# Lithium Ion Battery Module Thermal Run-Away Studies

A Battery Module Design and Analysis Case Study

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Design Automation Associates Inc.

# About DAA

**DAA implements Engineering and Manufacturing digital automation which improves manufacturers’ product development cycle times, cost, and quality**

## Qualifications

- 50 employees all US Based and ITAR compliant
- 22 years PLM Digital Engineering Experience
- 100+ clients
- Headquarters in Windsor Locks, CT

## Approach

- Deliver best in class consulting
- Collaborate with client
- Provide outstanding ROI

## Sample of Clients

Northrop Grumman, Collins Aerospace (A United Technologies Company), General Dynamics, ULA (United Launch Alliance), Curtiss-Wright, HondaJet, Lockheed Martin, Pratt & Whitney (A United Technologies Company), NASA, EaglePicher Technologies, LLC, Virgin Orbit

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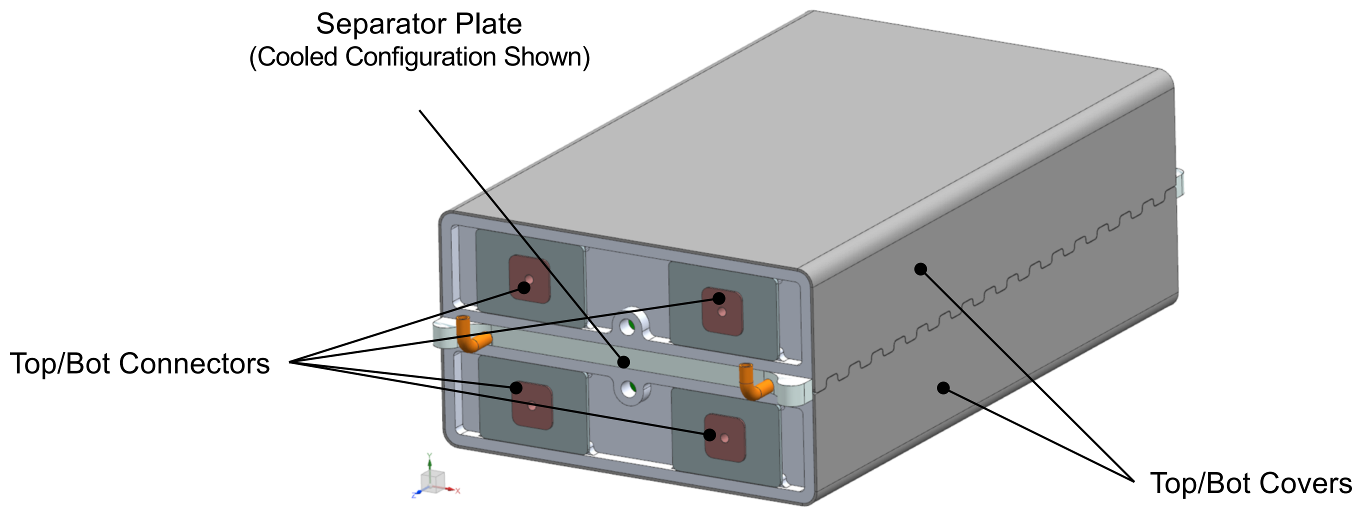
***95% of clients recommend DAA![1]***

# Abstract

A lithium-ion battery module is configured with two banks of cells separated by plates of various configurations with the intent of containing a thermal run-away chain reaction event. The transient study involves the initiation of thermal run-away for a row of cells on one bank and allowing other cells rows of the bank to run away due to heat transfer. Heat transfer through the dividing plate to the opposite bank is simulated for several plate configurations to test the susceptibility of the opposite bank to induced thermal run-away. Sensitivity to changes in plate material, geometry, and cooling are considered with considerations for minimizing space and weight requirements. General recommendations are made based on results and application.

