Towards the Development of a 3D Full Cell and External Busbars Thermo-Electric Model

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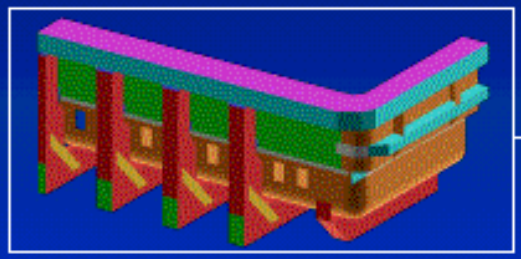
Plan of the Presentation

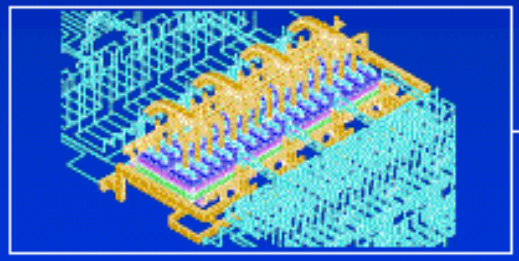
- Introduction
- "Complete" Full Cell Quarter Thermo-Electric Model
- Full Cell Half Thermo-Electric Model
- Full Cell Half + External Busbars Thermo-Electric Model
- Full Cell + External Busbars Thermo-Electric Model
- Cathode Half + External Busbars + Liquid Zone Thermo-Electric Model
- Relationship between Local Heat Transfer Coefficients at the Liquid/Ledge Interface and the Velocity Field
- Conclusions

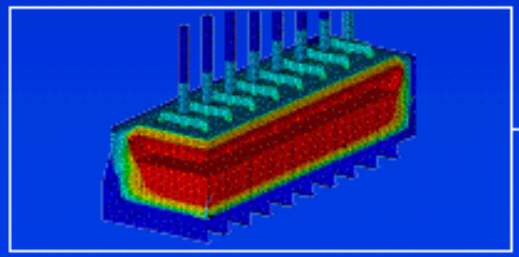
Modeling the Hall-Héroult Cell

Currently, we can fit Hall-Héroult mathematical models into three broad categories:

- Stress models which are generally associated with cell shell deformation and cathode heaving issues.
- Magneto-hydro-dynamic (MHD) models which are generally associated with the problem of cell stability.
- Thermal-electric models which are generally associated with the problem of cell heat balance.







Cell Design

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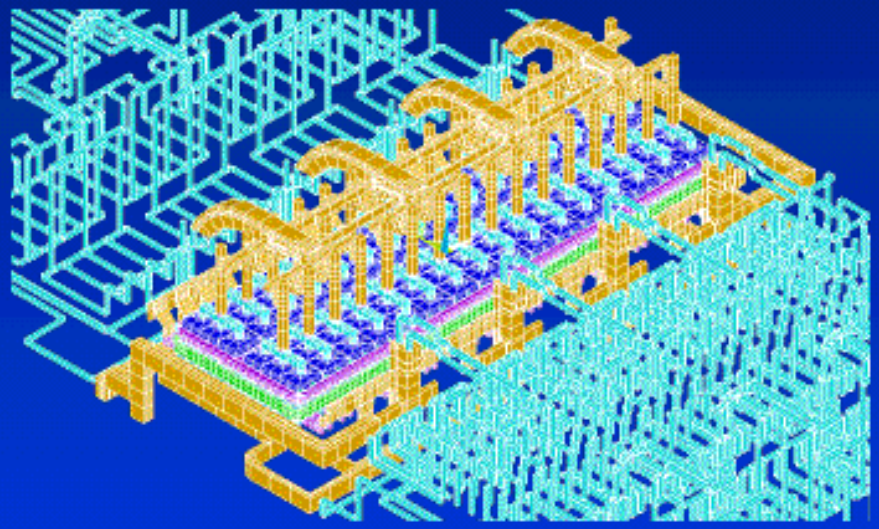
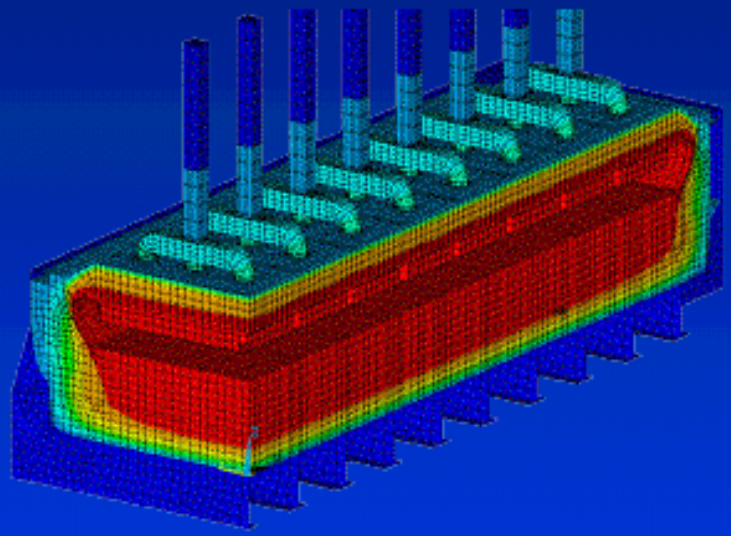
Modeling the Hall-Héroult Cell





MHD model:

centered around the liquid zone

Thermo-electric model:

