Taco Technical Bulletin

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LoadMatch® System Engineering Design Considerations

For design engineers the most cited concern about LoadMatch® systems, that arises, is the temperature cascade of the system. Because the water temperature in the loop changes, it would appear that the terminal units at the end of the loop are not going to be able to provide the necessary BTU's for the heating or cooling loads. So they ask, In a cooling system, how is your system able to provide the same capacity, including dehumidification, at the end of the loop experiencing 50^{o} F entering water when other units at the start of the loop are experiencing 40^{o} F entering water? This is a legitimate question.

An examination of basic heat transfer fundamentals will provide the answer.

Consider the single dimensional steady state heat transfer form of the Navier-Stokes equation, shown below.

$\Delta Q = U \times A \times \Delta T$

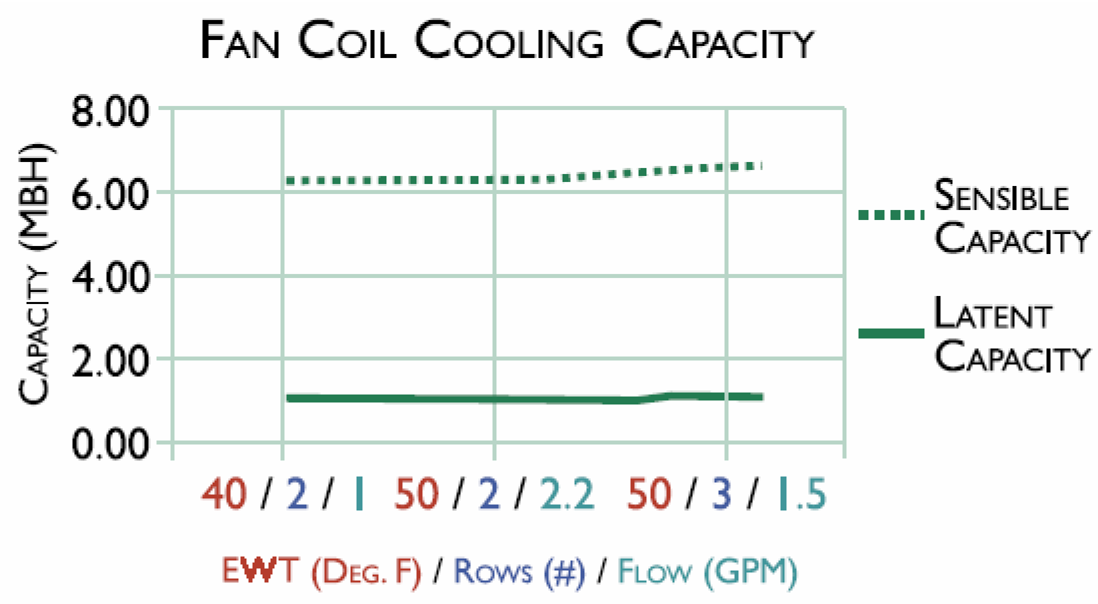
Where:

ΔQ is the heat transfer rate,
U is the heat transfer coefficient,
A is the surface area,
ΔT is the temperature difference (2)

Let's take a room that we want to maintain at 70^{o} F. If the room is at the beginning of the loop we have a 40^{o} F water supply, so the ΔT between the water supply and the room is a 30^{o} F difference (70^{o} F – 40^{o} F). However, at the end of the loop the water is at 50^{o} F, so now the ΔT is 20^{o} F (70^{o} F - 50^{o} F). In order to maintain the heat transfer of a terminal unit at constant capacity with a decreased ΔT, either the heat transfer coefficient or U value, or area A, or a combination of both, has to be increased.

The heat transfer coefficient or U value in a typical terminal unit is a function of fluid velocity, and the area A is a function of rows. The answer lies in increasing the flow rate through the heat exchanger or in adding more rows, or a combination of both, in order to compensate for the decreased ΔT. Following is an example of applying this simple concept to a typical fan coil unit (Figure #3 below):

Figure #3



As the above graph shows, the sensible and latent capacity of the terminal unit can be achieved in several ways by varying combinations of increased heat transfer coefficient or U value (velocity) or area A (number of rows).

At the beginning of the loop – shown by the point at the left of the graph - at 40° F entering water, utilizing a 2 row coil at 1 gpm, yields a given sensible and latent capacity. At the end of the loop - as shown by the point at the middle of the graph, we can achieve the same sensible and latent capacity (50° F entering water temperature) by increasing the U value or velocity (50° F entering water temperature, 2 rows, 2.2 gpm). As an alternative – shown by the point at the right of the graph - we can achieve the same capacity by increasing the area or number of rows (50 ° F entering water temperature, 3 rows, 1.5 gpm).

This is possible because the dew point of the airstream on the coil at ASHRAE room Comfort Zone conditions of 75F and 60% RH has a dew-point of 60F. Therefore an entering chilled water temperature of 50F is certainly capable of dehumidifying this air stream.

Despite concerns about the temperature cascade in a LoadMatch® cooling system, the use of basic principles of thermodynamics and psychrometrics, as described above, ***will result in comfortable room conditions, including dehumidification, in very humid climates.***

Software is now available that will calculate the temperature cascade automatically and provide a flow diagram printout of the entering water temperature at every terminal unit in the system. Using the flow diagram temperature cascade information the engineer selects the terminal unit for the correct cascaded entering water temperature at each terminal unit.

Another approach to selecting all the terminal units at different entering water temperatures is to select the terminal units at the same entering water temperature.

A recommendation is to use a worst case entering water temperature, taking into account the diversity of the system. Diversity is typically defined as the actual load divided by the design load. For our 10^{o} F design ΔT example, and assuming a 70 percent diversity factor, one can select all the units at 47^{o} F entering water temperature (47^{o} F = 40 + 0.7 x 10). Therefore, using this method, the process to select terminal units for a single pipe system is no different than selecting terminal units for a two pipe system.

A second concern about the temperature cascade that should be addressed here is a common misconception that the use of multiple terminal units on a loop adversely affects the temperature cascade. Again, an examination of basic heat transfer fundamentals will provide the answer. Take the steady state mass transfer equation, shown below:

$$\Delta Q = M \times Cp \times \Delta T$$

Where:

ΔQ is the heat transfer rate
M is the mass transfer rate
Cp is the specific heat
ΔT is the temperature difference (3)

In any loop the mass flow rate (M) is a function of the total load of all the terminal units, divided by the specific heat and the design ΔT for the system. Because the ΔT's are determined by the design, and not by the number of terminal units, the flow will always increase to match the load. Therefore the last terminal unit on a loop will never experience more than the design ΔT.

Interestingly, the more terminal units on a loop the better the temperature cascade will be at the last terminal unit. This concept is admittedly counterintuitive, but is the result of the diversity in the system. With more terminal units, there will be more diversity, and a better entering water temperature at the last terminal unit.