RECREATION FACILITY PERSONNEL

PASSING the TORCH 42nd annual Conference & Trade Show
April 7 - 10, 2019
RED DEER, ALBERTA
Who is Cimco?

- Canadian Ice Machine Company
- Around Since 1913
- Installed Over 50% Of The World’s Ice Rinks
- Engineer, Design Build, Manufacture, Install & Service Ammonia, CO₂ And Any Other Refrigerant Systems
Who am I?

- Gerald Curran
- District Manager – N. Alberta, Yukon, NWT, Nunavut
- Joined The Organization in 1981
- Senior Refrigeration Instructor – AARFP

Ever Evolving

- Witness To Changing Trends Within The Components Of The Refrigeration Industry
- Changing Trends On The Use Of Refrigerants In Our Systems
- Components and Control Technology Is Now Front And Center
Are We Concerned About!

- Aging Ice Facilities
- Aging Plant Rooms Not Up To New Codes
- Aging Mechanical Systems Operating Beyond Recommended Life Span
- Increased Energy Costs
- New Rules & Regulations
So, We Would Like!

- Education On Options For Current And Future Considerations
- Want To Make Sure We Maintain Quality Ice
- Want To Be More Aware Of The Right Choices
AGING ARTIFICIAL ICE SYSTEMS

What Do We Do?

Replace

Retrofit

Maintain

WHAT IS YOUR PRIORITY?
6 Considerations for Ice Plants

- Safety
- Efficiency
- Environment
- Cost
- Longevity
- Reliability
Safety

Protecting The Public, Employees And Visitors To The Facility

Factors That Influence Safety

- System Age / Design
  - Life Span, 50’s Technology
- Refrigerant Selection
  - Natural or Synthetic Refrigerant
- Refrigerant Charge
  - Excessive Charge, Receiver
Safety

Protecting The Public, Employees And Visitors To The Facility

Factors That Influence Safety

- Machine Room Design
  - Does it Meet CSA B52 Code, Building Code etc.
- Ventilation and Detection Design
  - Fan on the Wall?
- Maintenance
  - Scheduled Maintenance According to the Manufacture
- Training
Safety

Protecting The Public, Employees And Visitors To The Facility

Factors That Influence Safety

When We Look At Our Own Facility
The Question Becomes

Is our Ice Plant Safe?

Is our Ice Plant Room Safe?
Safety
Protecting The Public, Employees And Visitors To The Facility

DANGERS OF REFRIGERANTS

All Refrigerants Are Dangerous:

**Synthetics** (Freon, Opteon, R507, etc.) - *Displaces oxygen, flammable*
- Leaks in confined spaces can cause suffocation
- Damages environment

**Ammonia** - *Toxic, flammable*
- Suffocation and damage to air-way
- Chemical burns

**CO2** - *Displaces oxygen*
- At high concentrations in unventilated areas leaks can cause suffocation
Safety

Refrigerants

Occupational Exposure Limits of Different Substances

- R-744 (CO₂) - 5000 PPM
- Methane
- Natural Gas
- R-134a
- R-22
- R-290 (C₃H₈)
- R-32
- R-407C
- R-410A
- R-448a
- R-449a
- R-452B
- R-454B
- R-1233zd
- R-1234ze
- R-513A
- R-1234yf
- R-514A
- Gasoline
- Carbon Monoxide
- R-717 (NH₃)
- Chlorine

Toxicity Increases (More Dangerous) to the Right
Safety

Past History

✓ 1991: Alaska, R22, Maintenance Manager Was Killed By Asphyxiation
✓ 2010: Alabama, R22, Janitorial Worker Was Found Dead, Believed To Be Due To A Refrigerant Leak

Reality

✓ There Are in Excess of 5000 Ice Surfaces In North America
✓ Incidents Are Rare!
✓ With Proper Design And Maintenance, Refrigeration Facilities Are Safe
Refrigerants

- NH₃ (Ammonia)
- CO₂
- “Freon” (Synthetic)
- Hydrocarbons

Refrigerant Hazards

- Which is safe?
- All have their issues
- Large concentrations ALL can be fatal

Safety

Flammability
- Propane
- Ammonia
- Synthetics / CO₂

Toxicity

Asphyxiation
Safety

Our Machine Rooms - Are They Safe?

✓ Does it Meet the CSA B52-13 Code?
✓ Look for New Technology
✓ Reduced Charge
✓ You Should Know When Hazards Exist
✓ Control Hazards
Safety

Monitoring

✓ Know when the hazard exists
✓ Upgrade to a better monitoring system

Control the Hazards

✓ Proper Machinery Room Design
  ➢ (Ventilation)
  ➢ (Detection)
  ➢ Vestibule – Making Sure All Key Safeties Are In Place
✓ Proper Isolation Points To Mitigate Leaks
✓ Preventative Maintenance Programs
Safety

Proper Maintenance

- Ensure You Have A Contractor You Can Trust
- Follow Manufacturer’s Guidelines For Equipment
- Have A Capital Replacement Plan (Nothing Lasts Forever)

Training

- Plant Operators Have Better Training
  - Know What Not To Do
- Better Understanding Of Life Cycle Management
- Better Understanding Of Preventative Maintenance Programs
- Better Understanding Of Ice Plant Manuals
- Better Understanding Of The Supplier System Drawings
Safety

REDUCED REFRIGERANT CHARGE

Plate and Frame Heat Exchangers

Advantages
• Low Charge
• High Heat Transfer
• Small Footprint
• Expandable
• Maintainable
• No Cross Contamination

Plate And Frame Technology Was Invented In 1931, But Not Implemented In Arena Refrigeration Until The Mid 1990s.

