BUILDING PHYSICS

Psychrometry
Moisture transfer

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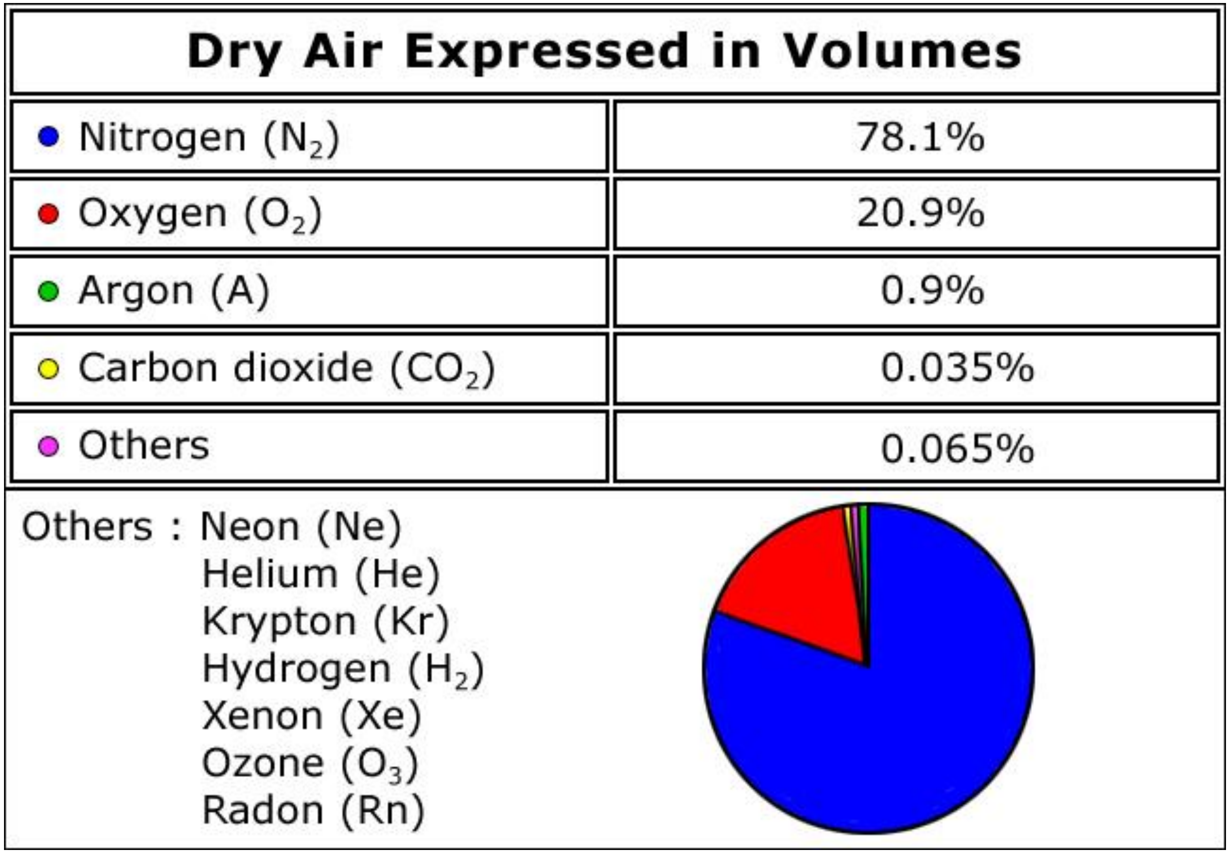
Psychrometry

- **Psychrometry** involves the study of the **properties of moist atmospheric air**, the basic medium in building physics and air-handling practise a binary **mixture of dry air and low pressure water vapour**.
- **Atmospheric air** is a mixture of dry air and any amount of water vapor.
- The amount of water vapor in moist air is variable, ranging from nearly zero to maximum 30 g water vapor per kg dry air depending on temperature and pressure at saturation.

Psychrometry

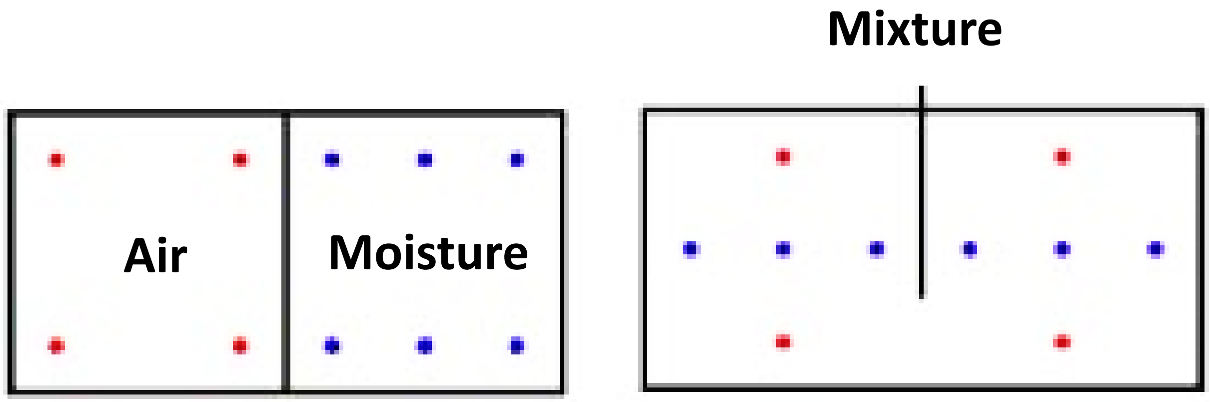
Composition of dry air are Nitrogen, Oxygen, Argon, Carbon dioxide and others.

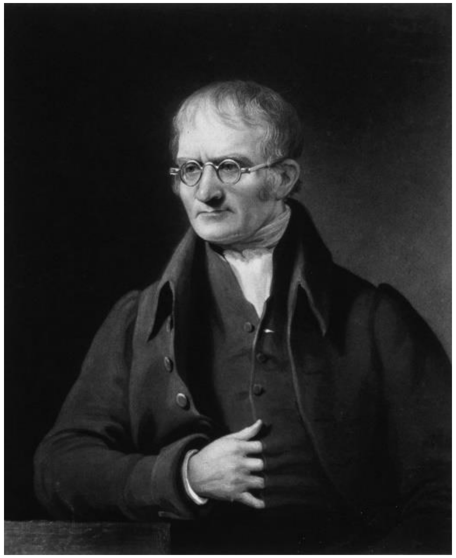


Dry Air Expressed in Volumes	
🔵 Nitrogen (N_2)	78.1%
🔴 Oxygen (O_2)	20.9%
🟢 Argon (A)	0.9%
🟡 Carbon dioxide (CO_2)	0.035%
🟣 Others	0.065%

Others : Neon (Ne)
Helium (He)
Krypton (Kr)
Hydrogen (H_2)
Xenon (Xe)
Ozone (O_3)
Radon (Rn)

Psychrometry
Dalton's law





John Dalton (1766-1844)

- The air in the atmosphere and within buildings may be considered as a **two-component gas mixture** of **dry air** and **water vapour**.

- Take the box hermetically divided by a partition. One part contains ***air*** gas molecules, the other part ***moisture*** ones. The pressure on the box wall is proportional to the number of molecules.

- Let us remove the hermetic partition. Now, both gases strive to completely fill the whole box capacity, **as if the other gas were non existent**. The box wall is acted upon by pressure from both gases: the **pressures of the *moisture* and *air* gases p_a and p_m** are proportional to the number of *moisture* and *air* molecules.

Psychrometry
Dalton’s law

DALTON'S LAW OF PARTIAL PRESSURES states that the **total pressure** **exerted** by a **gaseous mixture** is **equal** to the **sum of the partial pressures of each individual component in a gas mixture**.

