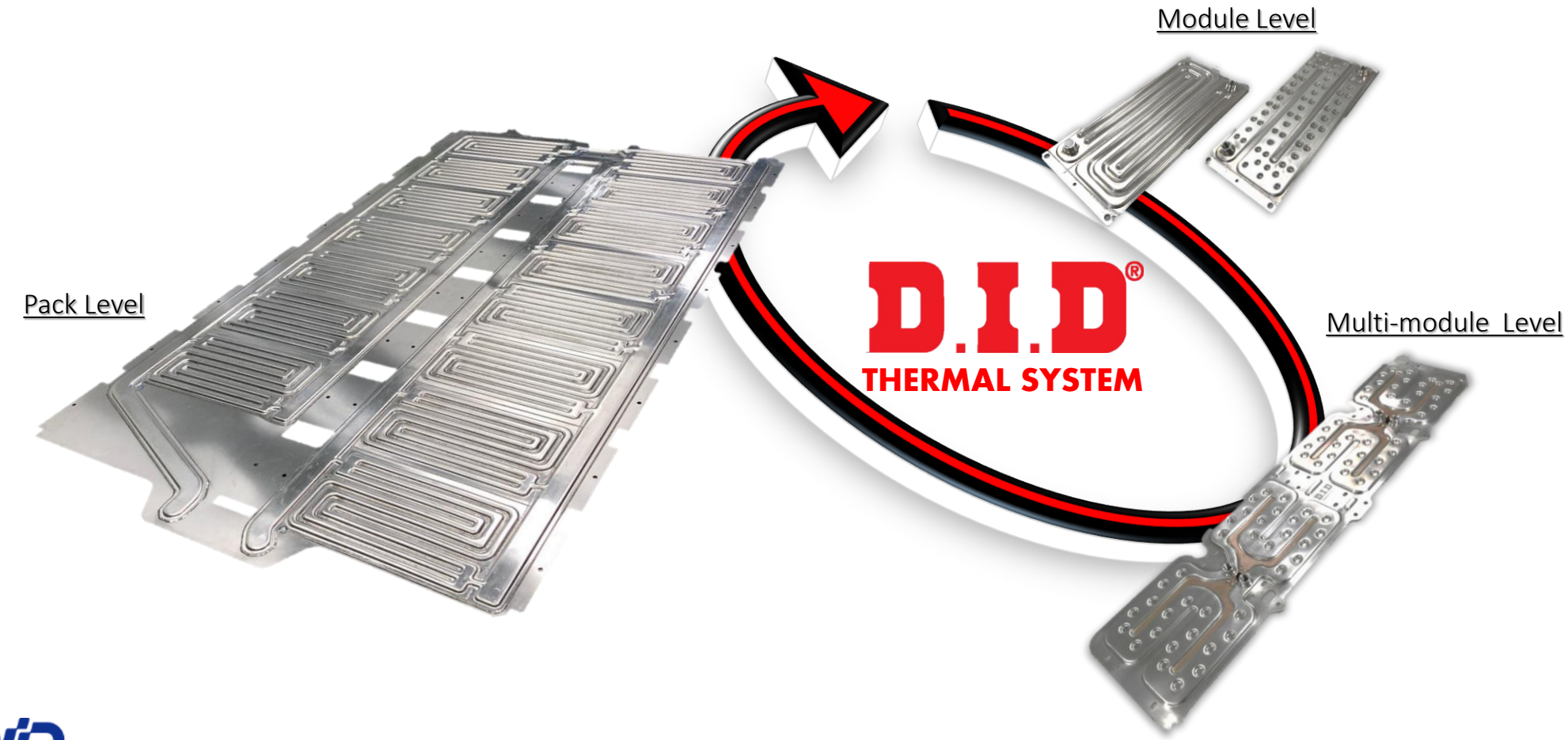
Proposal for a new cooling plate manufacturing method



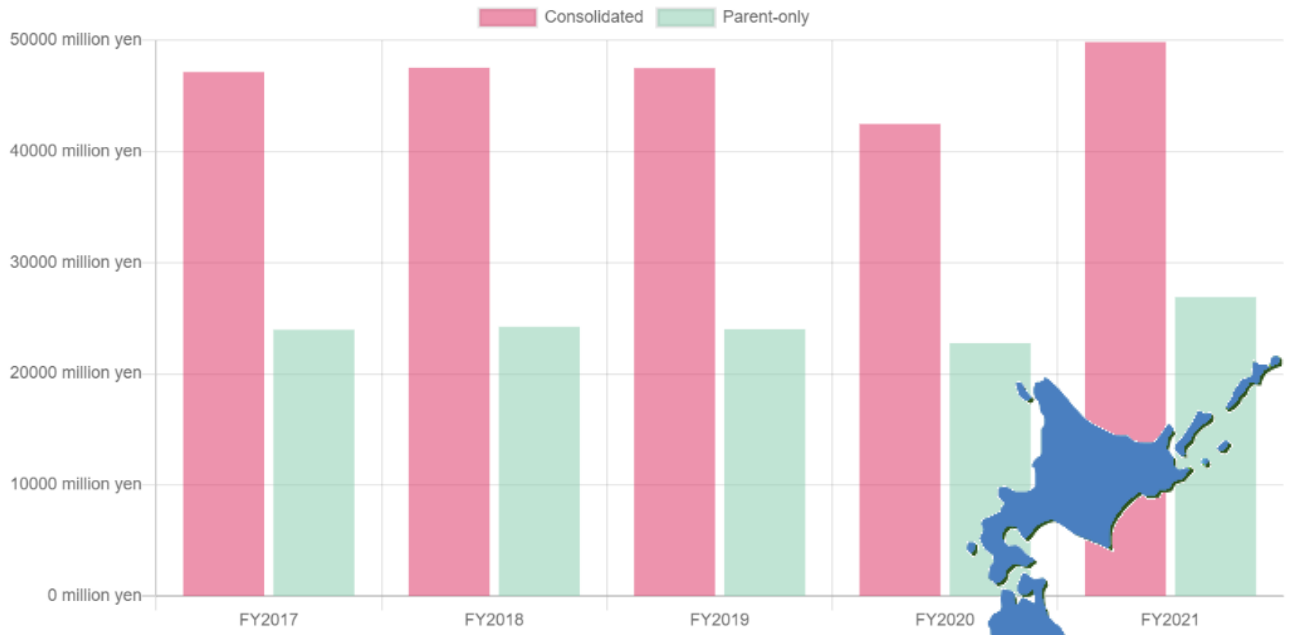
No.2212027203
Oct 08,2023
DAIDO KOGYO CO.,LTD.
R&D Dept . AIC Office
Adrian.S/Daigo.M

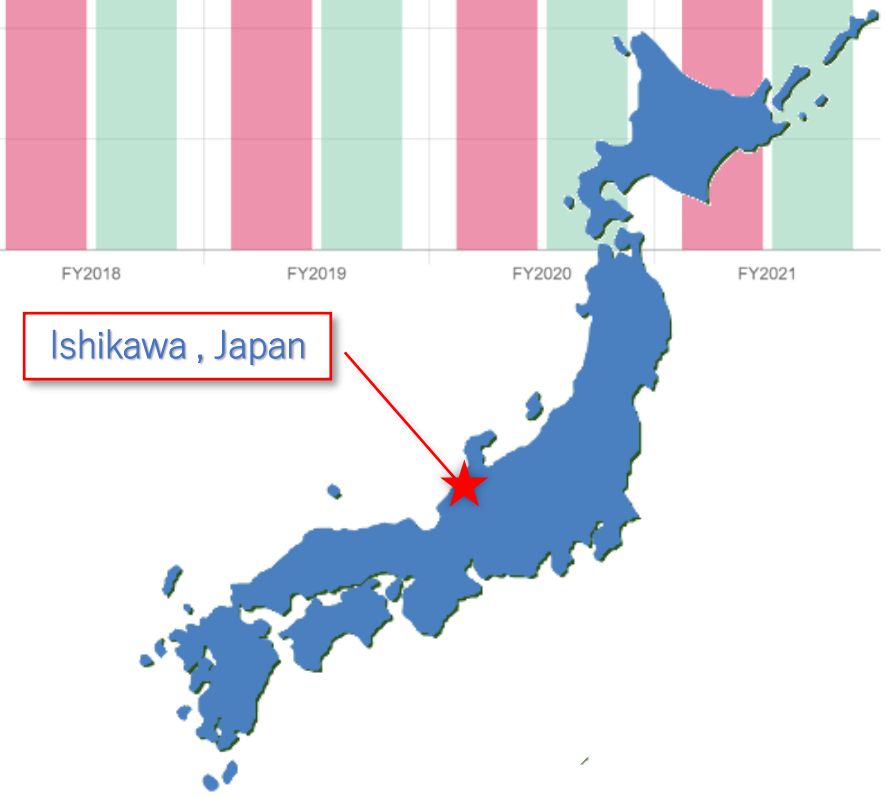
Company Profile

Profile

Company name	DAIDO KOGYO CO.,LTD.
President	Hirofumi Araya
Established	May 1933
Capital	3,536 million yen （≒26M $）
Net sales	49,847 million yen （≒366M $）
Ordinary income	3,119 million yen （≒23M $）
Net income	2,347 million yen （≒17M $）
Employees	Consolidated 2,326 (as of March 31,2022)
Businesses	Manufacture and sales of Motorcycle & Automotive Chains, Industrial Machinery Chains, Rims/Wheels, Conveyor Systems and Welfare Equipment.

Sales Trends





Global Network (12 countries)

- Tennessee U.S.A ; DAIDOCORPORATION OF AMERICA.
- Kentucky U.S.A ; IWIS-DAIDO LLC.
- ★ Bilbao Spain ; R&D OFFICE IN EUROPE.
- Bologna Italy ; DID EUROPE S.R.L.
- Sao Paulo Brazil ; DAIDO INDUSTRIAL E COMERCIAL LTDA.
- Amazonia Brazil ; DAIDOINDUSTRIA DECORRENTESDAAMAZONIALTDA.
- Changshu Chaina ; DAIDO CHAIN (CHANGSHU) CO.,LTD.
- Batangas Philippines ; D.I.D PHILIPPINES INC.
- Jawa Barat Indonesia ; P.T. DAIDO INDONESIA MANUFACTURING.
- Hanoi Vietnam ; D.I.D VIETNAM CO.,
- Selangor Malaysia ; DID MALAYSIA SDN.BHD.
- Rayong Tahiland ; DAIDO SITTIPOL CO.,LTD.
- Rayong Tahiland ; D.I.D ASIA CO.,LTD.
- Chonburi Tahiland ; INTERFACE Group.
- Karachi Pakistan ; ATLAS DID (PRIVATE) LTD.
- Rajasthan India ; DAIDO INDIA PVT. LTD.

DID Products

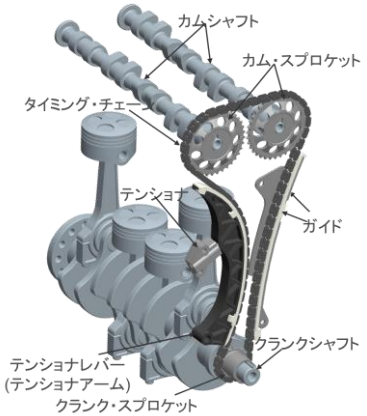
The 「D.I.D」 Brand Worldwide

Motorcycle Chain

Motorcycle Rim/ Wheel

Motorcycle Handlebar

Timing Chain System



Wheel for OHV

Car engine timing Chain

Tensioner

Vacuum Conveyance

Welfare Equipment

Industrial Chain

Conveyor system

Stair lift

Company history and strategic development direction

1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050

① Parts for Bicycle

② Parts for Motorcycle

③ Parts for Automotive

④ Parts for EV and FCV

⑤ Parts for eVTOL and Rocket

Daido's Business Transition / Expansion:

1933-1970	1960-2035	1970-2040	2020-2050	202X-20XX?
Bicycle	Motorcycle	Automotive	BEV・FCV	eVTOL・Rocket
Chains Rims	Chains Rims Swing-arms Handlebars	Timing Chains Other Engine Parts	Cooling plate	

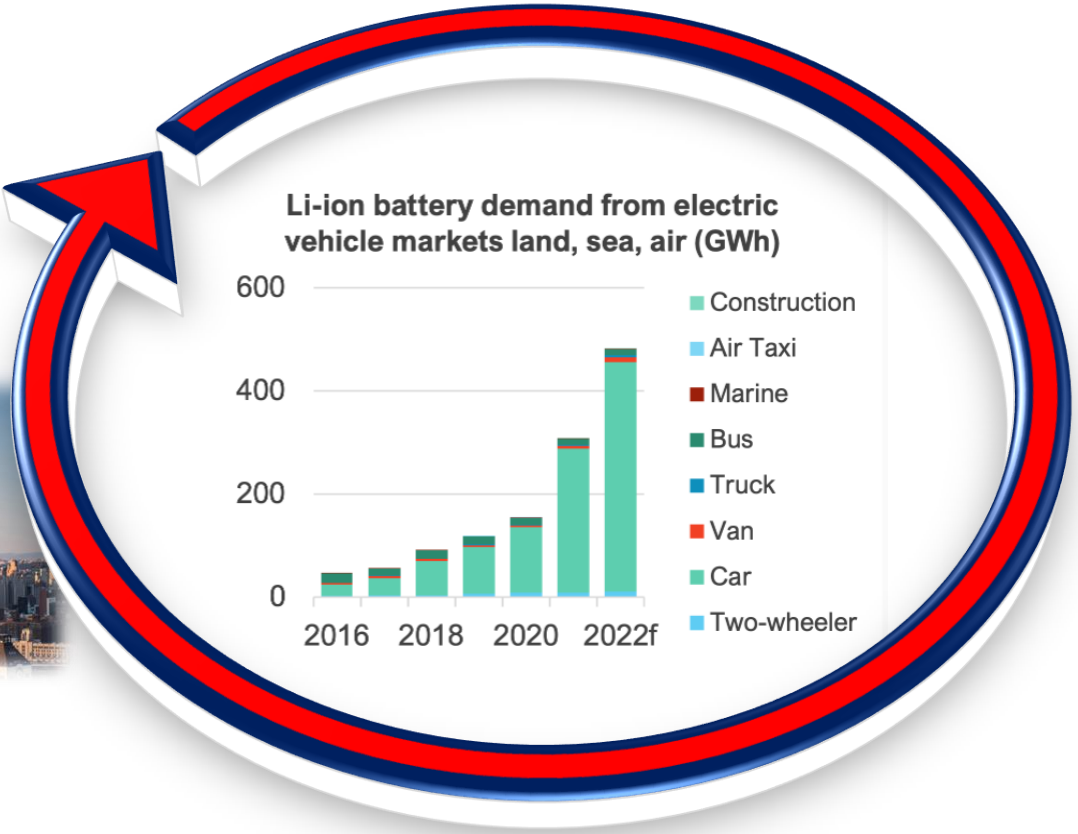
Technology Transfer from the U.K.

