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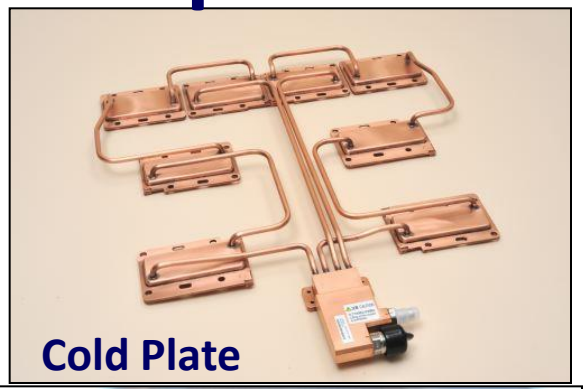
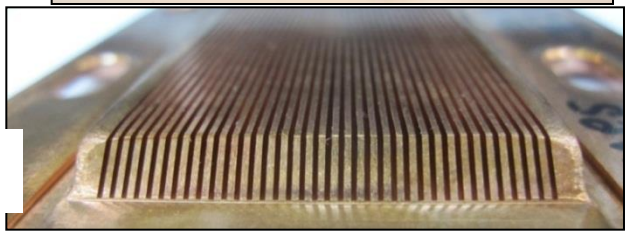
Liquid Cooling

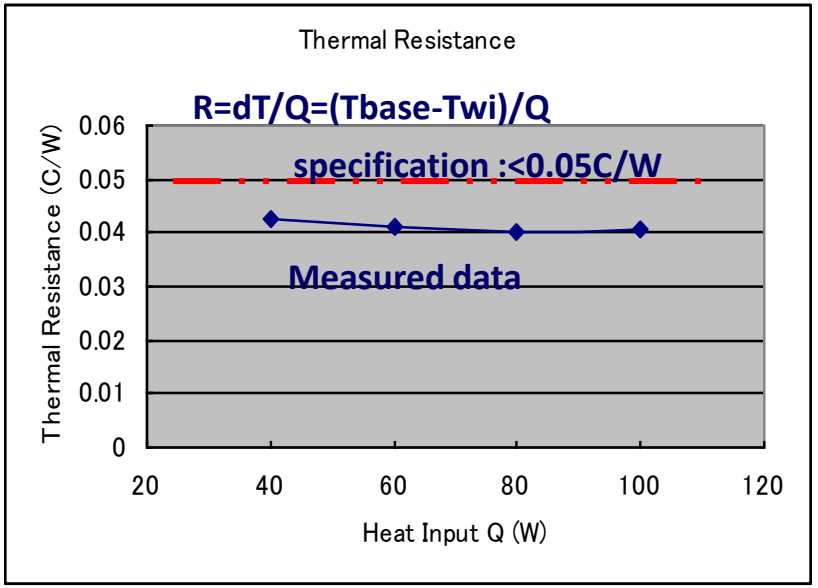
Cold Plate for Super Computer

CPU 20kW/Rack x 848 racks

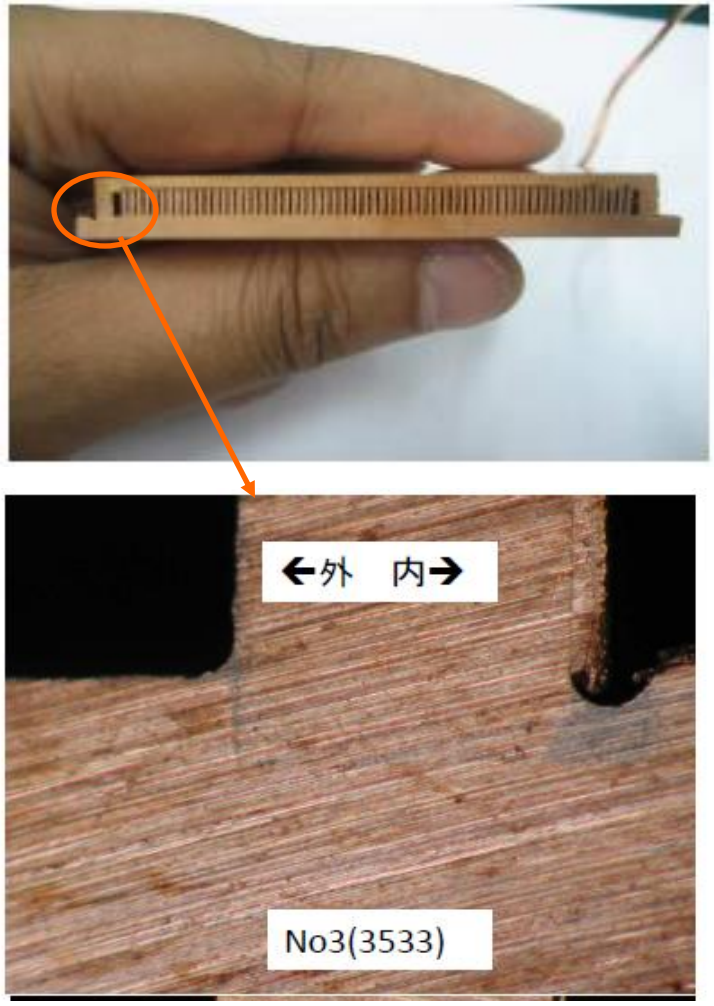
17MW/ a machine



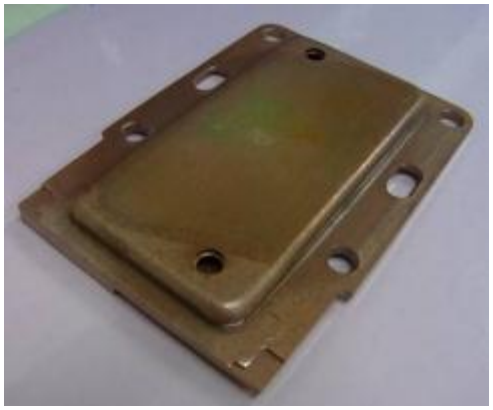


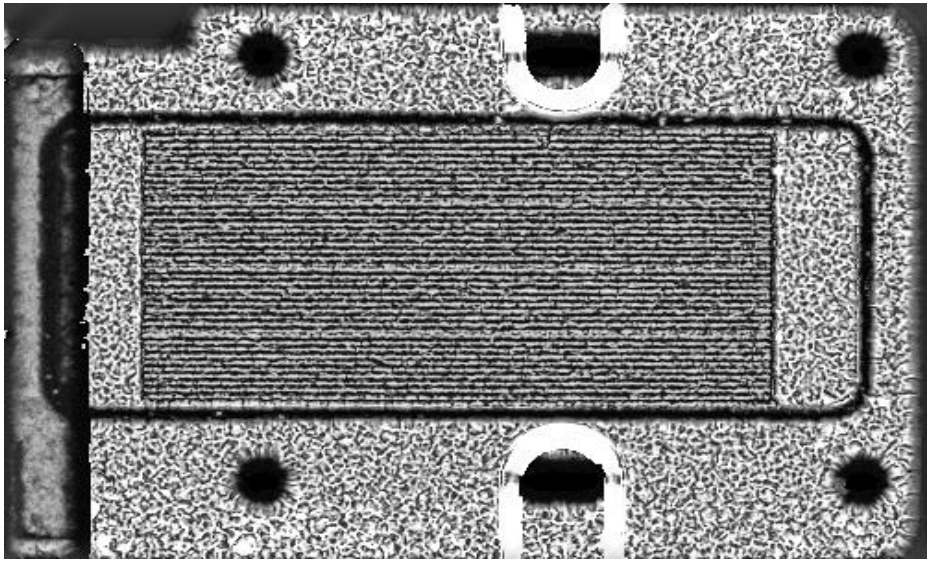


Liquid Cooling Cold Plate



Brazed Cold Plate
(Cross Section)