no need to include the liquid zone

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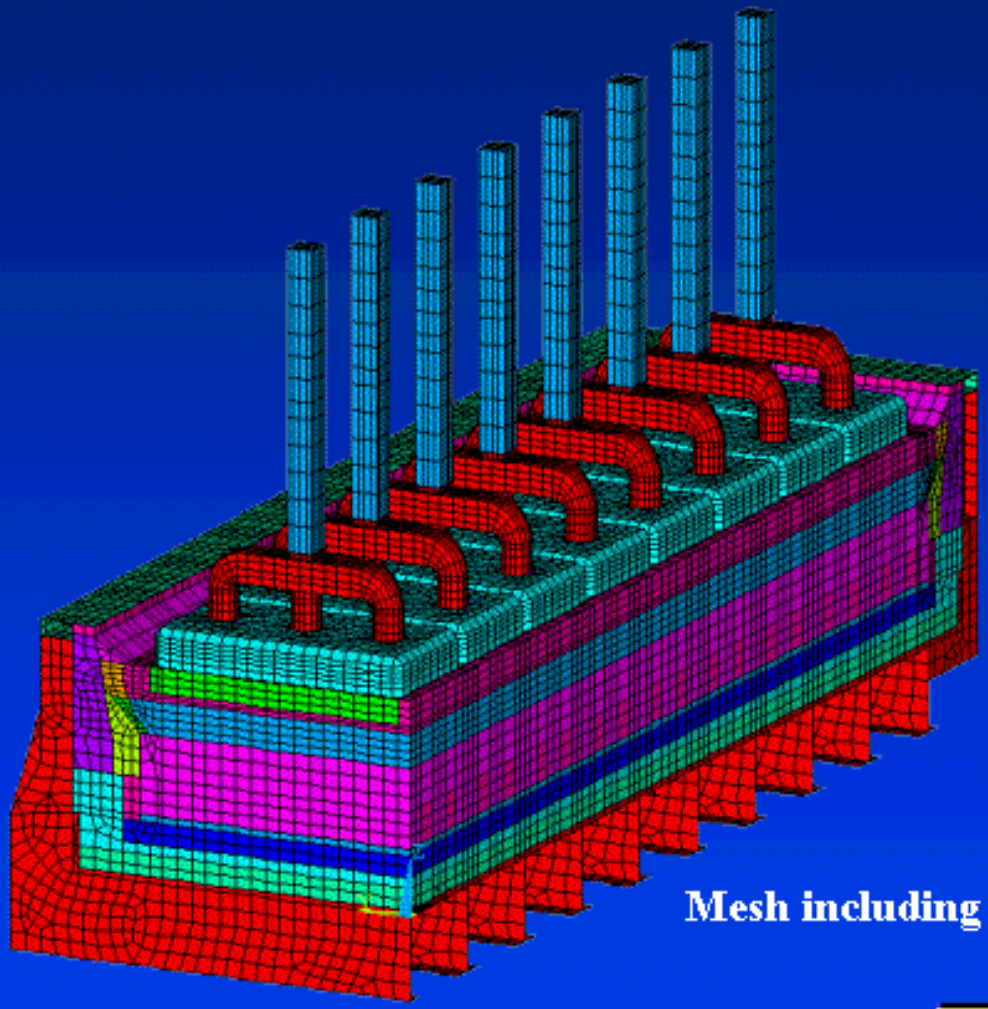
Full Cell Quarter Thermo-Electric Model



Mesh including the liquid zone

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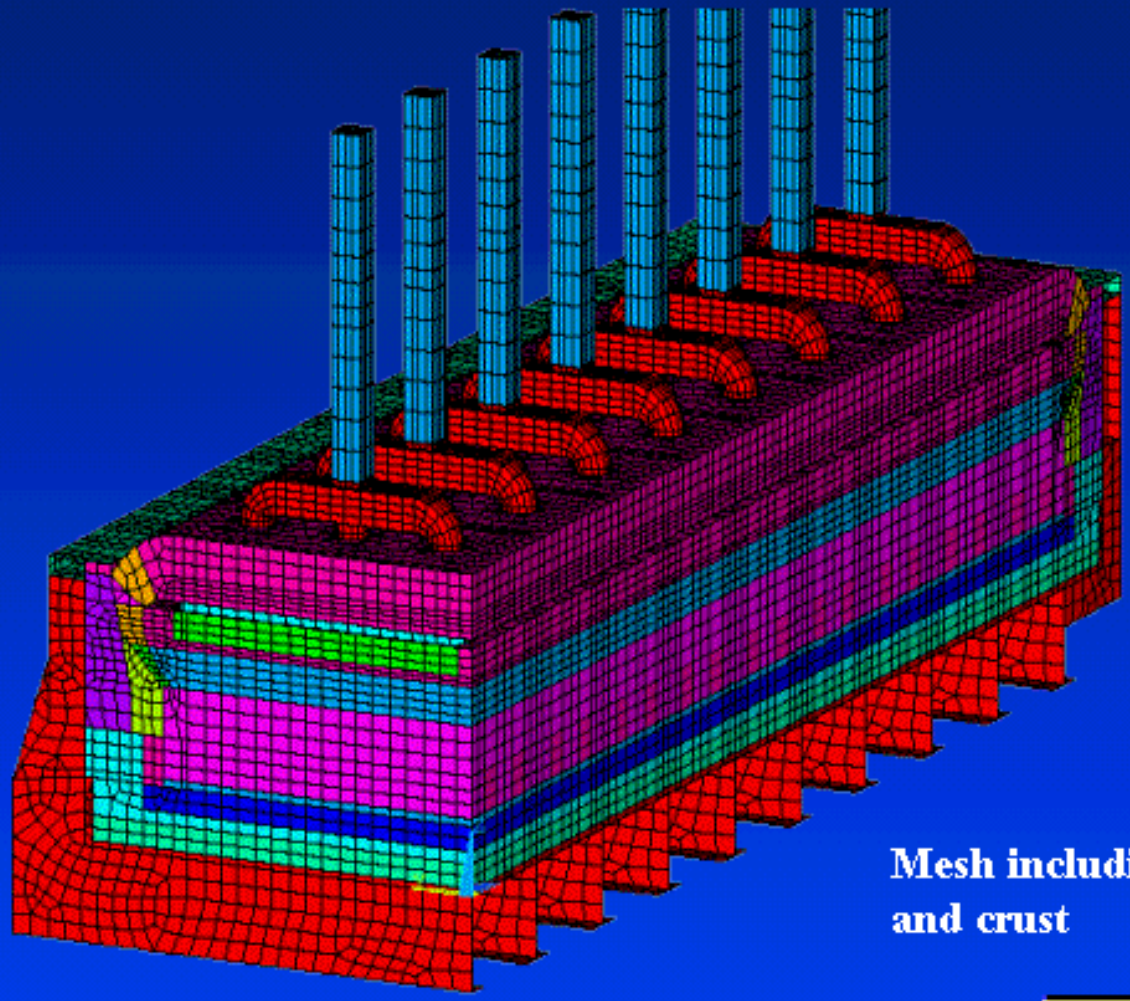
“Complete” Full Cell Quarter Thermo-Electric Model



