Advanced Techniques in Battery Cell Testing

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- **Job Title:**

System Line Manager Cell Test Systems

- **Education / work experience:**

Electrical Engineering and Business (TUGraz)

2017 – 2020	Samsung SDI Battery Systems Test Engineer
2021	Magna Steyr Fahrzeugtechnik Abuse Testing
2022	Samsung SDI Battery Systems Test Manager
2023 - present	AVL List GmbH System Line Manager


ITM

Challenges

Common questions we get from customers:

- My R&D isn't telling me, which cells they want to test in 5 years.
- What current range should I choose to be future proof?
- What cell format will be commonly used in future developments?
- What current accuracy is needed for battery cell testing?
- Is sub-millisecond really needed – for what would that be good?
- How many power channels per test chamber?
- EIS vs. DCIR vs. ACIR – what do I use when?
- What benefit results from having EIS in every channel vs. the classical approach with a standalone spectrometer?
- For what reason should I equip my test system with direct cooling?

Test Scenarios
R&D vs. Endurance

R&D-Testing

- What is R&D testing? (also called performance testing)
  - R&D testing is about determining the performance of the battery cell under all situations.
  - Special measurements like swelling
  - Generate digital twin of unit under test

- Why R&D testing required?
  - Input data for BMS
  - Specifications for pack development
  - Upfront simulation

R&D-Testing

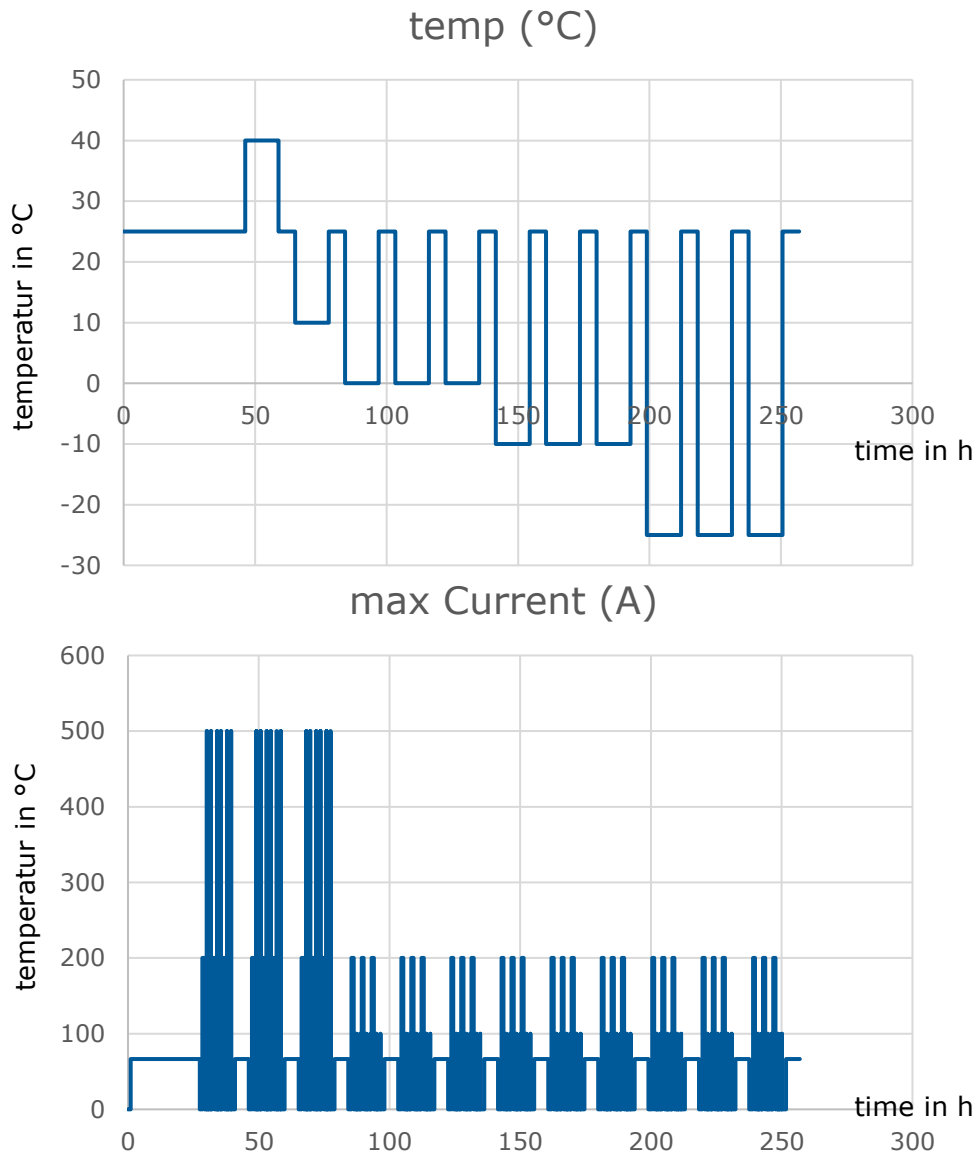
- What is required to execute R&D tests?
  - Higher accuracy
  - Fast setpoint frequency
  - Additional Measurements
    - EIS (Electrochemical impedance spectroscopy)
    - Additional temperature measurement
    - force and distance measurement

