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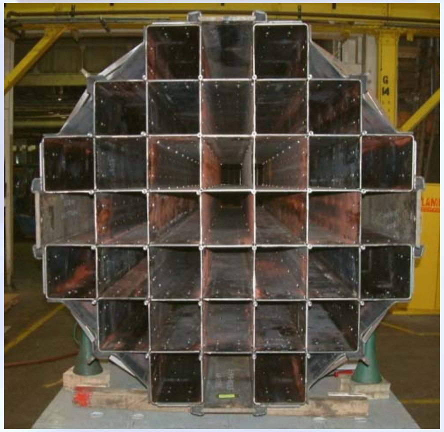
Thermal Evaluation of Loading and Drying Operations of a High Capacity Spent Fuel Storage Canister

October 6, 2010

Abstract 408



Introduction

Transfer cask is an essential component for processing fuel for dry storage

- Provides shielding to personnel during canister handling
- Allows the canister to be loaded into the concrete over pack
- Series of shells (steel-lead-NS4FR-steel)
- Clad temperatures are maintained below allowable by water cooling in the annulus between the cask and canister

Typical transfer cask

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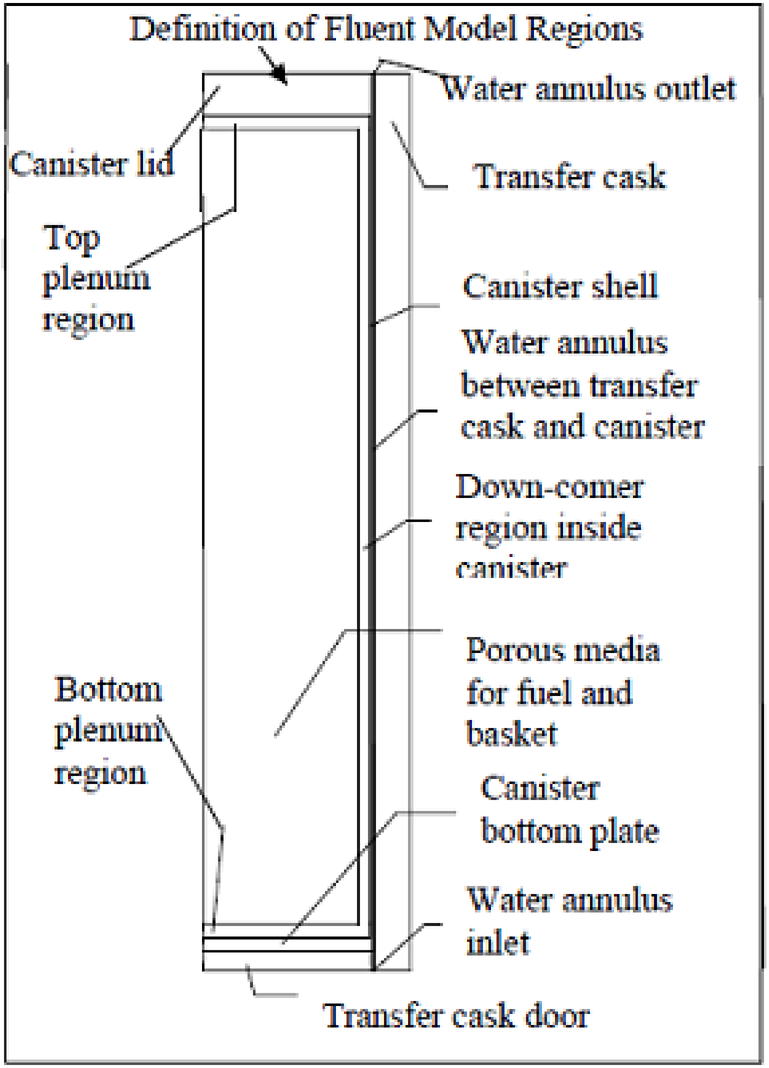
Canister / Transfer Cask Design

- Canister is the storage confinement boundary
- Carbon steel basket is designed for convection
  - Helium circulates between fuel and down comer regions
- Basket also rejects heat by radiation and conduction
- BWR basket is comprised of 45 structural carbon steel tubes to maintain the positioning of 87 BWR fuel assemblies



