Test probes and contacts for battery cell and EV-connector applications: Challenges and novelty solutions

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Contents

- Different Probe Types
- Cell Form Factors
- Application Range
  (Formation, OCV, AC DC-IR, EIS Hi-Pot)
- Probe Design and Implementation
- Preventive Maintenance and Cleaning

Different Probe Types for Testing (In General) & Requirements for Battery Test

Ultra Fine Pitch

Fine Pitch

Larger Pitches

On-Wafer

Socket

PCBA

pitch >100 mil … 2 cm
temperature monitoring
Kelvin test
4A … 400A CCC
aggressive tip

Connector

Battery

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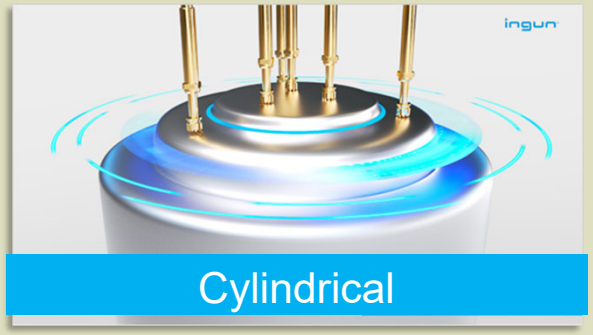
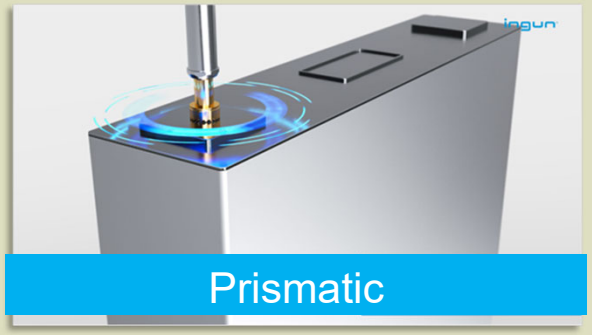
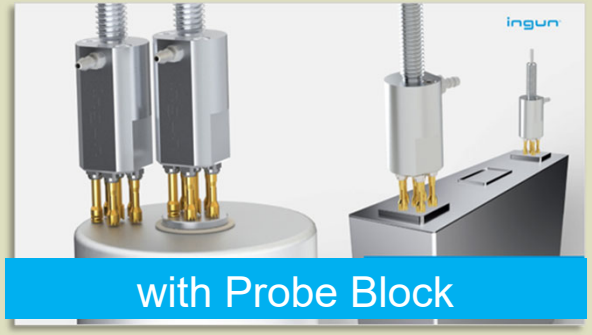
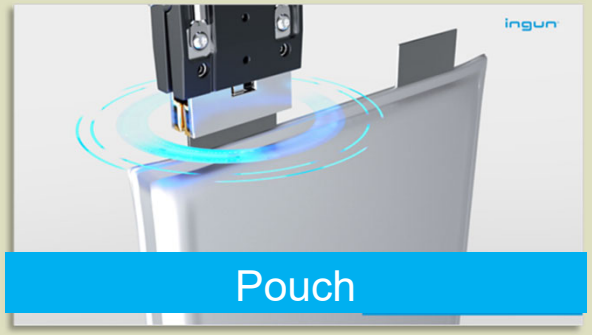
Cell Form Factors: Round-Prismatic-Pouch-(Coin)

- Shorter forming and testing times as well as saving energy.









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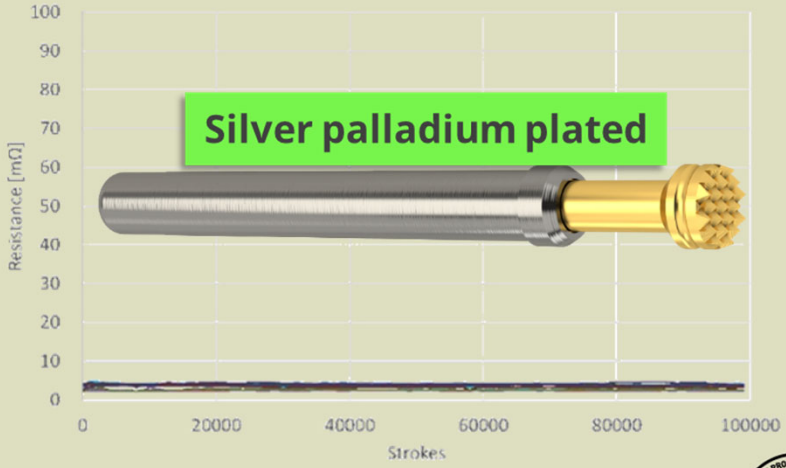
Special plating options

- Consists of palladium, which is vapor-deposited onto the base layer of silver
- Prevents a reaction with sulphur over time
- Low constant inner resistance R_i
- Results in a temperature increase consistently below 20 Kelvin



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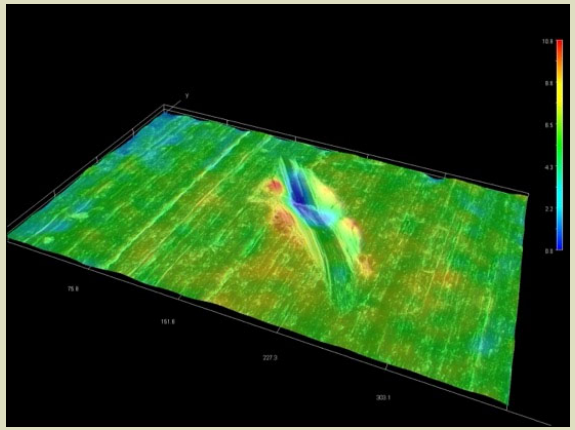
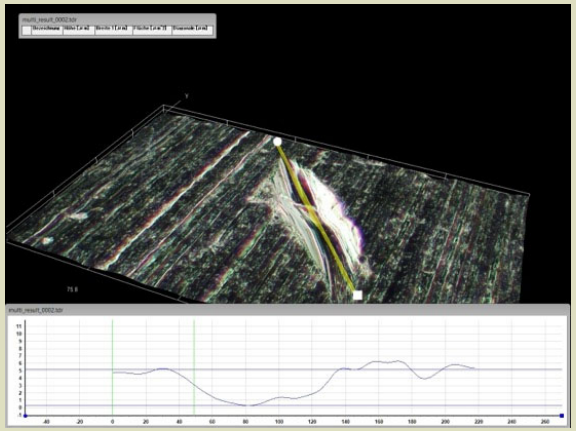
Probe Design: Bifurcated (Spreader) Tip



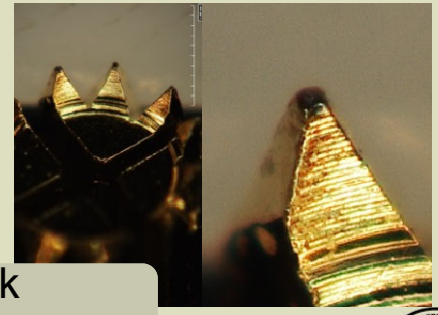
CRES improvement on surfaces such as Al (oxide!) through material displacement

Displacement / cutting-action:
Length: 0.2 to 0.5 mm
Width: ~0.1 mm
Depth: 5 to 20 µm



0 cycles

27k cycles



82k cycles

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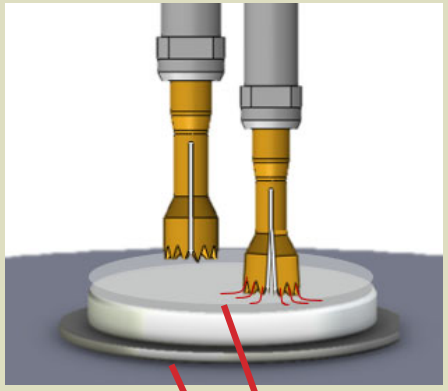
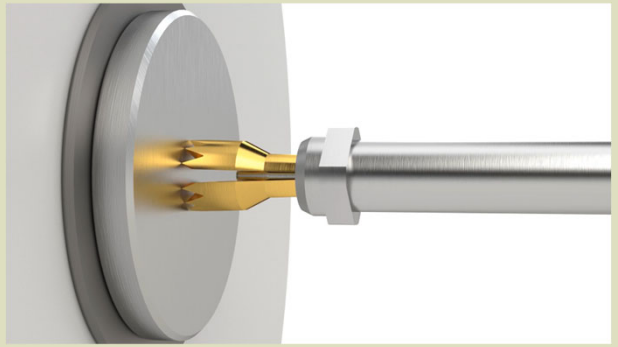
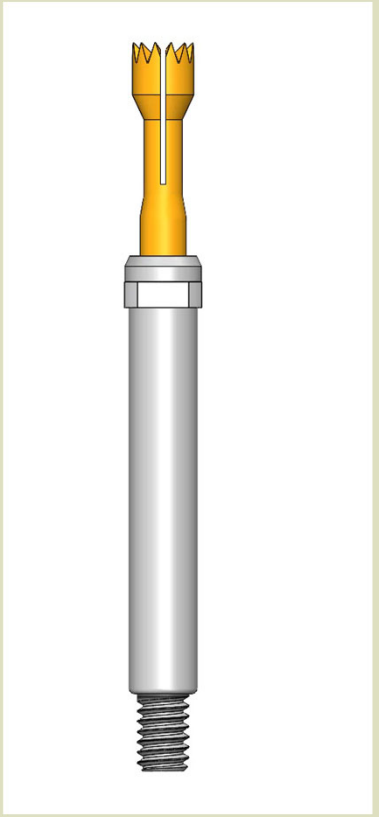
Probe Design: Bifurcated (Spreader) Tip