R&D vs. Endurance

- What is meant by **Endurance** Testing? (max. 1C)
  - Calendric Ageing
  - Life Cycling
  - CoP (Conformity of Production)
  - Ingoing quality control
  - End of Life Testing (with / without Fast-Charging)

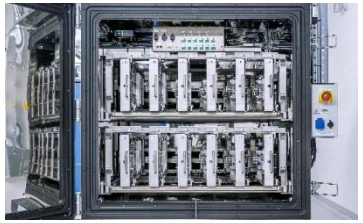
- What is meant by **R&D** Testing? (>3C)
  - Reference Parameter Test
  - OCV Characterisation Test
  - High Precision Coulometry (HPC)
  - Fast Charging Profiles / Methods
  - High Utilisation (space, time, energy)

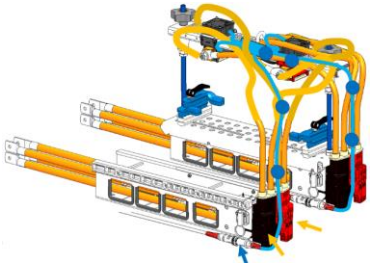
Example: Pulse test



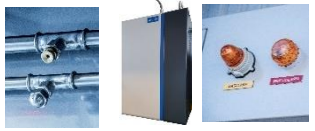
AVL Battery Cell Testsystem Components

ECO-line | Performance





Safety Systems

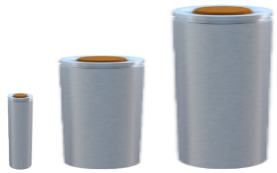


Automation	Battery Cell Tester	Climatic Chamber	Measurement	Cell Carrier	Safety System
Up to 64 channels/chamber Up to 1 kHz control and logging frequency	Voltage up to 9 V Current low range 2 – 5 A Current mid range 10 – 40 A Current high range 250 – 2400 A	Temperature range -40 °C to 90 °C Humidity control (optional) Volume 0,8 / 1 / 1,5 / 2 m³	Measurement of: Temperature (TypK/PT100/PT1000), Voltage, Pressure, Distance	Cell types: Cylindrical cell, prismatic cell, pouch cell preload, pressure and temperature sensors	Gas sampling unit Pressure relief Compressed air flushing Inertization Fire suppression

Battery Cycler Type Decision

Battery Cell Types

Cylindrical



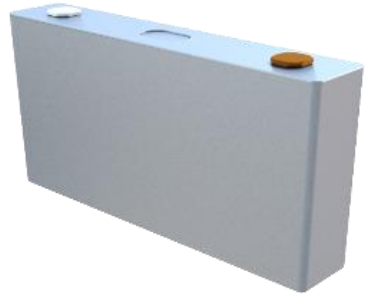
18650, 21700 46xx

<5Ah	25-37Ah
Endurance	Endurance
	R&D

Pouch

<5Ah Single Layer	<20Ah Multi Layer	<100Ah
R&D	R&D	Endurance
		R&D

Prismatic



40-320Ah
Endurance
R&D

AVL Battery Cell Cycler Portfolio

ECOline

- 12A, 50A, 100A, 300A, 600A
- Air-cooled
- Current accuracy 12A/50A: 0,05% FS
- Current accuracy 100A, 300A, 600A: 0,02% FS
- Measurement frequency: 100Hz
- Efficiency 75%
- Rise time 5ms
- max. 2x parallel

