Development of a 2D+ Dynamic Model of an Aluminum Reduction Cell

Marc Dupuis

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Plan of the Presentation

- The Hall-Héroult Cell
- Modeling the Hall-Héroult Cell
- Thermo-electric Steady State Models
  - Full 3D Cell Slice
  - Full 2D+ Cell Slice
- 1D Thermal Model Concept
- 1D Dynamic Model
- Full 2D+ Cell Slice Dynamic Model
- Models Response Comparison
  - Normal Operation, Eutectic Superheat
  - Normal Operation, Liquidus Superheat
  - Power Loss, Liquidus Superheat
- Conclusions

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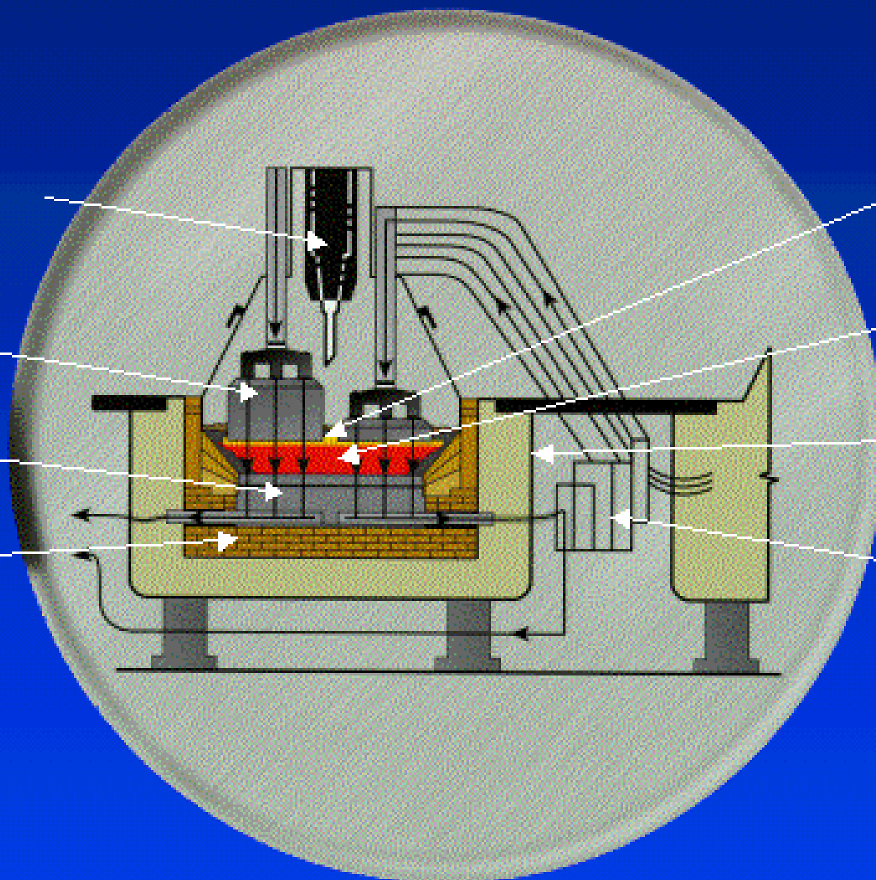
The Hall-Héroult Cell

- Superstructure
- Anode
- Cathode
- Lining Bricks



- Electrolyte
- Liquid Metal
- Steel Shell
- Busbar

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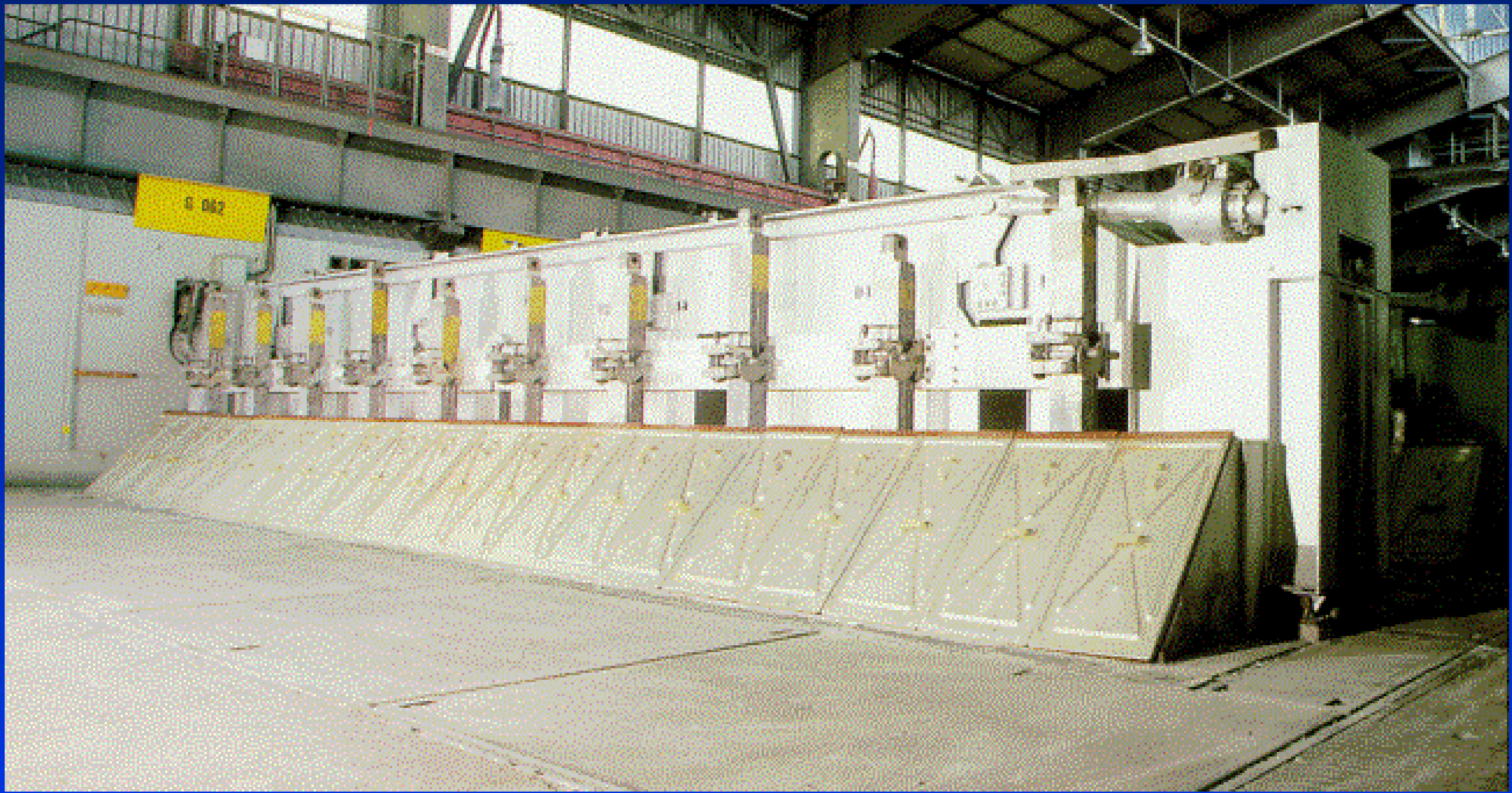
The Hall-Héroult Cell



The Most Modern Technology:

