HCFC Phase-out in China for Rigid Polyurethane Foam Applications

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Montreal, Canada
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HCFC Phase-out Schedule – Article 5 Parties

Consumption capped at 2015 levels

- 90% in 2013
- 65% in 2015
- 32.5% in 2020
- 2.5% service tail

Mandatory review of need for service tail in 2025

Current phase-out
Pre-Montreal 2007 amendment
Polyurethane – a Versatile Material

Density

Solid PU

Microcellular foam

Foam

Low-density foam

Hardness
Blowing Agents for Polyurethane Rigid Foam

ODP* 1.0

ODP 0.11

ODP 0

CFC 11

HCFC 141b

HFC

HFC 245fa or
HFC 365mfc

HFC 134a

Pentane
(cyclo-, iso-, & n-)

Isobutane,
n-butane**

Methylene Chloride**

Methyl formate**

CO₂

Water,
Liquid CO₂

* ODP = Ozone Depleting Potential
** Co-blowing agents
# Properties of Major Blowing Agents

<table>
<thead>
<tr>
<th>Blowing agent</th>
<th>M.W.</th>
<th>Boiling point (°C)</th>
<th>Density (g/cm³) @ 20°C</th>
<th>Gas λ (mW/mK) @ 10°C</th>
<th>Price in March 08 (RMB/Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFC11</td>
<td>137</td>
<td>23.8</td>
<td>1.4940</td>
<td>7.4</td>
<td>Phased-out</td>
</tr>
<tr>
<td>HCFC141b</td>
<td>117</td>
<td>32</td>
<td>1.2500&lt;sup&gt;10&lt;/sup&gt;</td>
<td>8.8</td>
<td>11.6</td>
</tr>
<tr>
<td>n-pentane</td>
<td>72</td>
<td>36</td>
<td>0.6262</td>
<td>14</td>
<td>10.5</td>
</tr>
<tr>
<td>iso-pentane</td>
<td>72</td>
<td>28</td>
<td>0.6201</td>
<td>13</td>
<td>10.5</td>
</tr>
<tr>
<td>c-pentane</td>
<td>70</td>
<td>50</td>
<td>0.7457</td>
<td>11</td>
<td>13.5</td>
</tr>
<tr>
<td>iso-butane</td>
<td>58</td>
<td>-11.7</td>
<td>0.5512&lt;sup&gt;25&lt;/sup&gt;</td>
<td>22.5</td>
<td></td>
</tr>
<tr>
<td>HFC245fa</td>
<td>134</td>
<td>15.3</td>
<td>1.3200&lt;sup&gt;25&lt;/sup&gt;</td>
<td>12.2@25°C</td>
<td>70.0</td>
</tr>
<tr>
<td>HFC365mfc</td>
<td>148</td>
<td>40.2</td>
<td>1.25</td>
<td>10.6@25°C</td>
<td>108.0</td>
</tr>
<tr>
<td>HFC134a</td>
<td>102</td>
<td>-27</td>
<td>12.4</td>
<td></td>
<td>38.0</td>
</tr>
<tr>
<td>H₂O/CO₂</td>
<td></td>
<td></td>
<td>16.6 @ 25°C</td>
<td></td>
<td>~0</td>
</tr>
</tbody>
</table>
Snapshot of Manufacturing of 141b in China

- Currently 4 manufacturers in China
- Concentrated in Eastern China
- Total production in 2007: 80kt
- Sanmei is the largest producer with nearly half of the market share
- 141b price has been falling over the last 10 years
Overview of Alternatives to 141b for Rigid Foam in China

<table>
<thead>
<tr>
<th></th>
<th>HFC</th>
<th>Hydrocarbon</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appliances</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water heaters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reefer containers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandwich panels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spray</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural foam</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Green: Commercialized
- Yellow: Being tested
- White: Not an option in a short term

Polyurethane
Appliances: Pentanes Dominate in China

- Total output was 52 million sets in 2007 - 60% of global output
- Accounted for 50% of total PU rigid foam in China
- Hydrocarbon (HC) widely used
  - c-pentane
  - c/i-pentane
- Small factories still using 141b due to high conversion costs
- Major challenges in 141b phase-out
  - HCs: high capital investment; higher thermal conductivity; safety
  - HFCs: significantly higher cost

Blowing agents used in Appliances

- HC 84.8%
- 141b 15.1%
- HFC 0.1%
Conversion Cost

- For a typical refrigerator manufacturing plant with 1m/a capacity
- Converting from 141b to c-pentane