Surface

- Oxide layer on aluminium battery tabs
- Oxide layer is less conductive
- Oxide layer must be actively removed
- Aggressive probe tip style with active head
- Displacement/pierce effect necessary to ensure a low contact resistance





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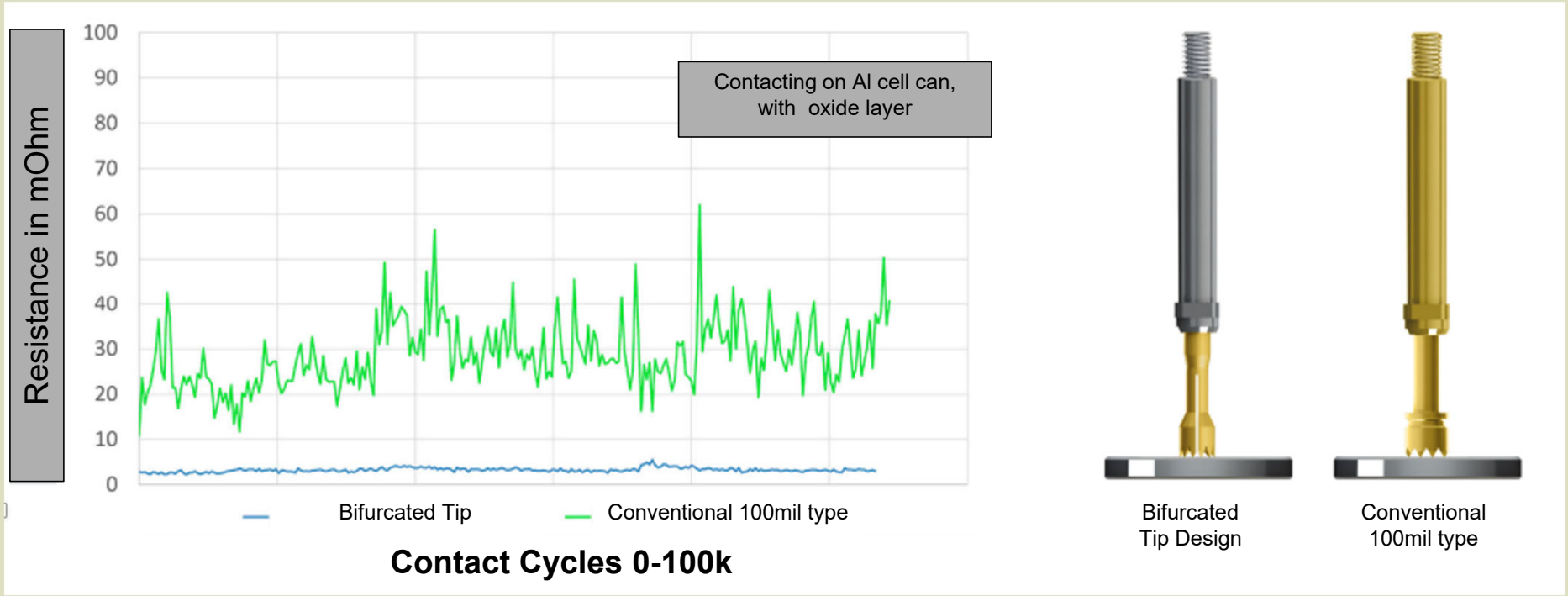
Comparison CRES Spreader Tip vs. "Conventional" (Drop-in Type)



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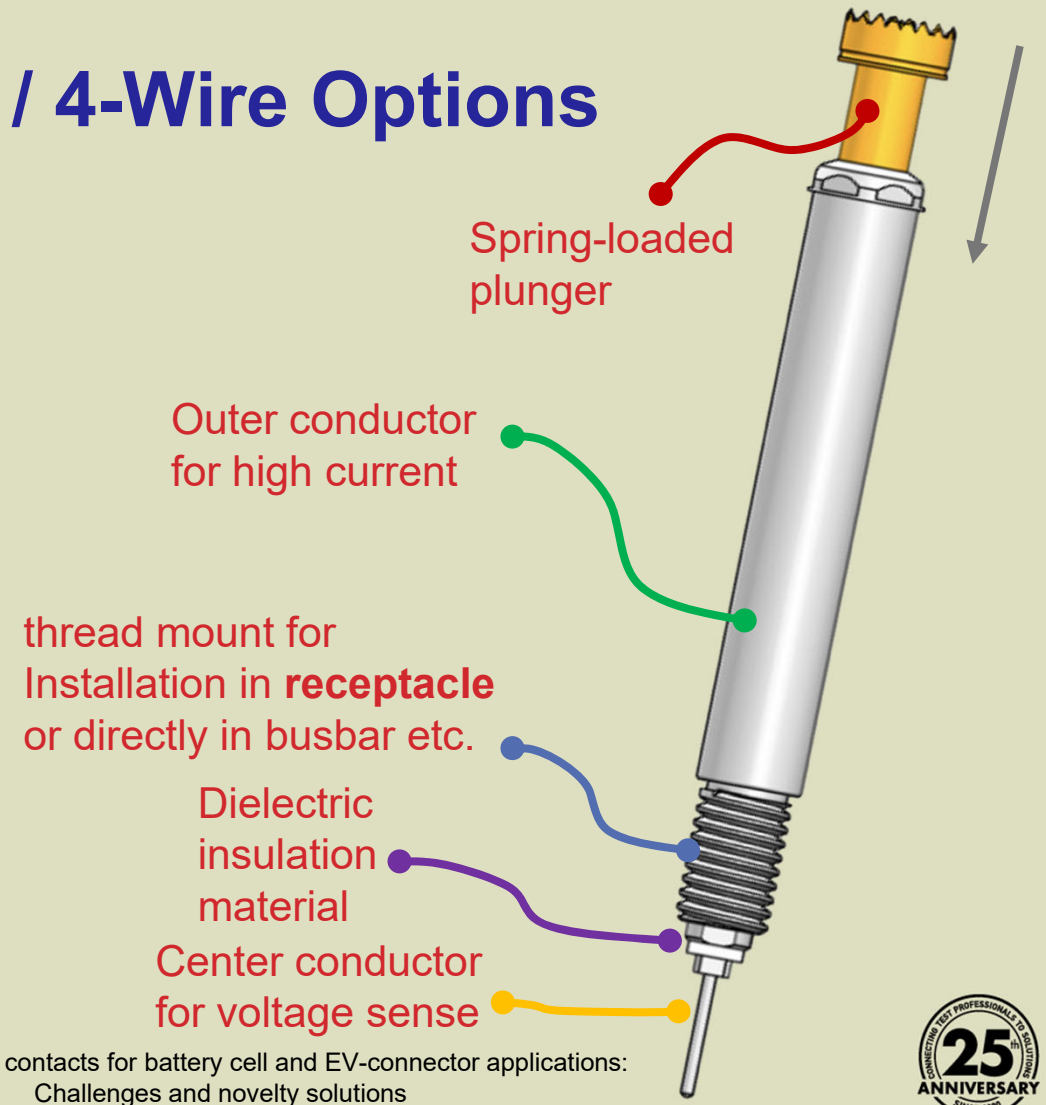
Probe Design / 4-Wire Options

A conventional probe consists of a

a. Plunger
b. Barrel
c. Spring

This design however has two probes in one – a thicker type which surrounds the thinner center conductor.

The two probes are separated by dielectric spacers.



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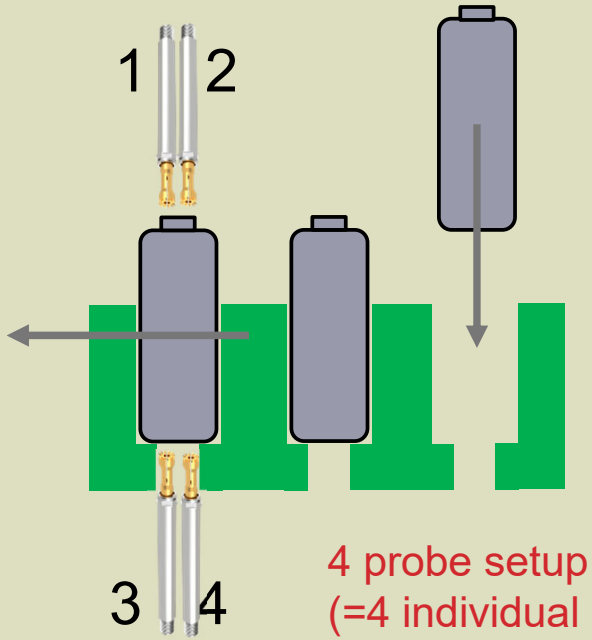
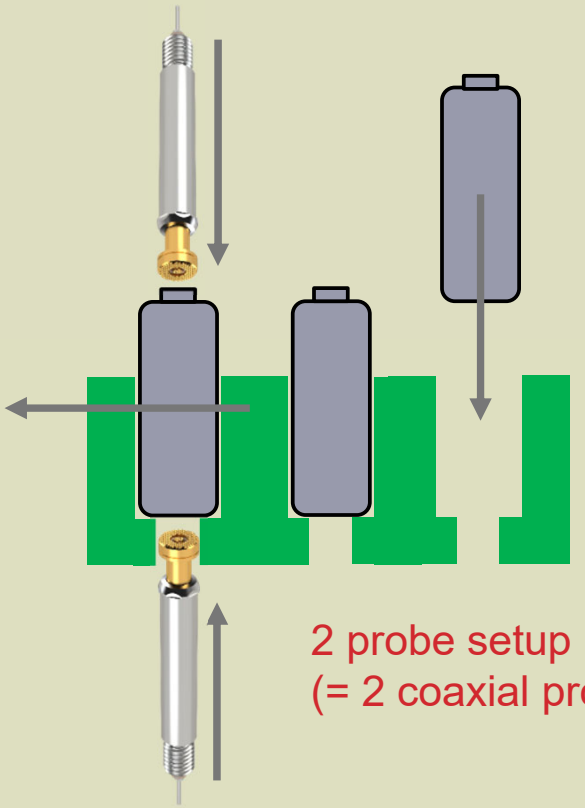
Application Range: Impedance (ACIR)