60 Years Later!

80 - 90% reduction in charge

700 LBS → 65 LBS
Safety

Movement from Shell & Tube Evaporators (Chillers) to Plate Frame Exchangers is now Normal

Greater Efficiency - Less Refrigerant Charge
Safety

Plate and Frame Heat Exchangers

Evaporative Condensers Being Replaced by Plate & Frame Exchangers To Reduce the Refrigerant Charge

Principle of Operation
Safety

Plate and Frame Heat Exchangers

Plate & Frame Exchangers Now Work in conjunction with Adiabatic Fluid Coolers

Further Reducing the Operating Ammonia Charge

Warm Glycol Supply

Cooled Glycol Return
Estimates of Service Lives

Published by (ASHRAE)
American Society of Heating, Refrigeration & Air Conditioning Engineers

<table>
<thead>
<tr>
<th>Equipment Item</th>
<th>Median Years</th>
<th>Equipment Item</th>
<th>Median Years</th>
<th>Equipment Item</th>
<th>Median Years</th>
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<tbody>
<tr>
<td>Air conditioners</td>
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<td>Air terminals</td>
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<td>Air-cooled condensers</td>
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<tr>
<td>Window unit</td>
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<td>Diffusers, grilles, and registers</td>
<td>27</td>
<td>Evaporative condensers</td>
<td>20</td>
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<tr>
<td>Residential single or split package</td>
<td>15</td>
<td>Induction and fan-coil units</td>
<td>20</td>
<td>Insulation</td>
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<td>Commercial through-the-wall</td>
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<td>VAV and double-duct boxes</td>
<td>20</td>
<td>Molded</td>
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<td>Water-cooled package</td>
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<td>Air washers</td>
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<td>Heat pumps</td>
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<td>Ductwork</td>
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<td>Pumps</td>
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<tr>
<td>Residential air-to-air</td>
<td>15</td>
<td>Dampers</td>
<td>20</td>
<td>Base-mounted</td>
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<tr>
<td>Commercial air-to-air</td>
<td>15</td>
<td>Fans</td>
<td>20</td>
<td>Pipe-mounted</td>
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<tr>
<td>Commercial water-to-air</td>
<td>19</td>
<td>Centrifugal</td>
<td>25</td>
<td>Sump and well</td>
<td>10</td>
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<td>Roof-top air conditioners</td>
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<td>Axial</td>
<td>20</td>
<td>Condensate</td>
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<td>Single-zone</td>
<td>15</td>
<td>Propeller</td>
<td>15</td>
<td>Reciprocating engines</td>
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<td>Multizone</td>
<td>15</td>
<td>Ventilating roof-mounted</td>
<td>20</td>
<td>Steam turbines</td>
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<td>Boilers, hot water (steam)</td>
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<td>Coils</td>
<td></td>
<td>Electric motors</td>
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<tr>
<td>Steel water-tube</td>
<td>24 (30)</td>
<td>DX, water, or steam</td>
<td>20</td>
<td>Motor starters</td>
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<td>Steel fire-tube</td>
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<td>Electric transformers</td>
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<td>Cast iron</td>
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<td>Heat exchangers</td>
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<td>Controls</td>
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<tr>
<td>Electric</td>
<td>15</td>
<td>Shell-and-tube</td>
<td>24</td>
<td>Pneumatic</td>
<td>20</td>
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<tr>
<td>Burners</td>
<td>21</td>
<td>Reciprocating compressors</td>
<td>20</td>
<td>Electric</td>
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<td>Furnaces</td>
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<td>Package chillers</td>
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<td>Electronic</td>
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<td>Gas- or oil-fired</td>
<td>18</td>
<td>Reciprocating</td>
<td>20</td>
<td>Valve actuators</td>
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<tr>
<td>Unit heaters</td>
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<td>Centrifugal</td>
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<td>Hydraulic</td>
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<tr>
<td>Gas or electric</td>
<td>13</td>
<td>Absorption</td>
<td>23</td>
<td>Pneumatic</td>
<td>20</td>
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<tr>
<td>Hot water or steam</td>
<td>20</td>
<td>Cooling towers</td>
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<td>Self-contained</td>
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<tr>
<td>Radiant heaters</td>
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<td>Galvanized metal</td>
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<tr>
<td>Electric</td>
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<td>Wood</td>
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<td>Hot water or steam</td>
<td>25</td>
<td>Ceramic</td>
<td>34</td>
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Notes: 1. ASHRAE makes no claims as to the statistical validity of any of the data presented in this table.
2. Table lists base values that should be adjusted for local conditions (see the section on Service Life).

Source: Data obtained from a survey of the United States by ASHRAE Technical Committee TC 1.8 (Akalin 1978).

* See Lovvorn and Hiller (1985) and Easton Consultants (1986) for further information.

* Data updated by TC 1.8 in 1986.
## Have You Created A Life Cycle Plan

<table>
<thead>
<tr>
<th>Priority Rank</th>
<th>Equipment</th>
<th>Safety Risk</th>
<th>Business Risk</th>
<th>ASHRAE Life Cycle</th>
<th>Estimated Age</th>
<th>Year to Replace</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Compressor #1</td>
<td>Critical</td>
<td>Critical</td>
<td>20</td>
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<tr>
<td></td>
<td>Compressor #2</td>
<td>Critical</td>
<td>High</td>
<td>20</td>
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<tr>
<td></td>
<td>Compressor #3</td>
<td>Critical</td>
<td>Medium</td>
<td>20</td>
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<tr>
<td></td>
<td>Compressor #4</td>
<td>Critical</td>
<td>Medium</td>
<td>20</td>
<td></td>
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<td>Chiller</td>
<td>Critical</td>
<td>Critical</td>
<td>24</td>
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<td></td>
<td>Condenser</td>
<td>High</td>
<td>High</td>
<td>15</td>
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<td></td>
<td>Electrical Panel</td>
<td>High</td>
<td>Medium</td>
<td>20</td>
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<td></td>
<td>Controls</td>
<td>High</td>
<td>Medium</td>
<td>15</td>
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<td></td>
<td>Dehumidifiers</td>
<td>Medium</td>
<td>Medium</td>
<td>15</td>
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<tr>
<td></td>
<td>Headers</td>
<td>Medium</td>
<td>High</td>
<td>25</td>
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<td></td>
<td>Floor</td>
<td>Medium</td>
<td>High</td>
<td>50</td>
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</tbody>
</table>
### Safety

Protecting The Public, Employees And Visitors To The Facility

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**Refrigeration Asset Report**

**SITE NAME:** Home Town Arena  
**SITE ADDRESS:** 123 Anywhere Street Manitoba  
**PLANT BUILT IN:** 1974  
**Report Date:** 20-Feb-19

The purpose of this asset report is to provide insight into the state of condition of the refrigeration equipment in your facility. Even with proper care and maintenance each component has an expected life cycle.