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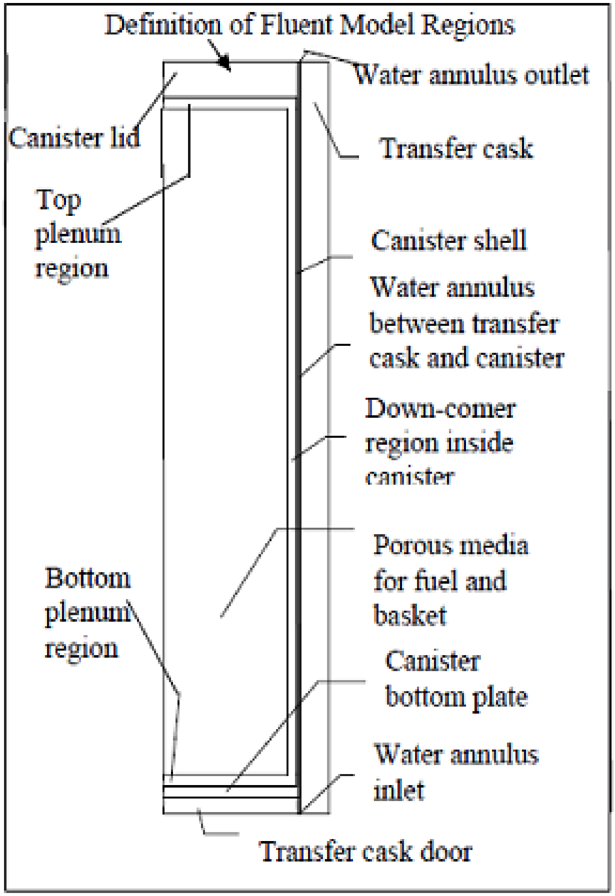
Fuel Vacuum Drying Process

- BWR fuel is loaded in canister under water (33 kW design basis)
- Heat is rejected from cask by water flowing through the canister-cask annulus
- Canister water is removed by purging canister with helium
- Upon canister lid welding, canister is evacuated to less than < 10 Torr
- Operations may decide to execute a cooling cycle
  - 24 hours of helium backfill to permit internal convection to reduce system temperatures



Definition of Fluent Model Regions

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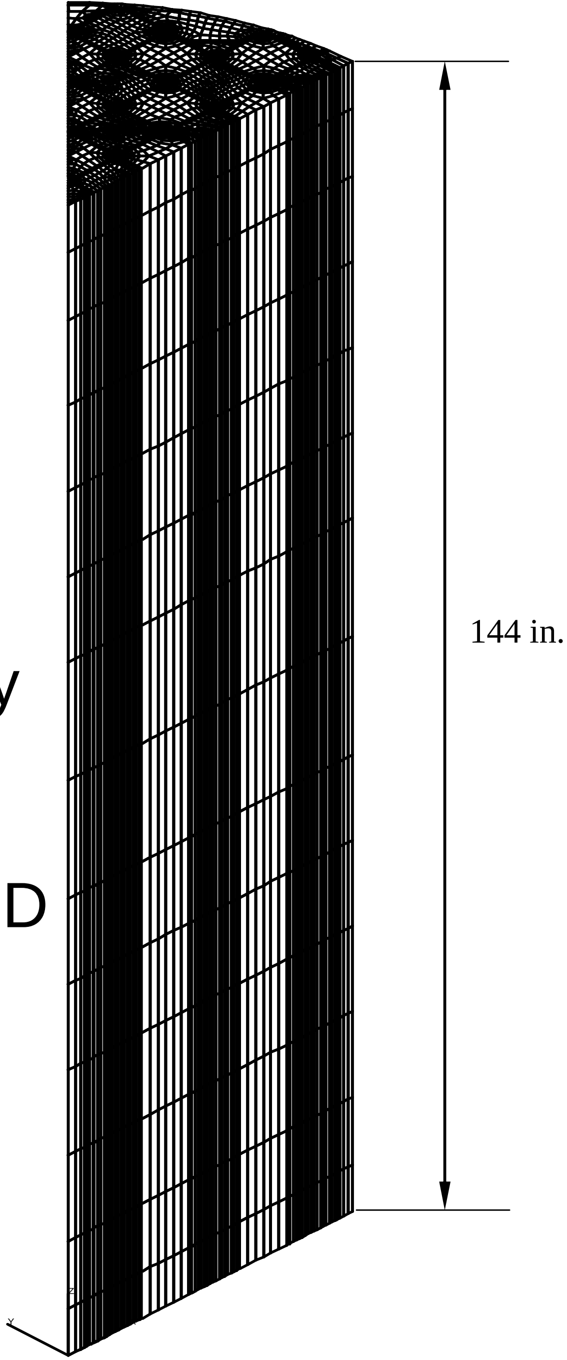
FEA Modeling for the Vacuum Condition

- 1/8th symmetry ANSYS model uses radiation and conduction through out the basket and canister
- Power distribution in the fuel is defined for a BWR fuel assembly
- Model ends are adiabatic
- Canister shell temperature is determined using a separate CFD model representing the basket and fuel as a homogeneous material



