Elyfog

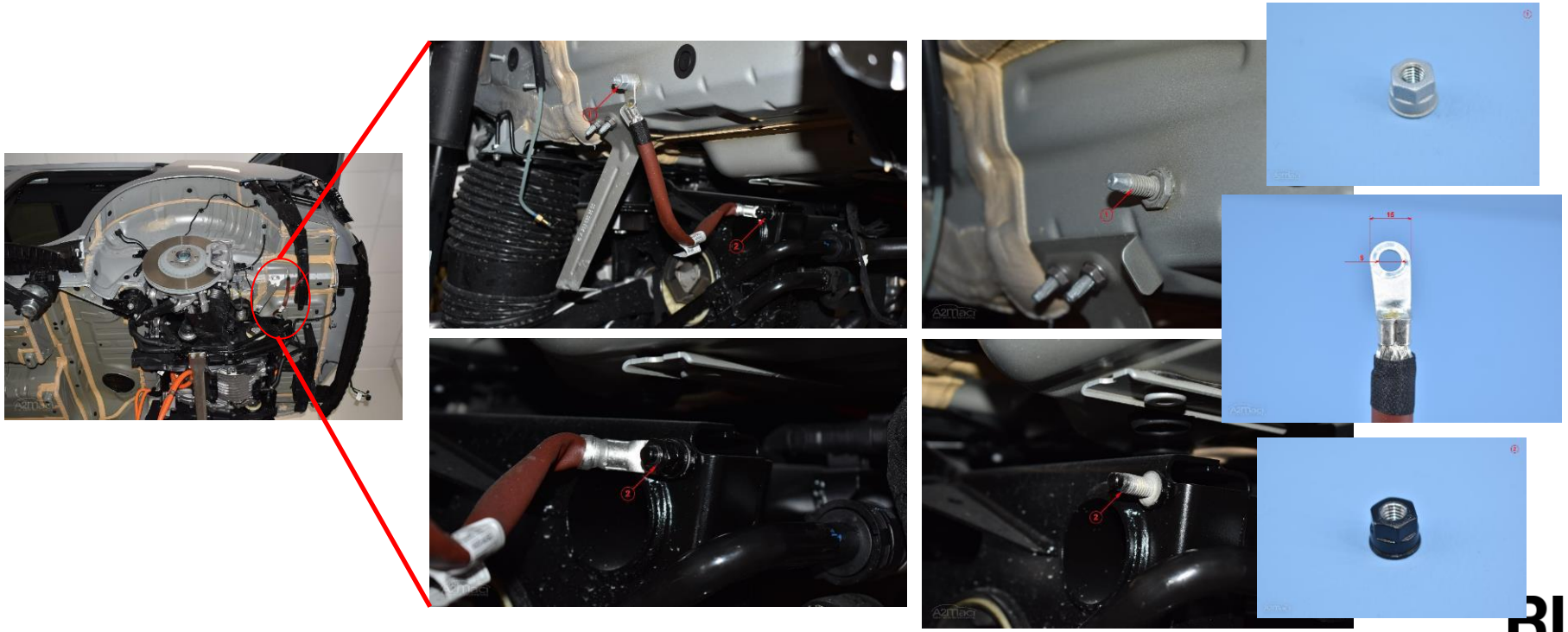
Long-term reliable electrical contacts in EV´s

Jan Skogsmo
RISE Research Institutes of Sweden AB

Elyfog

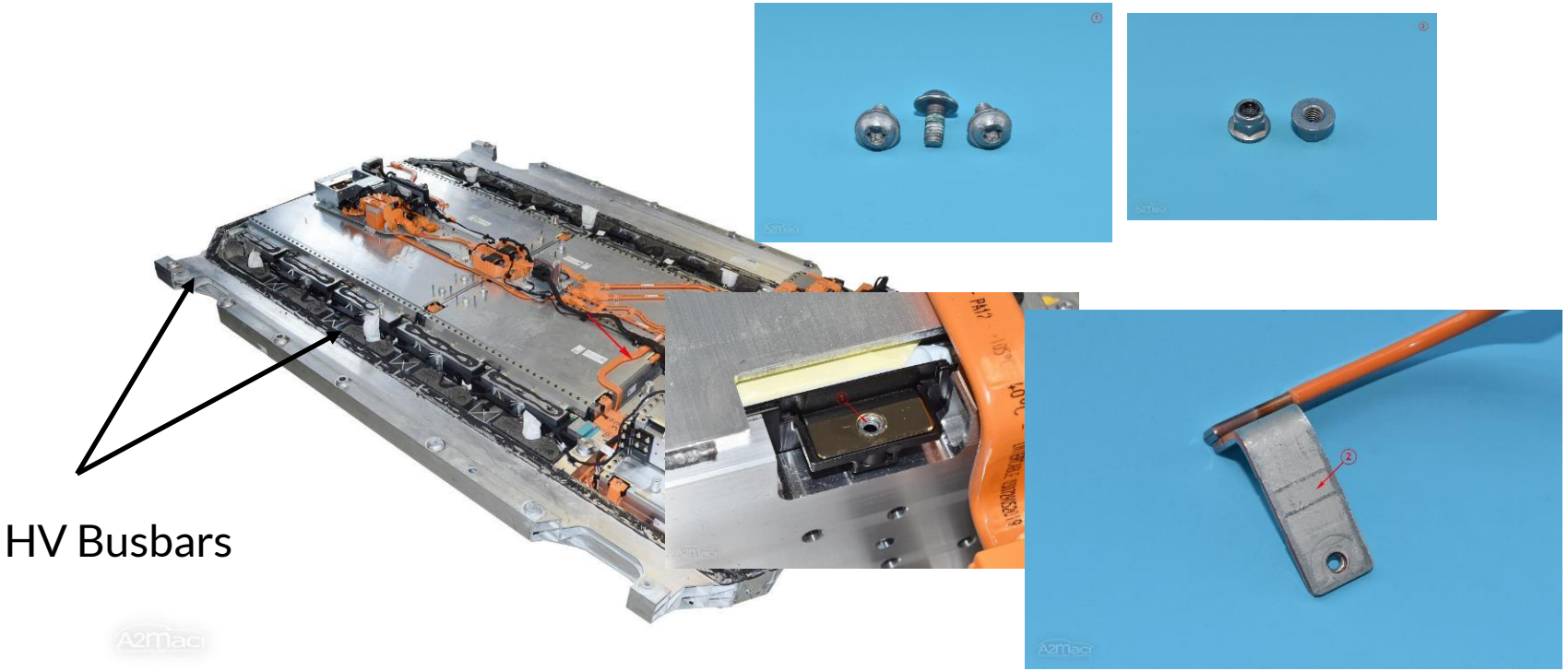
- VINNOVA – Circularitet – FFI – Våren 2023
- Dnr 2023-00810
- 2023-09-15 – 2026-09-15
- Total budget 11 979 000 SEK, Bidrag 5 600 000 SEK
- RISE, Scania CV, Volvo AB, Volvo Cars, Northvolt, Micropowers, Provexa, Husqvarna, Stanley, Atlas Copco, Bulten, Harting, Elpress

