Recent Development in Heat Pump Technology in Japan -Including Recent Progress in Basic Research

Masafumi KATSUTA
Waseda University
President of JSRAE

What is JSRAE

The Japan Society of Refrigerating and Air Conditioning Engineers was founded in 1925 in order to develop and disseminate refrigerating and freezing technology and related scientific technologies. Since then it has served nearly 88 years as a non-profit academic organization in a field of refrigeration, air conditioning, food refrigeration and related science and technology in JAPAN.

1.Survey, research, education and training, awards and certificate recognition for entitled engineers and scientists
2. Organization of annual JSRAE meeting, roundtable conferences, training short courses and workshops, technical visits and other events.
3. Publication of monthly journal "Reito"(refrigeration), Transactions of JSRAE and various books, textbooks, and handbooks.
4. Liaison with the International Institute of Refrigeration, IIR.
5. Implementation of correspondence education system.
6. Other miscellaneous activities essential to fulfill the objectives

Risk Assessment of Mildly Flammable Refrigerants
2012 Progress Report

The Japan Society of Refrigerating and Air Conditioning Engineers

Japanese Contribution to Montreal Protocol

☆ Targeting Area by good Japanese technologies
-Air-conditioning and refrigeration
-Foaming
-Solvency
-Destruction
-Recycling
-Cold chain
☆ Early implementation is very important to help developing countries meet 2013 and 2015 HCFC control target

Superior characteristics of HFC-32 (R32) for air-conditioners

☆ Lower GWP than R410A
(about one third of R410A)＜Climate-friendly＞
☆ Higher energy efficiency than R410A
Reduce the consumerôs cost to operate air-conditioners
☆ Smaller LCCP GHG emissions than the current R22
☆ Small Conversion Cost
☆ A bit flammable but acceptable (Class A2L)
☆ Daikinôs great contribution to release the indispensable patent on R32

Daikin, Mitsubishi and Hitachi provide R32 A/C to the market 2013

At ICR2011 Praha
Deputy Director, Ozone Layer Protection Promotion Division, METI of JAPAN

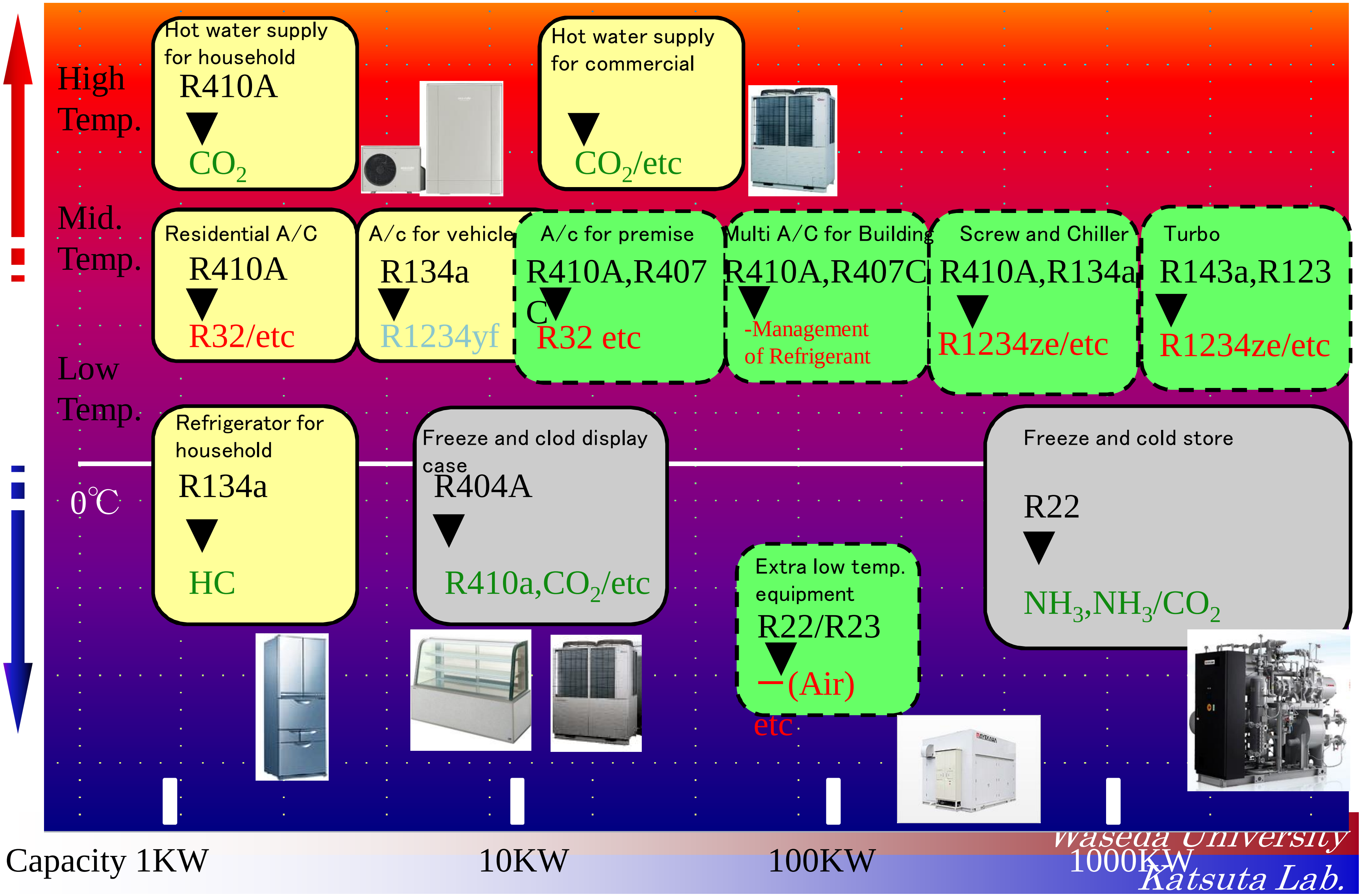
Conclusions

Using the risk mapping method, the risk of R1234yf ignition during retrieval/recharging was assessed. Data obtained from a questionnaire-based survey of automotive maintenance shops and from ignition and leak simulation tests was analyzed. As a result, the probability of ignition was rated at 10-18 (an extremely low level) and the severity of injury at I (slight), even for the worst case. The ignition risk of R1234yf was thus considered to be socially acceptable

Future Actions

Because the ignition risk of R1234yf was found to be socially acceptable, measures targeted at the main body of retrieval/recharging equipment are unnecessary. Nevertheless, JAMA is studying measures to further reduce the risks of R1234yf, including structural modifications to retrieval/recharging equipment to enable constant ventilation and, in addition, the attachment of caution labels to indicate that R1234yf is a flammable gas.

Candidate refrigerants for next generation classified by products by JDAIA



Ongoing IEA ANNEXES in Japan

- Annex 35 ñApplication of Industrial Heat Pumpsò until April 2014
  Prof. Uchiyama Tsukuba Uni.

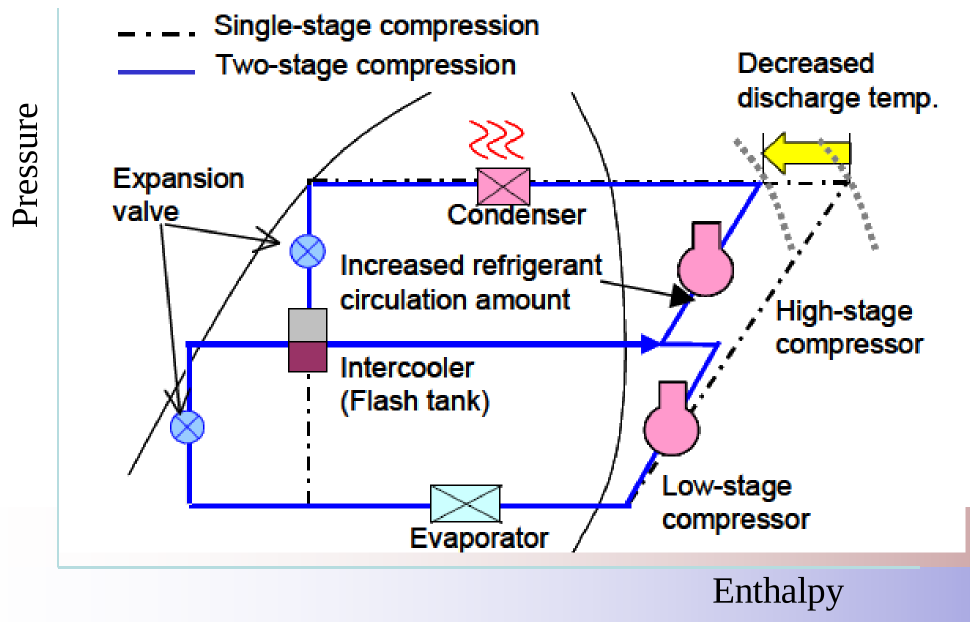
- Annex39 ñA common method for testing and rating residential HP and AC annual/seasonal performanceò Prof. Saito Waseda Univ.

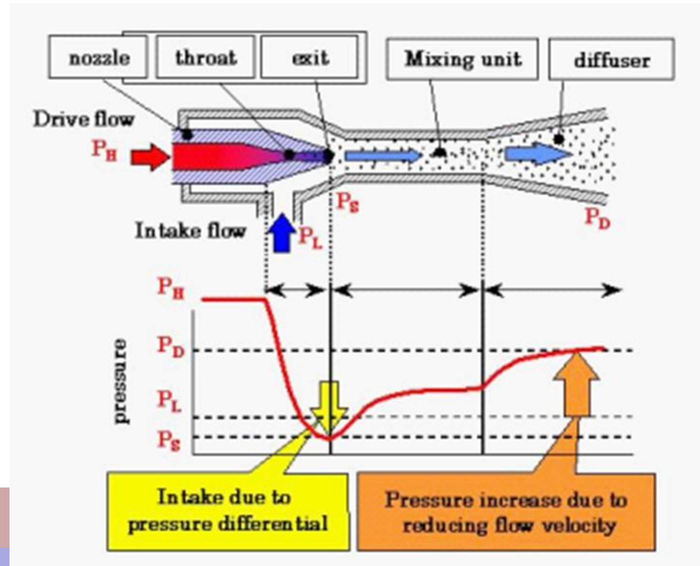
- Annex40 òHeat pump concepts for zero-energy buildingò
  Prof. Okuyama Nagoya Uni.

- Annex 41 òCold climate heat pumps (Improving low ambient temperature performance of Air-source heat pumps) Katsuta Waseda Uni.

