RESEARCH ON NATURAL REFRIGERANTS IN JAPAN

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INTRODUCTION

In Japan, we have the highest level technologies for natural refrigerant use in the world.

CO_2
- Residential heat pump water heater
- Commercial heat pump water heater
- Car air-conditioner
- Show case
- Bending machine

NH_3
- Industrial refrigerator

HC
- refrigerator for residential use

Water
- Centrifugal chiller
- Absorption chiller
- Absorption heat transformer

Air
- Air cycle refrigerator
- Desiccant air-conditioning


CO_2 Residential heat pump


CO_2 Commercial heat pump


CO_2 Car air-con.

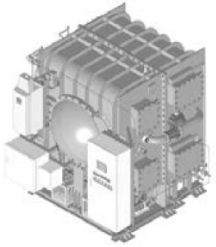

CO_2 Show case


CO_2 Bending


NH_3 industrial refrigerator


HC residential refrigerator

Air cycle ref.


H2O Centrifugal chiller


Absorption chiller


Absorption heat transformer


Desiccant air-conditioner

Development of these systems are supported by fundamental R&Ds
- Heat and mass transfer
- New devices development -heat exchanger, compressor, ejector……
- System technology –system development, simulation, control…..

FUNDAMENTAL RESEARCH

Fundamental research –Heat transfer

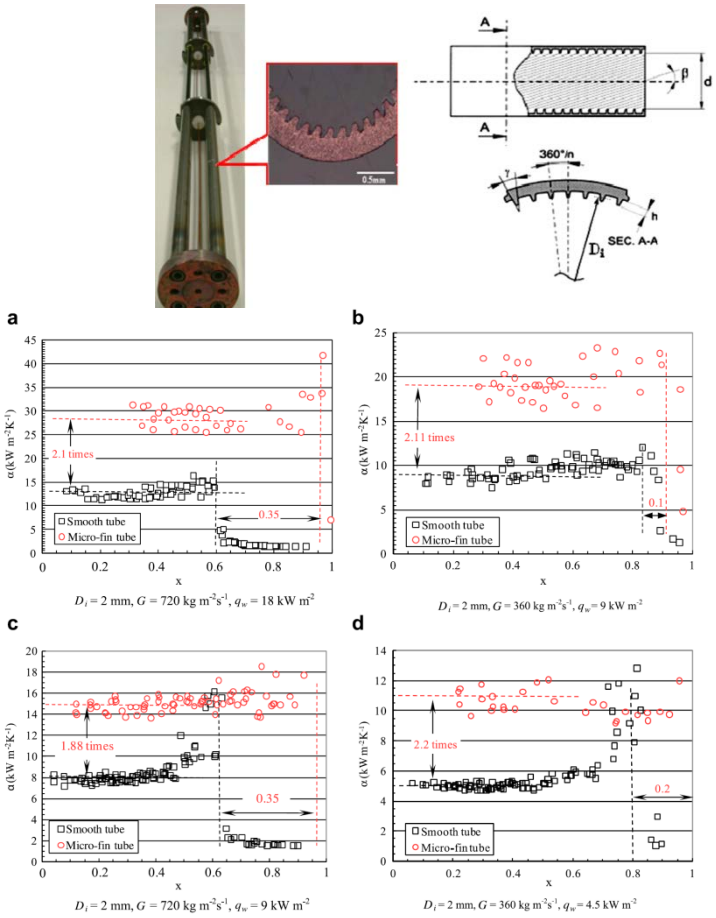


Fig. Comparison of CO_2 evaporating heat transfer for smooth tube and Micro-fin tube 2mm

Chaobin Dang, Nobori Haraguchi, Eiji Hihara, international journal of refrigeration 33(2010) 655–663

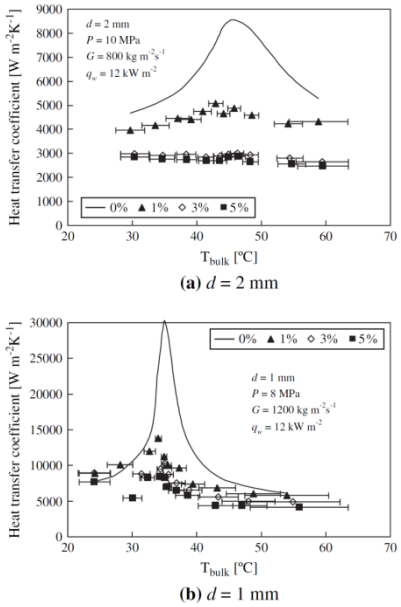


Fig. Gas cooler heat transfer coefficient Effect of oil contamination, 1,2 mm

Chaobin Dang, Koji Iino, Ken Fukuoka, Eiji Hihara, International journal of refrigeration 33(2007) 724–731

