

Steel Solutions for Cooling Plates in Battery Electric Vehicles

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Authors: E. ASARE / T. KRIM / M. MABROUKI / A. GREGOIRE / P. SANZEY



$$\frac{\partial f_{i,j}(\vec{x}, \vec{c})}{\partial x_i} = \sum_{k \neq i} c_{k,j}$$

R&D
STEEL

A hand holding a grey marker is writing the word 'STEEL' in large, bold, black capital letters on a whiteboard. Above the word, the letters 'R&D' are written in red. The background of the whiteboard is white, and the hand is positioned on the right side of the frame.

HV-Battery | Adaptable battery steel solutions

- **Maximize the cell volume** inside the HV-Battery (up to ~5% of volume increase)
- **Less intrusions** through a steel shield compared to Aluminum, with same weight and load case.
- **Cost reduction (~33%)** vs Aluminum thanks to Steel Solutions
- Improved **CO₂ footprint (-44%)** with steel solutions compared to Aluminum (with end-of-life credits)
- **Surface solutions** fulfilling OEM requirements on both anti-corrosion and safety

How Steel Solutions can be used for BEVs Cooling Plates ?

* LCA calculation in line with ISO 14040/44:2006 principles and SPE-14040-14

S-in motion® HV-Battery Housing (B-Segment BEV)



Top cover: Mild Steels or others

- Zinc or zinc-magnesium (Zagnelis®) based metallic coating

Upper cross members: MartINsite® 1500HB

- Zinc based metallic coating

Frame (including brackets): MartINsite® 1500, DP1180, DP780

- Zinc based metallic coating

Cooling system (2 steel plates): CR3 (IF, DX54D)

- AluSi® coating for cold stamping

Lower cross-members: DP780

- Zinc based metallic coating

Shield plate: MartINsite® 1500

- Zinc based metallic coating

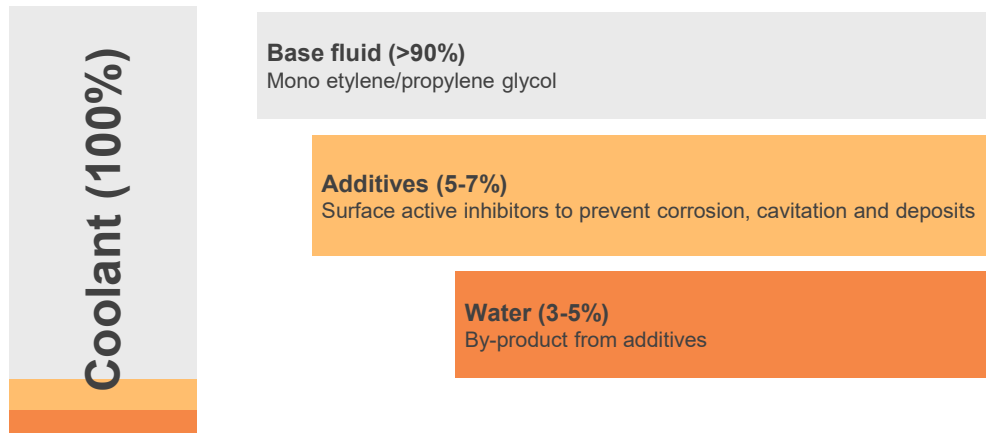
Note - PHS can also be considered instead of MartINsite®1500

Agenda 1/3

- **Steel Solutions compatibility with glycol-based coolants**
- Steel Solutions anti-corrosion performances
- Conclusion

Cooling Plates on BEVs | Glycol-based coolants compatibility with Steel substrates

Chemical composition of coolants

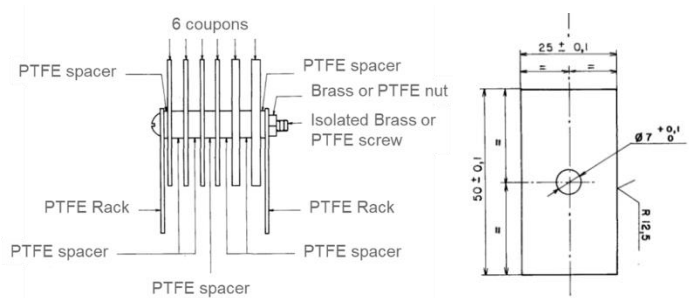


Main corrosion inhibitors

- **Mineral:** nitrites, nitrates, phosphates, silicates, molybdate, borate
- **Organic:** triazole, carboxylate, benzoate, amine, amine phosphate
- Some chemicals are not allowed in coolants by some of the OEMs: amines, borates, nitrites and phosphates
- While corrosion inhibitors can improve the corrosion resistance of steel substrates, it is necessary to validate their compatibility with our coating solutions

