Air Conditioning
&
Refrigeration

Lectures

Definitions and Moist Air Properties

:

Definitions:

Air conditioning: Is the science and practice of controlling the indoor climate in term of temperature , air motion , humidity , air purity and noise.

Refrigeration: Is the process of removing the undesirable heat from a given body to maintain it at a desired lower temperature than its environment.

Heating:

Is the transfer of heat to a space by virtue of a difference in temperature between the source and the space. This process may take by different forms such as direct radiation and free convection to the space.

Cooling:

Is the transfer of heat from a space to a space by virtue of difference in temperature between the source and the space. In the usual cooling process air is circulated over a surface maintained at a low temperature.

Humidification:

Is the transfer of water vapor to atmospheric air. Mass transfer is associated with heat transfer which causes an increase in the concentration of water vapor in the air.

Dehumidification:

Is the transfer of water vapor from atmospheric air which lead to lower the concentration of water in the air. This process is mostly accomplished by circulating the air over a surface maintained at a sufficiently low temperature to cause the condensation of water vapor from the mixture.

Cleaning:

The cleaning of air usually implies filtering the air to remove contaminant gases from air. Filtering is most often done by several types of filters.

Air motion*:*

The motion of air in the vicinity of the occupant should be sufficiently gentle to create uniform comfort conditions in the space.

Moist air :

Working substance in air conditioning is the moist air which is a mixture of two gases . One of these is dry air which itself is a mixture of a number of gases and the other is water vapor which may exist in a saturated or super heated state. Both are treated as perfect gases since both exist in the atmosphere at low pressures. In addition Gibbs-Dalton laws for non reactive mixture of gases can be applied to the dry air part only to obtain its properties as a single pure substance.

$T_1 = T_2 = T$

$V_1 = V_2 = V$

$P_1 + P_2 = P$

$m_1 + m_2 = m$

$P_1 . V_1 = m_1 . R . T_1$ & $P_2 . V_2 = m_2 . R . T_2$

$P_t = P_a + P_v$

$m_1 . h_1 + m_2 . h_2 = m . h$

Properties of moist air:

The properties of moist air are called psychrometric properties and the subject which deals with the behavior of moist air is known as psychrometry. In air conditioning practice all calculations on the dry air part since the water vapor part is continuously variable. The actual temperature of moist air is called the dry bulb temperature DBT . The total pressure which is equal to the barometric pressure is constant. The other relevant properties are :

Humidity ratio (ω), Relative Humidity (ϕ), Dew Point Temperature (DPT), Enthalpy (h), Specific Heat ($C_{p.h}$), and Wet Bulb Temperature (WBT).

Humidity ratio or moisture content (ω):

$\omega = m.v/m_a = 0.622 * P_v/P_a = 0.622 * P_v/(P_t - P_v)$, and P_v is:

$P_v = P_s - P_{at} * A * (DBT - WBT)$

Where A is constant =6.66 E-4 1/°C, and

P_{at}= atmospheric pressure.

Relative humidity (RH):

$RH = \Phi \% = V_s/V_v = P_v/P_s$

Dew Point Temperature (DPT or T_d):

Is the temperature of saturated moist air at which the first drop of dew will be formed the moist air is cooled at constant pressure i.e. the water vapor in the mixture will start condensing.

Enthalpy of moist air (h):

$h = h_a + \omega . h_v$ where, $h_a = C_{p.a}\, T = 1.005\, T$ and,

$h_v = C_{p.w}\, T_d + h_{f.g} + C_{p.v}\, (T - T_d)$ at $T_d = 0.0$, Then:

$h_v = 2501 + C_{p.v}\, T = 2501 + 1.84\, T$, so that:

$h = 1.005\, T + \omega\, (2501 + 1.84\, T)$

Humid specific heat (Cph):

$C_{p.h} = C_{p.a} + \omega * C_{p.v}$

Density of moist air (ρ):

It is the ratio of total mass of moist air to the volume:

$\rho = (m_a + m_v) / V$

Wet bulb temperature (WBT):

Is the temperature of moist air reads by a wicked bulb thermometer with its wick is wetted by water.

Latent heat (Q_L) :

Is the heat added or removed from the moist air at constant DBT i.e. increases or decreases its moisture contents.

Sensible heat (Q_s):

Is the heat added or removed from the moist air at constant moisture content.

Applications of air conditioning and refrigeration:

- Residential and industrial air conditioning.
- Air conditioning of vehicles.
- Food processing, storage and distribution.
- Chemical process in industries.
- Special applications of refrigeration.

Examples:

1- Calculate the vapor pressure of moist air at a state of DBT = 20 ºC , WBT = 15 ºC and $P_{a.t}$ = 95 kPa.

Solution : from steam tables for Pat = 101.3 kPa the saturation pressure is Ps = 1.704 kPa at WBT = 15 ºC.
Use the equation of vapor pressure :

$P_v = P_s - P_{a.t} * A * (DBT - WBT)$

$P_v = 1.704 - 6.66 E{-4} * 95. * (20 - 15)$, then:

P_v = 1.388 kPa.

2- Calculate the relative humidity of moist air the state condition of example 1 .

Solution: at DBT = 20 ºC the saturated pressure P_s = 2.337 kPa therefore Φ % = P_v/P_s =1.388/2.337 Φ = 59.5 % .

3- Calculate the moisture content of moist air at the same state condition of example 1.

Solution: $\omega = 0.622 (P_v / P_a)$ and

$P_a = P_{a.t} - P_v = 95. - 1.388$

Then ω = 0.00923 kg water vapor / kg dry air.

4- Calculate the dew point of moist air at the same state condition of example 1.

Solution: The dew point temperature corresponding to P_v=1.388 kPa is about 12 ºC from the steam table.

4- Calculate the specific volume of moist air at similar state of previous examples .

Solution : use the ideal gas law to the dry air alone .

$V_a = m_a . R_a . T_a / P_a$

$P_a = P_{at} - P_v$; P_a =95000-1388 =93612 Pa

Then V_a = 1. * 287 *(273+20) / 93612 = 0.898 m^3

Consider water vapor mixed with the dry air.