4 probe setup
(=4 individual probes)



2 probe setup
(= 2 coaxial probes)

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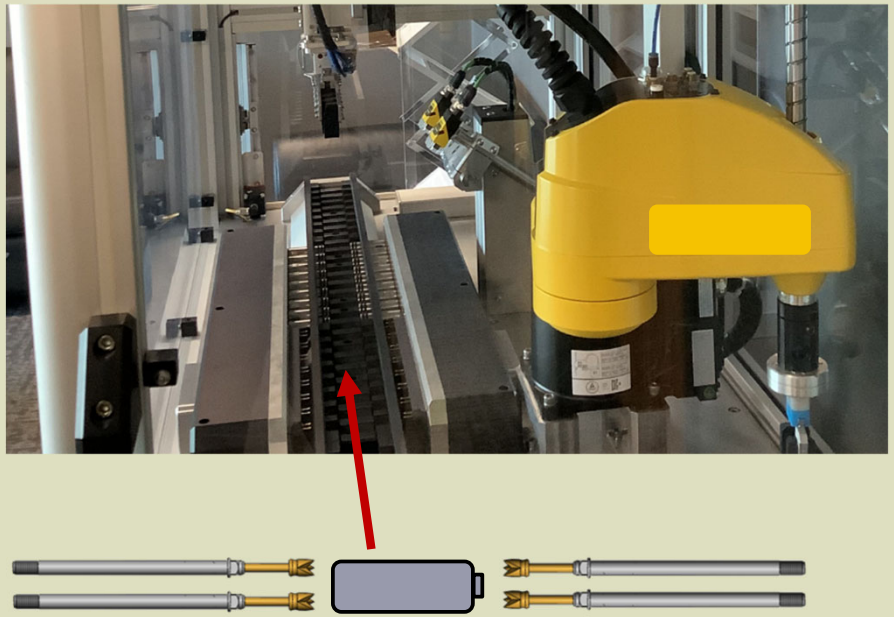
Electrochemical Impedance Spectroscopy (EIS)

This is a powerful, yet complex method to determine material and electrode characteristics. In the heart of the tester its still **spring probes** that need to make final contact with the cell.

- Generation of a sine current & voltage with variable frequency.
- The impedance spectrum is calculated from the change in current and voltage as well as the phase shift.
- With an EIS measurement system, a separate AC-IR measurement is no longer necessary.



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Application Range: Open Circuit Voltage (OCV)

- Quick test of the voltage of the battery
- To sort out faulty cells
- Conveyor based system
- “straightforward” application when it comes to the test probe choice, easier than impedance or formation

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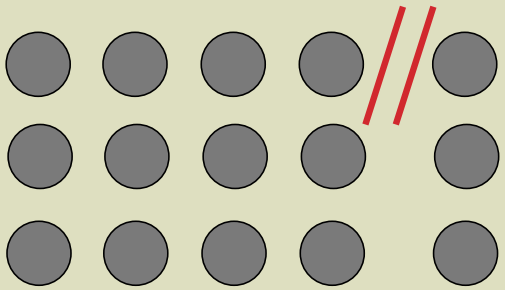
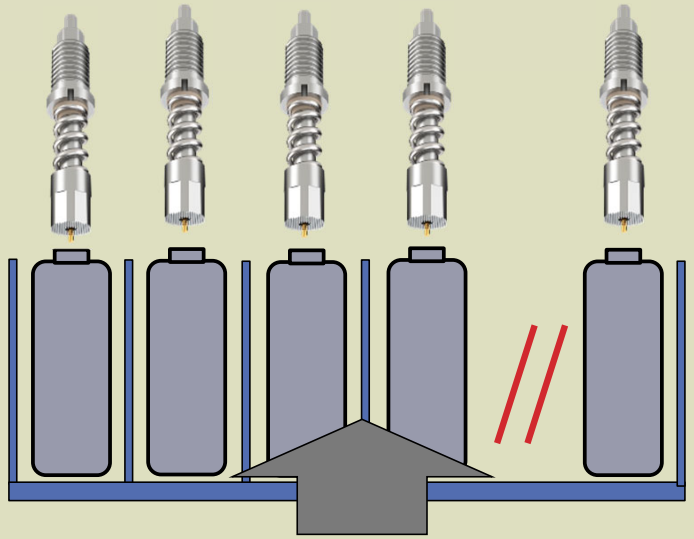
Application Range: Battery Cell Formation

- Activating the battery, initial charge, cycling
- Probes need to stay in tray for several years
- Long duration of the test → can contaminate probe tips
- Gold-plated tips work best for this test
- Rack-based systems with trays





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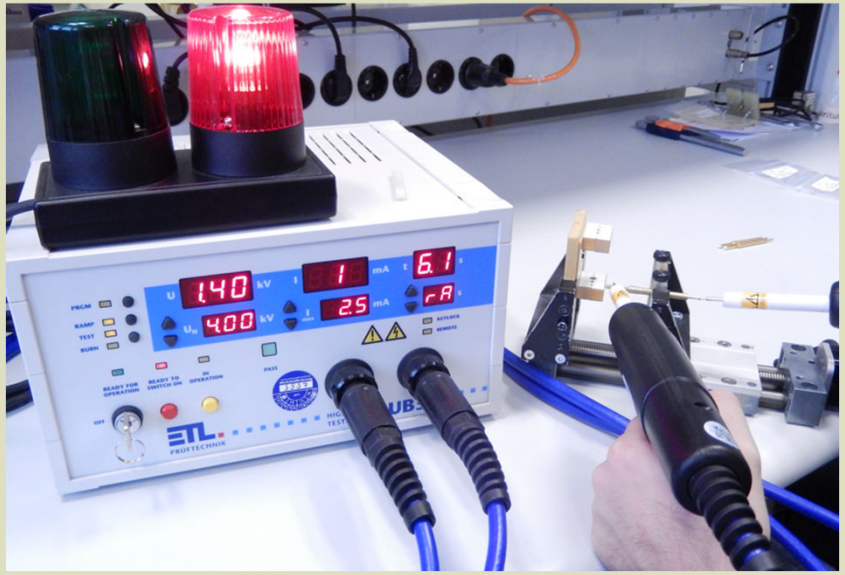
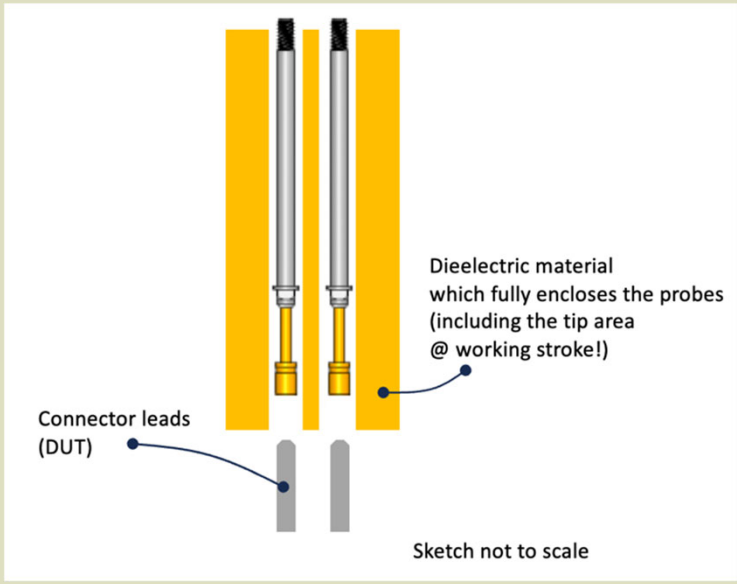
Application Range: Hi-Pot





- For battery cells: Checking dielectric withstanding voltage between anode and cathode
- Here, a coaxial probe itself is tested for hi-pot
- On the right side, techniques are shown to “encapsulate” the probe with additional dielectric material to increase the voltage handling capability between probes.