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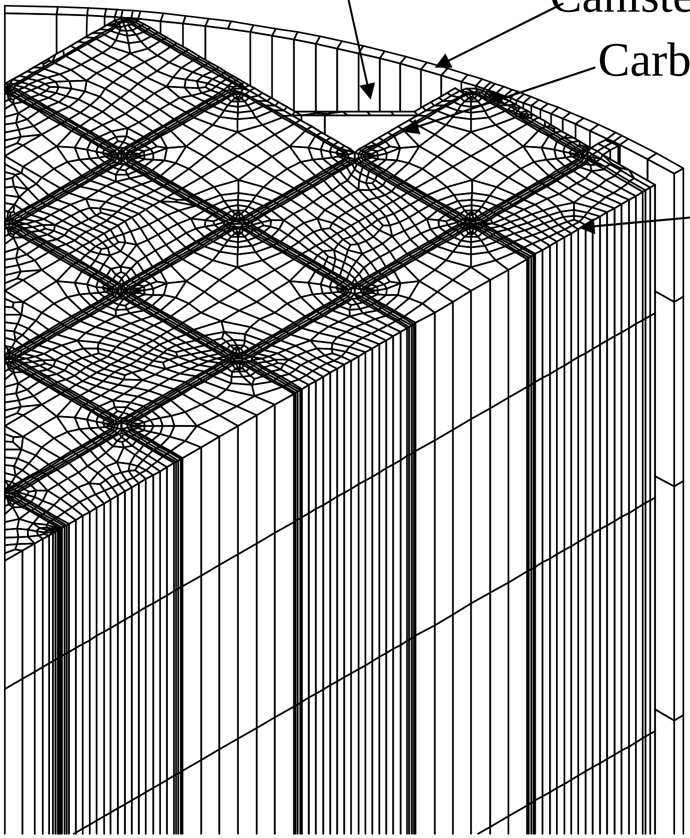
Model for the Basket

