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Analysis of the Thermal Response of A Spent Nuclear Fuel Transportation Cask Design to the 2001 Baltimore Tunnel Fire Event

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Introduction

- Baltimore Tunnel Fire Event
- Howard Street Tunnel Fire Model
- Spent Fuel Transportation Cask Analysis
- Results/Conclusions

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Baltimore Tunnel Fire, July 18, 2001

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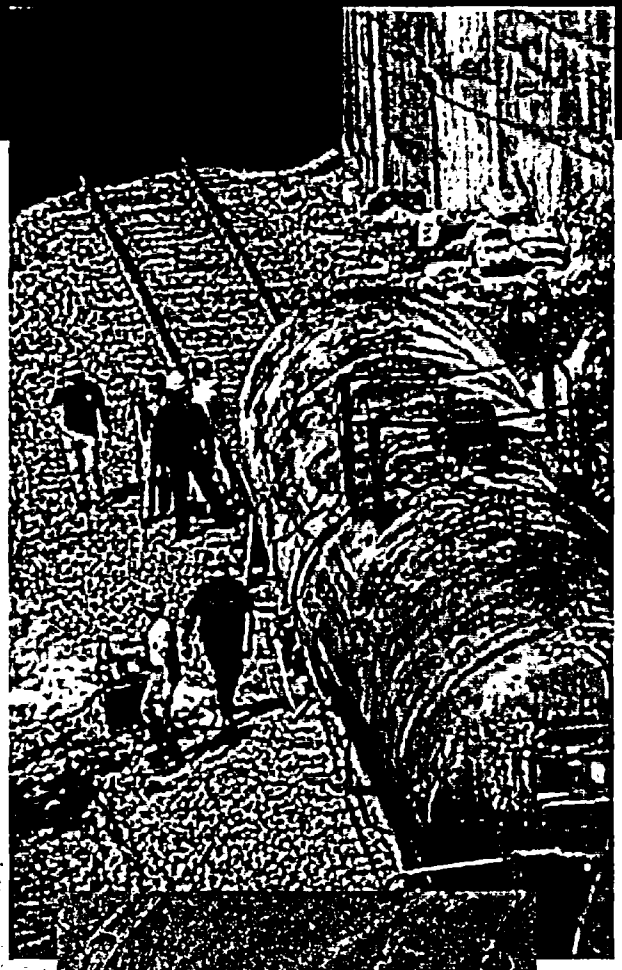

