Basic Humidity Definitions

EdgeTech Moisture and Humidity Systems

Dalton's Law

John Dalton was the first to surmise that the **total pressure** (P_m) exerted by a mixture of gases or vapors is the **sum** of the pressures of each gas if it were to occupy the same volume by itself. The pressure which each gas (such as air) exerts is called its **partial pressure**. If P_x, P_y, and P_z represent the respective partial pressure of gases X, Y, and Z in a mixture, Dalton's Law states:

$$P_m = P_x + P_y + P_z + \ldots$$

Elementary as it may seem, the concept of Dalton's law is often overlooked in considering problems in humidity, because on forgets that the "water" in a gas is actually a gas itself and must be treated in accordance with the gas laws. Air must be considered a mixture of gases - oxygen, nitrogen, and water vapor (neglecting the minor constituents). All discussions of humidity can then be reduced to discussions of water vapor pressure, and all definitions encountered in humidity can be expressed in terms of vapor pressure.

Dew Point

Dew point is that unique temperature to which the air (or any gas) must be cooled in order that it shall be saturated with respect to **water**.

Frost Point

Frost point is that unique temperature to which the air (or any gas) must be cooled in order that it shall be saturated with respect to ice.

The dew point or frost point DEFINES the partial pressure of the water vapor in the gas, from the Smithsonian Meteorological Tables.

Relative Humidity

Relative Humidity is the ratio of the actual vapor pressure (as defined by the Tables) in the mixture to the saturation vapor pressure, with respect to water, at the prevailing dry bulb temperature.

Example 1. (Metric Units)

If dew point = 10°C and dry bulb = 25°C:

$$RH = \frac{\text{Vapor Pressure at 10°C}}{\text{Vapor Pressure at 25°C}}$$

$$= \frac{12.272\text{mb}}{31.671\text{mb}} = 38.7\%$$

If frost point = -45°C and dry bulb = -40°C

$$RH = \frac{\text{Vapor Pressure at -45°C (Actual)}}{\text{Vapor Pressure at -40°C (with respect to water)}}$$

$$= \frac{0.07198\text{mb}}{0.1891\text{mb}} = 38.1\%$$

Example 2. (English Units)

If dew point = 50°F and dry bulb = 90°F

$$RH = \frac{\text{Vapor Pressure at 50°F}}{\text{Vapor Pressure at 90°F}}$$

$$= \frac{.3624\text{" Hg}}{1.422\text{" Hg}} = 25.5\%$$

If frost point = -50°C and dry bulb = -40°C

$$RH = \frac{\text{Vapor Pressure at -50°F (Actual)}}{\text{Vapor Pressure at -40°F (with respect to water)}}$$

$$= \frac{1.990\times10^{-3}\text{" Hg}}{5.584\times10^{-3}\text{" Hg}} = 35.7\%$$

NOTE: RH is arbitrarily defined with respect to water even though it seems that it should be with respect to ice at **-40°C (-40°F)**.

PPM by Volume

Parts per million (PPM) by volume is the ratio of the partial pressure of the water vapor to the partial pressure of the dry gas.

Example 1. (Metric Units)

If frost point = -60°C and system total pressure is 1013 mb (14.7 PSIA)

$$PPMv = \frac{\text{Parts}}{\text{Million}}$$

$$= \frac{\text{Vapor Pressure at -60°C}}{\text{Total Pressure - Water Vapor Pressure at -60°C}} \times 10^6$$

$$= \frac{10.80 \times 10^{-3}\text{ mb}}{(1013 - 10.80 \times 10^{-3})\text{mb}}$$

= 10.7 PPM (by volume)

Example 2. (English Units)

If frost point = -70°F and system total pressure is 14.7 PSIA (29.92"Hg):

$$PPMv = \frac{\text{Parts}}{\text{Million}}$$

$$= \frac{\text{Vapor Pressure at -70°F}}{\text{Total Pressure - Water Vapor Pressure at -70°F}} \times 10^6$$

$$= \frac{4.974\times 10^{-4}\text{" Hg}}{(29.92 - .004974)\text{" Hg}} \times 10^6$$

= 17 PPM (by volume)

I I M y V t

Parts per million (PPM) by weight of dry gas is identical to PPM by volume except that the weight ratio changes with the molecular weight of the carrier gas.

