District Cooling and Building Cooling System Interface: Design and Practice

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INTRODUCTION

The district cooling technology has inherent advantages of being cost effective and environmentally sustainable, but the building side HVAC must be designed to work together effectively.

The effective utilization needs considerable attention on building side HVAC design.

Typically HVAC design starts from heat load calculation for the building, ETS design, and Equipment selection such as AHU, pumps etc.

This presentation discusses what it takes to design an effective HVAC system for an energy efficient building and eventually an energy efficient district cooling system.
Presentation Content

- Importance of Accurate Cooling Load Calculation
- Energy Transfer Station (Design and Practice)
Why is Accurate Load Calculation Important?

We observe property developers often overestimate cooling requirements.

Impact of over estimation

- Cost
- Space
- Comfort
Cost

a) Typical DC Provider Charges*
   - Connection Charge: One off fee to be paid to get the connection (QAR 2000-3000/TR approx.)
   - Demand Charge: This is an annual charge, levied by DC Company for providing District Cooling Service to the building (QAR 1000/TR/YEAR)
   - Consumption Charges: Based on meter reading

b) Installation Cost
   - Installation cost for ETS, AHU/FCU, piping, controls etc. cost around QAR 7000-8000/TR.

* Values are indicative and illustration purposes only. Values varies for building types (commercial/residential) and also from one DC provider to another.
Space

- Space for ETS: Correct sizing of HVAC equipment such as PHE, AHU/FCU can increase saleable space and possibly more head room (false ceiling height)

Comfort

- Oversizing of HVAC system is detrimental to comfort and indoor air quality. Oversized system leads to the short cycling (frequent starting and stopping) and will have adverse impact on:
  - Humidity control: Require AC running all the time
  - Space temperature: Uneven temperature inside the AC space
Why is overestimation happening??

- Cooling load calculation is more complicated than heating load.

- For estimating cooling load one has to consider the unsteady state process, as the peak cooling load occurs during the daytime and the outdoor condition vary significantly throughout the day due to solar radiation.
Observation:

a) Cooling load based on Rule of thumb

- Rule of thumbs were developed for HVAC sizing that worked based on the construction on that time.
- Rule of thumbs do not distinguish between good building design and bad building design.

b) Computerized cooling load using software

- While software makes cooling load calculation easier it is also facilitating mistakes. The engineer must be well versed in the load calculation procedure and functionalities of the used software.
- Mind the defaults.
- Design temperature with worst outdoor/indoor temperature
- Use a factor of safety considering uncertainties
## Case Study

<table>
<thead>
<tr>
<th>Condition</th>
<th>Base Model Parameters (ASHRAE design condition)</th>
<th>Base Model Load (TR)</th>
<th>Manipulated Model Parameters (Extreme weather condition)</th>
<th>Increased in Load (TR)</th>
<th>Additional Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outdoor Design Condition</strong></td>
<td>Summer Design Dry-Bulb 42.9 °C</td>
<td>380 TR</td>
<td>Summer Design Dry-Bulb 46.1 °C</td>
<td>456 TR (19%)</td>
<td>• QAR 228,000 Connection Charge</td>
</tr>
<tr>
<td></td>
<td>Summer Coincident Wet-Bulb 22.4 °C</td>
<td></td>
<td>Summer Coincident Wet-Bulb 30 °C</td>
<td></td>
<td>• QAR 76,000/ YR Demand Charge</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• QAR 608,000 (Installation Cost)</td>
</tr>
<tr>
<td><strong>Indoor Design Condition</strong></td>
<td>22 deg C, 50% RH</td>
<td></td>
<td>22 deg C, 50% RH</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Outdoor Design Condition:
  - Summer Design Dry-Bulb 42.9 °C
  - Summer Coincident Wet-Bulb 22.4 °C

- Indoor Design Condition:
  - 22 deg C, 50% RH
Suggestions

- Cooling load Calculation is not required for extreme condition which will occur for couple of hours and will not impact building cooling requirement. The ASHRAE tabulated temperature data is adequate for calculating peak load calculation.

- Cooling load calculations shall be based on accurate information pertaining to the building construction and there is no need to consider design margin.