Technical Solution for Cold Climate HP

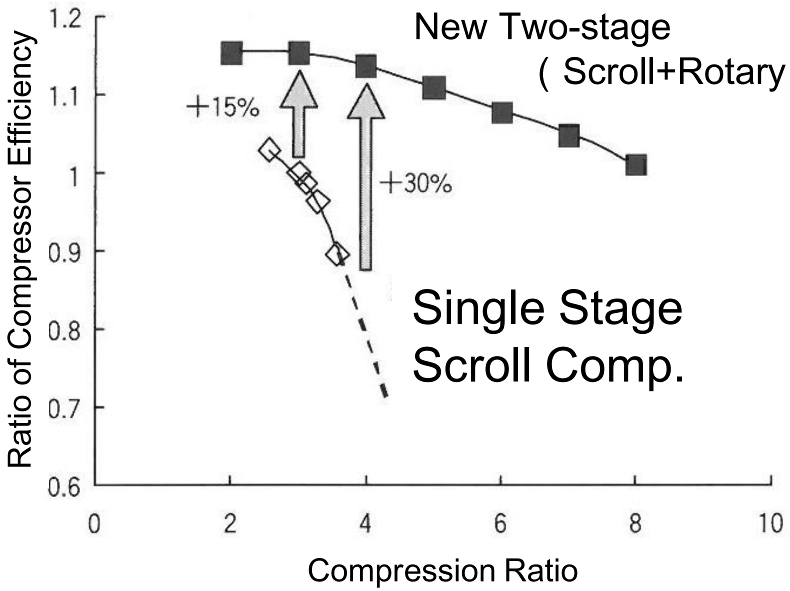
	Effect
Heat Exchanger	To shorten defrost period by using appropriate control or surface treatment
Two Stage Compressor	To improve compressor efficiency and decrease discharge temperature under high differential pressure
Injection	To increase heating capacity by increasing refrigerant flow rate
Ejector	To lift up compressor input pressure by utilizing expansion energy



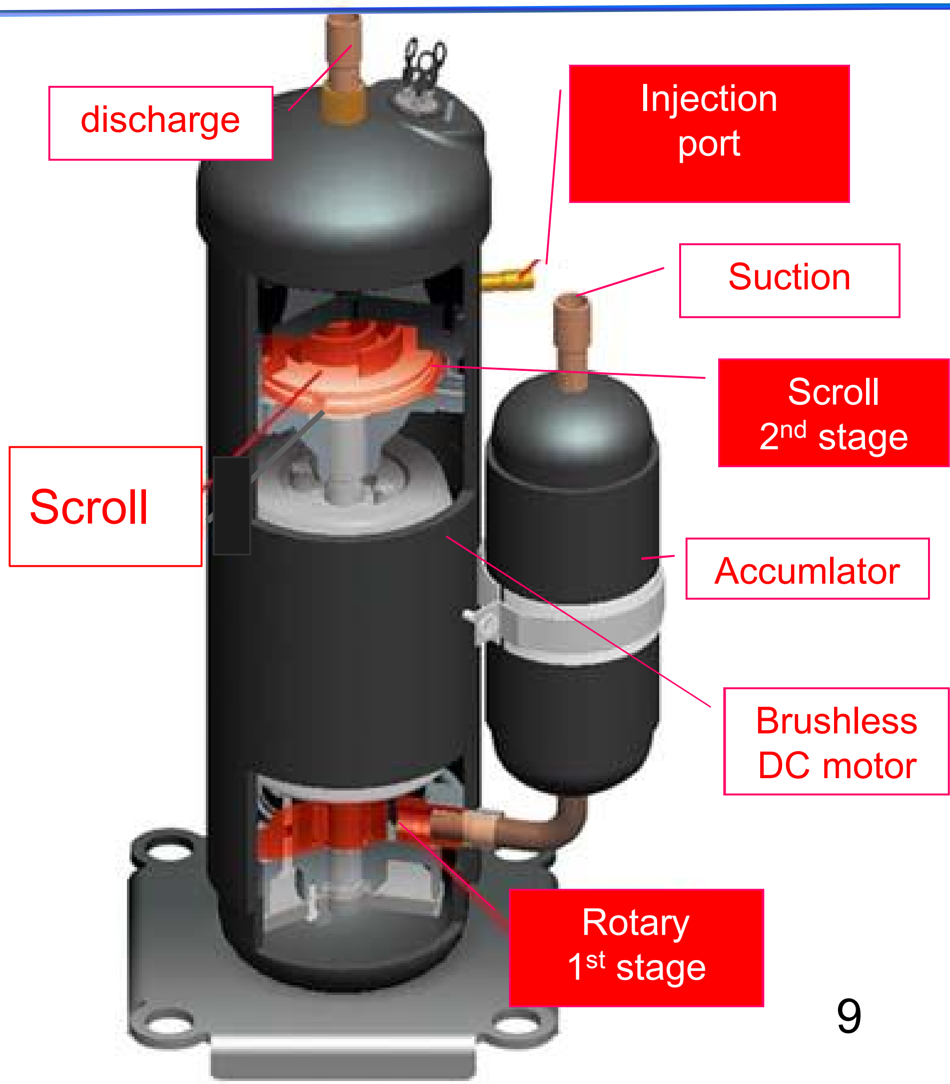


(3)CO_2 Heat pump for Hot Water : Q-ton

CO² Heat pump for hot water : Q-ton



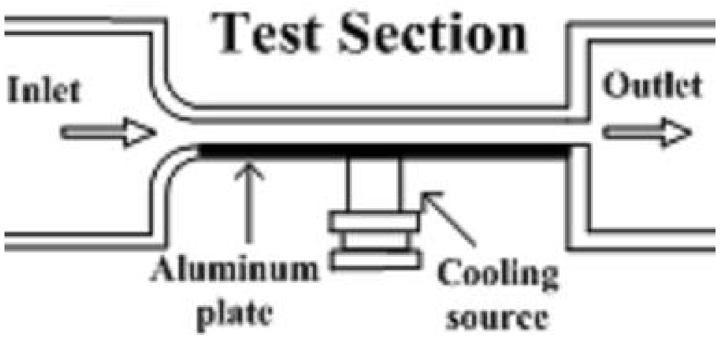
Ratio of Compressor Efficiency
VS Compression Ratio

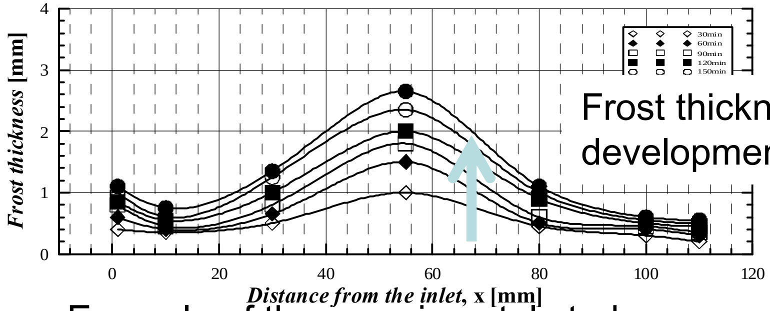


New Two-stage compressor
(Scroll+Rotary)

Fundamental Study 1

AN EXPERIMENT ON THE FROSTING OF LAMINAR HUMID AIR FLOW ON A FLAT ALUMINUM PLATE





Example of the experimental study

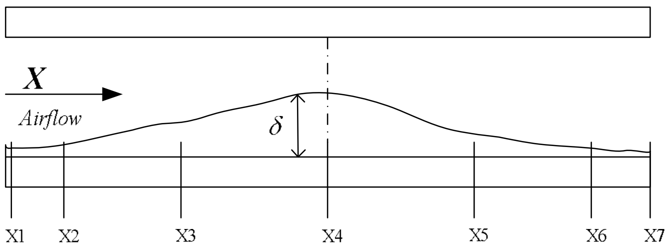
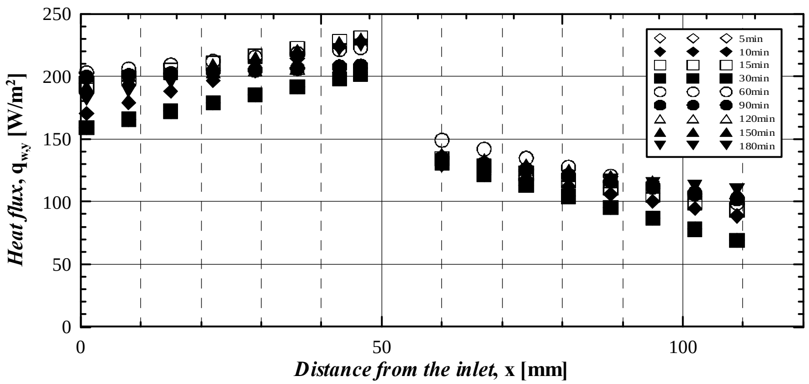


Fig. 2 Schematic of typical frost thickness profile



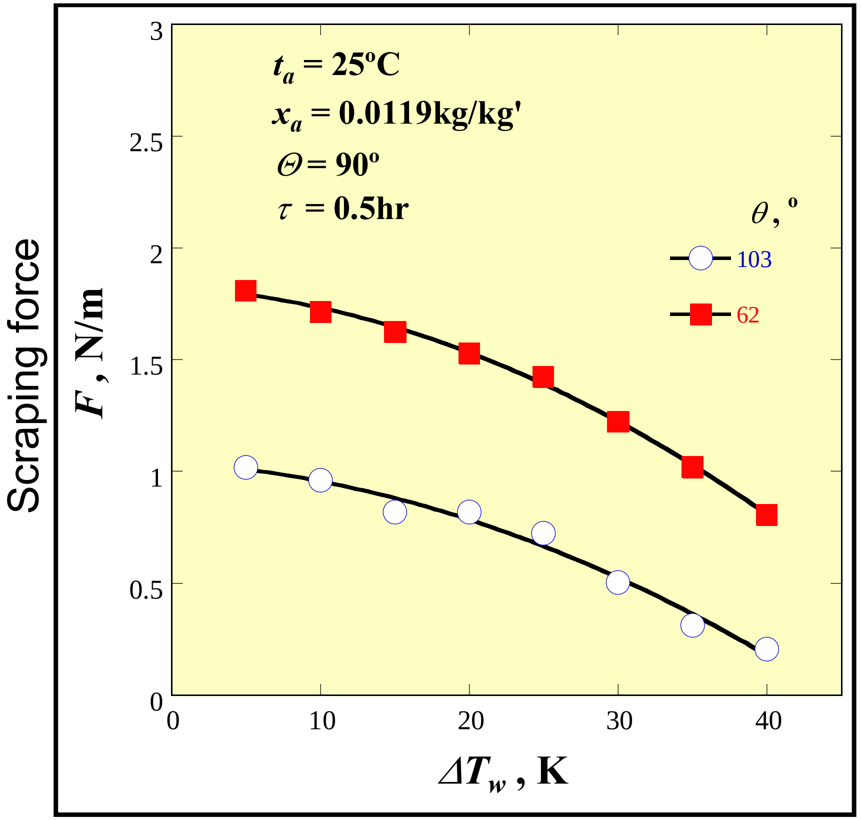
Example of Heat Flux

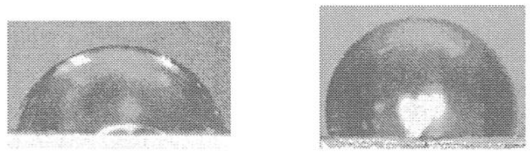
Heat flux derived from Data reduction calculation method and experiment result of frost thickness and temperatures

The heat and mass transfer characteristics of the humid airflow in frosting conditions have been experimentally investigated in this study.

Fundamental Study 2

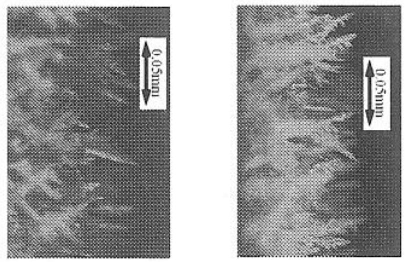
Experimental research of frost deposition phenomenon
(with the aim of mechanical defrosting)





θ=62° θ=107°

Droplet on surface



θ=62° θ=107°

Observation of frost layer

Scraping force is measured by dragging sharp edge on the cooling surface

Å The scraping force decreases when the cooling surface temperature decreases.