The AP30 from Pechiney

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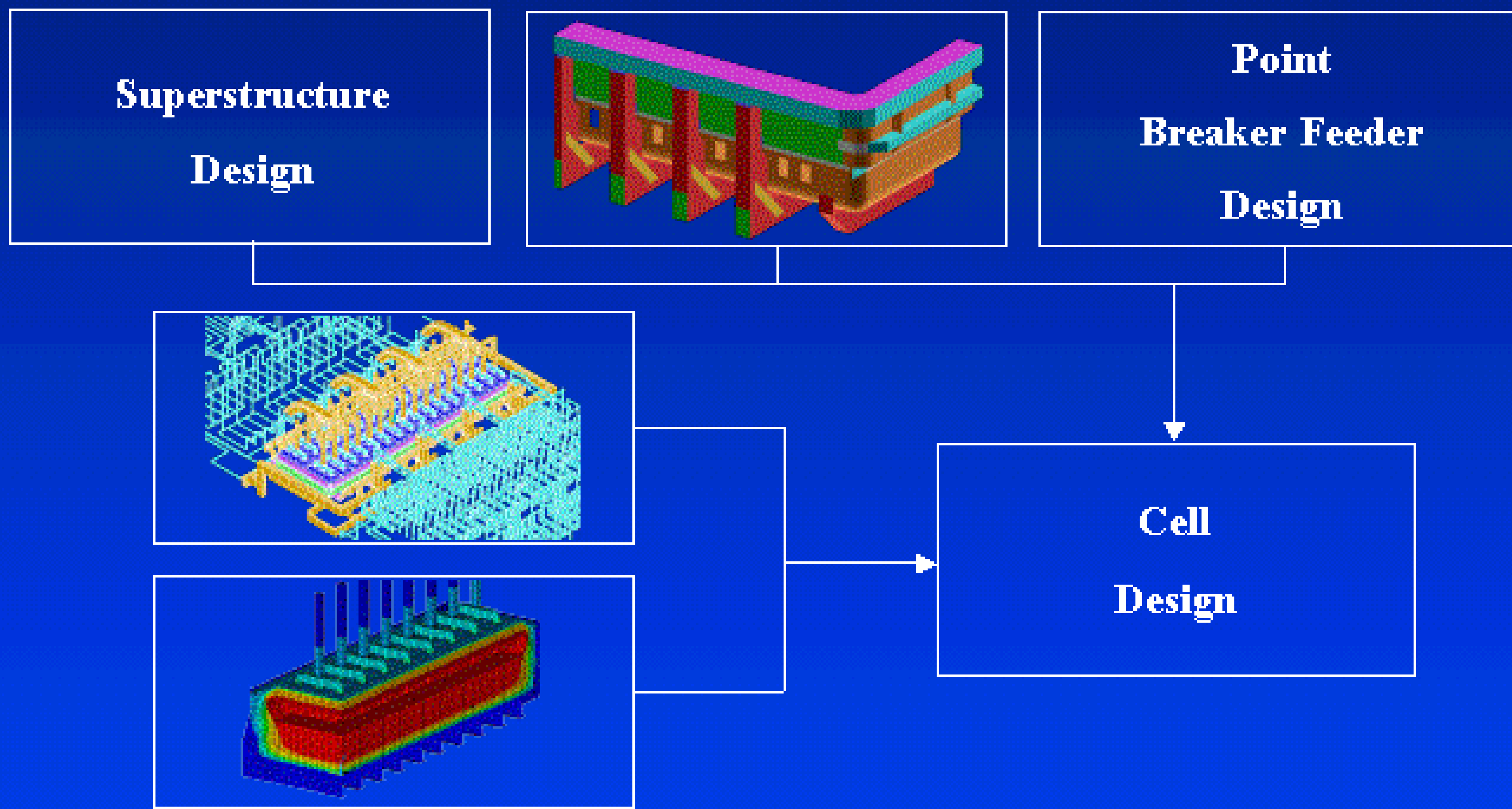
Modeling the Hall-Héroult Cell



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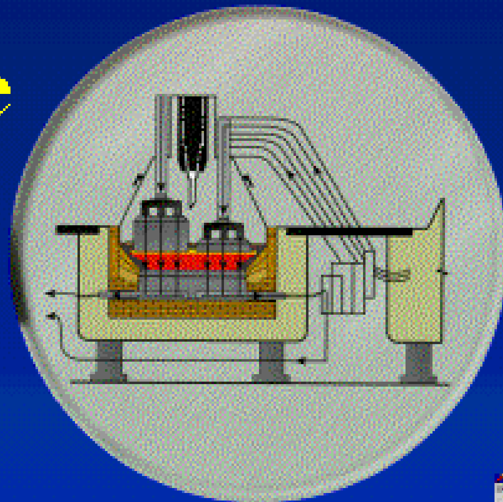
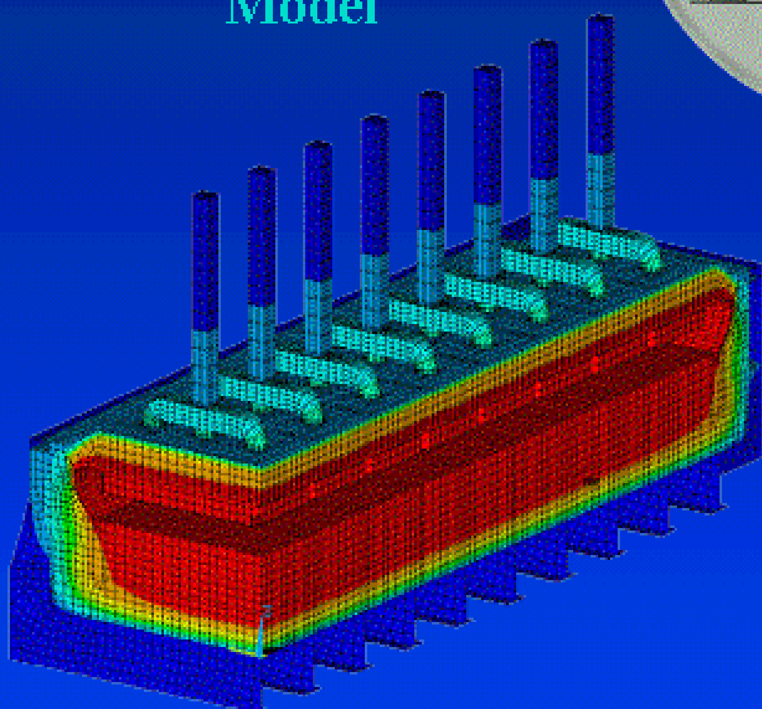
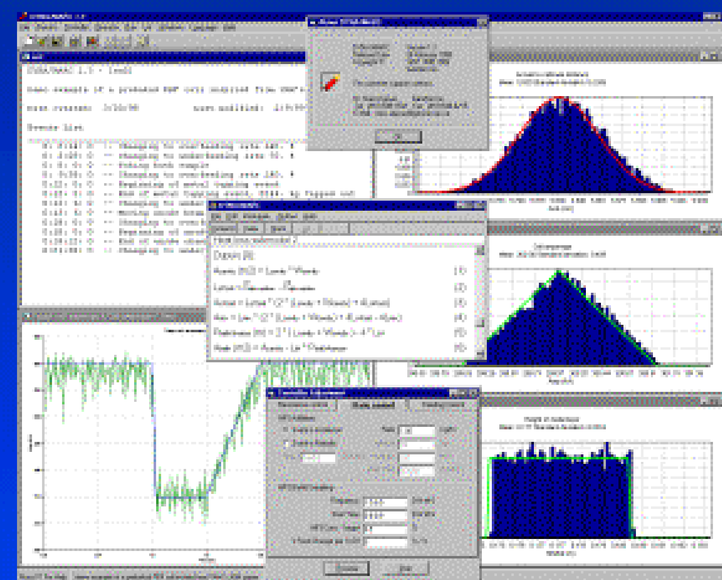
Modeling the Hall-Héroult Cell



Thermo-electric
3D Steady State
Model



Thermo-electric
1D Dynamic Model



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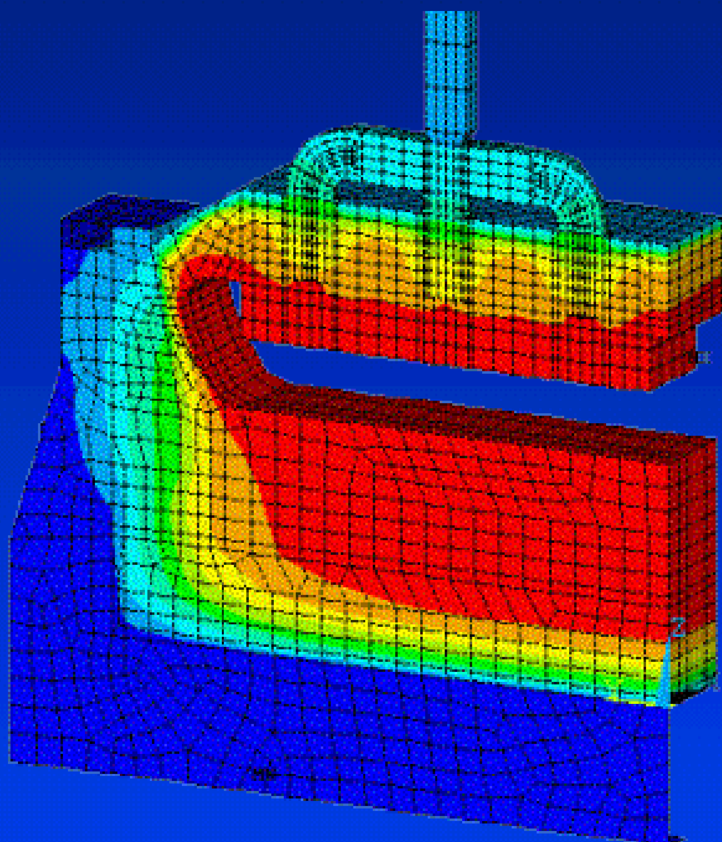
The Full 3D Cell Slice S.S. Model



- Most efficient (fast and accurate) steady-state model available
- Require around 30 min. CPU to converge S.S. solution on a Pentium II 266 MHz PC

