NATURAL REFRIGERANTS
FOR HEAT PUMPS
AND AIR-CONDITIONING SYSTEMS

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Artificial or Natural Refrigerants?

- Performances
  • COP
  • Capacity
  • Cost

- Safety
  • Pressure, Temperature
  • Flamability
  • Toxicity

- Environment
  • Ozone layer
  • Global warming
  • Hazardous fluids
EU context

• The EU directives
  - Energy Performances of buildings (EPBD)
  - Renewable Energy Sources for Heating (RES-HC) in preparation

• Certification and label for heat pumps
  - EU-CERT
  - Ecolabeling
Environmental Context

• The REACH directive (01 July 2007)
  - Registration, Evaluation, Authorisation and Restriction of Chemicals
  - « The Directive requires that industry supply the information required to identify and manage the chemical risks. For substances deemed most hazardous, safety information must be provided to consumers. Manufacturers and importers are obliged to register substances they produce or import in quantities over 1 ton per year. Failure to register may prevent the substance from being manufactured, imported, or used in the EU market. »

• The WEEE directive (2003)
  - Waste electrical and electronic equipments
  - Setup collection, recycling and recovery targets for all types of electrical goods. )
Environmental Context

• The main legislation for Ozone Depletion Substance are:
  - The Montreal protocol in 1987 and his successive amendment
  - The European directive °2037/2000 in date of 29/06/2000

• The main texts on climate change are:
  - The Kyoto protocol, adopted 10/12/1997, which entered into force 16/02/2005.
  - The EC F-gas regulation (14/06/2006)
Global Warming

• The EU F-Gas regulation:
  The fluids concerned by this future legislation are:
  • HFC : hydrofluorocarbons
  • PFC : perfluorocarbons
  • SF6 : sulphur hexafluoride

For stationary applications, this regulation concerns:
  • Containment
  • Recovery
  • Training and certification
  • Reporting
  • Labelling
  • Control of use
  • Placing on the market
Global Warming

• The EU F-Gas regulation:

- 2006: Publication
- 2006: Entry into force
- 2007: Effective
- 2008: Deadline Member State certification scheme + penalties
- 2009: Deadline mandatory certification for companies & personnel
- 2010: Deadline EU commission review
- 2011:
The future for HFC's

• International Panel on Climate Change (IPCC) position
  - Refrigerant bank of 10 Gt CO2 eq. (for a 37 Gt CO2 eq. total annual emission)
  - Emphasize on containment and recycling

• The European position
  - Consensus by the major Industrial Refrigeration companies to promote 'natural refrigerants'
  - Strict legislation in some countries (Austria, Switzerland and Denmark)
  - German car manufacturers adopt CO2 for automotive applications, August 2008
  - Revision of the F-gas regulation in 2011
Artificial or Natural Refrigerants?

Tendency of product legislation

The preparation of new legislation for products shifted from safety towards environment.

Source: Daikin Europe 2006 environmental report
Natural Refrigerants

What is natural refrigerant?

The name "natural" is used to label a number of solutions in the refrigeration and climate technology.

There are five solutions, all with a different area of application: Water, Air, Carbon Dioxide, Ammonia and Hydrocarbons.

Why natural refrigerants?

Natural refrigerants have zero Ozone Depletion Potential (ODP) and low or zero Global Warming Potential (GWP)

Natural refrigerants have good transport properties and allow efficient thermodynamic cycles
Natural Refrigerants

• Hydrocarbons
  - Butane, Propane, Propylene, mixtures
  - Already used in domestic refrigerators and small AC systems

• Ammonia
  - Used in large industrial refrigeration units

• Carbon dioxide
  - Used in industrial refrigeration and as transport media
  - Under development for car AC

