MODELING POWER MODULATION

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Plan of the Presentation

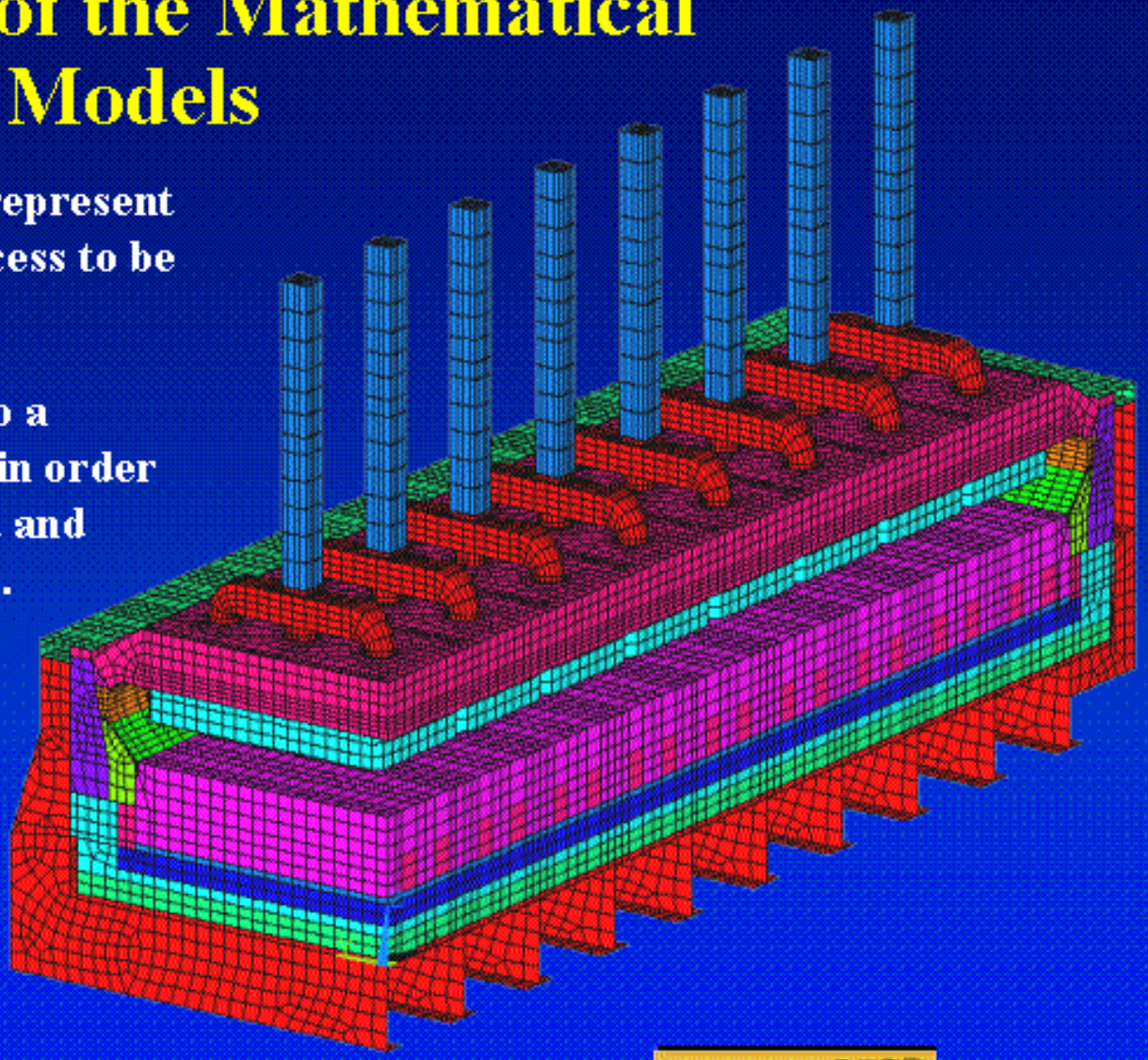
- Introduction
- Description of the mathematical models
  - ANSYS based 2D+ full cell slice model
  - "Lump parameter+" model
- Modeling the thermal response of power modulation
  - ANSYS based 2D+ full cell slice model results animation
  - Model results comparison
- Performing power modulation without affecting the cell heat balance
  - "Lump parameter+" model results
- Conclusions

Introduction

- In the context of an electrical power shortage in the USA, aluminum smelters are more and more forced to include a "power modulation" clause when renewing their long-term power supply contracts.
- The terms of those power modulation clauses are generally profitable to both the smelter and the power company, assuming that this practice does not have a significant negative impact on the smelter operations.
- Unfortunately, this power modulation can be quite harmful to the cells if not done properly.
- Yet nowadays, mathematical models can be used in order to avoid having to learn how to perform power modulation by doing experiments on a 1 billion dollars smelter !

Description of the Mathematical Models

- The model must accurately represent the key behaviors of the process to be modeled.
- The model must be limited to a manageable size/complexity in order to keep both its development and computation time affordable.
- For example, an ANSYS based full 3D cell quarter dynamic model would be an unmanageable "monster"



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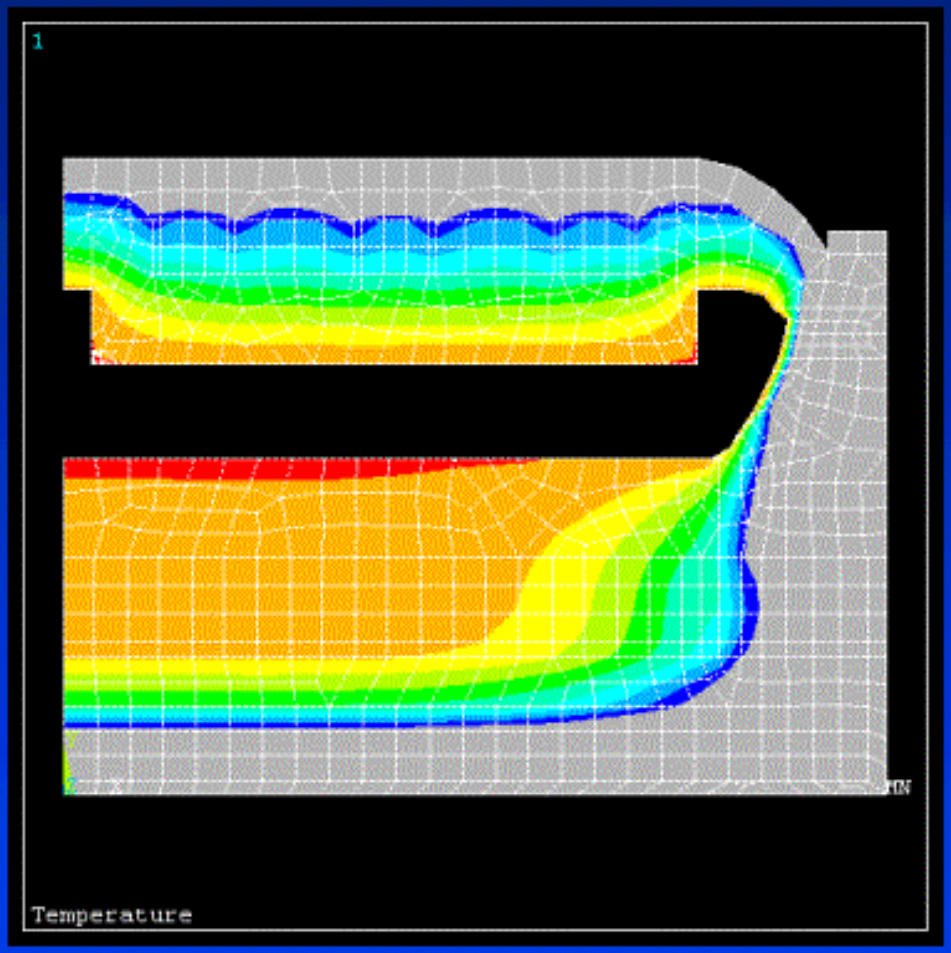
The 2D+ Full Cell Slice Dynamic Model



