Seneca College BES 705

(20160824 Revision)

1 – HVAC to Pneumatic Control Systems

https://senema.senecac.on.ca/videos/3400/building-controls - Control Systems Video

SAQ 1.1: Gauge Pressure

All of the pressure references here are gauge pressure. What is “gauge pressure”?

Solution:

Gauge pressure is the difference between system absolute pressure and the prevailing atmospheric pressure. That is, absolute pressure = atmospheric pressure + gauge pressure, or in psi, psia = psi(atmospheric) + psig.

SAQ 1.2: Standard Cubic Inches

What does the word “Standard” refer to in Standard Cubic Inches per Minute (SCIM)?

Solution:

This is actually more complicated than it might seem, because there are at least two ways to interpret the term standard in this context:

STP - Standard Temperature and Pressure - is defined by IUPAC (International Union of Pure and Applied Chemistry) as air at 0°C (273.15 K, 32°F) and 105 pascals (1 Pa = 10^{-6} N/mm² = 10^{-5} bar = 0.1020 kp/m² = 1.02×10^{-4} m H2O = 9.869×10^{-6} atm = 1.45×10^{-4} psi (lbf/in²)); STP is commonly used to define standard conditions for temperature and pressure which is important for the measurements and documentation of chemical and physical processes:

- STP - commonly used in the Imperial system of units - as air at 60°F and 14.696 psia (15.6°C, 1 atm)

NTP - Normal Temperature and Pressure - is defined as air at 20°C (293.15 K, 68°F) and 1 atm (101.325 kN/m², 101.325 kPa, 14.7 psia, 0 psig, 29.92 in Hg, 760 torr). Density 1.204 kg/m³ (0.075 pounds per cubic foot); **NTP is commonly used as a standard condition for testing and documentation of fan capacities.**

SAQ 1.3: Normally – Open/Normally Closed

What does it mean to say that a device is normally open or normally closed?

Solution:

Normally open or normally closed defines the default status of the device should the power to it be interrupted. That is, the device returns to this default position as a result of the internal mechanism when electrical or pneumatic power to the device is off.

SAQ 1.4: Throttling Range and Proportional Band

Maybe these are two ways of saying the same thing, but what other information is required in order to relate one to the other?

Solution:

$$\text{Since } \frac{\text{Throttling range}}{\text{Sensor span}} \text{ x } 100\% = \text{Proportional band}$$

It follows that the factor that relates throttling range to proportional band is the sensor span, that is, the difference between the maximum and minimum limits of the device.

SAQ 1.5: Coefficient of Expansion

Define "coefficient of expansion" for the metals in the bimetal strip. Why do the dissimilar values result in curvature of the strip?

Solution:

The coefficient of thermal expansion describes how the size of an object changes with a change in temperature. Whereas our focus in regard to thermal expansion is often change in volume, in the case of solids, as with our bimetal strip, it is the change in linear dimensions that we are interested in. So, the linear thermal expansion coefficient relates the change in a material's linear dimensions to a change in temperature. It is the fractional change in length per degree of temperature change. The change in the linear dimension can be estimated as:

$$\frac{\Delta L}{L} = \alpha_L \Delta T$$

Where α_L is the linear thermal expansion coefficient for the metal. It follows that in the bimetal strip, since the two materials have different values of α_L, the changes in length of the two metals, ΔL, are different. Since the metals are bonded together, the only way that the different changes in length can be manifested is through curvature in which the outside arc is longer than the inside arc (the reason that the sprinter prefers the inside lane on the race track).

SAQ 1.6: Friction Loss in Pipes

Why do you suppose the resistance to flow—and therefore the energy loss—is inversely related to pipe diameter? Do you know the relationship that defines energy loss in terms of pipe diameter?

Solution:

Resistance to flow occurs primarily at the walls of the pipe or duct due to the roughness of the material. In a small diameter conduit, a greater proportion of the fluid is in contact with the walls than is the case in a large diameter conduit. In fact, the energy loss due to friction in fluid flow is described by the following relationship:

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

where:

h_f is the energy loss due to friction
f is the “friction factor” which takes into account the roughness of the pipe or duct material
L is the length of pipe or conduit
D is the effective diameter of the pipe or conduit
V is the linear velocity of flow
And g is a dimensional constant (the acceleration due to gravity).

It follows from this formula that, all other things being equal, the smaller D is, the greater h_f is.

2 – Auxillary Control Devices

SAQ 2.1: Cooling and Dehumidification

We have made the statement that “dehumidification normally occurs whenever the cooling is on.” Why is this so?

