HVAC Fundamentals & Components

Course No. ENRG 55A

HVAC Fundamentals & Components Outline

- A – Introduction to physical principles of HVAC & systems
  - Conversion of units
  - Concept of work, power, and energy
  - Overview of psychrometric analysis of the air conditioning
  - Thermodynamic laws and heat transfer principles
  - Estimate of sensible and latent heat changes
  - Analysis of thermal comfort
- B – Load calculations
  - Heating loads
  - Cooling load
  - Use of psychrometric tables and various software packages for heating and cooling estimates
- C – Conveyance systems
  - Principles of conveyance systems
  - Types of conveyance equipment and components
  - Nameplate data interpretation
- D – Principles of heating systems
  - Types of heating equipment & components
  - Nameplate data interpretation
- E – Cooling systems
  - Principles of the refrigeration cycle
  - Types of equipment & components
  - Nameplate data interpretation
- F – Air-handling systems
  - Diffusers, and registers
  - Dampers, louvers, filters, fans

HVAC Fundamental & Components

A. Introduction to physical principles of HVAC & systems
   1. Conversion of units
      a. **Temperature**
      b. Pressure
      c. Horse power
      d. Power (kWh)
      e. British Thermal Units/hr (BTU/hr)
      f. Tons
   2. Concept of work, power, and energy
   3. Overview of psychrometric analysis of the air conditioning system
      a. Psychrometric processes and calculations
         i. Sensible or latent processes
         ii. Air side equation
         iii. Air side mixing
         iv. Summary of process line calculations
      b. Room sensible heat ratio (RSHR) & room cubic feet per minutes (CFM)
         i. Room sensible heat ratio
         ii. Room sensible heat ratio line
         iii. Design CFM (CFM)
         iv. Multiple room sensible heat ratios
      c. The coil sensible heat ratio (CSHR)
         i. Coil sensible heat ratio without ventilation
         ii. Coil sensible heat ratio ventilation
         iii. Construction of the RSHR & CSHR
         iv. Coil By-pass factor
         v. Thermodynamic laws and heat transfer principles
         vi. Estimate of sensible and latent heat changes
         vii. Analysis of thermal comfort

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Conversion of Units

a. Temperature:

Definition: It is a thermodynamic property that indicates heat intensity or the amount of heat level in a substance or process. Heat intensity could be coldness or hotness.

Temperature scale: A thermometer is the instrument used to measure the temperature of a substance

Types of Thermometers: Celsius, Fahrenheit, Kelvin, and Rankine

System of International (SI) Units

Celsius scale: Measures ice point of water at 0^oC and boiling point of water at 100^oC

Kelvin scale: Measures ice point of water at 273^oK and boiling point of water at 373^oK. However, Kelvin scale measure absolute zero (0^oK) is (-273^oC) on the Celsius scale

English System Units (US Customary Units)

Fahrenheit scale: Measures ice point of water at 32^oF and boiling point of water at 212^oF

Rankine scale: Measures ice point of water at 492^oR and boiling point of water at 672^oR; In addition, Rankine scale absolute zero temperature at 0^oR is -460^oF on Fahrenheit scale

NB: Absolute zero temperature is the temperature set point when all molecules cease to move.

