A JAMES CROPPER COMPANY

DEVELOPMENT AND VALIDATION OF AN EMI ENHANCED SMC FOR BEV APPLICATIONS

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Outline

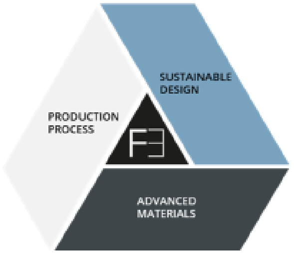
- Project - Introduction
- HVBE Technical Requirements
- EMI Basics
- Competitive Analysis
- Project Overview – Problem, test methods, results
- Summary of Findings
- What's Next?

INTRODUCTION

FORWARD ENGINEERING

AUTOMOTIVE. COMPOSITE. SOLUTIONS.

YOUR PARTNER FOR AUTOMOTIVE. COMPOSITE. SOLUTIONS.



Industry Leading Design & Engineering Partner for Sustainable Products and Economical Lightweight Solutions

- "Material & Production Based Engineering" – from concept to series production
- Accelerate product development by asking and answering the right questions at the right time
- Increase confidence in performance-, cost- and CO2 forecasts
- Reduce validation costs & time with target-oriented CAE-analysis
- Enable well-founded decisions & empower our customer with unique material and technology know-how
- Offer independent & flexible service in a strong composite network in Germany and globally

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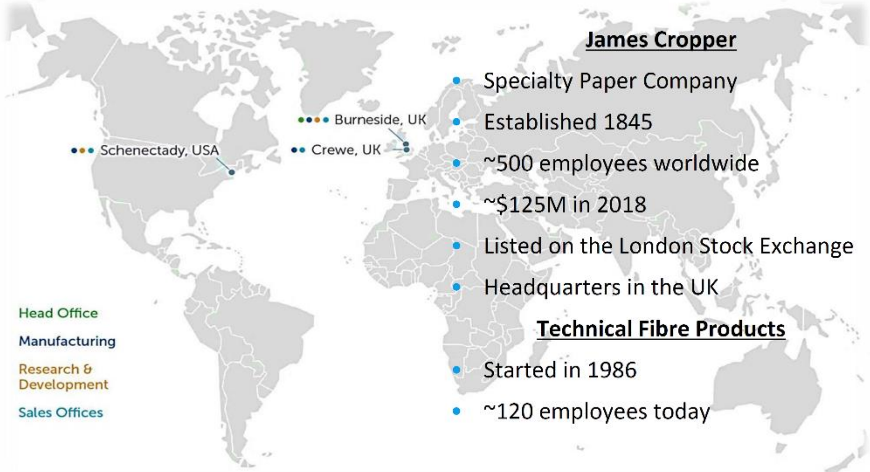
Company Profile



James Cropper

- Specialty Paper Company
- Established 1845
- ~500 employees worldwide
- ~$125M in 2018
- Listed on the London Stock Exchange
- Headquarters in the UK

Technical Fibre Products

- Started in 1986
- ~120 employees today

TECHNICAL FIBRE PRODUCTS INC. www.tfpglobal.com

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TECHNICAL FIBRE PRODUCTS

INTRODUCTION

Objectives

- Determine potential for Nonwoven as an EMI solution in BEV applications
- Determine Capable Application of Nonwovens into SMC Components
- Evaluate EMI Shielding Effectiveness of Solution for BEV battery enclosure lid
- Validate Solution for Commercial SMC Applications

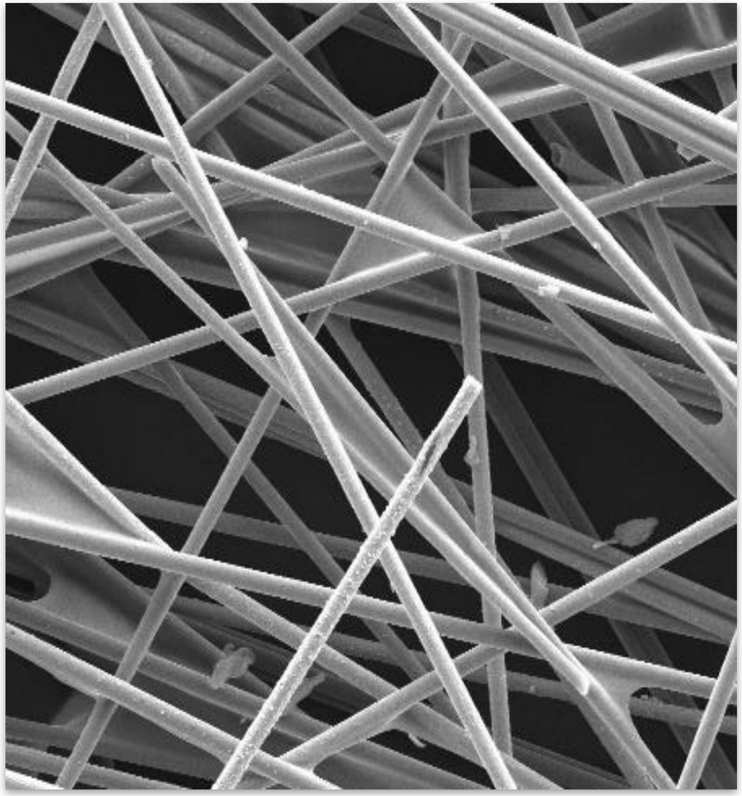
Collaborating Partners

- IDI Composites
- INEOS
- Forward Engineering
- Technical Fibre Products

WHAT IS A NONWOVEN?

- Synonyms: veil, scrim, mat, paper
- Made with a wet-laid process similar to pulp paper
- Discontinuous fiber and binder
- Pourous

- Typical Fibers: glass, polyester, aramid, carbon, metal-coated carbon
- Typical Binders: Poly vinyl alcohol, polyester, styrene acrylic

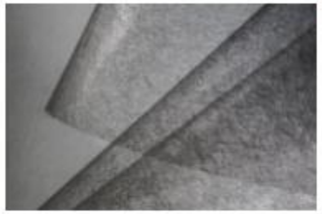


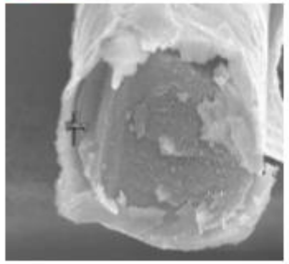
SHIELDING EFFECTIVENESS IS FUNCTION OF ______

- Conductivity of the fiber
- Fiber distribution
- Areal weight and # of layers of veil

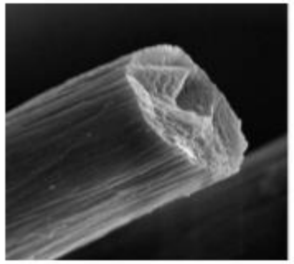
	Metals		Carbon Powders & Fibers			Shielding Composites			Conductive Composites				Static Dissipative Composites			Anti-Static Composites			Base Polymers			
Ω/sq	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	1	10^{1}	10^{2}	10^{3}	10^{4}	10^{5}	10^{6}	10^{7}	10^{8}	10^{9}	10^{10}	10^{11}	10^{12}	10^{13}	10^{14}	10^{15}	10^{16}