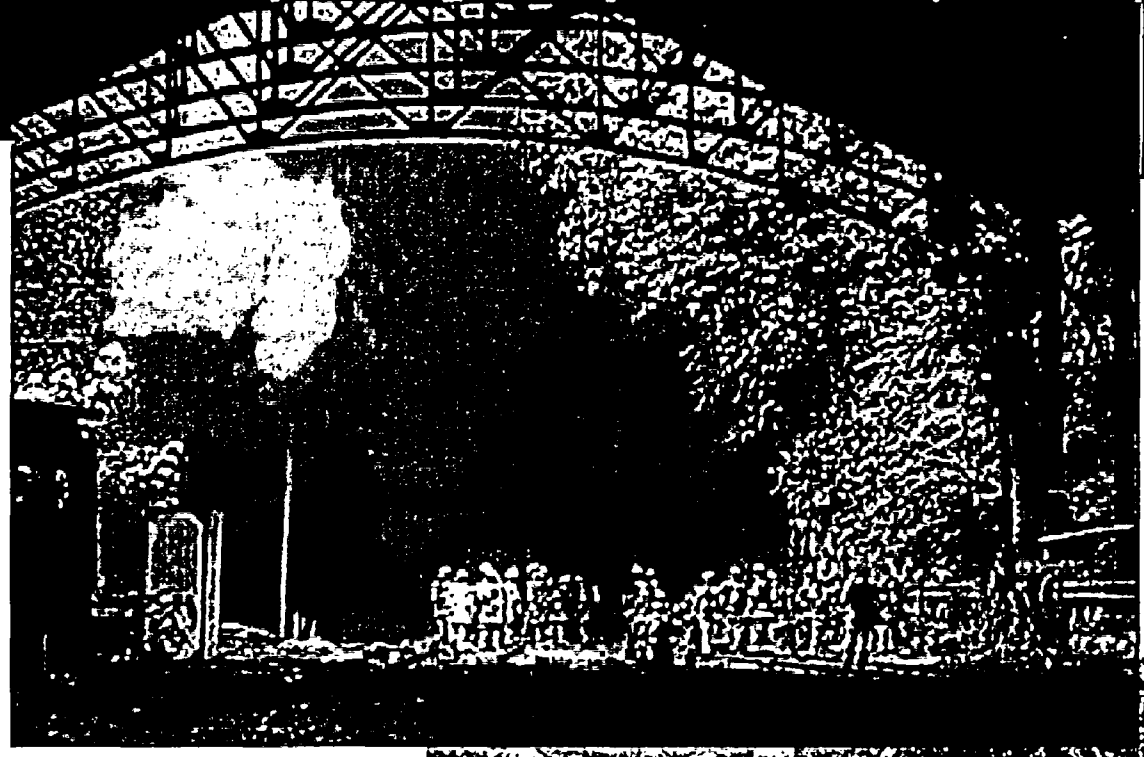

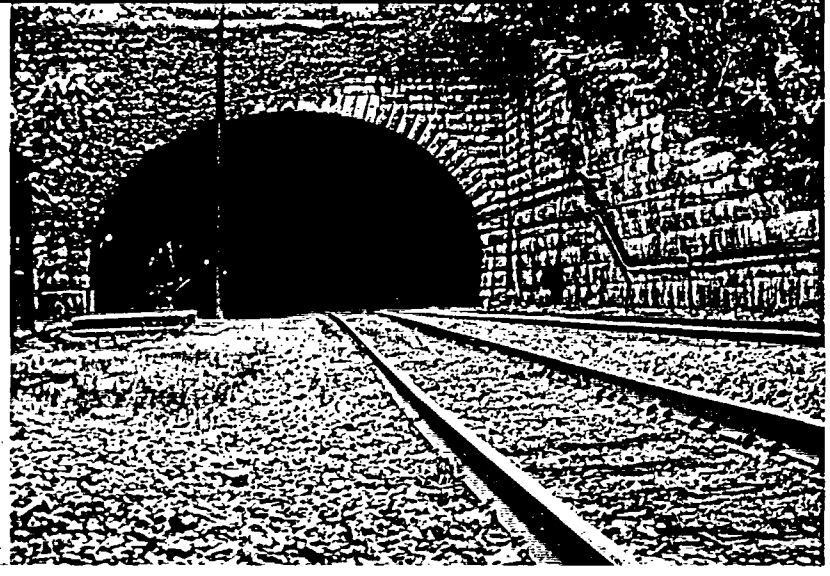

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NIST Howard Street Tunnel Fire Model

- Fire Dynamics Simulator (FDS)
  - Computational Fluid Dynamics (CFD)
- Validated Against Test Data
  - Memorial Tunnel Fire Test Program
- Full 3D Tunnel Model
  - Included Railcars

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NIST Howard Street Tunnel Fire Model

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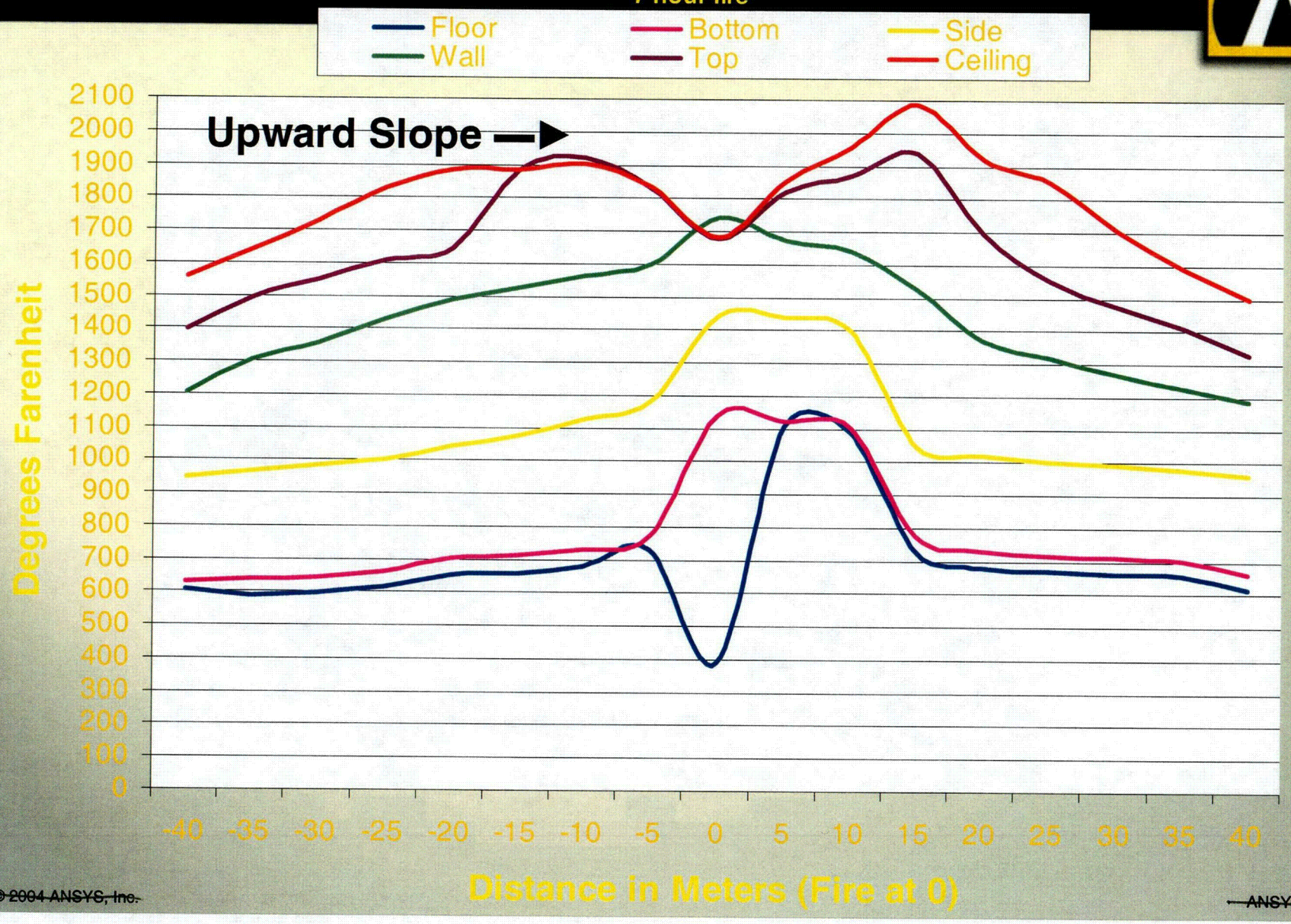
FDS Temperature Results

