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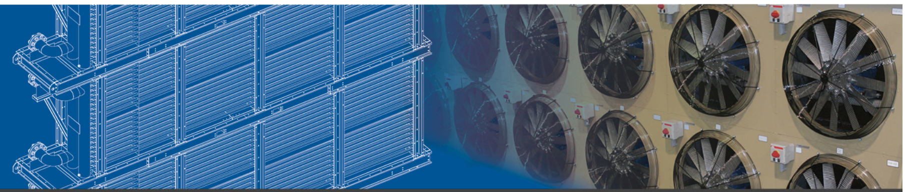

Technical Bulletin

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DETERMINING DEFROST WATER VOLUME

Introduction:

Refrigerated warehouses and food processing facilities typically use cooling coils to cool air as it is circulated in the refrigerated space. Air is made up of a mixture of gases, mainly nitrogen, oxygen, carbon dioxide, and water vapor.

As air passes over cooling coils, the dry bulb temperature is reduced. This change in temperature is called “sensible cooling” and the energy associated with this temperature change is called “sensible heat”. Water vapor in the air passing over a cooling coil is condensed into liquid water whenever the surface temperature of the coil is below the dewpoint temperature of the air. If the surface temperature of the coil is below the dewpoint temperature and is also below freezing (32F), then frost will form. The removal of water vapor from the air is called “latent cooling” and the energy associated with this change in moisture content of the air is called “latent heat”. Unlike sensible cooling, latent cooling is not accompanied by a change in temperature (latent meaning “hidden”). The ratio of sensible heat to total heat (sensible + latent) is called the Sensible Heat Ratio, and is an indication of the amount of moisture being removed from an airstream during the cooling process.

System designers need a simple method to calculate the amount of moisture removed by cooling coils from air in refrigerated spaces in order to determine:

A) Total sewerage requirements for the facility, and
B) Proper drain piping sizes to handle peak flowrates during defrost.

This article will present two simple calculation methods for determining these important design parameters.

Determining Total Volume of Moisture Removed:

In order to estimate the volume of water generated from defrosting (or wet fin) air coolers, the hours per day the cooler(s) operate along with the Sensible Heat Ratio (SHR) must be known. Assuming a room relative humidity of 90%, the SHR for an air cooler operating at various temperatures will be as shown in Table 1 below:

Table 1: SHR for 90%rh Air at Various Temperatures

Room Temp, F	Air SHR
45	0.59
32	0.70
10	0.85
-10	0.93
-30	0.98

The amount of moisture accumulated on the surfaces of the air cooler(s) that will be drained as condensed water in high temp rooms or as melted frost in medium and low temp rooms, can be estimated using the following formula:

$$Gal/day = 1.35t(1 - SHR)Q$$

where:
t = Operating Time, hours/day
SHR = Air Sensible Heat Ratio
Q = Room Total Cooling Load, tons (note: 1 ton = 12,000 Btuh)

1.35 (constant) = 12,000 Btuh/ton / (8.33 lbs/gal x 1,068 Btu/lbs)
8.33 lbs/gal = liquid density of water
1,068 Btu/lbs = latent heat of vaporization of water

Example 1:
Room Temp: 45F
Operating Time: 12 hours/day
Room SHR (from Table 1): 0.59
Room Cooling Load: 50 tons
Condensed Water Volume = 1.35 x 12 x (1-.59) x 50 = 332 gal/day

Example 2:
Room Temp: -10F
Operating Time: 16 hours/day
Room SHR (from Table 1): 0.93
Room Cooling Load: 100 tons
Defrost Water Volume = 1.35 x 16 x (1 - 0.93) x 100 = 151 gal/day

Determining Peak Defrost Water Flowrate

To determine the peak defrost water flowrate leaving a frosted coil surface, first calculate the volume of water yielded by a cooling coil during defrost using the following equation:

$$V_{def} = 0.0937 \times A_{surf} \times \left[\frac{\left(\frac{1}{S_{fin}} - t_{fin} \right)}{2} \right] \times \varepsilon$$

$where:$

$V_{def} =$ *Volume of Defrost Water, gallons*

$A_{surf} =$ *Total Frosted Surface Area, sq ft*

$S_{fin} =$ *Fin Spacing, fins per inch*

$t_{fin} =$ *Fin Thickness, inches*

$\varepsilon =$ *Fraction of Frost Blockage (50% = 0.5)*

Note: This equation assumes frost has average density of 150 kg/m3 (Besant 1999), approx. 1/6th that of liquid water.

Example 1:
Total Surface Area = 4,500 sq ft
Fin Spacing = 4 fins per inch
Fin Thickness = 0.012 inches
Fraction of Frost Blockage = 0.5
Volume of Defrost Water = 0.0937 x 4,500 x (1/4-0.012)/2 x 0.5 = 25 gallons

In order to then determine the peak flowrate, an estimate of the length of defrost time must be made. For hot gas defrosting, the majority of defrost water flows to the drain in a relatively short period of time. To estimate peak flow rate of defrost water an estimated duration of defrost of 5 minutes can reasonably be made (Stoecker 1983).

To calculate peak flowrate, simply divide the volume of defrost water by the estimated duration of defrost. For the example:

Estimated peak defrost flowrate = 25 gal/ 5 min = 5 gpm

Drain lines can now be sized based on the calculated peak defrost flowrate. The maximum peak flowrate for a facility will be the combined flowrates for the maximum number of cooling coils expected to defrost simultaneously.

Sizing Sloping Drain Lines

The American Society of Plumbing Engineers (ASPE) publishes sizing methods for vertical and sloping drains (ASPE 1999). The following table is taken from the ASPE Data Book Volume 2, page 8.

Table 2: Approximate Discharge Rates and Velocities in Sloping Drains, n = 0.015*

Actual Inside Diameter of Pipe, inches	½-Full Flow Discharge Rate and Velocity Based on ¼ inch/ft Slope	
	Discharge, gpm	Velocity, fps
1 3/8	3.13	1.34
1 ½	3.91	1.42
1 5/8	4.81	1.50
2	8.42	1.72
2 ½	15.3	1.99
3	24.8	2.25
4	53.4	2.73
5	96.6	3.16
6	157	3.57
8	340	4.34
10	616	5.04
12	999	5.67

* n = Manning coefficient, which varies with the roughness of the pipe.

Manufacturers' installation instructions should also be consulted for correct sizing and design of air cooler drain lines (Colmac 2003).

Conclusions

The author has described a simple method based on Sensible Heat Ratio (SHR) for determining the total amount of moisture that will be removed from air in a refrigerated facility over a 24 hour period. The facility designer needs this information to correctly estimate sewerage requirements. Also presented is a method to estimate the peak defrost water flowrate during defrost for an air cooling coil. This information is needed to correctly size drain lines. Finally, reference is made to a standard method for sizing sloping drain lines based on ½ -Full pipe flow at ¼ inch/ft slope.

References

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