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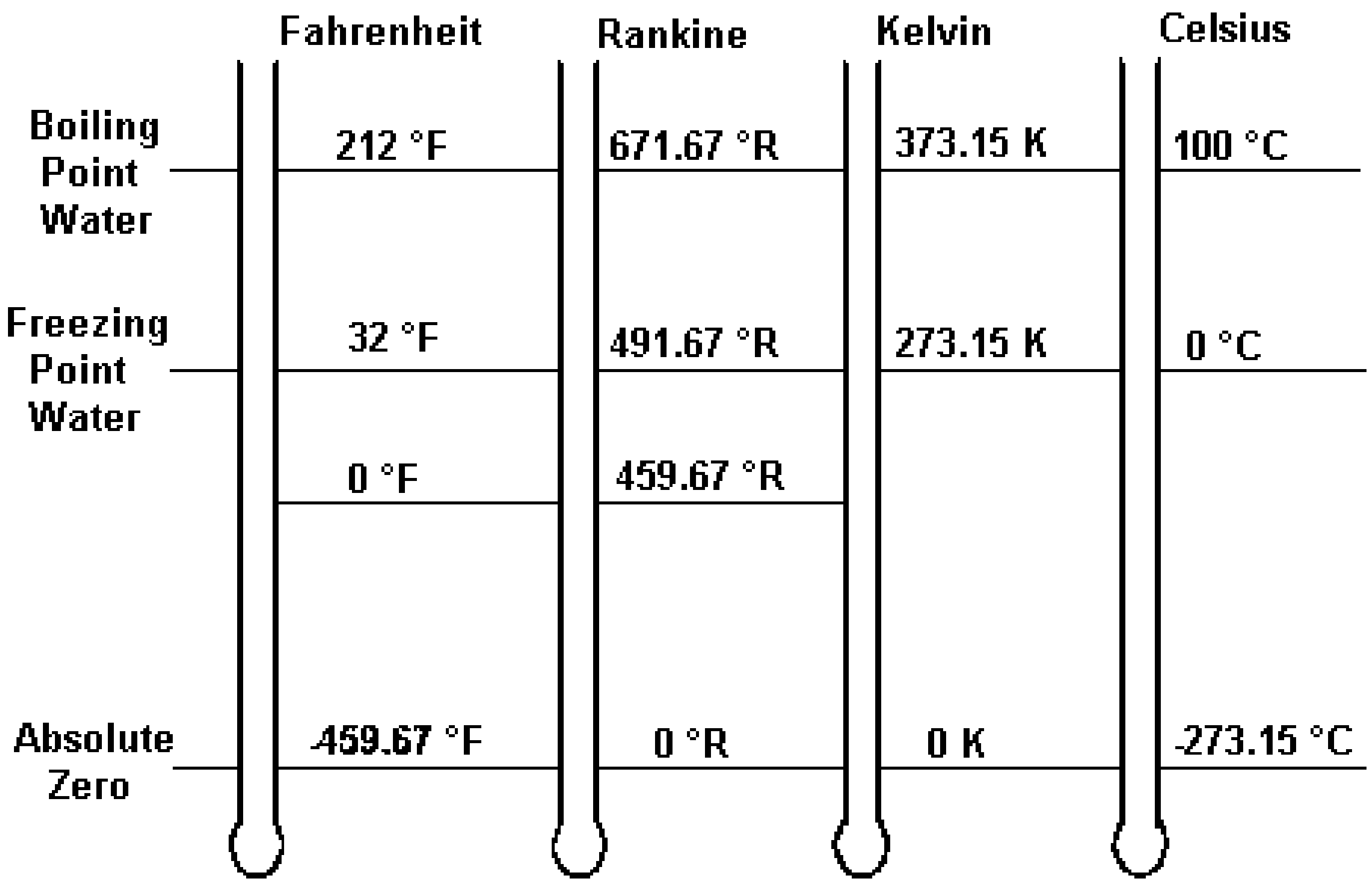
Temperature conversions



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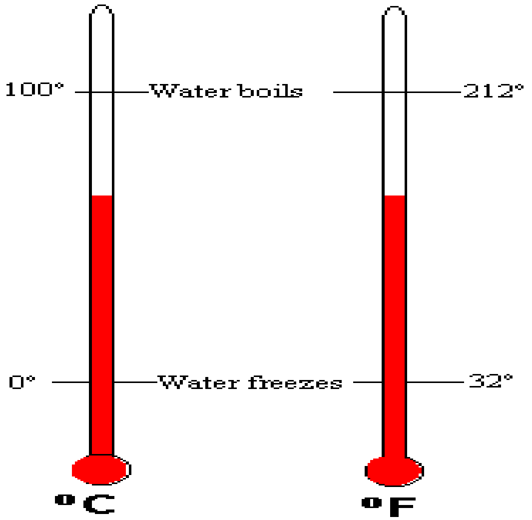
Temperature: Fahrenheit to Celsius conversion



