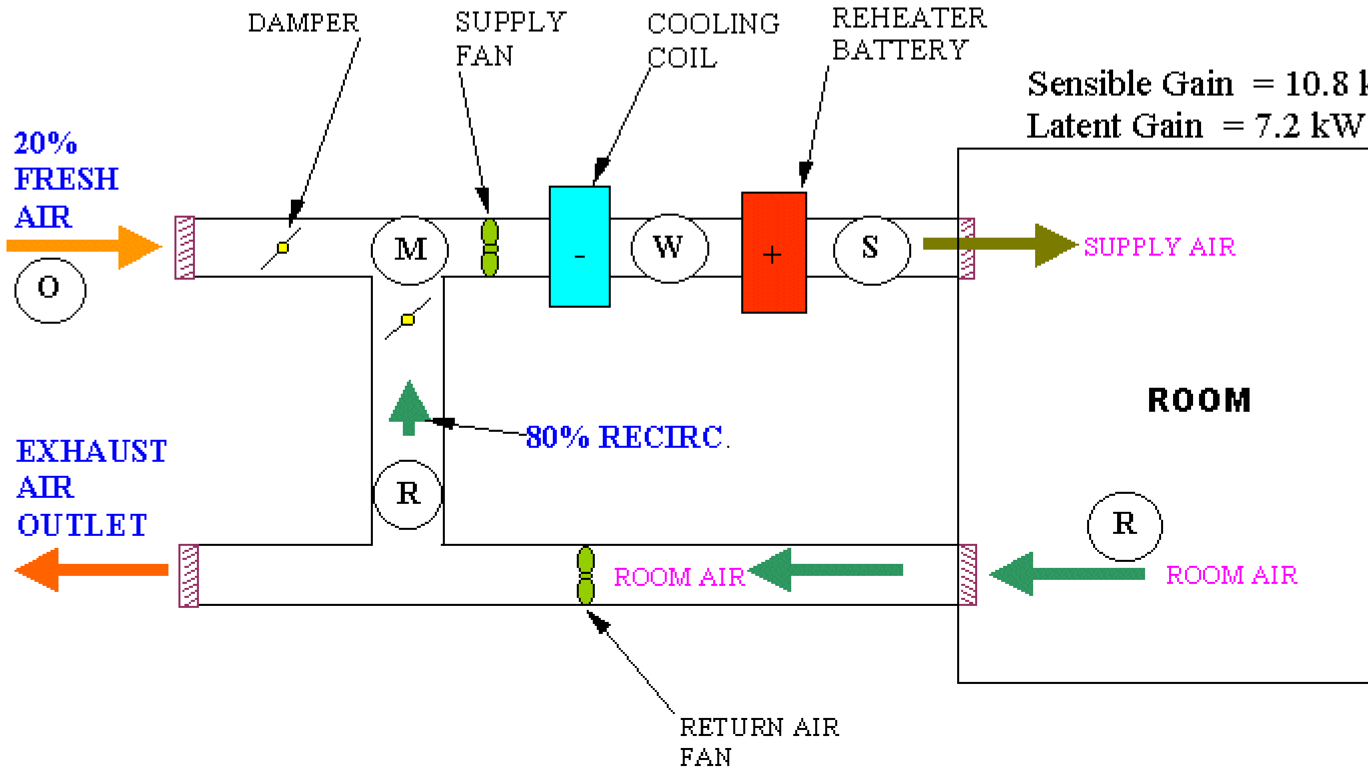
Examples of Psychrometric Calculations for Summer

Example 1. Summer Cycle

A room is to be maintained at 22^{o}C dry-bulb temperature, 50% saturation, when the sensible heat gain is 10.8 kW in summer.
The latent heat gain is 7.2 kW.
Determine the cooling coil and reheater outputs required by using a psychrometric chart if the plant schematic is as shown below.

DATA:
Outdoor condition is 28^{o}C, 80% saturation.
The outdoor air and recirculated air ratio is 20%/80%.
The Apparatus Dew Point ADP is 8^{o}C
Neglect the cooling coil contact factor.