• Others fluids
  - Water
  - Air
### Natural Refrigerants

<table>
<thead>
<tr>
<th>Substance name</th>
<th>GWP</th>
<th>Code</th>
<th>Major hazard</th>
<th>Flamability</th>
<th>Toxicity</th>
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<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>1</td>
<td>R744</td>
<td>High pressure</td>
<td>None</td>
<td>5000 ppm</td>
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<td>Ammonia</td>
<td>0</td>
<td>R717</td>
<td>Toxic</td>
<td>15-30 vol%</td>
<td>25 ppm</td>
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<tr>
<td>Propane</td>
<td>20</td>
<td>R290</td>
<td>Fire</td>
<td>2.2-9.5 vol%</td>
<td>2500 ppm</td>
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<tr>
<td>Butane</td>
<td>20</td>
<td>R600</td>
<td>Fire</td>
<td>1.5-8.5 vol%</td>
<td>800 ppm</td>
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<tr>
<td>IsoButane</td>
<td>20</td>
<td>R600a</td>
<td>Fire</td>
<td>1.8-8.5 vol%</td>
<td>600-1000 ppm</td>
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</tbody>
</table>

**Major information and risks concerning natural refrigerants**
Hydrocarbons

Domestic refrigeration

Three fluids are mainly used: HFC-134a, HC-600a and blend of HC-600a/HC-290

Hydrocarbon usage is increasing worldwide (global parity with HFC-134a), except North America

Commercial refrigeration

70% of the market for commercial freezers is using HC-600a

Unitary AC

Mainly HFC, HC are used only for small system (below 3-4 kW cooling capacity)

Heat Pumps

Mainly HFC, HC are used in low charge system (GSHP or EAHP)
Hydrocarbon heat pumps

<table>
<thead>
<tr>
<th>Type</th>
<th>Fluid</th>
<th>Charge (kg)</th>
<th>COP</th>
<th>Specific charge (g/kW)</th>
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<tbody>
<tr>
<td>Ground-Water</td>
<td>R134a</td>
<td>5.2</td>
<td>4.14</td>
<td>291</td>
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<td>R290</td>
<td>1.30</td>
<td>4.56</td>
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<tr>
<td>Ground-Water</td>
<td>R407c</td>
<td>2.81</td>
<td>4.43</td>
<td>244</td>
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<tr>
<td>Ground-Water</td>
<td>R410a</td>
<td>2.04</td>
<td>4.44</td>
<td>249</td>
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<tr>
<td>Ground-Water</td>
<td>R417a</td>
<td>3.02</td>
<td>4.44</td>
<td>296</td>
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<td>Air-Water</td>
<td>R290</td>
<td>1.72</td>
<td>3.25</td>
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<td>R404a</td>
<td>2.98</td>
<td>3.25</td>
<td>300</td>
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<td>R407c</td>
<td>5.48</td>
<td>3.31</td>
<td>630</td>
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<td>Evap-Water</td>
<td>R290</td>
<td>3.75</td>
<td>4.50</td>
<td>276</td>
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<td>R407c</td>
<td>7.93</td>
<td>4.00</td>
<td>750</td>
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<td>R410a</td>
<td>8.40</td>
<td>4.80</td>
<td>999</td>
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</table>

Comparison of average characteristics and performances of hydrocarbon and F-gas commercial heat pumps
**CO2**

**Domestic refrigeration**

CO2 is adopted by some global companies for bottle cooler or ice-cream vending machine.

**Large size refrigeration**

CO2 two-stage or cascade systems adopted in Europe (up to 5 MW cooling capacity)

**Mobile AC**

CO2 is presently tested by all major car companies

**Heat Pump Water Heater**

The Eco-Cute Water Heater (4-6 kW), 230 000 unit supplied in 2005.

The Carrier project (60 kW), 8 prototypes in USA and some in Europe
NH3

Large size refrigeration

NH3 in cascade indirect systems adopted in Europe and North America (up to 5 MW cooling capacity)

NH3 for ice rink with heat recovery for swimming pools or buildings

Heat Pump

Large heat pump for district heating (several MW)

Some prototypes for small heat pump
Conclusions 1/1

• The use of artificial refrigerants will be more complicated and will induce extra costs

• F-gas might be banned in Europe?

• Artificial refrigerants are not sustainable alternatives!
Conclusions 1/2

• Natural refrigerants have large potential for small to large heat pumps and A/C systems.

• Developments are required to optimise such heat pumps and A/C systems.

• Natural refrigerants are sustainable and are the right choice.
Thank you for your attention!