Solution:
When the dry bulb temperature of moist air is reduced, the relative humidity (which is the ratio of the amount of moisture in the air to the amount that would be contained at that temperature when the air is saturated) increases. There is a temperature at which the relative humidity would increase to 100%, and that is the dew point. Air that is in direct contact with the cooling coils is typically cooled to its dew point, even though the bulk temperature of the air is somewhat warmer. As a result, moisture condenses on the cooling coils, thereby reducing the humidity of the bulk air.

SAQ 2.2: Sensitivity and Accuracy

Is sensitivity, as defined here, the same as accuracy of the device?

Solution:
Sensitivity and accuracy are two entirely different quantities. Sensitivity as we have defined it is the relative response of the device to the change in conditions, as in change in pneumatic pressure to change in air temperature. Accuracy refers to how well the device recognizes the actual conditions; that is, does it actually “see” 60°F air as 60°F air, or does it “see” it as 65°F air. Because of damage or lack of calibration a very sensitive device can still be totally inaccurate.

3 – Electric and Electronic Controls

SAQ 3.1: Modulation

What does the term "modulating" mean?

Solution:

We're most familiar with the term "modulation" in regard to radio transmission; AM means "amplitude modulation" and FM means "frequency modulation", which are two different ways of sending signals that can be interpreted by a receiver. The "amplitude" and "frequency" being referred to are the characteristics of the radio waves.

The working principle here is that information can be conveyed in a signal by varying an essential characteristic, and it is this varying ability that is being referred to in a modulating control device. So, instead of there being just two positions—such as open and closed—the modulating device has a continuous range of positions between its two extremes.

SAQ 3.2: Power and Resistance

How exactly is power related to the resistance of the potentiometer?

Solution:

The simple electrical relationship between power and resistance is:

$$\mathbf{P = I^2R}$$

in which I is the electrical current flowing through the device. It follows that the power lost by the potentiometer (as heat) is directly proportional to its resistance setting.

4 – Combination Control Systems

SAQ 4.1: Psychrometry

Define the following terms:

1. wet bulb temperature
2. dry bulb temperature
3. relative humidity
4. absolute humidity (or humidity ratio)
5. psychrometry
6. enthalpy
7. dew point

Solution:

1. wet bulb temperature is the temperature of air measured by a thermometer in which the bulb is enclosed in a water-saturated cloth; evaporation of water from the cloth, the rate of which depends on how much moisture is in the air, lowers the temperature that is sensed by the thermometer in proportion to the rate of evaporation.

2. dry bulb temperature is the temperature of air measured by a dry thermometer; there is no lowering of temperature due to evaporation of water. This is the temperature that we normally refer to when setting a thermostat or talking about occupant comfort.

3. relative humidity is the ratio of the quantity of moisture in air per unit of dry air to the quantity of moisture in air per unit of dry air at saturation, expressed as a percentage.

4. absolute humidity or humidity ratio is the quantity of moisture in air per unit of dry air; it is normally expressed as grams of H_2O/kg of dry air, grains of H_2O/lb. of dry air, or similar mass units.

5. psychrometry is the study of the physical and thermodynamic properties of moist air.

6. enthalpy is effectively the total energy content in the air/water mixture compared to a standard base temperature, ordinarily 0°C. Changes in enthalpy, represented by ΔH are the amount of energy required to bring about a change in conditions of the moist air; ΔH is normally expressed in kJ/kg of dry air or Btu/lb of dry air.