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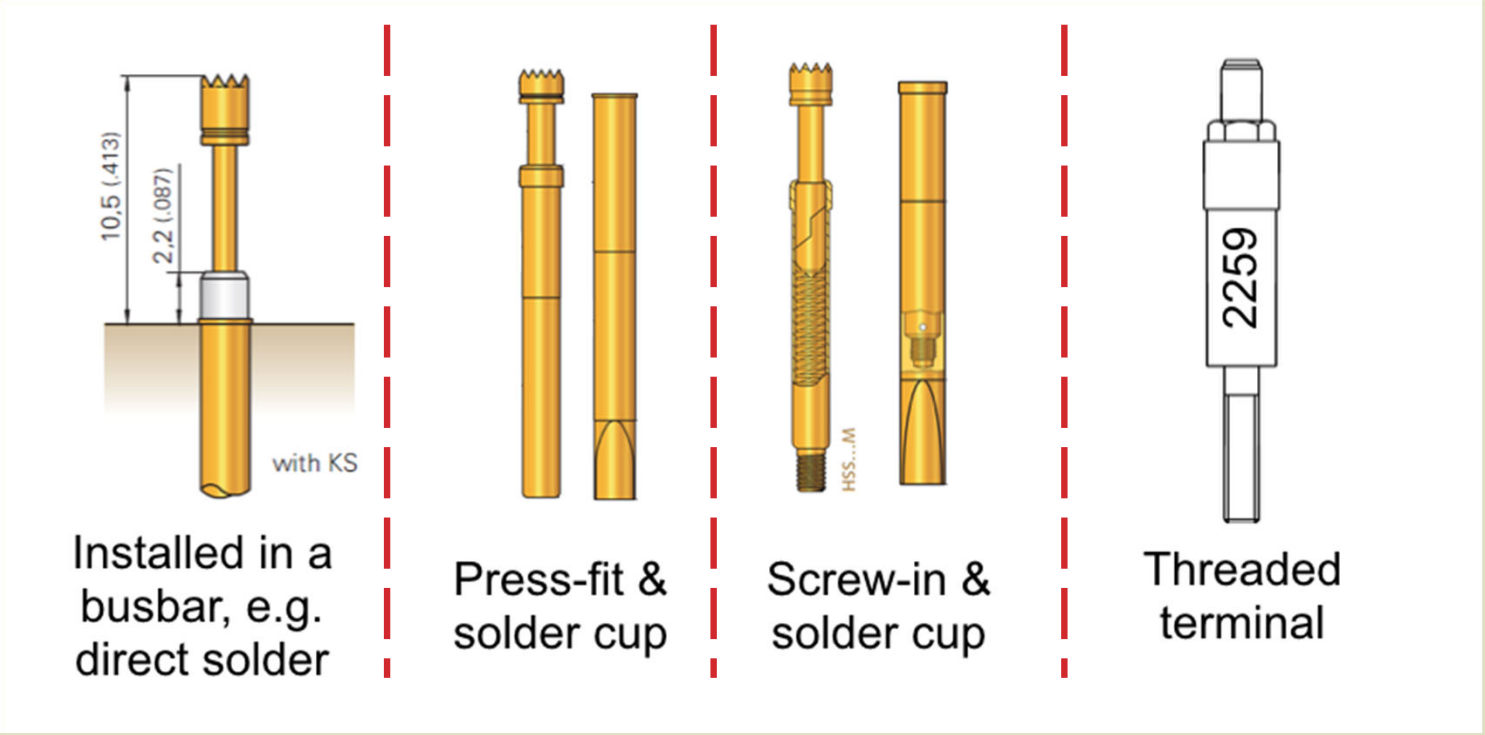
Mounting / Installation Methods



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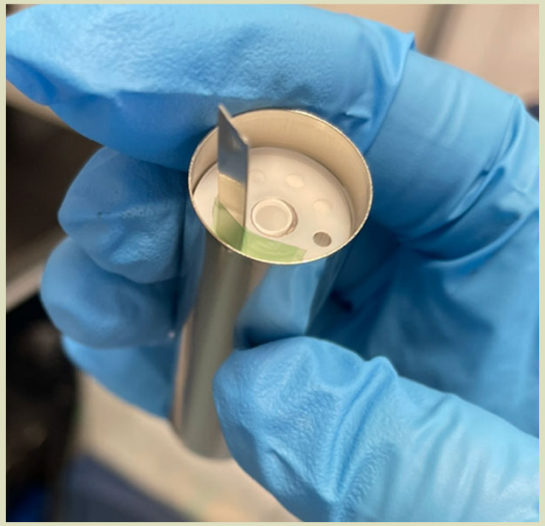
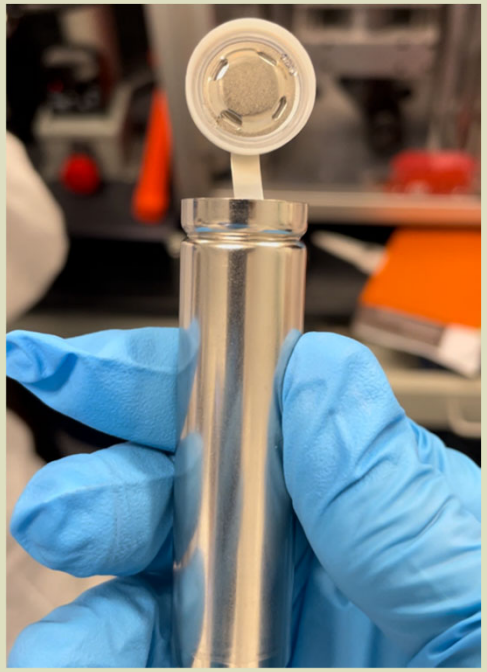
Battery Contacting: Round (Cylindrical) Cells





Left: Jelly roll, cylindrical, with tabs, separator and anode & cathode
Middle: Jelly roll placed in cylindrical can.
Right: Cap welded to tab. **Test Probes** now would be used to check for the integrity of the weld joint and to do a hi pot check between + and -

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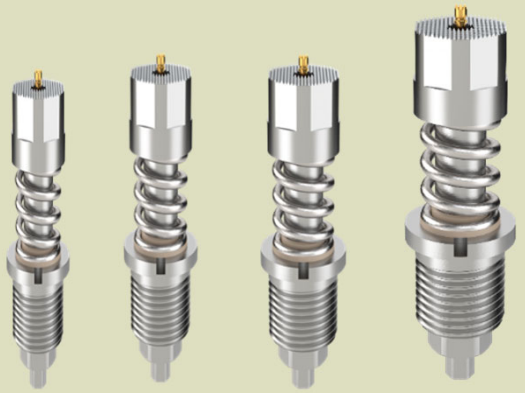
Battery Contacting: Prismatic Cells

- Heavy-duty probes needed that are capable of handling higher currents, for some applications in the 50 or 500 A range
- Voltage Sensing with AWG-20 Cable crimp: 11 A
- Scalable family



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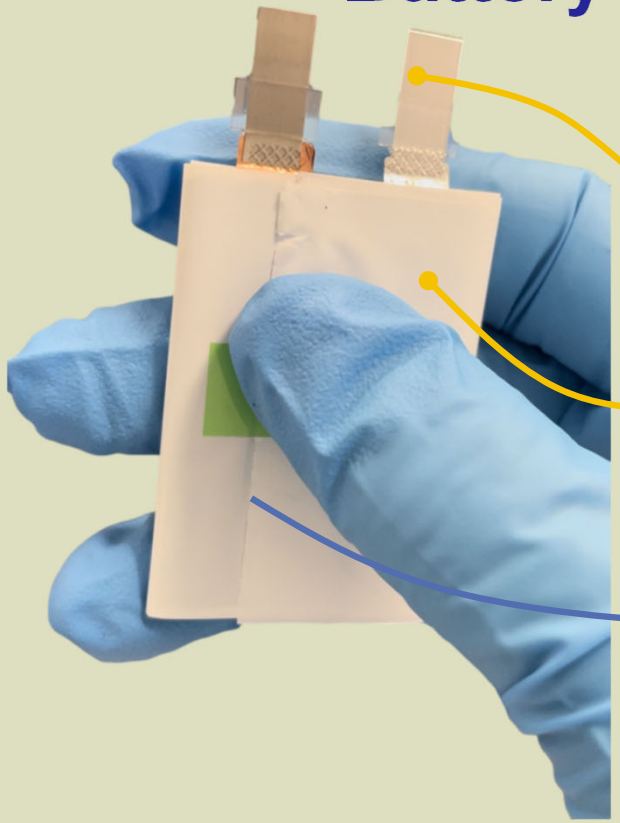
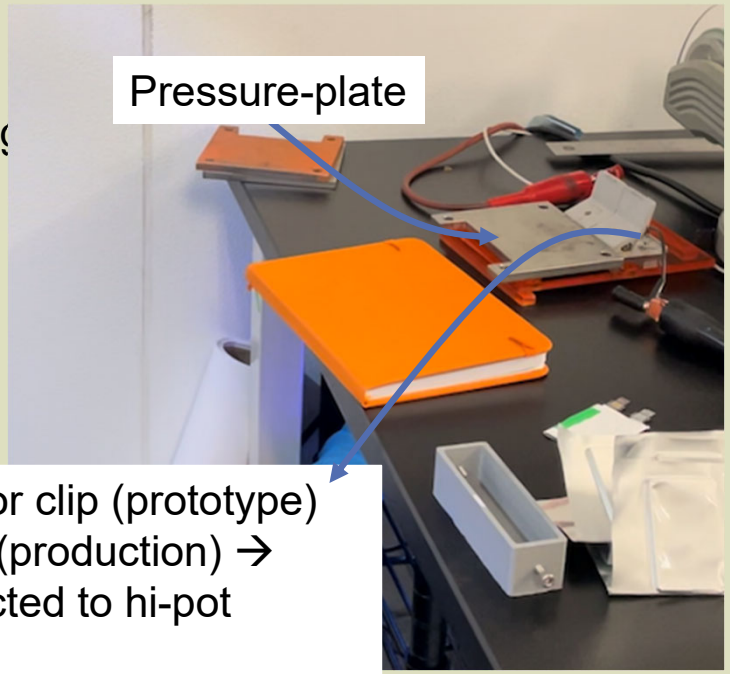
Battery Contacting: Pouch Cells



Tabs of the pouch (anode and cathode)