Spain

New products through activities at aic

Urgent need to develop new businesses to meet the shift to electrification

eVTOL



ESS

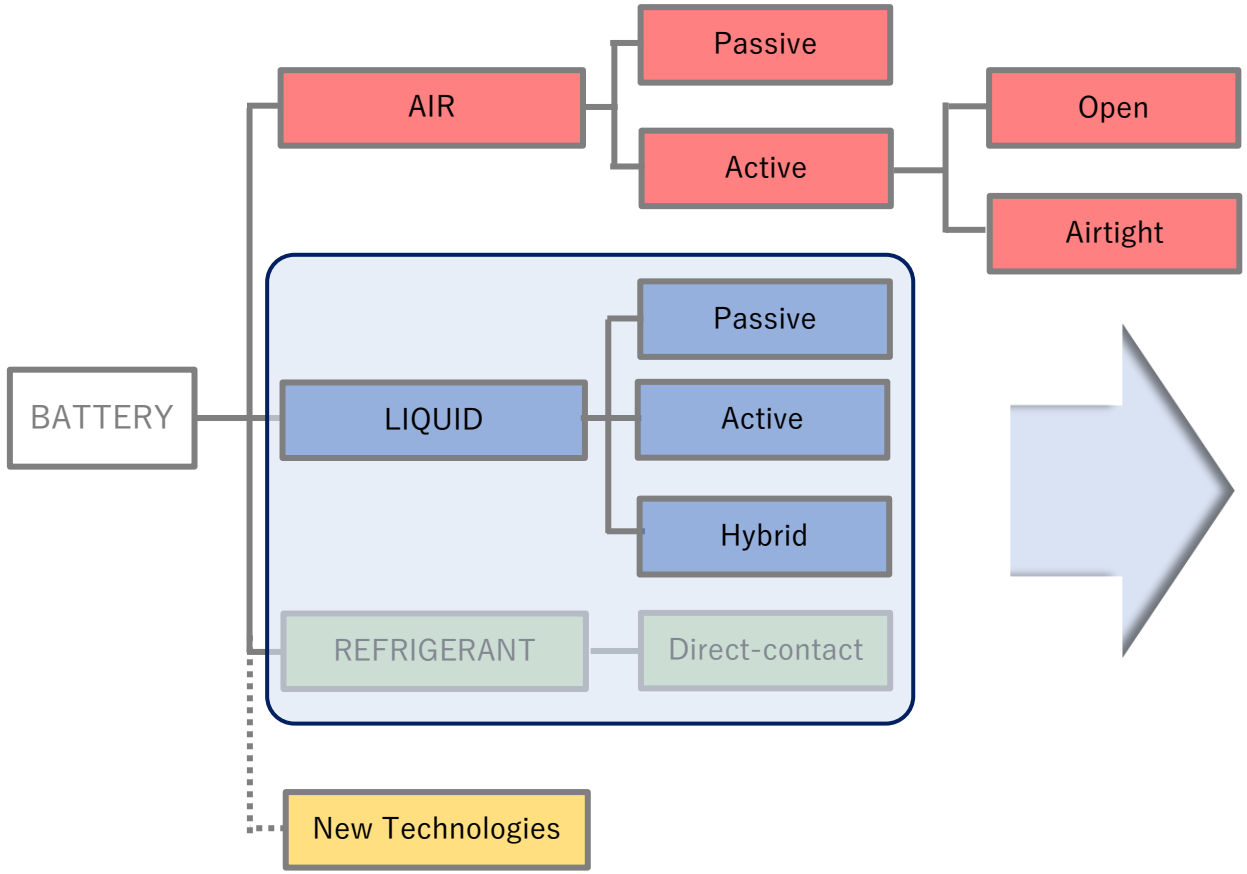
Marine

ev

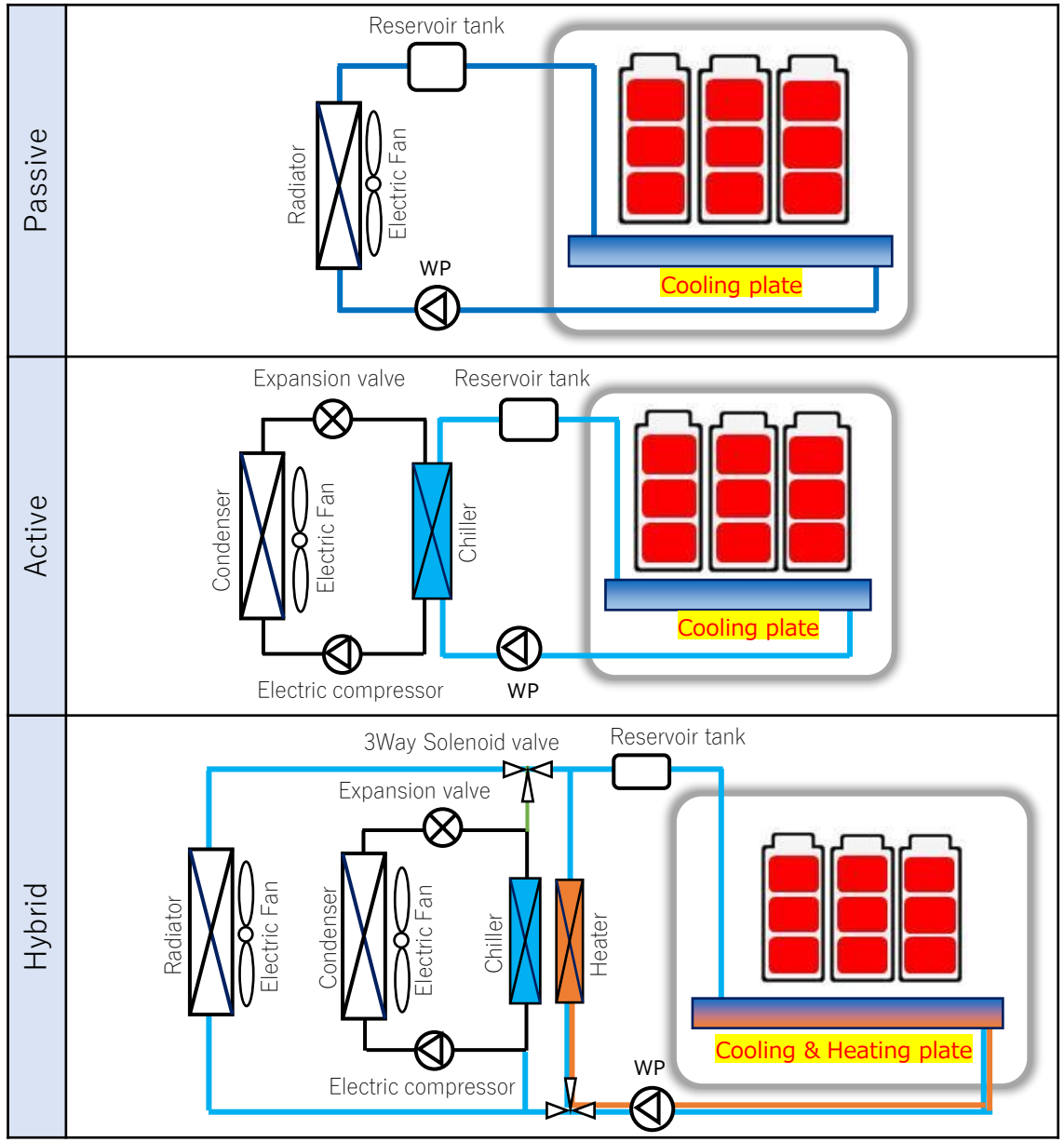
Heavy-Duty

Thermal Management Trends for **LiB**

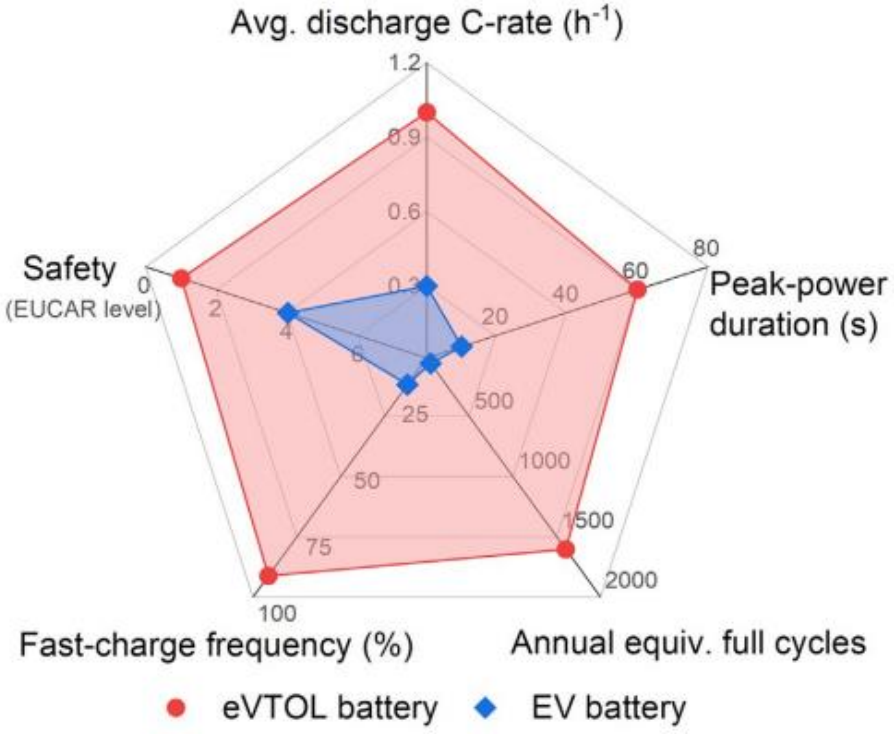
➢ Summary of LiB thermal management system



➢ Liquid System Overview



eVTOL vs **ev** battery requirements



Cited in Joule 5, 1644-1659, July 21, 2021 ª 2021 Elsevier Inc

eVTOL battery requirements

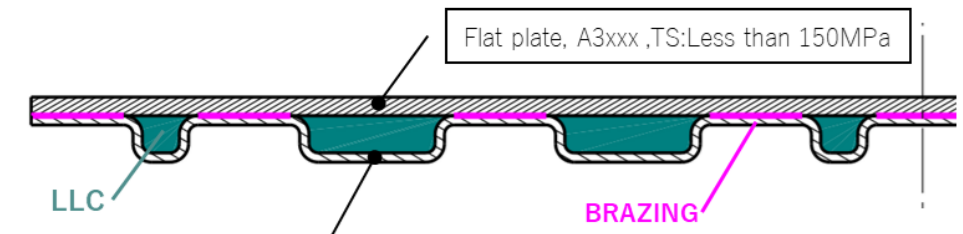
Operational conditions	eVTOL battery
Driving/cruising C-rate	Need 1C
Size of battery	Relatively big
Power requirements	Need higher
Peak power duration	Typically lasting 30-120s
Battery lifetime	Shorter
Fast-Charging(5～6C?) frequency	More

Do **ev** cooling plates work for **eVTOL** ?

ev cooling plates

TYPE		Conventional products	
		Brazing	Roll-Bond
Material	Flexibility	3XXX series (<TS:150MPa)	1XXX,3XXX series (<TS:150MPa)
Material	Temper	O,H1X (Clad sheet)	O,H1X
Joining Technology		Brazing	Rolling
Productivity (Cycle time of joining)		600°C-40min<	Depends on rolling speed

Conventional product



➢ **Issues in product enlargement**

1) Deformation (deterioration of flatness) due to brazing temperature effects.
2) Material strength loss due to annealing.

