Calculating Heating and Cooling Coil Performance

Using two formulas, an HVAC engineer can calculate off-design performance of heating and cooling coils

There are many situations in which the performance of heating/cooling coils needs to be known at conditions other than those for which they were purchased. One such situation would be that the cooling load has increased—what room temperature can now be maintained? Another situation would be that the occupants are complaining that the building is too hot or too cold—is the coil performing to its full capability, and if so, what can be done to improve the situation?

Methods are available to calculate the performance of a coil under any conditions with considerable accuracy. If the flow rates of air and water remain unchanged, calculations are simple enough to be done by an HVAC engineer without expertise in heat transfer. However, most HVAC engineers are not aware of these methods and face considerable difficulties when the need for such calculations arises.

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Two formulas follow by which the effects of changing air and water temperatures can readily be calculated. Their use is illustrated by three examples.

Formulas

For purely sensible heating or cooling, the following equation should be used:

$$\frac{Q_1}{Q_2} = \frac{(T_{a1} - T_{w1})}{(T_{a2} - T_{w2})} \quad (1)$$

where

Q = heating or cooling capacity of coil
T_a = temperature of air entering the coil
T_w = temperature of water entering the coil

Subscripts

1 = conditions at which performance is known
2 = conditions at which performance is needed

This formula is applicable if the flow rates of air and water are unchanged and the changes in temperatures from the design conditions are moderate, say 20 F or less.

When a coil does sensible cooling as well as dehumidification, the total cooling capacity, Q_t, can be calculated by the following equation:

$$\frac{Q_{t1}}{Q_{t_2}} = \frac{(h_{a1} - h_{w1})}{(h_{a2} - h_{w2})} \quad (2)$$

where

h_a = enthalpy of air at coil inlet
h_w = enthalpy of saturated air evaluated at inlet water temperature

Subscripts

1 = conditions at which performance is known
2 = conditions at which performance is needed

This formula should be used only if both the original and new conditions involve dehumidification.

Example 1

A switchgear room is provided with a recirculating fan-coil unit that maintains the temperature at 100 F. The unit is rated at 100,000 Btuh, with chilled water entering at 55 F. New switchgear (all sensible load) is to be installed, adding a load of 10,000 Btuh. Calculate the resulting room temperature using Equation 1:

$$\frac{100,000}{110,000} = \frac{(100 - 55)}{(T_{a2} - 55)}$$

$$T_{a2} = 104.5 \text{ F}$$

Thus, the new switchgear will raise the room temperature from 100 to 104.5 F.

Example 2

The conditions are the same as in Example 1, but the room temperature must not exceed 102 F. Calculate the required chilled-water temperature to achieve this, again using Equation 1:

$$\frac{100,000}{110,000} = \frac{(100 - 55)}{(102 - T_{w2})}$$

$$T_{w2} = 52.5 \text{ F}$$

Thus a chilled-water supply temperature of 52.5 F is required to maintain a 102 F room temperature.

Example 3

A fan-coil unit was purchased with the following performance rating by the supplier:

- Entering air temperature = 95 F DB/75 F WB
- Entering chilled-water temperature = 55 F
- Leaving air temperature = 66 F DB/58 F WB
- Chilled-water flow = 243 gpm
- Air flow rate = 20,000 scfm

The unit was installed and flow rates balanced to the above-listed values. The following measurements were then taken:

- Entering air temperature = 90 F DB/73 F WB
- Entering chilled-water temperature = 52 F
- Leaving air temperature = 63 F DB/56 F WB

Is the coil's performance better than or inferior to its rated performance?

Plotting the rated performance on the psychrometric chart shows that latent cooling is involved, so Equation 2 will be used.

- Enthalpy of entering air (h_e) at 95 F DB/75 F WB = 38.7 Btu per lb
- Enthalpy of leaving air (h_l) at 66 F DB/58 F WB = 25.2 Btu per lb
- Rated total cooling capacity = 4.5 × cfm ($h_e - h_l$) = 4.5 × 20,000 (38.7 − 25.2) = 1,215,000 Btuh (the factor of 4.5 represents density of standard air multiplied by 60 to convert cfm to cfh.)

The enthalpies at measured inlet and outlet air conditions are 36.8 and 23.9 Btu per lb, respectively.

- Measured total cooling capacity = 4.5 × 20,000 (36.8 − 23.9) = 1,161,000 Btuh
- Enthalpy of saturated air at 55 F = 23.2 Btu per lb
- Enthalpy of saturated air at 52 F = 21.5 Btu per lb

Applying Equation 2, we can now calculate the cooling capacity at the rating conditions from the test conditions as follows:

$$\frac{1,161,000}{Q_{t2}} = \frac{(36.8 - 21.5)}{(38.7 - 23.2)}$$

$$Q_{t_2} = 1,179,000 \text{ Btuh}$$

The rated cooling capacity is 1,215,000 Btuh. Hence, the measured performance is inferior to the rated performance.

Conclusion

Two simple formulas have been given with which off-design performance of heating and cooling coils can easily be calculated by engineers without heat transfer expertise. Note that Equation 1 is derived from basic heat transfer theory, and Equation 2 is based on a semi-theoretical correlation that has been well-verified with test data (see Reference 1). Interested readers should consult the references listed at the end of the article for more information. Ω

References

1) Kusuda, T., "Effectiveness Method for Predicting the Performance of Finned-Tube Coils," *Heat and Mass Transfer to Extended Surfaces*, ASHRAE Symposium, January 27-30, 1969, Chicago, Ill.

2) Kays, W. M., and A. L. London, *Compact Heat Exchangers*, 3rd edition, McGraw-Hill, New York, 1984.