Flat jelly roll, zig-zag fold, with separator

Jelly roll, not in Pouch yet



Pressure-plate

Alligator clip (prototype)
Probe (production) → connected to hi-pot tester

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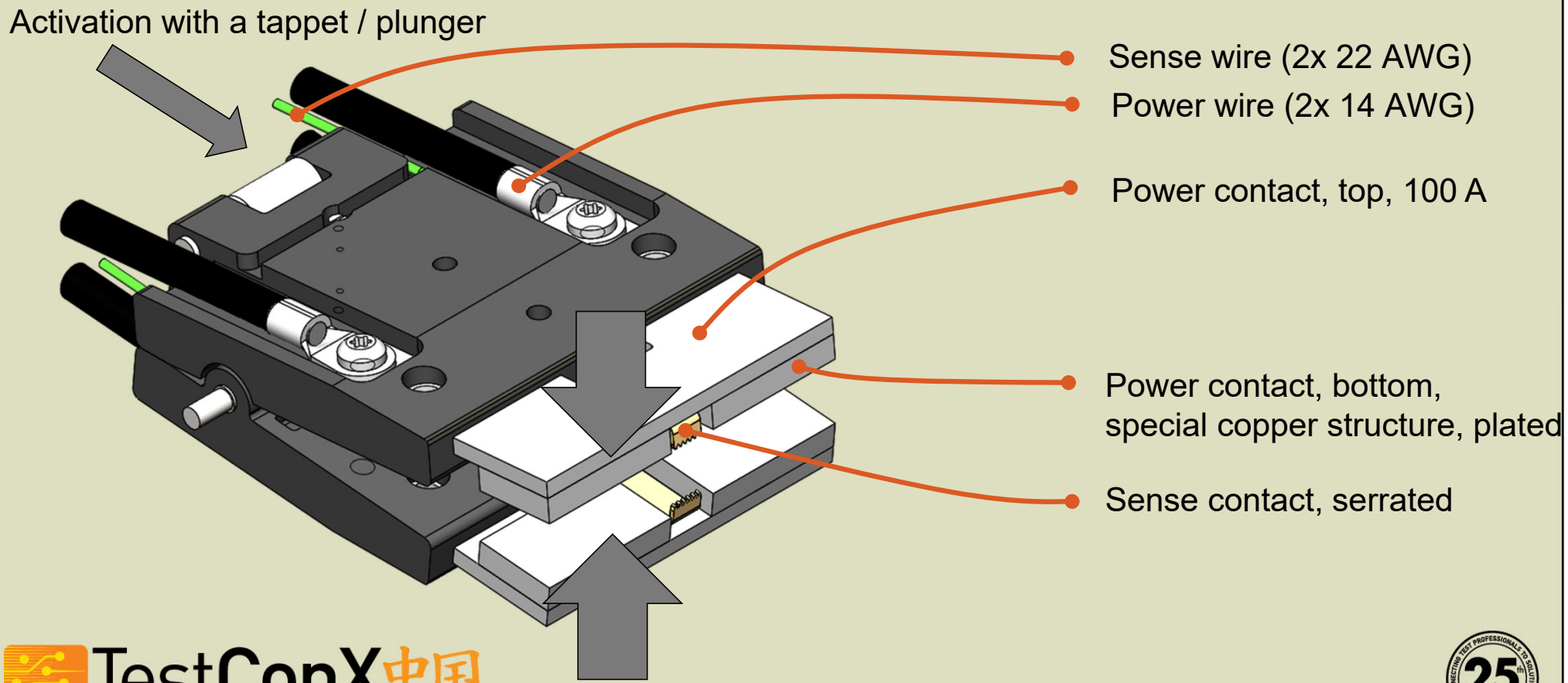
Battery Contacting: Pouch Cell with “Clip Probe”



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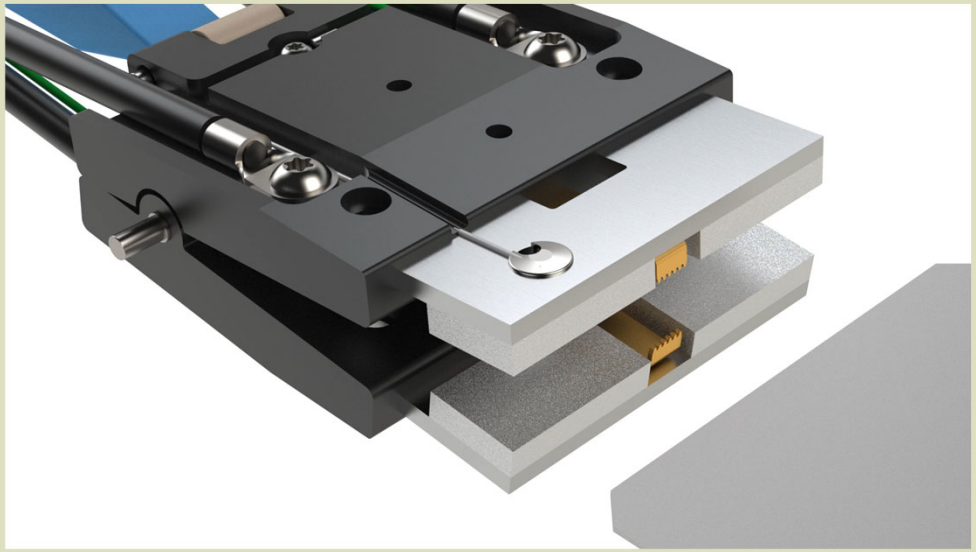
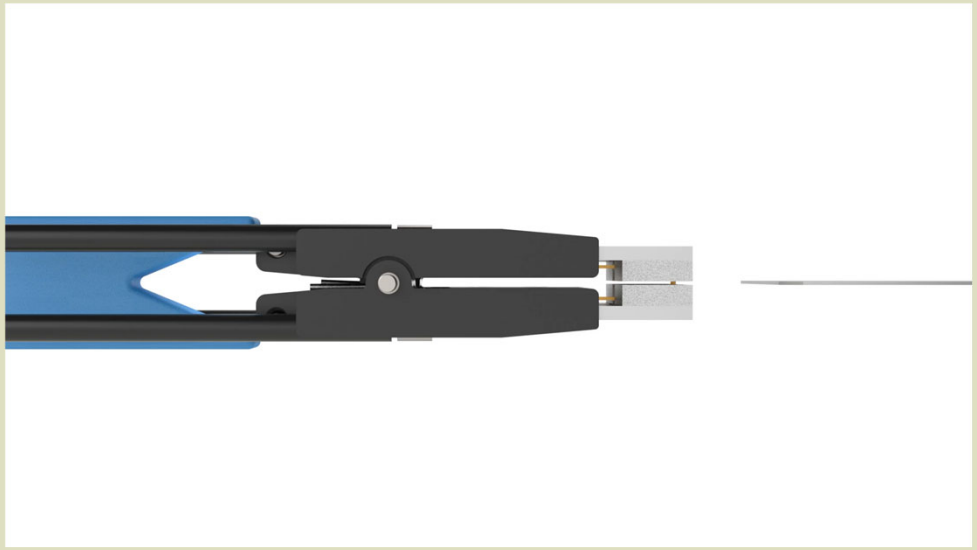
Battery Contacting: Pouch Cell Auto vs Manual





Axle mounting

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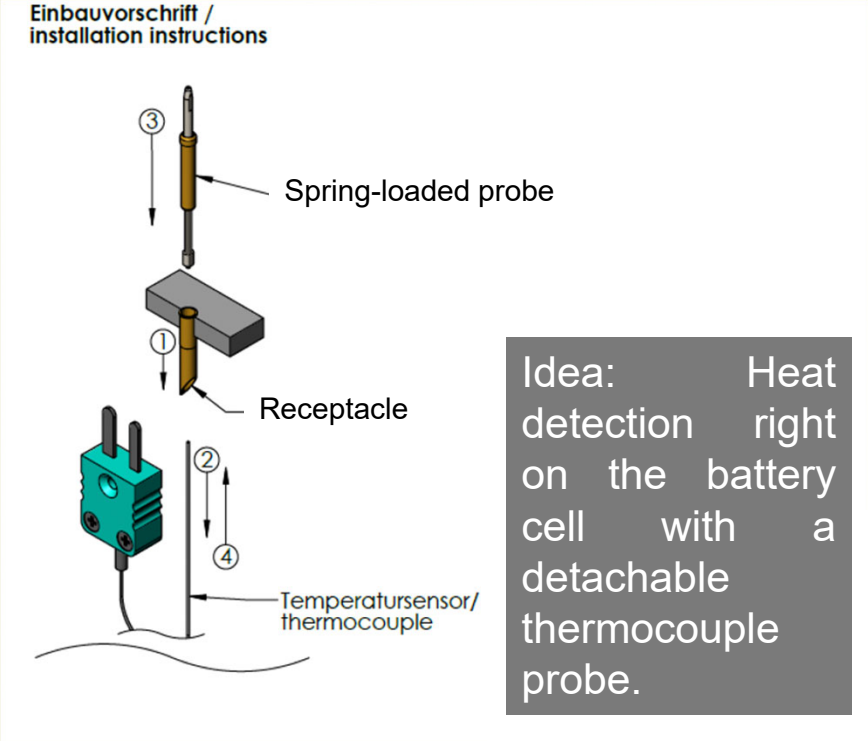
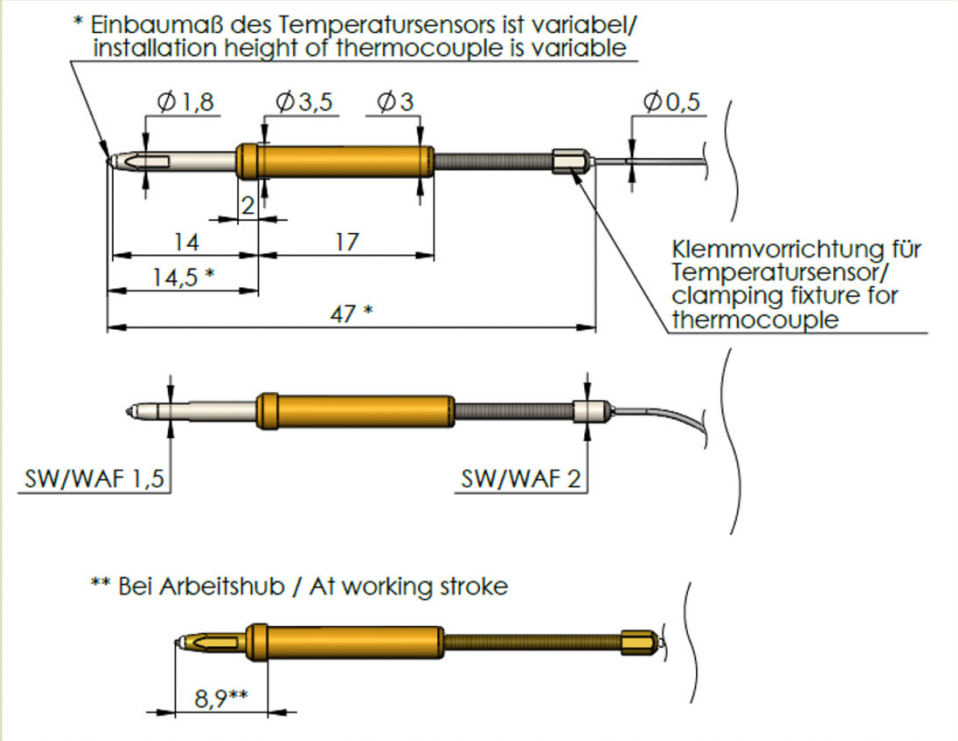
Temperature Measurement



Idea: Heat detection right on the battery cell with a detachable thermocouple probe.