Equations for temperature conversions

$$^{o}C = \frac{5}{9}\left(^{o}F - 32\right) \longrightarrow (1)$$

$$^{o}F = \frac{9}{5}{}^{o}C + 32 \longrightarrow (2)$$

or

$$^{o}F = 1.8^{o}C + 32 \longrightarrow (3)$$

Example (1):

Convert 20°C to Fahrenheit degrees (°F)

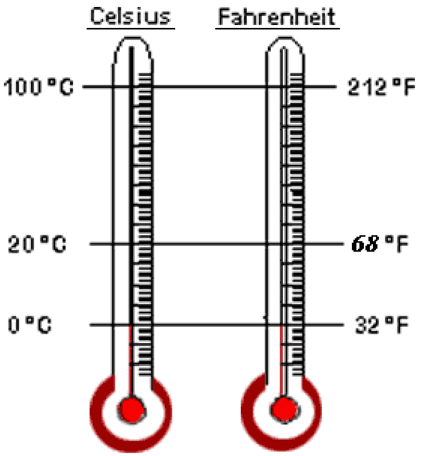
Solution

Using equation 2 or 3

$$F = 1.8C + 32$$

$$\Rightarrow F = (1.8 \times 20) + 32$$

$$\therefore F = 68^{o}F$$



Celsius and Fahrenheit Thermometers

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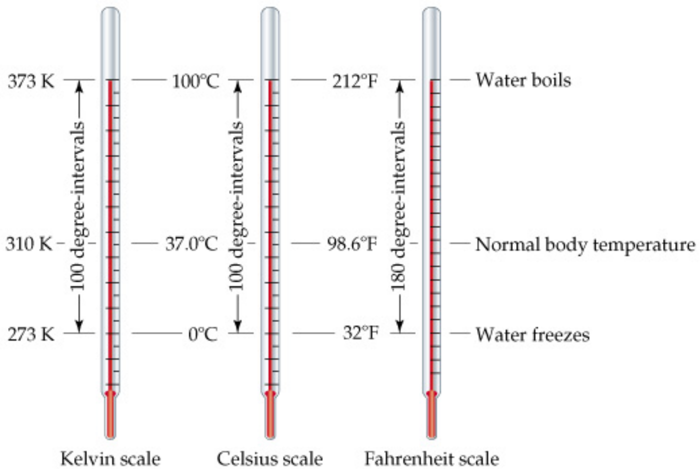
Equations for Celsius to Kelvin conversion and Fahrenheit to Rankine



$$^oK = ^oC + 273 \longrightarrow \quad (4)$$

$$^oR = ^oF + 460 \longrightarrow \quad (5)$$

Example (2):

Convert 82°F to Rankine degrees

Solution:

From equation (5)

$$R = F + 460$$

$$\Rightarrow R = 82 + 460 = \underline{542^oR}$$

Example (3)

Convert 104°F to Kelvin degrees

Solution:

From equation (1)

$$C = \frac{5}{9}(^oF - 32) \longrightarrow \quad (1)$$

$$\Rightarrow C = \frac{5}{9}(104 - 32) = \frac{5}{9}(72) = \frac{360}{9}$$

$$\therefore C = 40^oC$$

Also using Equation (4)

$$K = ^oC + 273$$

$$\Rightarrow K = 40 + 273$$

$$\therefore \underline{K = 313^oK}$$

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Exercises on temperature conversions

Problem 1:

Convert the following Celsius temperature readings to equivalent temperatures on the Fahrenheit scale:

A. -76^oC
B. 95^oC
C. -115^oC

Problem 2:

In a manufacturing process, the temperature passing across a heating coil is increased from 40^oF to 160^oF. Estimate the temperature rise in degrees Celsius.

Problem 3:

Convert the following temperatures in Kelvin to equivalent temperatures in degrees Rankine

A. 125^oK
B. 210^oK

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b. Pressure unit conversion

1. Definition: Pressure is defined as a measure of the intensity of a force at any given point on the contact surface or in short, we say pressure is force exerted on a substance per unit area. Units for pressure include: inches mercury, inHg; inches water column, inwc or inches water gauge, inwg; pound per square inches, lb_f/in^2, or lb_f/ft^2, Pascal, etc.

