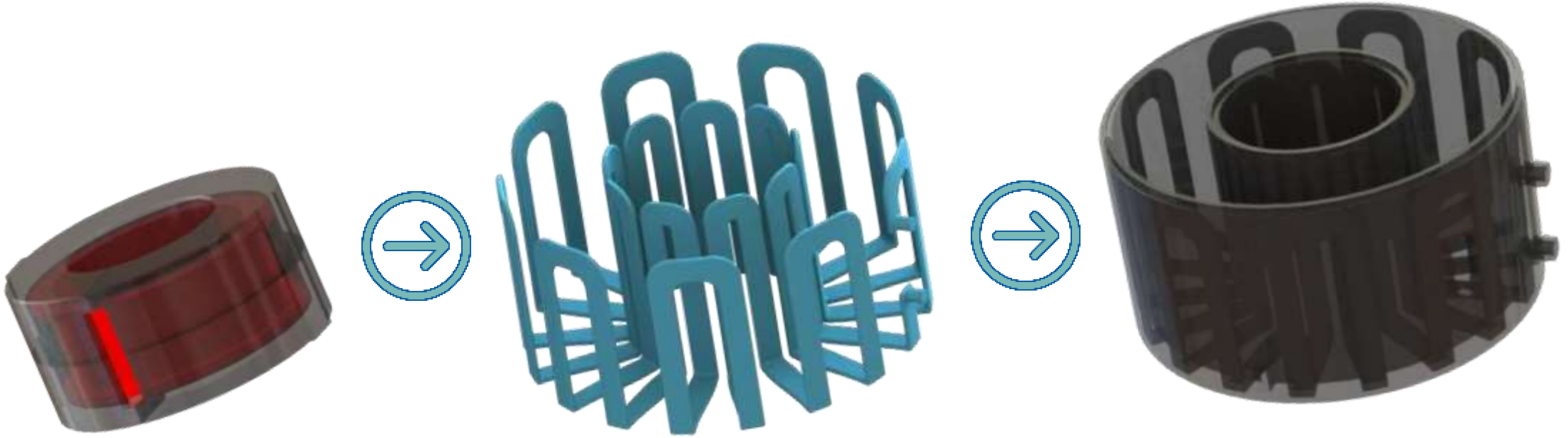
coolgap

coolgap

DISRUPTIVE TECHNOLOGY FOR HEAT TRANSFER



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7. Results (tests)
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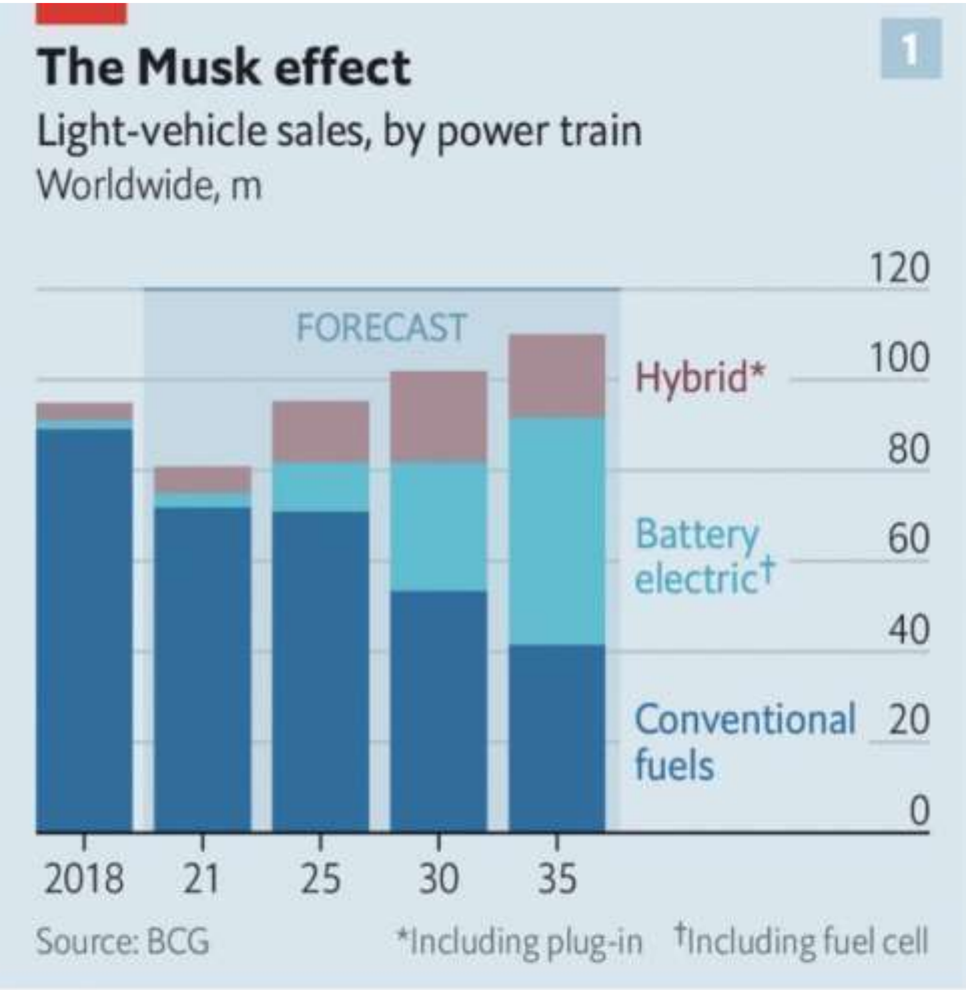
Introduction: Global electric car stock



The Economist

Hyundai

Kona Electric

- First fire reported in Ulsan plant
- Second fire reported in Ulsan plant

Tesla

Model S

- Sudden fire when driving (LA)

Tesla

Model S & X

- Caught on fire while parked (Pittsburgh)
- Sudden fire at negative ambient temperature (Lake Champain)
- Exploded in an underground garage (Shangai)
- Caught on fire while parked (HK)
- Burned down while supercharging (Belgium)
- Burst into flames while charging (England)

Hyundai

Kona Electric

- Exploded due to Unprovoked fire, unplugged (Montreal)
- Fire while charging (SK)
- Fire while parked (SK)
- Fire while charging in underground parking (SK)
- Fire while driving (Austria)

2019

BMW

BMW i8

- Bega to smoke while in the car dealership. Placed in a water tank to prevent battery from exploding (Netherlands)

Hyundai

Kona Electric

- Fire while parked at full charge (SK)
- Burned down due to a fire after full charge in a charging station (SK)
- Fire while charging (SK)
- Fire while charging (Jeju)
- Fire while parked (SK)
- Fire while charging in a rapid charging service
- **Recall of 77,000 Kona Evs**

2020

Porsche

Taycan

- Exploded while parked (Florida)

Tesla

Model3

- Exploded in a parking while charging (Shanghai)

Hyundai

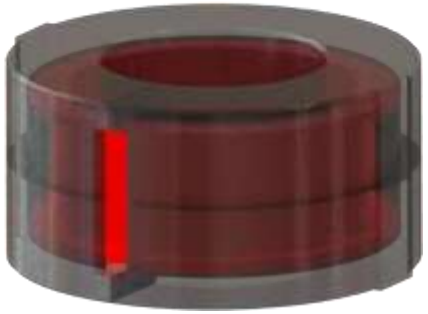
Kona Electric

- Fire while charging in a taxi company (SK)

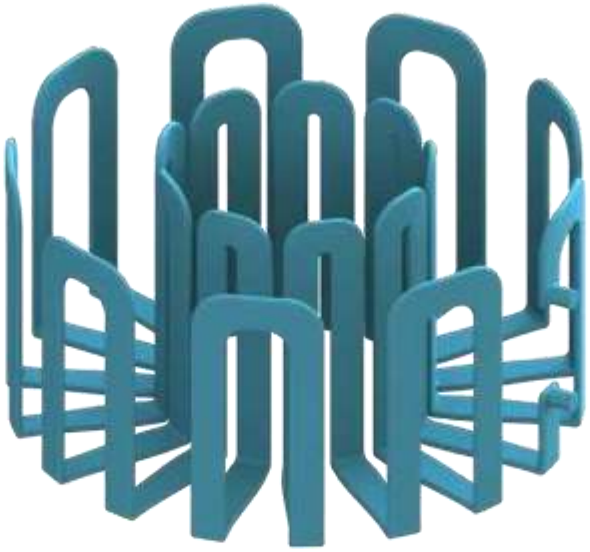
2021

What is Coolgap?