### Capital Replacement

<table>
<thead>
<tr>
<th>COMPRESSOR #1 Arena (Reciprocating)</th>
<th>ASHRAE Life Cycle</th>
<th>Existing Age</th>
<th>Estimated Condition</th>
<th>Replace</th>
<th>Comments</th>
<th>Budget Cost (2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacture:</strong> Mycom</td>
<td>20 Years</td>
<td>4</td>
<td><strong>Excellent</strong></td>
<td>2035</td>
<td>New Compressor in 2012 46678 Hours- Due for Overhaul 2018</td>
<td>$45,000.00</td>
</tr>
<tr>
<td><strong>Model #:</strong> N4M</td>
<td></td>
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<tr>
<td><strong>Serial #:</strong> 4110582</td>
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<td></td>
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</tr>
<tr>
<td><strong>Motor HP:</strong> 75 HP Leesen</td>
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</tr>
<tr>
<td><strong>Motor Serial #:</strong> G15020L.00 F 365T</td>
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<tr>
<td><strong>Soft Starter:</strong> No</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>HEAT EXCHANGER Shell &amp; Tube</th>
<th>ASHRAE Life Cycle</th>
<th>Existing Age</th>
<th>Estimated Condition</th>
<th>Replace</th>
<th>Comments</th>
<th>Budget Cost (2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacture:</strong> CIMCO</td>
<td>24 Years</td>
<td>19</td>
<td><strong>GOOD</strong></td>
<td>2025</td>
<td>Chiller was replaced in 1999 - Life expectancy is 20-30 Years</td>
<td>$100,000.00</td>
</tr>
<tr>
<td><strong>Model #:</strong> 20x12-20x9</td>
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<tr>
<td><strong>Serial #:</strong> 255480A / B</td>
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<table>
<thead>
<tr>
<th>CONDENSER Evaporative Condenser</th>
<th>ASHRAE Life Cycle</th>
<th>Existing Age</th>
<th>Estimated Condition</th>
<th>Replace</th>
<th>Comments</th>
<th>Budget Cost (2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacture:</strong> Evapco 2x3HP fans</td>
<td>15 Years</td>
<td>18</td>
<td><strong>GOOD</strong></td>
<td>2027</td>
<td>Replaced In 2001</td>
<td>$95,000.00</td>
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<tr>
<td><strong>Model #:</strong> ATC 1058</td>
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<tr>
<td><strong>Serial #:</strong> W017007</td>
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<table>
<thead>
<tr>
<th>DEHUMIDIFIER #1 (Mechanical)</th>
<th>ASHRAE Life Cycle</th>
<th>Existing Age</th>
<th>Estimated Condition</th>
<th>Replace</th>
<th>Comments</th>
<th>Budget Cost (2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manufacture:</strong> Blanchard Ness</td>
<td>15 Years</td>
<td>n/a</td>
<td><strong>Poor</strong></td>
<td>2018</td>
<td>Past Life Expectancy</td>
<td>$40,000.00</td>
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<tr>
<td><strong>Model #:</strong> BA75G-250/5/80</td>
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<td><strong>Serial #:</strong> 93040028</td>
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</table>
### Safety: Protecting The Public, Employees And Visitors To The Facility

<table>
<thead>
<tr>
<th>ELECTRICAL/STARTER PANEL</th>
<th>Existing Age</th>
<th>Estimated Condition</th>
<th>Replace</th>
<th>Comments</th>
<th>Budget Cost (2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arena Manufacture: Celco Controls</td>
<td>20 Years</td>
<td>27</td>
<td>Fair</td>
<td>2021</td>
<td>Installed in 1991</td>
</tr>
<tr>
<td>Model #: N/A</td>
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</tr>
<tr>
<td>Serial #: 1866</td>
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<table>
<thead>
<tr>
<th>CONTROL System</th>
<th>Existing Age</th>
<th>Estimated Condition</th>
<th>Replace</th>
<th>Comments</th>
<th>Budget Cost (2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arena Manufacture: Mixed</td>
<td>15 Years</td>
<td>19-Apr</td>
<td>Fair</td>
<td>2018</td>
<td>Combination of controls - Chronostat, Honeywell - Celco</td>
</tr>
<tr>
<td>Model #: N/A</td>
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<table>
<thead>
<tr>
<th>BRINE PUMP (Base/Pipe Mounted) Arena</th>
<th>Existing Age</th>
<th>Estimated Condition</th>
<th>Replace</th>
<th>Comments</th>
<th>Budget Cost (2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacture: Taco</td>
<td>20 Years</td>
<td>19</td>
<td>GOOD</td>
<td>2023</td>
<td>Replace in 1999 900 USGPM @52ft</td>
</tr>
<tr>
<td>Motor: WEG 20 HP</td>
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<tr>
<td>Frame/Model #: 256T DPG050Q4P</td>
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<tr>
<td>Model #: FE5010</td>
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<td>Serial #: 991544</td>
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</table>
## BUSINESS RISK OF EQUIPMENT FAILURE