Examples of mechanical connectors: Ground connection Electric Motor



Source : A2mac1 – Mercedes EQC

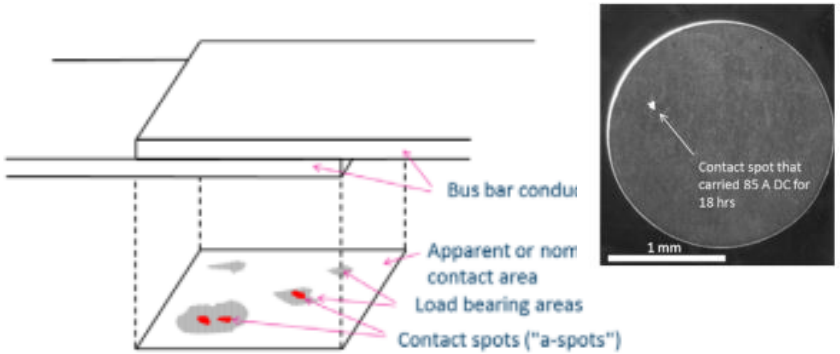
Examples of mechanical connectors: HV Busbar



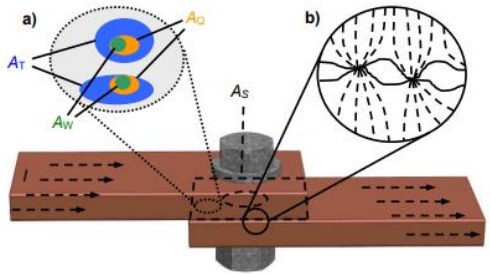
Source: A2mac1 – Mercedes EQC

Contact area

- Micro roughness in contact area
- Nominal contact area > Load bearing area > Electrical contact area
- Only small spots ”a-spots” carries the current

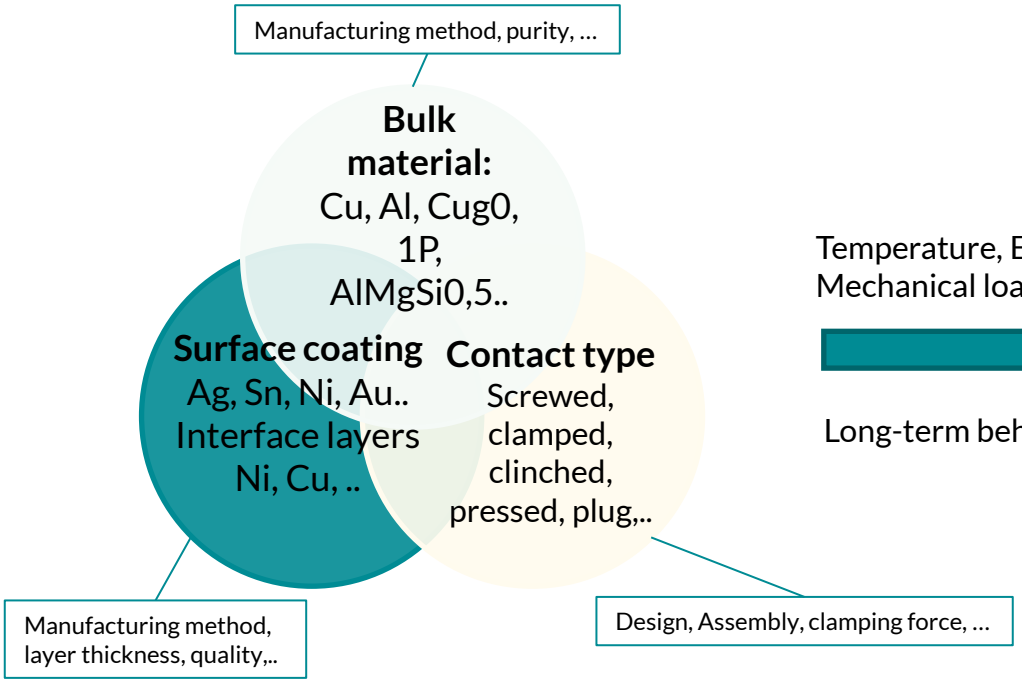


Source: [3]



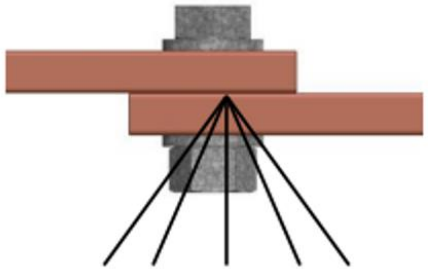
Source: [1]

Long-term stability of a contact



Temperature, Enviroment, Mechanical loads

Long-term behaviour

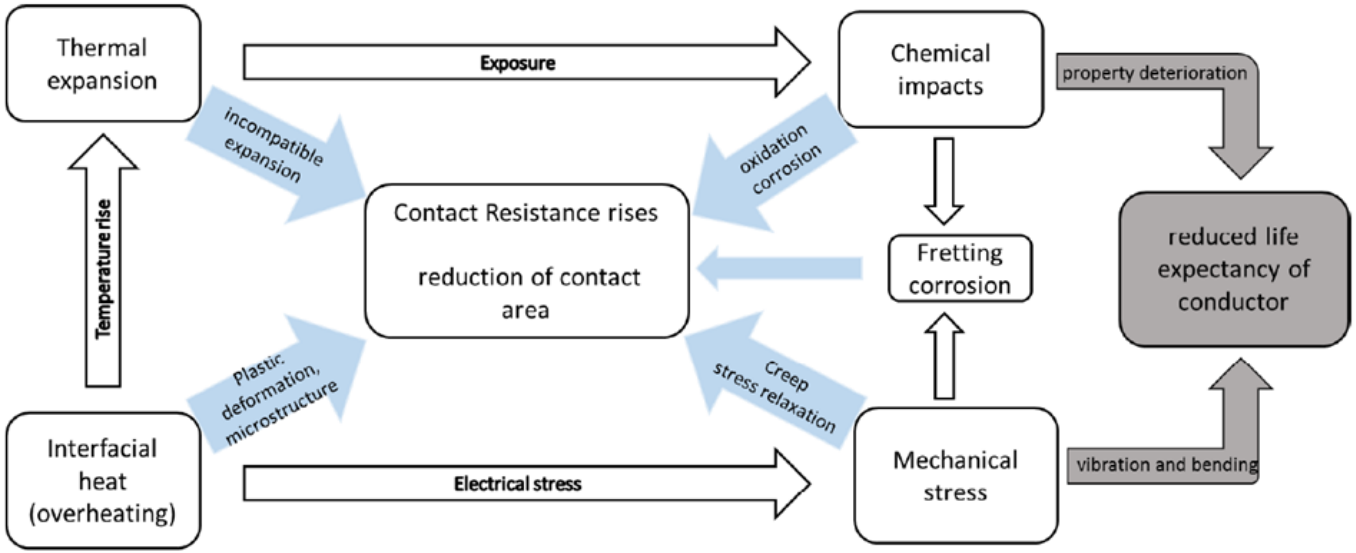


Degradation mechanisms:

- Chemical reactions / Diffusion layers
- Fretting
- Electromigration
- Setting
- Interdiffusion
- Oxidation/Corrosion

Source: according to [1]

The problem for the customer



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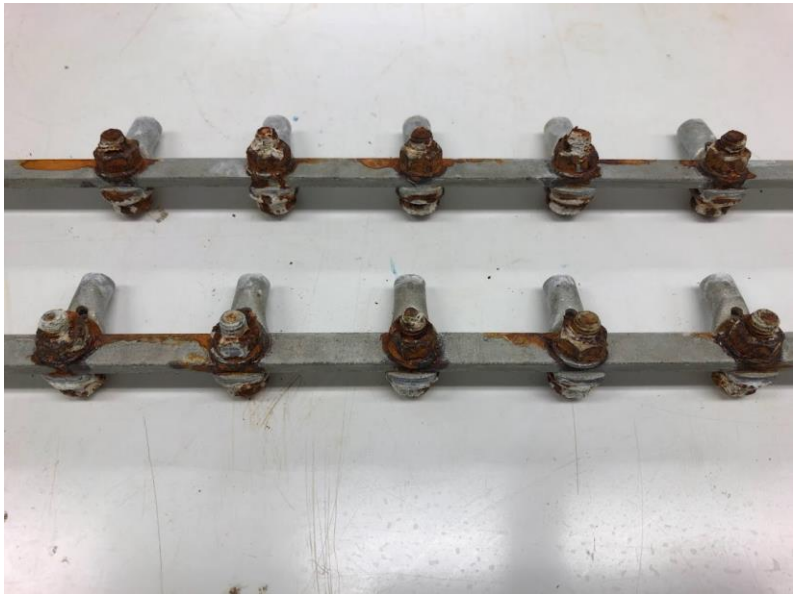
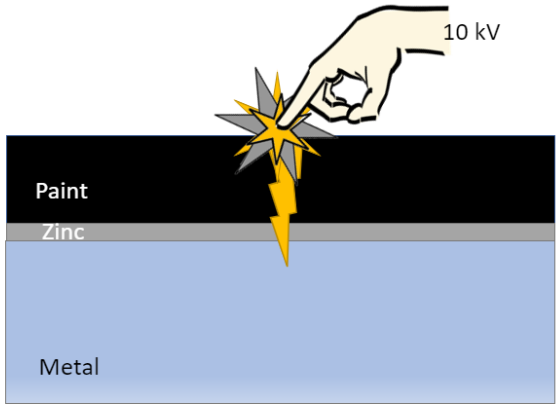
Oxidation and corrosion is a severe threat



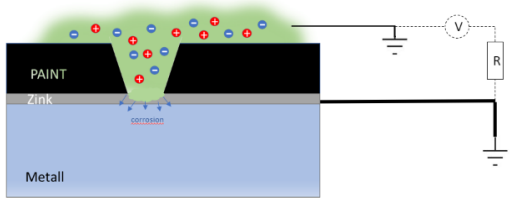
4 weeks in corrosive environment

Examples of corroded contacts

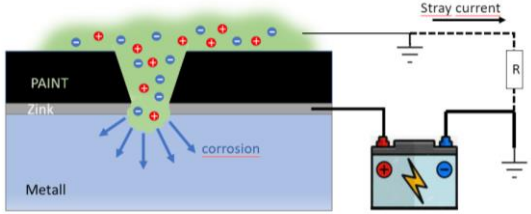
ESD – Electro Static Discharge

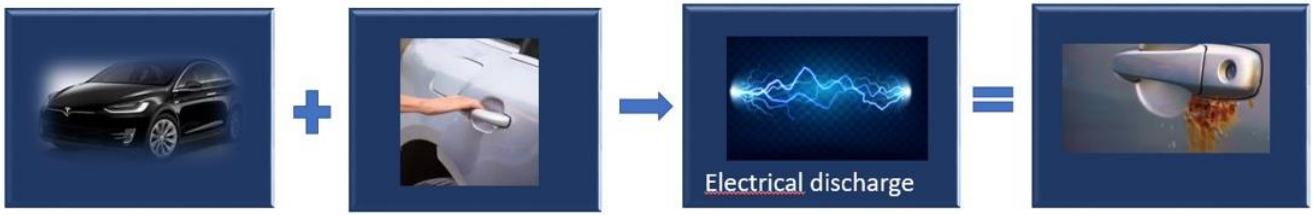


Small ”natural” electrostatic potential causes slow galvanic corrosion



Large ”forced” electrostatic potential causes fast galvanic corrosion





EMC directive 2014/30/EU

ANNEX I

ESSENTIAL REQUIREMENTS

1. **General requirements**

Equipment shall be so designed and manufactured, having regard to the state of the art, as to ensure that:

(a) the electromagnetic disturbance generated does not exceed the level above which radio and telecommunications equipment or other equipment cannot operate as intended;

(b) it has a level of immunity to the electromagnetic disturbance to be expected in its intended use which allows it to operate without unacceptable degradation of its intended use.

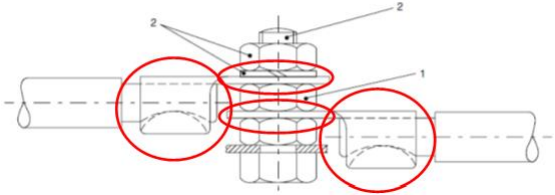
2. **Specific requirements for fixed installations**

Installation and intended use of components

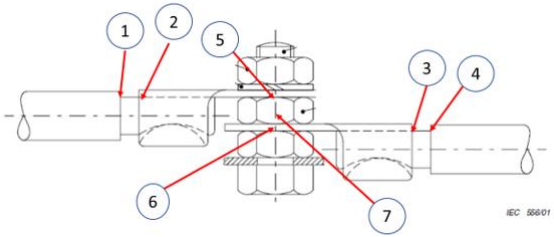
A fixed installation shall be installed applying good engineering practices and respecting the information on the intended use of its components, with a view to meeting the essential requirements set out in point 1.