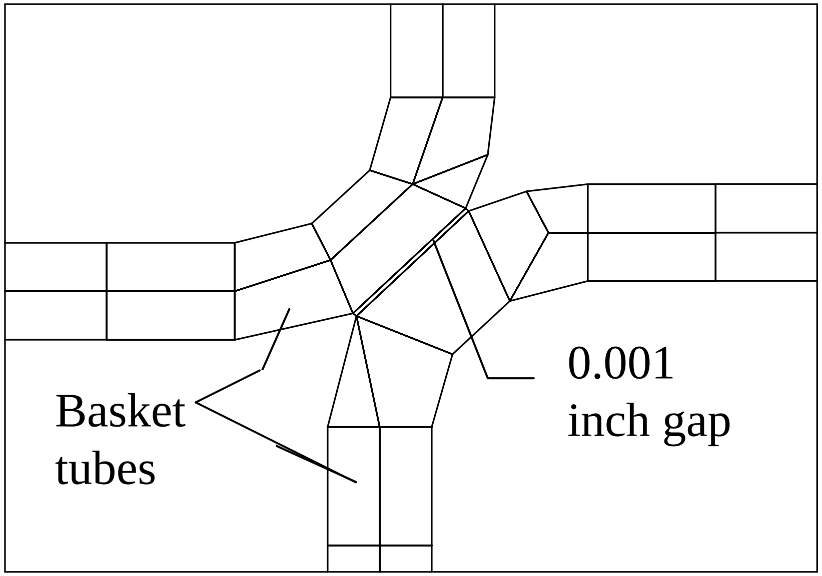


Elements in this region are not shown

Canister shell

Carbon steel basket tubes

Homogenized fuel region

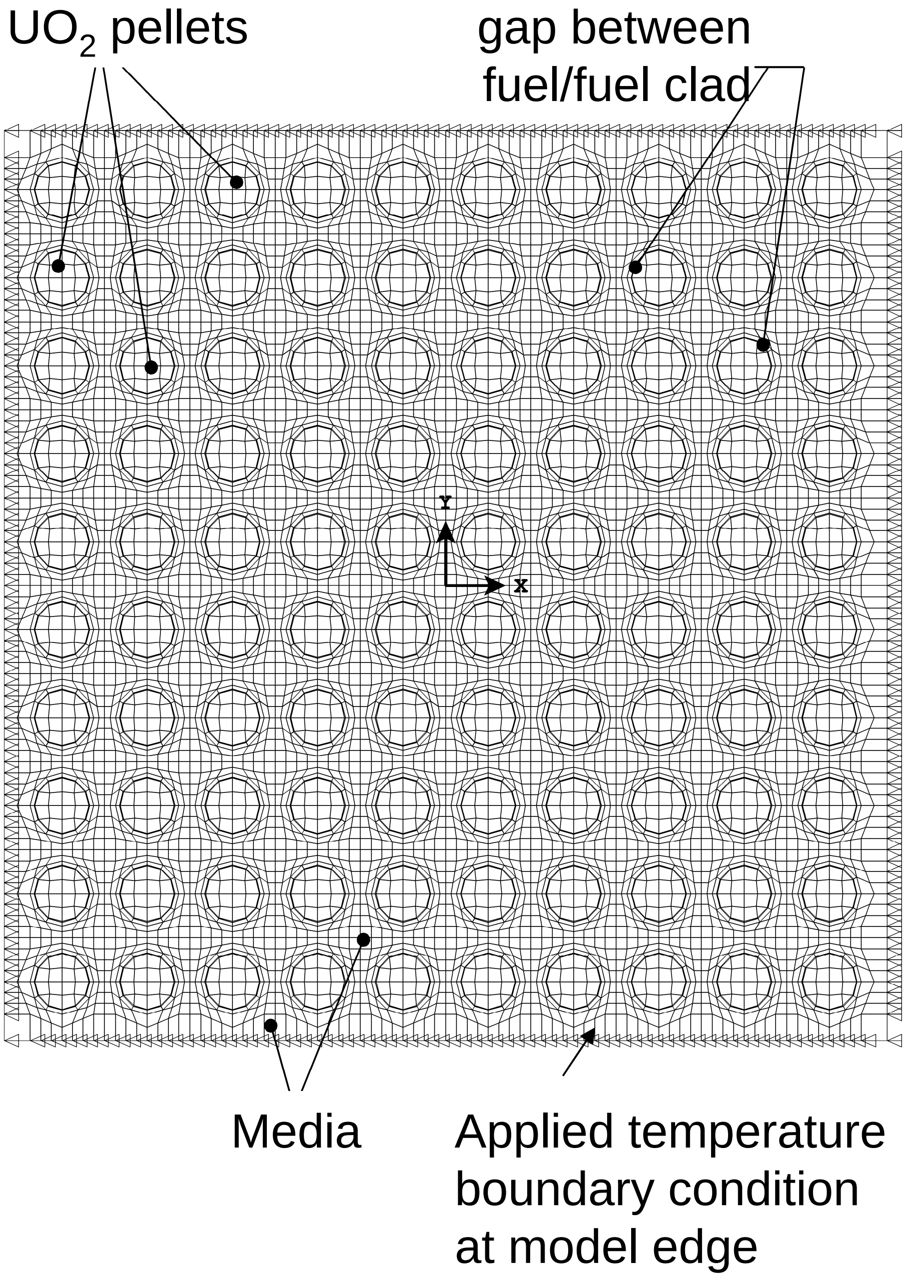


Basket tubes

0.001 inch gap

Fuel Model

- Detailed model of the fuel provides orthotropic thermal conductivity properties