Mesh including the liquid zone and crust

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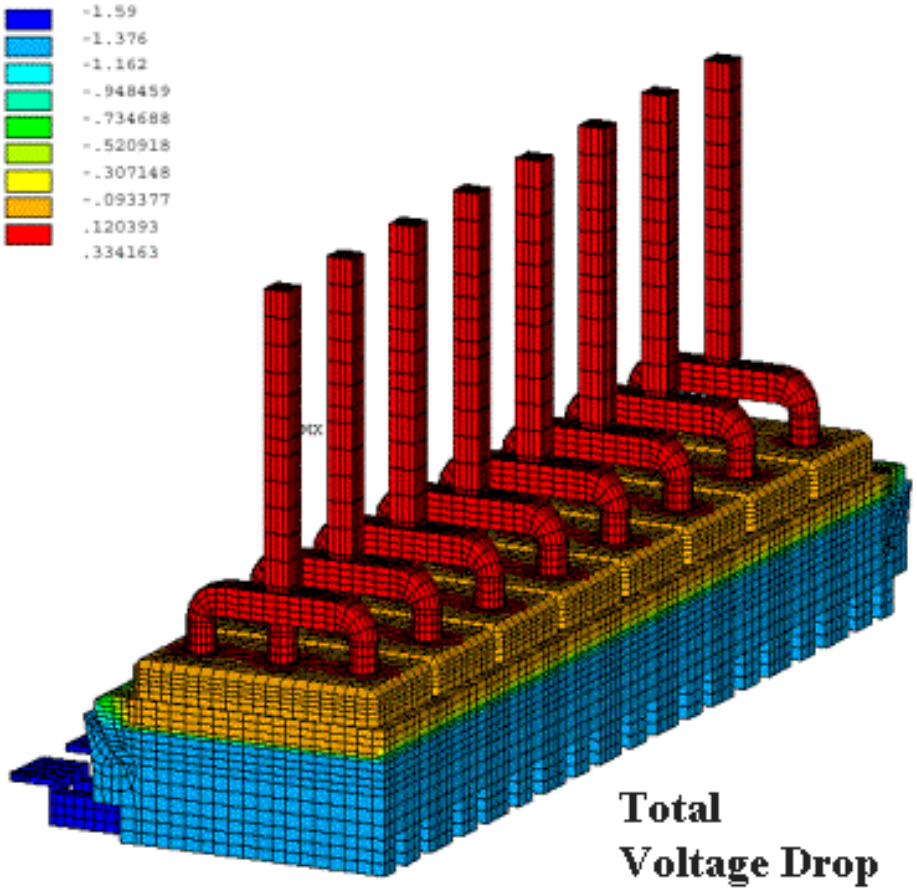
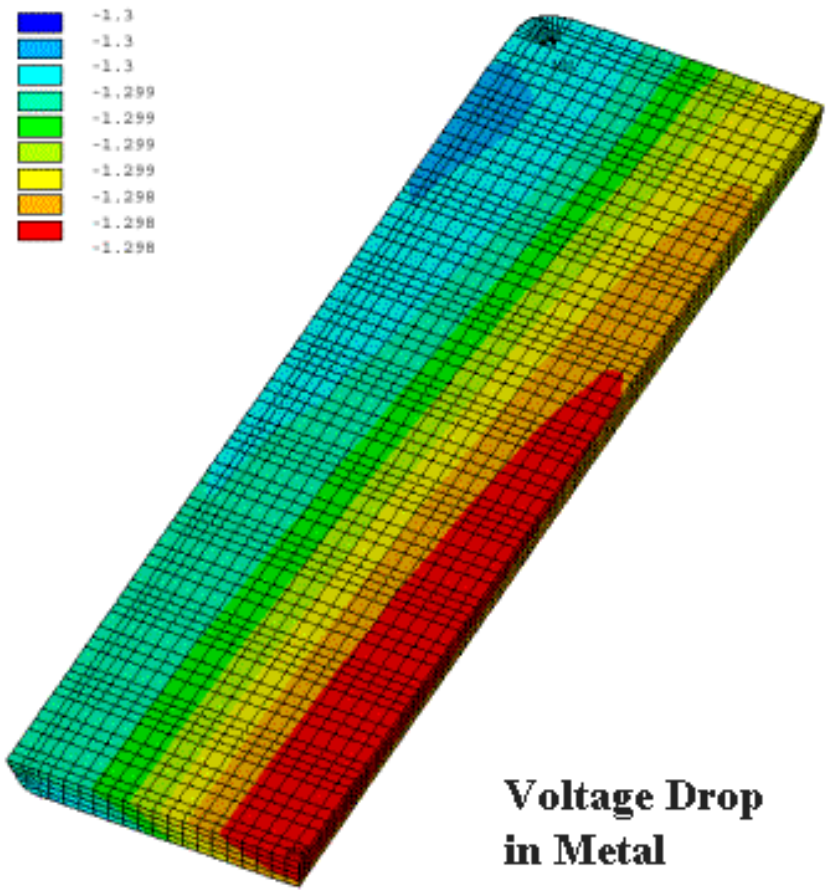
“Complete” Full Cell Quarter Thermo-Electric Model



Total
Voltage Drop



Voltage Drop
in Metal

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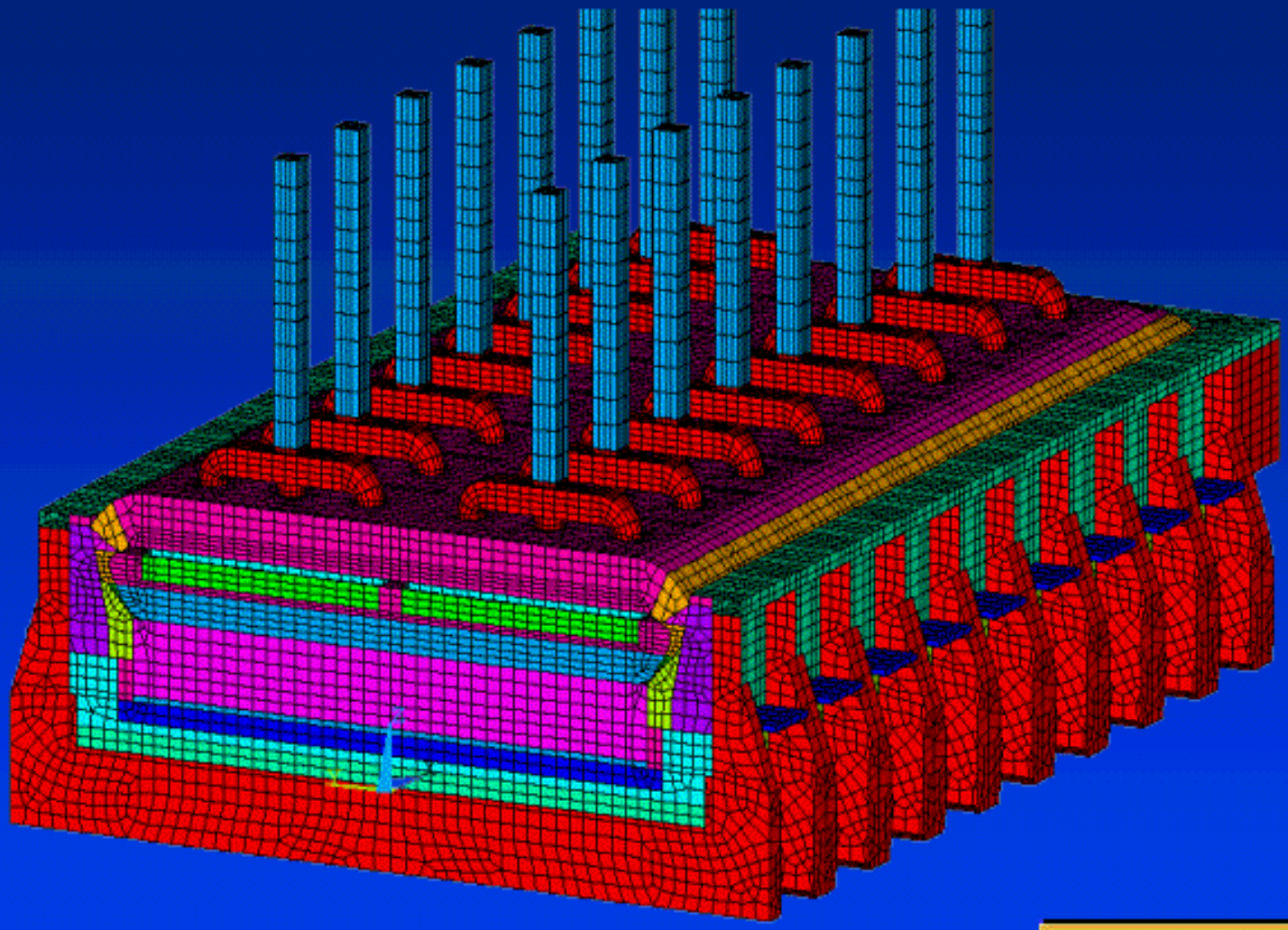
Full Cell Half Thermo-Electric Model



