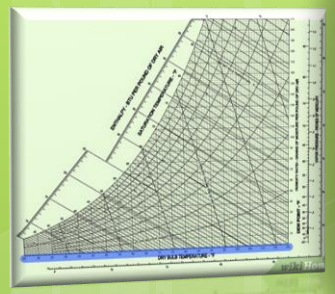
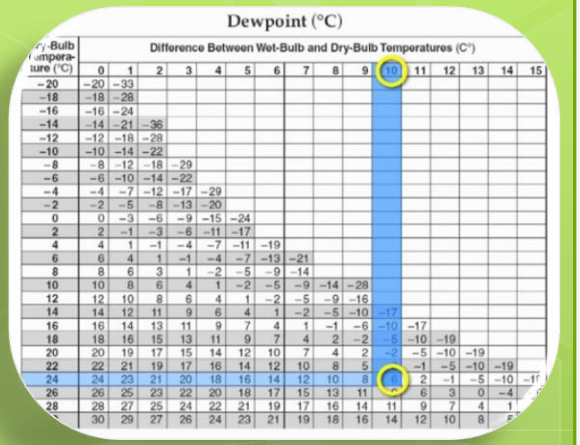




ENVIRONMENTAL & SAFETY OF MINES SUBJECT

Properties and Behavior of Air

College of Petroleum & Mining Eng.

Mining Engineering Dept.

4th Class

Lecture No. 1 – Chapter 2

Mr. Omer Haitham Kanam

Overview

- Air as Fluid in Mine Ventilation
- Air Types
- Chemical Properties of Air
- Pressure Concept
- Psychometric Properties
- Mathematical Equations
- Examples 2.1 and 2.2

Air as Fluid in Mine Ventilation

- Definition of Air Generally
- Definition of Air Thermodynamically
- Definition of Air Chemically

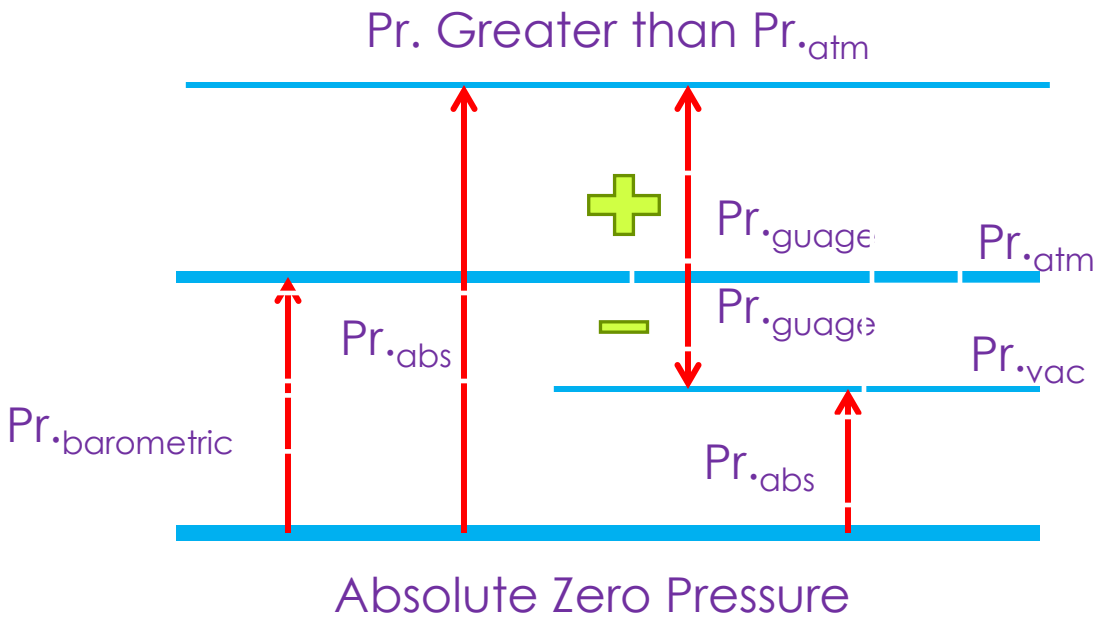
Air Types

- **Dry air** doesn't exist in normal atmospheres.
- **Saturated air** is containing all the water vapor possible at existing conditions of T. & Pr.