Å Wet ability is very sensitive to scraping force

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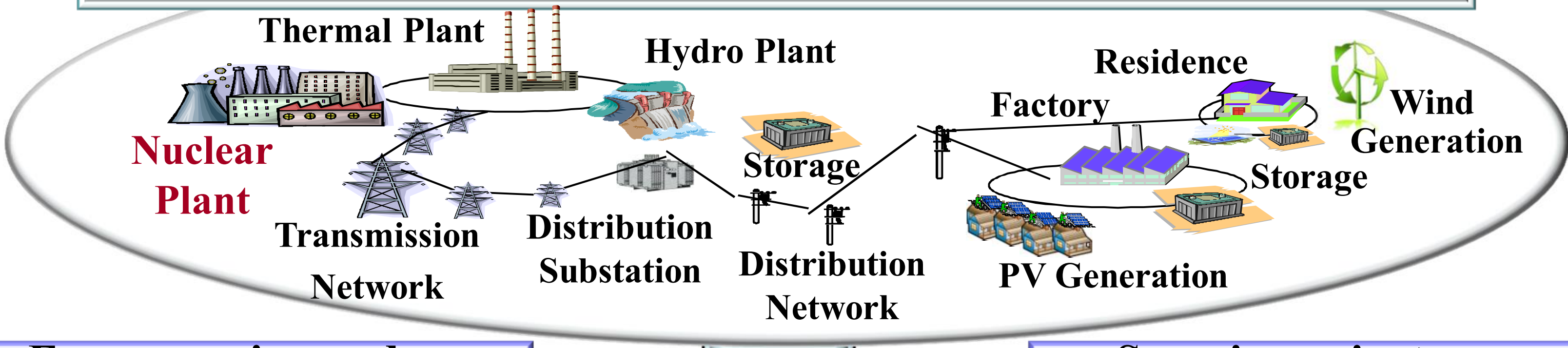
New Technology Development Regarding Electricity

Power source mixture centered on large scale facilities

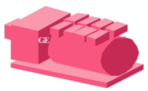


Energy saving and conservation

Securing private power source

Best mixing of energy by distributed energy and network

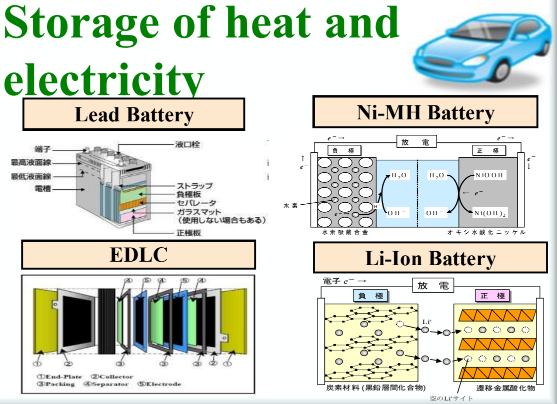
Clean Energy Technology



- LNG Thermal Plant (1GW)
- Gas Combined Cycle (0.3GW)
- Gas Engine (10KW – 1MW)
- IGCC (Clean Coal Generation)
- Fuel Cell

Utilization of Renewable energy

Storage of heat and electricity



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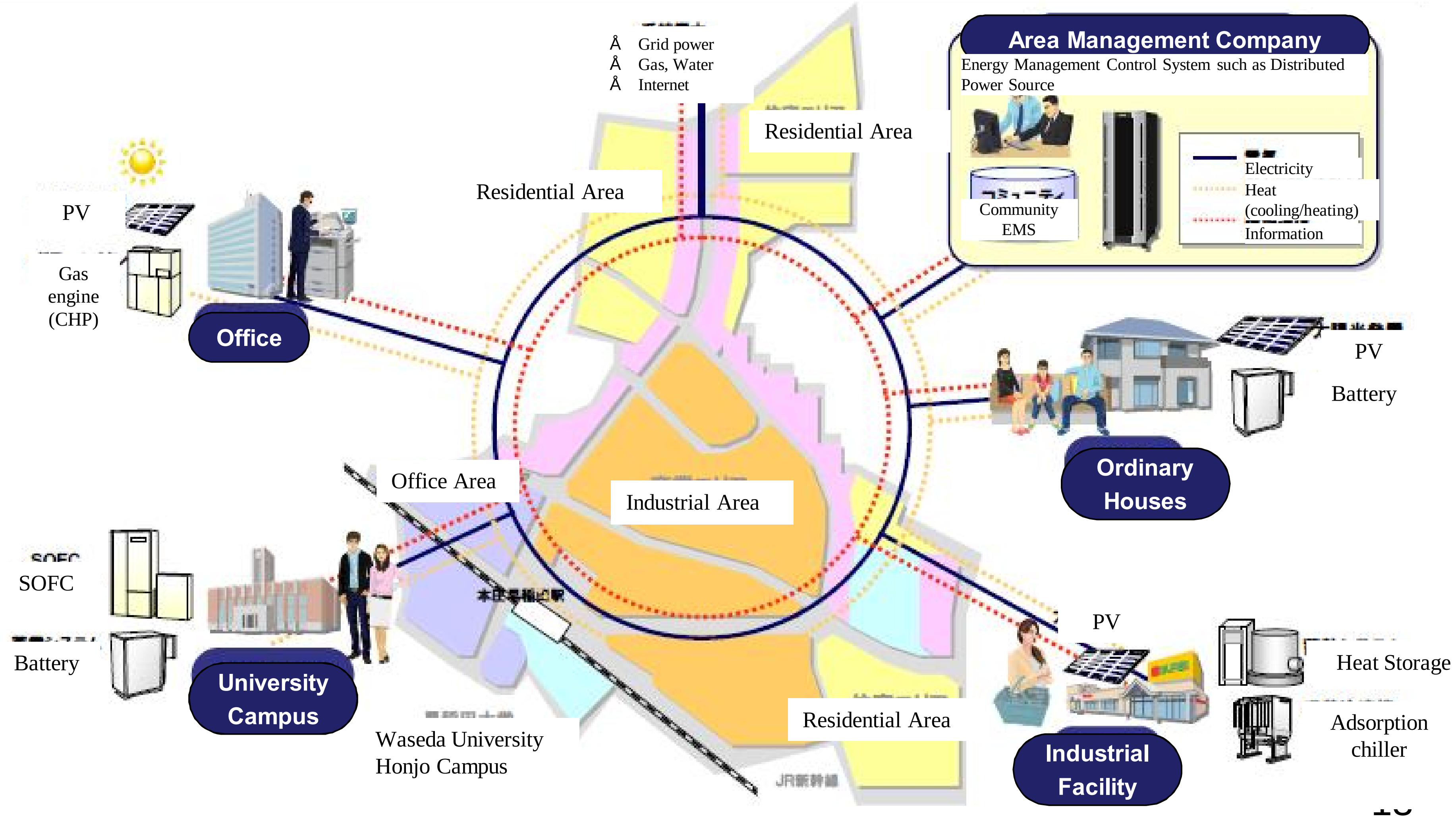
Example of Smart Grid Project and EMS　KATSUTA

Concept of Future Business Model (Log-Term Vision)



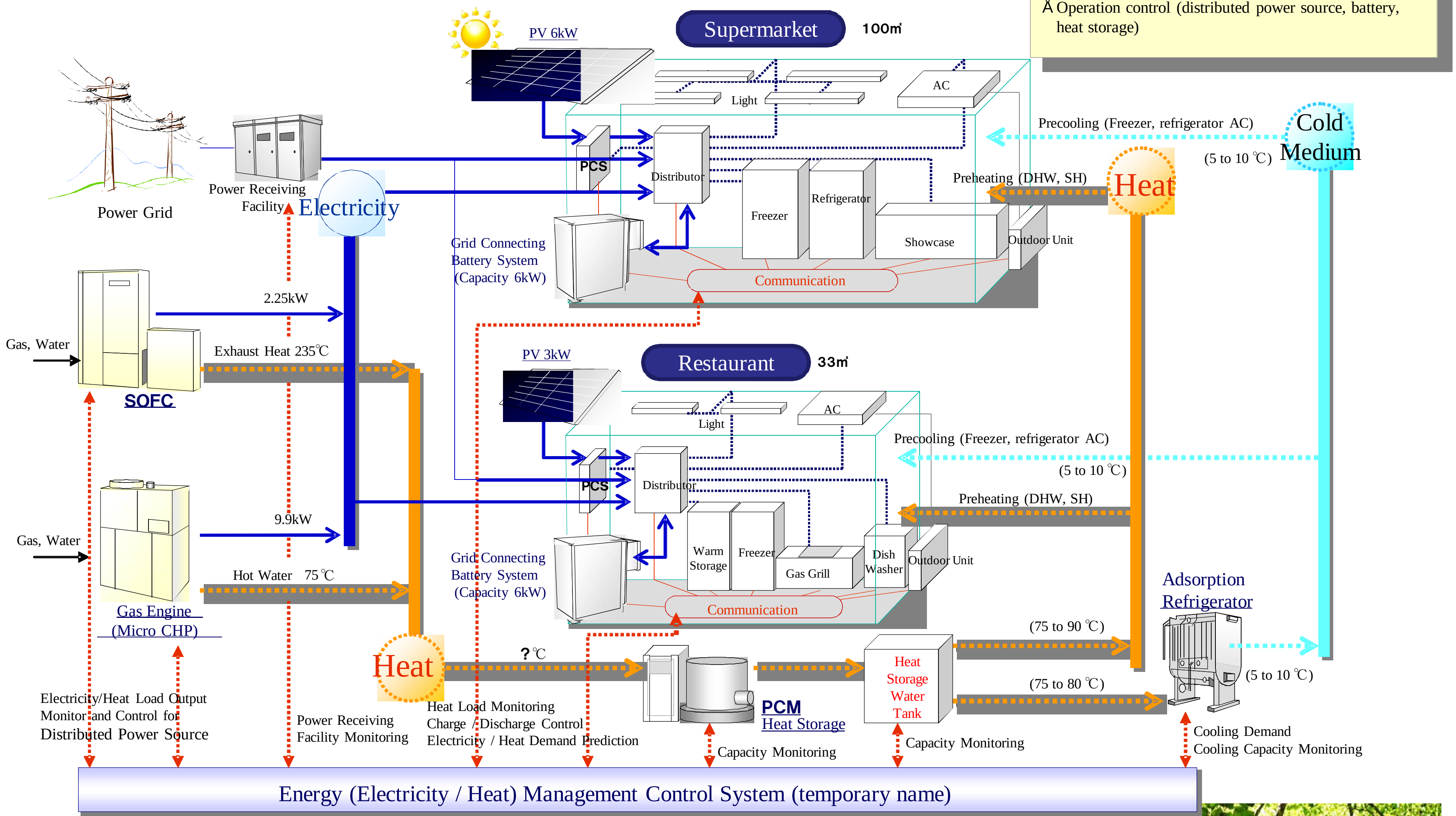
Empirical Study of Electricity-Heat Usage Optimization and CO2 Reduction by the Development of Energy Management Control System such as Distributed Power Source (Region I)