Temperature Measurement

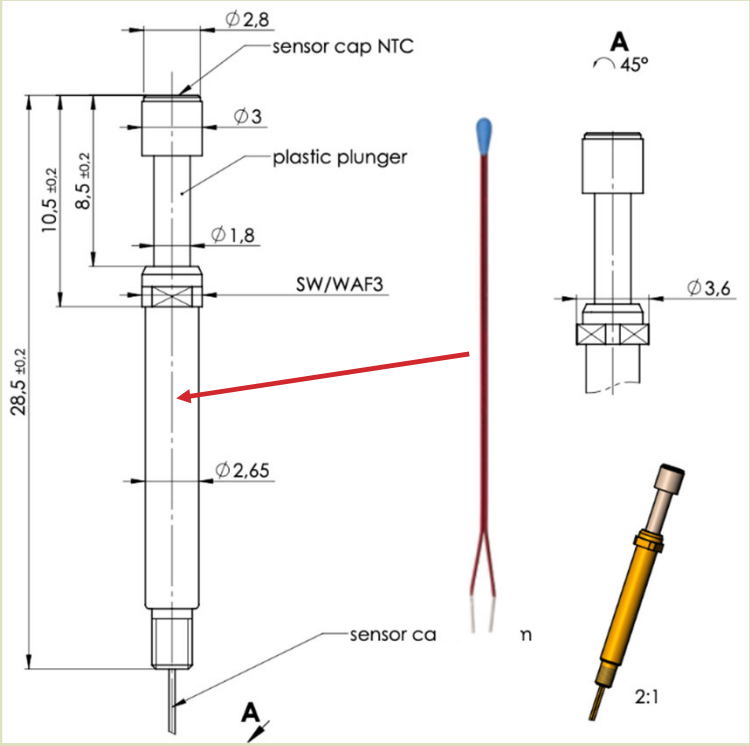
Different sensor types:

- K-type
- Pt100 type
- NTC (thermistor) based probe

Combination of thermal sensors inside the high-current probe block allow for detection of surface temperature.

Applications include:
- Early thermal runaway detection of the battery cell

- Detecting contact resistance changes through temperature change → necessitates probe cleaning or eventually probe replacement



Contacting of Connectors

Battery: Module / Pack

Electronics: BMS, Inverter etc.

Challenge:
- no witness mark requirement
- accessibility

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Contacting of Connectors: Round Connectors

Free-state. The insulating tip of the round-post HV/high current connector can be seen.

Unit slides over the round post connector. No scratching because the blades do not compress during insertion but only at working stroke.

Compressed blades can be seen. Connector is tested at this stage. Upon release the blades retract immediately.

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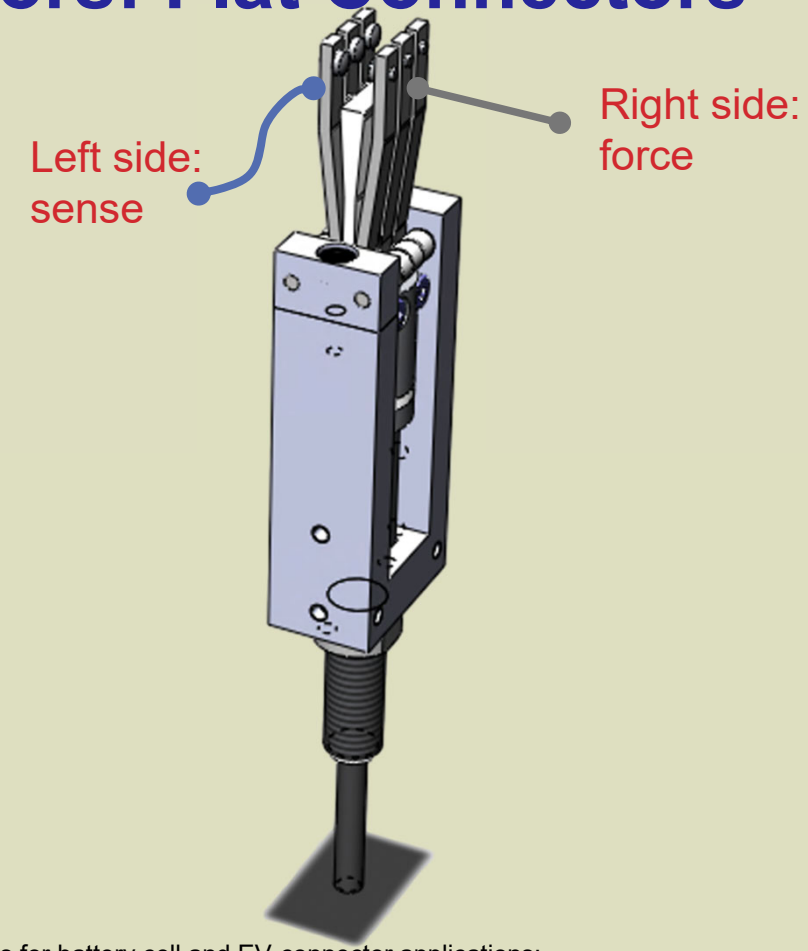
Contacting of Connectors: Flat Connectors

Specifications:

- For thicker spades ~2mm thickness x 16 mm width (.079”x .63”)
- max. thickness = 3mm / .12”
- Max. stroke 18mm / .7”
- Operating stroke 15mm / .59” @ .079” spade thickness
- Spring force at working stroke: 60 N / 216 oz-f
- CCC:
  - Force: 250 A
  - Sense: 100 A



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Contacting of Connectors: Flat Connectors

First photo: free state. Unit slides over the blade connector. No scratching because the blades are not fully compressed prior to working stroke conditions.

Second photo: Unit at working stroke. Connector is tested at this stage. Upon release the blades retract immediately.

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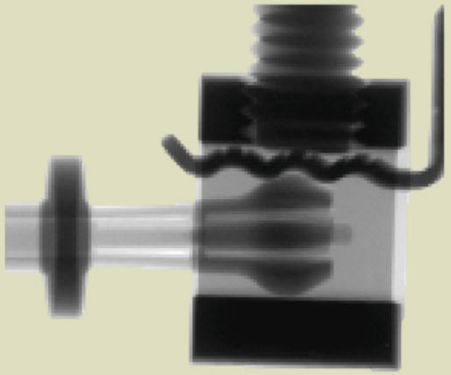
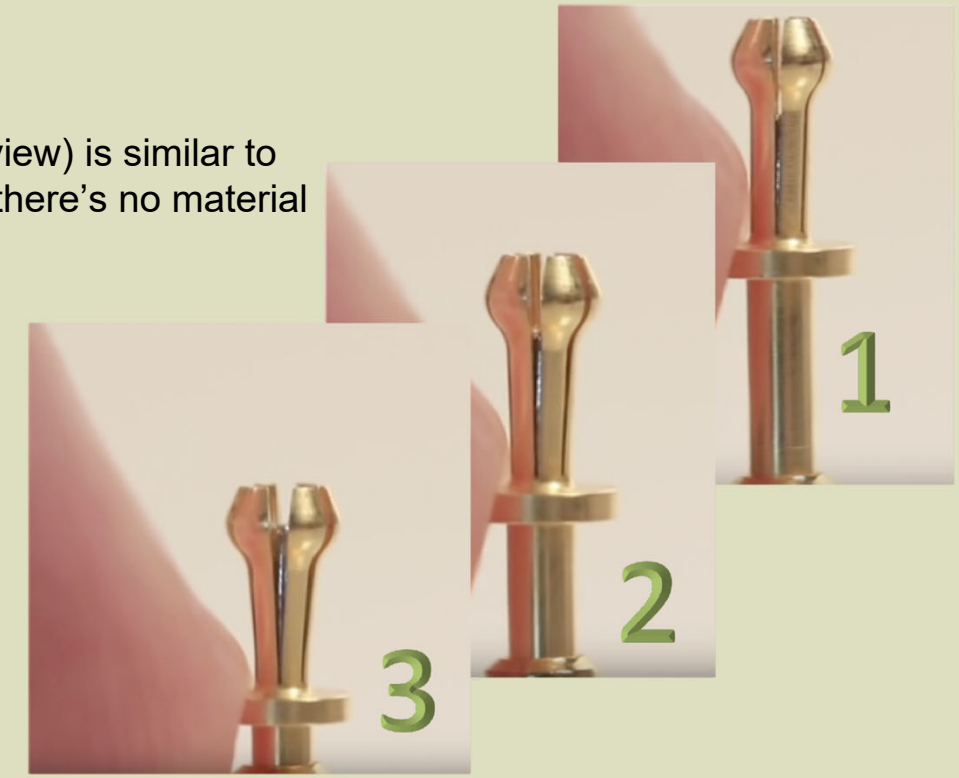
Working with Hard-to-Reach Connectors: Accessing with Splayed Tip Probes