This empirical law was observed by John Dalton in 1801 and is related to the ideal gas laws. In building engineering only an atmospheric air is considered as gas mixture of dry air and moisture, thus:

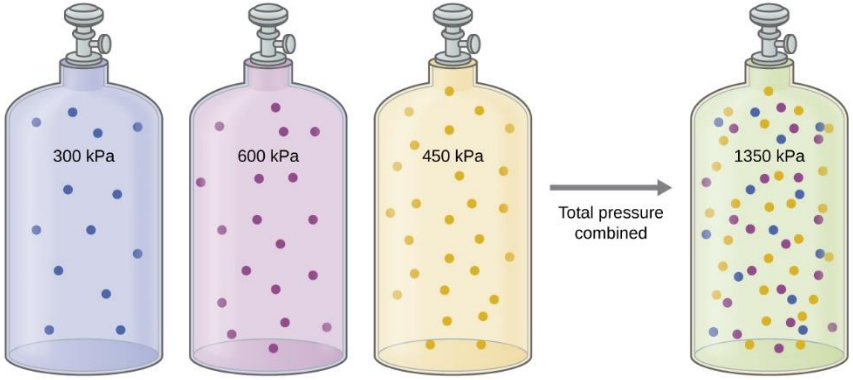
$$\boxed{p_0 = p_a + p_m}$$

p_0 – is an overall mixture pressure of dry air and moisture

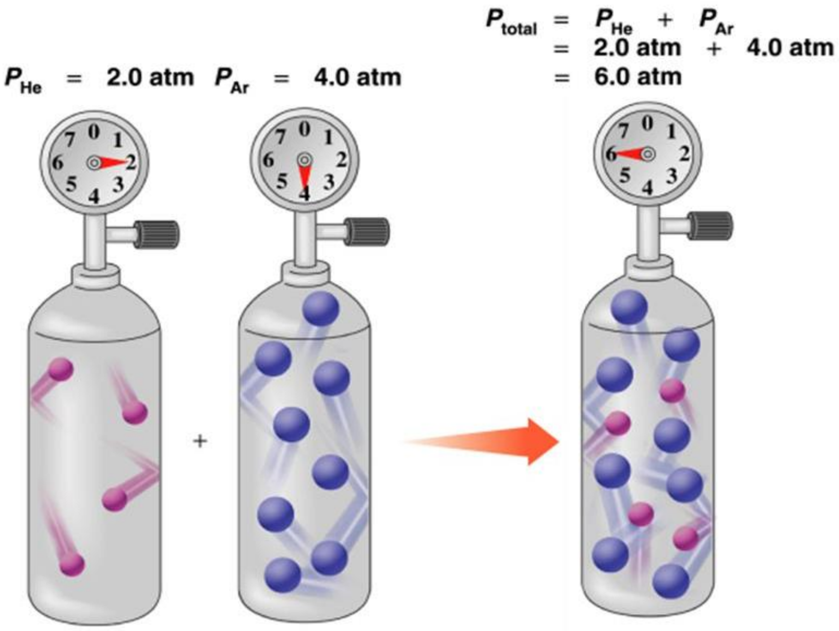
P_a p_m – are the pressure of the components or partial pressure of the components

Psychrometry
Dalton’s law

Total pressure



Gas mixture



Psychrometry

Moisture content (g)

$$\boxed{g = \frac{m_m}{m_a}}$$

- **Moist air** is a two-component mixture of dry air and water vapour. **Moisture content** of a moist air is defined as the ratio of the mass of water vapour to the mass of dry air. **Moisture content** is expressed as the number of kilograms of water vapour per kilogram of a dry air **[g/kg], [kg/kg]**.

- The amount of water vapour varies from zero (dry air) to a maximum that depends on temperature and pressure.

$$g = \frac{m_m}{m_a} = \frac{R_a}{R_m} \cdot \frac{p_m}{p_a}$$

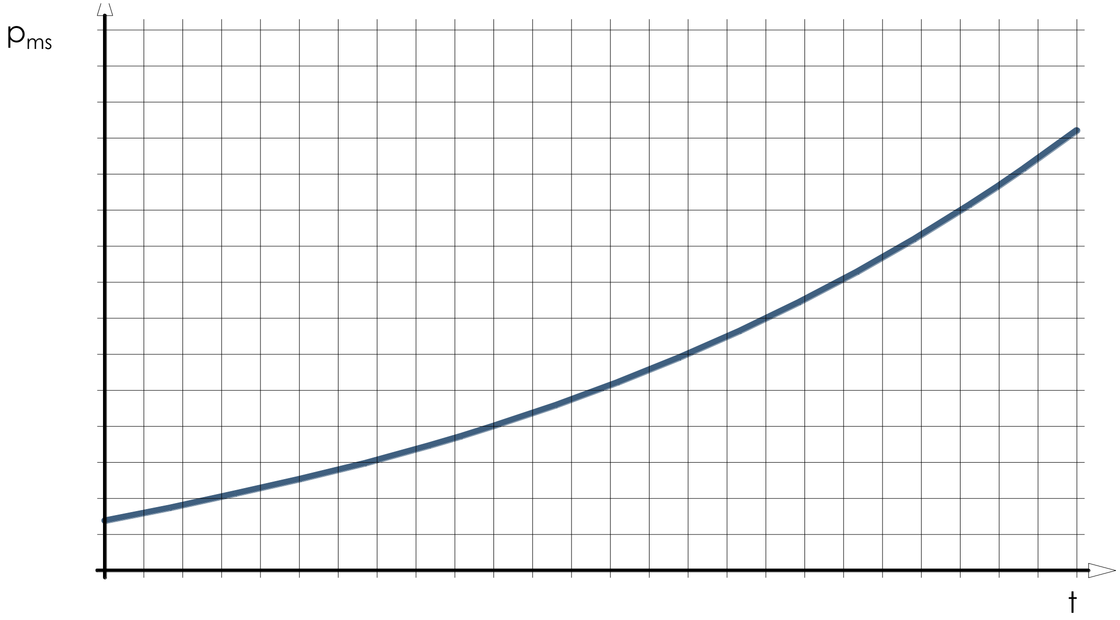
$$\boxed{g = 0.622 \frac{p_m}{p_0 - p_m}}$$

- Substituting ideal gas equation to the definition of moisture content, expressing p_a by p_0-p_m and substituting specific gas constant of air and moisture, **moisture content can be expressed by partial pressure of the moist**.

Psychrometry
Saturation vapour pressure (p_{ms})

The **maximum vapour pressure which** can exists in any given temperature is the **saturation vapour pressure**.

Under this condition the water vapour in the mixture can coexist in neutral equilibrium with surface of water at the same temperature and the **moist air** said to be **saturated with vapour**.



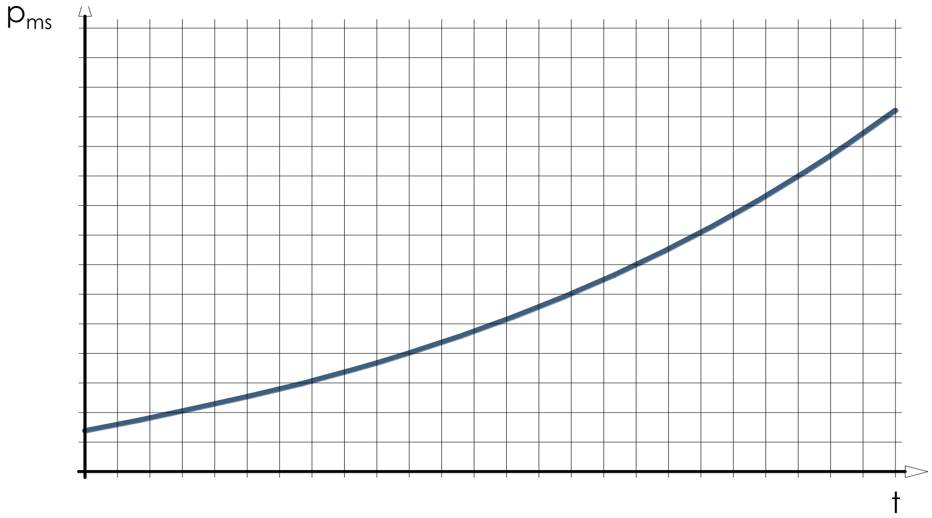
Saturation pressure

Psychrometry

Saturation vapour pressure (p_{ms})

- **Saturation vapour pressure** is a function only of temperature and is independent of the dry air which simultaneously occupies the same space. The **value of saturation pressure is given in p_{ms}-t diagram or steam tables.**
- In p_{ms}-t diagram is often used for describing moisture behaviour of composite building materials.
- Saturation pressure can expressed (based on the previously developed equation) by moisture content:

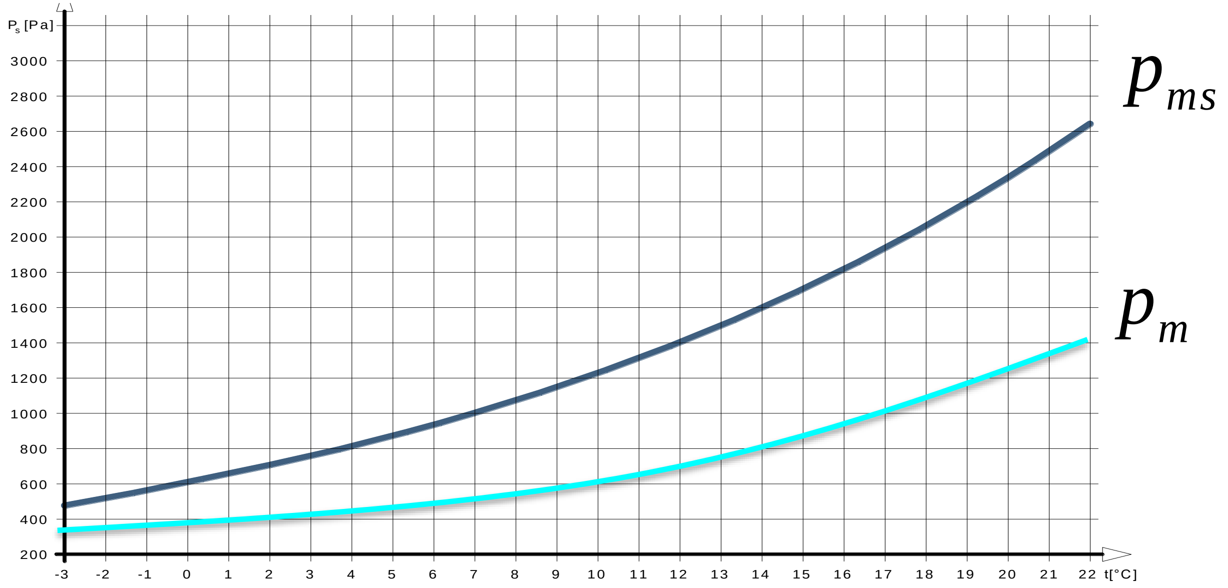
p_{ms}-t diagram



$$\boxed{p_{ms} = p_0 \frac{g}{0.622 + g}}$$

Psychrometry

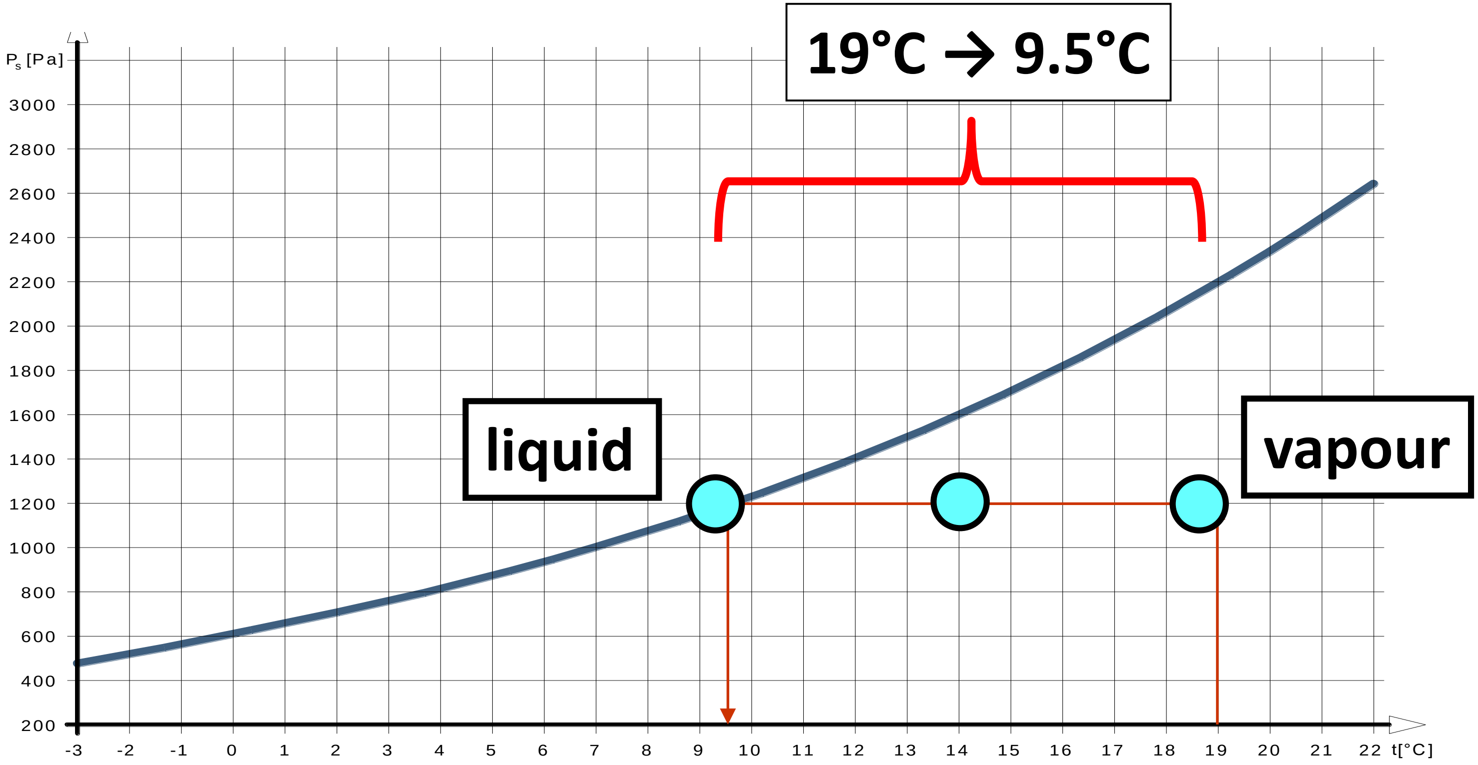
Relative Humidity



- Relative humidity is defined as the **ratio** of the **partial pressure of water vapor (*p*m)** in a gaseous mixture of air and water vapor to **the saturated vapor pressure of water (*p*ms)** at a same **temperature**.
- That is, a ratio of how much energy has been used to free water from liquid to vapor form to how much energy is left.
- Relative humidity is expressed as a percentage and is calculated in the following manner:

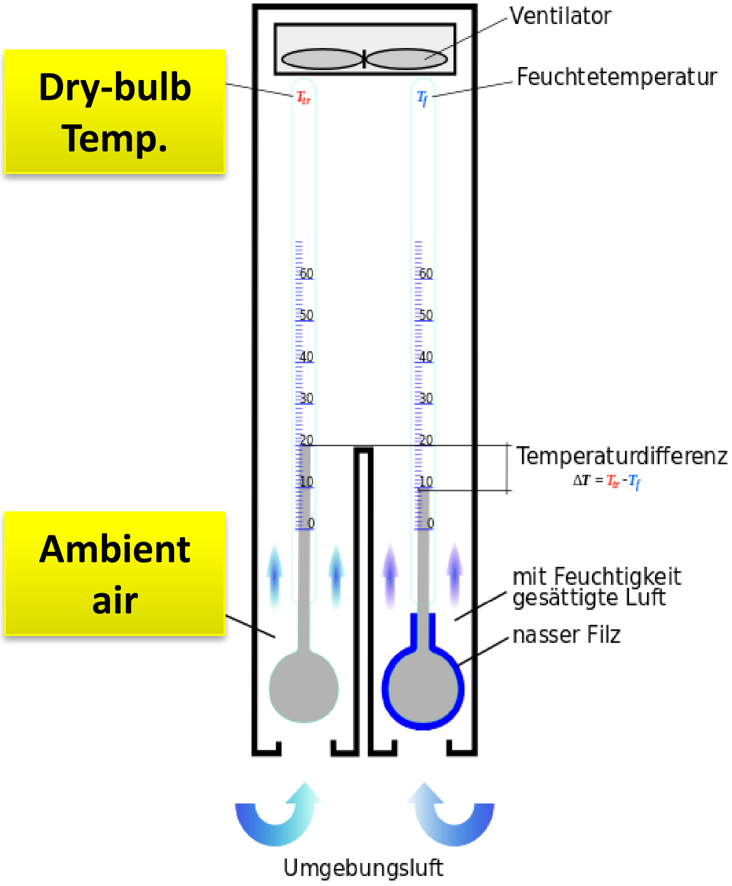
$$RH = \frac{p_m(t)}{p_{ms}(t)}$$

Psychrometry – **Dew points**



- The **dew point** is the **temperature** to which a given parcel of humid air must be cooled, at constant barometric pressure, for water vapor to condense into liquid water. The condensed water is called dew when it forms on a solid surface. The dew point is a saturation temperature.
- The dew point is associated with relative humidity. A high relative humidity indicates that the dew point is closer to the current air temperature. Relative humidity of 100% indicates the dew point is equal to the current temperature and the air is maximally saturated with water. When the dew point remains constant and temperature increases, relative humidity will decrease.

Psychrometry
Dry and wet bulb temperatures


Dry-bulb Temp.

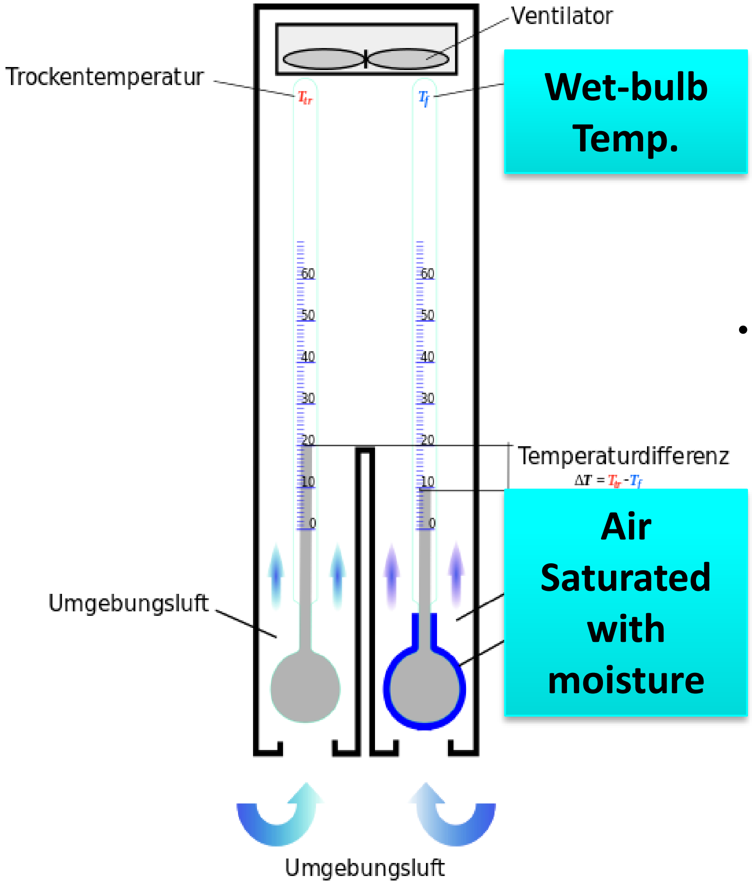
Ambient air

Psychrometer

The dry-bulb temperature is the **temperature of air** measured by a **thermometer** freely exposed to the air but **shielded from radiation and moisture.**

In construction, it is an important consideration when designing a building for a certain climate. It is one of "the most important climate variable for human comfort and building energy efficiency".

