Thermal Response of Various Spent Nuclear Fuel Transportation Cask Designs to the 2001 Baltimore Tunnel Fire Event

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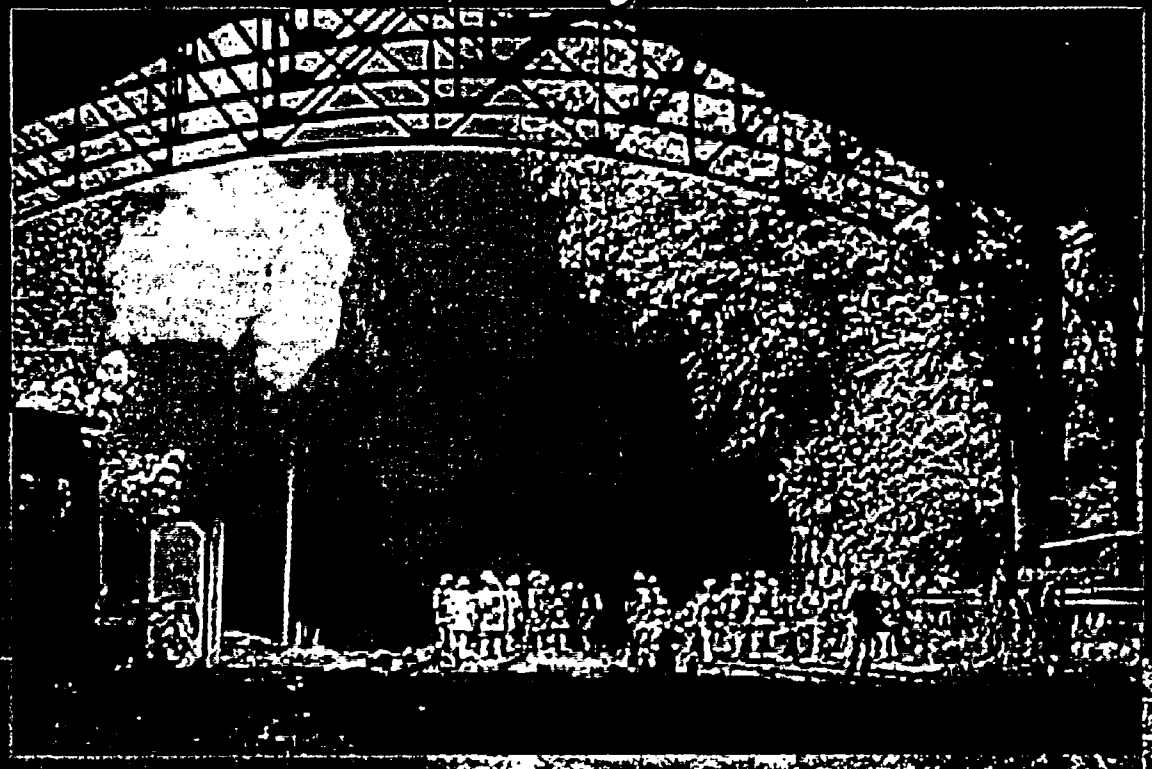
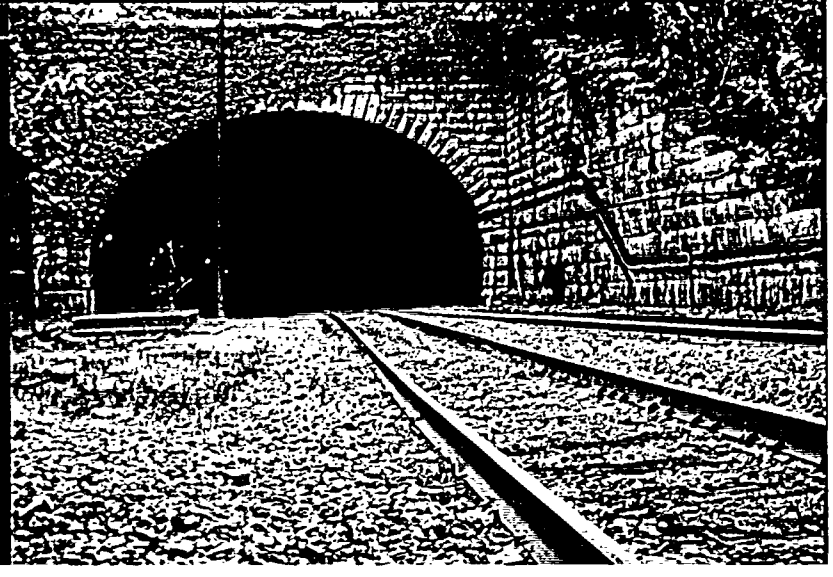
2004 ASME Pressure Vessels & Piping Conference
La Jolla, San Diego, CA
July 25-29, 2004