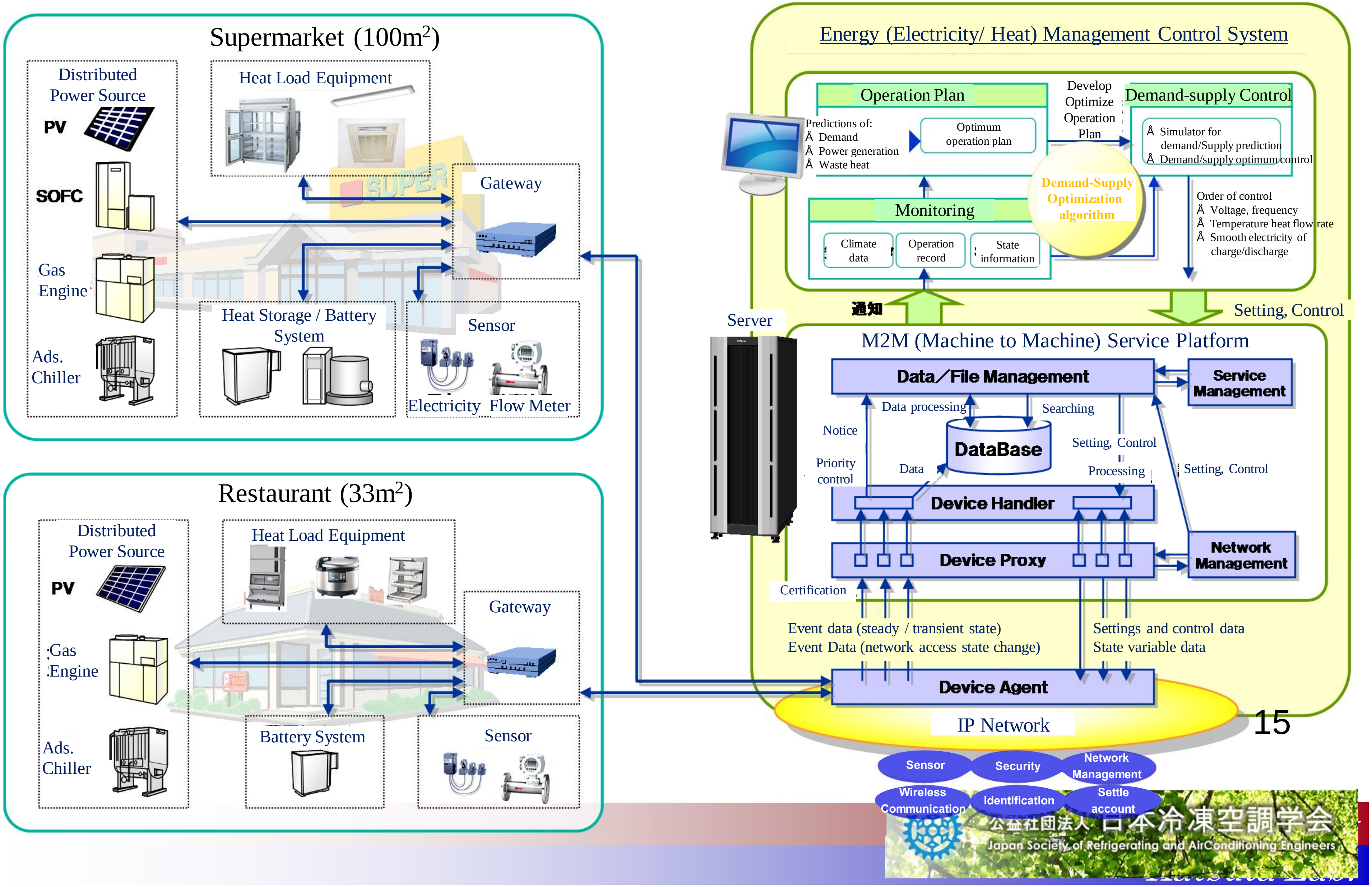
JSRAE

2011-2013 Field Test System Image (1/15 model)

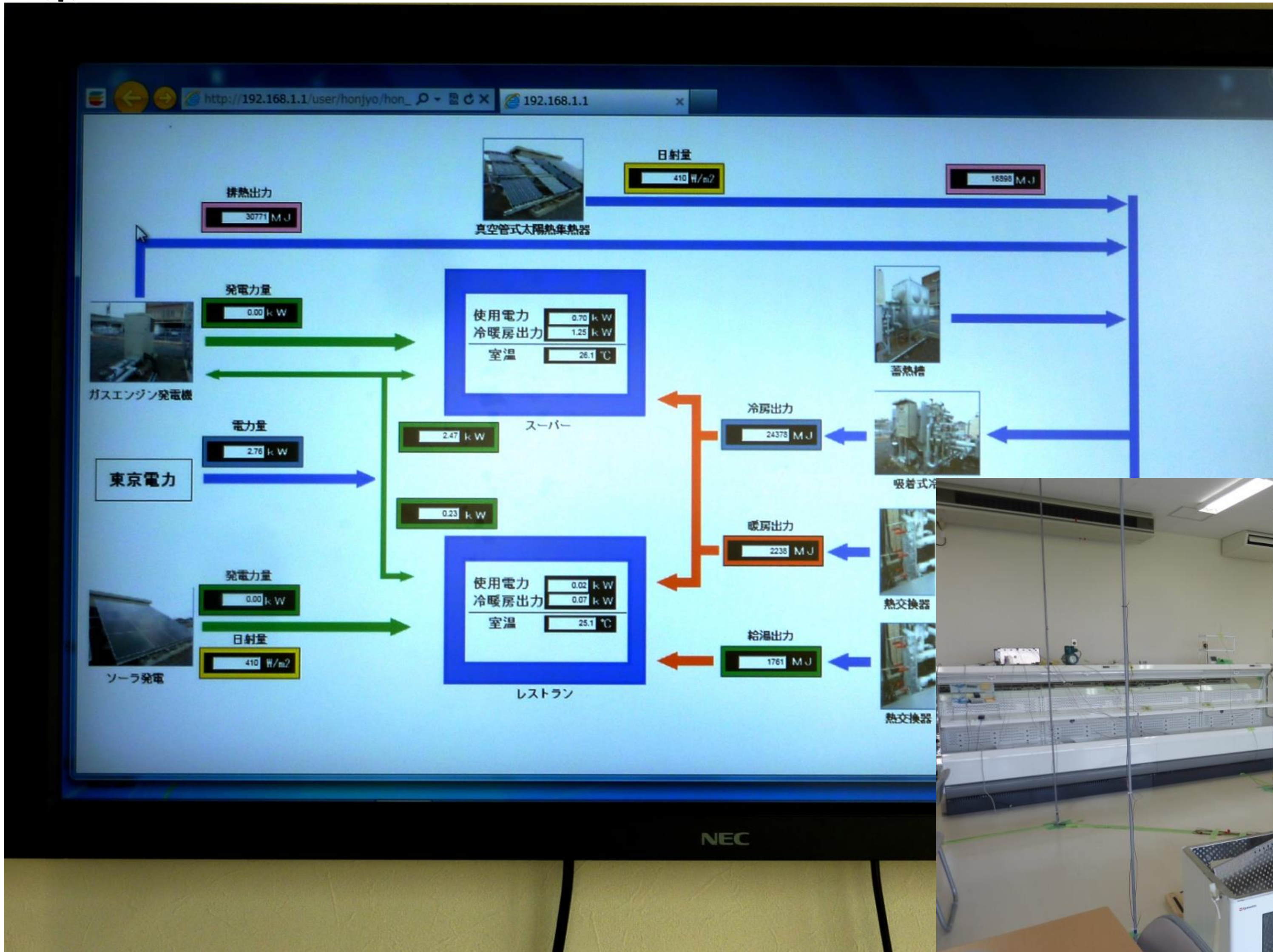
ñHonjo Smart Energy Townò PJ
Next Generation Industrial Facility / Office WG

ñ1/15 Field Test System of Industrial facilityò
Å Simulated heat load test for supermarket and restaurant
Å Supply/demand balance of electricity and heat
Å Operation control (distributed power source, battery, heat storage)




Supermarket (100m2)
Distributed Power Source
PV
SOFC
Gas Engine
Ads. Chiller
Heat Load Equipment
Gateway
Heat Storage / Battery System
Sensor
Electricity
Flow Meter
Restaurant (33m2)
Distributed Power Source
PV
Gas Engine
Ads. Chiller
Heat Load Equipment
Gateway
Battery System
Sensor
Energy (Electricity/ Heat) Management Control System
Operation Plan
Develop Optimize Operation Plan
Demand-supply Control
Predictions of:
Demand
Power generation
Waste heat
Optimum operation plan
Simulator for demand/Supply prediction
Demand/supply optimum control
Demand-Supply Optimization algorithm
Monitoring
Climate data
Operation record
State information
Order of control
Voltage, frequency
Temperature heat flow rate
Smooth electricity of charge/discharge
通知
Setting, Control
Server
M2M (Machine to Machine) Service Platform
Data／File Management
Service Management
Data processing
Searching
Notice
DataBase
Setting, Control
Priority control
Data
Processing
Setting, Control
Device Handler
Device Proxy
Network Management
Certification
Event data (steady / transient state)
Event Data (network access state change)
Settings and control data
State variable data
Device Agent
IP Network
Sensor
Security
Network Management
Wireless Communication
Identification
Settle account
公益社団法人 日本冷凍空調学会
Japan Society of Refrigerating and AirConditioning Engineers

Photos of the Test Facility


日射量
排熱出力
真空管式太陽熱集熱器
発電力量
使用電力
冷暖房出力
室温
蓄熱槽
ガスエンジン発電機
電力量
東京電力
スーパー
冷房出力
暖房出力
熱交換器
給湯出力
レストラン
ソーラ発電
NEC

『Recent Development in Heat Pump Technology in Japan -Including Recent Progress in Basic Research』

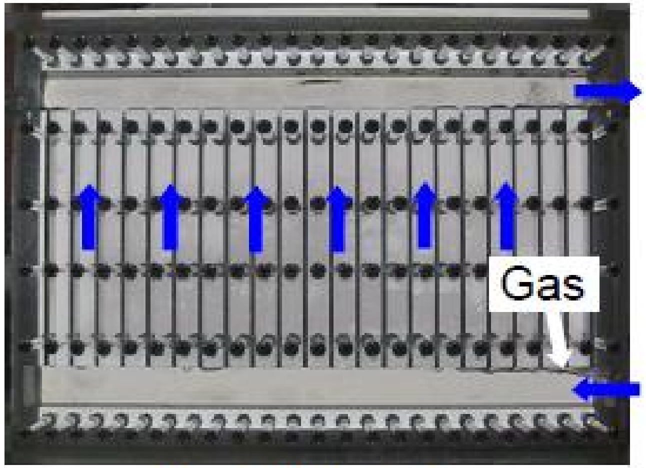
Recent Progress in Basic Research Special focus on Heat Exchanger From JSRAE Annual Conference

・Development of all aluminum micro-channel heat exchanger for air-conditioner
The issues
/Flow distribution or mal-distribution of refrigerant two phase flow
/Another problem is to improve the drainage of condensed water when it is used as an evaporator
/ Heat Transfer using New Low GWP Refrigerant

・Frost and Defrost Phenomena
/Micro and Nano Structure
/ Fin Geometry
/ Visualization
/ Chemical Treatment
/Desiccant → No-frost Refrigerator

The gas-liquid flow distribution in multiple upward channels that simulate the evaporator in a cooling unit was examined experimentally. Attention was directed to the similarity between the refrigerant flow and the air-water flow.
At first, the refrigerant two-phase flow in the channels was visualized to make clear the flow characteristics in the dividing and combining headers. Then, the air-water flow was observed under following four air and water velocity conditions at the header entrance: (i) superficial velocities equal to the refrigerant flow, (ii) equal kinetic energies, (iii)equal quality and mass flow rate, (iv) equal Baker map parameters. It was found that the condition of the equal kinetic energies at the header entrance could simulate the refrigerant flow quite closely. The air and water distribution ratios to
the branches were measured under two conditions, equal kinetic energies and equal Baker map parameters, to examine
the influence of the flow inlet conditions on the flow distribution characteristics.