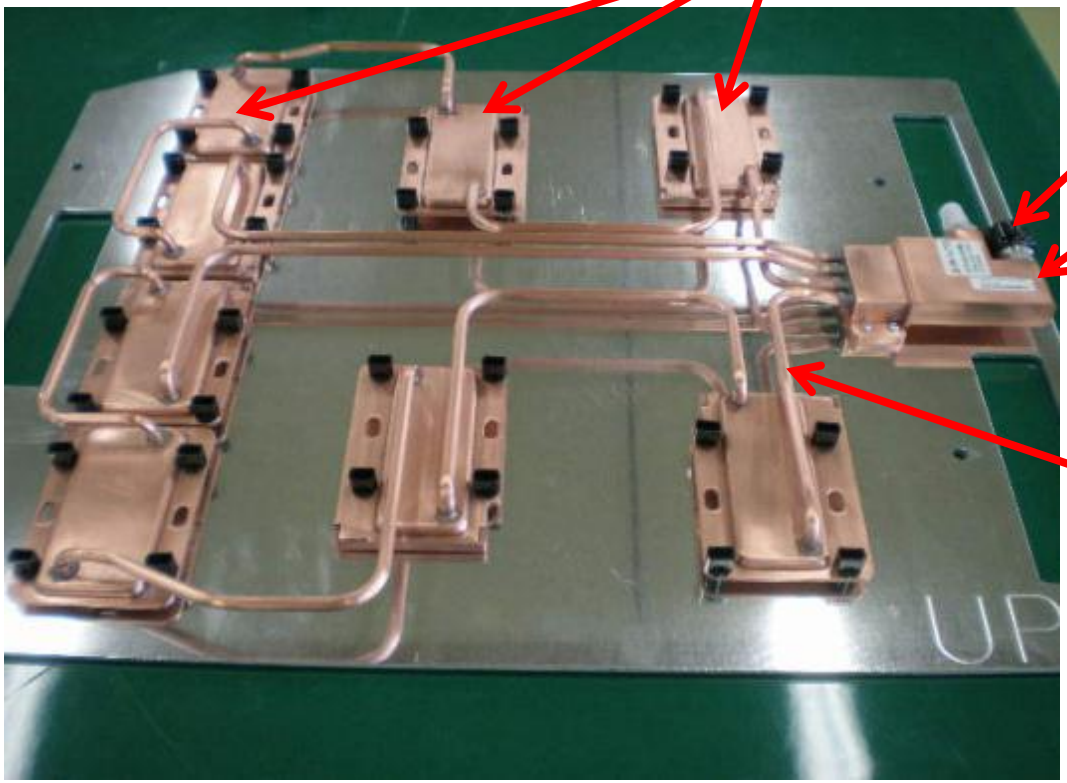




Brazed Sample Inspection by
Ultrasonic Microscope

Cold Plate Assembly

Coupler



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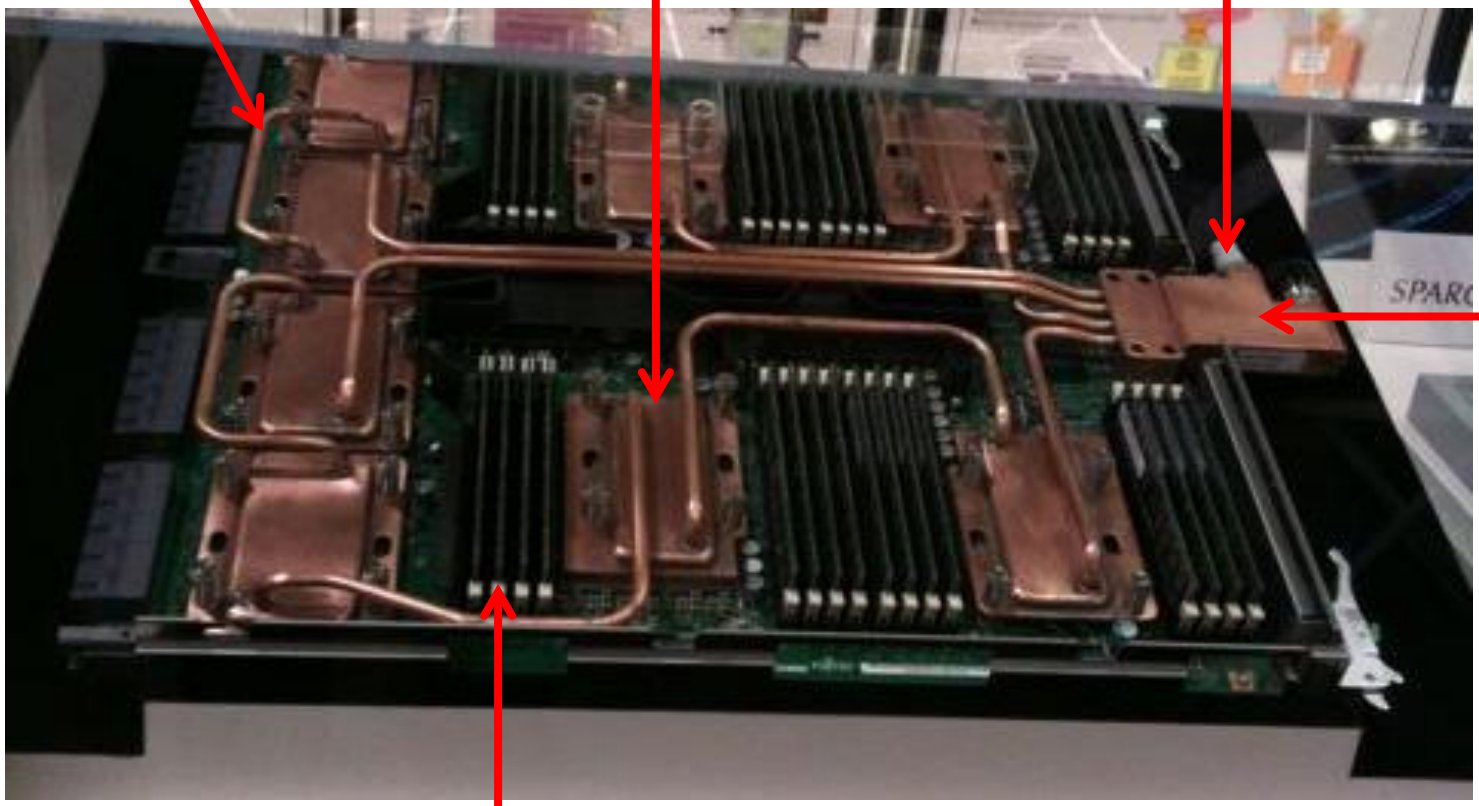
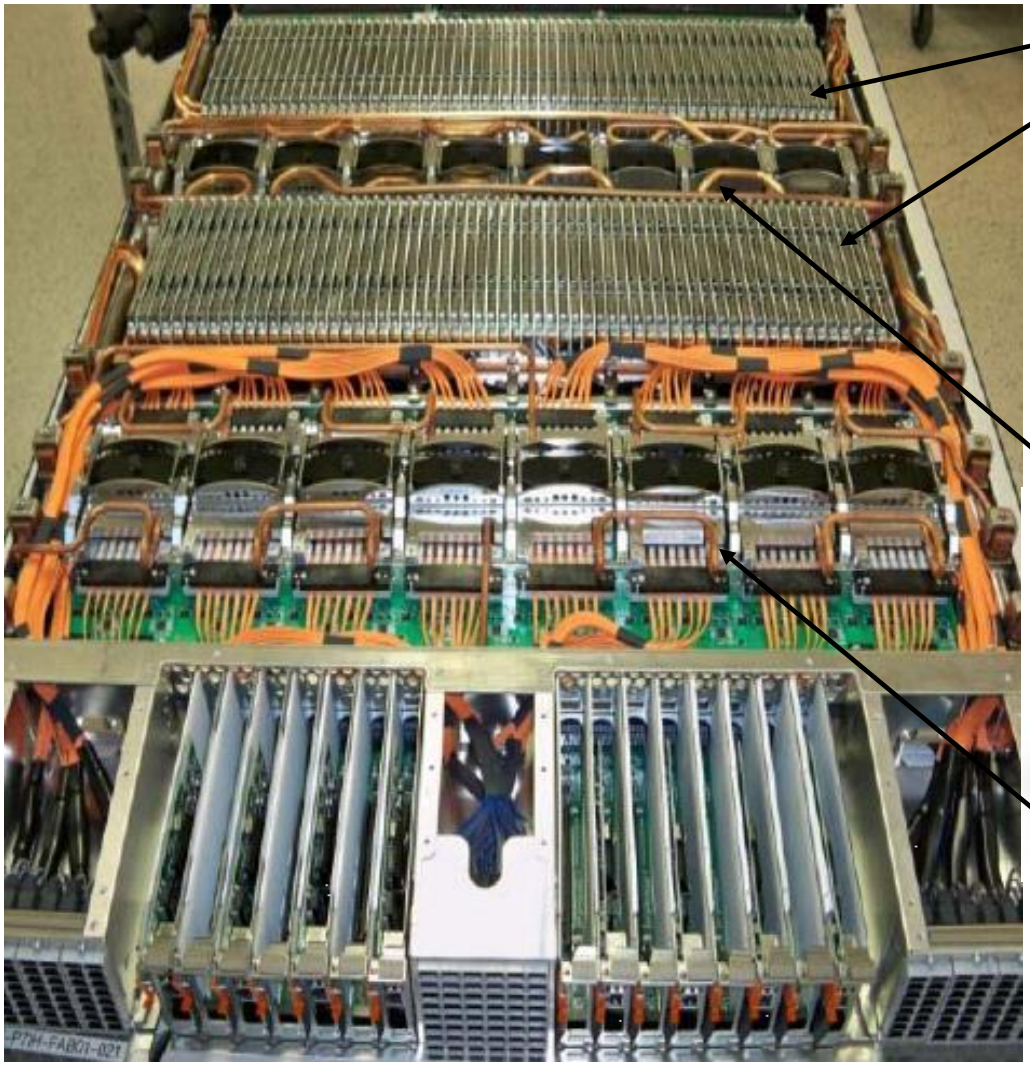
Cold Plate assembly on the Motherboard

For super computer

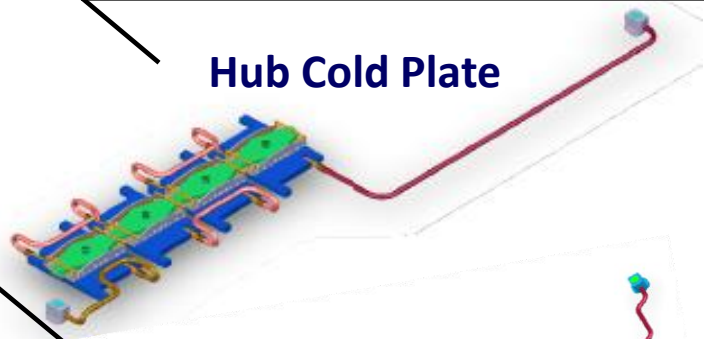


Cold Plate and Heat Pipe Cooler for a Super Computer

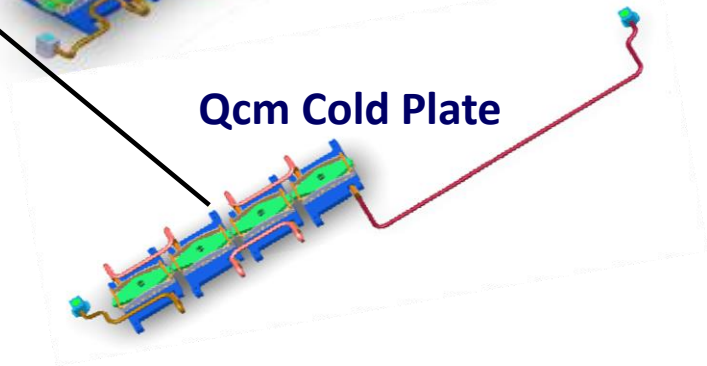
Heat Pipe Heat Spreader for DIMM



Hub Cold Plate

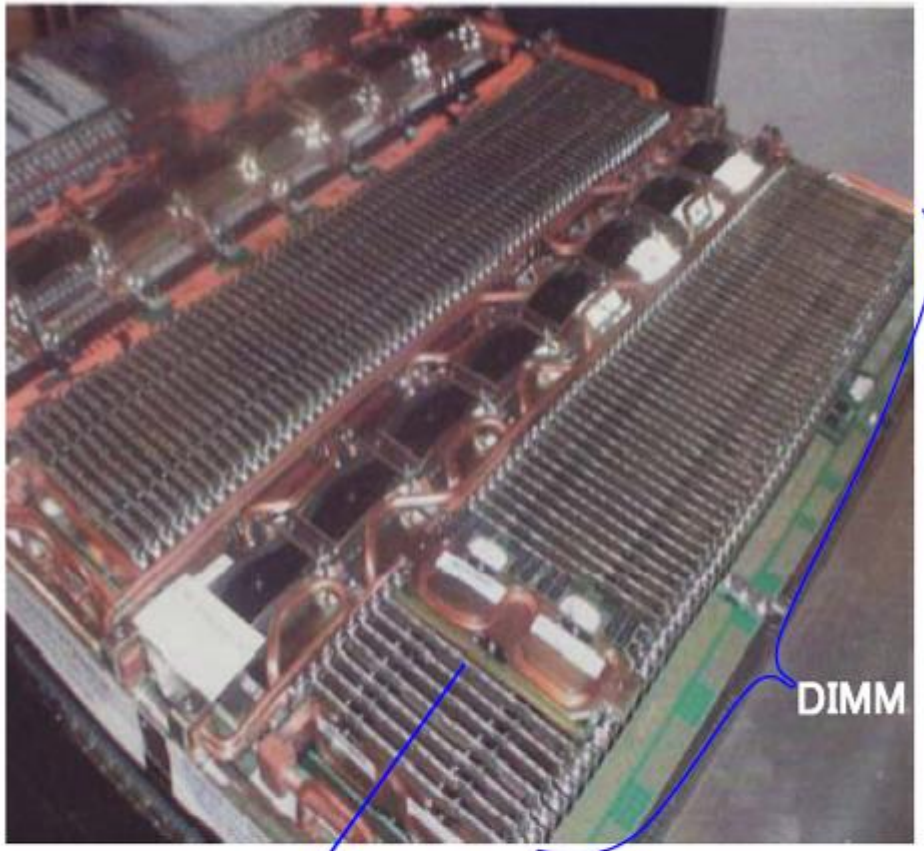


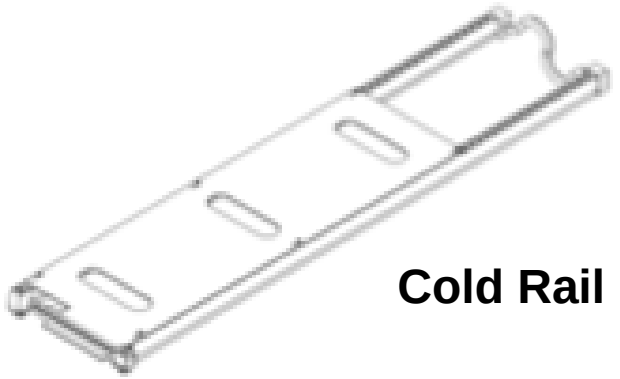
Qcm Cold Plate



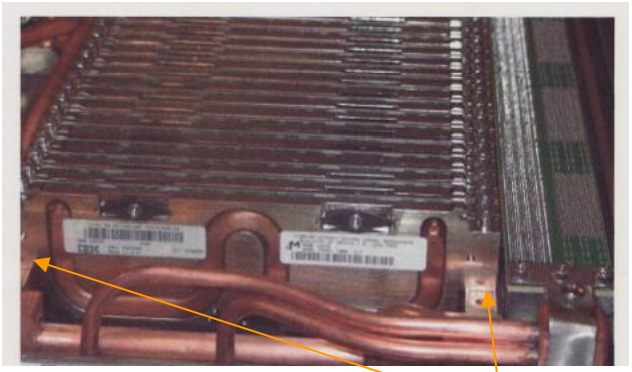
DIMM (Dual Inline Memory Module) Cooling

