A Unique Calorimeter-Cycler for Evaluating High-Power Battery Modules

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Acknowledgment

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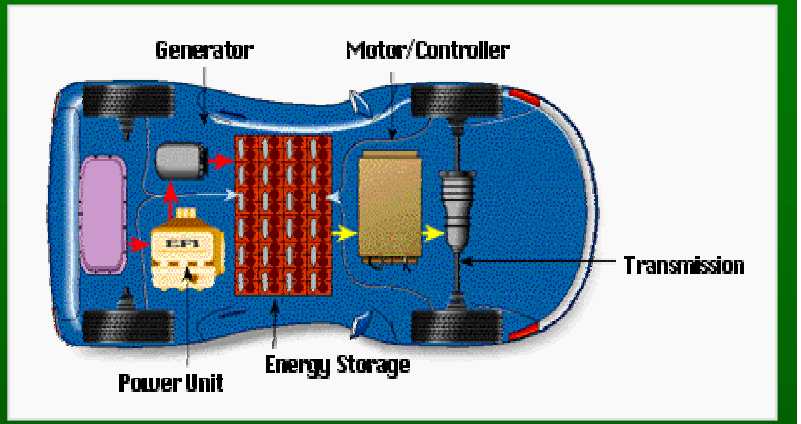
Presentation Outline

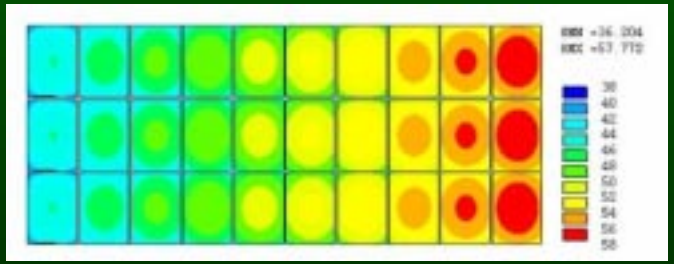
- Background
- Objectives
- Description of equipment
- Calibration results
- Recent results for a VRLA module
- Summary

Background

- HEV/EV performance and life-cycle cost are influenced by battery pack including temperature



- Uneven temperature distribution in a pack leads to unbalanced modules and reduced performance



- Pack thermal management is needed to regulate modules evenly within the desired operating range, particularly for HEV batteries

Background

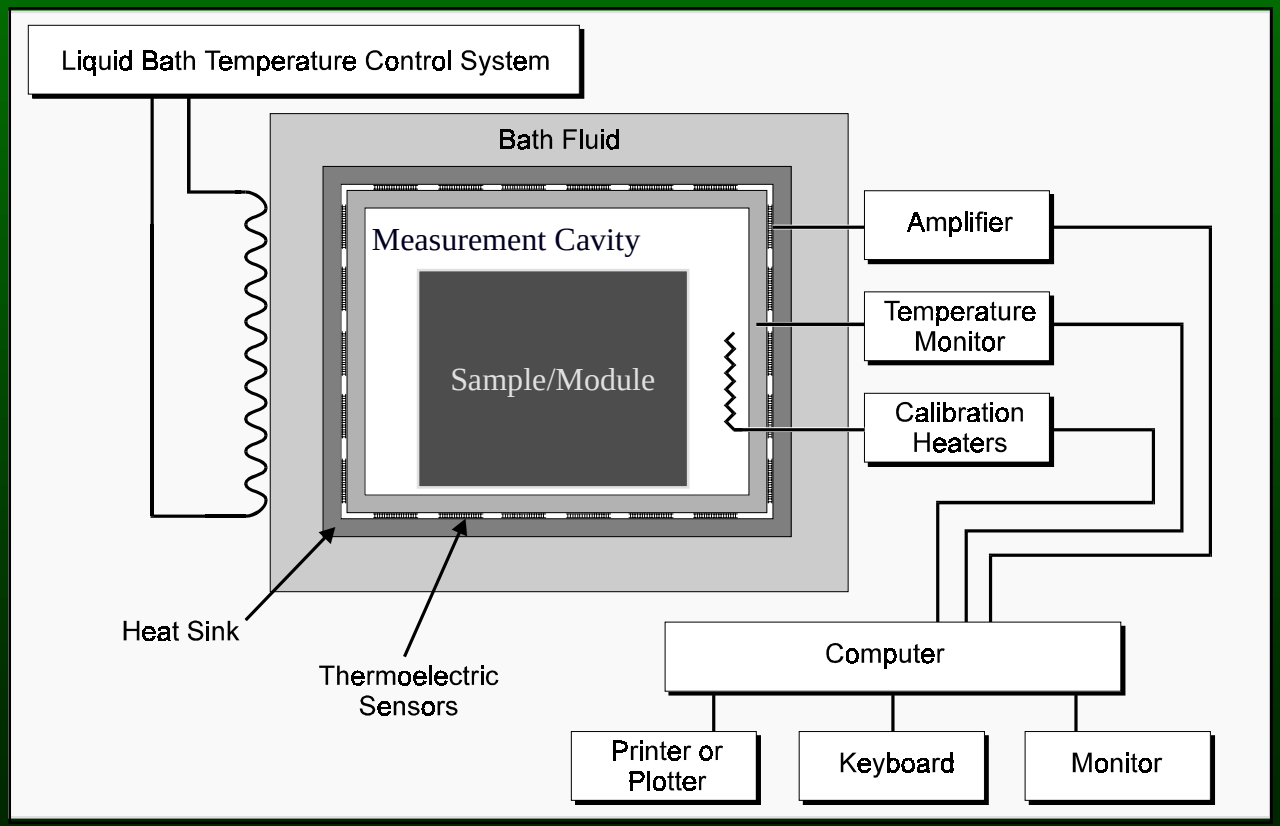
- To properly design a pack's thermal management system, accurate data on heat generation from modules under various charge/discharge profiles are needed
- Calorimetry has been used to provide accurate heat generation data
- A custom-made calorimeter was needed
  - To test full-size modules
    - Avoid scale-up issues from cell levels
    - Capture all element such as inter-cell connectors
  - Standard calorimeters use small cavities