<table>
<thead>
<tr>
<th>Number of Compressors</th>
<th>Business Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 x Compressor</td>
<td>Critical: If failure occurs ice surface non-functional and loss in revenue. Emergency Replacement – 12 Weeks</td>
</tr>
<tr>
<td>No Redundancy</td>
<td></td>
</tr>
<tr>
<td>2 x Compressors</td>
<td>High: If failure occurs will result in poor ice conditions and potential lost revenue.</td>
</tr>
<tr>
<td>No Redundancy</td>
<td></td>
</tr>
<tr>
<td>2 x Compressors</td>
<td>Medium: If failure occurs will result in increased run hours and no back up capabilities.</td>
</tr>
<tr>
<td>Full Redundancy</td>
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</tr>
<tr>
<td>3 or More Compressors</td>
<td>Medium: If failure occurs will result in increased run hours and no back up capabilities.</td>
</tr>
<tr>
<td>No Standby</td>
<td></td>
</tr>
<tr>
<td>3 or More Compressors</td>
<td>Low: If failure occurs will result in normal operating until the repairs/replacement has occurred.</td>
</tr>
<tr>
<td>One Standby</td>
<td></td>
</tr>
</tbody>
</table>
# Safety

*Protecting The Public, Employees And Visitors To The Facility*

## Business Risk of Equipment Failure

<table>
<thead>
<tr>
<th>Number of Chillers</th>
<th>Business Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No Redundancy</strong></td>
<td>Critical: If failure occurs ice surface non-functional and loss in revenue.</td>
</tr>
<tr>
<td></td>
<td>Emergency Replacement – 12 Weeks</td>
</tr>
<tr>
<td><strong>Partial Redundancy</strong></td>
<td>High: If failure occurs will result in poor ice conditions and increased</td>
</tr>
<tr>
<td></td>
<td>operational issues to maintain ice.</td>
</tr>
<tr>
<td><strong>Full Redundancy</strong></td>
<td>Medium: If failure occurs will result in normal operating until the repairs/</td>
</tr>
<tr>
<td></td>
<td>replacement has occurred.</td>
</tr>
</tbody>
</table>
## BUSINESS RISK OF EQUIPMENT FAILURE

<table>
<thead>
<tr>
<th>Number of Condensers</th>
<th>Business Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Redundancy</td>
<td>High: If failure occurs will result in poor ice conditions and potential lost revenue. Emergency Replacement: 10 Weeks</td>
</tr>
<tr>
<td>Partial Redundancy</td>
<td>Medium: If failure occurs will result in operational challenges to maintain ice.</td>
</tr>
<tr>
<td>Full Redundancy</td>
<td>Low: If failure occurs will result in normal operating until the repairs/replacement has occurred.</td>
</tr>
</tbody>
</table>
**Safety  Protecting The Public, Employees And Visitors To The Facility**

### BUSINESS RISK OF EQUIPMENT FAILURE

<table>
<thead>
<tr>
<th>Electrical/Control Panels</th>
<th>Business Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Redundancy</td>
<td>High: If failure occurs will result in poor ice conditions and operational issues. Repair components are usually readily available so the repair can be made in a timely manner.</td>
</tr>
</tbody>
</table>
# Safety

**Protecting The Public, Employees And Visitors To The Facility**

## Business Risk of Equipment Failure

<table>
<thead>
<tr>
<th>Refrigeration Equipment</th>
<th>Safety Risk</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell &amp; Tube Chiller</td>
<td>Critical</td>
<td>1</td>
</tr>
<tr>
<td>Reciprocating Compressors</td>
<td>Critical</td>
<td>2</td>
</tr>
<tr>
<td>Evaporative Condenser</td>
<td>High</td>
<td>3</td>
</tr>
<tr>
<td>Electrical/Control Panel</td>
<td>High</td>
<td>4</td>
</tr>
<tr>
<td>Dehumidifiers</td>
<td>Medium</td>
<td>5</td>
</tr>
<tr>
<td>Concrete Floor/Headers</td>
<td>Medium</td>
<td>6</td>
</tr>
</tbody>
</table>
## BUSINESS RISK OF EQUIPMENT FAILURE

<table>
<thead>
<tr>
<th>Refrigeration Equipment</th>
<th>Safety Risk</th>
<th>Replacement (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell &amp; Tube Chiller</td>
<td>Critical</td>
<td>12</td>
</tr>
<tr>
<td>Reciprocating Compressors</td>
<td>Critical</td>
<td>10</td>
</tr>
<tr>
<td>Evaporative Condenser</td>
<td>High</td>
<td>8</td>
</tr>
<tr>
<td>Concrete Floors/Headers</td>
<td>High</td>
<td>Months</td>
</tr>
<tr>
<td>Dehumidifiers</td>
<td>Medium</td>
<td>8</td>
</tr>
<tr>
<td>Electrical/Control Panel</td>
<td>Medium</td>
<td>12</td>
</tr>
</tbody>
</table>
Safety Summary

- Current Design Or Future Design
- Refrigerant
  - All Refrigerants Have Risks, Make Sure You Account For Them In Your Safety Assessment
- Design
  - Designed For Service
  - Proper Application
  - Newest Safety Features Available
Safety Summary

- Maintenance
  - Inspect And Monitor Equipment
  - Create A Capital Replacement Plan
  - Follow Manufactures Recommendations
  - Have A Trusted Contractor Who Will Do The Required Maintenance

- Training
  - Are We Adequately Trained
  - More Site Specific Training
Safety Summary

- CSA-B52-13 - Code Compliance Report
  - Grandfather Clause???
  - Is Your Machine Room Safe

- Refrigeration System Audit
  - Do You Really Know How Good Your Systems Components Are?
  - What Is Your Equipment's Current Lifespan
  - What is Your Risk Tolerance
AGING ARTIFICIAL ICE SYSTEMS

What Do We Do?