Thermal image camera

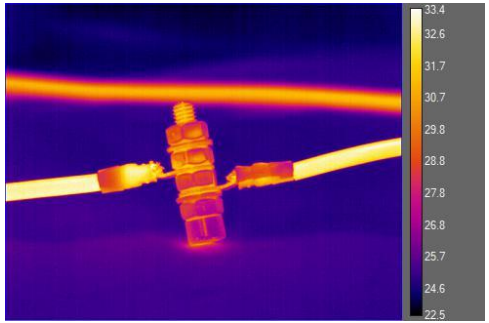
Suspected dominating resistance sites



Measuring points

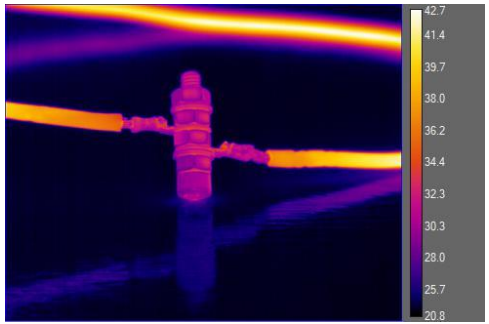


Crimped cable connections



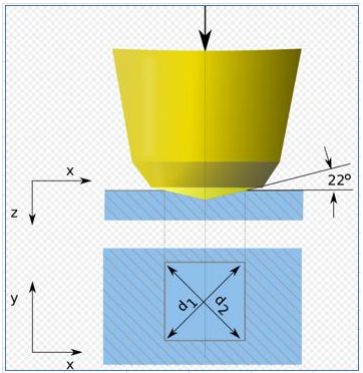
Thermal imaging show high heat generation in left crimp

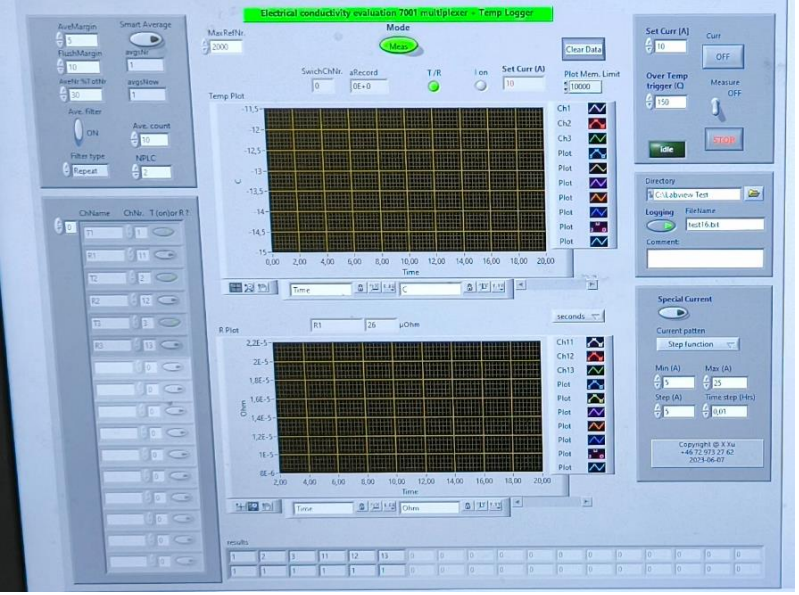
Soldered cable connections

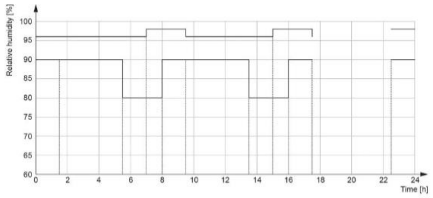


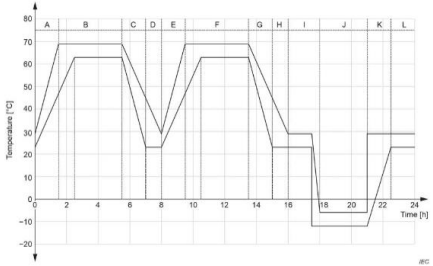
Hardness of conducting coatings

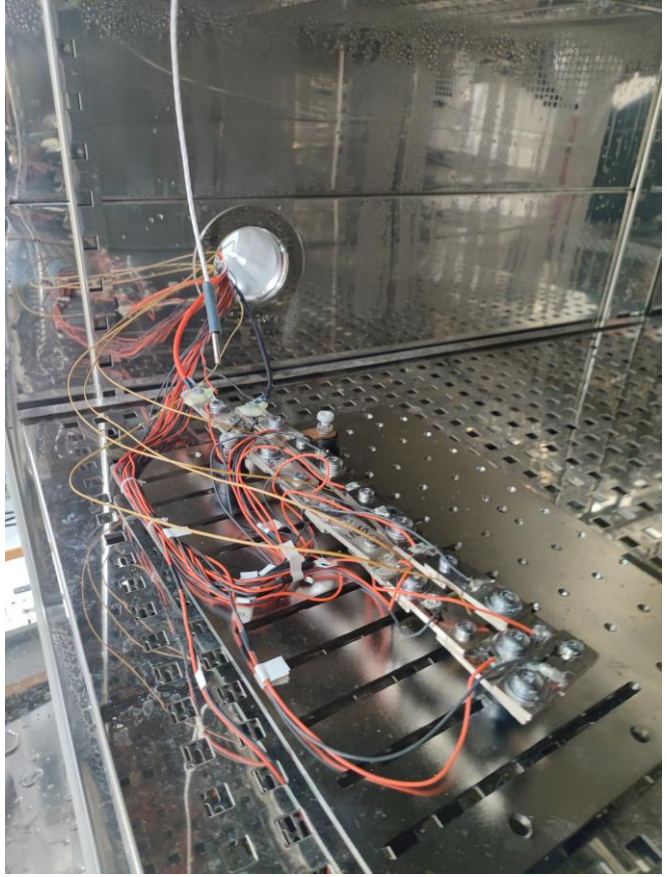
Vickers











Testing at Provexa Technology: Serial connected busbars with electric load and microohm measurement on every connection. Busbars are exposed in climatic chamber according to IEC 60068-2-38