Cooling method of DIMM : Liquid cooling + Heat spreader





Cold Rail



Cold Rail

Heat spreader Plate(DMS1) with Heat pipe

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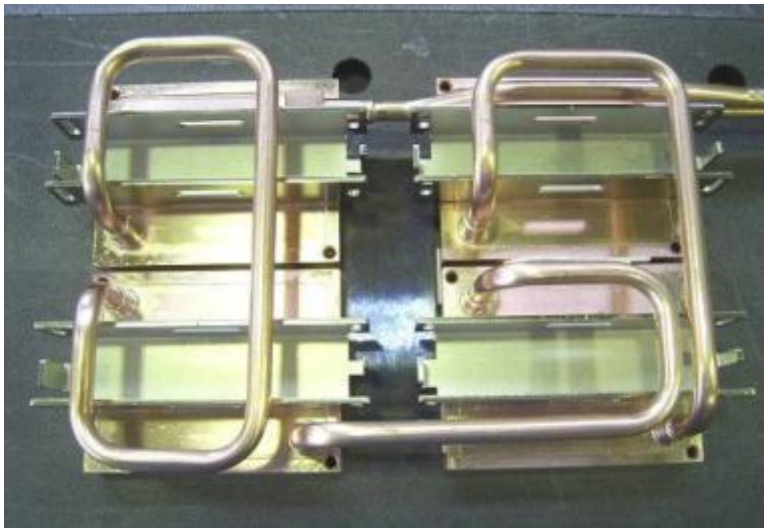
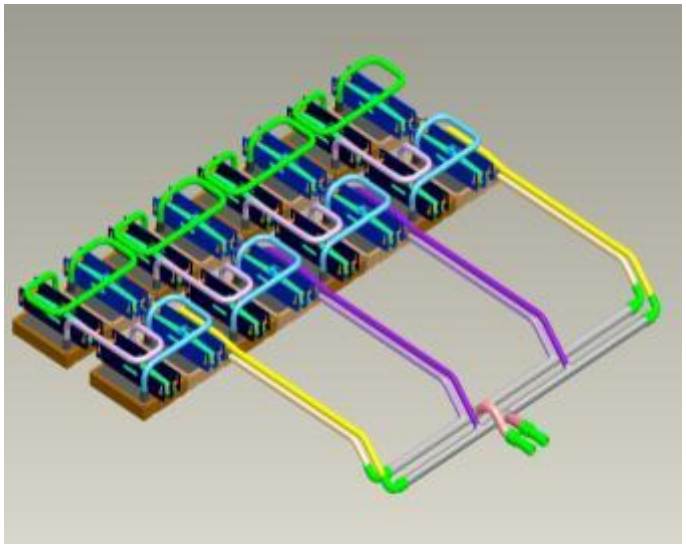
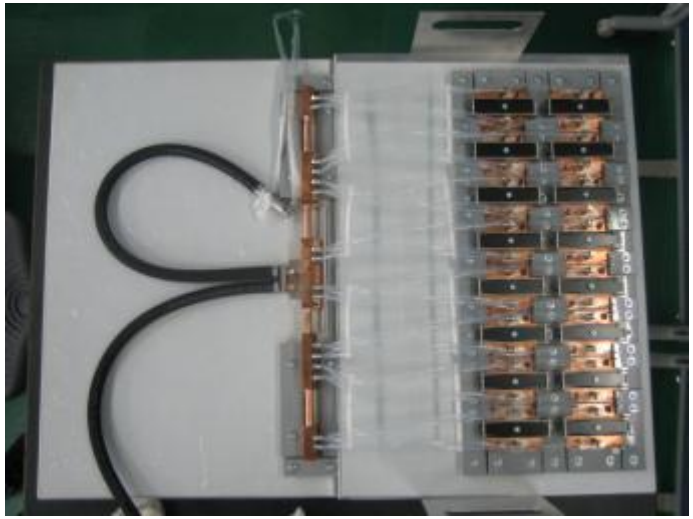
Mini Channel Cold Plate Assemblies: Different Types







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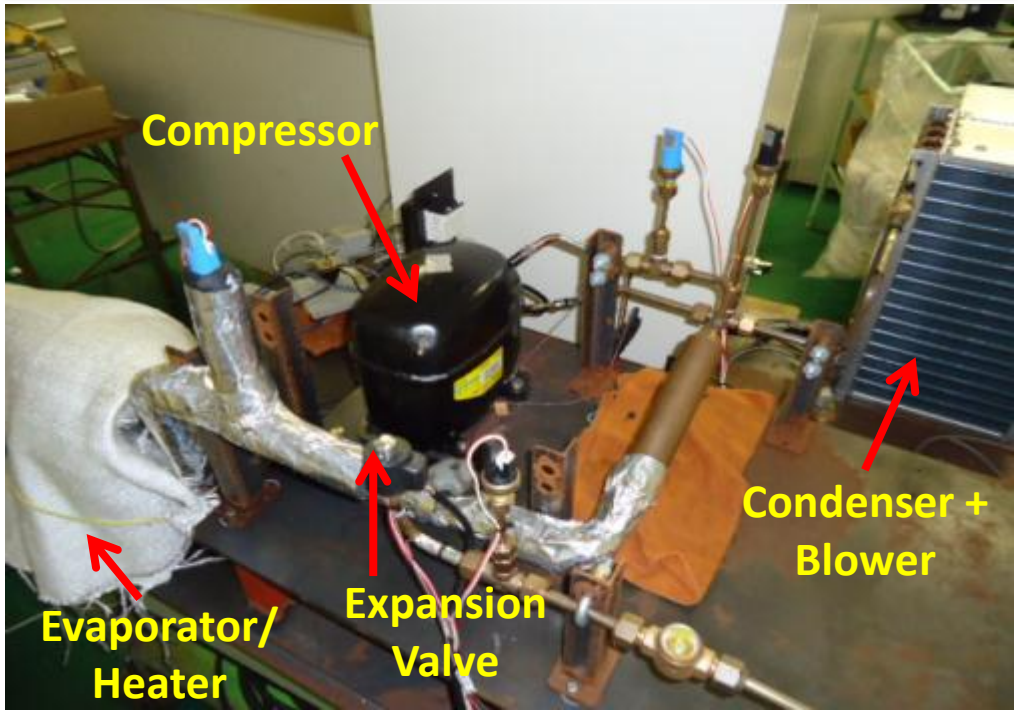
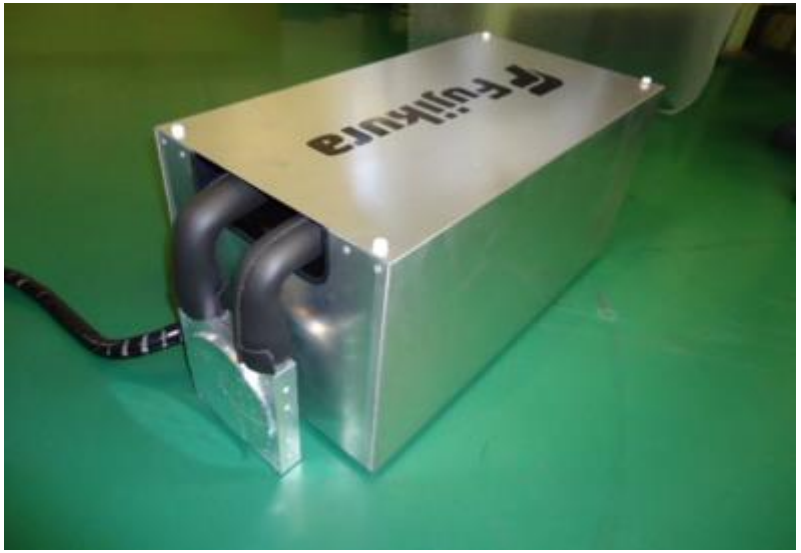
Modular Refrigerator

Fujikura MRU Development

Prototype # 1 (Proof of Design)

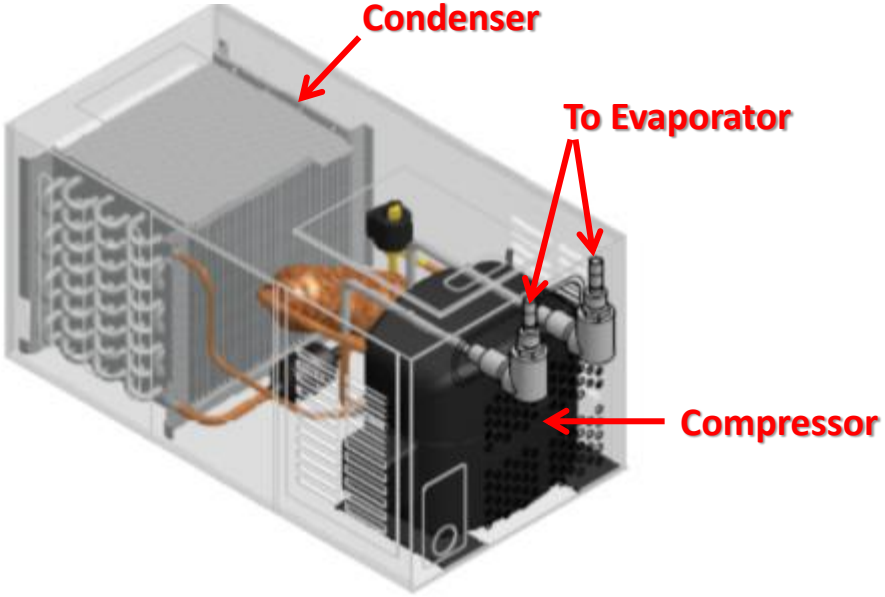


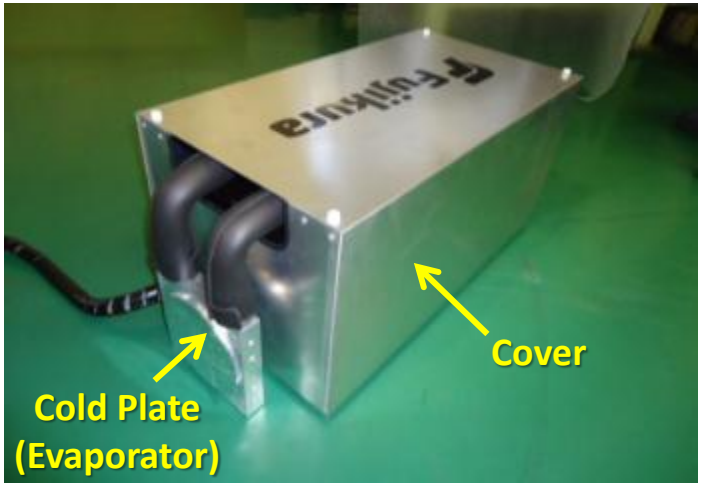
Prototype # 2 (Compact and high performance)



