R404A replacements in Commercial refrigeration.
**Agenda**

- **F-Gas: business consequences**
- Introduction to HFOs and Solstice® family
- **R404A replacement:**
  - R407F
  - Solstice® N40 (R-448A)
  - HDR110
F-Gas – Control of Use in Commercial Refrigeration

New Installation Bans*
(only main bans affecting Refrigeration shown here)

Stationary Refrigeration Equipment requiring HFC >2500 GWP

New Commercial Refrigerators / Freezers (hermetically sealed systems) >150 GWP

Centralised multipack systems >40kW capacity using HFC >150 GWP / except primary circuit (not distributed) of cascade system where <1500 GWP is acceptable


RAC & H/Pump equip. pre-charged with F-gases must be included in a registered Quota system beginning 2017

Virgin F-gases >2500 GWP for servicing ref equip. With charge size of >40 T CO₂-eq (~10kg R404A)

Recycled and reclaimed F-gases with >2500 GWP for servicing ref equip with a charge size of >40 T CO₂-eq

Exemptions include Military equipment and refrigeration applications below -50 Deg C

Maintenance & Service Bans*
(only those affecting Refrigeration shown here)

NOTE: R407F (<1825 GWP) repl. for R404A - can be used for servicing without end date (beyond 2030...)

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F-Gas – Phase Down

Phase Down Mechanism

- What is your Strategy for Change?
  - Refrigerant leak / charge reduction
  - Educate your team and your customers on this change
  - Improve your understanding of the low GWP alternatives to R404A
  - Understand the minor differences in ‘how they are applied’
  - Become more comfortable with the differences → glide / flammability / high pressures / different system technologies etc..
  - Refrigerant choice – STOP using R404A wherever possible
  - Mindset - Change provides Opportunities for your business

F-gas Regulations will Challenge our Industry Opportunities

<table>
<thead>
<tr>
<th>Year</th>
<th>CO₂ eq.</th>
<th>Sales Capped % of 2009-2012 Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>-7%</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>-37%</td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>-55%</td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>-69%</td>
<td></td>
</tr>
<tr>
<td>2027</td>
<td>-76%</td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>-79%</td>
<td></td>
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</tbody>
</table>
## Introduction to Solstice® family

<table>
<thead>
<tr>
<th>Solstice® HFO molecules</th>
<th>Nonflammable (ASHRAE A1)</th>
<th>Mildly flammable (ASHRAE A2L)</th>
<th>Examples of potential applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-134a</td>
<td><strong>Today</strong></td>
<td>Solstice® yf GWP* &lt; 1</td>
<td>Auto A/C, Vending, Refrigerators</td>
</tr>
<tr>
<td>GWP=1430</td>
<td></td>
<td>Solstice® ze GWP* &lt; 1</td>
<td>Chillers, CO₂ Cascades Refrigerators</td>
</tr>
<tr>
<td>R-123</td>
<td>Solstice® zd GWP* = 1</td>
<td></td>
<td>Centrifugal Chillers</td>
</tr>
<tr>
<td>GWP= 77</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

GWP = Global Warming Potential

*IPPC5
**Introduction to Solstice® family**

<table>
<thead>
<tr>
<th>Solstice® Blends</th>
<th>Examples of potential applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non Flammable (ASHRAE A1)</strong></td>
<td></td>
</tr>
<tr>
<td>R-134a GWP=1430</td>
<td>Solstice® N13 (R-450A) GWP* = 547</td>
</tr>
<tr>
<td>R-404A GWP=3922</td>
<td>Solstice® N40 (R-448A) GWP* = 1273</td>
</tr>
<tr>
<td>R-22 GWP=1810</td>
<td>Solstice® N20 GWP* = 891</td>
</tr>
<tr>
<td>R-410A GWP=2088</td>
<td>Solstice® L41 (R-447A) GWP* = 572</td>
</tr>
</tbody>
</table>

*IPPC5

**Today**

**Coming soon**
R407F: Independent Measured Performance Comparison

Efficiency comparisons (Independent verification)

- Important improvements in MT applications ~ 10%
  - Climate / system specific / optimisation during retro-fit
- Still large improvements at LT conditions ~ 6%
- Clear overall improvement in Energy Efficiency shown by R407F

Considerable reduction in operational / running costs

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Introducing N40 (R448A): Capacity & COP

BITZER Software: semi-hermetic compressor (4GE-23Y)

Mean Pressures / Suct. Temp = -4°C (LT); 20°C (MT) / Useful Superheat = 5K / Subcooling = 0K

- Under system-like conditions, both R407F and N40 (R448A) provide capacity above 95% of R404A in low and medium temp applications
- Under medium temp system conditions, R407F and N40 (R448A) provide the best efficiency (COP)
- Under low temp system conditions, N40 (R448A) provides the highest COP

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R448A (best) and R407F (better) provide the highest combined energy efficiency.

Due to lower discharge temperature, R448A is less likely than R407A or R407F to require liquid injection**.