Performance

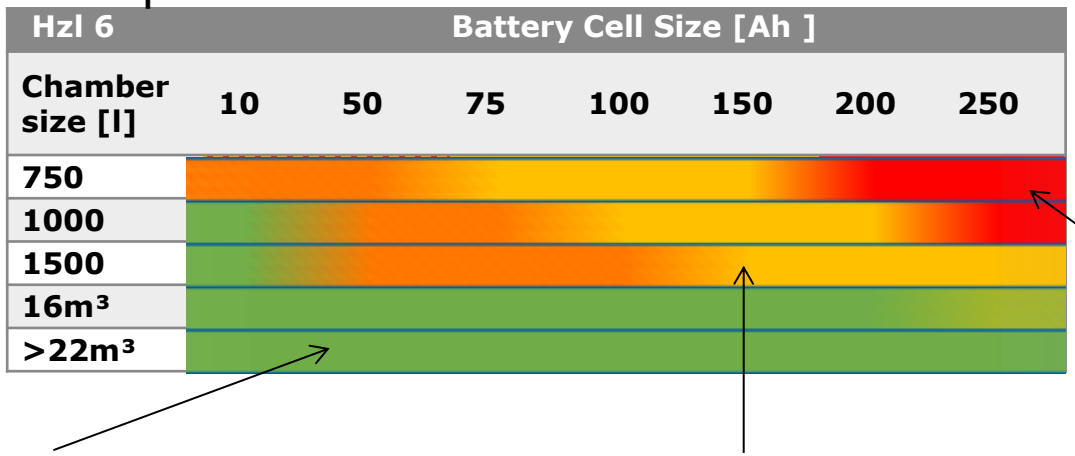
- 300A, 600A
- Water-cooled
- Current accuracy: 0,01% AV
- Measurement frequency: 1kHz
- Efficiency 88%
- Rise time 0,5ms
- EIS on every channel
- max. 4x parallel

Safety

Safety Concept based on AVL Safety Evaluation

Matrix is based on explosive gas release amount, release behavior/curve and volume of test chamber.
Target: Remain always below 50 % LEL

Example Decision Matrix:



Hzl 6	Battery Cell Size [Ah]						
Chamber size [l]	**10**	**50**	**75**	**100**	**150**	**200**	**250**
750							
1000							
1500							
16m³							
>22m³							

Unlikely to reach explosive atmosphere due to total venting
→ **"compressed air flushing"**

Possibility to detect explosive atmosphere with first venting detection an provide a counter measure
→ **"event triggered inertization"**

Fast formation of explosive atmosphere. No possibility to react with counter measures in suitable time
→ **"permanent inertization"**

Note:
The decision matrix in dependency of battery cell capacity is representative for the safety relevant boundary conditions like gas release rate, gas release amounts, etc.
The clustering of battery cell capacity is not generally valid and only applicable, if the battery cell show the same safety boundary conditions as assumed within this presentation.
The indent use of a battery cell climatic chamber will never refer to a dedicate cell power, only to safety related boundary conditions like gas release rates, gas release amount, etc..

Internal Resistance

DCIR and ACIR

Direct Current Internal Resistance

- Measurement possible during testing
- Constant current in charge/discharge direction

Result:

- Internal resistance at one specific setpoint
- Real-world performance

Challenge:

- Non-linear behaviour of resistance: measurement only at one setpoint
- Polarisation effects: DC pulse can induce electrochemical polarization within the battery
- SOC drift

Alternating Current Internal Resistance

- Internal resistance measurement at 1kHz
- Fast incoming inspection

Result:

- Internal resistance at one specific setpoint
- Rough proxy of state of health

Challenge:

- Normally additional measurement equipment required
- Special layout of the power and sense cables

