



synthesites



Your partner in
process monitoring
and control



Intelligent Process Monitoring and Online Quality Control for Advanced Composites Manufacturing

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May 2017



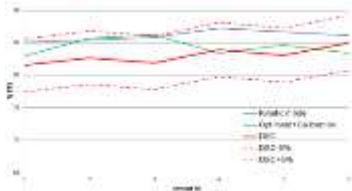
optimold system for monitoring resin cure, resin viscosity, mixing ratio quality and resin quality



optiflow system for optimising mould filling, process automation and simple process control



Sensors (durable/ disposable, flexible, gate, custom)



Real-time calculation of T_g / degree of cure/ viscosity/ resin quality



Automation, design and prototyping solutions

Companies



R&D Centres and Universities



On-going

Recotrans: Multimaterial recyclable manufacturing for the transportation industry (2017-2020)
Partners: Aimplas (CO), Fraunhofer, Daimler, Far UK, Stadler, INEA, Istanbul University, Arkema
RTM and pultrusion, Glass fibre, reactive thermoplastic and polyester
Automotive and rail applications

Completed

Ecomise: First-time right composites manufacturing (2013-2016)
Partners: DLR (CO), Faser I., Bombardier, Hutchinson, Airborne, Loop, Dassault Systemes, NLR
RTM and RTI, Glass and carbon fibre, epoxy

Coaline: Injection pultrusion with microwave curing and injection of coatings (2013-2017)
Fraunhofer ICT, Aimplas, Resoltech, Rescoll, Acciona

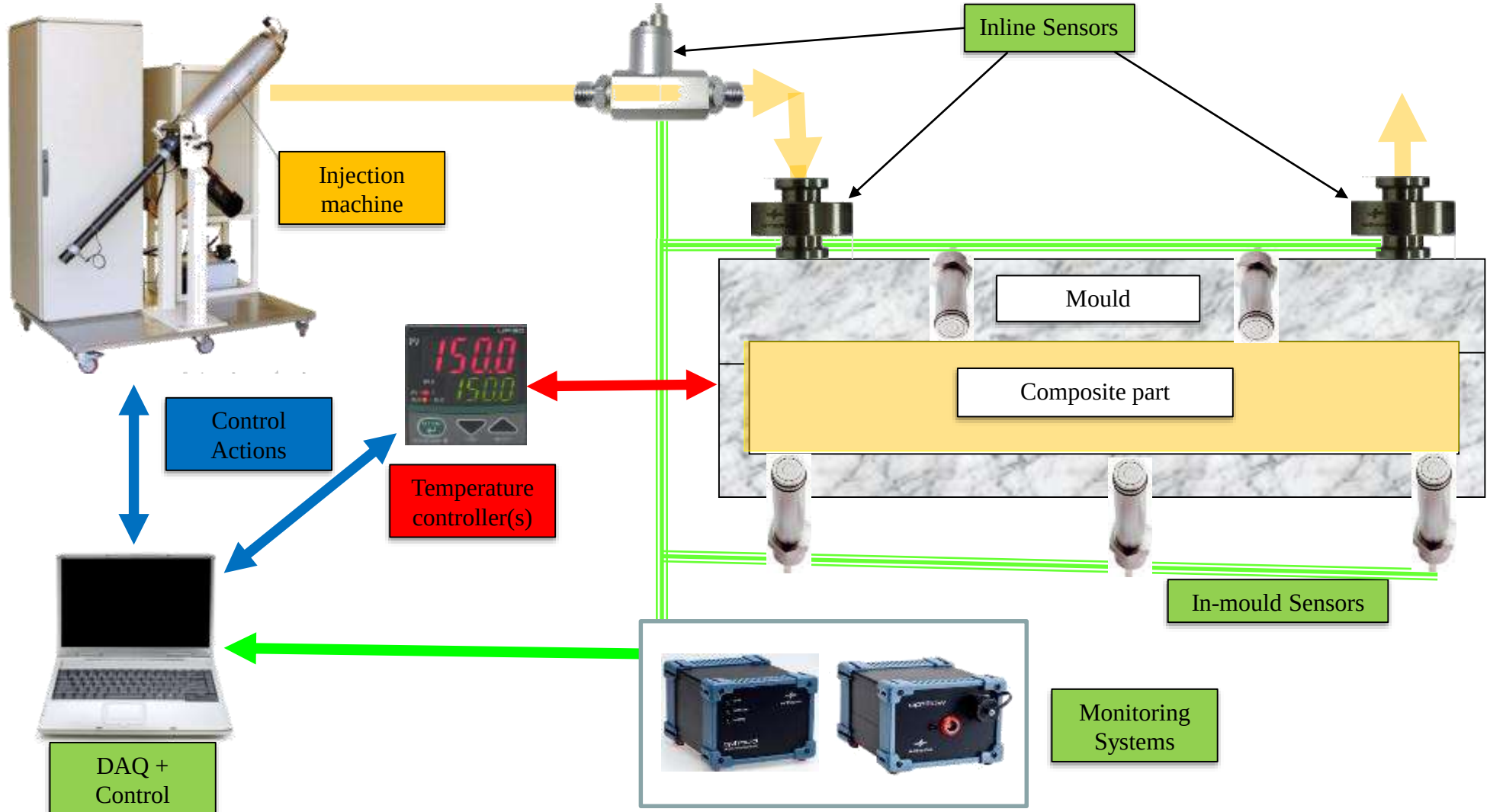
iREMO: intelligent Reactive Moulding (2009-2012)
RTM, Light RTM and Infusion

Glass and carbon fibre, epoxy and polyester

MAC-RTM: Microwave curing (2011-2013)

Fraunhofer ICT and Aimplas

- **Check resin quality and adjust process accordingly**
- **Detect accurately resin arrival at critical locations**
 - **Open/close valves based on sensors' feedback**
- **Monitor viscosity changes and decide when start heating**
- **Identify minimum viscosity and decide about pressure**
- **Detect unexpected events and follow alternative routes**
- **Improve simulation accuracy and design intelligent strategies**
- **Real-time decision of the cure cycle based on T_g and degree of cure (depends on the resin) rather than time**



Real-time measuring of

- Resin's electrical resistance (from 100 KOhm up to 50 TOhm) and
- temperature (0.1°C accuracy)

Characteristics

- Non-intrusive
- Range of sensors
- Operational indicators
- Fast Acquisition
- Compact design
- Wireless
- Quality and Process control



