Today’s Agenda

- Global Refrigerant Landscape
- Intro CO$_2$ as a Refrigerant
- CO$_2$ Safety & Maintenance
The Move Towards Low GWP Refrigerants

Step 1 - Elimination of Ozone Depleting Refrigerants (CFC & HCFC)
Step 2 - Phase Down of Global Warming Refrigerants (HFC)
Step 3 - Ramp up of low GWP Commercial Refrigeration Equipment

Step 1. Completed
Thinning of the Ozone Layer
Caused by **CFC & HCFC**
(Banned)

Step 2. Ongoing
Global Warming
Caused by **HFC**
(Phased Down / Usage Bans)

Step 3. Ongoing
Natural/Low GWP
Refrigerants
(Growing)

CFC = Chlorofluorocarbon
HCFC = Hydrochlorofluorocarbons
HFC = Hydrofluorocarbons
Early European Measures to Reduce and Eliminate HFCs

Europe: policy action at the national level

- Norway: HFC tax
- Sweden: considering HFC tax
- Denmark: HFC tax + HFC bans
- Germany: investment grants for natural refrigerants
- Switzerland: tight F-Gas Regulation & HFC bans
- Austria: HFC bans for certain sectors
- Slovenia: HFC tax
- France: has considered HFC tax
- Spain: HFC tax
- Netherlands: tax deductions for users installing naturals
- UK: accelerated tax relief for CO2 heat pump water heaters
Refrigerant Change Being Driven by Regulations and Voluntary Actions

### Regulations

- **Montreal Protocol**
  - Targets Ozone Depletion (R-22) Signed in 1987

- **North American Proposal**
  - Targets CO\(_2\) Emissions (High Global Warming)

### Organizations

- **United Nations Framework Convention on Climate Change**
- **CCAC**
  - CLIMATE AND CLEAN AIR COALITION TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS
- **IPCC**
  - INTERGOVERNMENTAL PANEL ON climate change
- **California Environmental Protection Agency**
- **Air Resources Board**
- **GreenChill**
- **U.S. ENVIRONMENTAL PROTECTION AGENCY**
- **Advanced Refrigeration Partnership**
- **Danish Ministry of the Environment**
  - Environmental Protection Agency
  - HFC Ban & Tax
- **Environment Canada**
- **Australian Government**
  - Department of Sustainability, Environment, Water, Population and Communities
  - Carbon Tax
- **European Commission**
  - F-Gas Regulation
- **Ammonia 21**
  - everything natural
- **Shecco**
  - ATMOsphere faster to market
  - natural refrigerants
Global Temperatures

2015 Was The Warmest Year Since 1880

- December 2015
- Nations agreed to limit global temperature increase to 2 C
- Countries to update pollution reduction pledges by 2020

This means reducing emissions by 40–70% by 2050 compared to 2010!
Baseline is annual average of total quantity (CO2 equivalent) placed on the EU market from 2009 to 2012.
## F-Gas Regulations – Equipment Bans

<table>
<thead>
<tr>
<th>Service And Maintenance Ban</th>
<th>GWP</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFCs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Placing on the market’ (New Equipment) Bans</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic refrigerators and freezers</td>
<td>150</td>
<td>Jan. 2015</td>
</tr>
<tr>
<td>Refrigerators and freezers for commercial use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(hermetically sealed systems)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refrigerators and freezers for commercial use</td>
<td>150</td>
<td>Jan. 2022</td>
</tr>
<tr>
<td>(hermetically sealed systems)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationary refrigeration equipment</td>
<td>150</td>
<td>Jan. 2022</td>
</tr>
<tr>
<td>(except equipment for temperatures below -50 deg C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multipack centralized refrigeration systems for commercial</td>
<td>150</td>
<td>Jan. 2022</td>
</tr>
<tr>
<td>use with a capacity of ≥ 40 kW (140 kBTU/hr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(except in the primary refrigerant circuit of cascade systems,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>where fluorinated greenhouse gases with a GWP of less than</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1500 may be used)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Movable room air-conditioning appliances</td>
<td>150</td>
<td>Jan. 2020</td>
</tr>
<tr>
<td>(hermetically sealed equipment which is movable between rooms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>by the end user)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single split air-conditioning systems containing &lt; 3 kg</td>
<td>750</td>
<td>Jan. 2025</td>
</tr>
</tbody>
</table>
## F-Gas Regulations – Leak Detection

