Introduction to Psychrometry

Chapter 1

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Chapter 1
Introduction to Psychrometry

Learning Outcomes

Learning Outcomes:

When you have studied this chapter you should be able to:

1 Explain what is meant by the term ‘Psychrometry’.
2. Relate ‘Dalton’s law of Partial Pressures’ to the term ‘Atmospheric Pressure’.
3. Explain what is meant by the term ‘Saturated Vapour Pressure’.
4. Use a ‘Psychrometric Chart to find:
   a. A saturated vapour pressure for a given temperature.

   Find, for a given air sample, the following:
   b. The moisture content
   c. The percentage saturation
   d. The relative humidity.
5. Explain what is meant by the ‘wet-bulb’ temperature and its use in the ‘psychrometric equation’.
6. Show how the Psychrometric Chart is used to determine:
   a. Dew-point temperature
   b. Specific Enthalpy

Suggested Study Time:

(a) For study of chapter material;

(i)	Initial on-screen study	**1 hour**
(ii)	Printing of notes and subsequent in-depth study	**2 hours**

(b) For completion of the quick revision study guide **½ hour**

Total estimated study time 3½ hours

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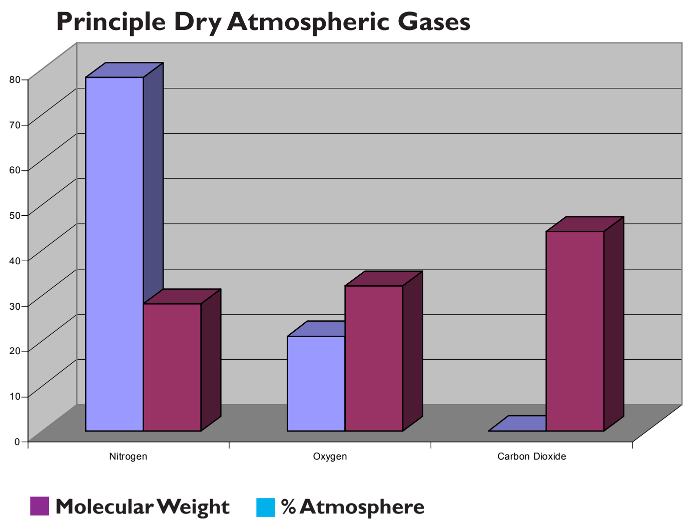
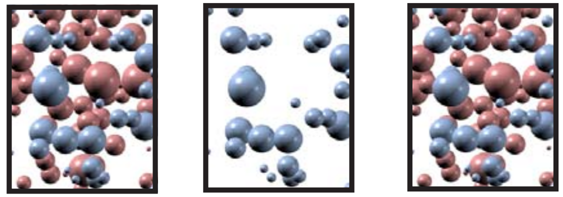
Introduction to Psychrometry

The Atmosphere

Psychrometry is the study of atmospheric air and its associated water vapour. Air comprises a mixture of gases[†1.1] of which nitrogen makes up 78%, oxygen 21% and carbon dioxide and the inert gases (such as argon, neon, krypton, helium etc.) the remainder. These are known as the **dry** gases of the atmosphere.



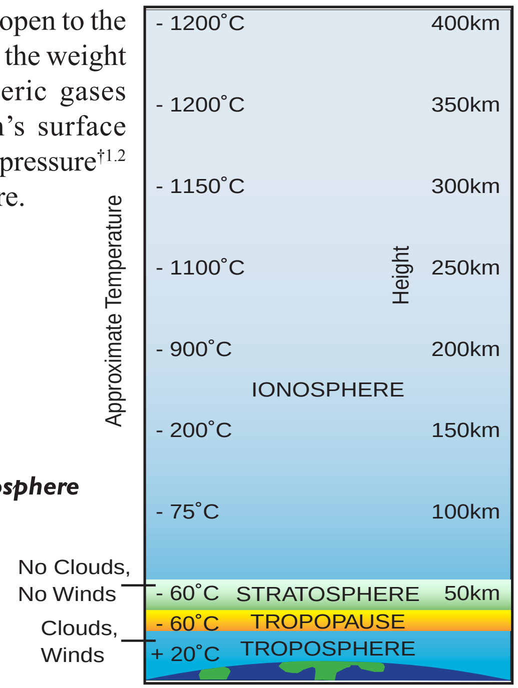
In the air mixture, the dry gases and associated water vapour behave according to 'Dalton's law of Partial Pressures'. That is they behave independently of one another and the pressure each exerts combine to produce an overall '**atmospheric pressure**'.



Gas A at partial pressure P_A | ***Gas B at partial pressure P_b*** | ***Gas A + B at total pressure $P_A + P_B$***

Dalton's Law, illustrates that if two gases are combined into the same volume, the total pressure is the sum of the individual partial gas pressures.

In a vessel open to the atmosphere, it is the weight of the atmospheric gases above the earth's surface that produce the pressure[†1.2] of the atmosphere.



The Earth's Atmosphere

Since at normal temperatures and pressures we are unable to condense these gases out from the atmosphere, for the purpose of psychrometry, this mixture of gases can be treated as if it were a single 'ideal' or perfect gas behaving as a single element known as '**dry air**'.