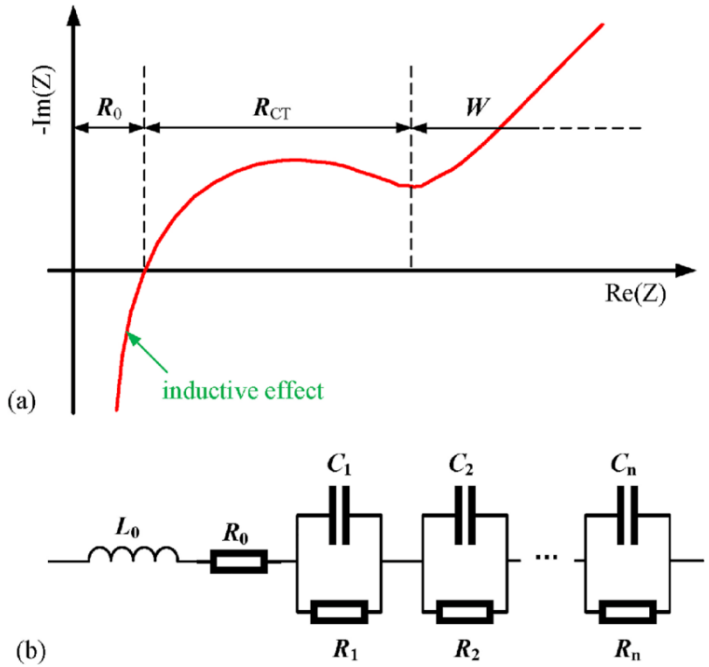
EIS

Electrochemical Impedance Spectroscopy (EIS)
small signal AC current or voltage stimulus (potentiostat/galvanostat instrument) from mHz to kHz

Result:
- Higher detailed health state of the battery cell
- Extended information about internal cell damage/aging
- Equivalent circuit can be created for simulation model

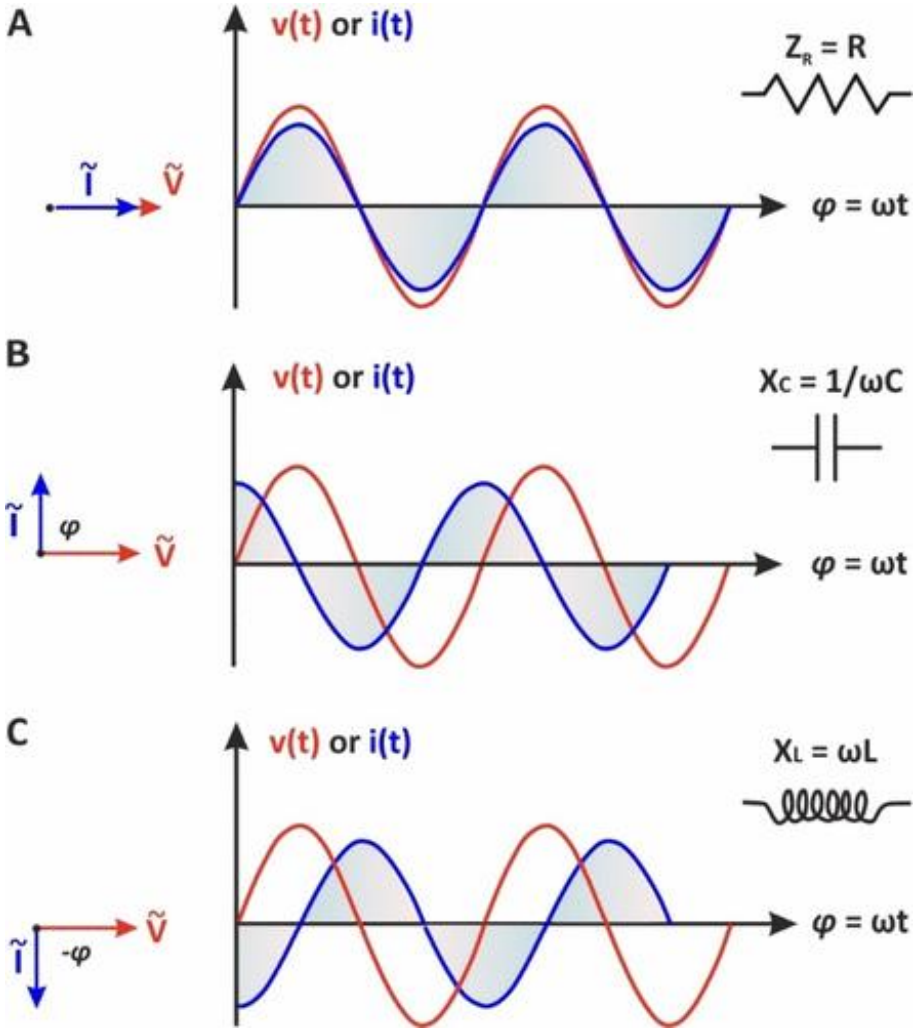
Challenge:
- Longer measurement time (low frequency)
- Normally additional measurement equipment required
- Special layout of the power and sense cables