VS.

eVTOL cooling plates requirements

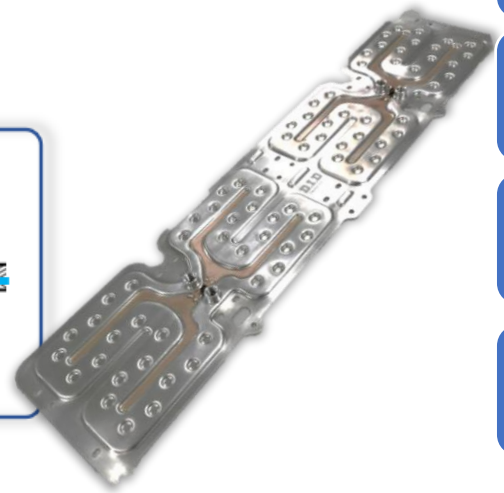
1) Optimal thermal circuit design for cell characteristics
2) Flexible manufacturing technology for application from small to large capacities
3) Low cost and high flatness quality
4) Lightweight
5) Integration with battery enclosures
6) Low carbon footprint

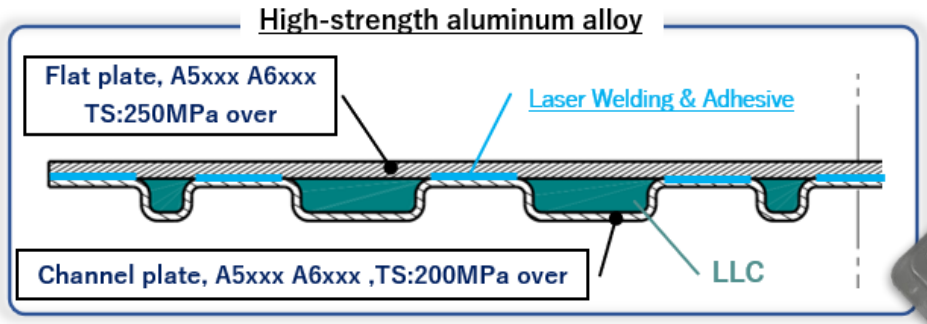
New cooling plates manufacturing method for **eVTOL**

D.I.D® cooling plates

TYPE		DID cooling plates (TRL 6)	
Material	Flexibility	(3XXX),5XXX,6XXX series TS:200MPa<	
	Temper	O,H1X,H3X,T4,T6	
Joining Technology		Laser Welding	LLC-resistant Adhesive
Productivity (Cycle time of joining)		Welding speed: 10m/min<	140°C-20min

VS.



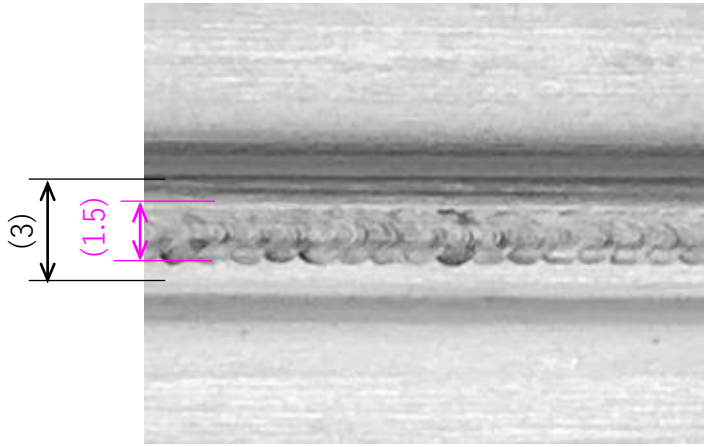


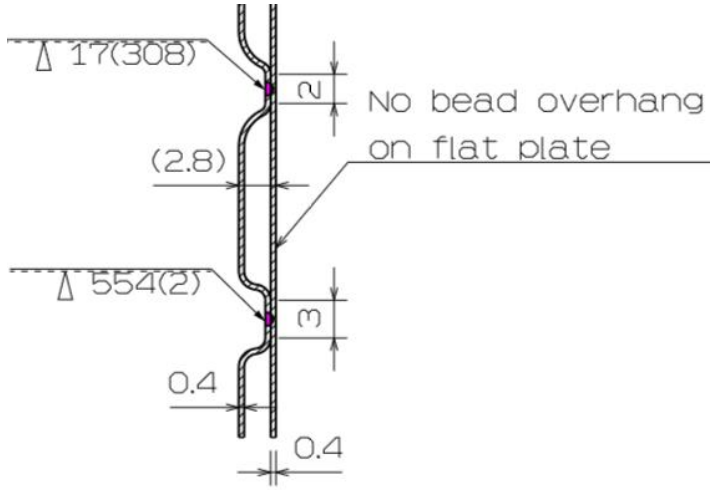
eVTOL cooling plates requirements

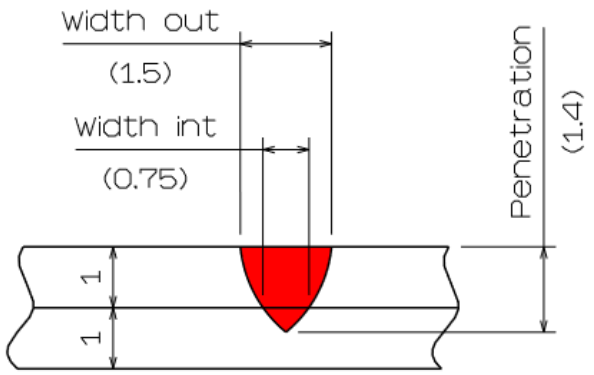
1) Optimal thermal circuit design for cell characteristics
2) Flexible manufacturing technology for application from small to large capacities
3) Low cost and high flatness quality
4) Lightweight
5) Integration with battery enclosures
6) Low carbon footprint