**The coolant is not neutral regarding different metallic surfaces.
The first step is to identify the coatings compatible with various coolants available on the market.**

Cooling Plates on BEVs | Methodology for coatings compatibility with coolants – NFR15-602-7



Reactor (V=750mL)

Coolant temperature	Coolant concentration	Synthetic corrosive water	Air bubbling	Duration
100°C	33v%	Na ₂ SO ₄ – 148mg/L NaCl – 165mg/L NaHCO ₃ – 138mg/L	100mL/min	14 days

Several OEMs coolants were tested with this methodology.
Mass gain/loss is a key indicator to evaluate corrosion (maximum of 2.5mg/sample).
NFR15-602-7 is similar to ASTM D2570-16.

Cooling Plates on BEVs | Coolant compatibility with Steel Solutions – Coolant n°1

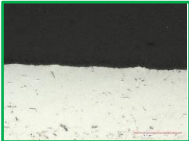
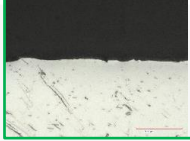
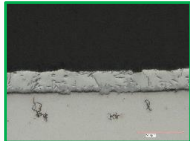
Material	Aluminium	AluSi® for cold-stamping	Galvalume®	GI	ZA
Coolant n°1 T = 100°C Time = 14 days					

Substrate	Coating type	Coating	Mass gain [mg/sample]	Mass loss [mg/sample]	Corrosion depth [µm]
Aluminium (Al 6016)	None	None	0	1.8	0.24
Steel	Aluminum-based	AluSi® (90% Al, 10% Si) for cold-stamping	1.3	2	0.28
		Galvalume® (55% Al, 43.4% Zn, 1.6% Si)	1.1	6.3	0.7
	Zinc-based	GI (Continuous hot dip galvanized)	1.0	2.5	0.14
		ZA (95% Zn, 5% Al)	5.0	1.5	0.08

ZA not OK because of mass gain. Galvalume not OK because of mass loss. Very good results on AluSi®.

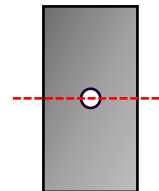
Different aspect under the PTFE spacer (confined area) → Micro-cuts were performed on all samples

Cooling Plates on BEVs | Coolant compatibility with Steel Solutions – Coolant n°1

Substrate	Coating type	Coating	Healthy Area	Area under PTFE spacer
Aluminium (Al 6016)	None	None		
Steel	Aluminum-based	AluSi® (90% Al, 10% Si) for cold-stamping		
		Galvalume® (55% Al, 43.4% Zn, 1.6% Si)		
	Zinc-based	GI (Pure Zn)		
		ZA (95% Zn, 5% Al)		



1/2 coupon after corrosion test for crosscut observations



Corrosion occurred under the PTFE spacer on Galvalume®, ZA, and GI.

Results are OK for Aluminum and AluSi®.

Cooling Plates on BEVs | Coolant compatibility with Steel Solutions – Coolant n°2