  - Radiation by superelement
  - Includes conduction by helium
- Heat generation applied to the pellets
- Gaps between pellet and clad are included



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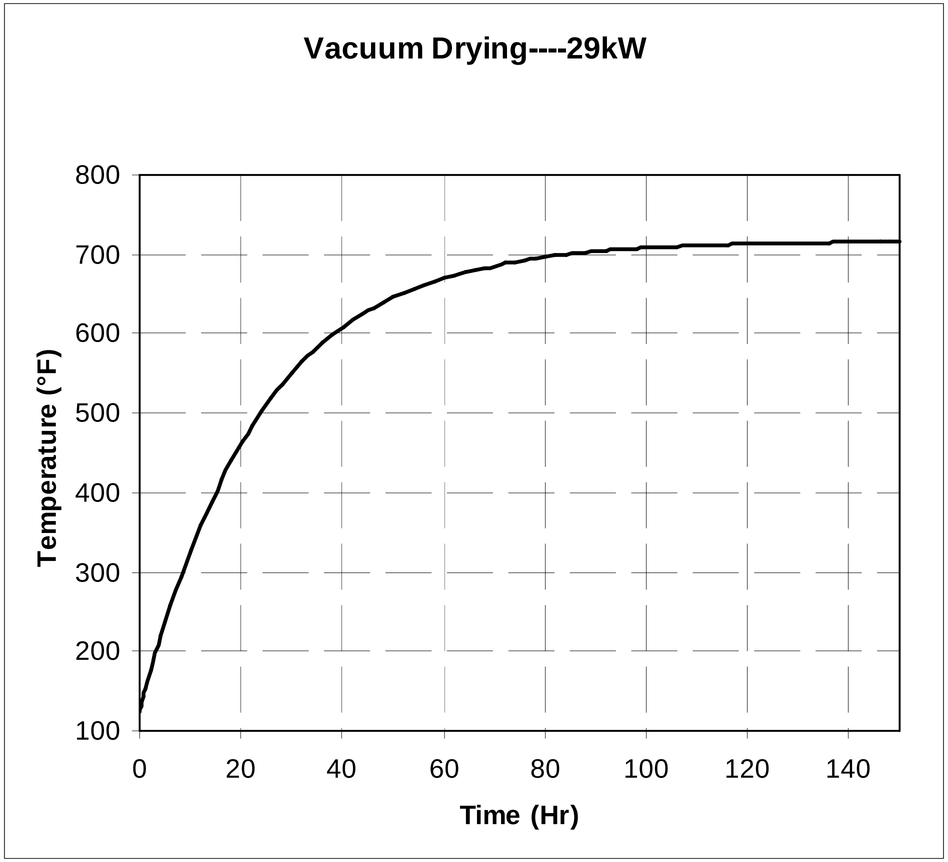
Results for 29kW BWR Fuel Heat Load for Vacuum Condition