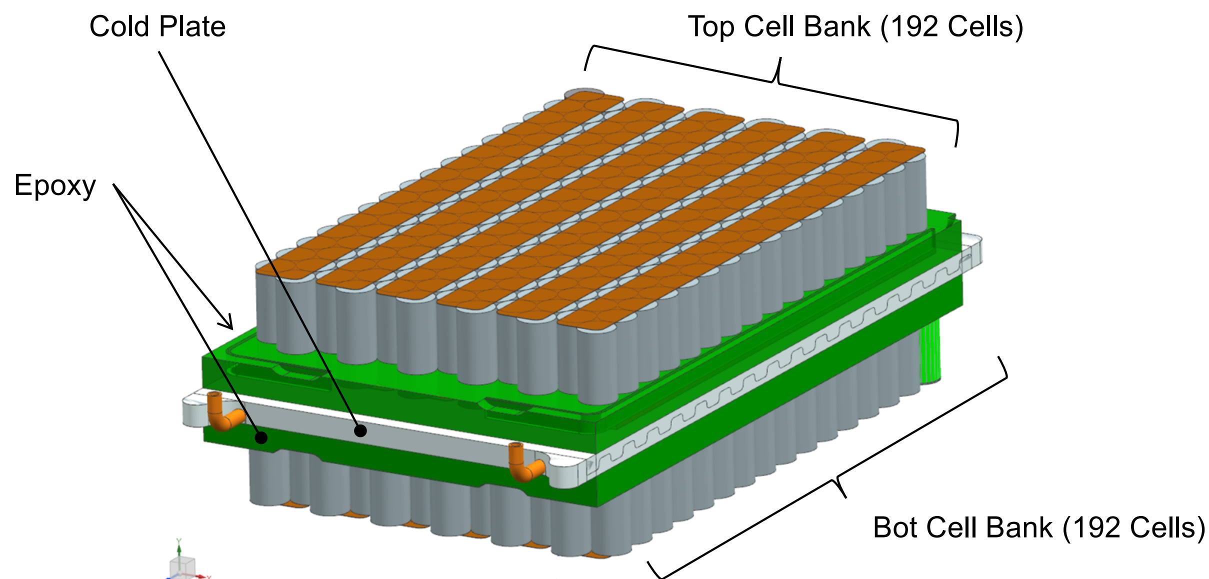



Dual Bank Li-Ion Battery Module w/ Separator Plate

# Introduction

## 12s16p 26650 Battery Module Characteristics

- Dual bank module, banks electrically isolated with cold plate
- Each bank: 12 rows in series, 16 parrallel cells per row (192 cells, ~38V)
- 26650 LiFePo4 cells (Similar to C-cells but 30% longer)
- Module dimensions ~53L x 30W x 17H cm
- Epoxy material to ~1/3rd cell length, thermally conductive, electrically insulating, Cotronics Duralco 4538
- Aluminum cold plate (53L x 30W x 1.5Thk cm)
- Copper bus connectors




Battery Module w/o Covers

# Introduction

## Study Scenario

Abuse initial condition consisting of:

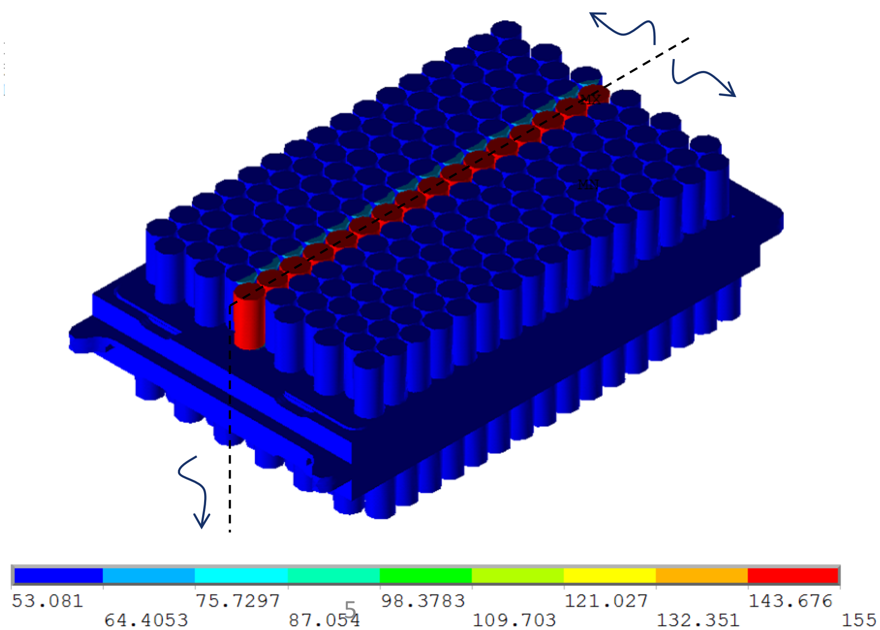
- 60°C Steady Ambient Temperature
- Initiated run-away temperature applied to one row of top bank cells ($T_0$ = 155°C)

Thermal Transient:

- All cells exceeding run-away threshold temperature (T > 150°C) start heat generation process (514,240,000 W/m^3) for 2 sec, to reach 520°C
- Cells cool naturally following 2 sec run-away

Question:

Does heat transfer through cold plate potentially create run-away conditions in opposite bank?