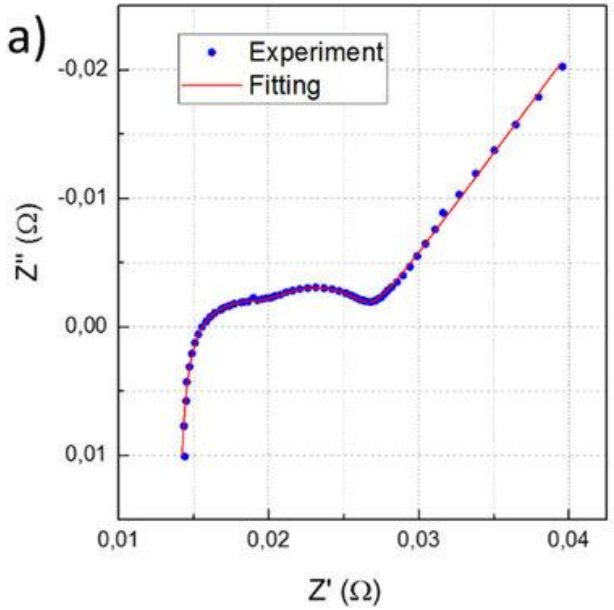
Nyquist plot

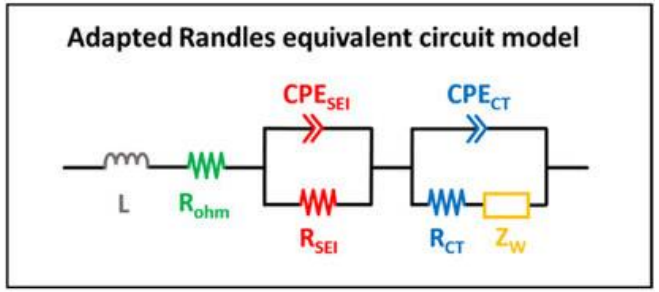


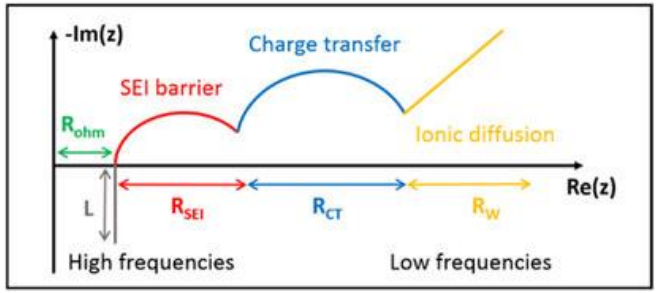
https://www.researchgate.net/figure/a-A-typical-EIS-measurement-of-the-LIB-presented-in-the-Nyquist-plot-b-Corresponded_fig1_360146667

Time Domain Measurement







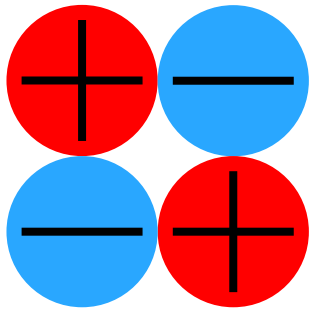


https://www.researchgate.net/figure/a-A-typical-EIS-Nyquist-plot-of-the-cell-at-23-C-and-curve-fitting-using-an-Adapted_fig3_346417102

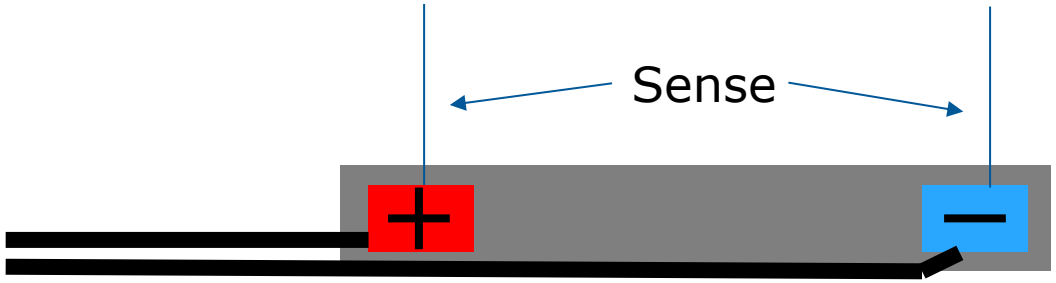
https://pubs.acs.org/doi/10.1021/acsmeasuresciau.2c00070