- Quite accurate FE 2D+ thermal model implemented in a dynamic model
- Requires 25 min. of CPU to compute 1 hour of operation using 2 min. time steps on a Pentium III 800 MHz PC

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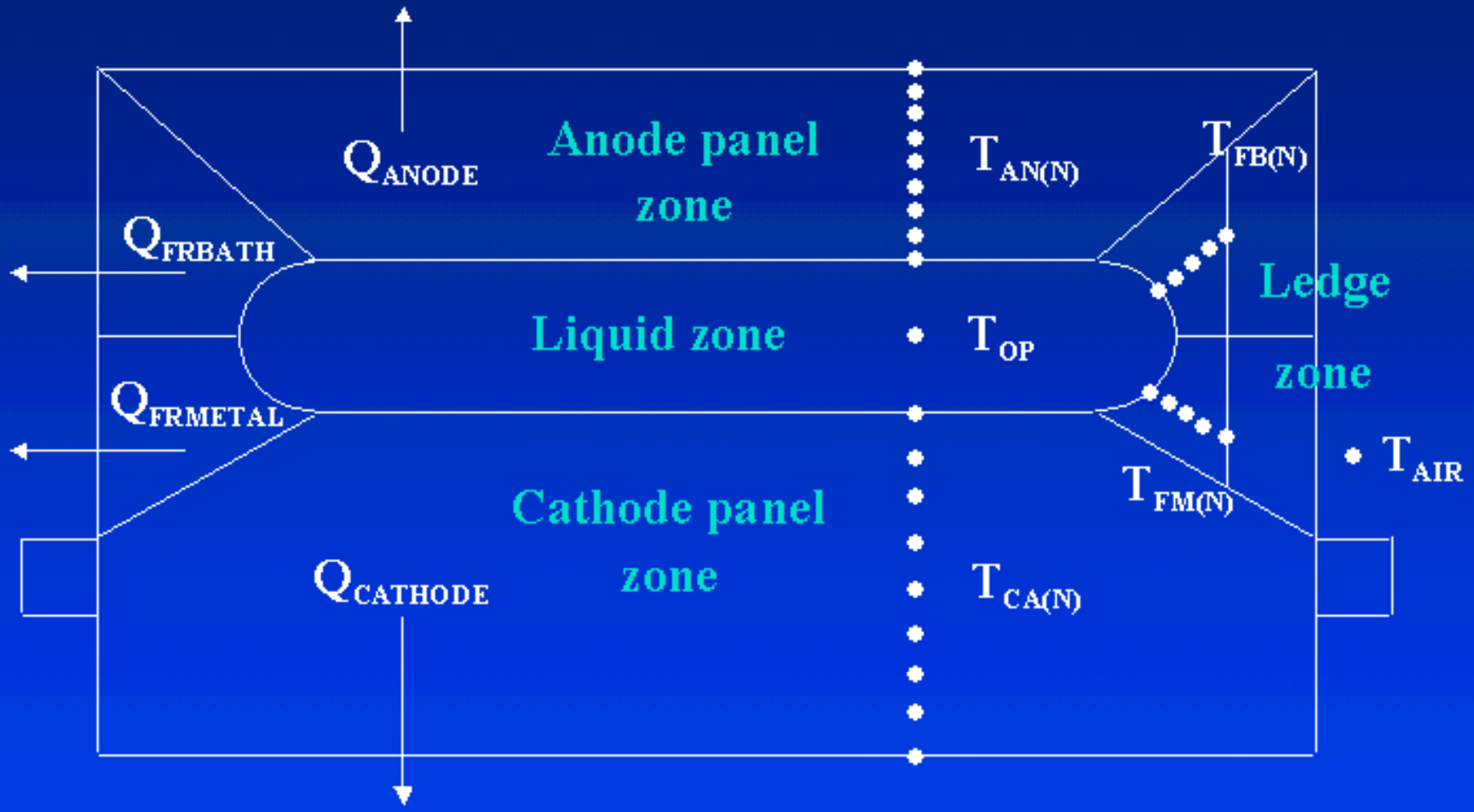
"Lump Parameter+" Thermal Model Concept



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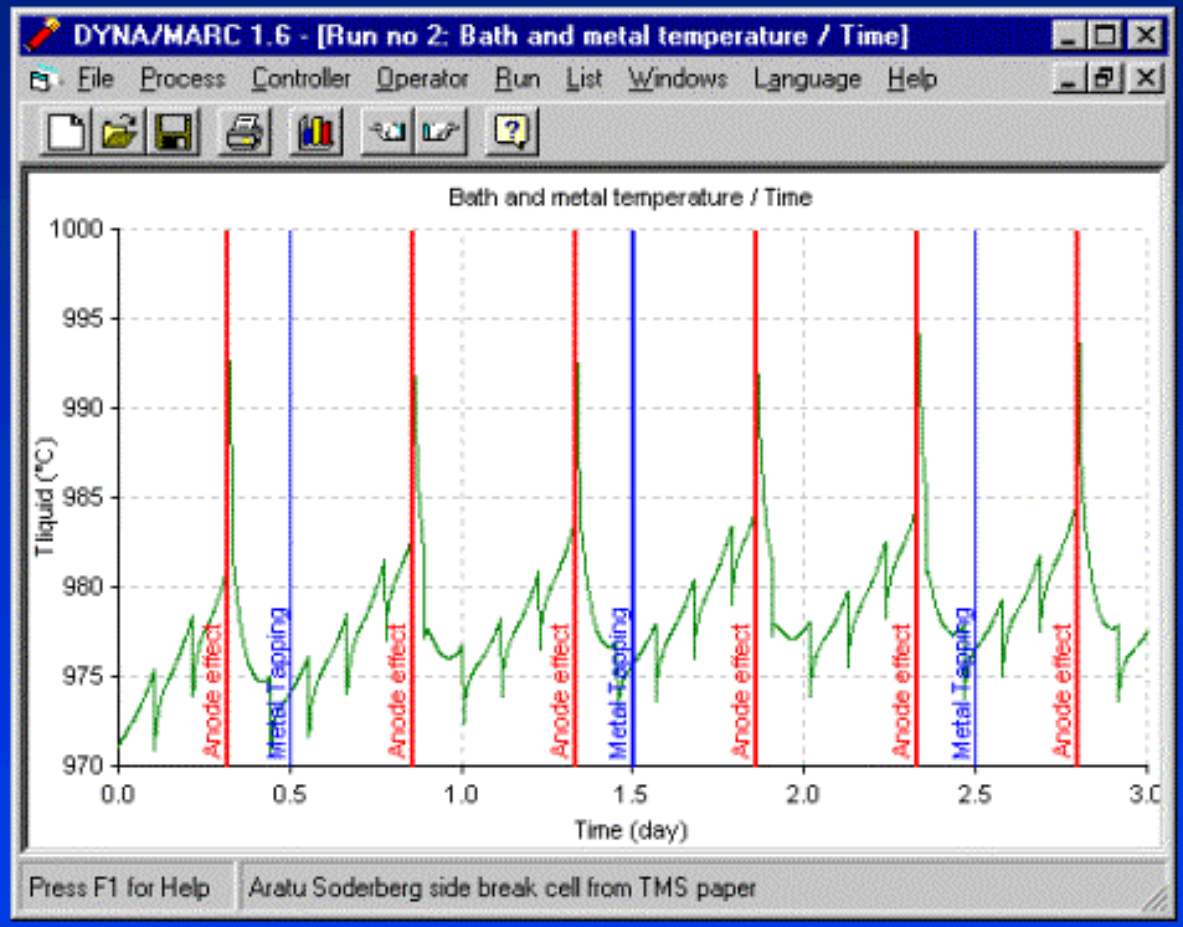
"Lump Parameter+" Full Cell Dynamic Model



- Less accurate "lump parameter+" thermal model implemented in a dynamic model
- Requires only seconds to compute 3 days of operation using 2 min. time steps on a Pentium III 800 MHz PC

