Implementation of Alternative Refrigerants in Japan - Safety assessment and legislation for the use of A2L refrigerants -

Tetsuji Okada
The Japan Refrigeration and Air Conditioning Industry Association (JRAIA)

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Who is JRAIA?

The **Japan Refrigeration and Air conditioning Industry Association (JRAIA)**

- Established in 1949.
- 164 member companies including the associate members. (as of 1st of June 2016)
- The business fields of the member companies are:
  - Air conditioning (residential, commercial, automotive)
  - Refrigeration (commercial, industrial, transport)
  - Ventilation
  - Chiller
  - Heat pump system (HP water heaters)
  - Refrigerants
  - Parts
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1. Background

2. Requirements for the alternative refrigerants

3. Key Activities in Japan

4. Legislation in Japan

5. Consideration points for the risk assessment

6. Conclusion
1. Background

WHY A2L refrigerants NOW?

- In order to tackle the mitigation of global warming, there is a call for alternative refrigerant with lower GWP than currently used in non-A5 countries.

- However, most of the refrigerants proposed as the alternatives are classified as lower flammability class (A2L).

- In Japan, the government, academic sectors and industry swiftly cooperated together for the safe use of A2L refrigerants and greater contribution to the mitigation of global warming as soon as possible.

- Today, we would like to present the current status in Japan.
2. Requirements for Alternative Refrigerants

Actions to phase down HFCs have been started sector by sector in Japan by considering not only environment performance but also safety, energy efficiency and economic feasibility.

<table>
<thead>
<tr>
<th>S+3E</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety (precondition)</strong></td>
<td>• Low Toxicity</td>
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<tr>
<td></td>
<td>• Low Risk of Flammability</td>
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<tr>
<td><strong>Environment Performance</strong></td>
<td>• Ozone Depletion Potential = 0</td>
</tr>
<tr>
<td></td>
<td>• Low Global Warming Potential</td>
</tr>
<tr>
<td><strong>Energy Efficiency</strong></td>
<td>• Superior for LCCP* value</td>
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<td></td>
<td>• Similar performance at high load cooling</td>
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<tr>
<td><strong>Economic Feasibility</strong></td>
<td>• Reasonable Cost</td>
</tr>
<tr>
<td></td>
<td>• Acceptable level in Developing Countries</td>
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</table>

LCCP*: Life Cycle Climate Performance
3. Key Activities in Japan: Basic Procedure for RA

**START**

[A] Set the tolerance level of the risk: probability of the accidents (ignition)

- Extract the flammability risks including source of the fire and refrigerants leakage
- Clarify the difference of intended-use and predictable miss-usage
  - Set the product range for the risk assessment
  - Selection of the risk assessment procedure and the stage of the life-cycle

Minimize the risk

- Dispersing fan, Ventilation, Isolation valve, Alarm

Estimate the risk

- Estimate of the leakage probability
- Estimate of the probability of generating a flammable area
- Probability of the fire source

**Is the risk within the tolerance level?**

**No**

- Consider additional safety measures

**Yes**

Commercialization, market research

Decisive quality criteria:

[A] > [B1] × [B2] × [B3]

- guidelines • manuals
- standard, legislation

**COMPLETION**
3. Key Activities in Japan: Key Partners

**Industry**
- Japan Automobile Manufacturers Industry Association (JAMA)
- Japan Refrigeration and Air Conditioning Industry Association (JRAIA)

**Government**
- Ministry of Economy, Trade and Industry (METI)
- New Energy and Industrial Technology Development Organization (NEDO)

**Academic sector**
- National Institute of advanced industrial science and technology (AIST)
- Tokyo University
- Kyushu University
- Tokyo University of Science, Suwa
- Japan Society of Refrigerating and Air conditioning Engineers (JSRAE)
- Safety committee within JSRAE

**Lower-flammable refrigerants risk project (NEDO project)**

**[Aim]**
1. Acquire base data (flammability, ignition, gravity of the accident)
2. Review of risk assessment
3. Issue of the report
3. Key Activities in Japan: Timescale

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</tr>
</thead>
<tbody>
<tr>
<td><strong>Mini-Split</strong></td>
<td>Residential</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Split</strong></td>
<td>Commercial</td>
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<tr>
<td><strong>VRF</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Chiller</strong></td>
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<td></td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td>Refrigeration equipment</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

- **Risk Assessment** for more complicated large AC products and refrigeration equipment will be concluded by the end of 2016.
- **Implementation of safety measures** for these products will follow soon.
Select the life-cycle-stage for risk assessment