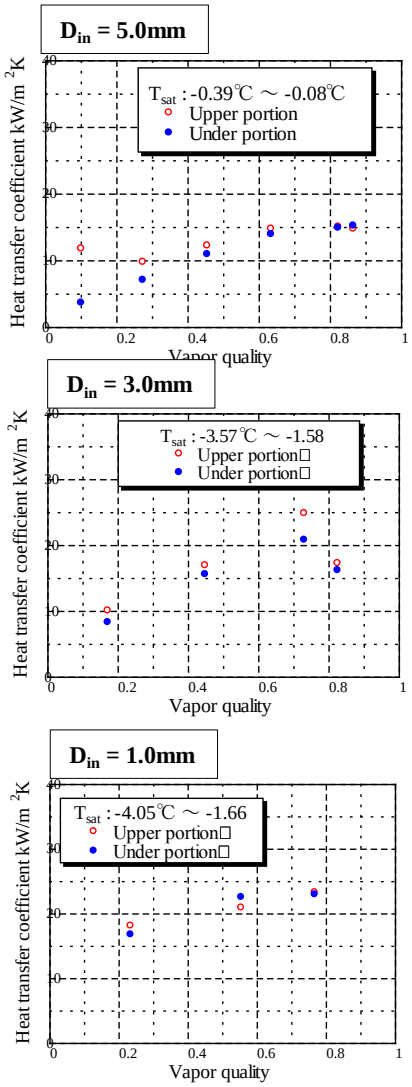
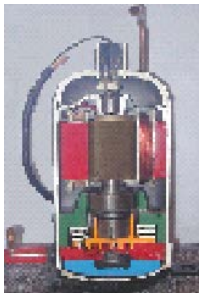


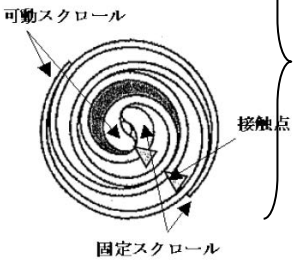
Fig. Ammonia mini channel Evaporating heat transfer

NEW DEVICE DEVELOPMENT

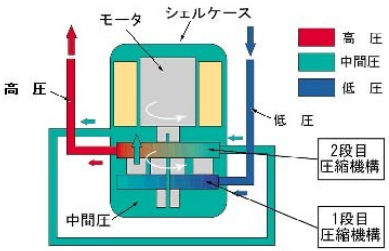
Comp.



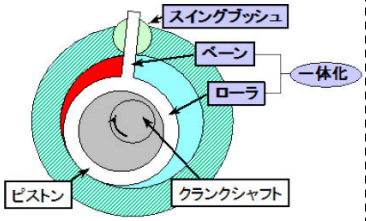
Scroll



Two stage



Swing



Rotary

Combi.. of Rotary and scroll

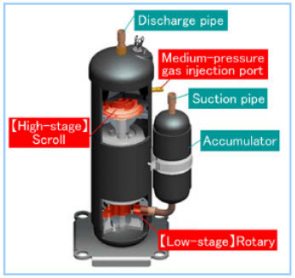
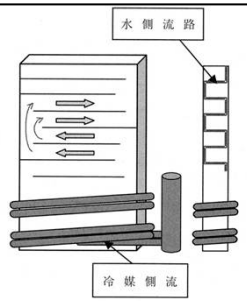
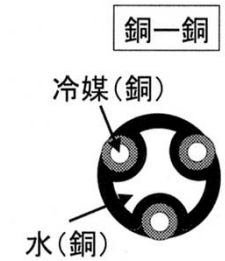


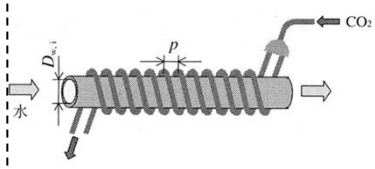
Figure 1 Two-stage GSR compressor

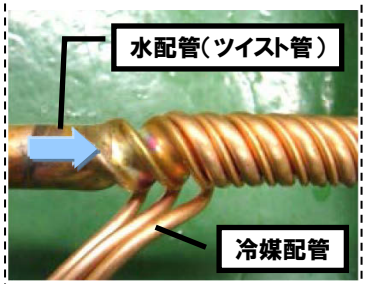
CO_2-Water Heat ex.