Two-phase Flow Distributions in Multi-pass Channels
Comparison of Refrigerant Flow and Air-water Flow



(a) $M = 5.2$ kg/h, $x = 0.3$

Prof. Hirota　Mie University

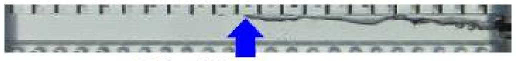
Two-phase Flow Distributions in Multi-pass Channels Comparison of Refrigerant Flow and Air-water Flow

(a) Refrigerant flow

(b) Equal superficial velocities

(c) Equal kinetic energies

(d) Equal quality and mass flow rate



(e) Equal Baker map parameters

Comparison of gas flows in the dividing header

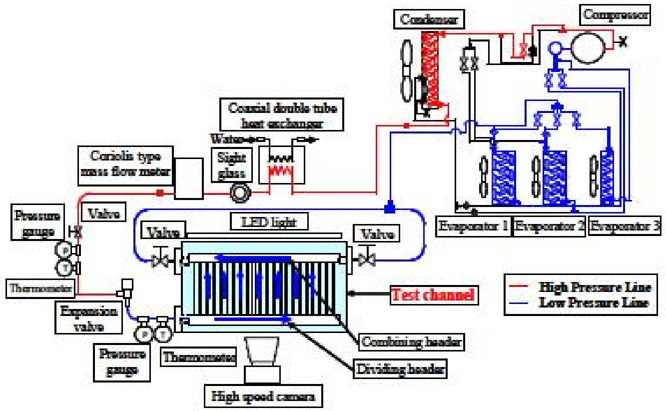


Fig. 1 Flow visualization ...s for refrigerant flow

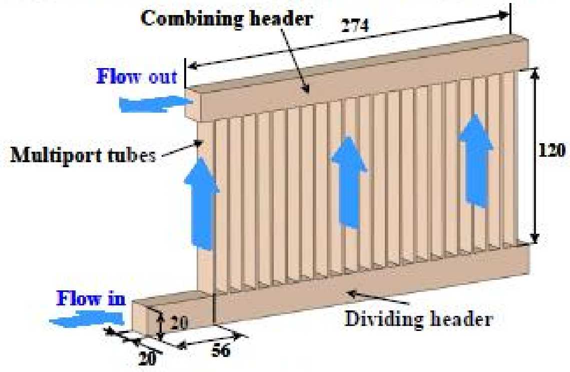
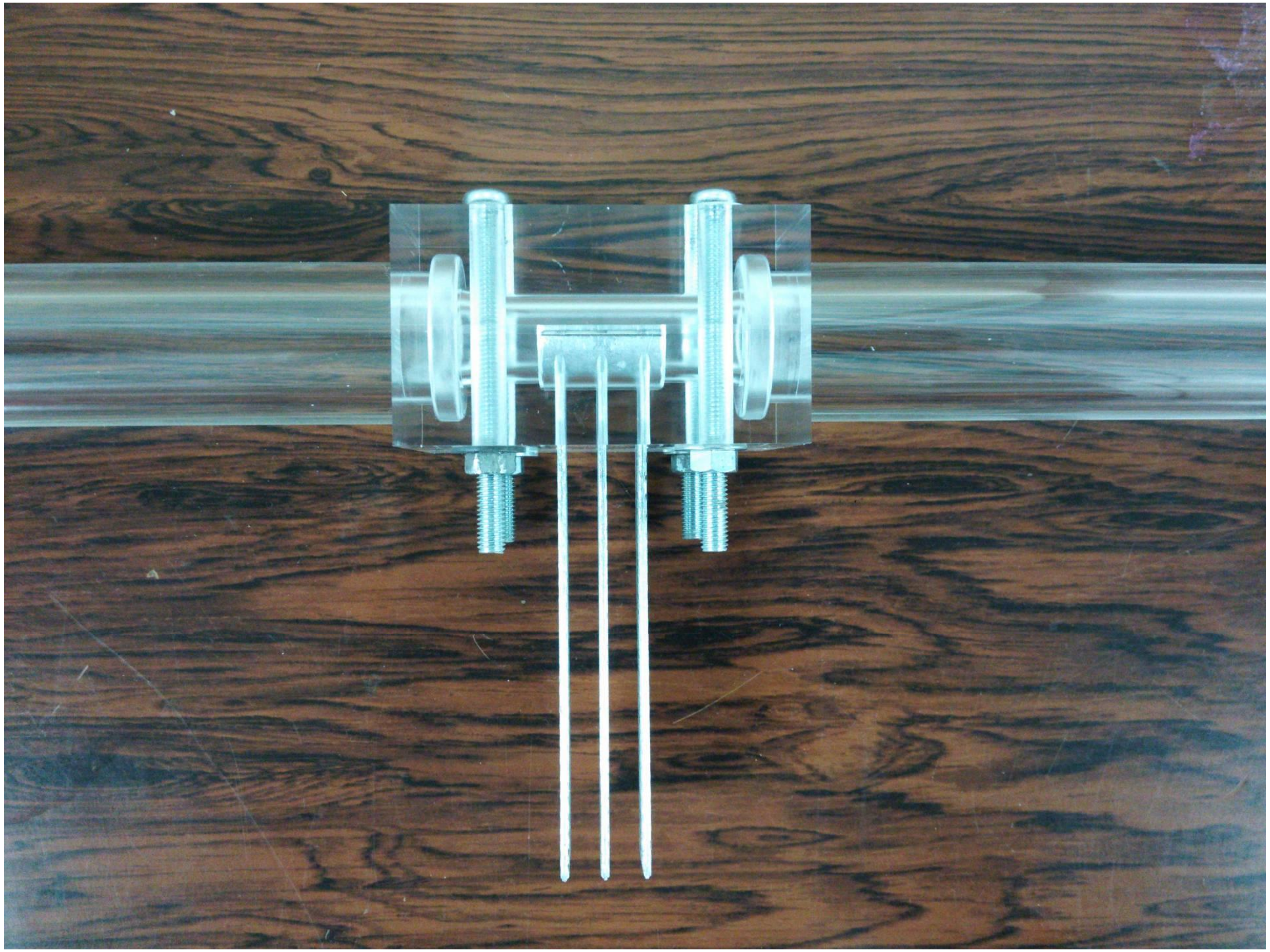
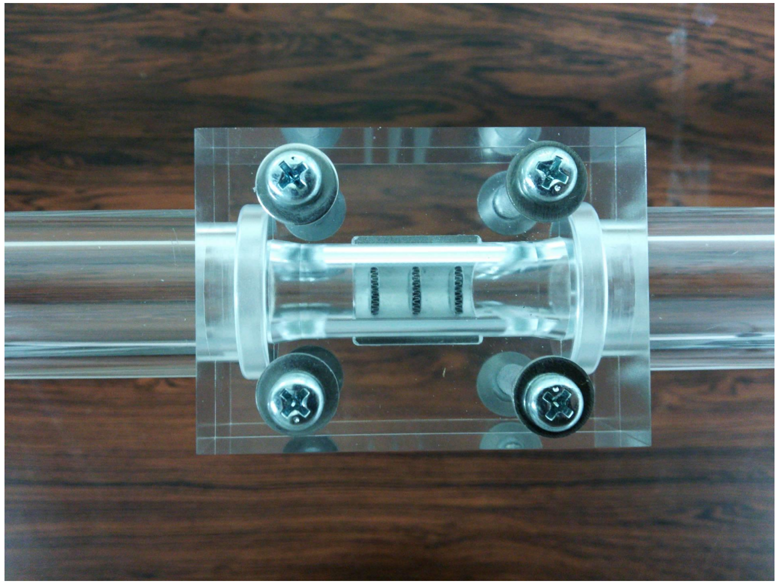


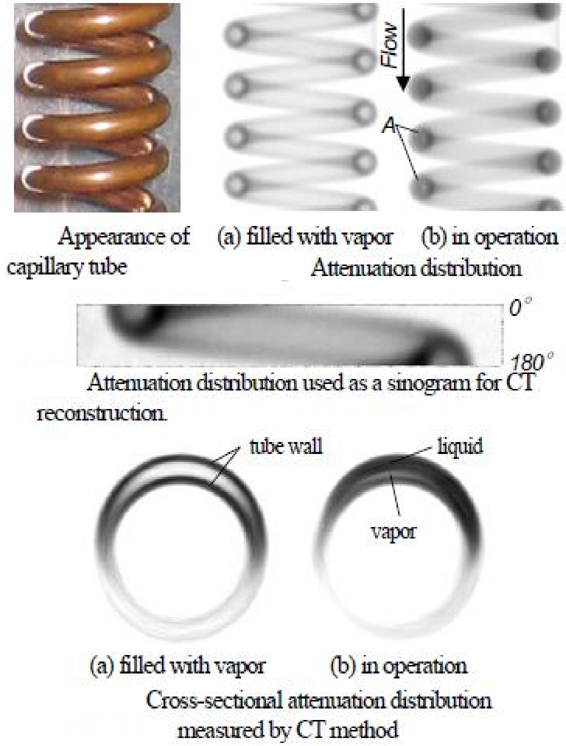
Fig. 2 Details of the test cha...





Prof. Asano　Kobe University
Typical Example ;
Neutron Radiography Application

Inspection of Refrigerant Behavior in Refrigerating System based on Flow Visualization by Neutron Radiography



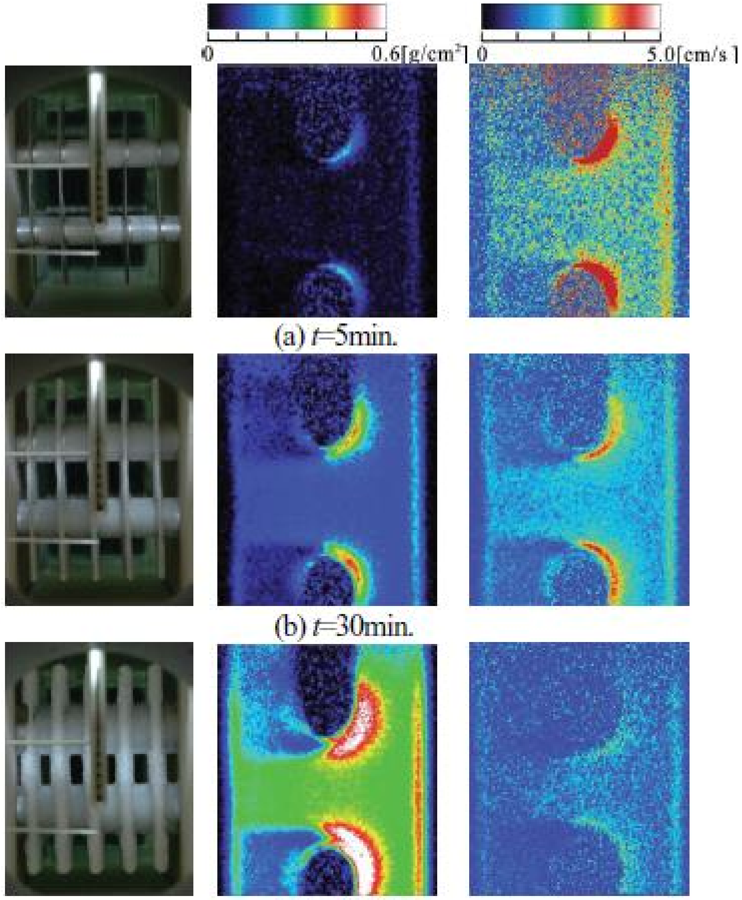
In order to design / improve gas-liquid two-phase flow equipment or to construct numerical analysis model of gas-liquid two-phase flow, it is required to understand flow behavior, since the performance strongly depends on interface structure in gas-liquid two-phase flow and the structure depends on conduit configuration and operating condition. However, it is difficult to visualize flow behaviors in real equipment generally made from metal. Neutron radiography is effective to visualize gas-liquid two-phase flows in a metallic vessel due to its attenuation characteristics.
From neutron radiographs, it is possible to visualize liquid behaviors and to measure 2D void fraction distributions quantitatively via some image processing methods. Moreover, 3D void fraction can be obtained by CT method. In this paper, the principle of neutron radiography is explained and some application examples on refrigerating system are introduced.