Advantages of Laser Welded Cooling Plates

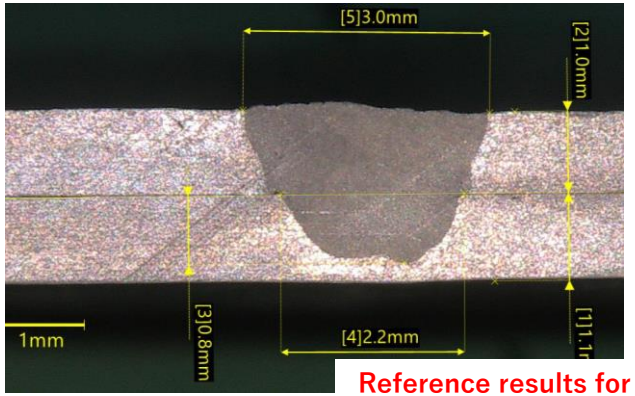
Section B-B ; Lap welding

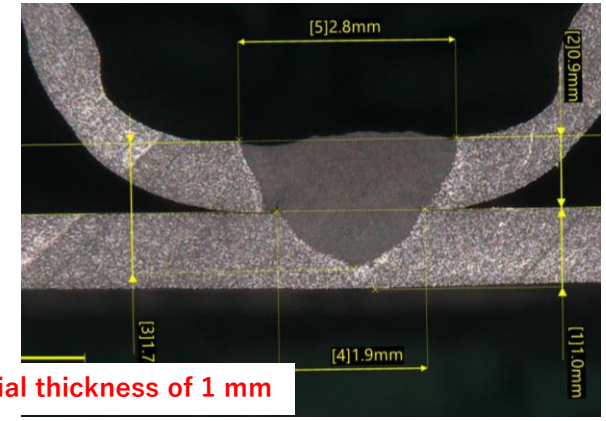






:mm

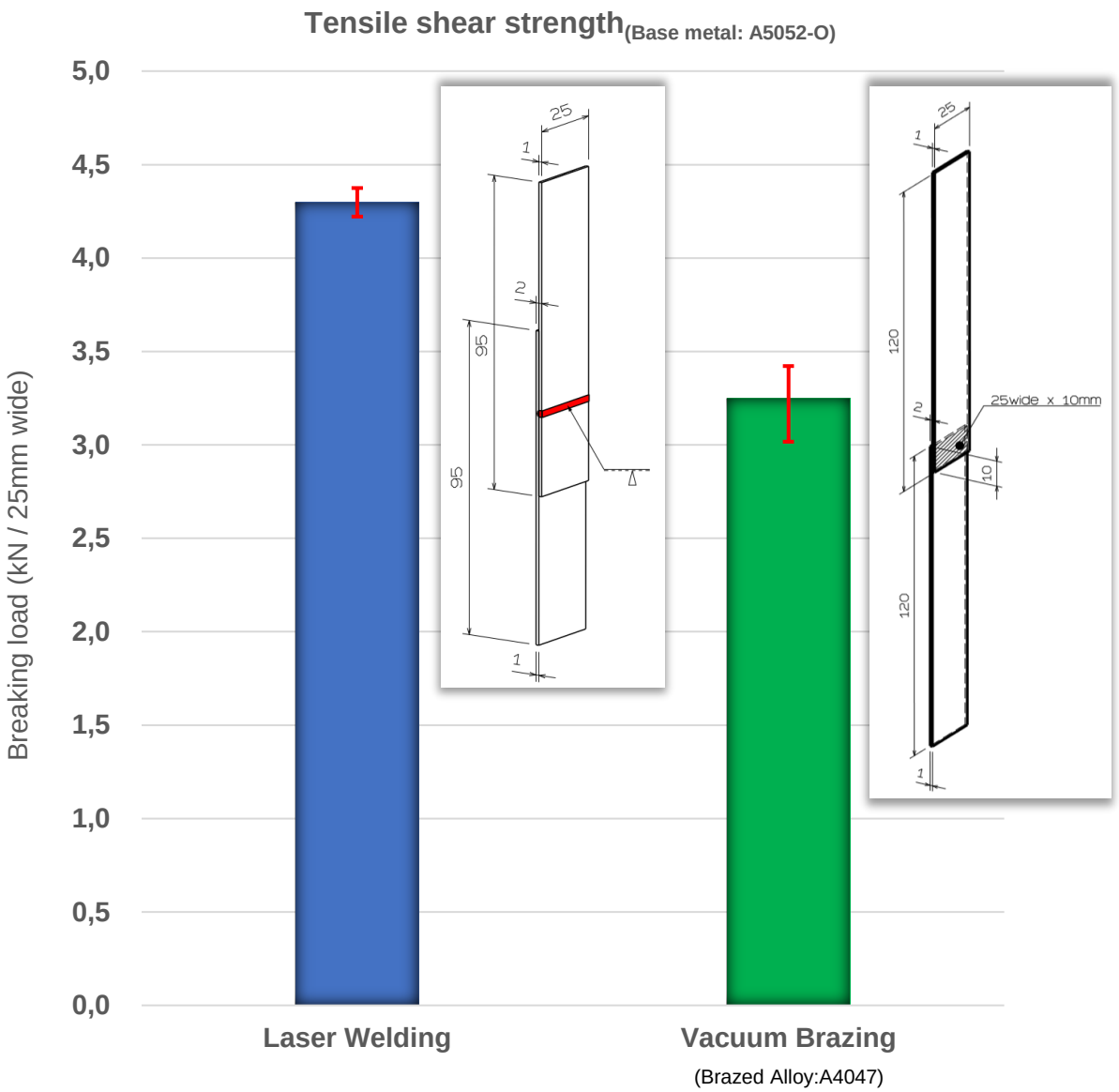


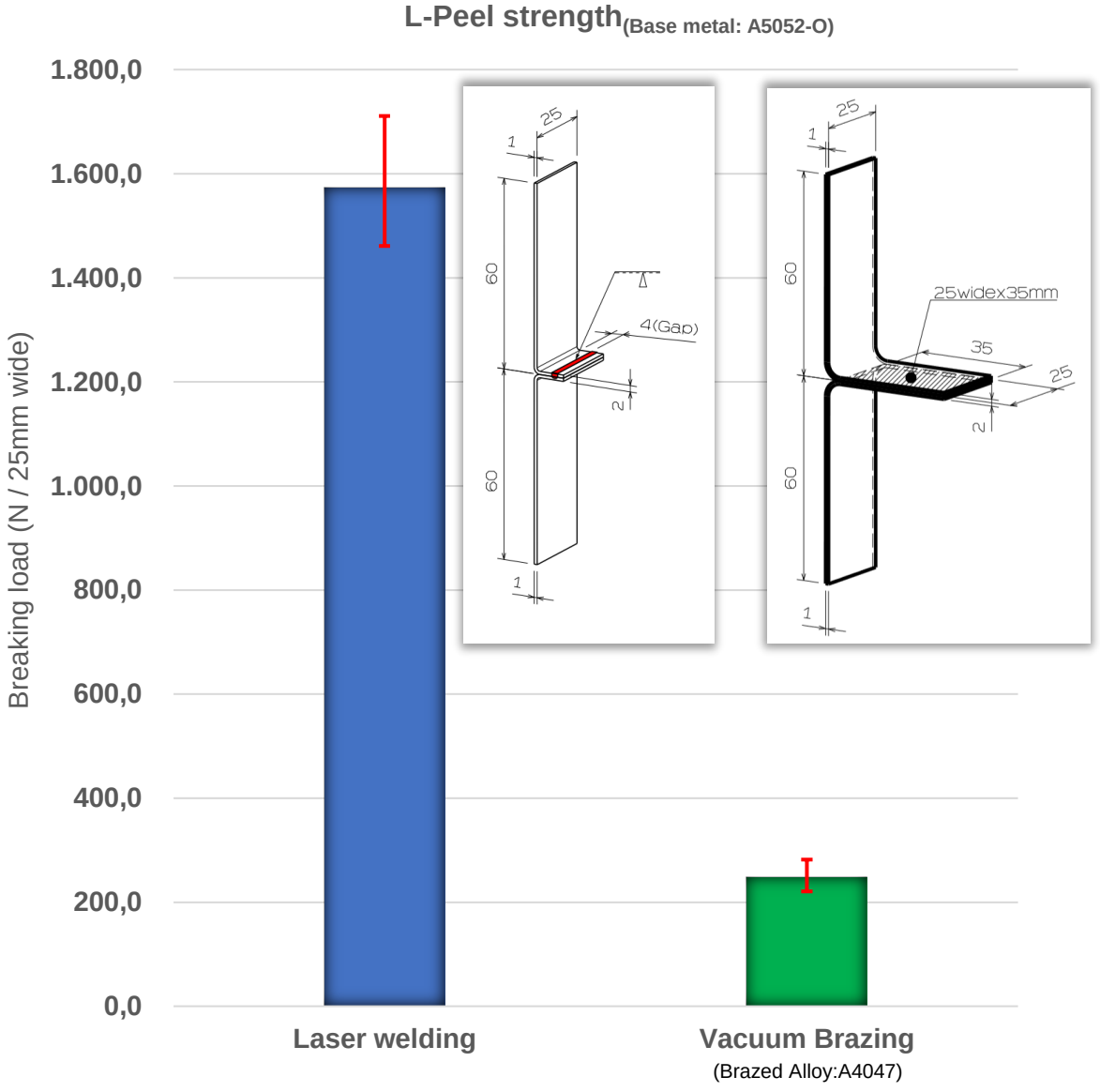


Reference results for a material thickness of 1 mm

Width out > More than 150% of material thickness	**3.0**	**2.8**
Width in > More than 30% of Width out	**2.2**	**1.9**
Penetration > More than 140% of material thickness	**1.8**	**1.7**

Advantages of Laser Welded Cooling Plates

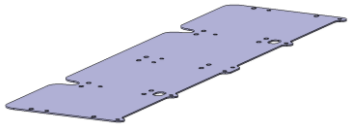




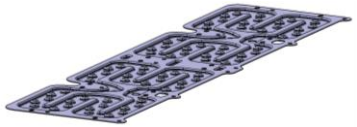
Process flow overview of “ **Laser welding** ”

Bare coil materials

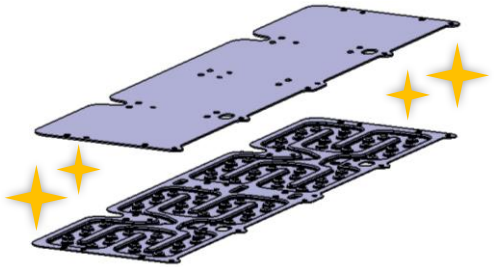
Flat plate ; Blanking press



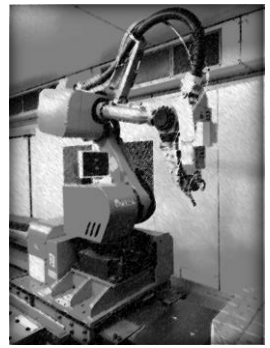
Press working



Channel plate
; Tandem or transfer press
(Assumed 5～7 processes)



Pretreatment
(Degreasing & Cleaning)



Laser Welding
Cycle time ; 1min/pcs <

Flatness
Leveling

Inspection(IN-Line)
Leak Test & Pressure Test

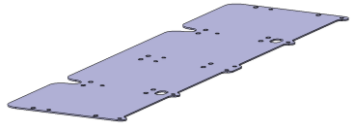
Final Inspection

Packing
Dispatch

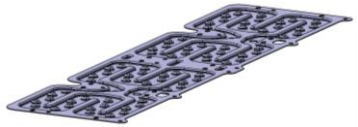
Process flow overview of “ LLC-resistant Adhesive ”

Bare coil materials

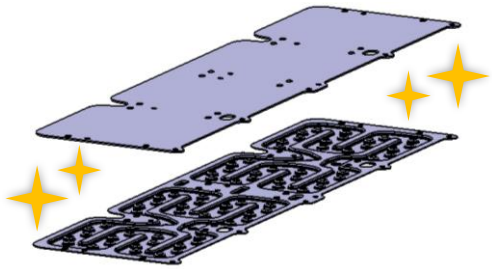
Flat plate ; Blanking press



Press working

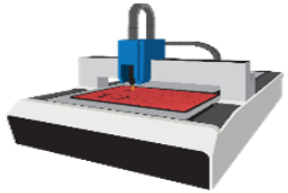


Channel plate
; Tandem or transfer press
(Assumed 5～7 processes)



Pretreatment
(Surface Treatment)

Pretreatment
(Degreasing & Cleaning)



Adhesive application

Oven Cured
MAX140°C-20min

Trimming

Inspection(IN-Line)
Leak Test & Pressure Test

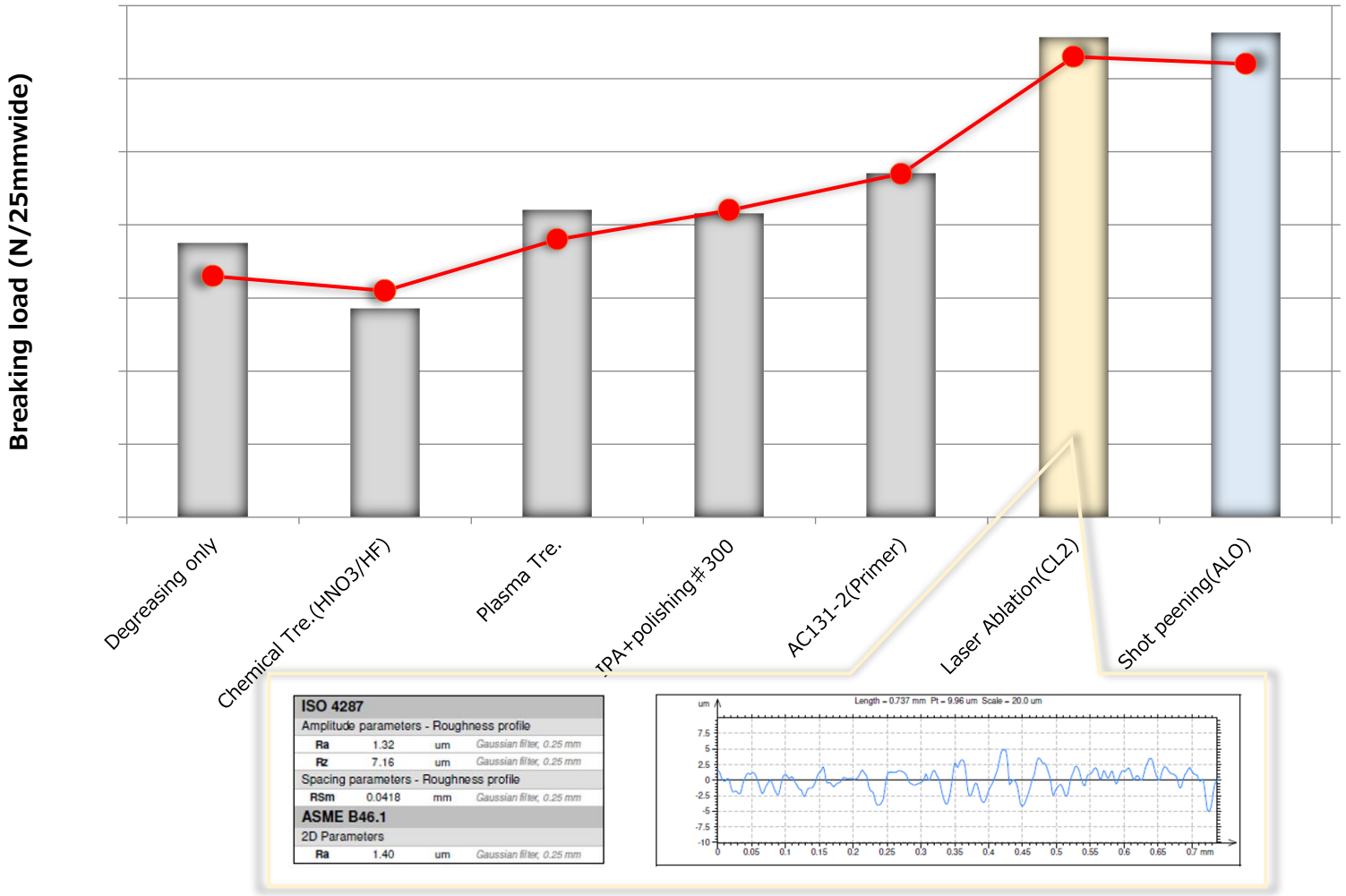
Final Inspection

Packing
Dispatch

LLC-resistant Adhesive technology optimized for Cooling Plate

➢ **Optimization of processes that affect Joining performance and cost.**

Relationship between adhesive peel strength and surface treatment



➢ Test conditions

- Adhesion area : 25 x 35mm
- Curing conditions : 140℃-20min
- Test speed : 5mm/min