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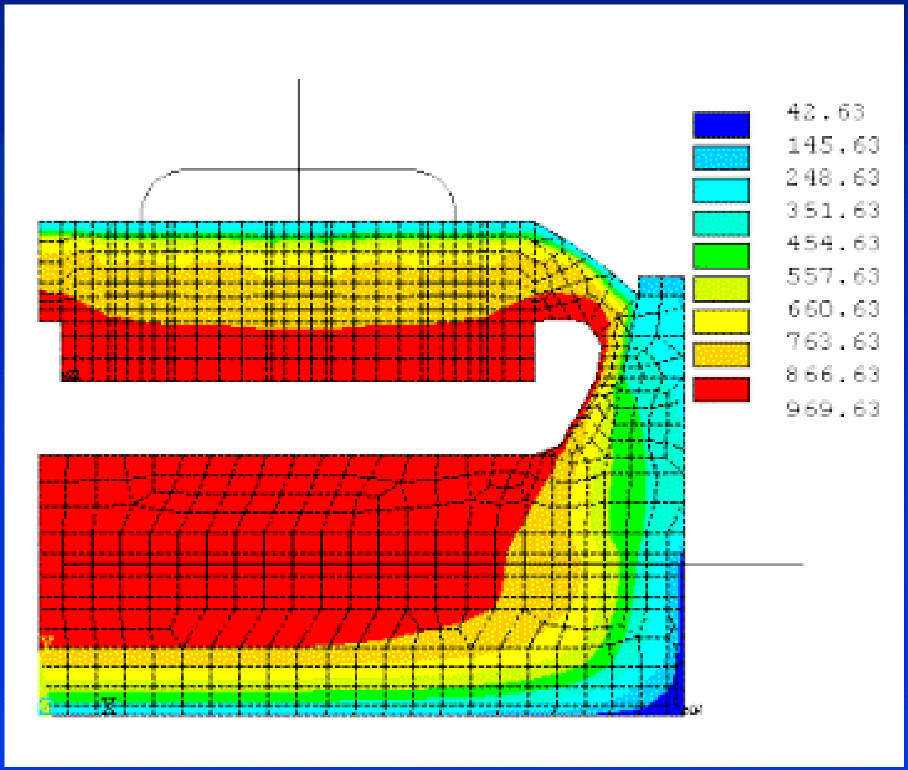
The Full 2D+ Cell Slice S.S. Model



- Fastest FE steady-state model available
- Require less than 5 min. of CPU to converge S.S. solution on a Pentium II 266 MHz PC

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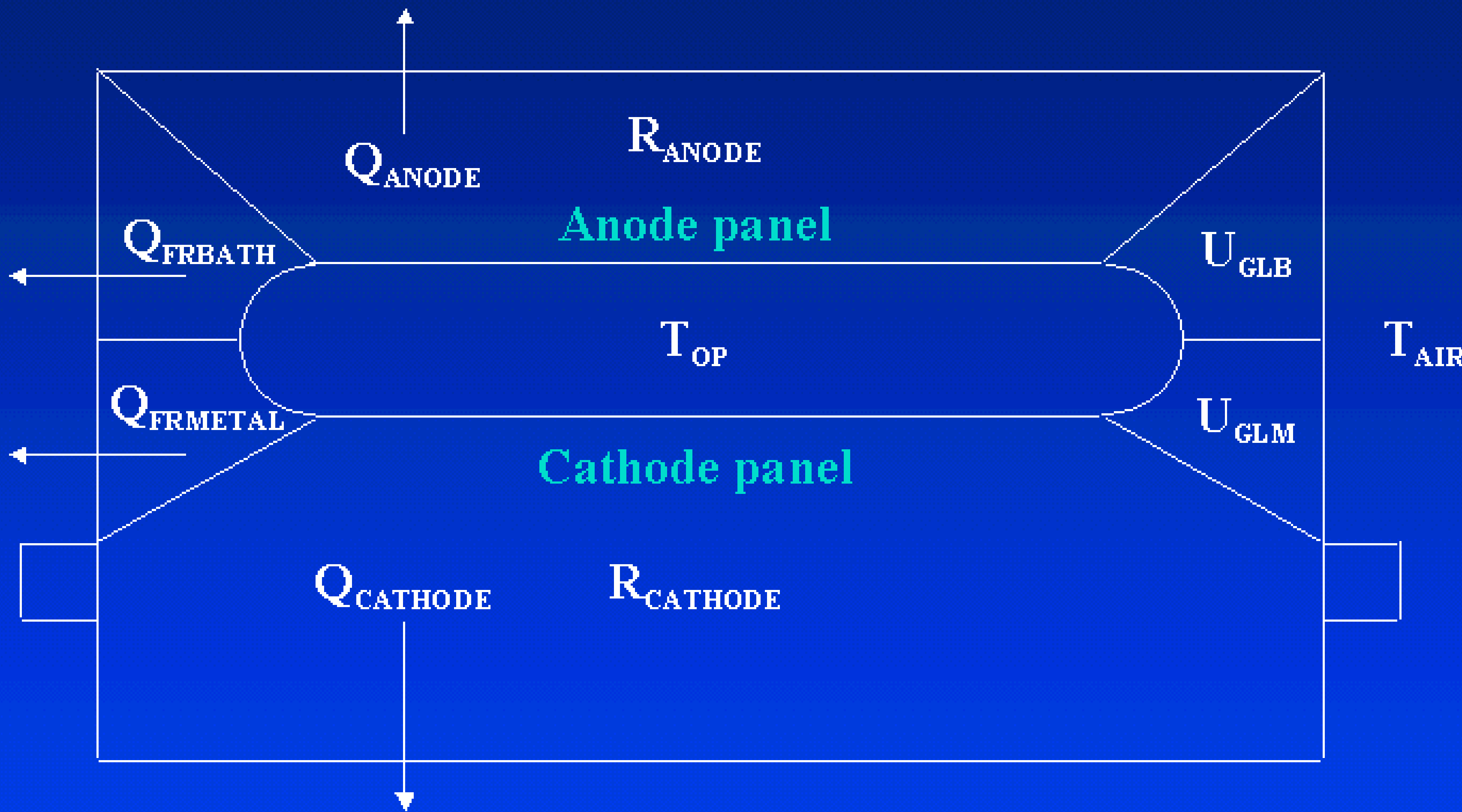
1D Thermal Model Concept



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1D Thermal Model Equations

$$Q_{ANODE} = R_{ANODE} * (T_{OP} - T_{AIR})$$

$$Q_{CATHODE} = R_{CATHODE} * (T_{OP} - T_{AIR})$$

$$Q_{FRBATH} = h_{FRB} * A_{BATH/LEDGE} * (T_{OP} - T_{MLT}) = U_{GLB} * A_{BATH/LEDGE} * (T_{OP} - T_{AIR})$$

$$Q_{FRMETAL} = h_{FRM} * A_{METAL/LEDGE} * (T_{OP} - T_{MLT}) = U_{GLM} * A_{METAL/LEDGE} * (T_{OP} - T_{AIR})$$

$$U_{GLB} = \frac{1}{\left(\frac{1}{U_{FLXB}} + \frac{1}{U_{FRB}}\right)}$$

$$U_{GLM} = \frac{1}{\left(\frac{1}{U_{FLXM}} + \frac{1}{U_{FRM}}\right)}$$

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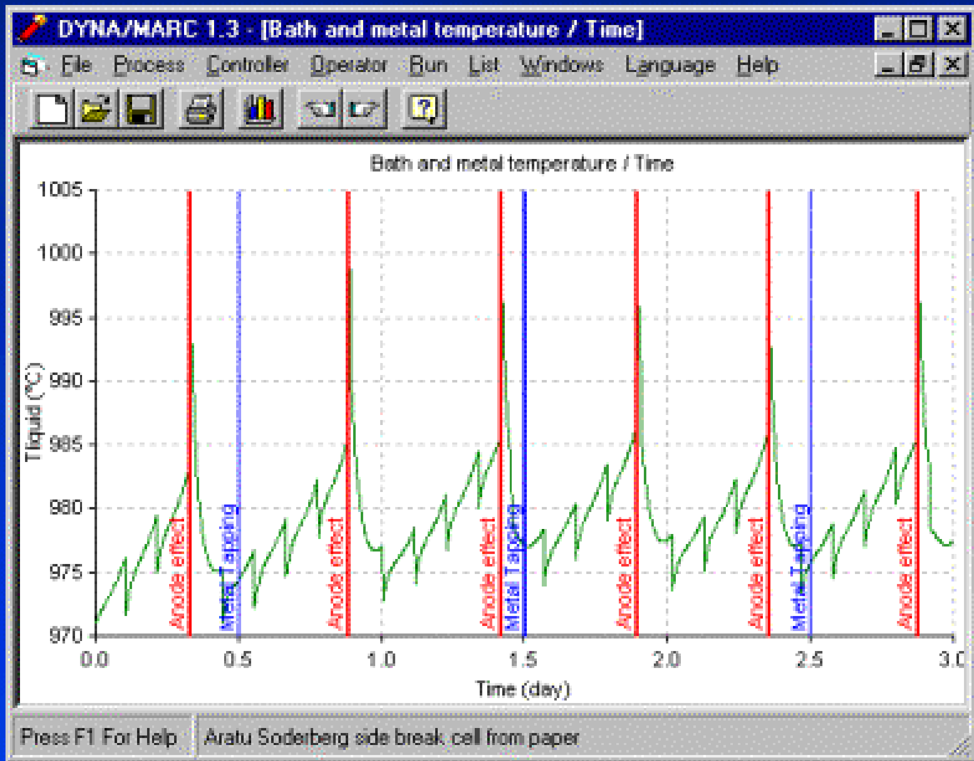
The 1D Dynamic Model