Introduction

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

Baltimore Tunnel Fire, July 18, 2001

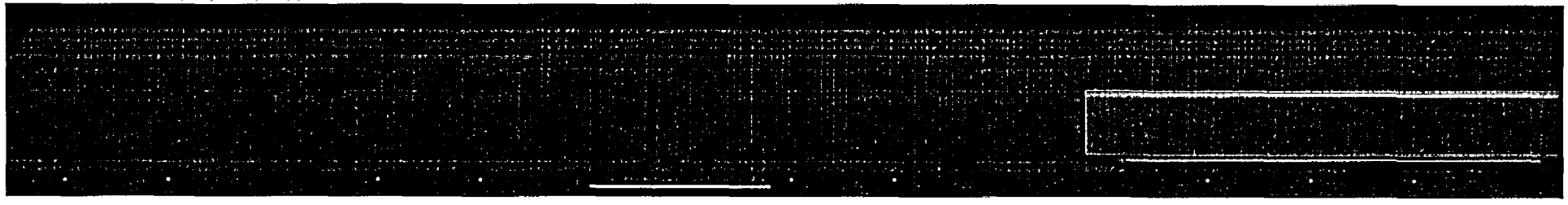


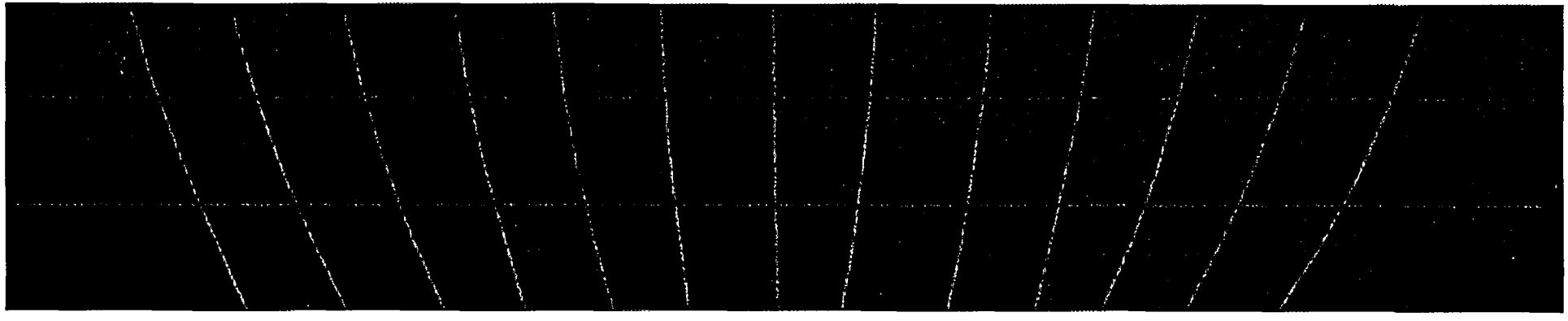


NIST Howard Street Tunnel Fire Model

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

NIST Howard Street Tunnel Fire Model