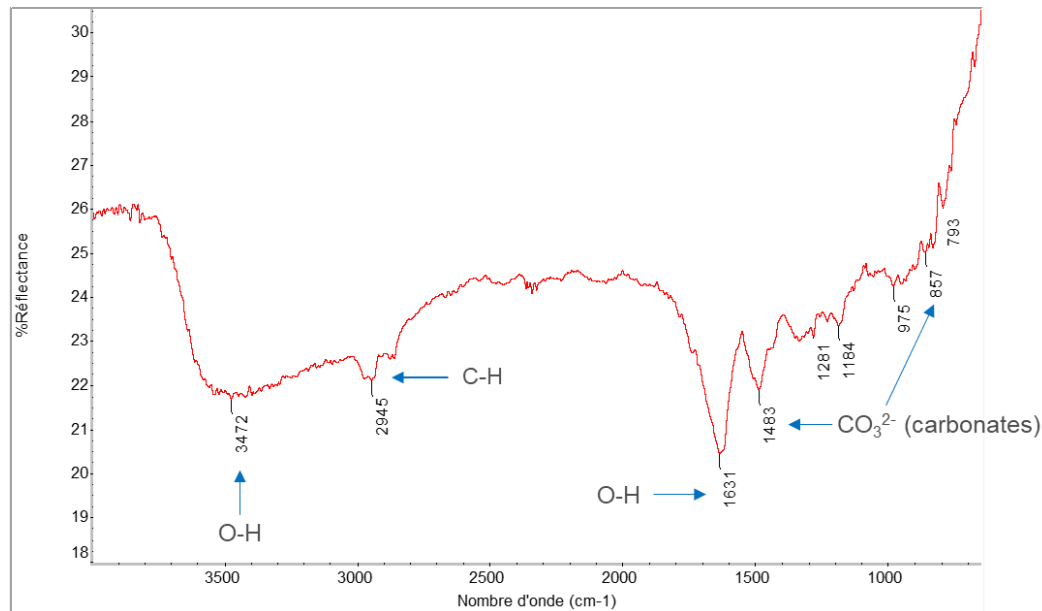
Material	Aluminium	AluSi® for cold-stamping	Galvalume®	GI	ZA
Coolant n°2 T = 100°C Time = 14 days					

Substrate	Coating type	Coating	Mass gain [mg/sample]	Mass loss [mg/sample]	Corrosion depth [μm]
Aluminium (Al 6016)	None	None	0.5	1.2	0.16
Steel	Aluminum-based	AluSi® (90% Al, 10% Si) for cold-stamping	1.8	0	/
		Galvalume® (55% Al, 43.4% Zn, 1.6% Si)	1.2	1.1	/
	Zinc-based	GI (Continuous hot dip galvanized)	35	1.1	0.06
		ZA (95% Zn, 5% Al)	51	0.3	/

Formation of insoluble compounds on GI and ZA. Very good results on Galvalume® and AluSi®.

Deposits on GI and ZA were characterized via FTIR and SEM at cross section.

Cooling Plates on BEVs | Coolant compatibility with Steel Solutions – Coolant n°2 – FTIR analysis



The spectrum is obtained by doing the ratio between:

- The spectrum of a sample with deposit
- The background spectrum of a sample without deposit (before corrosion test)

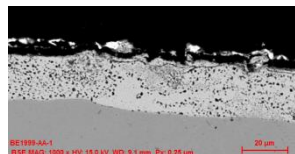


Glycol-based coolant before (left) and after (right) 14-days of testing

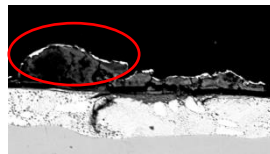
Only carbonates functions and OH groups are detected, confirming that the deposit is essentially made of zinc hydroxide and zinc carbonate (and/or zinc hydroxy-carbonate) coming from coating oxidation.

The deposit seems to be free of organic compound.

Cooling Plates on BEVs | Coolant compatibility with Steel Solutions – Coolant n°2 – SEM analysis



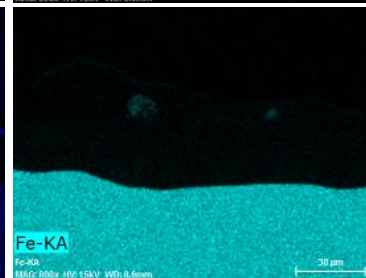
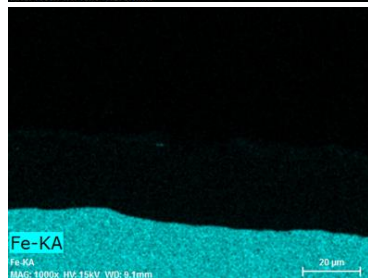
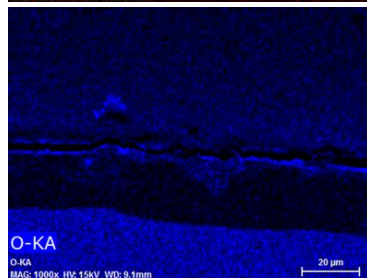
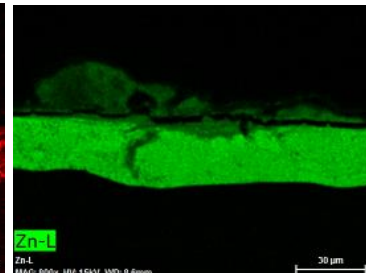
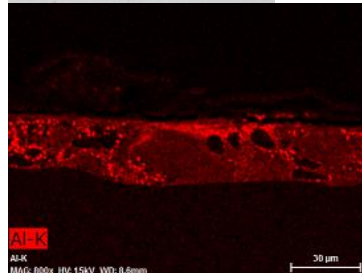
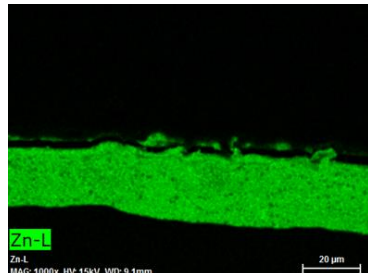
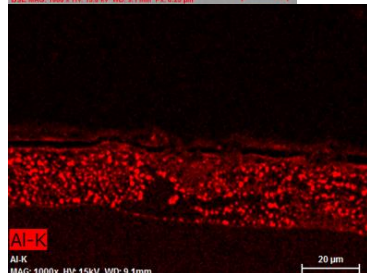
ZA coating before test