Chemical Properties of Air

Pressure Concept

- P_{abs}: it's a pressure measured from absolute vaccum.
- P_{gauge}: it's the pressure measured with measuring instruments & it's above P_{atm}.
- $P_{vac.}$:It's measured below P_{atm}.
- P_{atm}:It's the pr. In the surrounding atmosphere.



Psychometric Properties

- Psychrometry
- Is the science of studying thermodynamic properties of moist air and the use of these to analyze humid air conditions and processes.
- State Point
- Determination of certain psychometric properties of air at given conditions.

Mr. Omer Haitham

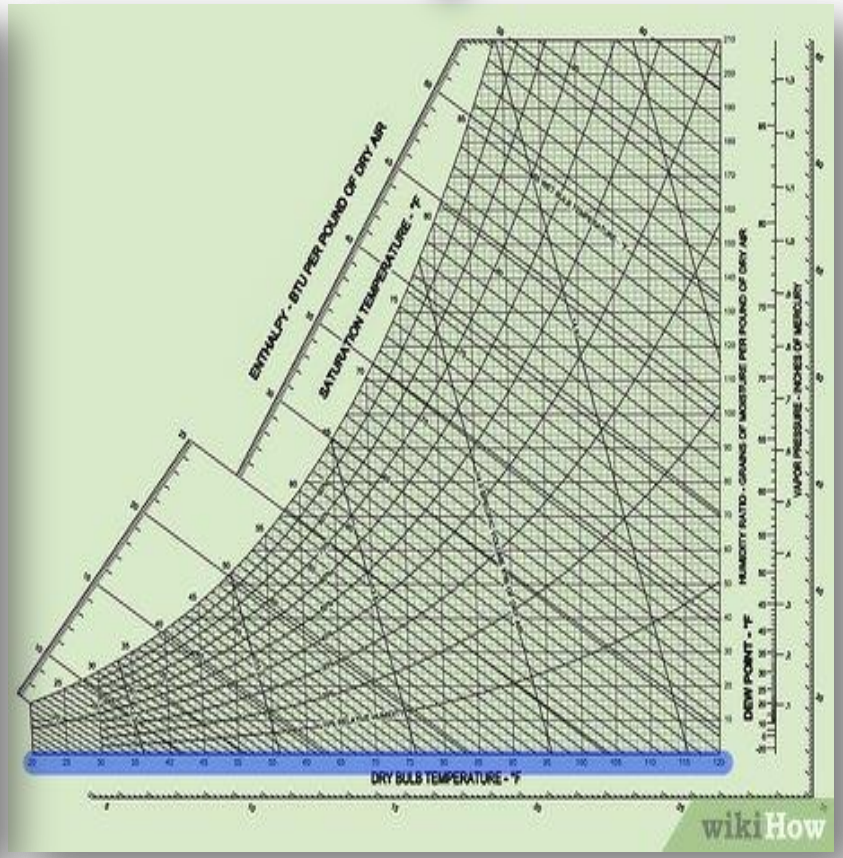
Psychometric Properties

TABLES

CHARTS

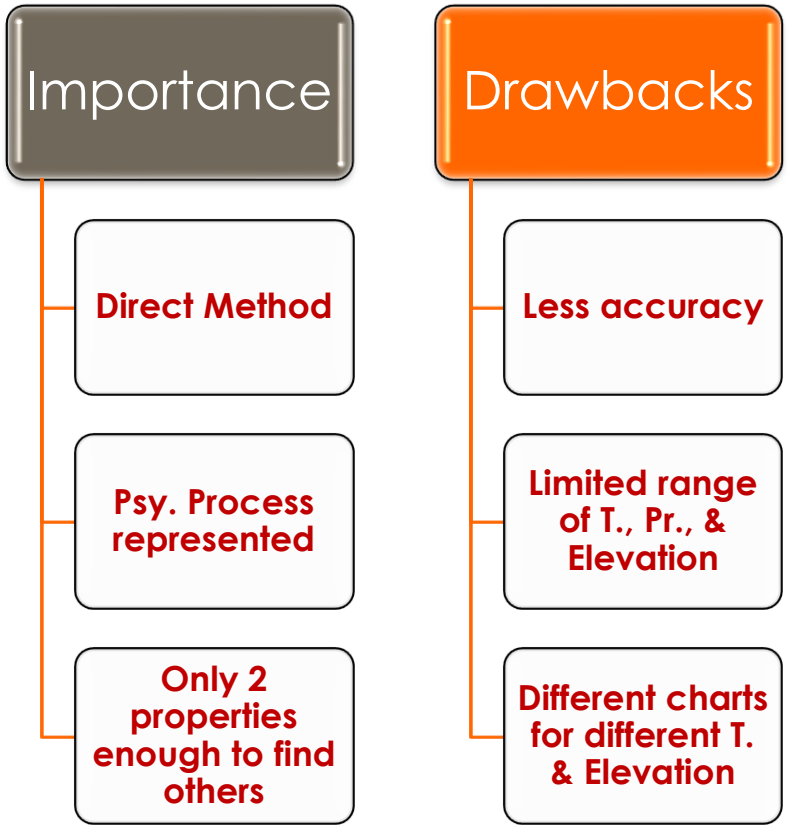
Dewpoint (°C)

Dry-Bulb Temperature (°C)	Difference Between Wet-Bulb and Dry-Bulb Temperatures (C°)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
−20	−20	−33														