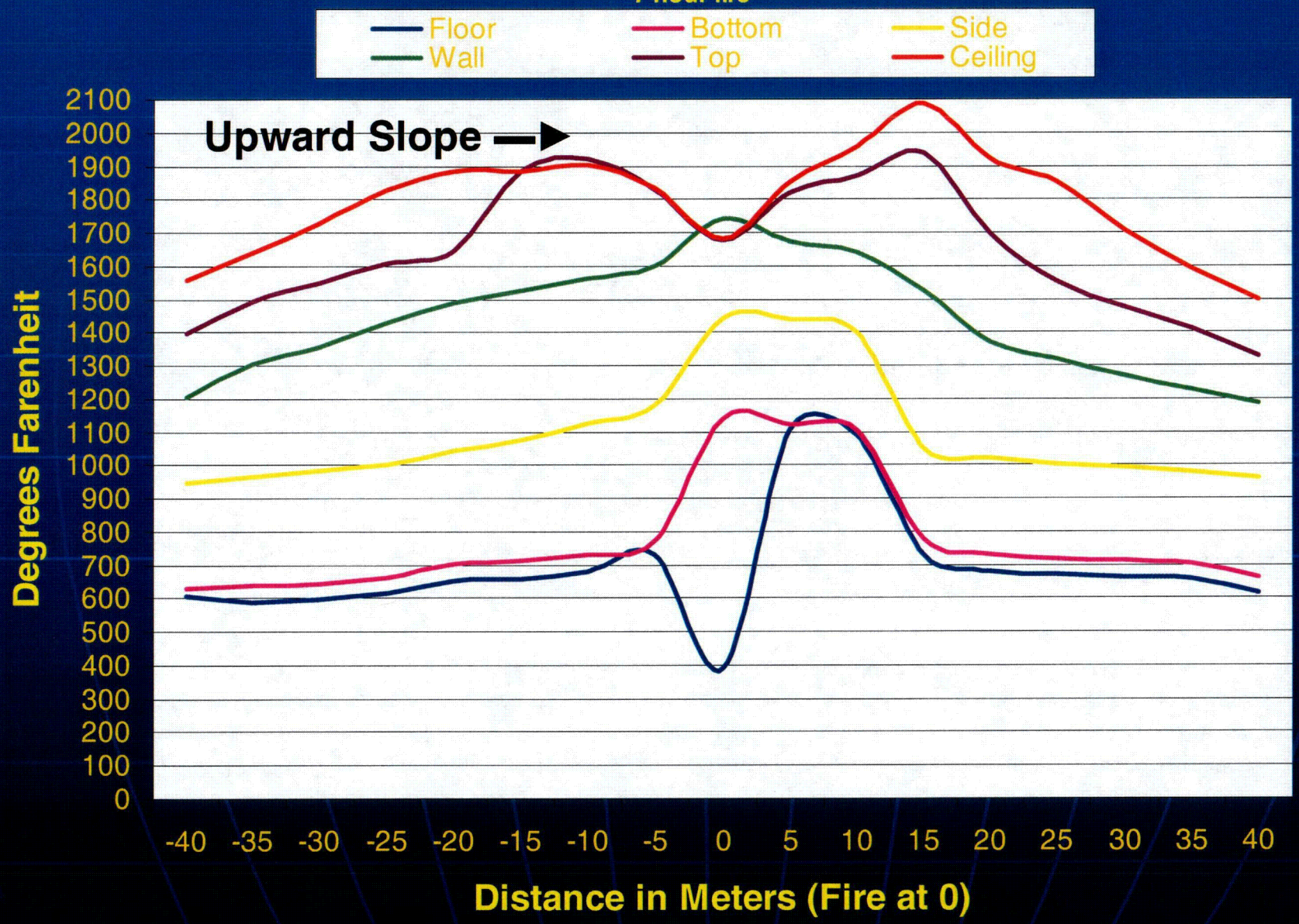




FDS Temperature Results

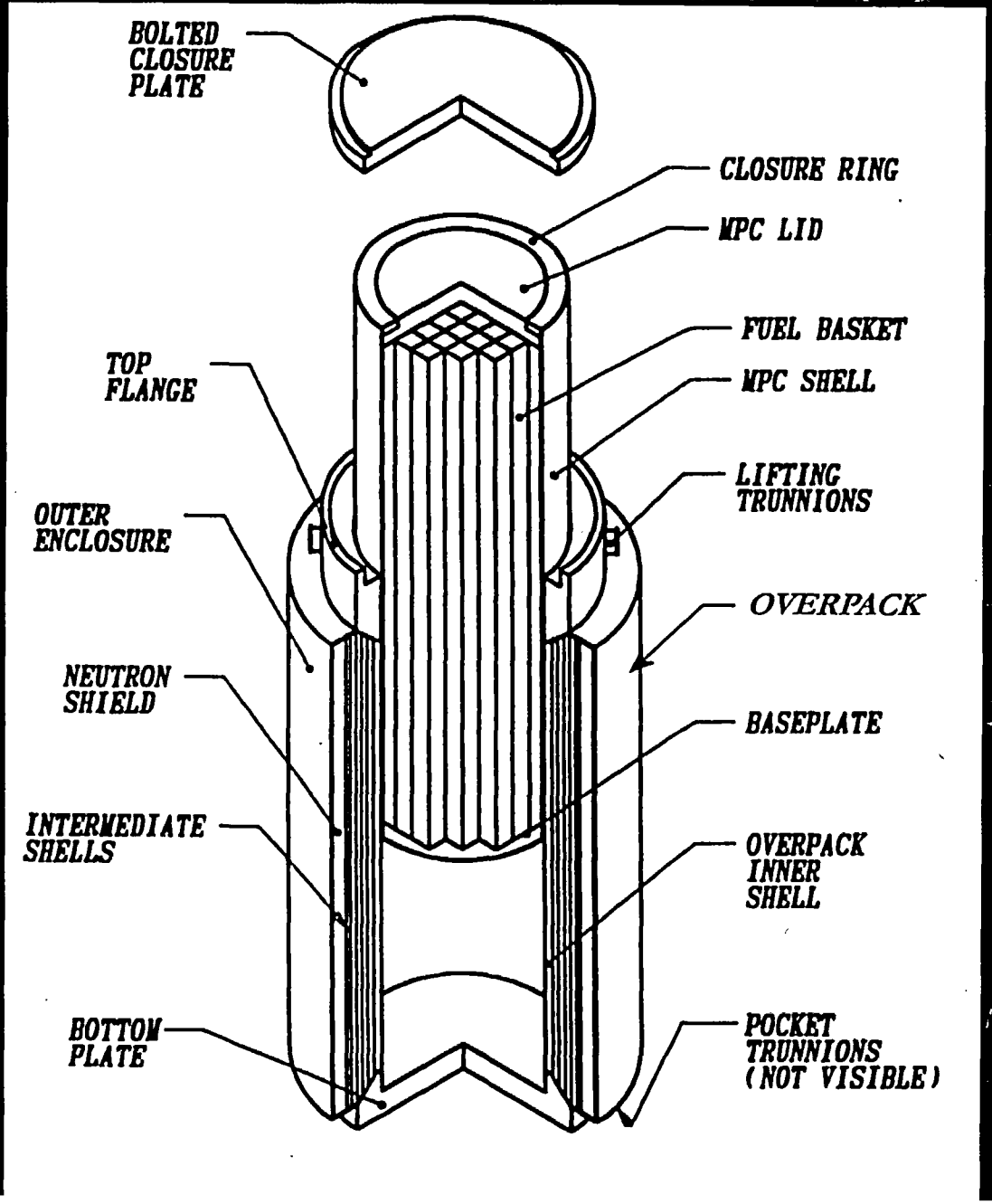
Tunnel Temperatures

7 hour fire



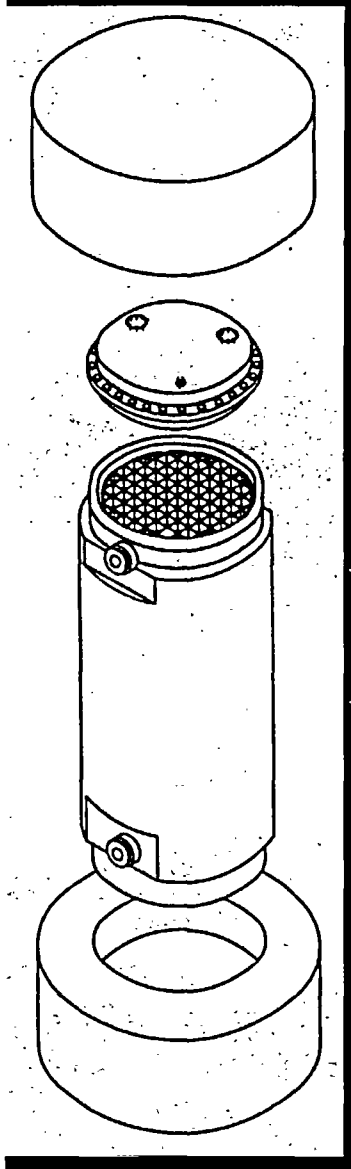
C01

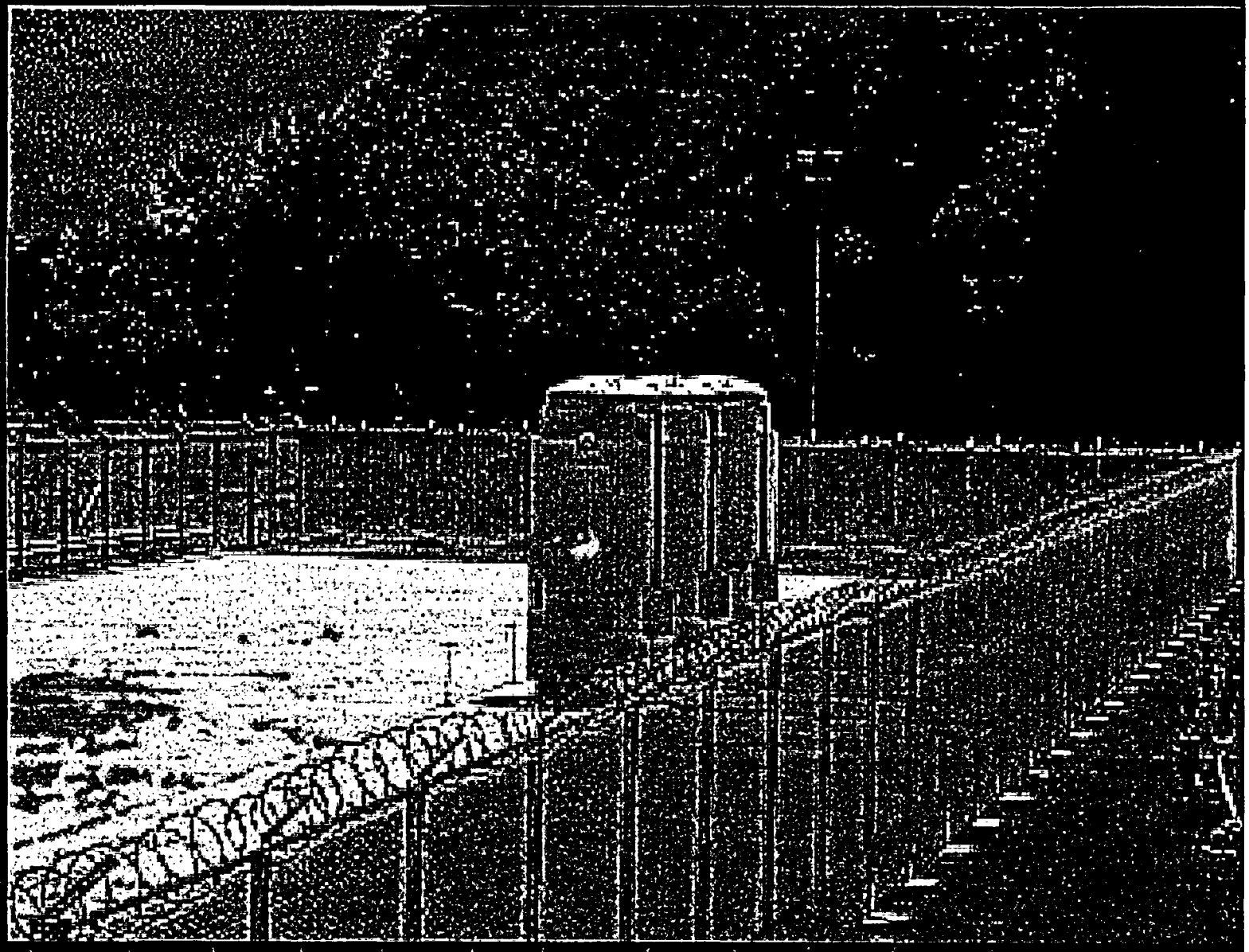
HOLTEC HI-STAR 100 Cask



HI-STAR 100 Rail Cask

TN-68 Spent Fuel Cask





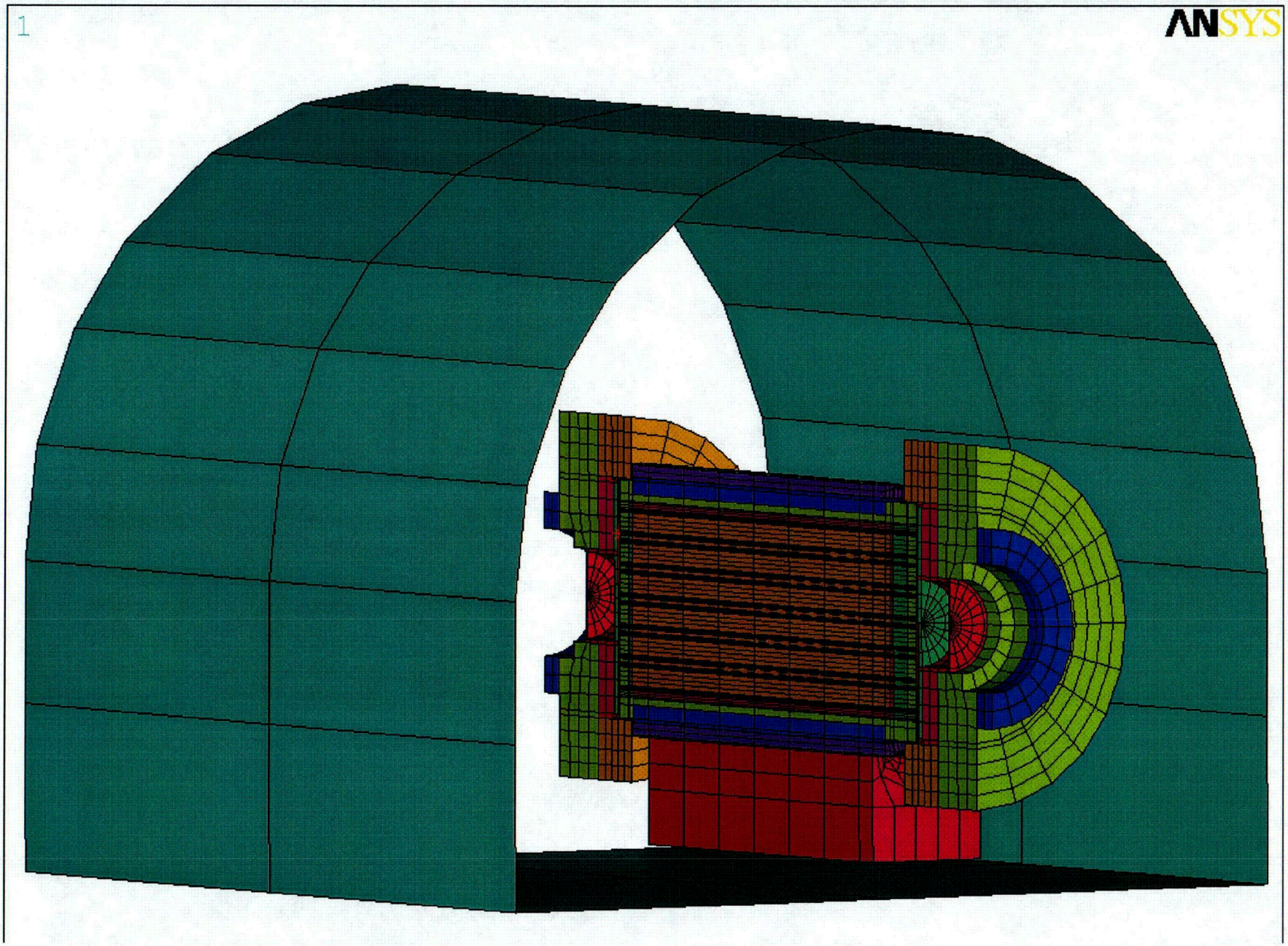
Cask Analysis Model Details

- HI-STAR 100 Spent Fuel Cask
  - Model Developed in ANSYS®
  - 3D half symmetry
  - Explicit geometry representation
  - Fuel assemblies homogenized
  - Conduction, convection, and radiation
  - Cask transport cradle included
  - Tunnel walls included
  - Model contains over 149,000 elements

Cask Analysis Model Details, cont.