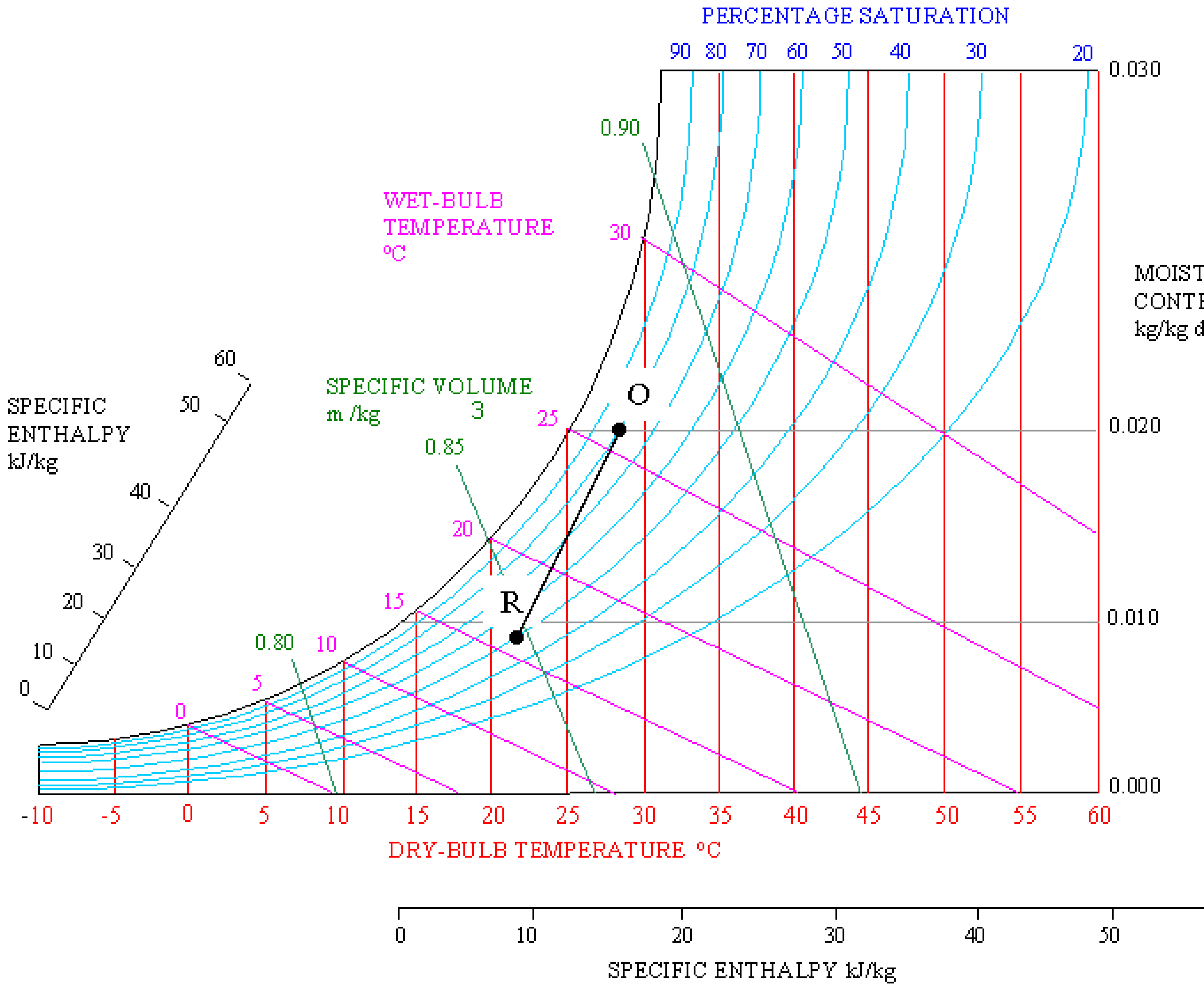
Procedure (Summer Cycle)

1. Draw schematic diagram of air-conditioning plant (see above)

2. Plot room condition R on psychrometric chart.

3. Plot outside condition O on psychrometric chart.

4. Join points O and R.


PERCENTAGE SATURATION
90 80 70 60 50 40 30 20
0.030
0.90
WET-BULB
TEMPERATURE
°C
30
MOIST
CONT
kg/kg d
60
50
40
30
20
10
0
SPECIFIC
ENTHALPY
kJ/kg
SPECIFIC VOLUME
m /kg 3
O
25
0.020
0.85
20
R
15
0.010
0.80
10
5
0
0.000
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60
DRY-BULB TEMPERATURE °C
0 10 20 30 40 50
SPECIFIC ENTHALPY kJ/kg

5. Find the mix point M by measuring the length of the line O-R and multiply this by the mixing ratio.

On a full size CIBSE psychrometric chart this measures 85mm.
The ratio of recirculated air is 0.8.
85mm x 0.8 = 68mm
Measure down the O-R line from point O by 68mm.
This determines point M .