Power Cable Arrangement

- Keep cables short as possible
- Low inductance of power cables



- Power and Sense 90°C layout



Thermal Stability

Thermal Stability

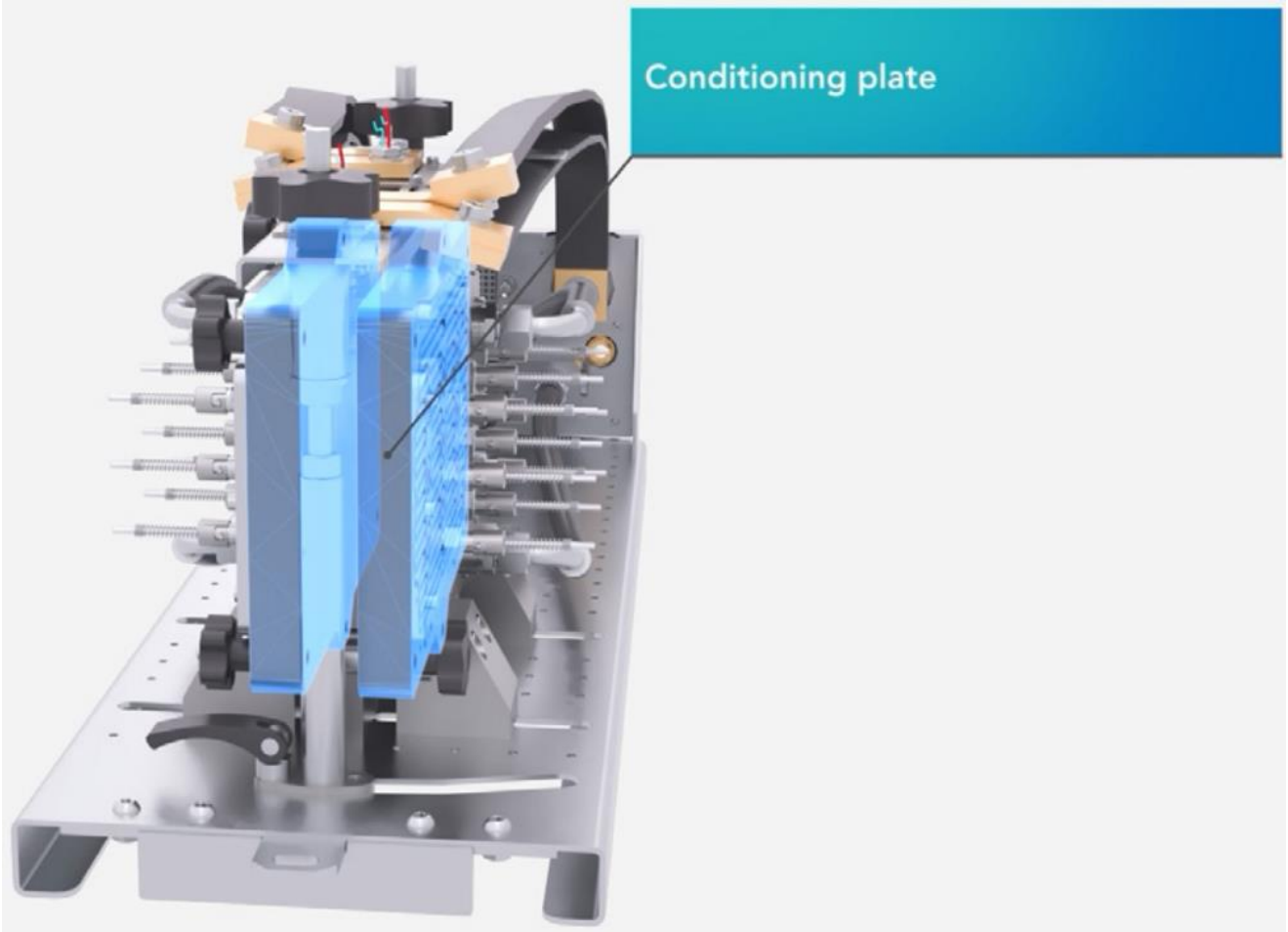
Why is Battery Cell heating up?