Note: *Psychrometry is a specialised area of thermodynamics but obviosuly has applications in air conditioning. None the less, in order to fully appreciate the material within this course you need to be familiar with the gas laws, the first law of thermodynamics and the concepts of internal energy, enthalpy and other gas properties. For those of you who lack this experience I have included within the extra notes - 'Thermodynamics Refresher, a brief set of notes covering these topics which you are advised to study before continuing.*

Basic Thermodynamics Xtra

A consequence to Dalton's law of Partial Pressure is that the total enthalpy of a mixture of gases will equal the sum of the enthalpies of each component part, i.e.:

$$h = m_1 .h_1 + m_2 . h_2 + m_3 .h_3 + ... \text{ etc.}$$

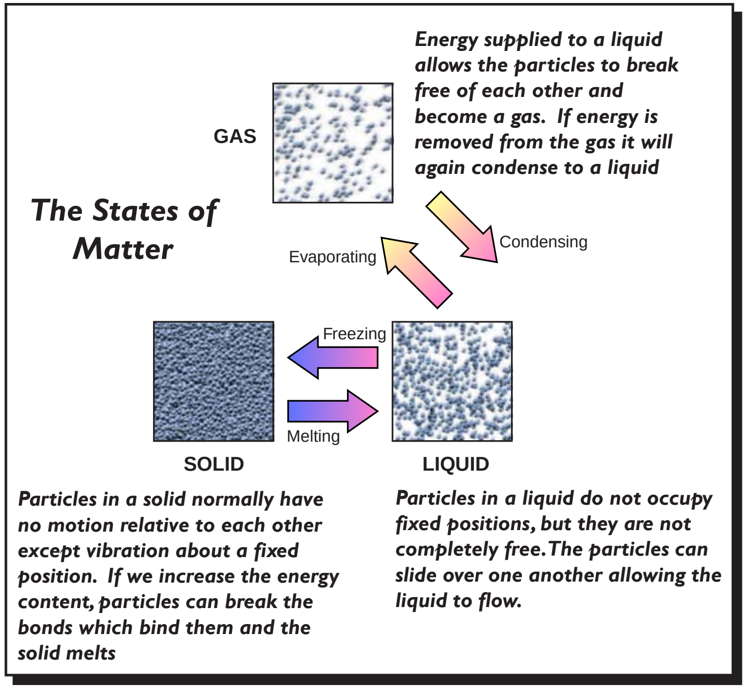
Water Vapour

In addition to these dry gases, the air also contains varying amounts of water vapour. At normal temperatures and pressures, water is able to exist in both a liquid and a gaseous (or vapour) form, but it cannot be treated in the same way as the other gases of the atmosphere because its quantity, and hence proportion are continually varying.

Water vapour is said to be associated *with dry air and the more vapour associated with the dry gases, the more humid the air. At sea level, atmospheric pressure is normally within the range 95 to 105 Pa, but this depends upon weather conditions. The agreed international standard atmosphere has a pressure of 101.325 kPa (1013.25 mbar) and this* reduces *at the rate 0.013 kPa per metre of height* above *sea level and* increases *at the same rate* below *sea level.*

The water vapour is completely independent of the dry atmospheric gases, and its behaviour is not affected by their presence of absence, but for any given temperature there is a maximum amount of vapour that can be absorbed or associated with a given volume of air. In addition, although the actual quantity of water is quite small, it can have a dramatic effect on our perception of comfort.

(Under certain conditions the mass of water vapour will change due to condensation or evaporation (known as ***dehumidification*** *and* ***humidification*** *respectively), but the mass of dry air will remain constant. It is therefore convenient to relate all properties of the mixture to the mass of* ***dry air*** *rather than to the combined mass of air and water vapour).*



Saturated Vapour Pressure (P_{ss})[†1.3]

Heat is a form of internal energy. This is a thermodynamic property[†1.4] and represents the internal energy of the molecules. With increase temperature there is an increase in molecular activity and thus more water can escape from the liquid into the gas as water vapour or steam. After a while however, even at this increased temperature, the air will become fully saturated with water vapour so that no more water can evaporate unless we again increase the temperature.

The pressure produced by the water vapour in this fully saturated condition is known as the **saturated vapour pressure** (p_{ss}) and since at a given temperature the air cannot absorb more water than its saturated condition, the saturated vapour pressure is the maximum pressure of water vapour that can occur at any given temperature.

Eventually of course, if we continue to supply heat the water will boil, and this will occur when the saturated vapour pressure is equal to the atmospheric pressure.

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Psychro Chart

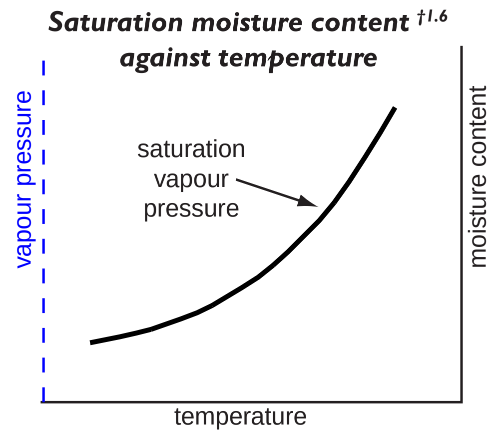
Psychrometric Chart

There is a fixed relationship[†1.5] between saturated vapour pressure and temperature, for example;

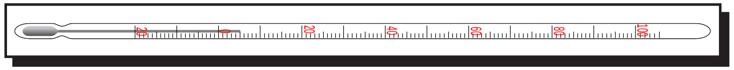
Temperature (°C)	10.0	20.0	30.0	40.0	50.0	60.0
Pressure (Pa)	1.23	2.34	4.24	7.38	12.33	19.92

and this relationship forms the basis for the **psychrometric chart** (click adjacent symbol), which is essentially a plot of vapour pressure against air temperature.