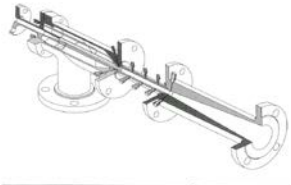
Piping embedded

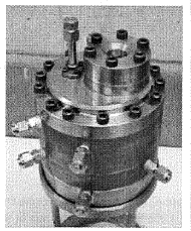




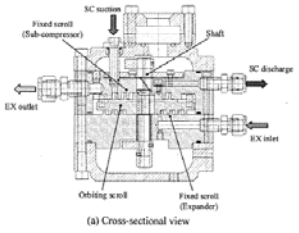
Ejector Expander

Ejector





Expander



(a) Cross-sectional view

NEW SYSTEM~ABSORPTION HEAT TRANSFORMER

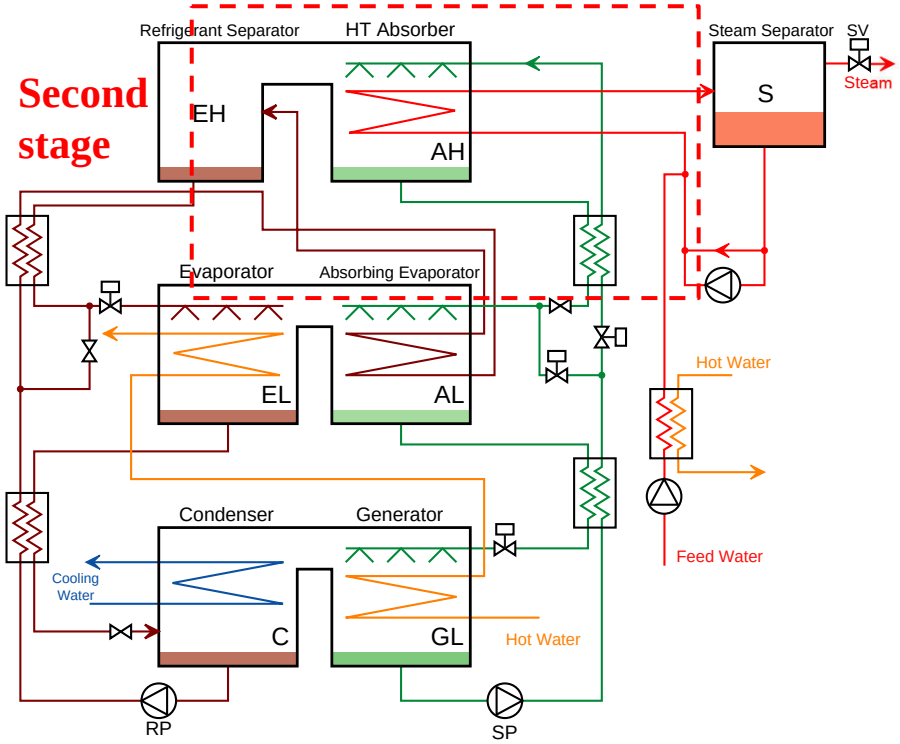


Fig. Double stage absorption heat transformer

(National project by NEDO)

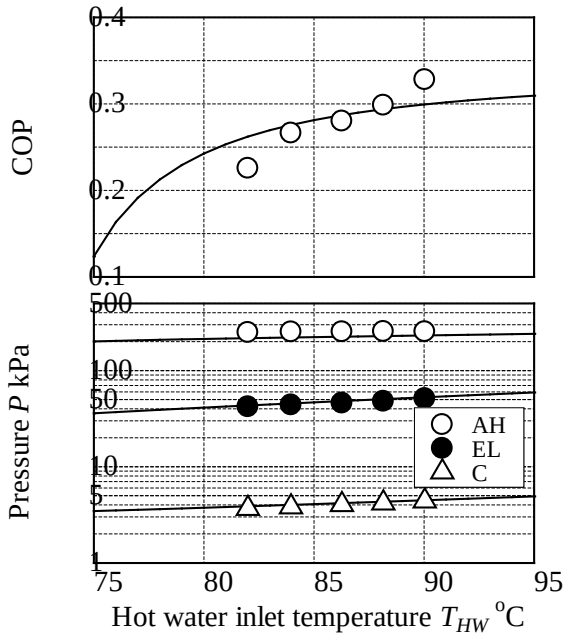


Fig. Results

With this cycle, 180 ℃ steam can be produced fro 90 oC waste hot water.

NEW SYSTEM～

Evaluation of CO_2 refrigeration system for convenience store

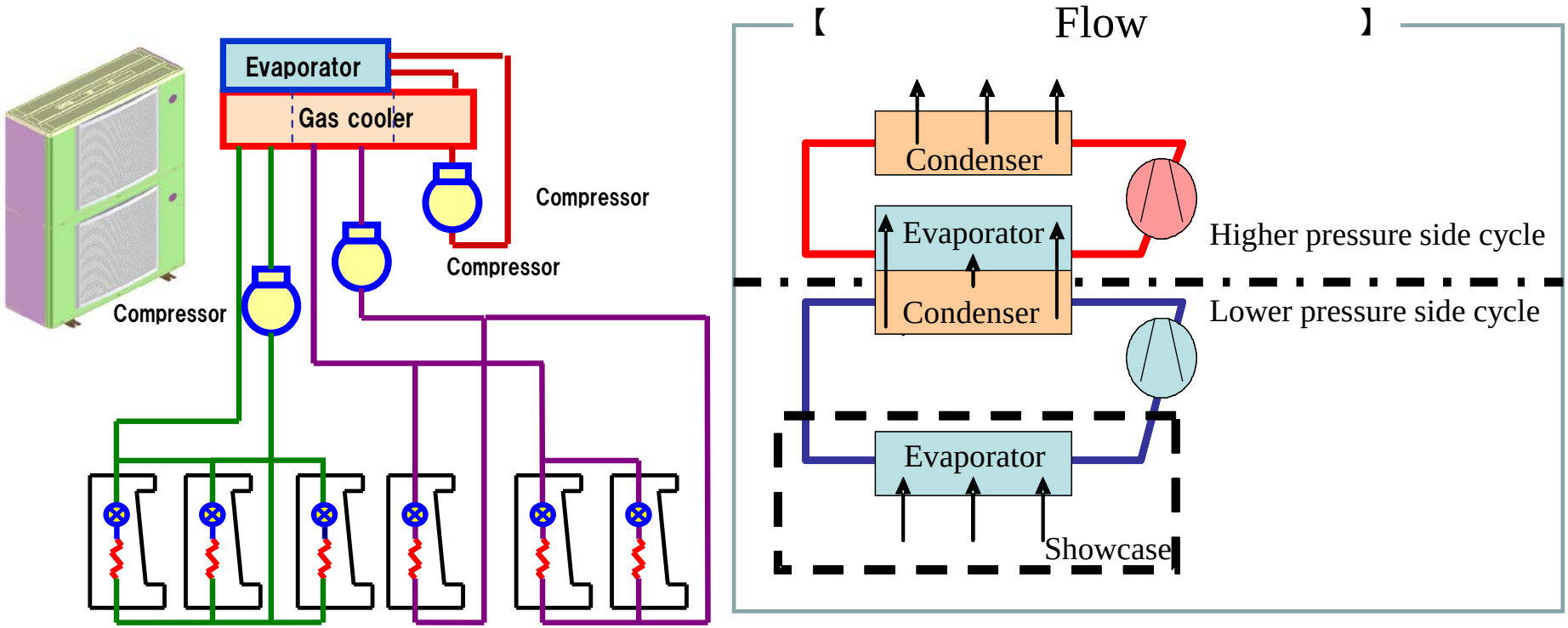
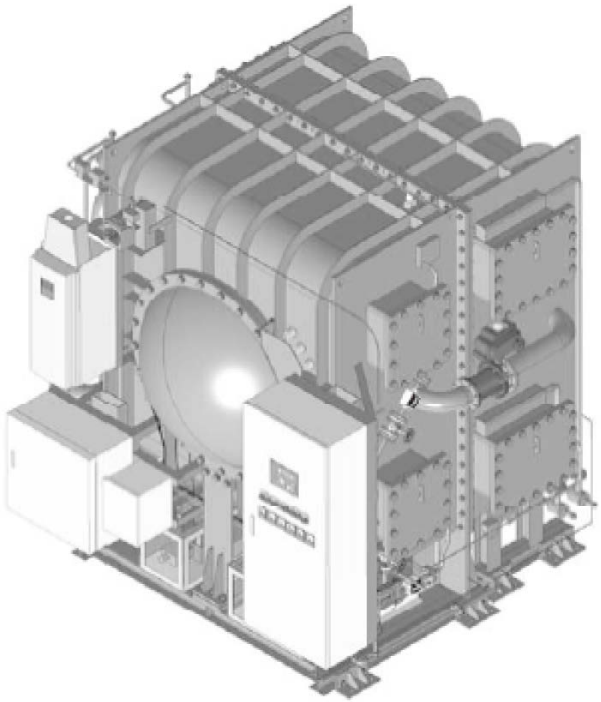


