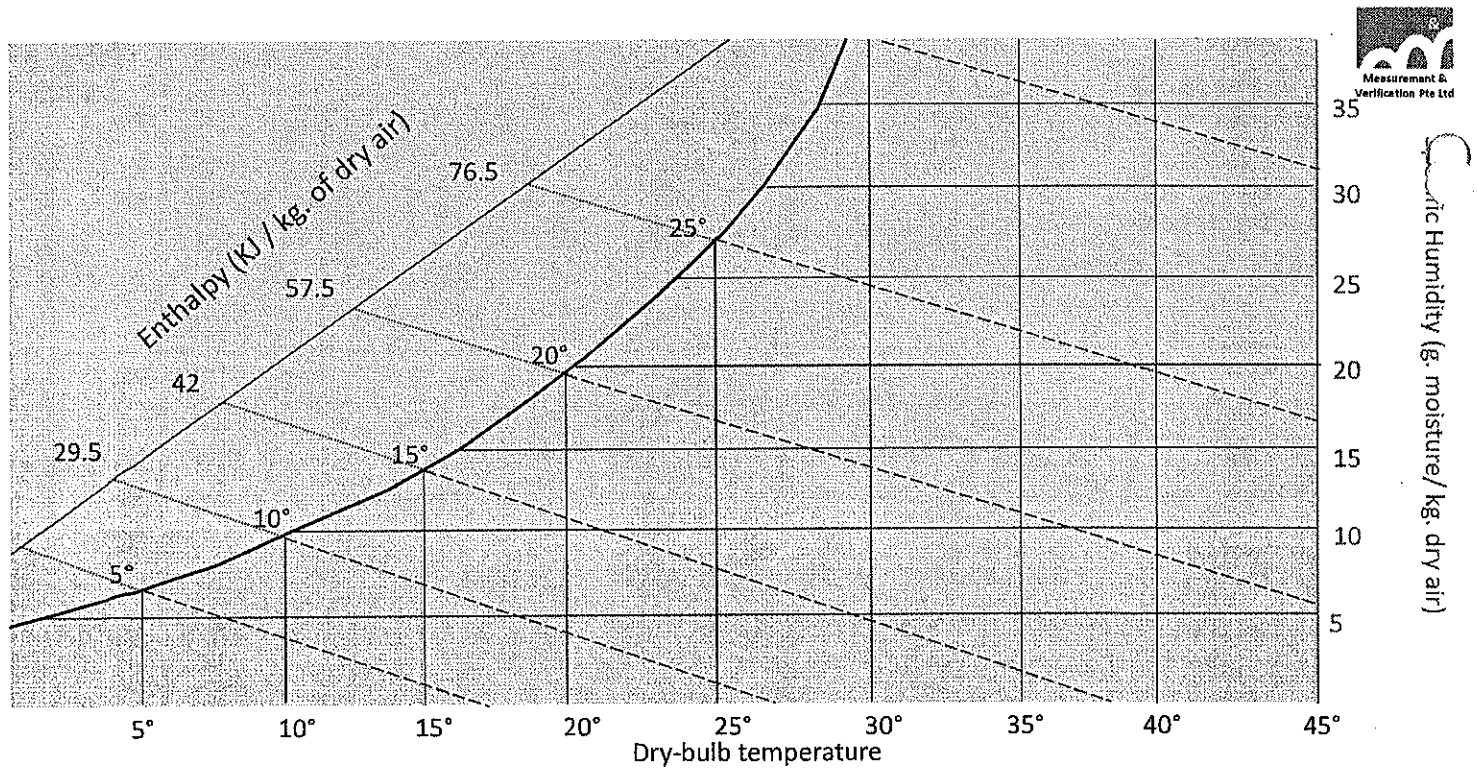


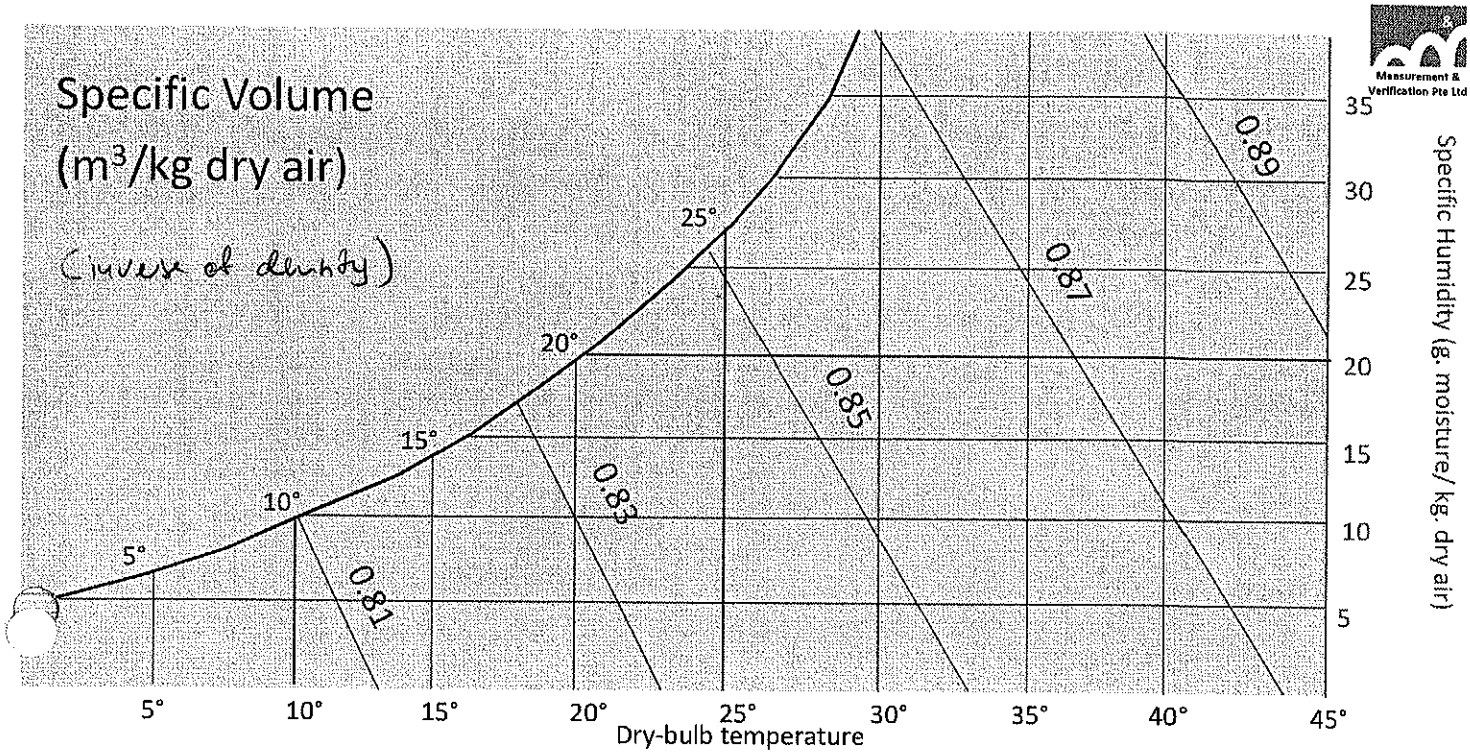