Although the CIBSE Psychrometric Chart is derived on the basis of the relationship between vapour pressure and temperature, the published chart does not show vapour pressure but rather shows moisture (vapour) content against temperature as this is more useful to the user.



Normal air temperature, as you might expect, can be measured by a normal mercury-in-glass thermometer



This is known as the **Dry-bulb** temperature (t_{db}) because the bulb of the thermometer is kept dry *(as opposed to the wet-bulb thermometer which we will introduce later)*. Vapour pressure (p_s) is the actual pressure of vapour existing at any particular location and time and temperature and is a property of the moisture content of the air.

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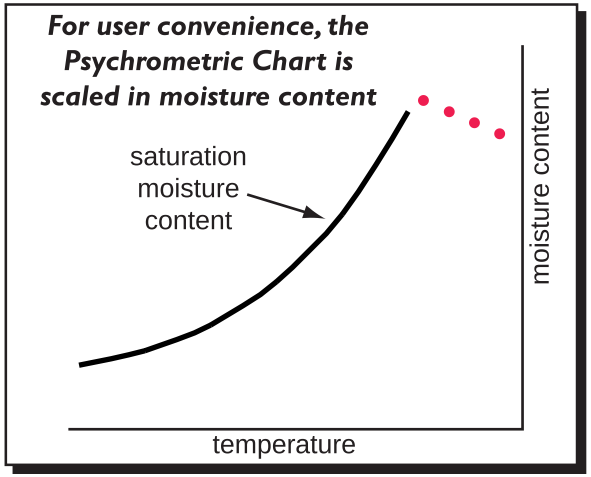
Psychro Chart

Moisture content (g)

Dry-bulb temperature and vapour pressure are the two basic parameters which determine the humid condition of atmospheric air, but other properties can be derived from them and likewise, they can be derived from other properties. In practice we are not really interested in the pressure exerted by the vapour in a mixture of air and water vapour, but we do need to know the quantity of water that exists at any time. One way of measuring this amount in by the moisture content and can be expressed in kg of water vapour per kg of dry air (kg/kg of dry air). *[The term 'humidity ratio' was used in the past, but is not common today].*

$$g = \frac{\text{mass of water vapour (kg)}}{\text{mass of dry air (kg)}} = \frac{m_s}{m_a}$$

The moisture content is shown on the right-hand side of the psychrometric chart (click adjacent symbol).



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Psychro Chart

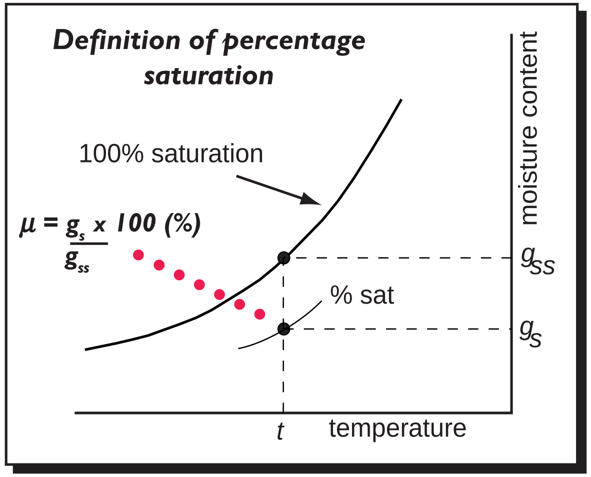
Percentage saturation (μ)

Percentage saturation is a useful guide to comfort as the human body tends to respond to relative saturation rather than moisture content, and is the ratio between the actual moisture content of the sample (g_s) and the moisture content of a sample of saturated air (g_{ss}), at the same temperature.

$$\mu\ (\%) = \frac{\text{moisture content of sample} \times 100\ \text{(kg)}}{\text{moisture content of saturated air (kg)}}$$

$$= \frac{g_s \times 100}{g_{ss}}$$

The property is shown on the psychrometric chart and to make the chart easier to use, the chart also includes lines of constant percentage saturation (click adjacent symbol).



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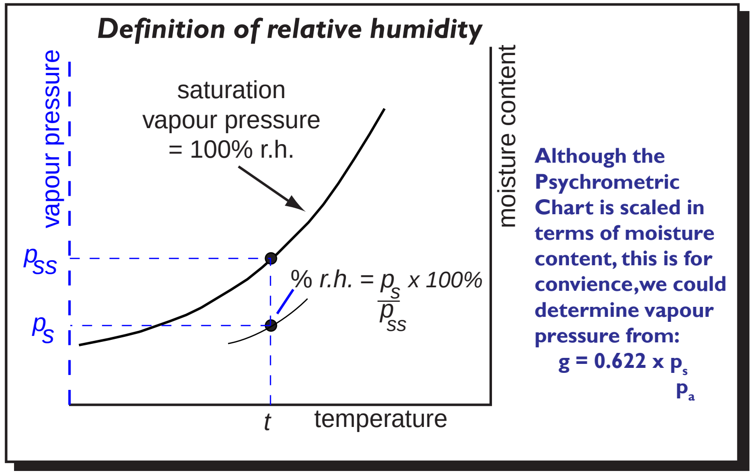
Relative humidity (*rh*)

Although percentage saturation is the preferred method of expressing the humidity ratio, relative humidity is another method of measuring the amount of water vapour present in the air, and is a hangover from the days of 'imperial' measurement. It is the ratio of the vapour pressure of an air sample to the saturated vapour pressure at the same temperature, and is usually expressed as a percentage.

$$rh\ (\%) = \frac{\text{partial pressure of water vapour in sample}\ \text{(Pa)}}{\text{partial pressure of water vapour in saturated air}\ \text{(Pa)}} \times 100$$

$$= \frac{p_s}{p_{ss}} \times 100 \quad \text{(at the same dry-bulb temperature)}$$



Definition of relative humidity

Percentage saturation or relative humidity are frequently used in specifications as a requirement of air humidity conditions[†1.7]. However, as the relationship between vapour pressure and moisture content is not quite linear, their will always be a slight (but not usually significant) difference between them.