Nonwoven Materials





Metal coated fiber



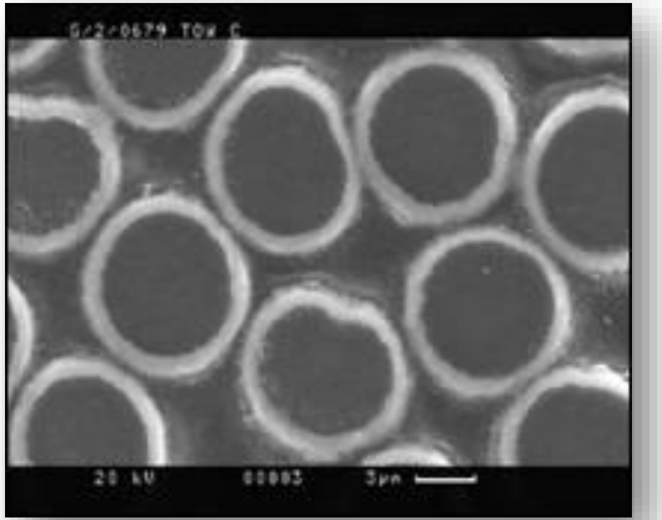
Conductive fiber

Fiber blends

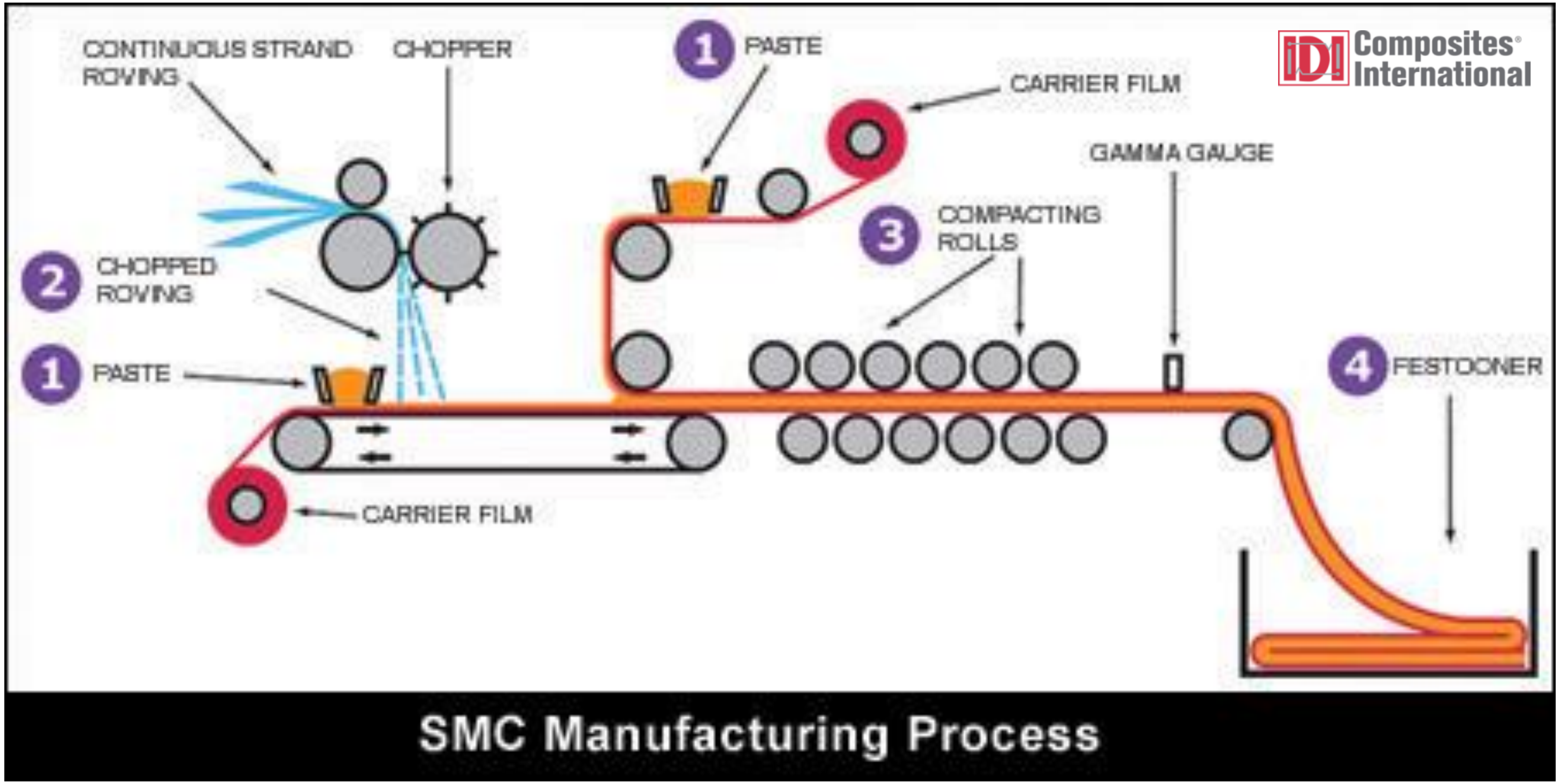
Anti-static fibers

TFP TUNING FOR EMI SHIELDING IN FRP

- Areal weight: 2 - 200 g/sm
- Veil thickness: 30 µm - 6 mm
- Fiber length: 3 - 25 mm
- Fiber diameter: 6 - 25 µm
- Coatings: Ni & Cu
- Veil Production: Binder, Loading, Other



WHAT IS SMC?

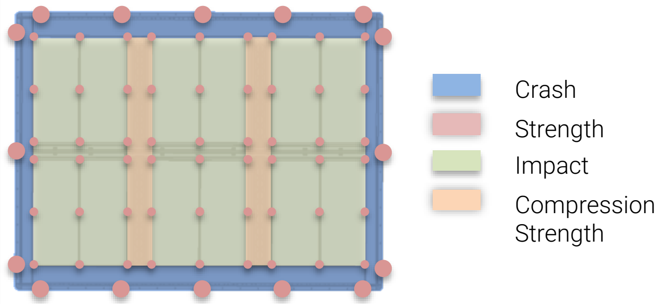

CONTINUOUS STRAND ROVING
CHOPPER
1 PASTE
CARRIER FILM
Composites International
GAMMA GAUGE
3 COMPACTING ROLLS
2 CHOPPED ROVING
1 PASTE
4 FESTOONER
CARRIER FILM
SMC Manufacturing Process

BEV HV BATTERY ENCLOSURE

BEV HV PACK

HV Battery Enclosure/Pack Terminology

- Enclosure – Structure which support and protects the cells
- Modules – House the energy storage cells
- Cells – Capture chemistry, anodes & cathodes which store/release energy
- Thermal Management – Heat Exchange to Cool/Heat Cells
- HV Bus – Conductors between modules, in/out of pack
- BMS – Battery Management System



Enclosure Structure

- Cover
- Tray
- Cross Members
- Longitudinals
- Headers

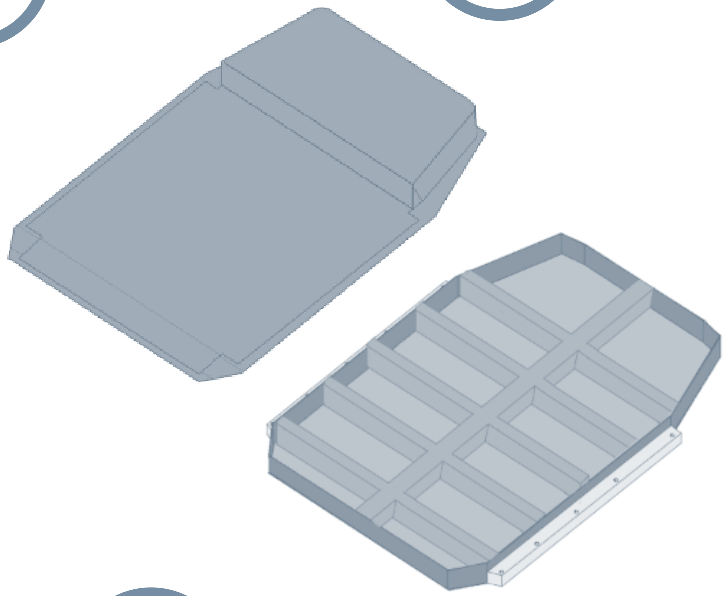
MAIN REQUIREMENTS FOR HV BATTERY ENCLOSURE

Global torsion & bending stiffness
→ Intelligent load path management

Mechanical shock & Durability
→ High strength attachments for modules & enclosure

Side/Front/Rear Crash or Crush
→ Structural integrity
→ Energy absorbing structure

Ground impact
→ Energy absorbing tray



Fire resistance (internal/external)
→ FST-appropriate material & design
→ Thermal Runaway appropriate design

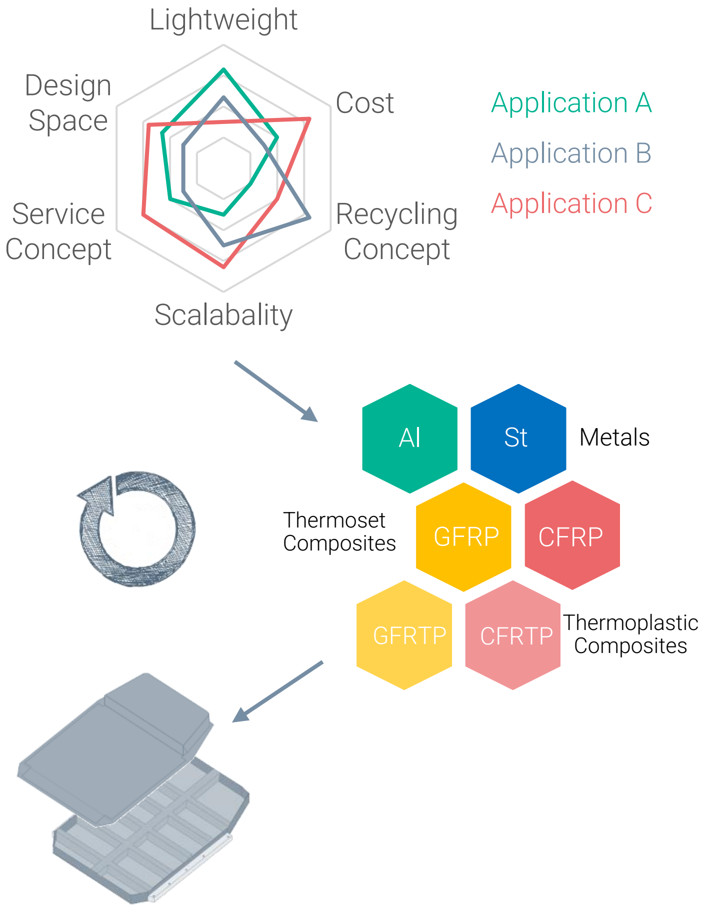
Thermal Management
→ Appropriate Material Concept
→ Cooling System Integration

Moisture/ Liquid Intrusion
→ Sealing Layout
→ Corrosion Resistance

EMC & Grounding
→ Electroconductive material & design

Sustainability
→ Low Carbon Footprint (<CO_2/GWP)
→ EOL – End of Life Strategies

MULTI-MATERIAL & TECHNOLOGY DESIGN TOOLBOX



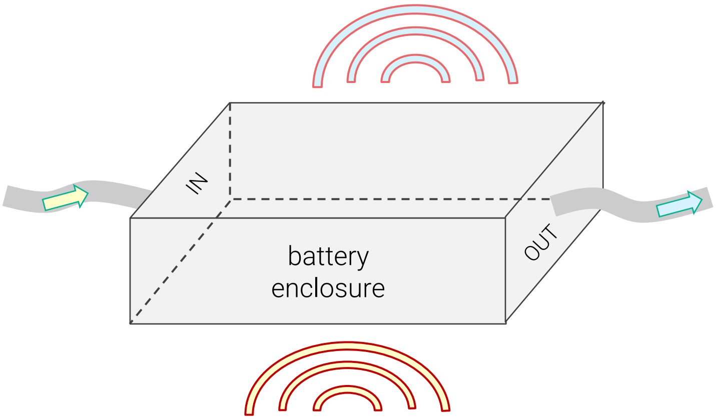
- Cover, Tray Panel
  - ✓ Al-sheet
  - ✓ St-sheet
  - ✓ SMC
  - ✓ FRP thermoset (NCF/WF)
  - ✓ **FRTP organosheets (NCF/WF)**
  - ✓ …
- Cross-member, Longitudinal / Lateral Beam
  - ✓ Al-extrusion
  - ✓ St-profiles (roll-formed/welded)
  - ✓ FRP Pultrusion / Pullwinding
  - ✓ …
- Node
  - ✓ Al-cast
  - ✓ SMC
  - ✓ Injection molding
  - ✓ Additive manufacturing (metal / FRP)
- Energy Absorber
  - ✓ Al-extrusion
  - ✓ Injection Molding
  - ✓ Compressible cores (foams, honeycomb)