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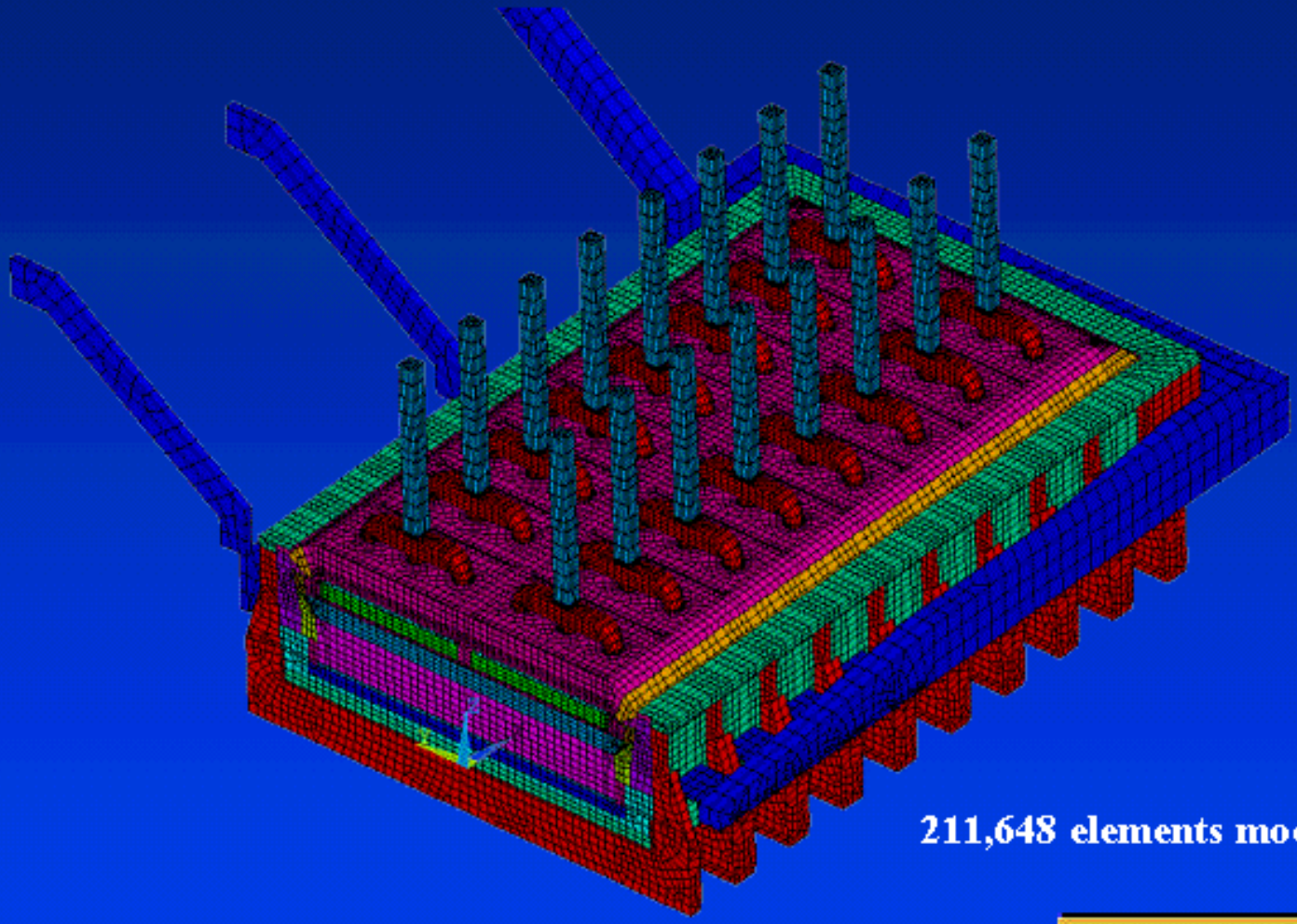
Full Cell Half + External Busbars
Thermo-Electric Model



211,648 elements model

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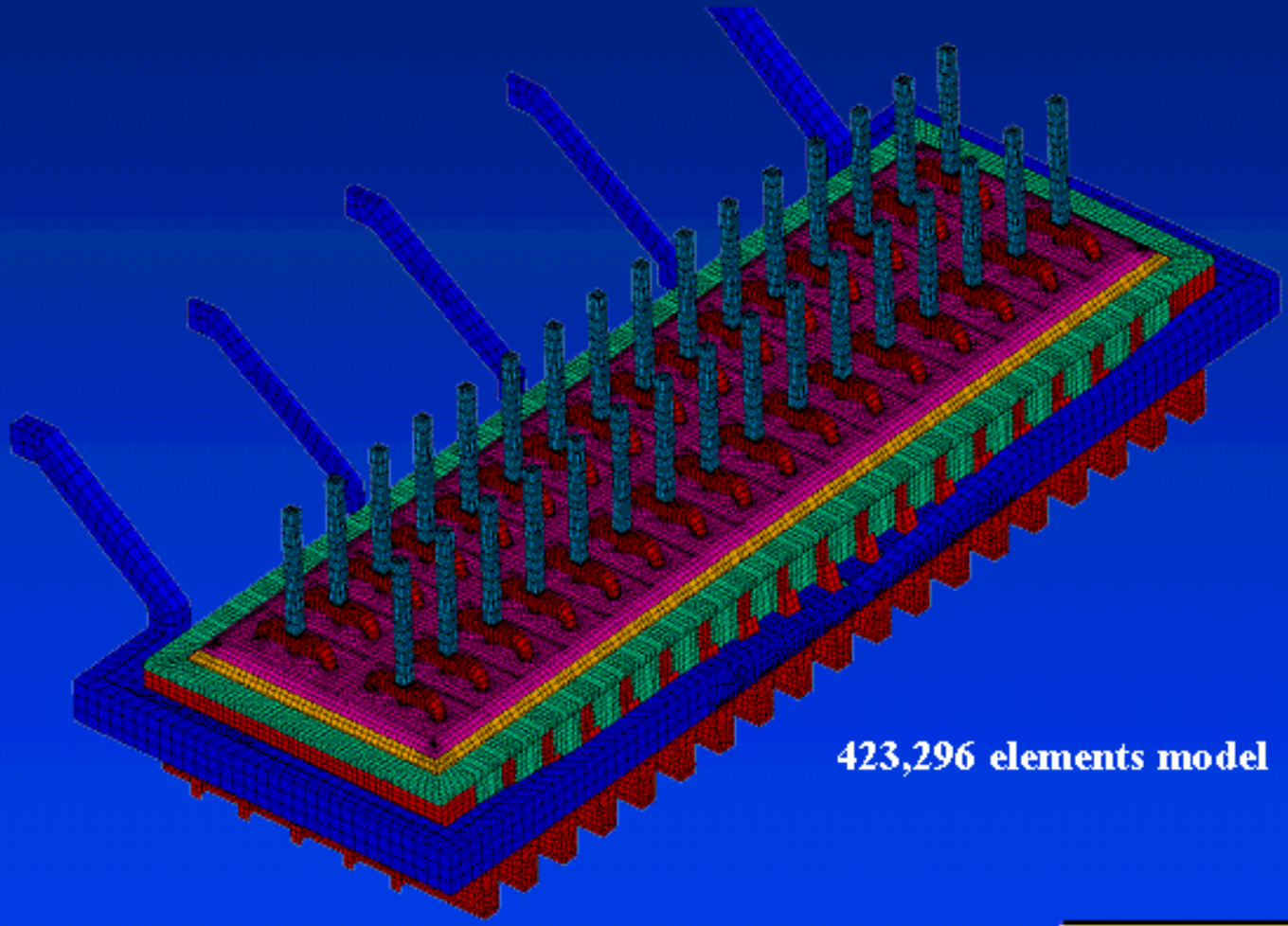
Full Cell + External Busbars
Thermo-Electric Model