- Compute thousands of steady-state solutions in seconds
- Compute weeks of dynamic operation in seconds using 2 min. time step

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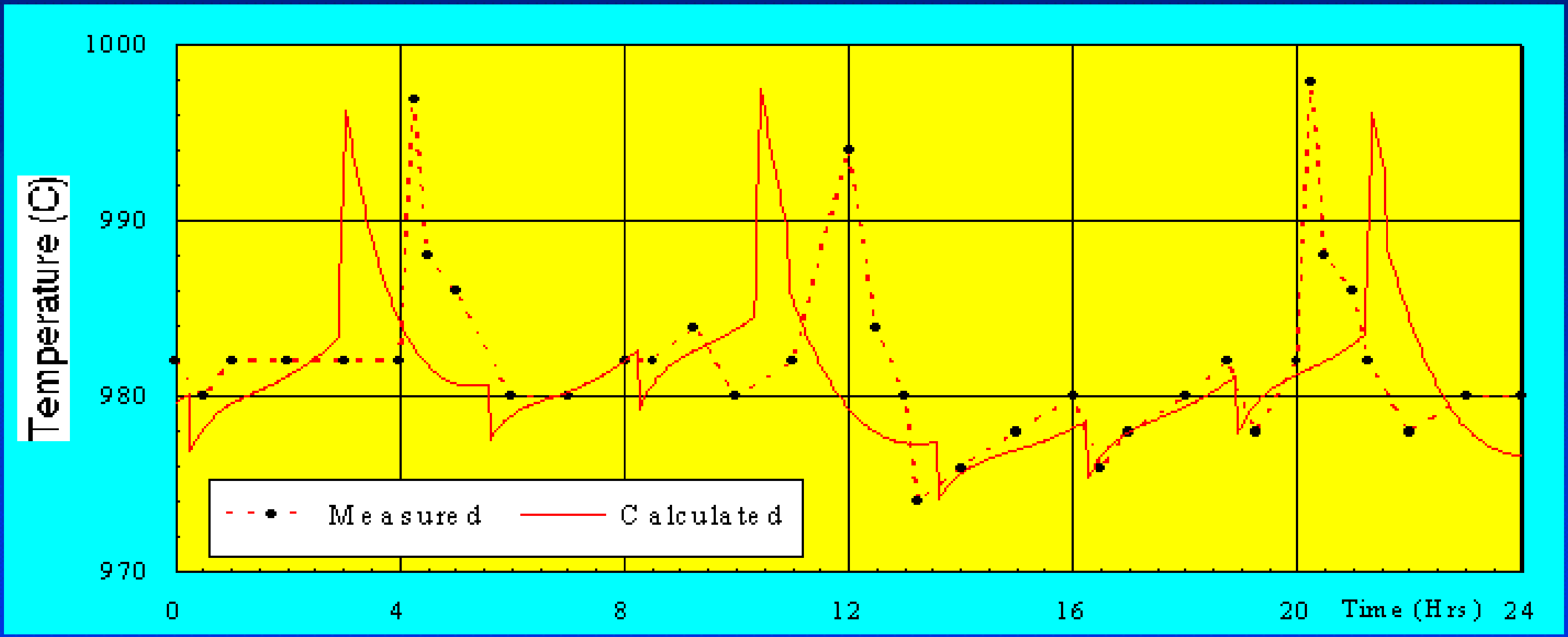
The 1D Dynamic Model



- Accurate reproduction of measured cell behavior (TMS 96)

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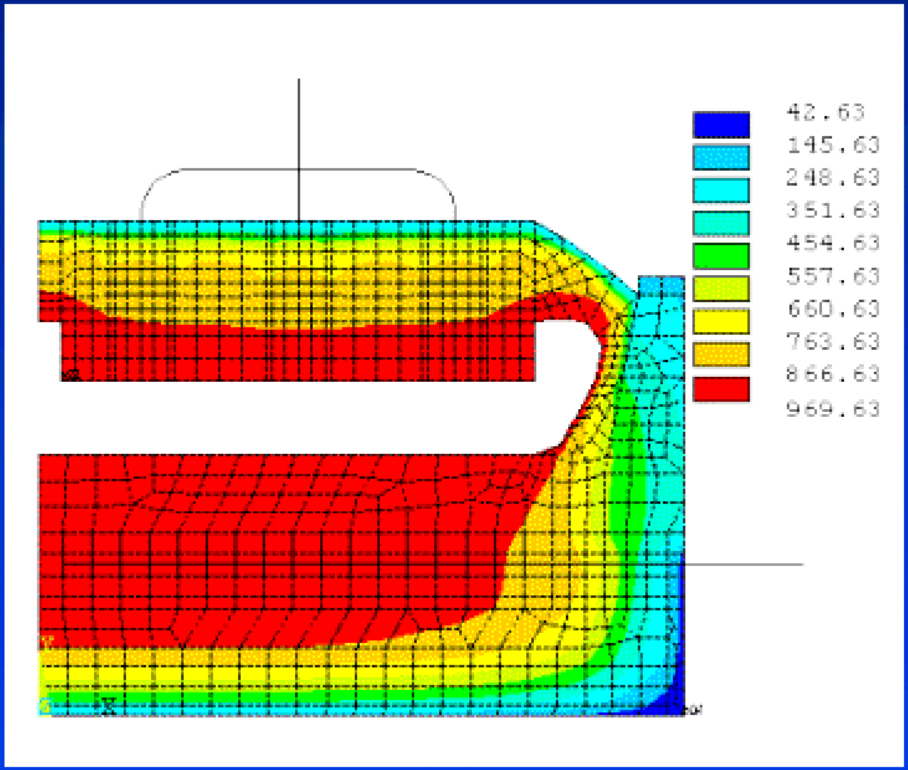
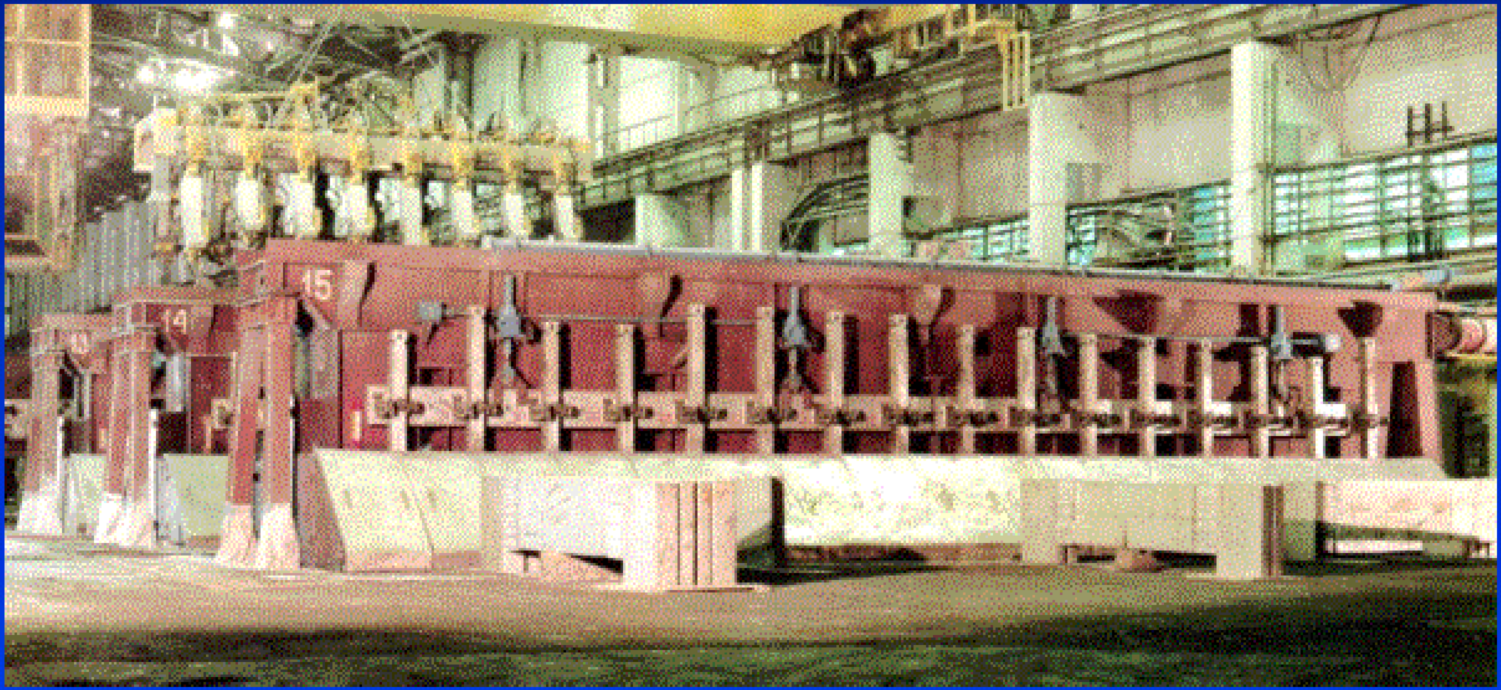
The 2D+ Full Cell Dynamic Model