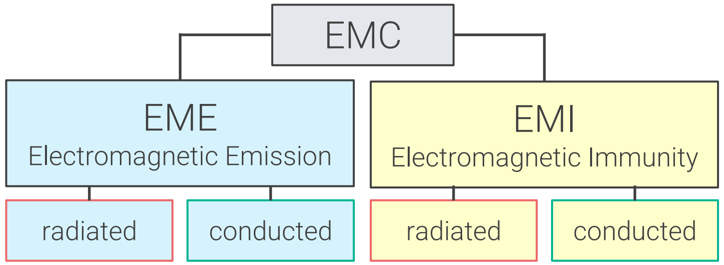
differential

- ✓ FRP Sandwich (thermoset / thermoplastic)
- ✓ Organosheet Overmolding
- ✓ Thermoset Overmolding

integrative

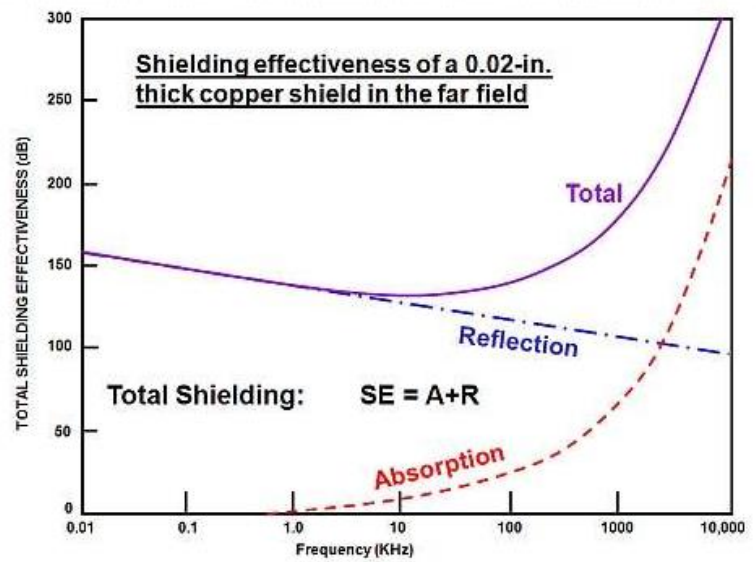
BASICS OF EMC





- Description
  - Electromagnetic Compatibility (EMC) consists of…
    - EME → ability to operate without interfering with other devices
    - EMI → ability to operate within a specified electromagnetic environment
  - Dispersion of electromagnetic fields
    - By radiation („antenna principle“)
    - By conduction
- Findings for automotive application
  - EMC-shielding needed to prevent…
    - Disturbing influences from HV-system on LV-system (e.g. BUS-system with sensors and actors)
    - Disturbing influences from external emitting devices on HV-system
  - EMC-shielding to be applied on global structure
  - EMC-shielding needed for enclosure as well as harness
  - Especially high frequency AC-devices/harness to be shielded

BASICS OF EMI



[edn.com]

- Total shield effectiveness curve is result of reflection and absorption
- Calculation method:
  - Absorption $A = 20log_{10}^{e^{\frac{t}{\delta}}}$

    → skin depth $\boldsymbol{\delta} = \sqrt{\frac{2}{\mu\omega\sigma}}$

  - Reflection $R = 20log_{10}^{\left|\frac{(z_0+z_1)^2}{4z_0z_1}\right|}$

  Z_0 ≙ wave impedance of air

  Z_1 ≙ wave impedance of material

  t ≙ thickness of metal sheet

  μ ≙ relative permeability

  ω ≙ angular frequency of current (2π × f)

  σ ≙ electrical conductivity

- Conclusions
  - Electromagnetic shielding at (relevant) higher frequencies can be improved by
    - ✓ lowering specific resistance
    - ✓ thickening (conductive) material
  - Material / design to be adapted accordingly

EMC-CHALLENGE FOR GFRP COMPOSITE DESIGN

Material	Ω*m (@20°C)
Copper	$0.0175*10^{-6}$
Aluminium	$0.0270*10^{-6}$
Iron	$0.1000*10^{-6}$
Stainless Steel	$0.2080*10^{-6}$
Carbon Fibre (HT)	0.01-0.1
E-Glas Fibre	10^{17}
Aramid Fibre (HM)	10^{17}

+ EMC-appropriateness -

material`s ohmic specific resistance

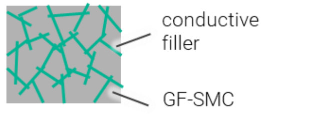
[Roechling Automotive]

Al-foil applied on cover made of GF-SMC
(BMW 2 series Active Tourer PHEV)

- Starting point
  - Glass fibre is electrically isolating
- Consequence
  - Inappropriate shielding of electromagnetic fields with enclosure components made of GFRP / GFRTP
- Approach
  - Application of EMI countermeasures

→ targeted attributes for feature selection
- ✓ Economic
- ✓ Ease of Processing
- ✓ Space efficient/Packaging
- ✓ Lightweight

TYPICAL EMI COUNTERMEASURES

Countermeasure	Example
Metal Foil	
Resin Additives / Fillers	
Carbon fibre compound	
Integrated e-conductive layers	
Veil (Nonwoven)	
Metal/Conductive Coating	

SMC EMI COUNTERMEASURES | BENCHMARK ANALYSIS

#1 Compounding	#2 Part Forming	#3 Post-Process	#4 Assembly	#5 Use-Case	#6 End of Life
▪ Semi-Finished Part	▪ Drapability ▪ Geometry Complexity	▪ Surface preparation ▪ Preforming + Joining	▪ Robustness during part mounting	▪ Operation robustness ▪ Performance / Functionality	▪ Material separation ▪ Recycling

EMI Countermeasures	Process Application	Entrance Barrier Step #						Comments	Relative Added Part Costs* [%]
		1	2	3	4	5	6		
TFP Veil integrated	Option A1	$						slight increase of mechanical properties	+ 1[illegible]5
Veil (overmolded)	Option B1		$					mtrl handling, high risk of veil rupture during overmolding	[illegible]
Metal Foil (post-joined)	Option B3			$$$				current „state of the art“, geometry/packaging constraints	+ [illegible]
Metal Foil (overmolded)	Option B		$$					limited evidence for series production, geometry restrictions	+ [illegible]
Metal Mesh	Option B2		$$$					geometry/preform, potential to improve impact strength	+ [illegible]
Metal Coating	Option C2			$$$				dedicated coating line, labor, environ. impact, handling, low robustness	+ [illegible]
Carbon Black	Option A3	$$						significant decrease of mechanical properties	+ [illegible]
CF Chopped	Option A2	$						uniform distribution challenging, slight incr. mech. prop’s	[illegible]
CF Biaxial	Option B2		$$					formability/drapability, improved mechanical properties	+ 4[illegible]

LOWER COST ↕ HIGHER COST

*) Reference ≙ GF-SMC cover (*geometry see other* slide)
@ 10.000-100.000 units/year

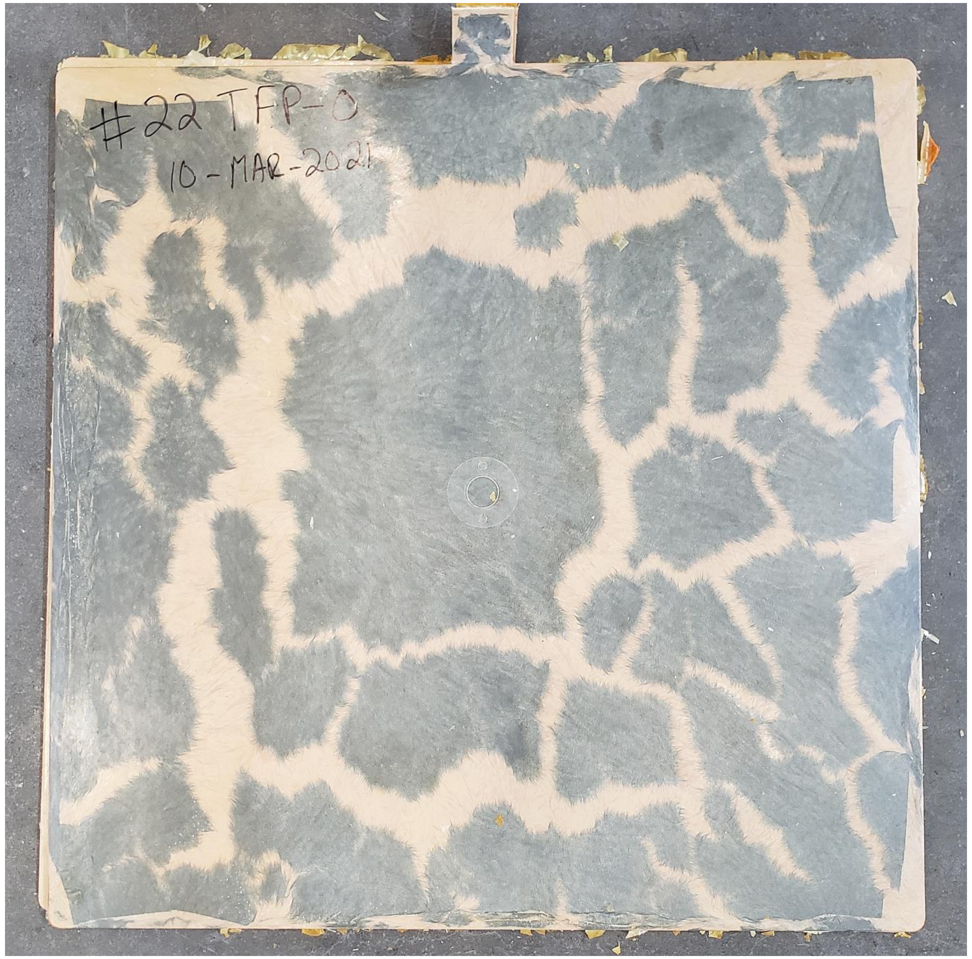
Legend: benefitial | low impact | med impact | high impact | $-$$$ cost effort

