**ENGINEERING WHITE PAPER**

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# Water Coil Basics

**Selection software programs abound and each one of our coil manufacturers has their own program to facilitate easy selection & pricing. But what is missing in the software is the logic behind the how & why we select a particular coil for an application. With a dozen variables which make up a coil's physical construction there are countless solutions available when designing a coil.**

**The trick is knowing which one of those solutions is optimal for your application and which ones are problematic. This white paper is meant to give you a basic understanding in how to select a coil & an explanation as to why.**

## Cooling & Heating coil leaving air temperatures

There are typical values we use for leaving air temperature, but do you know why we use them? 55F leaving air temp off a cooling coil was used traditionally because when you add mostly sensible heat to the air in a room and the supply air is at 55F db & near saturation the room air will find itself near 50%rh when maintaining the room temperature near the mid 70's.

There are times when we want to pull more moisture out of the room air- think theater or auditorium with lots of people adding moisture to the air as they breath & perspire. In this case, we may use a colder cooling coil temperature to increase condensation of moisture from the entering air on to the coil. There are other ways to increase condensation on a coil like adding more rows and/or slowing down the airflow rate. Typically, we weigh these options and if we cannot get there using rows & slower moving air then we must consider colder water too.

There are new energy code versions requiring limits on how cold of water you can use but physics prevails over codes every time. So be aware of these restrictions and be ready to advise your engineer depending on where your job is located (which code reigns), what type of building or process you are dealing with, and the limitations of the coil & the physics (psychrometrics & heat transfer) involved.

In heating we see around 95F maximum because any hotter and the supply air will stratify near the ceiling and not get to the occupied zone below. In general, most energy codes in the PNW require us to use a maximum hot water temperature of 120F.

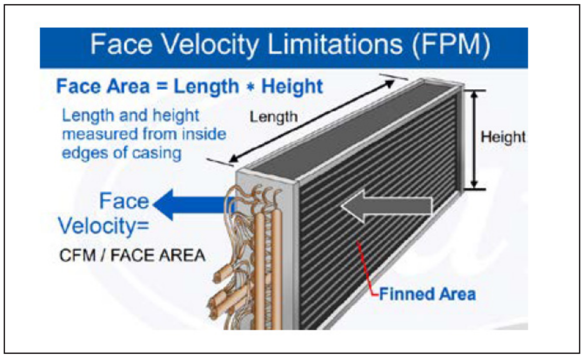
## Moisture carryover on a cooling coil

Typically, specification and the engineers who write them will restrict the selection of cooling coils to 500fpm face velocity (sometimes down to as low as 400fpm) to avoid moisture carryover. Moisture in the entering air will condense on the coil when the coil surface is below the dew point of the air. This is by design and typically needed to some degree. This carry over of moisture/water will occur when the speed of the air is high enough that it pulls condensing moisture from the trailing edge of the coil. This can cause problems to components downstream like filters & fans plus the air handler itself.

## Free Area verses Face Area

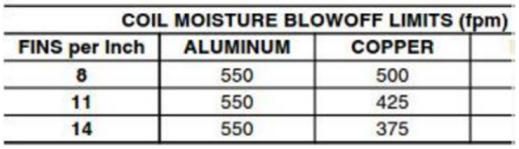
A coil's free area is defined by the finned length x finned width and expressed in square feet. Airflow velocity (feet per minute or fpm) is derived by dividing the volumetric flow rate or cfm of the air by the square footage of the finned area of the coil (ft2). In equation form it looks like this cfm/sqft of coil area = fpm. Again, the typical maximum face velocity allowed is 500fpm.

But to be clear 500fpm is just a safe number to preclude moisture carry over in any case, however it is often far to conservative preventing much better solutions to custom coil design. This is because it does not account



for the actual face velocity nor the actual face velocity at which water will carry over from a cooling coil. In the past coil manufacturers published coil charts which allowed the selector to push a specific design to the actual moisture carry over velocities. These charts are no longer provided but rather coil manufacturers place this arbitrarily low 500fpm to avoid issues in all cases. Think training wheels for novices who might be using their software. This safety is at the expense of better selections by an experience engineer, so in the absence of these moisture carry over charts we must use practical benchmarks to avoid missing out on a best selection that might push a bit over 500fpm.