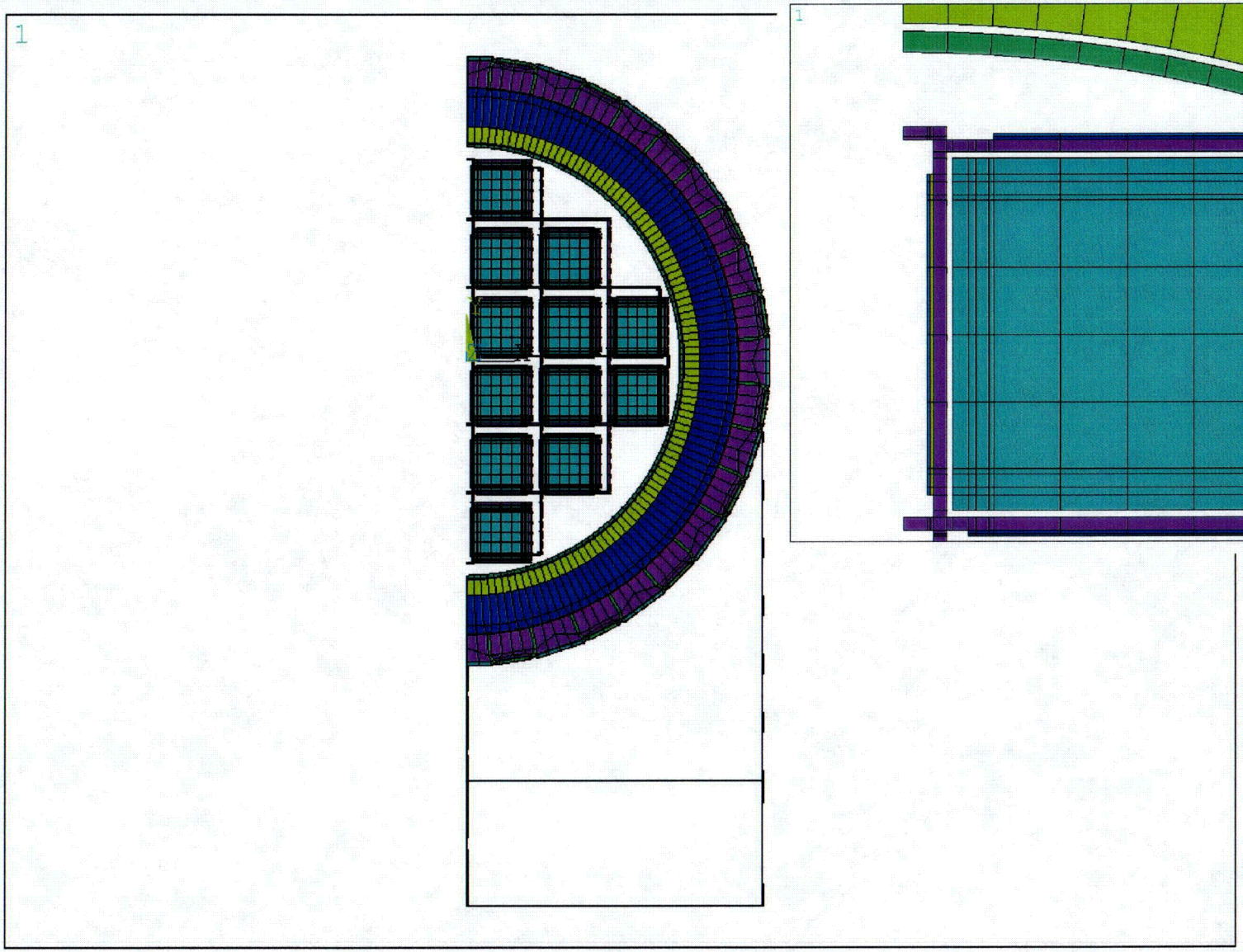
- TransNuclear (TN) 68 Spent Fuel Cask
  - Model Developed in COBRA-SFS
  - 3D half symmetry
  - Explicit geometry representation
  - Fuel assemblies explicitly modeled
  - Conduction, convection, and radiation
  - Tunnel walls included
  - Model contains approximately 139,000 nodes

HI-STAR 100 Analysis Model (with Tunnel Walls)



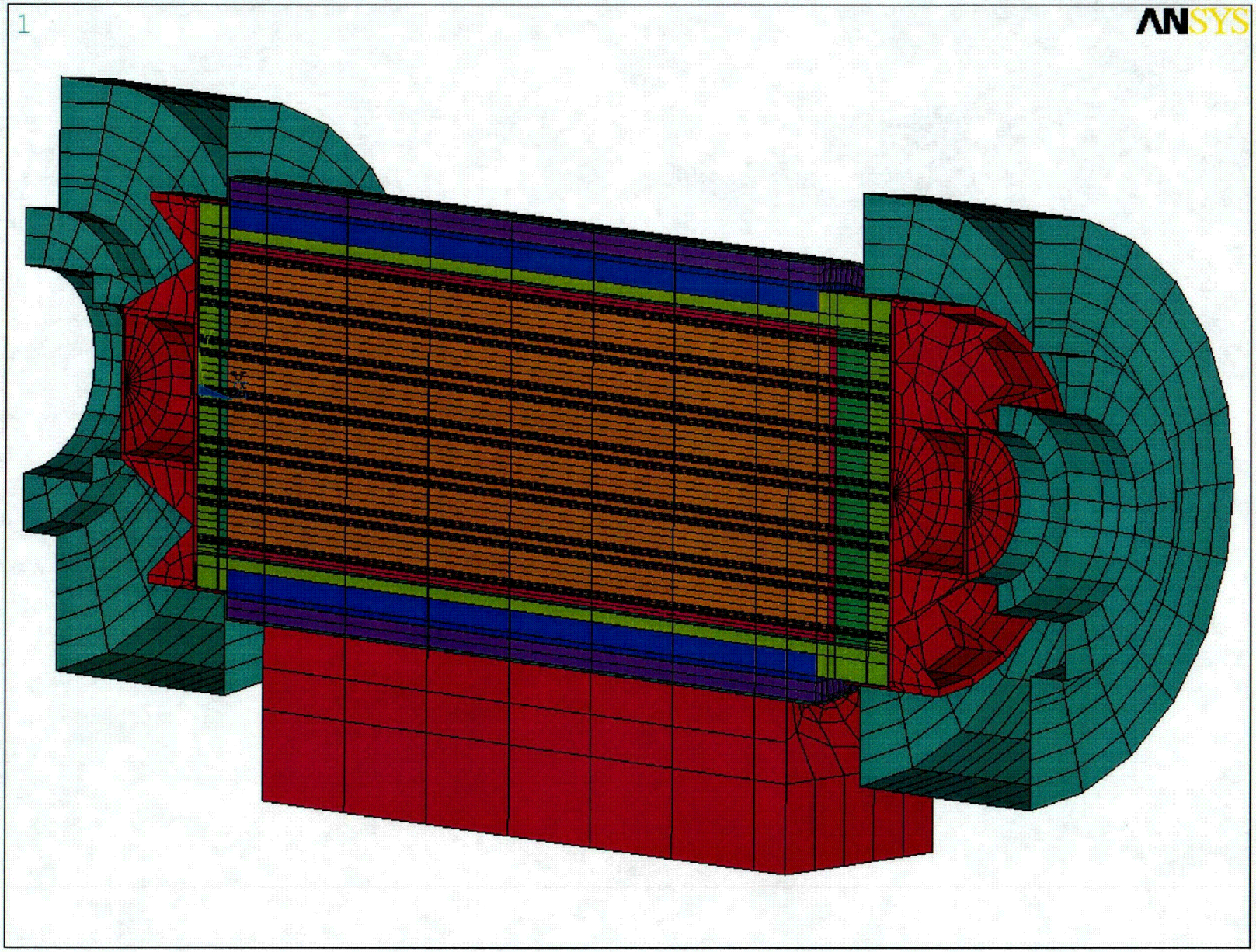
C02

HI-STAR 100 Element Plot – (No Fill Gas)