If there is more recirculated air than outside air at the mix point, then point M will be closer to point R than point O.

6. Find the room ratio.
This is the sensible to total heat gain ratio.

Total heat = 10.8 kW sensible + 7.2 kW latent = 18 kW total.
Heat ratio = 10.8 / 18.0 = 0.6

Plot this ratio on the protractor, bottom segment, on the psychrometric chart and transfer this line onto the chart so that it passes through point R.

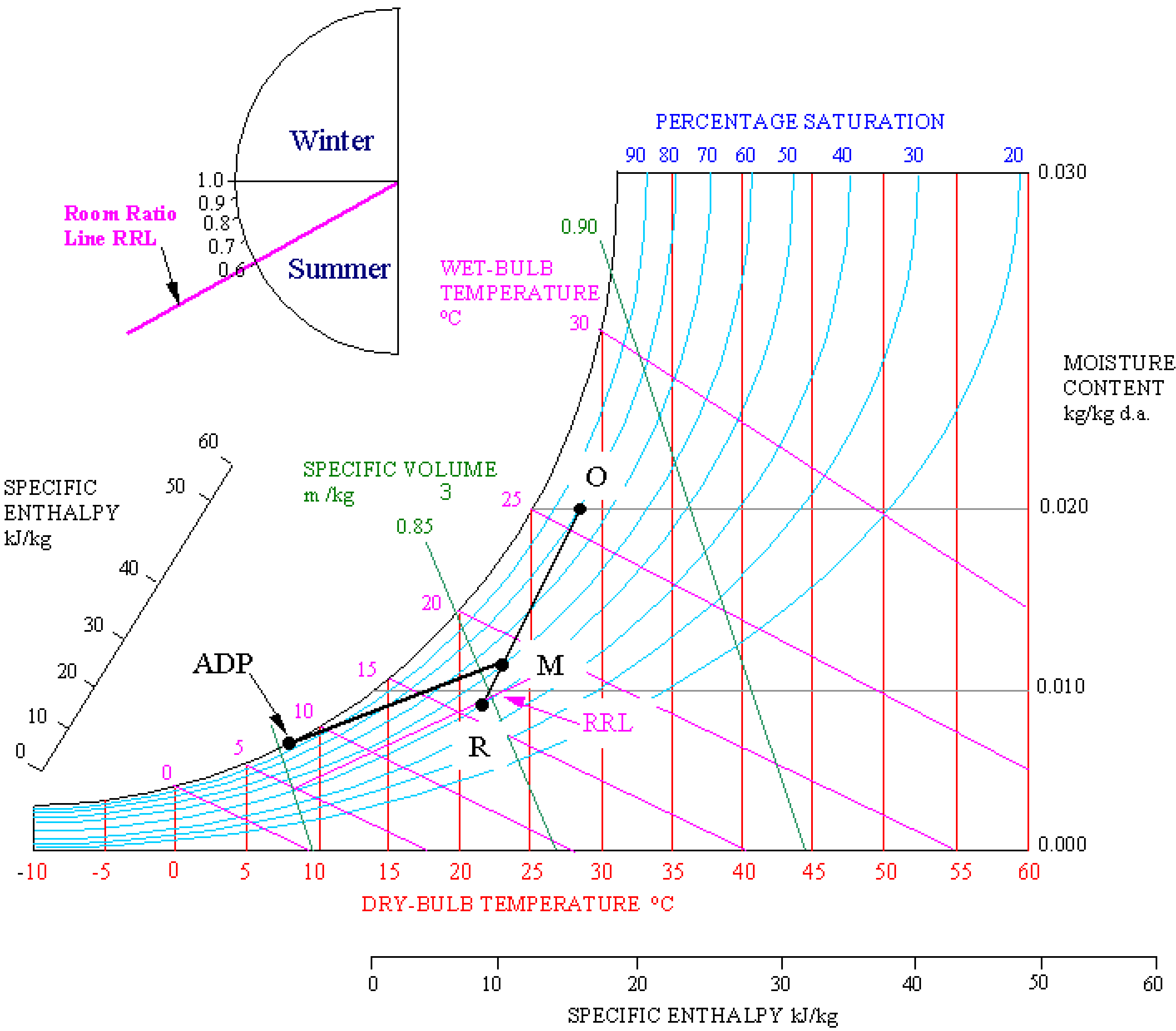
7. Plot the Apparatus Dew Point ADP of the cooling coil.
This is on the 100% saturation curve.