The actual face velocity is determined by knowing the free area of the finned area- in layman's terms, the air gaps between the fins & tubes. For example, I could have two coils with the same finned dimensions (h x w) at the same cfm and the selection software will list both at 500fpm. Yet one coil has 6 fins per inch (fpi) while the other has 14fpi. We know intuitively that the coil with only 6fpi will have a much slower face velocity than the one with 14fpi because it has less stuff blocking the air from passing through it. Thus, it has more free area for the same volumetric airflow rate (cfm), therefore it will have the lower velocity (cfm/fpm = area in square feet).



COIL MOISTURE BLOWOFF LIMITS (fpm)

| FINS per Inch | ALUMINUM | COPPER |
|---|---|---|
| 8 | 550 | 500 |
| 11 | 550 | 425 |
| 14 | 550 | 375 |

*Example of a coil manufacturers face velocity guidance as it relates to fins per inch and max face velocity*

## Coil Height & Moisture Carryover issues

Coil height can also contribute to water separating from the trailing edge of a cooling coil. The taller the coil the more likely this may happen when running higher speeds (>500fpm) through a cooling coil. To avoid this potential for moisture separation when running higher face velocities limit the height of a coil buy using stacked coils with intermediate drain pans. A rule of thumb is greater than 48" is a tall coil.

## Heating coils are not subject to moisture carryover

Heating coils do not have a maximum face velocity requirement since there is no moisture to carry over since there is no condensing of moisture from the supply air occurring. The only limitation is air pressure drop (apd) you can deal with as apd increases with face velocity.

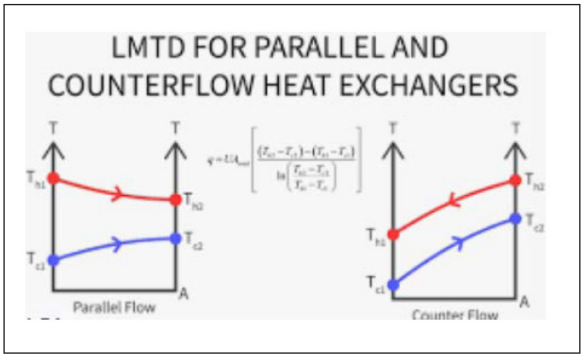
## Glycol & the use of Turbulators

When water freezes it expands and if it's trapped in a coil, it will burst or break the coil's metal holding that water in the coil. Freezing coils can occur when freezing outside air is introduced into a duct or ahu and the water is cool (chilled water) and/or it is not moving (pump is off). You may use glycol in either cooling or heating coils but typically you'll see it in chilled water systems as heating systems are active during winter. Also, sometimes piping is outside (think air source heat pumps). So we can freeze protect with heat trace, keep pumps running, or use glycol (antifreeze). Often times, glycol is the most practical approach or the only approach that works. In this case our engineers specify propylene glycol (PG) over ethylene glycol (EG) as it is safer when exposed to humans. We also use PG tables to determine the appropriate concentration (%) required in our water system based on our winter ambient design day temperature. For example, in Seattle our design day is about 22F which only requires 20%pg. But glycol has a downside as it makes our heat transfer less efficient and caused more water pressure drop through our system. You can select your water side of the coil to minimize water pressure drop. You can also select your coil to maximize heat transfer even with glycol included.

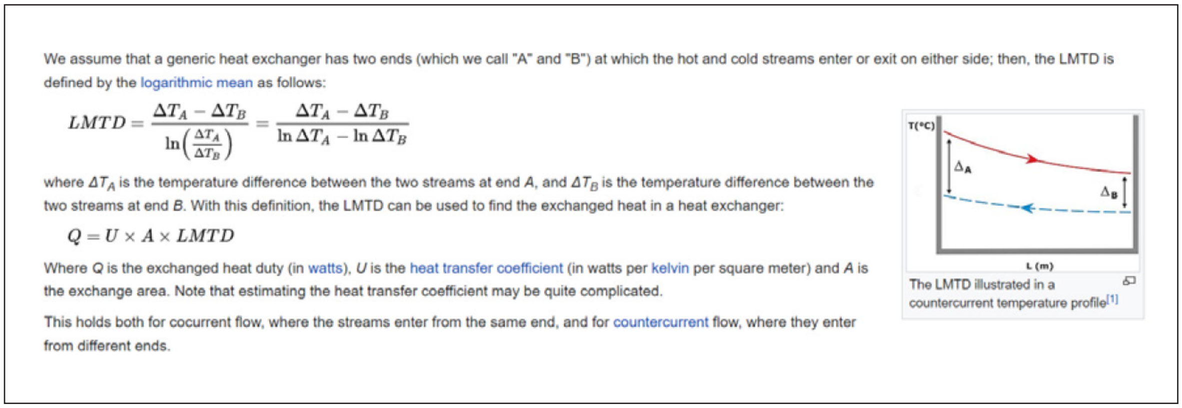
One trick to know when designing a coil with glycol is employing turbulators in your design. Turbulators are a coiled wire pulled (stretched) through a coil tube and makes a pattern like riffling in a gun. What it does or affords you is more turbulence which causes more heat transfer which may be needed due to the reduction of heat transfer with the addition of glycol. But a caution- it does add water pressure drop and works best in chilled water systems. So only typically use them when you just can't get that chilled water coil to reach the capacity you need at your conditions and the resultant water pressure drop is acceptable.