- Steady state maximum clad is achieved in four days
- Peak clad temperature is less than the allowable 400°C (752°F)



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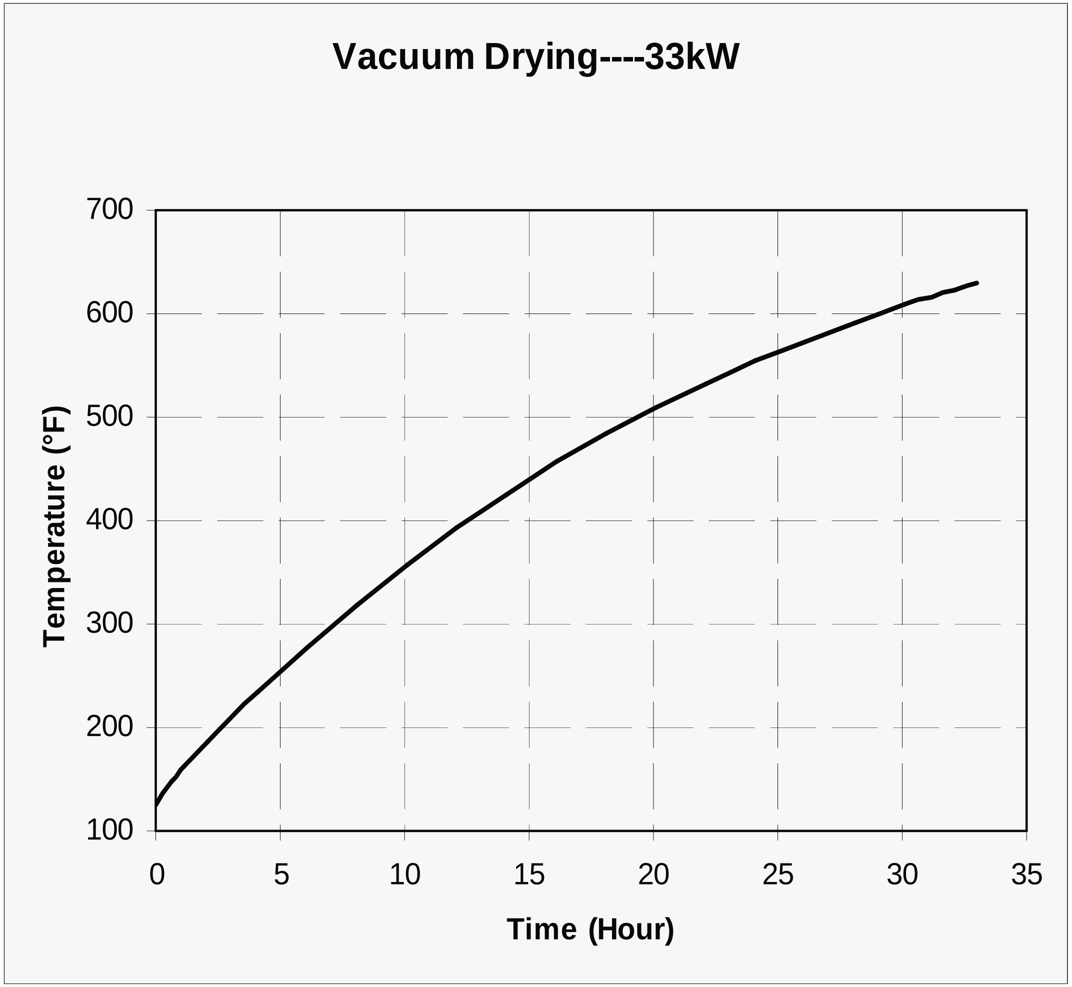
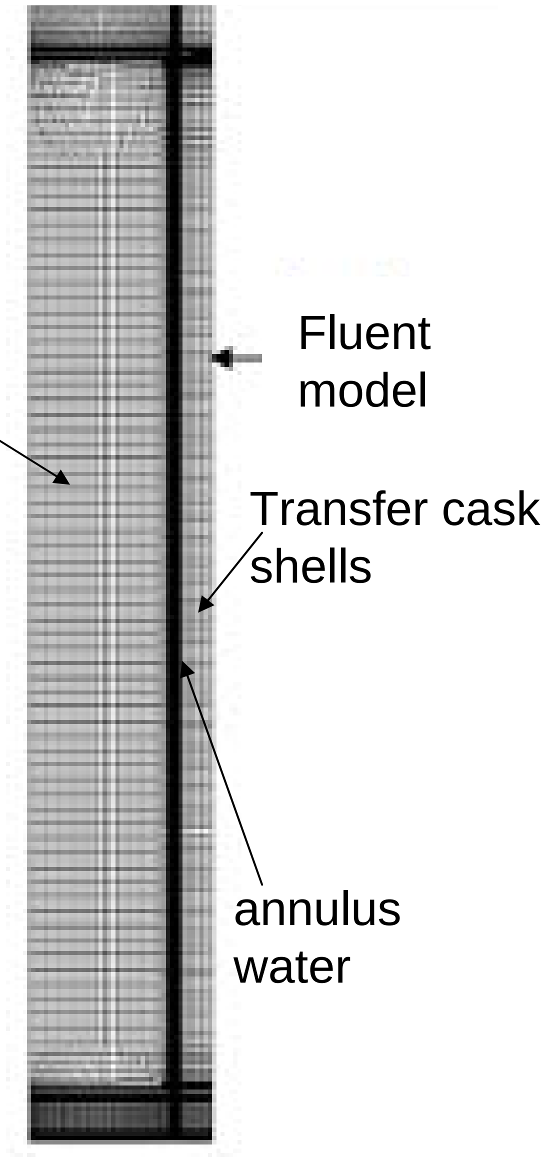
Results for 33 kW BWR Fuel Heat Load for Vacuum Condition