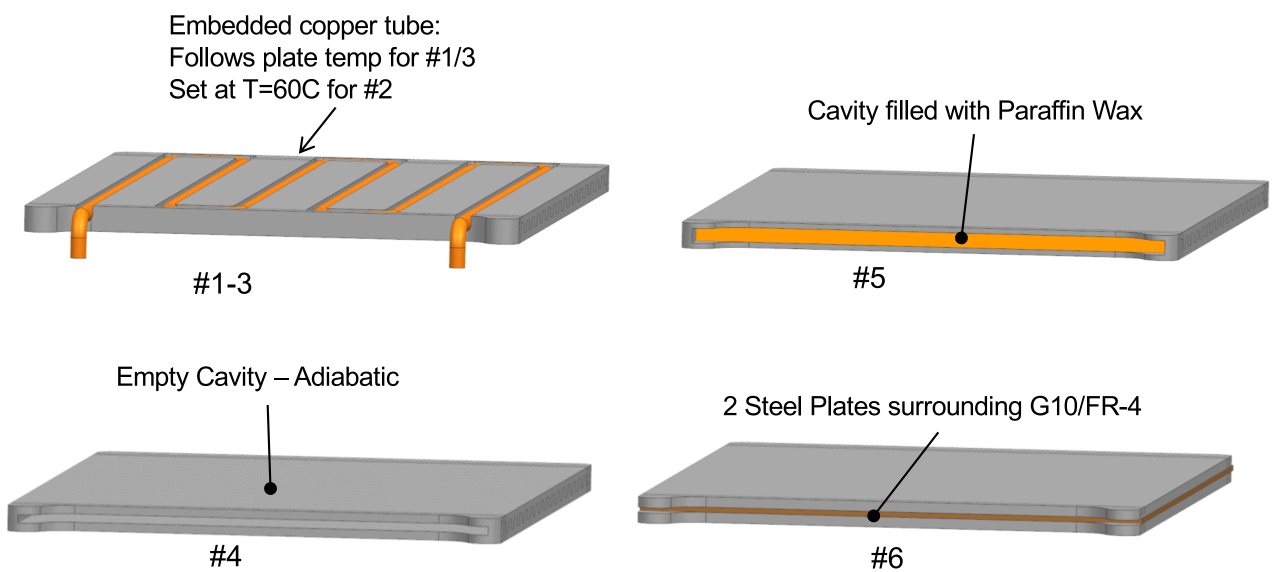


# Introduction

## Cold Plate Configurations

Study was performed for the following cold plate configurations:

1. Aluminum Plate, Cooling Deactivated
2. Aluminum Plate with Pumped Liquid Cooling
3. Stainless Steel Plate, Cooling Deactivated
4. Hollow Aluminum Plate
5. Hollow Steel Plate filled with paraffin phase change material (PCM)
6. Double Steel Plate with G10/Fr-4 insullator

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# Introduction

## Approach and Assumptions

Approach:

1. Transient conduction – external convection solution
2. ANSYS APDL Solution Sequence
3. Inital “Abuse” conditions: Module $T_0$ = 60°C, Run-away cell row $T_0$ = 155°C
4. Initiate 2 sec. heat generation event for any cells exceeding 150°C to get to 520°C
5. Allow heat to dissipate, initiate run-away in adjacent cells
6. Continue transient until initiations stop (may or may not reach opposite bank)

Assumptions:

1. Negligible contact resistances between parts
2. Radiation not considered
    - *Radiation is next logical addition to analysis; expected to increase propgation rate between cells of run-away bank but impede propgation to opposite bank becasue of added heat transfer to cover.*
3. 2 sec. time step
4. Criteria for initiating cell run-away: $T_{AVG}$ > 150°C
5. Cells modelled using empirical bulk average orthotropic properties
6. External film coefficient 1.5 W/(m^2-C)
7. Negligible internal convection