Relationship between g, µ and rh

We are now in a position to derive useful expressions for moisture content and percentage saturation in terms of partial pressure and hence compare percentage saturation with relative humidity.

If we consider the humid air mixture, the moisture (vapour) content of the air can be expressed either as a specific value or as a ratio, as we noted before, of the mass of vapour to the mass of dry air.

Thus by definition $g = \frac{m_s}{m_a}$

but from the perfect gas laws: $\mu = \frac{p\,.V}{R\,.T}$ so that

$$\mu_a = \frac{p_a\,.\,V_a}{R_a\,.\,T_a} \quad \text{and} \quad \mu_s = \frac{p_s\,.\,V_s}{R_s\,.\,T_s}$$

Thus we can also define moisture content as:

$$g = \frac{p_s\,.\,V_s}{p_a\,.\,V_a} \times \frac{R_a\,.\,T_a}{R_s\,.\,T_s}$$

but for a mixture, the volumes and the temperatures must be equal, i.e. $V_s = V_a$ and $T_s = T_a$ so that the above formula can be simplied to:

$$g = \frac{p_s}{p_a} \times \frac{R_a}{R_s}$$

But since we know the value of the gas constants, a ratio can be found for R_a / R_s, so that $g = 0.622\,\frac{p_s}{p_a}$

and we also know from Dalton's Law of partial pressure that $p_a = p_{atm}$ [†1.8] $- p_s$ and finally therefore: $g = 0.622\,\frac{p_s}{(p_{atm} - p_s)}$

Comparision of percentage saturation and rh

From the previous definition, we know that

$$\mu = \frac{g_s}{g_{ss}} \times 100 \ \%$$

but using the above expression derived from moisture content, we can also express the percentage saturation as:

$$\mu = \frac{p_s \cdot (p_{atm} - p_{ss})}{p_{ss} \cdot (p_{atm} - p_s)} \times 100 \ \%$$

Compare this to the definition of relative humidity:

$$\text{rh } (\phi) = \frac{p_s}{p_{ss}} \times 100 \ \%$$

Since p_{atm} is very much bigger than p_s or p_{ss}, then the relative humidity is very nearly equal to the percentage saturation. i.e.

$$\phi \simeq \mu$$

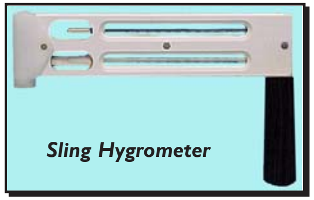
Although relative humidity and percentage saturation are useful guides to comfort, it is not always practical to measure them directly. In fact measurement of humid air has always been a problem and the most practical method is to use a wet-bulb thermometer[†1.9].

Wet-bulb temperature (t_{wb})

The wet-bulb temperature, as the name implies, is the air temperature measured by a thermometer with a bulb covered with a muslin cloth sleeve and kept moist with distilled or clean water. It was devised as a means of assessing the humidity of the air, but as the actual reading is influenced by air movement, there are two variations of this temperature.

1. The Sling Wet-bulb

The 'sling wet-bulb' temperature reading obtained in moving air[†1.10] – preferably above 2 m/s. It can be obtained by whirling a 'sling hygrometer' or by using the more cumberson, but more accurate 'Assman hygrometer' which is fan-assisted.



Sling Hygrometer

Assman Hygrometer

2. The Screen Wet-bulb

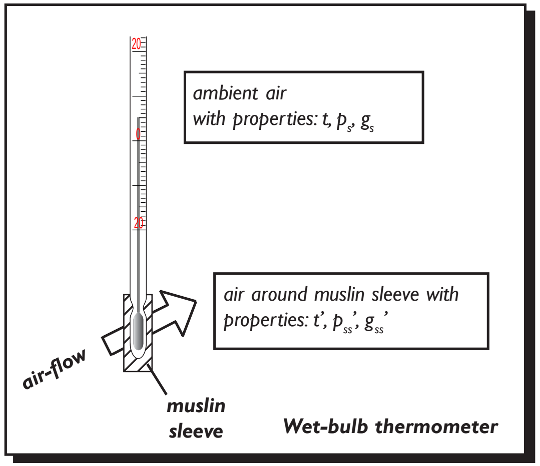
The screen wet-bulb temperature is the reading obtained in still air. This is usually used for meteorological data and is obtained from a wet-bulb thermometer installed into a 'Stevenson Screen' (from which this type of measurement gets its name). This is a slatted enclosure, designed to screen direct radiation from the instruments, but equipped with wet and dry-bulb thermometers and maximum and minimum thermometers.

Of the two methods of reading wet-bulb, the sling reading is considered to be more accurate and is therefore preferred by air-conditioning engineers.

The Psychrometric Equation

The psychrometric equation links the dry-bulb and the wet-bulb temperatures to their corresponding vapour pressures and to the atmospheric pressure.

Consider air flowing across the bulb of a wet-bulb thermometer:



Moisture will be evaporated from the muslin cloth sleeve around the bulb and will be taken up (associated) with the surrounding air. For this evaporation to take place heat must be supplied and this can only come from the surrounding air, i.e the latent heat of evaporation gained by the moisture on the surface of the muslin as it associates with the air, must equal the sensible heat lost from the surrounding air, in other words there must be a drop in the wet-bulb temperature to compensate for the increase in mosture content to the air around it.