Example 1. (Metric Units)

If frost point = -60°C and system total pressure is 1013 mb, and the carrier gas is hydrogen:

$$PPM_W = PPM_V \times \frac{\text{Mol. wt. of } H_2O}{\text{Mol. wt. of carrier gas}}$$

$$= 10.7 \times \frac{18}{2} = 96.3 \text{ PPM (by weight)}$$

Example 2. (English Units)

If frost point = -70°F and system total pressure is 14.7 PSIA, and the carrier gas is hydrogen:

$$PPM_W = PPM_V \times \frac{\text{Mol. wt. of } H_2O}{\text{Mol. wt. of carrier gas}}$$

$$= 17 \times \frac{18}{2} = 153 \text{ PPM (by weight)}$$

Molecular weight of common gases

Acetylene	26	Helium	4
Air	29	Hydrogen	2
Ammonia	17	Methane	16
Argon	40	Nitrogen	28
CO_2	44	Oxygen	32
CO	28	Sulfur Dioxide	64
Ethylene	28	Water	18

Dew Point/Frost Point Relationships

Below 0°C (32°F), dew point hygrometers measure the frost point temperature rather than the dew point. the Tables below permit conversion from dew to frost point. For a more accurate conversion, consult Table 102 of smithsonian Meteorological Table.

Metric Units (°C)

F.P.	D.P.	F.P	D.P.	F.P.	D.P.	F.P.	D.P.
0	0	-12	-13.4	-24	-26.6	-36	-39.4
-1	-1.2	-13	-14.5	-25	-27.7	-37	-40.5
-2	-2.3	-14	-15.6	-26	-28.8	-38	-41.6
-3	-3.4	-15	-16.7	-27	-29.9	-39	-42.6
-4	-4.5	-16	-17.8	-28	-30.9	-40	-43.7
-5	-5.6	-17	-18.9	-29	-32.0	-41	-44.7
-6	-6.8	-18	-20.0	-30	-33.0	-42	-45.8
-7	-7.9	-19	-21.1	-31	-34.1	-43	-46.8
-8	-9.0	-20	-22.2	-32	-35.2	-44	-47.9
-9	-10.1	-21	-23.3	-33	-36.2	-45	-49.0
-10	-11.2	-22	-24.4	-34	-37.3	-46	-50.0
-11	-12.3	-23	-25.5	-35	-38.4		

English Units (°F)

F.P	D.P.	F.P.	D.P.	F.P.	D.P.	F.P.	D.P.
32	32	10	7.4	-12	-16.7	-34	-40.3
31	30.8	9	6.3	-13	-17.8	-35	-41.4
30	29.7	8	5.2	-14	-18.9	-36	-42.4
29	28.6	7	4.1	-15	-20.0	-37	-43.5
28	27.5	6	2.9	-16	-21.1	-38	5-44.5
27	26.4	5	1.8	-17	-22.2	-39	-45.6
26	25.2	4	0.7	-18	-23.3	-40	-46.6
25	24.1	3	-0.4	-19	-24.3	-41	-47.7
24	22.9	2	-1.5	-20	-25.4	-42	-48.7
23	21.8	1	-2.6	-21	-26.4	-43	-49.8
22	20.7	0	-3.7	-22	-27.5	-44	-50.8
21	19.6	-1	-4.8	-23	-28.6	-45	-51.9
20	18.5	-2	-5.8	-24	-29.6	-46	-52.9
19	17.4	-3	-6.9	-25	-30.6	-47	-54.0
18	16.2	-4	-8.0	-26	-31.7	-48	-55.0
17	15.1	-5	-9.1	-27	-32.8	-49	-56.1
16	14.0	-6	-10.2	-28	-33.9	-50	-57.1
15	12.9	-7	-11.3	-29	-35.0	-51	-58.2
14	11.8	-8	-12.4	-30	-36.1	-52	-59.2
13	10.7	-9	-13.5	-31	-37.2	-53	-60.3
12	9.6	-10	-14.6	-32	-38.2		
11	8.5	-11	-15.6	-33	-39.3		

REFERENCE: Smithsonian Meteorological Tables, Sixth Revised edition, List, Robert J., Publication No. 4014, Smithsonian Institution, Washington, D.C.

Pressure Conversion

As the total pressure of a gas sample changes, all of the partial pressures comprising the total pressure change in the same ratio.