process monitoring sensor = electrical resistance + Temperature (RTD) sensors

Durable
sensor



High Temp RTM

- Resin arrival
- Viscosity rise
- Gelation
- End-of-cure

Durable
bag sensor



Vacuum Infusion

- Resin arrival
- Viscosity rise
- Gelation
- End-of-cure

Flexible
sensor



VI and RT cure

- Resin arrival
- Viscosity rise
- Gelation
- End-of-cure

Inline sensor



- Adjust cycle
- Online Mixing ratio check
- Avoid resin purging

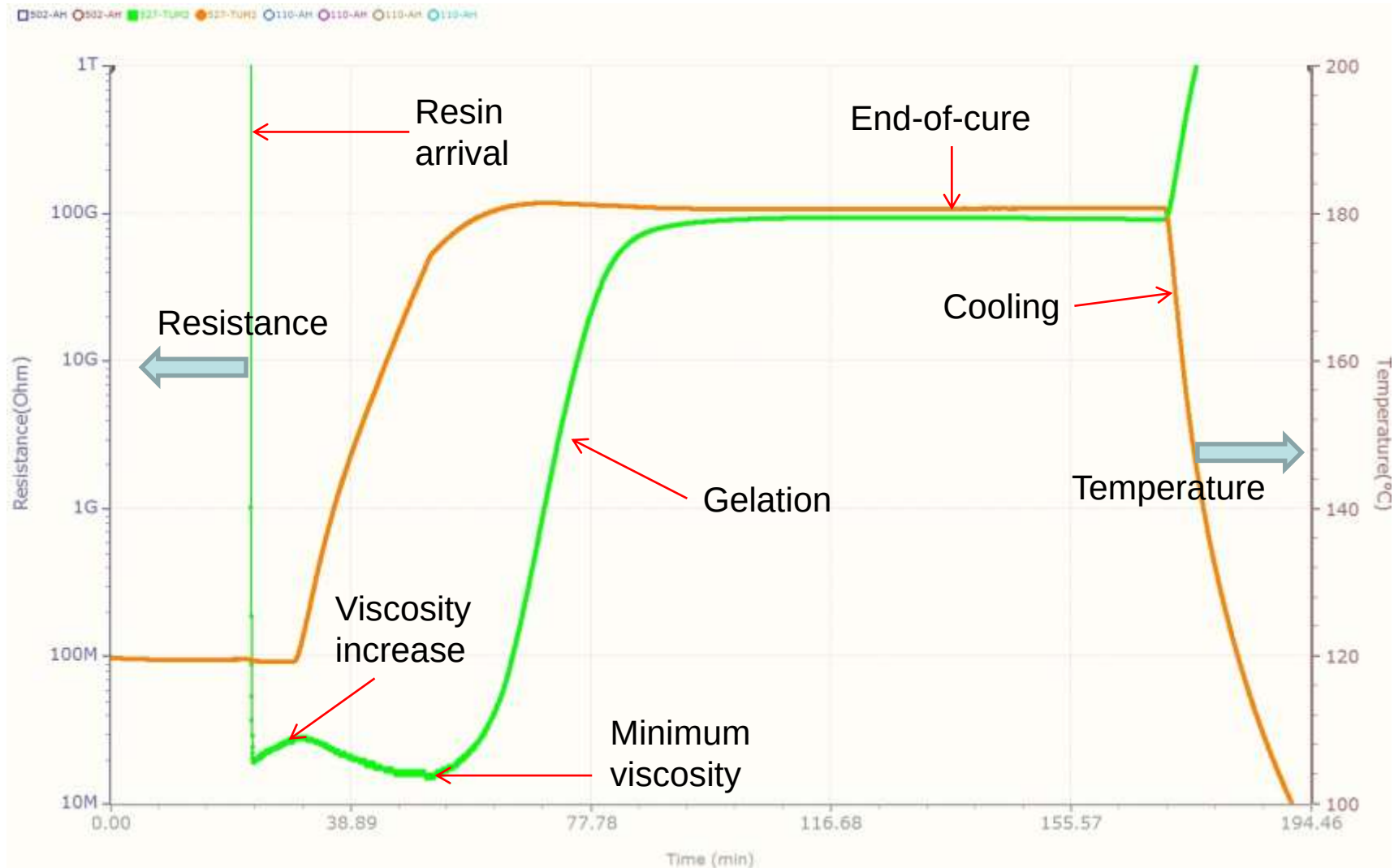
Resin pot
sensor

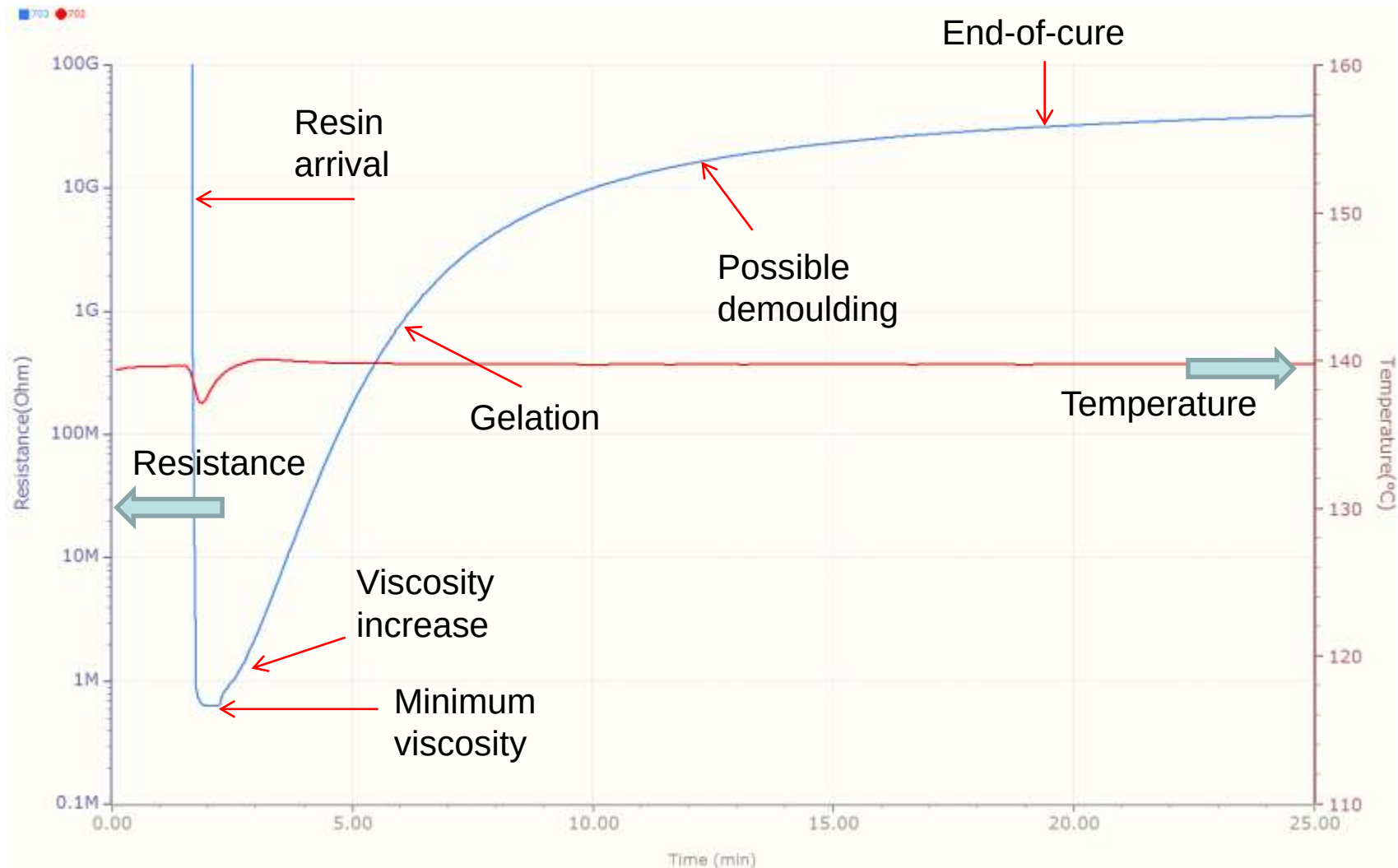


Check of

- Mixing ratio
- Resin Quality
- Resin aging
- Adjust cycle

A typical RTM6 cure cycle as measured with Optimold







- 4 temperature and resin arrival sensors
- Electrical resistance-based measurements and RTD temperature sensing
- Continuous connection checking
- One relay output for process automation

In-mould
Durable



- High Temp RTM

Gate
Durable



- ideal for infusion in oven/ autoclave (gates, pipelines, pots etc.)

Flexible
Disposable

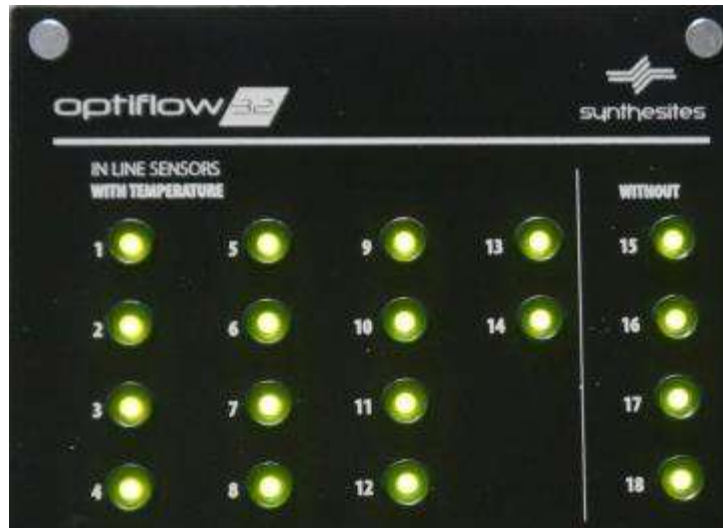


- Infusion and RTM
 - Curved surfaces
- In the laminate for development
 - Over the peel-ply
 - Suitable for very long parts
- no extra protection for Carbon Fibre Preforms

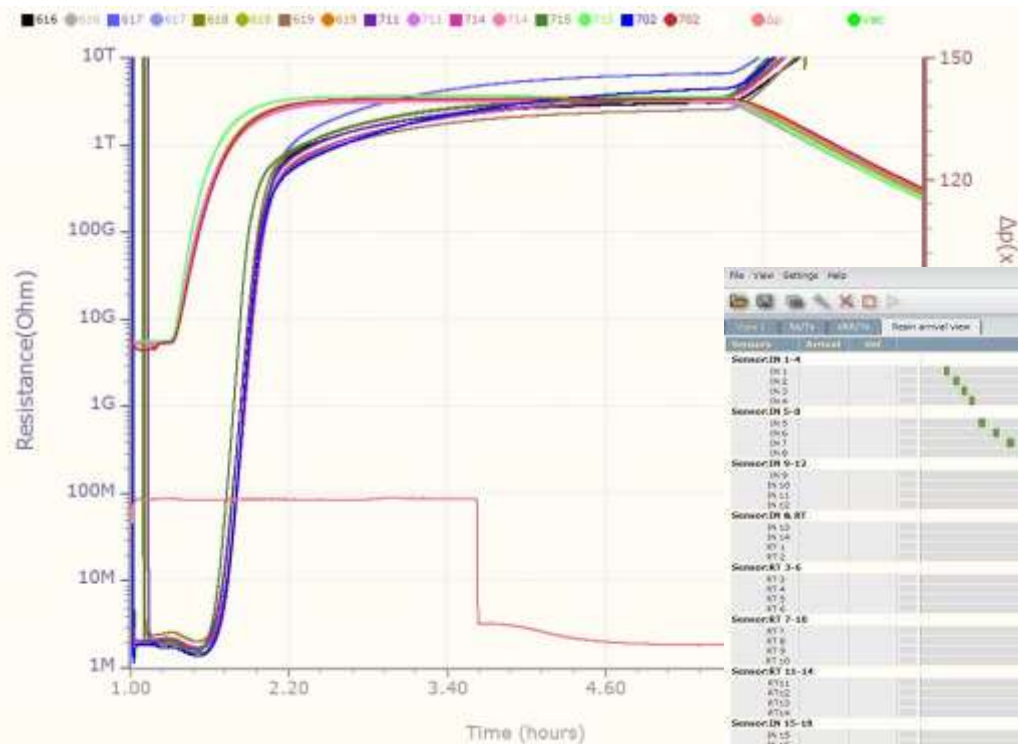
FloWire
Disposable



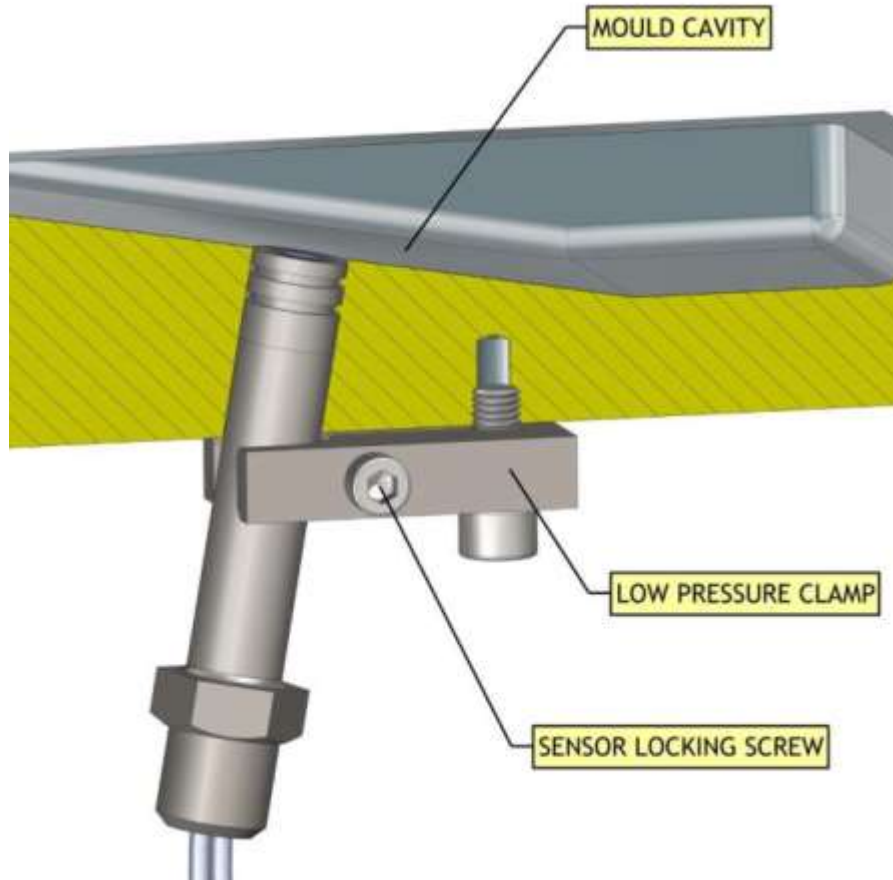
Multiple Resin arrival and temperature sensors for ovens/autoclaves