−18	−18	−28														
−16	−16	−24														
−14	−14	−21	−36													
−12	−12	−18	−28													
−10	−10	−14	−22													
−8	−8	−12	−18	−29												
−6	−6	−10	−14	−22												
−4	−4	−7	−12	−17	−29											
−2	−2	−5	−8	−13	−20											
0	0	−3	−6	−9	−15	−24										
2	2	−1	−3	−6	−11	−17										
4	4	1	−1	−4	−7	−11	−19									
6	6	4	1	−1	−4	−7	−13	−21								
8	8	6	3	1	−2	−5	−9	−14								
10	10	8	6	4	1	−2	−5	−9	−14	−28						
12	12	10	8	6	4	1	−2	−5	−9	−16						
14	14	12	11	9	6	4	1	−2	−5	−10	−17					
16	16	14	13	11	9	7	4	1	−1	−6	−10	−17				
18	18	16	15	13	11	9	7	4	2	−2	−5	−10	−19			
20	20	19	17	15	14	12	10	7	4	2	−2	−5	−10	−19		
22	22	21	19	17	16	14	12	10	8	5		−1	−5	−10	−19	
24	24	23	21	20	18	16	14	12	10	8	6	2	−1	−5	−10	−18
26	26	25	23	22	20	18	17	15	13	11	9	6	3	0	−4	−9
28	28	27	25	24	22	21	19	17	16	14	11	9	7	4	1	−3
30	30	29	27	26	24	23	21	19	18	16	14	12	10	8	5	1