Fig. Cascade refrigeration system SANDEN

National project by NEDO

NEW SYSTEM ～CENTRIFUGAL CHILLER



Feature

- Water is refrigerant
- New compressor for water refrigerant is developed.
- COP 5.1
- All most the same size with conventional system.
- Oil free
- Cooling capa. 100 USRT

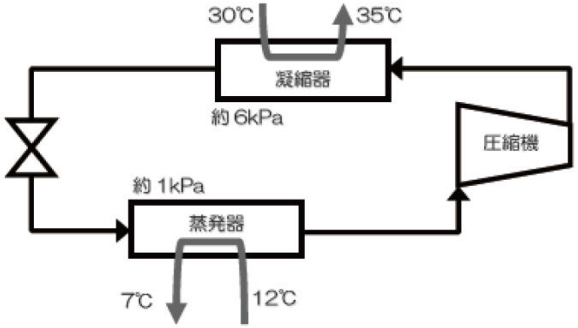


Fig. Water refrigerant centrifugal chiller

Produced by Kawasaki

表２　製品機仕様（参考）

冷凍能力		USRT(kW)	100(352)
COP		-	5.1
消費電力		kW	69
電動機定格		kW	110
冷媒		-	水
冷水	入口温度	℃	12
	出口温度	℃	7
	流量	m3/h	60.5
	圧力損失	kPa	80
	接続口径	-	100A
冷却水	入口温度	℃	30
	出口温度	℃	35
	流量	m3/h	74.4
	圧力損失	kPa	80
	接続口径	-	100A
駆動方式		-	インバータ
冷媒ポンプ		kW	0.2
真空ポンプ		W	50
電源		-	3φ、400/440V (50/60Hz)
サイズ	長さ	m	2.46
	幅	m	2.45
	高さ	m	2.55
質量		t	約 7.5

山内正史，水を冷媒としたターボ冷凍機，日本冷凍空調学界，平成２４年度最新の冷媒と利用技術の動向，セミナー資料

NEW SYSTEM~CO_2 HEAT TRANSPORTATION

Heat transportation system whose refrigerant is CO_2

Conventional

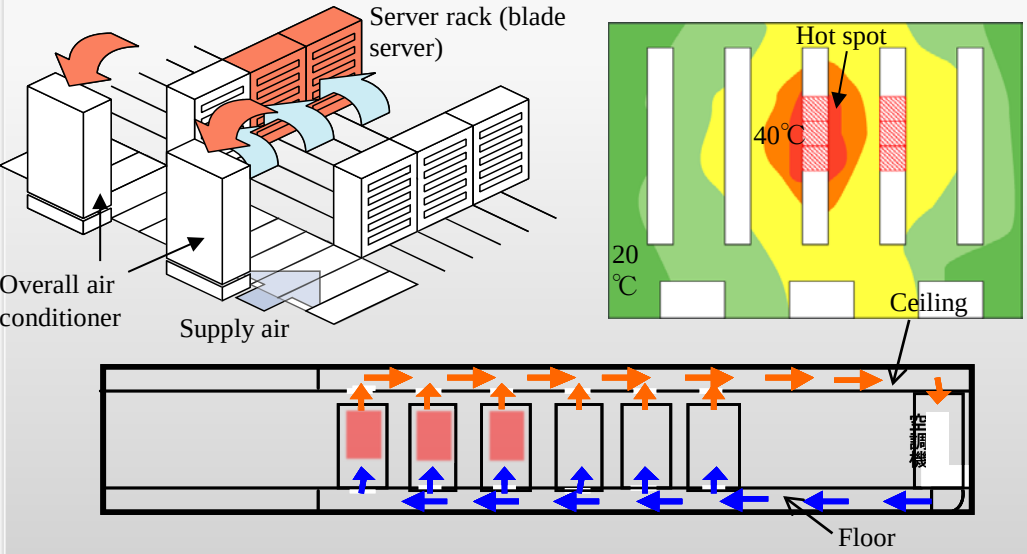


Fig. Conventional data center
(Overall air-conditioning method)

Hot spot occurs ➡ some server stops
Fan power increases
Temp. of circulated air decrease ➡ Energy use increase