At the surface of the muslin sleeve the air is considered to be at saturation moisture content (g_{ss}')[†1.11], so that the latent heat gain is proportional to the difference in moisture content between the film of air surrounding the muslin sleeve and the surrounding air, i.e. to ($g_{ss}' - g_s$).

Similary, the sensible heat lost is proportional to the temperature difference between the bulb and the ambient temperature, i.e. to ($t - t'$), and since one process is the cause of the other we may equate them as:

$$B \,.\, (g_{ss}' - g_s) = C \,.\, (t - t') \quad \text{– (equation 1)}$$

where B and C are constants which relate to surface area and latent heat. But from our earlier equation for moisture content, we known that:

$$g_s = 0.622 \frac{p_s}{p_{atm} - p_s}$$

and

$$g_{ss}' = 0.622 \frac{p_{ss}'}{p_{atm} - p_{ss}'},$$

and since p_s and p_{ss}' are both very small compared to p_{atm} we may re-write these equations more simply as:

$$g = 0.622 \frac{p_s}{p_{atm}} \quad \text{and} \quad g_{ss}' = 0.622 \frac{p_{ss}'}{p_{atm}}$$

Hence by substituting these expressions for moisture content into our equation 1, we get:

$$0.622 \,.\, B \,.\, \frac{(p_{ss}' - p_s)}{p_{atm}} = C \,.\, (t - t')$$

From which we obtain:

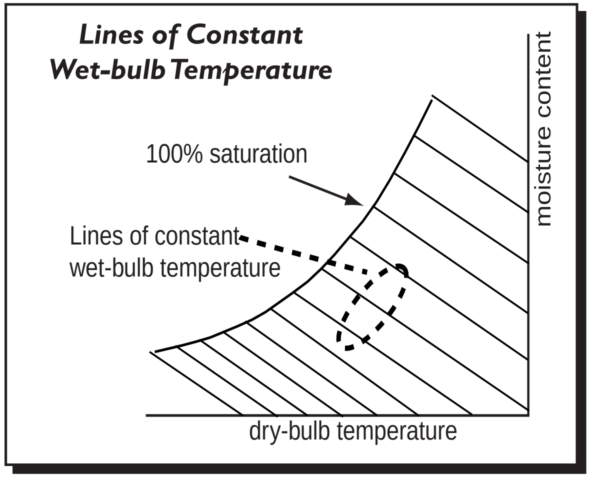
$$p_s = p_{ss}' - p_{atm} \,.\, A \,.\, (t - t').$$

where ***A*** is known as the **psychrometric constant** and the difference between the dry-bulb and the wet-bulb temperatures **($t - t'$)** is known as the **wet-bulb depression**.

Now the rate of moisture evaporation is different if the air is above or below freezing point (0°C) and between still and moving air *(a standard speed of 2 m/s is used, but between about 2 m/s and 20 m/s the effect of air velocity is practically constant)*. Different values of the psychrometric constant are therefore quoted to cater for these conditions:

Psychrometric Constants	
Sling:	$A = 6.66 \times 10^{-4}$ (K^{-1}) *for t' greater than 0 °C*
	$A = 5.94 \times 10^{-4}$ (K^{-1}) *for t' less than 0 °C*
Screen:	$A = 7.99 \times 10^{-4}$ (K^{-1}) *for t' greater than 0 °C*
	$A = 7.20 \times 10^{-4}$ (K^{-1}) *for t' less than 0 °C*

Wet-bulb temperature is also shown on a psychrometeric chart and to assist with humidification processes (*those which increase the moisture content*), they are shown as lines of constant wet-bulb temperature (click adjacent symbol).



Note: When working with the psychrometric equation, it is important to remember that the **saturated vapour pressure** (p_{ss}') is taken at the **wet-bulb** temperature.

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Psychro Chart

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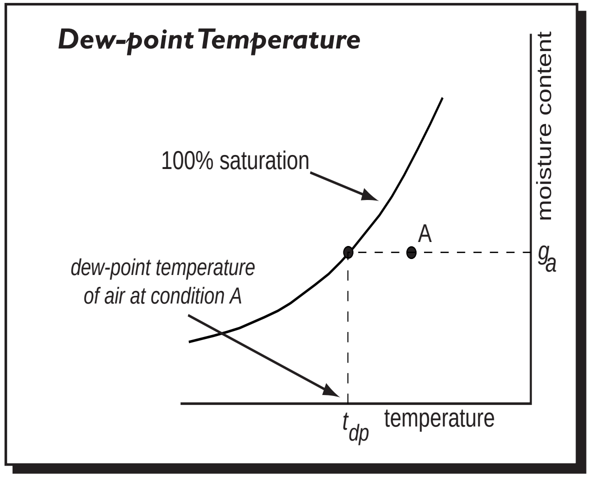
Psychro Chart

Dew-point temperature (t_{dp})

The dew-point temperature is a very important property in air-conditioning[†1.12] as it determines if water will be condensed from air when it is cooled. This occurs when a sample of air is cooled to the point where its vapour pressure reaches its saturated vapour pressure. For example, suppose air is being cooled at constant vapour pressure (i.e. constant moisture content). Eventually, the temperature of the air will reach a point where the air is fully saturated (on our psychrometric chart – the 'saturation line) and if the temperature drops lower than this point, water vapour will begin to condense. This point in known as the **dew-point temperature** (t_{dp}) and again can be represented on our psychrometric chart (click adjacent symbol).



