New Case studies on Low GWP alternative refrigerants for HFCs.

ABHIJEET KUDVA
5th March 2014
Honeywell

$39-39.5B in sales*

54% sales outside U.S.

- 1,300 sites, 70 countries
- 132,000 employees
- Morristown, NJ headquarters
- Fortune 100

Aerospace

Performance Materials and Technologies

Automation and Control Solutions

Transportation Systems

*2013 guidance
Honeywell’s refrigerants key attributes

**Cost Effective**
Keeping operating costs lower than expected
- Lower initial cost than other alternatives
- Universal solutions in all climates
- Skills needed are similar to those used for current equipment

**Environment**

**Safe And Sustainable**
- Meeting ever-increasing global energy standards
- Low-GWP and low-TEWI designs
- Near drop-in solutions with performance that allow for low cost of adoption and reduction of maintenance requirements

**Performance**
Solstice™ refrigerants help enhance energy efficiency in all climates
- Commercial refrigerant solutions for supermarkets, HVAC conditioning, transportation, climatization, vending and more
- All solutions designed to maximize energy efficiency
- Developed for installation ease and long service life
Solstice: A Growing Family of Molecules and Blends

Auto Air-conditioning

Blowing Agents

Aerosols / Solvents

Stationary A/C and Refrigeration

Pipeline of 4th Generation Products being commercialized
# Honeywell’s Solstice™ low GWP refrigerants

## Solstice™ HFO’s – low and medium pressure applications

<table>
<thead>
<tr>
<th>Current Product</th>
<th>Non Flammable (ASHRAE A1)</th>
<th>Mildly Flammable (ASHRAE A2L)</th>
<th>Examples of Potential Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFC-134a</td>
<td></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, Heat Pumps, CO₂ Cascades, Refrigerators</td>
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<tr>
<td>R-123</td>
<td>Solstice zd GWP &lt;1</td>
<td></td>
<td>Centrifugal Chillers</td>
</tr>
<tr>
<td>GWP= 77</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

## Solstice™ HFO Blends

<table>
<thead>
<tr>
<th>Current Product</th>
<th>Solstice™ N Series Reduced GWP Option Non Flammable (ASHRAE A1)</th>
<th>Solstice™ L Series Lowest GWP Option Mildly Flammable (ASHRAE A2L)</th>
<th>Examples of Potential Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFC-134a</td>
<td>N-13 – GWP ~600</td>
<td></td>
<td>Chillers, Med-temp Refrigeration, CO₂ Cascades</td>
</tr>
<tr>
<td>GWP=1430</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCFC-22</td>
<td>N-20 – GWP ~1000</td>
<td>L-20 – GWP &lt;300</td>
<td>Stationary A/C, Refrigeration</td>
</tr>
<tr>
<td>GWP=1810</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-404A</td>
<td>N-40 – GWP ~1380</td>
<td>L-40 – GWP &lt;300</td>
<td>Med- &amp; Low-Temp Refrigeration</td>
</tr>
<tr>
<td>GWP=3922</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-410A</td>
<td></td>
<td>L-41 – GWP &lt;600</td>
<td>Stationary A/C Applications</td>
</tr>
<tr>
<td>GWP=2088</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Low GWP Refrigerants in Stationary AC Systems

## TRADITIONAL

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Operating Pressure</th>
<th>Flammability</th>
<th>GWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-22</td>
<td>1810</td>
<td>Non-flammable</td>
<td>2088</td>
</tr>
<tr>
<td>R-407C</td>
<td>1774</td>
<td>Mildly flammable</td>
<td>675</td>
</tr>
<tr>
<td>R-410A</td>
<td>2088</td>
<td>Non-flammable</td>
<td>675</td>
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</tbody>
</table>

## TODAY

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Operating Pressure</th>
<th>Flammability</th>
<th>GWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solstice™ N20</td>
<td>~1000</td>
<td>Non-flammable</td>
<td>2088</td>
</tr>
<tr>
<td>Solstice™ L20</td>
<td>&lt;300</td>
<td>Mildly flammable</td>
<td>675</td>
</tr>
<tr>
<td>Solstice™ L41</td>
<td>&lt;600</td>
<td>Non-flammable</td>
<td>2088</td>
</tr>
</tbody>
</table>

## THE FUTURE

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Operating Pressure</th>
<th>Flammability</th>
<th>GWP</th>
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</thead>
<tbody>
<tr>
<td>CO₂</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>HFO L41</td>
<td></td>
<td>Mildly flammable</td>
<td>675</td>
</tr>
<tr>
<td>HFC32</td>
<td></td>
<td>Non-flammable</td>
<td>675</td>
</tr>
<tr>
<td>HFO L20</td>
<td></td>
<td>Mildly flammable</td>
<td>~300</td>
</tr>
<tr>
<td>HFC N20</td>
<td></td>
<td>Non-flammable</td>
<td>~1000</td>
</tr>
<tr>
<td>HCs</td>
<td></td>
<td>Highly flammable</td>
<td>~20</td>
</tr>
</tbody>
</table>

### System redesign necessary if using refrigerants with higher operating pressures

- Operating Pressures
  - HCs: Highly flammable, GWP < 20
  - HFO L20: Mildly flammable, GWP < 300 (N20) / ~1000 (L20)
  - HFO N20: Non-flammable, GWP = 675 (R32), GWP < 600 (L41)
  - HFO L41: Non-flammable, GWP = 2088
  - HFC 410A: Non-flammable, GWP = 2088, Properties enable cost-effective efficient system
  - HFC 407C: Non-flammable, GWP = 1824, Utilizes R22 design
  - HCFC 22: Non-flammable, GWP = 1824, Utilizes R22 design
  - CO₂: Very high pressure, Major changes needed, Typically higher adoption cost, Low efficiency, GWP = 1
Haier Network Smart Appliance Project - World’s first Solstice L41 A/C