<table>
<thead>
<tr>
<th>Conversion items</th>
<th>Estimated costs (k Euros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pentane storage tank (35m³)</td>
<td>100</td>
</tr>
<tr>
<td>Preblending, an intermediate storage tank, and piping (assuming 200m)</td>
<td>150</td>
</tr>
<tr>
<td>Cabinets foaming machines (4)</td>
<td>320</td>
</tr>
<tr>
<td>Doors foaming machines (2)</td>
<td>150</td>
</tr>
<tr>
<td>Venting system</td>
<td>50</td>
</tr>
<tr>
<td>Pentane detection system with detectors, and modification of 40 jigs</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total conversion cost</strong></td>
<td><strong>870</strong></td>
</tr>
</tbody>
</table>
Reefer Containers: 141b Dominates

- Almost 100% global reefer containers were produced in China in 2007
- Total PU consumption in 2007: 50kt
- 98% blown with 141b – HFCs and HCs used mainly due to export requirements
- Major challenges in 141b phase-out
  - HFCs: high blowing agent cost, e.g. ca USD720 cost increase per FEU if HFC365mfc / HFC227ea is used
  - HCs: high capital investment; safety

Blowing agents in reefers

Output of reefer containers

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Almost 100% of the global reefer containers were produced in China in 2007. The total PU consumption in 2007 was 50kt. Nearly 98% of the containers were blown with 141b, with HFCs and HCs used primarily due to export requirements. The major challenges in the 141b phase-out include:

- **HFCs**: high blowing agent cost, e.g. a cost increase of approximately USD720 per FEU if HFC365mfc or HFC227ea is used.
- **HCs**: high capital investment and safety concerns.

![Blowing agents in reefers](image)

![Output of reefer containers](image)
Sandwich Panels: 141b and Water Dominate

- Total market size: 40kt PU system
- Some continuous panel manufacturers switching to HC and water from 141b
- Almost all discontinuous panel manufacturers are using 141b
- Major challenges in 141b phase-out
  - Water: poor thermal insulation and adhesion
  - HC: high capital investment; safety

Blowing agents in continuous panels

Blowing agents in discontinuous panels

* Mainly for low density open-cell panels
Pipe: 141b and Water Dominate

- Pipe consumed 50kt rigid PU foam in 2007
- Water blowing technology accounted for 9.5% - mainly for the district central heating segment
- HC has 0.5% share
- Major challenges in 141b phase-out
  - Water: poor thermal insulation and adhesion
  - HCs: high capital investment; safety

Blowing agents in pipes

<table>
<thead>
<tr>
<th>Blowing Agent</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>9.5%</td>
</tr>
<tr>
<td>HC</td>
<td>0.5%</td>
</tr>
<tr>
<td>HCFC</td>
<td>90.0%</td>
</tr>
</tbody>
</table>
Spray Foam: Close to 100% 141b

- Market demand in 2007: 60kt PU system
- Main applications: cold storage rooms and residential buildings
- Residential building insulation market: explosive growth - as the Chinese government implements stricter energy saving regulations
- 141b is used – water technology only used in open cell foam for some niche applications
- Major challenges in 141b phase-out
  - HC will not be an option due to safety concerns (safety measures difficult to implement in China!)
  - Water: poor thermal insulation and adhesion
  - HFC is 5-8 as times more expensive cf 141b

Blowing agents in spray foam

Spray foam for residential building insulation

- CAGR = 117%

![Beijing Olympic Stadium insulated with Huntsman’s PU system](image)

![Standard Chartered Bank, Pudong insulated with Huntsman’s PU system](image)
Huntsman’s Strong Commitment to China

- Huntsman have many 1st mover advantages
- Huntsman pioneered the HCFC141 phase-out
  - 1st to introduce c-pentane blowing technology and the patented c/i-pentane blowing technology to China in 1995

MDI Plant’s Commercial operation 2006

ATC Shanghai 2008

1st foreign TS center
1992

1st MDI plant proposed
1995

1st foreign system house
1996

1st bulk delivery supplier
1997
Conclusions

- HC is the preferred blowing technology in the Appliances industry and is entering other applications
- 141b is still the dominant blowing agent for other rigid foam applications
- Adoption of HFCs is limited due to its high cost
- CO₂ blowing technology is limited by its poor adhesion and thermal insulation property
- Huntsman is leading in the development of blowing agent technologies in China
Thank You!

Huntsman
Enriching lives through innovation