**Requirements will vary depending on the actual operating conditions.
Emerson Performance: Solstice® N40 (R-448A)

- Copeland Liquid and EVI Scroll
- Medium and Low Temperature

**Scroll System Analysis**
@ -6.7°C / 48.9°C

- Capacity (Midpoint/SH 5K Performance)
  - Baseline
  - R404A
  - N40
  - 17% > R404A

- COP (Midpoint/SH 5K Performance)
  - Baseline
  - R404A
  - N40
  - 11% > R404A

**Semi-Hermetic System Analysis**
@ -31.6°C / 43.3°C

- Capacity (Midpoint/SH 5K Performance)
  - Baseline
  - R404A
  - N40
  - 15% > R404A

- COP (Midpoint/SH 5K Performance)
  - Baseline
  - R404A
  - N40
  - 10% > R404A

‘N40 provides superior Energy Efficiency to that of R-404A with reduced GWP’

Qualified for Use
3rd Party evaluations: Solstice® N40 (R-448A)

Oak Ridge National Laboratory (US)
- Supermarket System Evaluation
  ✓ Reduced compressor power by 3.7%
  ✓ Increased refrigeration capacity by 7.5%
  ✓ Increased system COP by 11.6%

Tewis Smart Systems
- Laboratory Test in Simulated Supermarket set-up vs R-404A

Consumption during the whole testing period in a non-optimized drop-in test prior to corrections on temperature and humidity.

“After this laboratory test, we are convinced that R-448A complements the current portfolio of alternatives for refrigeration systems by providing the lowest GWP, safest, maximum savings refrigerant for optimized characteristics in an R-404A direct retrofit.”

Note: Tewis Smart Solutions (internal)
3rd Party evaluations: Solstice® N40 (R-448A)

**Toshiba Refrigeration (Japan)**
- Condensing Unit Performance trial
  - Ambient tests at 32°C & 43°C to JIS 8623 (std)
  - N40 showed 4-16% higher COP and excellent match in capacity

**ASDA (UK)**
- Successful >14 months trial store comparison
  - Improved capacity and efficiency vs. R404A
  - Simple retro-fit with minimal system adjustment
  - Discharge Temp close to R404A level (no liq injection required on LT)

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‘Solstice N40 is well engineered refrigerant to meet requirement as an alternative to R404A’
### Refrigerants roadmap: R-404A

#### Medium temperature and low temperature stationary refrigeration

**Performax LT (R-407F) is preferred option**
- Already commercial
- Homologated by most components manufacturers
- Proven experience in commercial, industrial and food service applications over Europe
- Closer cost to R-404A than Solstice N40

**Solstice N40 (R-448A) could be interesting if:***
- Further GWP reduction is desired
  - Environmental goal
  - Tax country
- Slight improvement of T\(_{\text{dis}}\) vs R-407F is required
  - Solstice N40: T\(_{\text{dis}}\) still higher than R-404A
  - Solstice N40: T\(_{\text{dis}}\) still lower than R-22

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**Better**

<table>
<thead>
<tr>
<th>Performax LT (R-407F)</th>
<th>Solstice® N40 (R-448A)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td>R-404A (A1, 3922 / 3943)</td>
</tr>
<tr>
<td><strong>GWP 4(^{th}) / 5(^{th})</strong></td>
<td>1824 / 1764</td>
</tr>
<tr>
<td><strong>Class</strong></td>
<td>A1</td>
</tr>
<tr>
<td><strong>Potential app. Use</strong></td>
<td>MT and LT stationary refrigeration</td>
</tr>
<tr>
<td><strong>Drop-in (1) Cap.</strong></td>
<td>Similar</td>
</tr>
<tr>
<td><strong>Drop-in (1) Eff.</strong></td>
<td>5% to 10% higher</td>
</tr>
<tr>
<td><strong>Compressor (2)</strong></td>
<td>Recip, Scroll, Screw</td>
</tr>
<tr>
<td><strong>Comments</strong></td>
<td>No TXV change, Higher T(_{\text{dis}}) in LT</td>
</tr>
<tr>
<td><strong>Status</strong></td>
<td>Commercial</td>
</tr>
</tbody>
</table>

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1. Drop-in test in a non-optimized system
2. Suitable compressor technology, check with Honeywell technical department for qualified models
HDR110 (GWP<150): Self-Contained System Evaluation

- **ASHRAE 72 standard test:**
  - 3/4 HP Reach-in R404A Freezer placed in a chamber at 25°C
  - Cabinet volume filed with glycol/water test simulators and frozen food

- **Near drop-in test of HDR-110:**
  - TXV was slightly adjusted to provide appropriate superheat
  - No oil change required. Typical charge optimization carried out
  - Evaporator position inverted to **get counter-flow configuration**
24h Freezer Performance: HDR-110 vs R404A

- Capacity within 5% of R404A
- Efficiency increased by 6%
- Maximum discharge temperature (108°C) within compressor limits

**HDR-110 under Evaluation by Major Equipment Manufacturers**

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