Usage of a Full 3D Transient Thermo-Electric F.E. Model to Study Thermal Gradient Generated in the Lining During a Coke Preheat

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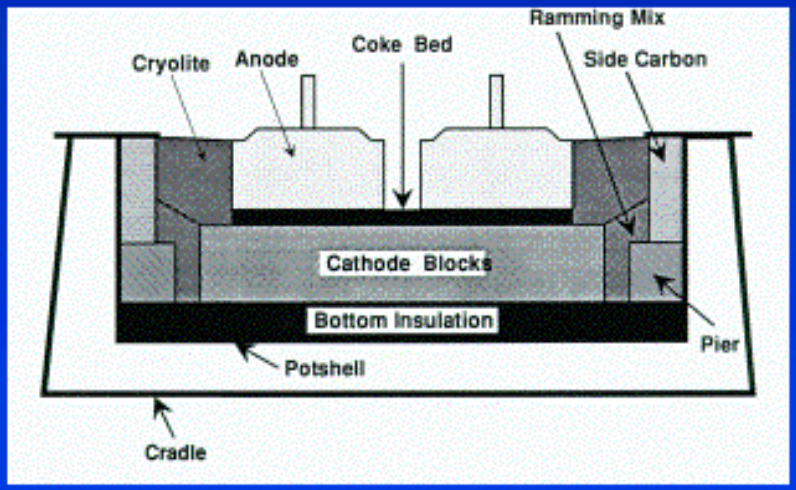
Plan of the Presentation

- Introduction
- Thermo-Electric F.E. Preheat Model Description
  + Conversion from a standard operation model
- Transient Thermal Model Solution
  + Solution time comparison
- Model Validation
- Model Applications
  + Possible extension to stress model
- Conclusions

Introduction

- Little published information is available on how to actually design a coke preheat as raised by Dunn et al [3].
- It would be nice to be able to design a coke preheat that minimizes the preheat duration without producing excessive harmful thermal gradients in the cathode lining.
- To do so, there are many design parameters that can be optimized:
  - the total duration of the preheat
  - the number of shunts
  - the resistance of the shunts
  - the schedule of shunt removal
  - the shape of the coke bed
  - etc



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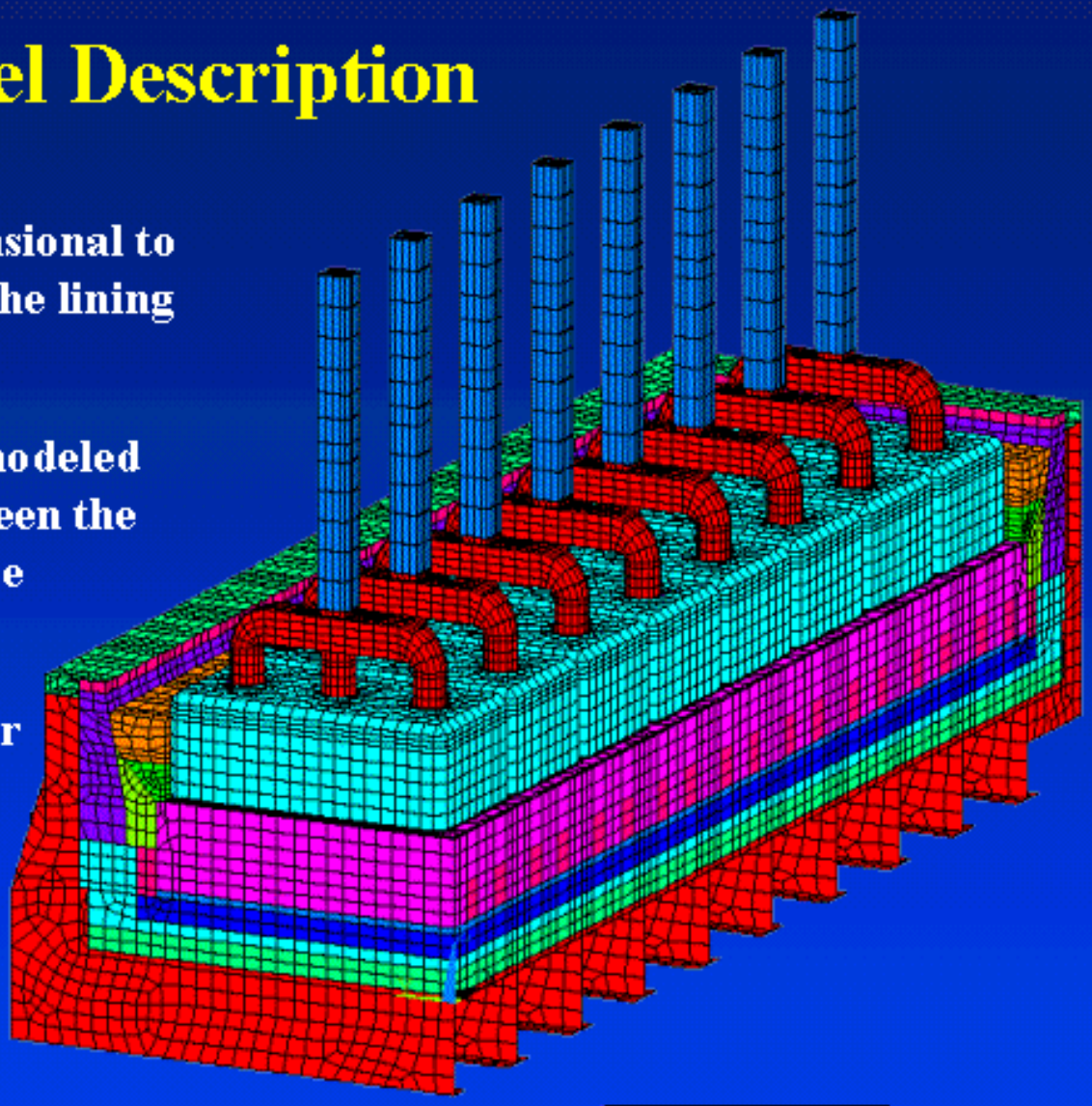
Model Description

- The model must be three-dimensional to study the thermal gradients in the lining in all directions
- The whole assembly has to be modeled because the heat partition between the anode and the cathode cannot be assumed
- To be rigorous a full cell quarter needs to be solved
- The model must obviously be run in transient mode