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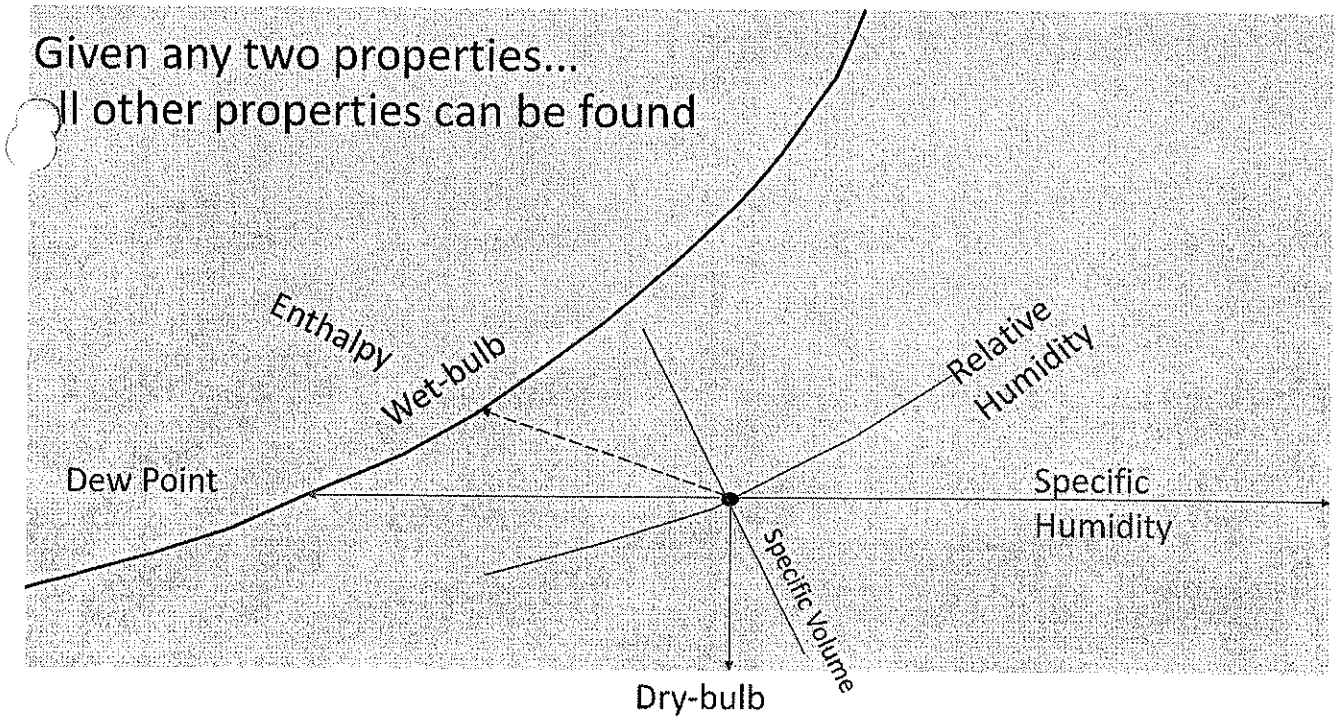