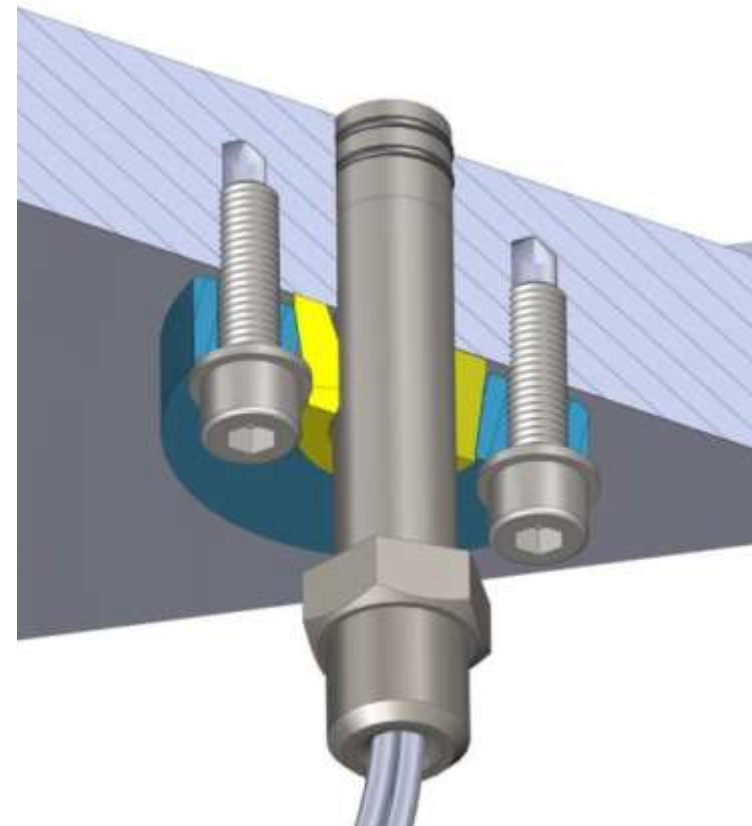
- 32 temperature and resin arrival sensors
- Electrical resistance-based measurements and RTD temperature sensing
- Continuous sensor check
- Relay outputs for process automation



optiview DAQ software
for optimold and
optiflow systems



Low-pressure (<10 bar) clamp with sensor installed in a typical tool



High-pressure (>10 bar) clamp with sensor installed in a typical tool



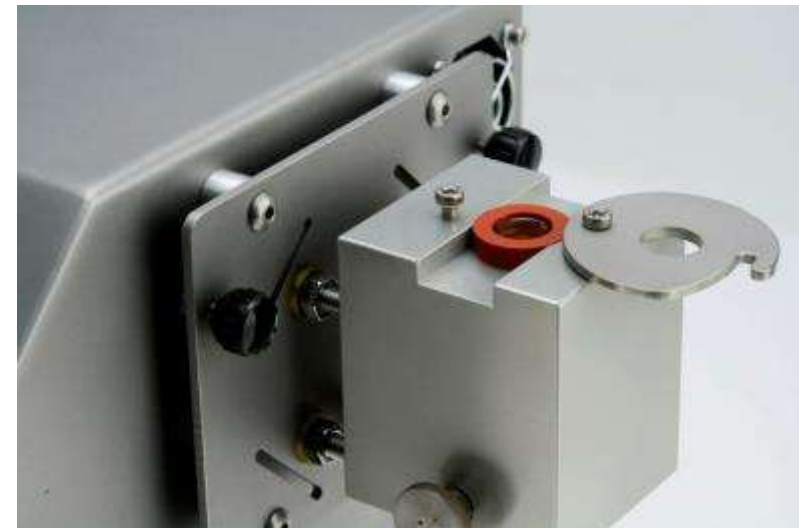
SWADGELOK FITTING



CUSTOM-MADE ADAPTOR
FOR METAL TOOL



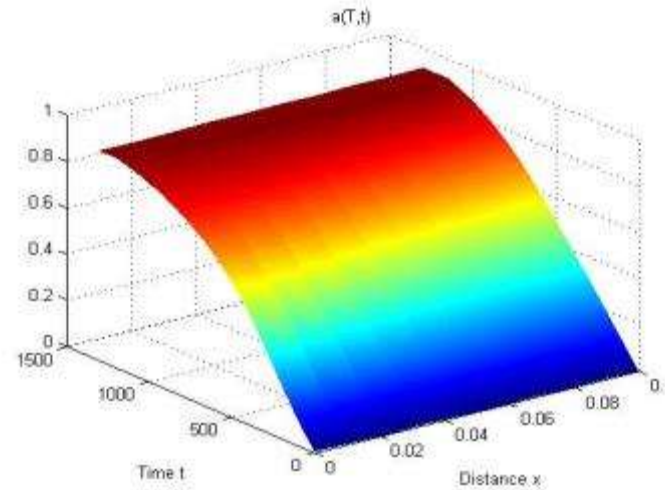
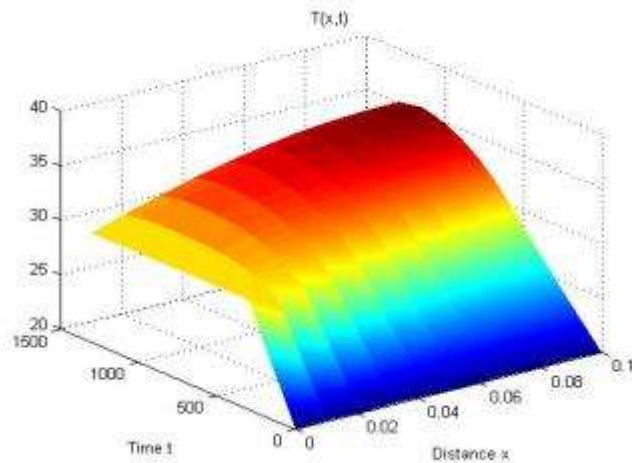
CUSTOM-MADE
ADAPTOR FOR
COMPOSITE TOOL



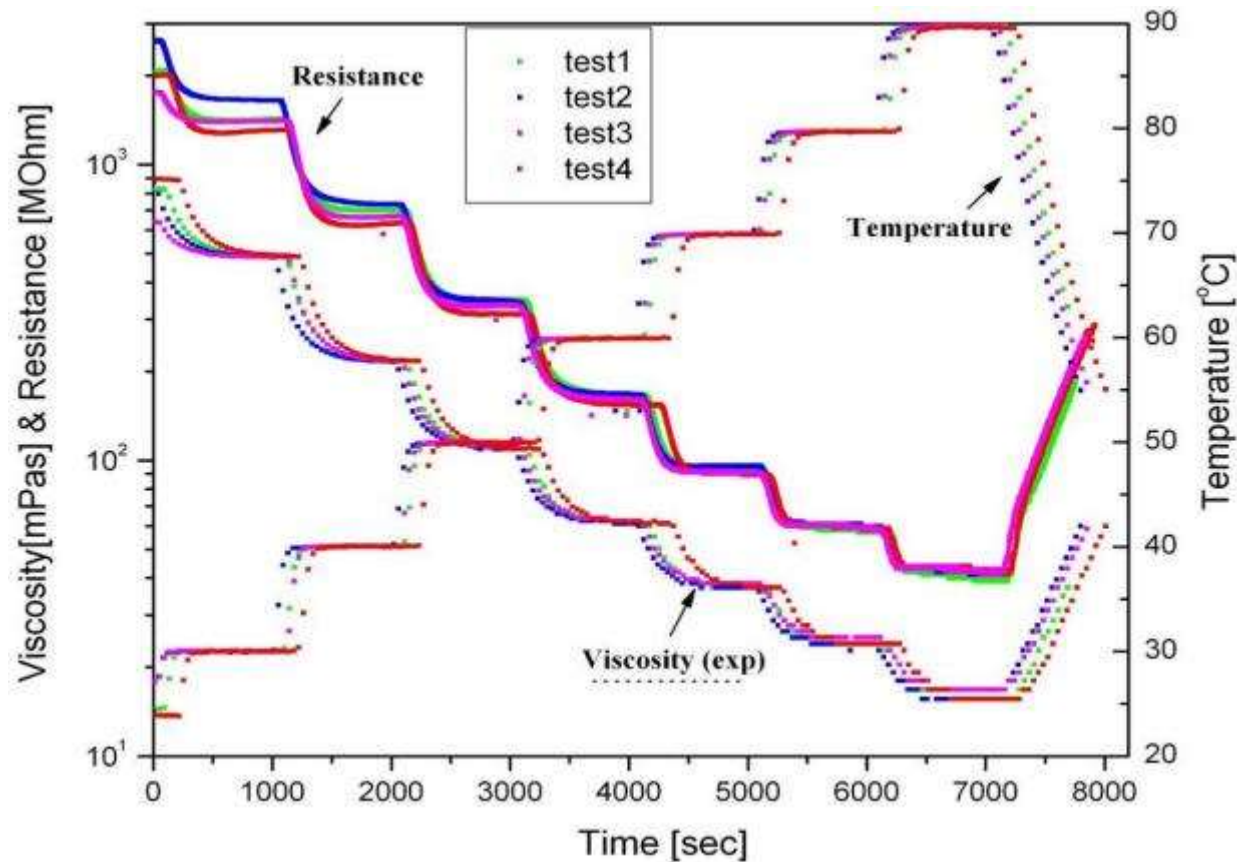
Simulation of curing profiles producing coupons for DSC evaluation 17