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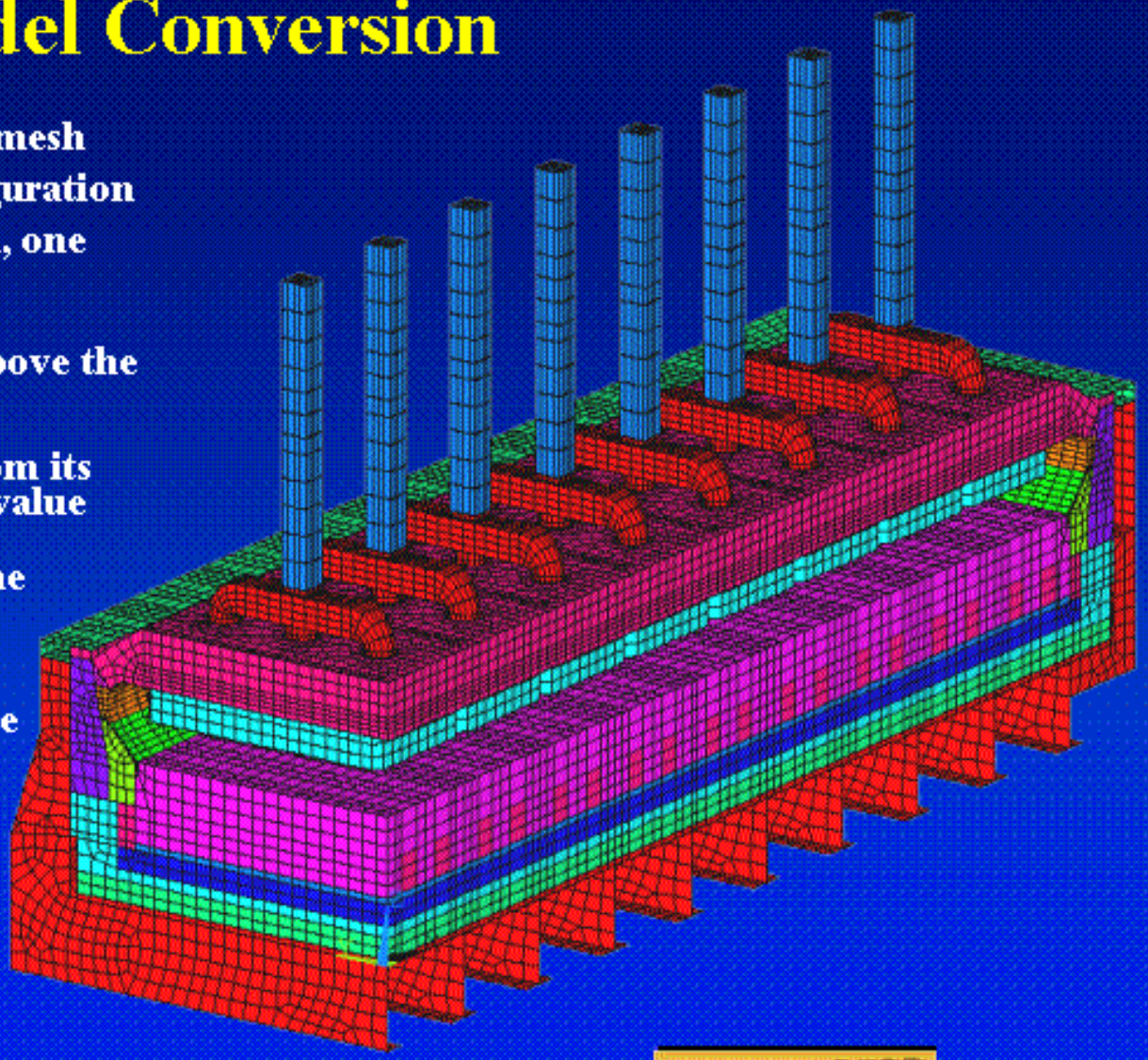
Model Conversion

- To convert a 3D full cell quarter mesh from a standard operation configuration into a coke preheat configuration, one simply has to:
  - remove the crust elements above the anodes
  - redefine the anode height from its mid life value to its as build value
  - add the coke bed on top of the cathode blocks and/or under the anodes
  - move the anodes on top of the coke bed
  - change the ledge material into the appropriate filling material and adjust the geometry



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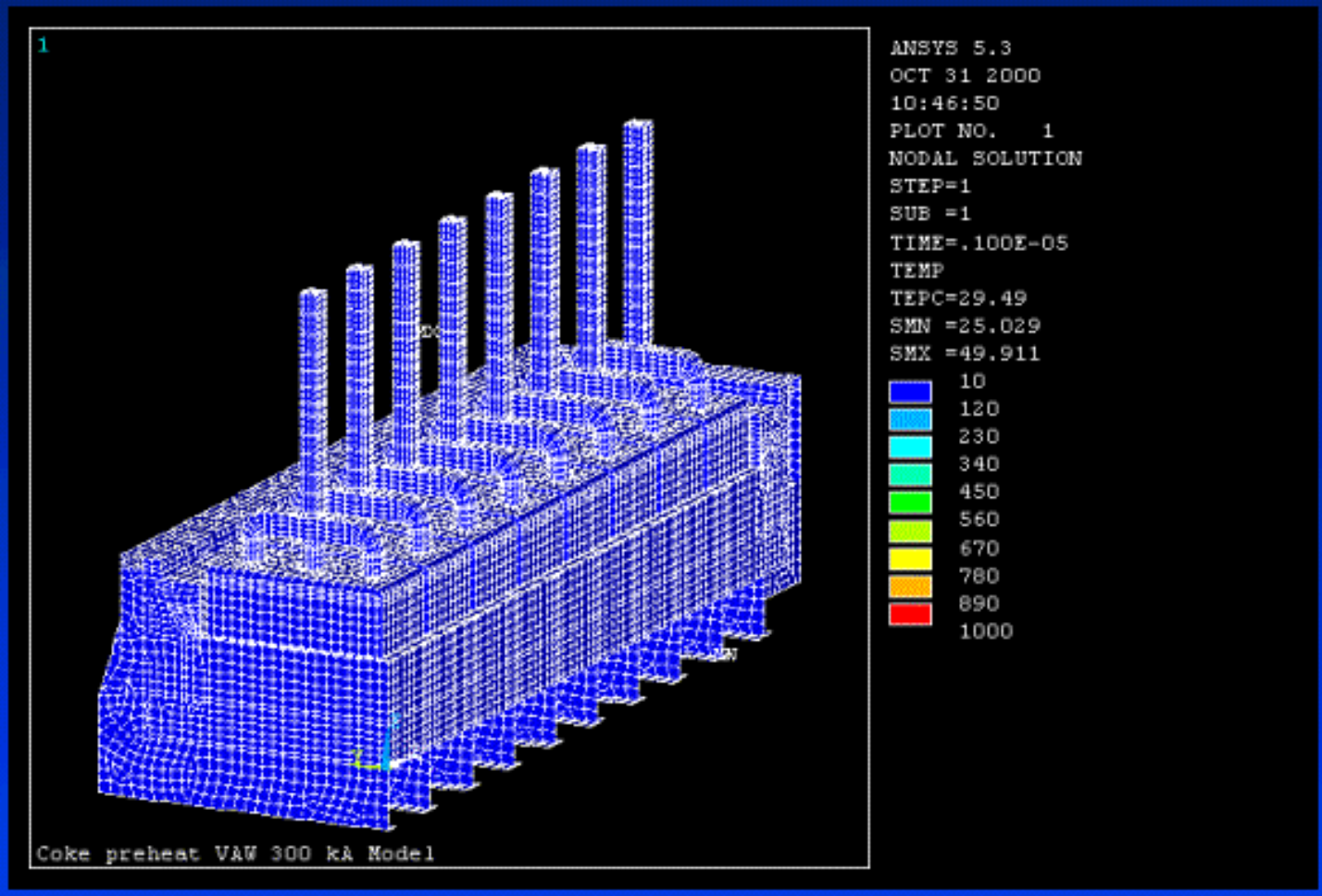
Transient Thermal Model Solution



