Refrigeration & Cooling
Existing & Innovative Energy Efficient Solutions

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Why Focus on Refrigeration?

• Refrigeration & Cooling is responsible for approx. 20% of all Electricity consumption in Ireland

• In Large Industry – 10 to 60% of Large Industry Electricity Consumption is for Refrigeration depending on the Industry (Refrigeration SWG 2009)

• Supermarkets – up to 60% Electricity used on refrigeration.

• Refrigeration or Chillers are almost always a significant energy user (SEU) - ISO-50001

• Refrigeration systems are thought of as being complicated in comparison with other utilities such as hot water, compressed air, steam etc.
Different Refrigeration Systems

- Large Commercial/Light Industrial
- Large Scale Food Industry Systems
- Low Temperature Distributed Cooling
- Industrial Scale Chilled water systems
Large Commercial/Light Industrial

- Very often cold room and freezer room type installations
- Vast majority food manufacturing & distribution
- Pharmaceutical and Biotech coldrooms use same equipment
- Historically – Freon Based refrigerants (copper distribution)
- Chiller type system with secondary refrigerant sometimes used.
Large Commercial/Light Industrial Equipment/Systems

- Semi-hermetic Compressors (Recip, Scroll, Screws)
- Typically air-cooled condensers
- Typically Direct Expansion Evaporators using HCFC
- Relatively large inventory of refrigerant due to DX distribution
Large Scale Food Industry Systems

- Some of the largest refrigeration systems in the country are used in Food production facilities such as meat processing, convenience foods, dairy products.
- Ammonia historically due to scale
- Distributed Ammonia & Secondary Systems
- Dairies - generally +2° Chilled water
Large-scale Food Industry Systems

Equipment/Systems

• Invariably Screw Compressors – recip’s often for w’ends etc
• Typically evaporative condensers
• Typically Flooded Evaporators, air coolers, cooling tunnels, PHE’s Shell & Plate
• Surge drums, Economisers, Pump Vessels, Liq Receivers etc.
• Large Steel pipe distribution, Ammonia detection
Low Temp Distributed Cooling

- Centralised Chiller plants with distribution of cooling to processing plants (Chemical & Pharmaceutical)
- Glycols, Methanol, Dowtherm, Syltherm etc. Heat Transfer Media
- Historically black box chillers – redundancy, construction, testing
- Historically Freon based refrigerants due to safety considerations. Almost exclusively Ammonia now for new Installations.
- High risk cooling with spikey cooling profile
Low Temp Distributed Cooling

Equipment/Systems

• Invariably Screw Compressors –
• Typically water-cooled condensers
• DX or Flooded Evaporators, PHE’s – low charge
• Surge drums, Economisers, Pump Vessels, Liq Receivers etc.
• Atex & Hazardous Area classification Issues
Industrial Scale Chilled Water Systems

- Centralised Chiller plants with distribution of chilled water to AHU’s and Process users e.g. Purified Water Loop Coolers etc.
- Very Much Seasonal Loads – some loads all year round
- Used in Secondary Pharma, Biotech, medical devices, sometimes in administration
Industrial Scale Chilled Water Systems

Equipment/Systems

• 2 real alternatives –
  ➢ Air-Cooled Chillers (Screw & recip compressors)
  ➢ Water-Cooled Centrif Chillers
• Completely Different Chillers on almost every level
• Chilled water distribution network
• 2-way and 3-way valves at users
Factors Affecting Energy Consumption in Industrial Refrigeration Systems
Refrigeration Onion Diagram

Biggest Factor affecting Energy use in any refrigeration system is the nature and magnitude of Cooling load.
8 points to note for Refrigeration System Savings

1. Challenge Cooling Loads
2. Have Multiple Cooling bands if practical
3. Minimise heat transfer steps
4. Minimise Parasitic Loads
5. Invest in Surface Area
6. Beware of Inefficient Part Load Performance
7. Look for opportunities to recover heat
8. Monitor COSP
1. Challenge Cooling Loads
As a utility engineer – don’t accept any loads at face value!
Design and Operational viewpoint

Make a spreadsheet of all the cooling loads and try to put peak average and base loads on it

<table>
<thead>
<tr>
<th>Cooling Load</th>
<th>Base</th>
<th>Average</th>
<th>Peak</th>
<th>Required Temp</th>
<th>Coolant Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHU 1</td>
<td>0</td>
<td>200</td>
<td>450</td>
<td>15° C</td>
<td>6° C</td>
</tr>
<tr>
<td>PUW Loop Cooler</td>
<td>0</td>
<td>40</td>
<td>500</td>
<td>20° C</td>
<td>6° C</td>
</tr>
</tbody>
</table>
1. Challenge Cooling Loads
   Strive for Ambient Cooling