Tunnel Temperatures

7 hour fire



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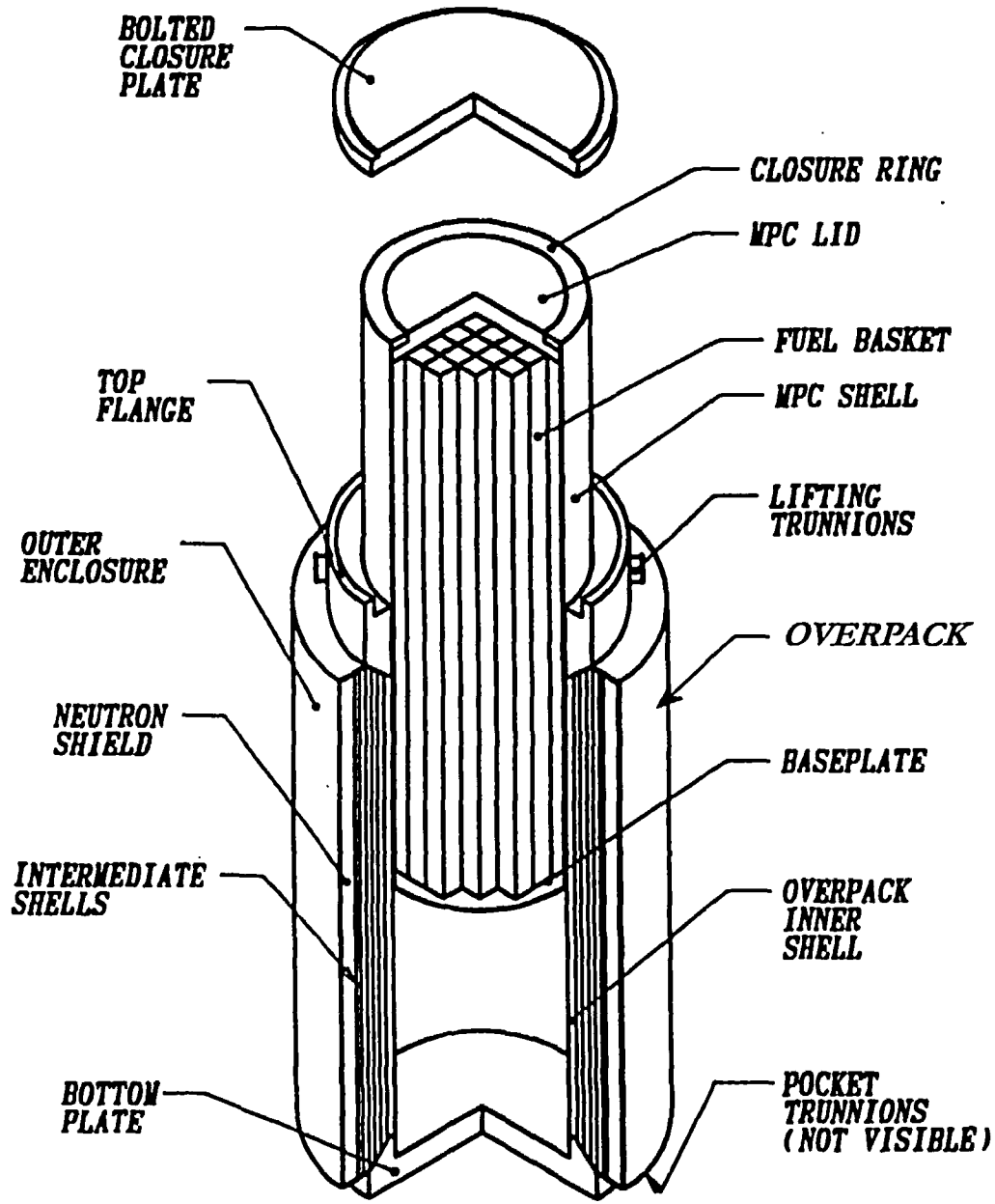
C01

Spent Fuel Transportation (Rail) Cask



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Spent Fuel Transportation (Rail) Cask