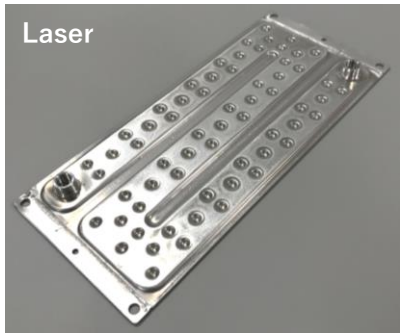
➢ Fracture mode

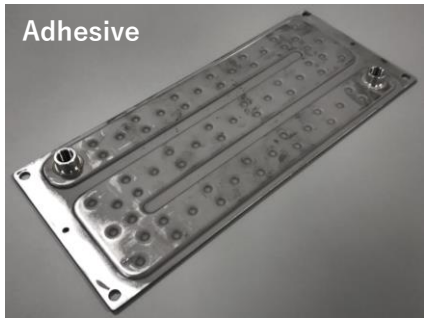
Cohesive Failure

Examples of DID cooling plates made with new manufacturing methods

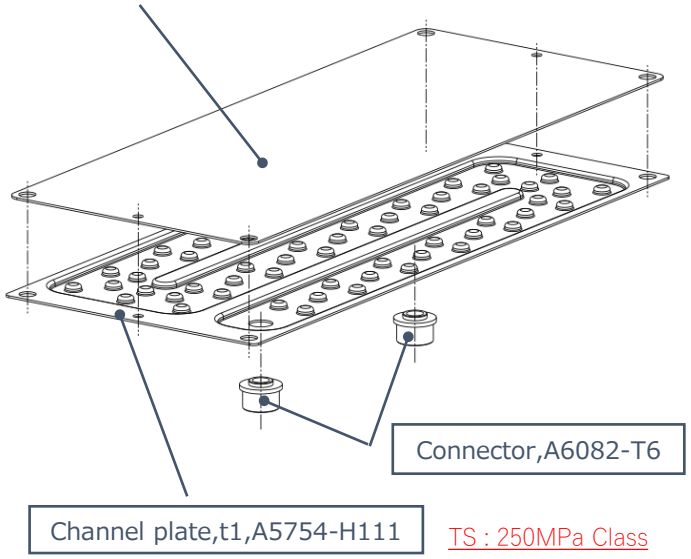
➢ Module level

Individual/Convex

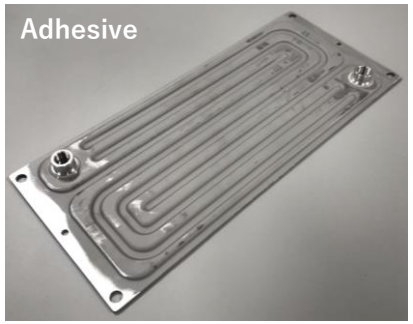




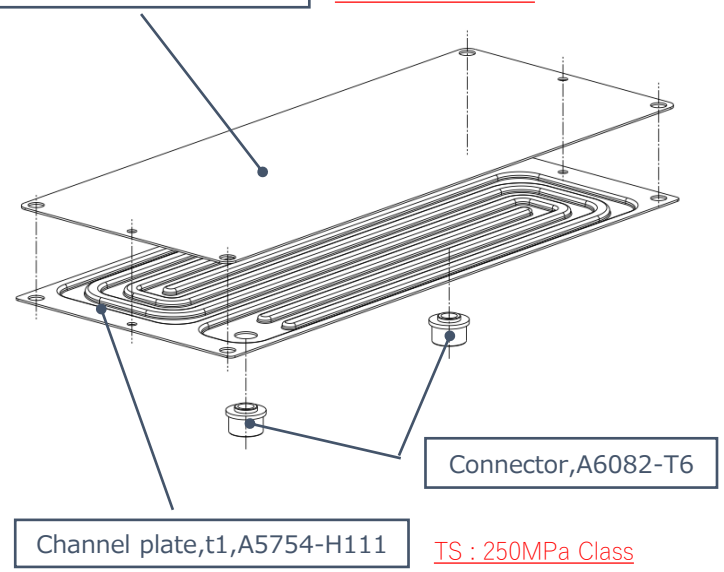
<Parts Configuration>



Multiline



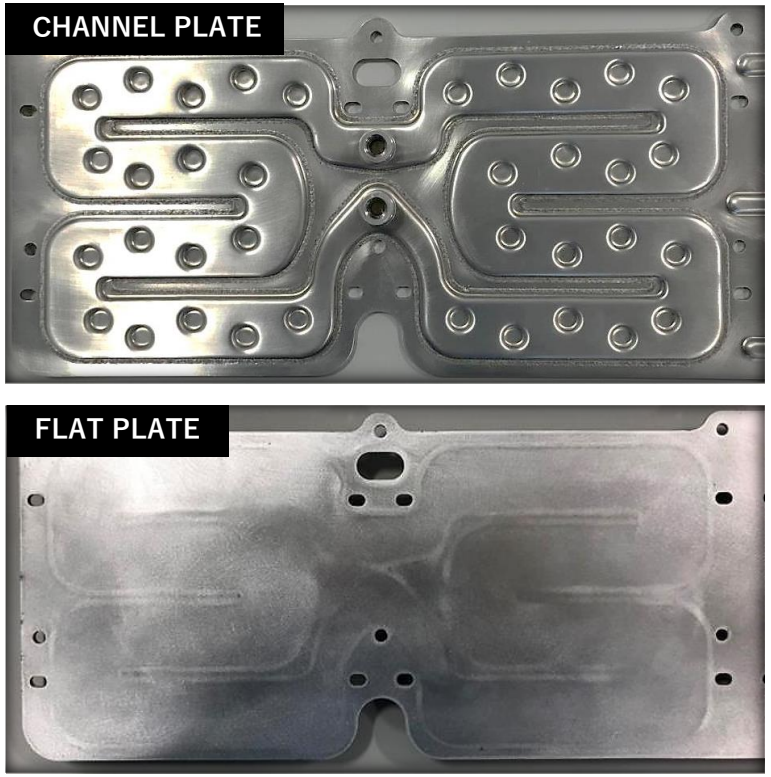
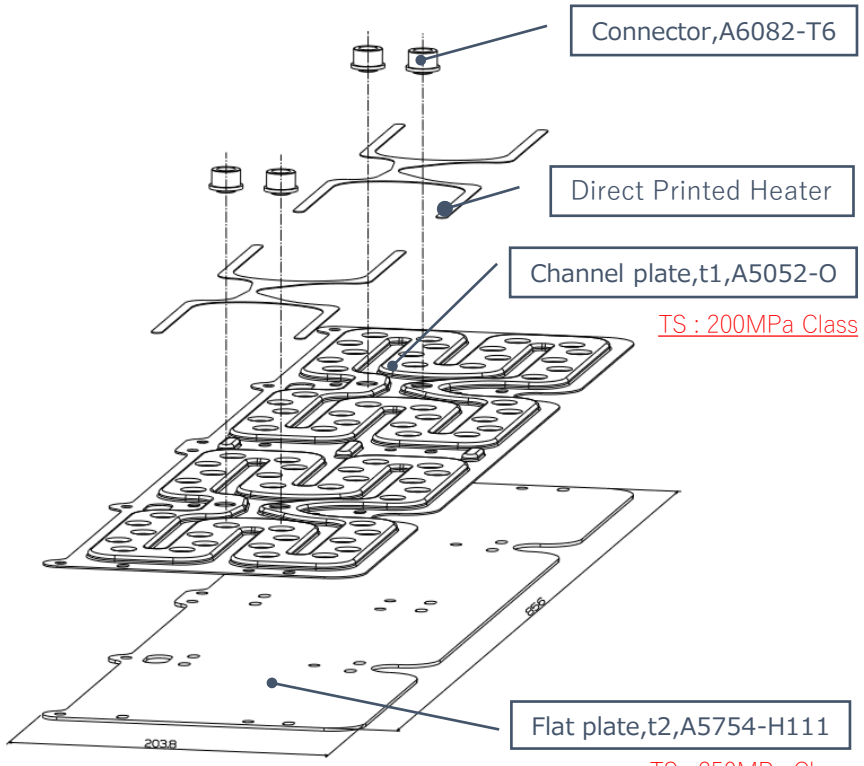
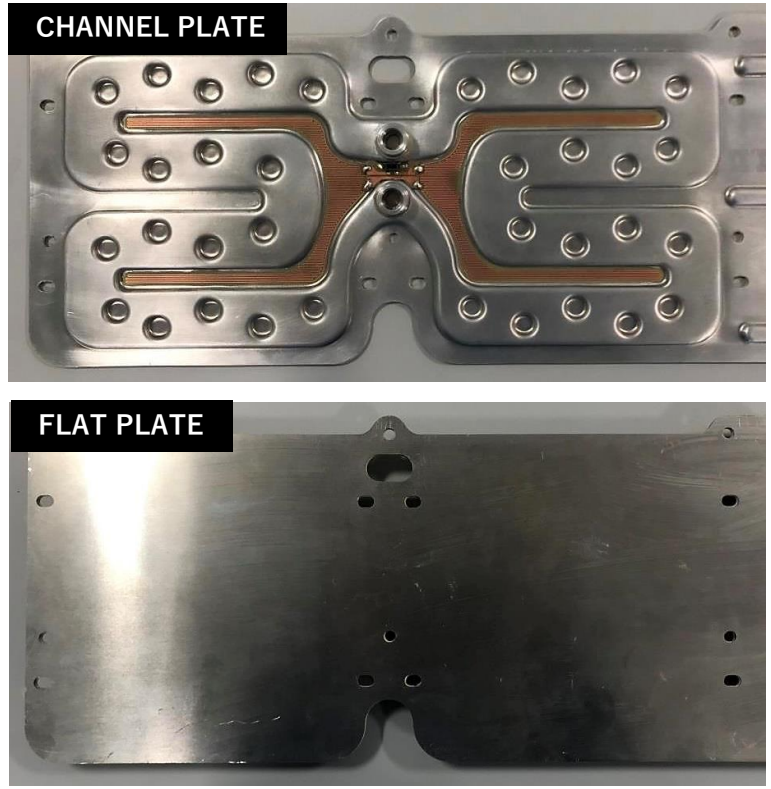
<Parts Configuration>



Joining Technology	Laser Welding	LLC-resistant Adhesive	Laser Welding	LLC-resistant Adhesive
Joint area	≒ 1,624 mm	≒ 16,000 mm2(≒Brazing)	≒ 3,322 mm	≒ 20,500 mm2(≒Brazing)
Size , L x W x H	355 x 151 x 5 mm		355 x 151 x 5 mm	
Total Weight	316 g	320 g	328 g	332 g

Examples of DID cooling plates made with new manufacturing methods

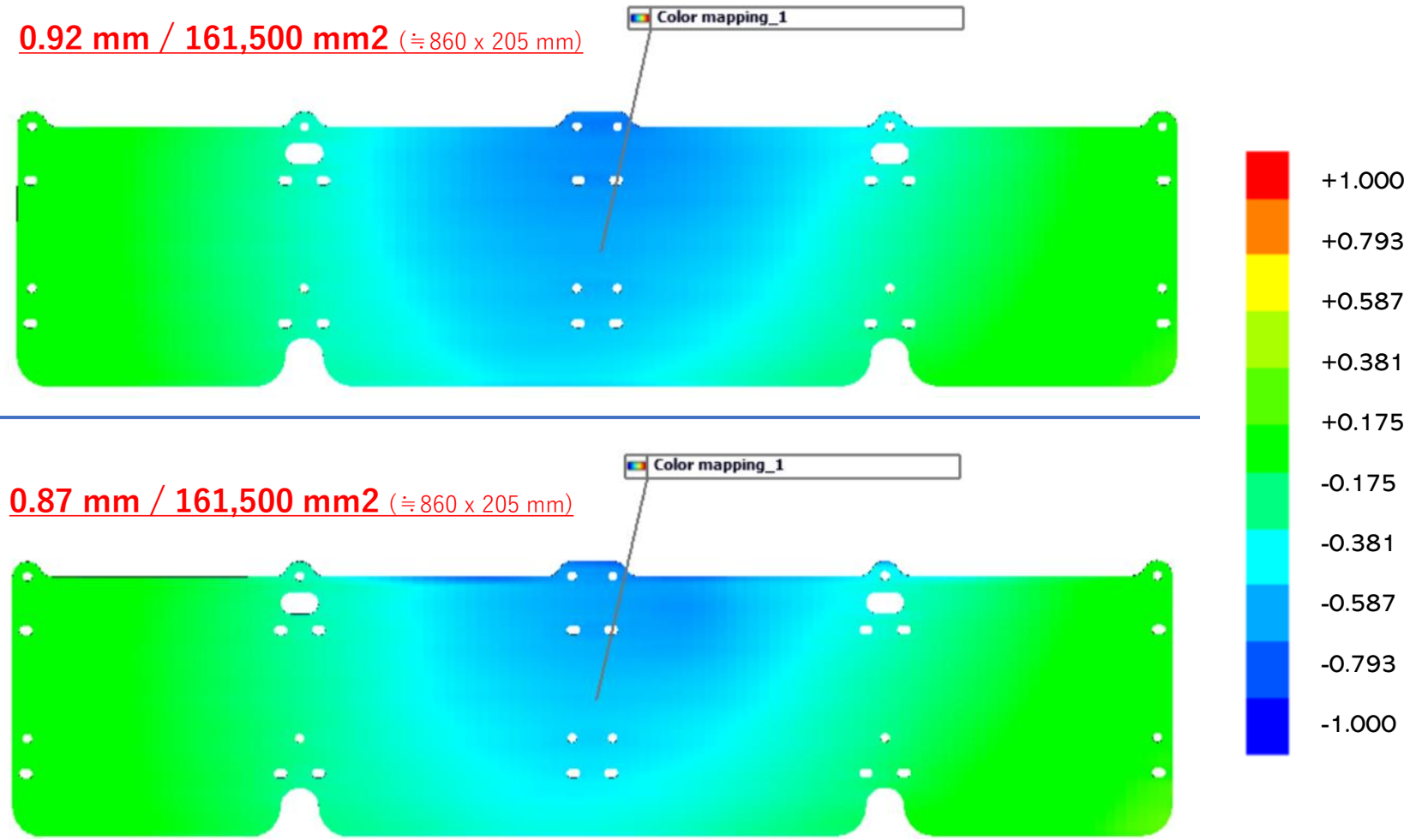
➢ Multi-module level

Laser Welding		LLC-resistant Adhesive
		
Joint area	≒ 6,000 mm	≒ 66,000 mm2(≒Brazing)
Size , L x W x H	860 x 205 x 7 mm	
Total Weight	1,458 g	

Flatness quality assurance

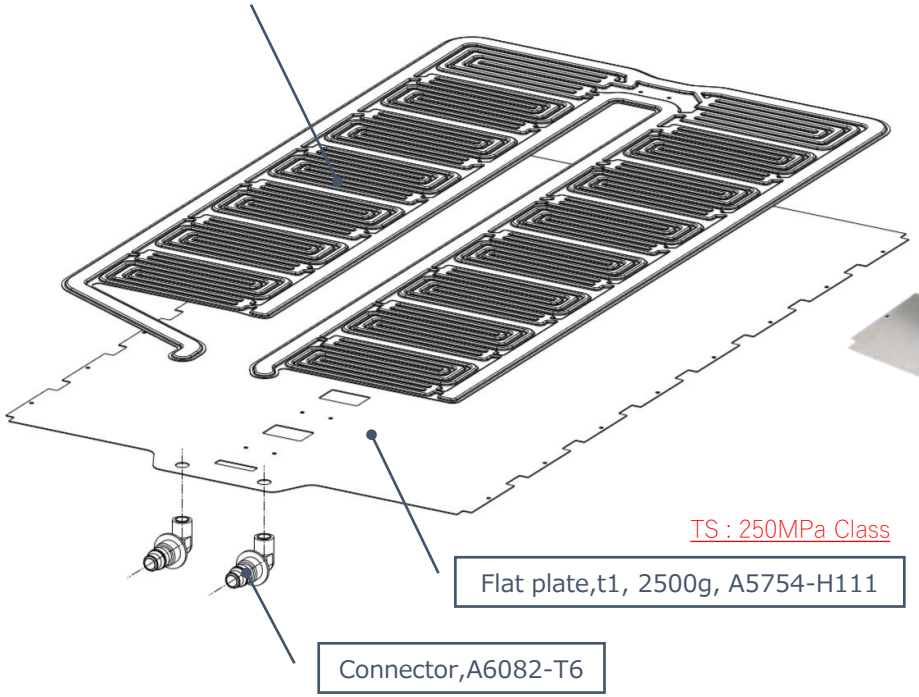
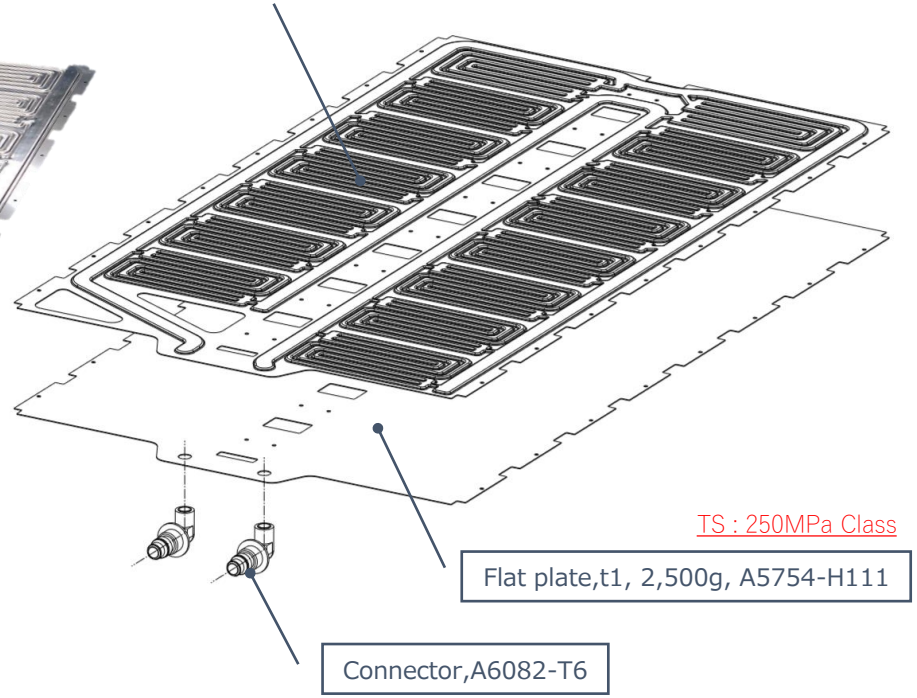
➢ **Multi-module level**