Technology Readiness Level

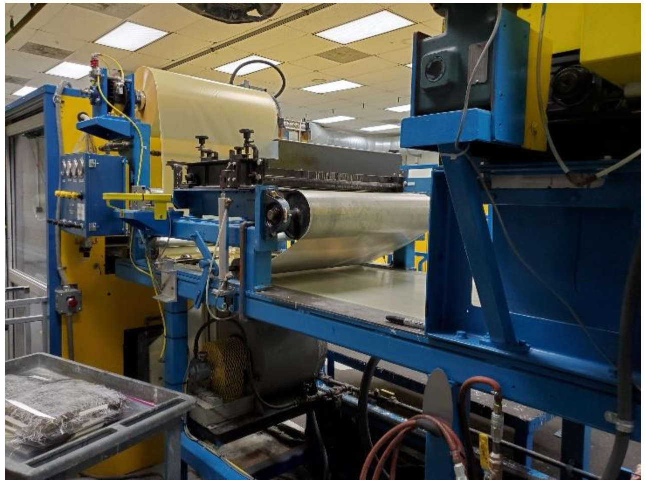
TFP EMI ENHANCED SMC DEVELOPMENT & VALIDATION

- Manufacturability of Composites Panels incorporating TFP Functional Veils
- Plaque Level evaluation of Shielding Effectiveness Performance of TFP Veils in Composite Applications (TP, TS)
- Manufacturability of Composites Components incorporating TFP Functional Veils
- Component Level evaluation of Shielding Effectiveness Performance of TFP Veils in Composite Applications (TP, TS)