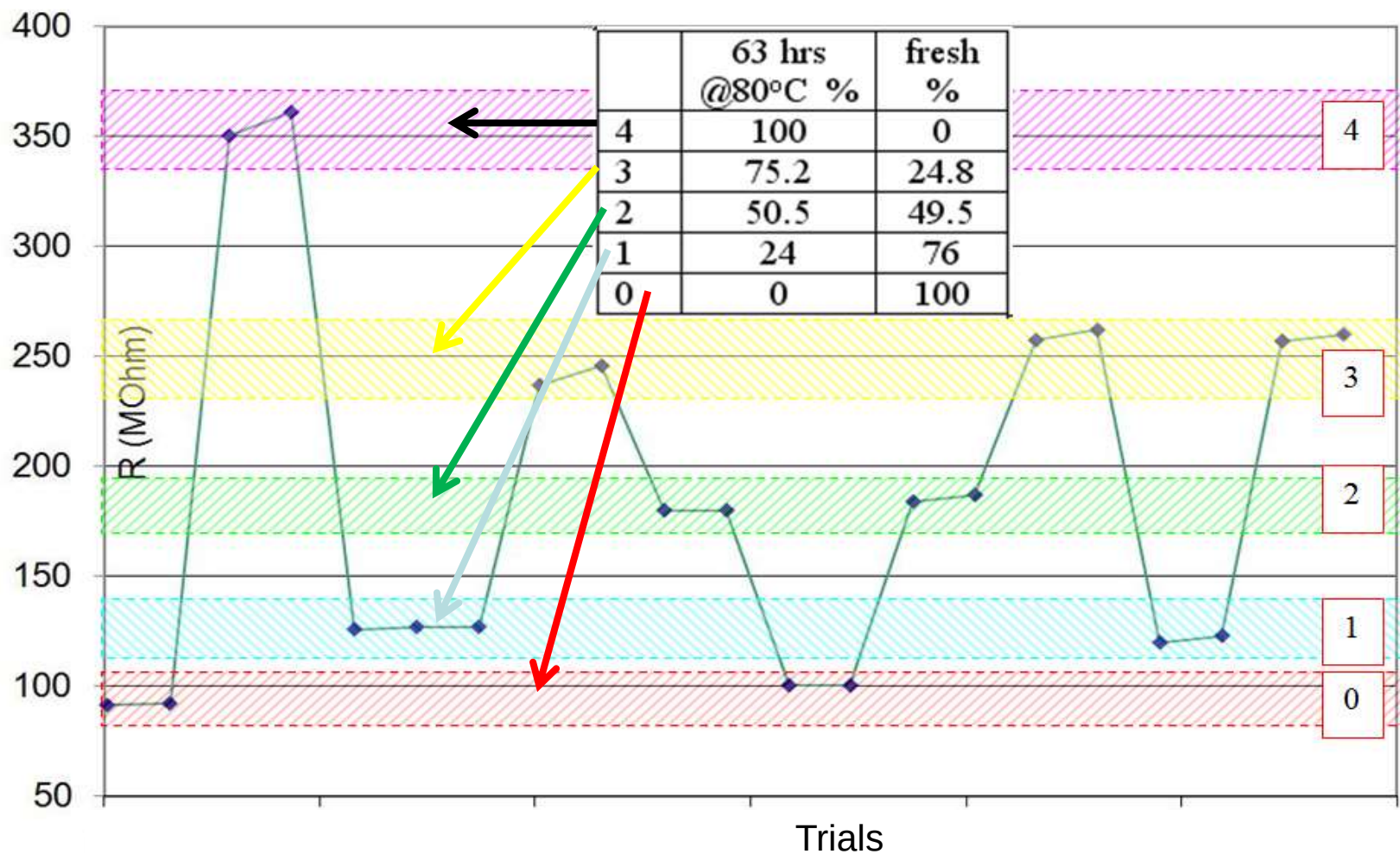
Calibrators for Optimold and OptiFlow systems



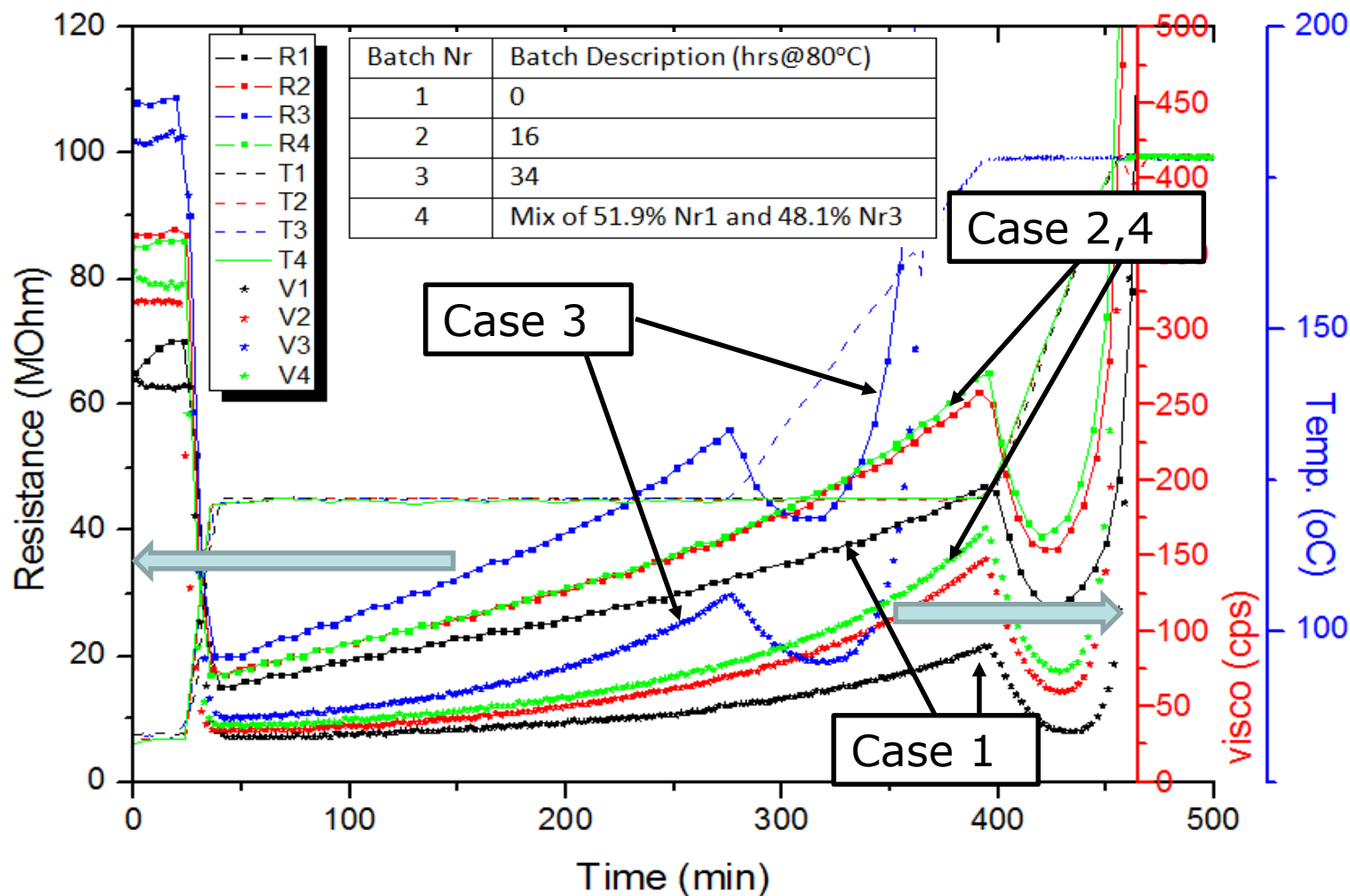
- ✓ Optimise temperature profile using 1-D or 2-D models based on targets and constraints
- ✓ Robust Optimisation: include statistical deviations
- ✓ Sensitivity analysis of the optimal case: Check the robustness of the optimal profile based on statistical deviations.



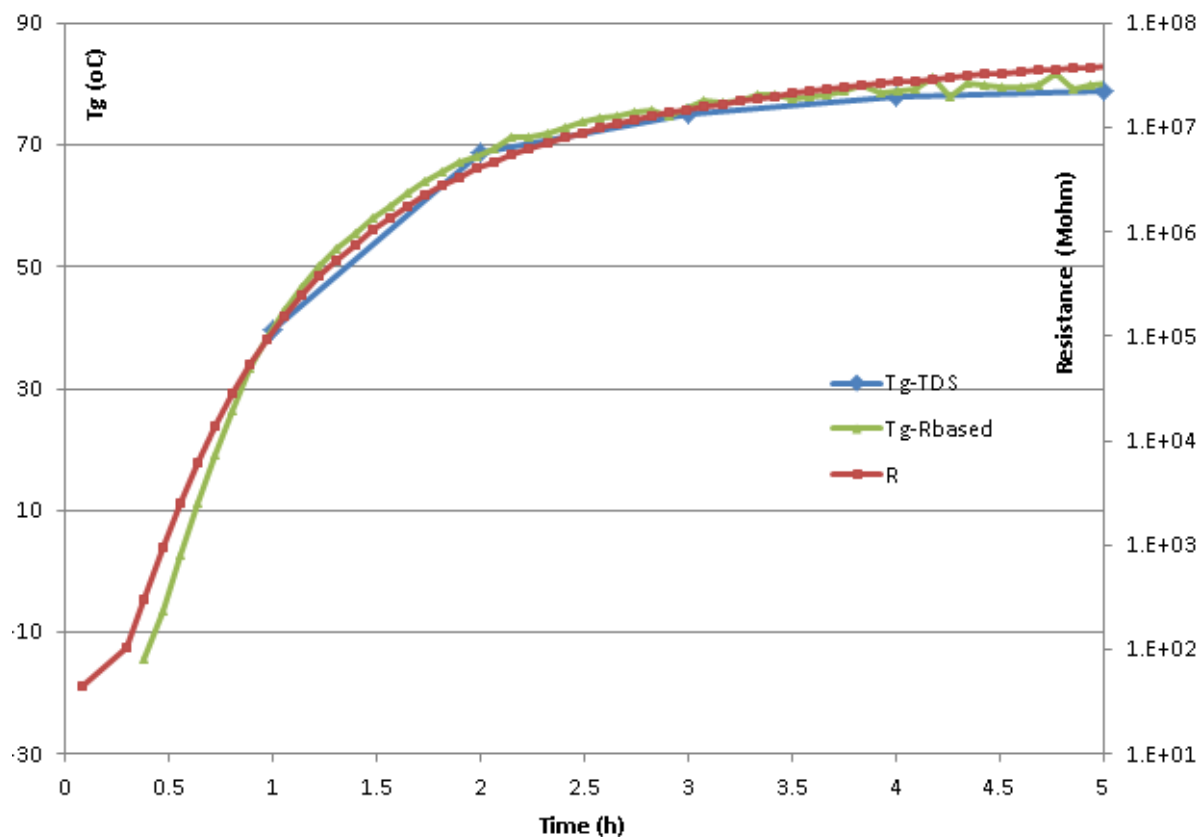
Resistance and viscosity monitoring of Bakelite's neat L20 epoxy resin at various temperatures