Can fit into 19 inch rack

Fujikura Modular Refrigeration Unit





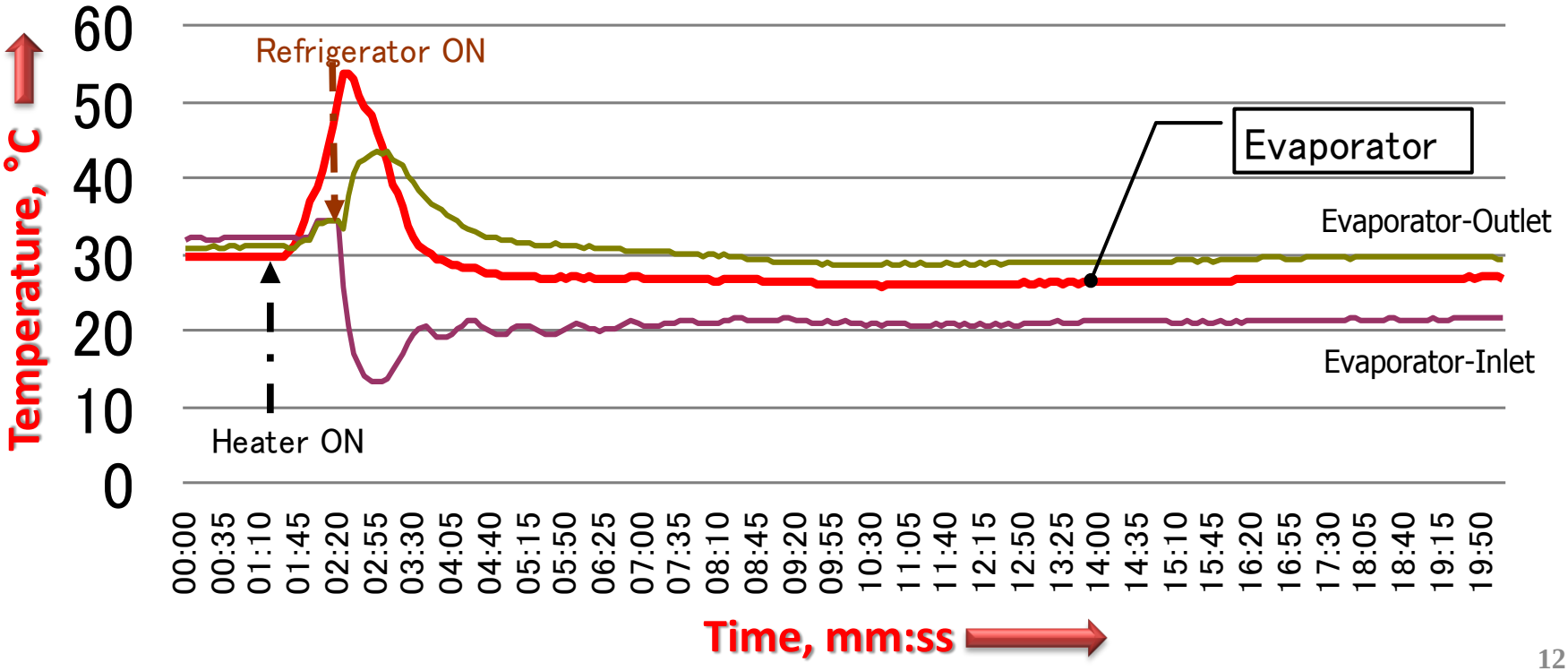
Cover On

- Total cooling solution designed & development by Fujikura Group using in-house technology
  - ✓ Evaporator made by FETL with advanced cold Plate manufacturing technology.
  - ✓ Heat pipe application inside MRU unit to improve COP.
  - ✓ SUS flexible tube piping made by Fujikura-Numazu.
  - ✓ Assembled & inspected by Fujikura Compo Sakura with high reliability.
- Target system price: ~ 5000 USD

Cover Off

Fujikura MRU: Test Results

- ✓ Evaporator temperature controlled at around 25 – 26 °C
- ✓ Heater Input 1.8 kW



Technology comparison: Evaporator Heat Transfer Coefficient

Evaporative heat transfer coefficient range for each technology is dependent on:

- ✓ Evaporator design & thickness
- ✓ Operation orientation
- ✓ Heat flux
- ✓ Heat transfer length

Evaporative Heat Transfer Coefficient

50 k
40 k
30 k
20 k
10 k

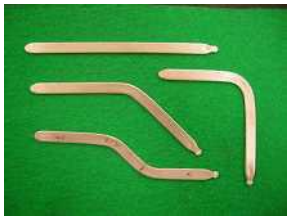
Liquid Pumped Cooling

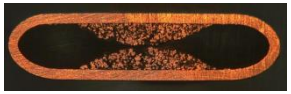
- ✓ Single phase cooling
- ✓ Pumped circulation

5 – 10 k

Thin Heat Pipes

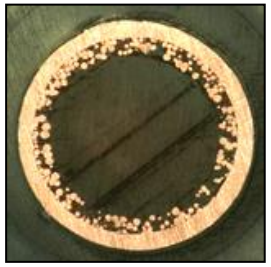
- ✓ One dimensional heat flow
- ✓ Two phase passive cooling





8 – 15 k

Cylindrical Heat Pipes



10 – 20 k

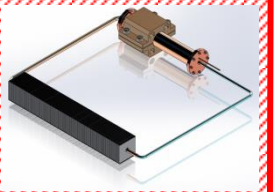
Vapour Chambers

- ✓ Two dimensional heat flow
- ✓ Two phase passive cooling
- ✓ Heat spreading device

15 – 35 k

Loop Heat Pipes

- ✓ Highly developed evaporator
- ✓ Two phase passive cooling
- ✓ High heat flux and long distance capability



20 – 50 k

Thermal Control Technology →

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Heat Spreader

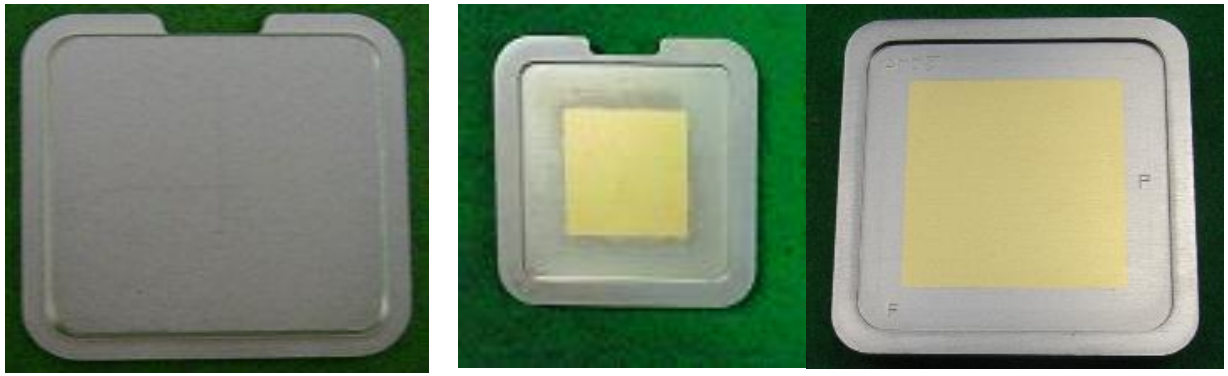
Heat Spreader of Chips

A heat spreader is important part to be spreading heat and guard for silicon chips.

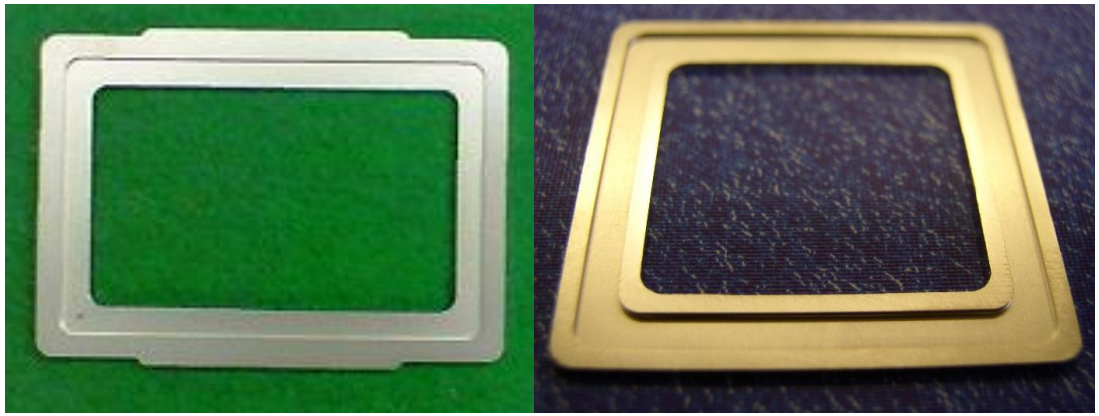
Cold forged → Electro Ni plating → Gold plating