Inspection of Refrigerant Behavior in Refrigerating System based on Flow Visualization by Neutron Radiography

Quantitative Evaluation of Frosting Phenomena by Using Neutron Radiography
- Evaluation of Frosting Phenomena on Finned-tube Heat Exchanger with 5mm fin pitch -

Ryosuke MATSUMOTO*, Tomoya YOSHIMURA*, Hisashi UMEKAWA*
Takeyuki AMI* and Yasushi SAITO**

On the cooling surface of the heat exchanger, the frost grows up with having a spatial distribution due to the
effects of temperature and humidity profiles and the flow field in the heat exchanger. Therefore, the mass transfer
coefficient of the frost formation has a temporal and spatial distribution on the heat transfer surface. This study focuses
on the frost formation on the fin-tube heat exchanger with 5mm fin pitch investigated by using neutron radiography.
The visualization of the frost formation was estimated by the attenuation of the neutron beam through the water. The
visualization image of the neutron radiography shows clearly the frost formation phenomena. Local mass transfer
coefficient can be calculated from the differential images of the neutron radiography.



(c) t=120min.

Digital camera | Frost formation m_f [g/cm^2] | Mass transfer coefficient h_D [cm/s]

Fig.3 Experimental results on fin pitch F_p=10mm at u=1.1m/s.

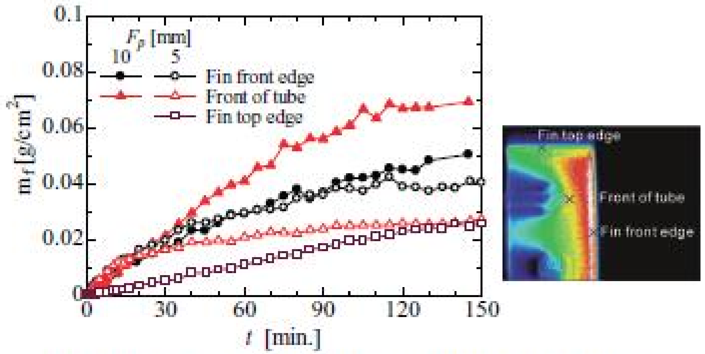


Fig.5 Comparison of local frost weight for unit surface.

Development of all aluminum micro-channel heat exchanger for air-conditioner

*Daikin Industries, LTD., Kanaoka-cho, Kita-ku, Sakai, Osaka, 591-8511, Japan

In order to reduce the weight of air-conditioner, a new type micro-channel heat exchanger is applied for heat pump system. The micro-channel heat exchanger has high performance compared with a conventional fin and tube type heat exchanger due to its characteristic configuration. However, there are some challenges, when the micro-channel heat exchanger is applied for heat pump system. One of the most difficult problems is to improve the drainage of condensed water when it is used as an evaporator. To solve this problem, a new shape fin named ñInsertion waffle louver finò is proposed. In addition, the specifications of the heat exchanger, such as louver configurations and tube arrangement, are optimized for heat pump system. As a result, the micro-channel heat exchanger can reduce the weight about one third and the amount of containing refrigerant about one fourth compared with a conventional fin and tube type heat exchanger.

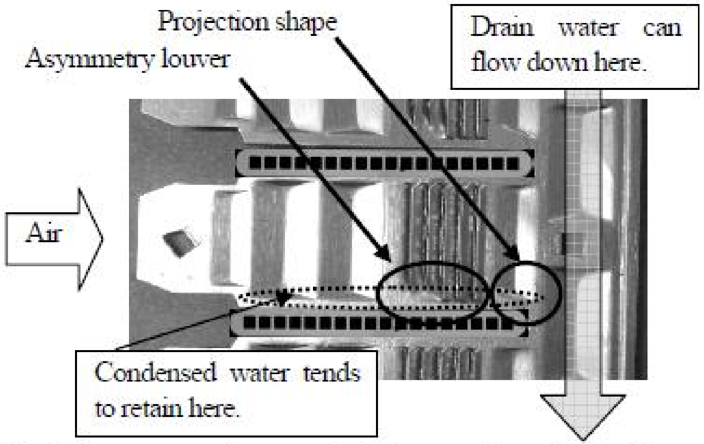


Fig.5 Improvement for smooth drainage on "Insertion waffle louver fin"

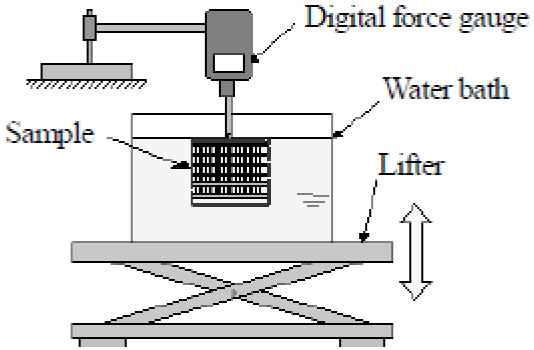


Fig.6 Schematic diagram of test facility for water dipping test

Experimental Study on Flow Boiling of R1234ze(E) in a Multi-Port Tube

**Interdisciplinary Graduate School of Engineering Sciences, Kyushu Univ., Fukuoka 816-8580, Japan

The pressure drop and flow boiling heat transfer characteristics of R1234ze(E) in a horizontal multi-port tube with 0.85 mm rectangular mini-channels are investigated experimentally. The experiments are carried out in the mass velocity range of 100 to 400 kg/(m2 s) and heat flux range of 10 to 20 kW/m2. The frictional pressure drop on the adiabatic flow and the boiling flow of R1234ze(E) are measured. The effects of mass velocity, quality and heat flux on the boiling heat transfer are clarified. The measured frictional pressure drop and boiling heat transfer are compared with several previous correlations.

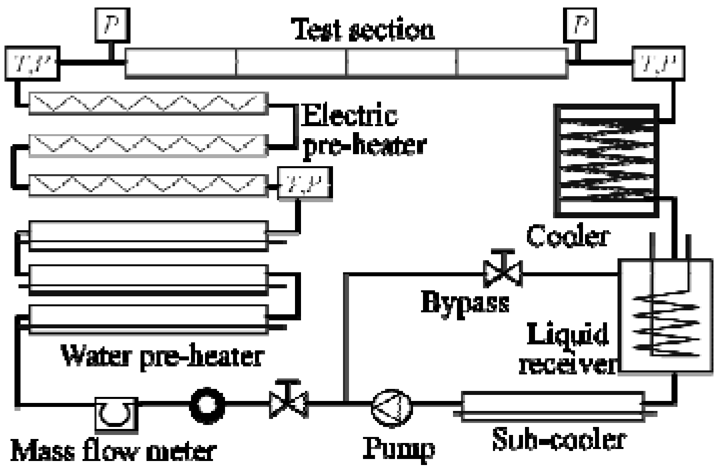
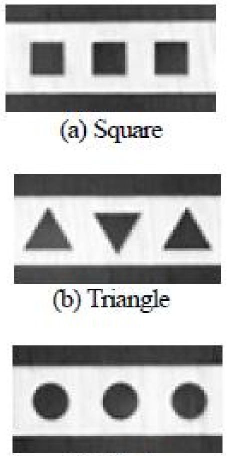


Fig. 1 Schematic view of the test loop.

Development of all aluminum parallel flow type heat exchanger

R & D Center, Sumitomo Light Metal Industries, LTD., 3-1-12, Chitose, Minato-ku, Nagoya, Aichi, 455-8670, Japan

In this paper, in order to examine the all aluminum heat exchanger using micro channel tube as an outdoor heat exchanger of an air-conditioner, it was checked that how affect micro channel tube inside geometry and louver fin pitch for all aluminum heat exchanger performance. The heat exchanger using triangle shape micro channel tubes and narrow pitched fins showed higher performance. Our all aluminum heat exchanger showed a better corrosion resistance than the products on the market.



(a) Square

(b) Triangle

(c) Circle

Fig. 1 Cross section figure of micro channel tube.

Effects of surface properties on frosting phenomena

○Sho INOUE*, Yuji SUZUKI*, Kyosuke MATSUMOTO* and Hidetoshi OHKUBO*
* Graduate School of Engineering, Tamagawa University, Machida-shi, Tokyo, 194-8610, Japan

When the surface temperature of a solid is below the solidification point of water, water vapor in air condenses on the solid surface to from the frost. This phenomenon is generally known as the frost formation, and is a transient phenomenon in which both heat transfer and mass transfer take place simultaneously. In engineering, the frost formation is a process associated with such consumer products as refrigerators and heat pumps. In this study, the effects of surface properties on frosting phenomena ated.

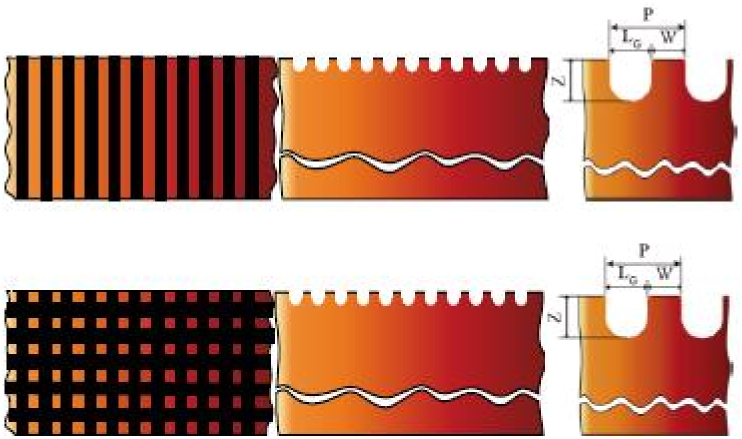


Fig.1 Heat transfer plate

冷却面表面性状は溝の幅 L_G=0.25mm，凸部表面の幅 W=0.25mm，溝のピッチ P=0.5mm，溝の深さ Z=0.7mm である．

Study on Control of Crystal Growth of Frost

Hidetoshi OHKUBO* and Sho MATSUSHITA*
* Graduate School of Engineering, Tamagawa Universi

Frost deposition is a transient phenomenon in which both heat and mass transfer occur simultaneously. When the surface temperature falls below the freezing point of water, water vapor condenses resulting in formation of a frost layer on the surface. The frost layer can be considered as a porous layer of ice which contains humid air. In this study, the formation and growth of frost crystals were observed using a microscope and a high speed camera. And possibilities of the formation and growth of frost crystals within boundary layers were investigated.