Objectives for the Calorimeter

- To obtain accurate heat generation data from modules under various cycles
- To obtain accurate energy efficiency data
- To validate/calibrate thermal and electrochemical models
- To evaluate physical and electrochemical design changes that could lead to improved modules

Calorimeter Design

- Single-ended heat conduction type
- Heat flux measured between the sample and a heat sink
- The heat sink is kept at a constant temperature



Calorimeter Specifications

- Cavity dimensions: 21 cm W x 39 cm L x 26 cm H
  8.2 in W x 15.3 in L x 10.2 in H
- Maximum heat rate: 100 W
- Minimum detectable heat effect: 10 J (at 25ºC)
- Lowest Accuracy: ± 5%
- Baseline stability: ± 1 mW at uniform ambient T
- Bath temperature range; -30ºC to 60ºC (±0.001°C)
- Internal calibration heater: 1 W to 80 W

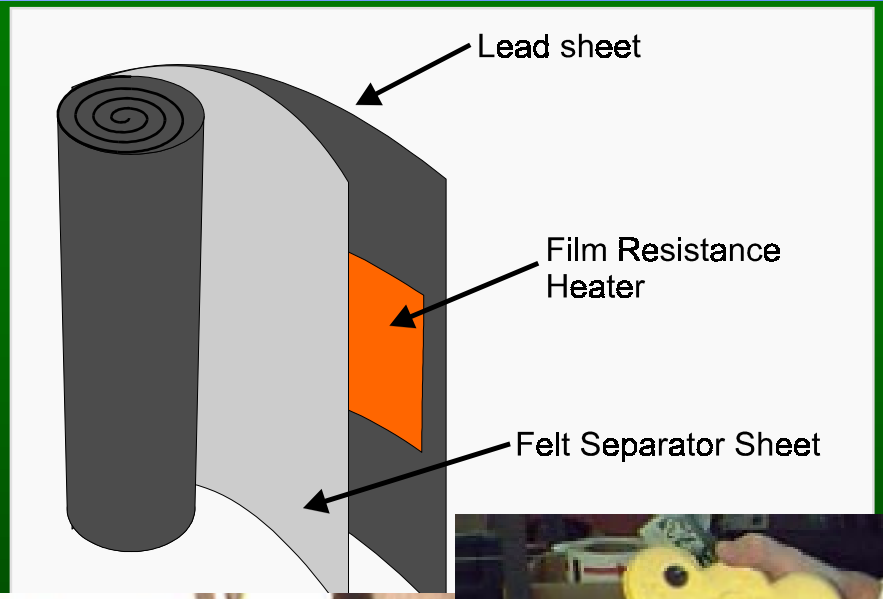
Battery Calorimeter for Large Modules

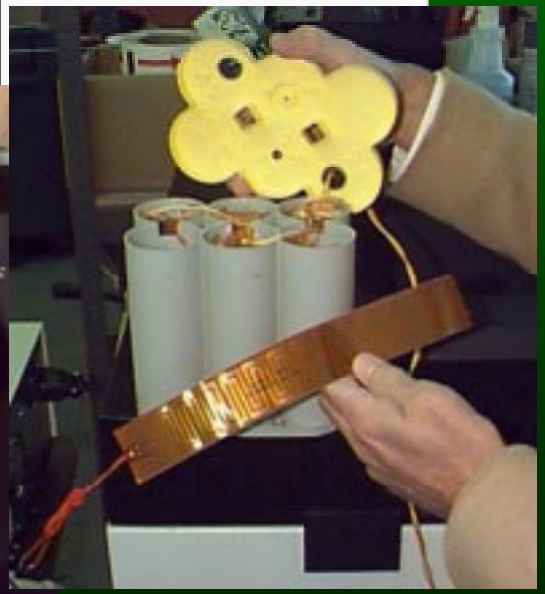
Calorimeter Cavity

- Air, fan mixing
- Liquid, stir mixing

Simulated Battery Module

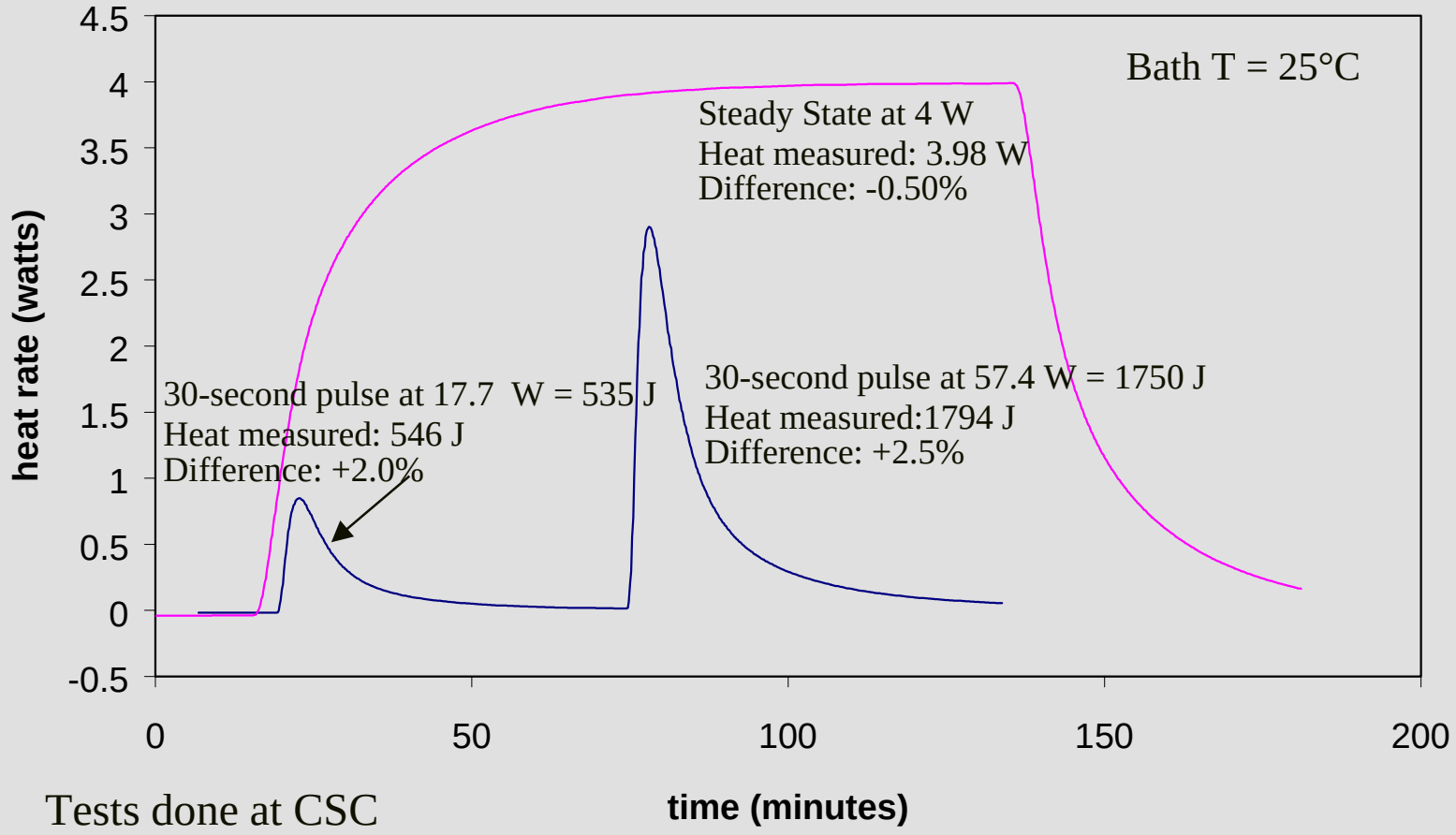
- Spiral-wound VRLA
- Six cells
- Similar thermal mass
- Similar thermal conductivity
- Similar heat generation rate





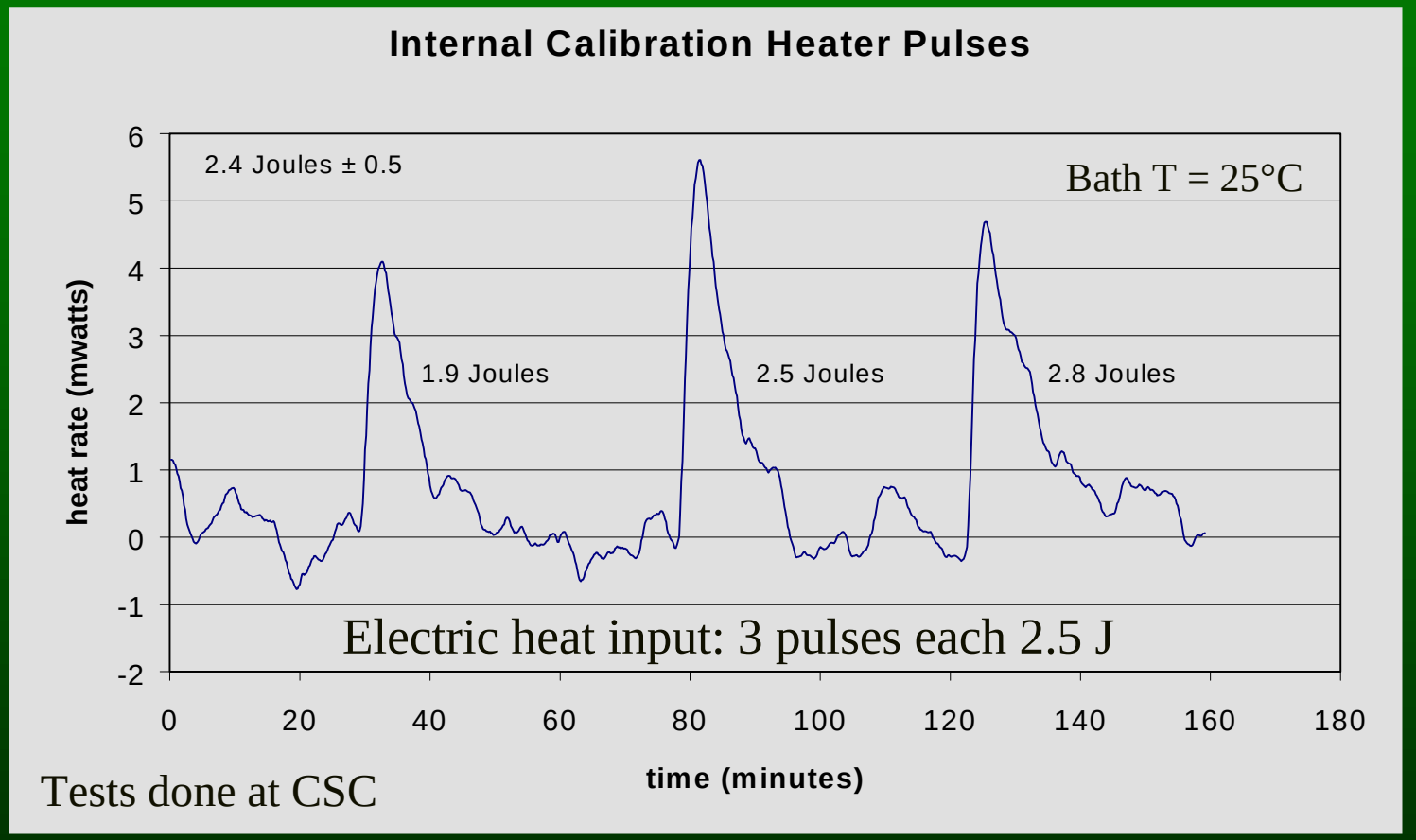
Results with Internal Calibration Heaters