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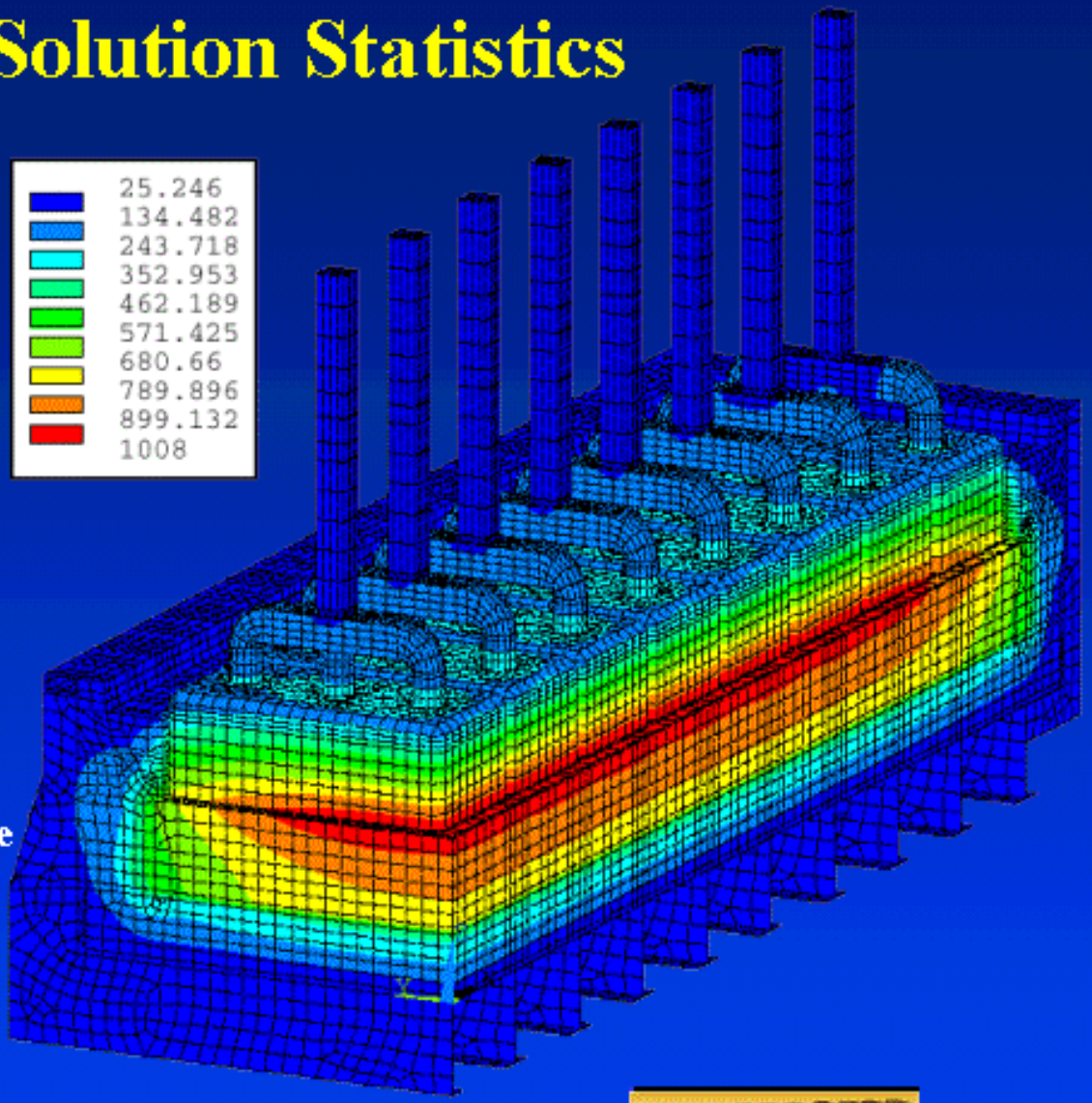
Transient Solution Statistics

- 30 hours preheat
- 4 shunts dropped at 5, 10, 15 and 20 hours
- Full amperage is 300 kA
- 36 load steps required
- 95,777 finite elements used
- 171.5 CPU hours of Pentium III single 800 MHz processor with 384 MB of RAM required
- The results file containing all the 36 load steps results required 3.711 GB of disk space