Busbar mounting plate is designed to fit in HALT/HASS testing

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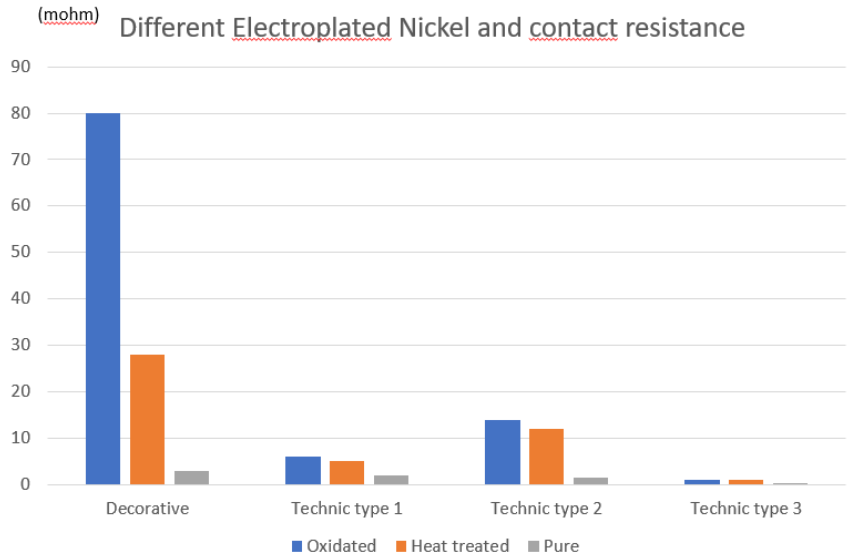
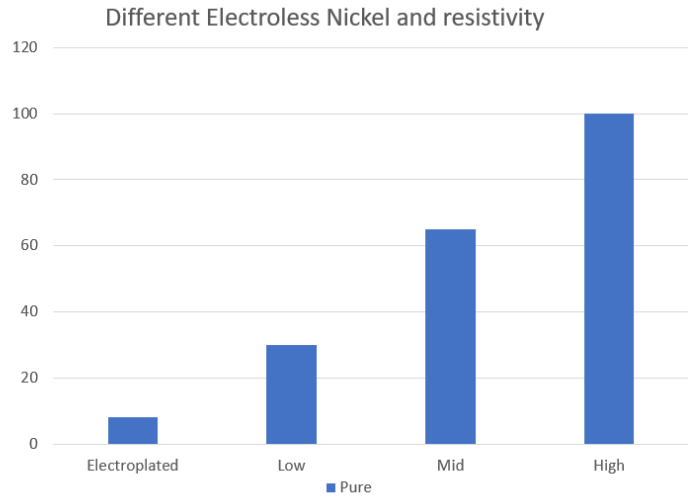
Nickel coatings for electrical contacts

See below list for different nickel platings and their electrical resistivity.

Materia	Electrical resistivty microhm-cm
Nickel as pur metal	6,85
Bright nickel	10
Mattnickel	8,6
Sulfamatenickel	7,76
EN low phosphorus	30
EN mid phosphorus	65
EN High phosphorus	100

There are big difference in contact resistance for different Ni-coatings





Phosphorous content

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Resistance measurement on conductive coatings

- Multimeter is not possible to use: the probes contact resistance will drown the results
- 4-point measurement with a relatively high current can measure down to μΩ

Megger mikroohm measurement unit with 2 voltage probes and 2 current probes

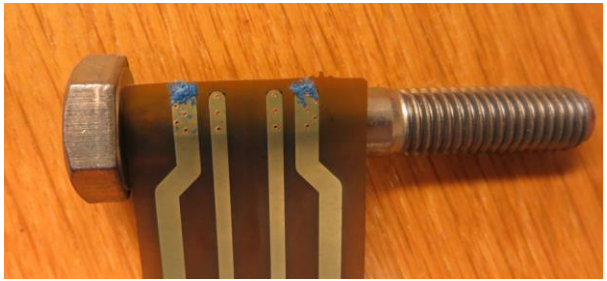
Multimeter (2-p) versus Microohmmeter (4-p)

- Two point multimeter measurement works well if the resistance is ~Ω
- The measurement of R also includes the contact resistance R1 and R2
- The contact resistance is normally one or a few mΩ
- If the resistance R is m Ω or μΩ this measurement does not work

- The multimeter has an internal resistance of 10 Mohm when measuring voltage
- The contact resistance then becomes negligible
- The current in the loop is constant
- Power supply and ampmeter is built into an instrument
  for four-point measurement
- Calculation of resistance is made in the instrument
- The measuring current needs to be relatively high
- (1 – 10 A or higher) otherwise the voltage will be very low and inaccurate to measure for low resistance

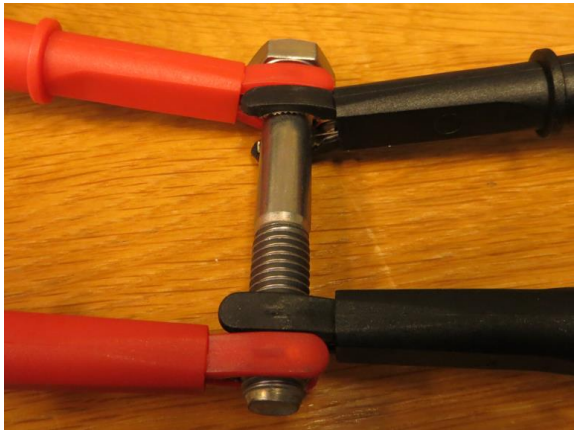
Resistance measurement of coated parts

4-point square resistance



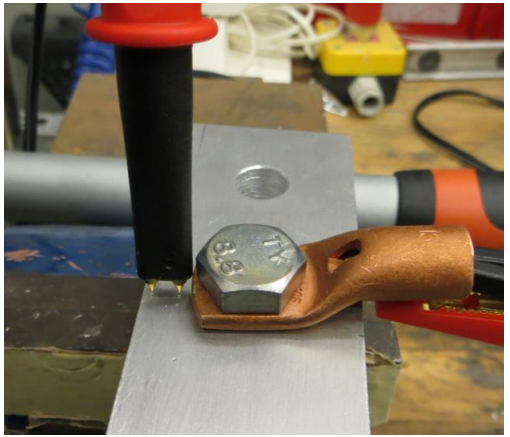
Soft contact probes
No penetration of soft coatings, like passivation layers or oxides

4-point sharp probes



Probes penetrating to metal

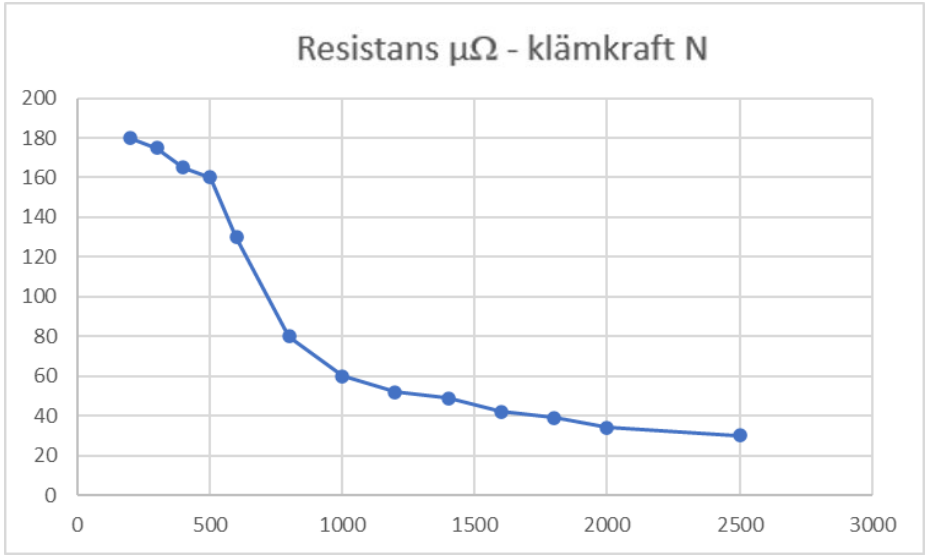
4-point sharp probes clamped contact surfaces