Time constant of the calorimeter without sample is 11.5 minutes



Tests done at CSC

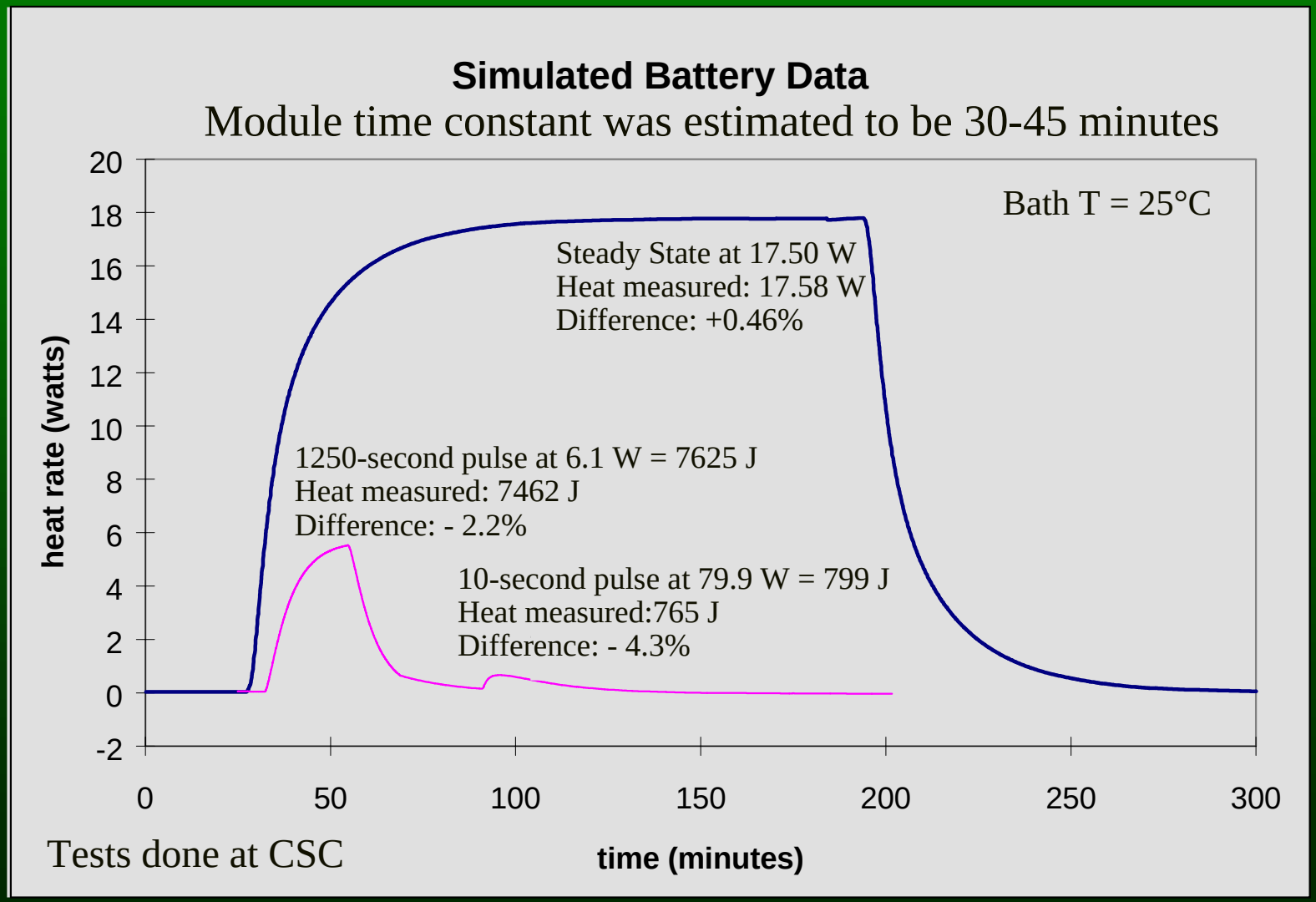
Results: Sensitivity and Reproducibility