423,296 elements model

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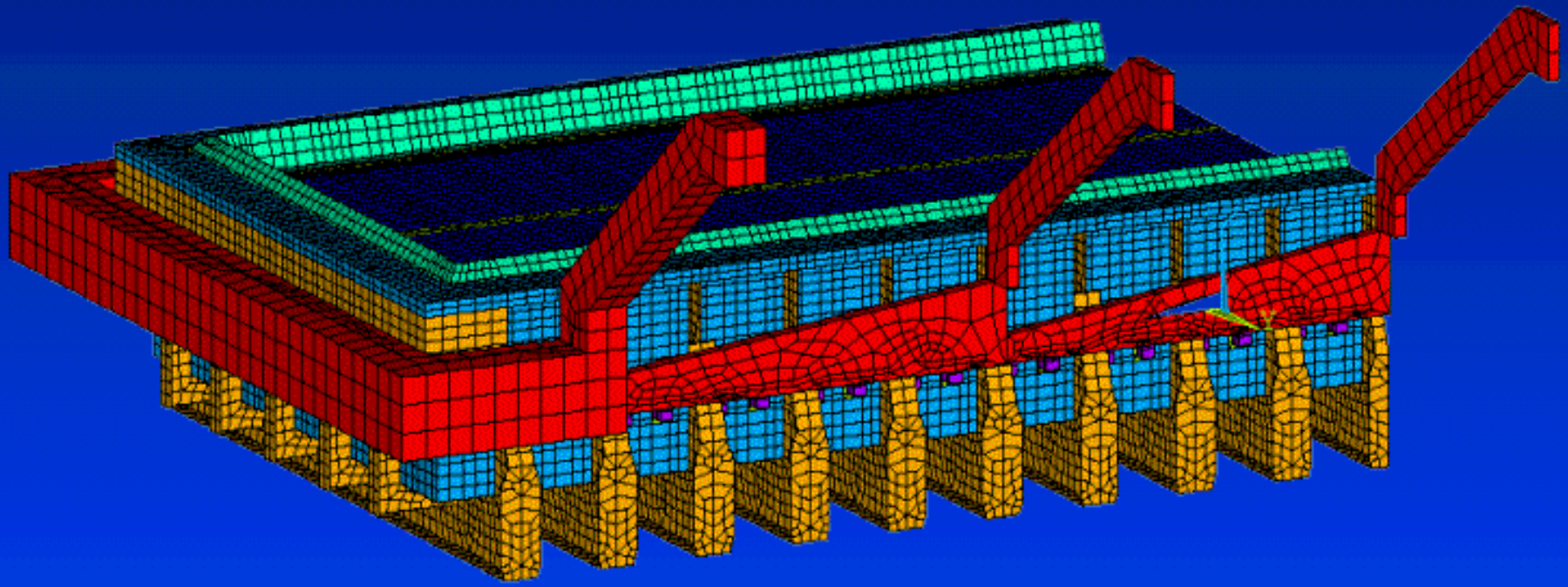
Cathode Half + External Busbars + Liquid Zone Thermo-Electric Model