- Replace
- Retrofit
- Maintain

WHAT IS YOUR PRIORITY?
EFFICIENCY
Efficiency

Maintaining Budgets with Rising Energy Costs

Efficiency Factors

- Design Conditions
- Refrigerant Selection
- Component Selection
- Design Type
- Heat Usage

Defining Efficiency

\[ COP = \frac{3\, kW}{1\, kW} = 3.0 \]

ICE RUNS IN OUR VEINS.
Refrigerant Selection
What To Consider?

- Electricity Costs (50%)
- Operator Costs (24%)
- Installation Costs (19%)
- Maintenance (7%)
Refrigerant Selection

Yearly Consumption

<table>
<thead>
<tr>
<th>Month</th>
<th>NH3</th>
<th>R134a</th>
<th>CO2 Indirect</th>
<th>CO2 Direct</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>90,000</td>
<td>80,000</td>
<td>70,000</td>
<td>60,000</td>
</tr>
<tr>
<td>February</td>
<td>80,000</td>
<td>70,000</td>
<td>60,000</td>
<td>50,000</td>
</tr>
<tr>
<td>March</td>
<td>70,000</td>
<td>60,000</td>
<td>50,000</td>
<td>40,000</td>
</tr>
<tr>
<td>April</td>
<td>60,000</td>
<td>50,000</td>
<td>40,000</td>
<td>30,000</td>
</tr>
<tr>
<td>May</td>
<td>50,000</td>
<td>40,000</td>
<td>30,000</td>
<td>20,000</td>
</tr>
<tr>
<td>June</td>
<td>40,000</td>
<td>30,000</td>
<td>20,000</td>
<td>10,000</td>
</tr>
<tr>
<td>July</td>
<td>30,000</td>
<td>20,000</td>
<td>10,000</td>
<td>0</td>
</tr>
<tr>
<td>August</td>
<td>20,000</td>
<td>10,000</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>10,000</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Refrigerant Selection

Yearly Consumption

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH3</td>
<td>~1,000,000</td>
</tr>
<tr>
<td>R134a</td>
<td>~1,200,000</td>
</tr>
<tr>
<td>CO2 Indirect</td>
<td>~800,000</td>
</tr>
<tr>
<td>CO2 Direct</td>
<td>~600,000</td>
</tr>
</tbody>
</table>
Refrigerant Selection

R-22 Retrofit

R-448A - Honeywell  R-449A - Chemours

- Either have very similar performance characteristics at rink conditions and there is no real difference between them
- Require POE lubricant for the compressors.
- Only suitable for use in DX type evaporator
- Expect about a 10-12% performance decrease with these refrigerants based on selection using DEW and BUBBLE point temperatures in the evaporator and condenser respectively.
Equipment Selection

- Refrigeration (High Differential)
- Air Conditioning (Low Differential)
- Refrigeration (Subcritical/Transcritical)
- Air Cooled / Water Cooled
- Reciprocating Compressors
- Screw Compressors
A Typical 100 Ton Artificial Ice System Will Produce The Following Waste Heat; Heat That Is Available For Heat Reclaim

Refrigeration Capacity (100 Tr. = 1,200,000 Btuh)
Electrical Input (150 Hp = 2545 X 150 = 381,750 Btuh)

Total Waste Heat Available = 1,581,750 Btuh

✓ A Typical Home Requires A 80,000 Btu/Hr Furnace
✓ The Waste Heat Could Heat 20 Homes All Winter
COMPARATIVE STUDY OF REFRIGERATION SYSTEMS FOR ICE RINKS

CanmetENERGY, Varennes
July 2013
## Plant Options (Canmet)

### Table 12: Energy Consumption of Refrigeration Systems

<table>
<thead>
<tr>
<th>Case</th>
<th>Assembly Type</th>
<th>Refrigerant</th>
<th>Compressors kWh/year</th>
<th>Slab Pump kWh/year</th>
<th>Heat Rejection Equipment kWh/year</th>
<th>Total kWh/year</th>
<th>Variation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Packaged</td>
<td>R717</td>
<td>279,200</td>
<td>73,300</td>
<td>54,500</td>
<td>407,000</td>
<td>6</td>
</tr>
<tr>
<td>A2</td>
<td>On site</td>
<td>R717</td>
<td>245,000</td>
<td>73,300</td>
<td>65,000</td>
<td>383,400</td>
<td>0</td>
</tr>
<tr>
<td>A3</td>
<td>On site</td>
<td>R717</td>
<td>267,800</td>
<td>122,200</td>
<td>63,600</td>
<td>453,600</td>
<td>18</td>
</tr>
<tr>
<td>A4</td>
<td>Packaged</td>
<td>R717</td>
<td>264,000</td>
<td>73,300</td>
<td>74,900</td>
<td>412,200</td>
<td>8</td>
</tr>
<tr>
<td>A5</td>
<td>Packaged</td>
<td>R717</td>
<td>298,500</td>
<td>73,300</td>
<td>74,600</td>
<td>446,400</td>
<td>16</td>
</tr>
<tr>
<td>C1</td>
<td>Split-packaged</td>
<td>R744</td>
<td>263,400</td>
<td>14,700</td>
<td>13,000</td>
<td>291,100</td>
<td>-24</td>
</tr>
<tr>
<td>C2</td>
<td>Split-packaged</td>
<td>R744</td>
<td>281,200</td>
<td>73,300</td>
<td>19,900</td>
<td>374,500</td>
<td>-2</td>
</tr>
<tr>
<td>H1</td>
<td>On site</td>
<td>HCFC R22</td>
<td>411,900</td>
<td>122,200</td>
<td>16,100</td>
<td>550,200</td>
<td>44</td>
</tr>
<tr>
<td>H2</td>
<td>Packaged</td>
<td>HFC R507A</td>
<td>368,800</td>
<td>73,300</td>
<td>26,200</td>
<td>468,400</td>
<td>22</td>
</tr>
<tr>
<td>H3</td>
<td>Modular</td>
<td>HFC R410A</td>
<td>465,300</td>
<td>36,200</td>
<td>53,100</td>
<td>554,600</td>
<td>45</td>
</tr>
<tr>
<td>H4</td>
<td>Modular</td>
<td>HFC R507A</td>
<td>323,900</td>
<td>97,800</td>
<td>63,900</td>
<td>485,500</td>
<td>27</td>
</tr>
<tr>
<td>H5</td>
<td>Packaged</td>
<td>HFC R134A</td>
<td>339,300</td>
<td>73,300</td>
<td>106,000</td>
<td>518,600</td>
<td>35</td>
</tr>
</tbody>
</table>