2. Mathematically, we've $$\Pr essue(P) = \frac{Force(F)}{Area(A)}$$

3. There are three types of pressures used to describe fluid (air, water etc.) in motion. These include: Static Pressure (SP), Velocity Pressure (VP) and Total Pressure (TP)

4. Mathematically, we've $$TP = SP + VP$$

Where: TP = the total pressure which is the sum of static and velocity pressures
SP = the static pressure is the pressure of the fluid at rest. It is calculated by using *"Bernoulli's Equation"* or measured by manometers, barometers, Bourdon tube gages etc.

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + H_p = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g} + H_f$$ Where: SP = $\frac{p_1}{\gamma}, \frac{p_2}{\gamma}$

This flow energy equation applied to flow in a duct and pipe

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VP = the velocity pressure is used to measure velocities and flow rates in piping and ducts.

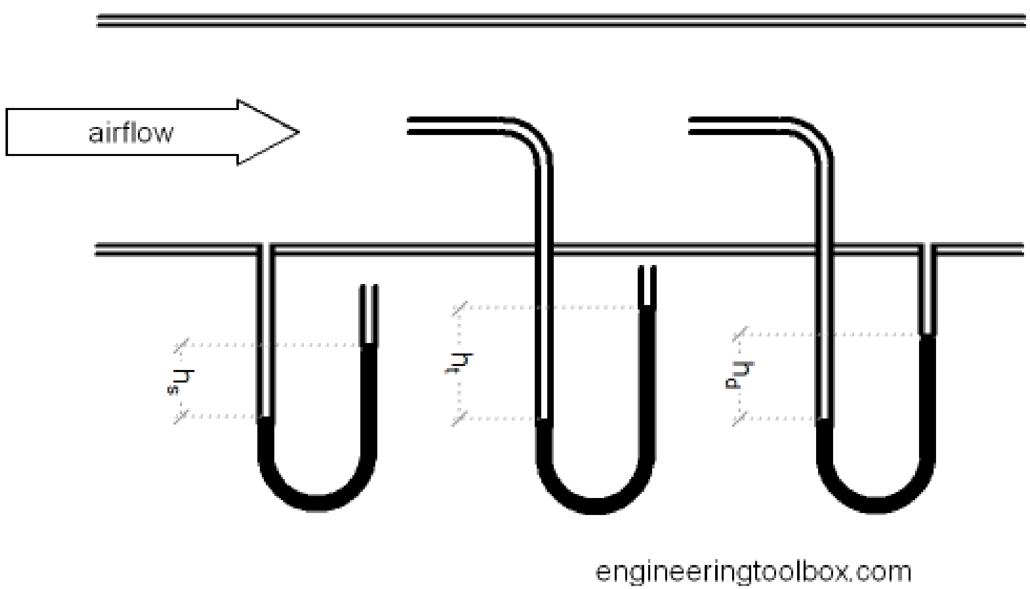
VP can be calculated using the equation $VP = \frac{V^2}{2g}$, from *Bernoulli's Equation*

$$\Rightarrow V = \sqrt{2gVP}$$

VP is measured using *pitot tube*

Pitot Tube

The pitot tube is a simple and convenient instrument to measure the difference between **static, total** and **dynamic pressure (or head)**.