Probes penetrating to metal but clamped contact surfaces have intact coatings or oxide layers

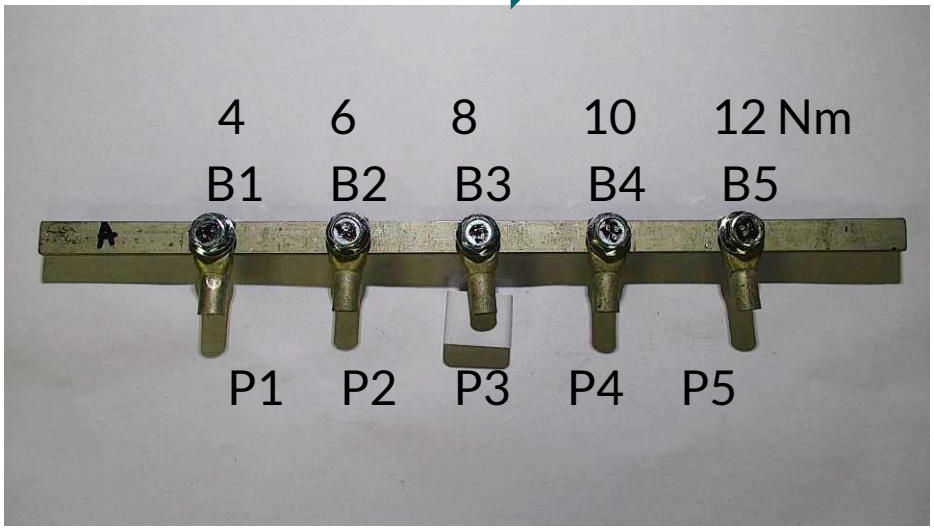
Set up for measuring contact area and resistance as a function of force

tinplated copper cable lug pressed by M10 screw against nickelplated copper bar

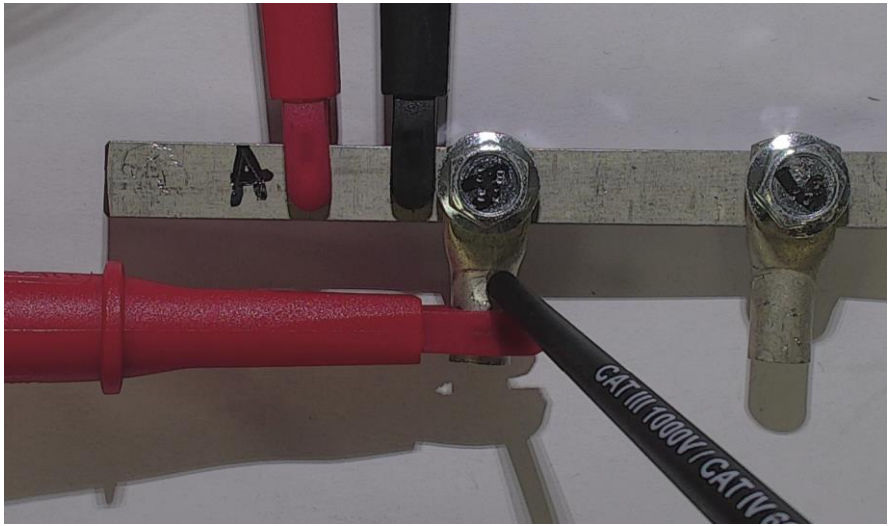


Contact pressure (tightening torque) vs. Contact resistance

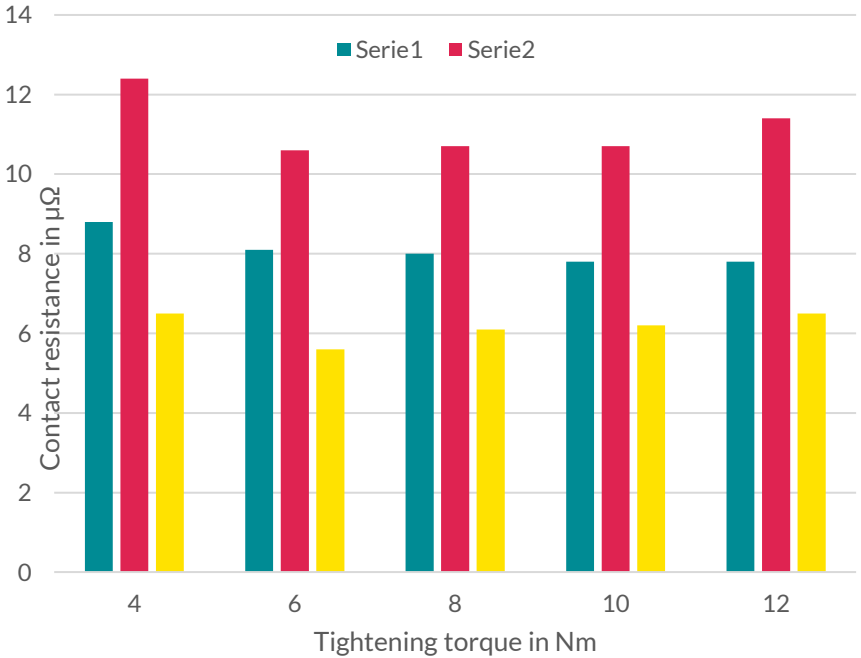
Increased tightening torque

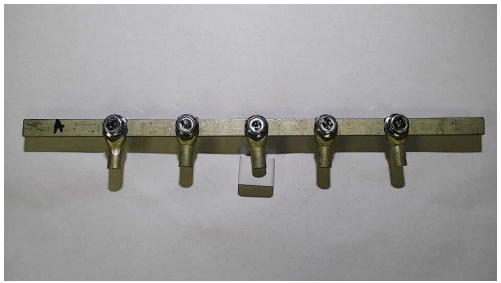


Red = Current Black = Voltage



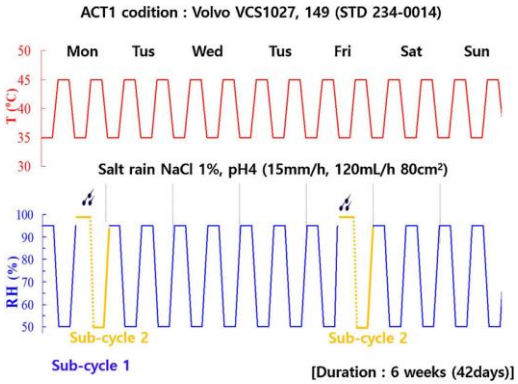
Contact resistance vs. Climate

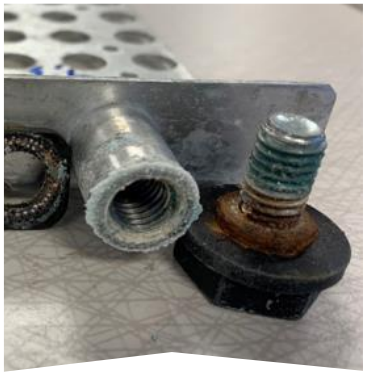




- Serie 1: busbar-cable lug
- Serie 2: after busbar-cable lug after 2 weeks climate chamber
- Serie 3: busbar-screw head after 2 weeks climate chamber