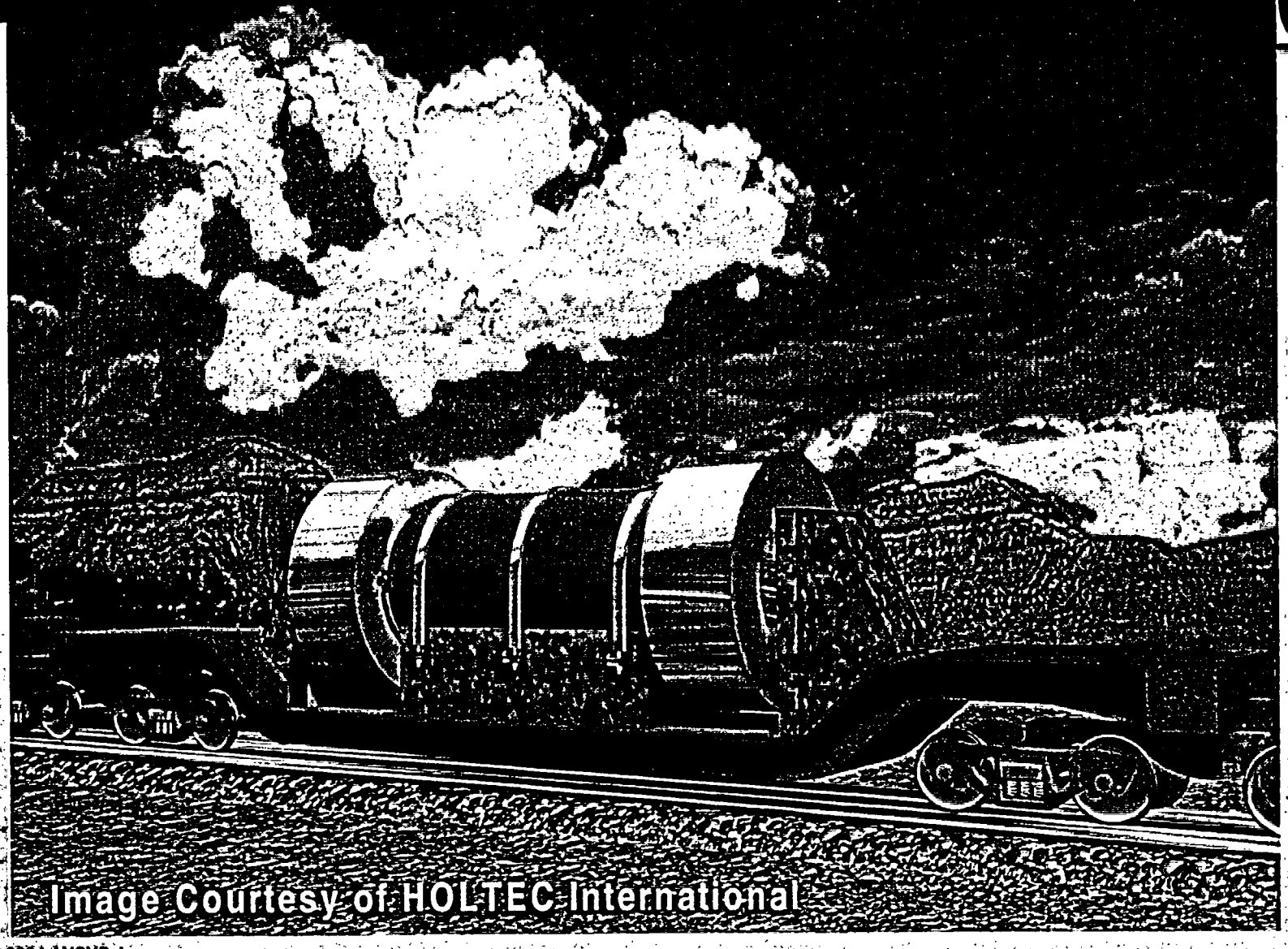

Image Courtesy of HOLTEC International

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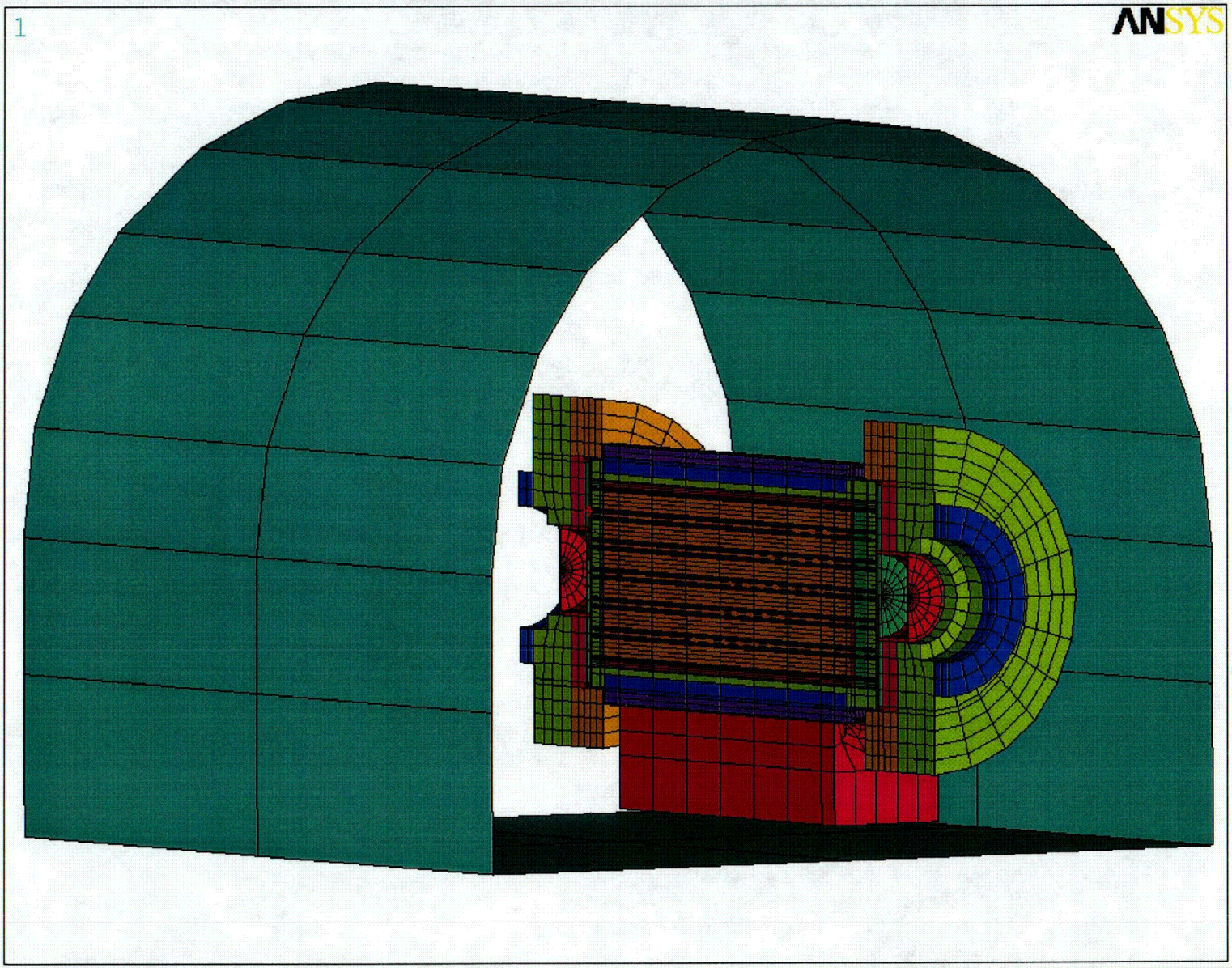
Spent Fuel Rail Cask Analysis Model (with Tunnel Walls)