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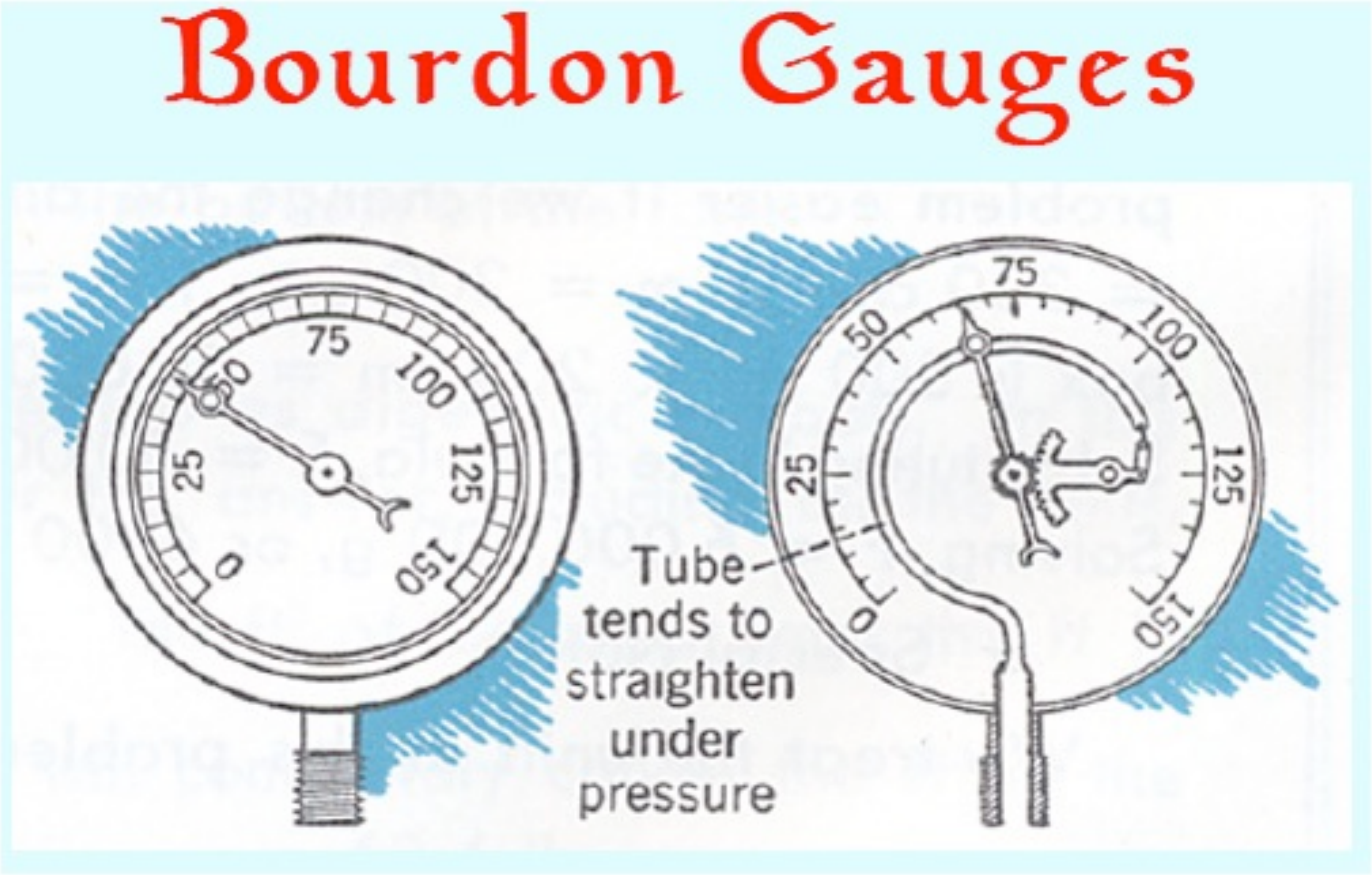