- The C1 refrigeration system using CO₂ consumes less energy, 18% less than Unit A2. This is mostly due to the CO₂ directly recirculating in the rink slab.
- Unit C2 that is CO₂–based uses a secondary fluid in the rink slab and is a more realistic comparison to ammonia systems.
Efficiency Summary

- **Refrigerant Selection**
  - Select the correct refrigerant for your application and conditions

- **Design**
  - Select appropriate equipment
  - Use equipment that was designed for the application
  - Integrate heat reclaim when possible

- **Ongoing Improvement**
  - Monitor energy consumption to ensure equipment is working properly
  - Implement technologies when possible which can save money over the long term
## Environmental Agreements

<table>
<thead>
<tr>
<th>Agreement</th>
<th>Date</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montreal Protocol</td>
<td>1987</td>
<td>Ozone Depletion</td>
</tr>
<tr>
<td>Paris Accord</td>
<td>2016</td>
<td>Mitigate Global Warming</td>
</tr>
<tr>
<td>Kigali Agreement</td>
<td>2016</td>
<td>HFC Use/Production</td>
</tr>
</tbody>
</table>
**Environmental**

Protecting the Future

**Environmental Agreements**

**Global CO2 Emissions**

HFC Phase-down Not a Phase-Out But May be Charged Based On GWP Potential

Takes effect end of 2019 when at least 20 member countries ratify

Businesses should start planning now for a low-GWP future.

Kigali has created a framework for regulatory bodies to address global warming
Environmental

R-22 Phaseout (Montreal Protocol)

- 2013: 62 million lbs
- 2014: 52 million lbs
- 2015: 22 million lbs
- 2016: 18 million lbs
- 2017: 13 million lbs
- 2018: 9 million lbs
- 2019: 4 million lbs

R-22 Production (million lbs)
# Environmental

## Timeline of Refrigerant Technologies

<table>
<thead>
<tr>
<th>Era</th>
<th>Refrigerants</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>1800s-1920s</td>
<td>Industrial Chemicals (Methyl Chloride, Sulfur Dioxide, Ammonia, etc.)</td>
<td>Toxic Flammable</td>
</tr>
<tr>
<td></td>
<td>CFCs (R-12)</td>
<td>High ODP, Highest GWP</td>
</tr>
<tr>
<td></td>
<td>Chlorine Single Bond</td>
<td></td>
</tr>
<tr>
<td>1930s</td>
<td>HCFCs (R-22)</td>
<td>Lower ODP, High GWP</td>
</tr>
<tr>
<td></td>
<td>Less Chlorine Single Bond</td>
<td></td>
</tr>
<tr>
<td>1950s</td>
<td>HFCs (R-134a)</td>
<td>No ODP, High GWP</td>
</tr>
<tr>
<td></td>
<td>No Chlorine Single Bond</td>
<td></td>
</tr>
<tr>
<td>1990s</td>
<td>HFOs and HFO Blends</td>
<td>No ODP; Low GWP</td>
</tr>
<tr>
<td>Today</td>
<td></td>
<td>No Chlorine; Double Bond</td>
</tr>
</tbody>
</table>

**ICE RUNS IN OUR VEINS.**
New Regulations

Stand-Alone Medium Temperature Systems (Self-contained Systems)
Maintaining product temperatures above 0 Celsius
January 1, 2020  >650 GWP

Stand-Alone Low Temperature Systems (Self-contained Systems)
Maintaining product temperatures from 0 Celsius to above -50 Celsius
January 1, 2020  >1500 GWP

Centralized Refrigeration Systems (Parallel Racks, Condensing Units)
January 1, 2020  >1500 GWP

Chillers For Air-Conditioning
January 1, 2025  >700 GWP

Domestic Refrigeration
January 1, 2025  >150 GWP

Mobile Refrigeration Systems
January 1, 2025  >2200 GWP
Global Warming Potential of Different Substances

- R-717 (NH3): 0
- R-1233zd: 1
- R-1234yf: 1
- R-1234ze: 1
- R-744 (CO2): 1
- R-514A: 2
- R-290 (C3H8): 3
- R-123: 79
- R-454B: 466
- R-513A: 573
- R-452B: 675
- R-32: 677
- R-448a: 1273
- R-134a: 1300
- R-449a: 1397
- R-22: 1760
- R-407C: 1774
- R-410A: 1924