MANUFACTURABILITY

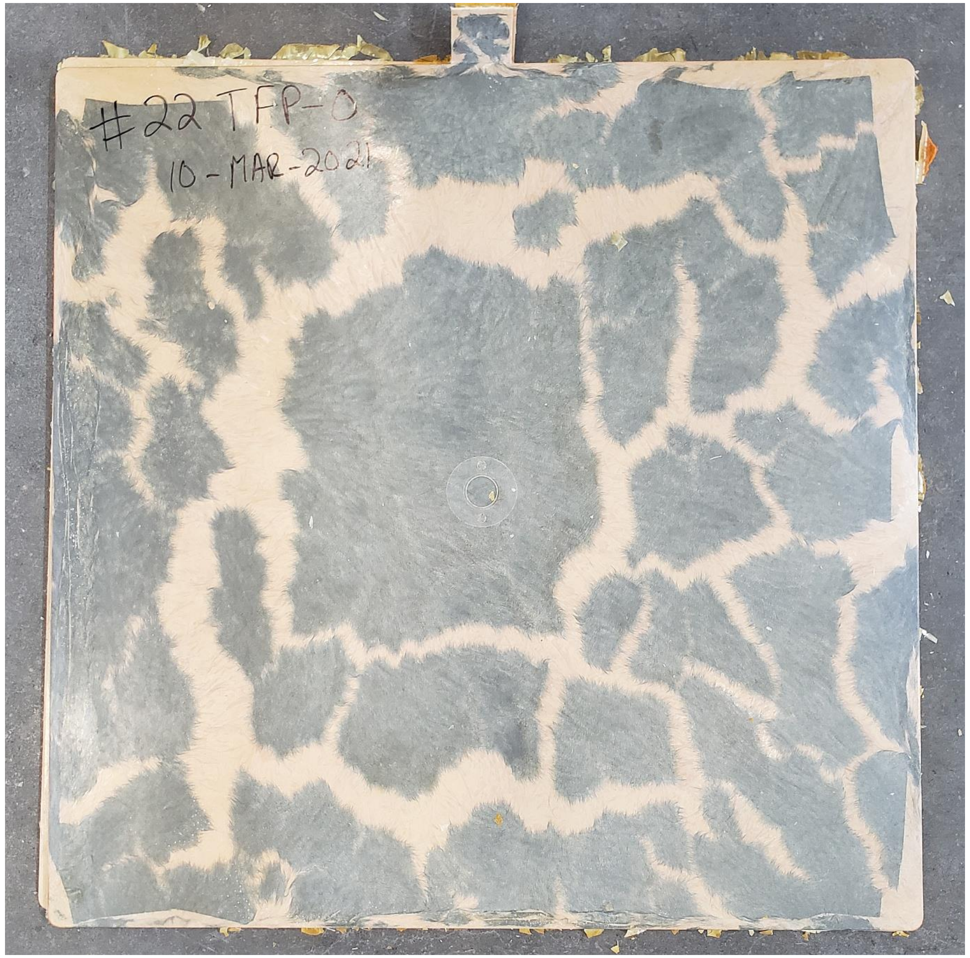


TFP EMI ENHANCED SMC PRODUCTION AT INEOS COMPOSITES

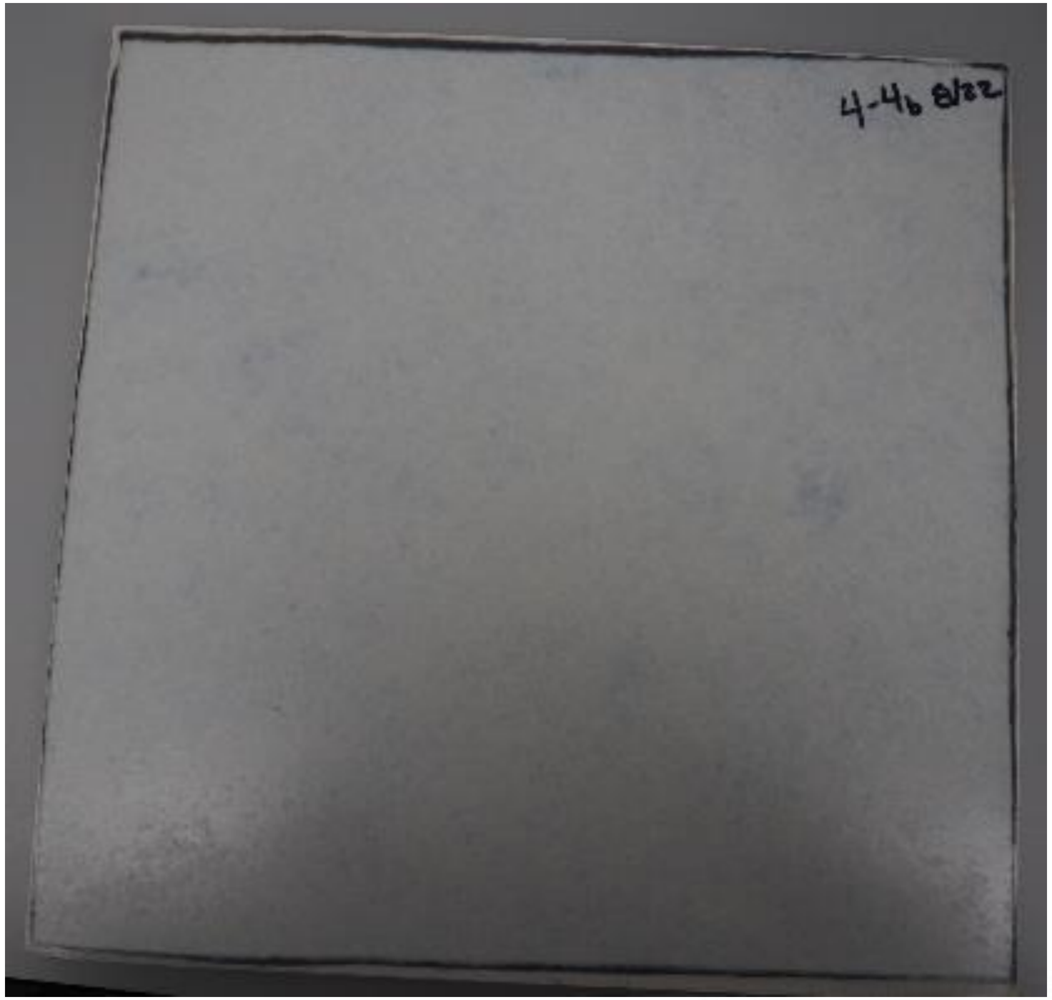


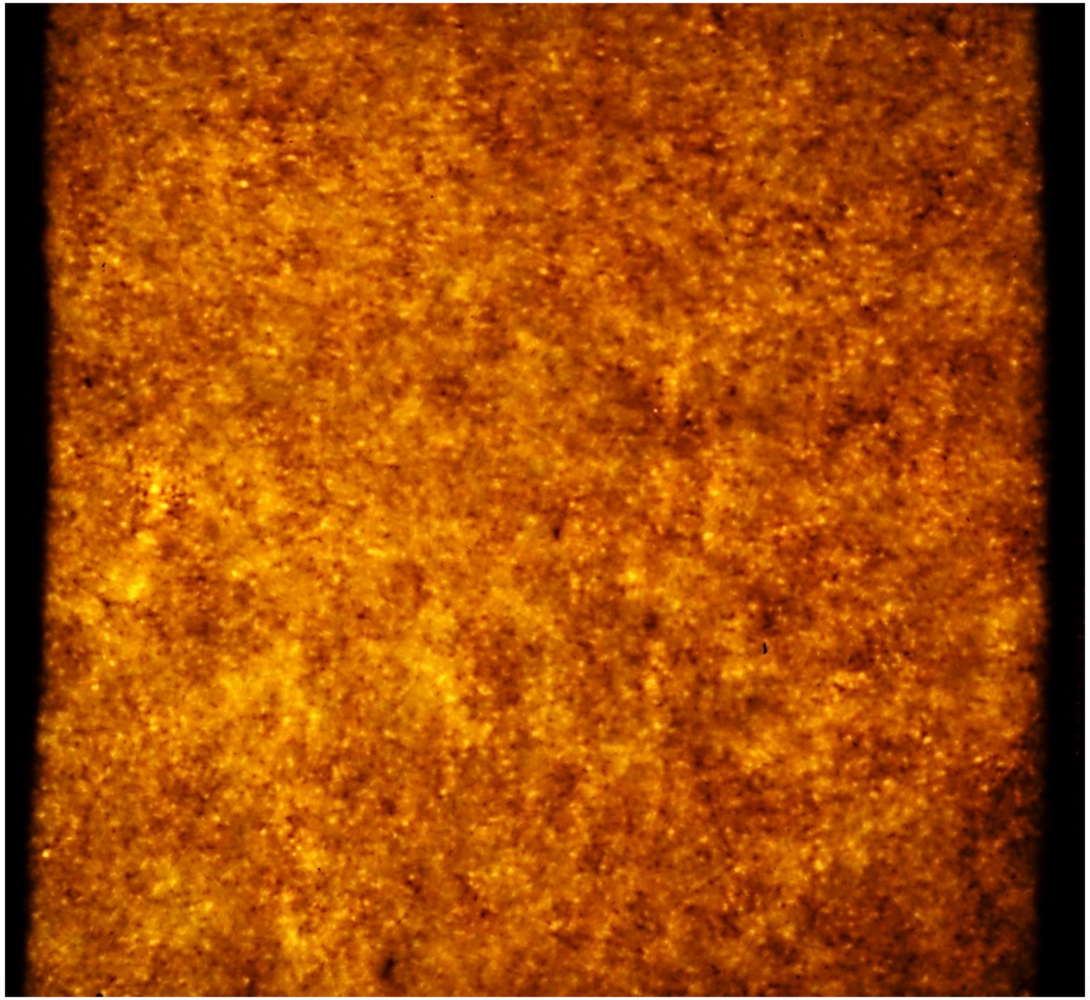
TFP EMI ENHANCED SMC MOLDING AT INEOS COMPOSITES

MOLDED COMPONENT MANUFACTURABILITY



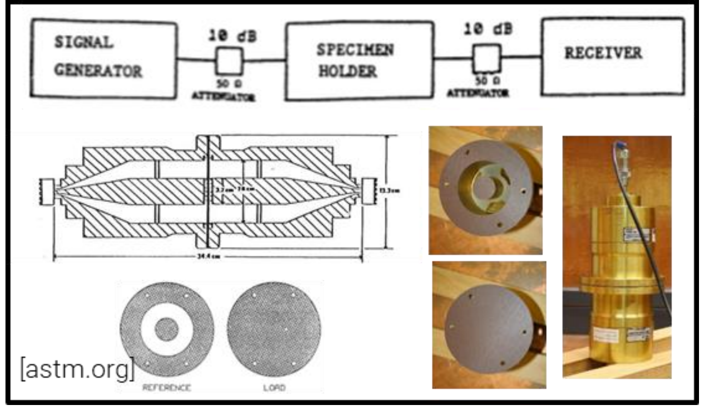
INTEGRATION OF TFP FUNCTIONAL NONWOVEN





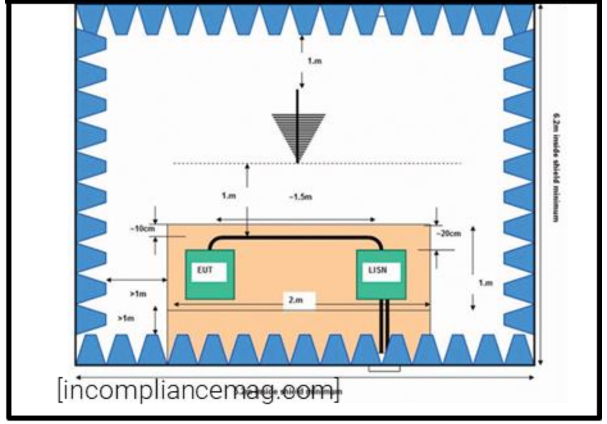
TESTING AND VALIDATION METHODS

ASTM D4935



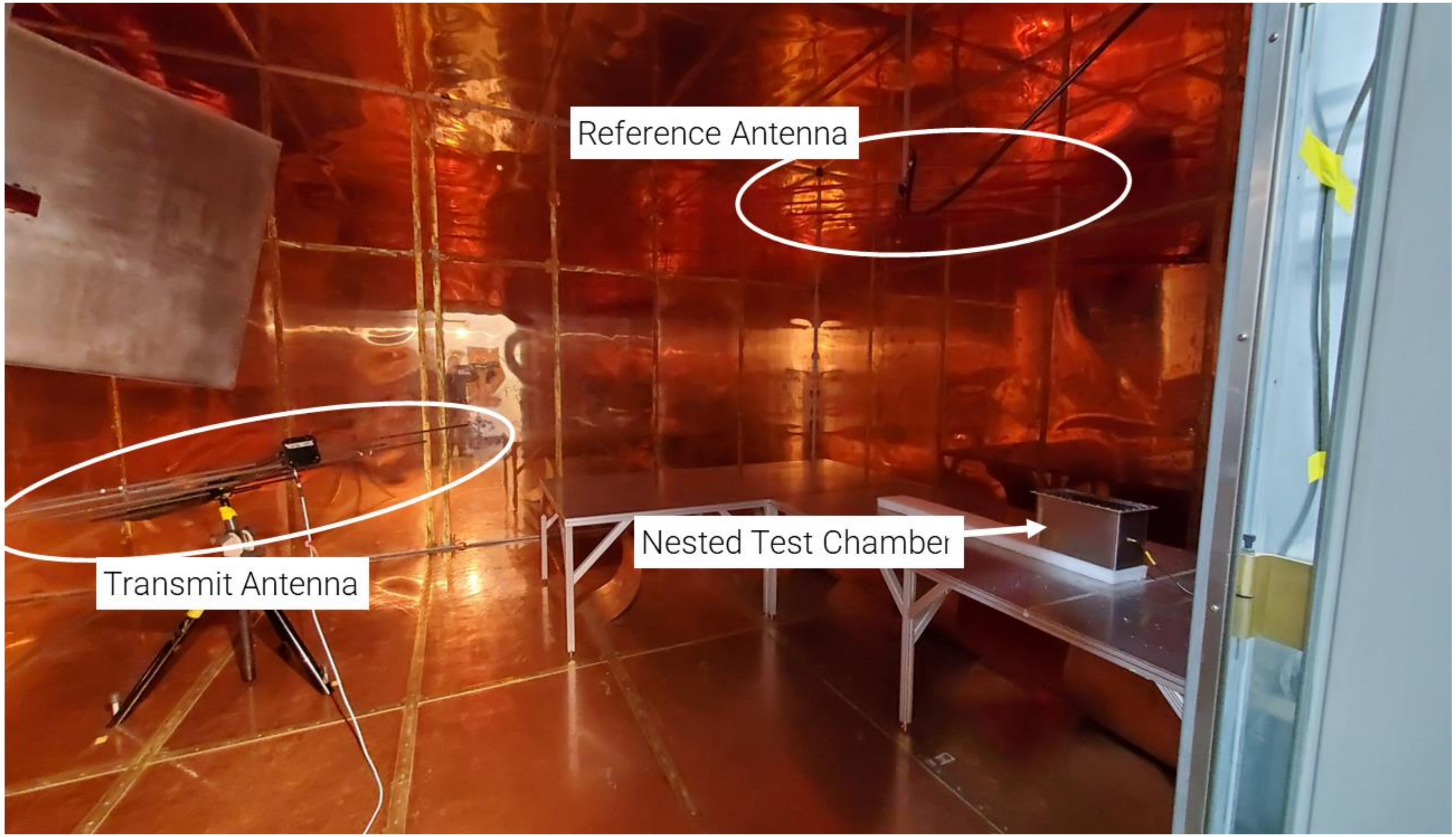
IEEE 299

CISPR 25

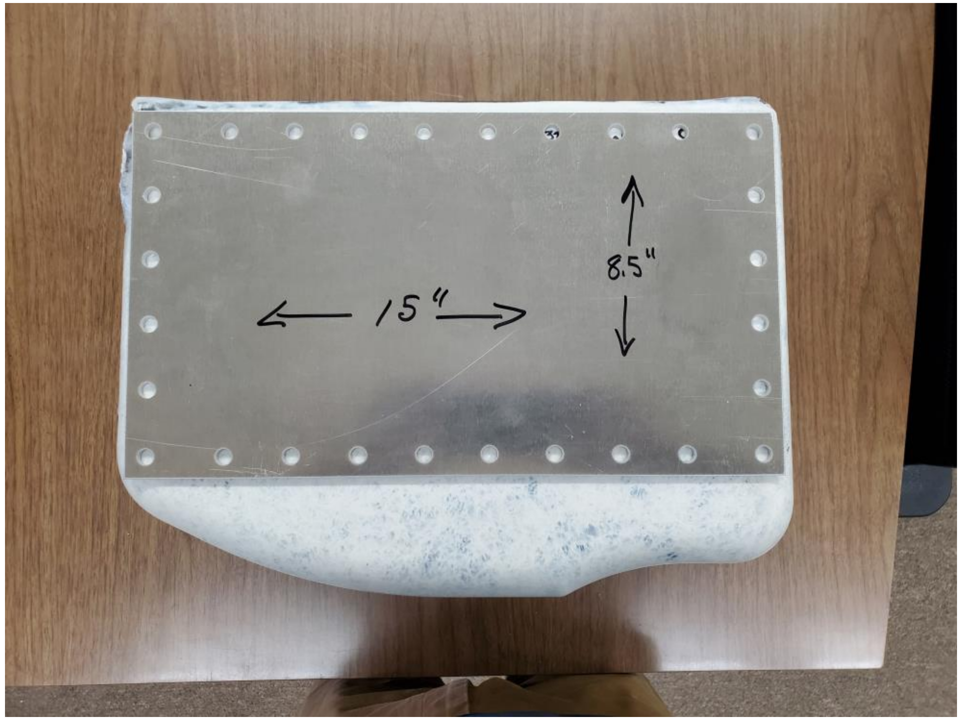


- Sample Level
  - For material comparison potentially used in housing of electric devices
  - ASTM D4935 - Standard Test Method for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials
  - IEEE 299 - Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures
- Component/Subsystem Level
  - For final design validation of electric devices in automotive application
  - „CISPR 25“ as a common test standard
    - Conducted in chambers with absorbing elements
    - Setup on table or vehicle basis