Coolgap is an **indirect liquid cooling** system that consists on a **snake-shaped duct** that removes heat directly from the source.



Heat generated in core gap

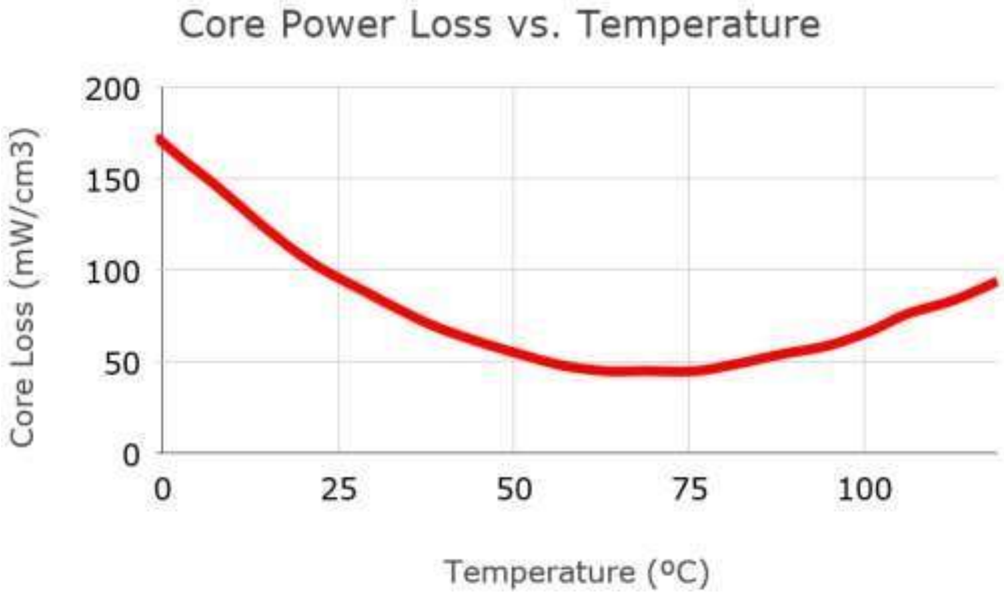


Liquid surrounds the heat source

Case external view

Why Coolgap?

- IC **core** and **copper losses** significantly increase with temperature.
- Liquid cooling becomes necessary when significantly increasing **power density**.
- Temperatures in excess of 45°C will rapidly degrade **battery lifetime.**
- **Liquid** cooling is much more efficient than **gas cooling.**

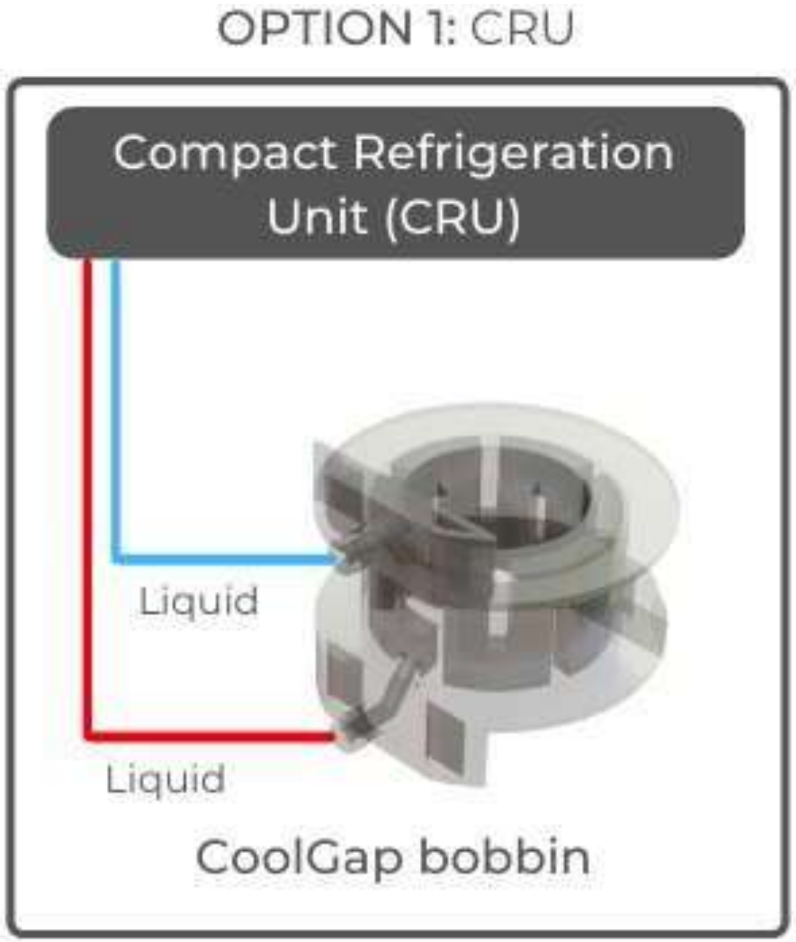


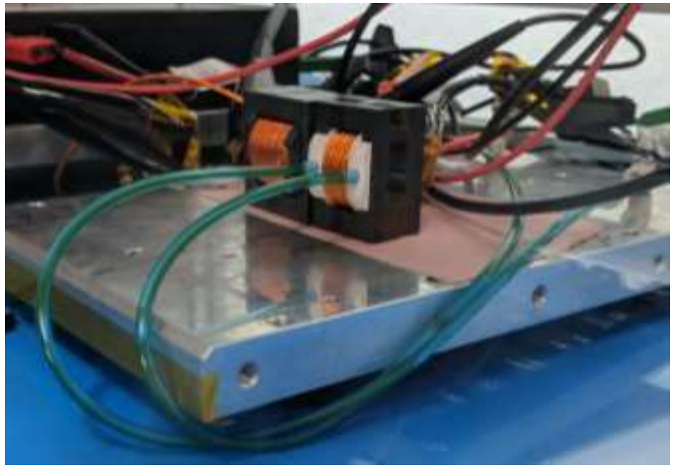
Working principles

Coolant	Flow type	e.g.	h*	Efficiency
Gas	Free	Passive heatsink	2 to 25	Low
	Forced	Fan, RDHx (rear door heat exchangers)	25 to 250	
Liquid	Free	Static immersion	50 to 1000	
	Forced	**Pump, closed loop or immersion**	**100 to 20000**	
	Phase change	2-Phase inmersion	2000 to 100000	High

*h = heat transfer coefficient (W/m2K)