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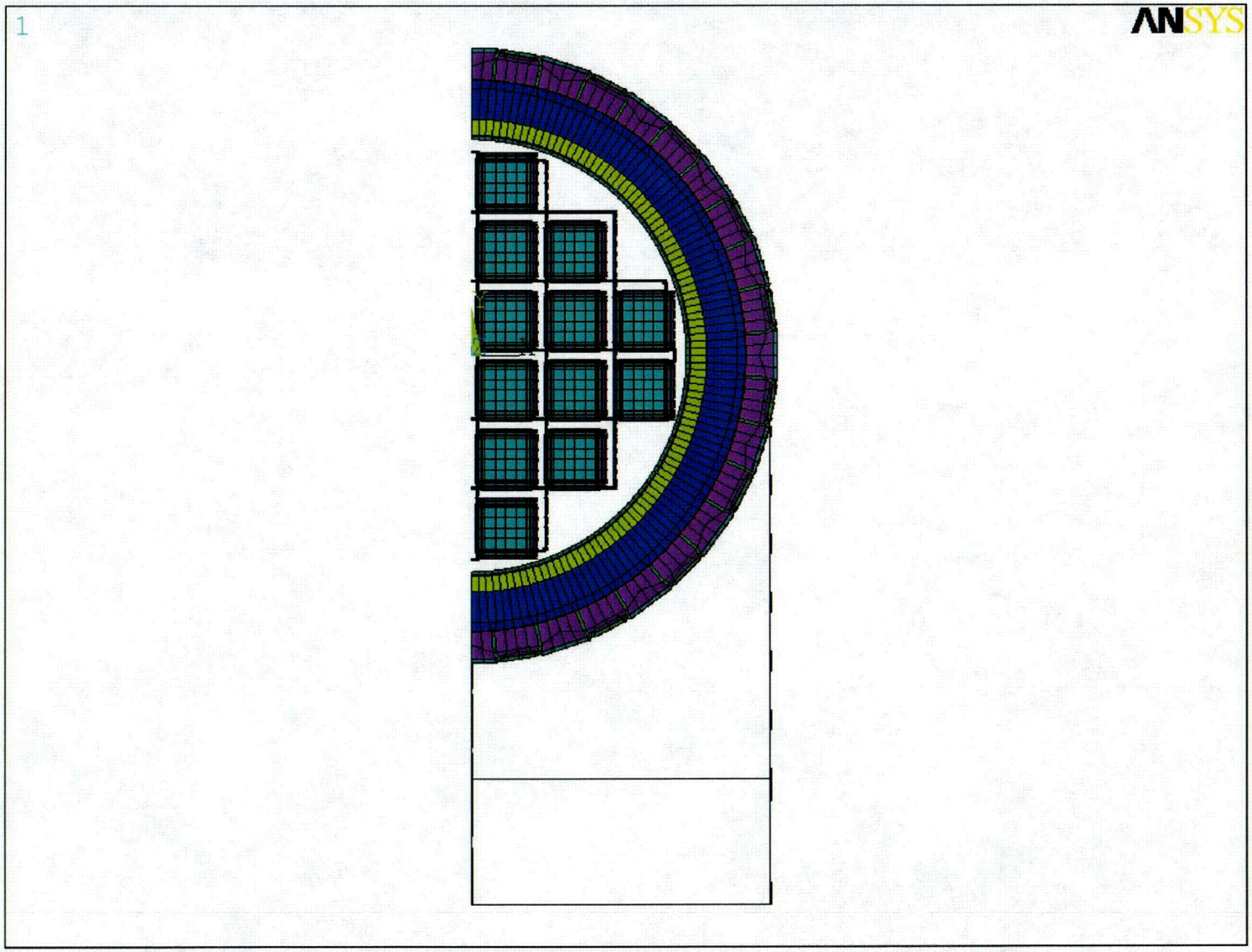
C02

Cask Element Plot – (No Fill Gas)