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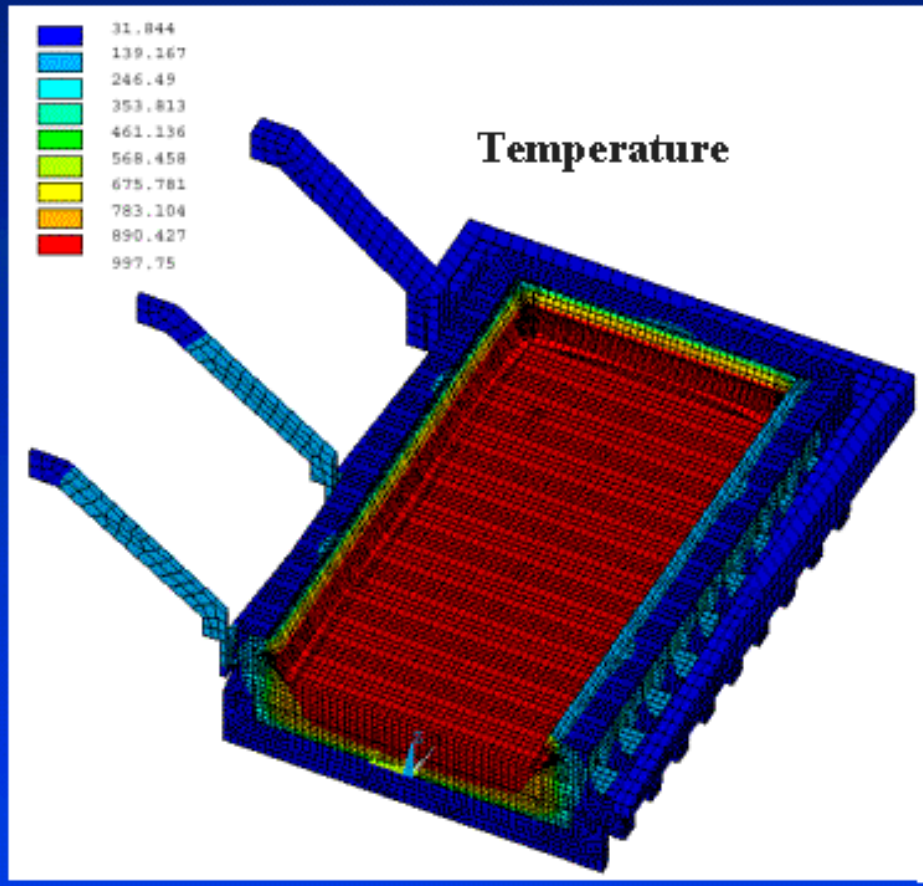
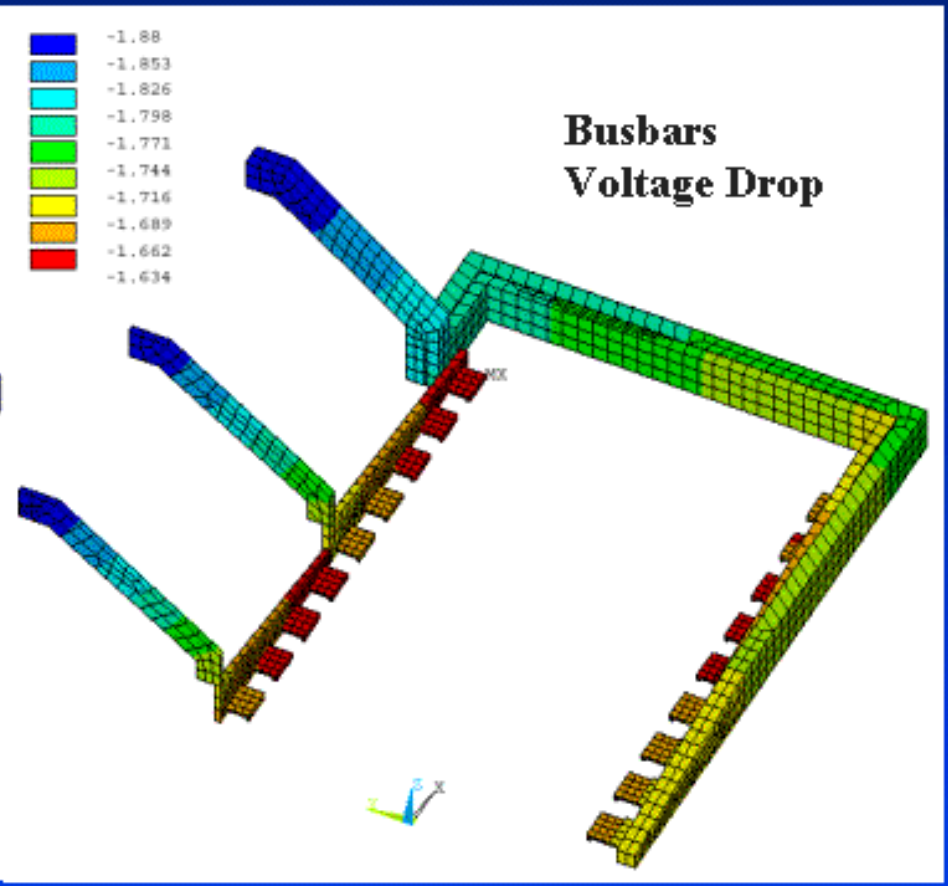
Cathode Half + External Busbars + Liquid Zone Thermo-Electric Model





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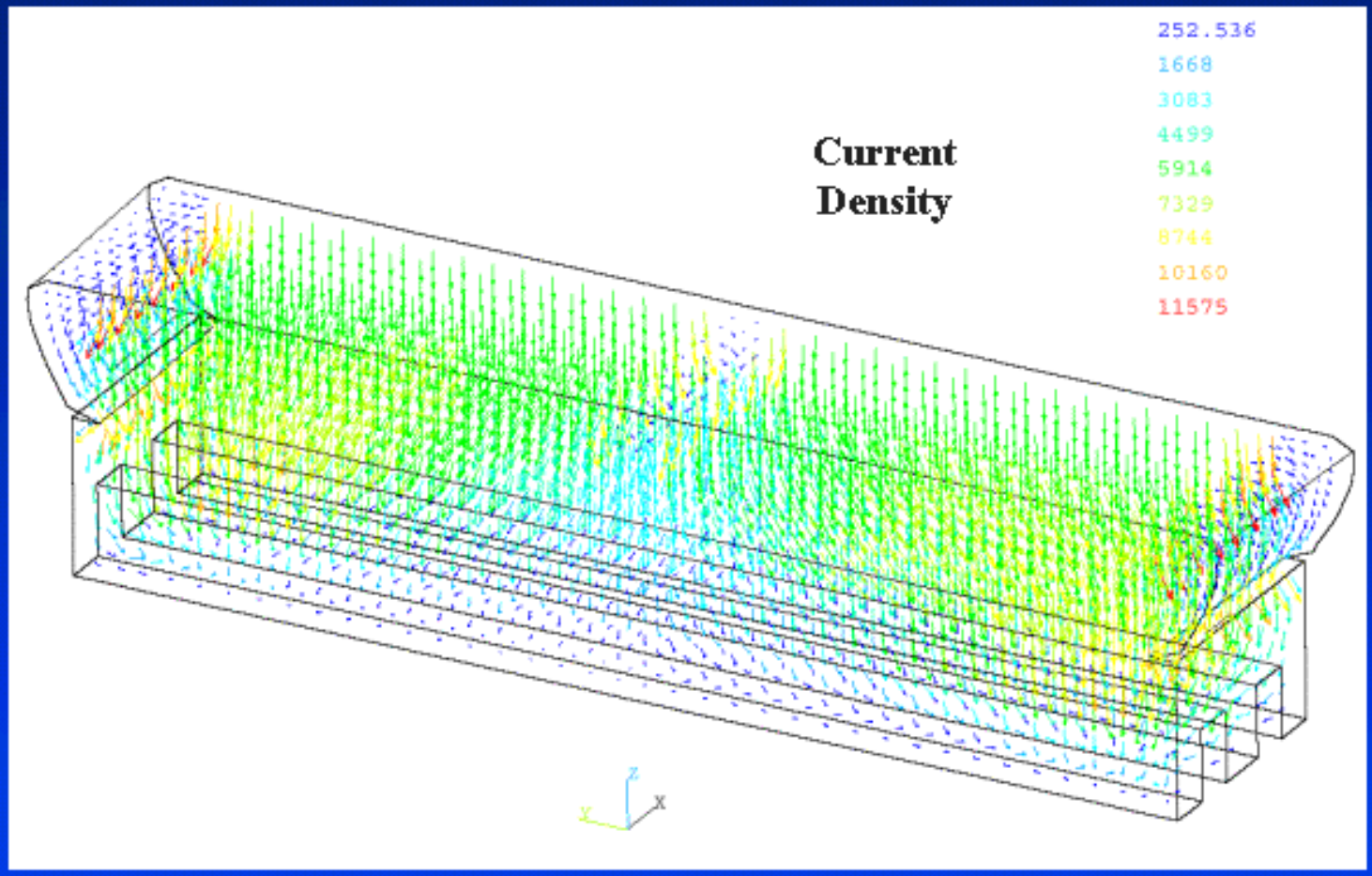
Cathode Half + External Busbars + Liquid Zone Thermo-Electric Model