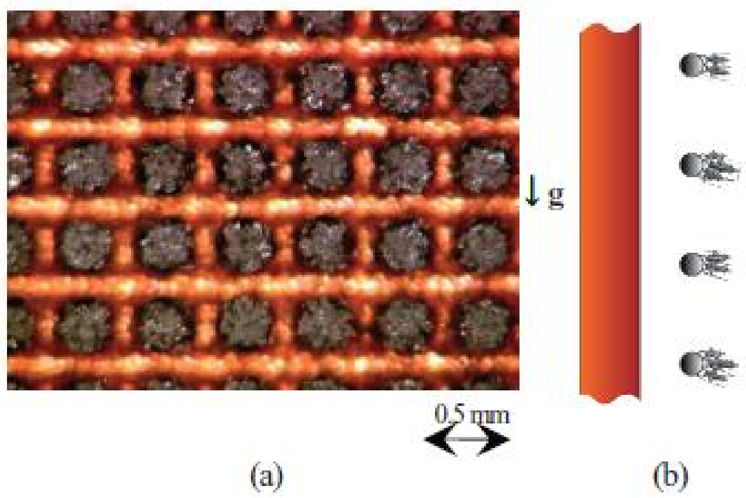


Fig.1 Control of crystal growth of frost

Technical Trend of Hydrophilic Surface Treatment chemical for Heat Exchanger

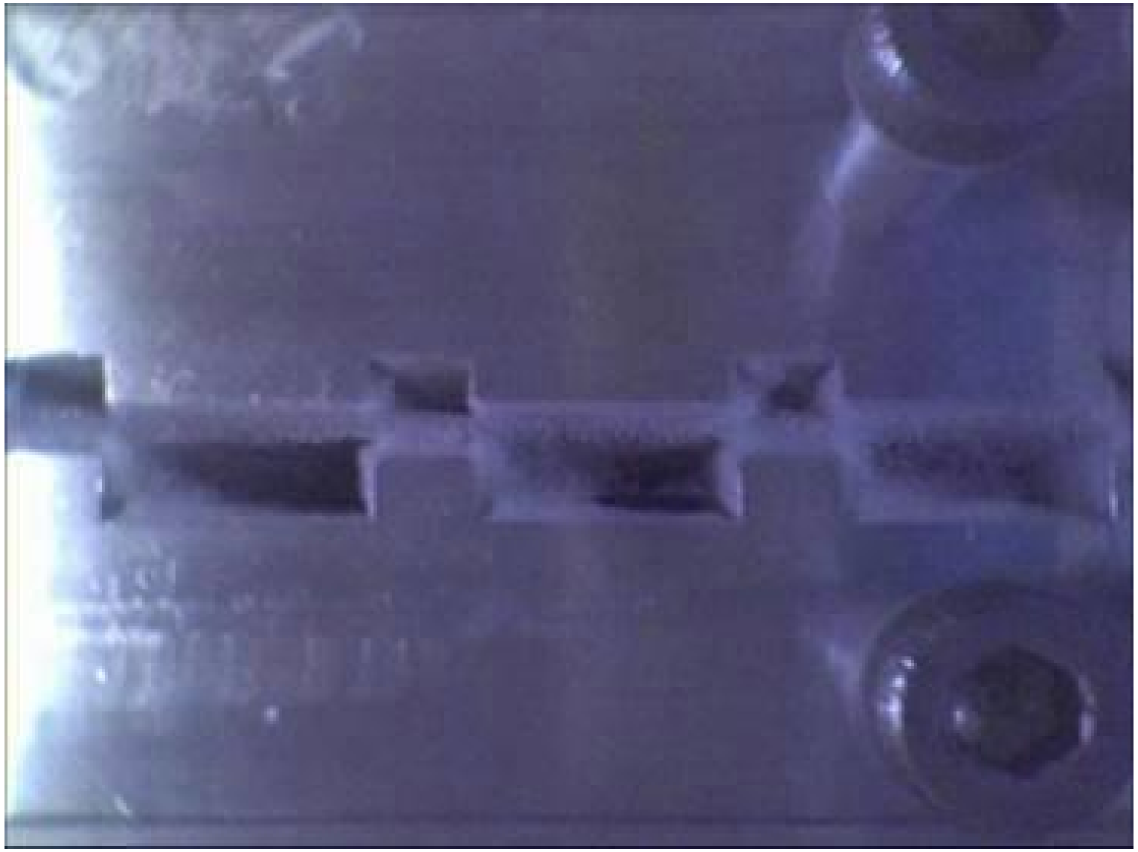
Abstract

More and more car and household air-conditioners are being used around the globe every year. The surface coating of the heat exchanger in air–conditioners needs to provide a variety of functions including hydrophilicity, corrosion resistance, odor prevention, and antibacterial properties. Furthermore, the surface treatment technology needs to satisfy environmental regulations. These functions are required not only by air-conditioner manufactures in Japan but also manufactures around the world. We developed surface coating solutions which are providing these functions, and we are actively promoting these technologies around the world.

This report includes a summary of the history of development of our surface coating chemical, manufacturing process of air-conditioners, compliance with environmental regulations and our latest development trends.

Study on the Frosting Phenomena Between Concavity and Convexity Plate under Forced Convection
The effect of air conditions on the hydraulic and heat transfer performance

In the motor vehicle industry, the diffusion of electric vehicle (EV) is accelerating. High efficiency and securement of the heating are requested for the air conditioning equipment for vehicles. The most effective way to heat is using heat pump, but the decreasing of heat transfer coefficient and the pressure drop caused by the frost of evaporator could be a big problem. Therefore the inhibition of frost in evaporator is especially required. The performance increase of the finless heat exchanger is expected, because it can flush the dew condensation water. The aim is to establish the evaluation technique of the defrosting characteristic. The fundamental characteristic of the heat transfer coefficient, the pressure drop, and the frost growth was grasped. From the experiment, the block of flow channel by frost was seen in the angle part of upper position of concavity and convexity plate (test section).



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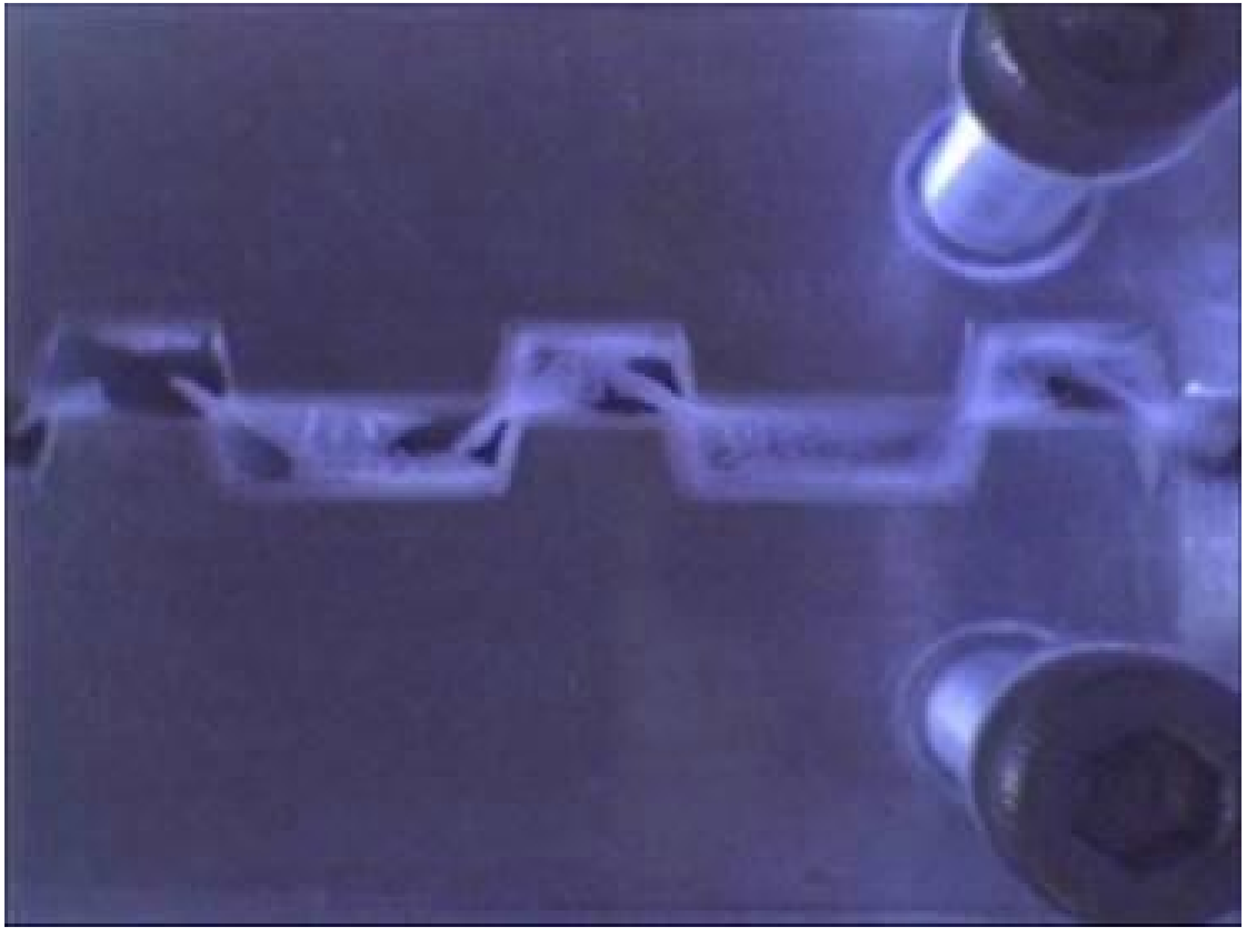
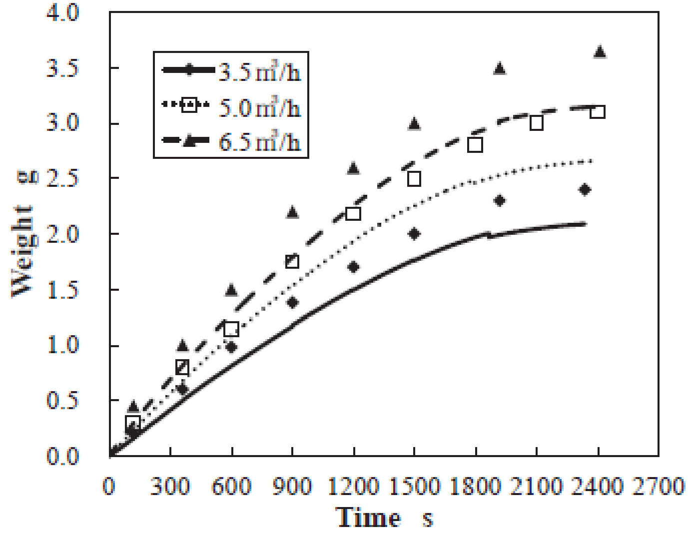
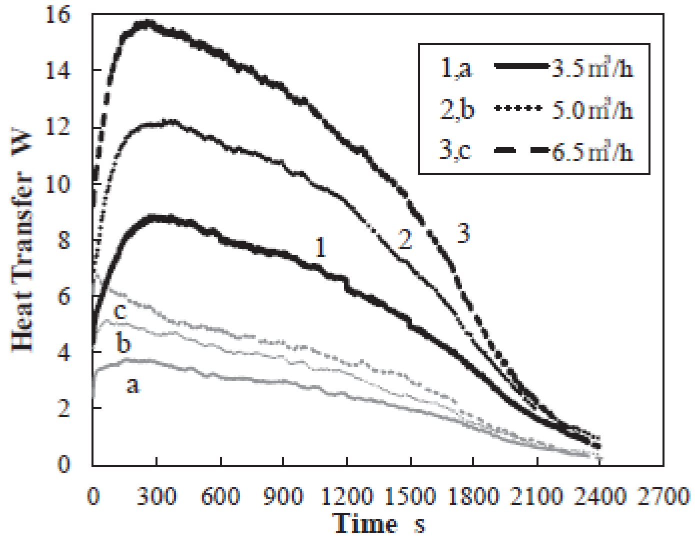




Plot : Actual Measured Value   Line : Calculated Value

Fig.10 Variation of frost weight with time (No.14, Flow Rate)



1~3 : Amount of Heat Transfer   a~c : Latent Heat

Fig11 Variation of Heat Transfer with time (No.14, Flow Rate)

Development of a No-Frost Heat Pump System and Cycle Simulation

Energy Engineering Research Laboratory, Central Institute of Electric Power Industry

We propose a frost-free air source heat pump water heater (ASHPWH) system with integrated solid desiccant, in which frosting can be retarded by dehumidifying air before entering the evaporator of ASHPWH. Heat exchanger coated by solid desiccant is arranged in tandem with evaporator. During desorption process, regeneration air is cycled between desiccant-coated heat exchanger and evaporator to recover sensible heat and latent heat of the regeneration air. Numerical simulation is carried out at the frosting conditions. The results show that COP is in the range of 3.3~3.8, which is 10~20% higher than that of conventional system using hot gas defrost.