- More than 70% reduction in GWP versus R410A
- Lower discharge pressure than R32
- Lower discharge temperature than R32
- Lower power consumption than R410A and R32 at high ambient temperature

**Solstice™ L41 outperforms other alternatives in high ambient A/C**
Solstice™ L41 vs R32 vs R410a in stationary A/C

- R-32 has been proposed as an R-410A replacement
  - Similar performance to R-410A
  - GWP of 675, a 67% reduction

- Solstice L41 blend outperforms R-32:

  1. GWP
     - GWP of 600 for L41 vs. 675 for R-32

  2. Discharge Temperature
     - L41 has lower discharge temperatures than R32
     - Important in very warm climates
     - Less cost to mitigate

  3. High Ambient Temperature Performance
     - R32 power consumption increases at high temps
     - Adds to peak electricity demand issues

  4. Flammability
     - L41 has higher minimum ignition energy and lower flame speed – lower risk
     - Much less flammable than propane (R290)
     - Lower cost to mitigate

HFO blends offer cost-effective performance
HFO-1234yf: lowest carbon footprint in Automobile

Similar performance

Lowest carbon footprint

HFO-1234yf: lowest carbon footprint of all AC technologies
Solstice ze: replacing R134a in medium pressure chillers

- Solstice™ N13 & Solstice™ ze: similar efficiency to R134a
- Solstice N13: potential use in existing equipment
- Solstice ze good candidate for new equipment
  - Up to +5% CoP in chiller
  - Cooling capacity -25% @ ARI conditions
    - Can be overcome by design
  - Examples available in the market
Solstice™ ze chillers

Solstice™ ze Screw Chiller
(Geoclima)

Solstice™ ze Centrifugal Chiller
(Compressor)
(Geoclima, Turbocor)

Solstice™ ze in chillers in exhibition shows
Solstice zd: replacing R123 in low pressure centrifugal chillers

Solstice™ zd

- Replacement of R123
- Similar efficiency to R123
- It can provide higher capacity with minor system modifications
- Due to higher pressure than R123, system modifications may be required

Solstice™ zd can match efficiency of R123 and provide higher capacity
Commercial Refrigeration and 407F

Performax™ LT: the best solution

- Mimics R22 performance
- Composed of commonly used HFC components
- Meets refrigeration specifications
- Limited modification at installation
- No change of major components
- Known system technology
- Safety and service standards as R22/R404A
- Same skills for technicians
- Same installation
- More than 600 installations and no issues

Lower GWP*

Lower energy consumption

Reduction of direct CO₂ emissions: 52%

Reduction of TEWI* up to 40%

Operations costs reduction up to 10%

Best solution to improve efficiency and reduce carbon footprint & running cost

* GWP: Global Warming Potential
TEWI: Total Equivalent Warming Impact
Reduced/Low GWP Options for Commercial Refr.

Reduced GWP Options:
- Currently available refrigerant - Performax LT *(R-407F)*
  - GWP reduction of over 50% relative to R-404A. GWP ~15% lower than R-407A.
  - Performance is superior to both R-404A and R-407A.
- We have a developmental refrigerant, N-40
  - N-40 can be used in existing R-404A equipment with little or no modifications
  - GWP reduction of over 65% as compared to R-404A with higher efficiency.

Low GWP Options:
- L-40 is the lowest GWP option that has capacity consistent with R-404A
  - GWP reduction of over 90% relative to R-404A with superior efficiency.
Conclusions
Solstice platform key for your future

- **Stationary AC Systems**
  - **Solstice L41** good option as R410A replacement.
  - Outperforms other alternatives in high ambient conditions
    - High COP at high condensing temperatures
  - **Solstice L20 and N20**: potential alternatives to R22/R407C in residential AC
    - Solstice L20 performs well in high ambient

- **High Pressure Chillers**
  - **Solstice L41** good option as R410A replacement
    - Minor system modifications may be required
    - Critical temperature higher than 410A&R32 → Better suited for high ambient
    - Lower GWP than 410A&R32 and lower discharge temperature than R32
  - **Solstice L20** is a potential alternative to R407C

- **Medium pressure centrifugal chillers** – Replacing R134a
  - **Solstice™ ze** for new equipment: high efficiency, available on the market
  - **Solstice N13** promising option for replacing R134a in existing equipment

- **Low pressure centrifugal chillers**
  - **Solstice™ zd** as replacement of R123: higher capacity, similar efficiency

*Solstice platform is key for the future of your business*
Commercial Status of Solstice™ Products

**Solstice™ yf**
- In commercial use by auto industry now
- Sample quantities available today for stationary applications

**Solstice™ ze**
- Commercially available today
- Announced world scale plant for 2013

**Solstice™ zd**
- Commercial plant on stream 2nd quarter 2014
- Sampling for chiller, foam and solvent applications

**Solstice™ Blends**
- Contains Solstice ze and/or yf blended with other products
- Recently announced availability of Solstice™ L-41
- Currently sampling to OEM’s, compressor manufacturers and AREP

*Working with Industry to Commercialize Solstice™*
Partners all around the world

- Technology leadership enables our partners to
  - Achieve real progress
  - Create positive impact in their business and in their world

- Trialling Honeywell’s Genetron® and Solstice™
  - Thermodynamic analysis
    - Genetron Properties Suites → most advanced simulator in the market (free)
    - Three R&D laboratories (US, India, Shanghai)
    - Experts’ support
  - Samples
  - Analysis of results
  - Publications, media exposure, congresses…

We look forward to collaborating with you in trials / research programs
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