Global Solutions for Ammonia Industrial Refrigeration

MAYEKAWA’s lineups and results of “Natural Refrigerants”

Atmosphere 2009
October 19th 2009
Mayekawa Mfg. Co., Ltd.
Kuniaki Kawamura
Founded: 1924
Location: Tokyo, Japan
Turnover: 1.1 million EURO
Employees: 3,000 (33 countries)
Company founded in 1924.
Over 70,000 Screw and Piston compressors running in more than 100 countries.
MYCOM International Branches

Worldwide:
• 33 countries
• 8 production plants
• 119 offices

Europe:
• 1 production plant
• 6 offices
### The comparison of CFC refrigerants and natural refrigerants

<table>
<thead>
<tr>
<th></th>
<th>HCFC</th>
<th>HFC</th>
<th>NWFs</th>
</tr>
</thead>
<tbody>
<tr>
<td>The name of refrigerant</td>
<td>R22</td>
<td>R134a, R410A</td>
<td>NH₃, CO₂, HC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R407C, R404A</td>
<td>H₂O, AIR</td>
</tr>
<tr>
<td>Ozone depletion potential (ODP)</td>
<td>0.055</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Global warming potential (GWP)</td>
<td>1810</td>
<td>1770 ～ 3920</td>
<td>0 ～ 3</td>
</tr>
<tr>
<td>Leakage</td>
<td>Much</td>
<td>Much</td>
<td>No</td>
</tr>
<tr>
<td>Odor/Smell</td>
<td>No</td>
<td>No</td>
<td>NH₃ : Sharp odor</td>
</tr>
<tr>
<td>Flammability</td>
<td>No</td>
<td>No/Lower</td>
<td>NH₃: Lower flammability</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>H₂: Higher flammability</td>
</tr>
<tr>
<td>Coefficient of performance (COP)</td>
<td>1.00</td>
<td>0.90</td>
<td>1.05 ～ 1.2</td>
</tr>
</tbody>
</table>

* GWP used here is a 100-year GWP based on the data from Japan Fluorocarbon Manufacturers Association (JFMA). [http://www.jfma.org/database/table.html](http://www.jfma.org/database/table.html)
* COP is the comparison value when R22=1.
Development Concepts

• High efficiency
• Low refrigerant charge
• Less leakage
NH3 Installations in the industrial refrigeration field in Japan.

• ~1990: less 2%
• 2008: 80%

* Tough Regulations for NH3 in Japan
The Fluorocarbon-Free Option for the sake of the planet
Natural Refrigerant-Based Refrigerators and Air-conditioners

Global Developments in Action on Fluorocarbons
The world is moving forward to prevent climate change and protect the ozone layer.

When ozone layer depletion was recognized as a global environmental problem caused by fluorocarbons, the “Montreal Protocol on Substances that Deplete the Ozone Layer” was adopted, under which production of CFCs has been completely phased out in developed countries including Japan. Global actions are also being taken for the phase out of production of HCFCs, which were introduced as the alternatives to CFCs.

In addition, HFCs, the alternatives to CFCs and HCFCs, are controlled under the “Kykoto Protocol” because they have a significant impact on climate change though they don’t have any impact on ozone depletion.

In order to protect the ozone layer and prevent climate change, various measures are taken in Japan, including recovery and destruction of fluorocarbons in equipment such as refrigerators and air-conditioners, and promotion of the use of alternative products.

Fluorocarbons are approximately 100 - 10,000 times stronger greenhouse gases than CO₂.

Study Reveals
Growing Importance of HFCs in Climate Warming

The large contribution of projected HFC emissions to future climate forcing


Abstract

The consumption and emissions of hydrofluorocarbons (HFCs) are projected to increase substantially in the coming decades in response to regulation of ozone-depleting gases under the Montreal Protocol. The projected increases result primarily from sustained growth in demand for refrigeration, air-conditioning (AC) and insulating foam products in developing countries assuming no new regulation of HFC consumption or emissions. New HFC scenarios are presented based on current hydrofluorocarbon (HFC) consumption in leading applications, patterns of replacements of HCFCs by HFCs in developed countries, and gross domestic product (GDP) growth. Global HFC emissions significantly exceed previous estimates after 2025 with developing country emissions as much as 80% greater than in developed countries in 2050. Global HFC emissions in 2050 are equivalent to 2–15% CO₂e-equivalent of projected global CO₂ emissions in business-as-usual scenarios and contribute a radiative forcing equivalent to that from 4–13 years of CO₂ emissions near 2050. This percentage increases to 28–43% compared with projected CO₂ emissions in a 450-ppm CO₂ stabilization scenario. In a hypothetical scenario based on a global cap followed by an annual reduction in consumption, HFC radiative forcing is shown to peak and begin to decline before 2050.