<table>
<thead>
<tr>
<th>Equipment Category</th>
<th>Stationary Refrigeration and A/C</th>
<th>Mobile Refrigeration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 to 50 tonnes CO₂e</td>
<td>50 to 500 tonnes CO₂e</td>
</tr>
<tr>
<td>Without Leak Detection</td>
<td>12 Months</td>
<td>6 Months</td>
</tr>
<tr>
<td>With Leak Detection</td>
<td>24 Months</td>
<td>12 Months</td>
</tr>
</tbody>
</table>

- **281 lbs**: 500 tonnes CO₂e
- **770 lbs**: 770 tonnes CO₂e
Canada & US Regulatory Bodies

**Regulatory Body: Environment Canada (EC)**
- **Sector Specific**
- **Limits High GWP Refrigerants**
  - Centralized REF Systems
  - Stand-alone Commercial REF Systems
  - Commercial AC
  - Mobile REF
  - Aerosols
  - Motor Vehicle AC (MVAC)
  - Domestic REF
  - Domestic AC

**Regulatory Body: Environmental Protection Agency (EPA)**
- **Sector Specific**
- **Limits Specific Refrigerants**
  - Retail Food REF
    - Supermarket Systems
    - Remote Condensing Units
    - Stand-Alone Units
  - Vending Machines
  - Aerosols-Propellants
  - Foams (Insulation Materials)
  - Motor Vehicle AC (MVAC)
## EPA’s Final Rule (July 20th, 2015)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MT &lt;2,200 BTU/hr. and not contain flooded evap. New</td>
</tr>
<tr>
<td>R-410A</td>
<td>OK</td>
<td>-</td>
<td>OK</td>
<td>-</td>
<td>Jan. 1, 2019</td>
</tr>
<tr>
<td>HFC-134a</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>Jan. 1, 2019</td>
</tr>
</tbody>
</table>

### Likely Alternatives

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MT &lt;2,200 BTU/hr. and not contain flooded evap. New</td>
</tr>
<tr>
<td>R-448A/449A</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>Neither SNAP-approved, nor banned</td>
</tr>
<tr>
<td>R-450A/513A</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
</tr>
<tr>
<td>R-290</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>OK</td>
</tr>
<tr>
<td>R-744</td>
<td>OK</td>
<td>-</td>
<td>OK</td>
<td>-</td>
<td>OK</td>
</tr>
<tr>
<td>R-717</td>
<td>OK (in primary loop of secondary CO2 sys.)</td>
<td>-</td>
<td>OK (in primary loop of secondary CO2 sys.)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Abbreviated; see EPA final rule for complete listing.
### Environmental Protection Agency (EPA)

<table>
<thead>
<tr>
<th>End Use</th>
<th>Unacceptable Refrigerants</th>
<th>Proposed Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand Alone Units (Retrofit)</td>
<td>404A, 507A</td>
<td>July 20, 2016</td>
</tr>
</tbody>
</table>
New vs. Retrofit Systems

• New
  – “Date upon which the refrigeration circuit is complete, the system can function, the system holds a full refrigerant charge, and the system is ready for its intended purpose”
  – Supermarket may undergo an expansion and continue to use existing refrigerant “if there is sufficient cooling capacity within the system to support the expansion” — considered “not changing the intended purpose of the system”
    • Adding additional cases, compressors and refrigerants that were not supported by original system would be “new”

• Retrofit
  – Use of a refrigerant in an appliance that was designed for and originally operated using a different refrigerant
  – Recognize that expansion devices, filter driers, gaskets and oils may need replacement due to compatibility properties of the different refrigerants
# Proposed Rule - Chillers/Cold Storage