- All inputs /defaults/building characteristics used for the calculation must be verified during construction and signed off by the Engineer.
Plate Heat Exchangers

Following design Information needs to be provided to Supplier/Manufacturer

1. **Heat Exchanged**: From the Cooling load Calculation

2. **Cold Side Temperature**:  
   - Chilled Water In : 5°C (By DC provider)  
   - Chilled Water Out : 14°C (By DC provider)

3. **Hot Side Temperature**:  
   - Chilled Water In : (15 / 15.5 /???) (By Building Designer)  
   - Chilled Water Out: (6/6.5/???) (By Building Designer)
PHE : Hot side temperatures

Following Equation Quantifies the Heat Flow

\[ Q = U \times A \times LMTD \]

\( Q \): Amount of Heat Transferred; W (Btu/hr)

\( U \): Heat Transfer Coefficient; W/m² * 0K (Btu/hr*ft²*0°F)

LMTD: Log –mean temperature difference across the Plate/coil surface

The larger the LMTD the smaller the heat exchanger

(Less costly, less space) : Should we go for higher LMTD?
\[ \text{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln \left( \frac{\Delta T_1}{\Delta T_2} \right)} \]

1. \[ \text{LMTD} = \frac{11.10 - 6.30}{\ln \left( \frac{11.1}{6.3} \right)} = 8.47^\circ \text{C} \]
2. \[ \text{LMTD} = \frac{11.60 - 6.80}{\ln \left( \frac{11.6}{6.8} \right)} = 9.00^\circ \text{C} \]
**LMTD IMPACT**

<table>
<thead>
<tr>
<th>PHE OUT/IN</th>
<th>LMTD for AHU/FHU</th>
<th>PHE IMPACT</th>
<th>Impact on AHU/FCU</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5 °C / 15.5 °C</td>
<td>8.47</td>
<td>Cheaper, smaller in size</td>
<td>Smaller</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Costlier</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Larger in size</td>
</tr>
<tr>
<td>6.0 °C / 15.0 °C</td>
<td>9.00</td>
<td>Costlier (20% approx.), Larger in size</td>
<td>Cheaper due to increase in LMTD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Smaller in size</td>
</tr>
</tbody>
</table>

**Suggestion:**

While specifying for PHE, building Designer must evaluate LMTD effect on AHU/FCU with lower water temperature. There is huge potential of capital and life cycle cost.
4. Pressure Drop:  
(By Building Designer)

Pressure Drop is a driving force in PHE's creating turbulence to get high U value. In calculation DP can dramatically change Heat Transfer Area required.

\[ Q = U \times A \times LMTD \]

Larger allowed pressure meaning smaller heat exchanger and hence cheaper.

**Impact of pressure**

<table>
<thead>
<tr>
<th>Pressure Difference (DP)</th>
<th>Cost and size</th>
<th>Pump size and running cost</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 kPa</td>
<td>Lower</td>
<td>Higher</td>
<td>Power consumption is directly proportional to pump head</td>
</tr>
<tr>
<td>30 kPa</td>
<td>Higher</td>
<td>Lower</td>
<td></td>
</tr>
</tbody>
</table>

**Suggestion:**

Determine pressure drop taking following in account

- Allowed pressure drop by DC provider (150 kPa at the tie-in point for Lusail City)
- By evaluating life cycles analysis for chilled water pumping cost and pump cost.
5. **Pressure rating : (By Building Designer)**

Higher the pressure rating costlier the Heat Exchanger.

Pressure rating = Hydrostatic head + Pump dynamic head

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**PUMP - SUPPLY SIDE**

- Static Pressure: 130 M
- Pump Shut-Off Pressure: 45 M
- Total Pressure: 175 M
- PHE Rating: 20 Bar

**PUMP - DISCHARGE SIDE**

- Static Pressure: 130 M
- Pump Residual Pressure: 10 M
- Total Pressure: 140 M
- PHE Rating: 16 Bar

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FIG. 1

FIG. 2
6. **Performance Rating:**

"The plate heat exchangers shall be certified in accordance with the AHRI Liquid-to-Liquid Heat Exchangers Certification Program"

Some manufacturers sell PHEs "In accordance with AHRI standard 400" OR "As per AHRI Standards" which is a misleading term and does not really mean they are providing AHRI performance certified units.
Control Valve

Conventional Control valve: Flow varies with change in Cv of Valve + pressure fluctuation.

\[ Q = \frac{C_v}{\sqrt{\Delta P}} \]
Pressure Independent Control Valve (PICV)

PICV: Flow varies with change in Cv and not affected by system pressure fluctuation.
Conclusion

• Accurate cooling load calculation by the building HVAC designer is vital for both customer and utility provider.

• Building HVAC design should consider the system and not just components; PHE and AHU.

• PHE cost increase $\Rightarrow$ lower AHU coil cost; implies an optimum solution. Equipment selection with understanding of thermodynamics has potential benefit which should not be overlooked.

• The extent to which Heat Exchangers (PHE, AHU & FCU) can raise the chilled water temperature inside building can affect both capital and operational cost.
THANK YOU