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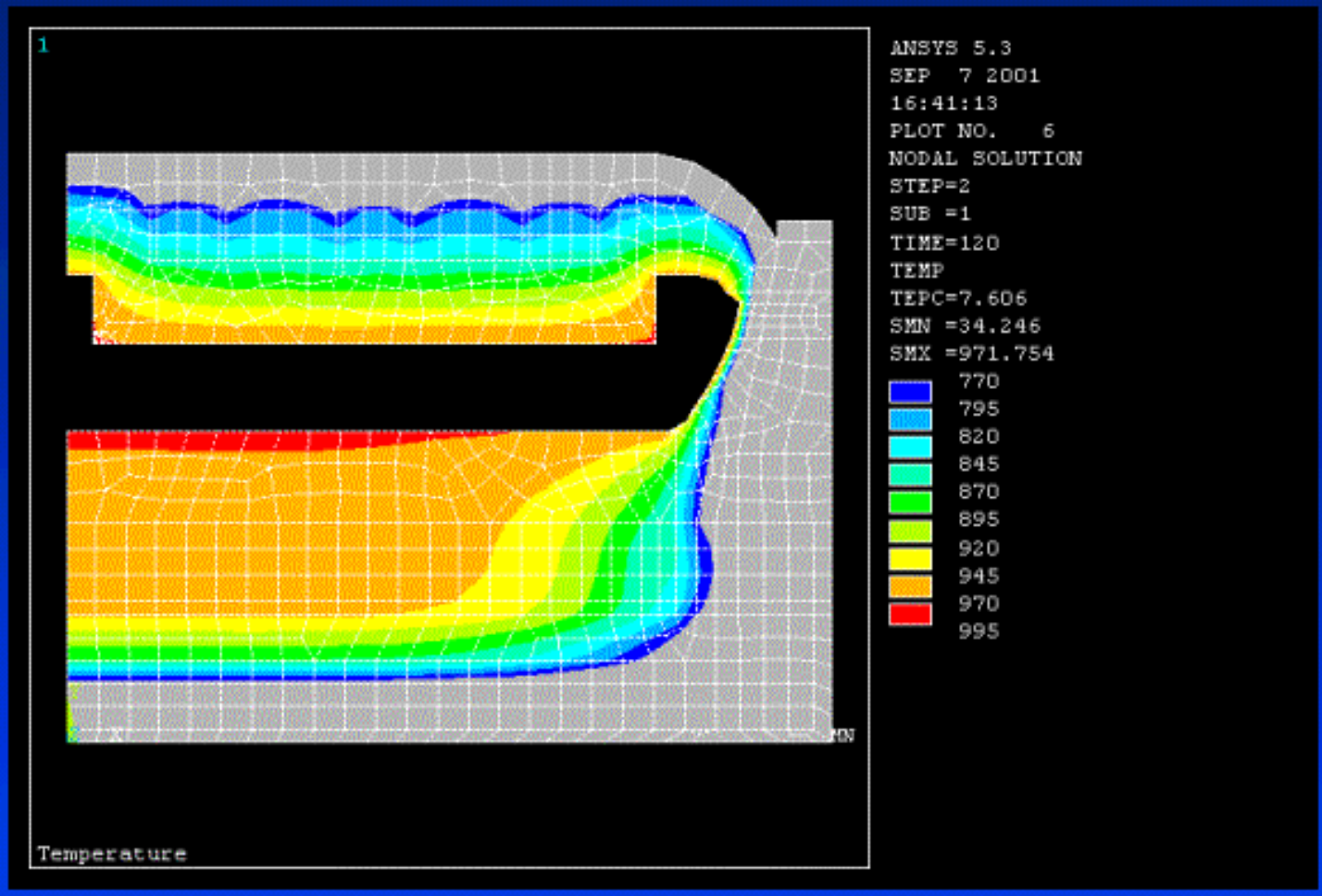
Modeling Normal Operation



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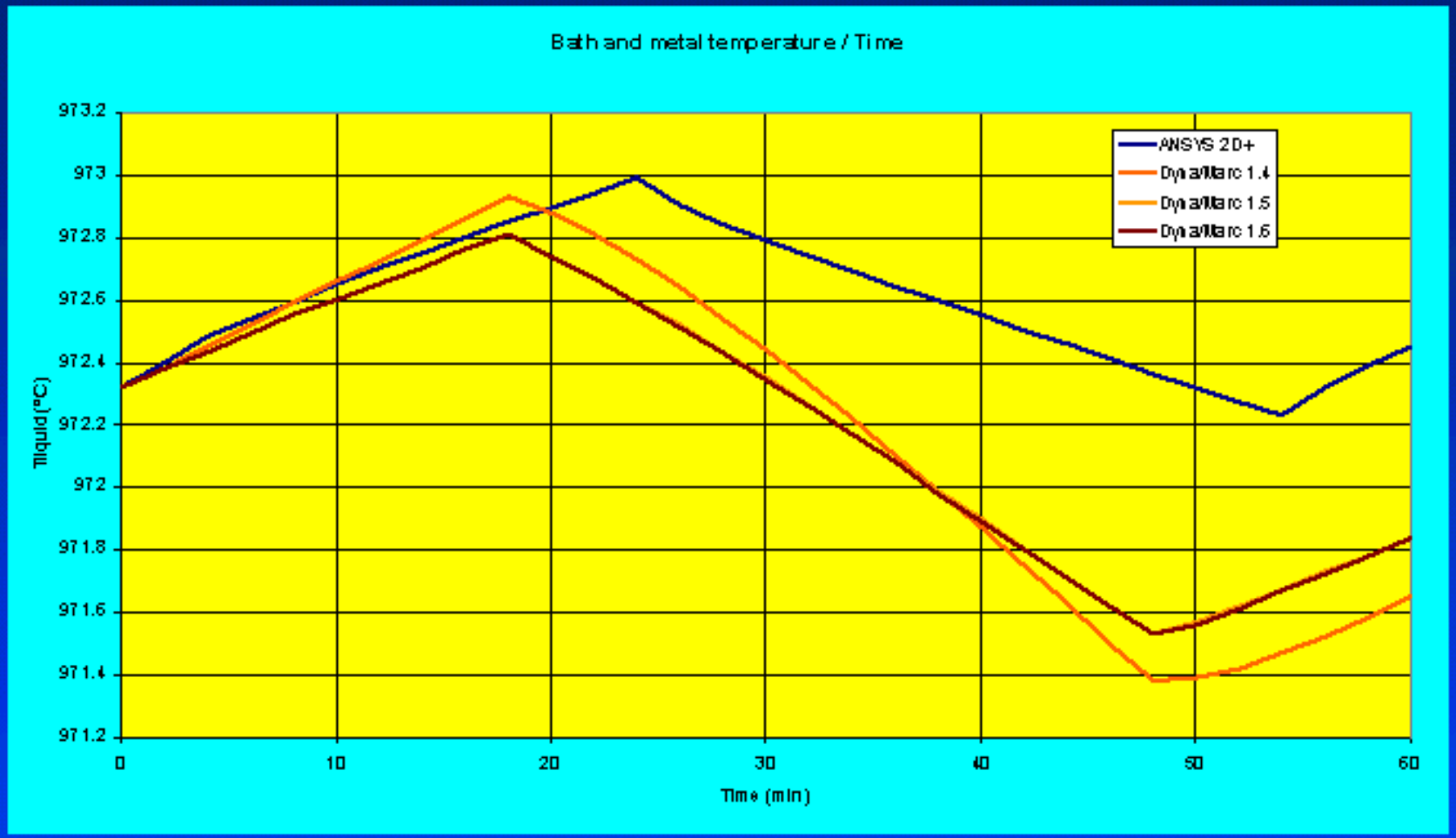
Modeling Normal Operation