<table>
<thead>
<tr>
<th>End Use</th>
<th>Unacceptable Refrigerants</th>
<th>Proposed Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air Conditioning</strong></td>
<td>FOR12A, FOR12B, 134a, 227ea, 236fa, 245fa, 125/134a/600a (28.1/70/1.9), 125/290/134a/600a (55.0/1.0/42.5/1.5), 404A, 407C, 410A, 410B, 417A, 421A, 422B, 422C, 422D, 423A, 424A, 434A, 438A, 507A, RS-44 (2003 composition), THR-03</td>
<td>January 1, 2024</td>
</tr>
<tr>
<td><strong>Centrifugal Chillers (New)</strong></td>
<td>FOR12A, FOR12B, 134a, 227ea, KDD6, 125/134a/600a (28.1/70/1.9), 125/290/134a/600a (55.0/1.0/42.5/1.5), 404A, 407C, 410A, 410B, 417A, 421A, 422B, 422C, 422D, 424A, 434A, 437A, 438A, 507A, RS-44 (2003 composition), SP34E, THR-03</td>
<td>January 1, 2024</td>
</tr>
<tr>
<td><strong>Refrigeration</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
California Air Resource Board (CARB)

- $20 million of incentives for low-GWP refrigeration systems
- HFC phasedown in California, if no global or national plan
- Sales ban on all refrigerants with a GWP > 2500 beginning Jan 1, 2020

<table>
<thead>
<tr>
<th>End Use</th>
<th>Maximum GWP</th>
<th>Proposed Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary Refrigeration (New)</td>
<td>150</td>
<td>January 1, 2020</td>
</tr>
<tr>
<td>Household Refrigerators/Freezers (New)</td>
<td>150</td>
<td>January 1, 2021</td>
</tr>
<tr>
<td>Stationary AC (New)</td>
<td>750</td>
<td>January 1, 2021</td>
</tr>
</tbody>
</table>

CARB Proposed Strategy
Proposed Regulatory Measures – Canada

Objective: Minimize the impact of HFCs on the climate

1. Phase-down
   • Gradually reduce HFC consumption from a baseline over ~20 years
   • Baseline level in 2019 down to 15% in 2036
   • Applies to companies importing bulk HFCs
   • Would not apply to pre-charged equipment – targeted under product specific bans

Phase-down primary approach to reduce HFC usage
## Proposed Regulatory Measures – Canada

### 2. Product Bans

<table>
<thead>
<tr>
<th>Product</th>
<th>GWP Limit</th>
<th>Proposed Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile Air-conditioning</td>
<td>150</td>
<td>2021 model year</td>
</tr>
<tr>
<td>Stand-alone medium temp commercial refrigeration</td>
<td>650</td>
<td>2020</td>
</tr>
<tr>
<td>Stand-alone low temp commercial refrigeration</td>
<td>1,500</td>
<td>2020</td>
</tr>
<tr>
<td>Centralized refrigeration</td>
<td>1,500</td>
<td>2020</td>
</tr>
<tr>
<td>Chillers (air conditioning only)</td>
<td>700</td>
<td>2025</td>
</tr>
<tr>
<td>Domestic refrigeration</td>
<td>150</td>
<td>2025</td>
</tr>
<tr>
<td>Mobile refrigeration</td>
<td>2,200</td>
<td>2025</td>
</tr>
</tbody>
</table>

Currently considering feedback already received from interested stakeholders
Global Efforts to Reduce HFCs

- Four proposals to phase-down HFCs under the Montreal Protocol have now been put forward
  - India, European Union, Island States led by Micronesia, Canada/U.S./Mexico (i.e.: North American Proposal)
- On July 2, 2015, the U.S. Environmental Protection Agency finalized its rule under their Significant New Alternatives Policy (SNAP) Program:
  - Changes the status of certain HFCs to unacceptable in specific end uses
  - Targets HFCs used in aerosols, refrigeration and air-conditioning and foam blowing
- Other jurisdictions such as the EU and Japan have implemented or are developing regulations to limit HFC growth and minimized their emissions
North America and India Proposals for Amendment to the Montreal Protocol

North America

Non-A5 Countries (U.S.)