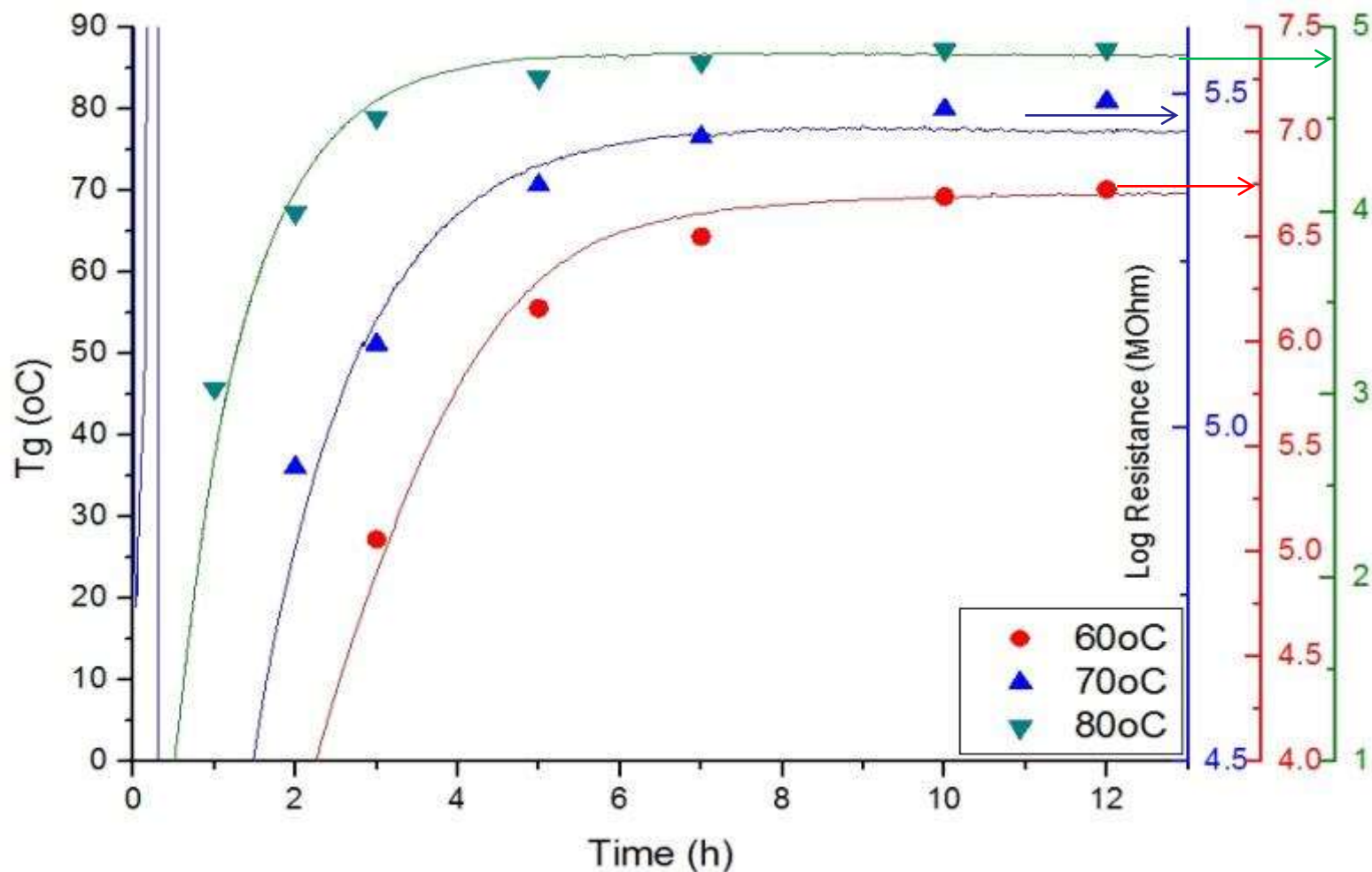
Resistance vs mixing ratio of fresh and aged monocomponent resin



Viscosity, Resistance and temperature vs. time for 4 resin batches

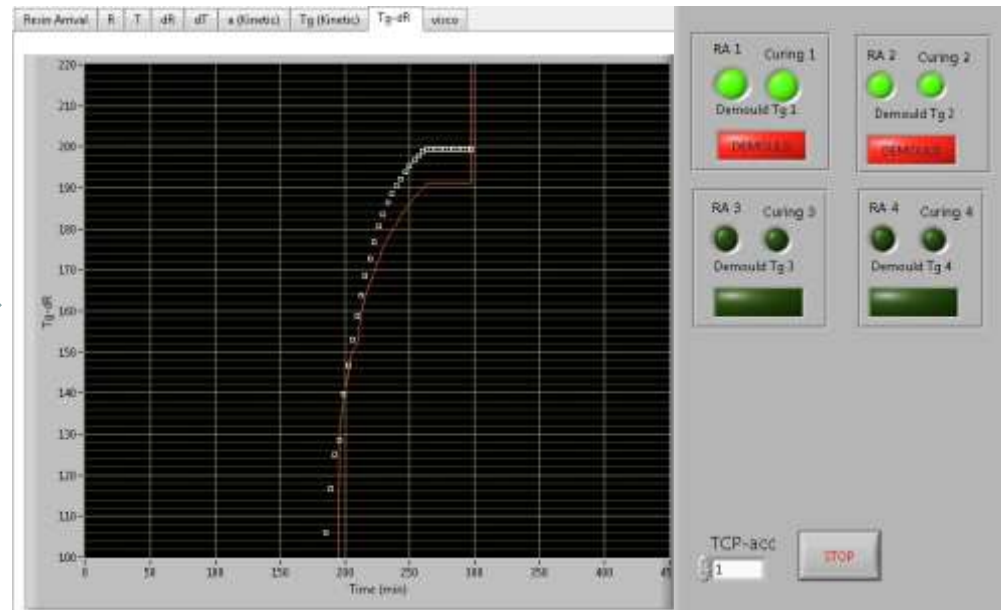
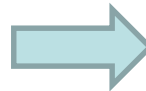
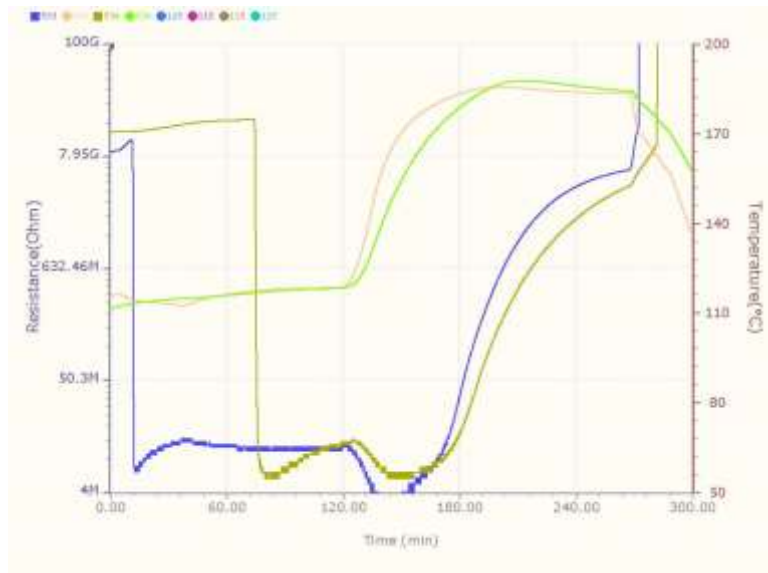


Hexion Epoxy resin: Correlation between resistance, Tg real-time prediction and Tg as provided in the TDS (isothermal run)



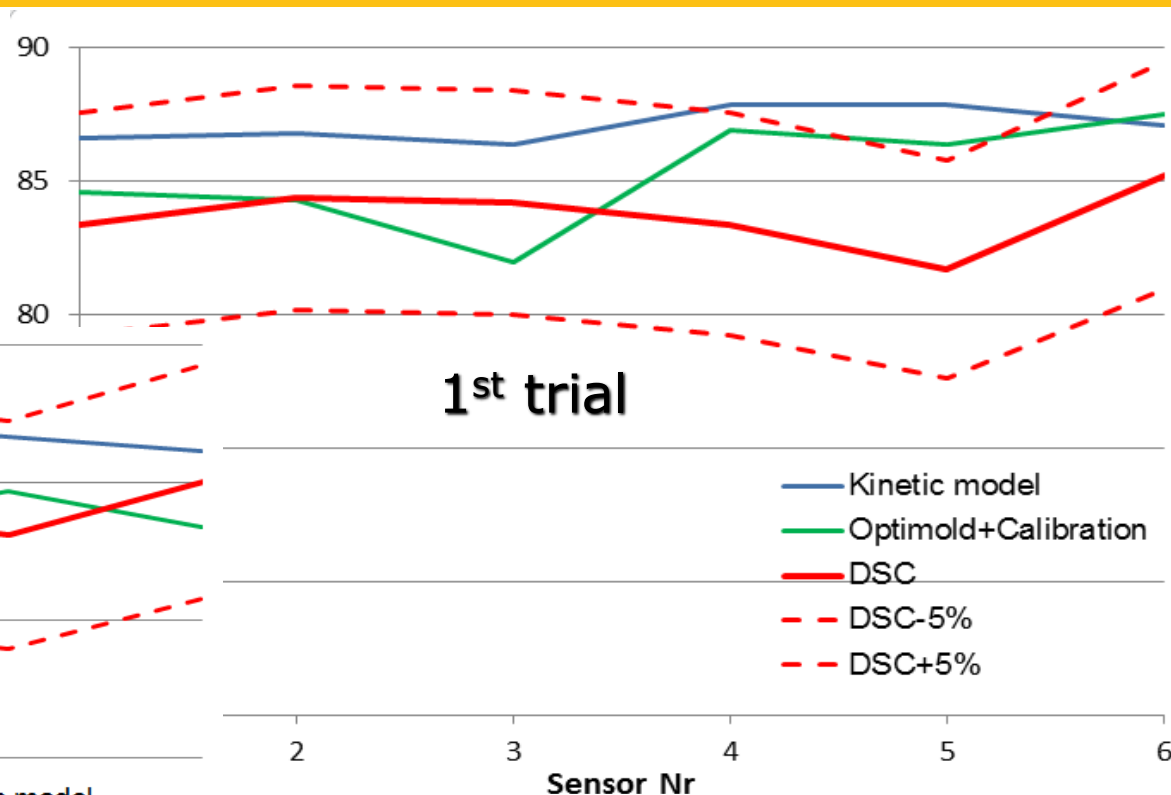
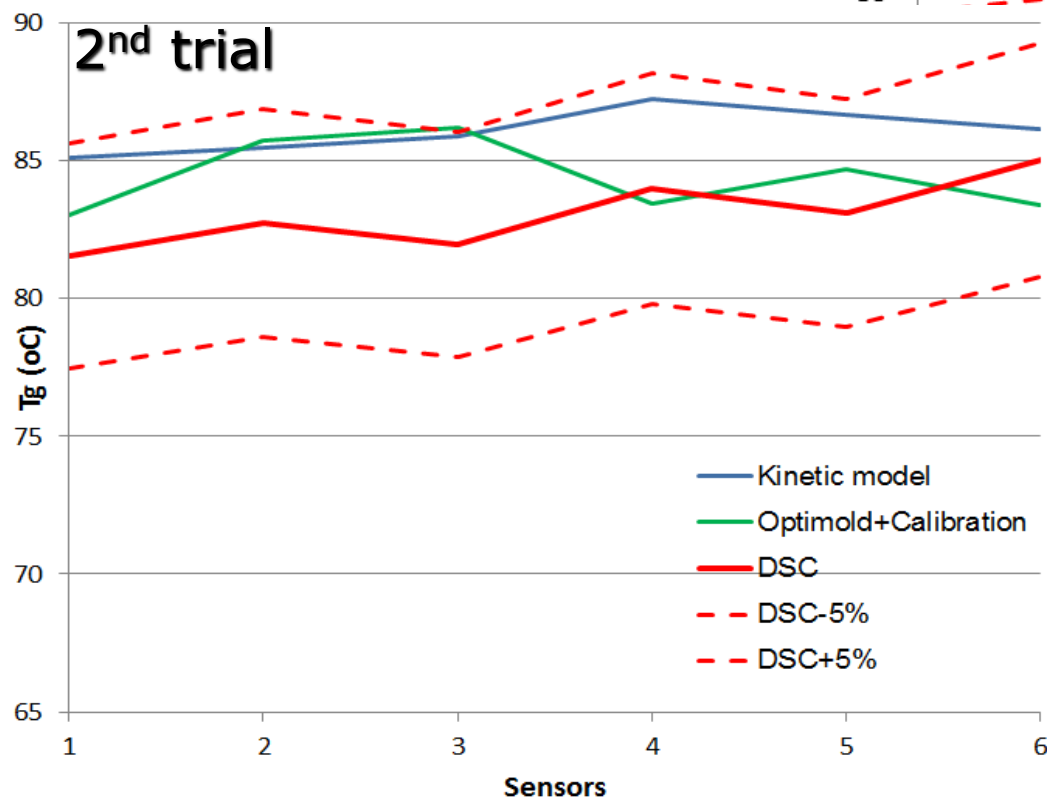
Correlation between resistance and Tg (iso-T)

