LOW CHARGE AMMONIA AND CO2 REFRIGERATION SOLUTIONS

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Star Refrigeration

26th June 2019
Ammonia and CO$_2$ in refrigeration

carbon dioxide

CO$_2$

ammonia

NH$_3$

160+ years

140+ years
**Why the move away from HFC’s?**

**F-Gas Regulation Timeline**

- Reduced availability of HFCs driven by F-Gas Regulation
- Escalating HFC costs
- Ammonia & CO2 unaffected by F-Gas Regulations

*Average GWP*

- Baseline = average consumption between 2009 & 2012
Why the move away from HFC’s?

F-GAS REGULATION & HFC LEGISLATION

Escalating legislative pressure to reduce or eliminate the use of high-GWP refrigerants, including:

**Revised EU F-Gas Regulation (517/2014)**
- Availability of HFCs reduced by 79% between 2015 and 2030
- Step-wise bans on installation and servicing of systems with higher-GWP refrigerants

**Kigali Amendment to the Montreal Protocol, agreed October 2016**
- 197 countries agree to cut HFC production and consumption by >80% by 2047
- HFC phase down plan

**Proposed UK penalties of up to £200,000 for F-Gas violations**

Rising HFC costs

IMPACT OF HFC RESTRICTIONS

- Significant and sustained price increases for HFCs
- Stable pricing for CO2 & NH3

Analysis: [Star Refrigeration]

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>GWP</th>
<th>Cost, Jun-15</th>
<th>Cost, Jun-19</th>
<th>Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>R717 (NH3)</td>
<td>0</td>
<td>£ 1.27</td>
<td>£ 1.32</td>
<td>4%</td>
</tr>
<tr>
<td>R744 (CO2)</td>
<td>1</td>
<td>£ 2.92</td>
<td>£ 2.94</td>
<td>1%</td>
</tr>
<tr>
<td>R134a</td>
<td>1430</td>
<td>£ 7.93</td>
<td>£ 31.63</td>
<td>398%</td>
</tr>
<tr>
<td>R422D</td>
<td>2729</td>
<td>£ 15.08</td>
<td>£ 76.51</td>
<td>507%</td>
</tr>
<tr>
<td>R404A</td>
<td>3922</td>
<td>£ 7.28</td>
<td>£ 50.02</td>
<td>687%</td>
</tr>
</tbody>
</table>

- 250kg R422D = Over £19,000!
Why CO2?

- Natural substance (GWP = 1, ODP = 0)
- Not covered under F-Gas
- Non flammable, classified as non-toxic
- Cost effective, available everywhere, non-patented
- Improved efficiency vs traditional DX HFC in mild to cold climates
- High volumetric efficiency ➔
  - Small pipe work
  - Lower charge
  - Reduced materials / installation costs
Why Ammonia?

• Natural substance (GWP = 0, ODP = 0)
• Good efficiency vs traditional systems in any climate
• Cost effective, available everywhere, non-patented
• Development of low charge and packaged systems
• Not covered under F-Gas
• >100 years experience of use
• Wide application range
• Low cost refrigerant
Refrigerant Selection

Typical Capacity Coverage by Technology

- **R744 Chill range typically 20kW to 500kW**
- **R717 chill range typically 200kW +**
- **R744 freezer/cold store range typically 20kW to 250kW**
- **R717 freezer/cold store range typically 100kW +**
- **Not restricted to these ranges**
- **Example – R744 2,400kW @ -50°C [Freeze dried coffee]**

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Case Study – Single Stage Trans-critical CO₂

- 5,300 m³ +2°C Chill Store [96kW Cooling Duty]
- 15,000 kg / HR potatoes [+5°C to +2°C]
- K65 copper pipework
- Remote gas cooler
- Trans-critical CO₂ System
- Low pressure receiver for enhanced efficiency
- Non-flammable refrigerant [no DSEAR]
- Non-toxic refrigerant [no DSEAR]
- Environmentally responsible (GWP = 1, ODP = 0)
- Future proof solution [no F-Gas]
- Chill/cold store applications [-18°C]
Case Study – Two Stage Trans-critical CO₂