The ADP is $8^{0}C$.

The wet bulb and dry bulb temperatures at this point will be equal.

8. Join points M and ADP.

TYPICAL SMALL AIR HANDLING UNIT

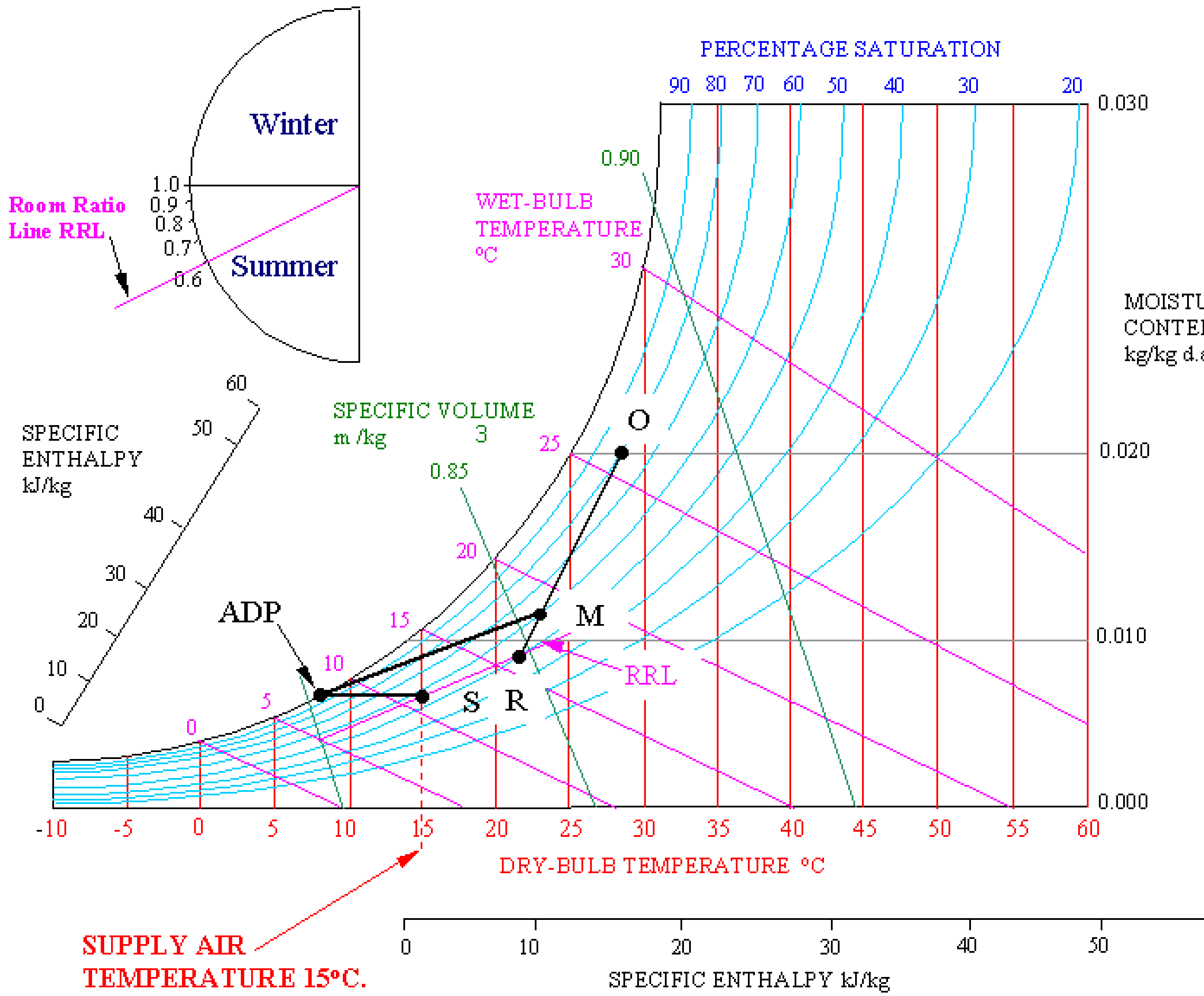


Winter
1.0
0.9
0.8
0.7
0.6
Summer
Room Ratio
Line RRL
PERCENTAGE SATURATION
90 80 70 60 50 40 30 20
0.030
0.90
WET-BULB
TEMPERATURE
°C
30
MOISTURE
CONTENT
kg/kg d.a.
SPECIFIC
ENTHALPY
kJ/kg
60
50
40
30
20
10
0
SPECIFIC VOLUME
m3/kg
0.85
25
O
0.020
20
ADP
15
M
0.010
10
RRL
R
5
0
0.000
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60
DRY-BULB TEMPERATURE °C
0 10 20 30 40 50 60
SPECIFIC ENTHALPY kJ/kg