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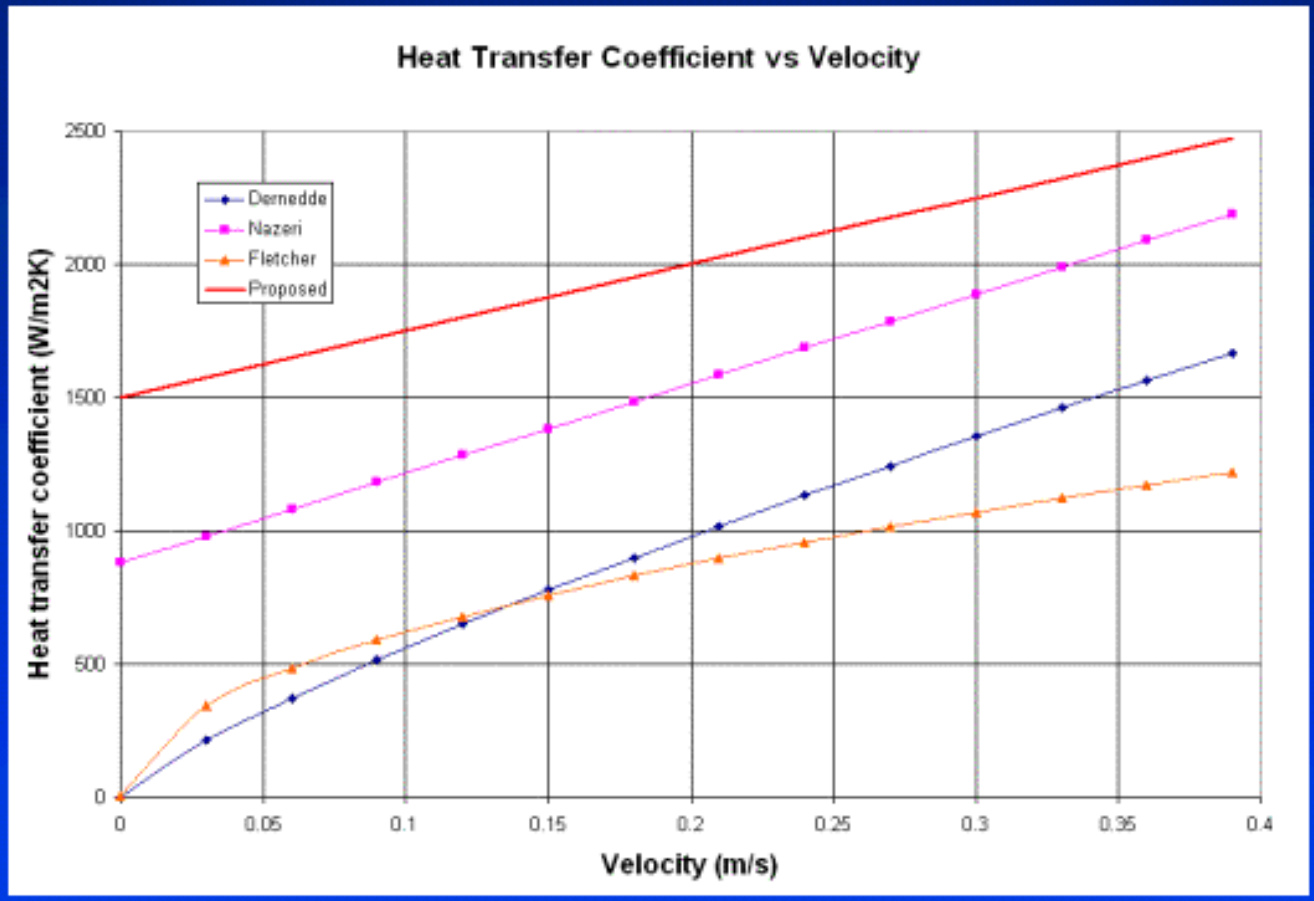
Relationship between Local Heat Transfer Coefficient at the Liquid/Ledge Interface and the Velocity Field

$$N_u = 0.0365\ R_e^{4/5}\ P_r^{1/3}$$

$$h_{(W/m2K)} = 880 + 3360\ V_{(m/s)}$$

$$N_u = 1.38 + 1.27\ R_e^{1/2}$$

$$h_{(W/m2K)} = 1500 + 2500\ V_{(m/s)}$$



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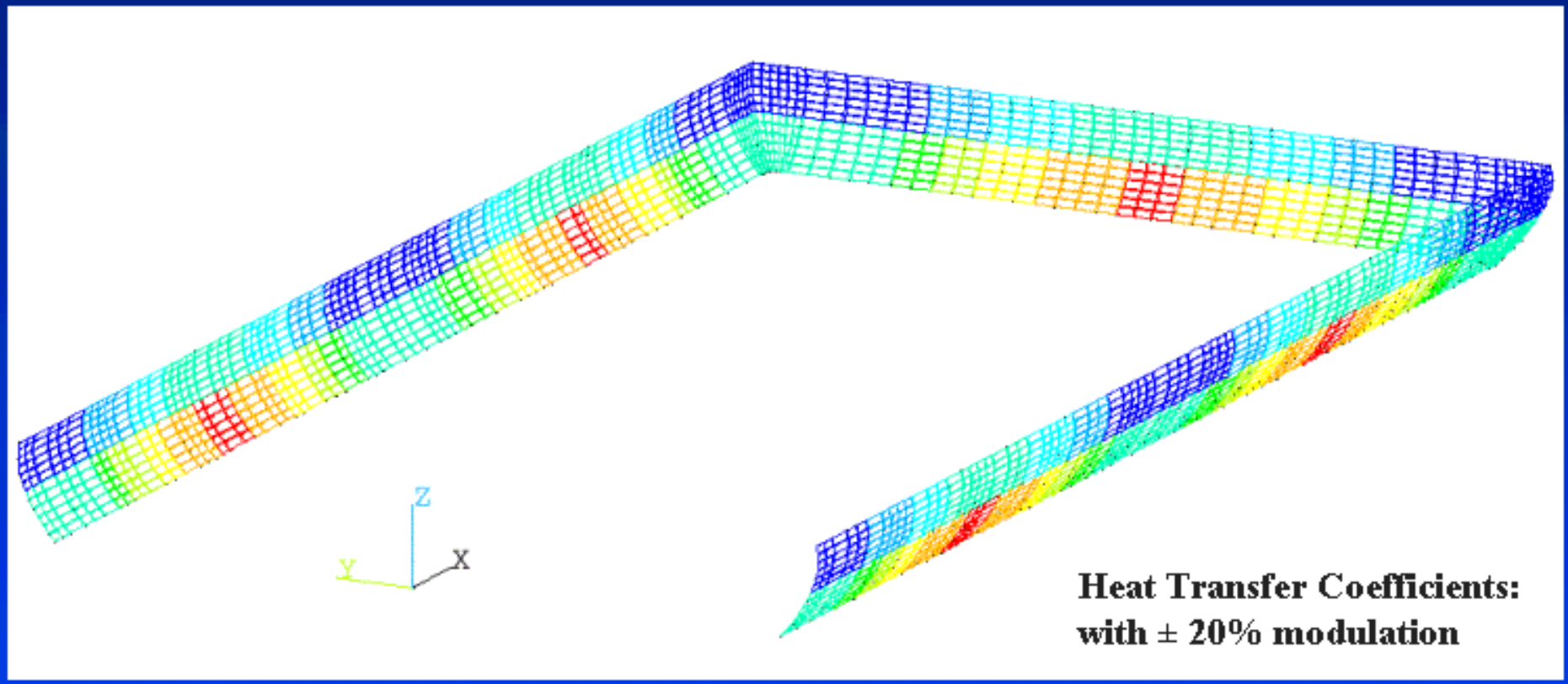
Relationship between Local Heat Transfer Coefficient of the Liquid/Ledge Interface and the Velocity Field



