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Dry Storage Cask Thermal Analyses

by

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Background

- Thermal analyses of spent fuel dry storage and transport systems are mostly performed using a Computational Fluid Dynamics (CFD) program like FLUENT.
- The thermal models developed for CFD analyses are three-dimensional to closely replicate the actual designs.
- Some model simplifications are made:
  - Fuel assemblies are modeled as a homogeneous medium;
  - Some small structures such as basket supports, trunnions are usually not incorporated into the analyses models;
- These FLUENT models have been benchmarked against the best available experimental data.

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Thermal Model Development

- 3-D thermal models have replaced 2-D and 2-D axi-symmetric models:
  - advanced computer technology
  - more reliable and accurate numerical methods
  - more realistic prediction of fluid flow and heat transfer in a system
- Modeling uncertainties are evaluated in numerical analyses
  - uncertainty of the applied boundary conditions
  - spatial discretization (numerical) errors
  - effective properties and approximation of fuel region as porous media

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Temperature Predictions

- Peak Cladding Temperature (PCT) limit is set by the regulators.
- Analyses compute a conservatively higher PCT:
  - The pressure loss through storage cells is overstated;
  - Axial dissipation of heat by the fuel pellets is neglected;
  - No credit is taken for contact between adjacent components;
  - The most severe environment is analyzed;
  - Bounding heat load and heat distribution are analyzed;
  - In the pressurized canister, higher gas pressure enhances the thermosiphon action. A lower gas pressure is assumed.
- The above assumptions lead to a higher predicted MPC shell temperature.

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Temperature Predictions

- In some cases, the assumptions made to compute a conservatively higher PCT may result in computing non-conservative lower component temperatures.
  - In the horizontal direction, the assumption of centered cask and fuel over-estimates PCT, but it under-estimates MPC shell temperature in the location of contact with fuel assemblies.
- Predicted component temperatures are used in other evaluations
  - material corrosion in marine environment
  - performance of material during drop accident.

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Conclusions

More realistic analyses should become the primary goal of CFD analyses:

- Full scale 3-D model with less model simplification;
- Use the actual heat load and heat distribution in fuel loading campaign;
- Use actual pressure loss through fuel assemblies;
- Use actual fuel properties at the fuel burnup of interest, since high burnup may change the fuel cladding and rod material properties, and the axial burnup profile.

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