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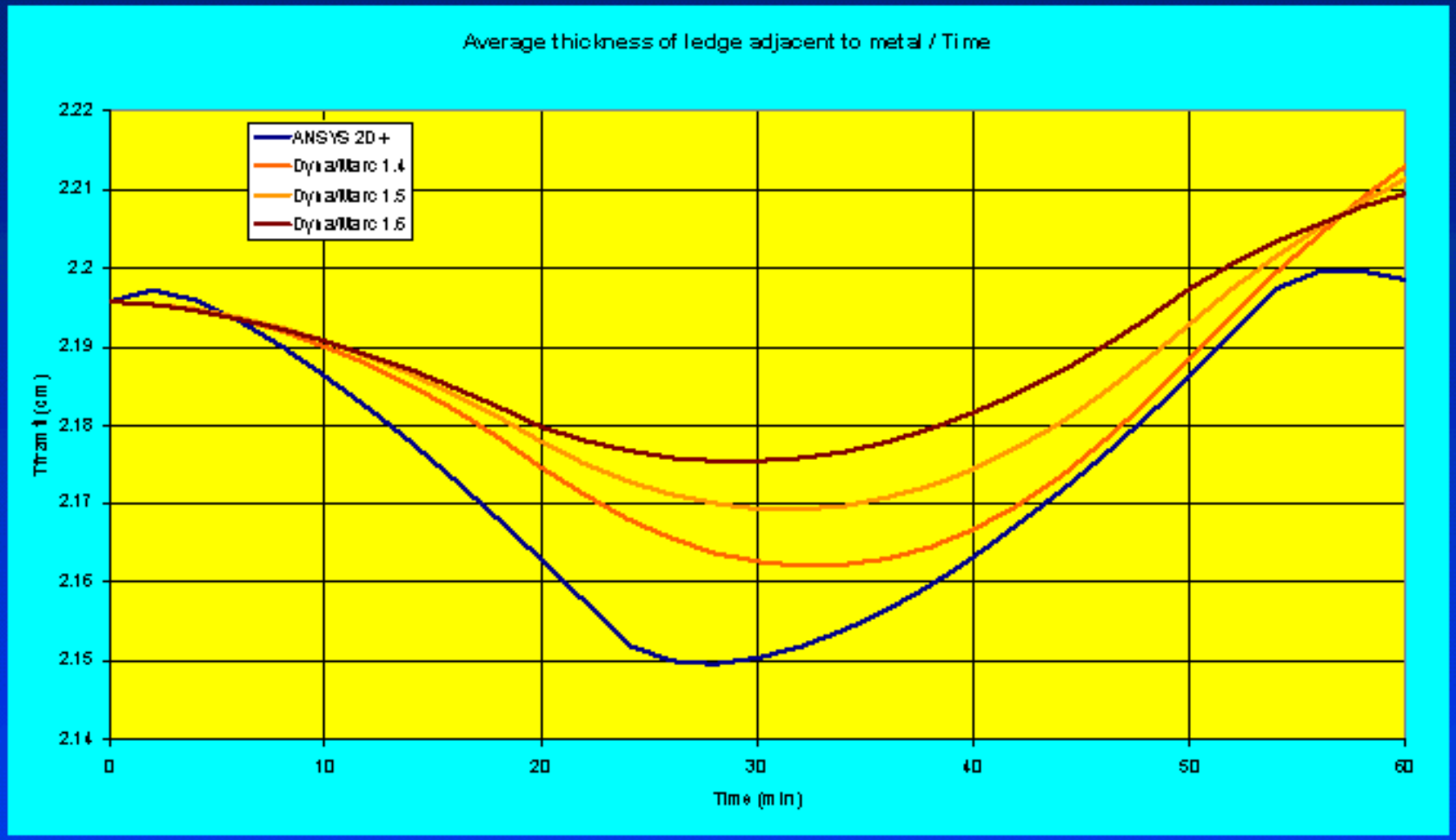
Modeling Normal Operation



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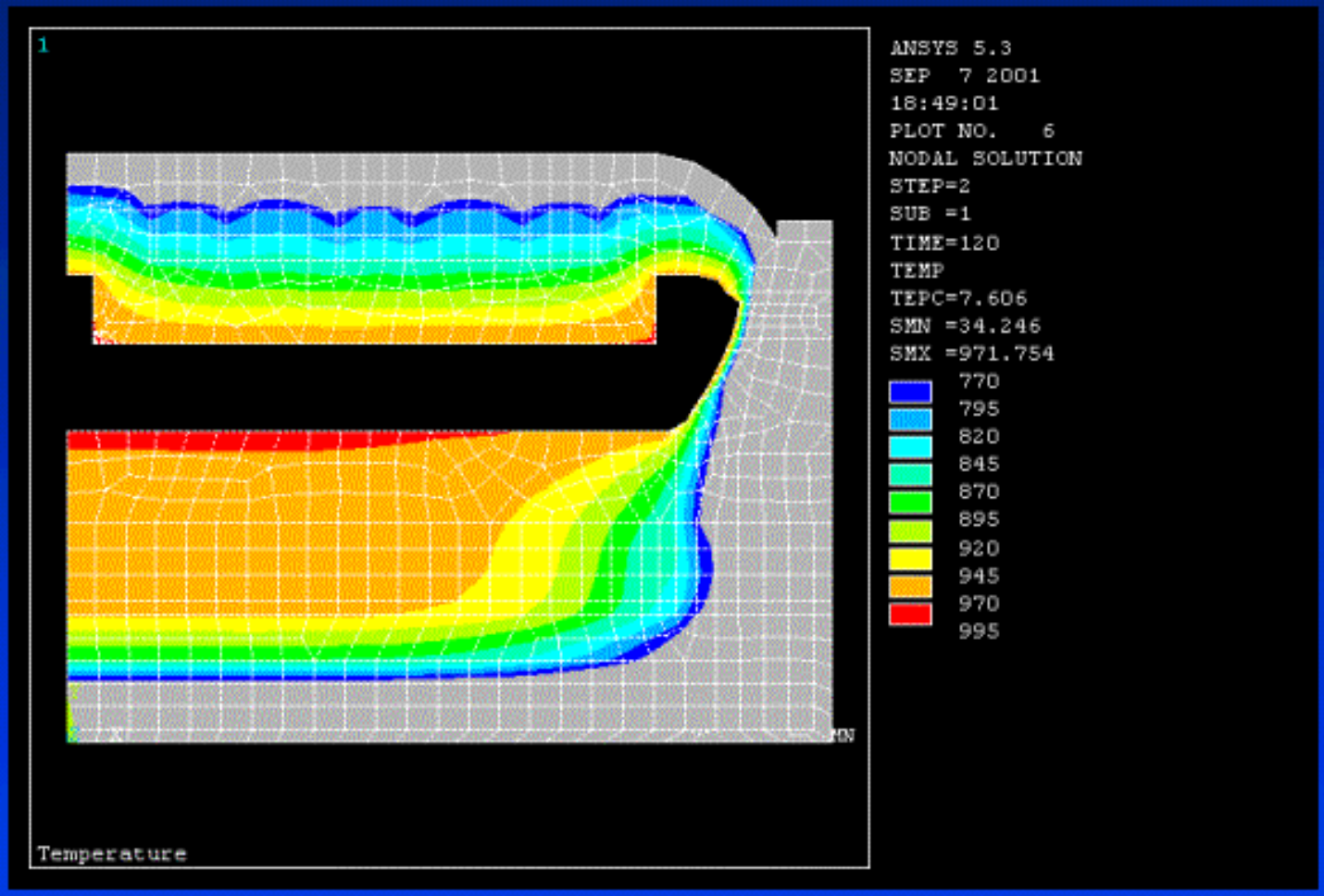
Modeling Total Power Failure