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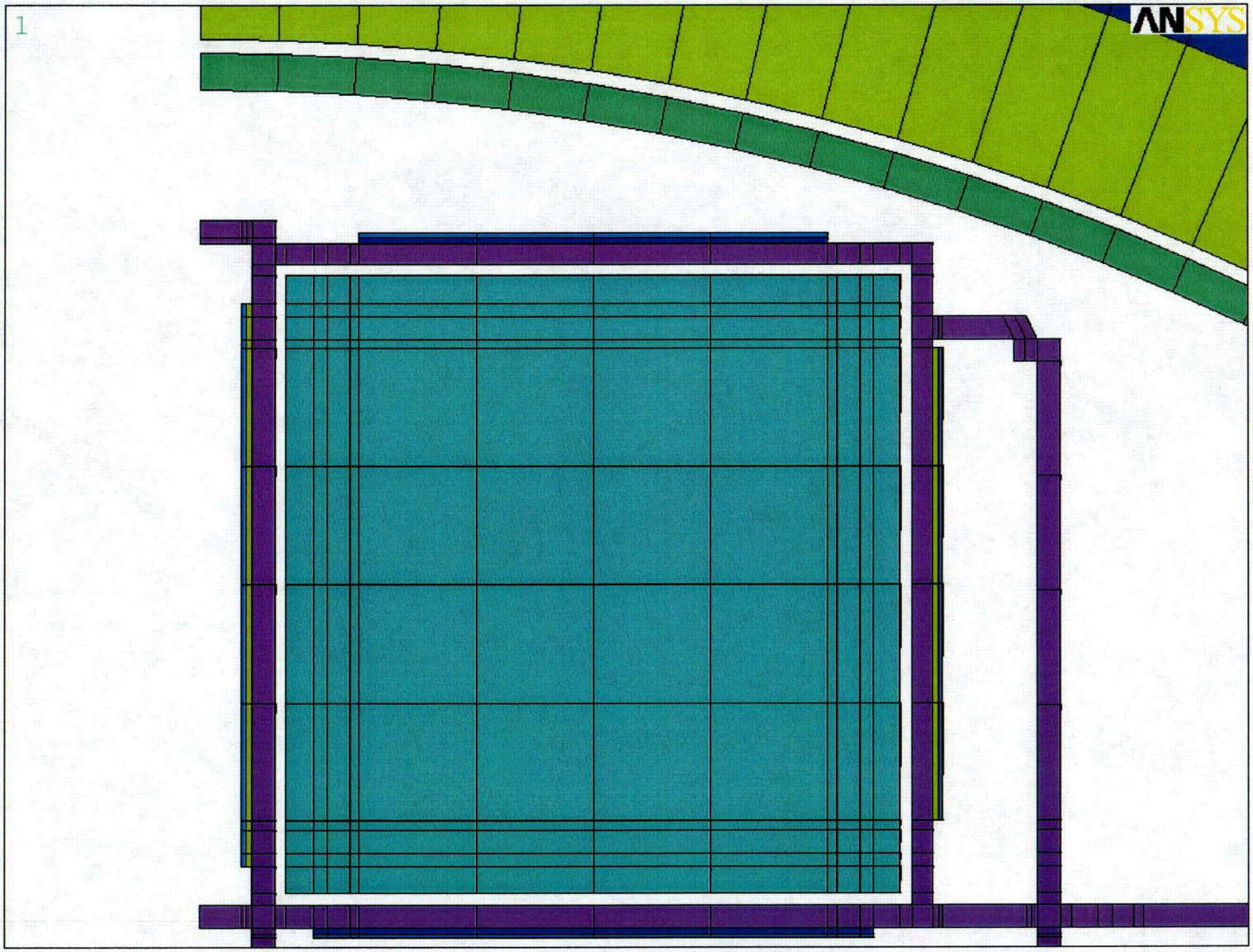
C03

Cask Plot – Fuel Cell Detail



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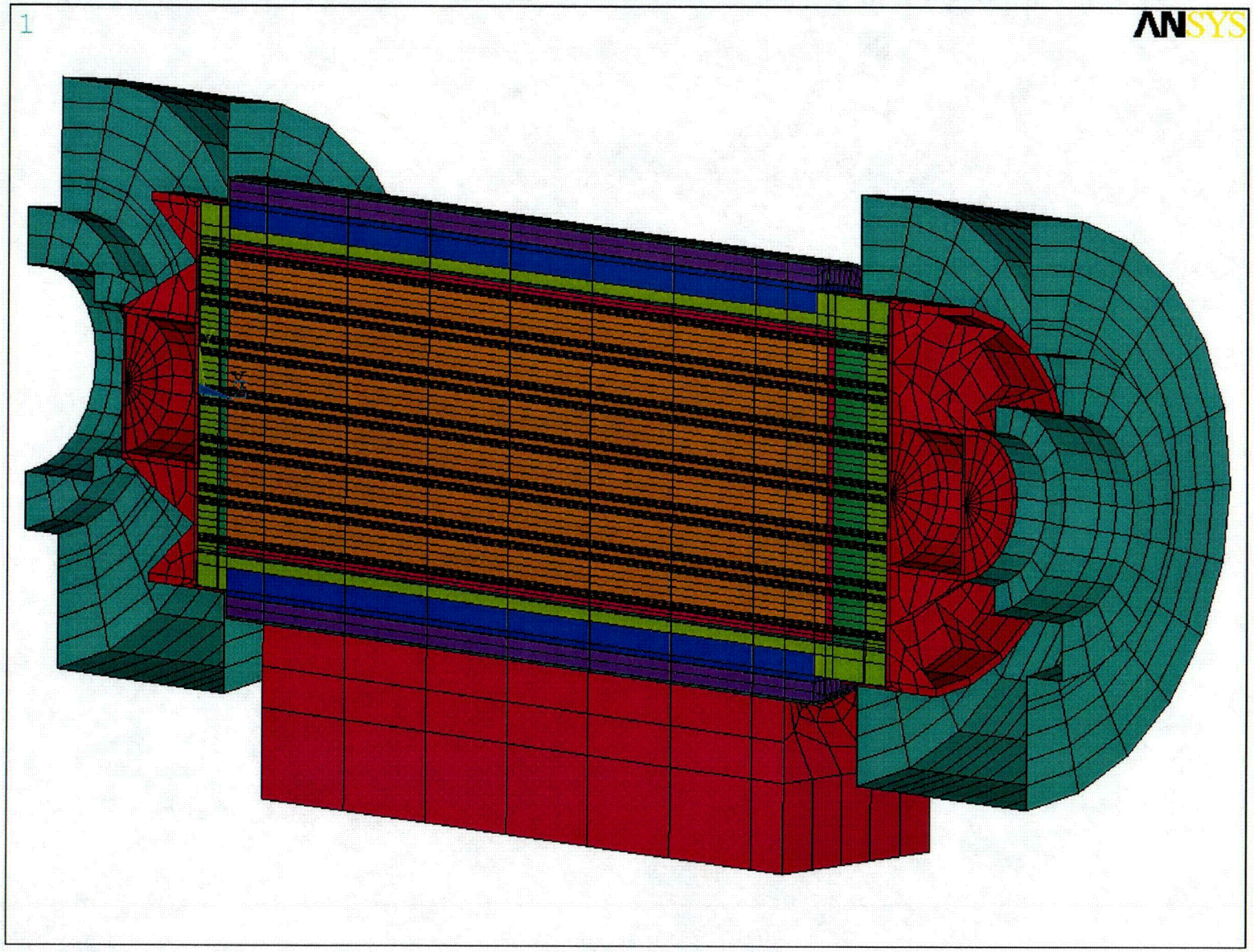
Cox