R.H. = Actual moisture / Maximum moisture
100% Relative Humidity
80% Relative Humidity
60% Relative Humidity
40% Relative Humidity
20% Relative Humidity
5°
10°
15°
20°
25°
30°
35°
40°
45°
Dry-bulb temperature
5
10
15
20
25
30
35
Specific Humidity (g. moisture/ kg. dry air)


WET BULB
Wet-bulb is the simplest and most practical way to measure moisture
WET BULB TEMPERATURE LINES
5°
10°
15°
20°
25°
5°
10°
15°
20°
25°
30°
35°
40°
45°
Dry-bulb temperature
5
10
15
20
25
30
35
Specific Humidity (g. moisture/ kg. dry air)

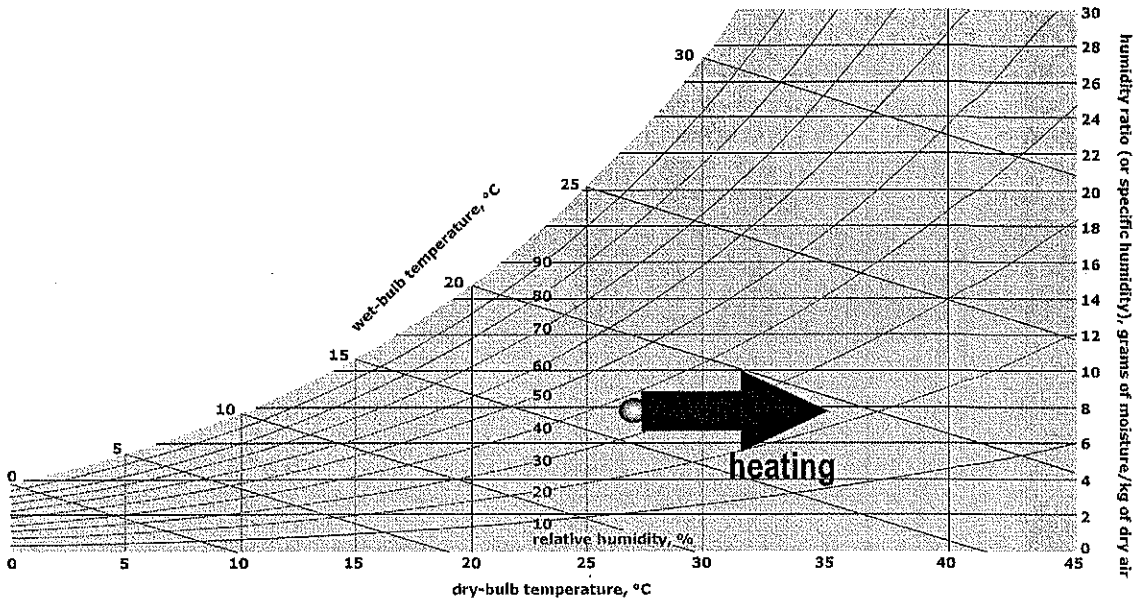

30° Dry-bulb
20° Wet-bulb
25°
20°
15°
10°
5°
5°
10°
15°
20°
25°
30°
35°
40°
45°
Dry-bulb temperature
35
30
25
20
15
10
5
Specific Humidity (g. moisture/ kg. dry air)


Enthalpy (KJ / kg. of dry air)
76.5
57.5
42
29.5
25°
20°
15°
10°
5°
5°
10°
15°
20°
25°
30°
35°
40°
45°
Dry-bulb temperature
35
30
25
20
15
10
5
ific Humidity (g. moisture/ kg. dry air)