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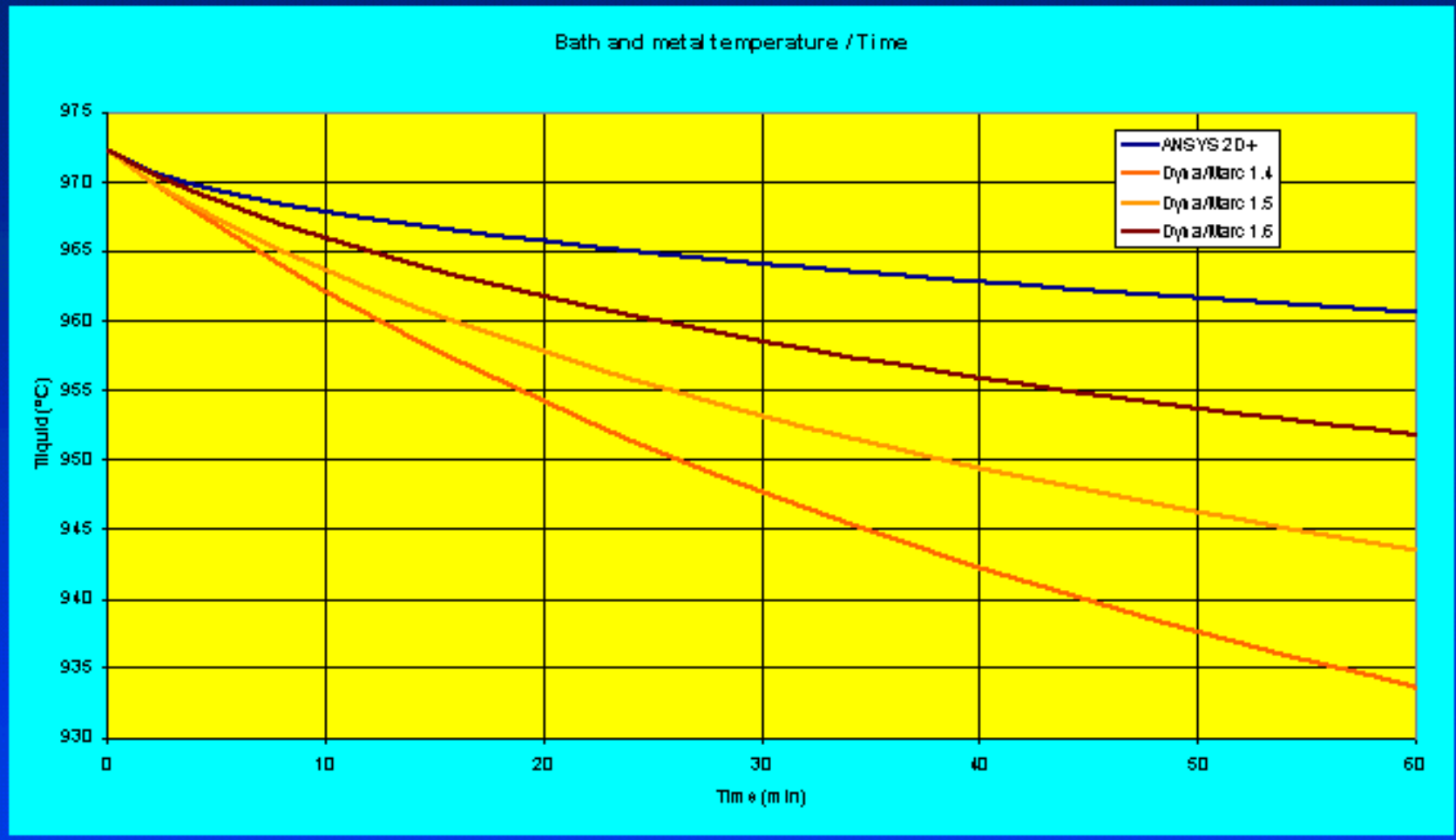
Modeling Total Power Failure



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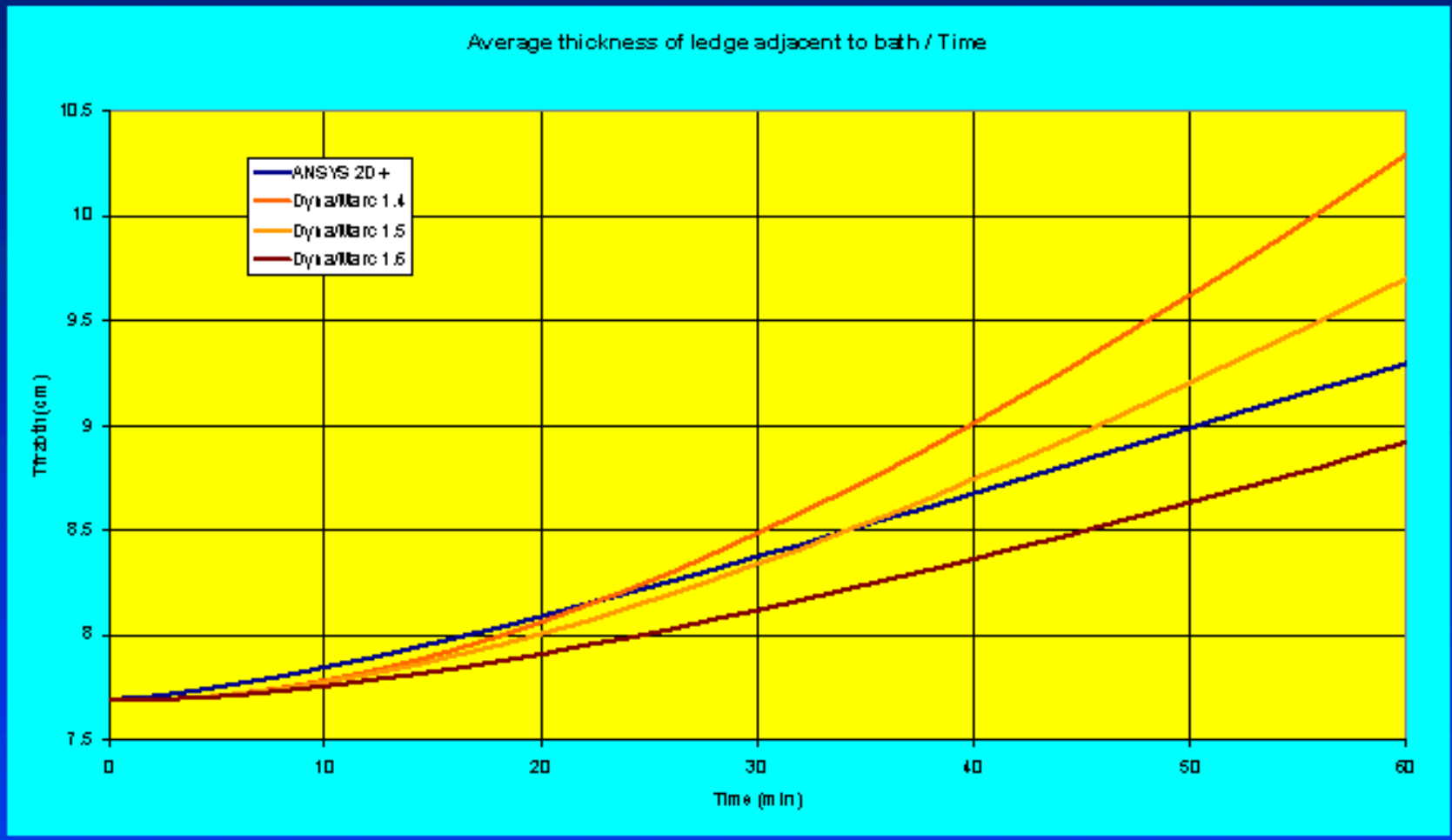
Modeling Total Power Failure