http://www.pnas.org/content/106/27/10949
Commitment on Natural Refrigerants

NATURAL FIVE

- NH₃: Semi-Hermetic Screw Compressor Unit
- CO₂: Commercial / Industrial Eco-Cute System
- H₂O: Adsorption Chiller
- HC: Commercial / Industrial Air-Conditioning / Water-Supply Heat Pump
- Air: Dehumidifying Air Refrigerant System [Air Ref]
## "Natural Five" Refrigerants and Product Solutions

<table>
<thead>
<tr>
<th>Refrigerant (Natural Five)</th>
<th>NH₃ R-717</th>
<th>CO₂ R-744</th>
<th>HC Hydrocarbon</th>
<th>H₂O R-718</th>
<th>Air R-728</th>
</tr>
</thead>
<tbody>
<tr>
<td>90°C</td>
<td>Utility hot water</td>
<td></td>
<td></td>
<td>Heat recovery</td>
<td></td>
</tr>
<tr>
<td>60°C</td>
<td>Utility hot water</td>
<td>Heating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10°C</td>
<td>Chilled water</td>
<td>Ice making</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-15°C</td>
<td>Cold storage, Freezer, Fish boat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-25°C</td>
<td>Specific Refrigeration needs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-40°C</td>
<td>Freezer, Freeze-dry, Super Low temp storage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-50°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-60°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-100°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Notes
- Conventional system
- Eco-Cute
- Nat’l Proj.
- Nat’l Proj.
- Nat’l Proj.
- Nat’l Proj.
- Air-cycle
- Butane + Propane
- Adsorption
- Heat recovery
- National Projects

### Specific Refrigeration needs
- Utility hot water
- Chilled water
- Heating
- HVAC
- Cryogenics
- Chiller
- Heat recovery

### Temperature Ranges
- 90°C
- 60°C
- 10°C
- -10°C
- -15°C
- -25°C
- -40°C
- -50°C
- -60°C
- -100°C
• High Efficiency: Compressors and IPM Motors

• Low Charge:
  * Secondary Refrigerant System (CO2)
  * Direct Expansion System

• Less Leakage: Hermetic Motors

NH₃

Ammonia
Semi-hermetic Refrigeration Package

2007 Ministry of the Environment
[Enterprise of Technical Development Against Global Warming]
High Efficiency Motor (IPM motor)

Benefits of IPM motor

- 5~10% better in efficiency
- 40% smaller in size
- Higher speed possible

Moment of inertia is reduced, rotational response, power factor, motor efficiency improved
NH₃ Semi-hermetic motor

- Safety improved
- Compact
- High efficiency

Motor docked to compressor

Building the stator

Patent Pending
NH3 Compressor with IPM motor
**Application**

**NH₃/CO₂ system**

- NH₃ Compressor specifically developed for this system
- Water-cooled Condenser
- CO₂ Condenser
- CO₂ Receiver
- Package
- CO₂ Pump
- Air cooler
- Warehouse

> NH₃ charge reduction

> No risk of NH₃ leaking in the storage room
Installation in Japan

Distribution center
30% Reduction of CO2 Emission

Hybrid Cooling System Using NewTon3000

Target: Industrial Refrigerated Warehouses (for Class F)
- **Improved Safety**: By developing [Semi-hermetic compressor], Mayekawa improved the problem of refrigerant leak.
- **Non-Freon**: A system in which ammonia circulates as the primary refrigerant and CO2 as the secondary refrigerant.
- **Energy Saving**: As a unit exclusively for the refrigerated warehouse, CO2 2.0 at Class F. Compared to conventional Freon refrigerants, about 20% energy saving.

Efforts to Reduce CO2

Case Study

10,000t Refrigerated Warehouse
Inside Temperature: -25°C

Power Consumption

<table>
<thead>
<tr>
<th>Conventional System</th>
<th>Hybrid Cooling System</th>
</tr>
</thead>
<tbody>
<tr>
<td>317kW</td>
<td>222kW</td>
</tr>
</tbody>
</table>
Heat Pump packages using Ammonia Scroll compressors

Capacity per Unit (-5/50C):
Cooling  35kW
Heating 47kW
Refrigerant charge: 6kg
(Direct expansion system)
Structure of scroll compressor

Wrap specifically designed for ammonia. Low and high temperature models.