Objective

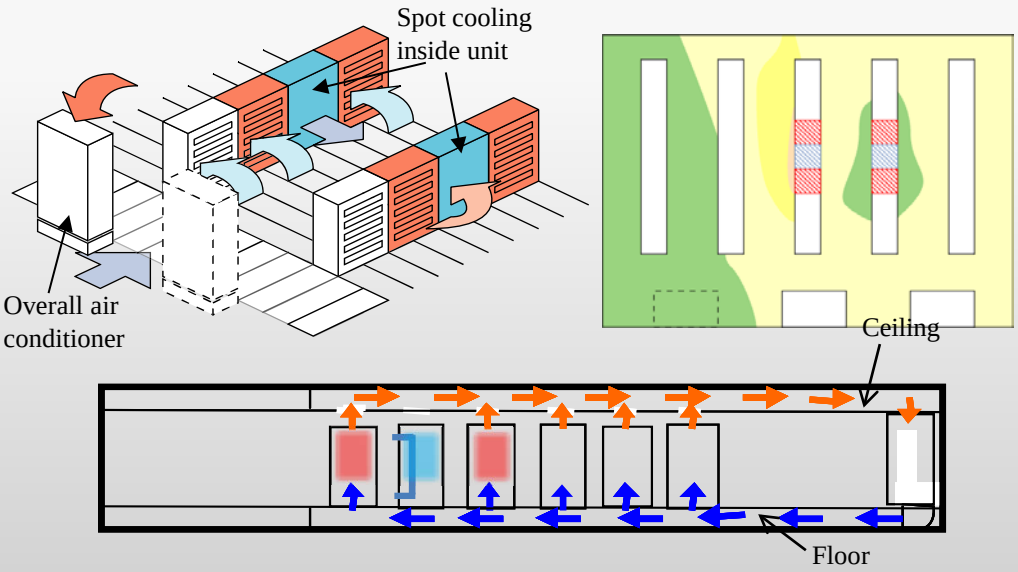
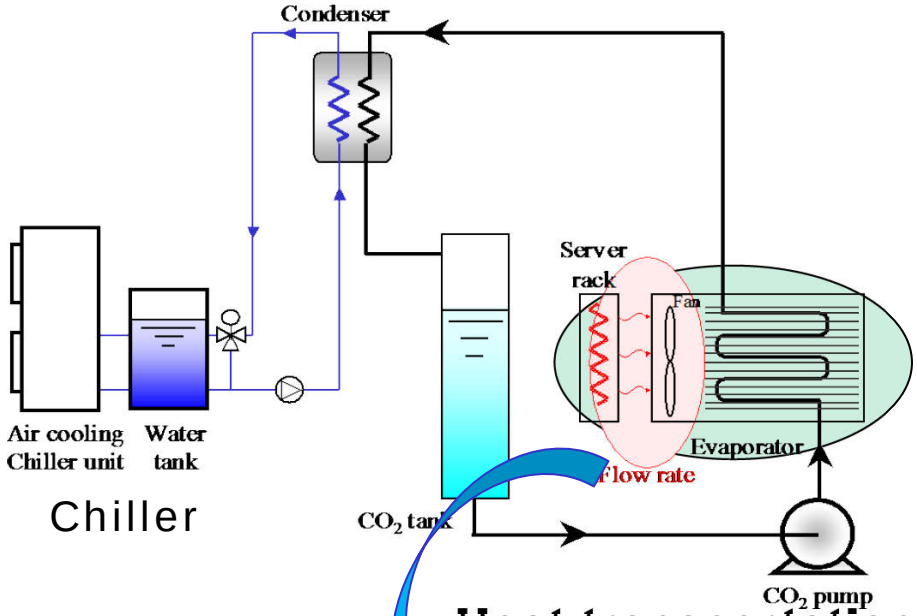
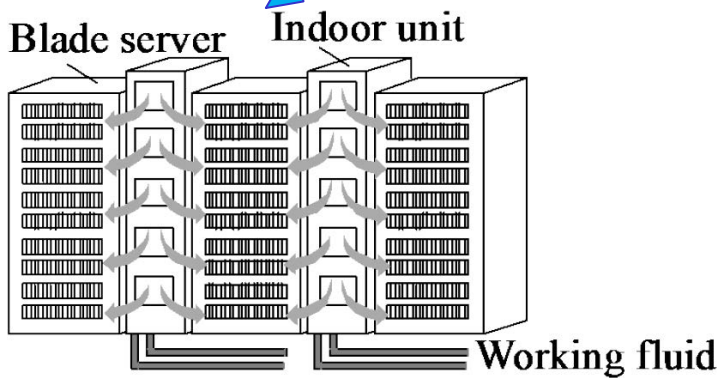


Fig. Spot- air conditioning system (combining spot cooling unit with overall air-conditioner)

NEW SYSTEM~CO_2 HEAT TRANSPORTATION





Spot cooling system consists of
- chiller
- heat transportation system
- spot cooling unit

To realize effective spot cooling method, heat transportation system is very important.

This system has very good potential with higher performance because CO_2 is good transport medium.