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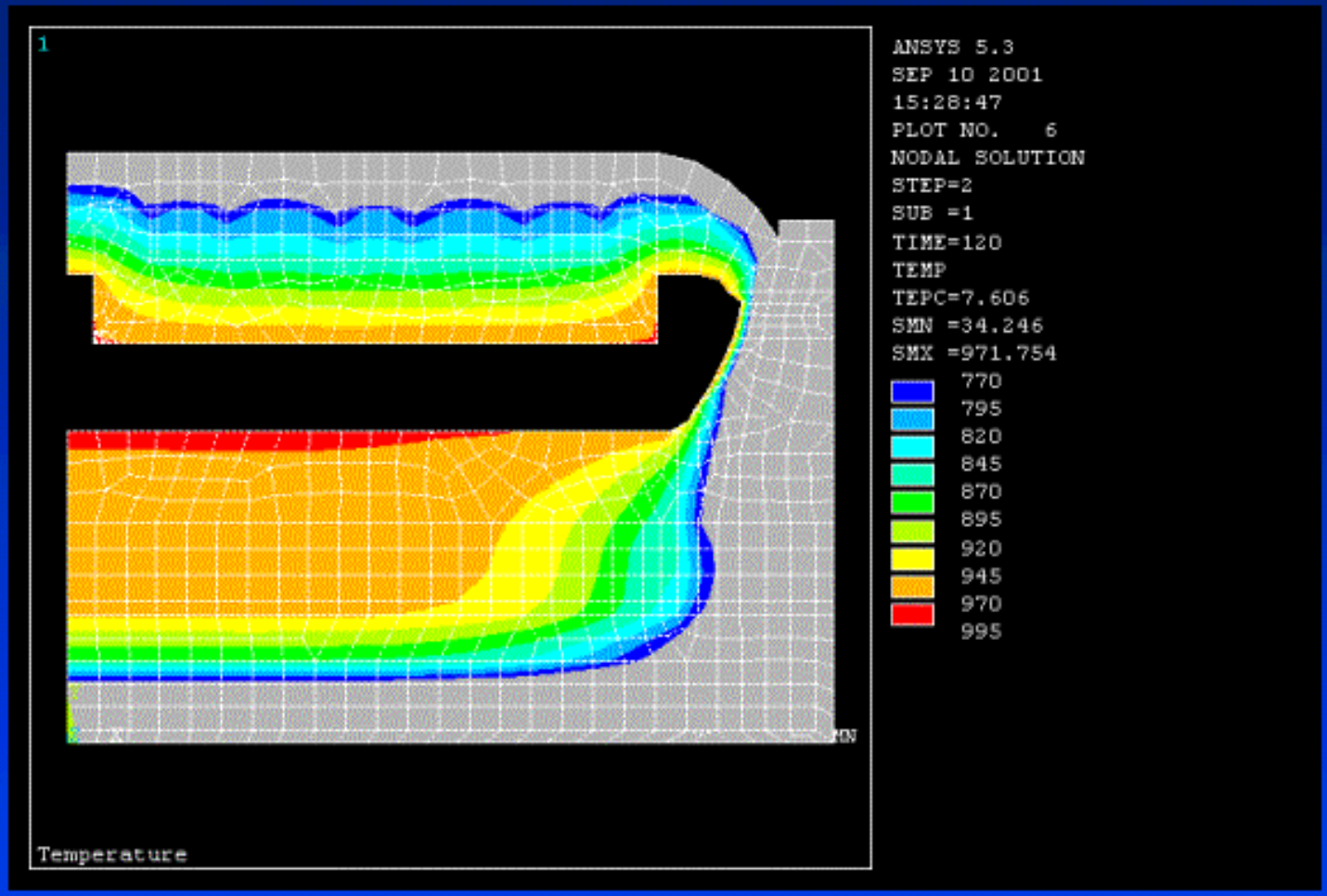
Modeling Power Modulation

- The cell was run at its nominal 300 kA amperage for one hour.
- The cell amperage was then suddenly dropped to 250 kA and kept at that reduced amperage for one hour without changing the anode cathode distance (ACD).
- Finally, the amperage was then suddenly increased back to 300 kA and the simulation was carried out for one additional hour.

Modeling Power Modulation



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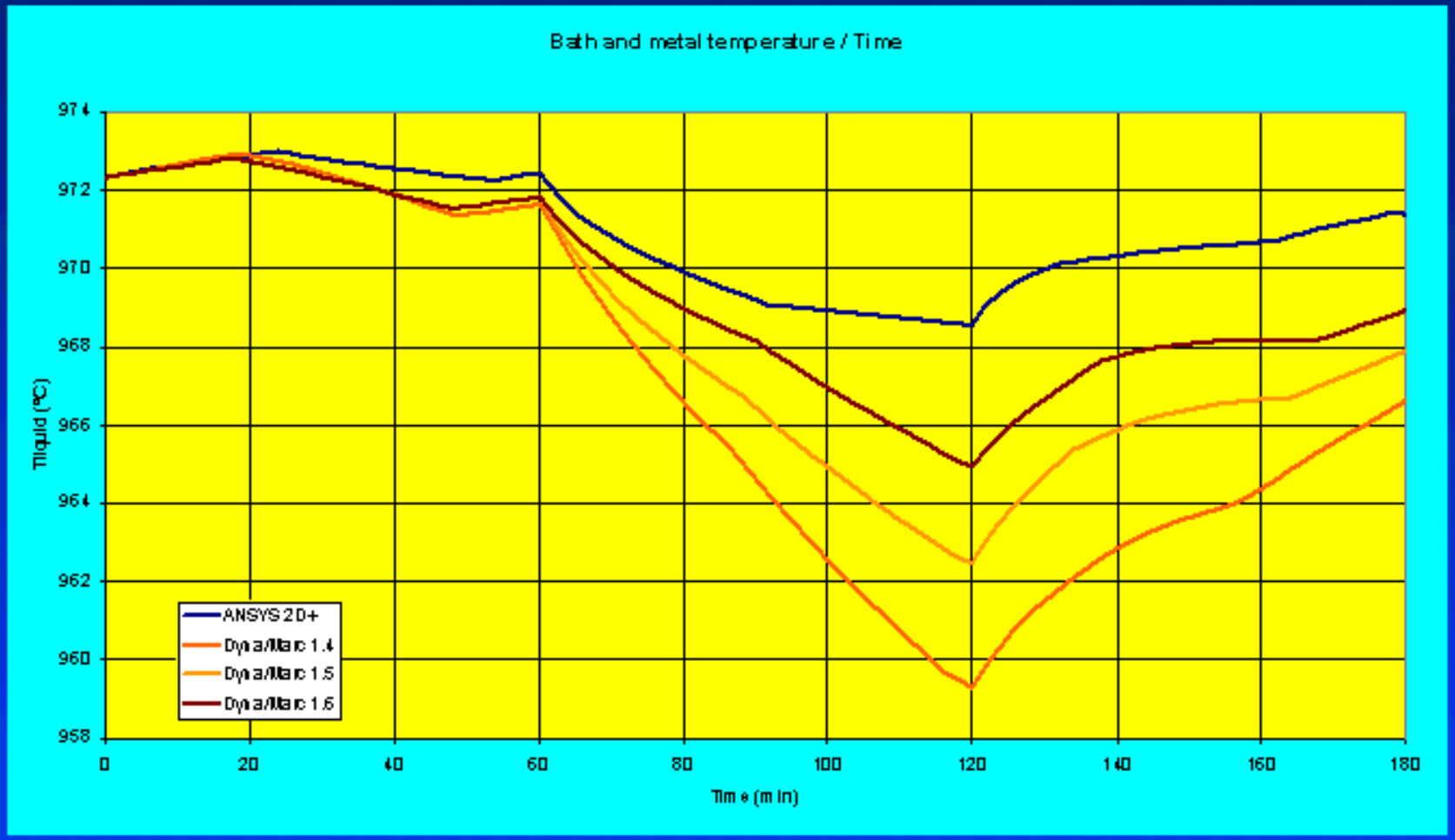
Modeling Power Modulation



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Modeling Power Modulation

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Modeling Power Modulation

- The cell was run at its nominal 300 kA amperage for three hours.
- The cell amperage was then suddenly dropped to 250 kA and kept at that reduced amperage for six hours.
- At the same time, the anode cathode distance (ACD) was increased from 5 to 7.2 cm.
- Finally, the amperage was then suddenly increased back to 300 kA, the ACD decreased back to 5 cm and the simulation was carried out for three additional hours.