ZA coating after test



AluSi® for cold-stamping



Oxygen map allows to confirm that the deposit observed is linked with the oxidation of the coating (approx. 10 to 30µm).
Such oxides could detach and clog the cooling system.

Cooling Plates on BEVs | Coolant compatibility with Steel Solutions – Coolant n°3

Material	Aluminium	AluSi® for cold-stamping	Galvalume®	GI	ZA
Coolant n°3 T = 100°C Time = 14 days				Not tested because of previous bad results	

Substrate	Coating type	Coating	Mass gain [mg/sample]	Mass loss [mg/sample]	Corrosion depth [µm]
Aluminium (Al 6016)	None	None	2.1	0.9	0.13
Steel	Aluminum-based	AluSi® (90% Al, 10% Si) for cold-stamping	2.2	0.2	/
		Galvalume® (55% Al, 43.4% Zn, 1.6% Si)	1.1	1.7	/
	Zinc-based	GI (Pure Zn)	Not tested because of previous bad results		
		ZA (95% Zn, 5% Al)	3.6	2.5	0.16

Similar trends observed with Coolant n°3, confirming the interest of aluminum-based coatings for cooling plates applications.

Cooling Plates on BEVs | Summary of results with various coolants

Substrate	Coating type	Coating	Coolant 1	Coolant 2	Coolant 3
Aluminium (Al 6016)	None	None			
Steel	Aluminum-based	AluSi® (90% Al, 10% Si) for cold-stamping			
		Galvalume® (55% Al, 43.4% Zn, 1.6% Si)			
	Zinc-based	GI (Pure Zn)			Not tested
		ZA (95% Zn, 5% Al)			

Zinc-based coatings cannot be used in contact with glycol-based coolants because of insoluble compounds formation.