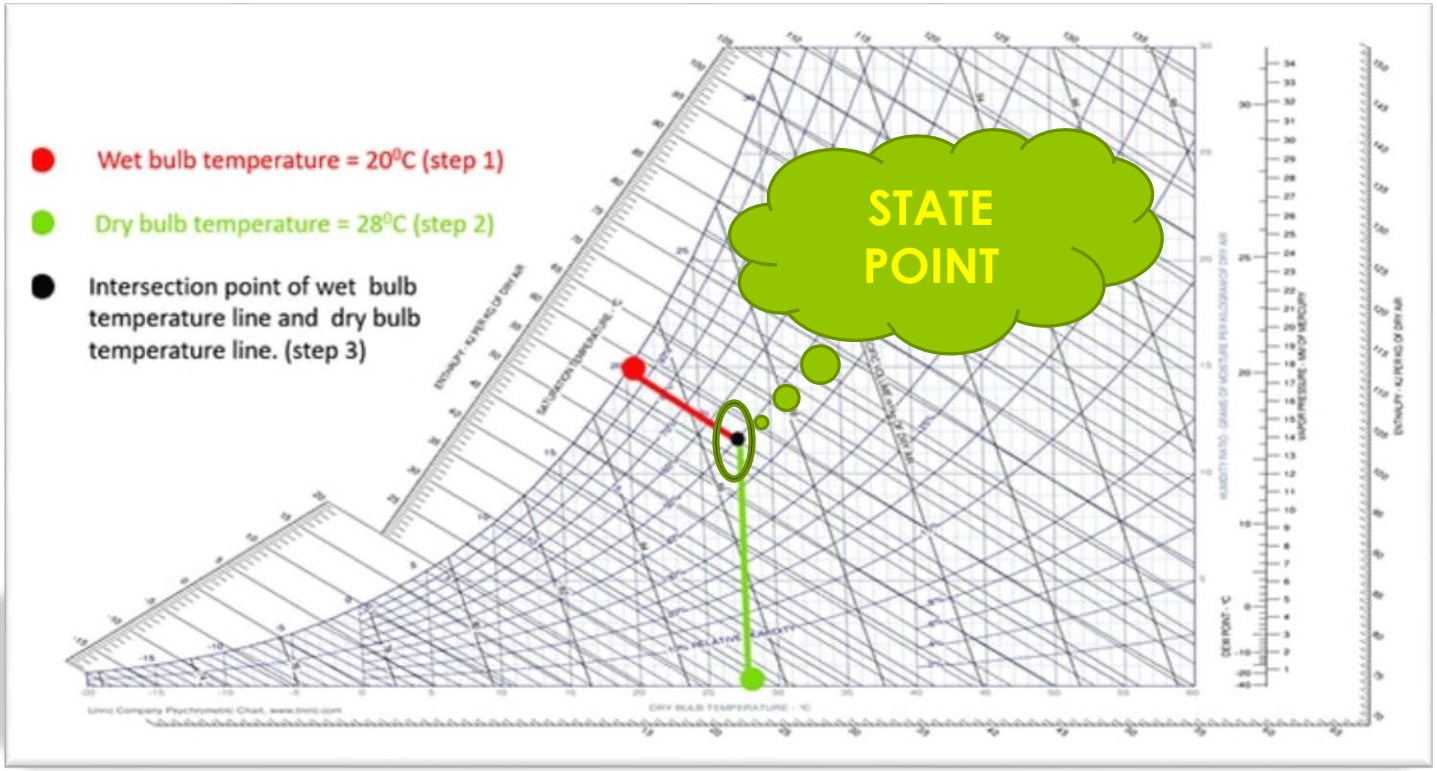
Psychometric Chart

- It's a graph plot relating all psychometric properties.



Psychometric Properties

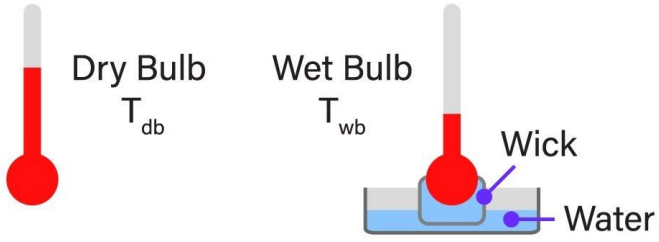
- A state point is fixed by any 2-points on psychometric chart @ a known Pr.$_{barometric}$



Psychometric Properties

- **Tdb:** Temp. indicated by a conventional dry thermometer (a measure of heat content "sensible" of the air)

- **Twb:** Temp. at which water evaporating into air can bring air to saturation adiabatically at that temp. (a measure of the evaporating capacity of the air indicated by thermometer with a wetted wick)



Mathematical Equations

- Pr.Barometric

$$p_b = p_a + p_v \qquad (2.1)$$

- Pr.Saturation

$$p_s = 0.18079 \exp\left(\frac{17.27t_d - 552.64}{t_d + 395.14}\right) \text{ in. Hg} \qquad (2.2)$$

- Pr.vapor

$$p_v = p'_s - \frac{(p_b - p'_s)(t_d - t_w)}{2800 - 1.3t_w} \text{ in. Hg} \qquad (2.3)$$

Note: to compute ps' substitute twb for tdb then use eq.2.5 to calculate ws. Substituting ps for pv and find all properties