$V_v = m_v . R_v . T_v / P_v$

V_v = 0.00923 *461 * (273 + 20) / 1388 = 0.898 m^3; where for one kg of dry air $\omega = m_v$ =0.00923 $kg_{w.v}/kg_{d.a}$ It can be seen that the volume of dry air and that of water vapor are the same as explain earlier $V = V_a = V_v$.

5- Calculate the approximate enthalpy of humid air at DBT = 20 ºC and WBT = 15 ºC and 101.325 kPa .

h=1.005 * 20+0.00923 * (2501+1.84 * 20)=43.5 kJ/kg

Home Work:

Use steam table & equations for moist air, at DBT=35 ºC, WBT=23 ºC and Pa=101.35 kPa, calculate the followings:

(i) RH

(ii) ω,

(iii) DPT,

(iv) Enthalpy ,

(v) Specific Vol.

Saturated Water and Steam

t	p_s	v_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
0·01	0·006112	206·1	0*	2500·8	2500·8	0†	9·155	9·155
1	0·006566	192·6	4·2	2498·3	2502·5	0·015	9·113	9·128
2	0·007054	179·9	8·4	2495·9	2504·3	0·031	9·071	9·102
3	0·007575	168·2	12·6	2493·6	2506·2	0·046	9·030	9·076
4	0·008129	157·3	16·8	2491·3	2508·1	0·061	8·989	9·050
5	0·008719	147·1	21·0	2488·9	2509·9	0·076	8·948	9·024
6	0·009346	137·8	25·2	2486·6	2511·8	0·091	8·908	8·999
7	0·01001	129·1	29·4	2484·3	2513·7	0·106	8·868	8·974
8	0·01072	121·0	33·6	2481·9	2515·5	0·121	8·828	8·949
9	0·01147	113·4	37·8	2479·6	2517·4	0·136	8·788	8·924
10	0·01227	106·4	42·0	2477·2	2519·2	0·151	8·749	8·900
11	0·01312	99·90	46·2	2474·9	2521·1	0·166	8·710	8·876
12	0·01401	93·83	50·4	2472·5	2522·9	0·180	8·671	8·851
13	0·01497	88·17	54·6	2470·2	2524·8	0·195	8·633	8·828
14	0·01597	82·89	58·8	2467·8	2526·6	0·210	8·594	8·804
15	0·01704	77·97	62·9	2465·5	2528·4	0·224	8·556	8·780
16	0·01817	73·38	67·1	2463·1	2530·2	0·239	8·518	8·757
17	0·01936	69·09	71·3	2460·8	2532·1	0·253	8·481	8·734
18	0·02063	65·08	75·5	2458·4	2533·9	0·268	8·444	8·712
19	0·02196	61·34	79·7	2456·0	2535·7	0·282	8·407	8·689
20	0·02337	57·84	83·9	2453·7	2537·6	0·296	8·370	8·666
21	0·02486	54·56	88·0	2451·4	2539·4	0·310	8·334	8·644
22	0·02642	51·49	92·2	2449·0	2541·2	0·325	8·297	8·622
23	0·02808	48·62	96·4	2446·6	2543·0	0·339	8·261	8·600
24	0·02982	45·92	100·6	2444·2	2544·8	0·353	8·226	8·579
25	0·03166	43·40	104·8	2441·8	2546·6	0·367	8·190	8·557
26	0·03360	41·03	108·9	2439·5	2548·4	0·381	8·155	8·536
27	0·03564	38·81	113·1	2437·2	2550·3	0·395	8·120	8·515
28	0·03778	36·73	117·3	2434·8	2552·1	0·409	8·085	8·494
29	0·04004	34·77	121·5	2432·4	2553·9	0·423	8·050	8·473
30	0·04242	32·93	125·7	2430·0	2555·7	0·436	8·016	8·452
32	0·04754	29·57	134·0	2425·3	2559·3	0·464	7·948	8·412
34	0·05318	26·60	142·4	2420·5	2562·9	0·491	7·881	8·372
36	0·05940	23·97	150·7	2415·8	2566·5	0·518	7·814	8·332
38	0·06624	21·63	159·1	2411·0	2570·1	0·545	7·749	8·294
40	0·07375	19·55	167·5	2406·2	2573·7	0·572	7·684	8·256
42	0·08198	17·69	175·8	2401·4	2577·2	0·599	7·620	8·219
44	0·09100	16·03	184·2	2396·6	2580·8	0·625	7·557	8·182
46	0·1009	14·56	192·5	2391·8	2584·3	0·651	7·494	8·145
48	0·1116	13·23	200·9	2387·0	2587·9	0·678	7·433	8·111
50	0·1233	12·04	209·3	2382·1	2591·4	0·704	7·371	8·075
55	0·1574	9·578	230·2	2370·1	2600·3	0·768	7·223	7·991
60	0·1992	7·678	251·1	2357·9	2609·0	0·831	7·078	7·909
65	0·2501	6·201	272·0	2345·7	2617·7	0·893	6·937	7·830
70	0·3116	5·045	293·0	2333·3	2626·3	0·955	6·800	7·755
75	0·3855	4·133	313·9	2320·8	2634·7	1·015	6·666	7·681
80	0·4736	3·408	334·9	2308·3	2643·2	1·075	6·536	7·611
85	0·5780	2·828	355·9	2295·6	2651·5	1·134	6·410	7·544
90	0·7011	2·361	376·9	2282·8	2659·7	1·192	6·286	7·478
95	0·8453	1·982	398·0	2269·8	2667·8	1·250	6·166	7·416
100	1·01325	1·673	419·1	2256·7	2675·8	1·307	6·048	7·355

† u and s are chosen to be zero for saturated *liquid* at the triple point

$$* \; h_f = p[\text{bar}] \times 10^5 \left[\frac{\text{N/m}^2}{\text{bar}}\right] \times v_f \left[\frac{\text{m}^3}{\text{kg}}\right] \times 10^{-3} \left[\frac{\text{kNm}}{\text{Nm}} \text{ or } \frac{\text{kJ}}{\text{J}}\right]$$
$$= p v_f \times 10^2 = 0{\cdot}006112 \times 0{\cdot}0010002 \times 10^2 = 0{\cdot}0006112 \text{ kJ/kg}$$