Production

Logistics

Installation

Use

Service

Disposal

Risk assessment

Safety

Probability calculation (collateral)

Stages for risk assessment
3. Key Activities in Japan: Base case [Mini-split]

**Basic procedure**

**[A] Set the tolerance level of the risk**: probability of the accidents (ignition)

**Estimate the risk**
- [B1] Estimate of the leakage probability
- [B2] Estimate of the probability of generating a flammable area
- [B3] Probability of the fire source

**Minimize the risk**

**Decisive quality criteria:**

\[ [A] > [B1] \times [B2] \times [B3] \]

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[A] Set the tolerance level of the risks: probability of the serious accidents

- Acceptable number of fatal accident; Once (P) in the estimated period among the number of product units within each life-stage period

- Fatal accident means “ignition”.

- **Number of product units (N) within each life-stage:**
  - During use: 10 million units x 10 years (product life)
  - During storage / transport / maintenance / disposal: 10 million units x 1 year

- **Estimated time period (T):**
  - 100 years: mini-split, VRF (estimate by the use without maintenance)

- **Tolerance level of the risk: (P / (N x T))**
  - During use: $10^{-10}$ units/year
  - During storage / transport / maintenance / disposal: $10^{-9}$ units/year
4. Key Activities in Japan: Base case [Mini-split]

[B1] Estimate of the leakage probability
- Rapid leakage probability in Japan market: 0.023%
  Calculation of leakage probability for HVAC servicing companies (JRAIA member) is averaged by market shares of each company.

[B2] Estimate of the probability of generating a flammable area
- Leak rate and amount from the equipment:
  Entire charged refrigerants in 4 min.
  (refer to IEC60335-2-40)
- Assumed room size and equipment:
  Set severe condition with small room
  - Leak space: floor area 7m² x height 2.4m
  - Wall mounted AC 1.8m above the floor
- Formula:

Probability of generating a flammable area = \frac{\text{Generated volume of flammable area} \times \text{Duration}}{\text{Space-volume} \times \text{Total time}}
[B3] Probability of the ignition source

- Evaluation of the ignition sources
  
  Test result: Refrigerants did not ignite by tobacco or gas lighters, but ignited with open mild flame by candles and matches.

- Probability of the ignition source
  
  Probability was estimated from statistic data of gas fire accidents, the number of residences and residential floor areas in Japan.
Test result of the Risk Assessment

Safety criteria (Use) Ignition probability $\approx 10^{-10}$, (Others) Ignition probability $\approx 10^{-9}$

<table>
<thead>
<tr>
<th>Life stage</th>
<th>Ignition probability (R32 (A2L))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistic</td>
<td>$4.1 \times 10^{-17}$</td>
</tr>
<tr>
<td>Installation</td>
<td>$2.7 \times 10^{-10}$</td>
</tr>
<tr>
<td>Use (Indoor)</td>
<td>$3.9 \times 10^{-15}$</td>
</tr>
<tr>
<td>Use (Outdoor)</td>
<td>$1.5 \times 10^{-10}$</td>
</tr>
<tr>
<td>Service</td>
<td>$3.2 \times 10^{-10}$</td>
</tr>
<tr>
<td>Disposal</td>
<td>$3.6 \times 10^{-11}$</td>
</tr>
</tbody>
</table>

- After safety criteria was determined, risk assessment over the total life cycle was conducted.
- If the risk level exceeds the safety criteria, additional safety measures must be taken to satisfy the criteria. They are to be applied to the safety manual and guideline. Required practices should follow depending on the necessity.

In this risk assessment, wall mounted ACs were proven to be within the tolerance level for ignition possibility, even without additional safety measures.

The details of activities and the progress reports are available in the following website: [http://www.jsrae.or.jp/jsrae-committee/binensei/risk_eng.html](http://www.jsrae.or.jp/jsrae-committee/binensei/risk_eng.html)

Source: JSRAE
4. Legislation in Japan: Measures and Act

The equipment over the tolerance level of risk (Decisive quality criteria) must adapt safety measures below;

**i Design to prevent pooling**: Dispersing fan, Ventilation, Isolation valve to minimize flammable area

**ii Set detector / alarm**

“High pressure gas safety act” covers flammability as well as toxicity. Currently the revision of classification in this act is under consideration by adapting the safety measures stated above. In addition to international standards such as ISO5149 and IEC60335-2-40, Japan is considering to add the safety obligation set for each equipment to prevent the fire during gas leak by adapting two JRA standards below;

- JRA GL-20: JRAIA guideline
- JRA 4068: JRAIA standard
4. Legislation in Japan: Revision of Classification

1. What is “High Pressure Gas Safety Act”? This act is the regulation for high pressure gas, but covers toxicity and flammability of the refrigerants, and applies to HVAC equipment of the size above certain refrigerant volume.