Psychrometry
Dry and wet bulb temperatures



Wet-bulb Temp.

Air Saturated with moisture

Psychrometer

- **Wet-bulb temperature** – the temperature read from wet-bulb thermometer;

  Wet-bulb temperature is measured using a thermometer that has its **bulb wrapped in a film that is kept wet with water**. Such an instrument is called, a wet-bulb thermometer.
- At relative humidity's below 100%, water evaporates from the bulb which **cools the bulb below ambient temperature.** To determine relative humidity, ambient temperature is measured using an ordinary thermometer, better known in this context as a dry-bulb thermometer.

  At any given ambient temperature, relative humidity results in a difference between the dry-bulb and wet-bulb temperatures; the wet bulb is colder. The **precise relative humidity** is determined by finding one's **wet-bulb** and **dry-bulb** temperatures on a **psychrometric chart.**

Psychrometry
Specific Enthalpy (*h*)

Moist air is a mixture of dry air and water vapor.
In atmospheric air, water vapor content varies from 0 to 3% by mass.

The **enthalpy of moist and humid air** includes:

- **enthalpy of the dry air** - the **sensible** heat,
- **enthalpy of the evaporated water in the air** - the **latent** heat

The **total enthalpy** - sensible and latent heat - is used when calculating cooling and heating processes.

Psychrometry
Specific Enthalpy of Moist Air (h)

The amount of heat in air is referred to as enthalpy.
Specific enthalpy of moist air can be expressed as:

$$\boxed{h = h_a + g \cdot h_w}$$

where

h - specific enthalpy of moist air **[kJ/kg]**
h_a - specific enthalpy of dry air [kJ/kg]
g - humidity ratio [kg/kg]
h_w - specific enthalpy of water vapor [kJ/kg]

Psychrometry
Specific Enthalpy (*h*)

Heat content per unit mass, is the sum of the internal (heat) energy of the moist air, including the heat of the air and water vapor in it.

$$\boxed{h = c_{pa} \cdot t + g \cdot (c_{pm} \cdot t + r_0)}$$

h – Specific enthalpy of moist air **[kJ/kg]**

c_{pa} – Specific heat of dry air at constant pressure = 1 [kJ/kgK]

c_{pm} – Specific heat of overheated steam at constant pressure = 1.86 [kJ/kgK]

g – humidity ratio [kg/kg]

r_0 – Specific enthalpy of water = 2500 [kJ/kg]

Psychrometry

Specific Enthalpy of Dry Air - Sensible Heat

Assuming constant pressure conditions the specific enthalpy of dry air can be expressed as:

$$\boxed{h_a = c_{pa} \cdot t}$$

where

h_a - specific enthalpy of dry air [kJ/kg]
t - air temperature [C]
c_{pa} - specific heat of air at constant pressure [kJ/kgC]

?

Psychrometry

Specific Heat of Air

At **normal atmospheric pressure** of **1.013 bar** - the **specific heat of dry air** - C_{pa} - will vary with temperature.

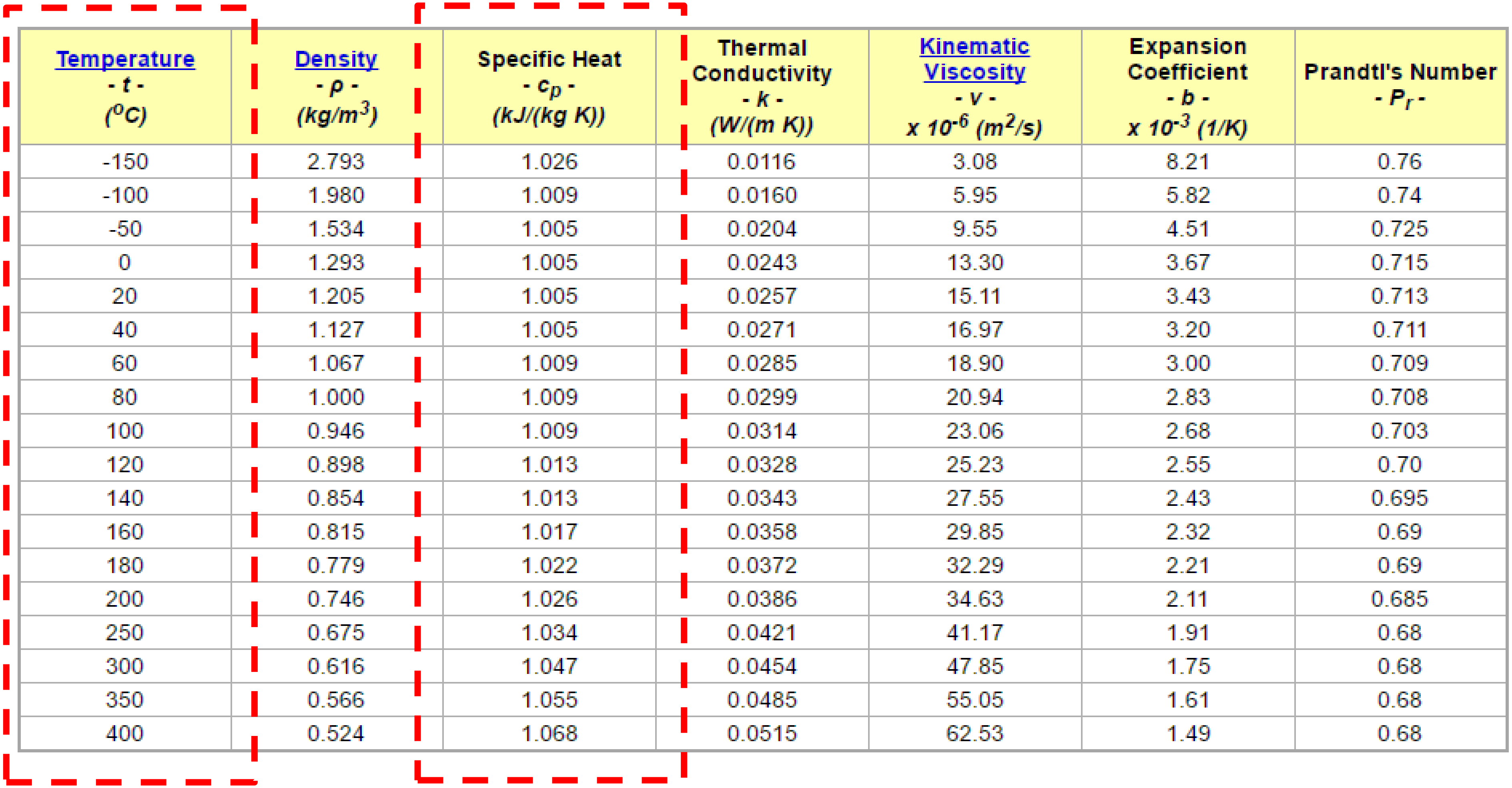
- ***For ordinary calculations*** - a value of specific heat **c_{pa} = 1.0 kJ/kgK** (equal to kJ/kg°C) - is normally accurate enough

- ***For higher accuracy*** - a value of **c_{pa} = 1.006 kJ/kgK** (equal to kJ/kg°C) - is better

- ***For highest accuracy*** - the value of the specific heat of air should be **interpolated to the temperature**