Magnitude of Effect Increases (Worsens) to the Right
| Type          | Product R-Number | ODP\(^1\) | GWP\(^2\) | ODP\(^1\) | GWP\(^2\) | ODP\(^1\) | GWP\(^2\) | ODP\(^1\) | GWP\(^2\) | ODP\(^1\) | GWP\(^2\) | ODP\(^1\) | GWP\(^2\) | ODP\(^1\) | GWP\(^2\) | ODP\(^1\) | GWP\(^2\) | ODP\(^1\) | GWP\(^2\) | ODP\(^1\) | GWP\(^2\) | ODP\(^1\) | GWP\(^2\) |
|--------------|------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| CFC          | 12               | 1         | High      | 10900     | High      | 10900     | High      | 10900     | High      | 10900     | High      | 10900     | High      | 10900     | High      | 10900     | High      | 10900     | High      | 10900     | High      | 10900     |
|              | 502              | 0.33      | High      | 4657      | High      | 4657      | High      | 4657      | High      | 4657      | High      | 4657      | High      | 4657      | High      | 4657      | High      | 4657      | High      | 4657      | High      | 4657      |
| HCFC         | 22               | 0.055     | Medium    | 1810      | Medium    | 1810      | Medium    | 1810      | Medium    | 1810      | Medium    | 1810      | Medium    | 1810      | Medium    | 1810      | Medium    | 1810      | Medium    | 1810      | Medium    | 1810      |
|              | 123              | 0.060     | Medium    | 77        | Medium    | 77        | Medium    | 77        | Medium    | 77        | Medium    | 77        | Medium    | 77        | Medium    | 77        | Medium    | 77        | Medium    | 77        | Medium    | 77        |
|              | 401A             | 0.033     | Medium    | 1182      | Medium    | 1182      | Medium    | 1182      | Medium    | 1182      | Medium    | 1182      | Medium    | 1182      | Medium    | 1182      | Medium    | 1182      | Medium    | 1182      | Medium    | 1182      |
|              | 401B             | 0.036     | Medium    | 1288      | Medium    | 1288      | Medium    | 1288      | Medium    | 1288      | Medium    | 1288      | Medium    | 1288      | Medium    | 1288      | Medium    | 1288      | Medium    | 1288      | Medium    | 1288      |
|              | 402A             | 0.019     | Medium    | 2788      | Medium    | 2788      | Medium    | 2788      | Medium    | 2788      | Medium    | 2788      | Medium    | 2788      | Medium    | 2788      | Medium    | 2788      | Medium    | 2788      | Medium    | 2788      |
|              | 402B             | 0.030     | Medium    | 2416      | Medium    | 2416      | Medium    | 2416      | Medium    | 2416      | Medium    | 2416      | Medium    | 2416      | Medium    | 2416      | Medium    | 2416      | Medium    | 2416      | Medium    | 2416      |
|              | 408A             | 0.024     | Medium    | 3152      | Medium    | 3152      | Medium    | 3152      | Medium    | 3152      | Medium    | 3152      | Medium    | 3152      | Medium    | 3152      | Medium    | 3152      | Medium    | 3152      | Medium    | 3152      |
|              | 409A             | 0.046     | Medium    | 1909      | Medium    | 1909      | Medium    | 1909      | Medium    | 1909      | Medium    | 1909      | Medium    | 1909      | Medium    | 1909      | Medium    | 1909      | Medium    | 1909      | Medium    | 1909      |
| HFC          | 23               | 0         | Zero      | 14800     | High      | 14800     | High      | 14800     | High      | 14800     | High      | 14800     | High      | 14800     | High      | 14800     | High      | 14800     | High      | 14800     | High      | 14800     |
|              | 32               | 0         | Zero      | 675       | Medium    | 675       | Medium    | 675       | Medium    | 675       | Medium    | 675       | Medium    | 675       | Medium    | 675       | Medium    | 675       | Medium    | 675       | Medium    | 675       |
|              | 134a             | 0         | Zero      | 1430      | Medium    | 1430      | Medium    | 1430      | Medium    | 1430      | Medium    | 1430      | Medium    | 1430      | Medium    | 1430      | Medium    | 1430      | Medium    | 1430      | Medium    | 1430      |
|              | 404A             | 0         | Zero      | 3922      | High      | 3922      | High      | 3922      | High      | 3922      | High      | 3922      | High      | 3922      | High      | 3922      | High      | 3922      | High      | 3922      | High      | 3922      |
| HFO          | 1234yf           | 0         | Zero      | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       |
|              | 1234ze           | 0         | Zero      | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       |
| Natural/Not in Kind | 170          | 0         | Zero      | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       | 6         | Low       |
|              | 290              | 0         | Zero      | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       |
|              | 600a             | 0         | Zero      | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       | 3         | Low       |
|              | 717              | 0         | Zero      | 0         | Low       | 0         | Low       | 0         | Low       | 0         | Low       | 0         | Low       | 0         | Low       | 0         | Low       | 0         | Low       | 0         | Low       | 0         | Low       |
|              | 744              | 0         | Zero      | 1         | Low       | 1         | Low       | 1         | Low       | 1         | Low       | 1         | Low       | 1         | Low       | 1         | Low       | 1         | Low       | 1         | Low       | 1         | Low       |
|              | 1150             | 0         | Zero      | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       | 4         | Low       |
|              | 1270             | 0         | Zero      | 2         | Low       | 2         | Low       | 2         | Low       | 2         | Low       | 2         | Low       | 2         | Low       | 2         | Low       | 2         | Low       | 2         | Low       | 2         | Low       |
# Refrigerant Choice

## Table 4: Main Refrigerants and Their Environmental Impact

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Components</th>
<th>GWP&lt;sup&gt;(1)&lt;/sup&gt;</th>
<th>ODP&lt;sup&gt;(2)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-717</td>
<td>Ammonia</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R-744</td>
<td>Carbon dioxide (CO₂)</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>R-11</td>
<td>Pure</td>
<td>3800</td>
<td>1.0</td>
</tr>
<tr>
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<td>76</td>
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<td>1420</td>
<td>0</td>
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<tr>
<td>R-143A</td>
<td>R-133/142A/134A</td>
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<td>0</td>
</tr>
<tr>
<td>R-143B</td>
<td>R-132/134A</td>
<td>2100</td>
<td>0</td>
</tr>
<tr>
<td>R-143C</td>
<td>R-122/134A</td>
<td>1800</td>
<td>0</td>
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<tr>
<td>R-141A</td>
<td>R-134/133</td>
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<tr>
<td>R-141B</td>
<td>R-125/134A/600</td>
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<td>0</td>
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<tr>
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<tr>
<td>R-142C</td>
<td>R-125/134A/600A</td>
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<td>0</td>
</tr>
<tr>
<td>R-143A</td>
<td>R-125/142A/124A</td>
<td>2100</td>
<td>0</td>
</tr>
<tr>
<td>R-143B</td>
<td>R-125/143A/124A</td>
<td>4000</td>
<td>0</td>
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</tbody>
</table>