Configurations





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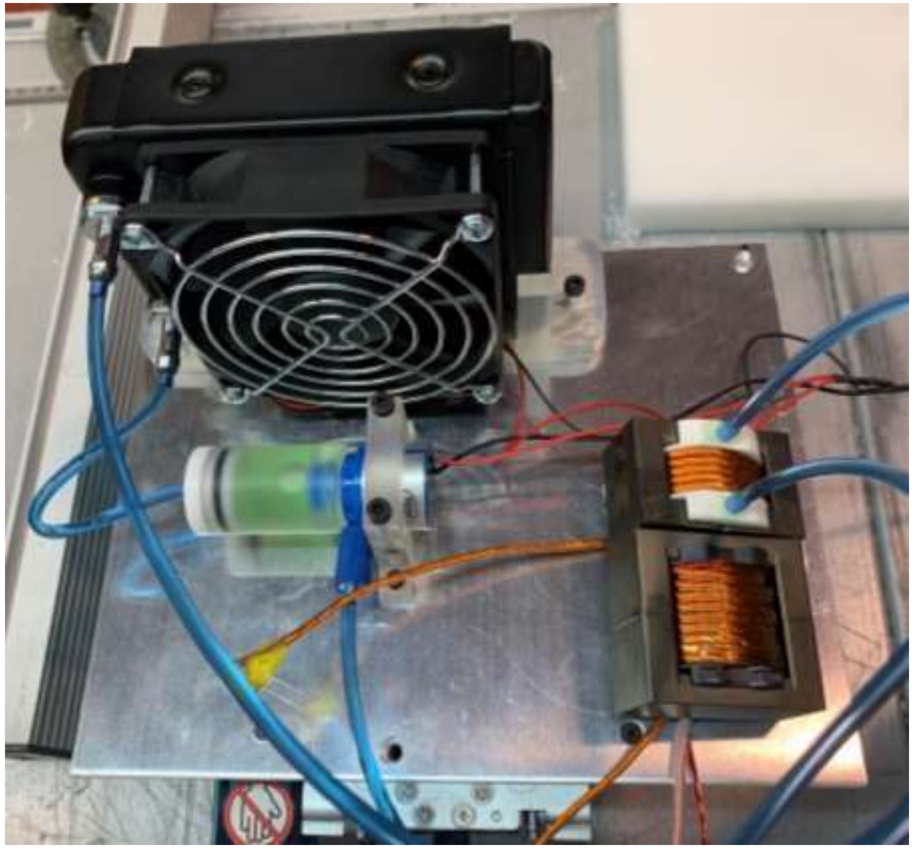