Psychrometry

Specific Heat of Air

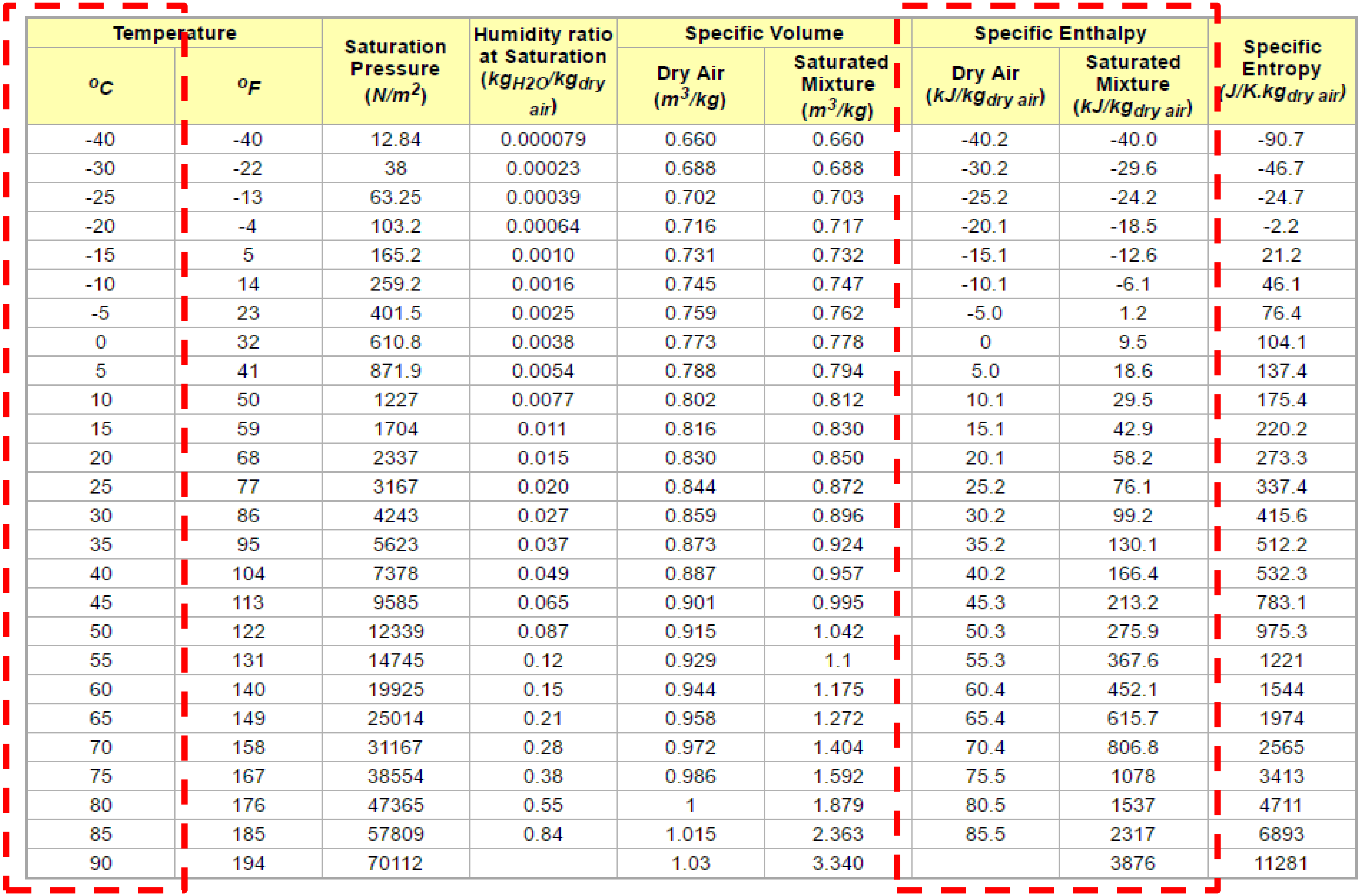


Temperature - t - (^oC)	Density - ρ - (kg/m^3)	Specific Heat - c_p - ($kJ/(kg\ K)$)	Thermal Conductivity - k - ($W/(m\ K)$)	Kinematic Viscosity - ν - $x\ 10^{-6}$ (m^2/s)	Expansion Coefficient - b - $x\ 10^{-3}$ ($1/K$)	Prandtl's Number - P_r -
-150	2.793	1.026	0.0116	3.08	8.21	0.76
-100	1.980	1.009	0.0160	5.95	5.82	0.74
-50	1.534	1.005	0.0204	9.55	4.51	0.725
0	1.293	1.005	0.0243	13.30	3.67	0.715
20	1.205	1.005	0.0257	15.11	3.43	0.713
40	1.127	1.005	0.0271	16.97	3.20	0.711
60	1.067	1.009	0.0285	18.90	3.00	0.709
80	1.000	1.009	0.0299	20.94	2.83	0.708
100	0.946	1.009	0.0314	23.06	2.68	0.703
120	0.898	1.013	0.0328	25.23	2.55	0.70
140	0.854	1.013	0.0343	27.55	2.43	0.695
160	0.815	1.017	0.0358	29.85	2.32	0.69
180	0.779	1.022	0.0372	32.29	2.21	0.69
200	0.746	1.026	0.0386	34.63	2.11	0.685
250	0.675	1.034	0.0421	41.17	1.91	0.68
300	0.616	1.047	0.0454	47.85	1.75	0.68
350	0.566	1.055	0.0485	55.05	1.61	0.68
400	0.524	1.068	0.0515	62.53	1.49	0.68

Specific Enthalpy - Psychrometric table with moist humid air properties

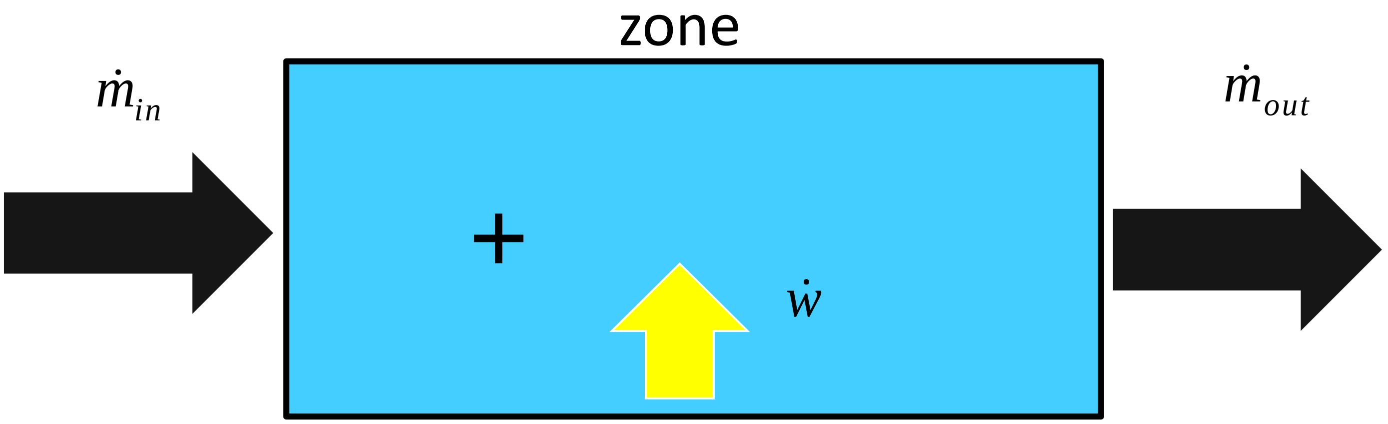
- pressure of water vapor at saturation
- humidity ratio at saturation
- specific volume of dry air
- specific volume of saturated mixture
- specific enthalpy of dry air
- specific enthalpy of saturated mixture
- specific entropy of saturated mixture

of humid air are indicated in the table below:



Temperature		Saturation Pressure (N/m^2)	Humidity ratio at Saturation ($kg_{H2O}/kg_{dry\ air}$)	Specific Volume		Specific Enthalpy		Specific Entropy ($J/K.kg_{dry\ air}$)
°C	°F			Dry Air (m^3/kg)	Saturated Mixture (m^3/kg)	Dry Air ($kJ/kg_{dry\ air}$)	Saturated Mixture ($kJ/kg_{dry\ air}$)	
-40	-40	12.84	0.000079	0.660	0.660	-40.2	-40.0	-90.7
-30	-22	38	0.00023	0.688	0.688	-30.2	-29.6	-46.7
-25	-13	63.25	0.00039	0.702	0.703	-25.2	-24.2	-24.7
-20	-4	103.2	0.00064	0.716	0.717	-20.1	-18.5	-2.2
-15	5	165.2	0.0010	0.731	0.732	-15.1	-12.6	21.2
-10	14	259.2	0.0016	0.745	0.747	-10.1	-6.1	46.1
-5	23	401.5	0.0025	0.759	0.762	-5.0	1.2	76.4
0	32	610.8	0.0038	0.773	0.778	0	9.5	104.1
5	41	871.9	0.0054	0.788	0.794	5.0	18.6	137.4
10	50	1227	0.0077	0.802	0.812	10.1	29.5	175.4
15	59	1704	0.011	0.816	0.830	15.1	42.9	220.2
20	68	2337	0.015	0.830	0.850	20.1	58.2	273.3
25	77	3167	0.020	0.844	0.872	25.2	76.1	337.4
30	86	4243	0.027	0.859	0.896	30.2	99.2	415.6
35	95	5623	0.037	0.873	0.924	35.2	130.1	512.2
40	104	7378	0.049	0.887	0.957	40.2	166.4	532.3
45	113	9585	0.065	0.901	0.995	45.3	213.2	783.1
50	122	12339	0.087	0.915	1.042	50.3	275.9	975.3
55	131	14745	0.12	0.929	1.1	55.3	367.6	1221
60	140	19925	0.15	0.944	1.175	60.4	452.1	1544
65	149	25014	0.21	0.958	1.272	65.4	615.7	1974
70	158	31167	0.28	0.972	1.404	70.4	806.8	2565
75	167	38554	0.38	0.986	1.592	75.5	1078	3413
80	176	47365	0.55	1	1.879	80.5	1537	4711
85	185	57809	0.84	1.015	2.363	85.5	2317	6893
90	194	70112		1.03	3.340		3876	11281

Moisture balance of an internal environment



ρ (kg/m³) – density of the air = 1,2

g_{in} (g/kg) – vapour quantity per unit volume of the entering air

g_{out} (g/kg) – vapour quantity per unit volume of the leaving air

w (g/kg, kg/kg)– moisture arising from internal source

V (m³/h) – volume flow rate of mechanical or natural ventilation

$$\dot{m}_{in} + \dot{w} = \dot{m}_{out}$$

$$\dot{w} = \dot{V} \cdot \left(g_{out} \cdot \rho_{out} - g_{in} \cdot \rho_{in}\right)$$

$$g_{in}\rho_{in}\dot{V}_{in} + \dot{w} = g_{out}\rho_{out}\dot{V}_{out}$$

$$g_{\max} = g_{out} = \left(g_{in} \cdot \rho_{in} + \frac{\dot{w}}{\dot{V}}\right) \div \rho_{out}$$

Moisture balance of an internal environment

Moisture development is the consequence of the **presence and activity of occupants**. Obviously excessive moisture development increases the risk of damage to be imparted to dwellers and operators of the building.