**Legend:**
- Bold font = frequently used in ice rinks
- <sup>(1)</sup> GWP: Global-warming potential
- <sup>(2)</sup> ODP: Ozone depletion potential

*Source: ASHRAE Handbook Fundamentals 2009, Refrigerants*
HFCs are going away and in fact are already seeing a shrinking marketplace both in the European Union and in North America.
CHEMOURS
HFO Refrigerants

- Opteon™ YF (HFO-1234yf):
- Opteon™ XP10 (R-513A)
- Opteon™ XP40 (R-449A)
- Opteon™ XP44 (R-452A):
- Opteon™ XL55 (R-452B):
- Opteon™ XP30 (R-514A):

HONEYWELL
HFO Refrigerants

- Solstice L40X (R-455A)
- Solstice YF (R-1234yf)
- Solstice zd (R-1233zd)
- Solstice ze (R-1234ze)
- Solstice N13 (R-450A)
- Solstice N40 (R-448A)
COST
COST ?
Cost of Ownership

Total Cost of Ownership

- Purchase
- Repairs
- Maintenance
- Power Consumption
- Service
- Support
- Security
- Training
Cost of Ownership

Component Selection Is Important

- Type of Compression
- Type of Condensing Unit
- Type of Evaporation Unit
- Type of Refrigerant
- Horsepower per Ton
- Heat Reclaim
- Based on TIME OF PURCHASE TO GRAVE
Cost of Ownership

Life cycle cost

- **Co2 dir**
  - Lifecycle costs: $4,449,138 (-$1,446,079)
  - Payback time: 9.7 years

- **CO2 ind**
  - Lifecycle costs: $4,985,832 (-$909,384)
  - Payback time: 11.5 years

- **Ecochill**
  - Lifecycle costs: $4,621,307 (-$1,273,909)
  - Payback time: 9.3 years

- **THP**
  - Lifecycle costs: $5,311,112 (-$584,104)
  - Payback time: 7.6 years

- **Built Up**
  - Lifecycle costs: $5,033,165 (-$862,051)
  - Payback time: 9.2 years

- **Freon**
  - Lifecycle costs: $5,895,216

Total Life cycle cost: $21,982,509
Cost of Ownership

Life cycle cost

Costs [$] vs Lifetime [years]
Reliability

Keeping the ice and Maintaining the Ice – NHL Quality

Redundancy

Construction
Reliability – The Right Tool

**COMPRESSION**

- **Hermetic**
  - No Maintenance
  - No Rebuild
  - Short Life

- **Open Reciprocating**
  - Maintenance
  - Rebuild
  - Lasts almost indefinitely

- **Open / Packaged Screw**
  - Maintenance
  - Rebuild
  - Lasts a lot longer between rebuilds
Reliability – The Right Tool

CONDENSATION

Induced Draft Evap. Condensers
- High Maintenance
- Scale Problems
- Short Life

Forced Air Evap Condenser
- High Maintenance
- Scale Problems
- Leaks

Adiabatic Fluid Cooler Or Condenser
- Low Maintenance
- No Scale / Ice Build Up
- No Remote Sump System
Reliability – The Right Tool

EVAPORIZATION

Shell & Tube Chiller
- High Maintenance
- Carbon Steel Tubes
- Mid Efficient
- Large Refrigerant Charge

Plate & Frame
- Low Maintenance
- Stainless Steel or Titanium
- Lasts almost indefinitely
- Replaceable Gaskets
- Low Refrigerant Charge
Reliability – The Right Tool

Commercial Style

Industrial Style
AGING ARTIFICIAL ICE SYSTEMS

What Do We Do?

Replace

Retrofit

Maintain

WHAT IS OUR PRIORITY?
Replacement

Advantages:
- Brand new plant
- Complete Warranty
- Take advantage of new technologies

Disadvantages:
- Equipment Costs
- May require building changes
- Building Costs…
Replacement Outside Stand Alone

- Lowest Cost
- Commercial Grade
- Adapted for Rink Conditions
- Synthetic Refrigerant
- High Energy Usage
- Low Lifespan
Replacement

- NH₃ Refrigerant
- Industrial Grade
- Engineered For Rink Conditions
- Low Charge
- Smart Connected
Replacement – Heat Reclaim

- Any Refrigerant
- Industrial Grade
- Engineered For Rink Conditions
- Low Charge
- Inherent Heat Reclaim
Replacement – CO2 System

- CO2 Refrigerant
- Industrial Grade
- Engineered For Rink Conditions
- Direct Floor or
- Indirect (Glycol / Brine)
- Available Heat Reclaim
Retrofit

✓ Make use of existing infrastructure
✓ Like for Like

Advantages:
✓ Reduced costs
✓ Take advantage of existing equipment
✓ Can take advantage of a lot of new tech
✓ Can do piece by piece

Disadvantages:
• Not everything is new
• Partial Warranty
Retrofit

- Make use of existing infrastructure
- Add additional features
- Take advantage of new technologies
- Reduce charge
- Potential for Heat Reclaim
Do Nothing

Advantages:
✓ No Cost

Disadvantages:
• Don’t address any of the concerns
• No improvement to the plant
• No improvement to safety
• Unknowns
• Risk of Shutdown
• Risk of Injury if equipment fails
Need To Do What’s Right For You, Based On Your Primary Criteria

Typically The Refrigeration Plant Is “Part Of The Building” Make Sure The Plant Itself Can Last As Long As It Needs To

Consider All The Options, Retrofit And Replacement, And All The Factors.

Ask Questions

To Make Sure What You’re Getting, Is Right For You!

Thank You