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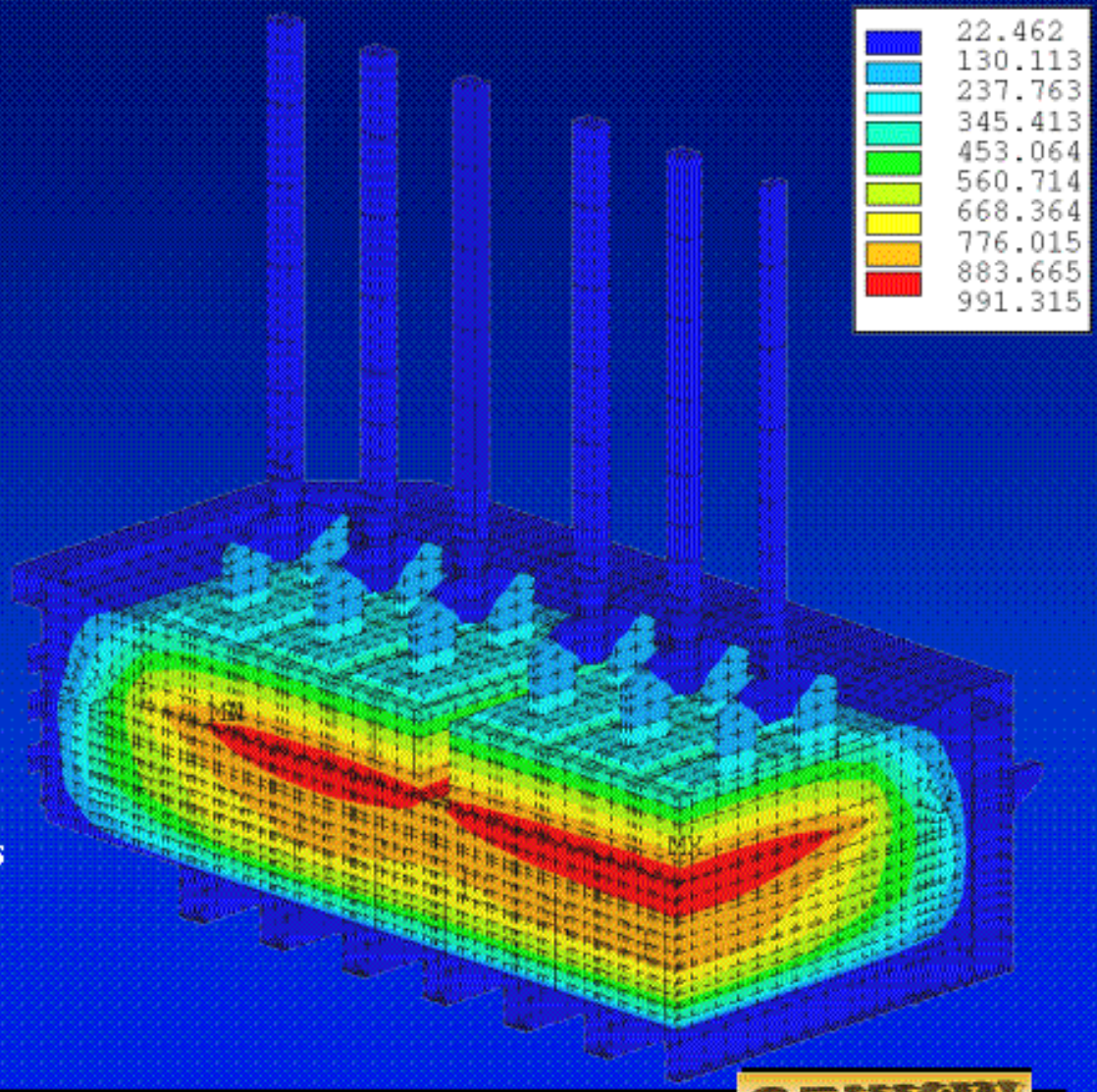
1993's Model Transient Solution Statistics

- 36 hours preheat
- 4 shunts dropped at 5, 10, 15 and 20 hours
- Full amperage is ~150 kA
- 45 load steps required
- ~33,000 finite elements used
- ~48 CPU hours of HP715
- The results file containing all the 45 load steps results required 1.935 GB of disk space



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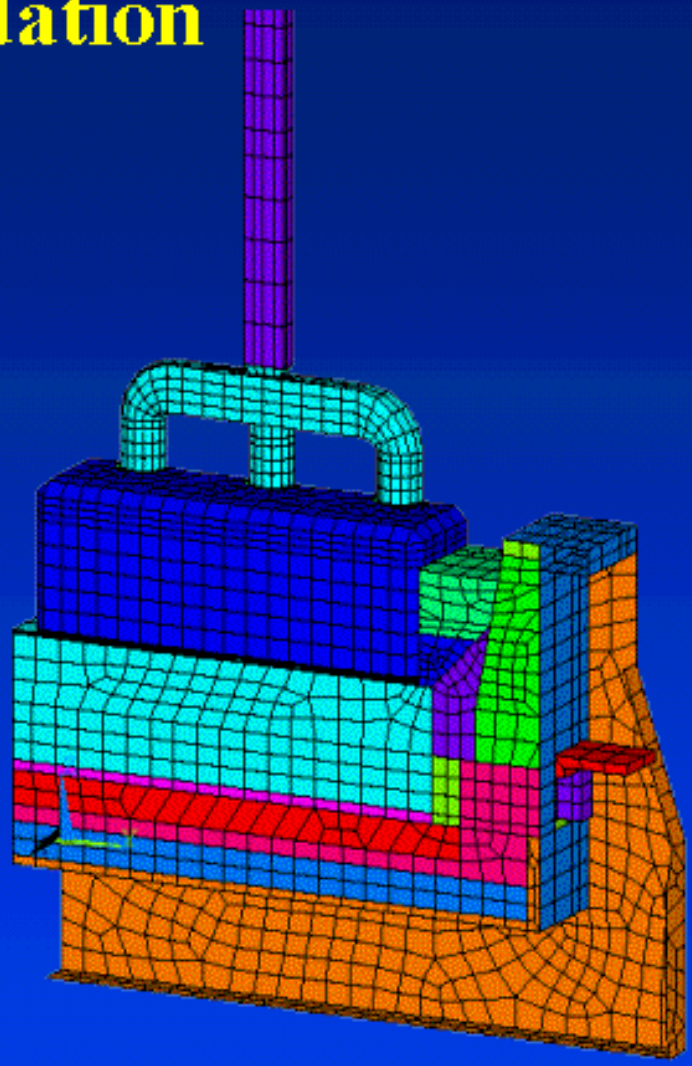
Model Validation

- The model is typically calibrated to reproduce the measured temperature evolution curves by adjusting hard to assess properties like the evolution of the coke bed resistivity with time/temperature by trial and error
- The model calibration runs could be done using only a subset of the full model like a full cell side slice model