Main moisture sources in residential buildings:

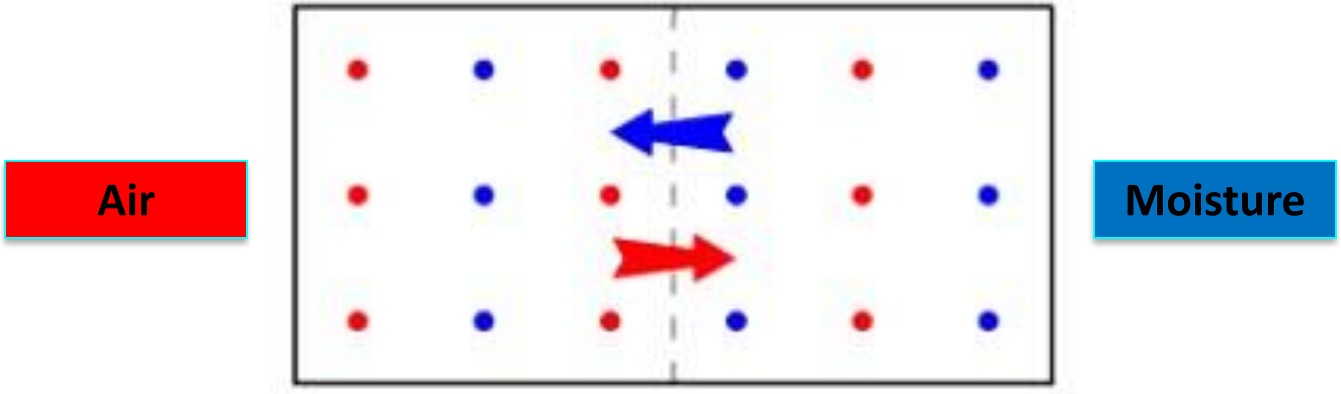
- Occupancy – **40 g/h**, pers, evaporation (breathing)
- Everyday activities: cleaning, washing, showering, drying – **2.5 liters** / pers / week

Most of the moisture arising in the room leaves with the ventilation air. There is also vapour diffusion across walls and floors, however, for moisture balance in a room, the quantity of moisture leaving by diffusion is negligible.

Note, that **saturation limit depends on temperature**, so at a **low temperature** a rather low (absolute) humidity causes a **high relative humidity**, while at a **high temperature**, for a comparatively **low relative humidity** there is a high absolute humidity.

Vapor transfer

Mechanism of vapor transfer

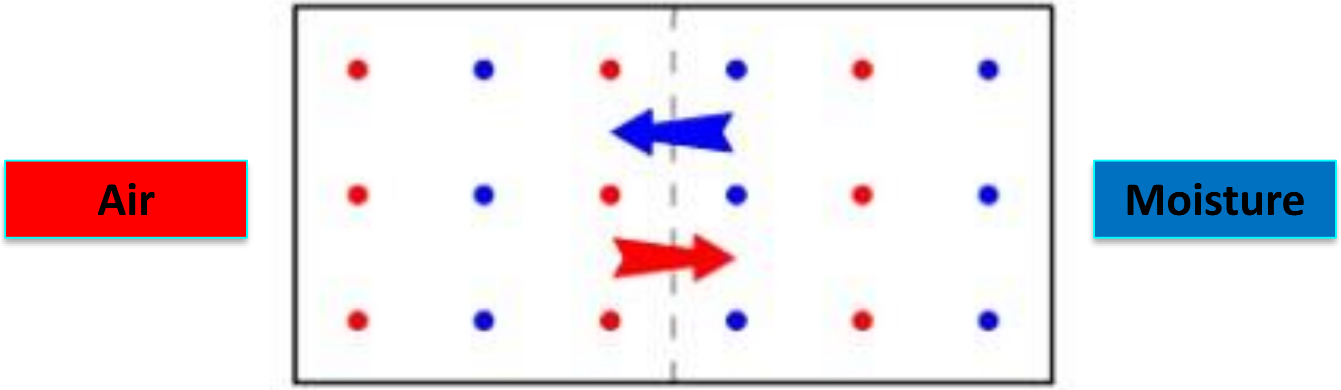


Let us take a box divided by a partition. Let its respective divisions contain different gas mixtures of **air gas** and **moisture** molecules.

The **partial pressure** of the air gas is lower than the partial pressure of the **moisture** gas.

Vapor transfer

Mechanism of vapor transfer



If the partition is not completely tight, **gas molecules can pass through**, then the difference between partial pressures of the air gas starts to flow to the opposite division, and so does moisture gas.

This is the driving mechanism of the vapor diffusion through building elements.

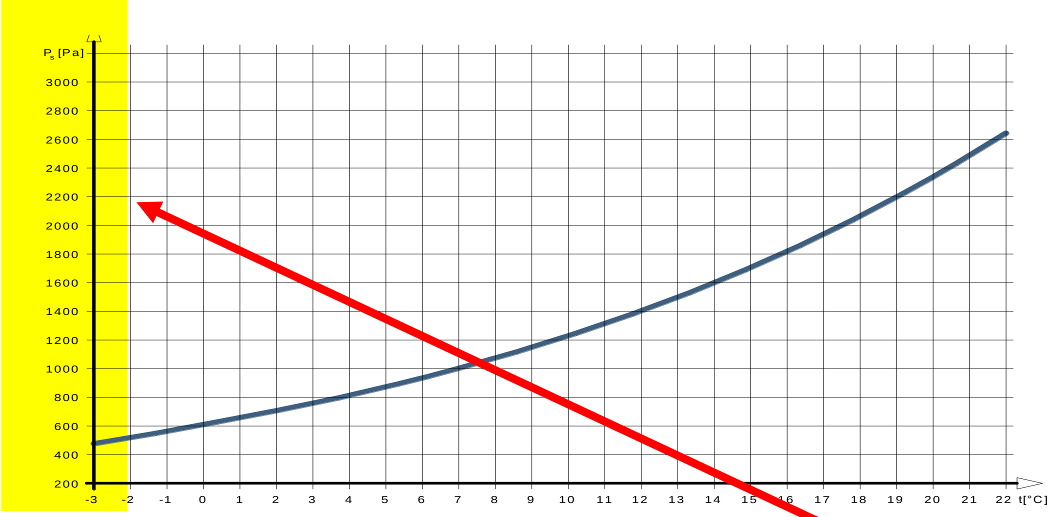
Vapor transfer
Scope of calculation

Water vapor transfer (diffusion) is the movement of water vapor through vapor-permeable materials. Vapor diffusion happens through a solid material even when the material has no holes.

When water vapor diffuses through a **vapor-permeable material**, the **driving force** is either:

- **vapor pressure difference** (in which case the water vapor moves from the zone of higher vapor pressure to the zone of lower vapor pressure) or/and
- **temperature difference** (in which case the water vapor moves from the warm zone to the cold zone).

Vapor transfer
Scope of calculation



Vapor diffusion

- Due to the different indoor and outdoor air conditions, generally there is a **difference between the partial water vapor pressures in indoor and outdoor air**. This pressure difference is the **driving mechanism of vapor flow** (usually called **diffusion**) through permeable building elements.
- Note that only the partial water vapor difference is spoken about. The **barometric pressure of the indoor and outdoor moist air are the same**. Certainly, at **equal barometric pressures, if the vapor pressure is higher inside**, the partial pressure of the dry air is higher outside and in the opposite direction a dry air flow develops.

Vapor transfer
Scope of calculation

The **quantity of vapor**, leaving the room by diffusion is very small in comparison with that, leaving with the **ventilation air**.

However **vapor flow through building elements has to be calculated** in order to check the partial pressure distribution within the element and to prevent **CONDENSATION !**

It follows from the above that vapor diffusion should be analyzed if

- there is a significant **vapor pressure difference** between the indoor space and the environment, and
- there is a significant **temperature difference**.