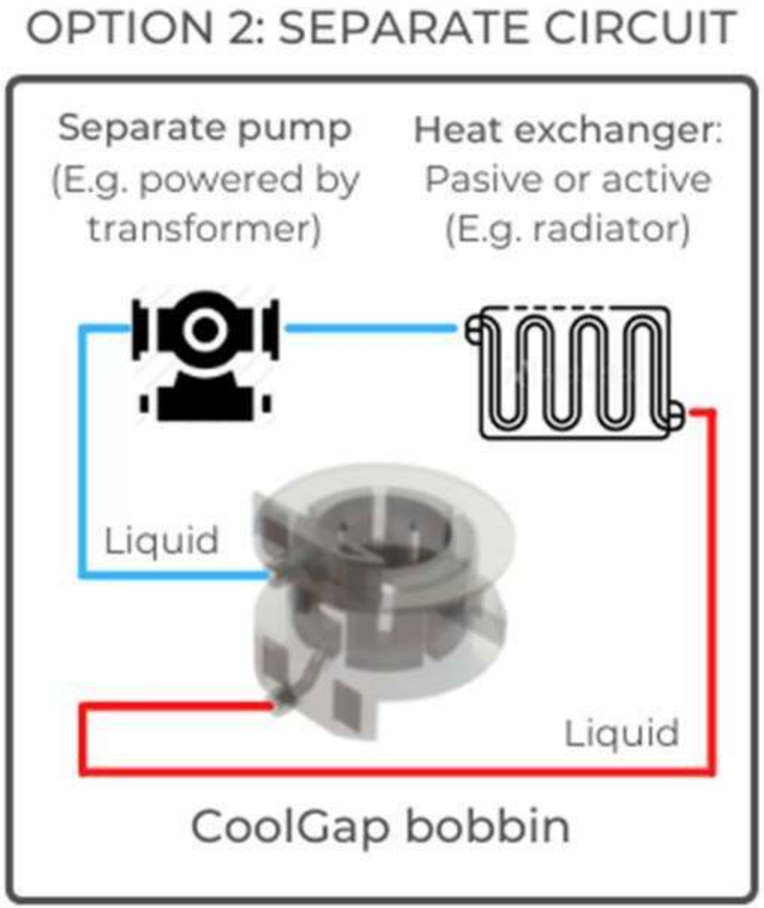

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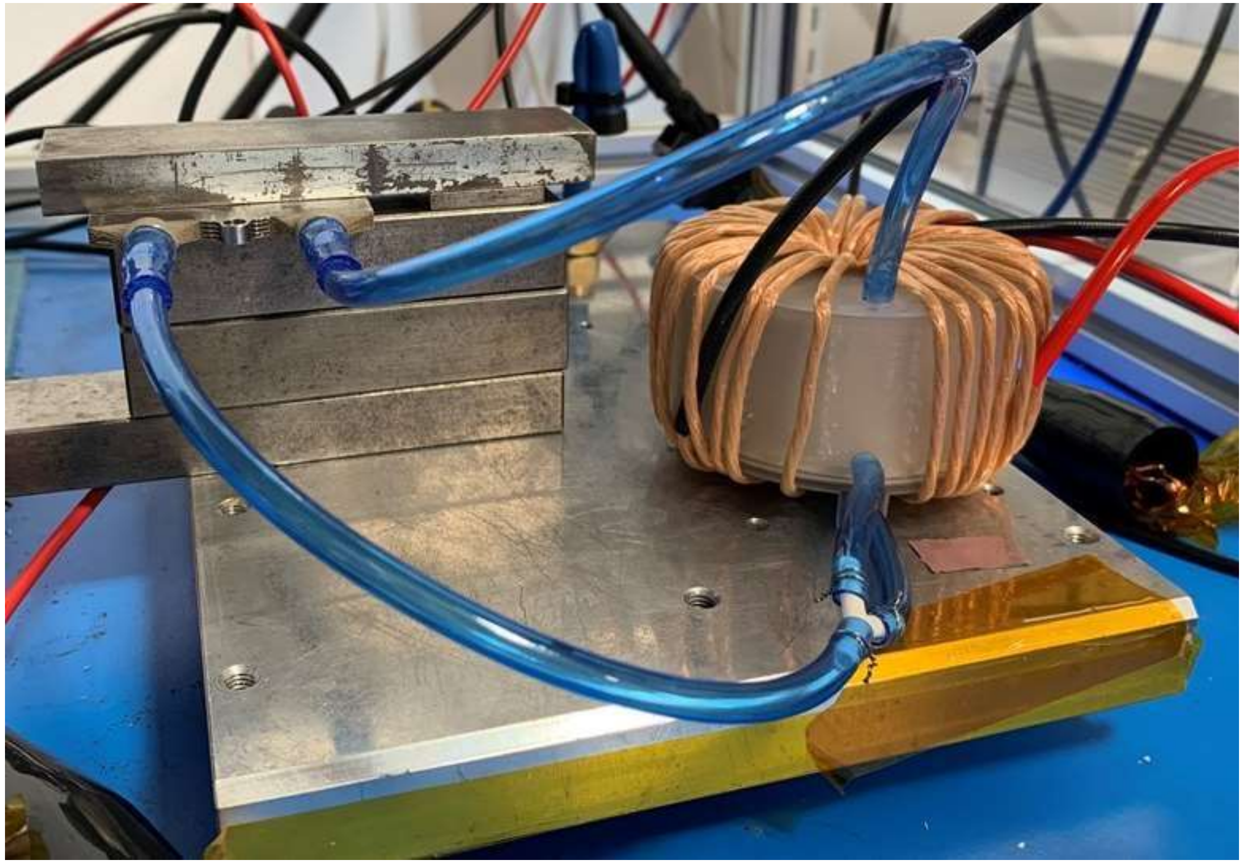
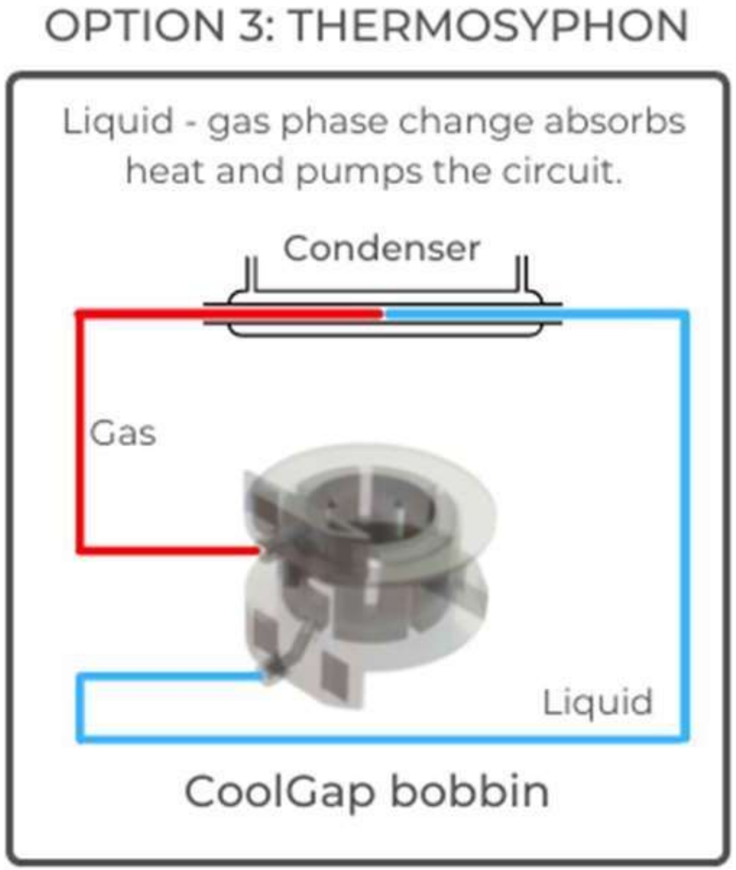
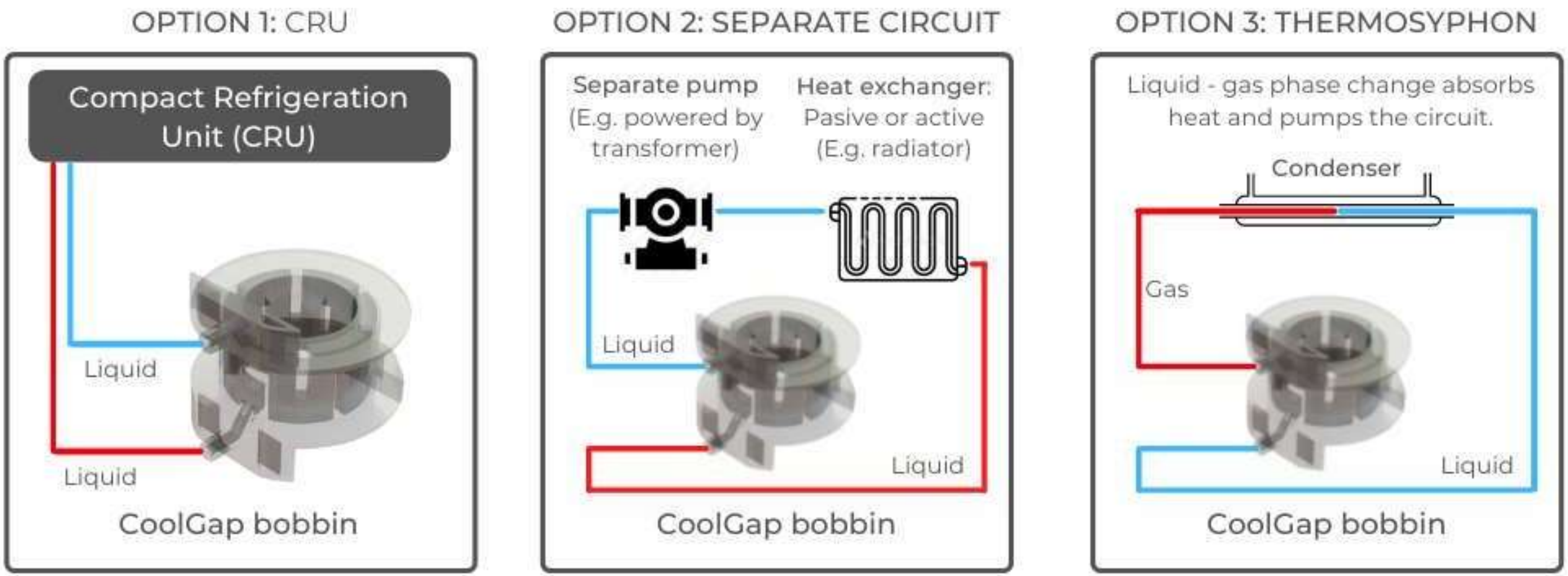
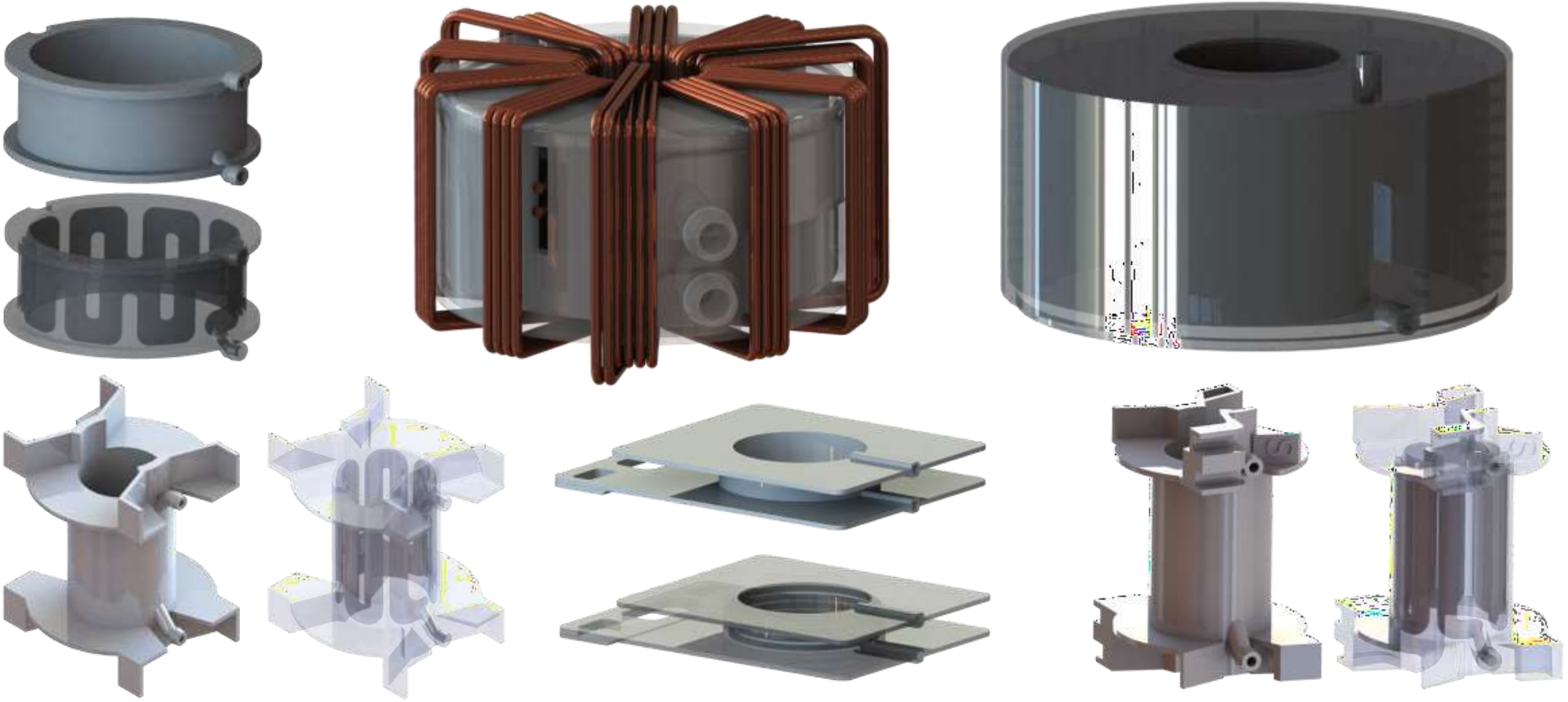




