Heat Pump Related Activities of International Institute of Refrigeration (IIR)

Chicago, May 16th, 2023

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Professor, Seoul National University (Korea)
Importance of Heat Pumps
Promotion of Electric Heat Pumps

The U.S. Department of Energy (DOE) announced a $250 million funding opportunity to accelerate electric heat pump manufacturing in America (April 18, 2023)

“Electric heat pumps offer a cheaper, more reliable option for heating and cooling that isn’t prone to dramatic price swings and helps to strengthen the nation’s energy independence.” U.S. Secretary of Energy Jennifer M. Granholm.

Source: www.energy.gov/articles/biden-harris-administration-announces-250-million-accelerate-electric-heat-pump
Source: www.intgas.com/ko/energy-efficiency_program/residential-energy-efficiency/
50% of heating demand will be covered by heat pumps in 2045

Fig. IEA Roadmap for 2050 Net zero

Heat Pump Energy Coverage

- The heat pump coverage is on the rise and expected to continue growing.

**Global heat pump capacity** will increase, mainly replacing that of natural gas boilers.

Heat pumps contribute over half of the 29% decrease in demand for fossil fuels in space and water heating in the APS by 2030, reducing natural gas demand the most.

International Institute of Refrigeration and Heat Pump Related Activities
International Institute of Refrigeration (IIR), an intergovernmental organization, gathers global scientific and technical knowledge in all refrigeration sectors, with 59 member countries.

IIR is committed to advancing refrigeration knowledge for sustainable development worldwide.

Source: iifir.org/, en.wikipedia.org/wiki/International_Institute_of_Refrigeration
Section A
Cryogenics and liquified gases

A1 Cryophysics and cryoengineering
A2 Liquefaction and separation of gases

Section B
Thermodynamics, equipment and systems

B1 Thermodynamics and transfer processes
B2 Refrigerating equipment

Section C
Biology and food technology

C1 Cryobiology, cryomedicine and health products
C2 Food science and engineering

Section D
Storage and transport

D1 Refrigerated storage
D2 Refrigerated transport

Section E
Air conditioning, heat pumps and energy recovery

E1 Air conditioning
E2 Heat pumps and energy recovery
Heat Pump Related Activities by IIR

**Publications**
- International Journal
  - [Image of International Journal of Refrigeration](image)

**Conferences**
- International conferences
  - IIR International Congress of Refrigeration
    - [View the congress proceedings](link)
  - IIR-Gustav Lorentzen Conference on Natural Refrigerants
    - [View the conference proceedings](link)
  - IIR Conference on Sustainability and the Cold Chain
    - [View the conference proceedings](link)

- Sponsored conferences
  - [Image of 14th IEA Heat Pump Conference](image)

**Projects**
- Energy efficient cold chain
  - [Image of CoolFish](image)
  - [Image of ENOUGH](image)

- Off-grid solution
  - [Image of SOPHIA](image)

- Refrigeration/AC
  - [Image of INDEE](image)

Source: iifiir.org/
The IIR publishes an international journal that covers topics related to refrigeration, air conditioning, heat pumps, and other related areas.

- International Journal of Refrigeration (IJR), published by Elsevier for IIR, provides updated information on research and development in refrigeration, air conditioning, heat pumps and associated fields (IF: 4.41, JCR: 24.45%, EF: 12.04%, 2022)
Conferences

IIR organizes conferences related with various themes including heat pumps

IIR International Congress of Refrigeration

First held in 1908, the International Congress of Refrigeration of the IIR is a flagship event that converges industry and research. Covering all fields of refrigeration, the Congress, which takes place every four years, reunites key international stakeholders and provides perspectives on the future of the industry in line with sustainable development.

26th IIR International Congress of Refrigeration (ICR 2023)
August 21-25, 2023
Paris Congress Center | Paris, France

Source: iifir.org/
Source: www.icr2023.org/
IIR periodically publishes Informatory Notes as part of its official publications.
“High-temperature heat pumps are a key technology in the decarbonization of process industries.” by Ayou D. S., Corberan J. M., Coronas A. (2021)

- **Industrial heat consumption accounts for about 20%** of total global energy consumption and the vast majority of it is obtained from the combustion of fossil fuels (IEA, 2018)
- Industries have a strong **need for sustainable energy transition** to high-temperature heat pumps

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Source: “HIGH-TEMPERATURE HEAT PUMPS FOR INDUSTRIAL APPLICATIONS", October 2021, 45th Informatory Note on Refrigeration Technologies
Informatory Note 1: High Temperature Heat Pumps

Absorption heat transformers and absorption-compression heat pumps

- **Absorption heat transformers** and absorption-compression heat pumps

**Heat pump with a solution circuit**

**Absorption heat transformer**

- **High temperature heat supply** with heat pump can be achieved by integrating solution circuit with waste heat utilization

Source: “HIGH-TEMPERATURE HEAT PUMPS FOR INDUSTRIAL APPLICATIONS”, October 2021, 45th Informatory Note on Refrigeration Technologies
“Heat pumps can play an important role in meeting global targets for energy savings and low carbon emissions.” by Li X., Wang B. (2021)

- Room air conditioners and VRF systems account for the majority of air-conditioning system.
- In order to combat air pollution from traditional boilers, **ASHP plays an increasingly important role** in cases where **both heating and cooling** are required.