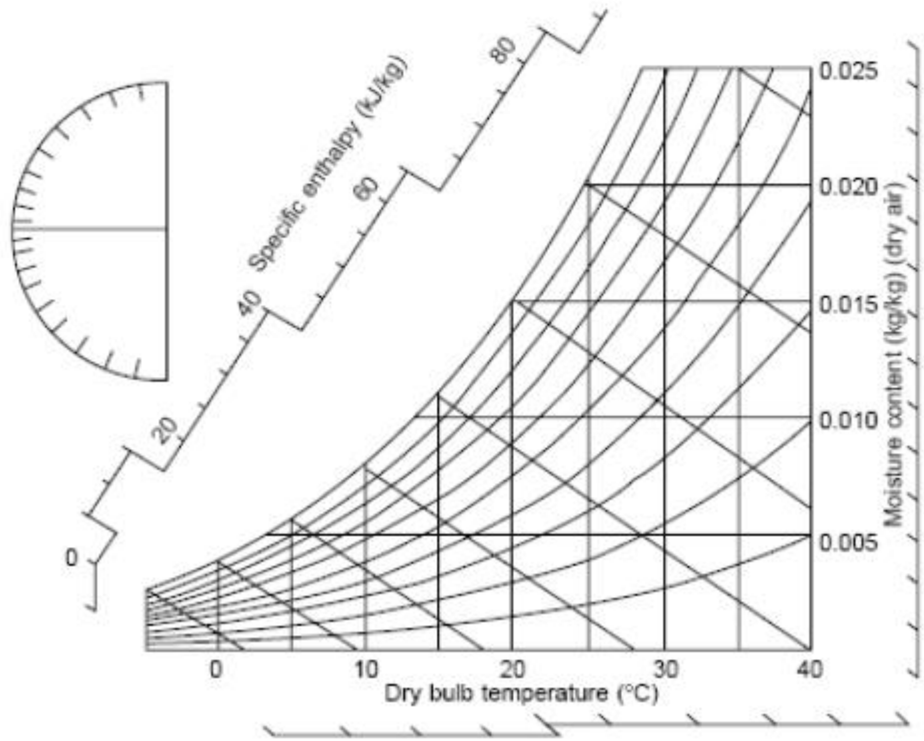
Saturated Water and Steam

p	t_s	v_g	u_f	u_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g
0·006112	0·01	206·1	0†	2375	0*	2501	2501	0†	9·155	9·155
0·010	7·0	129·2	29	2385	29	2485	2514	0·106	8·868	8·974
0·015	13·0	87·98	55	2393	55	2470	2525	0·196	8·631	8·827
0·020	17·5	67·01	73	2399	73	2460	2533	0·261	8·462	8·723
0·025	21·1	54·26	88	2403	88	2451	2539	0·312	8·330	8·642
0·030	24·1	45·67	101	2408	101	2444	2545	0·354	8·222	8·576
0·035	26·7	39·48	112	2412	112	2438	2550	0·391	8·130	8·521
0·040	29·0	34·80	121	2415	121	2433	2554	0·422	8·051	8·473
0·045	31·0	31·14	130	2418	130	2428	2558	0·451	7·980	8·431
0·050	32·9	28·20	138	2420	138	2423	2561	0·476	7·918	8·394
0·055	34·6	25·77	145	2422	145	2419	2564	0·500	7·860	8·360
0·060	36·2	23·74	152	2425	152	2415	2567	0·521	7·808	8·329
0·065	37·7	22·02	158	2427	158	2412	2570	0·541	7·760	8·301
0·070	39·0	20·53	163	2428	163	2409	2572	0·559	7·715	8·274
0·075	40·3	19·24	169	2430	169	2405	2574	0·576	7·674	8·250
0·080	41·5	18·10	174	2432	174	2402	2576	0·593	7·634	8·227
0·085	42·7	17·10	179	2434	179	2400	2579	0·608	7·598	8·206
0·090	43·8	16·20	183	2435	183	2397	2580	0·622	7·564	8·186
0·095	44·8	15·40	188	2436	188	2394	2582	0·636	7·531	8·167
0·100	45·8	14·67	192	2437	192	2392	2584	0·649	7·500	8·149
0·12	49·4	12·36	207	2442	207	2383	2590	0·696	7·389	8·085
0·14	52·6	10·69	220	2446	220	2376	2596	0·737	7·294	8·031
0·16	55·3	9·432	232	2450	232	2369	2601	0·772	7·213	7·985
0·18	57·8	8·444	242	2453	242	2363	2605	0·804	7·140	7·944
0·20	60·1	7·648	251	2456	251	2358	2609	0·832	7·075	7·907
0·22	62·2	6·994	260	2459	260	2353	2613	0·858	7·016	7·874
0·24	64·1	6·445	268	2461	268	2348	2616	0·882	6·962	7·844
0·26	65·9	5·979	276	2464	276	2343	2619	0·904	6·913	7·817
0·28	67·5	5·578	283	2466	283	2339	2622	0·925	6·866	7·791
0·30	69·1	5·228	289	2468	289	2336	2625	0·944	6·823	7·767
0·32	70·6	4·921	295	2470	295	2332	2627	0·962	6·783	7·745
0·34	72·0	4·649	302	2472	302	2328	2630	0·980	6·745	7·725
0·36	73·4	4·407	307	2473	307	2325	2632	0·996	6·709	7·705
0·38	74·7	4·189	312	2475	312	2322	2634	1·011	6·675	7·686
0·40	75·9	3·992	318	2476	318	2318	2636	1·026	6·643	7·669
0·42	77·1	3·814	323	2478	323	2315	2638	1·040	6·612	7·652
0·44	78·2	3·651	327	2479	327	2313	2640	1·054	6·582	7·636
0·46	79·3	3·502	332	2481	332	2310	2642	1·067	6·554	7·621
0·48	80·3	3·366	336	2482	336	2308	2644	1·079	6·528	7·607
0·50	81·3	3·239	340	2483	340	2305	2645	1·091	6·502	7·593
0·55	83·7	2·964	351	2486	351	2298	2649	1·119	6·442	7·561
0·60	86·0	2·731	360	2489	360	2293	2653	1·145	6·386	7·531
0·65	88·0	2·535	369	2492	369	2288	2657	1·169	6·335	7·504
0·70	90·0	2·364	377	2494	377	2283	2660	1·192	6·286	7·478
0·75	91·8	2·217	384	2496	384	2278	2662	1·213	6·243	7·456
0·80	93·5	2·087	392	2498	392	2273	2665	1·233	6·201	7·434
0·85	95·2	1·972	399	2500	399	2269	2668	1·252	6·162	7·414
0·90	96·7	1·869	405	2502	405	2266	2671	1·270	6·124	7·394
0·95	98·2	1·777	411	2504	411	2262	2673	1·287	6·089	7·376
1·00	99·6	1·694	417	2506	417	2258	2675	1·303	6·056	7·359

Psychrometric Chart:

All data essential for the complete thermodynamic and psychrometric analysis of air conditioning processes can be summarized in a psychrometric chart.