A5 Countries (Asia, etc.)

India

- Non-Article 5
- Article 5

GWP Weighted Cap (% of Baseline)

- North America
- India

Year

Cap (Percent of Baseline)
# Refrigerant Management

<table>
<thead>
<tr>
<th>Section - Current 608 (US)</th>
<th>Section 608 - Proposed (US)</th>
<th>Federal Halocarbon Regulation, 2003 (Canada)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Venting Prohibition</strong></td>
<td>CFCs, HCFCs</td>
<td>CFCs, HCFCs, HFCs</td>
</tr>
<tr>
<td><strong>Leak Test Frequency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Leak detection equipment or b) Regular leak inspection: i. Annually (50+lbs charge) ii. Quarterly (500+lbs charge) c) After equipment repair</td>
<td>a) Before charging b) Annually (&gt;=5.4TR)</td>
<td></td>
</tr>
<tr>
<td><strong>Leak Trigger Rate</strong></td>
<td>35% - Industrial/Commercial 15% - Comfort Cooling</td>
<td>20% - Industrial Commercial 10% - Comfort Cooling</td>
</tr>
<tr>
<td><strong>Leak Repair</strong></td>
<td>30 days: a) Repair the leak or b) Retrofit plan–1 year to complete</td>
<td>30 days: a) Repair the leak or b) Retrofit plan–1 year to complete</td>
</tr>
<tr>
<td><strong>Record Keeping</strong></td>
<td>CFCs, HCFCs (&gt;50lb charge) a) Reclamation</td>
<td>CFCs, HCFCs, HFCs (&gt;5lb charge) a) Reclamation</td>
</tr>
<tr>
<td><strong>Release Reporting</strong></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- **Leak >=100 kg**  
a) 24 hours for initial report  
b) 14 days for follow-up report  
- **Leaks >=10 kg**  
a) Included on semi-annual report
Alternatives for Refrigeration Applications

- **R-410A** Like
  - R446A, R447A, ARM-71a
  - R32/HFO Blends
  - 400-675
  - R32
- **R-404A & R-407/22** Like
  - R-404A
  - R444B = L20
  - L40, DR7
  - ARM-20b
  - R32/HFO Blends
- **R-134a** Like
  - HFC-1234yf
  - HFC-1234ze
  - R515A
  - ~600
  - HFC/HFO Blends
  - R450A = N13
  - R513A = XP10
- **R-123 Like** (V. Low Pr.)
  - DR2, N12, ARC 1
  - ~150
  - R-455A (HDR110)
  - DR3
  - ARM-20a

- CO₂

- NH₃

- ~300

- R290

- HFC-32

- R444B = L20

- L40, DR7

- ARM-20b

- R32/HFO Blends

- <150

- Non-Flammable

- A1

- A2L – Mildly Flammable

- A3 – Flammable

- B2L – Toxic, Mildly Flam.

- Qualitative – Not to Scale

- GWP Level

- R410A

- R404A

- (3922)

- R507A

- R448A

- R449A

- R449B

- R22

- R407A

- R407C

- R407F

- R452A = XP44

- ARM-35

- R450A = N13

- R513A = XP10

- R444B = L20

- L40, DR7

- ARM-20b

- R32/HFO Blends

- <150

-Queue 5

- A1 – Non-Flammable

- A2L – Mildly Flammable

- A3 – Flammable

- B2L – Toxic, Mildly Flam.
Intro CO\textsubscript{2} as a Refrigerant
Benefits of using CO$_2$ as a Refrigerant

- Naturally occurring in the environment
  - ODP = 0, GWP = 1
- Non Toxic, Non Flammable, Non Combustible
- Inexpensive refrigerant compared with HFCs
- Better heat transfer properties compared to conventional HFCs
- More than 50% reduction in HFC refrigerant charge possible
  - CO$_2$ lines are typically one to two sizes smaller than traditional DX HFC piping systems
- Excellent material compatibility
- System energy performance can be equivalent or better than traditional HFC systems
## R-744 vs HCFC/HFC

