Energy Efficiency Considerations in Refrigeration Systems

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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 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

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

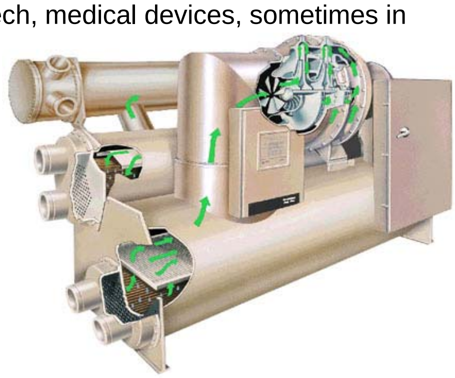
- Invariably Screw Compressors –
- Typically water-cooled condensers
- DX or Flooded Evaporators, PHE's – low charge
- Surge drums, Economisers, Pump Vessels, Liq Receivers etc.
- Atex & Hazardous Area classification Issues

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

Typically Air-cooled or Centrifugal Chillers used

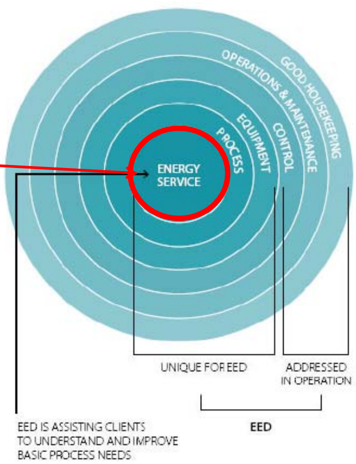
Distribution network to AHUs, fan-coils etc.



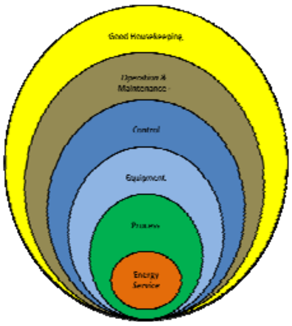
Factors Affecting Energy Efficiency in Industrial Refrigeration Systems

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

Top 8 Areas for Improved Efficiency

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

Cooling Load	Base	Average	Peak	Required Temp	Coolant Temp
AHU 1	0	200	450	15º C	6º C
PUW Loop Cooler	0	40	500	20º C	6º C

Top 8 Areas for Improved Efficiency

1. Challenge Cooling Loads

Strive for Ambient Cooling

Examples

- **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^{o}C (85% time)

Top 8 Areas for Improved Efficiency

2. Have multiple Cooling Bands

Don't be penalised on the majority of loads if only a few need extra cooling

Examples

- **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^{o}C coolant – dedicated H&C Skid with refrigerator
- **Industrial CHW** – Avoid process loads at <4^{o}C

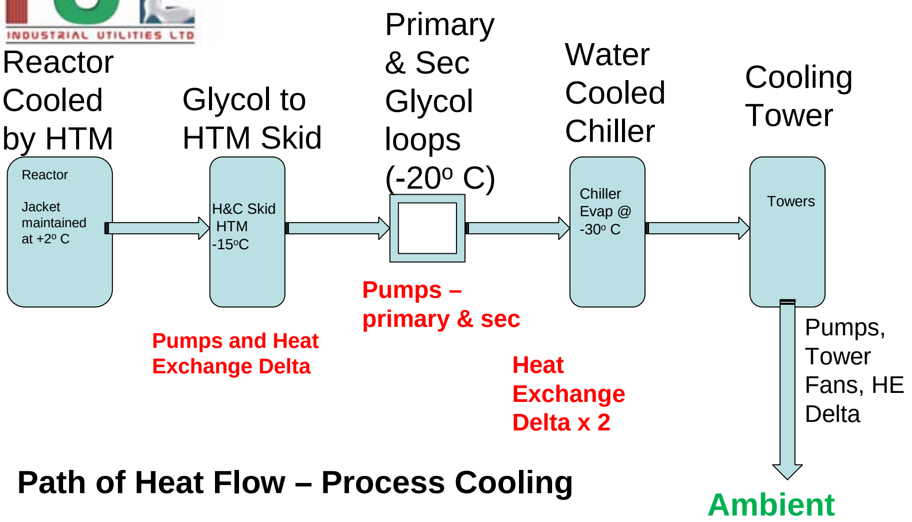
Top 8 Areas for Improved Efficiency

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

Top 8 Areas for Improved Efficiency



Path of Heat Flow – Process Cooling

Top 8 Areas for Improved Efficiency

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.