IEE299 NESTED CHAMBER EMI TESTING



IEE299 NESTED CHAMBER EMI TESTING



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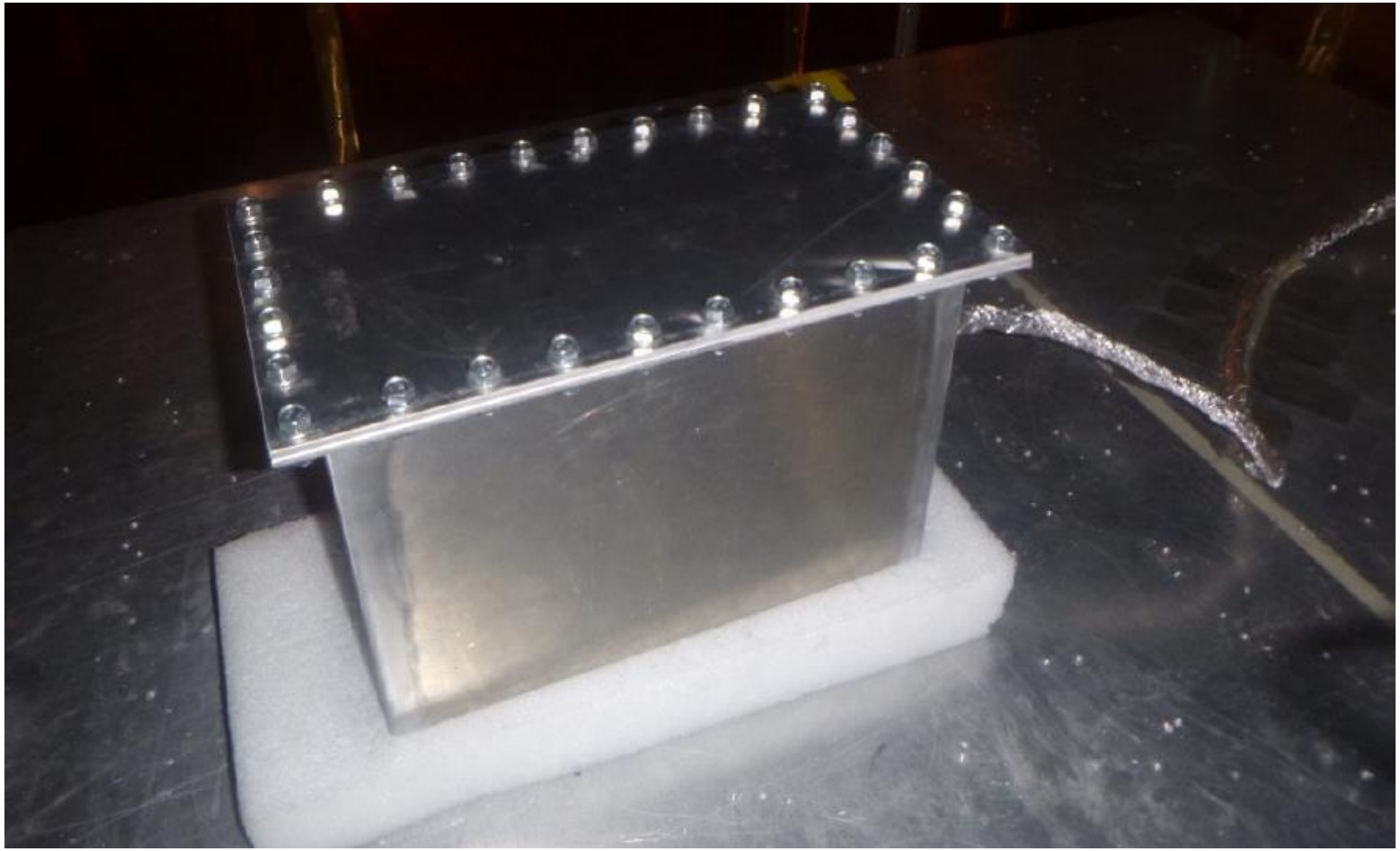

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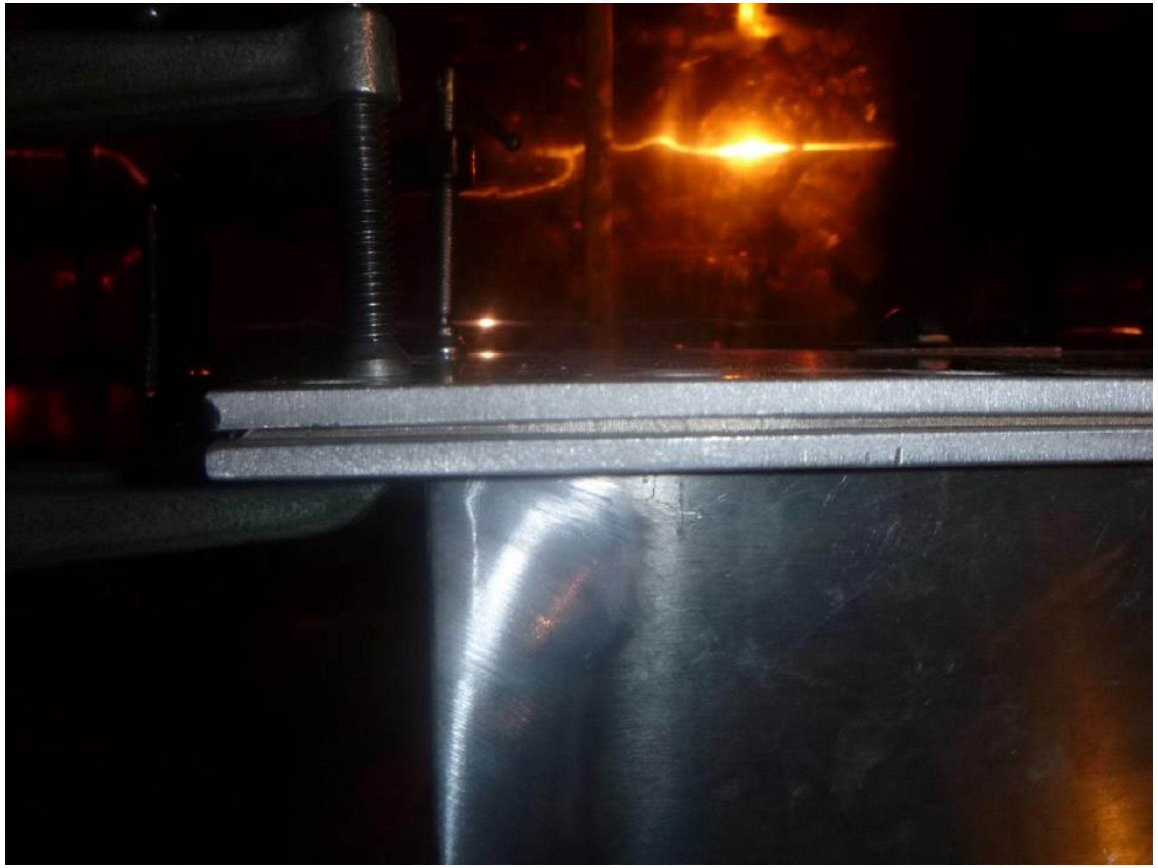

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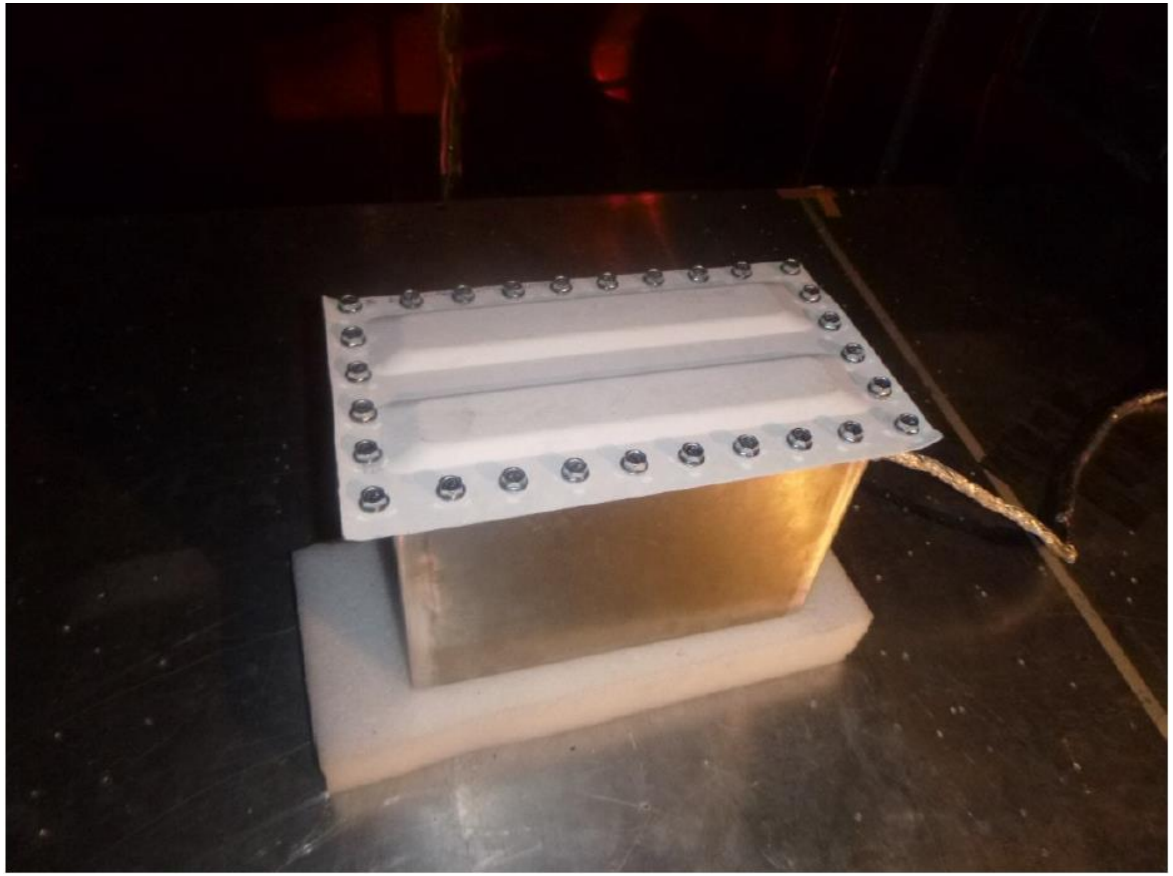