Modeling Power Modulation

DYNA/MARC 1.6 - [VAW3]

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DYNA/MARC 1.6 - [VAW3]

Demo example of a prebaked PBF cell inspired from VAW's JOM paper
eutectic superheat, example of power modulation

Date Created :  8/2/99          Last Modified :  9/12/01

Steady State Solution

_____________________________________________________
Cell amperage                          300.0 [kA]
Anode to cathode distance             5.00000 [cm]
Operating temperature                 972.885 [C]
Ledge thickness, bath level           6.97011 [cm]
Ledge thickness, metal level          2.07332 [cm]
Anode beam position                   15.0000 [cm]
Mass of metal                         22481.2 [kg]
Mass of bath                          8818.48 [kg]
Mass of dissolved alumina             211.643 [kg]
Mass of dispersed alumina              35.293 [kg]
Mass of alumina sludge                 0.8799 [kg]
Mass of dissolved aluminum fluoride   664.296 [kg]
Mass of dispersed aluminum fluoride     0.387 [kg]
Mass of aluminum fluoride sludge        0.0001 [kg]
Mass of calcium fluoride              264.554 [kg]
Mass of lithium fluoride                0.000 [kg]
Mass of magnesium fluoride              0.000 [kg]
Alumina feeding rate                  180.738 [kg/hr]
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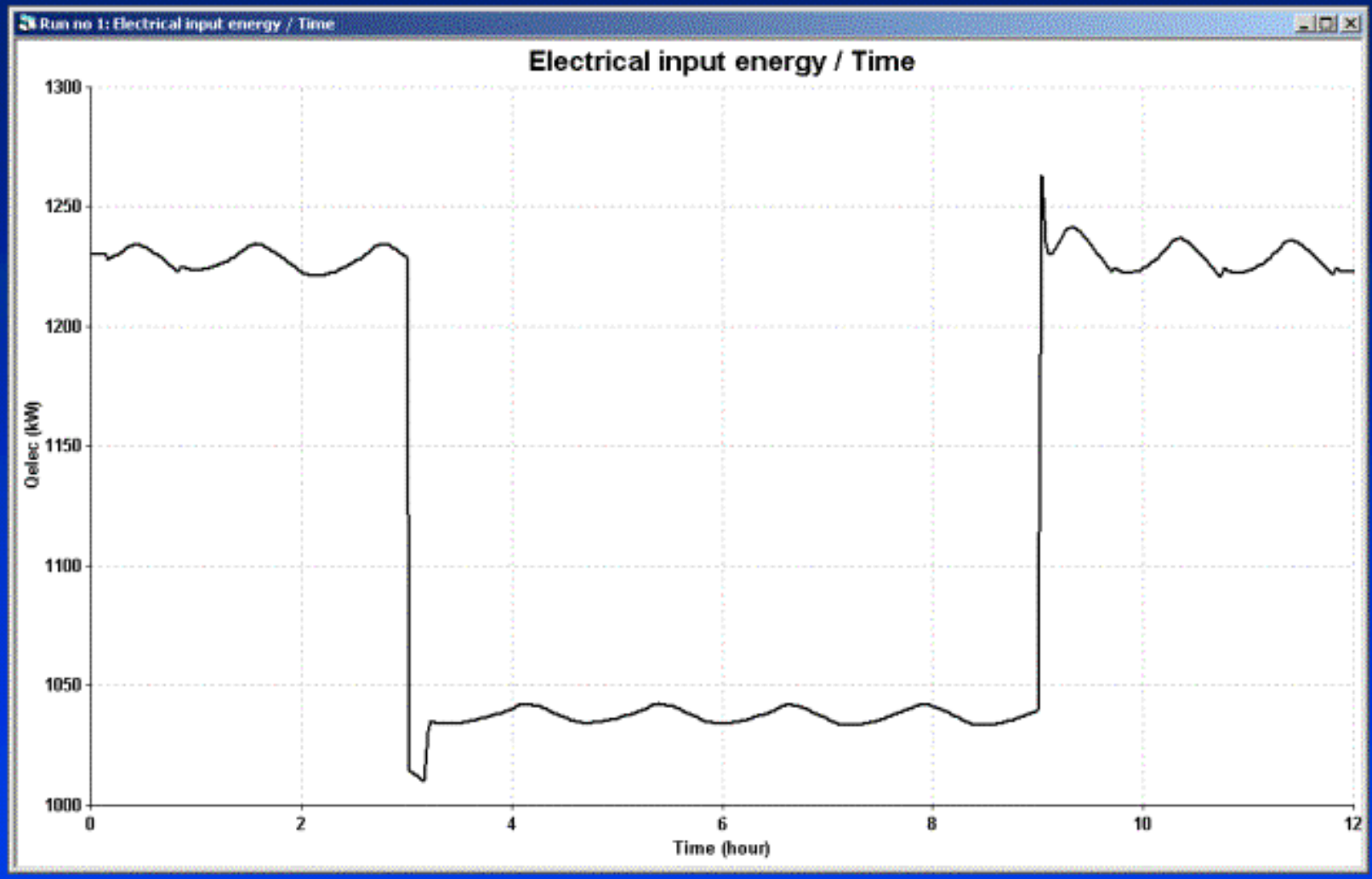
Modeling Power Modulation



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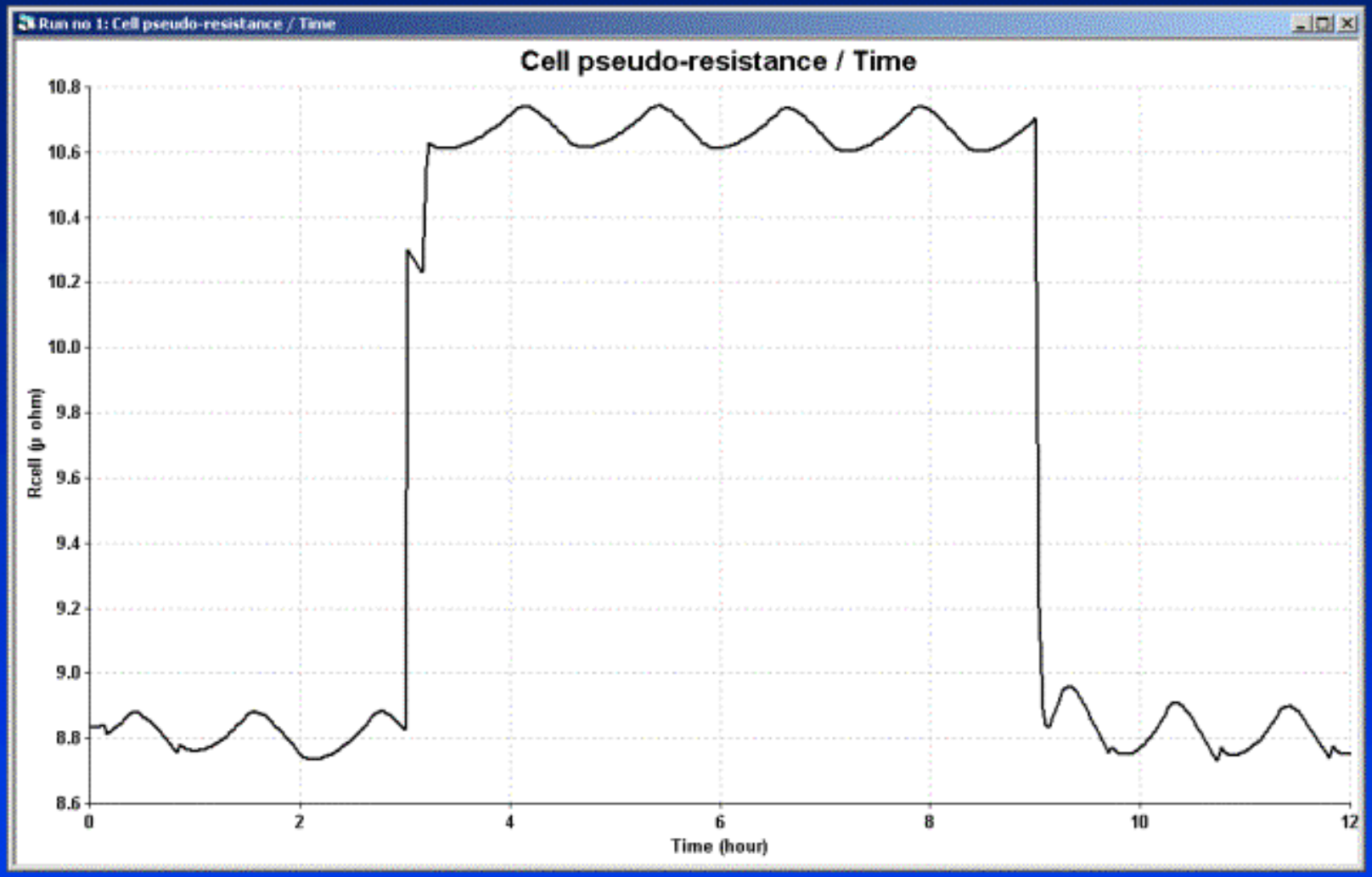