Mathematical Equations

- Relative Humidity

$$\phi = \frac{p_v}{p_s} \times 100\% \qquad (2.4)$$

- Specific Humidity

$$W = 0.622 \frac{p_v}{p_b - p_v} \text{ lb/lb (kg/kg) dry air} \times 7000 = \text{grains/lb dry air} \qquad (2.5)$$

- Degree of Saturation

$$\mu = \frac{W}{W_s} \times 100\% \qquad (2.6)$$

- Specific Volume

$$v = \frac{RT_d}{p_a} \text{ ft}^3\text{/lb (m}^3\text{/kg) dry air} \qquad (2.7)$$

Mathematical Equations

- Specific Weight

$$w = \frac{1}{v}(W + 1)\ \text{lb/ft}^3\ (\text{kg/m}^3) \qquad (2.8)$$

$$w = \frac{1.325}{T_d}(p_b - 0.378p'_v)\ \text{lb/ft}^3 \qquad (2.9)$$

- Enthalpy

$$h = h_a + h_v = c_p t_d + W(h_{fg} + h_f)$$
$$= 0.24t_d + W(1060 + 0.45t_d)\ \text{Btu/lb dry air} \qquad (2.10)$$

Example 2.1/2.2

- Given , *td* = 70°F , tw. = 50°F, *pb* = 29.921 in. Hg, find all remaining psychrometric properties of air at the state point using Appendix Table A.2.
- Also, find all properties using chart.

TABLE A.2 Psychrometric Data for Air-Water-Vapor Mixtures

Temperature, °F t	Properties of Water[a] and Steam: Saturation Pressure of Water and Steam, in. Hg p_s	Properties of Water[a] and Steam: Enthalpy: Saturated Water,[a] Btu/lb h_f	Properties of Water[a] and Steam: Enthalpy: Saturated Steam, Btu/lb h_g	Properties of Water[a] and Steam: Specific Volume of Sat. Steam, ft³/lb v_g	Properties of Dry Air at a Pressure of 29.921 in. Hg abs.: True Specific Volume, ft³/lb v_a	Properties of Dry Air at a Pressure of 29.921 in. Hg abs.: Enthalpy, Btu/lb h_a	Properties of Mixture of Dry Air and Sat. Steam at a Total Pressure of 29.921 in. Hg abs.: Volume of Mixture per lb of Dry Air, ft³ v_s	Properties of Mixture of Dry Air and Sat. Steam at a Total Pressure of 29.921 in. Hg abs.: Enthalpy of Mixture per lb of Dry Air, Btu h_s	Properties of Mixture of Dry Air and Sat. Steam at a Total Pressure of 29.921 in. Hg abs.: Specific Humidity Grains per lb of Dry Air W_s
1	$3.966\ (10)^{-2}$	−158.5	1061.5	14,080	11.604	0.24	11.62	1.12	5.777
2	$4.178\ (10)^{-2}$	−158.0	1062.0	13,400	11.630	0.48	11.65	1.40	6.084
3	$4.400\ (10)^{-2}$	−157.6	1062.4	12,750	11.655	0.72	11.56	1.68	6.348
4	$4.633\ (10)^{-2}$	−157.1	1062.8	12,140	11.680	0.96	11.70	1.98	6.745
5	$4.878\ (10)^{-2}$	−156.6	1063.3	11.550	11.706	1.20	11.72	2.28	7.106
6	$5.134\ (10)^{-2}$	−156.1	1063.7	11.000	11.731	1.44	11.75	2.58	7.478
7	$5.402\ (10)^{-2}$	−155.7	1064.2	10.480	11.756	1.68	11.78	2.88	7.867
8	$5.683\ (10)^{-2}$	−155.2	1064.6	9979	11.782	1.92	11.80	3.18	8.280
9	$5.977\ (10)^{-2}$	−154.7	1065.1	9507	11.807	2.16	11.83	3.49	8.711
10	$6.286\ (10)^{-2}$	−154.2	1065.5	9060	11.832	2.40	11.86	3.80	9.161
11	$6.608\ (10)^{-2}$	−153.7	1065.9	8636	11.857	2.64	11.88	4.11	9.633
12	$6.946\ (10)^{-2}$	−153.3	1066.4	8234	11.883	2.88	11.91	4.43	10.13
13	$7.300\ (10)^{-2}$	−152.8	1066.8	7851	11.918	3.12	11.94	4.75	10.64
14	$7.669\ (10)^{-2}$	−152.3	1067.3	7489	11.933	3.36	11.96	5.07	11.18
15	$8.056\ (10)^{-2}$	−151.8	1067.7	7144	11.959	3.60	11.99	5.40	11.73
16	$8.461\ (10)^{-2}$	−151.3	1068.1	6817	11.984	3.84	12.02	5.73	12.34
17	$8.884\ (10)^{-2}$	−150.8	1068.6	6505	12.009	4.08	12.05	6.06	12.96
18	$9.326\ (10)^{-2}$	−150.3	1069.0	6210	12.035	4.32	12.07	6.40	13.51
19	$9.789\ (10)^{-2}$	−149.8	1069.5	5929	12.060	4.56	12.10	6.75	14.28
20	0.1027	−149.4	1069.9	5662	12.085	4.81	12.13	7.10	14.99
21	0.1078	−148.9	1070.3	5408	12.110	5.05	12.15	7.45	15.73
22	0.1130	−148.4	1070.8	5166	12.136	5.29	12.18	7.81	16.51
23	0.1186	−147.9	1071.2	4936	12.161	5.53	12.21	8.18	17.32
24	0.1243	−147.4	1071.7	4717	12.186	5.77	12.24	8.55	18.16