Configurations summary

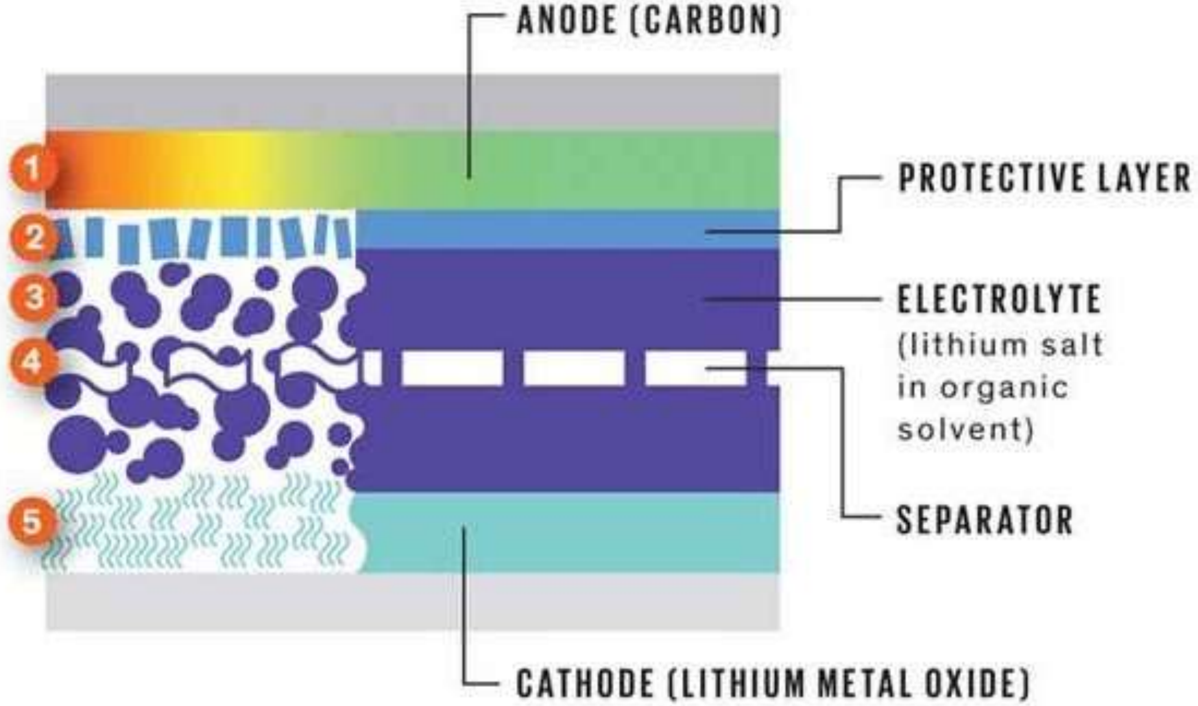


Applications



Thermal runaway

1. Heating starts.
2. Protective layer breaks down.
3. Electrolyte breaks down into flammable gases.
4. Separator melts, possibly causing a short circuit.
5. Cathode breaks down, generating oxygen.