Tests done at CSC

- Calorimeter integrated these heat pulses with a reproducibility of ±0.5 J
- Calorimeter baseline stability (noise level) is around ± 0.1mW

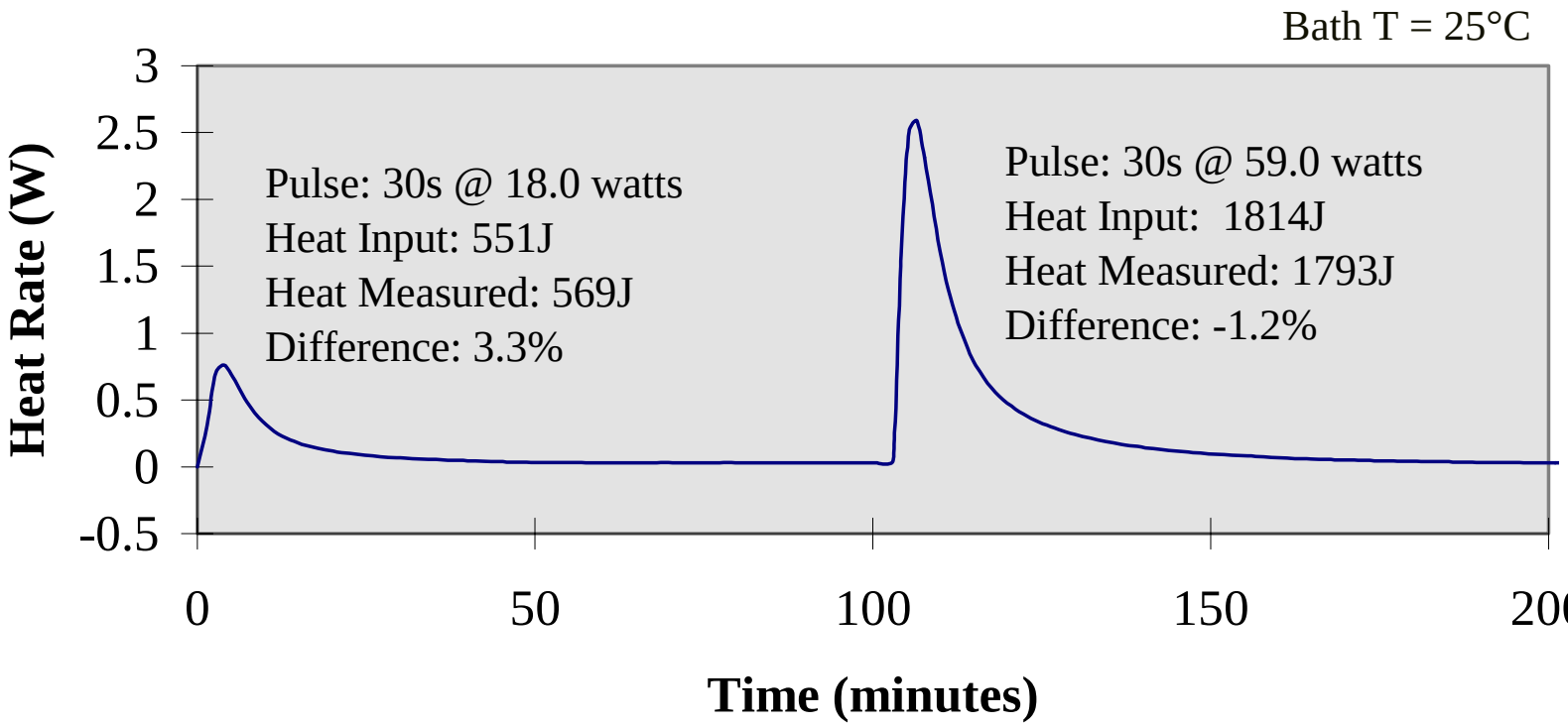
Results with the Simulated Module



Results with Internal Calibration Heaters

Tests done at NREL

Calorimeter Response Using Internal Heaters



Cycling Modules in the Calorimeter

We Use a High Power Cycler

- Cycling modules in the calorimeter
- Capable of simulating any driving power profile
- Up to 530 amps for HEV applications