TABLE A.2—(*continued*)

Temperature, °F t	Properties of Water[a] and Steam: Saturation Pressure of Water and Steam, in. Hg p_s	Properties of Water[a] and Steam: Enthalpy: Saturated Water,[a] Btu/lb h_f	Properties of Water[a] and Steam: Enthalpy: Saturated Steam, Btu/lb h_g	Properties of Water[a] and Steam: Specific Volume of Sat. Steam, ft³/lb v_g	Properties of Dry Air at a Pressure of 29.921 in. Hg abs.: True Specific Volume, ft³/lb v_a	Properties of Dry Air at a Pressure of 29.921 in. Hg abs.: Enthalpy, Btu/lb h_a	Properties of Mixture of Dry Air and Sat. Steam at a Total Pressure of 29.921 in. Hg abs.: Volume of Mixture per lb of Dry Air, ft³ v_s	Properties of Mixture of Dry Air and Sat. Steam at a Total Pressure of 29.921 in. Hg abs.: Enthalpy of Mixture per lb of Dry Air, Btu h_s	Properties of Mixture of Dry Air and Sat. Steam at a Total Pressure of 29.921 in. Hg abs.: Specific Humidity Grains per lb of Dry Air W_s
57	0.4684	25.1	1086.1	1336	13.020	13.70	13.23	24.45	69.28
58	0.4856	26.1	1086.5	1292	13.046	13.94	13.26	25.10	71.86
59	0.5033	27.1	1087.0	1249	13.071	14.18	13.29	25.76	74.54
60	0.5216	28.1	1087.4	1207	13.096	14.42	13.33	26.43	77.29
61	0.5405	29.1	1087.9	1167	13.122	14.66	13.36	27.11	80.14
62	0.5599	30.1	1088.3	1129	13.147	14.90	13.40	27.82	83.09
63	0.5800	31.1	1088.7	1092	13.172	15.14	13.43	28.54	86.14
64	0.6007	32.1	1089.2	1056	13.197	15.38	13.47	29.27	89.27
65	0.6221	33.1	1089.6	1022	13.223	15.62	13.50	30.03	92.51
66	0.6441	34.1	1090.0	988.6	13.248	15.85	13.54	30.79	95.86
67	0.6668	35.1	1090.5	956.8	13.273	16.10	13.58	31.58	99.32
68	0.6902	36.1	1090.9	926.1	13.298	16.35	13.61	32.38	102.9
69	0.7143	37.1	1091.3	896.5	13.324	16.59	13.65	33.20	106.6
70	0.7392	38.1	1091.8	868.0	13.349	16.83	13.69	34.04	110.4
71	0.7648	39.1	1092.2	840.5	13.374	17.07	13.72	34.90	114.3
72	0.7911	40.1	1092.6	814.0	13.399	17.31	13.76	35.79	118.4
73	0.8183	41.1	1093.1	788.4	13.425	17.55	13.80	36.69	122.6
74	0.8463	42.1	1093.5	763.8	13.450	17.79	13.84	37.61	126.9
75	0.8751	43.1	1093.9	740.0	13.475	18.03	13.88	38.55	131.3
76	0.9047	44.1	1094.4	717.0	13.501	18.27	13.92	39.52	135.9
77	0.9352	45.1	1094.8	694.9	13.526	18.51	13.96	40.51	140.6
78	0.9667	46.1	1095.2	673.5	13.551	18.75	14.00	41.52	145.5
79	0.9990	47.1	1095.7	652.9	13.576	18.99	14.04	42.56	150.6