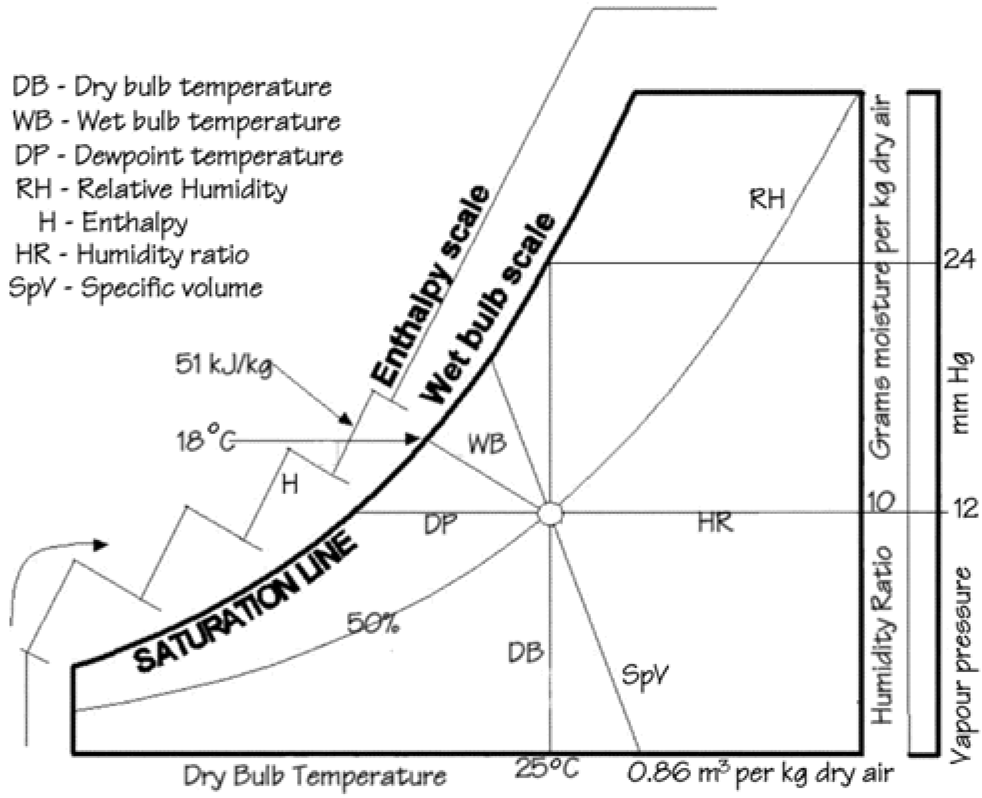
7. dew point is the dry bulb temperature at which an air/water mixture reaches saturation or 100% relative humidity.

SAQ 4.2: Using the Psychrometric Chart

There are three interrelated quantities regarding the characteristics of an air mixture: wet bulb temperature, dry bulb temperature, and relative humidity. Given the first two, how do you find the third, the % RH on the psychrometric chart. And given the point representing this air mixture on the chart, how do you find the following:

1) the moisture content of the air
2) the dew point
3) the enthalpy of the air mixture?

Solution:
The following diagram answers this question:



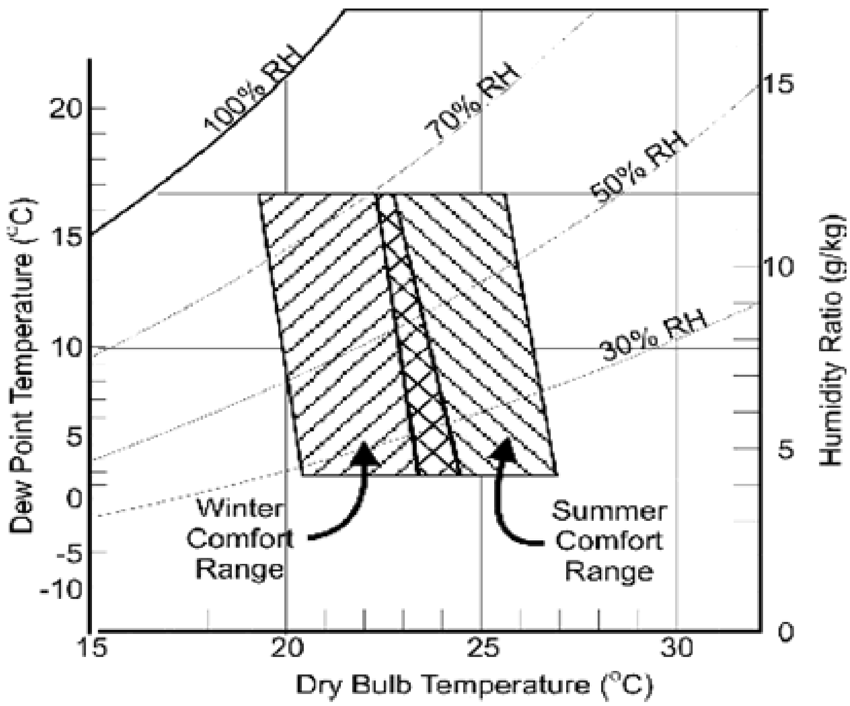
The intersection of the dry bulb temperature line (vertical) and the wet bulb temperature line (diagonal) defines the air:

- the curve on which the point lies is the relative humidity
- a horizontal line from this point to the scale on the right of the diagram gives the absolute humidity
- a horizontal line from this point to the temperature scale on the left of the diagram gives the dew point temperature
- a diagonal line up to the left (not the same diagonal as the wet bulb temperature scale lines) to the enthalpy scale gives the enthalpy of the air at those conditions.

SAQ 4.3: Comfort Zone

1) From the point of view of energy efficiency, we would probably like to increase the temperature in the summer and decrease it in the winter. What is the highest dry bulb temperature that is considered to be "comfortable" in the summer? Approximately what would the RH need to be in order to meet the comfort criterion at this temperature?
2) Similarly, what is the lowest temperature that you could use in the winter, and what would the RH need to be?