- More accurate FE 2D+ thermal model implemented in a dynamic model

- Require 1 hour and 30 min. of CPU to compute 1 hour of operation using 2 min. time step on a Pentium II 266 MHz PC

Demonstration Model Inspired from the VAW's 300 kA Cell (JOM Feb. 1994)



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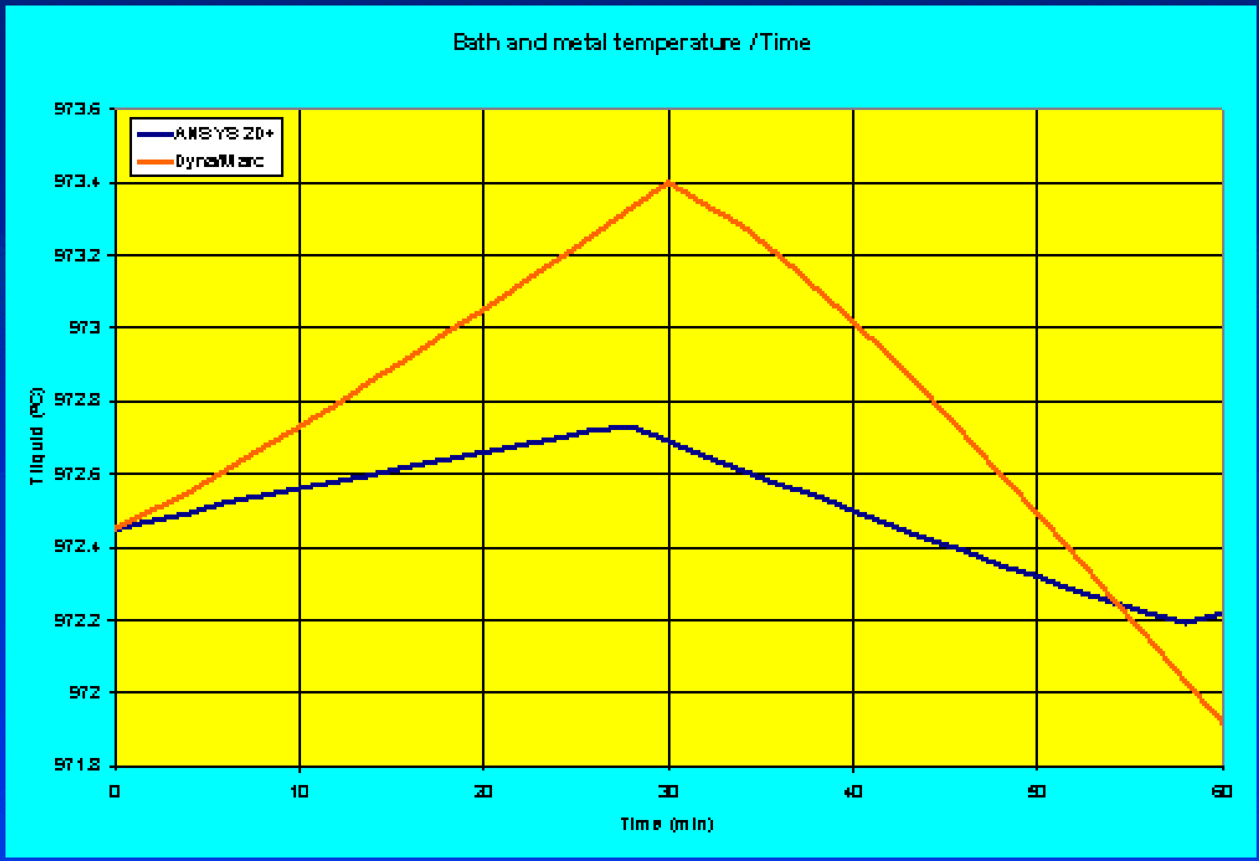
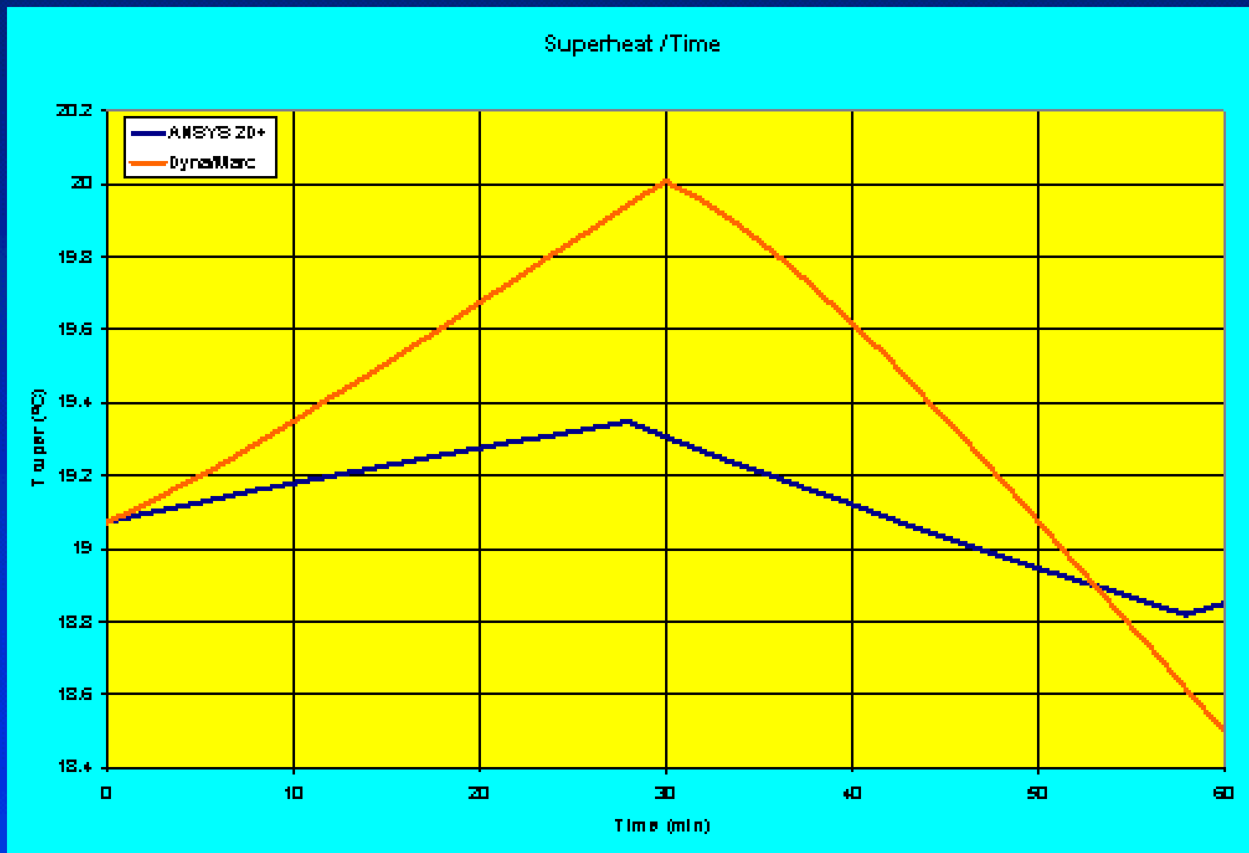
Models Response Comparison



