CFD Best Practice Guidelines (NUREG-2152), Thermal Modeling Issues, and Generic Communications Related to Vacuum Drying Operations

Jorge Solís

May 7, 2013

NEI Used Fuel Management Conference

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

NUREG-2152 "Computational Fluid Dynamics Best Practice Guidelines for Dry cask Application"

- CFD is used to analyze passive decay heat removal in spent fuel dry casks. Deficiencies and inaccuracies of CFD can be caused by a variety of errors and uncertainties

- Validation can be used to reduce uncertainties. Two categories of uncertainties have been identified in the use of CFD for dry cask applications : modeling uncertainties and application uncertainties

- Modeling uncertainties focus on turbulence models. Application uncertainties focus on used boundary conditions (at inlet and outlet vents)

NUREG-2152 “CFD BPG Cont.”

- NRC developed NUREG-2152 to provide practical advice for reviewing CFD methods used in vendor applications and for achieving high quality dry cask CFD simulations

- The report begins with a definition of the concepts of general errors and uncertainties in CFD and a comprehensive section providing guidelines on how to deal with these general errors and uncertainties

- Guidelines are given to draw the user’s attention to the likely sources of uncertainty when formulating a problem, and to know the sources of error inherent in CFD methods

NUREG-2152 “CFD BPG Cont.”

- A comprehensive section that deals with CFD BPGs for viscous incompressible turbulent flow calculations using Reynolds-Averaged Navier-Stokes (RANS) methods is provided

- A checklist of CFD BPGs is presented. The report provides one application example using CFD to analyze and evaluate dry cask thermal response. This section also discusses many issues that are dealt with in the CFD dry cask application. As a result, it provides guidelines based on validation and sensitivity analysis.

- A brief checklist of CFD best practice guidance designed to serve as a quick reference section is provided which is compiled as a summary of best practice advice given in the previous sections

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

NUREG-2152 "CFD BPG Cont."

- The report provides a description of the Grid Convergence Index (GCI) method as an acceptable and recommended method to obtain the discretization error
- If applicants choose to use the GCI method, it will not be challenged in the review process. If applicant choose to use another method, its adequacy will be more scrutinized in the review process
- This is not meant to discourage further development and use of new methods; in fact, the ASME Journal of Fluids Engineering encourages the development of alternative methods of estimation of error and uncertainty

NUREG-2152 - Summary

- CFD best practice guidelines to reduce modeling and application uncertainties for ventilated dry cask applications are developed
- Code validation against test data for a similar application with similar heat transfer and flow characteristics should be performed
- Based on validation, air flow regime should be properly determined (ventilated dry casks)
- Modeling and application uncertainty should be obtained (air flow regime, boundary conditions, effective properties, porous media parameters, etc.)
- To obtain the discretization error, the GCI method is recommended

Thermal Modeling Issues in Dry Casks
Porous Media

- For dry casks in vertical configuration porous media is used to represent the spent fuel
- Flow resistance factors are calculated using separate CFD analysis. Important geometry features are very difficult to represent
- Calculated peak cladding temperatures are very sensitive to these parameters. Therefore, accurate values are necessary, especially for cases with small margin
- Thermal-Hydraulic characterization of bounding fuel assemblies is needed to obtain accurate data and thus validate CFD analysis

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Thermal Modeling Issues in Dry Casks
Use of Grid Convergence Index Method

- Grid Convergence Index (GCI) method is used to obtain the discretization error. The method is well described in NUREG-2152 and in American Society of Mechanical Engineers (ASME), "Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer" (ASME, 2009)
- Modeling issues with the use of GCI method are typically related to the use of the method, specific problems are related to the different grids that are generated in order to determine the GCI
- Unrealistic apparent orders are obtained when the calculation does not follow the ASME recommendations

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Thermal Modeling Issues in Dry Casks
Dry Cask Validation Data

- No data exist for high heat loads and high gas pressure. Vendors rely on analytical capabilities to predict peak cladding temperatures
- Without experimental data code validation can't be performed for cases with small margin
- With designs constantly increasing both in technical complexity and heat loads, accurate calculations and measured data to validate the analysis methods are a necessity

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Generic Communications Related to Vacuum Drying Operations

- What is the vulnerability of vacuum drying systems to failure modes that would allow air ingress into the canister (and what actions have been taken or proposed to date)?
- Are vacuum drying systems correctly categorized with regards to their significance to safety?
- During vacuum drying, are design basis fuel cladding temperatures supported by our current understanding of the thermal models?
- Staff is considering issuance of a generic communication on this issue

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

CFD Best Practice Guidelines (NUREG-2152), Thermal Modeling Issues, and Generic Communications Related to Vacuum Drying Operations

Jorge Solís

May 7, 2013

NEI Used Fuel Management Conference