Cask Model with Impact Limiter Shells



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C05

Model Element Statistics

- Initial (Pre-Fire) Conditions of Transport
  - Conduction
    - Over 120,000 SOLID70 elements
    - Over 1,500 SHELL57 elements
  - Convection
    - INTERNAL - Over 14,800 SURF152 elements
    - EXTERNAL - Over 4,100 SURF152 elements
  - Solar Radiation
    - Over 4,000 SURF152 elements
  - Radiation Exchange (Internal and w/ Ambient)
    - 287 AUX-12 Generated MATRIX50 superelements

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Model Element Statistics (cont.)

- Fire Condition
  - Conduction
    - Preexisting sets of solid & shell elements
  - Convection
    - INTERNAL - Over 14,800 SURF152 elements (preexisting)
    - EXTERNAL - Over 4,100 SURF152 elements (newly defined with previous set "ekilled")
  - Solar Radiation
    - Non-applicable - "ekilled"
  - Radiation Exchange (Internal and w/ Ambient)
    - 287 prexisting MATRIX50 superelements
    - 1 MATRIX50 defined between tunnel and package

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Model Element Statistics (cont.)

- Post Fire (Cool-down) Conditions
  - Conduction
    - Preexisting sets of solid & shell elements
  - Convection
    - INTERNAL - Over 14,800 SURF152 elements (preexisting)
    - EXTERNAL - Over 4,100 SURF152 elements (previously defined set "ekilled", original set "ealived")
  - Solar Radiation
    - Non-applicable - remain "ekilled"
  - Radiation Exchange (Internal and w/ Ambient)
    - 288 prexisting MATRIX50 superelements

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Analysis Boundary Conditions

- Applied NIST Calculated Temperature and Flow Conditions
- Center of Cask Located 20 Meters from Fire Source
- 7 Hour Fire plus 23 Hour Cooldown
- Temperatures Extrapolated Using Power Function

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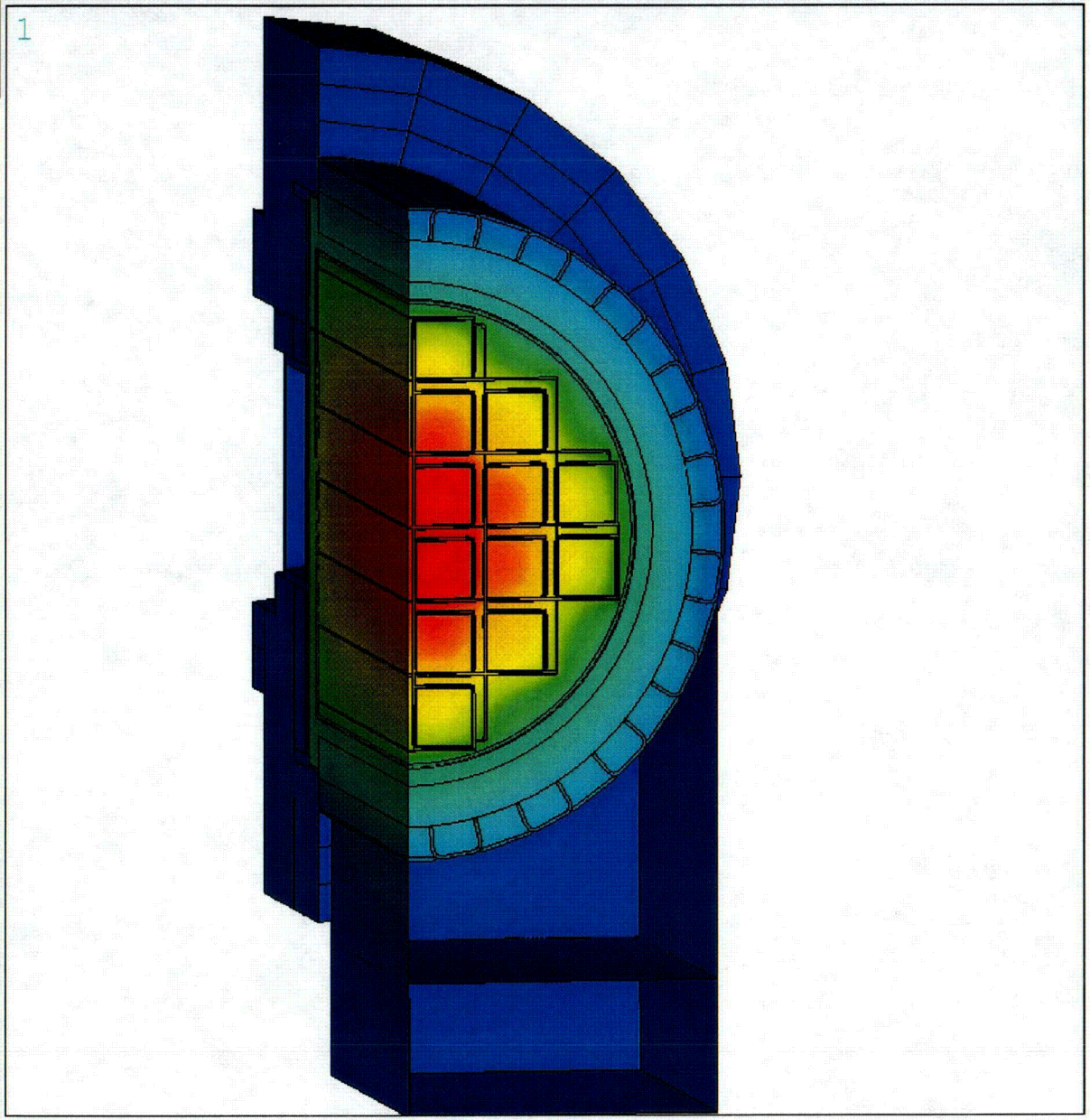
Cask Temperature Plot (Pre-Fire Conditions)