Example 1. (Metric Units)

If frost point = -60°C and system total pressure is 1013 mb (1.033kg/cm²), what is the dew point at 21kg/cm²?

$$\frac{\text{Vapor Pressure at -60°C}}{1.033 \text{ kg/cm}^2} = \frac{\text{Vapor Pressure at New Dew Point}}{21 \text{ kg/cm}^2}$$

Vapor pressure at new dew point = 10.80×10^3 mb x $\frac{21}{1.033}$ = .2195mb partial pressure

From the Vapor Pressure Tables (over ice), the Frost Point = -35.2°C

Example 2. (English Units)

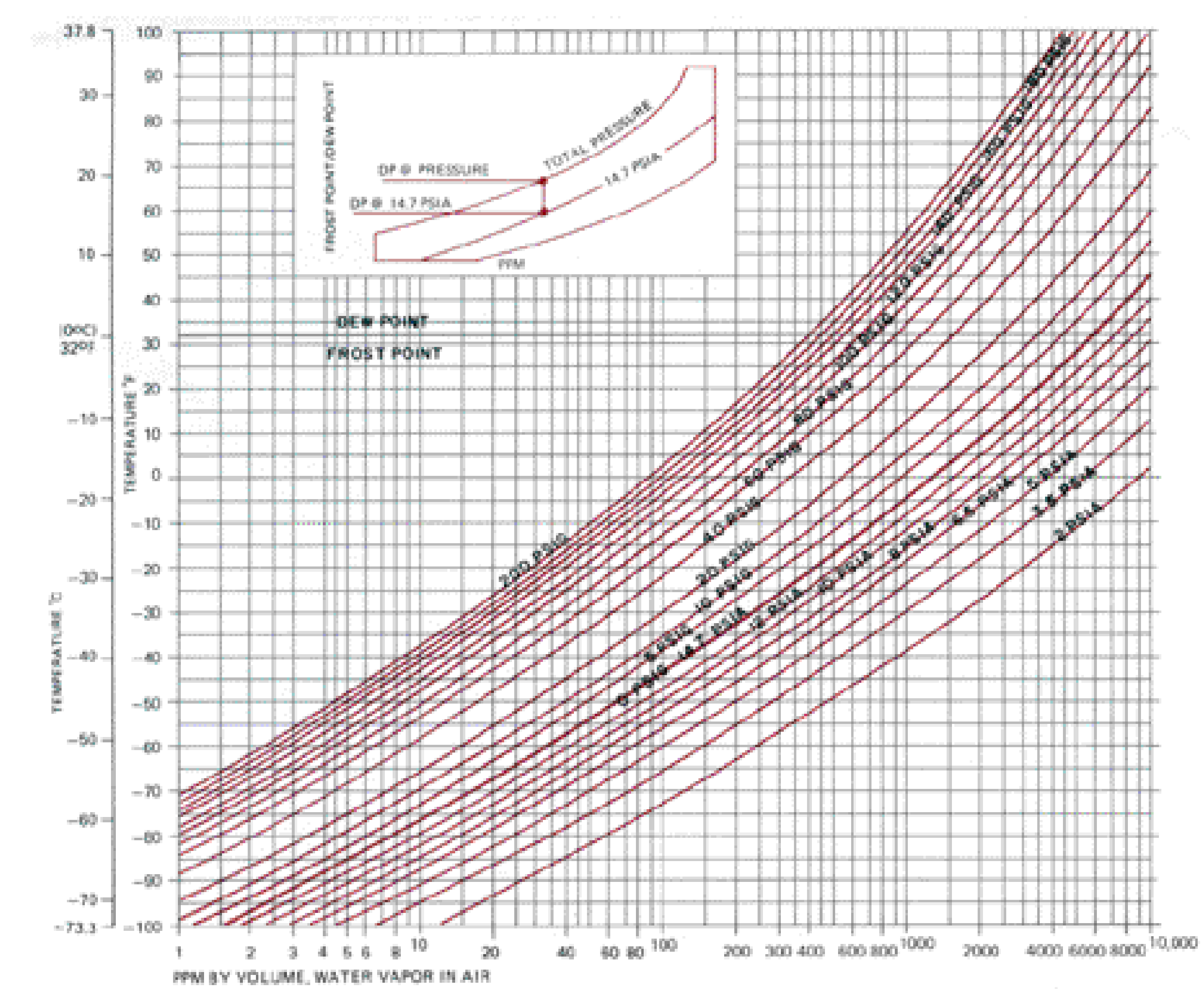
If frost point = - 10°F and system total pressure is 14.7PSIA, what is the dew point at 70PSIG (84.7 PSIA)?