CPU Package

IHS with Ni plating and gold plating



Stiffener



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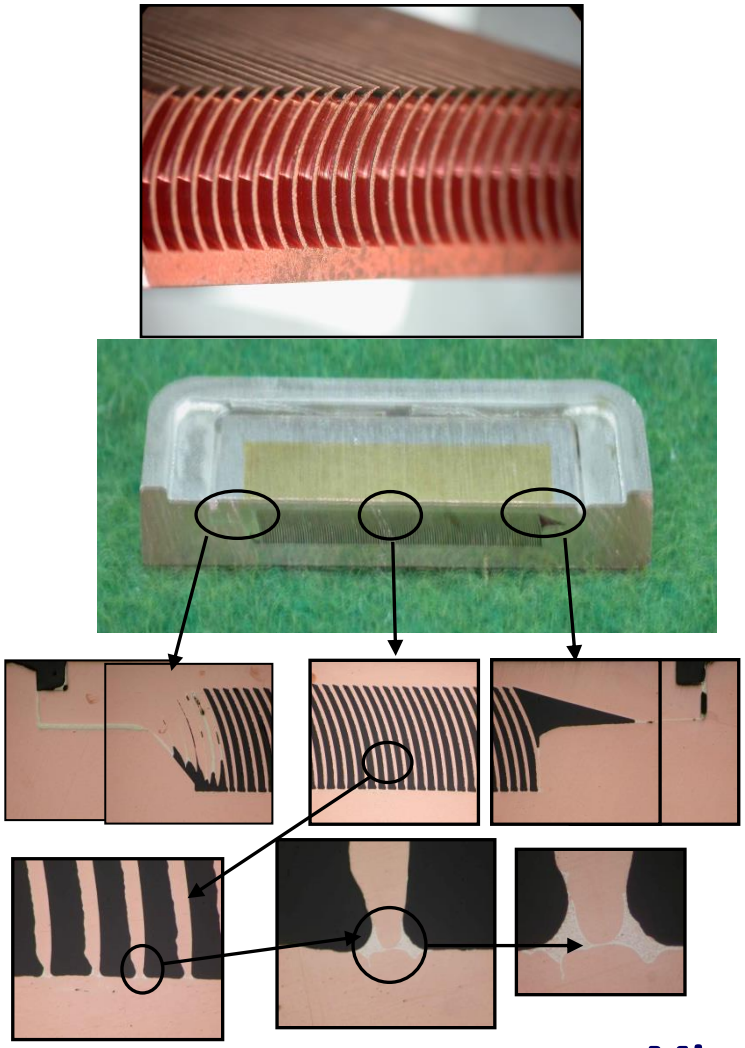
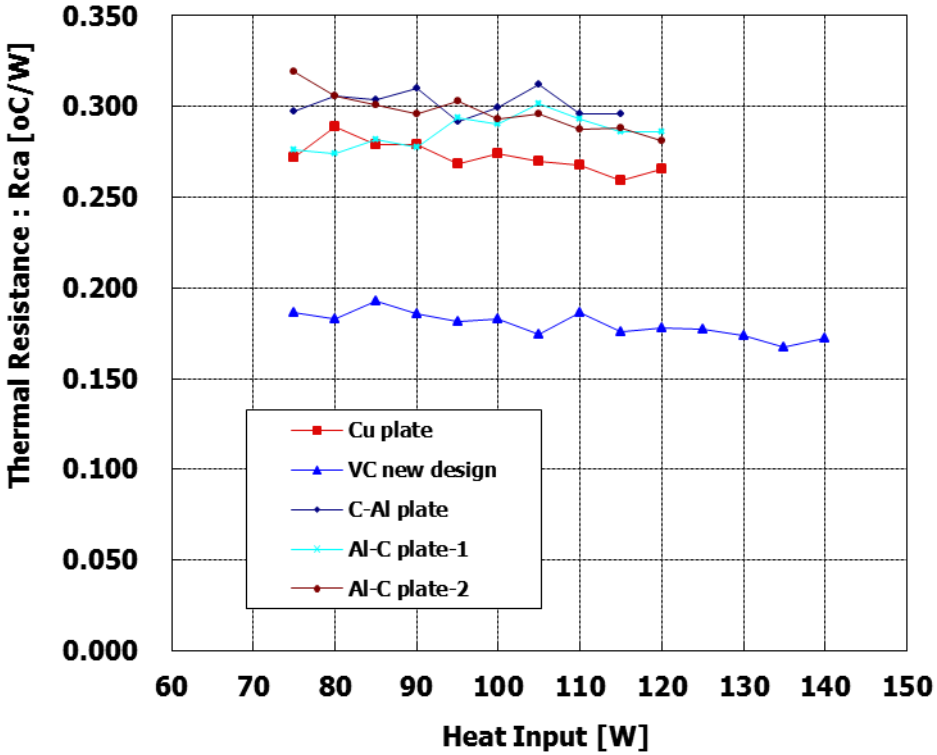
Micro-channel Vapor chamber



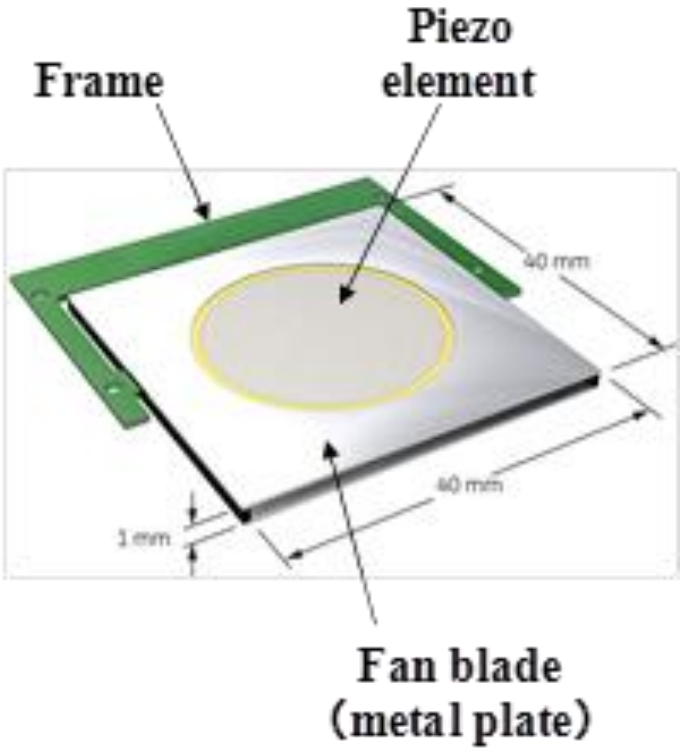


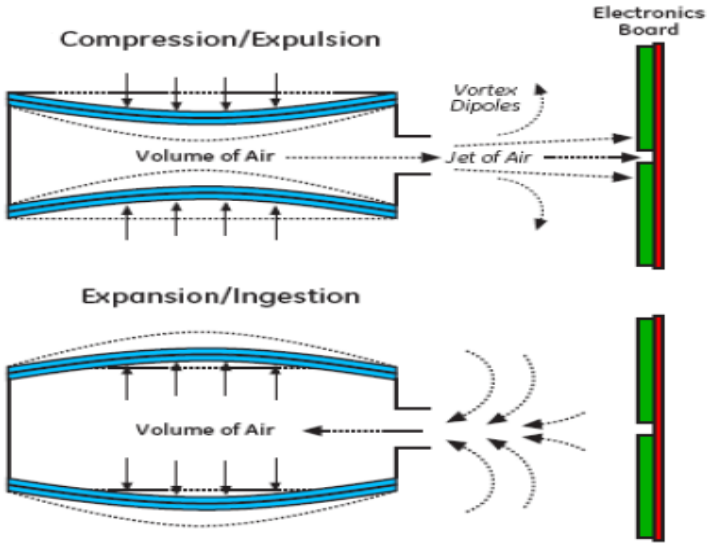
Thermal Resistance of Micro Channel Vapor Chamber

Micro skiving fin is available 0.1mm fin gap and 0.1 mm fin thickness.

Piezo Fan

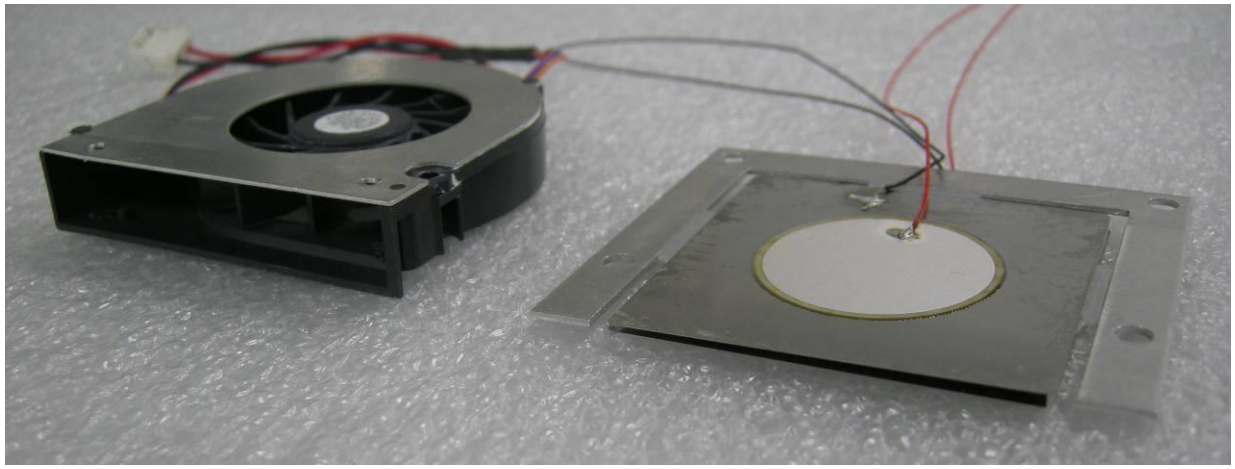
Piezo Fan (Dual Cool Jet): Heat Dissipating Element





Thin, Robust, Simple Structure

Features of DCJ



Thin DC fan for note-PC

◎Miniaturization of fan bearing has limitation on the size due to reliability. 3mm thick is required at this moment.

◎High rotation speed is needed when reducing the thickness, and it becomes a high noise and high power consumption.

◎Failure is caused from dust.

Ultra thin DCJ

◎1mm thickness is possible.

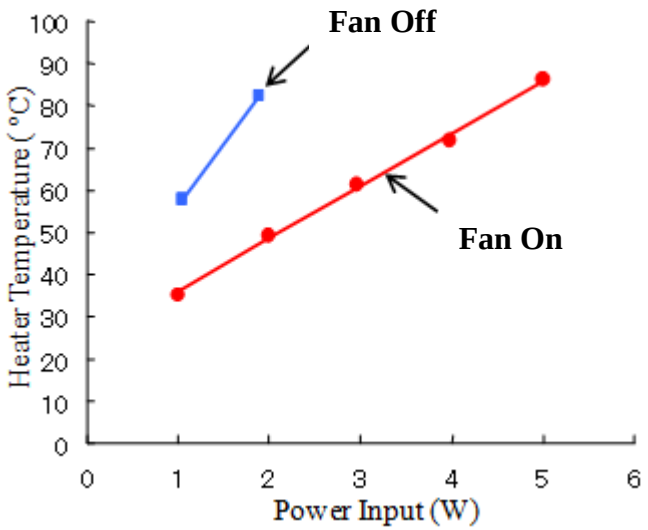
◎Low acoustic noise (<35dBA).

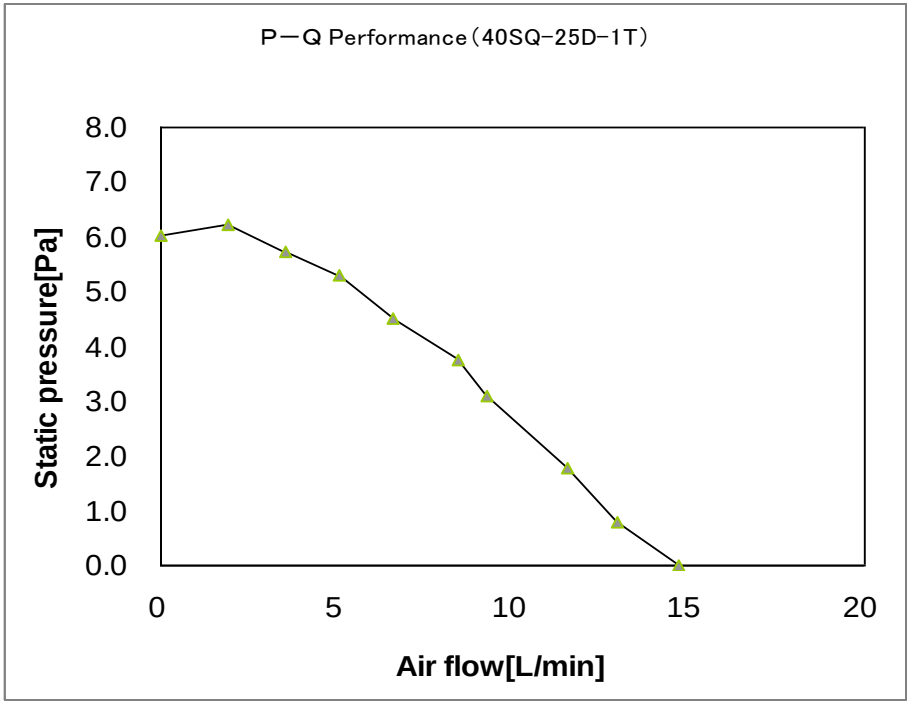
◎Low power consumption (<350mW).