   - **Light Industrial** – free cooling product before chilling
   - **Large Scale Food** – Use Ambient air for processing areas if temperatures are low.
   - **Low Temp HTM** – avoid tempered loops
   - **Industrial CHW** – HVAC use ambient air if below 15°C (85% time)
2. Have multiple Cooling Bands
Don't be penalised on the majority of loads if only a few need extra cooling

• **Light Industrial** – e.g. Ice Cream Freezers
• **Large Scale Food** – 10 Loop, -20 Loop, -30 Loop, in some cases dedicated systems for Blast Freezers
• **Low Temp HTM** – Perhaps only 1 or 2 reactors require -25°C coolant – dedicated H&C Skid with refrigerator
• **Industrial CHW** – use fan-coils with ambient cooled fluid
3. Minimise Heat Transfer Steps

Each heat transfer step is adding inefficiencies

- Pumps required – consuming electricity & adding heat
- Heat Transfer is impaired – reducing evaporating temperature
- Heat Gain through piping & Heat Exchanger
- Increased maintenance and reduced reliability
3. Minimise Heat Transfer Steps

- **Light Industrial** – very good usually from this viewpoint
- **Large Scale Food** – Usually pretty good -
- **Low Temp HTM** – Can be many steps before core cooling is done – area where most issues exist with multiple steps.
- **Industrial CHW** – sometimes secondary and tertiary loops are generated to keep primary system simple.

8 Points for Savings
8 Points for Savings

Path of Heat Flow – Process Cooling

Reactor Cooled by HTM
Reactor Jacket maintained at +2°C

Glycol to HTM Skid
H&C Skid HTM -15°C

Primary & Sec Glycol loops (-20°C)

Water Cooled Chiller
Chiller Evap @ -30°C

Chiller Evap @ -30°C

Pumps – primary & sec
Heat Exchange Delta x 2

Towers
Pumps, Tower Fans, HE Delta

Ambient
4. Minimise Parasitic Loads
Distribution Pumps use power directly and add heat to loop

- Match distribution power input with cooling load
- Valid for CTW, CHW, HTM, Pumped Nh3
- Have multiple pumps or VSD’s on pumps
- Avoid tertiary loops and booster pumps on large circuits
- Apply booster pumps to dedicated loads rather than penalising the entire circuit e.g. Vacuum pumps, capillary lines.
4. Minimise Parasitic Loads

- **Light Industrial** – usually pretty good from this viewpoint
- **Large Scale Food** – Avoid having Glycol pumps or CHW Pumps running full load during winter & weekends
- **Low Temp HTM** – Multiple Steps = Parasitic loads also old systems often have full flow through them with poor control
- **Industrial CHW** – two way valve systems preferable to 3-way and vary distribution pump speed with demand.
5. **Invest in Surface Area**

Reducing condensing temperature and raising evaporating temperature are 2 of the biggest areas for savings.

- Evaporative Condensers, water-cooled condensers before air-cooled condensers.
- Larger condensers will pay for themselves over and over.
- Work Towers hard to get low CTW – savings in the chiller.
- Check for head pressure control – may be keeping HP Higher than required.
- Keep fans in good condition on air-cooled condensers.
- Keep Surface area clean for good approach.
5. Invest in Surface Area
Reduction in condensing temperature and raising evaporating temperature are 2 of the biggest areas for savings.

- Compact Design heat exchangers give best approach on evaporation.
- Try to use standby evaporators in normal operation.
- Keep surface area of heat exchanger clean.
- Minimise pressure drops on suction lines (fridge circuit).
5. Invest in Surface Area
8 Points for Savings

5. **Invest in Surface Area**

- **Light Industrial** – could be more generous on surface area in condensers especially – fouling can be an issue
- **Large Scale Food** – Evap Condensers used, tendency for undersizing on evaporators (-10°C for Chilled water @+2), economisers
- **Low Temp HTM** – Black-box chillers – not using standby surface area
- **Industrial CHW** – tied into design of “off the shelf” chillers in a lot of cases. Can strive to lower CTW temperature – oversize towers, use borewell water for colder temps in summer.
6. Beware of Inefficient Part Load Performance

Design Performance often has little bearing on overall performance – design conditions rarely seen.