PSYCHROMETRIC CHART
Based on a barometric pressure of 101.325 kPa
Sensible/total heat ratio for water added at 30°C
Specific enthalpy (kJ/kg)
Wet bulb temperature (°C) (sling)
Specific volume (m^3/kg)
Percentage saturation
Dry bulb temperature (°C)
Specific enthalpy (kJ/kg)
Moisture content (kg/kg) (dry air



The chart which is most commonly used is ω vs. DBT. The chart is normally constructed for a standard atmospheric pressure of 101.325 kPa corresponding to the pressure at the mean sea level. The saturation line on the chart is the line of 100% RH and for all points on this line $P_v = P_s$.

Similarly one can show the lines of constant thermodynamic Wet bulb temperature, constant specific enthalpy and constant specific volume. The particular psychrometric chart given in the figure is for normal DBT range of 0 ºC to 50 ºC and humidity ratios of 0.0 to 0.03 kg/kg dry air. Psychrometric charts for other conditions such as subzero or high temperature can also be prepared.

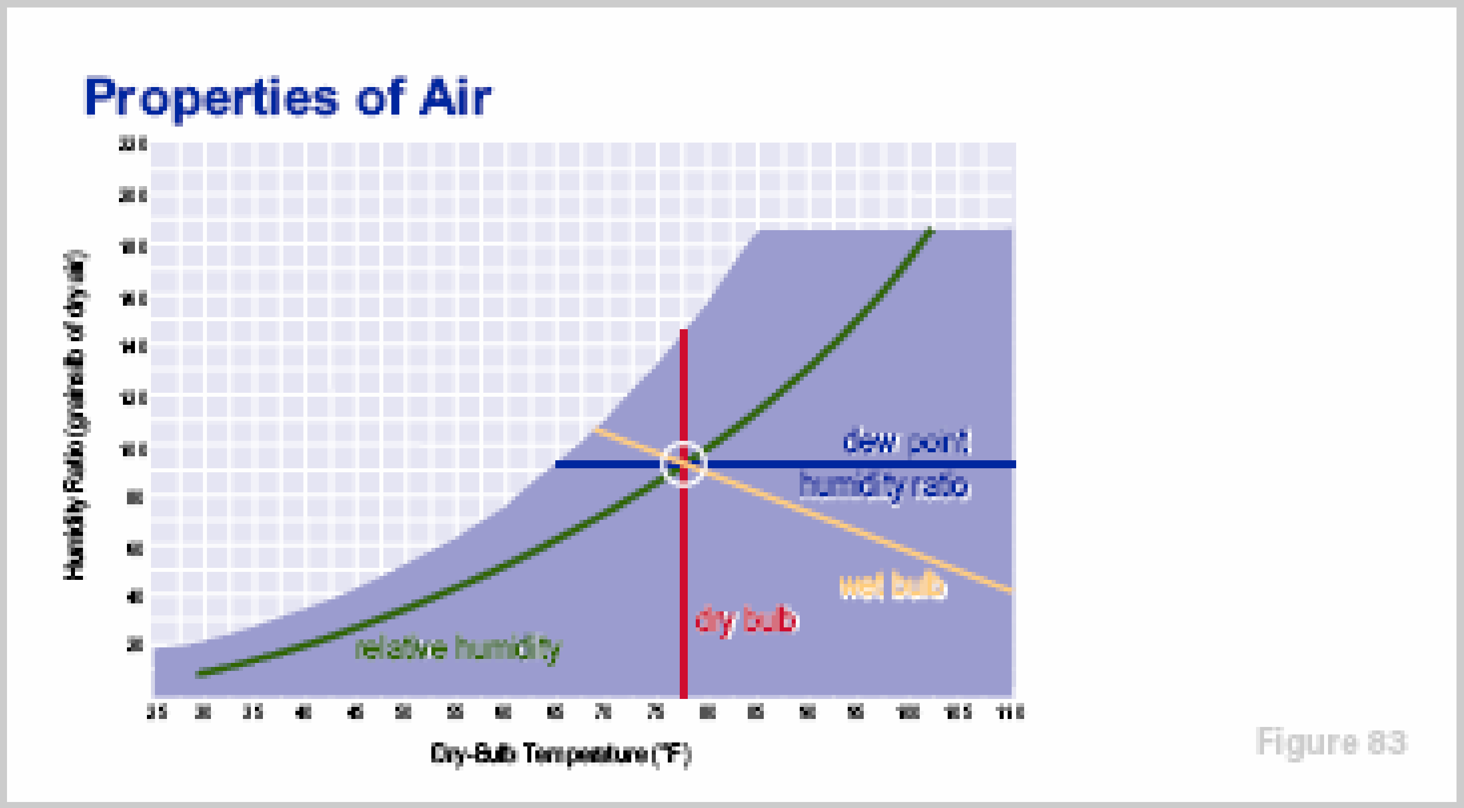


Figure 83

The lines of the psychrometric chart represent five physical properties of air: **dry bulb, wet bulb, dew point, humidity ratio,** and **relative humidity.** If any two of these properties are known, the remaining properties can be determined from the chart.

Examples :

1- A sample of moist air has a DBT of 43 ºC and WBT of 29 ºC , find using the psych. chart the following :

a- Specific humidity
b- Relative humidity
c- Dew point temperature
d- Specific enthalpy
e- Specific volume.