Solution:
The comfort zone is defined in the following diagram:



According to the diagram, the highest dry bulb temperature that would be considered “comfortable” in the summer is about 27°C, but to be comfortable, the RH would need to be well below 30%, probably of the order 15%. Similarly, the lowest temperature that would be considered comfortable in the winter is about 19°C, provided that the RH is well above 70%, say about 85%.

5 – VAV and VVT Controls

Guided Research Activity

Download PDF of Variable Frequency Drives – Energy Efficiency Reference Guide
https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/energystar/variable-frequency-drives-eng.pdf

6 – Computerized Controls

There are no web materials for this chapter.

7 – Building Performance Efficiency from Control

References

See the links below to downloaded the documents in PDF Format.

UK Carbon Trust publication, Building Controls – Realising Savings through the use of Controls, CTV032, 2007 https://www.carbontrust.com/media/7375/ctv032_building_controls.pdf

Natural Resources Canada, CANMET, Intelligent Building Operating Technologies, 2^{nd} Edition, May 2004 http://www.caba.org/AsiCommon/Controls/BSA/Downloader.aspx?iDocumentStorageKey=36cc11c6-b0f6-47a6-8ea1-0dd9e756d949&iFileTypeCode=PDF&iFileName=IS-2005-06

S1: Psychrometry and Psychrometric Chart

SAQ S1.1: Wet Bulb Depression and RH

Measurements taken with a sling psychrometer give a dry bulb reading of 22°C and wet bulb 16°C. What are:
a. The wet bulb depression
b. The relative humidity of the air
c. The absolute humidity of the air?

Hint: to answer b, you can use Table S1.1, but to find c you will need to use the SI psychrometric chart.

Solution:
a. Wet bulb depression = DB – WB = 22 – 16 = 6°C.
b. From Table S1.1, the RH for a DB of 22°C and wet bulb depression of 6°C is 54%.
c. From the Psychrometric Chart, the absolute humidity is found by locating the point defining this air at the intersection of the 22°C DB and 16°C WB temperatures, and then reading horizontally across to the absolute humidity (or humidity ratio) scale = 9.5 g moisture/kg dry air.

SAQ S1.2: Reading the Psychrometric Chart

A fresh air supply is measured to be at 25°C dry bulb and 21°C wet bulb. For this air, what are:
a. The relative humidity
b. Dew point
c. Absolute humidity
d. Enthalpy?

Solution:
This air is located on the SI Psychrometric Chart at the intersection of the 25°C dry bulb and 21°C wet bulb lines.
a. The point defining the air is on the 70% RH curve.
b. The dew point is 19.5°C, found by drawing a horizontal line to the left to the temperature scale.
c. The absolute humidity (or humidity ratio) is 14 g moisture per kg dry air, found by drawing a horizontal line to the right to the absolute humidity scale.
d. The enthalpy is 61 kJ/kg dry air, found by locating the diagonal enthalpy line on which the point defining this air lies.

SAQ S1.3: Heating the Air

The air supply of SAQ 1.6 is heated to 35°C without adding any moisture.
a. What is its relative humidity after heating?
b. How much moisture would need to be added in order to maintain its relative humidity at the same value it was before heating?

Solution:
Since no moisture is added, the absolute humidity remains constant at 14 g moisture per kg dry air while the temperature increases to 35°C.
a. The RH after heating is approximately 40% (just below the 40% curve on the chart).
b. To bring the RH back to 70%, the absolute humidity would need to be increased to 25.5 g H_2O/kg dry air, or an increase of 25.5 – 14 = 11.5 g H_2O/kg dry air. This is found by drawing a vertical line from the point defining the new hot air to the point where it intersects the 70% RH curve, and then reading the absolute humidity at that point.

SAQ S1.4: Mixing the Air

Outdoor air at 90°F dry bulb and 72°F wet bulb is being brought in through dampers to form 25% of a mixture with return air at 78°F dry bulb and 64°F wet bulb. What would be the dry bulb and wet bulb temperatures of the resulting mixture? As a result, is the total heat content of the mixture higher or lower than the heat content of the return air?

Solution:
Mixed air dry bulb temperature
= (% of outside air x temp. of outside air) + (% of return air x temp. of return air)
= (.25 x 90) + (.75 x 78)
= 81°F.
The mixed air is found on the Imperial unit psychrometric chart as discussed in the text. The wet bulb temperature of the mixed air at this point is 66°F. The heat content per pound of dry air has increased from approximately 29 to 31 Btu/lb. dry air.