$$\frac{\text{Vapor Pressure at -70°F}}{14.7 \text{ PSIA}} = \frac{\text{Vapor Pressure at New Dew Point}}{84.7 \text{ PSIA}}$$

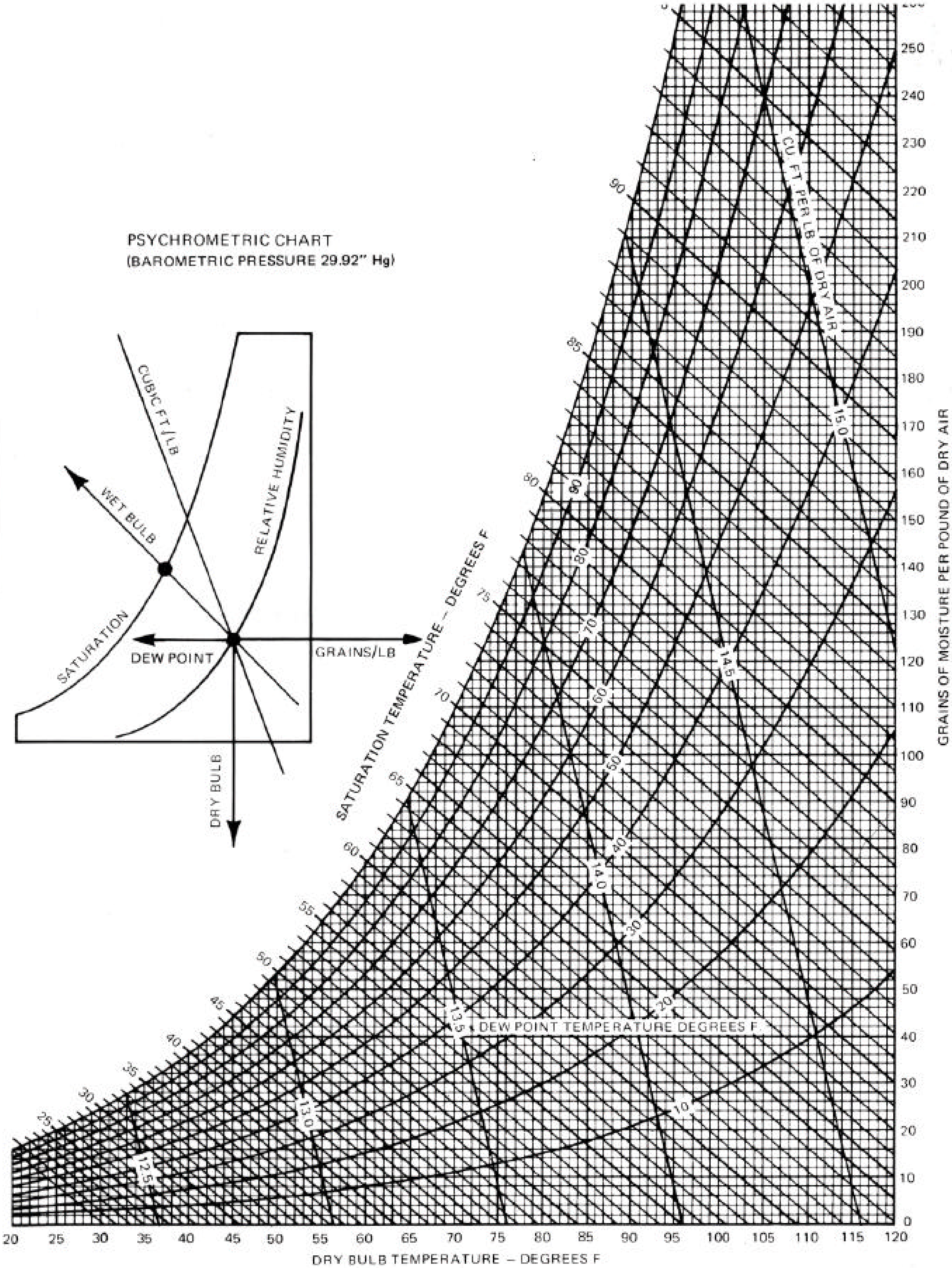
Vapor pressure at new dew point = 4.974×10^{-4} Hg x $\frac{84.7}{14.7}$ = 2.87×10^{-3} Hg partial pressure

From the Vapor Pressure Tables (over ice), the Frost Point = -44.5°F

Dew Point/Pressure Conversion Chart



PSYCHROMETRIC CHART
(BAROMETRIC PRESSURE 29.92" Hg)



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