	FLATNESS (FREE STATE FLATNESS)
Laser Welding	**0.92 mm / 161,500 mm2** (≒860 x 205 mm)
LLC-resistant Adhesive	**0.87 mm / 161,500 mm2** (≒860 x 205 mm)



Examples of DID cooling plates made with new manufacturing methods

➢ Pack level

Laser Welding	LLC-resistant Adhesive
Channel plate, t1,**2324g**, A5052-O TS : 200MPa Class  TS : 250MPa Class Flat plate,t1, 2500g, A5754-H111 Connector,A6082-T6	Channel plate, t1,2670g, A5052-O TS : 200MPa Class  TS : 250MPa Class Flat plate,t1, 2,500g, A5754-H111 Connector,A6082-T6
Joint area	**≒ 40,000 mm**	**≒ 260,000 mm2**(≒Brazing)
Size , L x W x H	**1,300 x 740 x 5 mm**	
Total Weight	**5,091 g** ←	→ **5,437 g**

Summaryy and future developments

- *More than 20% weight reduction compared to conventional products.*
- *Up to 20% cost reduction in material costs by using bare aluminum.*
- *More sustainable process, reduction in CO2 output during assembly process.*

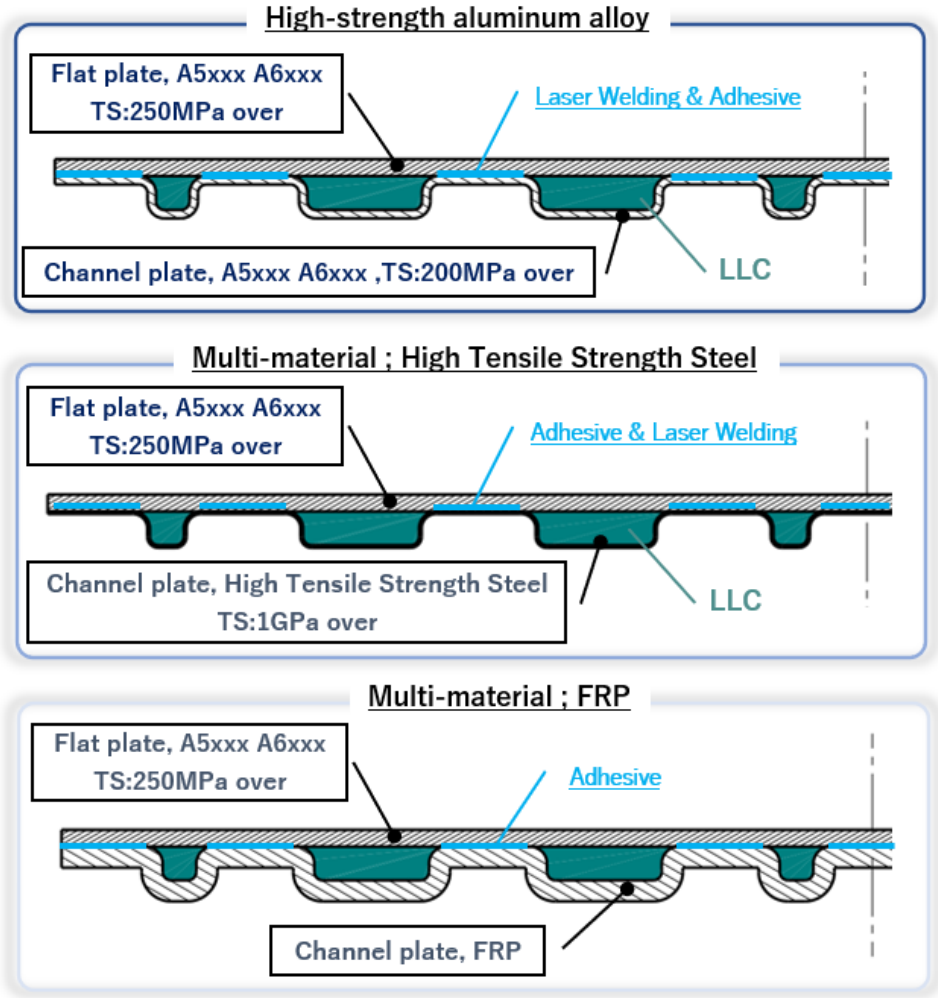
D.I.D®

TYPE		DID cooling plates (TRL 6)		Conventional products	
				Brazing	Roll-Bond
Material	Flexibility	(3XXX),5XXX,6XXX series TS:200MPa<		3XXX series (<TS:150MPa)	1XXX,3XXX series (<TS:150MPa)
	Temper	O,H1X,H3X,T4,T6		O,H1X (Clad sheet)	O,H1X
Joining Technology		Laser Welding	LLC-resistant Adhesive	Brazing	Rolling
Productivity (Cycle time of joining)		Welding speed: 10m/min<	140℃-20min	600℃-40min<	Depends on rolling speed

TRL 6
Lighter & Stronger

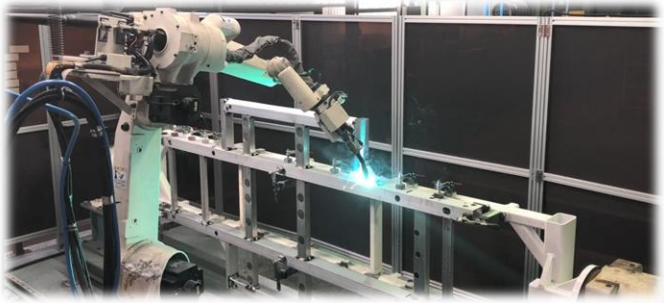
TRL 4
Low cost

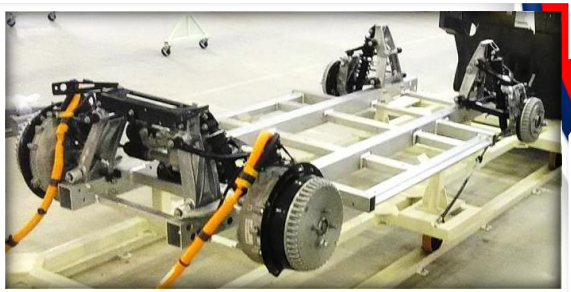
TRL 3
Ultralight



“ Trends for **LiB** ” **x** “ DID Aluminum Technology ”

➢ Joining Technologies





Welded structural ladder frame for Compact EV

Form ONE

山中漆器

Integrated production system as Tier1

High strength/lightweight rim

➢ Surface Treatment/Heat Treatment

Deep-drawn ATV wheel

➢ Press/Bender/Roll Forming

Cold Stamping/Cold Forging

Heat sink

High strength handlebar

Hybrid structure swingarm for motorcycle

With 90 years of manufacturing tradition and elemental technologies related to aluminum, we propose cooling plates for a new era.

eVTOL

ESS

D.I.D®
COOLING

Marine

ev

Heavy-Duty

Our thermal solutions are suitable for all types of electrification.

Thank you.

<For inquiries about our European projects, please contact us>
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ADDENDUM

Cooling Plate Performance Requirements Testing

The following information is our proprietary cooling plate performance evaluation.
Evaluation conditions are flexible according to customer requirements.

Pressure test

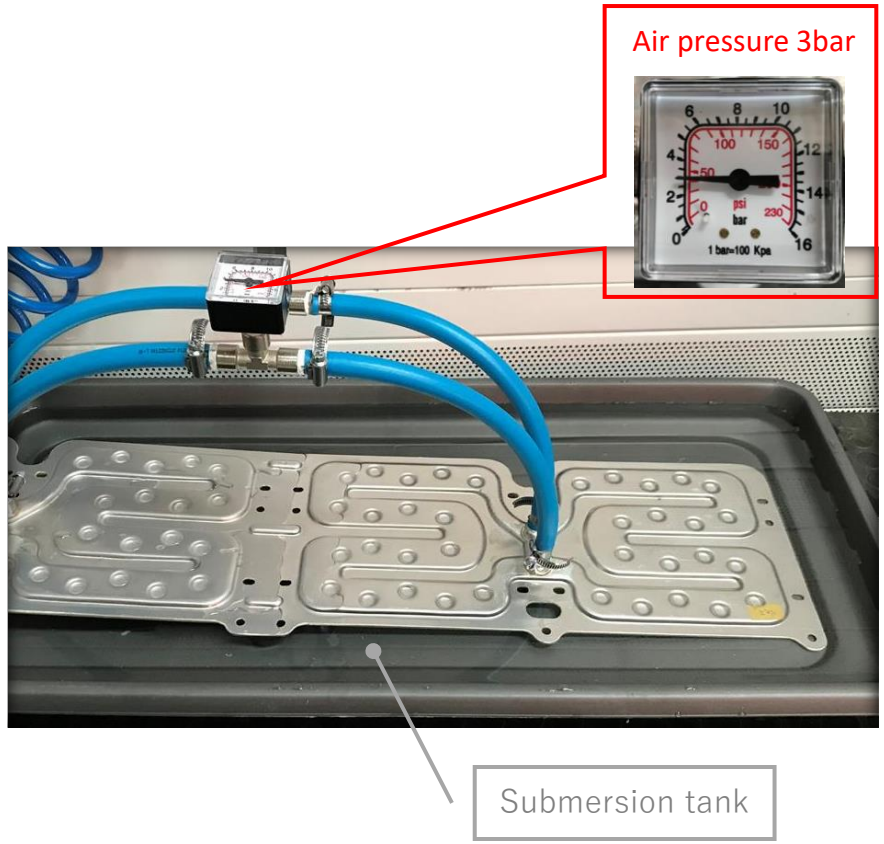
➢ Leak test

1. Test conditions

1) 100% sealing under 3.0 Bar air pressure
2) Applied air to plate submerged under water and ambient air

2. Results

⇒ **No air leakage above 3.0 bar**



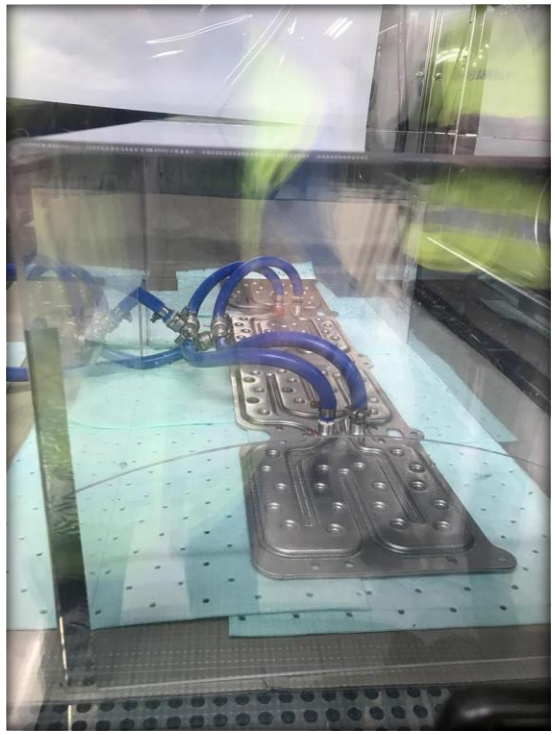
➢ Burst test

1. Test conditions

No damage to parts or leakage of coolant at pressures above 5 bar.