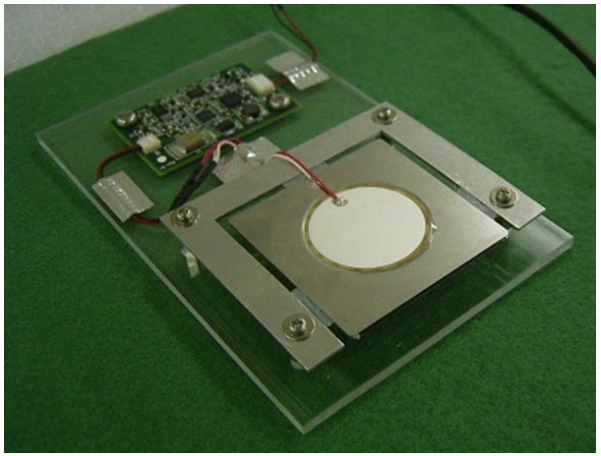
◎Simple structure.

Sample of DCJ (40SQ)

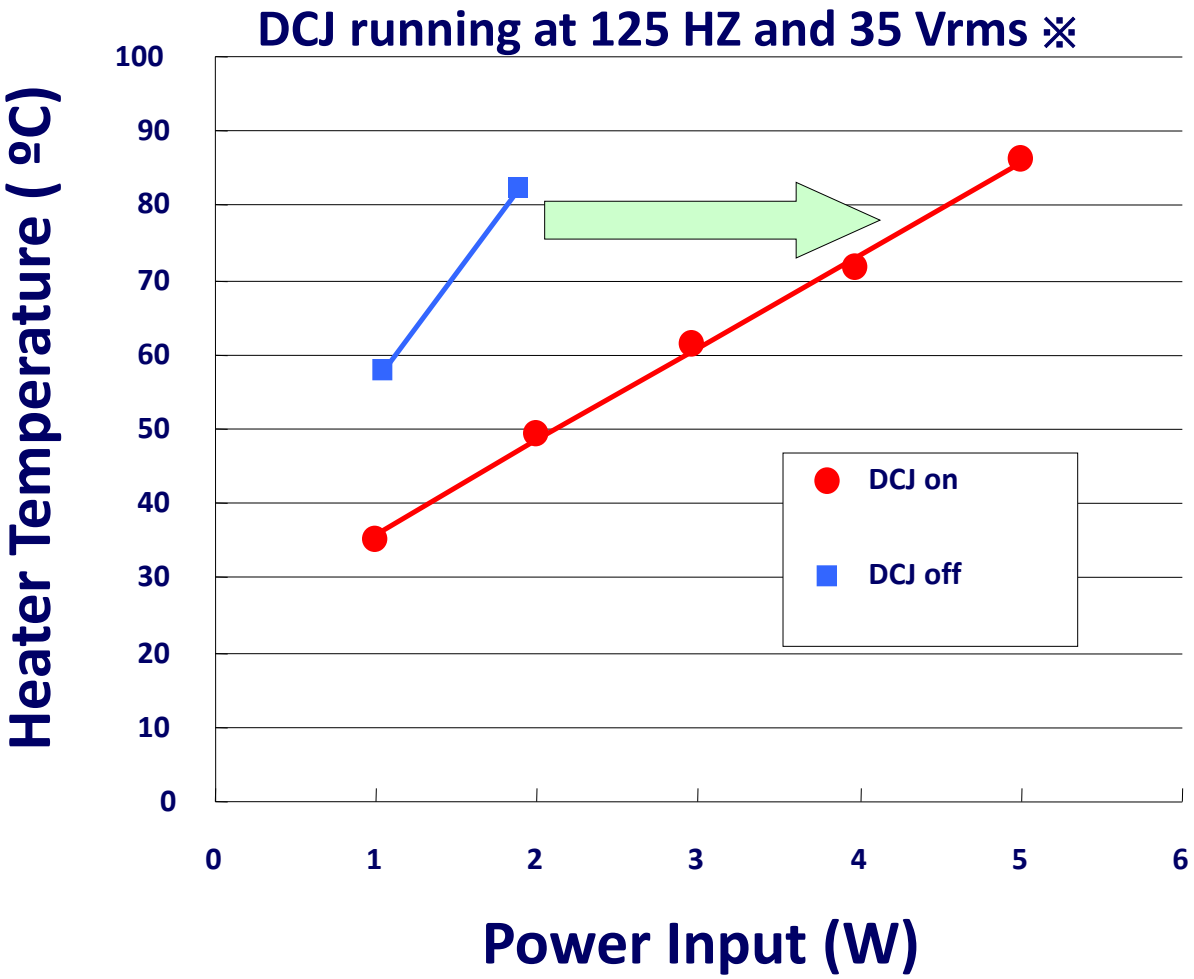
Size (main body: W x L x T)	40x40x1 [mm]
Size with frame (Wo x Lo)	60x50 [mm]
Input Voltage	DC 5 [V]
Driving Voltage*	AC 25 [Vrms]
Driving Frequency*	155 ±2[Hz]
Max. Air Flow Rate*	15 [LPM]
Max. Static Pressure*	6 [Pa]







Reference DCJ Testing Data for 5W Cooling



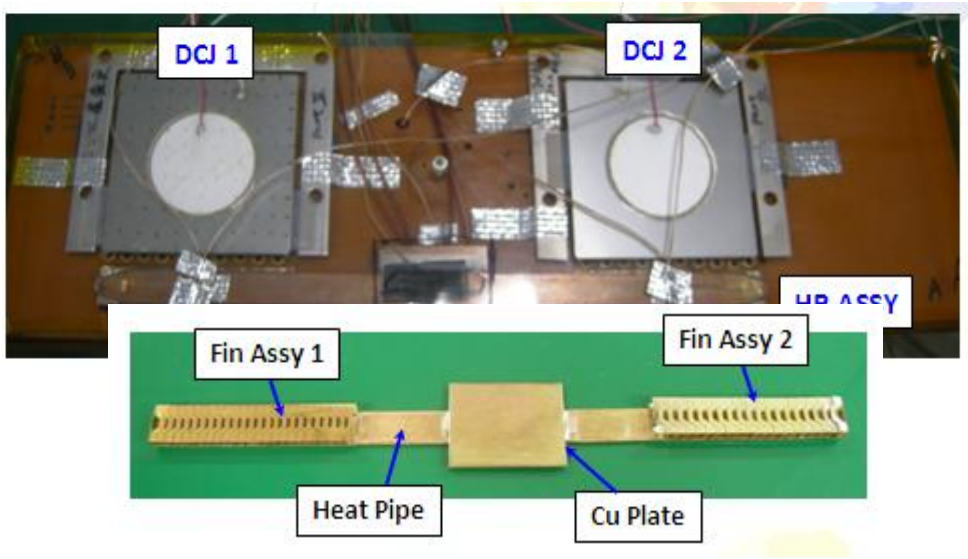
With DCJ cooling, CPU power can be increased up to 5 W

※Tested only one DCJ without any other thermal cooling parts

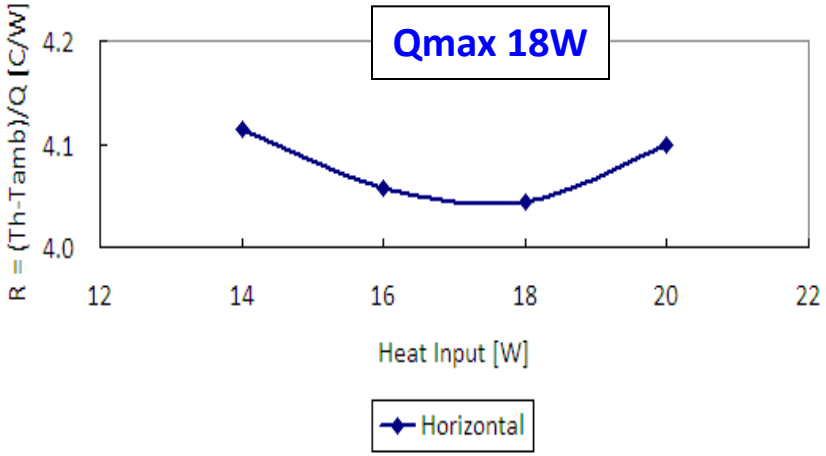
4: EXPERIMENTAL STUDY _ Fabricated Module

Specification

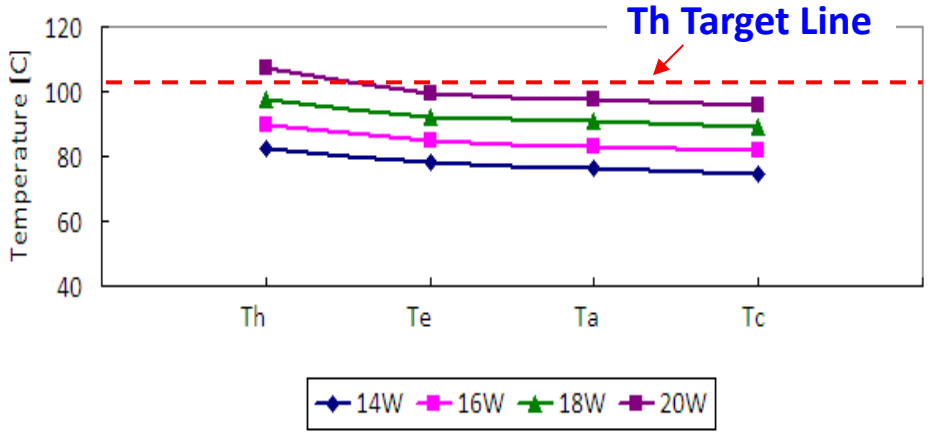
Heat Pipe : L 175.0mm W 8.5mm T 1.5mm
Module Weight : 20gmm (Including Fan)
Maximum Height : 4.5mm



Total Resistance



Temperature Profile



Current module Qmax is 18W

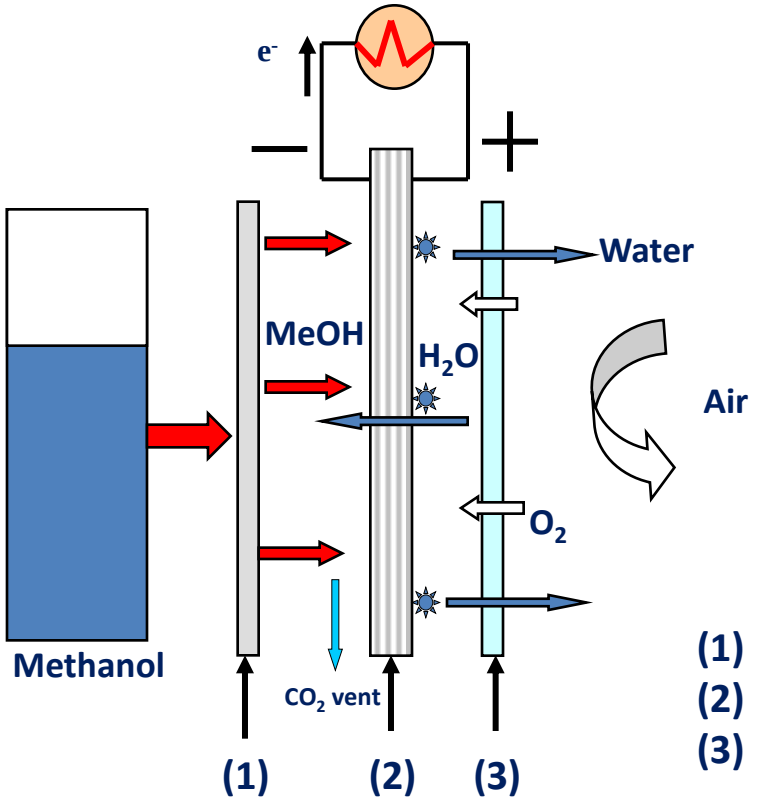
Direct Methanol Fuel Cell (DMFC)

Energy Density of Selected Fuels

Energy Sources	Volumetric Energy Density (Watt*hours/Liter)	Specific Energy Density (Watt*hours/kg)
Li-ion Batteries	450	200
Hydrogen + Container Compr (2000 psi)	520	248
Hydrogen/Metal Hydride	600	236
Methanol*	4,817	6,098
Formic Acid	2,050	1,724

***Methanol has the highest energy density.**

Technical highlight - Passive water balance



(1) Methanol permeable membrane
(2) DMFC MEA
(3) Air and water management layer

Water Balance Operation:

- Water is produced at the cathode.
- About 1/3 generated water is reused at anode for electrochemical reaction.
- About 2/3 generated water is released from the system.