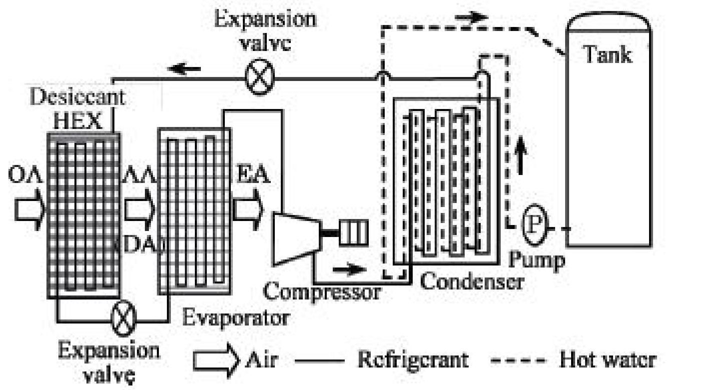


Fig.2 Open-air desiccant HEX type frost-free ASHPWH system

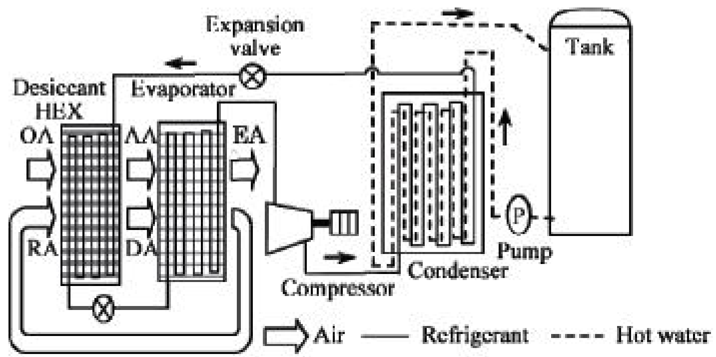


Fig.3 Air-recirculating desiccant HEX type frost-free ASHPWH system

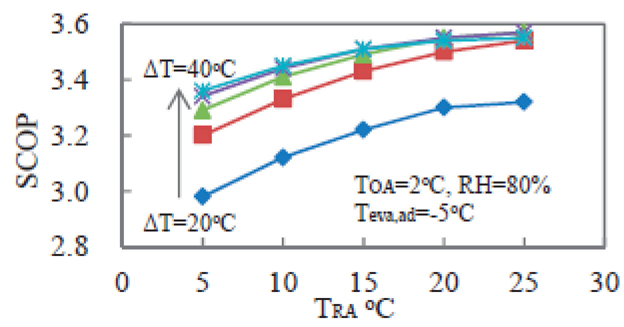


Fig.8 Effect of temperature differences between recirculating air temperature and desorption temperature in WH・DE mode

Development of All Aluminum Heat Exchanger for the Air Conditioners

In present all-aluminum heat exchanger for outdoor unit of cooling function air conditioner have a lot of demand
in China and Southeast Asia. And tend to increase demand in near future. Rather than the cross-fin type to use the round
tube and plate fin, the heat exchanger is a parallel flow type to use the micro channel tube and corrugated fin or serpentine type to use the round tube and plate fin. In this paper, examines about the performance and corrosion resistance of the heat exchanger

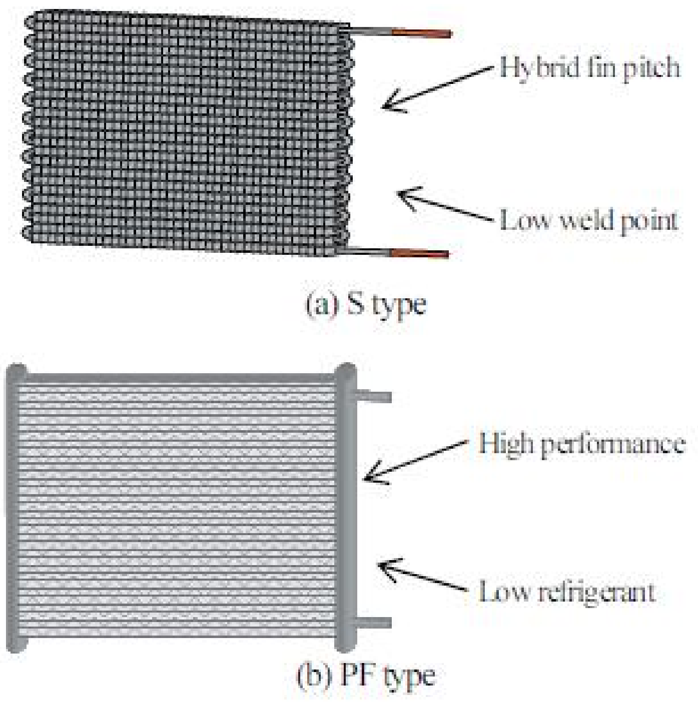


Fig. 2 Illustration of S type and PF type

New Heat Exchangers for Automobile Air Conditioner

To respond the needs of the downsizing and power saving, we developed two evaporators. One improves performance and is downsized by changing the pass constitution of the conventional RS evaporator, and becoming low-pressure loss. The Other is ECS evaporator which realizes saving energy consumption by having the ejector built-in in a tank, and collecting energy.

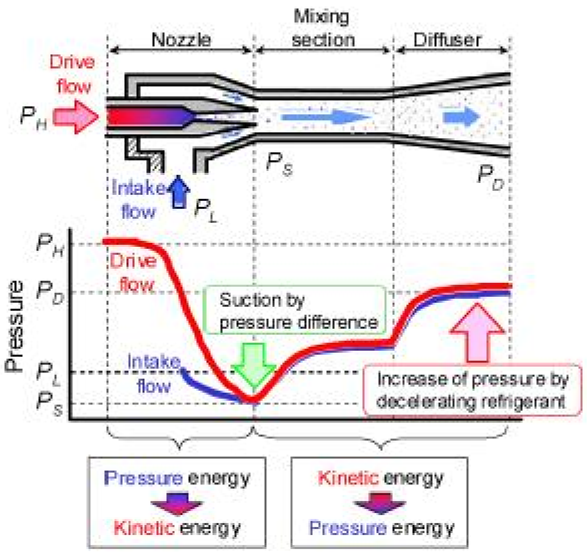


Fig.4 Ejector Operaing Principle.

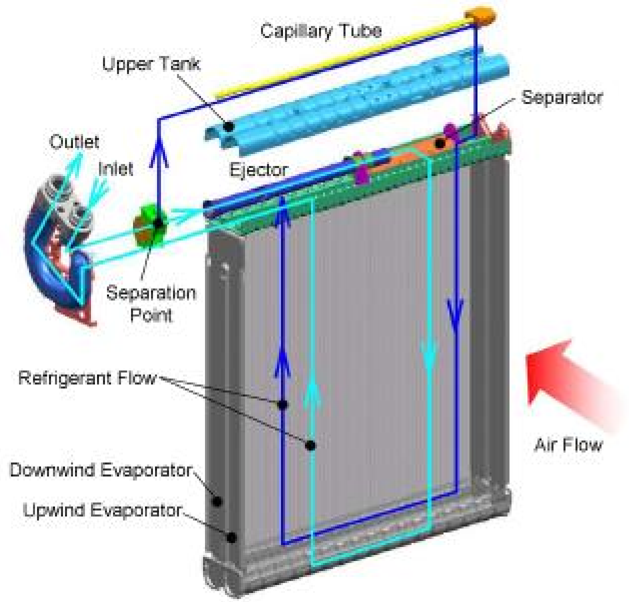


Fig.5 Structure and Refrigerant Paths of ECS Evaporator.

Second Announcement

The 24th IIR International Congress of Refrigeration

Improving Quality of Life, Preserving the Earth

August 16 – 22, 2015
Yokohama, Japan

http://www.icr2015.org

International Institute of Refrigeration (IIR)

Japan Society of Refrigerating and Air Conditioning Engineers (JSRAE)

Purpose of the 24th International Congress of Refrigeration

IIR International Congresses of Refrigeration, ICR, are milestone events. IIR congresses have been held once every 4 years since 1908. Each congress brings together large numbers of refrigeration stakeholders from all parts of the world. At each ICR, cryology, gas processing, thermodynamics, equipment and systems, biology and food technology, storage and transport, air conditioning, heat pumps, and energy recovery are all covered in depth, and important technical issues are discussed.

In 2015 (August 16 – 22), the 24th ICR will be held at Yokohama, Japan. The programme, calls for papers, registration, technical tours, and a wide range of historic and exciting places will be announced on the congress Web site (*www.icr2015.org*).

About IIR

The International Institute of Refrigeration (IIR, *www.iifiir.org*) is the only independent intergovernmental organization which promotes knowledge of refrigeration and associated technologies to address today's major issues, including food safety, protection of the environment (reduction of global warming, prevention of ozone depletion), and the development of the least developed countries (food, health). The IIR commits itself to improving quality of life and promotes sustainable development.

About JSRAE

In 1925, the Japan Society of Refrigerating and Air Conditioning Engineers, JSRAE (*http://www.jsrae.or.jp/jsrae/Eindex-2.html*), was established to develop and disseminate knowledge on refrigerating and freezing technology and related scientific technologies nationwide and also internationally. Since then, it has functioned over 85 years as a non-profit academic organization in the field.

Venue

PACIFICO YOKOHAMA provides a large space that meets the needs of world-scale conventions. Yokohama has very good access from the centre of Tokyo (30 min.), Narita International Airport (90 min.), and Haneda International Airport (25 min.) and in addition to the fine convention facilities has many wonderful hotels. As a cosmopolitan Japanese city, Yokohama has hosted numerous international conferences in the past, e.g. APEC 2010. Yokohama has truly first class international conference facilities and top-level infrastructure satisfies a variety of interests and offers budget plans for conference participants.

Important Dates

Abstract submission starts: April 1, 2014
Abstracts due date: October 10, 2014
Pre-Registration / Hotel bookings: winter 2014
Early Registration due date: May 8, 2015

Contact Us

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