- Also called “tulip-style”
- Probe tips expand upon compression
- The idea (from a mechanical point of view) is similar to the bifurcated probe design, however there’s no material displacement with this approach





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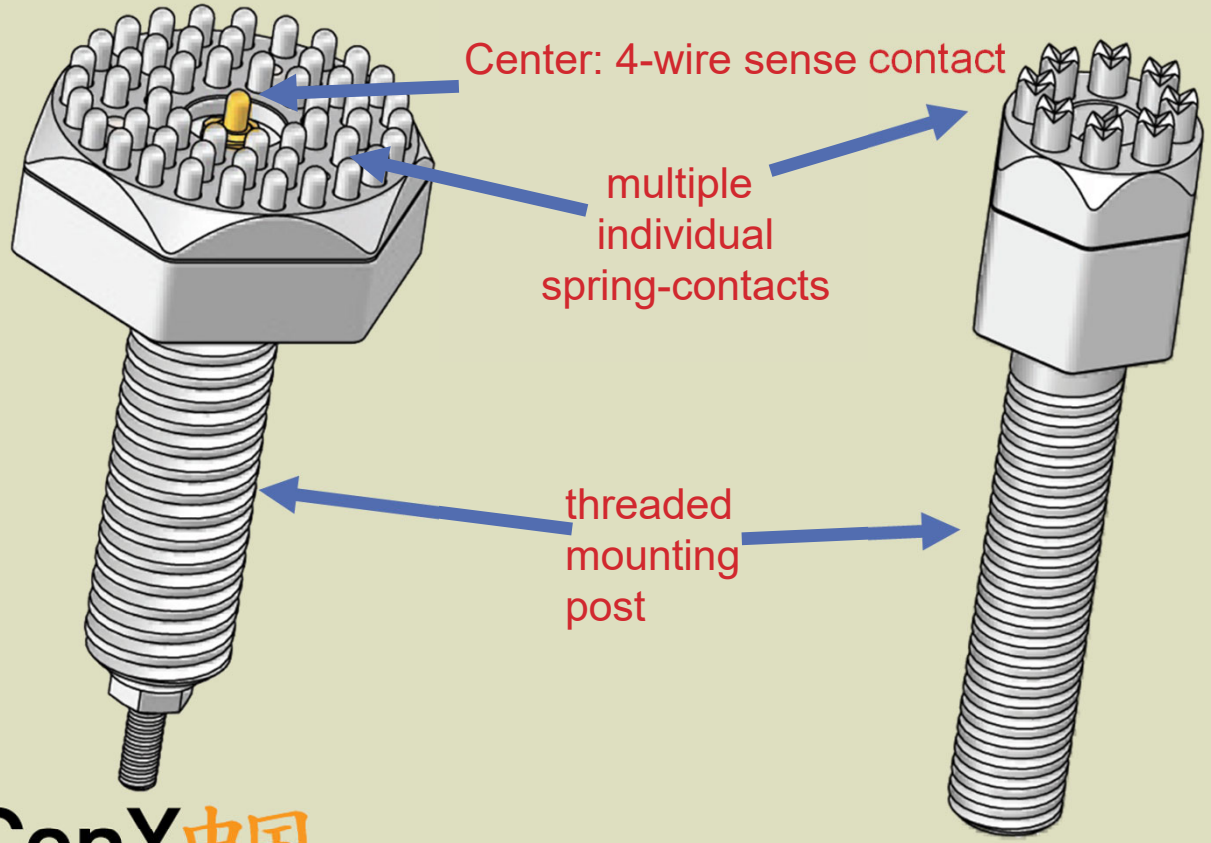
Contacting of Busbars with Multipoint ("Showerhead")- Probe Designs



Can be used for uneven surfaces

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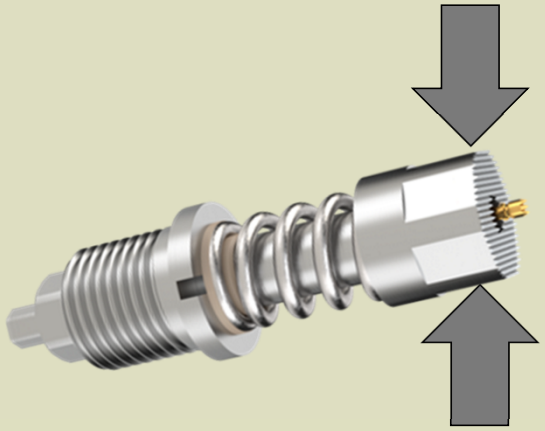
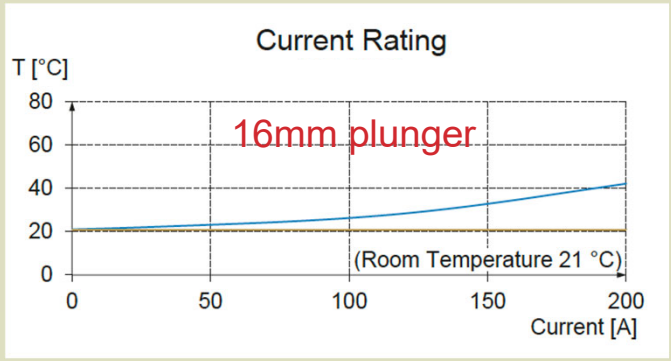
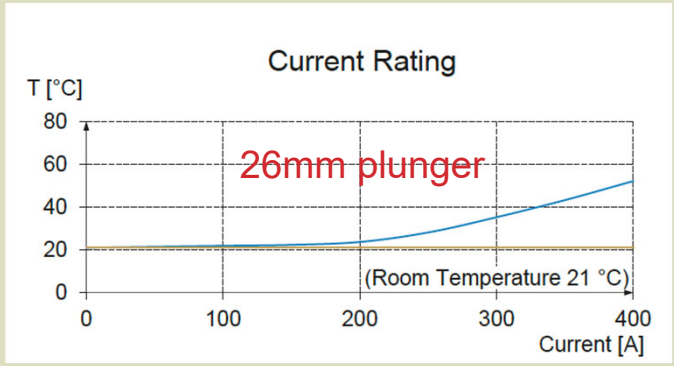
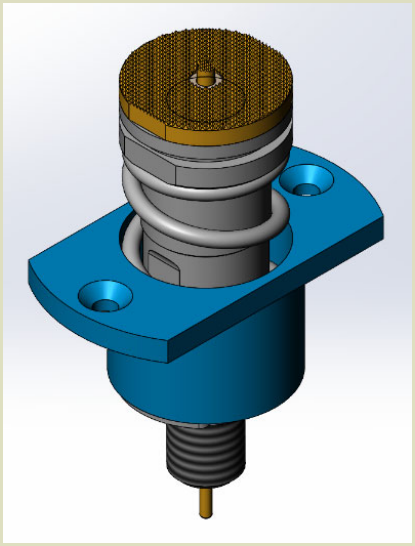
Lowering Probe Temperature with Larger Diameter Designs



18 mm and more to achieve lower temperature rise at higher currents







"Exposed spring"- design (common in in Asia)

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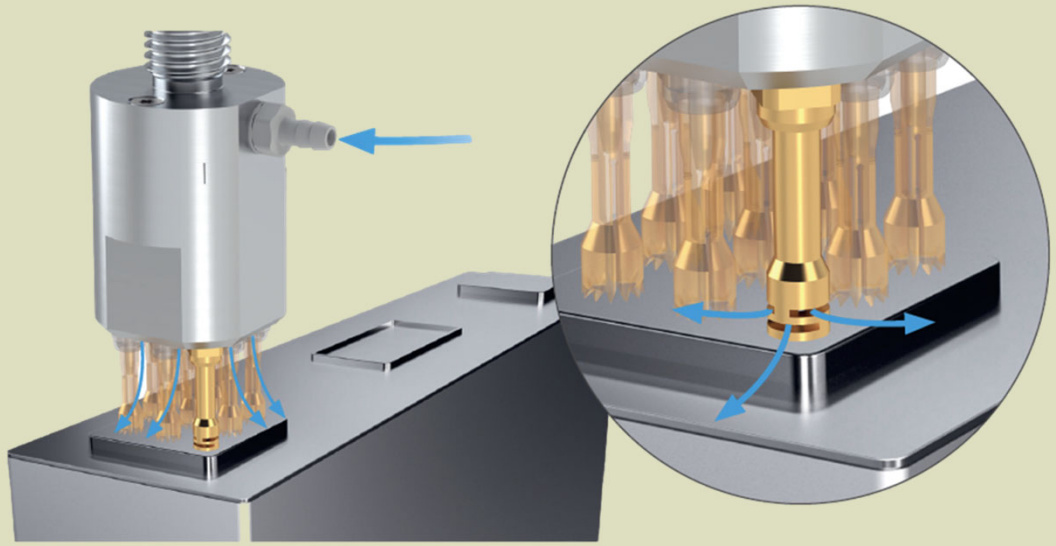
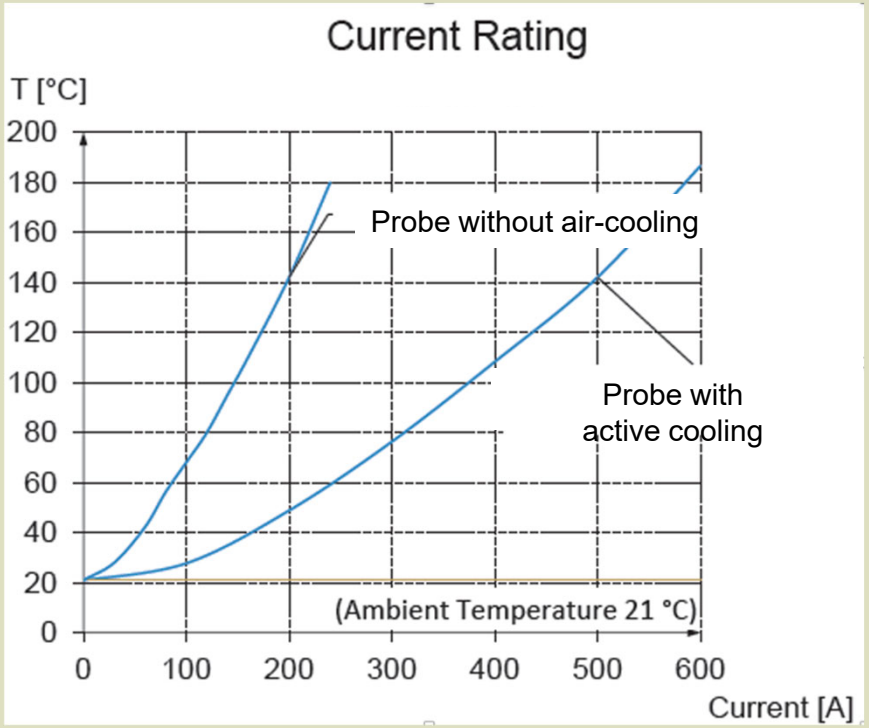
Lowering Probe Temperature with Forced-Air Cooling