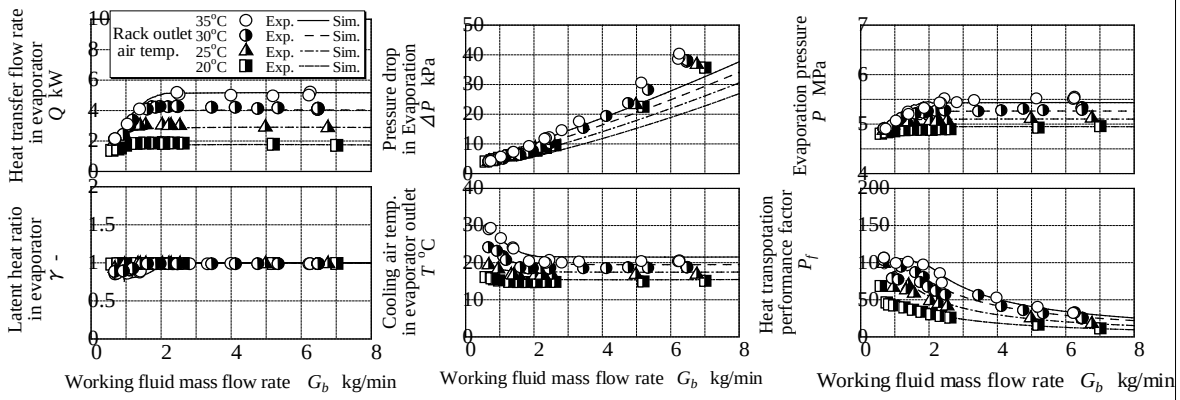
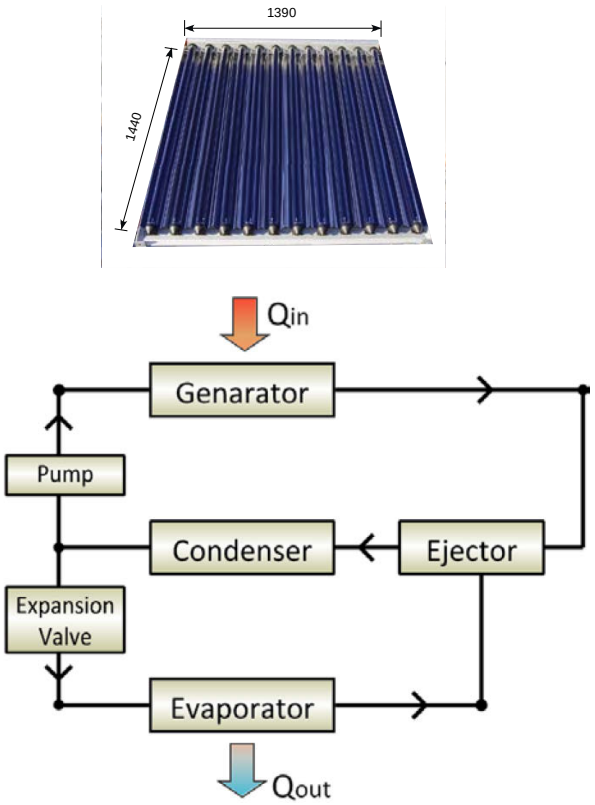


Fig. Results

NEW SYSTEM ~HC EJECTOR SOLAR COOLING



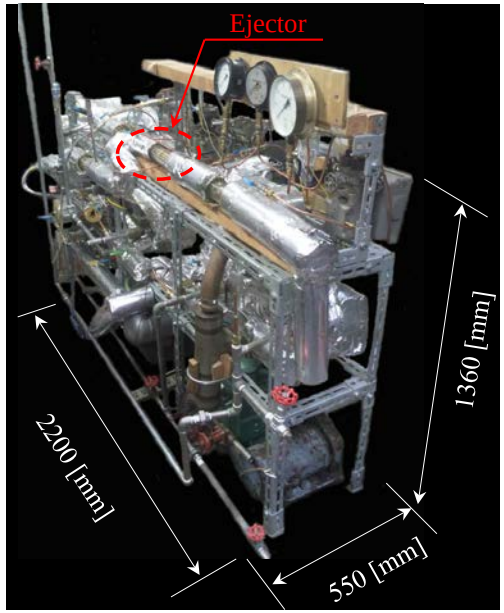
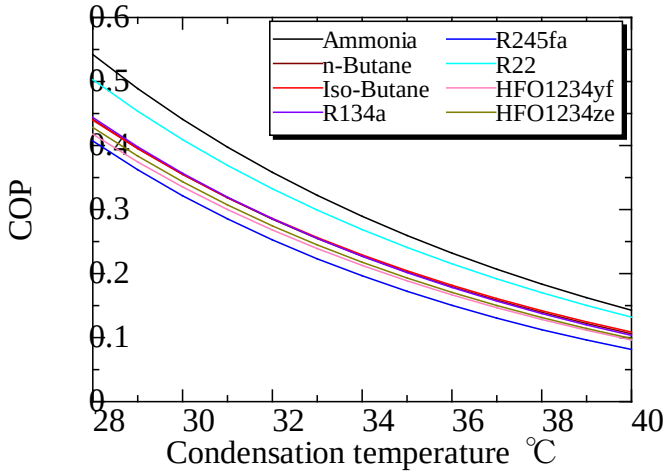
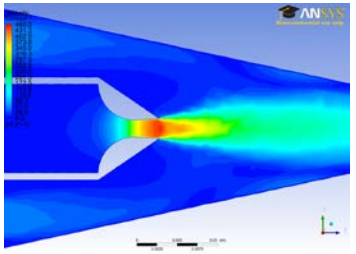


Fig. Ejector heat pump system





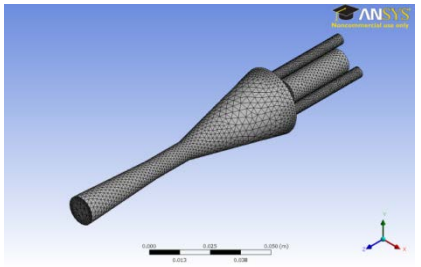
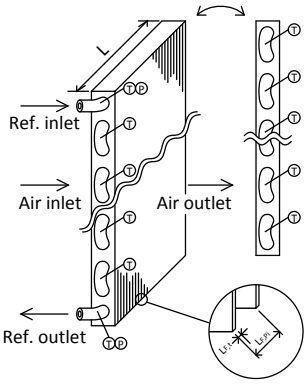


Fig. Simulation results

This system is ejector heat pump system without compressor.
This system can be driven by solar energy.
The best refrigerant for this system is ammonia, then HC.
We are going to realize this system with natural refrigerant.