Source: “AIR SOURCE HEAT PUMPS FOR SPACE HEATING AND COOLING”, January 2021, 41st Informatory Note on Refrigeration Technologies
Informatory Note 2: Air Source Heat Pumps (ASHP)

This Informatory Note suggests the state of the art of ASHP technologies, along with defrosting strategies and alternative refrigerants.

Multi-stage heat pumps

Defrosting strategies

(a) Heating mode

(b) Compressor shutdown

(c) Electric heating

(d) Hot water spray

(e) Hot gas bypass

(f) Reverse cycle

Source: “AIR SOURCE HEAT PUMPS FOR SPACE HEATING AND COOLING”, January 2021, 41st Informatory Note on Refrigeration Technologies
Measures to Mitigate Climate Change
The IIR published a Informatory Note, evaluating the cycle performance of low-GWP refrigerants (by Domanski P., Motta S. Y.)

### R-410A replacements for space-heating heat pumps

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>GWP Reg. value</th>
<th>GWP Latest value</th>
<th>SafetyClass</th>
<th>COP $\frac{\text{COP}<em>{\text{R-410A}}}{\text{COP}</em>{\text{R-410A}}}$</th>
<th>$\frac{Q_v}{Q_v,\text{R-410A}}$</th>
<th>$\frac{P_D}{P_S}$</th>
<th>Evap. Glide# (°C)</th>
<th>NBP (°C)</th>
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<tbody>
<tr>
<td>R-410A</td>
<td>2088</td>
<td>2256</td>
<td>A1</td>
<td>1</td>
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<td>3.1</td>
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<tr>
<td>R-290</td>
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<td>0.02</td>
<td>A3</td>
<td>1.006</td>
<td>0.57</td>
<td>3.0</td>
<td>-0.3</td>
<td>-42.1</td>
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<tr>
<td>R-454C</td>
<td>166</td>
<td>148</td>
<td>A2L</td>
<td>0.952</td>
<td>0.49</td>
<td>3.5</td>
<td>5.3</td>
<td>-45.8</td>
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<td>R-455A</td>
<td>166</td>
<td>148</td>
<td>A2L</td>
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<td>7.2</td>
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<tr>
<td>R-454B</td>
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<td>R-32</td>
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<tr>
<td>R-466A</td>
<td>733</td>
<td>808</td>
<td>A1</td>
<td>1.009</td>
<td>0.98</td>
<td>3.0</td>
<td>0.9</td>
<td>-51.7</td>
</tr>
</tbody>
</table>

- Overall, the existing trade-off between GWP and flammability implies that a significant share of future equipment will use flammable refrigerants

Source: “LOW-GWP REFRIGERANTS: STATUS AND OUTLOOK”, June 2022, 48th Informatory Note on Refrigeration Technologies
Performance of low-GWP Refrigerants

International Meetings on Climate Change

- The IIR participated in the Meeting of the Parties to the MOP 32* and COP 27*

*MOP 32: Meeting of the Parties to the Montreal Protocol in Montreal *COP 27: Conference of the Parties on Climate change in Sharm Al Sheikh

Source: “The IIR at the Hear of Sustainable Development”, IIR Activity Report(2022)
Future of Heat Pumps
Future of Heat Pumps

**Industrial stream generation heat pump**

**Natural refrigerant**

**Al-based fault detection**

\[ O_t = \sigma(W_{xo}x_t + W_{ho}h_{t-1} + W_{co}c_t + b_o) \]

\[ h_t = o_t \odot \tanh(c_t), y_t = W_{hy}h_t + b_y \]

**Digital Twin based control and operation**

**Heat pumps for Electric Vehicles**
Digital Twin Based Control

Digital Twin was developed to estimate the dynamic performance of heat pump.

\[ \text{ROR} = \frac{\Delta t_{on}}{\Delta t_{on} + \Delta t_{off}} \]

*ROR: refrigerant flow on ratio

Fig. Experimental apparatus for variable refrigerant flow (VFR) heat pump

Fig. Dynamic performance of VRF system

- A dynamic heat pump model with moving boundary layer approach was established to find **optimal operating strategy** reducing the thermal on-off of system.
The waste heat from electric devices was absorbed at intermediate temperature, using vapor injection technique showing increased heating capacity in winter.

*Fig. Schematic of (a) conventional and (b) multi-level waste heat recovery system

*Fig. Heating capacity and compressor work of the non-WHR, CWHR, MWHR system

- The waste heat from electric devices was absorbed at intermediate temperature, using vapor injection technique showing increased heating capacity in winter.
Heat pump performance was well-predicted using neural network

Using a single model based on deep learning, the performance of heat pump under frost growth can be accurately predicted, and optimal defrosting strategy was derived.

INSTITUT INTERNATIONAL DU FROID
INTERNATIONAL INSTITUTE OF REFRIGERATION

Climate Change

Clean heat and cooling forum: frontier challenges for delivering climate safety

International Conference

ICR 2023, August 21-25, Paris, France

Database for Refrigeration

The leading database for refrigeration information

Publications

Future Heat Pumps
Thank you