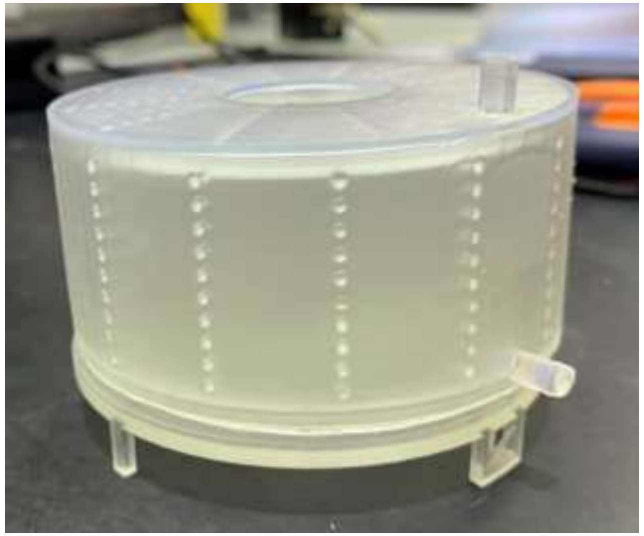


Bare

coolgap

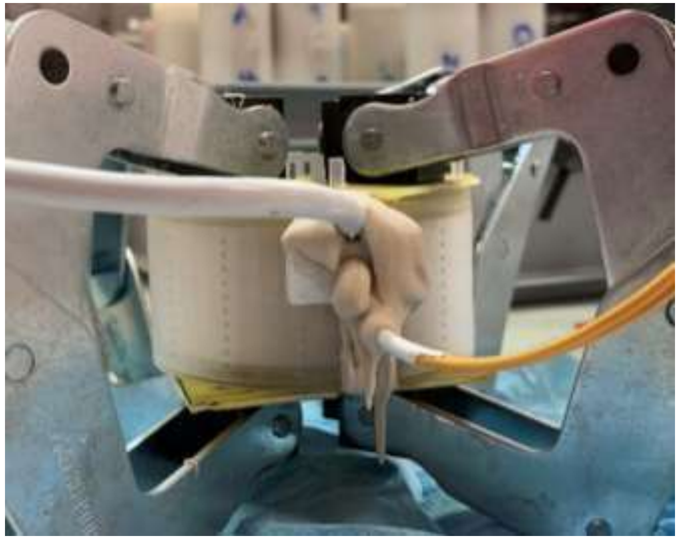
Inside

Prototype manufacturing



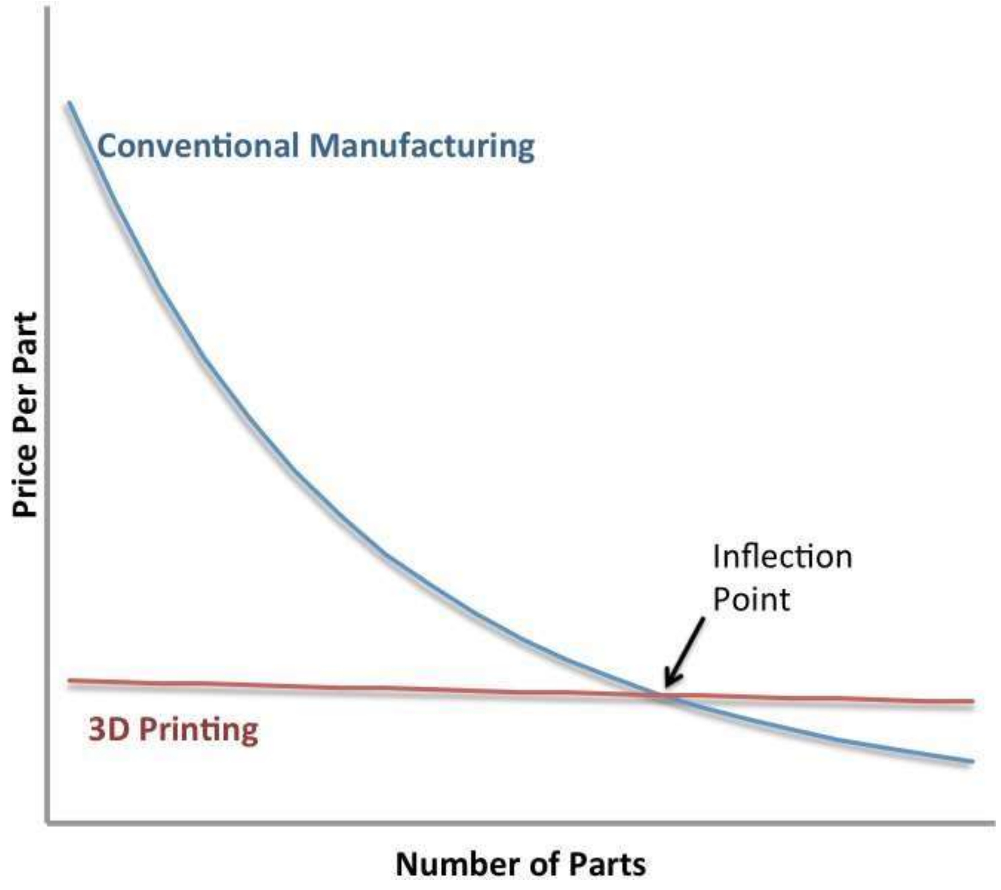
Printed part (clear resin).

Duct cleaning.



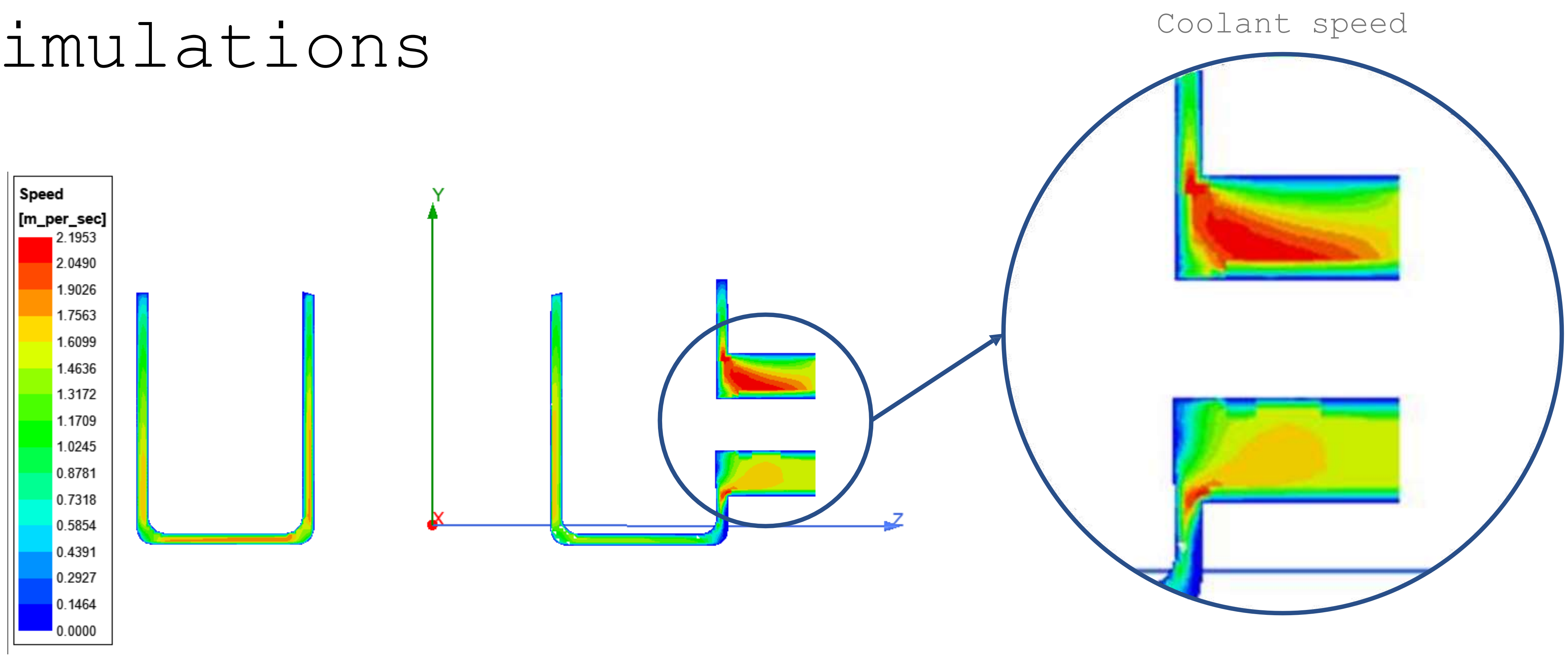
CoolMag injection.

Manufacturing challenges



- Inflection point difficult to calculate.
- Closed loop difficult to manufacture with injection process.
- 3D printing resins have low thermal conductivity.