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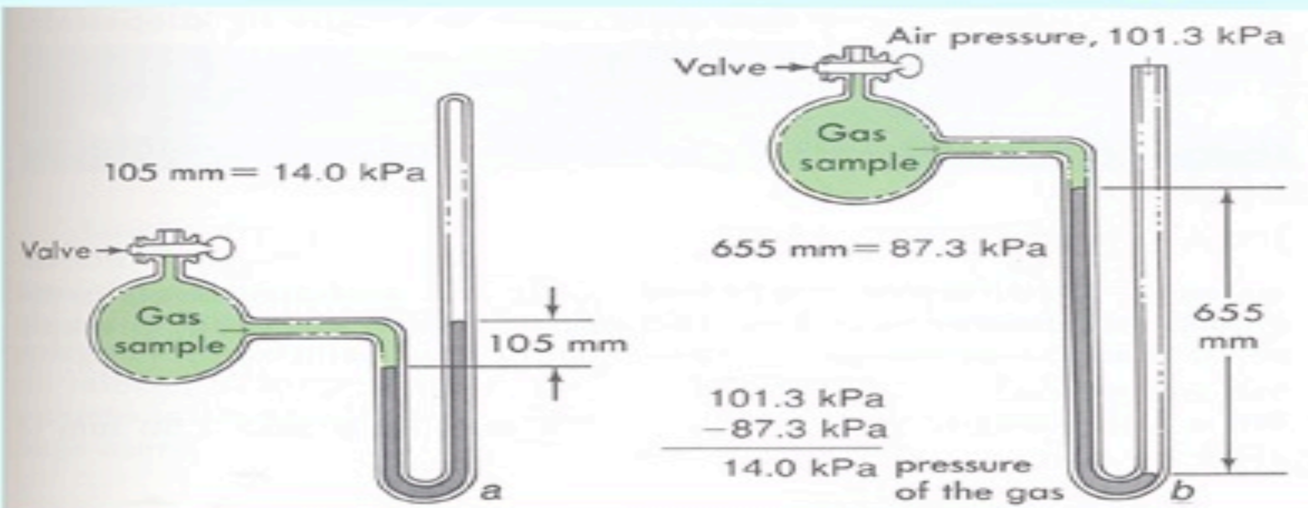
Total Force = (pressure)(area)

$$TF = pA$$

Manometers

Open & Closed tube manometers measure pressure.



One atmosphere = 760mm of Hg = 101 kPa.
So 1mm of Hg = 0.13 kPa.

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b. Pressure conversion cont'd

1. Convert 16.2 ft air to inches water gage (in wg)

Solution:

Using conversion factor: **1 *in.wg* = 69.6 *ft.air***

$$\therefore 16.2\,ft.air \times \frac{1 in.wg}{69.6\,ft.air} = 0.23 in.wg$$

2. Change the following quantities to the new units specified

A. 130 lb_f/in^2 (psi) to ft wg

B. 25 in. Hg to mm. Hg

Exercise:

Convert 20.5 in. Hg to lbf/in^2(psi)

Apply the following units conversion factors:

US Customary:

2.036 in. Hg = 1 lb_f/in^2 (psi)

1 psi = 2.3 ft. wg

Metric System/SI Systems:

1 Pa = 1 N/m^2

101.3 kN/m^2 = 1 atm

3386 Pa = in Hg

249.1 Pa = 1 mm Hg

Metric/SI systems – US Customary:

1 atm – 14.7 psia

1 atm – 760 mm Hg

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b. Pressure conversion cont'd

A. Given: 130 lb_f/in^2 to ft wg

$$1\frac{lb_f}{in^2} = 2.3\,ft.wg$$

$$\rightarrow \frac{130\,{}^{lb_f}\!/\!{}_{in^2}}{1\,{}^{lb_f}\!/\!{}_{in^2}} \times 2.3\,ft.wg = 299\,ft.wg$$

B. Convert 25 inHg to 1 mmHg

$$1inH_g = 3386P_a$$

$$\therefore 25inH_g \cong \frac{25inH_g}{1inH_g} \times 3386P_a = 84650P_a$$

$$249.1P_a = 1mmH_g$$

$$\therefore 84650P_a \cong \frac{84650P_a}{249.1P_a} \times 1mmH_g = 339.8mmH_g$$

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b. Pressure conversion continued

1. There are five types of pressure; namely: Pressure gage, vacuum pressure; atmospheric pressure and absolute pressure
   a. Pressure gage (P_{gage}): measures pressure in closed systems such as pipes, ducts, vessels etc.
   b. Vacuum pressure: (P_{vac}): It is the pressure that is measured below the atmospheric pressure
   c. Atmospheric pressure: P_{atm}: It is the pressure occupied by the weight of the atmosphere (universe). At the "Sea Level", the pressure is measured at approximately 14.696 psia (101,325 Pascal) and the value decreases as the "Altitude" atmosphere increases.
   d. Absolute pressure (P_{abs}) : It total of gage pressure and atmospheric pressure
   e. Zero Pressure also known as perfect vacuum is an area of space that has no pressure.