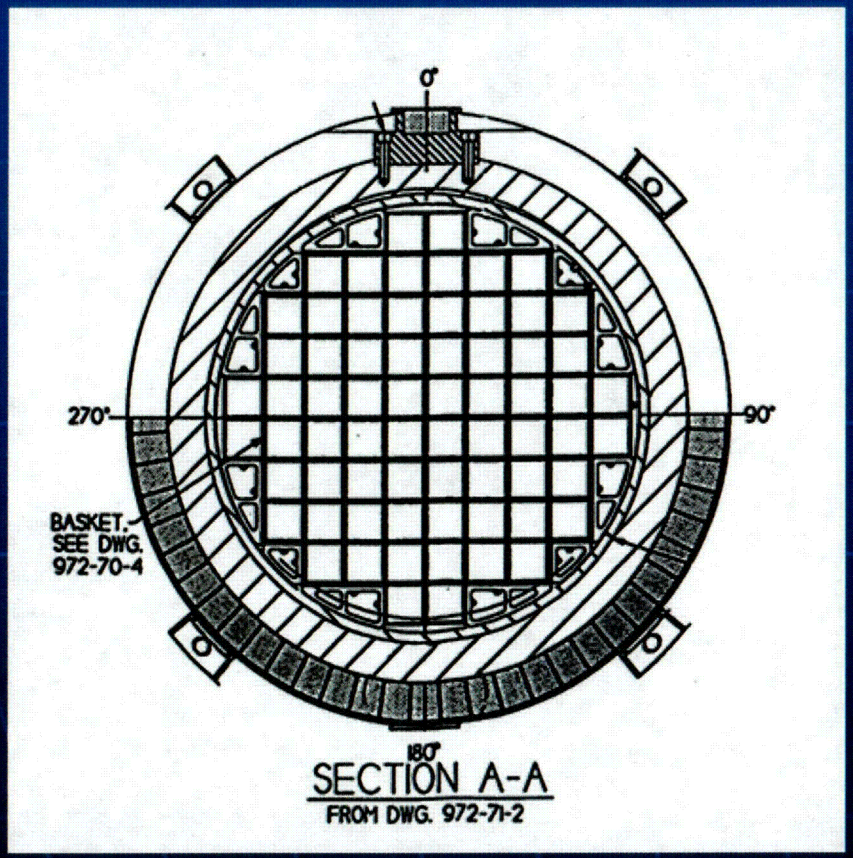
C03

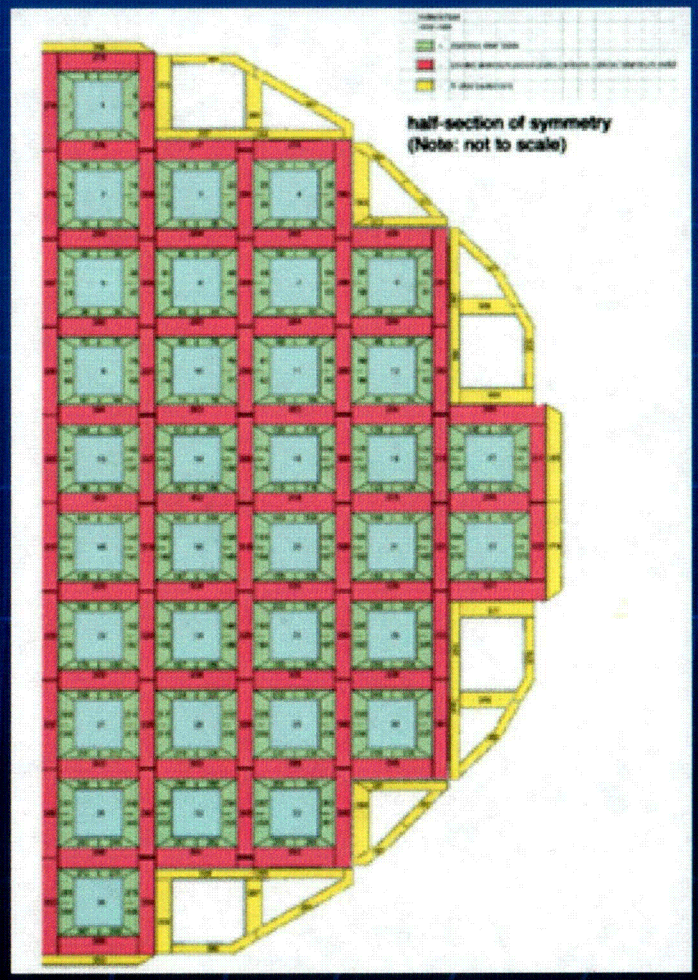
HI-STAR 100 model with Impact Limiter Shells