<table>
<thead>
<tr>
<th></th>
<th>R-744 (CO₂)</th>
<th>HFC / HCFC</th>
<th>Impact on R-744 Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Warming Potential</td>
<td>1</td>
<td>1300 to 4000</td>
<td>Future Proof</td>
</tr>
<tr>
<td>Ozone Depleting Potential</td>
<td>0</td>
<td>0 for HFC / High for HCFC</td>
<td>Future Proof</td>
</tr>
<tr>
<td>Saturation Pressures</td>
<td>Higher</td>
<td>Lower</td>
<td>Additional Safety Design</td>
</tr>
<tr>
<td>Operating Pressures</td>
<td>Higher</td>
<td>Lower</td>
<td>Specialized Components</td>
</tr>
<tr>
<td>Standstill Pressures (Power Outages)</td>
<td>Higher</td>
<td>Lower</td>
<td>Relief Valves/Tanks/ etc..</td>
</tr>
<tr>
<td></td>
<td>Rapid</td>
<td>Lower</td>
<td>Pressure Relief Venting</td>
</tr>
<tr>
<td></td>
<td>Pressure Rise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inert Gas</td>
<td>Yes</td>
<td>Yes</td>
<td>Copper may be used</td>
</tr>
<tr>
<td>Flammability</td>
<td>A1</td>
<td>A1</td>
<td>Not Flammable</td>
</tr>
<tr>
<td>Toxicity</td>
<td>No</td>
<td>No</td>
<td>Asphyxiate in High Concentrations</td>
</tr>
<tr>
<td>Odor</td>
<td>None</td>
<td>None</td>
<td>Leak Detection Required</td>
</tr>
<tr>
<td>Heat Transfer</td>
<td>Higher</td>
<td>Lower</td>
<td>Better Thermal Efficiency</td>
</tr>
<tr>
<td>High Ambient Performance</td>
<td>Lower</td>
<td>Lower</td>
<td>System Design to Compensate</td>
</tr>
<tr>
<td>Low Ambient Performance</td>
<td>Good</td>
<td>Higher</td>
<td>Subcritical Cascade Favorable</td>
</tr>
<tr>
<td>Cost per Pound</td>
<td>Low</td>
<td>Higher</td>
<td>Economical</td>
</tr>
<tr>
<td>Complexity of Systems</td>
<td>Higher</td>
<td>Lower</td>
<td>Higher First Cost, Training &amp; Experience</td>
</tr>
<tr>
<td>Adoption</td>
<td>Low</td>
<td>Higher</td>
<td>Higher First Cost</td>
</tr>
<tr>
<td>Legislation / Regulations</td>
<td>Low</td>
<td>Higher</td>
<td>Long-Term Viability</td>
</tr>
</tbody>
</table>

R-744 Provides Many Benefits Over HFC Options
The **critical point** is the condition above which distinct liquid and gas phases do not exist.

The **triple point** is the condition at which solid, liquid and gas co-exist.
Over 6,500 CO₂ Transcritical Stores Worldwide

Source: Shecco’s GUIDE to Natural Refrigerants - 2015
**CO₂ System Architecture**

### Traditional HFC
- **HFC Only**
- Max Press: 400 psig
- 1 Loop
- Highest GWP

### CO₂ Cascade
- **HFC + CO₂**
- Max Press: 500 psig
- 2 Loops
- Lower GWP

### CO₂ Transcritical
- **CO₂ Only**
- Max Press: 1740 psig
- 3 Loops
- Lowest GWP
CO₂ Hybrid Cascade System
CO₂ Pumped Secondary System
CO₂ Booster Refrigeration System

- High Pressure Controller
- HP Valve
- Gas Cooler/Condenser
- MT Compressors
- Controller
- MT Expansion
- Medium Temperature Evaporators
- LT Expansion Valve
- Low Temperature Evaporators
- Case Controller

Pressure Levels:
- 700-1600 psig
- 580 psig
- 450 psig
- 200 psig
Climate Impact on CO$_2$ System Architectures
CO$_2$ Safety & Maintenance
What You Need to Know About CO$_2$?