Top 8 Areas for Improved Efficiency

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 Diecharge Pressure Higher than required.
- Keep fans in good condition on air-cooled condensers
- Keep Surface area clean for good approach
- Compact Design heat exchangers give best approach on evaporation
- Try to use standby evaporators in normal operation
- Keep surface area of heat exchanger clean

Top 8 Areas for Improved Efficiency

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 particurlarly 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

Top 8 Areas for Improved Efficiency

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. (55C to 60C) (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

Top 8 Areas for Improved Efficiency

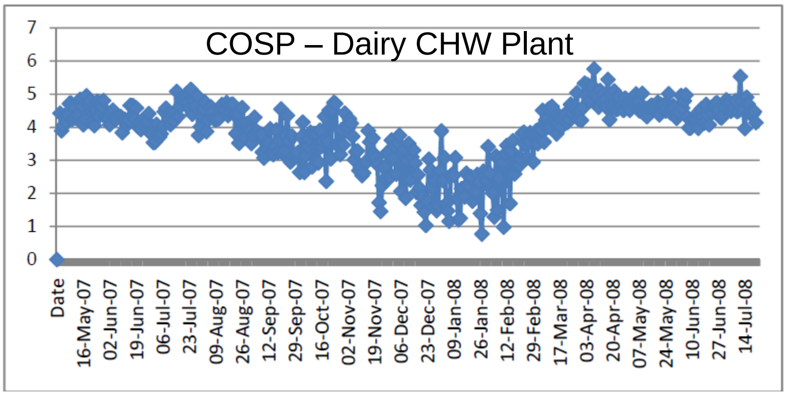
7. **Look for Opportunities to Recover Heat**

- **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

Top 8 Areas for Improved Efficiency

7. Monitor COSP

Coefficient of System Performance – True Picture of Efficiency



Top 8 Areas for Improved Efficiency

8. Monitor COSP

Coefficient of System Performance – True Picture of Efficiency

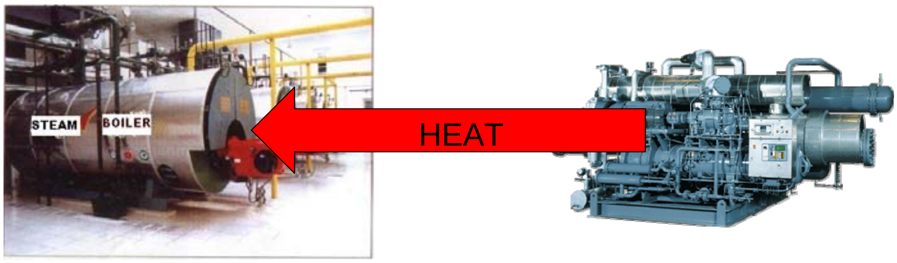
- Information derived from Flow, Temps & Power meters
- Parasitic Loads high relative to cooling load during winter
- Part Load efficiency poor
- Costing 4 times as much to do cooling during winter than during the summer
- Possible to identify low efficiency equipment
- Set EPI and target energy savings

Information is Power

Innovative Energy Efficient Solutions

- **Heat Pumps**
- **Organic Rankine Cycle**
- **Alternative Natural Refrigerants**

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 95º C Water.
Or
HYBRID Technology

Water temperature (° C)	Condensing temperature (° C)	Pressure (bar r)
95	99	60,3
90	94	54,5
80	84	44,1
60	64	27,8

Industrial Ammonia Heat Pump

Many Compressors limited to 40 Bar G Operating temperature – can give 60º C water

Some manufacturers making HP Compressors suitable for Heat Pumps capable of generating 95ºC 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

HYDROCARBON CHILLERS

Solution for ODP & GWP

Works for loads below viable size for Nh3

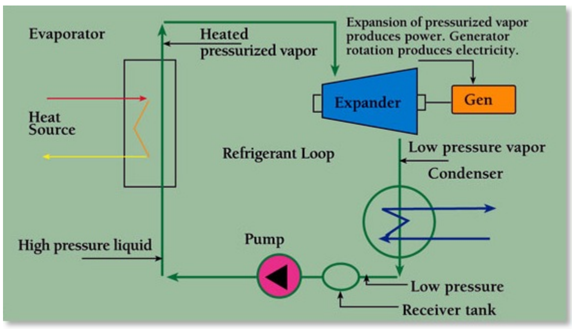
Minimal Charge for Safety

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