C04

COBRA-SFS Node map for TN-68



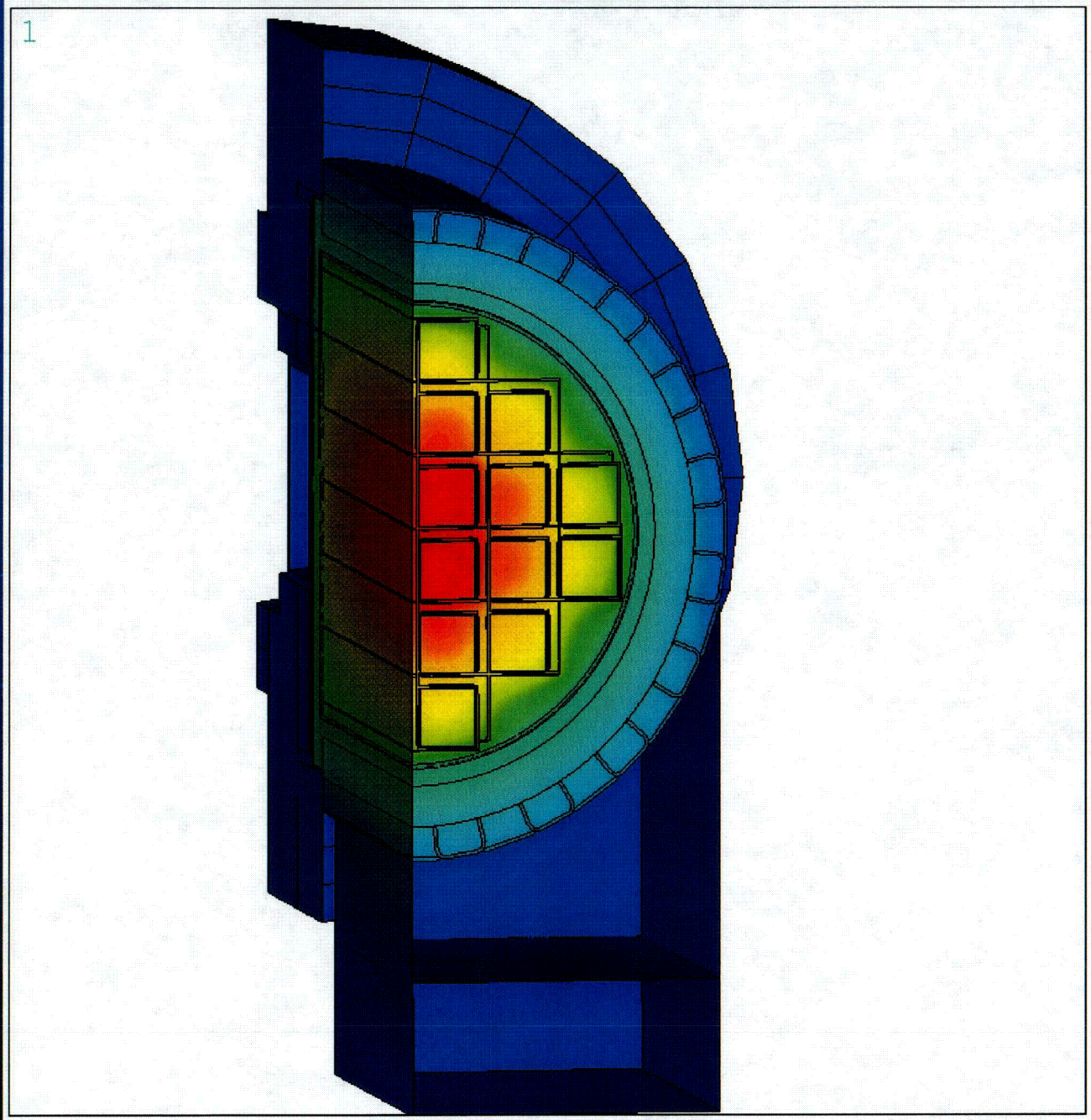


C05

Pre-Fire Analysis Conditions

- Equivalent to Normal Conditions of Transportation (NCT) in 10 CFR 71.71
  - Ambient Temperature 38°C (100°F)
  - Full Solar Insolation
  - Cask Surface Emmissivities: 0.3 for Stainless Steel, 0.85 for painted surfaces
- Maximum decay heat applied
  - TN-68 - 21.2 kW
  - HI-STAR 100 - 20 kW
- Steady state temperature solution obtained

HI-STAR 100 Temperature Plot (Pre-Fire Conditions)



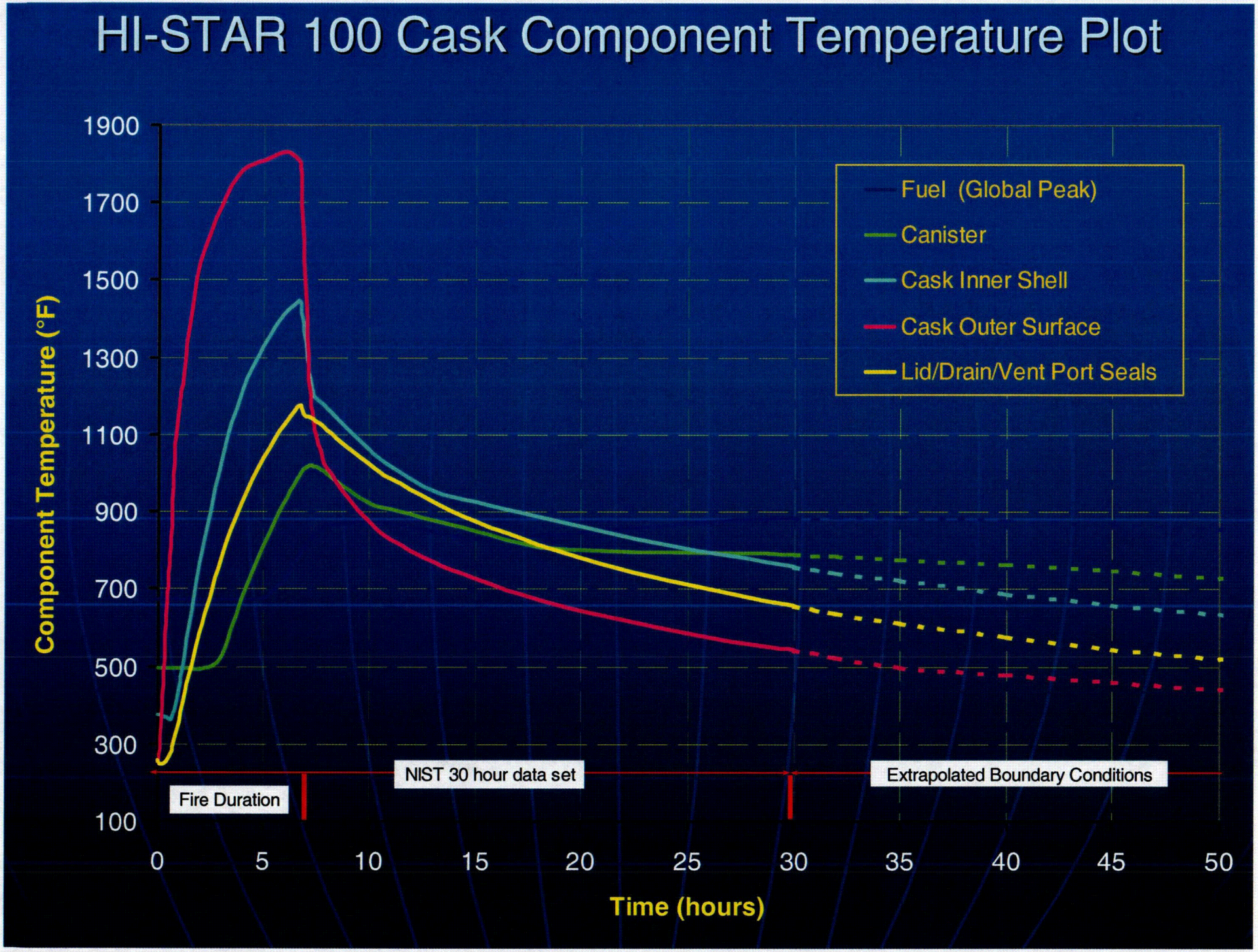
ANSYS 8.0
APR 1 2004
15:53:37
NODAL SOLUTION
STEP=10
SUB =1
TIME=.100E-02
TEMP (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
SMN =131.831
SMX =672.799