2. Step toward revision of classification for A2L refrigerants (legislations to assure safety)

3. Review System
   1) Risk Assessment
   2) Revision of classification ⇒ collaboration of government, academic sectors and industry
### 4. Legislation in Japan: Comparison

Global Legislation/Act for flammable refrigerants  
(mainly for the refrigerants with lower flammability)

<table>
<thead>
<tr>
<th></th>
<th>U.S.</th>
<th>Europe</th>
<th>Japan</th>
</tr>
</thead>
</table>
| Legislation/Act          | Clean Air Act, SNAP         | F–Gas Regulation, Act                     | Act on Rational Use and Proper Management of Fluorocarbons  
High pressure gas safety act |
| National legislation     | Building Code, IMC, UMC, etc. | Building Code                             | High pressure gas safety act                     |
| International standards  | ISO817 (refrigerant classification) | ISO5149 (safety)                         |                                                  |
| Standard/regulations (define ref types) | ASHRAE34                   | Relevant standards based on ISO           | High pressure gas safety act                     |
| Standard/regulations (safety) | ASHRAE15, UL60335-2-40, UL484, etc. | EN378, EN60335-2-40                       | High pressure gas safety act, JIS C9335-2-40, JRA standards, etc. |
4. Legislation in Japan: Target GWPs

Act on Rational Use and Proper Management of Fluorocarbons sets target GWP and its schedule (plan) for each designated product.

<table>
<thead>
<tr>
<th>Designated Product</th>
<th>Target GWP (Weighted Average GWP)</th>
<th>Target year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room air conditioning (Mini-Split)</td>
<td>750</td>
<td>2018</td>
</tr>
<tr>
<td>Commercial air conditioning (Split)</td>
<td>750</td>
<td>2020</td>
</tr>
<tr>
<td>Mobile air conditioning</td>
<td>150</td>
<td>2023</td>
</tr>
<tr>
<td>Condensing unit and refrigerating unit</td>
<td>1500</td>
<td>2025</td>
</tr>
<tr>
<td>Cold storage warehouses</td>
<td>100</td>
<td>2019</td>
</tr>
<tr>
<td>Urethane foam</td>
<td>100</td>
<td>2020</td>
</tr>
<tr>
<td>Dust blowers</td>
<td>10</td>
<td>2019</td>
</tr>
</tbody>
</table>
4. Legislation in Japan: Phasedown

(Unit: 10,000 CO₂ ton)

- Reduced volume of new-use by product transition (in 10 thousand ton)
- Reduced volume of maintenance-use by product transition
- Reduced volume of maintenance-use by inspection
- Estimate volume for maintenance-use
- Estimate volume for the new shipment

**BAU shipment equivalent**

**Estimate of the use of F-gas**

- Approx. 40% decrease
- Approx. 52% decrease

Estimate use in 2020:
- Approx. 43 million CO₂ ton

Estimate use in 2025:
- Approx. 36 million CO₂ ton

Estimate volume for maintenance-use

Reduced volume of new-use by product transition
5. Consideration Points : for Other Countries

In case of other countries to adapt similar risk assessment, the factors below should be taken into account;

[A] Set the tolerance level matching each country:
⇒ the minimum tolerance level is stated as $10^{-8}$ in ISO/IEC guide 51
   In Japan, strict tolerance level was adopted considering the probability of serious accident

[B1] Set leakage probability matching each country:
⇒ Skill level of installers and product qualities may have the affect on refrigerant leaks.

[B2] Set the estimate of the probability of occurrence of flammable area matching each country:
⇒ In HAT (High Ambient Temperature) area, due to the equipment size (= refrigerants volume) to match the load, the risk may be higher

[B3] Set probability of the fire source matching each country:
⇒ Probability should be estimated based on the research data of gas fire accidents, number of residences, and residential floor area data of each country.
5. Consideration Points: A2L and A3

Note that refrigerants’ ignition probability changes by its flammability. When compared with A2L, A3 has extremely high ignition probability at the preliminary discussion. JRAIA starts the risk assessment for A3 refrigerants.