Simulations



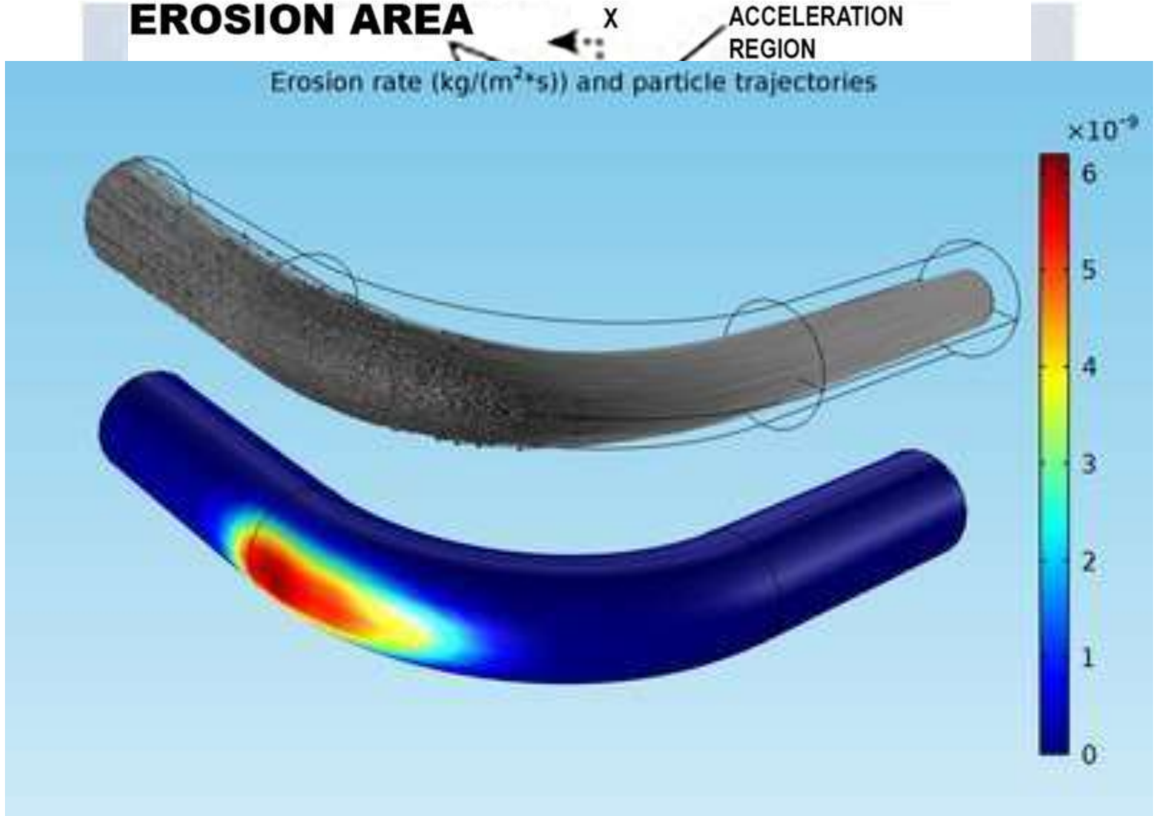
Simulation settings:

- Inlet velocity: 1 m/s.
- Outlet: Ambient pressure.
- Turbulent model: Zero Equation.

Poor duct design leads to:

- Not homogeneous mass flow.
- Undesired pressure drops.
- Increased speed and erosion in elbows.

Erosion



1.-Coolant flow separates in inner elbow radious.

2.-Recirculating flow generates cavitation zone in elbow.

3.-Effective cross section is reduced.

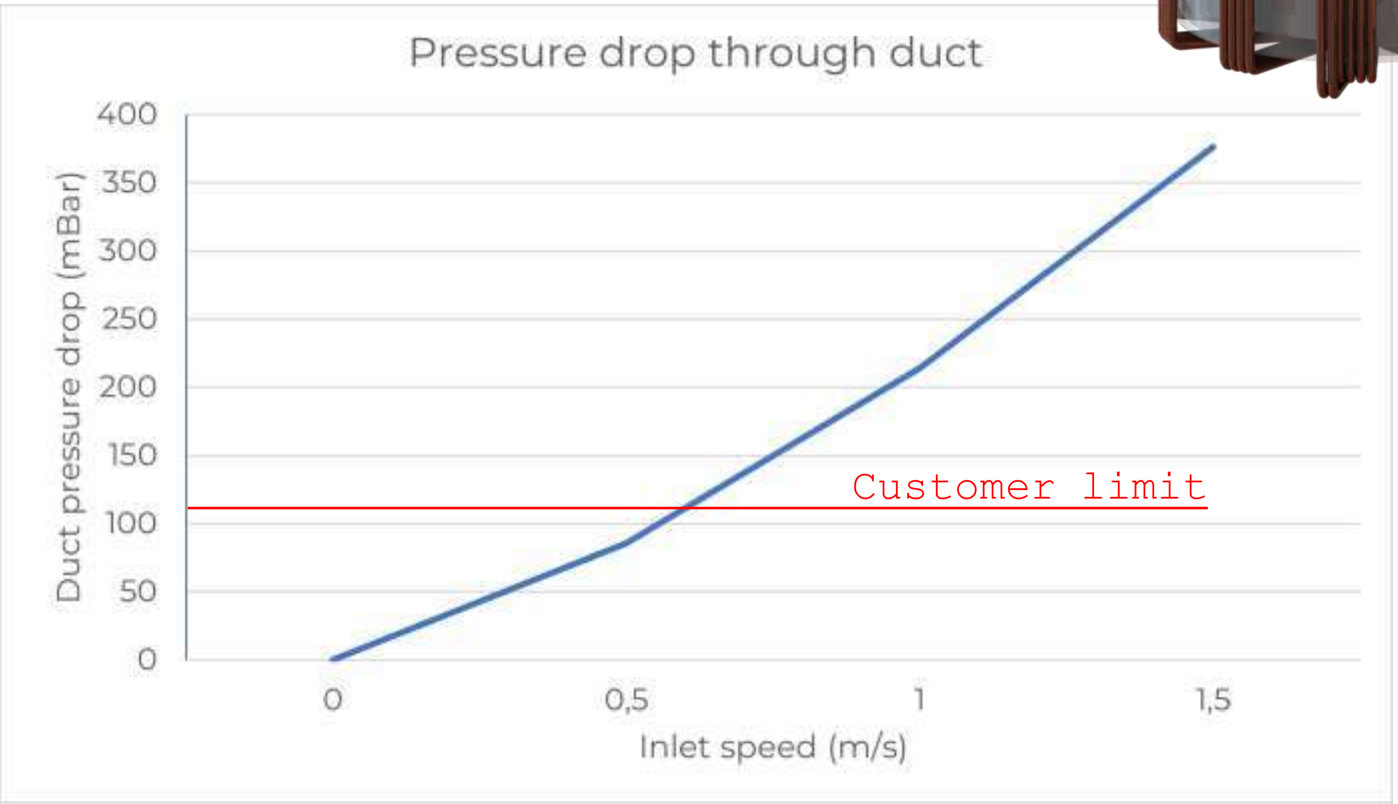
4.-Flow accelerates in elbow.

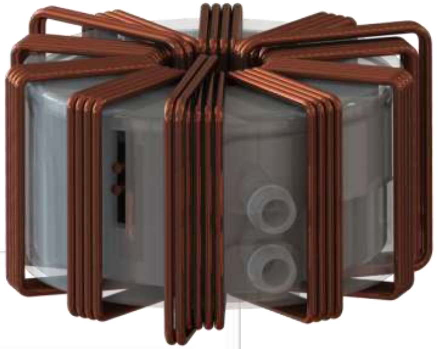
5.-Higher speed leads to higher erosion rate in outer elbow.

6.-Elbow failure

* Turbulence generators can be added to avoid this adverse effects.