Normal Operation, Eutectic Superheat

Models Response Comparison



Normal Operation, Eutectic Superheat

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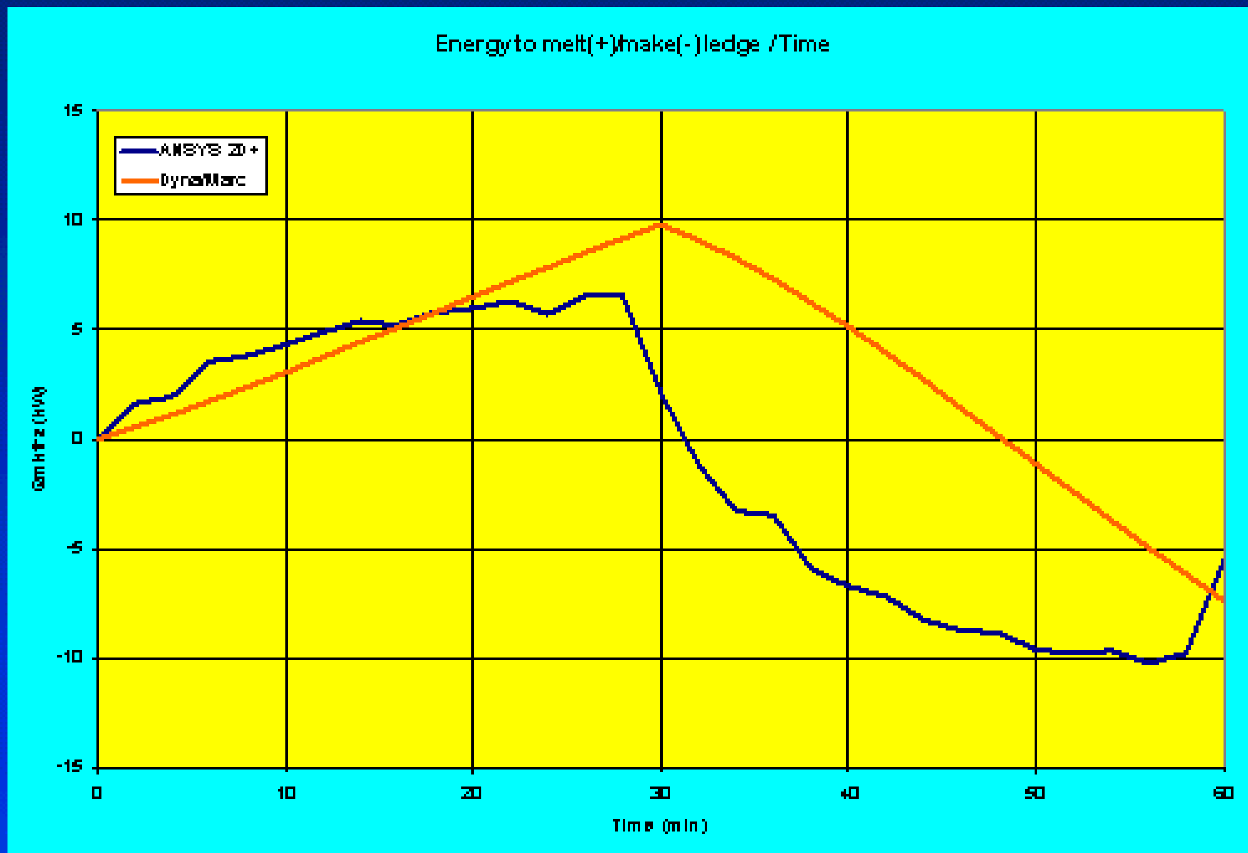
Models Response Comparison



Normal Operation, Eutectic Superheat

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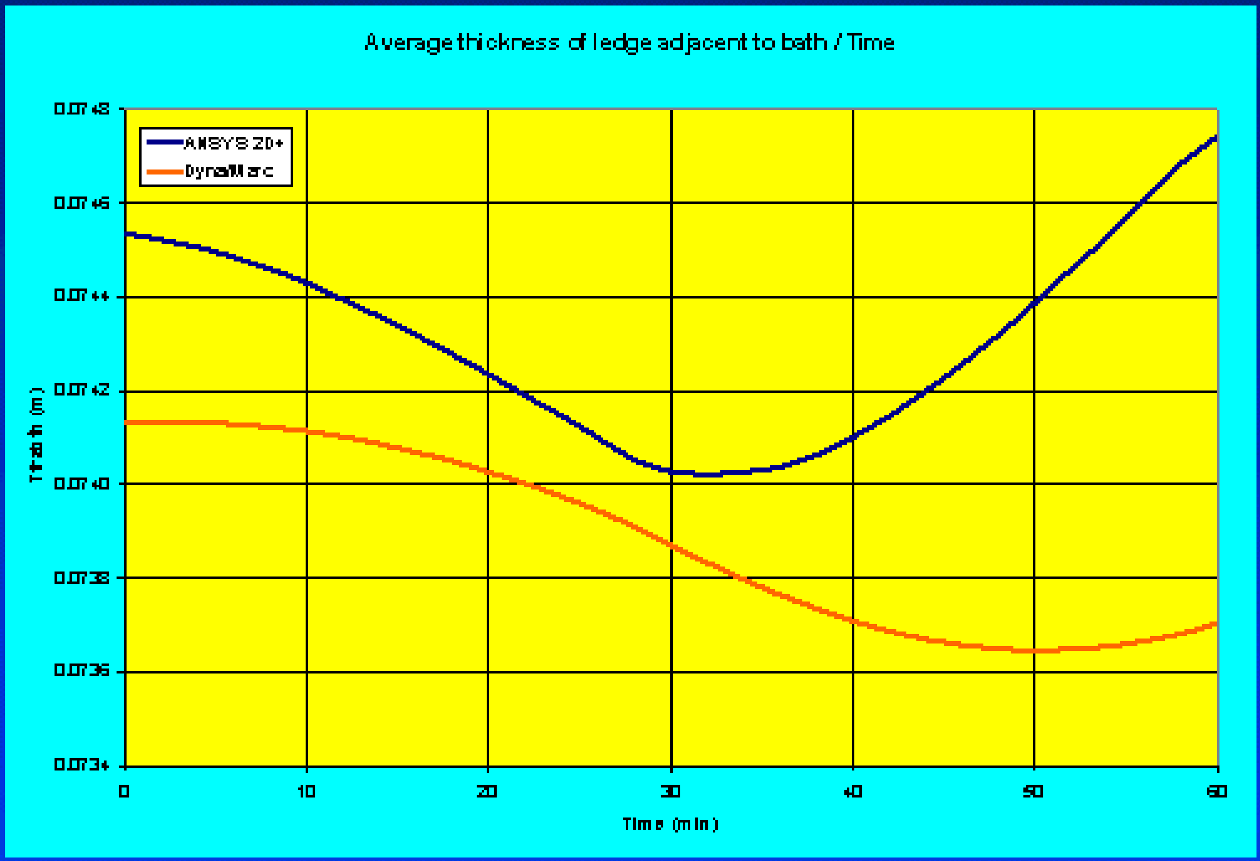