- Three Main Differences Between HFC and R-744 Systems
  - High Pressure
  - Low Critical Point
  - High Triple Point
- Dealing With Standstill Pressures
  - Managing Pressure Reliefs
  - Managing Power Outages
- Refrigerant Properties
  - Risk of Asphyxiation
  - Managing Moisture
Grades of $\text{CO}_2$ (R-744)

<table>
<thead>
<tr>
<th>Application</th>
<th>Purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial</td>
<td>99.5%</td>
</tr>
<tr>
<td>Bone Dry</td>
<td>99.8%</td>
</tr>
<tr>
<td>Anaerobic</td>
<td>99.9%</td>
</tr>
<tr>
<td>Coleman*</td>
<td>99.99%</td>
</tr>
<tr>
<td>Research</td>
<td>99.999%</td>
</tr>
<tr>
<td>Ultra-Pure</td>
<td>99.9999%</td>
</tr>
</tbody>
</table>

*Coleman Grade
- Used for refrigeration
- (<10ppm $\text{H}_2\text{O}$)
- Tanks cleaned and evacuated before filling
Charging R-744

- Charging equipment must be rated for at least 1305 psig (90 barg).
- Typically hydraulic hose or braded steel hose are used.
- All charging lines should be evacuated or purged prior to charging to reduce air and moisture into the system.
- To prevent dry ice formation, the evacuated system should be charged with R744 vapour to a pressure above the triple point, 60.9 psig (4.2 barg).
- To be conservative if the systems is at 145 psig (10 bar g) then it’s ok to charged with liquid.
Managing Power Outages

• Generator and Standby Condensing Units
• Need a Refrigerant Plan
  – Local Codes
  – Stock, Storage
  – Getting it to the Machine Room
• Concerns With Resumption of Power
Servicing R-744

- Finding leaks is challenging
- Dedicated set of gauges, high-pressure hoses and miscellaneous parts at each store
- Preventative maintenance schedule is critical with R-744
- Understand the consequences of trapping R-744
- Training of service personnel is required
CO₂ Booster Refrigeration System
Understanding Pressure Reliefs

Compressor Discharge
135 bar 1958 psig

PRV vented to outdoor
110 bar 1600 psig

PRV vented to outdoor
42 bar 600 psig

UL Comp. Suct.
90 bar 1305 psig

PRV vented to outdoor
42 bar 600 psig

PRV vented to outdoor
35 bar 500 psig
Pressure Relief Valve Installation

Flash Tank
650 psig
2 PRV with
3 way Valve

Gas Cooler
1600 psig
2 PRV with
3 way Valve
Leak Detection

- Fixed leak detection should be used
- 5,000 ppm (0.5 Vol.% in air) – initial alarm
  - Occupation Concentration Limit (OCL)
  - 10,000 ppm is 1 Vol.% in air
  - 15,000 ppm for a main alarm.
- Threshold Limit Value Time Weighted Average (TLV-TWA)
  - 8 hour workday / 40 hour work week
  - \( CO_2 = 5,000 \text{ ppm} \)
  - \( HFC = 1,000 \text{ ppm} \)
  - \( NH3 = 25 \text{ ppm} \)
- One 1L of dry ice will produce 845L of gas at 59°F (15°C) @ 1 Atm.

Source: ANSI/ASHRAE Standard 15-2013, 34-2013,
Conclusions

• CO$_2$ is an excellent low GWP refrigerant choice that holds many advantages over HFCs.

• Depending on the application and region of the world various system architectures choices are available to end users.

• Although CO$_2$ mirrors the current refrigeration practices, special considerations needs to be given to safety, handling and maintenance.
  • Higher Operating Pressures
  • Rapid Rise of Standstill Pressure when System is Off
  • Dry ice consideration
  • Moisture Considerations
Questions?

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