Refrigeration and Chilling

Reducing Electricity Costs and improving quality
Seamus Kerr, RSL Ireland

- MIEI, MIRI, MASHRAE
Law of Thermodynamics

- Energy cannot be created or destroyed. But it can be changed from one form to another.
- Refrigeration costs money.
First Law (closed system): \[ Q = m\Delta u + W / J \]
Heat entering a system can either increase temperature (internal energy) or be used to perform work on the surroundings. It is the law of energy conservation, i.e., energy cannot be created or destroyed.

Second Law (isolated system): \[ m\Delta s_{\text{total}} \geq 0 \]
The entropy change of any system and its surroundings, considered together, is positive, and approaches zero for any process that approaches reversibility. It is considered the fundamental law of natural science.

The two classical statements of the Second Law:

Clausius statement: It is impossible to construct a device that operates in a cycle and produces no effect other than the transfer of heat from a cooler body to a hotter body.

Kelvin-Plank statement: It is impossible to construct a device that operates in a cycle and produces no effect other than the raising of a weight and the exchange of heat with a single reservoir.

Third Law: It is impossible to cool a body down to absolute zero.
Thermodynamic Laws (simplified)

First Law: You can’t win, you can only break even.

Second Law: You can only break even at absolute zero.

Third Law: You can never reach absolute zero.
Refrigeration and Chilling

- ASHRAE have recently stated that “our industry is responsible for using almost 1/3 of the total energy consumed in the United States.”
- 17% of electrical power in Ireland is used in cooling (1990’s figure)
- Summer Max Demand
Refrigeration and Chilling

- 60% of supermarket energy costs is in refrigeration.
- 35 – 50% of a commercial/industrial plant energy cost for refrigeration/chilling/air conditioning
Reducing Electricity Cost.

A. Conserve the cold you have paid for!

B. Reduce the refrigeration manufacturing cost (efficient refrigerant plant).
A. Cold Conservation

Room Insulation, Air Entry, Product Load, Lighting and Cooler Fans
Product, People
A. Cold Conservation

- Room Insulation (Conductive and Radiation)
- Air Entry (Infiltration)
- Product Load
- Lighting and Fans
- People
Cold Conservation

1  Air Entry (Infiltration)
2  Product Load
3  Room Insulation (Conductive and Radiation)
4  People
5  Lighting and Fans
Cold Conservation - Air Entry

Psychometric Chart for Air at 101.325 kPa
Source: ASHRAE Publications
Cold Conservation- Air Entry

- Cooling Air Costs money
- 94 kJ/m\(^3\) from +25 °C to –10 °C
- 20m x 20m x 5m room = 2000 m\(^3\)
- Refrigerate t0 –10 °C in 1 hr
- 94 x 2000/3600 = 52 kW
Cold Conservation- Air Entry

- 28.8 kW Power Input
- €0.085/kWhr
- €2.49/hr
Cold Conservation- Air Entry

- 20m x 20m x 5m room @ -10°
- Door Openings Low Level 1.786 kW
- Door Openings High Level 8.928 kW
- 8hr working day for 300 days
- $8.928 \times 8 \times 0.085 \times 300 = €1717.17$
- Refrigeration Load Increased by 33%
- ASHRAE
Cold Conservation- Air Entry

- Poor door sealing
- Average Door 3m x 3m
- Average Off-set 10mm
- 0.06 m² hole
- 300mm x 200mm
Cold Conservation- Air Entry

- Freezer Application
- 0.06 m² hole causes loss of approx 0.03 m³/s
- Cooling Required = 186 kJ/m³ (+25° → -25°)
- 5.85 kW refrigeration
### Input data

- **Refrigerant**: R404A
- **Reference temperature**: Dew point temp.
- **Compressor type**: Single Compressor
- **Evaporating SST**: -32 °C
- **Condensing SDT**: 40 °C
- **Liquid subcooling**: 0 K
- **Suction gas temperature**: 20 °C
- **Operating mode**: Auto
- **Power supply**: 50 Hz, 400V-Y (40S)
- **Useful superheat**: 100%
- **Capacity regulation**: 100%

### Output data

<table>
<thead>
<tr>
<th>Compressor model</th>
<th>4DC-5.2Y-40S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling capacity</td>
<td>5.10 kW</td>
</tr>
<tr>
<td>Cooling capacity *</td>
<td>5.10 kW</td>
</tr>
<tr>
<td>Evaporator capacity</td>
<td>5.10 kW</td>
</tr>
<tr>
<td>Power input</td>
<td>3.59 kW</td>
</tr>
<tr>
<td>Current (400V)</td>
<td>7.29 A</td>
</tr>
<tr>
<td>Voltage range</td>
<td>380-420V</td>
</tr>
<tr>
<td>Condensing capacity</td>
<td>8.69 kW</td>
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<tr>
<td>COP/EER</td>
<td>1.42</td>
</tr>
<tr>
<td>COP/EER *</td>
<td>1.42</td>
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<tr>
<td>Mass flow</td>
<td>138.3 kg/h</td>
</tr>
<tr>
<td>Operating mode</td>
<td>Standard</td>
</tr>
</tbody>
</table>
Cold Conservation - Air Entry

- 3.59 kW Power Input
- €0.085/kWhr
- 24 hrs x 365 days
- \[3.59 \times 0.085 \times 24 \times 365 = €2673/\text{per door}\]
Cold Conservation

- Coldstore panels
- Other Leaks (non door)
- Re-cooling
- De-frosting
Reducing Electricity Cost.