## Counterflow & the Log Mean Temperature Difference (LMTD)

The orientation of the entering air to the entering water is important in maximizing heat exchange in a coil. There are two types to consider when designing a coil: counterflow & parallel flow. To maximize heat transfer counterflow is employed. This is where the coldest water heats the coldest air in a cooling coil or in a heating coil the hottest water hits the hottest air. A detailed analysis using the Log Mean Temperature Difference (LMTD) is how engineers determined this fact. Coil manufacturers employ counter flow configuration in the design of their coils, but it is important that they are installed correctly (not backwards) to ensure capacity is met. Fin tube layout is also subject to the physics of LMTD so be sure they install correctly.



The LMTD is a logarithmic average of the temperature difference between the hot and cold feeds at each end of the coil or heat exchanger. For a given heat exchanger with constant area and heat transfer coefficient, the larger the LMTD, the more heat is transferred. The use of the LMTD arises straightforwardly from the analysis of a heat exchanger with constant flow rate and fluid thermal properties. Below is the equation and a more detailed explanation as to how it is derived.



We assume that a generic heat exchanger has two ends (which we call "A" and "B") at which the hot and cold streams enter or exit on either side; then, the LMTD is defined by the logarithmic mean as follows:

$$LMTD = \frac{\Delta T_A - \Delta T_B}{\ln\left(\frac{\Delta T_A}{\Delta T_B}\right)} = \frac{\Delta T_A - \Delta T_B}{\ln \Delta T_A - \ln \Delta T_B}$$

where $\Delta T_A$ is the temperature difference between the two streams at end $A$, and $\Delta T_B$ is the temperature difference between the two streams at end $B$. With this definition, the LMTD can be used to find the exchanged heat in a heat exchanger:

$$Q = U \times A \times LMTD$$

Where $Q$ is the exchanged heat duty (in watts), $U$ is the heat transfer coefficient (in watts per kelvin per square meter) and $A$ is the exchange area. Note that estimating the heat transfer coefficient may be quite complicated.

This holds both for cocurrent flow, where the streams enter from the same end, and for countercurrent flow, where they enter from different ends.

The LMTD illustrated in a countercurrent temperature profile[1]

## Laminar flow, coil circuiting, & Turndown

On the water side of the coil pay attention to water velocities (fps) to ensure that velocities are not too slow or too fast. Coil water velocities running too fast in a heat exchanger typically manifest as high water pressure drop (ft of head or psi) but low water velocities don't always jump out at the selector. So, pay attention to the water velocities (fps) and the warnings that software might give with these selections to ensure that you don't run laminar at design flow rate or when turning down flow rate which can occur in variable pumped systems. Laminar flow (unlike turbulent) reduces heat transfer greatly. Also running around laminar flow (below the Reynolds number) can also cause control valves to hunt (cycle) as the coil goes from turbulent to laminar flow and back. To determine laminar flow you have to calculate the Reynolds number for the water flowing through that tube but in general a safe value is about 3ft per second (fps).

## Summary

When selecting a water coil be sure to do the following:

- know the purpose of the coil (application)
- select the water temperature based on the application
- don't let the arbitrary 500fpm max coil airflow velocity prevent you from the best coil selection...
- but rather know that minimizing fins per inch and limiting coil heights will help ensure that a higher coil face velocity (>500fpm) will not lead to moisture carry over
- understand counterflow and why it matters
- employ the use of turbulators when needed
- keep your coil from laminar flow throughout its operating conditions (not just a design flow)