From Resistance and Temperature to Real-time Tg reliable prediction



Curing time reduction over **30%**

Results from two VI cfrp trials and 6 cure sensors

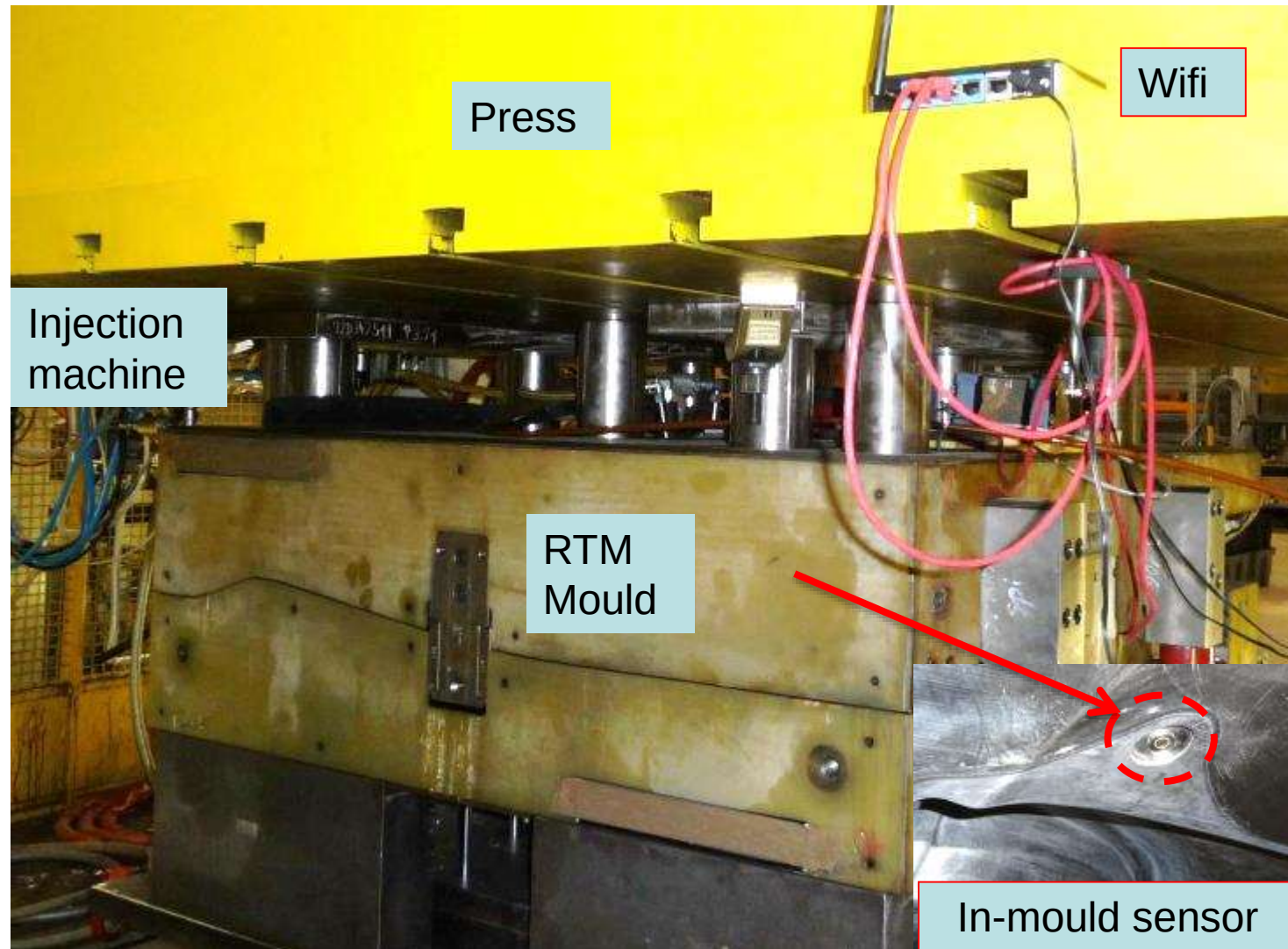


Besides the sharp exotherms and the noisy environment, Tg real-time final predictions lie within $\pm 5\%$ of DSC values (same as DSC accuracy margin)

Existing Tg models for the following epoxy resins:

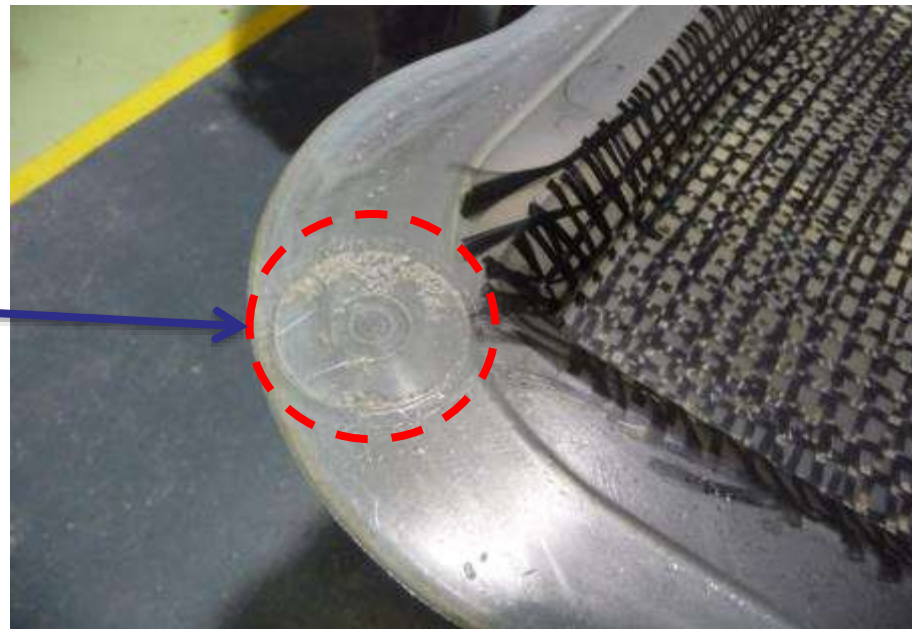
- **Hexcel:** RTM6™, 8552
- **Cytec:** Cycom890
- **Henkel:** Benzoxazine 99120
- **Hexion:** RIM035-RIMH037 and RIM035-RIMH038
- **Huntsman:** Araldite LY1564SP/XB3486, LY556-XB3917 and LY 564/22962
- **Resolution:** EPIKOTE™ Resin 862/EPIKURE™ Curing Agent W
- **Dow:** Voraforce

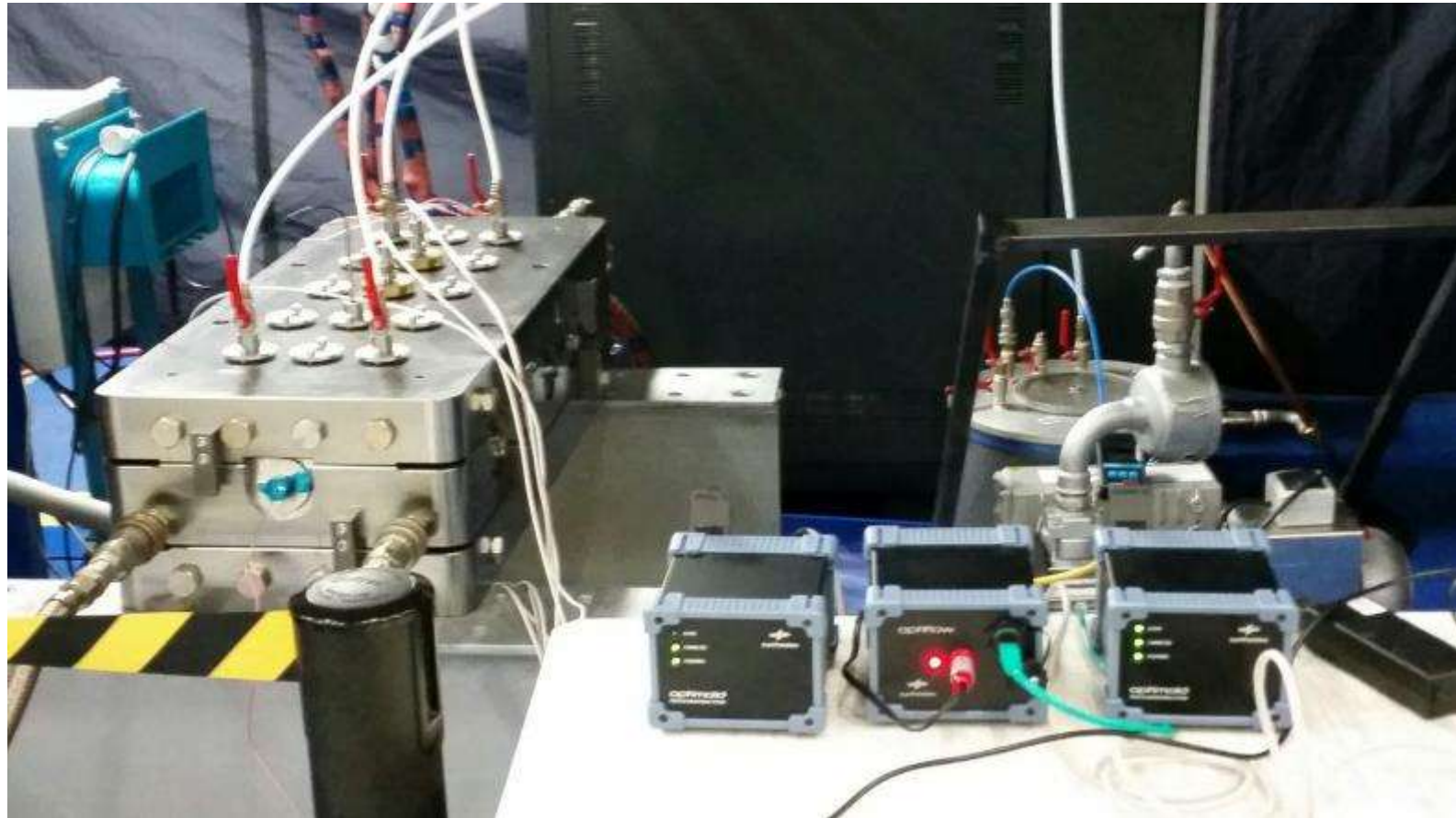
More resin calibration models are under development.