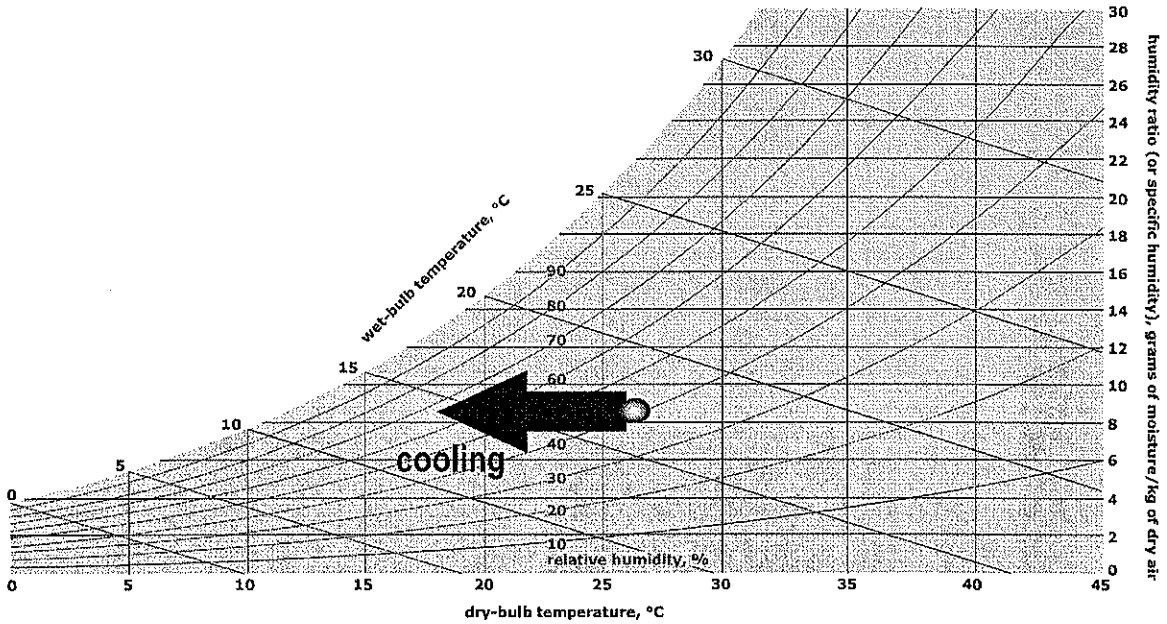

Specific Volume
(m³/kg dry air)
(Inverse of density)
25°
20°
15°
10°
5°
0.81
0.83
0.85
0.87
0.89
5°
10°
15°
20°
25°
30°
35°
40°
45°
Dry-bulb temperature
35
30
25
20
15
10
5
Specific Humidity (g. moisture/ kg. dry air)


Given any two properties...
ll other properties can be found
Enthalpy
Wet-bulb
Relative Humidity
Dew Point
Specific Humidity
Specific Volume
Dry-bulb