2- A sample of moist air has DBT of 24 ºC and at a saturation state , find using Psych. chart :

a- Specific humidity
b- Relative humidity
c- Dew point temperature
d- Specific enthalpy
e- Specific volume.

3- A sample of moist air has DBT of 30 ºC and with dry state , find the following using psych. chart .

a- Specific humidity

b- Relative humidity

c- Dew point temperature

d- Specific enthalpy

e- Specific volume.

4- A sample of moist air has a DBT of 35 ºC and WBT of 15 ºC at P_a=101.325 kPa, find using psych. chart the following:

a- Specific humidity

b- Relative humidity

c- Dew point temperature

d- Specific enthalpy

e- Specific volume.

Thank You

Air Conditioning

&

Refrigeration

Lectures

Air Conditioning Processes

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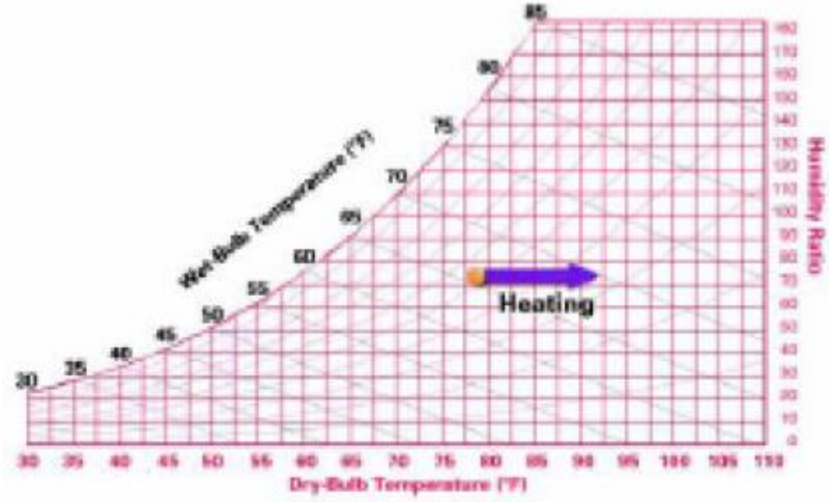
Air conditioning processes:

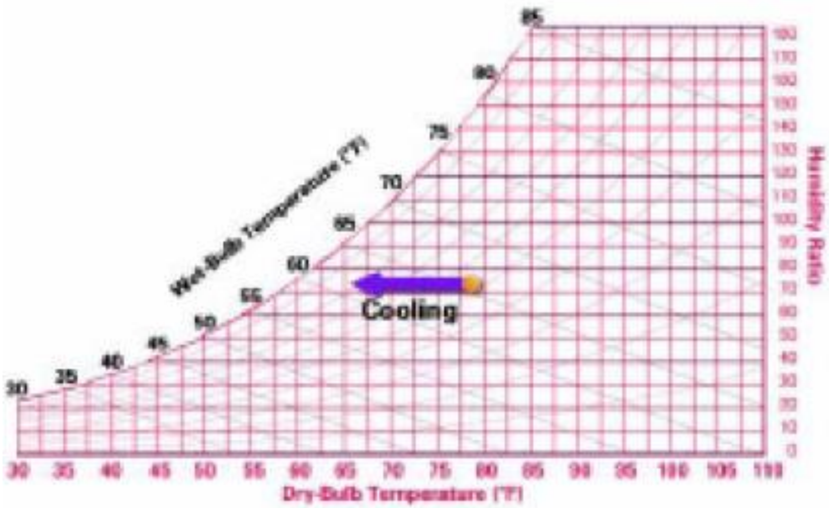
- **Sensible Heating**

If sensible heat is added to air, the air condition moves horizontally to the right.



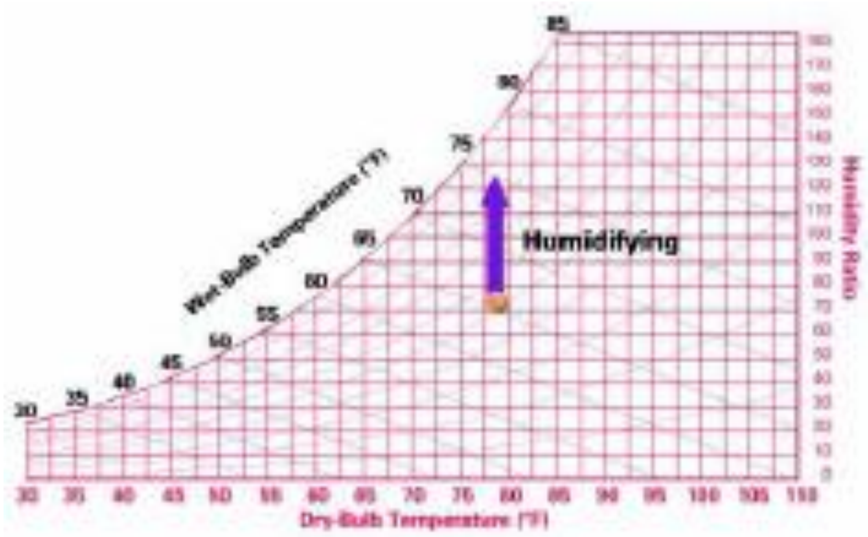
- **Sensible Cooling**

If sensible heat is removed from air, the air condition moves horizontally to the left.



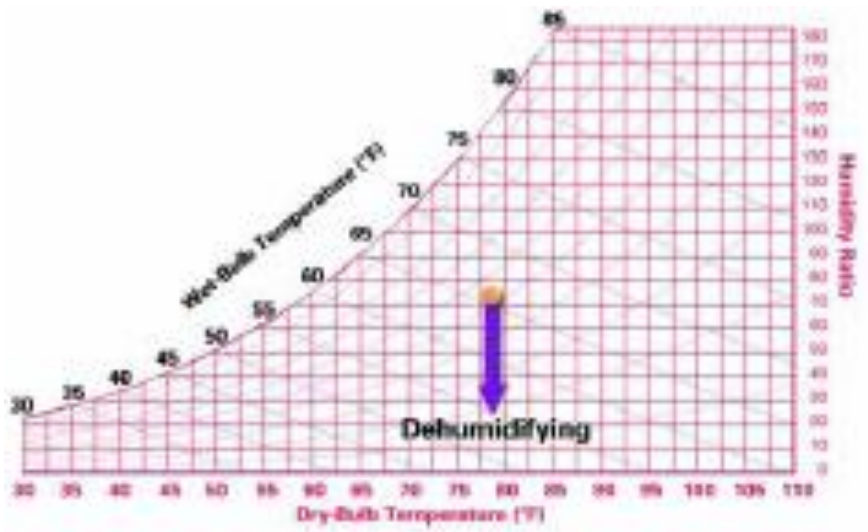
- **Humidification**

If moisture is added to air without changing the dry bulb temperature, the air condition moves upward along the dry bulb temperature line.