<u>In practice a steady state vapor flow is calculated</u>. Considering that the vapour diffusion is a very slow process, the mean temperature and the mean relative humidity of the outdoor air in the coldest winter-month are taken as design values.

Vapor transfer
Vapor conductivity and resistance

Vapor conductivity (δ)

Similarly to the heat flow, a **vapor conductivity coefficient** (or vapour diffusion coefficient) as a property of the material can be defined. The vapor conductivity is the vapor flow in time unit at unit pressure difference between to opposite surfaces of a cube of unit size. The **flow is during the calculation considerd always one-dimensional.** The unit of the **diffusion coefficient** is:

$$\left[\frac{g}{s \cdot m \cdot MPa}\right]$$

Vapor transfer
Vapor conductivity and resistance

Vapor resistance (R_v)

The vapor resistance of a material is a measure of the material's reluctance to let water vapor pass through. The vapor resistance takes into account the **material's thickness**, so can only be quoted for a particular thickness of material. It is measured in:

$$R_v = \frac{b}{\delta}\left[\frac{m^2 \cdot s \cdot MPa}{g}\right]$$

Vapor transfer
Overall vapor resistance of multilayers

The resistance of a multilayer element:

$$R = \sum_{j=1}^{n} R_j = \sum_{j=1}^{n} \frac{b_j}{\delta_j}$$

In case of **vapor transport** the surface resistance is very small, in practical calculations it **can be neglected**. Thus, partial pressure at the surface is assumed to be the same as in the air in contact with the **surface**.

$$R_i = 0 \quad R_e = 0$$

Vapor transfer
Overall vapor transfer

- Similarly to the heat transfer distribution, the **moisture transfer** can be calculated on the **basis of the balance condition**: the flow entering the system equals with the flow leaving the system. For multilayer walls.
- For any layer (because of the initial assumption), the above equation can be applied also locally.
- **Partial pressure values** have to be calculated for the **surfaces** and planes **between two layers.** Within one homogeneous layer the pressure distribution is linear.
- Now the designer's task is to check whether the calculated partial pressure values are **below the saturation** values everywhere in the cross section.

$$\boxed{\dot{m}_m = \frac{\Delta p_j}{R_j}}$$

$$\dot{m}_m = \frac{p_{mi} - p_{me}}{R} = \frac{p_{mi} - p_{me}}{\sum_{j=1}^{n} R_j} = \frac{p_{mi} - p_{me}}{\sum_{j=1}^{n} \frac{b_j}{\delta_j}} \left[\frac{g}{m^2 s} \right]$$

p_{mi}	partial water vapor pressure in the indoor air (Pa)	Δp_j	pressure difference between the two boundary planes of j-th layer
p_{me}	partial water vapor pressure in the outdoor air (Pa)	$\dot{m}_m$	Vapor flux (g/m^2,s)

Calculation of moisture transfer
Example

saturated vapor pressure of water

ti=20°C	RHi=65%	Pmsi= 2338 Pa	pmi=0,65*pmsi= 1520 Pa
te=-2°C	RHe=90%	Pmse= 516 Pa	pme=0,90*pmse= 464 Pa

		b m	h W/mK	k W/m^2K	R m^2K/W	ΔT °C	Temperature distribution		δ g/s,mMpa	Rd s,m2,Mpa/g	ΔP Pa	Distr. Part. Press
i	internal convection	-	8		0.125	1.8	$t_{iw}=t_i-\Delta t_i=$	18.2	-	0	0	1520
1	mineral wool	0.05	-	0.057	0.877	12.3	$t_{12}=t_{iw}-\Delta t_1=$	5.9	0.08	0.625	100	1420
2	brick	0.30	-	0.577	0.520	7.3	$t_{23}=t_{12}-\Delta t_2=$	-1.4	0.05	6.000	956	464
e	external convection	-	24		0.042	0.6	$t_e=t_{ew}-\Delta t_e$	-2.00	-	0	0	464
				SumR:	1.564	22.00			SumRd	6.625		
	U=1/SumR				0.639	W/m^2K						
	q = (ti-te) / SumR				14.07	W/m^2	m = (pmi-pme) / sumRd			159.40	g/m2s	

Calculate the partial pressure distribution of a two layer wall!

Heat calculation:

$$R_i=1/h_i;\ R_1=b_1/k_1;\ R_2=b_2/k_2;\ R_e=1/h_e$$

$$\sum R= R_i+ R_1 + R_2 + R_e$$

$$q=(t_i-t_e)/ \sum R$$

$$\Delta t_I=q\cdot R_I;\ \Delta t_1=q\cdot R_1;\ \Delta t_2=q\cdot R_2;\ \Delta t_e=q\cdot R_e$$

Checking: $\sum \Delta t=t_i-t_e$

Partial pressure calculation:

$$R_{d1}=b_1/\delta_1;\ R_{d2}=b_2/\delta_2$$

$$\sum R_d= R_1 + R_2$$

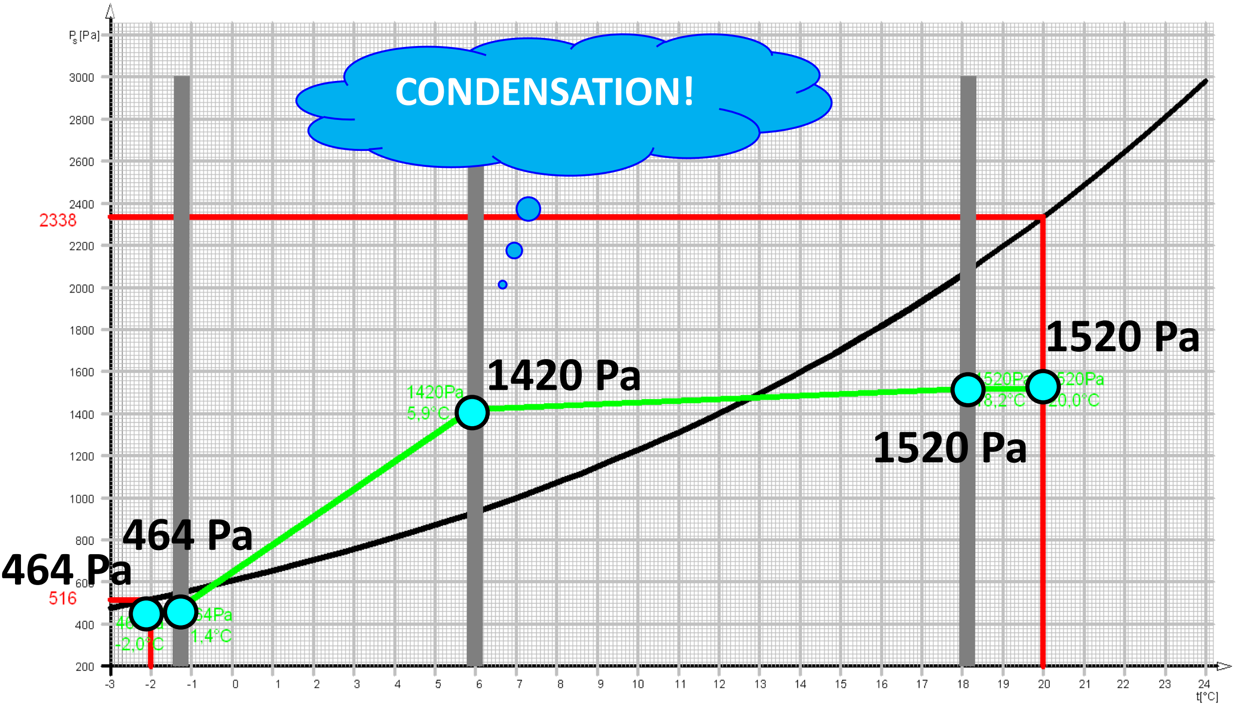
$$p_{mi}= p_{msi} \cdot RH_{i;};\ p_{me}= p_{mse} \cdot RH_e$$