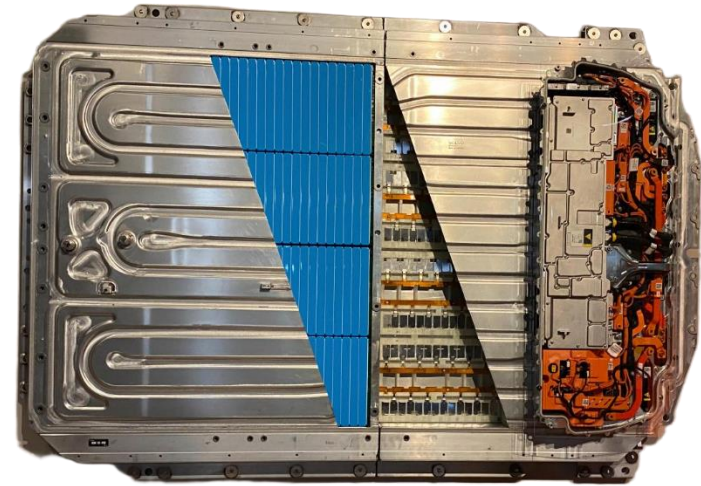
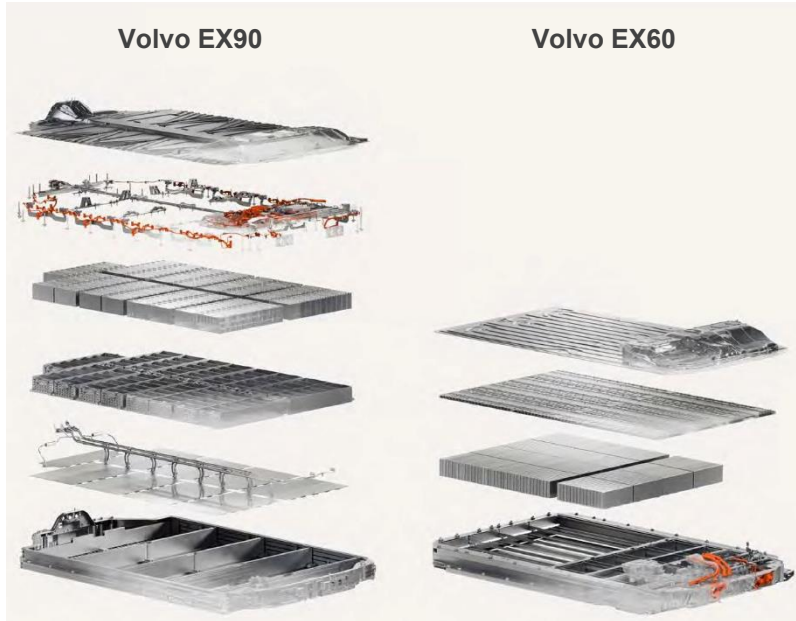
AluSi® for cold-stamping selected for this application because of its compatibility with usual glycol-based coolants.

Agenda 2/3

- Steel Solutions compatibility with glycol-based coolants
- **Steel Solutions anti-corrosion performances**
- Conclusion

Cooling Plates on BEVs | **New cooling plate architecture and associated constraints**

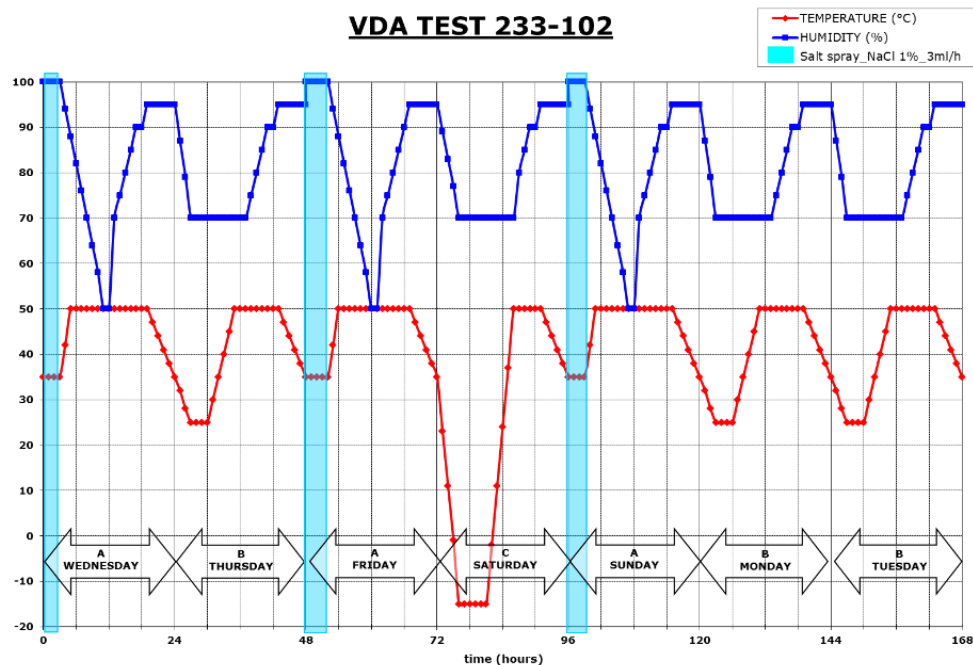
- New battery packs concepts are combining the top cover and the cooling plate (Volvo EX60, Volkswagen MEB+)
- **New criteria for coatings → anti-corrosion performances**



Volvo EX60 battery pack

Cyclic Corrosion Tests | VDA 233-102 (VDA-New or NVDA)

VDA TEST 233-102



Alternating salt fog (3 times/week) with wet phases (up to 95% RH), dry phases with temperature up to 50°C and freezing phase (-15°C).