SIMULATION TECH. ~HEAT EXCHNGER



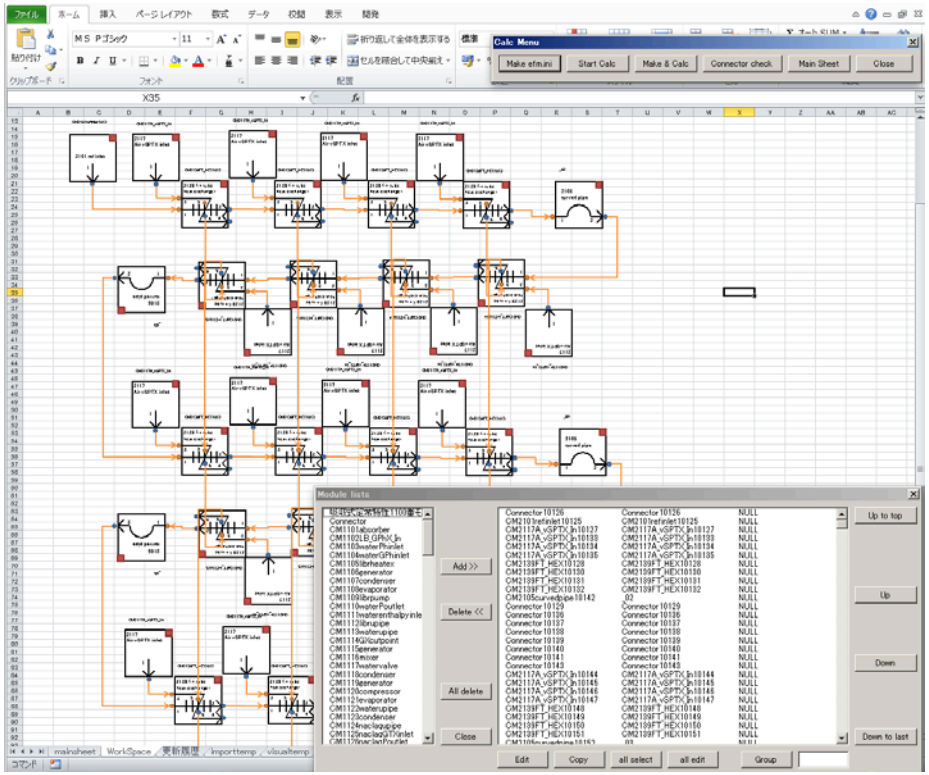


Fig. System flow

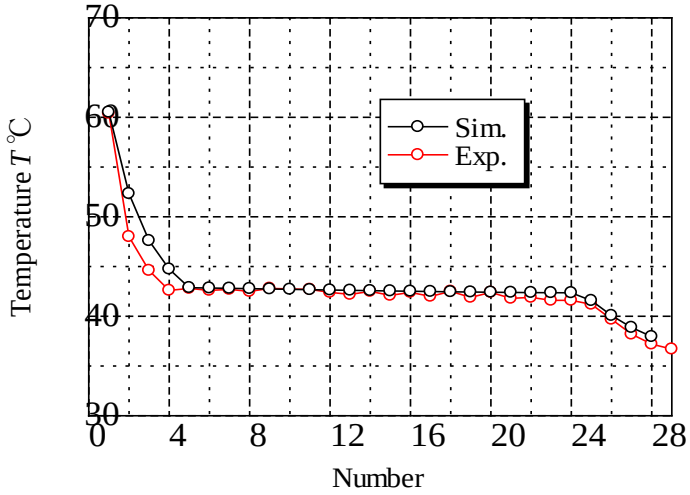


Fig. Results of condenser

We develop the system simulator “Energy flow +M”. This simulator is user friendly because this uses GUI.
This simulator can calculate performance of heat exchanger with high precision.

