

Whitepaper FDM

**AUTOMOTIVE THERMAL CYCLING: PROGRAMMING AND DATA-DRIVEN  
VALIDATION**

## Executive Summary

Thermal cycling tests are essential to assess the reliability and durability of automotive components exposed to extreme temperature variations. These tests simulate real-life conditions, from engine heat to cold climate exposure, identifying early-stage failures and validating design robustness. This whitepaper explores thermal cycling protocols, analysis techniques, and practical examples for the automotive sector.

## Thermal Cycling Test Programming

Thermal cycling involves repeatedly transitioning components between high and low temperatures within controlled environmental chambers.

### Typical programming parameters include:

- **Temperature range:** -40°C to +125°C
- **Ramp rate:** 2–10°C/min (based on component class)
- **Dwell time:** 30–60 minutes per plateau
- **Cycle repetitions:** 10–1000+ depending on life expectancy
- **Humidity inclusion:** optional for combined stress testing

FDM chambers offer programmable cycling with precise control and repeatability, critical for reproducibility and compliance.

## Compliance and Standards

Automotive thermal tests follow global standards such as:

- **ISO 16750-4** – Electrical/electronic component environmental testing
- **SAE J1211** – Component environmental stress testing
- **LV124** – German OEM automotive test requirements
- **IEC 60068-2-14** – Thermal shock and cycling

Proper documentation of all test variables is required for traceability and audit purposes.

## Data Analysis and Reporting

Modern thermal testing requires detailed monitoring and evaluation:

- **Key metrics:** resistance shifts, physical deformation, failure rate per cycle
- **Monitoring tools:** integrated sensors, real-time logs, thermal cameras
- **Reporting:** visual graphs of thermal transitions, failure mapping, deviation logs

FDM systems integrate easily with external data analysis tools or export CSV logs for custom dashboards.

## Case Study: ECU Thermal Stress Qualification

A Tier 1 automotive supplier validated an Engine Control Unit (ECU) for commercial vehicles using 200 thermal cycles between -35°C and +110°C. Early degradation in a PCB connector was identified through resistance monitoring and temperature mapping. A design adjustment reduced stress concentration, passing the final ISO 16750 validation in less than 6 weeks.

### F.lli Della Marca S.r.l.

Viale Arcangelo Ghisleri, 40/42  
00176 Rome - Italy

### Contacts

(+39) 06 298042

### Web

[www.dellamarca.it](http://www.dellamarca.it)

### **Conclusion**

Thermal cycling is a core element of automotive qualification and reliability engineering. With FDM's high-performance climate chambers, testing teams can simulate real-world conditions, detect weaknesses early, and ensure component compliance with international standards.

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