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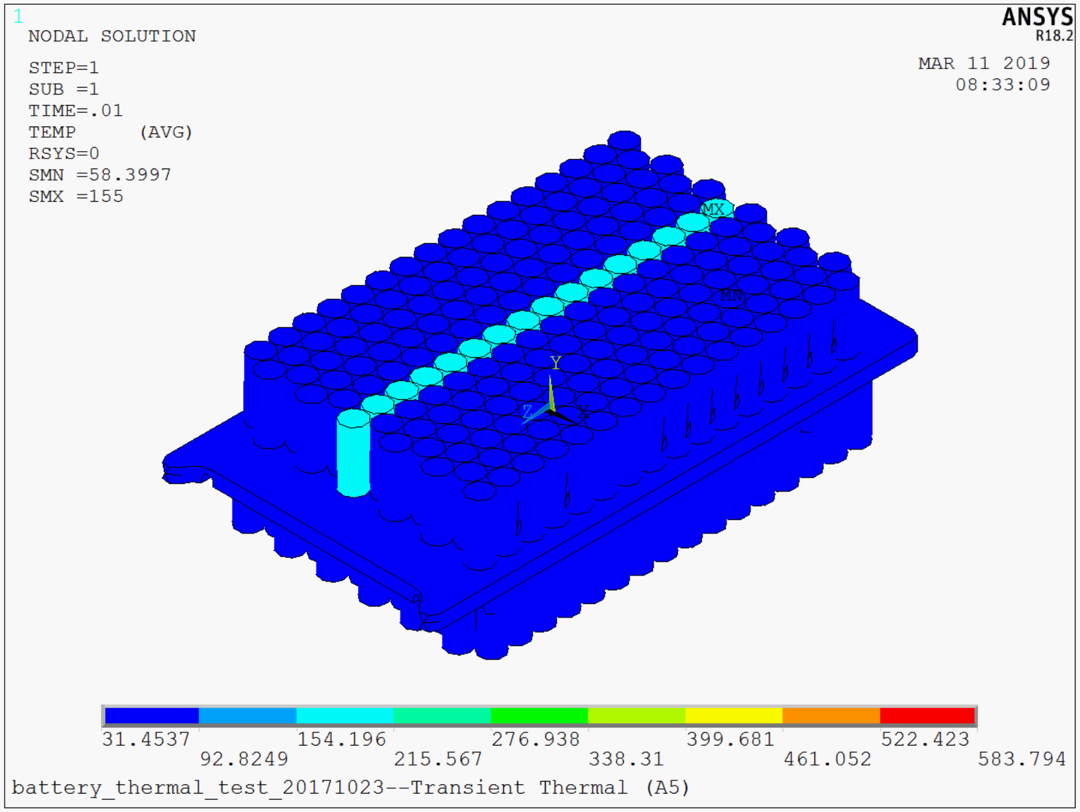
# Results

## Aluminum Plate, Cooling Deactivated

*Bottom bank initiates run-away in 828 sec.*

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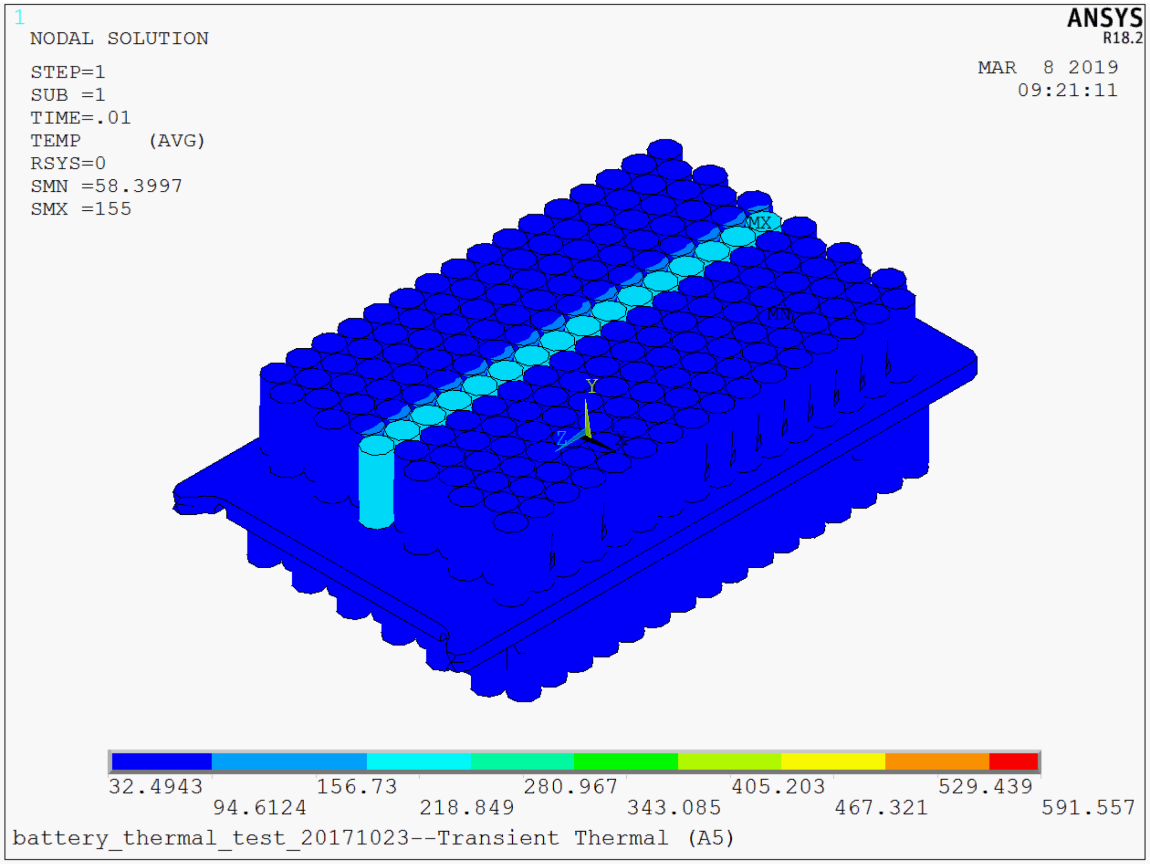
# Results