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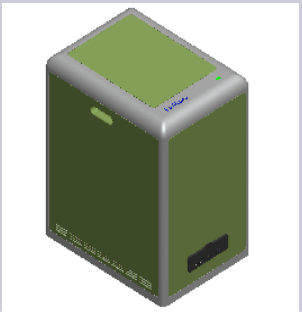
Direct Methanol Fuel Cell (DMFC)

DMFC is investigated based on our thermal and liquid feeding technology.

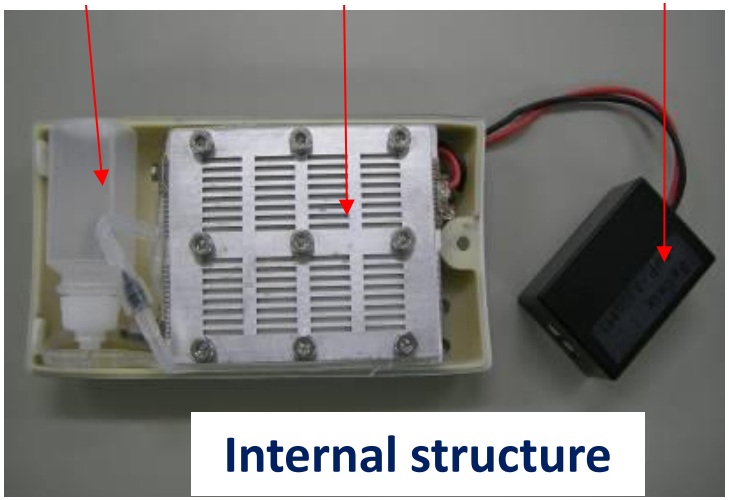
Strong point

- **Unique fuel delivering system**
- **Pocket size**
- **High energy conversion efficiency using exhaust heat (1kW type)**

	2W output prototype	1kW output prototype
		
Output power [W]	**2**	**1,000**
Size [mm]	**135 x 75 x 23**	**400 x 500 x 150**
Supplying water temperature [°C]	**-**	**50**
Applications	**Portable electronics device (Smart phone, mobile PC)**	**Aviation, Passenger ship, etc.**

2W DMFC

Package



Internal structure

1. Sequencing fuel bottle to charge fuel into the DMFC stack
2. Connecting DMFC to the portable electronic device.
3. DMFC will automatically start to charge the electronic device.

1. H × L × t : 75 × 140 × 38 mm
2. Weight without fuel : 230g (With fuel : 260g)
3. Power output : 4-5W·h for 1 fuel pushing.
4. Working time: up to 8 hours (Automatically stop)
5. Orientation independent
6. Working temperature : 10 – 35°C (0 -40°C in future).
7. Ambient relative humidity : 10 – 100%

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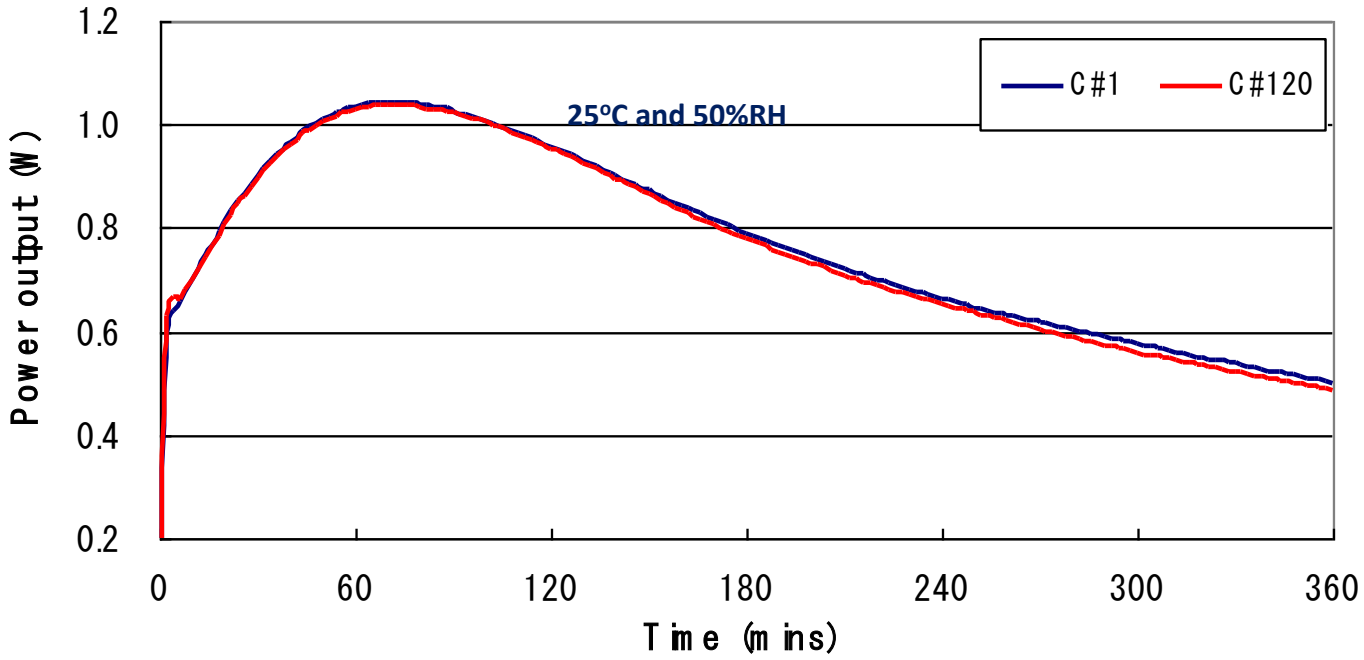
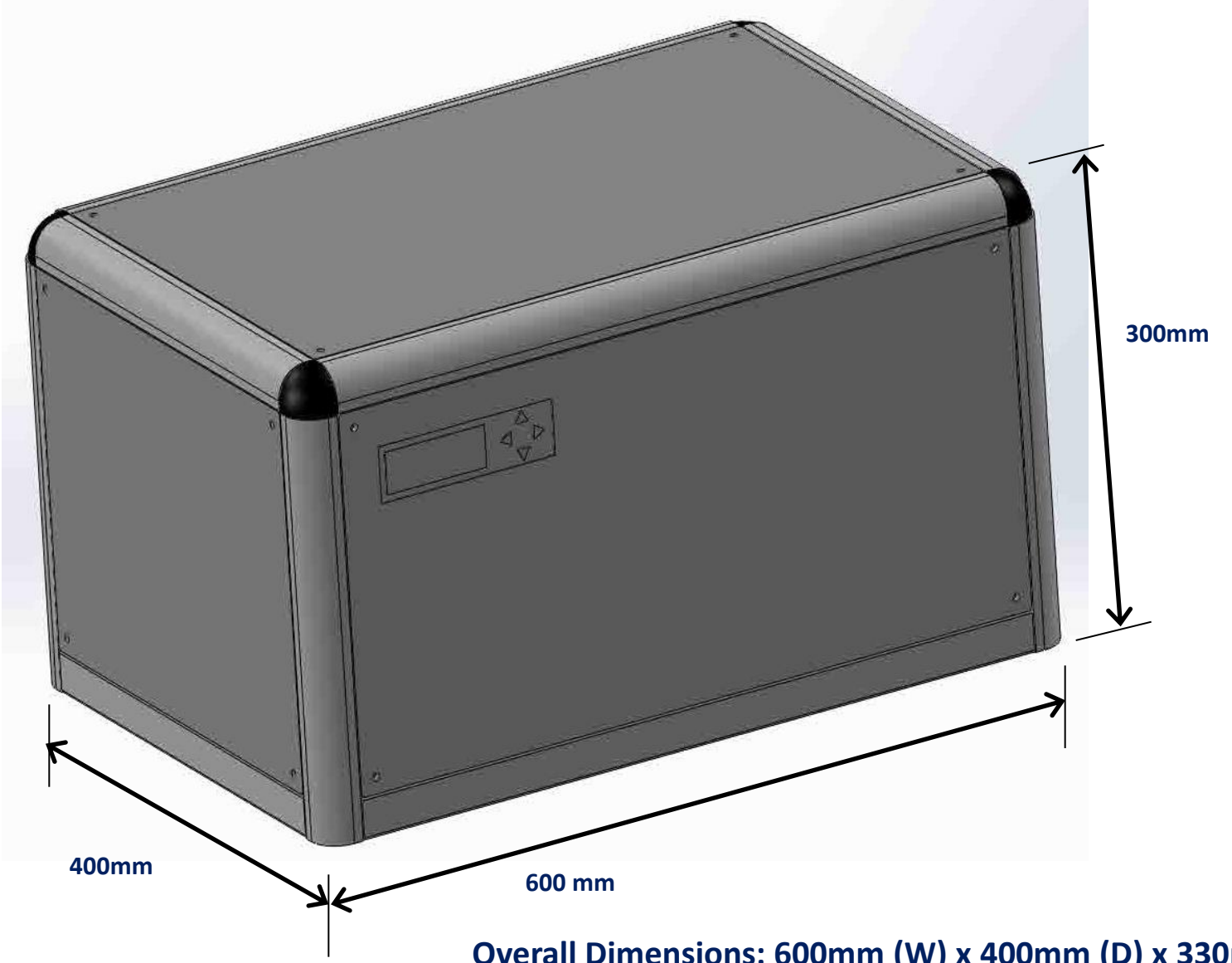
Performance & Durability of passive DMFC system



- Working time: 6 hours with one fuel charging.
- Total power output: C#1 (4.60W·h); C#120(4.55W·h).
- Fuel utilization: 1.4 W·h/g of fuel.
- We tested this DMFC charger in last 6 months for total 120 operation cycles.