ANSYS 8.0
APR 1 2004
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NODAL SOLUTION
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SUB =1
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RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
SMN =131.831
SMX =672.799

131.831
165.642
195.226
229.036
258.62
292.431
322.015
355.826
385.41
419.22
448.804
482.615
512.199
546.01
575.594
609.404
638.988
672.799

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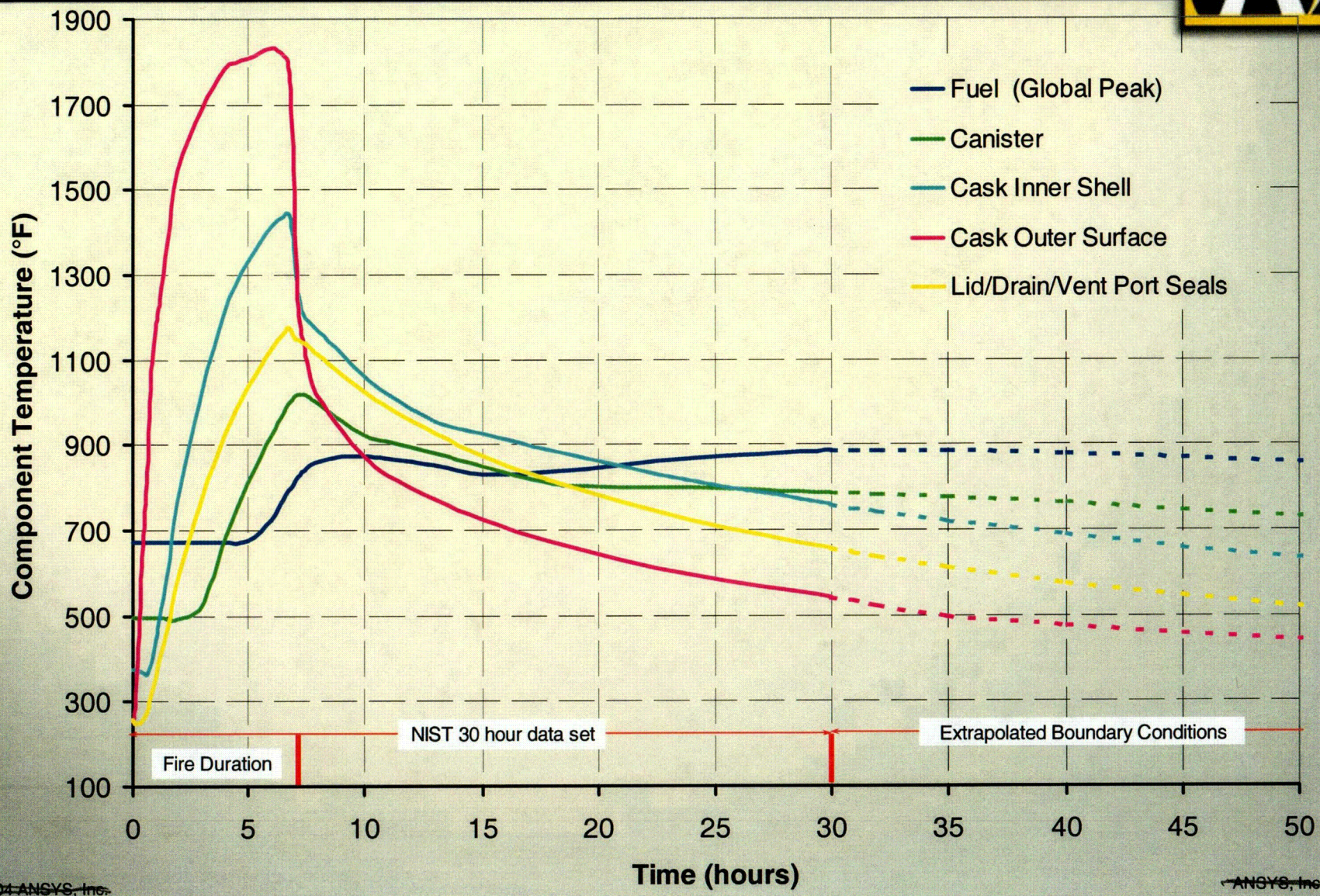
C06

Cask Component Temperature Plot



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C07

Results from Cask Analysis

- Maximum Spent Fuel Cladding Temperature Calculated: 887°F
- No Fuel Cladding Failure Expected
- No Failure of the Multi-Purpose Canister (MPC) Expected

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Conclusions

- Robust Nature of Rail Cask is Evident
- Fire Exposure Results in No Release of Radioactive Material
- Health and Safety of the Public is Protected

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- Mr. Jay Kivowitz (NTSB)
- Mr. Gene Poole (ANSYS, Inc.)

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