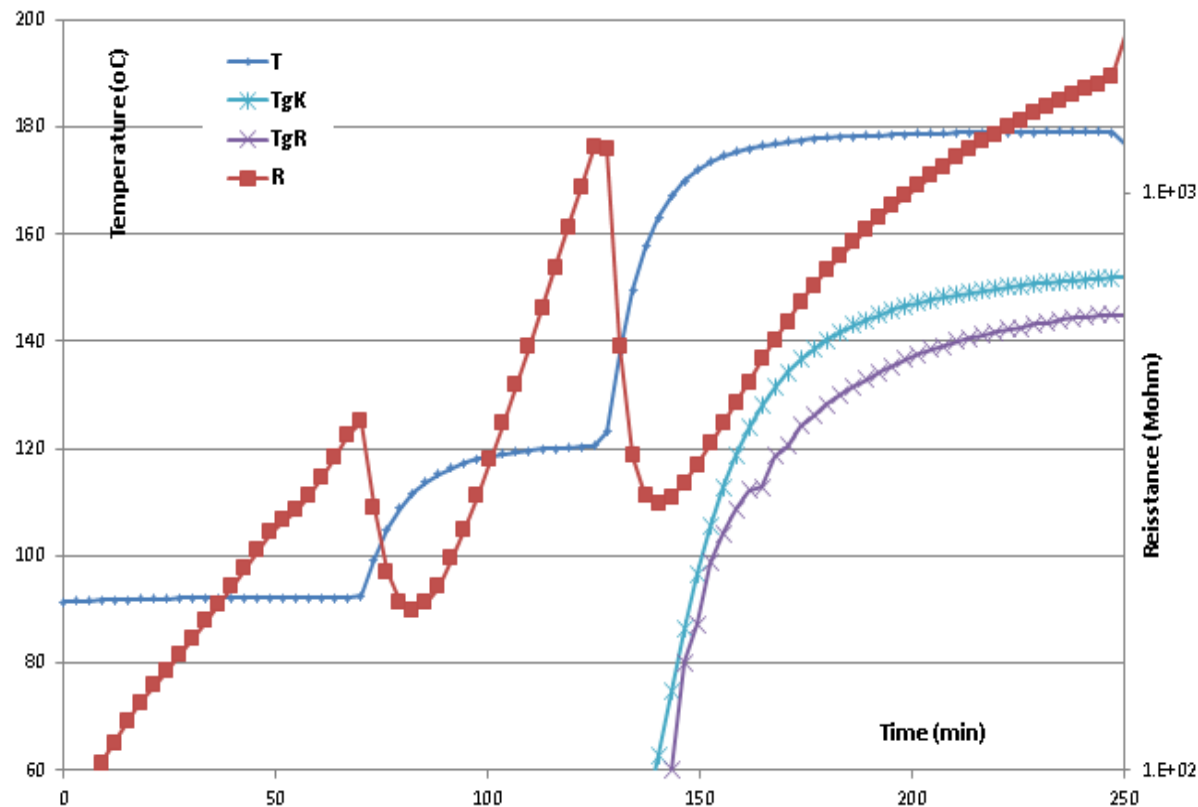


No direct contact with the
part is necessary

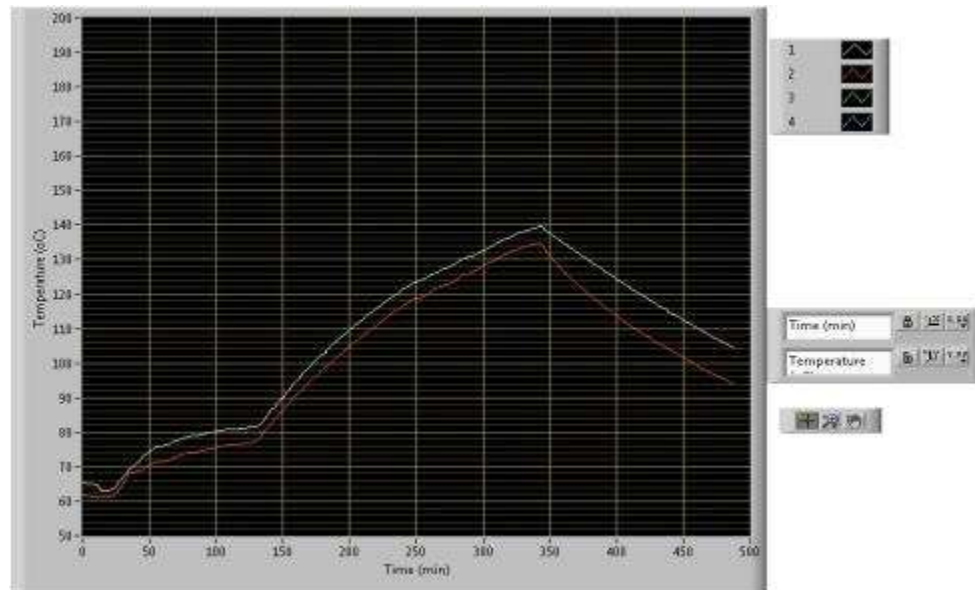
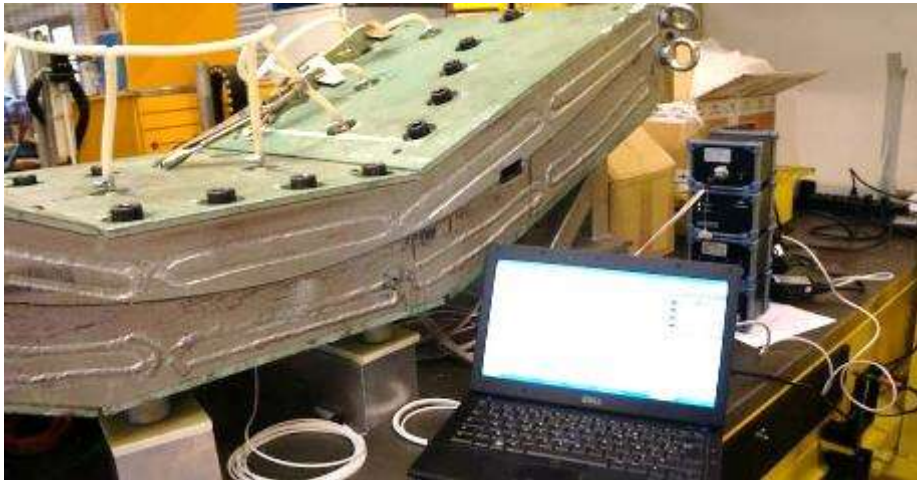


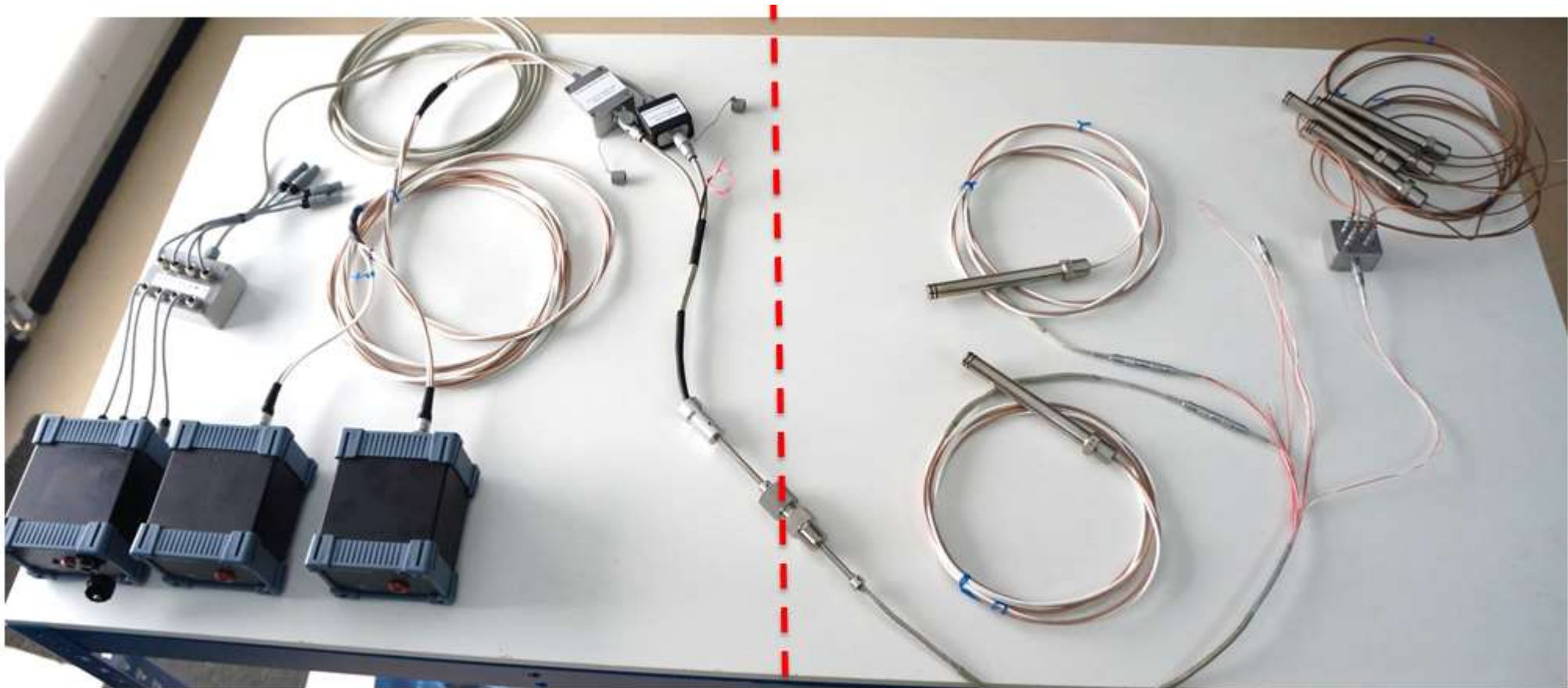


Sensorized RTM: 8 Resin Arrival and 2 Cure durable sensors from Synthesites in addition to 1 pressure sensor and 6 extra thermocouples.
(in collaboration with Airborne (NL) within ECOMISE project)