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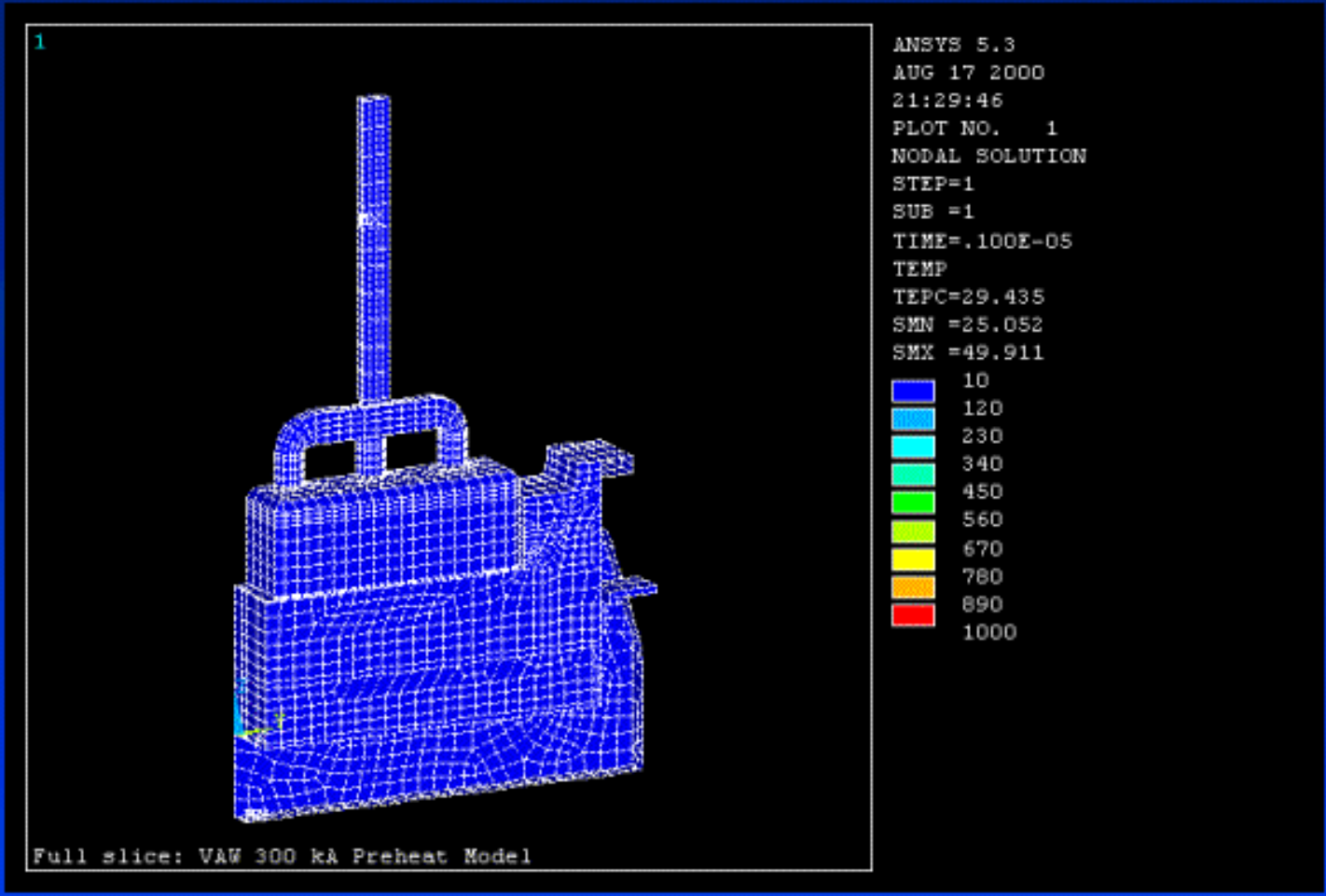
Model Validation



- Slice model 36 hours transient solution required only 3.14 CPU hours

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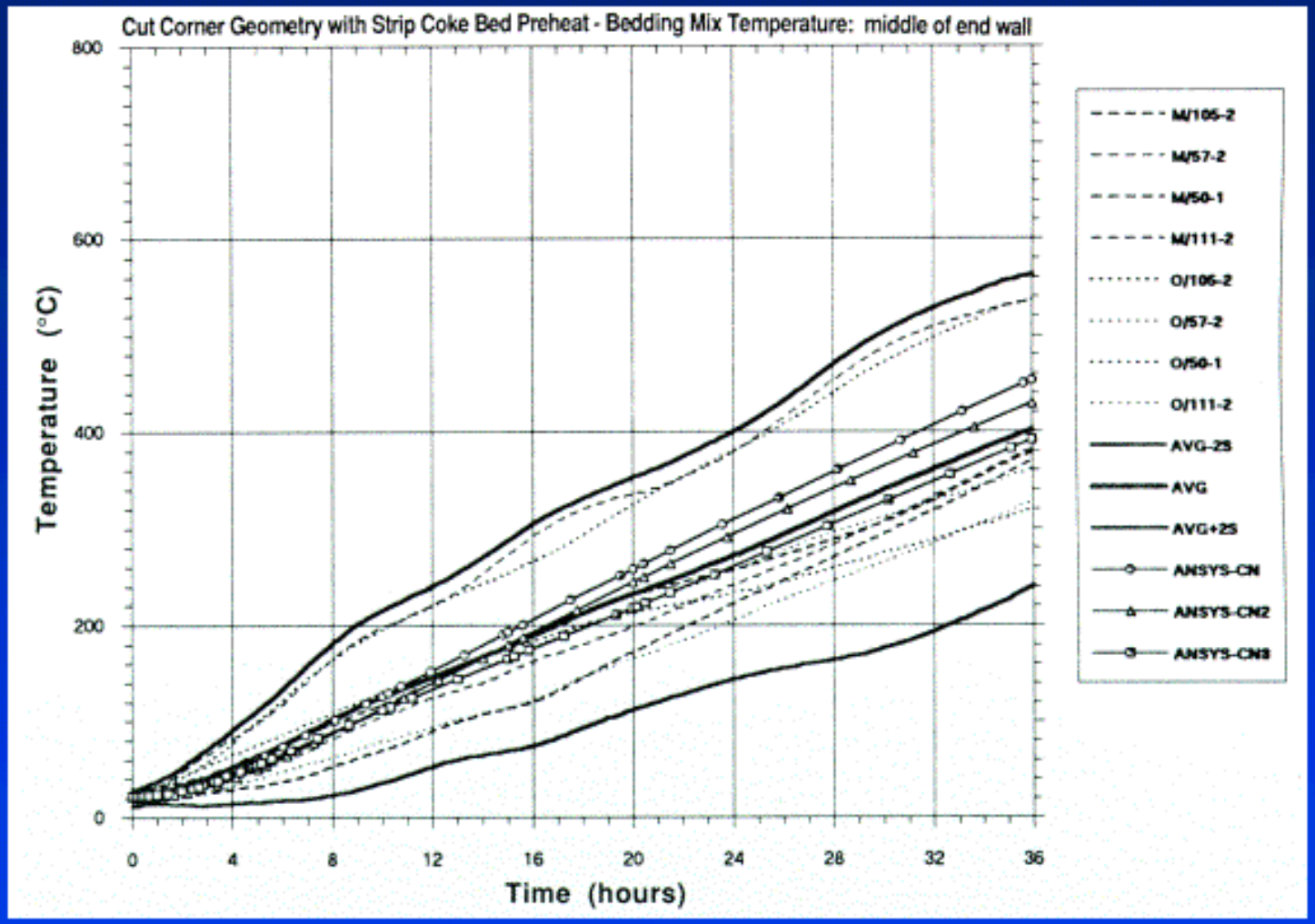
1993's Model Validation