9. Since there is no cooling coil contact factor we can proceed with reheating from point ADP.

10. Plot the supply air condition S.
The reheater process will be a horizontal line from point ADP to point S.
Point S is on the room ratio line.

The supply air temperature is 15°C.



Winter
Summer
Room Ratio
Line RRL
1.0
0.9
0.8
0.7
0.6
PERCENTAGE SATURATION
90 80 70 60 50 40 30 20
0.030
0.020
0.010
0.000
MOISTU
CONTE
kg/kg d.
0.90
0.85
WET-BULB
TEMPERATURE
°C
SPECIFIC VOLUME
m /kg 3
SPECIFIC
ENTHALPY
kJ/kg
0 10 20 30 40 50 60
O
M
R
S
ADP
RRL
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60
DRY-BULB TEMPERATURE °C
SUPPLY AIR
TEMPERATURE 15°C.
0 10 20 30 40 50
SPECIFIC ENTHALPY kJ/kg

SUMMER CYCLE CALCULATIONS

MASS FLOW RATE

When the supply air temperature has been found from the psychrometric chart then the mass flow rate of air can be calculated from the following formula:

$$H_s = m_a \times Cp \ (t_r - t_s)$$

where:

H_s	=	Sensible heat gain to room (kW)
m_a	=	mass flow rate of air (kg/s)
Cp	=	Specific heat capacity of humid air (approx.1.01 kJ/kg degC)
t_r	=	room temperature (°C)
t_s	=	supply air temperature (°C)

The supply air temperature is 15°C.
Rearranging the above formula gives:

$$m_a = H_s \ / \ (Cp \ (t_r - t_s))$$

$$m_a = 10.8 \ / \ (1.01 \ (22 - 15))$$

$$m_a = 1.528 \text{ kg/s}$$

COOLING COIL OUTPUT

The cooling coil output is as follows:

$$H_{cooling\ coil} = m_a \; (h_M - h_{ADP})$$

where:

$H_{cooling\ coil}$	=	Cooling coil output (kW)
m_a	=	mass flow rate of air (kg/s)
h_M	=	specific enthalpy at condition M (kJ/kg) determined from psychrometric chart.
h_{ADP}	=	specific enthalpy at condition ADP (kJ/kg) determined from psychrometric chart

The specific enthalpies at points M and ADP are shown on the psychrometric Chart below.

$$H_{cooling\ coil} = 1.528 \; (50 - 25)$$

$$H_{cooling\ coil} = \underline{38.2\ kW}$$

Note:

The cooling coil output of 38.2 kW is a much higher value than the sensible heat gain of 10.8 kW.
It should be remembered that the difference is these two values is mostly from the fresh air cooling load.
It takes quite a lot of energy in summer to cool fresh air coming into air handling units.
This can be minimised by bringing in minimum fresh air but not too little otherwise the building will suffer from lack of oxygen and feel stuffy.

Sometimes mistakes are made when sizing cooling apparatus.
If a cooling coil or indoor cooling unit is sized on the sensible heat gain only without allowing for fresh air load then it will be grossly undersized.
That is why psychrometric charts are required to calculate cooling coil output including fresh air loads.

So, don’t size cooling coil and indoor cooling units on sensible heat gain only if there is fresh air coming into the plant.
Size these items of plant using a psychrometric chart.