Realtime Tg prediction based on the kinetic model and resistivity for cure sensor #1.
(in collaboration with Airborne (NL) within ECOMISE project)





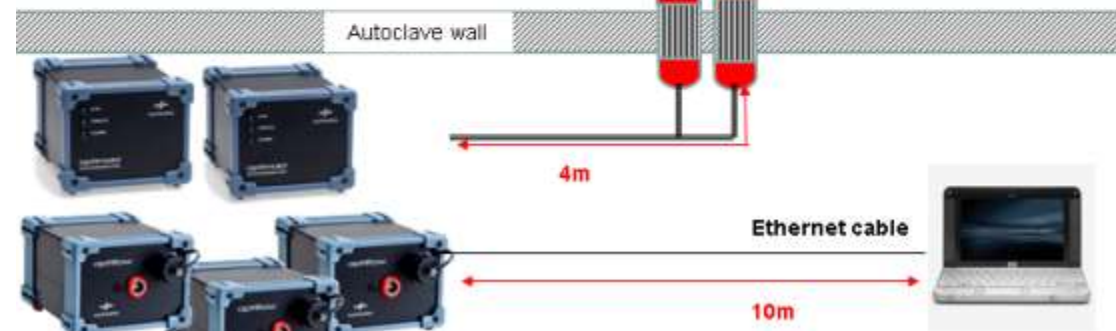
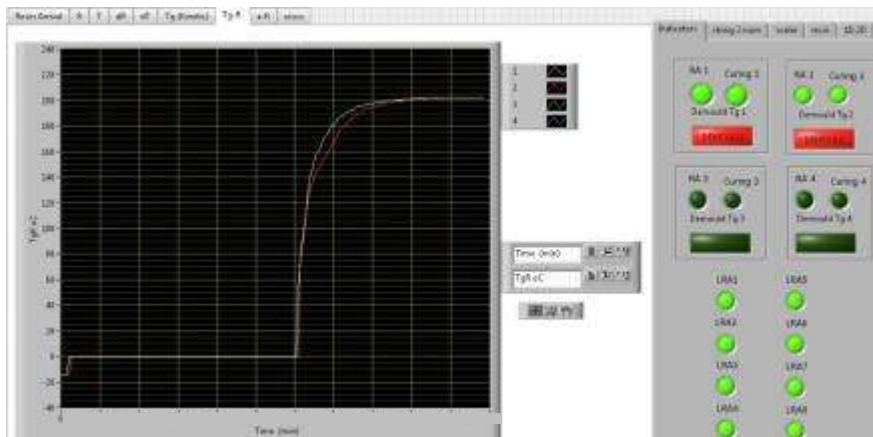
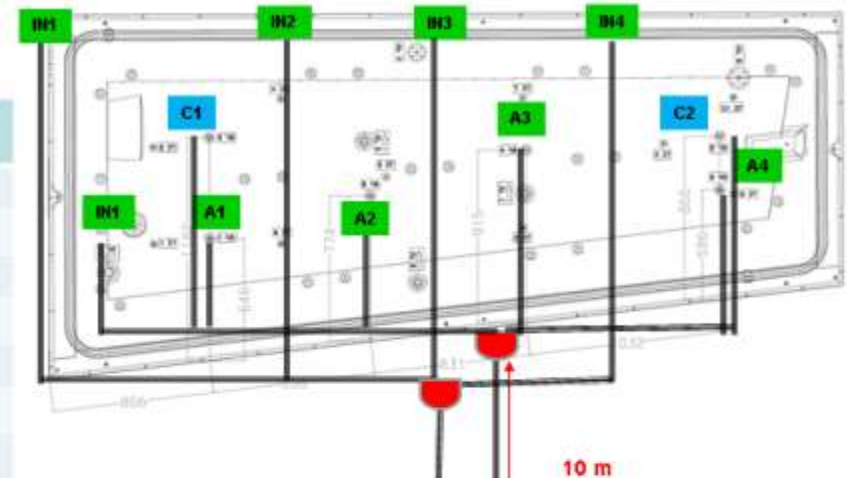
Outside of the autoclave

Inside of the autoclave

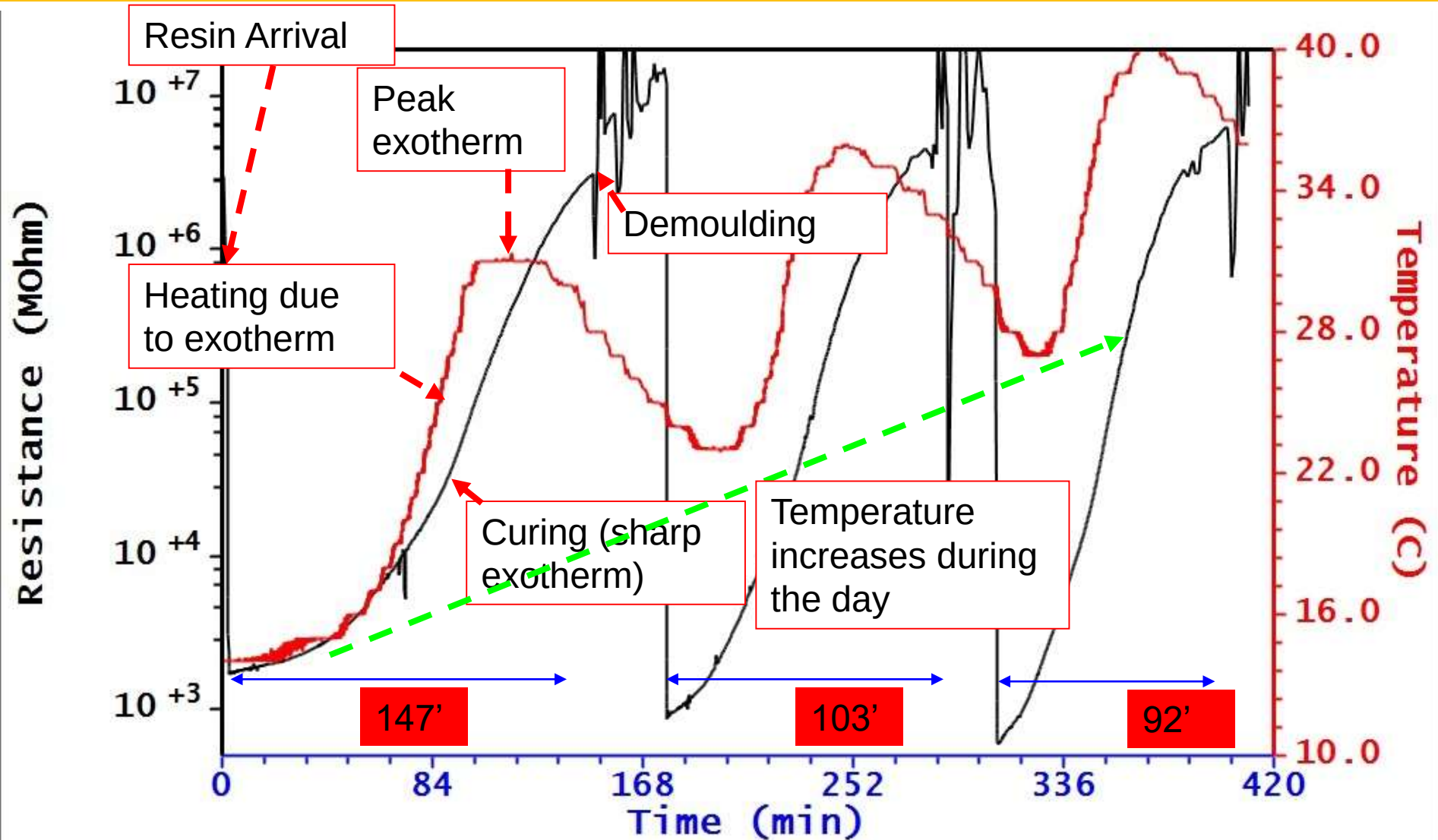


Sensor Location	Sensor Type
SP1	A1
SP2	C1
SP3	A2
SP4	A3
SP5	C2
SP6	A4

C = Cure sensor
A = Resin arrival and Temperature sensor

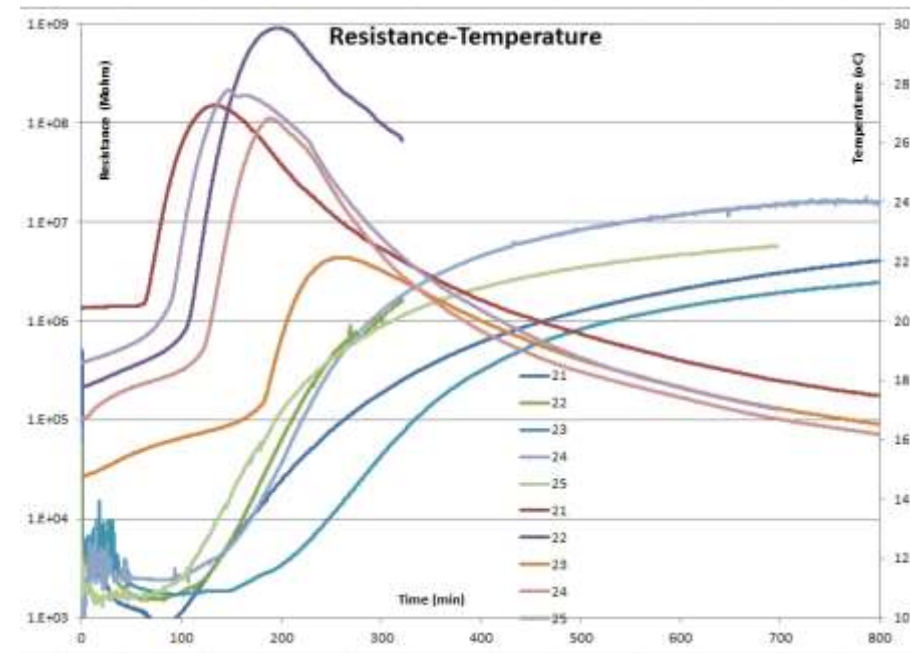


Real-time Tg prediction and demoulding decision based on targeted Tg.





Optimold system and in-mould sensor (insulated to eliminate 'artificial' resin cooling)



Low temperature curing cycles with varying catalyst ratio (Resistance and Temperature recordings)



@ Aimplas Pultrusion/Injection (Coaline project)



@ Acciona Infrastructures (iREMO project)

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