- **Dehumidification**

If moisture is removed from Air without changing the dry bulb temperature, the air condition moves upward along the dry bulb temperature line.

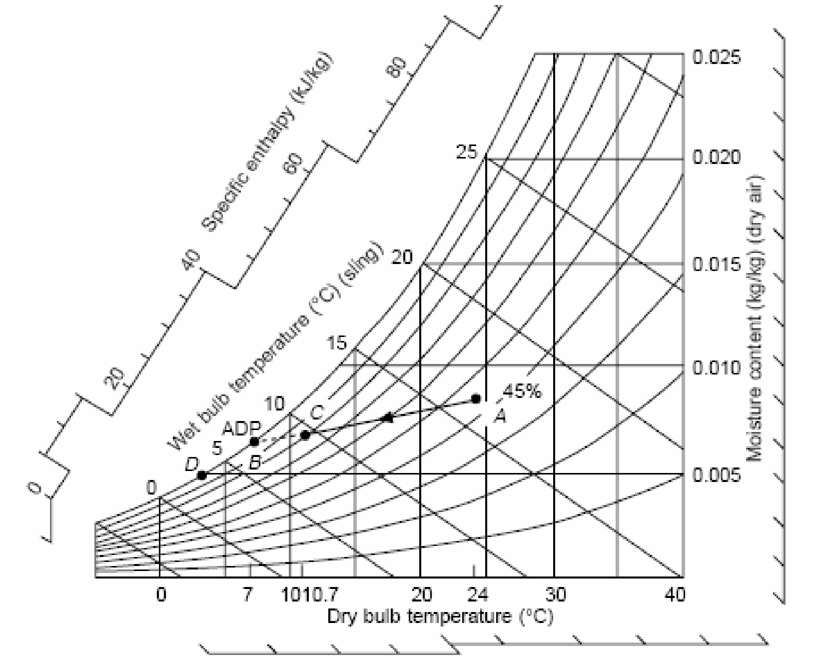


There are several methods that may be used to carry out the dehumidification process:

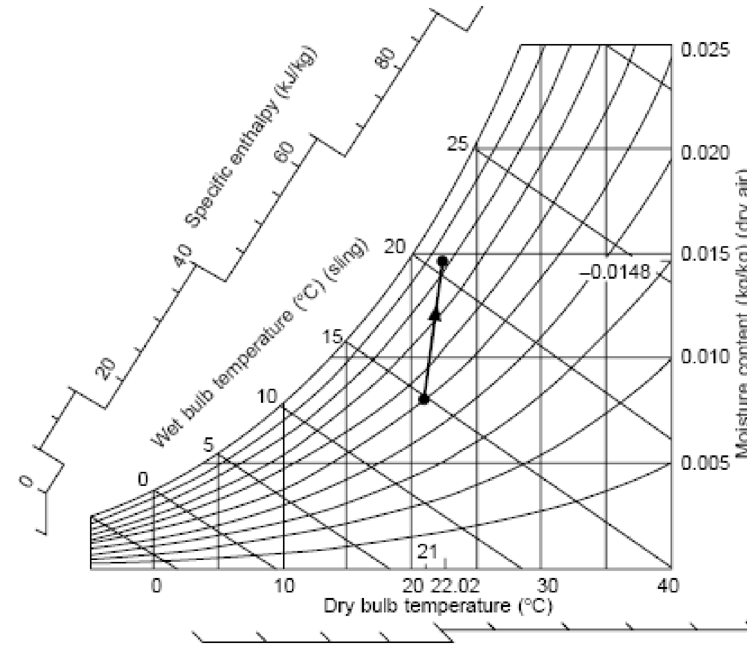
i) cooling the air to temperature below its dew point,
ii) using absorption process,
iii) using adsorption materials,
iv)compress and cool the air.
The first method represents the normal practice to cool and dehumidify the moist air in air conditioning systems.

Humidification of air can take place by injecting saturated or super heated steams inside the air conditioning ducts using fine nozzles and the equipment is called a humidifier.

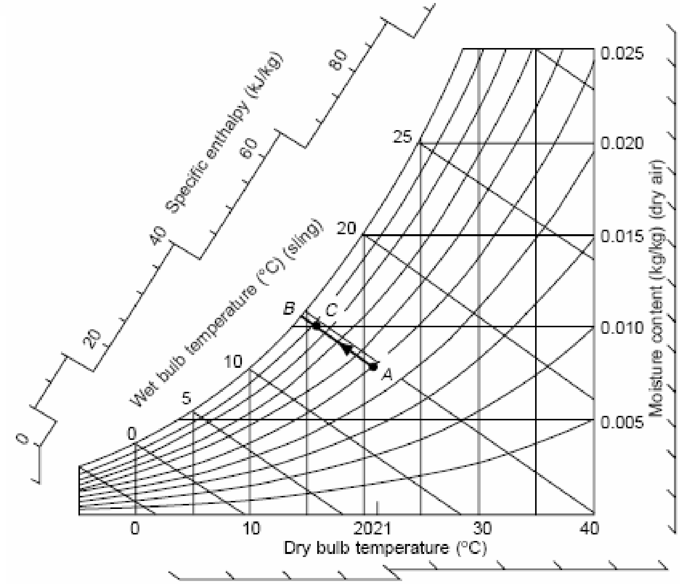
Cooling & Dehumidification



Heating & Humidification



Adiabatic Cooling



Examples :

1- Air at a state of DBT = 14 ºC, RH=50% is passed through a heating coil. The DBT is increased upto 42 ºC. Moisture content remain constant in this process, find :

a) WBT of the exit air.
b) The dew point temperature.
c) The sensible heat added by HC for 1.0 kg/s of air.