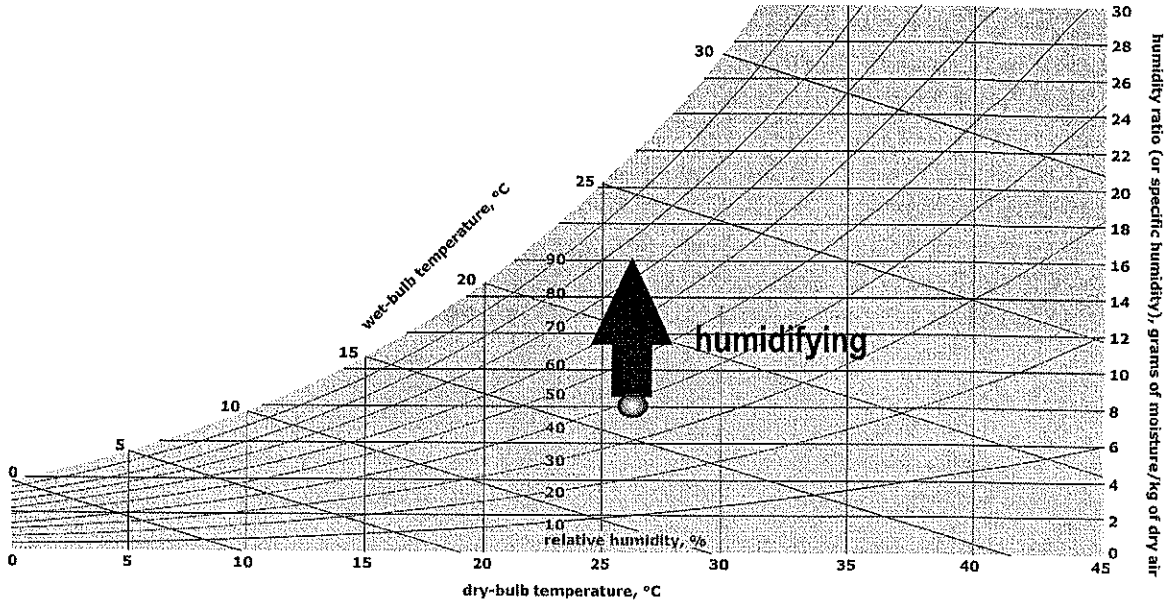
Effect of Adding Sensible Heat



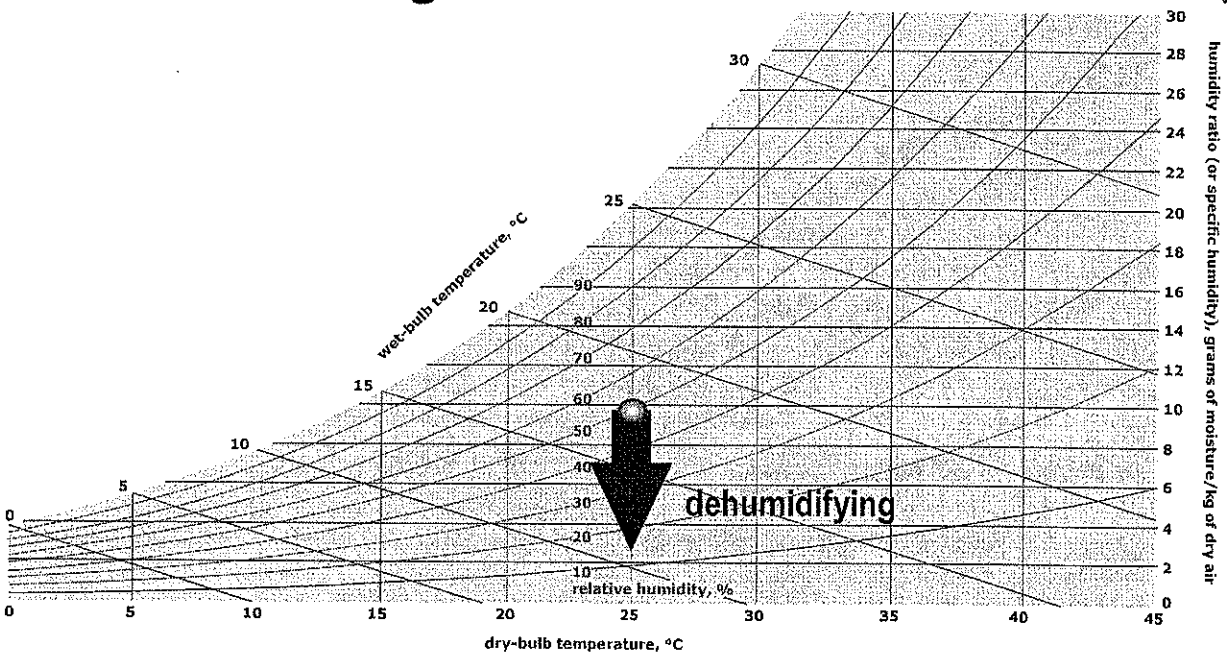
Effect of Removing Sensible Heat



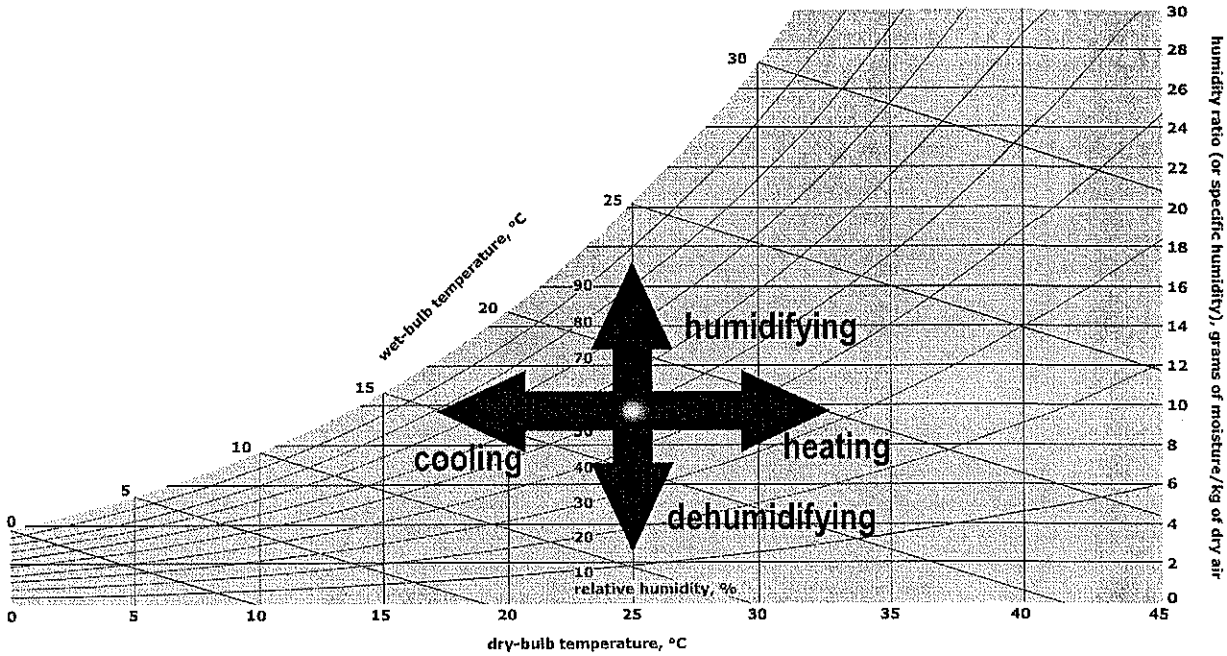
Effect of Adding Moisture



Effect of Removing Moisture

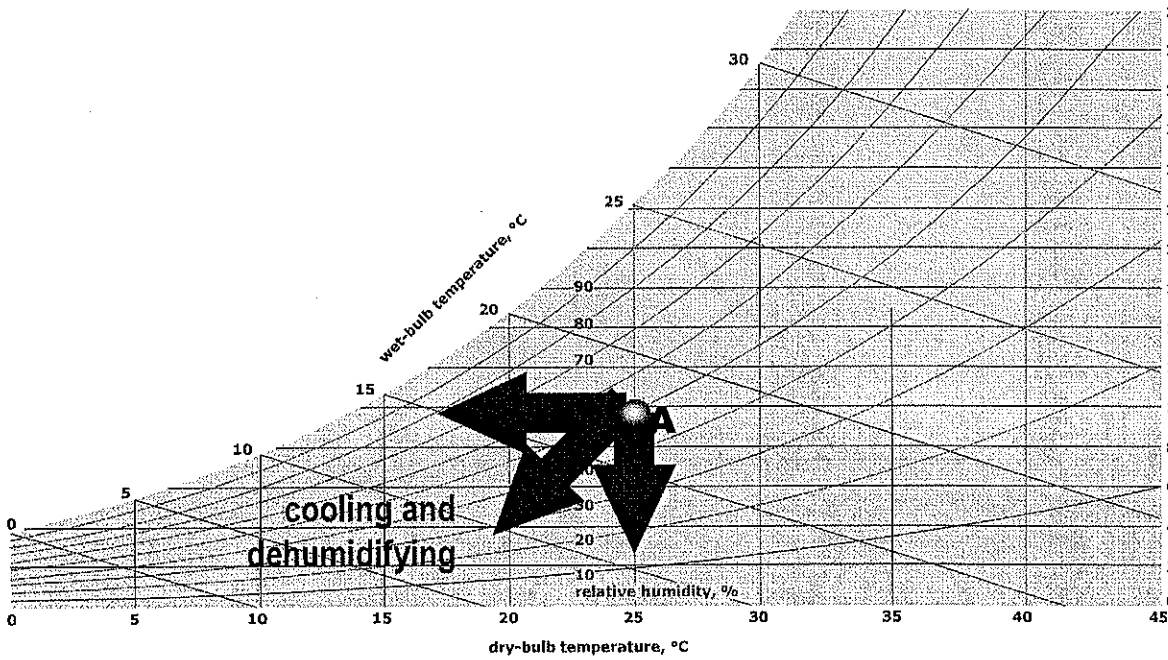


Removing Sensible Heat and Moisture



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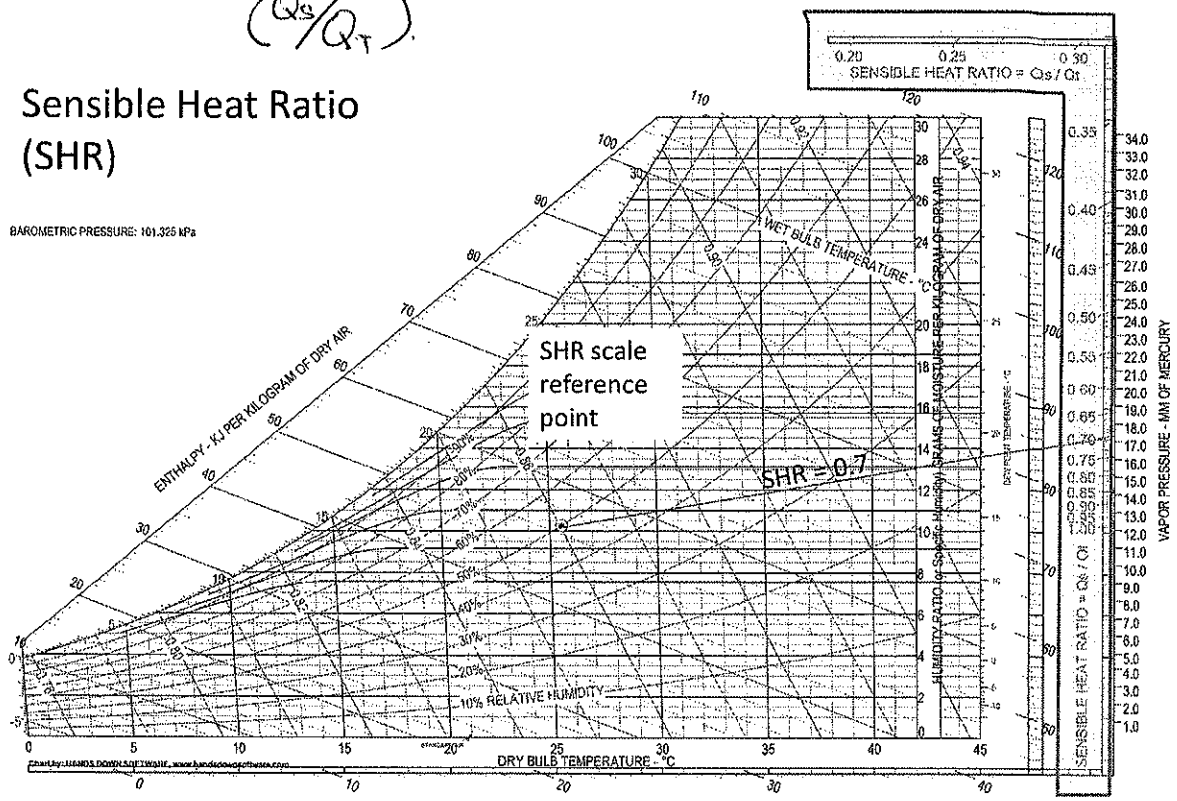
Removing Sensible Heat and Moisture



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(Q_S/Q_T)

Sensible Heat Ratio (SHR)



Most equips ⇒ 0.7 ~ 0.9
PAHU ⇒ 0.4

FORMULAE

Sensible load Q(W) = Ṁ (kg/s) x Cp (J/kg.k) x DT (C)

Total load Q (W) = Ṁ (kg/s) x Cp (J/kg.k) x DH (J/kg.k)

At standard air conditions
Density = 1.2 kg/m^3 and
Specific heat = 1004 J/kg.K

SI Formulars

Sensible KW = CMH x DT (C) / 3000

Latent KW = CMH x DW (g/kg dry air) / 1200

Total KW = CMH x DH (kj/kg) / 3000
~~(enthalpy)~~
(enthalpy)