Internal resistance

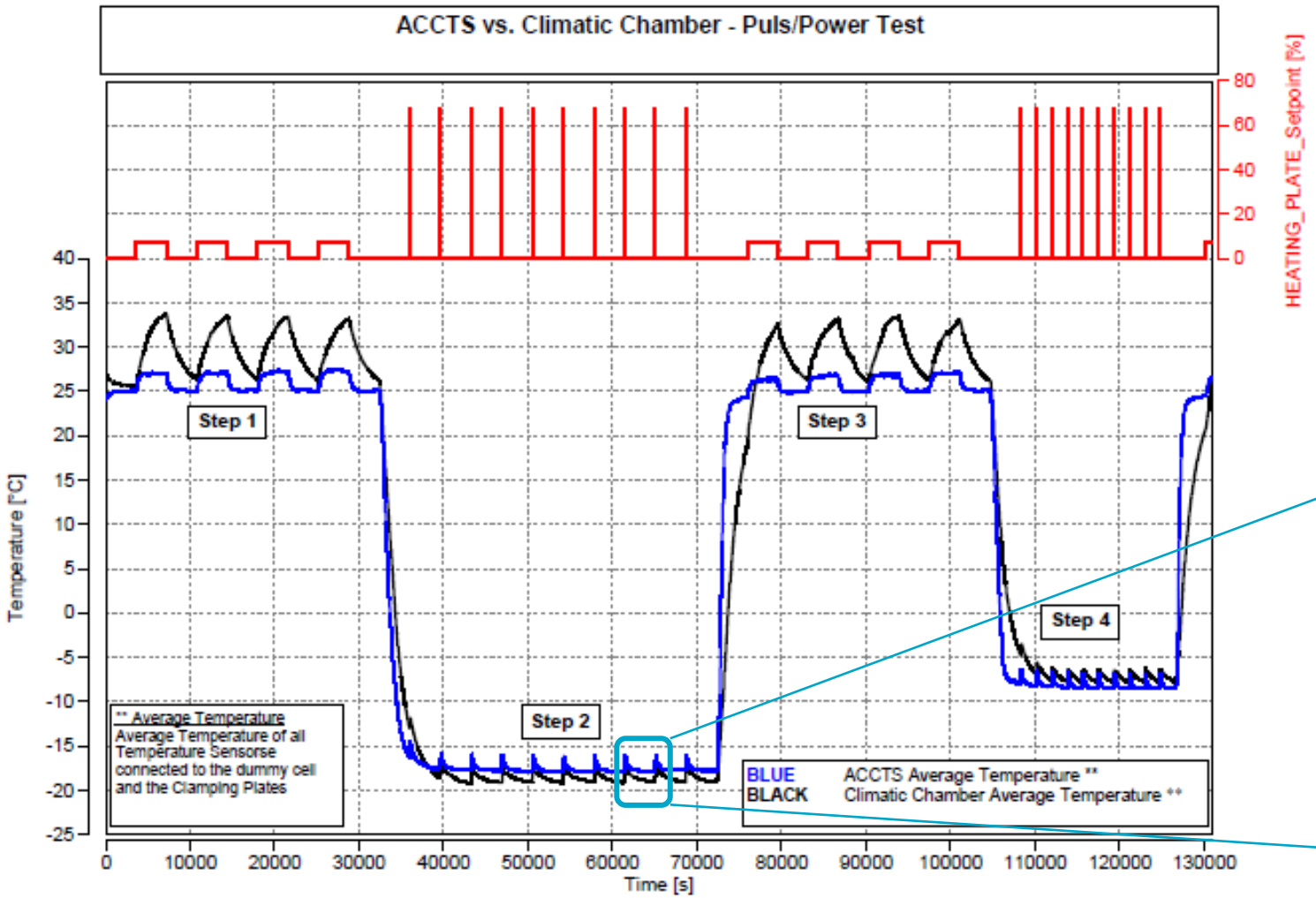
Why keep Battery Cell at Temperature Setpoint?

Exact measurements:

- Capacity
- DCIR

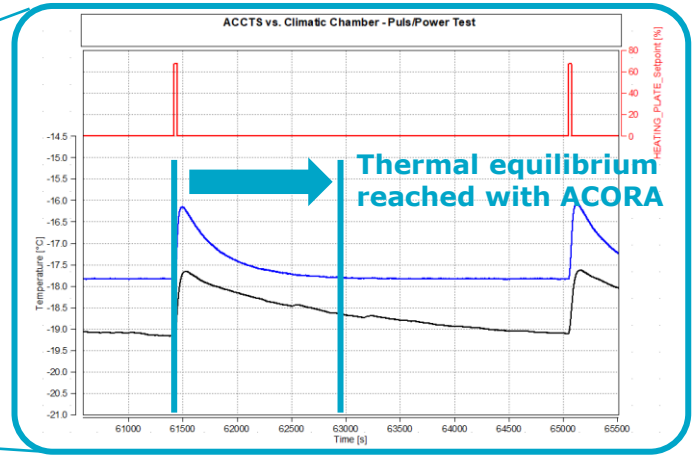


Test Results



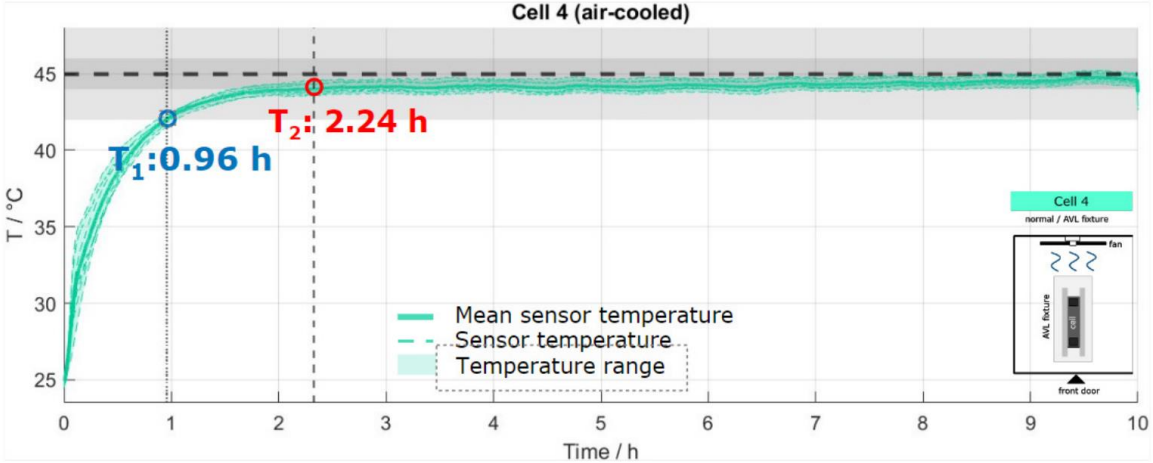
ACORA advantage

- Faster temp stabilisation and testing time reduction by up to 60%
- High repeatability, independent of testing position
- Reduction of energy consumption

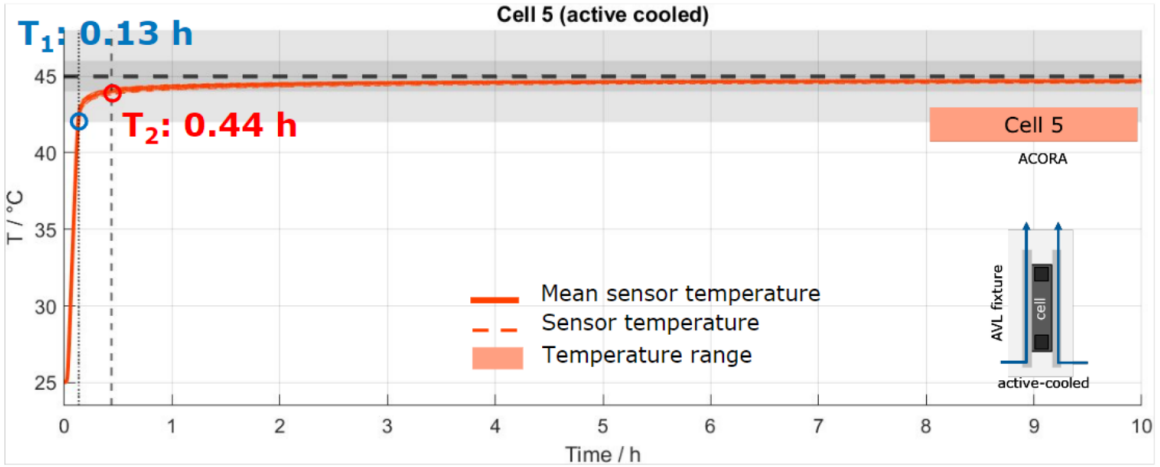


Note: data is only provided as indication and do not consist a guaranteed technical performance specification

University of Bayreuth – Test Results



Example result for air-cooled



Example result for active-cooled

Summary

Challenges

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Thank you

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