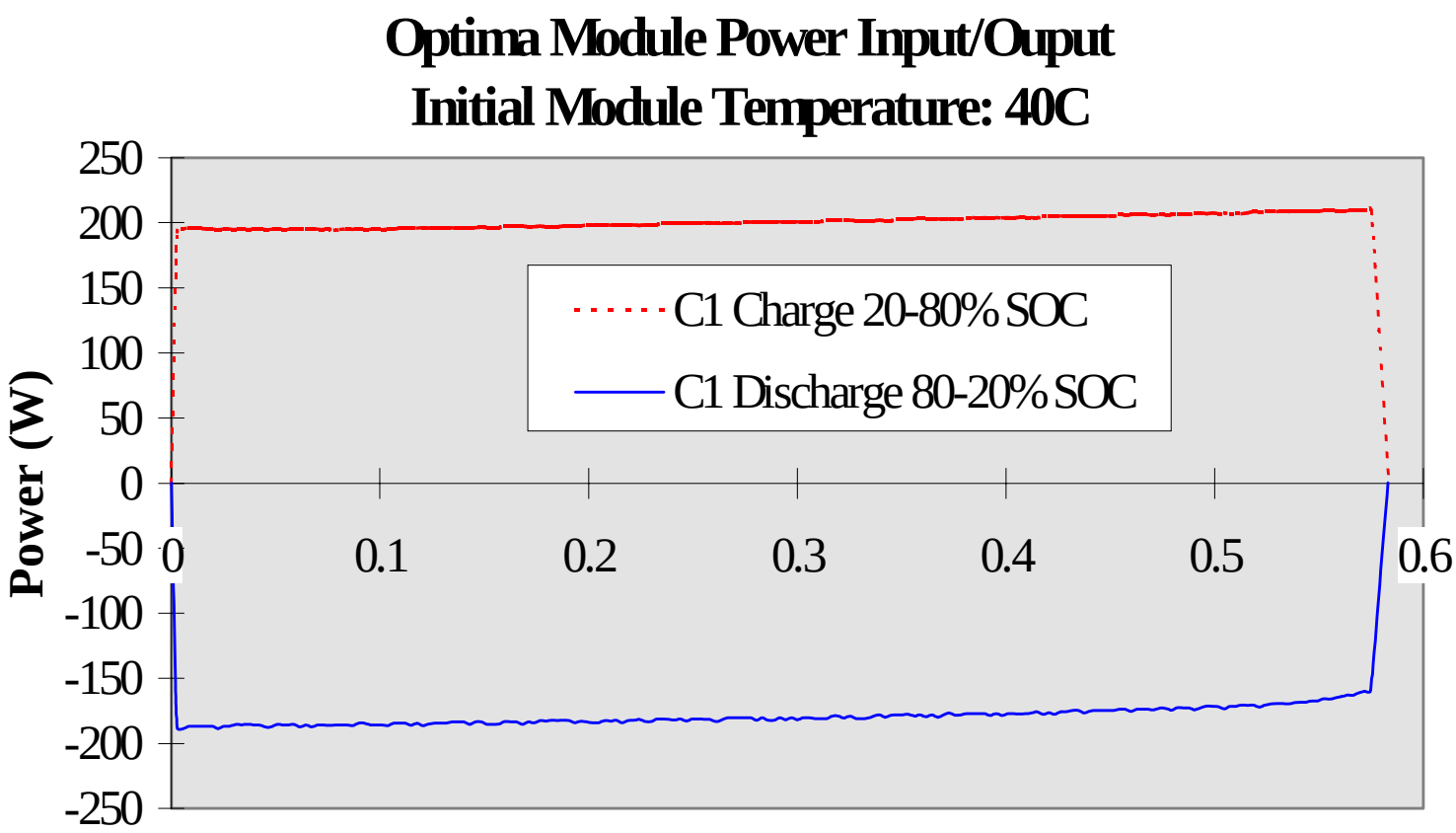
The Calorimeter/Cycler for High-Power Batteries