- 250 pizzas per hour @ +94°C to -18°C
- Dual operation spiral freezer / spiral chiller
- 200kW refrigeration capacity @ -30°C air temperature
- Remote gas cooler
- Trans-critical CO₂ system
- Low pressure receiver for enhanced efficiency
- Low refrigerant cost - £2,400 [vs HFC £32,000]
- Non-flammable refrigerant [no DSEAR]
- Non-toxic refrigerant [no DSEAR]
- Environmentally responsible (GWP = 1, ODP = 0)
- Future proof solution [no F-Gas]
### Case Study – Single Stage Sub-critical CO$_2$

- **2,150m$^3$ -23°C coldstore**
- **60kW refrigeration capacity**
- **Cascade system**
- **Sub-critical condensing through glycol circuit**
- **Duty / standby compressors & condensers**
- **Low pressure receiver for enhanced efficiency**
- **Non-flammable refrigerant [no DSEAR]**
- **Non-toxic refrigerant [no DSEAR]**
- **Environmentally responsible (GWP = 1, ODP = 0)**
- **Future proof solution [no F-Gas]**
Typical Charge – 2kg/kW
What is low charge?
Any ammonia system which requires a specific system charge of less than 10 lb/TR (1.3kg/kW) of refrigerant.
What is low charge?

The lowest possible charge required for stable operation of the unit over the full range of possible operating conditions while maintaining the system’s rated capacity.

Refrigerant Charge Reduction in Refrigerating Systems – IIR Informatory Note
### Case Study - Chill Storage

- **Distribution centre**
- **59,000m³ chill storage @ +2°C room temperature**
- **1,100kW of cooling duty**
- **2-off R717 chillers**
- **11-off glycol air coolers**
- **Exceeds EU Ecodesign Directive requirements**
- **Specific Energy Consumption 3.2kWh/m³/year**
- **Fully natural, future proof system**
- **No plant room required**
- **No water supply required**
- **Plug and play installation**
- **Simple to maintain**
- **<0.2kg/kW charge [214kg total]**
Chiller Technology

- Evaporator
- Condenser
- Low refrigerant charge
- Compact design
- Long lasting
- Integrated separation
Chiller Technology

- Compressor VSD
- EC Fans
- Floating suction pressure
- Floating condensing pressure
- Compressor sequencing
- PLC control
Case Study: Storage & Distribution

81,000m³ freezer @ -24°C
600kW total cooling capacity
4-off aluminium air coolers
Reverse cycle defrost
Floating condensing pressure
EC condenser Fans
Two compressors per system
Heat recovery
Economised screw compressors
Reverse Cycle Defrosting Flow Diagram

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Case Study – Freezer / Chill System

- Low pressure receiver system
- High efficiency [Compressor COP 1.57 @ design]
- Pump-free freezer design
- Low charge 0.62kg/kW [376kg total]
- Secondary glycol to UFHM
Reverse Cycle Defrost

- Single 4 way ball valve
- Reverse plant operation
- Electrical actuator
- Rapid defrost
Aluminium Evaporators

Key Component:

- Aluminium Coil

Metal

<table>
<thead>
<tr>
<th>Metal</th>
<th>Density kg/m³</th>
<th>Thermal Conductivity kW/ m² °C</th>
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<tbody>
<tr>
<td>Aluminium</td>
<td>2648</td>
<td>202</td>
</tr>
<tr>
<td>Carbon Steel</td>
<td>7833</td>
<td>45</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>7048</td>
<td>112</td>
</tr>
</tbody>
</table>

Excellent heat transfer

Very low charge

High efficiency
Regulation is driving increased interest

Low charge ammonia is already available

Possible to reduce ammonia charge by 95%+

Solutions from HVAC to freezers

New component technology development

New system development

Improved efficiency

Lower life cycle cost
Pricing Comparison:

Cold Store Application, Capital Investment

- Ammonia: +25% vs CO₂
- CO₂: -32% vs CO₂
- R449A: Natural

STAR REFRIGERATION
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PROPRIETARY AND CONFIDENTIAL
Pricing Comparison:

Cold Store Application, Operational Costs

- Ammonia
- CO2
- R449A
Questions
Thank you for your attention