We should also realise that moist air does **not** need to be cooled to its dew-point for condensation to occur. Any surface with a temperature below the dew-point of the moist air will, of course, get wet and it is important to appreciate this when trying to avoid problems of condensation.

Specific enthalpy (h)

Enthalpy (*see Thermofluids Refresher, page C-5a*) is a measure of energy, but although in psychrometry it is only the heat energy which is of interest, this is still referred to an enthalpy. Enthalpy is an *extensive* property, i.e its value depends upon the amount of substance present. An *intensive* property is therefore more useful since it does not depend upon the amount of material present. It is usually obtained by dividing the extensive property by its mass and is then known as **specific** property. Thus the **specific enthalpy** (h), is a measure of the heat energy (sensible and latent) of 1 kg of dry air plus its associated water vapour (*measured in units of kJ/kg*) relative to zero°C and zero moisture content.

To calculate the specific enthalpy for an air sample we can use Dalton's Law of Partial Pressures, i.e.,

$$h = h_1 + h_2 + h_3$$

where the specific enthalpy for each part of the air-mixture is given by: $h = mass \times specific\ heat \times \Delta t.$

Thus for example, to calculate the specific enthalpy for air at a dry-bulb temperature of 20°C and a moisture content of 0.005 kg/kg, we can proceed as follows:

Taking as our sample, 1 kg of dry air and its associated moisture content, the enthalpy of the dry air is given by:

$$h_1 = 1 \times 1.005 \times 20 = 20.1\ kJ/kgK,$$

where *1* is the mass of dry air,
1.005 is the specific heat of dry air and
20 is the air temperature relative to 0°C.

similarly the sensible heat energy of the moisture content is given by: $h_2 = 0.005 \times 1.89 \times 20 = 0.189$

where *0.005* is the moisture content
1.89 is the specific heat of water vapour and
20 is the air temperature relative to 0°C.

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Finally, the water vapour is considered to have evaporated at 0°C. We therefore have to include the latent heat of evaporation for the moisture content. Thus the latent heat energy of the moisture content is given by:

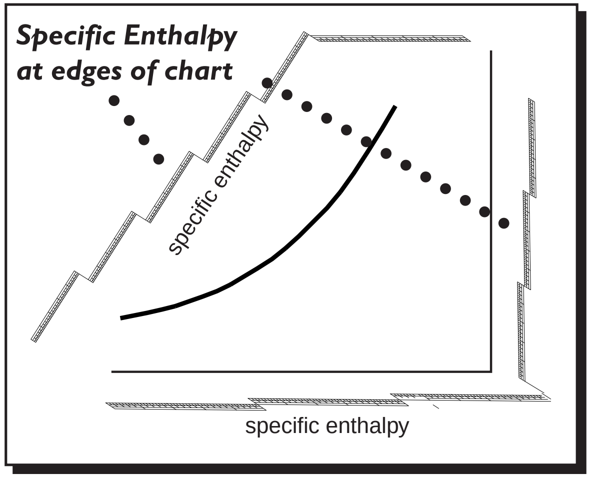
$$h_3 = 0.005 \times 2501 = 12.505$$

where *0.005* is the moisture content and
2501 is the latent heat of evaporation at 0°C[†1.13].

Thus the total enthalpy is given by $h_1 + h_2 + h_3$

$$= 20.1 + 0.189 + 12.505 = 32.794 = 32.8\ kJ/kg$$

However, specific enthalpy can be determined much more quickly by direct reading from the psychrometric chart.



Enthalpy scales are located 'around the edges' of the chart (click adjacent symbol), and there are no lines of constant enthalpy.

Psychro Chart

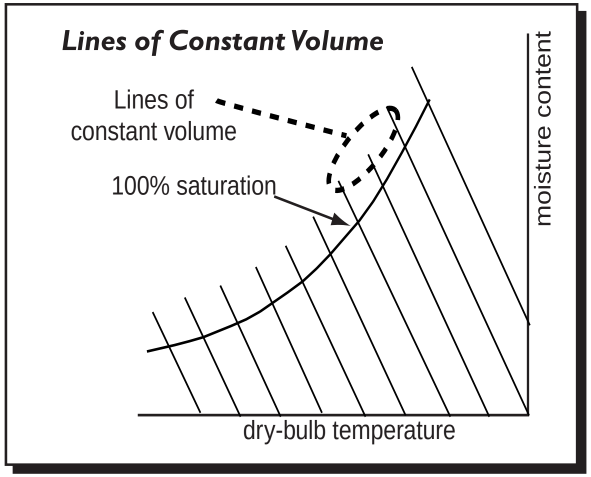
To therefore obtain the specific enthalpy of an air condition, a straight edge is used to join the corresponding enthalpy marks above to 100% saturation line with those on either the bottom, or the right-hand side of the chart (click on adjacent video symbol).

In addition to the temperatures already noted, the following psychrometric parameters may also be required.

Specific volume (*v*)

The specific volume, is the volume of unit mass of dry air at a given temperature normally expressed as m^3/kg and is also shown in the psychrometric chart (click adjacent symbol).

Note: that the specific volume is a measure of dry air, since the addition of any associated water vapour has no effect on the volume (Dalton's Law).



Psychro Chart

Density (ρ)

The density of air is taken for a moist air sample and therefore includes the mass of the associated water vapour. The specific volume however, is defined in terms of dry air and thus the specific volume is not the reciprocal of density.