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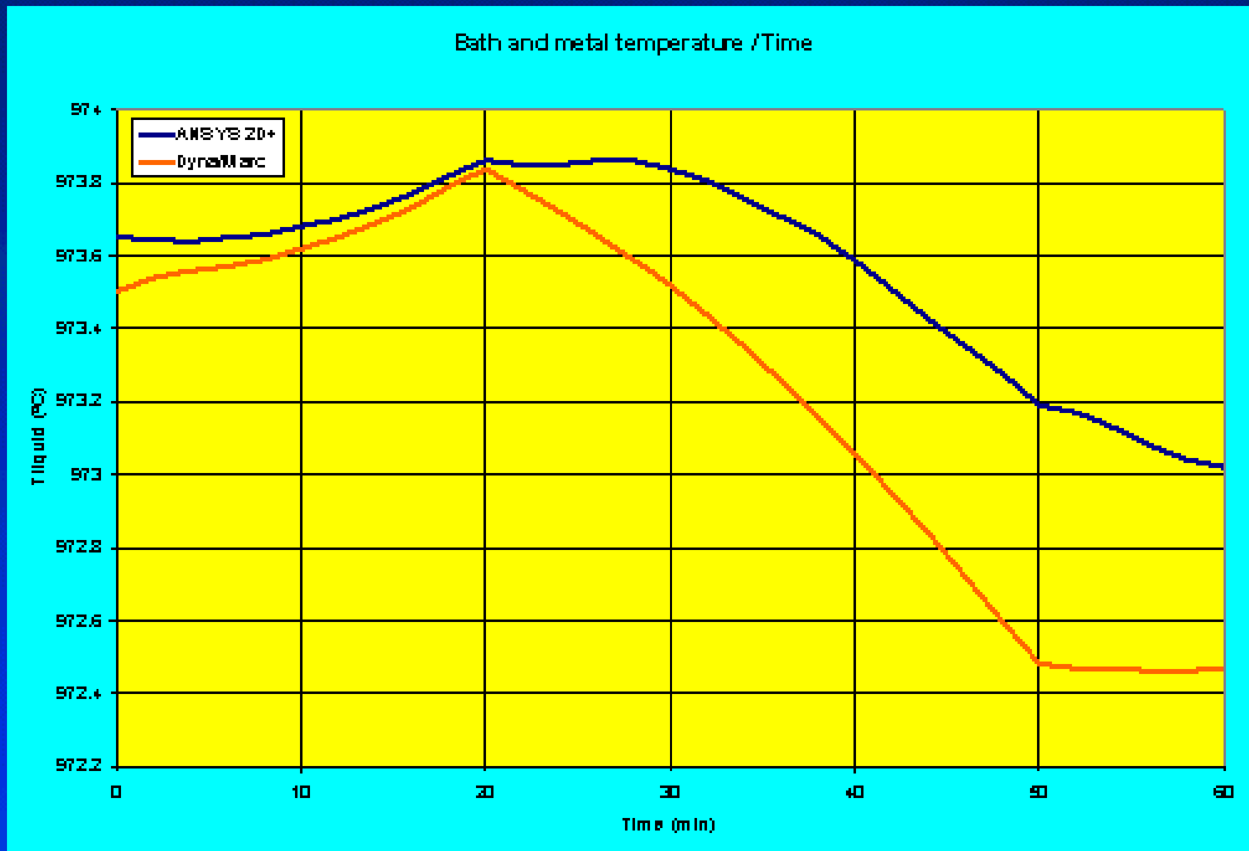
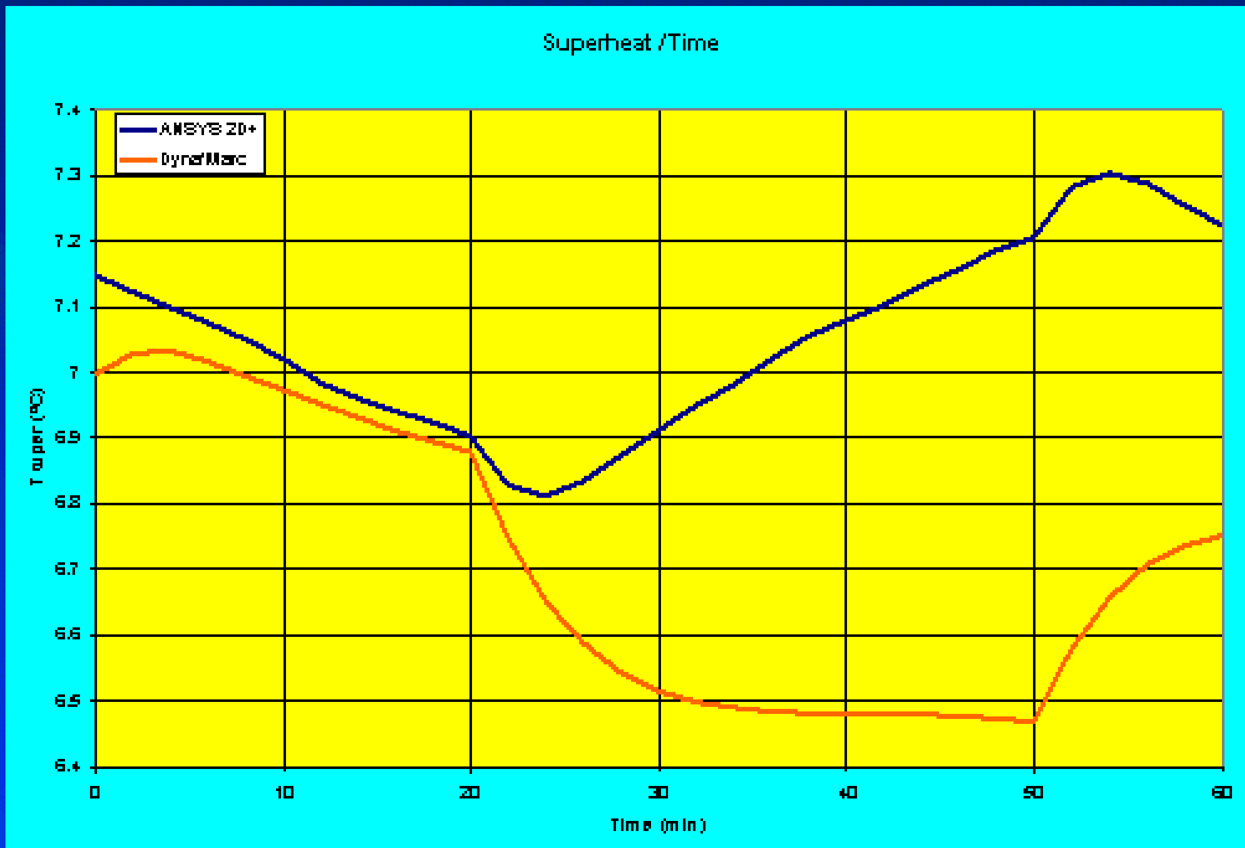


Normal Operation, Liquidus Superheat

Models Response Comparison



Normal Operation, Liquidus Superheat

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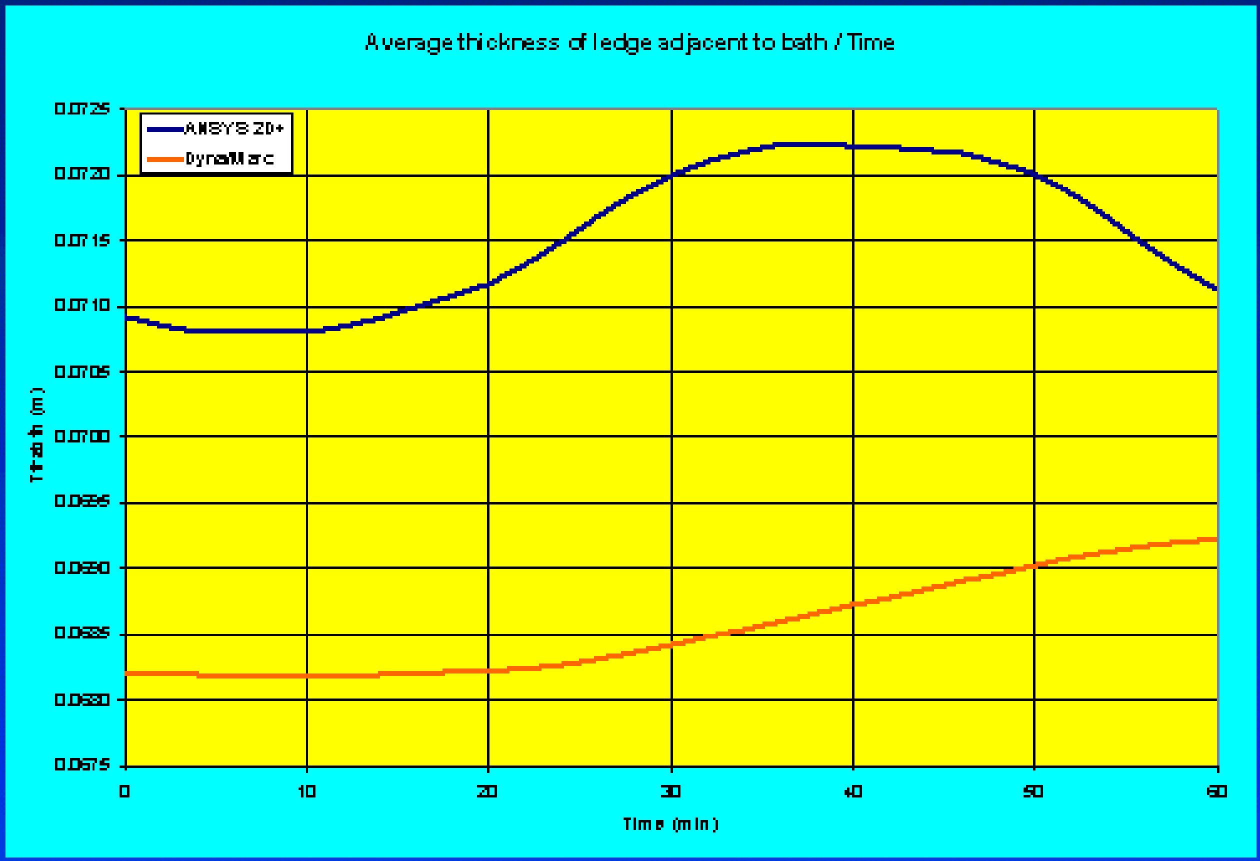
Models Response Comparison