Normal corrosion testing according to vehicle standards doesn't force the most common corrosion processes in EV systems





Result:
It has been observed that corrosion with NaCl influence doesn't always impact contact resistance

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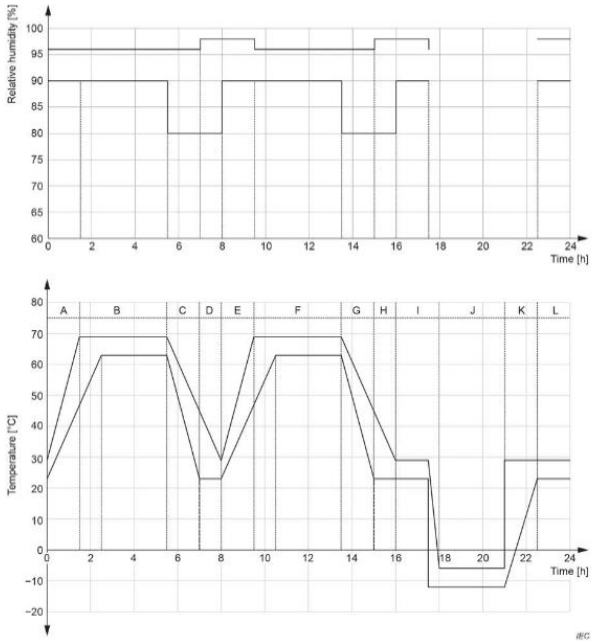
Normal electric environmental testing doesn't force the most common corrosion processes in an EV system



Forward
Need further testing/measurements with combination of humidity, salt and electric and thermic load

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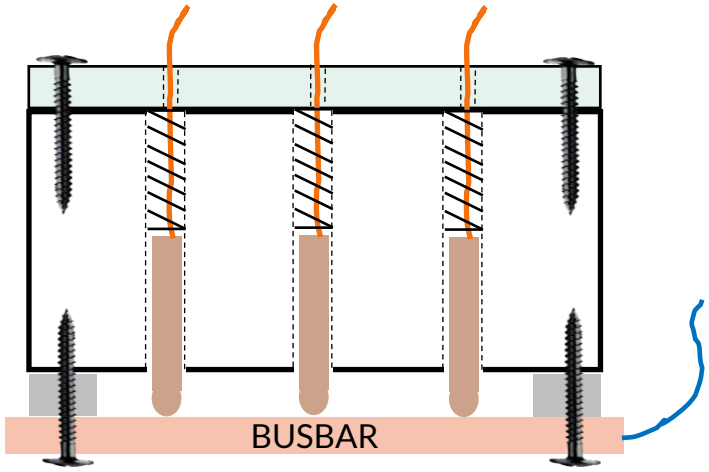
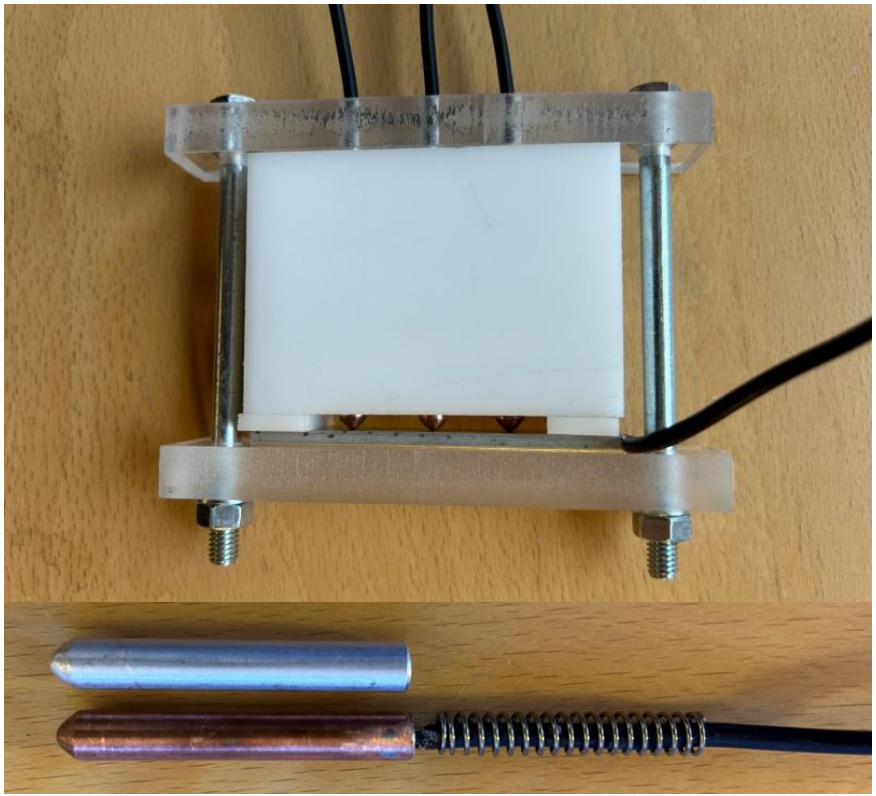
Test idea

- The test connection is a flat busbar plate and a rod with rounded tip forced towards the surface by a spring
- Plastic test fixture (POM)
- This should give a well-defined contact point

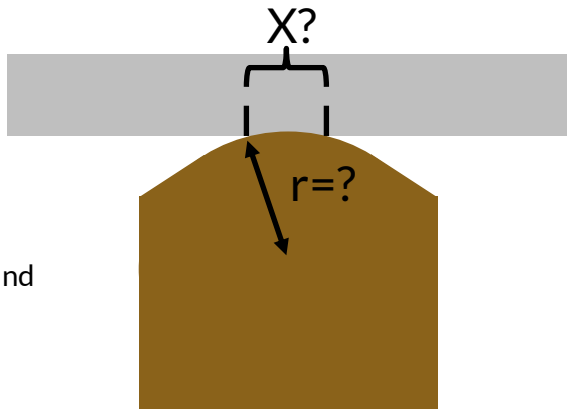


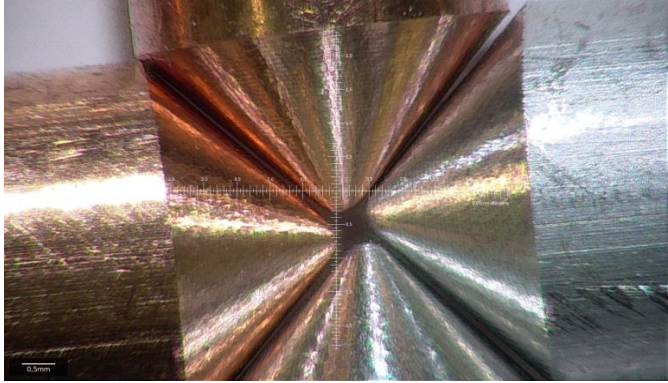


- To be developed into….
- And other ideas….