SIMULATION TECH. ~SYSTEM1

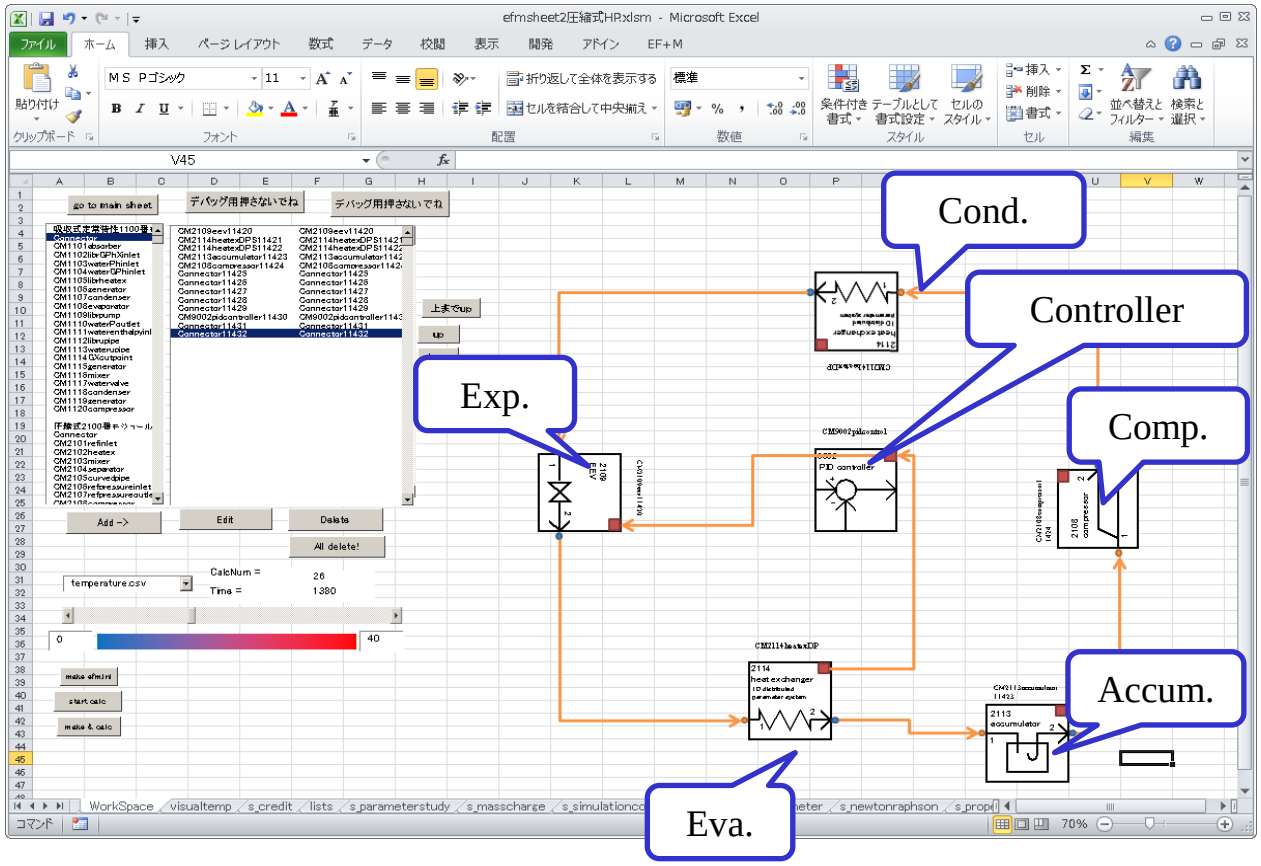


Fig. Simulator “Energy flow+M”

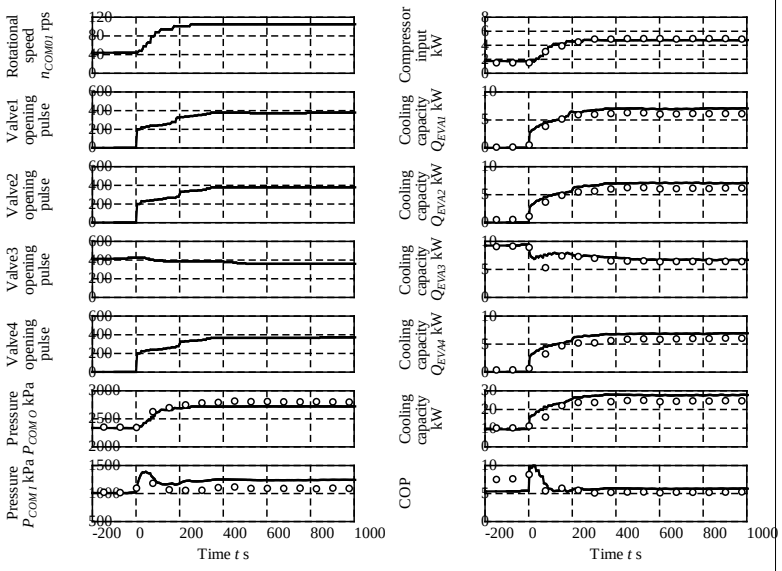


Fig. Simulation results
For dynamics of comp. cycle

With this simulator, we can change the refrigerant easily.
We can estimate every performance of the system that uses different refrigerant.

SIMULATION TECH. ~SYSTEM2

HC drop-in test.

Fig. Using R410a system for drop in test

Table Theoretical compression cycle

	R 410A (Original)	HC 600a (Drop-in)
Evaporation temperature, ℃	10.0	
Condensation temperature, ℃	45.0	
Sub cooled temperature, ℃	5.0	
Super heat temperature, ℃	5.0	
Adiabatic efficiency, -	1.0	
Theoretical COP, -	6.40	7.13
Refrigerant flow rate per a unit cooling capacity, kg/(s･kW)	0.0061	0.00357

Table Exp. & Sim. result (Rated cooling)

Refrigerant	R 410A (Original)		HC 600a (Drop-in)	
	Exp.	Sim.	Exp.	Sim.
Cooling capacity, kW	2.84	2.83	0.887	0.877
Electric input, kW	0.692	0.685	0.177	0.173
COP, -	4.11	4.13	5.00	5.07

Table Exp. & sim. result (Half load cooling)

Refrigerant	R 410A (Original)		HC 600a (Drop-in)	
	Exp.	Sim.	Exp.	Sim.
Cooling capacity, kW	1.36	1.47	0.370	0.430
Electric input, kW	0.250	0.260	0.0836	0.0968
COP, -	5.42	5.62	4.43	4.45

HC is very good refrigerant theoretically.
But only with drop in, the performance is getting worse.
We are now trying to optimize the air-conditioner with HC by simulation.

SIMULATION TECH. ~SIMULATOR

デモンストレーション