The exact relationship is given by:

$$\rho = \frac{(1 + g)}{v}$$

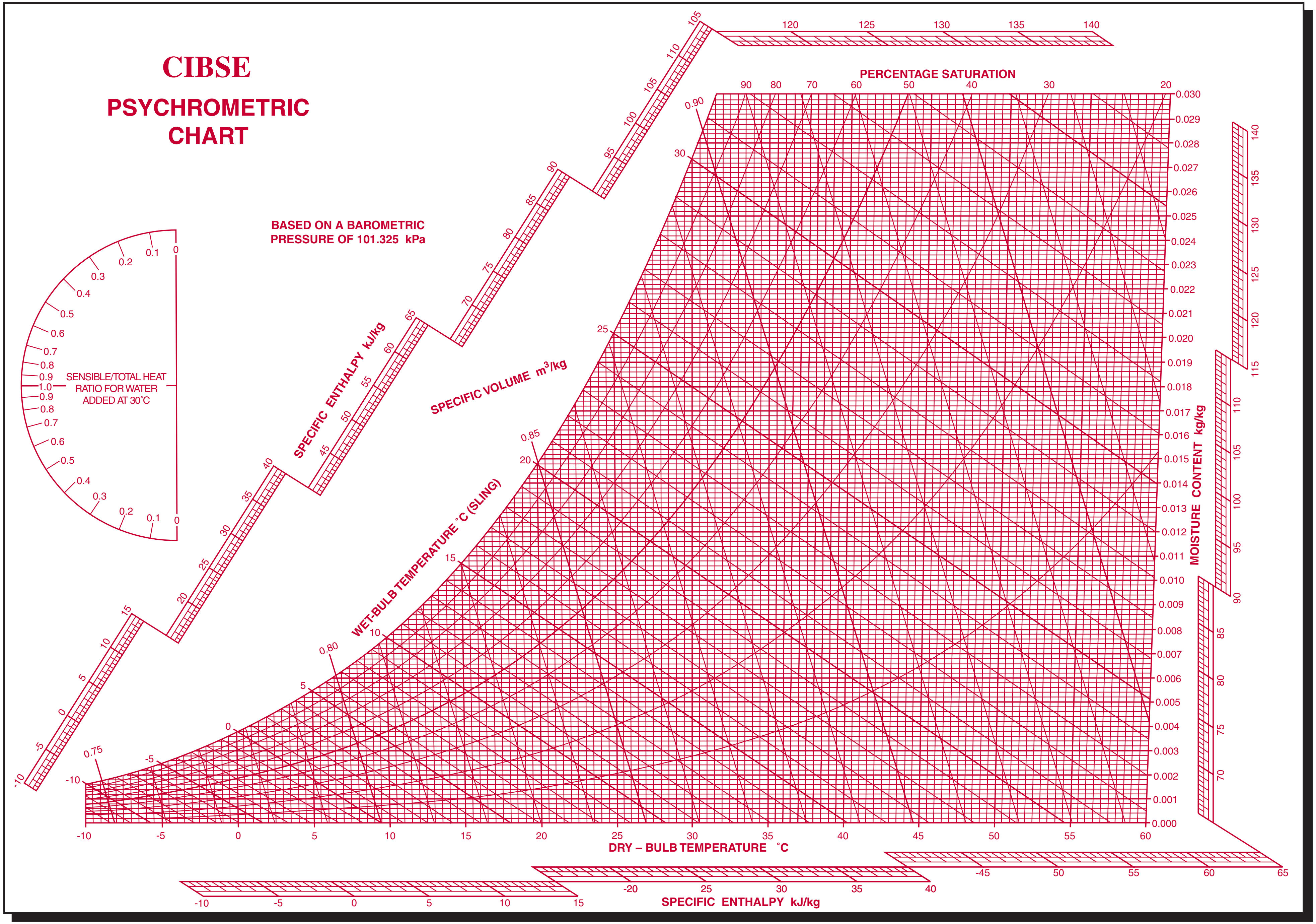
In practice however, the difference is very small and can be ignored[†1.14].

Thus, with the exception of vapour pressure and saturation vapour pressure, all these psychrometric parameters are brought together on the psychrometric chart, from which any two are sufficient to indentify an air condition, the others then being read from the chart as required (see chart overleaf).

In practice only two combinations[†1.15] are used;

dry-bulb (t_{db}) and wet-bulb (t_{wb}) temperature for measurements
and
dry-bulb temperature (t_{db}) and percentage saturation (μ) [or relative humidity (rh)] for specifications.

svp g % sat rh wb dew h v



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Quick Revision Study Guide 1

The following questions are intended as a quick study questionnaire to ensure you have grasped the general principles of this chapter.
It is intended that your answers should be, short-phrased, quick answers or sketches to the questions.
For suggested solutions to these questions, please refer to the Denco Website: www. denco.co.uk

1. 0.01 kg of steam with a specific enthalpy of 2,700 kJ/kg is mixed with 2.0 kg of dry air with a specific enthalpy of 20 kJ/kg. What is the specific enthalpy of the mixture?

2. Moist air has a dry-bulb temperature of 30°C, and a wet-bulb temperature of 20°C.
   Use a Psychrometric Chart to find
   a. The percentage saturation
   b. The moisture content
   c. The enthalpy
   d. The specific volume
   e. The dew-point temperature

3. Moist air at 25°C dry-bulb and 50% saturation, undergoes a process so that its condition is changed to 40°C dry-bulb and 30% saturation. Use a Psychrometric Chart to determine the change in specific enthalpy for the process.

4. The air inside a room during winter is at 20°C db and 40% saturation. If the temperature of the inside surface of a window is 9°C, will condensation form on the window glass?