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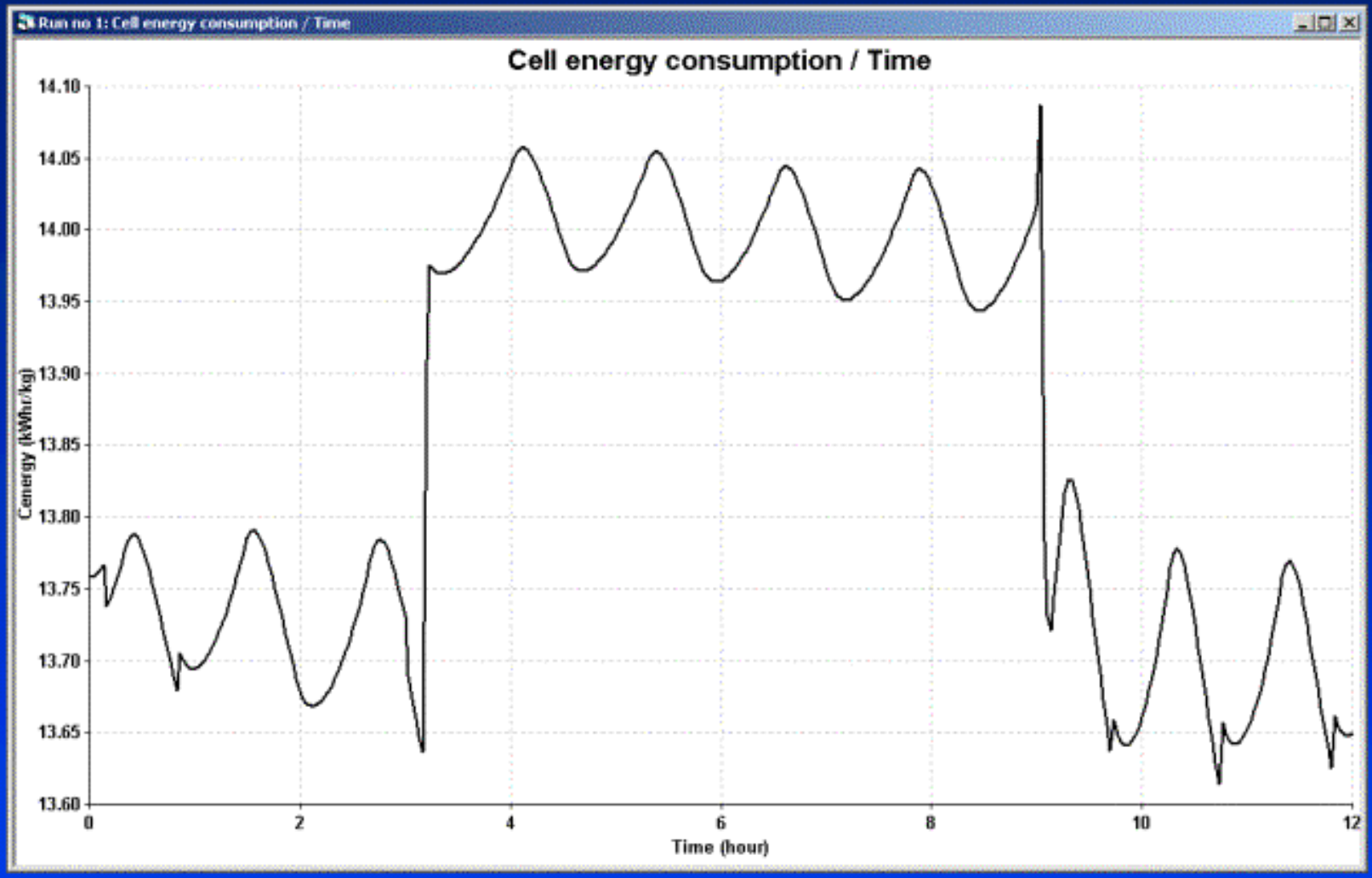

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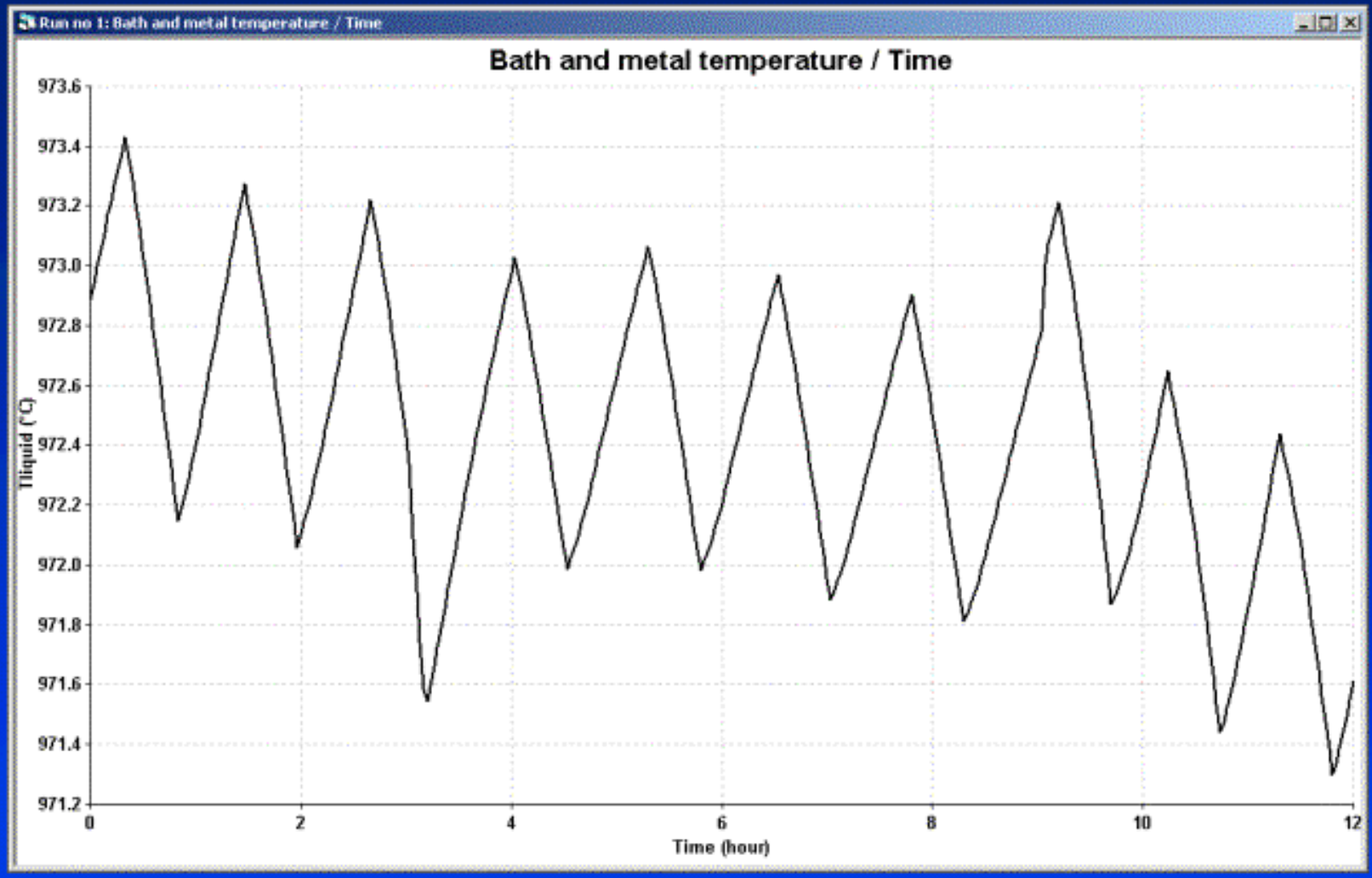
Modeling Power Modulation



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Conclusions

- The improved “lump parameter+” model can fairly accurately represent the thermal response of drastic events like a total power failure almost instantaneously.
- Both the 2D+ and the “lump parameter+” dynamic models were successfully used to compute the thermal response of a power modulation event.
- The “lump parameter+” model was used to demonstrate that it is possible to curtail down the input electrical power of a 300 kA cell up to 16% for a relatively long period of time without affecting significantly its thermal balance.