ENGINEERING WHITE PAPER

Internal use only

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Energy Balance & the Energy Equations

In EWP 11 (Heat Balance) Ken taught us about the heat balance in water cooled chiller system and why it is important not to just use 3gpm/ton when sizing a cooling tower. This white paper is meant to expand on the heat balance & energy equations for air and water as it relates to typical equipment schedules.

As a quick review the energy equation has both an air & water equivalent and they equate as shown below:

4.5 * cfm * Δh (enthalpy) = Q = 500 * gpm * ΔT

We can break down the airside equation further to its sensible and latent components as follows:

Q_{Total} = $Q_{sensible}$ + Q_{Latent}

$Q_{sensible}$ = 1.085 * cfm * ΔT and Q latent = 0.69 * cfm * ΔW (grains of moisture)

It's important to note that the airside "constants" of 4.5 (total), 1.085 (sensible) and 0.69 (latent) are based on standard air conditions defined by ASHRAE (60°F saturated air at sea level with a density of 0.075 lb/ft3). These constants will vary slightly with small departures from the standard condition defined above. In most hvac applications the difference is not great enough to warrant recalculating the constants but at very high & very low temperatures and/or large elevation changes this constant must be adjusted accordingly.

The typical equipment schedule:

Too often we see schedules with fields that do not equate yet some of us do not bother or know to qualify (check) the values against each other. When this does not happen, we can oversize equipment making it too costly or causing it to perform poorly. If we get the job (usually we do not), then we end up oversizing this equipment which can lead to operational issues once installed.

Below is an example of a schedule that makes sense. Here we can see a nominal 350ton air cooled chiller is selected to do 323tons of cooling. We know this because the energy equation tells us that 646gpm with a 12degree ΔT (54F-42F) gives us 3,876mbh (323tons). This is based on water (no glycol) so the constant we use in the energy equation is 500.

Air Cooled Chiller												
Manufacturer	**Model**	**Refrigerant**	**Capacity (Nominal)**	**Flow**	**PD**	**EWT**	**LWT**	**OAT**	**Volts**	**Phase**	**EER***	**IPLV***
Trane	RTAF	R513A	350	646	10	54	42	95	460	3	10.6	18.9

It looks like this… **Q= 500 * 646gpm * (54F-42F)**

The reason this schedule calls out a 350ton a/c chiller is because the manufacturer used in this schedule has a size 300ton & a size 350ton offering so they had to upsize to the 350ton to meet the engineer's load.

If we just bid to meet or exceed the 350tons nominal capacity listed in this schedule never checking the math we will probably oversize the chiller. In this example we only had a 340ton or a 380ton, and if we went by the nominal capacity listed then we would provide the 380ton. This would be 57tons more than the engineer needed or 18% oversized. The 340ton option would have been the right fit but now we are carrying extra cost, size, electrical, etc and we will probably lose the job because of it. Furthermore, if we did get the job and they were looking for low turndown operation we could be causing operational issues with our oversized selection.

You can also chase ghosts if you do not check capacities against the air or water conditions given. In this case (see schedule below) the scheduled Qsensible is 36,400btuh but when you calculate the Qsensible based on the scheduled 1600cfm & 19degree ΔT (78F-59F) you will note that this only comes to 32,984btuh. If you never bothered to calculate Qsensible at design conditions you may not get a selection or you may oversize the fan coil in this case as the schedule calls for 36.4mbh sensible cooling. This can make a big difference if this error runs through a schedule of dozens of fan coils. This is the type of error that leads to incorrect pricing at a large scale.

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FAN COIL UNIT SCHEDULE

UNIT MARK	TYPE	SERVICE	CFM	EXT. SP. (IN)	MIN OUTDOOR AIR	HEATING COIL: MIN HEATING CAP.	E.A.T.	L.A.T.	E.W.T.	L.W.T.	GPM	P.D. (FT H2O)	Cv	COOLING COIL: MIN. COOLING BTU/HR	SENS. CAP. (BTU/HR)	EAT DB/WB (F)	LAT DB (F)	LAT WB (F)	E.W.T.	L.W.T.	GPM	P.D. (FT H2O)	Cv	FLUID
FC-1-1	CEILING, CHILLED WATER	RM 119	1600	0.5	150	5,600	69.5	72.9	140	120	0.58	6	0.3	37,400	36,400	78/65	59	55	44	54	7.8	8	4.5	30% PG
FC-1-2	CEILING, CHILLED WATER	RM 115, 116	1000	0.5	100	6,264	69.4	75.2	140	120	0.83	6	0.4	14,000	13,500	78/65	66	62	44	54	3	8	1.6	30% PG
FC-1-3	CEILING, CHILLED	RM 114	400	0.5	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

A closer look at this schedule...

CFM	EXT. SP. (IN)	MIN OUTDOOR AIR	HEATING COIL: MIN HEATING CAP.	E.A.T.	L.A.T.	E.W.T.	L.W.T.	GPM	P.D. (FT H2O)	Cv	COOLING COIL: MIN. COOLING BTU/HR	SENS. CAP. (BTU/HR)	EAT DB/WB (F)	LAT DB (F)	LAT WB (F)	E.W.T.	L.W.T.	GPM
1600	0.5	150	5,600	69.5	72.9	140	120	0.58	6	0.3	37,400	36 400	78/65	59	55	44	54	7.8

Effect of glycol in the system:

Previously I mentioned the constant in the waterside energy equation is 500 when working with water but what happens when there is glycol. Below is a table for propylene glycol (PG) which shows the capacity derate for various concentrations of PG. As you can see from the table below a 30%PG concentration in the chilled water would result in a capacity derate of approxiately 6% or x0.94 derate. So, when you do have glycol in your water system then adjust the energy equation coeffient as follows...

500 x capacity factor or in this case 500 x 0.94 = 470

Propylene Glycol

Leaving Temperature Degrees F	30% Capacity Factor	30% Pressure Drop Factor	40% Capacity Factor	40% Pressure Drop Factor	50% Capacity Factor	50% Pressure Drop Factor
20	-	-	0.80	1.74	0.74	2.07
30	0.92	1.39	0.87	1.63	0.82	1.94
40	0.93	1.36	0.89	1.55	0.85	1.83
45	0.94	1.35	0.90	1.53	0.87	1.81
50	0.94	1.33	0.91	1.51	0.88	1.75
55	0.95	1.31	0.92	1.50	0.89	1.73
60	0.95	1.31	0.92	1.47	0.90	1.68
70	0.96	1.27	0.93	1.43	0.91	1.63
Minimum leaving fluid temperature	25°F		10°F		-10°F	
Minimum ambient	10°F		-4°F		-20°F	

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