- 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

C06

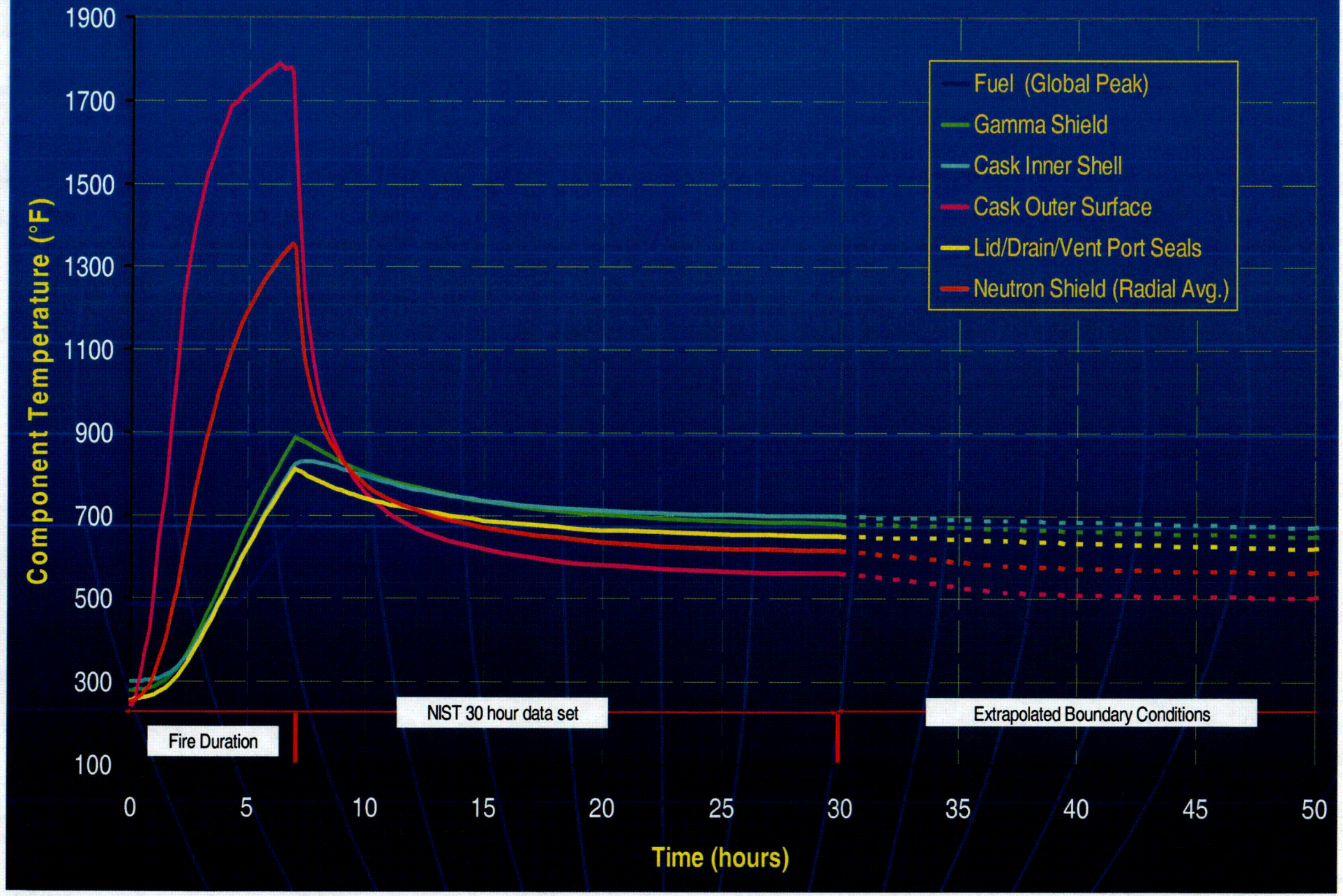
Fire Boundary Conditions

- Applied NIST Calculated Temperature and Flow Conditions
- Center of Cask Located 20 Meters from Fire Source
- 7 Hour Fire plus 23 Hour Cooldown (30 Hours total)
- Temperatures Extrapolated Using Power Function ($30<t<300$ hours)


HI-STAR 100 Cask Component Temperature Plot
Component Temperature (°F)
1900
1700
1500
1300
1100
900
700
500
300
100
0
5
10
15
20
25
30
35
40
45
50
Time (hours)
Fuel (Global Peak)
Canister
Cask Inner Shell
Cask Outer Surface
Lid/Drain/Vent Port Seals
Fire Duration
NIST 30 hour data set
Extrapolated Boundary Conditions

C07

TransNuclear-68 Cask Component Temperature Plot



C08

Results from Cask Analysis

- Maximum Spent Fuel Cladding Temperatures:
  - HI-STAR 100: 887°F
  - TN-68: 845°F
- No Fuel Cladding Failure Expected
- No Failure of the Multi-Purpose Canister (MPC) Expected for HI-STAR 100
- No Seal Failure Expected for the TN-68 (Max seal Temperature 811°F)

Conclusions

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

Acknowledgements

- Mr. Harold E. Adkins, Jr. (PNNL)
- Ms. Judith M. Cuta (PNNL)
- Dr. Brian Koeppel (PNNL)
- Dr. Kevin McGrattan (NIST)
- Mr. Jay Kivowitz (NTSB)