- Black-box chillers – often designed for a peak load – single compressor average loading 30% seen. Screw compressors particularly inefficient at part load – VSD technology
- Having multiple compressors to cater for peak load with a VSD on lead compressor if possible.
- Consider base load compressor – (recip perhaps) for weekend/night loads
6. **Beware of Inefficient Part Load Performance**

- **Light Industrial** – typically multiple small compressors (in packs or machinery rooms)
- **Large Scale Food** – good case for lead screw comp having VSD and base load comps
- **Low Temp HTM** – VSD’s where possible
- **Industrial CHW** – VSD’s on Centrifs becoming more popular, air-cooled chillers have multiple comps. Design for base load.
7. Look for opportunities to recover heat
Different heat streams from an Industrial refrigeration plant

- Cooling Load + Electrical Input = Heat Rejected
- Areas for Heat Recovery
  - Screw Compressors – Oil Cooling. (55°C to 60°C) (10 to 15% of THR)
  - De-superheating if Remote condensers (10 to 15% of THR)
  - Use all heat rejected if low grade heating source available (rare)
  - Heat Pump Technology moving very quickly

8 Points for Savings
8 Points for Savings

7. Look for Opportunities to Recover Heat

- **Light Industrial** – May have a coincidental washing load, desuperheating probably only viable opportunity
- **Large Scale Food** – Great opportunities for heat recovery if boilerhouse is close to Fridge Plant, desuperheating, oil heat recovery, heat pumps
- **Low Temp HTM** – Very difficult with packaged chillers, expensive, multiple heat exchangers, recertification etc.
- **Industrial CHW** – Heat Recovery Difficult – Base load heat pump probably most viable opportunity
8 Points for Savings

7. Monitor COSP
Coefficient of System Performance – True Picture of Efficiency

COSP – Dairy CHW Plant
8 Points for Savings

7. Monitor COSP
Coefficient of System Performance – True Picture of Efficiency

- Information derived from Flow, Temps & Power meters
- Parasitic Loads high relative to cooling load during winter
- Part Load efficiency poor
- Costing 4 times as much to do cooling during winter than during the summer
- Possible to identify low efficiency equipment
- Set EPI and target energy savings

Information is Power
Innovative Energy Efficient Solutions

- Heat Pumps
- Organic Rankine Cycle
- Alternative Natural Refrigerants
The Current Situation in Most Industrial Facilities:

- Most Sites have a use for hot water between 50°C & 80°C – washing, heating etc.
- Fossil Fuel Fired Boilers generating Hot water (some sites generate the hot water indirectly from Steam)
- Chiller Plant Running continuously Rejecting Heat to Atmosphere
- In Many cases the Refrigeration & Boilers are adjacent
Industrial Ammonia Heat Pump

Ammonia Excellent Properties for Heat Pump – However...

Discharge Pressure needs to be very High – up to 60 Bar G to get 95° C Water.

<table>
<thead>
<tr>
<th>Water temperature (° C)</th>
<th>Condensing temperature (° C)</th>
<th>Pressure (bar r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td>99</td>
<td>60,3</td>
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<td>90</td>
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<tr>
<td>60</td>
<td>64</td>
<td>27,8</td>
</tr>
</tbody>
</table>
Many Compressors limited to 40 Bar G Operating temperature – can give 60°C water

Some manufacturers making HP Compressors suitable for Heat Pumps capable of generating 95°C water

Hybrid technology – hybrid of absorption and Vapour Compression

Heat pumps are available from all sizes from domestic scale up to 1000’s of kW
Refrigeration capacity -12°C

Condensing 90°C

Sub-cooling

Desuperheating, oil cooling

Compression 1° stage

Compression 2° stage

Desuperheating, oil cooling

Refrigeration capacity -12°C
Industrial Ammonia Heat Pump Economics

Industrial Scale Heat Pumps – Payback 2 to 5 Years Depending on Application

Factors to Note

- Thermal Heating Fuel Cost
- Electricity Cost
- Water temperature required
- Low Stage compressors already in Existence? – Add High Stage
- Balance of Loads – does heating and cooling coincide?
Applications

Meat Industry
Dairy Industry
Convenience Foods
Secondary Pharma

Basically anywhere medium grade heating (50°C to 80°C) and “chilling” (-10°C to +8°C) is happening Simultaneously
HYDROCARBON CHILLERS

Solution for ODP & GWP

Works for loads below viable size for Nh3

Minimal Charge for Safety

Same technology as per HFC’s

Coldrooms, Freezers,
Conventional Water Chilling Applications
Organic Rankine Cycle

Method of Generating Electricity from Waste Heat
Uses Principle of running “Refrigeration Cycle in Reverse”

Electrical Efficiency – 20%
80% Low grade waste heat available
Organic Rankine Cycle

Applications

• Heat recovery
• Biomass
• Solar thermodynamic

THANK YOU