<table>
<thead>
<tr>
<th>Life Stage</th>
<th>Ignition probability</th>
<th>(ref. Propane (A3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logistic</td>
<td>$4.1 \times 10^{-17}$</td>
<td>$1.9 \times 10^{-8} \sim 5.0 \times 10^{-6}$</td>
</tr>
<tr>
<td>Installation</td>
<td>$2.7 \times 10^{-10}$</td>
<td>$1.5 \times 10^{-5} \sim 1.7 \times 10^{-5}$</td>
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<tr>
<td>Use (Indoor)</td>
<td>$3.9 \times 10^{-15}$</td>
<td>$5.9 \times 10^{-9} \sim 1.1 \times 10^{-4}$</td>
</tr>
<tr>
<td>Use (Outdoor)</td>
<td>$1.5 \times 10^{-10}$</td>
<td>$9.7 \times 10^{-13} \sim 1.9 \times 10^{-8}$</td>
</tr>
<tr>
<td>Service</td>
<td>$3.2 \times 10^{-10}$</td>
<td>$9.3 \times 10^{-6} \sim 1.7 \times 10^{-5}$</td>
</tr>
<tr>
<td>Disposal</td>
<td>$3.6 \times 10^{-11}$</td>
<td>$1.8 \times 10^{-5} \sim 1.3 \times 10^{-4}$</td>
</tr>
</tbody>
</table>
6. Conclusion

- In Japan, the conversion to A2L refrigerants started in the small sized ACs, with careful examination for its safety (sold over seven million units in 2015).

- The selection of alternative refrigerants must be made carefully by considering 「S+3E (Safety+ Environment performance, Energy efficiency, Economic feasibility)」

- Countries that are in the process of selecting alternative refrigerants should assess the risks of the candidates. We believe that the result done by Japan can help develop the way for the safe use of alternatives.

- Guideline, manuals and legislations in each country must be placed to take safety measures matching the risk levels to prevent accident and to encourage the use of A2L refrigerants.
Thank you for your kind attention.
Research committee for the risk assessment of mildly flammable refrigerants

Objective:
RISK 2.6.17 changed the restriction on refrigerants regarding their flammability and toxicity. However, the potential for a design fault incident was not considered. Therefore, this classification changed the restriction on mildly flammable refrigerants. In Japan, the classification, “non-hazardous” and “non-hazardous” is recognized in the High Pressure Gas Safety Act and the Fire Code in the Ministry of Labor in Environment. With the objectives of gathering essential data for the risk assessment of mildly flammable refrigerants, safety studies are being conducted by the research committee. Since 2011, various research have been conducted by the project “Development on Highly Efficient and Non-Flammable Air Conditioning Systems of the New Energy and Industrial Technology Development Organization (NEDO)”, the Japan Energy and Industrial Technology Development Organization (NEDO), the Japan Society of Refrigeration and Air Conditioning Engineers (JSRAE).

Members and observers:

Members:
- JRAIA: Japan Refrigeration and Air Conditioning Industry Association
- JSRA: Japan Society of Refrigeration and Air Conditioning Engineers
- JSRAE: Japan Society of Refrigeration and Air Conditioning Engineers
- JIA: Japan Institute of Applied Energy
- NEER: New Energy and Industrial Technology Development Organization (NEDO)
- JSRAE: Japan Society of Refrigeration and Air Conditioning Engineers
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Observers:
- Ministry of Economy, Trade and Industry
- New Energy and Industrial Technology Development Organization (NEDO)
- High Pressure Gas Safety Act
- Japan Electric Appliance Corporation

Program report 2014
Program report 2014 has been released in June 2015.

- Report in Japanese (PDF)
- Report in English (PDF)
- Report in Chinese (PDF)
- Report in English (PDF)

ICER2012 Workshop: Risk Assessment of Mildly Flammable Refrigerants was

Program:
1. Opening Remarks, Welcome by President
3. Research Project on Risk Assessment of Mildly Flammable Refrigerants: INOYAMA
4. Fundamental Experiments on Flammable Properties of 1.2,3-Trifluoropropane: Yutaka YAMAGUCHI
5. Hazard Assessment of the Application of Mildly Flammable Refrigerants: M. YAMASAKI
6. Overview of the Risk Assessment of Mildly Flammable Refrigerants: Takashi ONODA
7. The Current Status of R-1234yf Standardization: Takashi ONODA
8. Final Remarks: Takashi ONODA

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Contact:
Please contact any contributor describing details contents of the program report.

Chairperson: Eiji Inooka, Professor of the University of Tokyo
E-mail: inooka@jrcfa.or.jp

More Information!!

http://www.jsrae.or.jp/jsrae/committee/binensel/risk_eng.html

http://www.jraia.or.jp/english/symposium/index.html

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