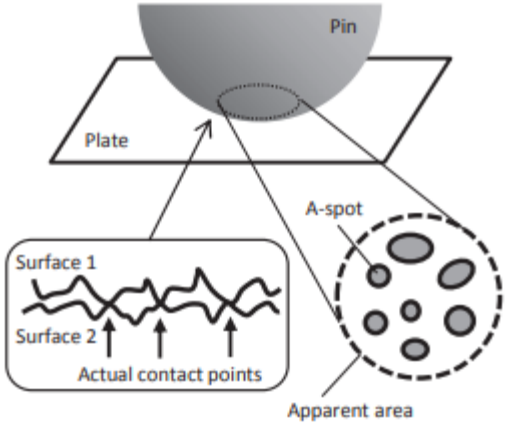
Contact tip

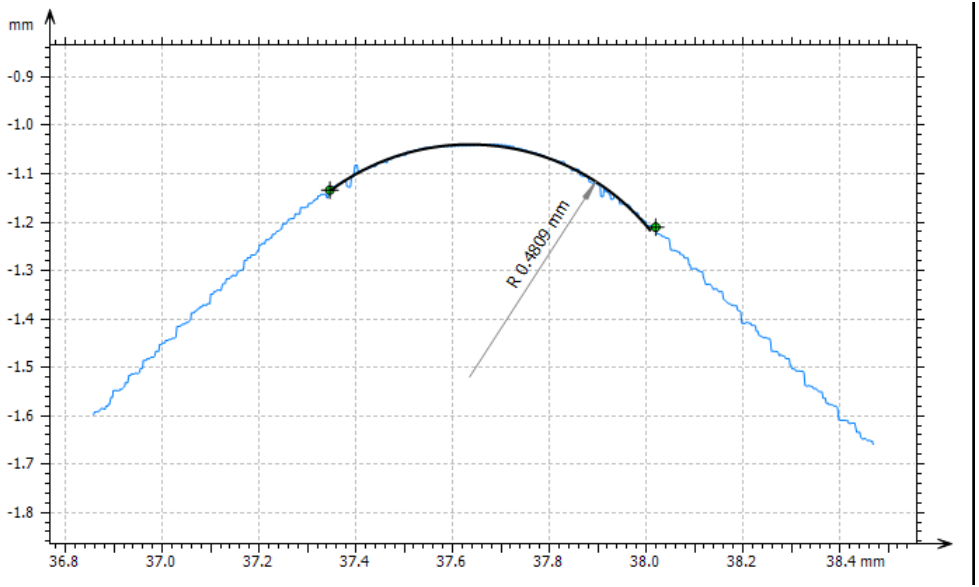
- Aim:
  - Defined indent that can be found
    Rather flat contact area
    No interlocking penetration
    Contact area = f(surface roughness)





CNC machining of 0,5 mm radius tips





Summary and outlook - Elyfog

- Electrical contacts and their long-time properties are very complex!
  - A combination of expertise from different disciplines are needed: Joining technology, surface technology, assembly, electrical engineering, corrosion testing, climate testing, mechanical testing.
  - Often not much pressure is needed to get good contact in virgin materials
  - Contact resistance might be good directly after assembly but setting, oxidation, humidity, corrosion, vibrations, and mechanical loads can worsen electrical properties quickly.
  - Measurements need to be conducted carefully and repeatable

- RISE has gathered expertise within several areas and is aiming to combine expertise for testing and characterization of electrical contacts with focus on bolted joints.

- Elyfog project with support from FFI has been approved and started V37-2024:
  - How to combine loads and accelerate testing with relevance to application case?
  - Solutions for long-term reliable contacts and guidelines: Surface treatment, material combinations, contact design, and assembly.

RI.
SE

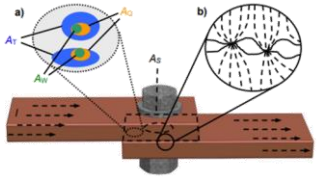
Testing and development of long-term reliable electrical contacts (ELYFOG)

Project content and scope

- The project focuses on bolted joints and mechanical joining for connectors and connections for electric vehicles. This applies mainly to demountable fixed joints, but not switches.
- Goal is to develop relevant testing methods and solutions for electrical contacts in electric vehicles. That includes testing under combined loading, new surface treatment solutions, optimized assembly parameters fulfilling requirement specifications for electrical contacts.

Project deliverables

- Analysis of application scenarios and relevant requirement specifications.
- Testing methods for combined loading and measurement of electrical contacts.
- Evaluated concepts for materials and surface treatment solutions for reliable contacts.
- Guidelines for fasteners, assembly, safety,…



Source: [1]

Project partners

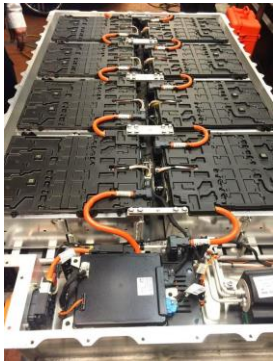
- RISE, Scania CV, Volvo AB, Volvo Cars, Northvolt, Micropowers, Provexa, Husqvarna, Stanley, Atlas Copco, Bulten, Harting, Elpress

Needed competences:

- Mechanical joining, electrical engineering, mechanical and environmental durability, material and surface treatment for electrical applications, education and information, standardization

Project details

- Apply for FFI Circularity (28 March 2023). Project start: Q3 2023. Project duration: 3 years. Project budget: >10 MSEK (50% in-kind)



Potential applications
- Busbar contacts
- Grounding contacts

Potential accelerated testing
- Mechanical loads
- Environmental loads
- Thermal loads
- Sequential vs. combined

Potential evaluation
- Contact resistance
- Oxidation and deformation
- Clamping force
- Surface degeneration

WP1
Concepts, specimens and requirement specifications

- Definition of application cases
- Definition of requirement specification for selected cases

WP2
Testing methodologies

- Measurement methods
- Development of test methods for combined loading
- Comparison with existing testing methods
- Validation of testing concept with field tests

WP3
Evaluation of selected concepts

- Testing of selected assembly parameters, surface treatments, conductor materials
- Testing in standardized tests and new combined test method
- Evaluation and ranking according to requirement specification and expected lifetime

WP4
Guidelines

- Writing of documents for internal and external education
- Instructions for assembly of electrical contacts
- Derivation of best practices

WP5
Project management

- Organise meetings and workshops
- Distribute results
- Report to VINNOVA
- Keep track of project budget
- WP leader: RISE