## Aluminum Plate, With Pumped Liquid Cooling

*Bottom bank does not run-away*

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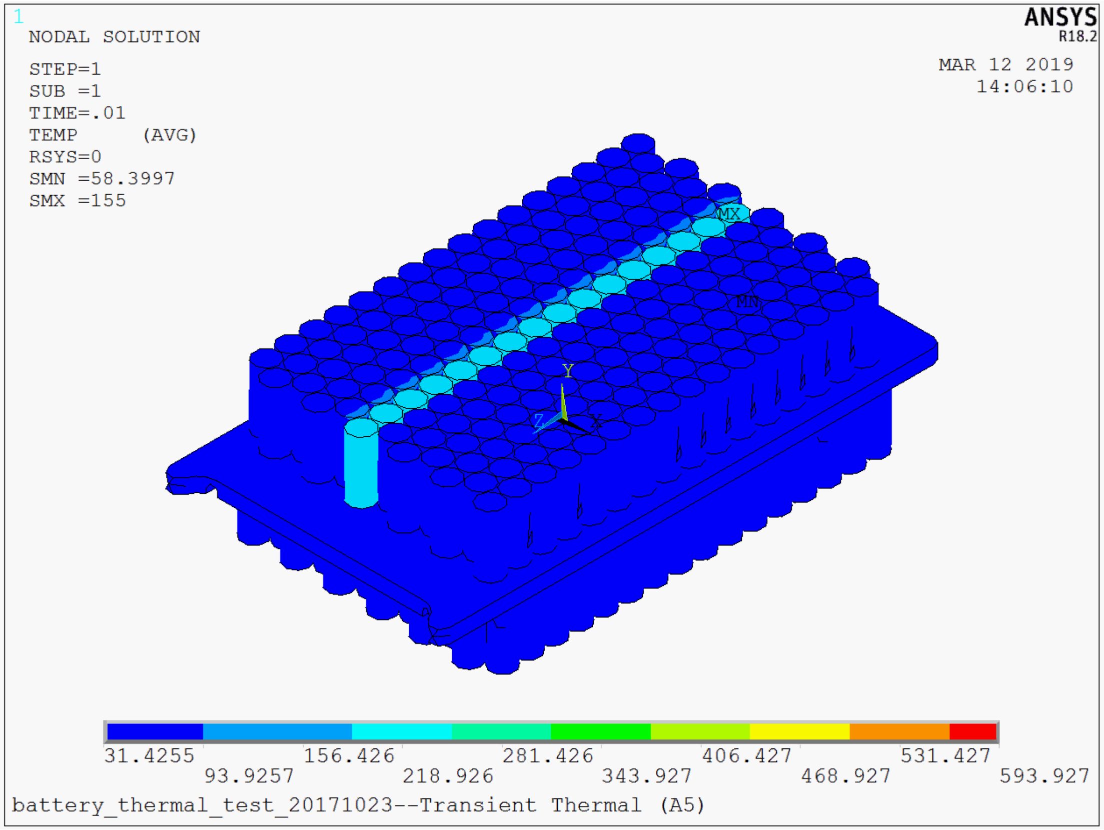
# Results