IP formulars

Sensible tons = 1.085 x CFM x DT (F) / 12000

Latent tons = CFM x DW (grain/lb dry air) / 17391

Total tons = 4.5 x CFM x DH (btu/lb) /12000

EXERCISE

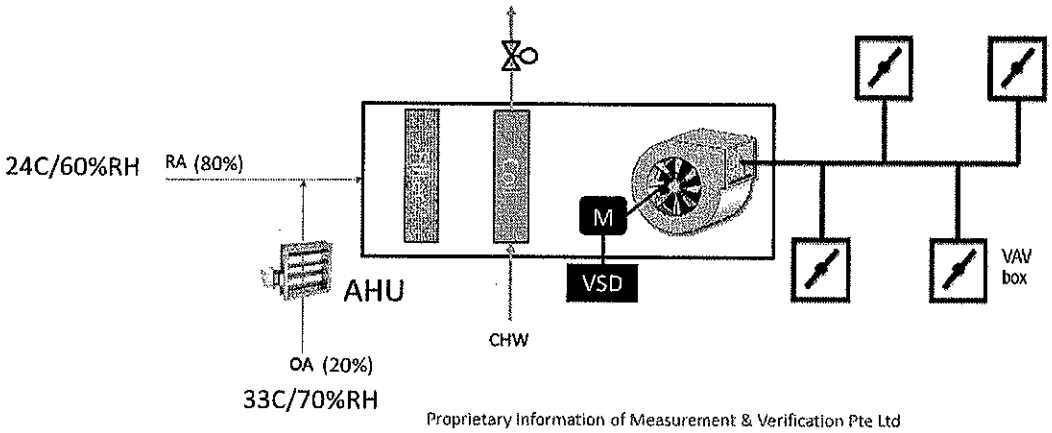
Exercise

Plot a typical air-conditioning process on the psyc chart.

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Question 1:

I'm starting with an outdoor condition of 33C and 70% Relative Humidity and I'm mixing that air with return air that is at 24C and 60% relative humidity. If the mixed air is 80% return air and 20% outside air, how do I find the correct mixed air temperature and % Rh and graph this on the psychometric chart properly?



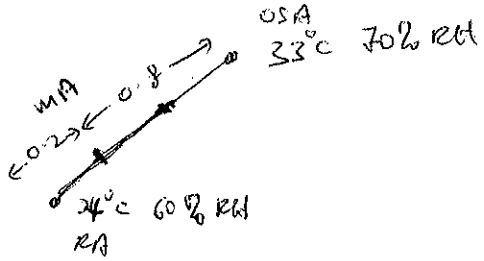
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Question 1 Answer

To find the solutions for this question I would approach the problem like this:

1. Plot OA point on chart at 33C, 70% Rh
2. Plot RA point on chart at 24C, 60% Rh
3. Connect the OSA point and the RA points to form the mixed air line.
4. Measure length of line OA to RA (eg "a" mm)
5. Measure along the MA line starting from the OA point, (OA CMH / Total CMH) x "a" mm. This is your MA temperature and humidity.
6. Or use the following simple formula to find the mixed air Db temperature.
(RA temp x RA%) + (OA temp x OA%) = Mixed Air temp, plot this on the MA line to find the corresponding %Rh

MA = (24°C × 0.8) + (33°C × 0.2)
= 19.2 + 6.6
= 25.8°C

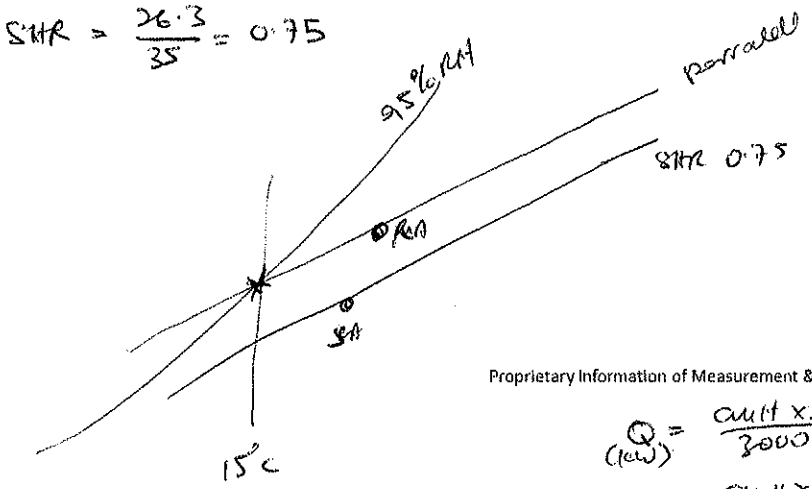


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Question 2:

How do I figure out the required supply air temperature for the room? I know that I need to find the structural heat gains, electrical heat gain, occupant load and infiltration load. I can add the sensible heat and latent heat gains for the space and figure out what the total heat gain for the room is. But how do I figure out the necessary supply air temperature and % Rh to maintain that room at 24C and 60% Rh?