Center for Transportation Technologies and Systems

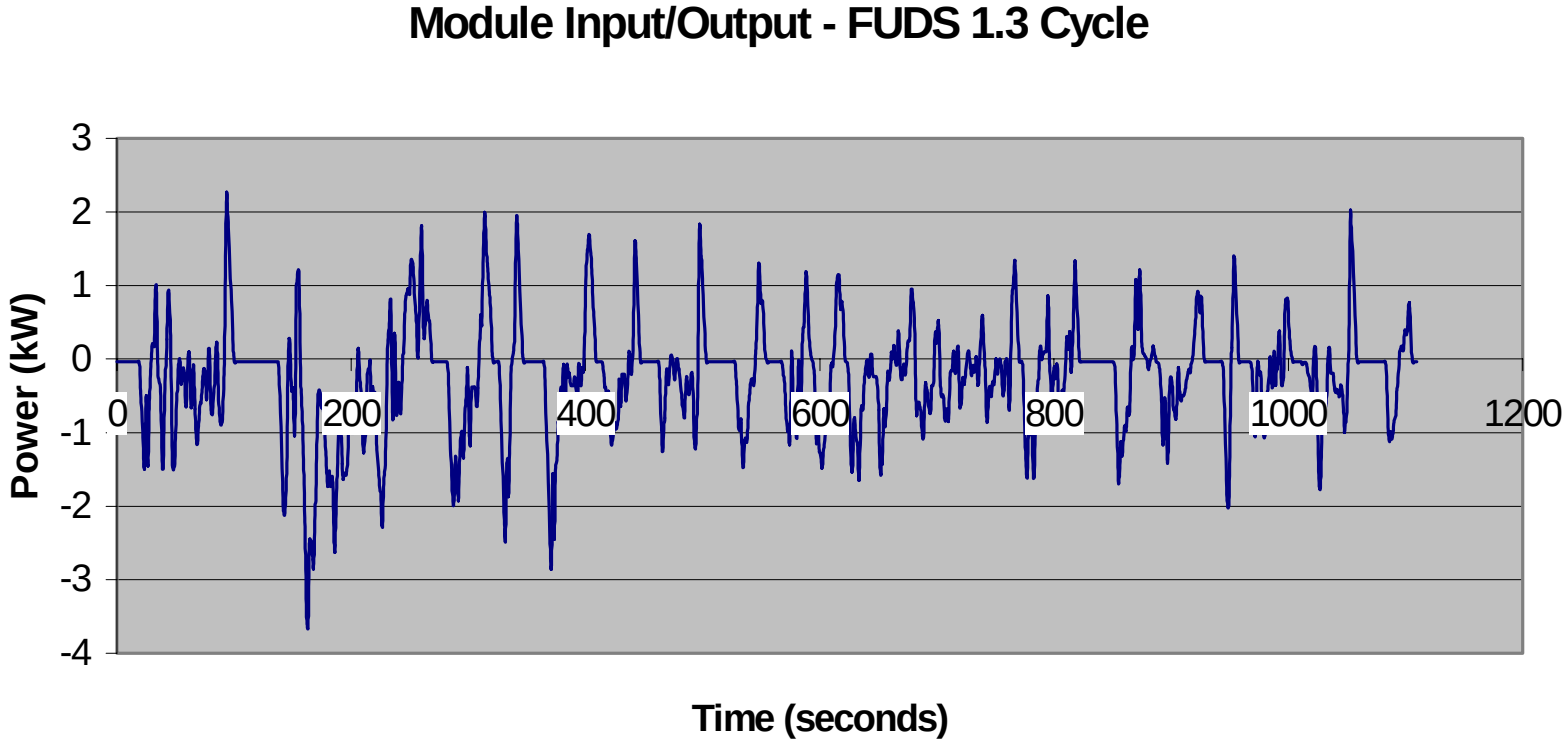
Recent Results with an HEV Module

- Constant Charge (C1 or C2)
- Constant Discharge (C1 or C2)
- FUDS 1.3 HEV Cycle

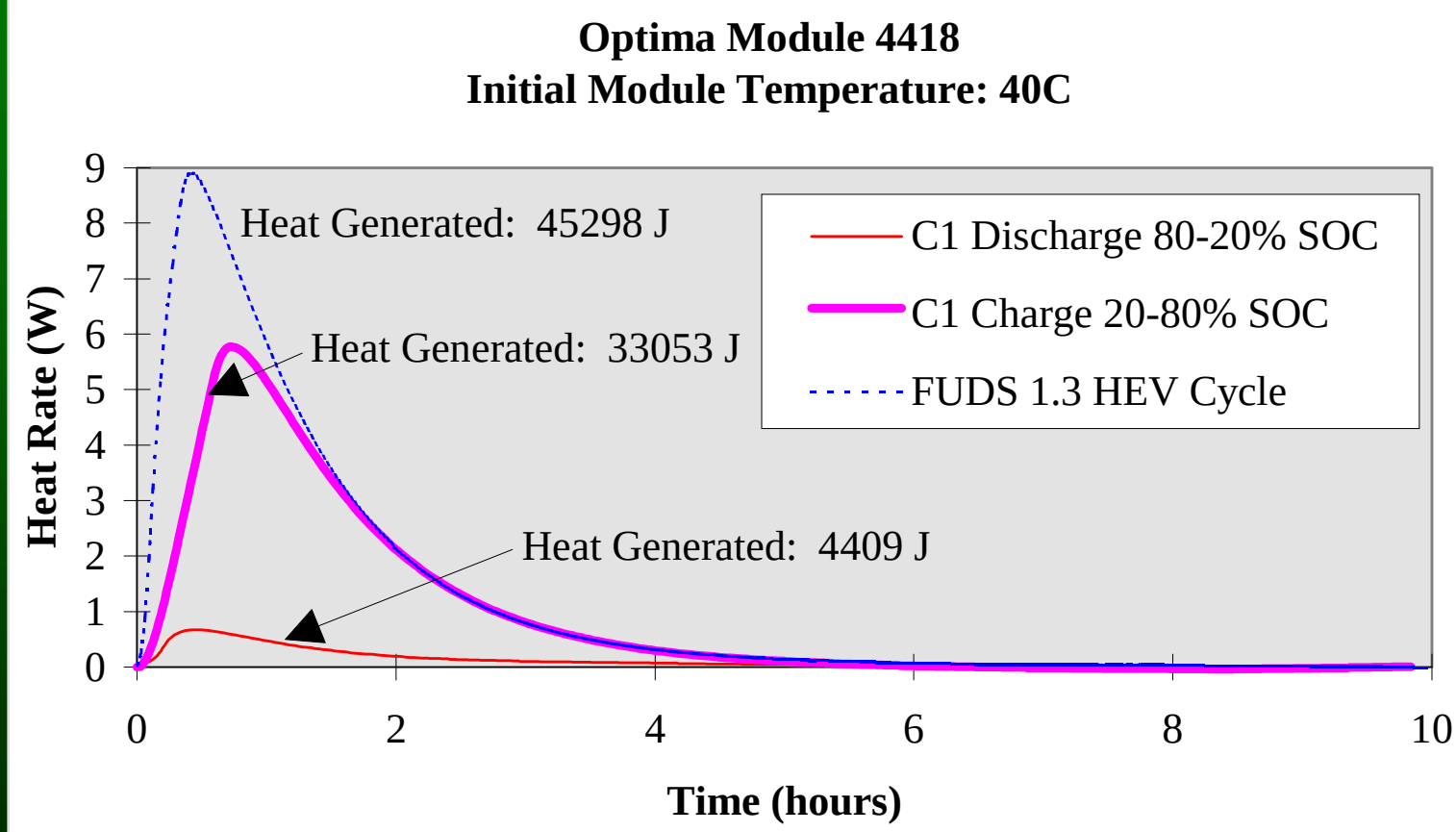
Constant-Current Profile for an HEV Module