Answers : a)19.5ºC , b) 3.9ºC , c) 28.6 kW

2-Air at condition of DBT = 45ºC , RH= 20 % enter to an air cooler and exit at RH= 60 % , find :

a) DBT of exit air.
b) The moisture content (ω) at exit.
c) Plot the psychrometric process.

Answers: a) 31.5 ºC, b) 17.5 gwv /kg da .

3- Moist ait at DBT =30ºC and WBT = 25ºC enter a cooling coil and exit from it at saturation state with DBT = 15 ºC. IF the air is supplied to the coil at 3 m^3/s ,find:

a) All the properties of air at inlet and outlet.
b) The sensible heat removed by the cooling coil.
c) Amount of moisture removed from the air by CC.

Answers:

a) h_{in} = 76 kJ/kg , ω_1=0.010 $kg_{w.v}/kg_{d.a}$, ν_1=0.882 m^3/s, RH_1= 66, $T_{d.p}$= 23.2 ºC, h_2 = 42 kJ/kg , ω_2=0.0107 $kg_{wv}/kg_{d.a}$, ν_2=0.831 m^3/kg, RH2=100 %
b) 115.6 kW, c) 0.0248 kg_{wv}/kg_{da}.

Thank You

Air Conditioning

&

Refrigeration

Lectures

Air Conditioning Processes

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Mixing process:

Adiabatic mixing of different quantities of air in two different states at constant pressure. The conditions of the mixing state may be found by the following relations and as shown the figure below :

$T_3 = (m_1 .T_1 + m_2 .T_2) / (m_1 + m_2)$ or;

$h_3 = (m_1 .h_1 + m_2 .h_2) / (m_1 + m_2)$ or;

$\omega_3 = (m_1 .\omega_1 + m_2 .\omega_2) / (m_1 + m_2)$;where m in kg/s

It is acceptable practice in air conditioning to use volume ratio rather than mass ratio:

$T_3 = (v_1 .T_1 + v_2 .T_2) / (v_1 + v_2)$;

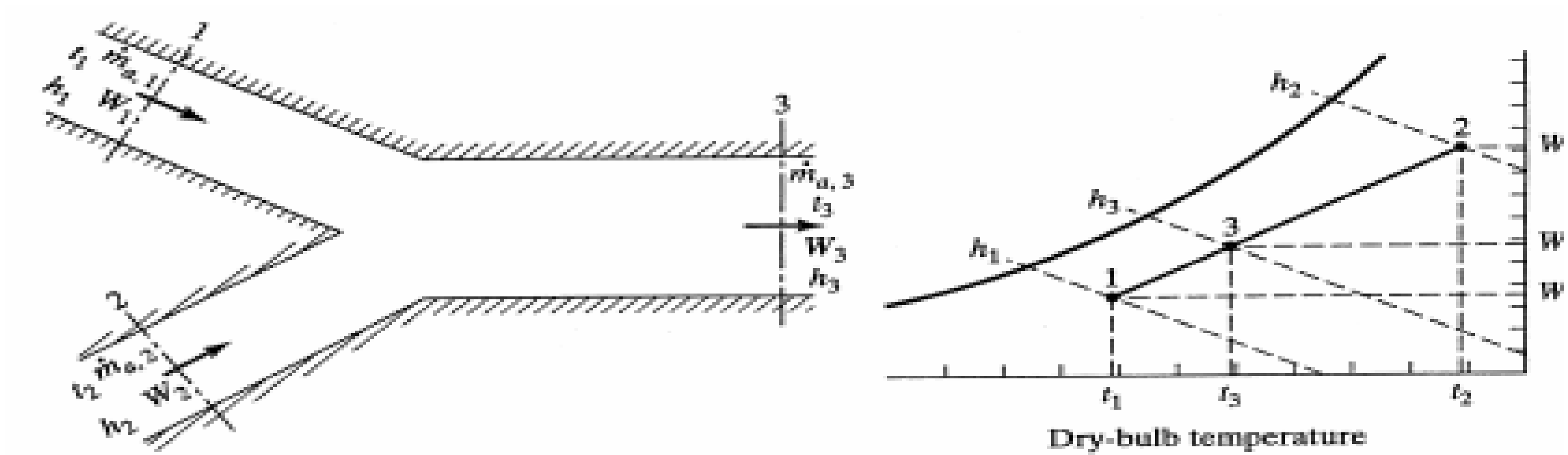
$h_3 = (v_1 .h_1 + v_2 .h_2) / (v_1 + v_2)$; and for ω

$\omega_3 = (v_1 .\omega_1 + v_2 .\omega_2) / (v_1 + v_2)$;where v in m^3/s

Example :

An air stream at DBT=21ºC ,WBT=14 ºC is mixed with an other one at DBT=28 ºC ,WBT=20 ºC. The mass flow rates were 1 kg/s for the first and 3 kg/s for the second. Find the moisture content, enthalpy, and the DBT for the mixture and plot the process on the chart.

Answers : 0.01 $kg_{w.v}/kg_{d.a}$, 52.15 kJ/kg , 26.25 ºC.



Air Conditioning Cycles :

There are two air conditioning cycle one for summer air conditioning and the other for winter air conditioning. The summer cycle has three types:

i) All out side air,
ii) All return air, and,
iii) Mixed air.

The winter air conditioning cycle can be done into two methods:

i) The first method is to preheat the air and then cooling it adiabatically up to a given point and then reheat it to the supply conditions.
ii) The second method is to use an air washer to humidify the air up to a given point then reheat it to the supply conditions.