2. Results

⇒ **No plate failure and no coolant leakage at 5 bar.**



*Burst Pressure results vary by cold plate design

Cycle test

➢ Thermal cycle test

1. Test conditions

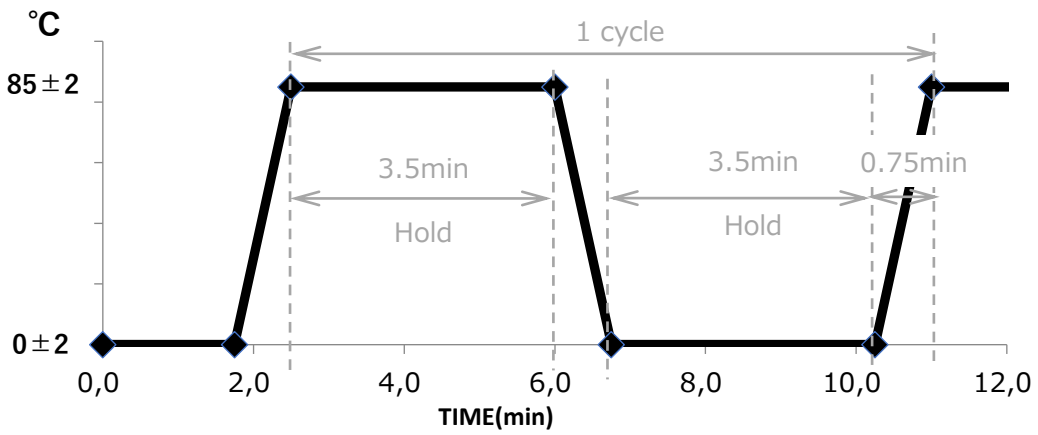
1) Coolant : 100% Glycol
2) Coolant temperature Range : 0°C to 85 ±2°C
3) Pressure : 2bar
4) Cycle time : 7cycle/hr.

⇒ Holding 3.5min at 0°C,3.5min @85°C, and 45sec transient time

2. Results

⇒ No Leak after 3,500 cycle

Thermal cycle



➢ Pressure cycle test

1. Test conditions

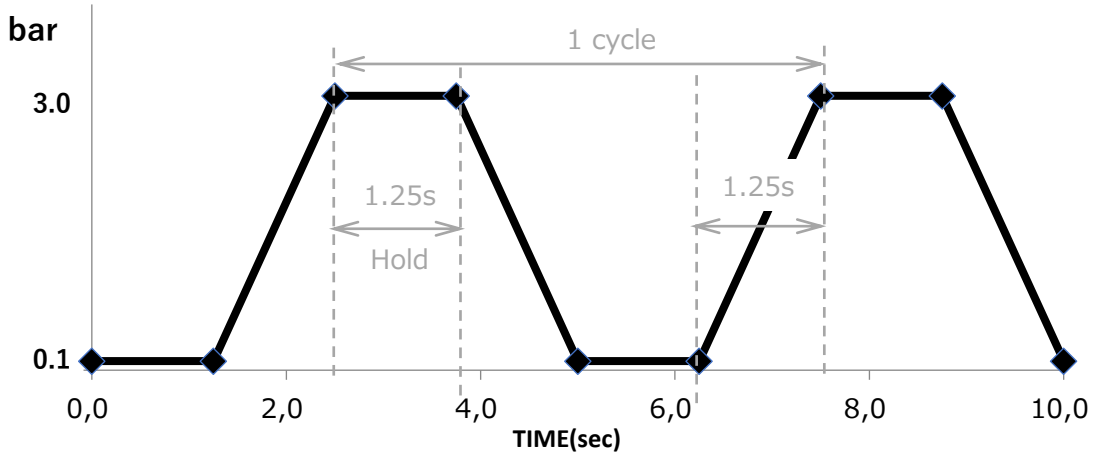
1) Coolant : 100% Glycol
2) Coolant temperature : 95°C
3) Pressure cycle : 0.1 to 3bar
4) Frequency : 0.2Hz(12 cycles/min)

⇒ Cycle : Pressure increase(1.25s),and hold(1.25s)