- Max steady state clad temperatures are at the 400°C (752°F) limit
- System cooling can be performed if required to continue operations



Thermal Evaluation of the Cooling Phase

- Convection in the basket is modeled using orthotropic Fluent porous media
- Down comer region (helium) is modeled with laminar flow
- Annulus region (water) is also modeled as laminar flow



Fluent model

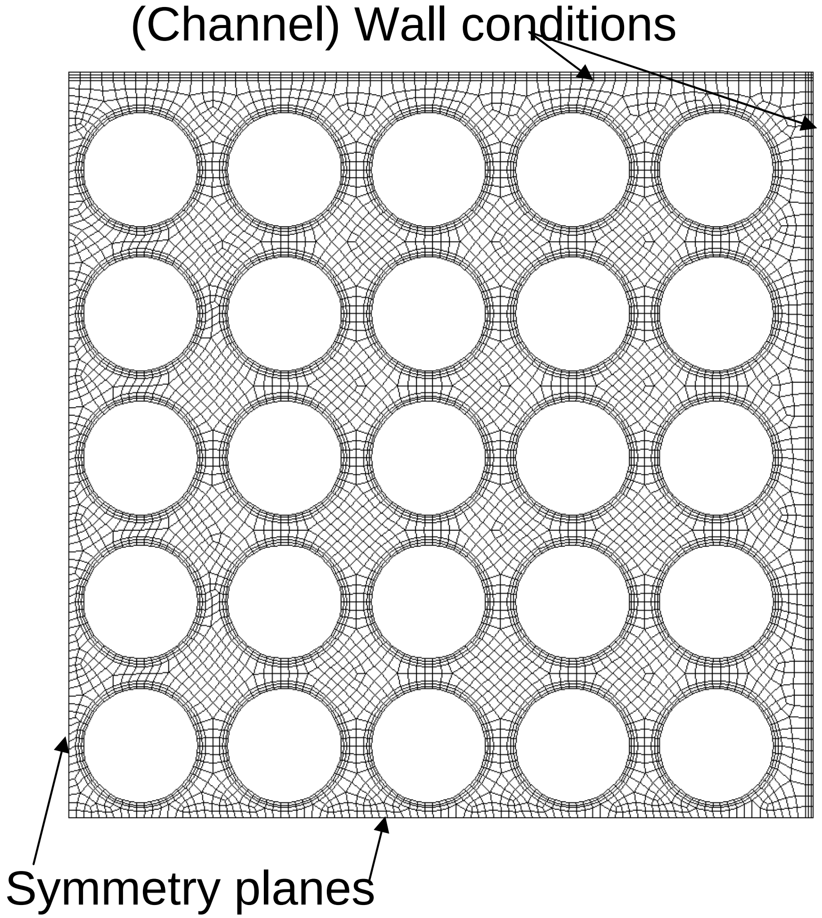
Transfer cask shells

annulus water

Porous Media Constant Determination for the BWR Fuel Rods

- Bounding configuration for maximum flow resistance is 10x10 assembly
- 3D CFD Model applies symmetry conditions and wall conditions to simulate the BWR channel
- Pressure drop/length yields the viscous loss coefficient in Fluent

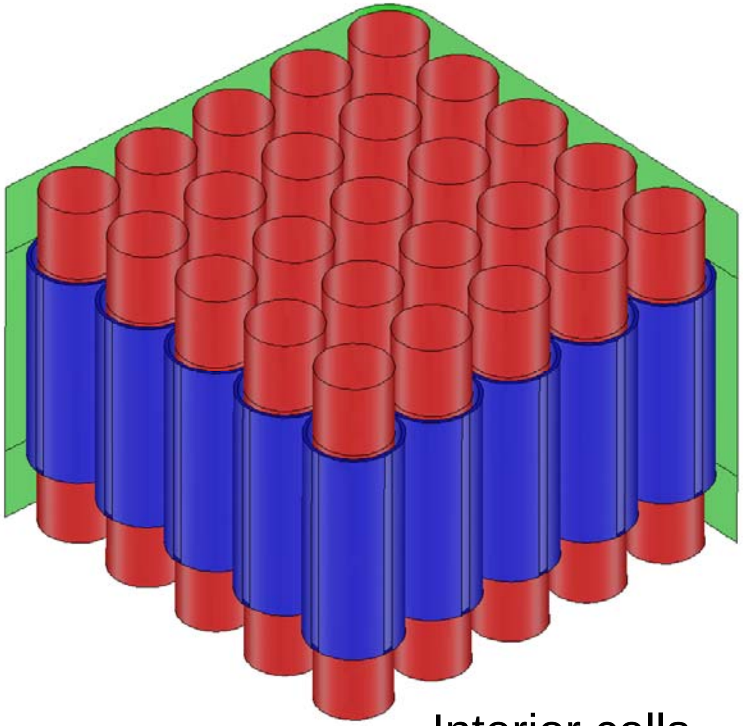
Cross section of 3D fuel rod model



Porous Media Constant Determination for the BWR Fuel Grids

- 3D CFD quarter grid model applies symmetry conditions and wall conditions to simulate the BWR channel
- Pressure drop/length yields the viscous loss coefficient in Fluent
- Coefficients for rods and grids are combined into a single coefficient