2. **Mathematical Relationship Between: P_{abs}, P_{atm}, P_{gage} and P_{vac}**

$$P_{abs} = P_{atm} + P_{gage} \longrightarrow (1)$$

$$or$$

$$P_{abs} = P_{atm} - P_{vac} \longrightarrow (2)$$

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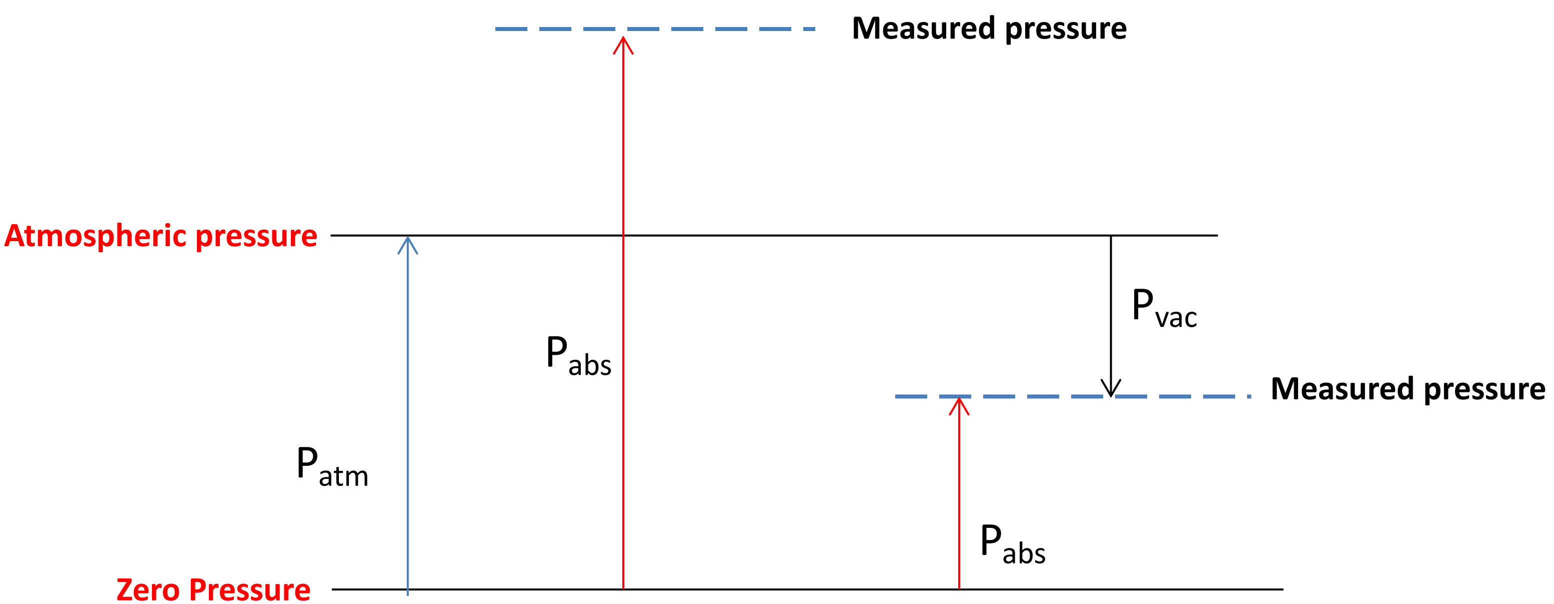
- Illustration