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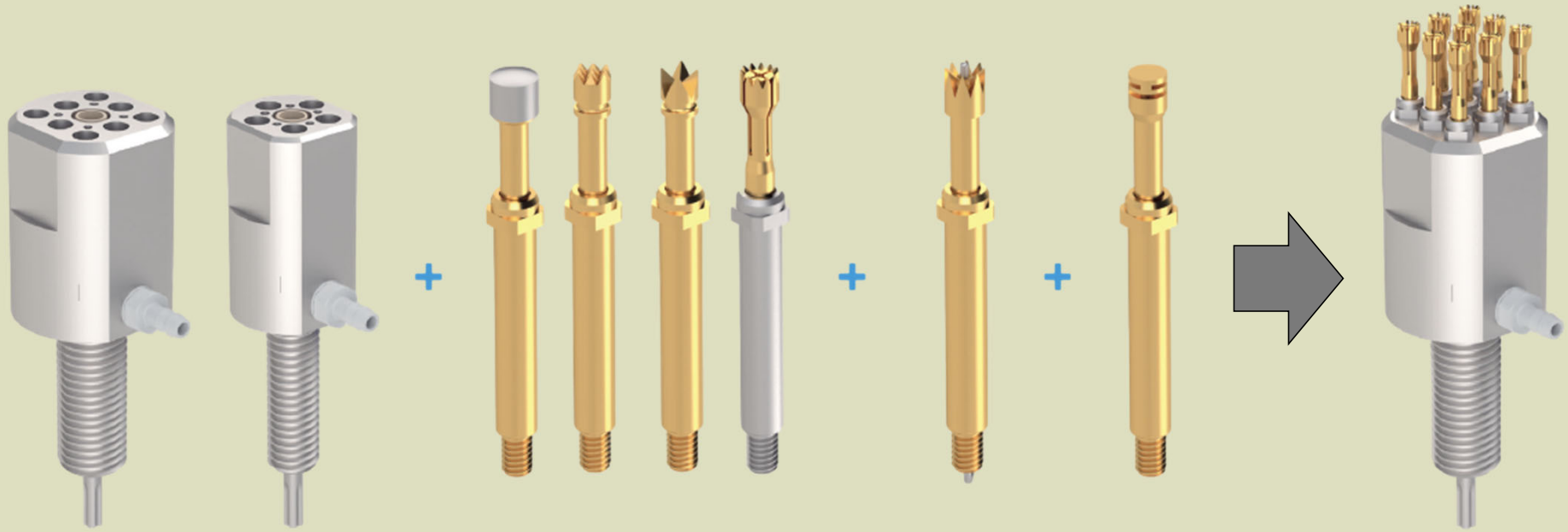
Combining Forced-Air, High-Current and Temperature-Sensing Probes in one Contacting Block



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Preventive Maintenance / Probe Tip Cleaning

3D-printed mock-up cell with eraser-type cleaning sheet, 4690 battery form factor, for use in tray

In-situ cleaning methods include the use of so-called “contact cleaning mats”.

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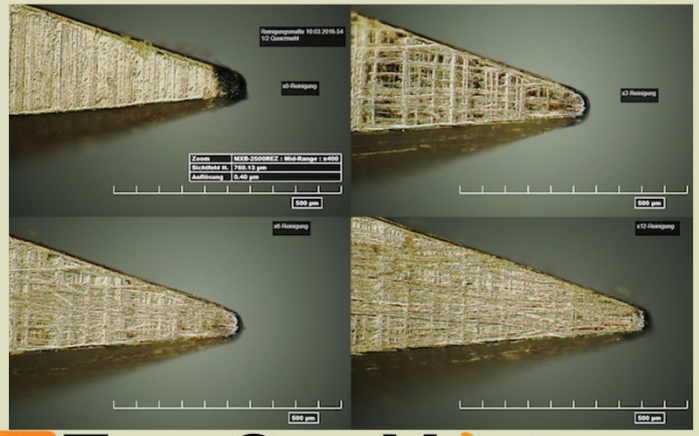
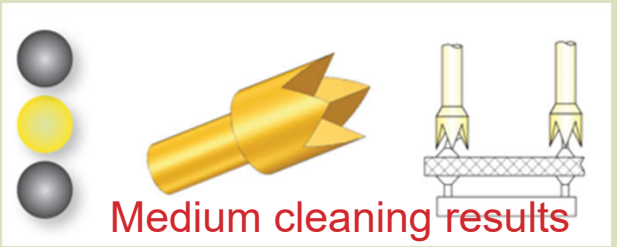
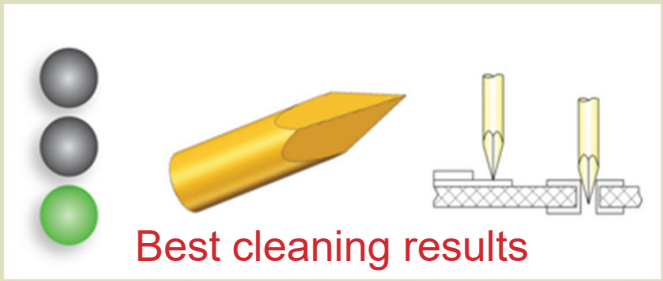
"Traffic Light"-System for Tip Styles vs. Cleaning Effectiveness

"Traffic light"-based system to show which tip styles work best for cleaning mats and which ones require other cleaning methods. Please note the results also vary based on the spring force, not only the actual tip style.







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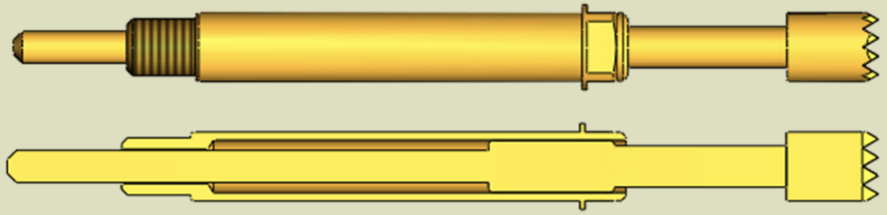
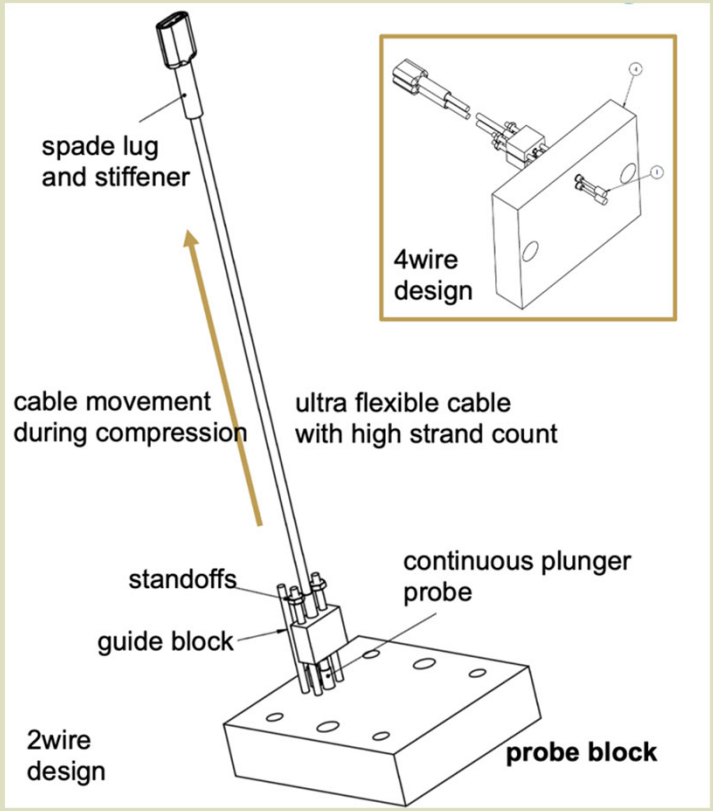
Extending Probe Life by Using Continuous Plunger Designs and Guide Blocks

- Continuous plunger probes carry the current through the plunger
- Cable moves in z-axis during compression
- Probe life can be in the several million cycles, depending on the probe architecture
- A guide block can help to avoid side-loads
- Side-load reduction can further extend probe life
- Ultra flexible cabling is required
- Suitable for both 2 wire and 4 wire measurements





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Conclusion / What we covered today…

- General introduction about PCBA test probes and which ones work well and what specific features are needed for battery cell / EV connector test
- We discussed different battery-related applications for use with spring-probes such as formation, open-circuit voltage test, hi pot and more
- Lastly, we covered how to cool probe blocks and how to extend probe life with different cleaning and installation methods (and how to keep the contact resistance low).

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