## Stainless Steel Plate, Cooling Deactivated

*Bottom bank initiates run-away in 996 sec.*

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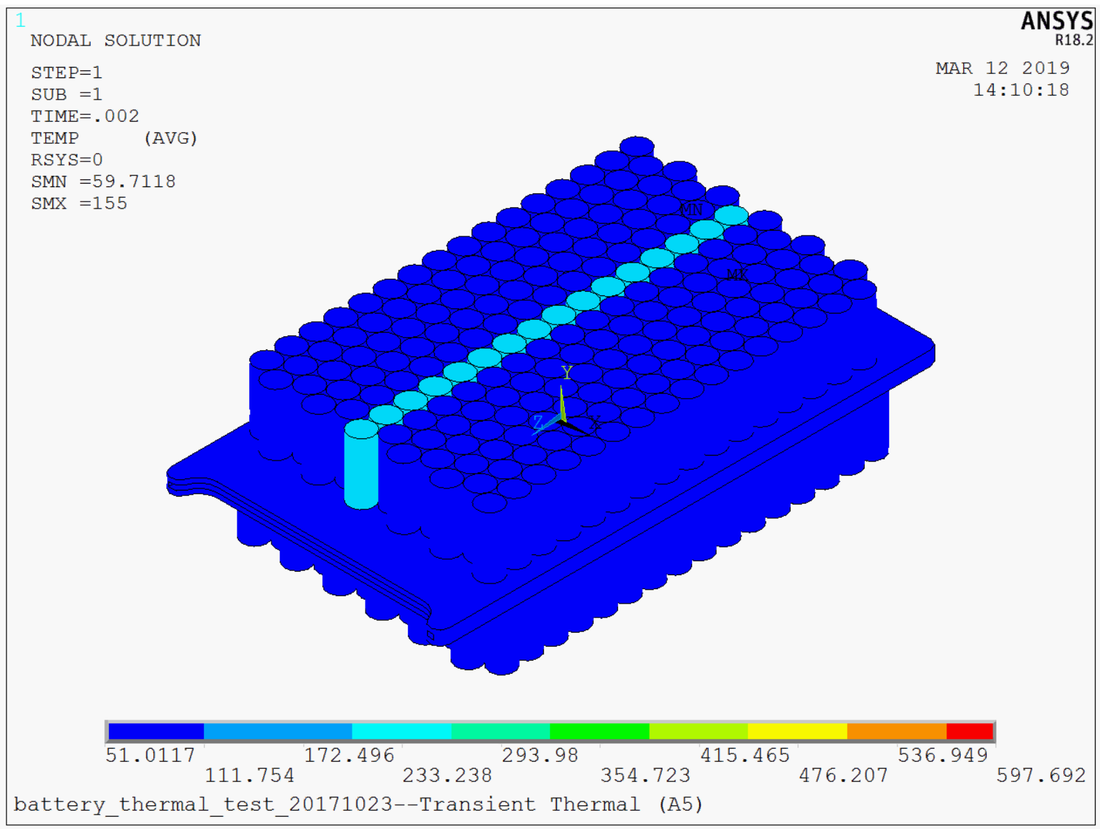
# Results | Hollow Aluminum Plate