25	0.1303	−146.9	1072.1	4509	12.211	6.01	12.27	8.92	19.04
26	0.1366	−146.4	1072.5	4311	12.237	6.25	12.29	9.31	19.96
27	0.1431	−145.9	1073.0	4122	12.262	6.49	12.32	9.70	20.92
28	0.1500	−145.4	1073.4	3943	12.287	6.73	12.35	10.09	21.92
29	0.1571	−144.9	1073.8	3771	12.313	6.97	12.38	10.49	22.98
30	0.1645	−144.4	1074.3	3608	12.338	7.21	12.41	10.90	24.07
31	0.1723	−143.9	1074.7	3453	12.363	7.45	12.43	11.32	25.21
32	0.1803	−143.4	1075.2	3305	12.389	7.69	12.46	11.75	26.40
33	0.1878	1.0	1075.6	3180	12.414	7.93	12.49	12.16	27.49
34	0.1955	2.0	1076.0	3062	12.439	8.17	12.52	12.57	28.63
35	0.2034	3.0	1076.5	2948	12.464	8.41	12.55	13.00	29.80
36	0.2117	4.0	1076.9	2839	12.490	8.65	12.58	13.42	31.02
37	0.2202	5.0	1077.4	2734	12.515	8.89	12.61	13.86	32.28
38	0.2290	6.0	1077.8	2634	12.540	9.13	12.64	14.30	33.58
39	0.2382	7.0	1078.2	2538	12.565	9.37	12.67	14.75	34.94
40	0.2477	8.0	1078.7	2445	12.591	9.61	12.70	15.21	36.34
41	0.2575	9.0	1079.1	2357	12.616	9.85	12.73	15.68	37.80
42	0.2676	10.1	1079.5	2272	12.641	10.09	12.76	16.16	39.30
43	0.2781	11.1	1080.0	2190	12.667	10.34	12.79	16.64	40.86
44	0.2890	12.1	1080.4	2112	12.692	10.58	12.82	17.13	42.47
45	0.3002	13.1	1080.9	2037	12.717	10.82	12.85	17.63	44.14
46	0.3119	14.1	1081.3	1965	12.742	11.06	12.88	18.13	45.86
47	0.3239	15.1	1081.7	1896	12.768	11.30	12.91	18.66	47.65
48	0.3363	16.1	1082.2	1829	12.793	11.54	12.94	19.19	49.51
49	0.3491	17.1	1082.6	1766	12.818	11.78	12.97	19.73	51.42
50	0.3624	18.1	1083.1	1704	12.844	12.02	13.00	20.28	53.40
51	0.3761	19.1	1083.5	1645	12.869	12.26	13.03	20.84	55.44
52	0.3903	20.1	1083.9	1589	12.894	12.50	13.06	21.41	57.56
53	0.4049	21.1	1084.4	1534	12.919	12.74	13.10	21.99	59.75
54	0.4200	22.1	1084.8	1482	12.945	12.98	13.13	22.59	62.01
55	0.4356	23.1	1085.2	1431	12.970	13.22	13.16	23.20	64.36
56	0.4518	24.1	1085.7	1383	12.995	13.46	13.19	23.82	66.78

(continued)

Solution: At t_w, read $p'_s = 0.3624$ in. Hg (1.224 kPa). At t_d, read $p_s = 0.7392$ in. Hg (2.496 kPa). Using Eq. 2.3,

$$p_v = 0.3624 - \frac{(29.921 - 0.3624)(70 - 50)}{2800 - (1.3)(50)} = 0.1463 \text{ in. Hg } (0.494 \text{ kPa})$$