2. Results

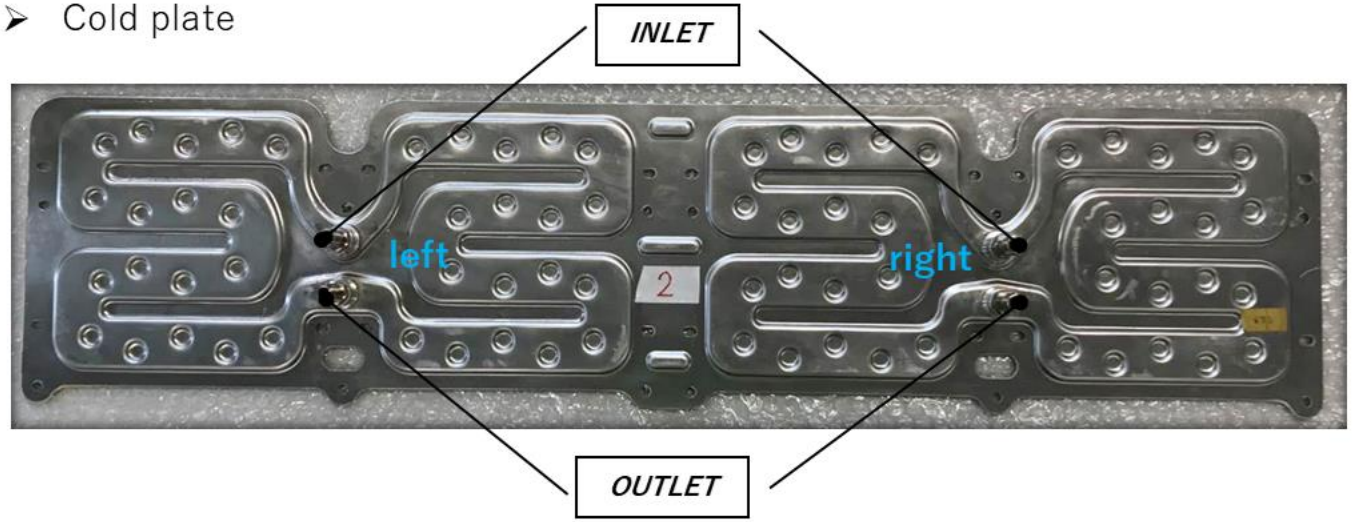
⇒ No Leak after 150,000 cycle

Pressure cycle

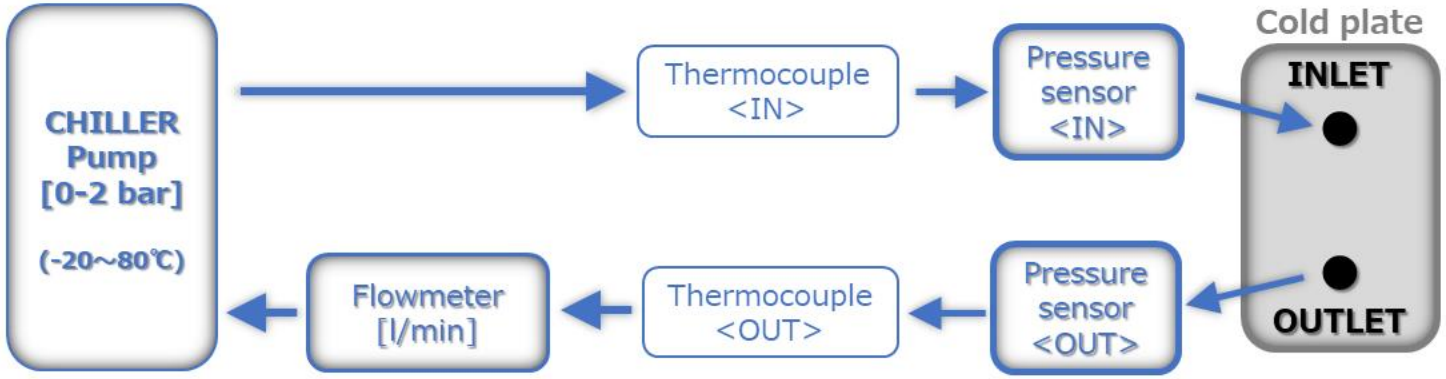


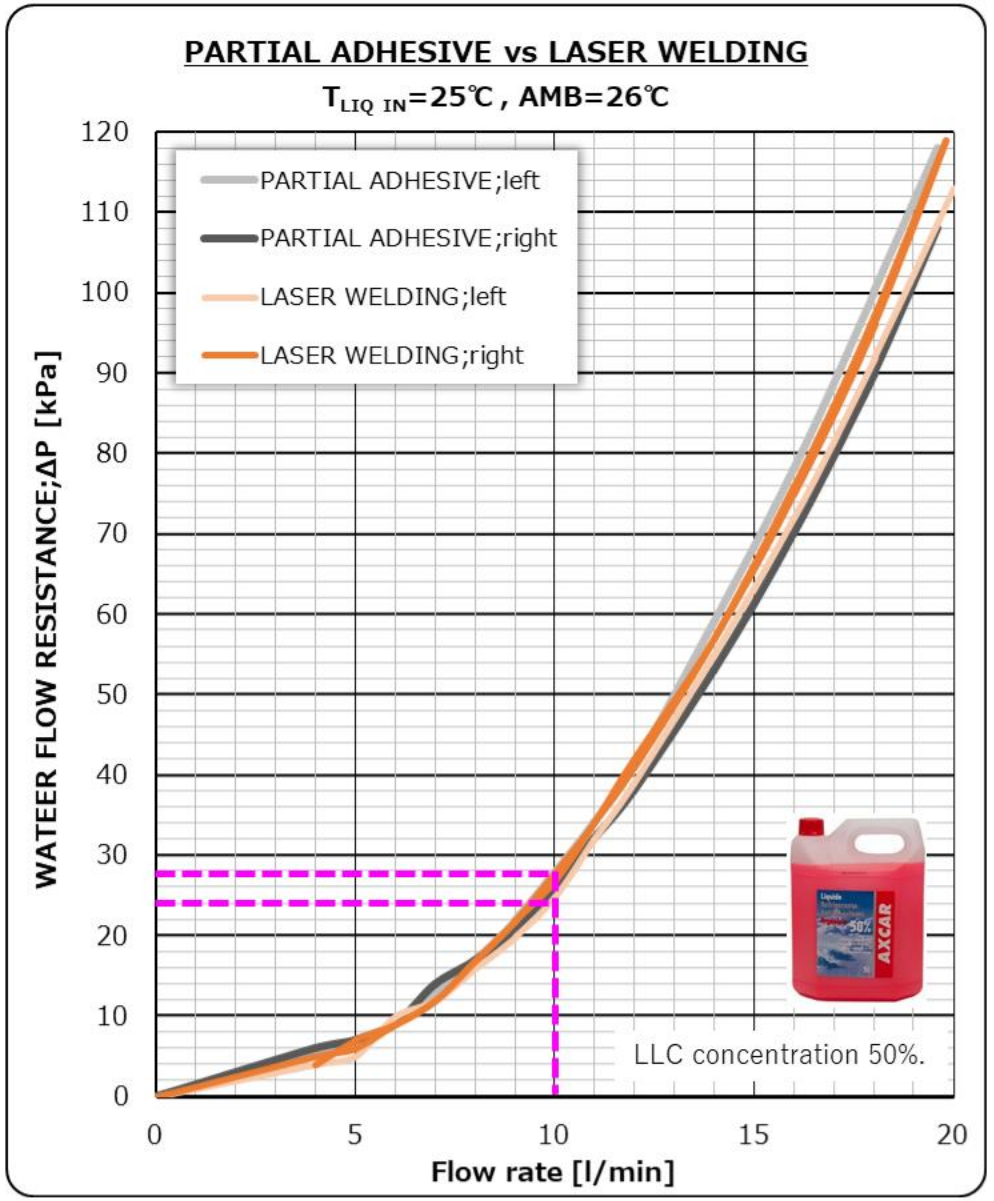
Water flow resistance test

➢ Cold plate



➢ Evaluation Method

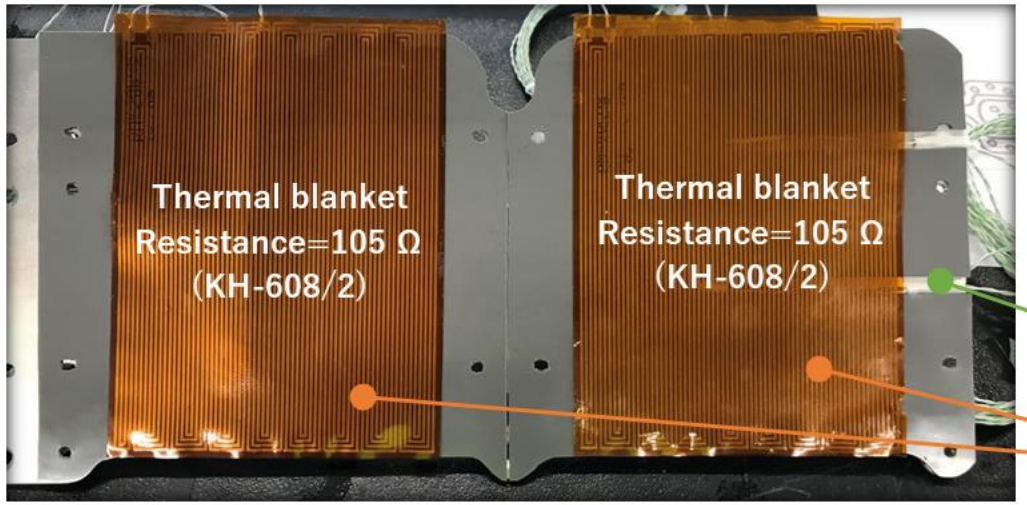


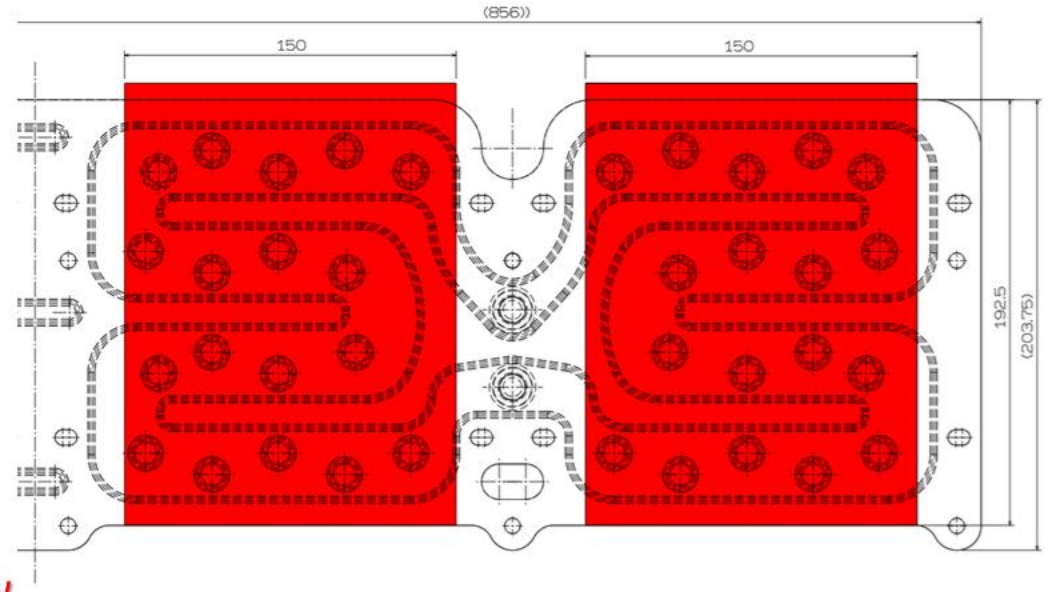


➢ The prototype's water flow resistance is 24-28 kPa at a flow rate of 10 L/min.

Fluid heat transfer test

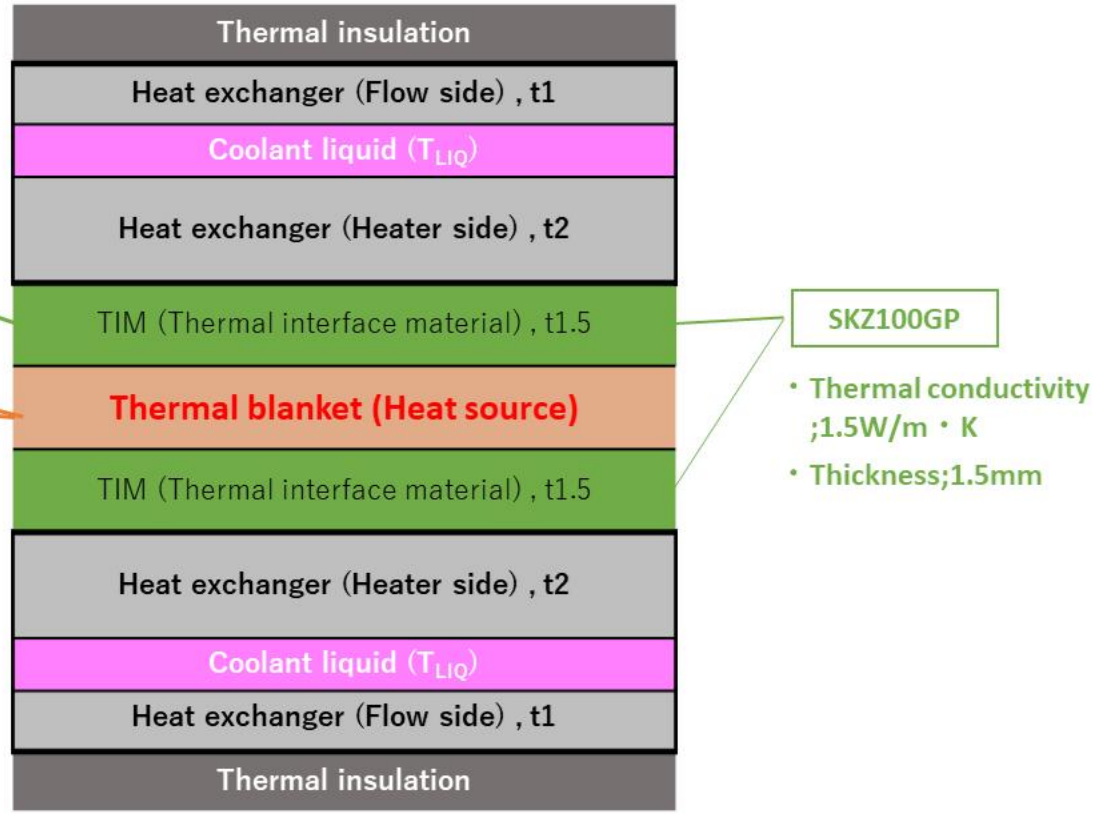
➢ Evaluation Method





➢ Heat Input Condition

1) Cross sectional schematic



2) Heat flux

$Q_{\text{Heat input}} = 210W$, Contact surface = 0.0288m2

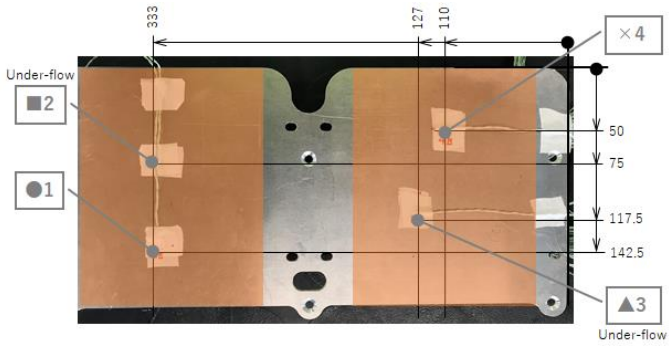
$$q_{\text{Heat flux}} = \frac{210}{0.0288} = 7291.7\ W/m2$$

Fluid heat transfer test

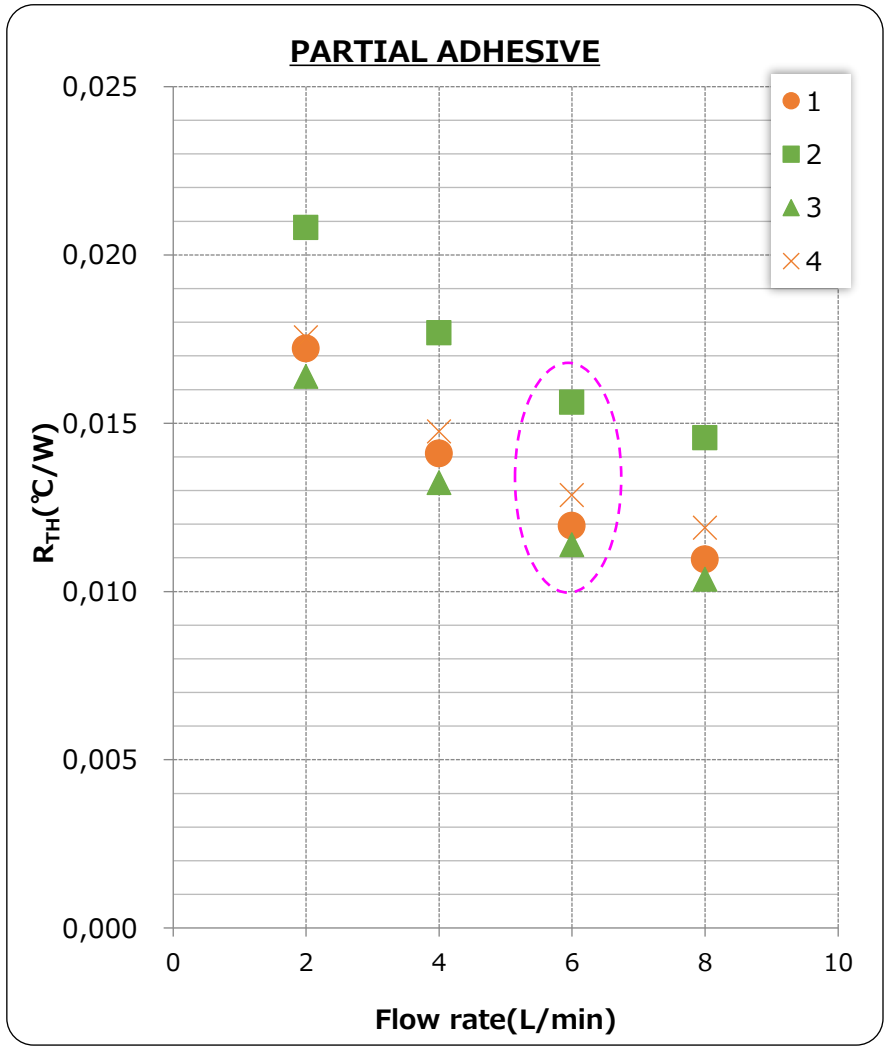
- Relationship between flow rate and Thermal Resistance(R_{TH})

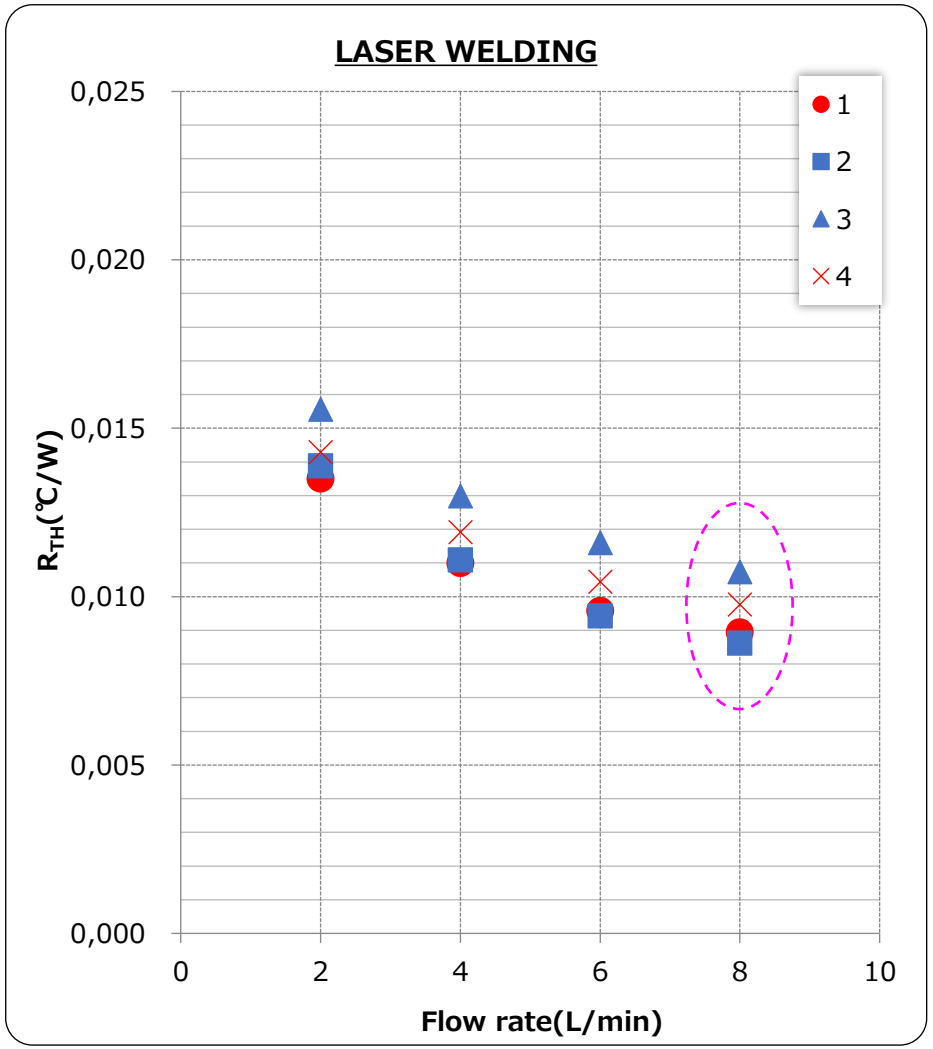
$$R_{TH} = \frac{\Delta T}{Q} = \frac{(T_{CP} - T_{LIQ\ IN})}{Q}$$

※ $T_{LIQ\ IN}$=25℃、AMB=26℃



Temperature measurement position
(Location of thermocouples)





- Thermal resistance is 0.015℃/W for the adhesive type and 0.011℃/W for the laser type.