Simulates Dubai climate, morning dew, frost in winter...

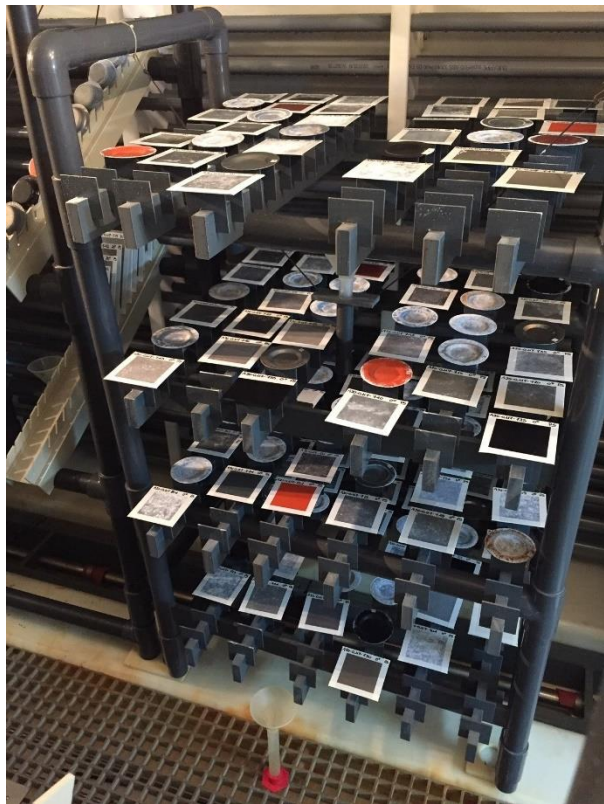
- $T^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and $\text{RH} \pm 3\%\text{RH}$ at defined temperature / humidity points.
- -When temperature ramps are passed through during periods of constant relative humidity, deviations of -8 % to +5 % RH are accepted.
- -Humidity values will not be measured at temperatures below 10°C.

1 cycle = 1 week
Alternating sub-cycles A, B, C:

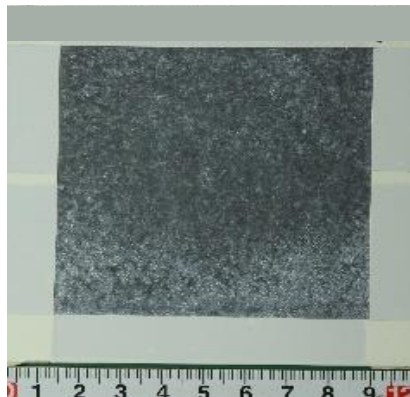


Widely used in Europe to simulate extreme conditions. Standard duration: 6 to 12 weeks (simulates several years on car)

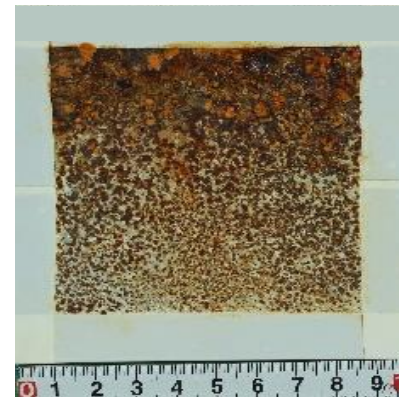
Cyclic Corrosion Tests | VDA 233-102 (VDA-New or NVDA) – Specific test for battery pack



Standard inclination
(20° from vertical)



Specific inclination
(sample to the ground)

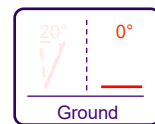


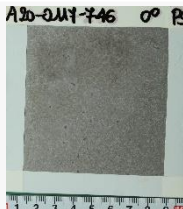
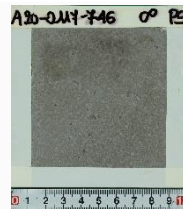
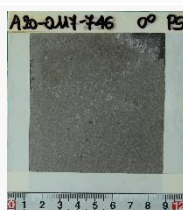
Sample of Zn/Mg based coated steel (Zagnelis® Protect 175 14µm) after 12 cycles of NVDA with standard inclination of 20° from the vertical (left) and specific positioning to the ground (right)

For studies linked with battery pack top cover, samples are positioned to the ground to simulate electrolyte retention.