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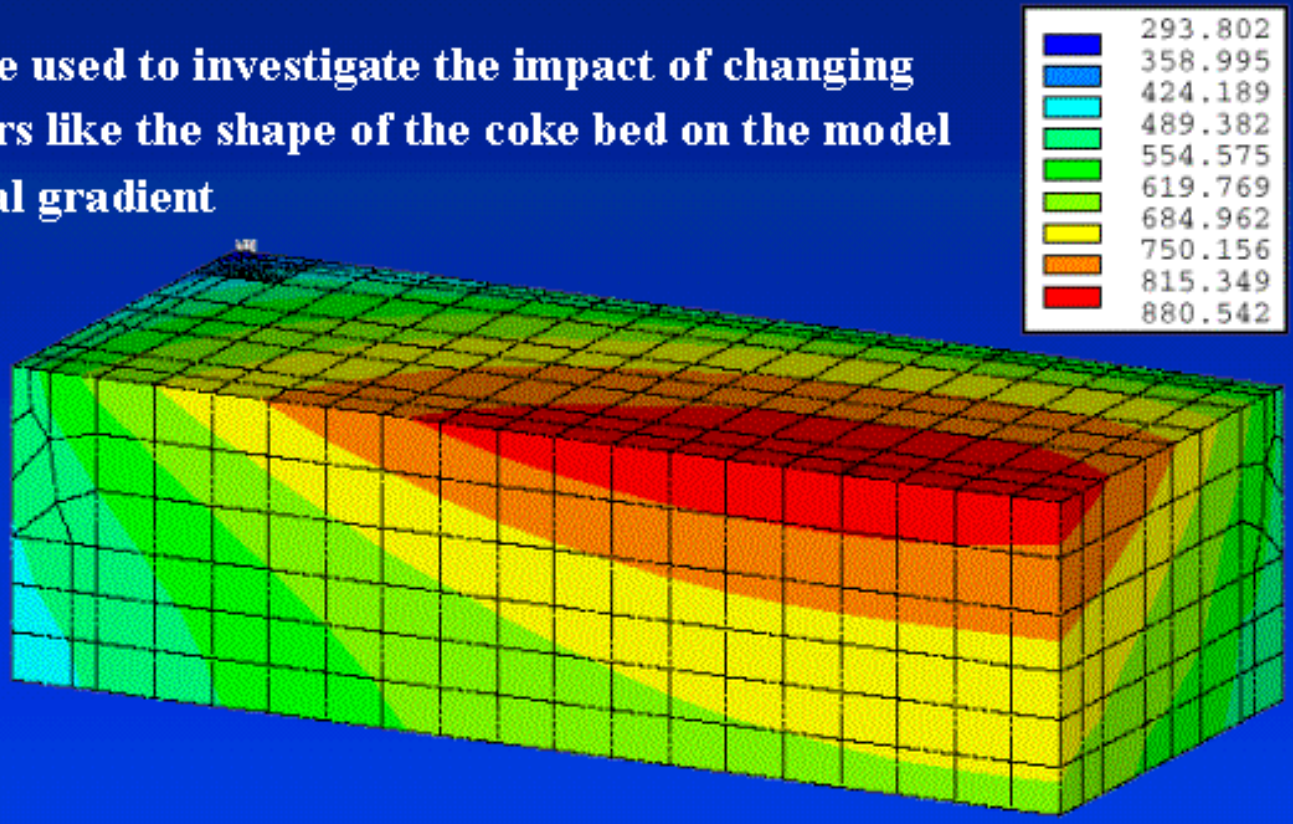
Model Applications

- The model can be used to investigate the impact of changing design parameters like the shape of the coke bed on the model predicted thermal gradient



First block thermal gradient after 30 hours

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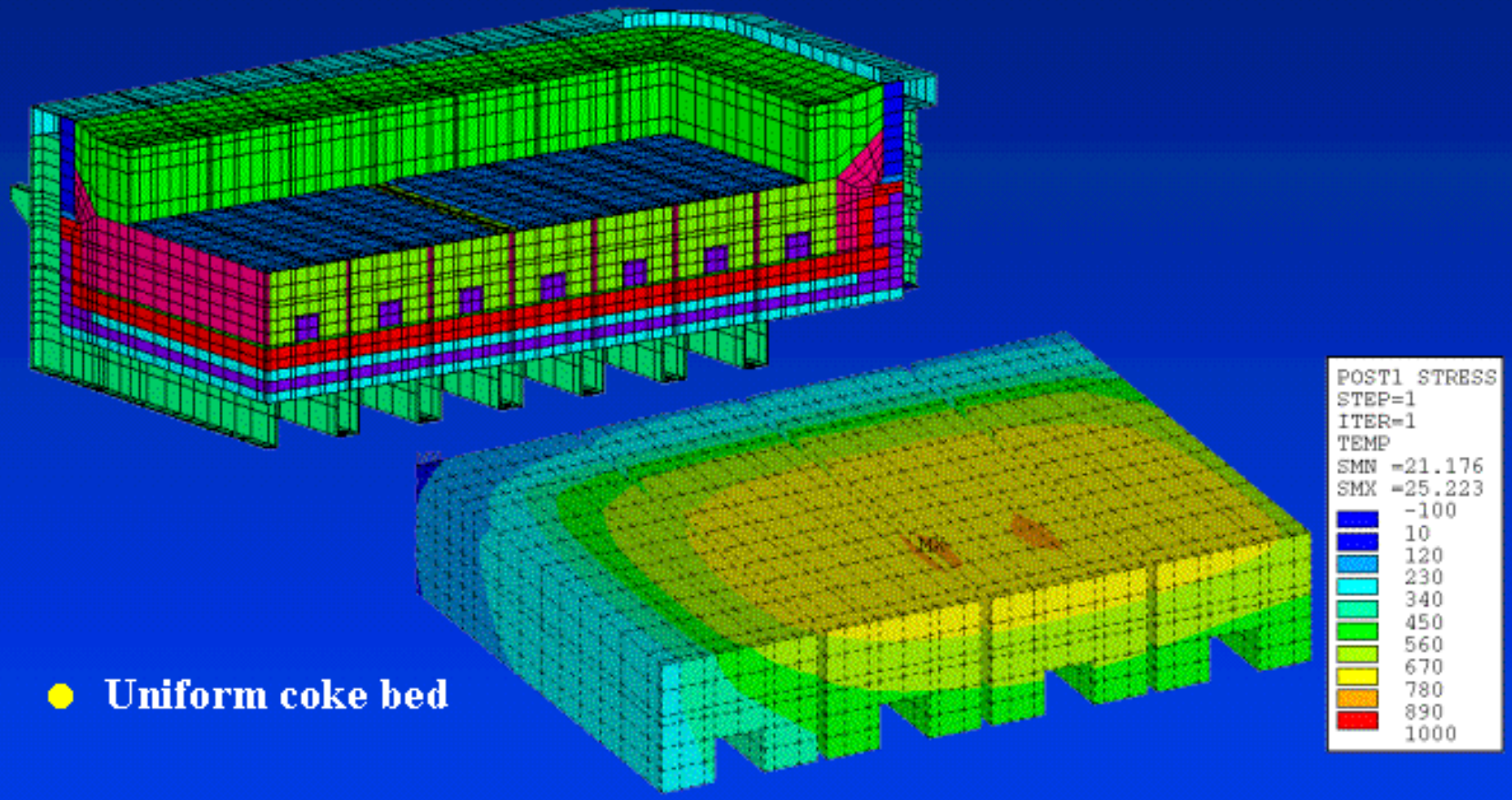
1993's Model Application