Weight 100kg: flangeless, steel cased hermetic structure.

Motor efficiency improved by IPMM with aluminum windings.

Equipped with oil pump. Easy startup.
# Specifications

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Pressure</td>
<td>2.7</td>
<td>[MPaA]</td>
</tr>
<tr>
<td>Design Temp.</td>
<td>120</td>
<td>[℃]</td>
</tr>
<tr>
<td>Operation Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cond. Temp.</td>
<td>30～55</td>
<td>[℃]</td>
</tr>
<tr>
<td>Evap. Temp.</td>
<td>-35～+10</td>
<td>[℃]</td>
</tr>
<tr>
<td>Cond. Pressure</td>
<td>1.167～2.311</td>
<td>[MPaA]</td>
</tr>
<tr>
<td>Evap. Pressure</td>
<td>0.0931～0.615</td>
<td>[MPaA]</td>
</tr>
<tr>
<td>Rotational Speed</td>
<td>1800～3600</td>
<td>[rpm]</td>
</tr>
<tr>
<td>Models</td>
<td>Low and High temp</td>
<td></td>
</tr>
<tr>
<td>Motor</td>
<td>Type of Motor</td>
<td>IPM</td>
</tr>
<tr>
<td>Max Power</td>
<td>15</td>
<td>[kW]</td>
</tr>
</tbody>
</table>
• Hot water and Hot dry air supply Heat-Pump
• Source : Air and Water
Industrial Hot Water Production Package

Awarded for: The 7th Electric-Load Leveling Equipments / systems [Heat Pump Thermal Storage Development Awards]

Water-Source Type is also available.
**Niederhasli**: Warmes Wasser im GC-Campus durch moderne Technologie

**CO2-Wärmepumpe installiert**

Im GC-Campus in Niederhasli liefert eine der ersten CO2-Wärmepumpen in der Schweiz pro Tag 4000 Liter Warmwasser. Die Maschine stammt aus Japan.

**Inga Struve**

EWZ-Projektleiter Georg Dubacher (von links), Masao Maekawa, Vorsitzender der japanischen Firma Mycom, und EWZ-Direktor Conrad Ammann erläutern die CO2-Wärmepumpe. (David Baer)
62% Reduction of CO2 Emission

**Targets:** Hospitals, hotels, welfare institutions, sports facilities, bathing facilities, facilities for boarding, food factories, etc.

- The best water supply ability in Japan (Air heat source 80kW, water heat source 90kW).
- Very little CO2 emission, compared with equipments run by burning the energy source. Emission could be cut by more than 60% than heavy-oil boilers.
- Enhanced heating operation (Water entering Eco-Cute at 65°C, exiting at 90°C).
- Flexible design of water supply system and storage tanks to meet your needs.
- Entering medium to large-scale water supply market as the electric equipment replacing hot-water boilers. The complete electrification is possible.

**Efforts to Reduce CO2 Emission**

<table>
<thead>
<tr>
<th>t-CO2/year</th>
<th>(annual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional System</td>
<td>160</td>
</tr>
<tr>
<td>Commercial Eco-Cute</td>
<td>60</td>
</tr>
</tbody>
</table>

**Case Study**

A Company Housing where Hot Water Supply is 20m³/day
The Number of People: 200

<table>
<thead>
<tr>
<th>System Type</th>
<th>Fuel Oil Boiler</th>
<th>Crude Oil Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td></td>
<td>59,040 ℓ / yr</td>
</tr>
<tr>
<td>Commercial Eco-Cute</td>
<td></td>
<td>22,153 ℓ / yr</td>
</tr>
</tbody>
</table>
- Ad-sorption Chiller Utilizing Solar Energy
Adsorption Chiller Packaged Unit

2005 ~2007 NEDO [Research and Development of New System Utilizing Solar Energy]
Installation in Japan

Air conditioner for shopping mall
64% Reduction of CO2 Emission

**Cooling System by Adsorption Chiller Using Solar Energy**

**Targets**
- Industrial furnace, incinerator, distillation tower, air-conditioning or cooling using warm discharged water from cooling water of engines etc.
  - Produces cool water from low-temperature heat source (below 75°C).
  - Water as refrigerant, silica gel as adsorbent, therefore environmentally friendly.
  - The body itself needs little electricity. Also, almost ZERO maintenance cost.