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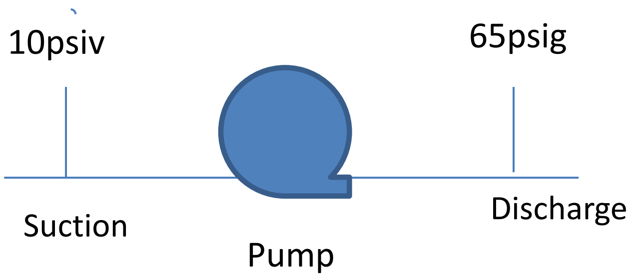
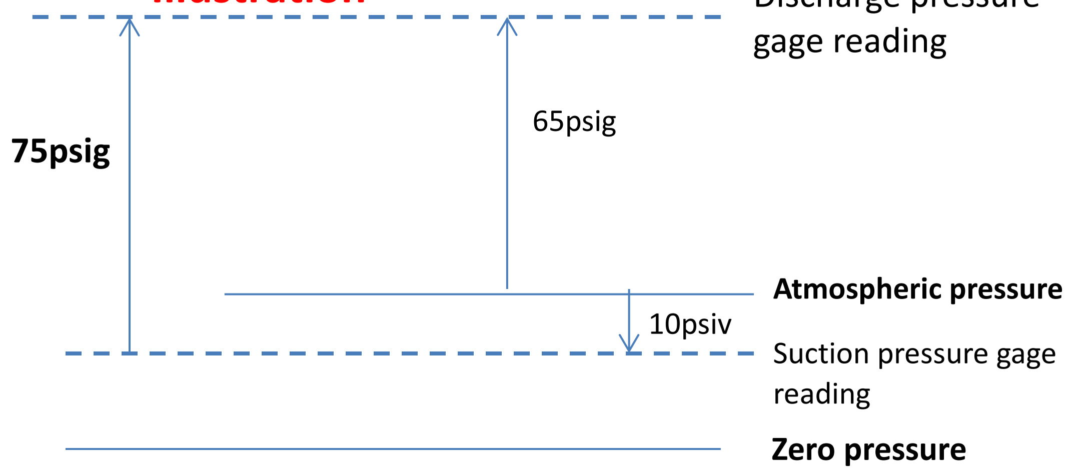
b. Pressure conversion continued

- **Example**
- The gages on suction gas and discharge gas lines of a pump is 10 psiv (lb/in^2 vac) and 65 psig, respectively. What is the pressure increase by the pump?
- **Solution:**



Illustration



- ***Mathematically***

$$PressureIncrease = 10 + 65 = 75\,psig$$

- **Exercise**

1. The pressure gage connected to the discharge of a cooling tower pump in Pharmaceutical Company in Emeryville, Oakland, California reads 28psig. Calculate the absolute water pressure at the pump discharge?
2. A 250 ft vertical pipe in a high-rise building is filled with chilled water. Estimate the pressure in psig that a valve in the bottom of the line will have to withstand.

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c. Horse power conversion

Definition: One horsepower is the work done at a rate of 550 pound$_{force}$-foot per second or 33000 pound$_{force}$ –foot per minute, which is equivalent to 745.7 watts

- **Mathematically**

$$1hp = 550\frac{lb_f - ft}{s}$$

$$or$$

$$1hp = 33000\frac{lb_f - ft}{\min}$$

- **Example:**
- Convert 11840 *lb_f--ft/min* to horsepower (hp)
- Solution:

$$33000\frac{lb_f - ft}{\min} = 1hp$$

$$\rightarrow 11840^{lb_f - ft}\!\!\diagup_{\min} \cong \frac{11840\frac{\cancel{lb_f - ft}}{\min}}{33000\frac{lb_f - ft}{\cancel{\min}}} \times 1hp = 0.36hp$$

- Exercise: Convert 250 hp to *lb_f-ft/s* .

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Milwaukee Area Technical College - Sustainable Facilities Operations
Laney College - Commercial HVAC Systems
City College San Francisco - Commercial Building Energy Analysis & Audits

Professional Development Materials, Presentations & Videos
National Institutes
Building Automation Systems Instructor Workshops
Webinars (e.g., BEST Talks)

Faculty Profile Videos
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National Science Foundation