$$m_m=(p_{mi}-p_{me})/ \sum R_d$$

$$\Delta p_I=0;$$

$$\Delta p_1= m_m \cdot R_{d1};\ \Delta p_2=m_m \cdot R_{d2};$$

$$\Delta p_e=0;$$



$t_{iw}=t_i- \Delta t_i;$

$t_{1,2}=t_{iw}- \Delta t_1;$

$t_{ew}=t_{1,2}- \Delta t_2=t_i+ \Delta t_i;$

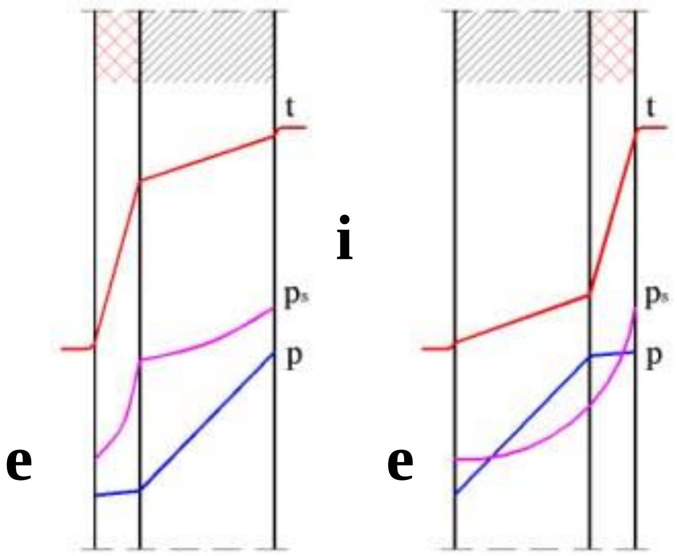
$p_{iw}=p_1 - 0$

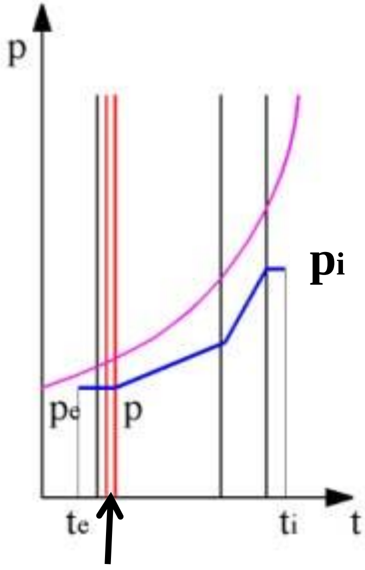
$p_{1,2}=p_{iw}- \Delta p_1$

$p_{ew}=p_{1,2}- \Delta p_2$

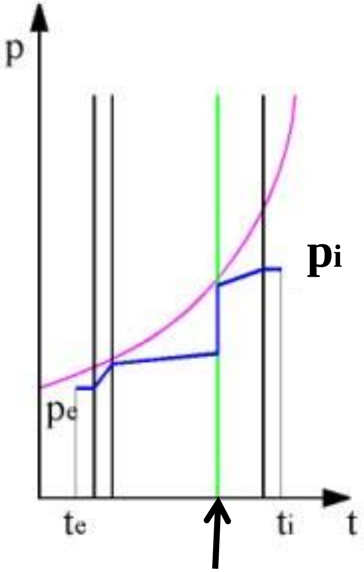
$p_e = p_{ew} - 0$

Vapour transfer
Design consideration





Vented air gap



Vapor retarder film

- The **risk of condensation** is the highest in the outside of the thermal insulation layers.
- **Thermal insulation** materials have high resistance against heat flow (->big temperature drop), but their **resistance against vapor flow is usually small**. The opposite relates to the materials of load-bearing and outside surface coatings layers. This is, why calculated partial pressure is near to the saturation value in the outside of the thermal insulation layer: the temperature is low, the partial pressure is high.
- The **risk of condensation can be prevented** if the **thermal insulation is outside** (the whole cross section is kept warm, the only problem is the resistance of the outside surface coating) - there is a slightly ventilated air gap between the outside surface coating and the thermal insulation - in this **air gap** the partial pressure is practically the same as in the outdoor air, if the thickness of the **air gap is min. 2 cm** and it is really vented there is a **vapor barrier** in the construction (a special **thin layer**) **having high resistance**.

Psychrometric Chart ASHRAE

A psychrometric chart is a graph of the physical properties of moist air at a constant pressure. The chart graphically expresses how various properties relate to each other, and is thus a graphical 'equation of state'. The thermophysical properties found on most psychrometric charts are:

Dry-bulb temperature is that of an air sample, as determined by an ordinary thermometer, the thermometer's bulb being dry.

Wet-bulb temperature is that of an air sample after it has passed through a constant-pressure, ideal adiabatic saturation process, that is, after the air has passed over a large surface of liquid water in an insulated channel. In practice, this is the reading of a thermometer whose sensing bulb is covered with a wet sock evaporating into a rapid stream of the sample air.

Dew point temperature is that at which a moist air sample at the same pressure would reach water vapor saturation. At this saturation point, water vapor would begin to condense into liquid water fog or (if below freezing) solid hoarfrost, as heat is removed. The dewpoint temperature is measured easily and provides useful information, but is normally not considered an independent property. It duplicates information available via other humidity properties and the saturation curve.

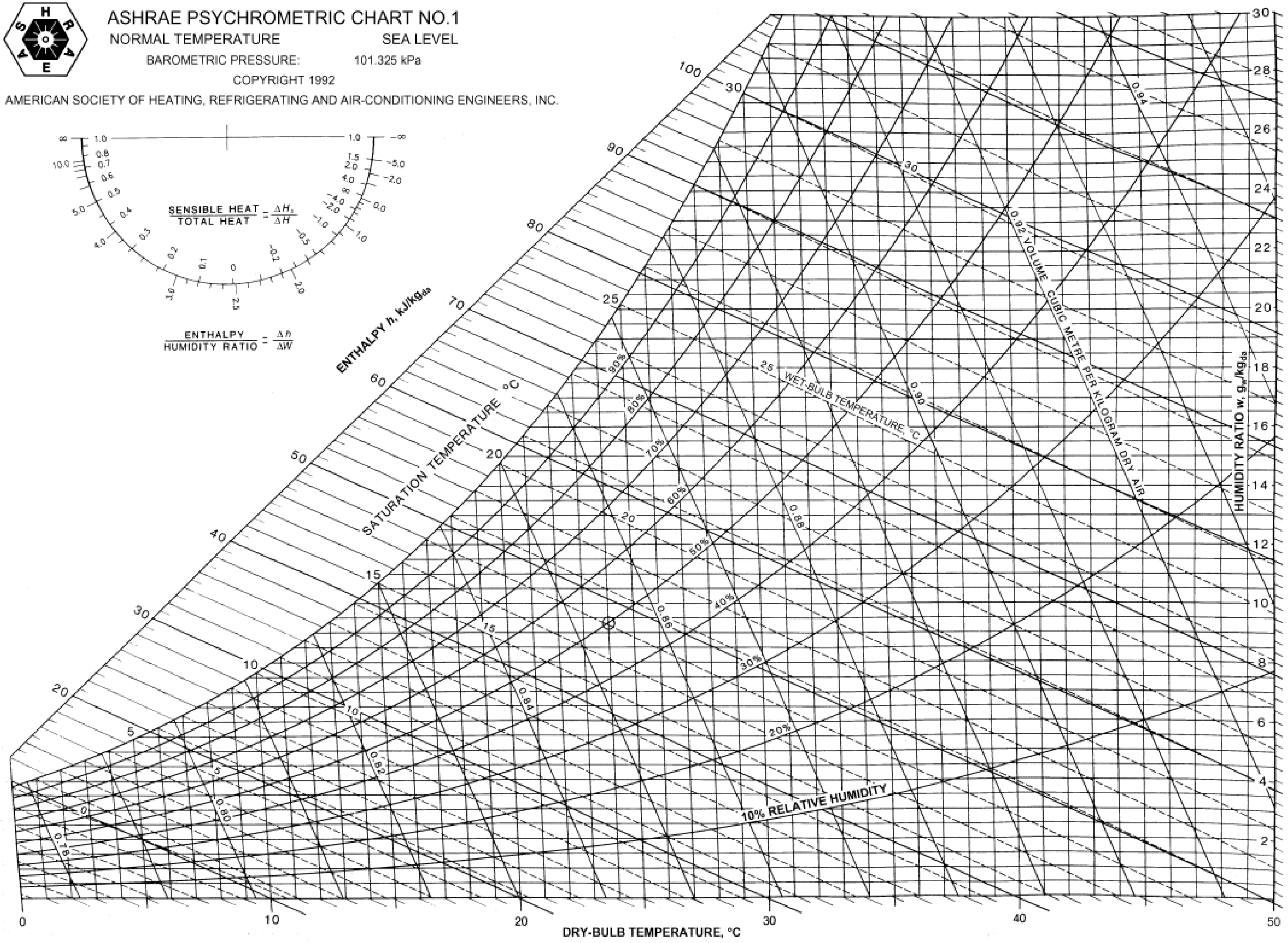
Relative Humidity is the ratio of the mole fraction of water vapor to the mole fraction of saturated moist air at the same temperature and pressure. The notion that air "holds" moisture, or that moisture dissolves in dry air and saturates the solution at some proportion, is an erroneous (although widespread) concept.

Humidity Ratio is the proportion of mass of moisture present in a unit mass of air at the given conditions (DBT, WBT, DPT, RH, etc.).

Specific Enthalpy symbolized by h, also called heat content per unit mass, is the sum of the internal energy of a thermodynamic system. These values correspond to the saturated state and are to be read parallel to WBT values.

Specific Volume, also called Inverse Density. Volume per unit mass.

The versatility of the psychrometric chart lies in the fact that by knowing two independent properties of some moist air, one of which is the chart's pressure, the other properties can be determined. Changes in state, such as when two air streams mix, can be modeled easily and somewhat graphically using the correct psychrometric chart for the location's air pressure or elevation relative to sea level. For locations at or below 2000 ft (600 m), a common assumption is to use the sea level psychrometric chart.



ASHRAE PSYCHROMETRIC CHART NO.1

NORMAL TEMPERATURE SEA LEVEL

BAROMETRIC PRESSURE: 101.325 kPa

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.