Quarter Three-Dimensional Model of the BWR Fuel Grid



Interior cells are not shown

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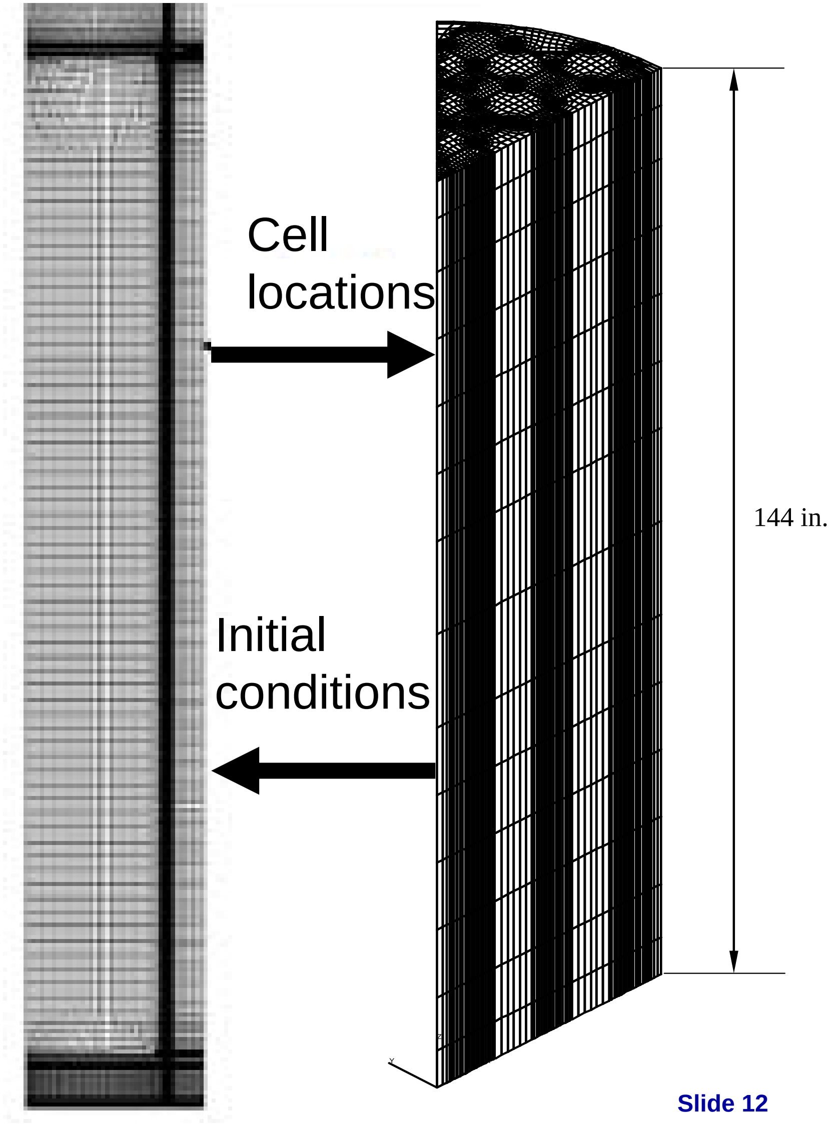
Initial Conditions for the Fluent Transient

- Initial conditions for the Fluent model are taken from the last time step of the ANSYS model
- ANSYS APDL uses Fluent cell locations to determine average temperature in ANSYS model



Fluent 2D model

ANSYS 3D model

Cell locations

Initial conditions

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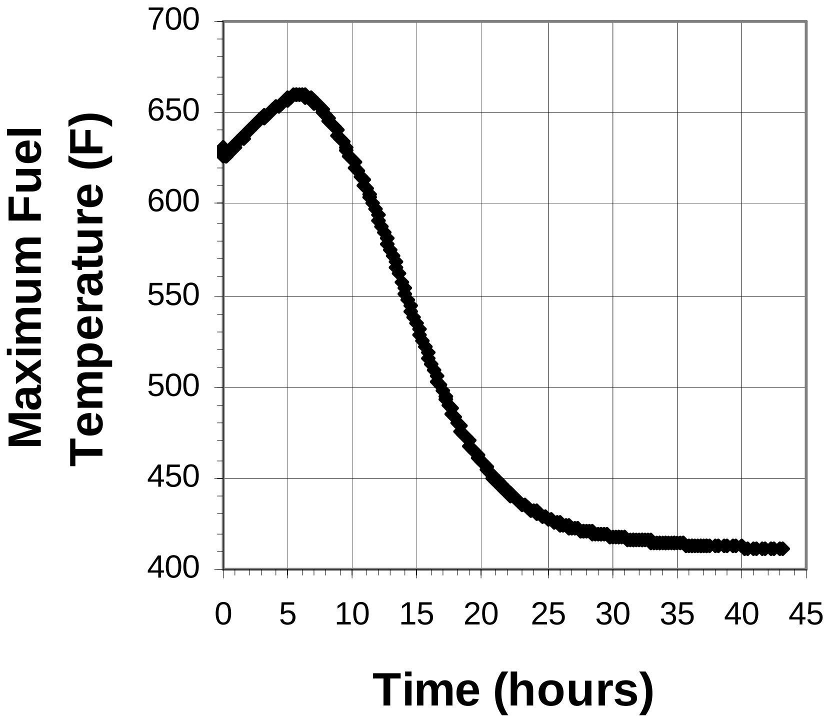
Transient Cool Down Results for Design Basis Heat Load

- Design basis maximum clad temperature continues to increase during cool down simulating the time for convection to become effective
- Steady state occurs in approximately 45 hours



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Conclusions

- Methodology described in this paper for the vacuum condition/cooling provides bounding vacuum drying temperatures for the 87 BWR fuel assembly design
- Maximum clad temperatures identified in the analyses confirm that the clad temperatures do not exceed 400°C (752°F)
- The thermal evaluation for system cooling required the use of two models
  - CFD model to perform the transient
  - ANSYS model to provide the initial conditions for the transient