**Efforts to Reduce CO2 Emission**

<table>
<thead>
<tr>
<th>(t-CO2/year)</th>
<th>(Annual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>64% Reduced</td>
</tr>
</tbody>
</table>

**Case Study**

**100USRT Industrial Process Cooling**
- Cold Water Temperature: 9°C

**Power Consumption**

<table>
<thead>
<tr>
<th>&lt;Conventional System&gt;</th>
<th>&lt;Adsorption Chiller&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>R134a Cooling Water</td>
<td>100kW</td>
</tr>
<tr>
<td></td>
<td>36kW</td>
</tr>
</tbody>
</table>

**MYEKOAWA**
• Mixed Refrigerants Heat-Pump (Butane and Propane)
Hydrocarbon Refrigerant Packaged Unit

2005 ~ 2007 NEDO [Energy-Saving Non-Freon Air-Conditioning and Refrigeration System]

([Industrial Technology Development Subsidizing Company])
At International Media Center of G8 Toyako summit in Hokkaido

Employed a cooling unit taking advantage of 7,000 tons of snow stocked underground, and as its subsystem, our environment-friendly building air-conditioner was introduced.
14% Reduction of CO₂ Emission

<table>
<thead>
<tr>
<th>COP</th>
<th>COP=3.7 (Air-Cooled)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COP</td>
<td>COP=3.7 (Air-Source)</td>
</tr>
<tr>
<td>COP</td>
<td>COP=3.3 (Supplying temperature 65°C air-source)</td>
</tr>
</tbody>
</table>

**Targets: Commercial / Industrial Air-Conditioning, Water-Supply**

<table>
<thead>
<tr>
<th>Supply Temperature</th>
<th>Applications</th>
<th>Suitable Markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>70°C</td>
<td>65°C Hot Water-Supply / Heating System</td>
<td>Food factories, hotels</td>
</tr>
<tr>
<td>50°C</td>
<td>45°C Heating System</td>
<td>Office buildings, factories</td>
</tr>
<tr>
<td>0°C</td>
<td>7°C Chilled Water Chiller System</td>
<td>Office buildings, factories</td>
</tr>
<tr>
<td>-5°C</td>
<td>-2°C Chilled Water Chiller / Supercooling / Ice Making System</td>
<td>Food factories</td>
</tr>
<tr>
<td>-15°C</td>
<td>Ice on Coil Ice Thermal Storage System</td>
<td>Food factories</td>
</tr>
</tbody>
</table>

**Efforts to Reduce CO₂ Emission**

- Conventional System: 28 t-CO₂/year
- Hydro Carbon: 24 t-CO₂/year

14% Reduced (annual)

**Case Study**

40 USRT Chilled Water Supply Machine
Chilled Water Temperature: 7°C

**Power Consumption**

- Conventional System: 43 kW
- Hydro Carbon: 36 kW

**MAYEKAWA**
• Air Cycle Refrigeration System
• For Low Temperature Applications
  -50 ~ -120 °C
Air Cycle Refrigeration Packaged Unit

2003 Developed at NEDO

[Technical Strategy for Rationalization of Energy Consumption Project]
Installation in Japan

-60°C ultralow cold storage
54% Reduction of CO2 Emission

Target: Ultra cold refrigerator for tunas and bonitos, rapid freezer, frost-breaking, etc.

- Using [Air] as the ultimate natural refrigerant, [Air Ref] is safe and eco/people-friendly.
- Due to the turbo compressor with integrated expander, high COP can be achieved, saving energy by 50% comparing the conventional types.
- Due to its low operating pressure, exempt from legal regulations.
- Directly cooling the air, Air Ref does not require a fan coil unit or piping for refrigerant in the storage.
- Dehumidifying agent reduces frosting in the storage. Defrosting is not required.

Efforts to Reduce CO2 Emission

<table>
<thead>
<tr>
<th>(t-CO2/year)</th>
<th>(annual)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional System</td>
<td>1,250</td>
</tr>
<tr>
<td>Air Ref</td>
<td>568</td>
</tr>
</tbody>
</table>

54% Reduced

Case Study

2,000 ton Refrigerator
Interior Temperature: -60°C

Power Consumption

- Conventional System: 281 kW
- Air Ref: 128 kW

MAYEKAWA
We can eliminate HFCs using Natural Refrigerants in industrial refrigeration applications. In the view of prevention of global warming we would like to offer 3 proposals below;

1. Promoting natural working fluids aggressively in the proven industrial field

2. Introducing natural working fluids in the possible commercial and consumer field

3. Recommending tightening of regulations of HFCs and encouraging the funding for the prevalence of refrigeration systems using natural refrigerants and its development.
Thank you very much for your Attention.