At p_v, read dew-point temperature from table, $t_{dp} = 27.5°\text{F}$ or $-2.5°\text{C}$ ($p_v = p_s$ at t_{dp}).
Using Eq. 2.4,

$$\phi = \frac{0.1463}{0.7392} \times 100 = 19.8\%$$

Using Eq. 2.5,

$$W = \frac{(0.622)(0.1463)}{(29.921 - 0.1463)} = 0.00306 \text{ lb/lb } (\text{kg/kg})$$

At t_d, read $W_s = 0.01577$ lb/lb (kg/kg). Using Eq. 2.6,

$$\mu = \frac{0.00306}{0.01582} \times 100 = 19.3\%$$

Using Eq. 2.1,

$$p_a = 29.921 - 0.1463 = 29.775 \text{ in. Hg } (100.54 \text{ kPa})$$

Using Eq. 2.7,

$$v = \frac{(53.3)(460 + 70)}{(29.775)(0.491)(144)} = 13.42 \text{ ft}^3/\text{lb } (0.8378 \text{ m}^3/\text{kg})$$

Using Eq. 2.8,

$$w = \frac{1}{13.42}(0.00306 + 1) = 0.0747 \text{ lb/ft}^3 \ (1.1965 \text{ kg/m}^3)$$

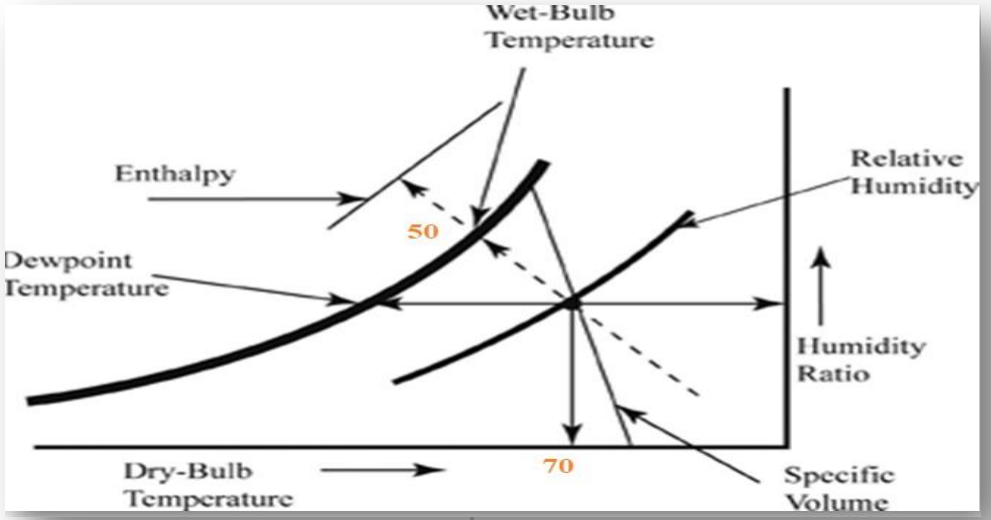
or from Eq. 2.9,

$$w = \frac{1.325}{530}(29.921 - 0.378 \times 0.1463) = 0.0747 \text{ lb/ft}^3 \ (1.1965 \text{ kg/m}^3)$$

Using Eq. 2.10,

$$h = (0.24)(70) + (0.00306)(1060 + 0.45 \times 70) = 20.14 \text{ Btu/lb } (46.85 \text{ kJ/kg})$$

Solution: Using Fig. 2.2,



$t_{dp} = 27.7°F$

$\phi = 20.0\%$

$W = 0.0031$

$h_{corr} = -0.08$

$h = 20.31 - 0.08 = 20.23$ Btu/lb (47.05 kJ/kg)

$v = 13.42$ ft^3/lb (0.8378 m^3/kg)

$w = 0.0748$ lb/ft^3 (1.1981 kg/m^3)

by air specific-weight chart (Fig. 2.3)

$W_s = 0.0158$ lb/lb (kg/kg)

$$\mu = \frac{0.0031}{0.0158} \times 100 = 19.6\%$$

END OF CH.-2