A. Conserve the cold you have paid for!

B. Reduce the refrigeration manufacturing cost.
   (efficient refrigerant plant).
AIR CONDITIONING
REFRIGERATION
INDUSTRIAL PROCESS
EVAPORATIVE COOLING

- Air-cooled heat rejection is often being preferred due to health & safety, water treatment and maintenance concerns.

- Acknowledged cost, energy and size advantages of water cooled systems are being outweighed by safety concerns and owner responsibilities.
EVAPORATIVE COOLING

- Wet Bulb is Typically 6°C to 12°C Lower Than Dry Bulb
- Lower Cold Water or Condensing Temperature By At Least the Wet Bulb to Dry Bulb Difference
- Chiller Absorbed Power Decreases 3% For Every 1°C Lower Condensing Temperature
### Semi-hermetic Reciprocating Compressors

#### Input data

- **Refrigerant**: R404A
- **Reference temperature**: Dew point temp.
- **Compressor type**: Single Compressor
- **Cooling capacity**: kW
- **Compressor model**: 6G-40.2Y
- **Evaporating SST**: -30 °C
- **Condensing SDT**: 40 °C
- **Liquid subcooling**: 0 K
- **Suction gas temperature**: 20 °C
- **Operating mode**: Auto
- **Power supply**: 50 Hz 400V-PW (40P)
- **Useful superheat**: 100%
- **Capacity regulation**: 100%

#### Output data

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<thead>
<tr>
<th>Compressor model</th>
<th>6G-40.2Y-40F</th>
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<tbody>
<tr>
<td>Cooling capacity</td>
<td>28.0 kW</td>
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<tr>
<td>Cooling capacity *</td>
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<td>Evaporator capacity</td>
<td>28.0 kW</td>
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<td>Power input</td>
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<td>Current (400V)</td>
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<td>Voltage range</td>
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<tr>
<td>Condensing capacity</td>
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<tr>
<td>COP/EER</td>
<td>1.53</td>
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<td>COP/EER *</td>
<td>1.53</td>
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<tr>
<td>Mass flow</td>
<td>760 kg/h</td>
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<td>Operating mode</td>
<td>Standard</td>
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- **Condensing SDT**: 32 °C
- **Liquid subcooling**: 0 K
- **Suction gas temperature**: 20 °C
- **Operating mode**: Auto
- **Power supply**: 50 Hz
- **Useful superheat**: 100%
- **Capacity regulation**: 100%

### Output data

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<tr>
<th>Compressor model</th>
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<tr>
<td>Cooling capacity</td>
<td>32.5 kW</td>
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<td>Cooling capacity *</td>
<td>32.5 kW</td>
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<td>Evaporator capacity</td>
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<td>Power input</td>
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<td>COP/EER</td>
<td>1.83</td>
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<td>COP/EER *</td>
<td>1.83</td>
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<tr>
<td>Mass flow</td>
<td>804 kg/h</td>
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<tr>
<td>Operating mode</td>
<td>Standard</td>
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</tbody>
</table>
Reduce Refrigeration Cost

A  1.53 COP
B  1.83 COP

20.0 % electricity saving on compressor + condenser + cooler.
Reduce Refrigeration Cost

- Evaporative Cooling Arguments For:
  - Lower Cold Water or Condensing Temperatures
  - Less Energy
  - Quieter
  - Smaller, Lighter
  - Lower Life Cycle Cost
Reduce Refrigeration Cost

- Evaporative Cooling Arguments Against
- Health and Safety Responsibilities
- Water Treatment Requirements
- Maintenance and Cleaning
- Water Consumption
Reduce Refrigeration Cost

Save money by reducing water consumption
Reduce Refrigeration Cost

- Remove air from systems
  - (Low Temp Ammonia)
- Manual Purging

- Automatic Purging
- 220 amps to 180amps
- $$(152\text{kW}-124\text{kW}=27\text{kW} \times 24 \times 365 \times 0.085 = €20100.00)$$
Reduce Refrigeration Cost

- Heat Recovery
Reduce Refrigeration Cost

- Heat Recovery
- De-superheater
- Divert Rejected Heat to Boiler Feed
- Divert Rejected Heat to Wash Water
- (15% of Total Rejected Heat available)
- Win – Win
Reducing Electricity Cost.

A. Conserve the cold you have paid for!
Reducing Electricity Cost.

A. Reduce the refrigeration manufacturing cost (efficient refrigerant plant).
Mr. Seamus Kerr, RSL Ireland

- THANK YOU

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