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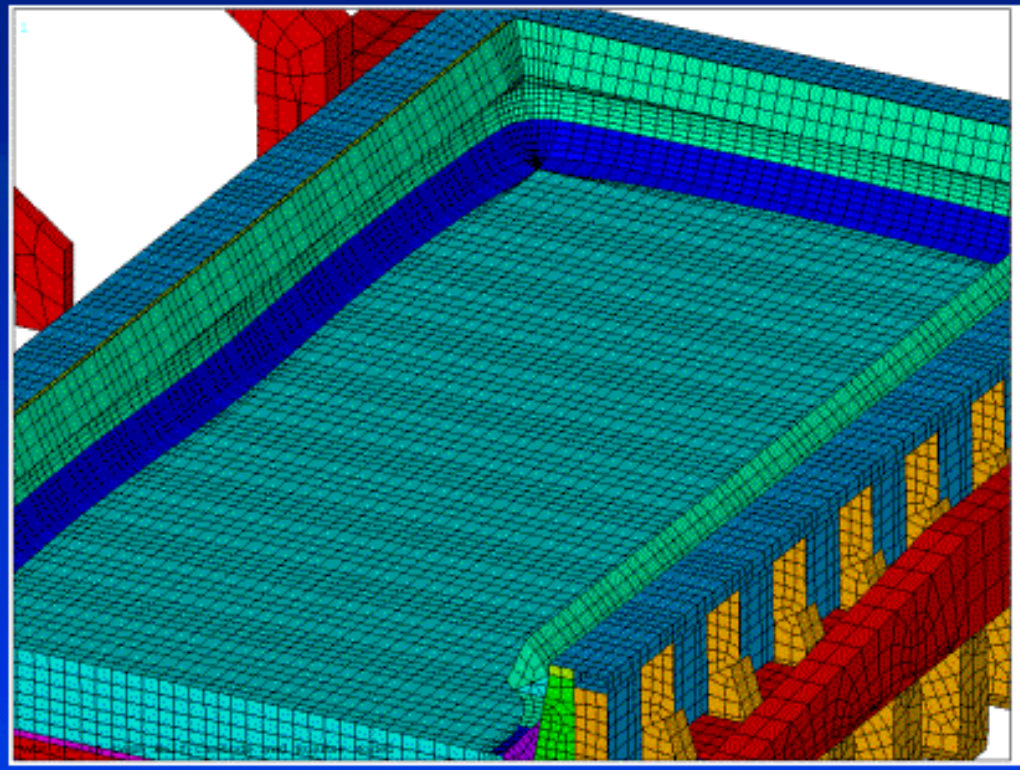
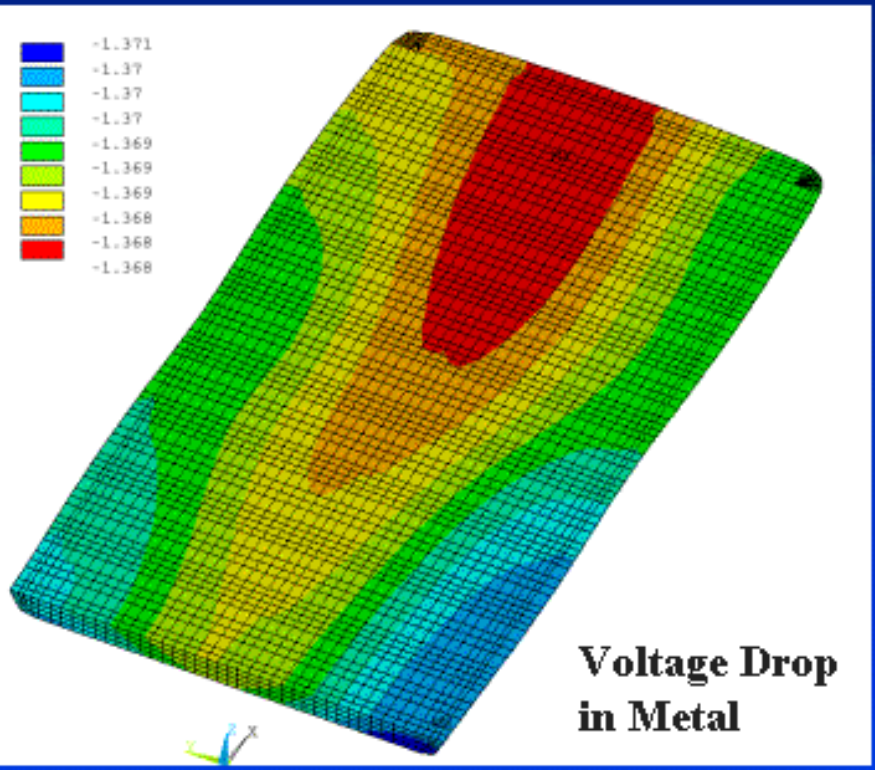
Relationship between Local Heat Transfer Coefficient of the Liquid/Ledge Interface and the Velocity Field





Voltage Drop in Metal

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Conclusions

- A 3D full cell quarter thermo-electric model and a 3D cathode half plus liquid zone and busbars thermo-electric model have been developed and solved using a PIII 800 MHz computer. The 105,096 elements full cell quarter thermo-electric model took 52.48 CPU hours and 75.68 wall clock hours to compute. The 127,988 elements cathode half plus liquid zone and external busbars thermo-electric model took 18.38 CPU hours and 22.25 wall clock hours to compute.
- From the above results, it can be assessed that it will not be practical, maybe not even possible to solve on that PIII computer the 423,296 elements full cell and external busbars model that has also been developed.
- A tentative relationship between the local heat transfer coefficient at the liquid/ledge interface and the local liquids velocity has been proposed. The concept of using local heat transfer coefficients has been successfully tested on a cathode half plus liquid zone and external busbars thermo-electric model.