The resulting corrosivity of the cyclic corrosion test is greatly increased.

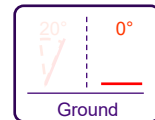
Cooling Plates on BEVs | Corrosion results on flat / deformed samples – NVDA – 12 cycles

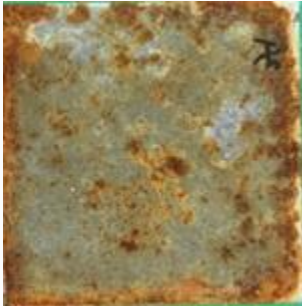
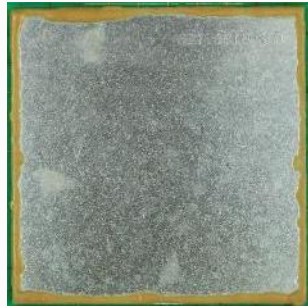


Cyclic Corrosion Test	Position of samples	Number of cycles	AluSi® 150 (25µm) for cold-stamping on DX54 0.6mm – Without e-coat	
VDA-New	To the ground	12		
		24		
		36		

Really high anti-corrosion performances of AluSi® for cold-stamping. No red rust observed after 36 weeks of VDA-New.

Cooling Plates on BEVs | Corrosion results on flat / deformed samples – NVDA – 12 cycles



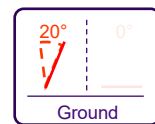
Cyclic Corrosion Test	Position of samples	Steel thickness [mm]	AluSi® 150 (25µm) for cold-stamping		
			Reference	Henkel Bonderite OPC-100	PFINDER Wax
VDA-New – 12 cycles	To the ground	0.7			

The main issue with AluSi for cold-stamping solution is the lack of cathodic protection.
Cut-edges and laser welded areas corrosion will be critical.

The challenge is no longer the surface itself, but local exposed steel areas generated during manufacturing.

→ Additional organic coating such as e-coat is required to ensure the proper corrosion protection of the cooling plate.

Cooling Plates on BEVs | Corrosion results on bended samples – NVDA – 12 cycles



Cyclic Corrosion Test	Position of samples	Target	AluSi® 150 (25µm) for cold-stamping on DX54 0.6mm – Without e-coat
VDA-New – 12 cycles	20° from vertical	Simulate 0T bending impact on AluSi® for cold-stamping performances	
		Simulate 1T bending impact on AluSi® for cold-stamping performances	
		Simulate 2T bending impact on AluSi® for cold-stamping performances	

Good formability of AluSi® for cold-stamping. No cracking of the coating observed even at 0T bending.

Agenda 3/3

- Steel Solutions compatibility with glycol-based coolants
- Steel Solutions anti-corrosion performances
- **Conclusion**

Conclusion and Takeaways

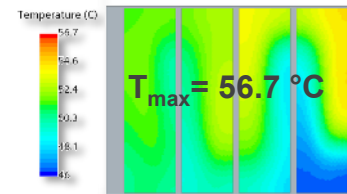
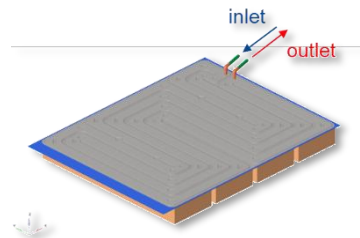
- **Best corrosion performances achieved with AluSi® coating.**
- Other benefits of metallic coated steel for battery cooling plates:
 - Significant cost saving potential (especially in combination with laser welding)
 - Easy implementation as an integrated cooling solution into steel battery tray designs (weight & cost saving potential)
 - CFD simulations shows only minor influence of cooling plate material on battery cells temperature

Note: The use of bare steel is also possible depending on customer requirements

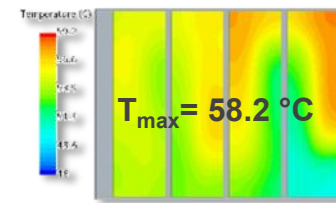
Open to collaborations with OEMs

Supported by:
 Federal Ministry
for Economic Affairs
and Climate Action

on the basis of a decision
by the German Bundestag



Aluminum



Steel



-20% invest
-30% part costs

Source: New Battery World Conference, 2025

Thank you

Global Research and Development