Assume room total heat = 35KW and room sensible heat = 26.3KW.



$$Q_{(kW)} = \frac{CMH \times \Delta T}{3000}$$

$$26.3 = \frac{CMH \times (24 - 15)}{3000}$$

$$CMH = 8,767$$

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Question 2 Answer

To find this answer requires the use of the sensible heat ratio. The sensible heat ratio is a ratio of sensible heat to total heat based on your space load. The protractor on the upper left side of the psychometric chart lets you plot the ratio or slope on the chart. Look closely at the protractor, the numbers on the inside radius are the ratios of sensible heat. Suppose your sensible heat ratio for your problem was 0.75 based on your rooms' sensible heat loads and latent heat loads: (sensible heat + latent heat = total heat) so that sensible heat divided by total heat = The Sensible Heat Ratio (SHR)

1. Draw a line from the center point on the base line of the protractor through the 0.75 on the radius of the protractor. This establishes your slope.
2. Now plot your desired Db and %RH for the space on the chart, 24C Db 60%RH.
3. Transfer the sensible heat line or slope (remember the protractor?) so that it starts at your desired room temperature (the RA point) and travels to the left at the .75 SHR slope and intersects the 95% curve on the chart, at 95%Rh.
4. The point of intersection will establish the required supply air temperature (the SA point) to maintain the desired space temperature.
5. You could select any desired supply air temperature located on this line in theory and adjust your CMH, but most A/C equipment delivers air at 95% Rh or higher so you are some what limited, so much for theories.

Question 3:

Now that I know what the required supply air temperature is, how do figure out what my CMH requirements are? Suppose the room total cooling load is 35KW and the room sensible cooling load is 26.3KW.

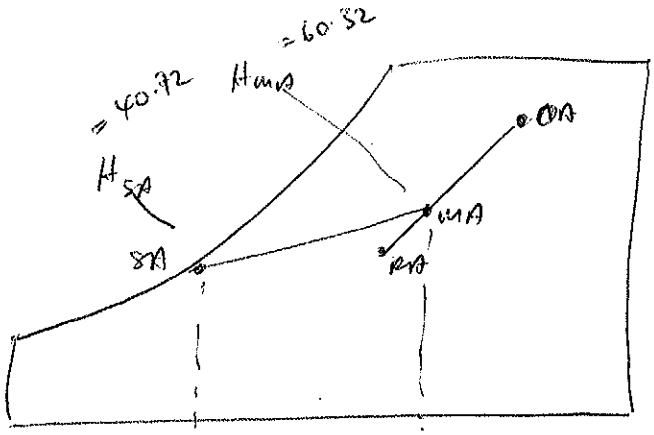
Question 3 Answer

1. Once you have established your supply air temperature, use the supply air temperature and the desired room air temperature to find the CMH, using the following formula:
   Sensible KW = CMH x DT (c) / 3000

2. Another method would involve the total heat formula:
Total KW = CMH x DH (kj/kg) / 3000. This requires you to find the enthalpy of the return air and supply air from the psychrometric chart.

Question 4.

In my original problem I was bringing in 20% OA at 33C and 70% Rh.
Size the coil to handle the total load.



Q_T (kw) $= \frac{CMH \times \Delta H}{3000}$

$= \frac{8767 \times (60.32 - 40.72)}{3000}$

$= 57.2$ kw

$Q_S = \frac{CMH \times \Delta T}{3000}$

$= \frac{8767 \times (25.8 - 15)}{3000}$

$= 31.6$ kw

Question 4 answer

Does the OA affect the load in the room? Simply stated NO!

The mixed air temperature is higher than the desired space air temperature, it does put an additional load on the cooling coil but the room never sees this added load.

1. Locate the MA point on the mixed air line and find the enthalpy corresponding to this point.
2. Locate the SA point on the chart and find the corresponding enthalpy.
3. Using the difference of these two values and the CMH that we found in question 3, solve for Sensible KW and total KW
Sensible KW = CMH x DT (c) / 3000
Total KW = CMH x DH (kj/kg) / 3000
4. Notice in this problem the total heat the coil sees is going to be more than the load of the room, the CMH will remain the same.

Question 5.

Is there a way to find the amount of moisture that the coil is removing from the air?

$\omega_{MA} = 13.5$ g/kg.

$\omega_{SA} = 10.1$ g/kg

g/hr $\Rightarrow$ CMH x ρ x $\Delta\omega$

$\Rightarrow$ 8767 x 1.2 x (13.5 - 10.1)

= 35,768 g/hr

1000 g = 1 l

l/hr = 35.7 l/hr

Question 5 Answer

Yes there is, the psychrometric chart that we've been using lists these values as, g of water/ kg of dry air. This is referred to as the humidity ratio W. Some charts list this as grains of moisture; note there are 7000 grains/lbs. Here's how to find the answer using our problem as an example.

1. Locate the MA point on the chart and extend a horizontal line to the right side of the chart and find the MA humidity ratio W
2. Locate the SA point on the chart and extend a horizontal line to the right side of the chart and find the SA humidity ratio W
3. Take the difference and use this modified formula:

g/Hr = CMH x Density (kg/m^3) x ΔW to find the grams of water per hour removed.

The density of air at "standard" conditions (21°C DB dry air at sea level) = 1.2 kg/m^3

THANK YOU