- Uniform coke bed

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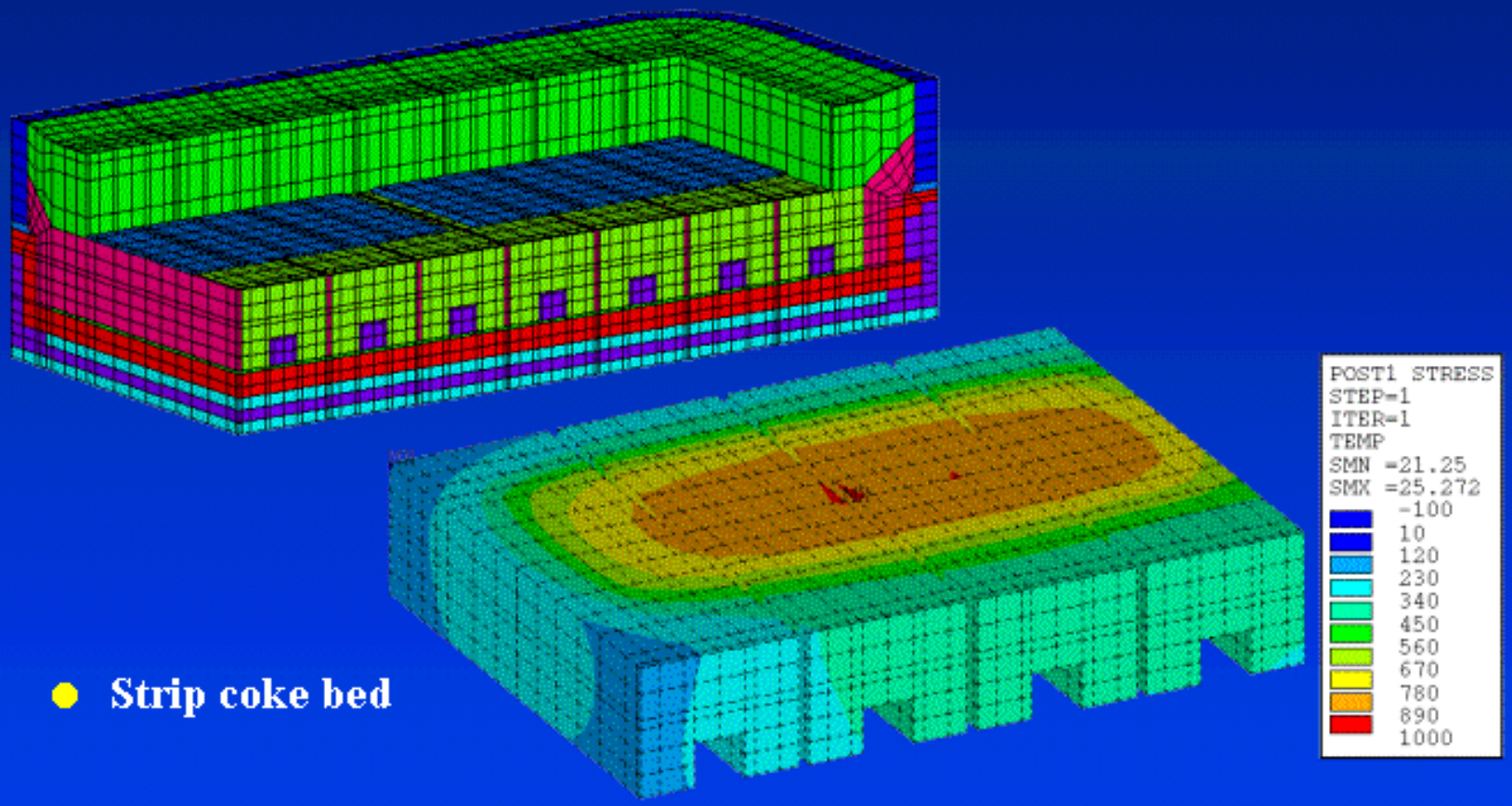
1993's Model Application