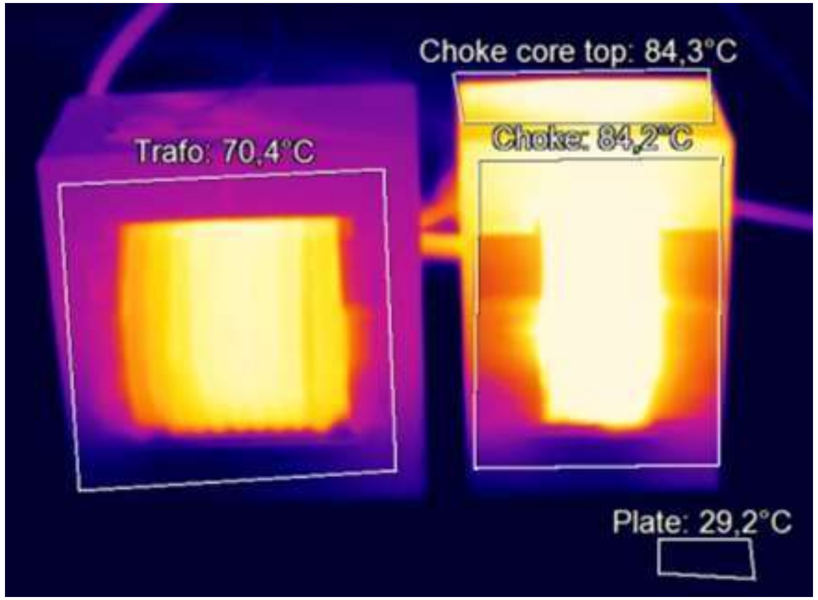
Pressure drop



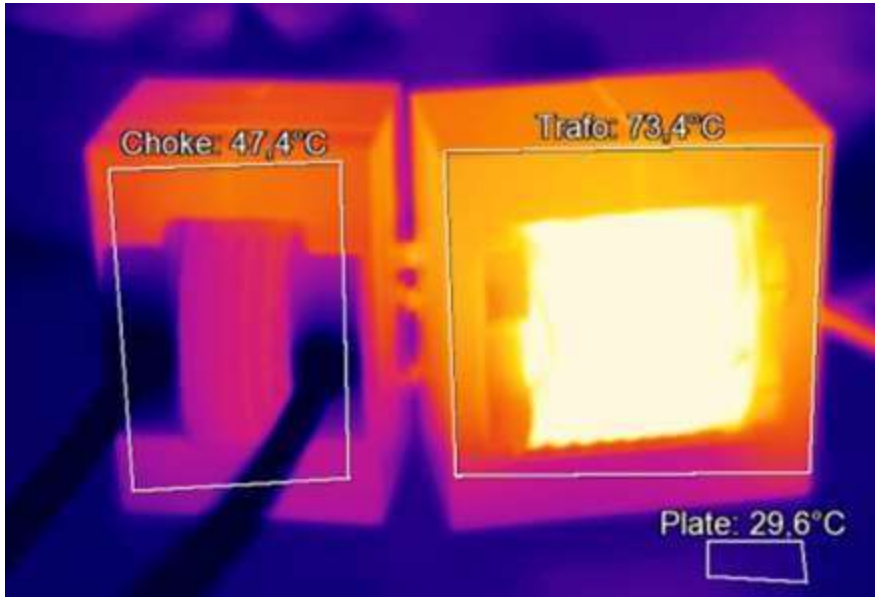


- Customers use to set maximum pressure drop through part to 100mbar.
- 3D power first version: 0.5 to 0.6 m/s maximum coolant speed.
- Well designed duct lead to lower pressure drops and enables higher mass flux.

Test bench



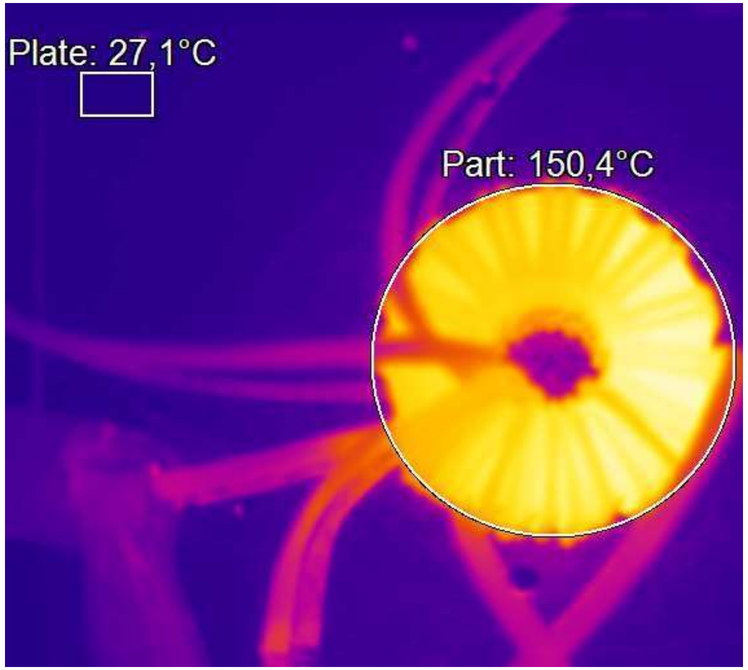
Choke temperature without Coolgap: 84,2°C.



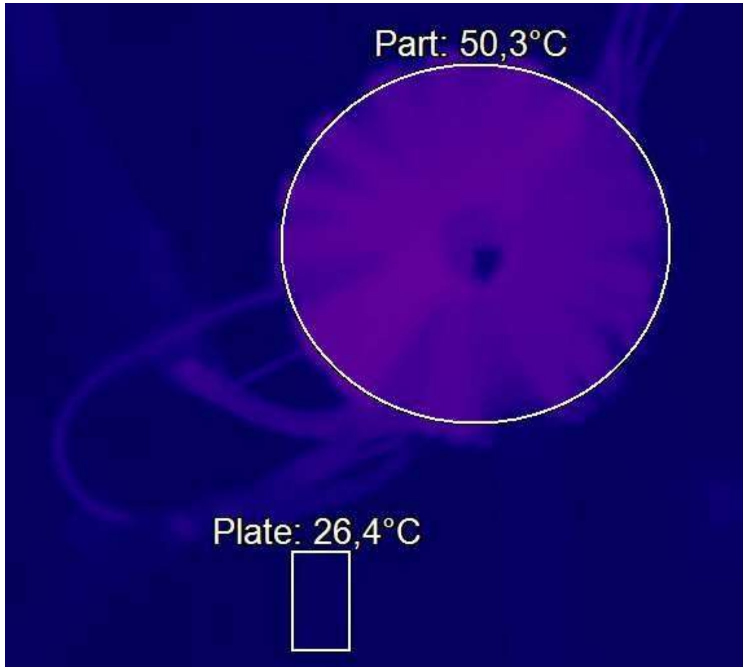
Choke temperature with Coolgap: 47,4°C.

36,8 °C reduction! (44%)

Test bench



3DP temperature without Coolgap: 150,4°C.



3DP temperature with Coolgap: 50,3°C.

100°C reduction! (67%)

Compatibility

	Type	Water	Ethylene glycol	Propylene glycol	Mineral oil	Refrigerants	Dielectrics
Polymers	Commodity plastics	A	A	B	A	F	B
	Engineered thermoplastic	A	A	B	A	A to F	B
	Elastomers	A	A	A	A	A to F	A to F
Metals	Aluminium	B	A	B	A	A	A
	Brass (plated)	A	A	B	A	A	A
	Copper	B	B	A	B	A	A
	Stainless steel	A	B	B	A	A	A

A Good compatibility
B Poor compatibility
F Bad compatibility

Conclussions

Cold plates

Coolant

Heat exchangers

Connectors

Tubing

Manifolds

Pumps

Conclussions

- Heat removed directly from source
- Global weight and volumen reduction
- Multiple configurations available
- Diversification: Coolgap technology can be applied to other fields
- Good duct design leads to higher dissipation and less erosion
- Up to 100°C tested temperature reduction
- Challenges to tackle: deterioration, leaks, particles…

Thanks!

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