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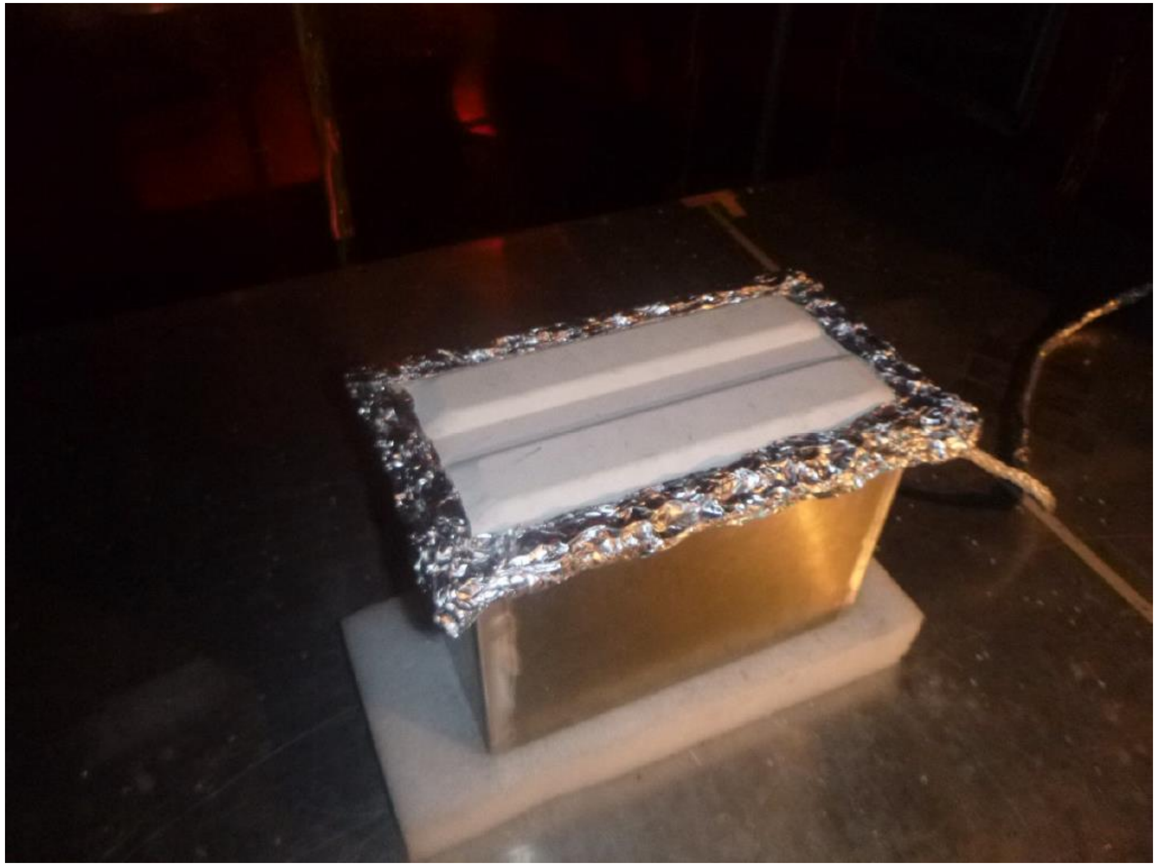

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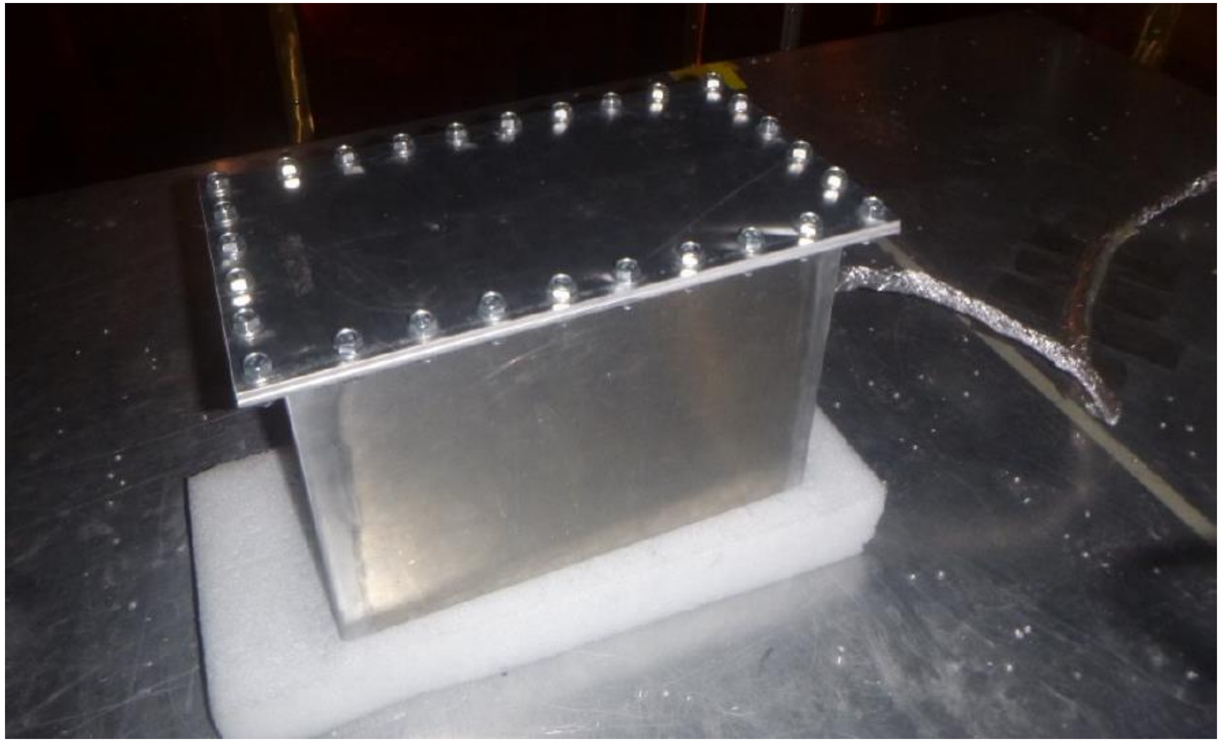
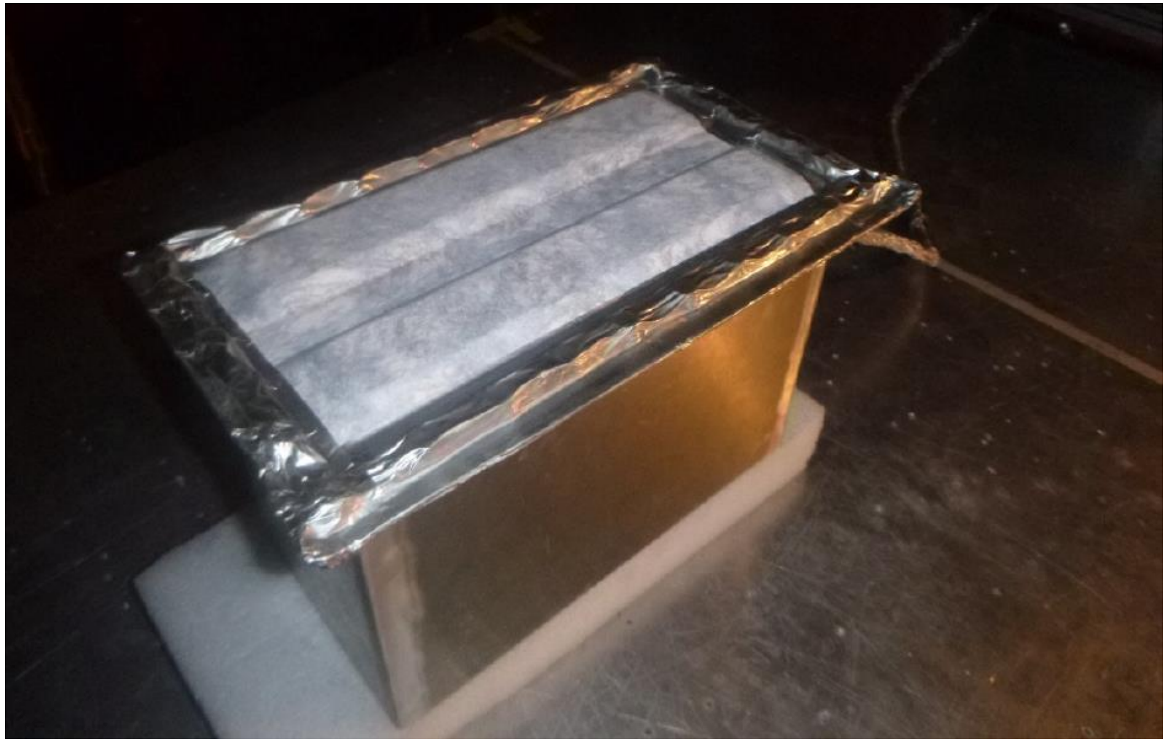
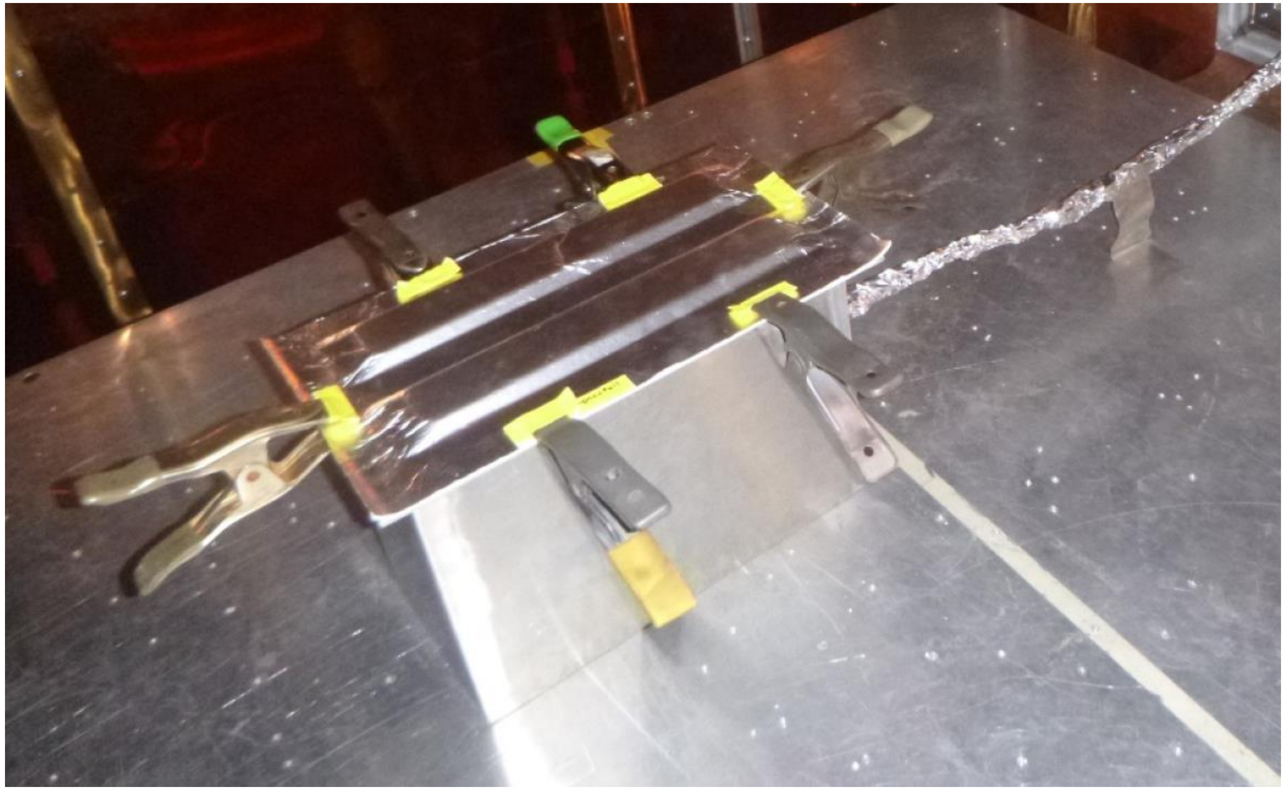