Psychrometric analysis

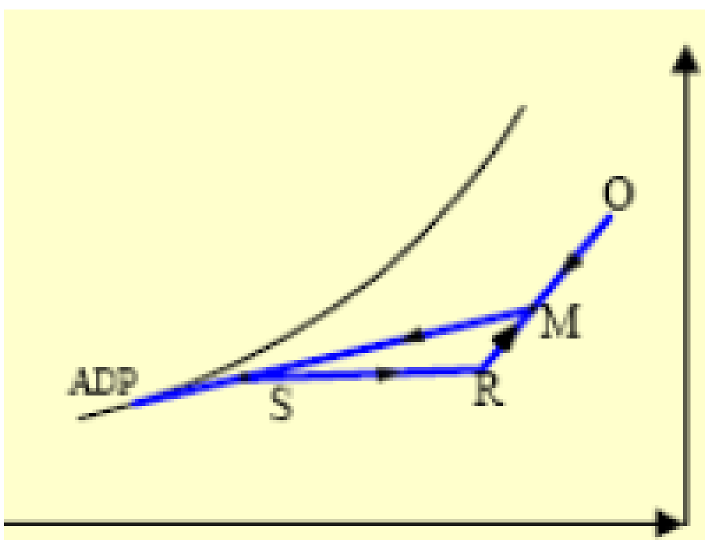
These analysis include summer air conditioning cycles and winter air conditioning cycles.

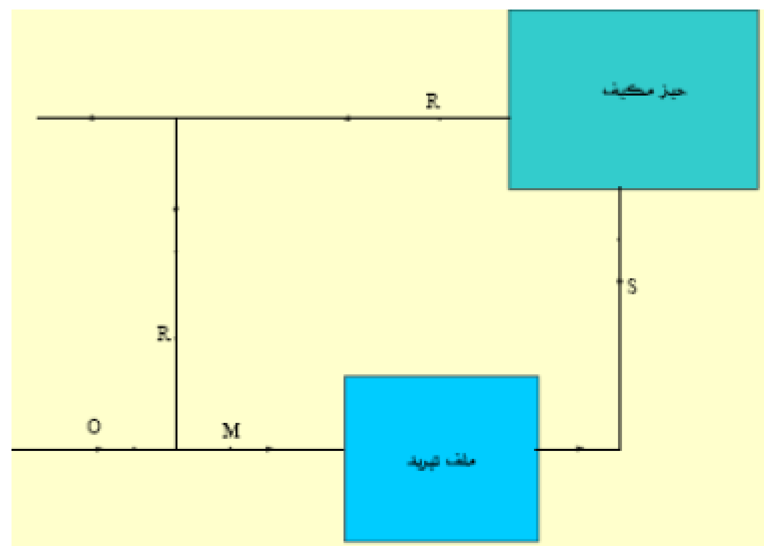
Summer cooling and dehumidification processes:

1- All outside air,

2- All return air,

3- Mixing of fresh air with return air as shown below.





Calculation procedure for mixing cycle :

The following steps is required to carry the analysis:

- Mark the inside and out side conditions on the chart .
- Calculate the $SHF=Q_s/(Q_s + Q_l)$ { if the sensible and latent heat are given}, and plot it as a parallel line starting from the inside conditions.
- Plot the supply condition. IF other conditions are given also plot them.
- Calculate the mixing conditions and plot them on the line between the inside and out side conditions.
- Connect the mixing point with the supply point by a line and find $T_{a.d.p}$ which represent the point where this line cross the saturation line.
- Calculate BPF and other required quantities.

  Where $BPF=(T_s-T_{a.d.p})/(T_m-T_{a.d.p})$

Use the following equations to calculate the required variables:

$Q_{s,r}=1.22 * V_s * (T_r - T_s)$, this can be used to find V_s.

$Q_{coil} = 1.2 * V_s * (h_m - h_s)$, for mixed air,

$Q_{coil} = 1.2 * Vs * (h_o - h_s)$, for all outside air,

$Q_{coil} = 1.2 * Vs * (h_r - h_s)$, for all return air,

$m_{vap} = m_s * \Delta\omega$, and the three conditions as in Q_{coil},

$Q_{chilled\ water} = m_{water} * c_{pw} * \Delta T_{water}$, Where $c_{pw}=4.2$ kj/kgK

Examples:

1- An air conditioned space is maintained at DBT=24ºC and RH=50% .The out side condition is DBT=38 ºC with WBT=27ºC.The space has a sensible heat gain of 24 kW and latent heat of 6kW. Use all out side air system find:

i) the supply condition of the air if the relative humidity at the supply point is taken to be 90%.
ii) volume flow rate of supplied air.
iii) the total cooling load of the cooling coil.
iv) the chilled water volume flow rate if its temperature rise is 5.6ºC.

Answers : Ts=12.2 ċ, hs=32.6 kJ/kg, Qcoil=95.6 kW, 1.06 m^3/s .

2- The sensible heat gain of a given space is 50 kW and its latent load is 15 kW. The inside condition is 26 ºC with 50% relative humidity. The space is air conditioned using all return air system. Find by assuming 90% saturation for the supply air:

i)the supply conditioned of the air, ii) volume flow rate of supplied air, iii) cooling coil load.

Answers : Ts=14.5c, hs=38.2 kJ/kg, vs=3.56 m3/s, Qcoil =65 kW.

3- An air conditioned space with inside condition of DBT=25.5 ºC ,WBT=18 ºC has a sensible heat=17.5 kW and a latent heat =12.3 kW. The space required an outside air of o.35 m^3/s at DBT=32.5 ºC, RH=50%. If RHs=90%, find: i) state of the supplied air and its mass flow rate, ii) cooling coil load, Plot the process on chart and calculate the BPF.

Answers: Ts= 11.5 c, hs= 29.5 kJ/kg, ms = 0.813 kg/s, Qcoil=24.8 kW , BPF=0.25

4- An air conditioned space is need to be maintained at DBT=24 ºC, RH= 50%. The space required 28.3 m^3/min fresh air. The sensible heat loss of the space is 66 kW and its latent is 16.5 kW. The outside design condition is DBT=7 ºC, RH= 80% . The mixed air is passes through a steam humidifier followed by a heating coil. The humidifier efficiency is 85% and the coil is heated the air up to 49 ºC, plot the air conditioning process on the chart, and find:

i) The supplied air mass flow rate at a given Ts= 49 ºC,
ii) the heating coil load.
iii) the humidifier heating load,
iv) the amount of steam required by the humidifier.

Answers: ms= 2.77 kg/s, Qcoil=78.0 kW, Qhum=16.9 kW , mvap= 0.00825 kg/s

Thank You