- Strip coke bed

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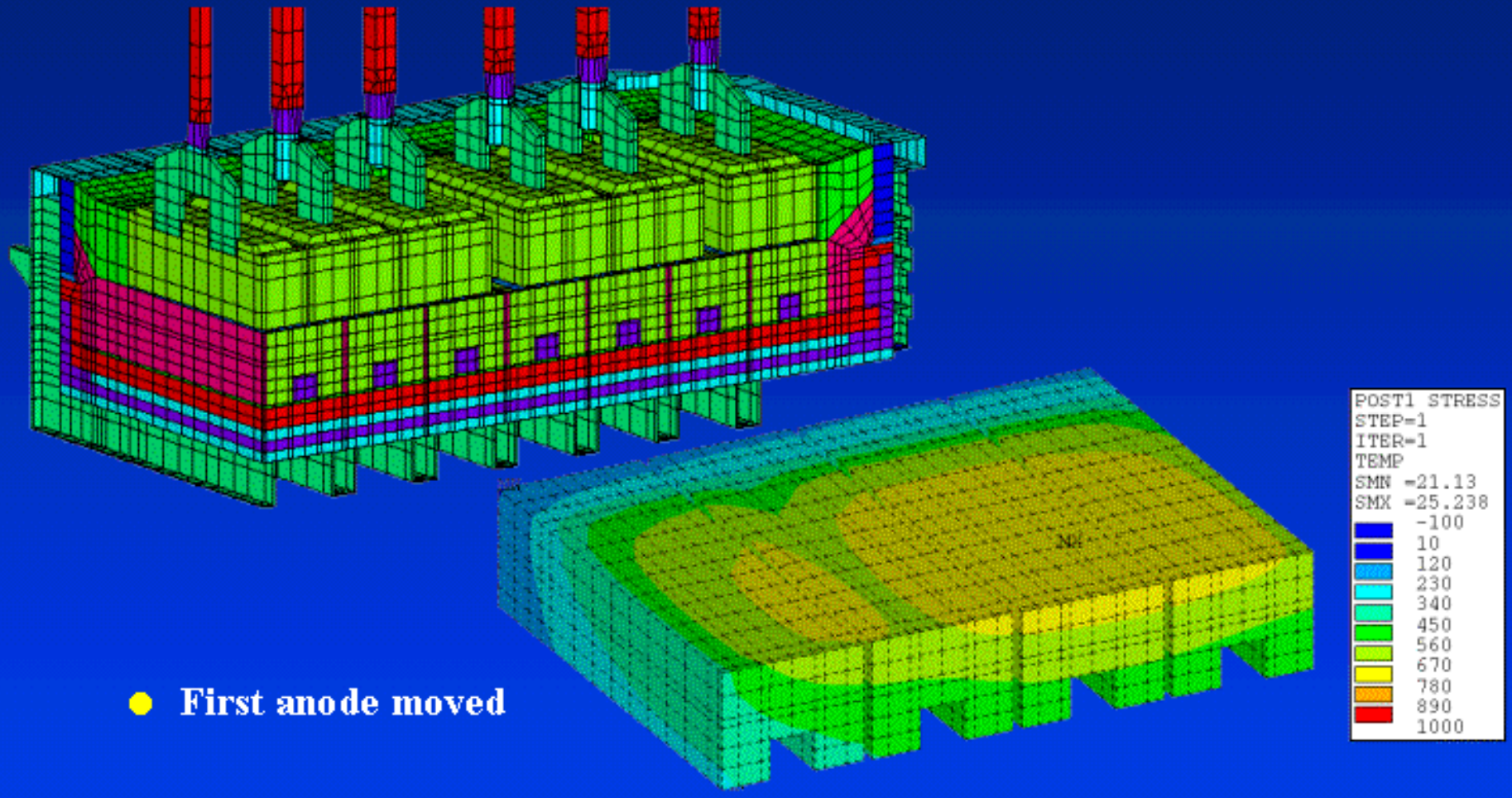
1993's Model Application



- First anode moved

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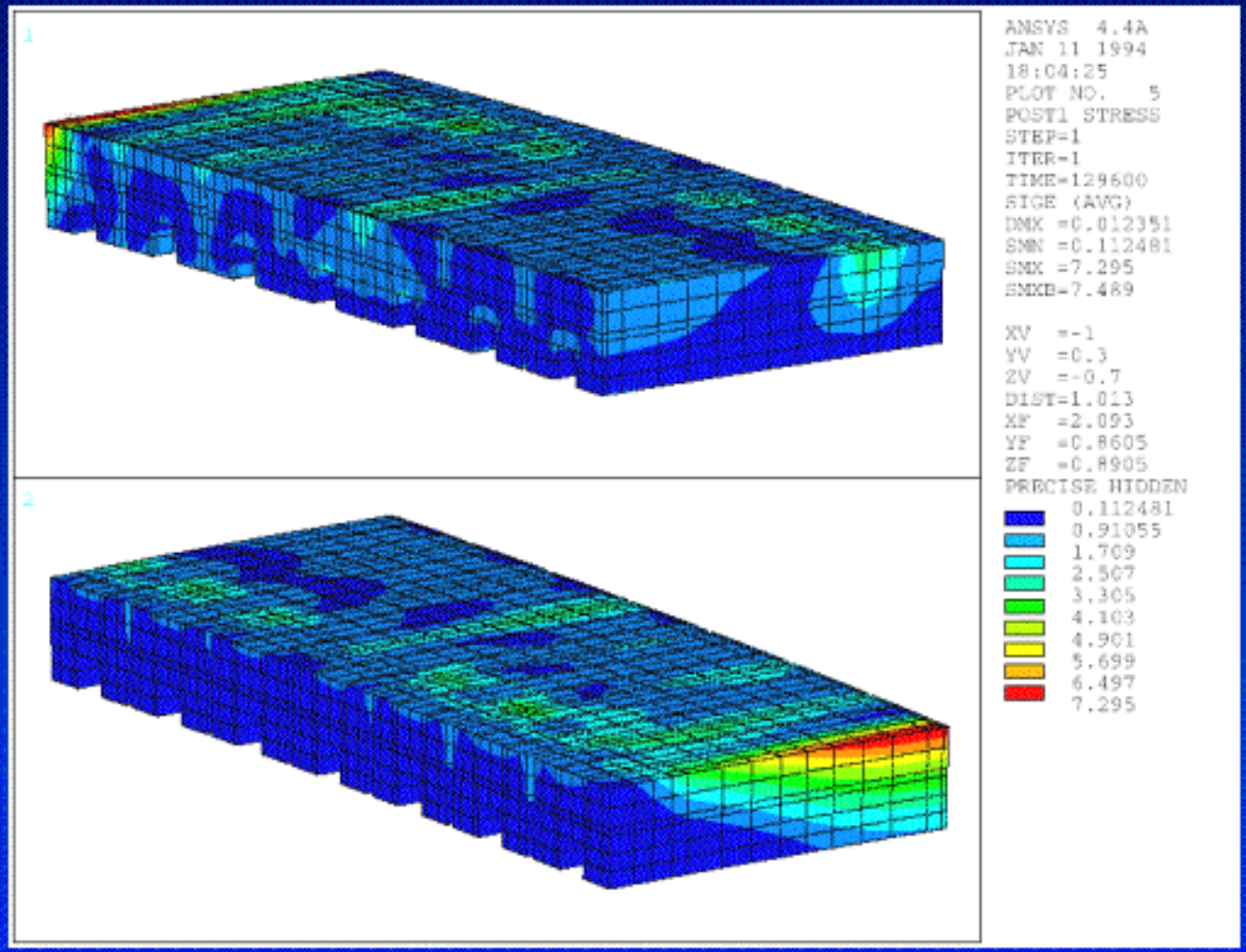
1993's Model Extension to Stress Analysis



Equivalent stress in the cathode panel at 36 hours – standard coke bed

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Conclusions

- It was demonstrated that it is now possible to solve a full 3D transient thermo-electric coke preheat model on an inexpensive Pentium III computer .
- It was also explained why the marginal cost of developing a coke preheat model is very small when a full 3D thermo-electric model in standard operation configuration is already available .
- As for the potential benefits of using such a coke preheat model to optimize the design of the coke preheat practices, any smelter experimenting a significant rate of early lining failure would easily identify them !