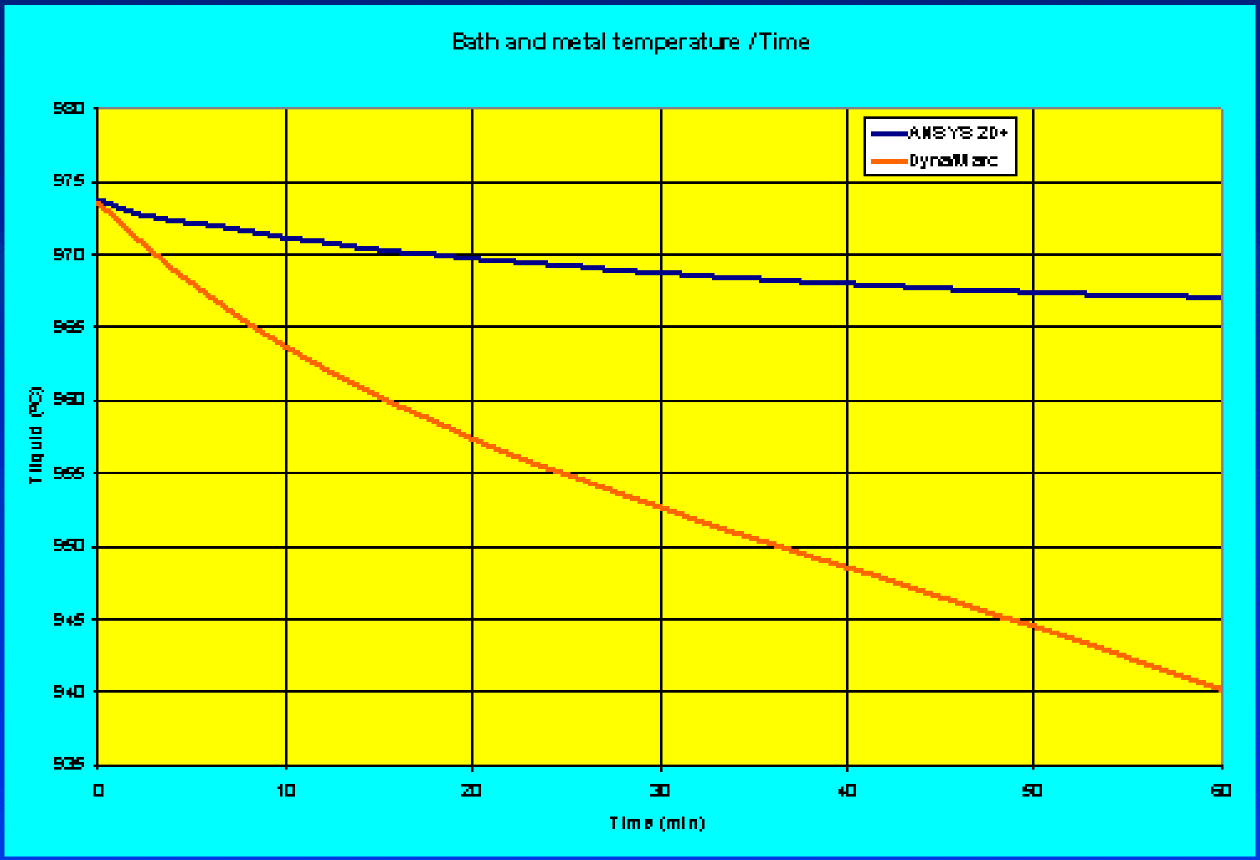
Normal Operation, Liquidus Superheat

Models Response Comparison



Normal Operation, Liquidus Superheat

Models Response Comparison



Power Loss, Liquidus Superheat

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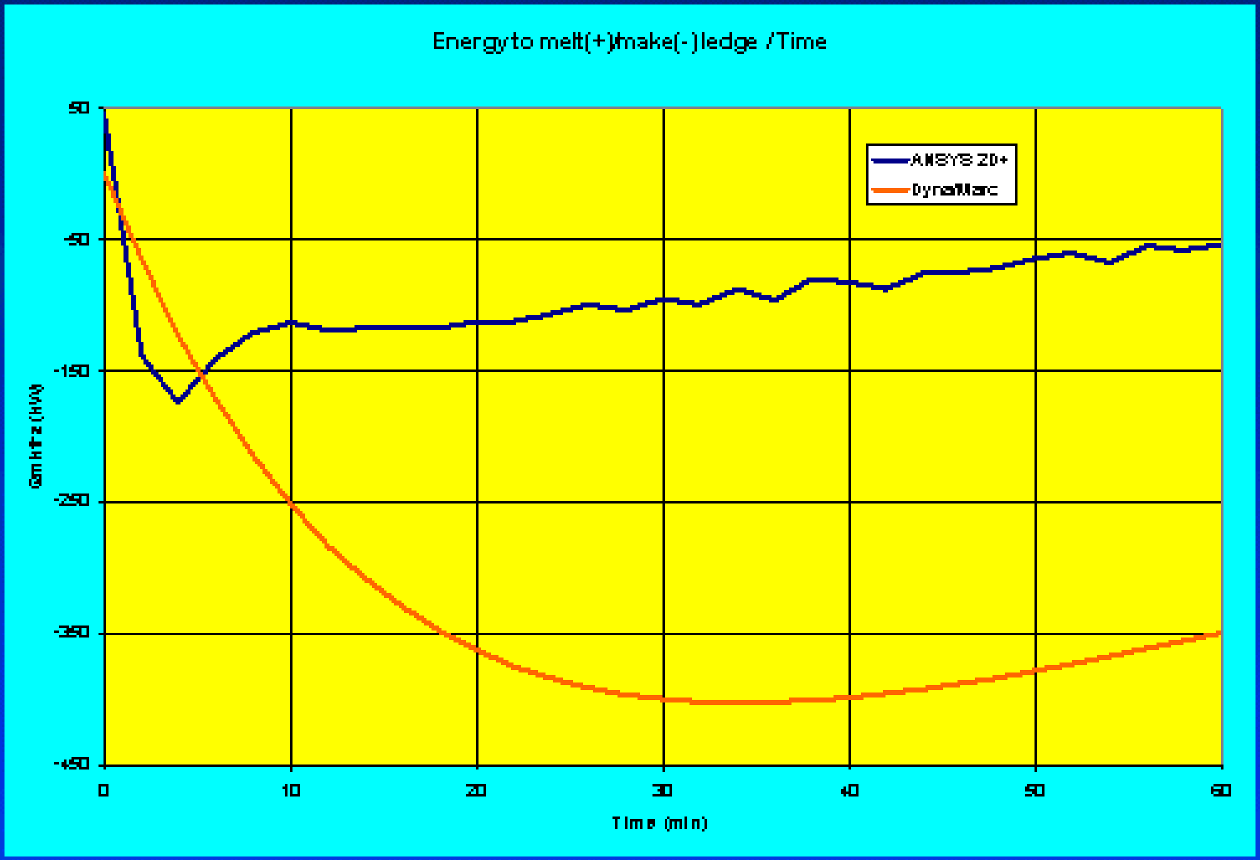
Models Response Comparison



Power Loss, Liquidus Superheat

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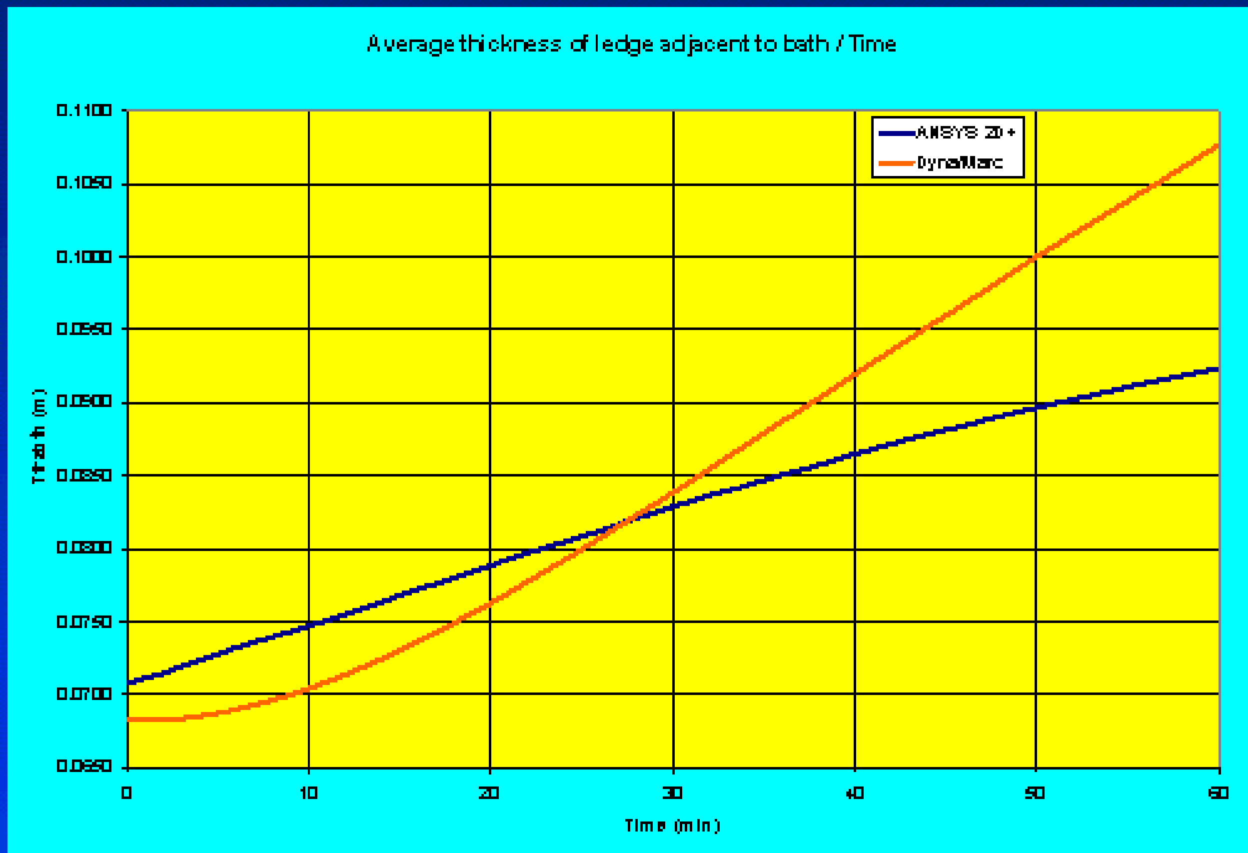
Models Response Comparison



Power Loss, Liquidus Superheat

Conclusions

- An ANSYS® 2D+ dynamic model has been successfully developed and tested.
- The ANSYS® 2D+ dynamic model has demonstrated that the thermal mass effect of the cell lining influences the cell dynamic.
- That influence cannot be neglected for extreme events like a long total power loss.