5. A sling psychrometer measured the dry and wet-bulb temperatures of moist air as 27°C and 19°C respectively. Determine the moisture content from the relevant equation, given that:
   (i) p_{ss} at 19°C is 2.196 kPa,
   (ii) the psychrometric constant is $6.66 \times 10^{-4}\ K^{-1}$

Chapter Notes

†1-1: Air;
is a mixture containing a group of gases of nearly constant proportions (% of atmosphere):

Nitrogen (N_2)	78.804	Methane (CH_4)	0.0002
Oxygen (O_2)	20.964	Krypton (Kr)	0.000114
Argon (Ar)	0.934	Hydrogen (H_2)	0.00005
Neon (Ne)	0.0018	Nitrous Oxide (N_2O)	0.00005
Helium (He)	0.000524	Xenon (Xe)	0.0000087

and a group of gases present in proportions, variable both in time and space (% of atmosphere):

Water Vapour (H_2O)	0 – 7
Carbon Dioxide (CO_2)	0.01 – 0.1 (Average about 0.032)
Ozone (O_3)	0 – 0.01
Sulphur Dioxide (SO_2)	0 – 0.0001
Nitrogen Dioxide (NO_2)	0 – 0.000002

(Ref Encylopaedia Britannica CD-ROM, 1998 Edition).

†1-2: Pressure;
force per unit area, i.e. the force spread over a particular area, is measured in newtons and area in square metres. So pressure is measured in newtons per square metre but it can also be measured in pascal *(symbol Pa, where 1 Pa = 1 N/m²)*.
Traditionally, it has also been common to express atmospheric pressure in units of bar or millibar, where 10 bar = 10^5 Pa, *(Bar: from the Greek meaning weight, thus a 'barometer' [a word again derived from the Greek meaning weight + measure], is an instrument to measure the weight or pressure of the atmosphere)*.

†1.3: Subscripts;
it is normal to apply the following subscripts:
s refers to water vapour (steam), eg P_s
a refers to dry air, eg P_a
ss refers to a saturated condition for water vapour in air, eg P_{ss}

†1.4: Internal Energy;
is the molecular energy possesed by a material and includes the kinetic energy of the molecules due to vibration and the potential energy associated with the forces between them.
Two terms can be used as a measure of this energy - the **Internal Energy** (symbol: U; unit:J) and the **Specific Internal Energy** (symbol: u; unit: J/kg).

†1.5: Saturated Vapour Pressure vs Temperature;
there is no simple relationship between temperature and saturated vapour pressure. The following equations have been developed by the National Engineering Laboratory as close curve fits to empirically measured data:
For water above 0°C

$$\text{Log}_{10} P_{ssw} = 28.59 - 8.2 \log_{10} T + 0.00248\,T - \frac{3142}{T}$$

where P_{ssw} is the saturated vapour pressure (bar) of vapour over water at an absolute temperature of T (K).
For ice below 0°C

$$\text{Log}_{10} P_{ssi} = 10.538 - \frac{2664}{T}$$

where P_{ssw} is the saturated vapour pressure (bar) of vapour over ice at an absolute temperature of T (K).

†1.6: Moisture Content;
is really a misnomer since what we are really referring to is 'vapour' content, but the term has used by the industry as such for many years and so we just have to accept the inaccuracy of the wording.

Notes

Notes

†1.7: Relative Humidity - to a Base of Pressure;
you will note that the relative humidity is based upon pressure, not mass of water vapour and is the traditional method of stating humidity as the 'sling psychrometer' (see page 1-8b) gave a measure of vapour pressure.

†1.8: Atmospheric pressure;

$$p_{atm} = p_a + p_s$$

†1.9: Psychrometer;
the word 'Psychrometer' is originally from the Greek meaning 'cold' + 'meter', i.e. literally meaning a measurer of cold. Its current meaning is two thermometers, mounted on the same scale, with indications of wet-bulb and dry-bulb temperatures. Hence the word 'Psychrometry' is the determination of the degree of humidity in the atmosphere by means of a psychrometer and is therefore used to define the study of atmospheric air and its associated water vapour.

†1.10: Use of Wet-bulb in Air Conditioning Duct;
a sling wet-bulb reading may also be obtained by installing a wet-bulb thermometer in a duct through which air is flowing at a reasonable velocity.

†1.11 Note the use of the *dash* (**'**) symbol to indicate that the reading is a wet-bulb reading.

†1.12 Dew-point Instruments;
there are commercial instruments which can measure the dew-point temperature directly. However, it is more usual to obtain a value by reference to tables of humid air properties, or to determine its value from the psychrometric chart using the measurements of other air properties.

†1.13: Latent heat;
values for temperatures other than zero °C, can be found from standard tables for the 'Thermodynamic Properties of Saturated Liquid Water and Dry Saturated Steam', more commonly known as 'Steam Tables'.

†1.14: Air Density and Specific Volume;
Although the difference between air density and the reciprocal of specific volume is small, it should be recognised that a difference does exist where this relates to different areas of work. For example, when measuring air-flow rates through pressure drop devices, it is usual to use air density. On the other hand, for air-conditioning load calculations, it is usual to use specific volume.

†1.15: CIBSE psychrometric chart;
the CIBSE psychrometric chart is strictly correct only for a total pressure of 101.325 kPa (i.e standard atmospheric pressure). Charts are available for other pressures, or correction factors may be used such as those quoted in the CIBSE Guide C1.
In addition, the principal axes of the chart are not, as is often assumed, dry-bulb temperature and moisture content, but **enthalpy** and moisture content. If you look carefully at a commercial psychrometric chart, you will see that the dry-bulb temperature lines are not quite parallel, nor vertical.