1KW DMFC



Overall Dimensions: 600mm (W) x 400mm (D) x 330mm (H)

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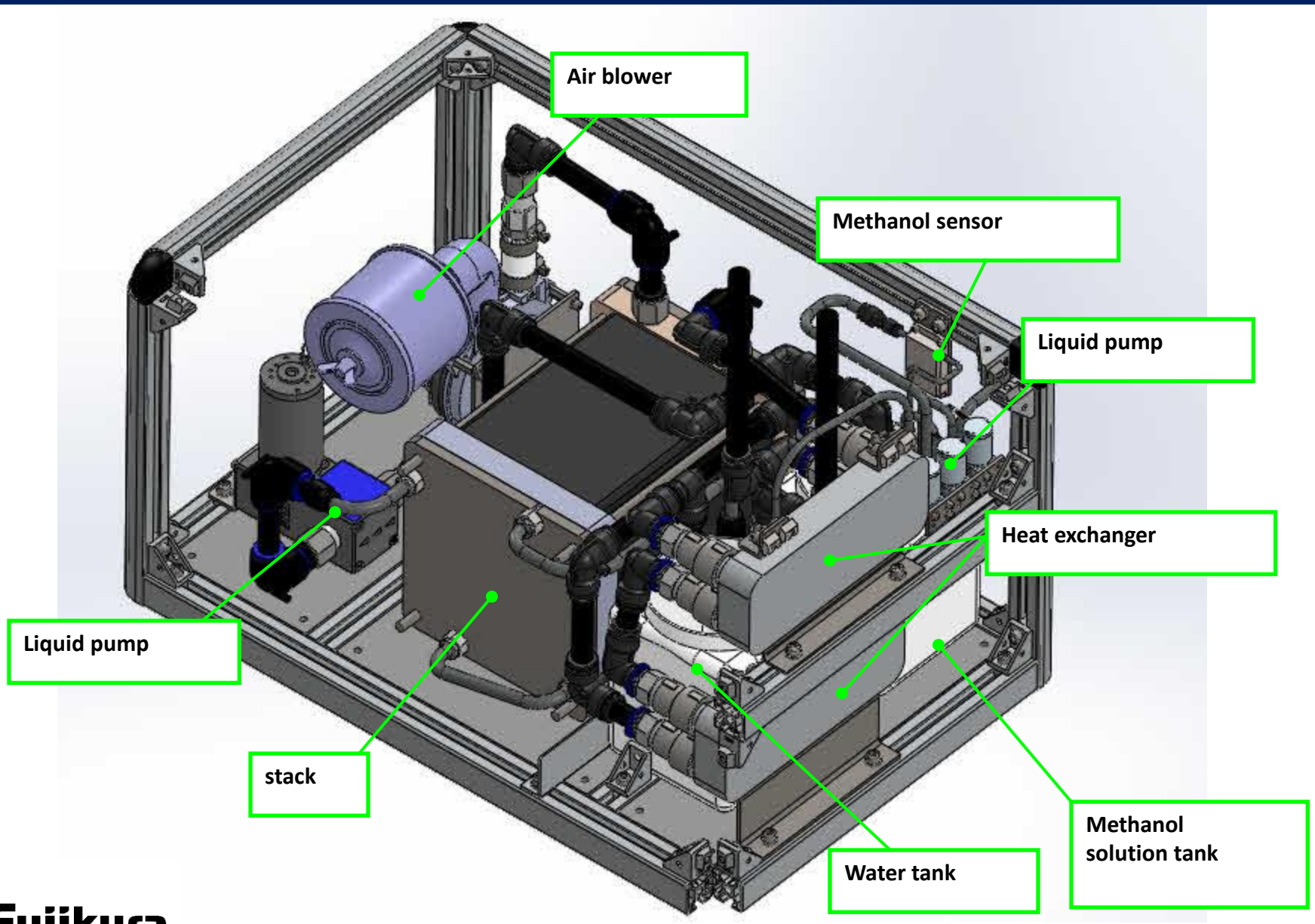
1KW DMFC



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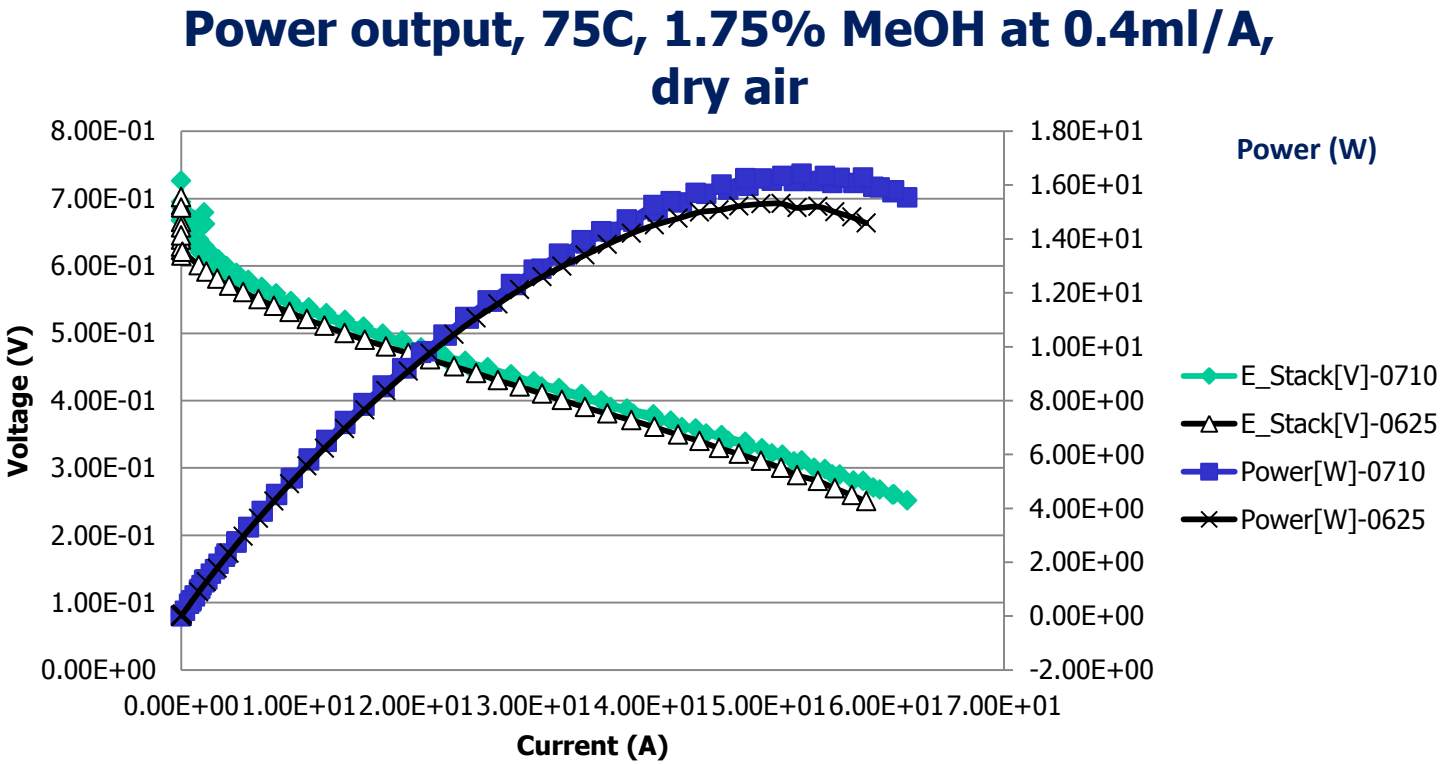
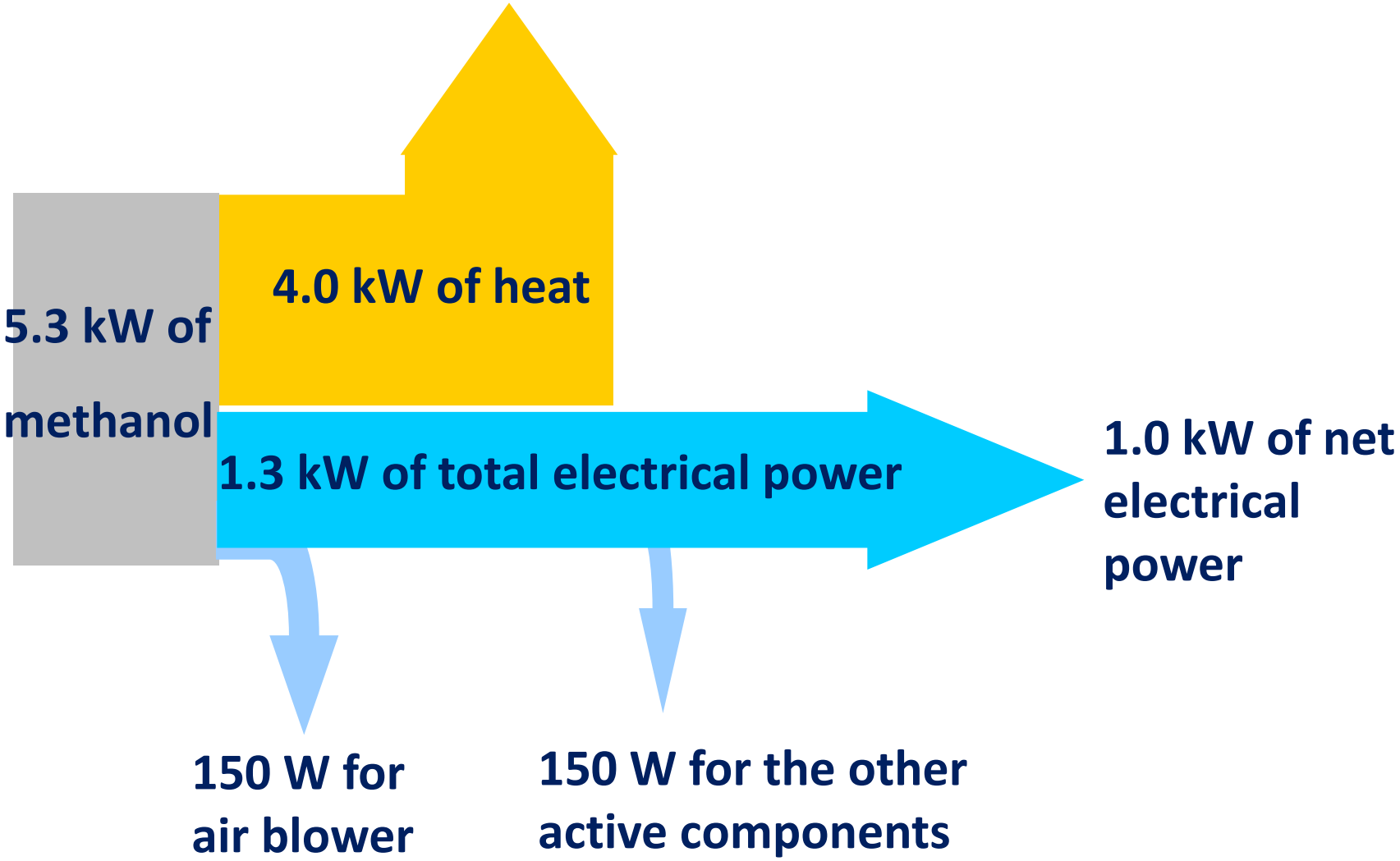
Performance of large active area single cell (180cm^2)



- The peak power output is 16.5W.
- Assume 61 cells in one stack, the stack power output is 1,000W.
- In order to increase the stack power output to 1,200W, 20% up of performance is needed.
- Our target is to increase single cell power output 20 to 25W.

Energy balance diagram of 1.0 kW DMFC



Fujikura

Thanks