HEATER BATTERY OUTPUT

The heater battery or reheater output is as follows:

$$H_{heater\ battery} = m_a \ (h_S - h_{ADP})$$

where:

$H_{heater\ battery}$ = Heater battery output (kW)

m_a = mass flow rate of air (kg/s)

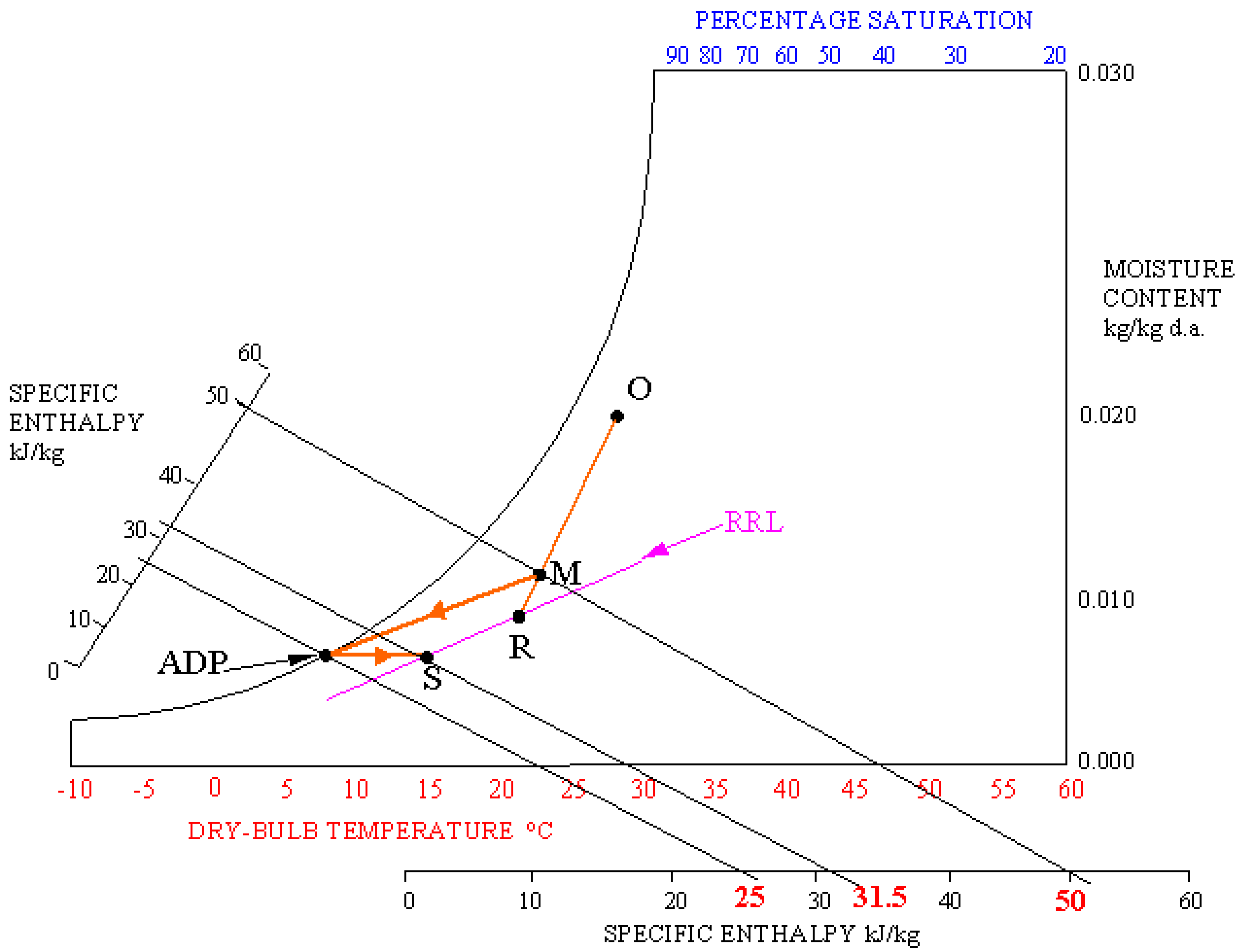
h_S = specific enthalpy at condition S (kJ/kg) determined from psychrometric chart.

h_{ADP} = specific enthalpy at condition ADP (kJ/kg) determined from psychrometric chart.

The specific enthalpies at points ADP and S are shown on the psychrometric Chart below.

$$H_{heater\ battery} = 1.528 \ (31.5 - 25)$$

$$H_{heater\ battery} = \underline{9.932\ kW}$$



PERCENTAGE SATURATION
90 80 70 60 50 40 30 20
0.030
MOISTURE CONTENT kg/kg d.a.
0.020
0.010
0.000
SPECIFIC ENTHALPY kJ/kg
60
50
40
30
20
10
0
O
RRL
M
R
ADP
S
-10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60
DRY-BULB TEMPERATURE °C
0 10 20 25 30 31.5 40 50 60
SPECIFIC ENTHALPY kJ/kg