*Bottom bank initiates run-away in 992 sec.*

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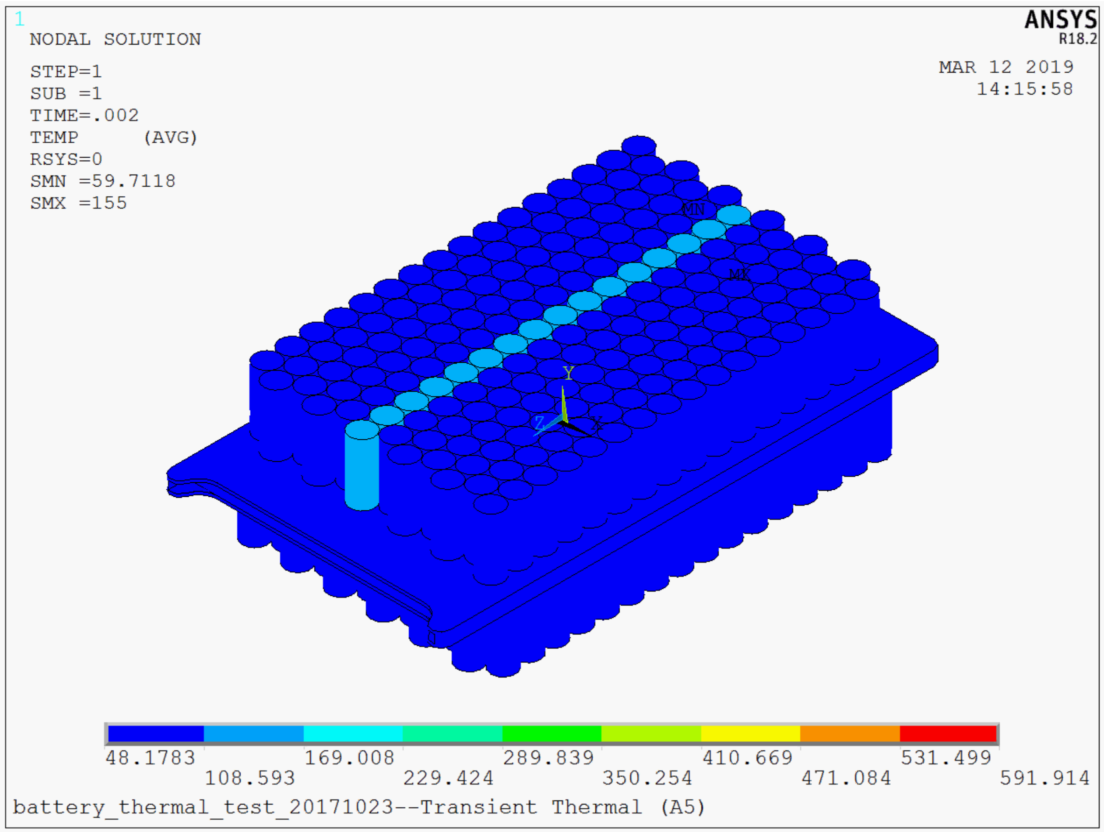
## Results

### Hollow Steel Plate Filled with Paraffin Phase Change Material (PCM)

*Bottom bank initiates run-away in 1392 sec.*

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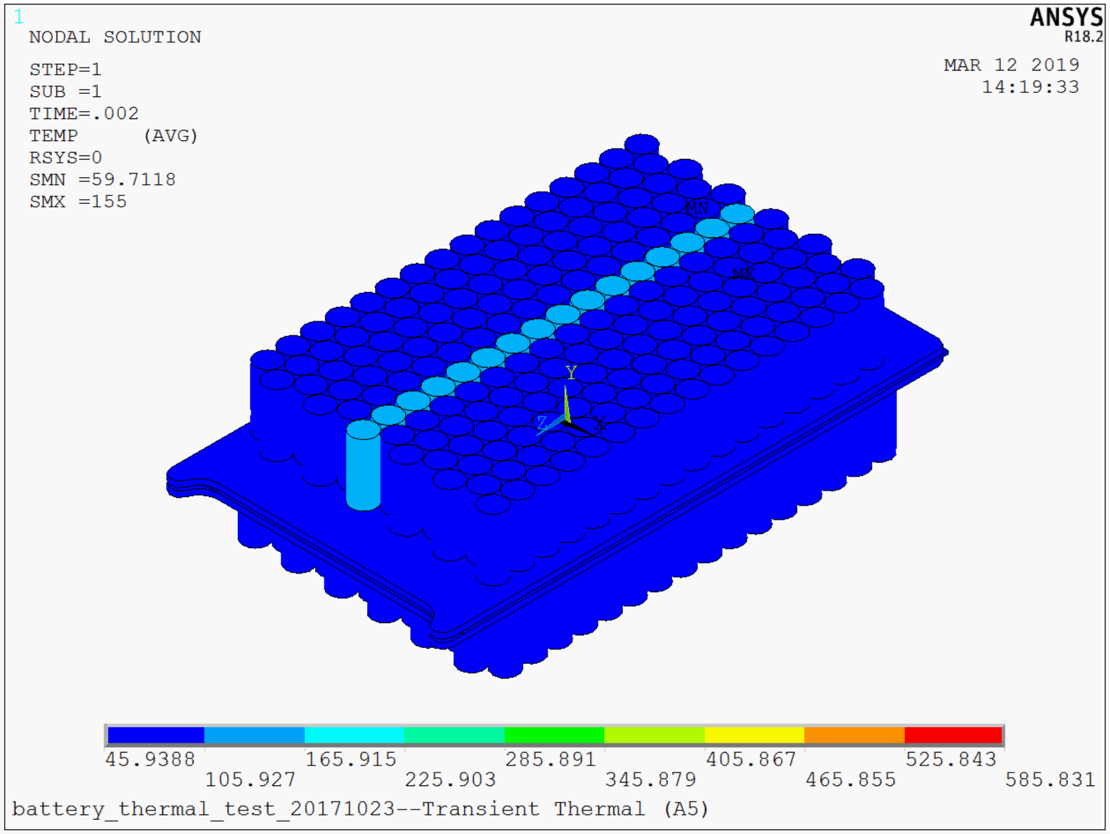
# Results