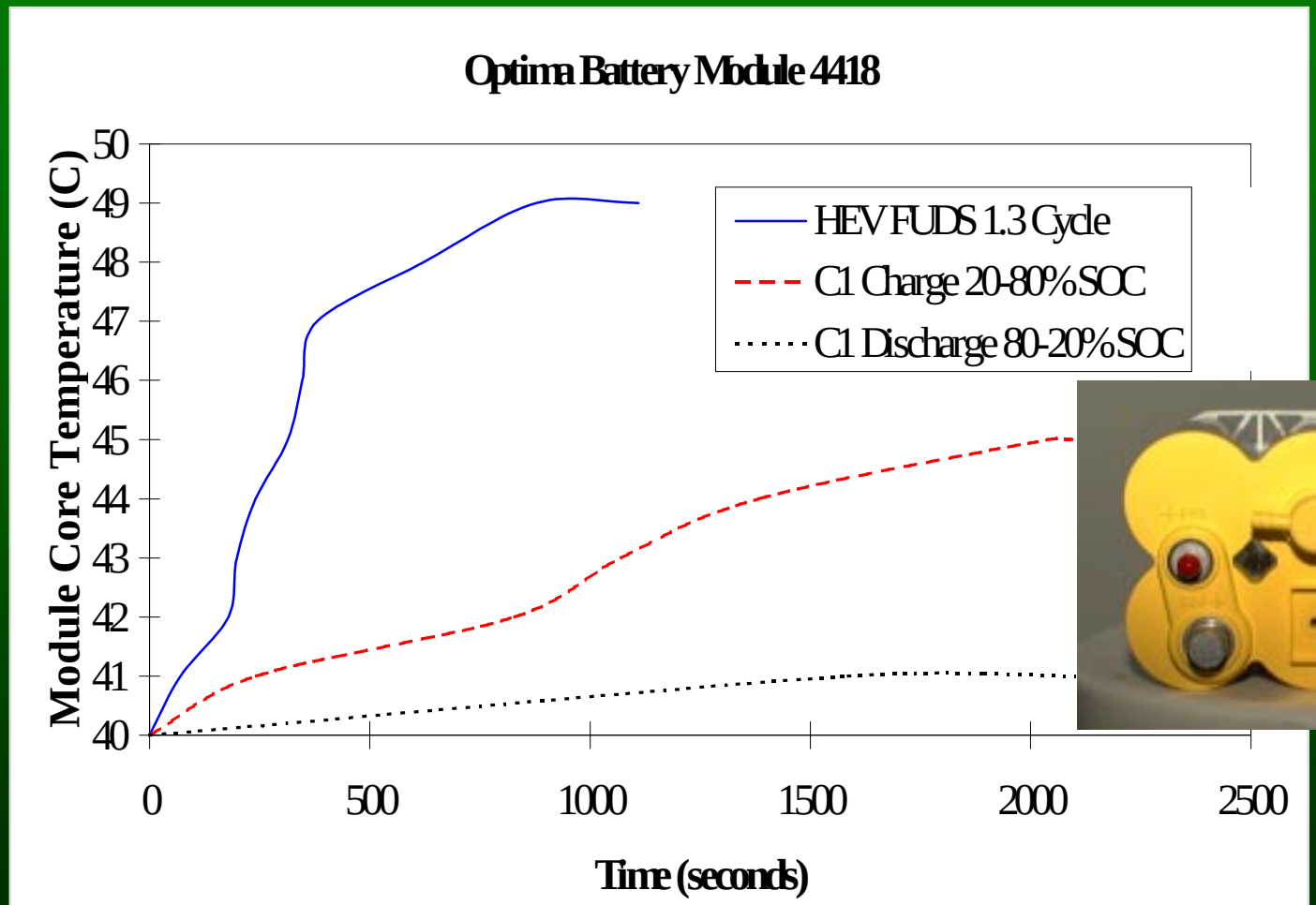
HEV FUDS 1.3 Power Profile for a Module



Response of the Calorimeter



Module Temperature during Cycling



Recent Calorimetry Data for an HEV Module

Cycle	Temp °C	Amperage	Initial SOC (%)	Final SOC (%)	Heat Generated (J)
Constant Charge	25	16.5	20	80	32679
Constant Discharge	25	-16.5	80	20	16702
Constant Charge	25	33.0	20	80	48868
Constant Discharge	25	-33.0	80	20	21705
Constant Charge	40	16.5	20	80	33053
Constant Discharge	40	-16.5	80	20	4409
Constant Charge	40	33.0	23	80	43428
Constant Discharge	40	-33.0	80	23	9237
HEV Cycle	40	FUDS 1.3	70	70	45298

Summary

- A new battery calorimeter for large modules has been developed and tested.
- Met specifications (baseline stability of ± 1 mW, min heat effect of 10 J, better than 5% accurate).
- A high power cycler is being used to cycle HEV modules in the calorimeter.
- Heat generation data currently being obtained for DOE HEV Program.
- Plan to test modules of different sizes and chemistries for other applications.

For Questions and Information

Standard or Custom Calorimeters

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