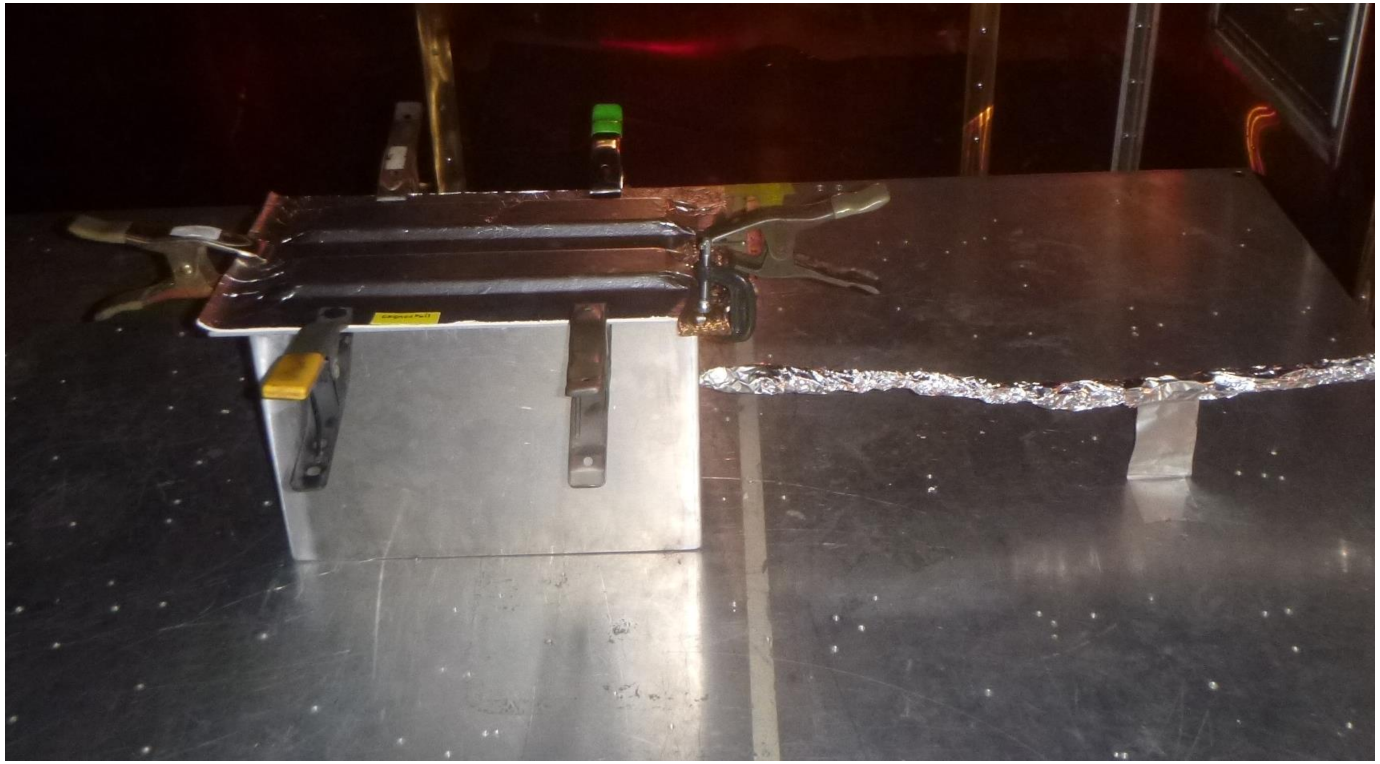


RESULTS – FIRST ROUND

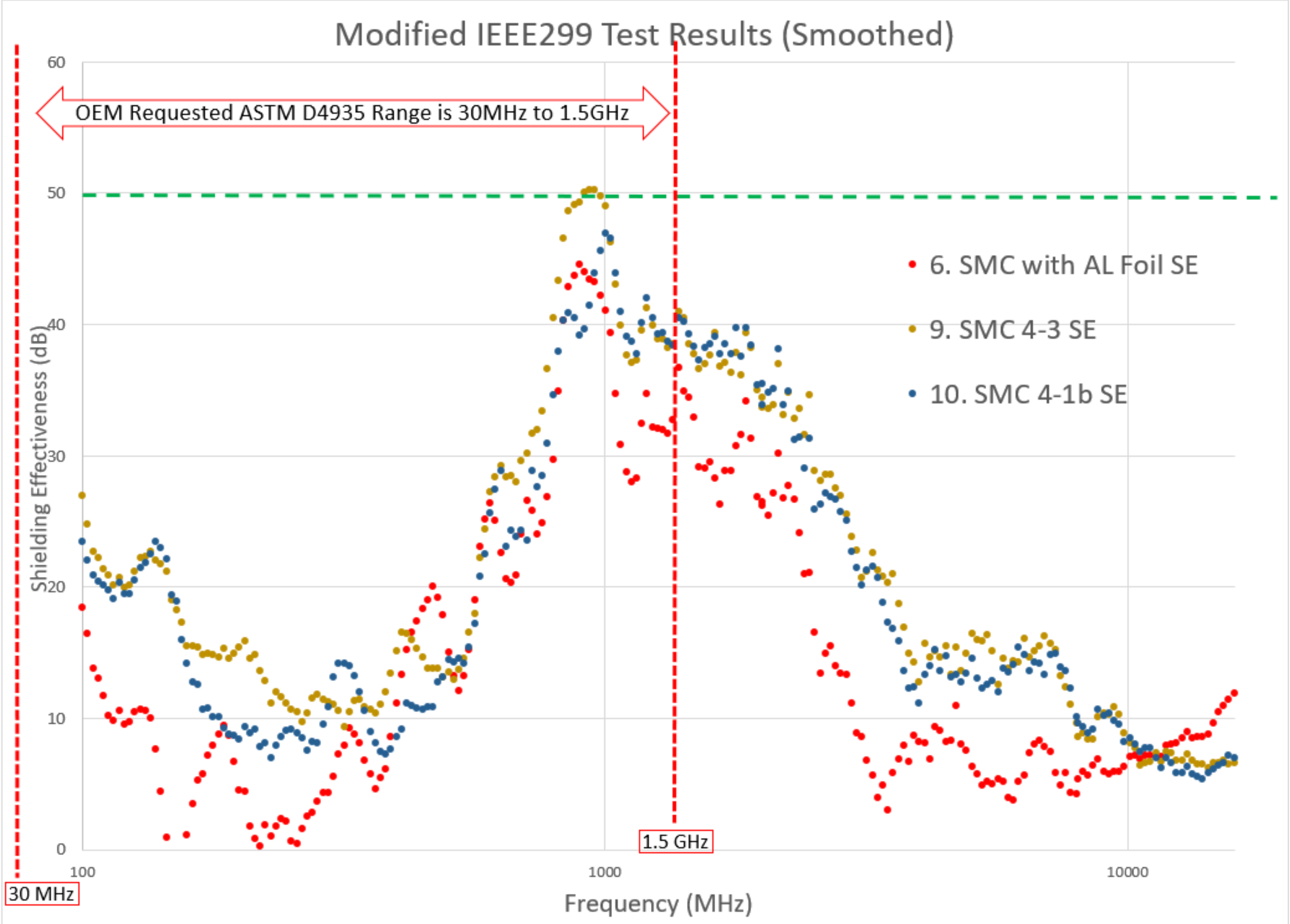
PROXY INCUMBENT APPROACH – METAL FOIL



PROXY INCUMBENT APPROACH – METAL FOIL



2nd ROUND | EQUAL OR BETTER THAN INCUMBENT



SUMMARY OF FINDINGS

- TFP nonwoven performs equal to or better than aluminum foil in the testing conducted
- Grounding the metallic material does not significantly affect the shielding effectiveness
- Understanding the system requirements, is critical to choosing the right materials
- Polymeric materials are a potential solution for a BEV HV battery enclosure

WHAT IS NEXT?

- TFP EMI ENHANCED SMC CAN BE COST EFFECTIVE SOLUTION FOR EMC IN HVBE
- TFP EMI ENHANCED SMC OFFERS THE FOLLOWING BENEFITS

  OEM – reduce cost/complexity

  Molders – more comp against metallic

  Compounders – SMC into larger market share, with more value
- THE TEAM HAS COMPLETED INTENSIVE FRONT END DEVELOPMENT WORK TO DEMONSTRATE THE PLAUSABILITY OF THIS TECHNOLOGY AND WELCOMES THE CHALLENGE OF VALIDATING THE SOLUTION AT SCALE

tfp

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Thank you!

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