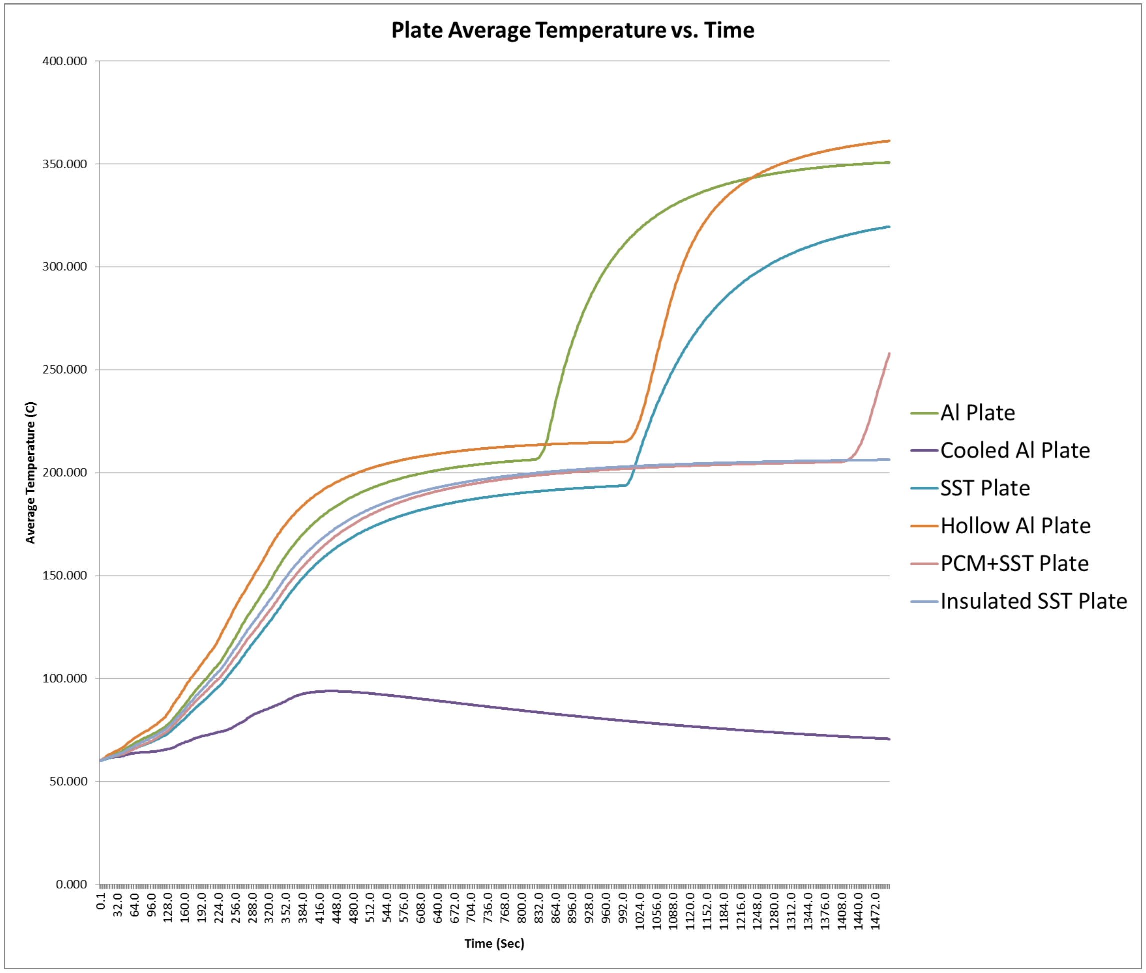
## Double Steel Plate with G10/Fr-4 Insullator

*Bottom bank does not run-away*



# Results

## Average Plate Temperature vs. Time

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# Conclusions

- Actively cooled plate provides best results
  - Greatest cost, complexity and overall space
  - Small to moderate plate space
- Isullated double plate prevents opposite side run away but requires sufficent thickess to be verified by analysis
  - Cheapest working solution
  - Moderate space and weight
  - Can be used with either steel or alluminum
- PCM filled plate did not work in this example but can be made to work with added volume
  - Requires the most plate space and weight at moderate cost
  - Need to address issues of contact guerentee and extreme thermal expansion
- Simple solid and hollow plates not likely to work unless made very large

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