RIC 2011
Thermal Hydraulics & Severe Accident Research

Computational Fluid Dynamics Applications and Activities in Research

Ghani Zigh
USNRC/RES
3/09/2011

Outline

- Introduction
- USNRC/RES CFD Activities
  - CFD Best Practice Guidelines
    - CFD Workshop
  - Licensing support
    - US APWR Advanced Accumulator (Scaling Uncertainty)
    - ESBWR (Inadvertent Actuation of an ICS)
    - Dry Casks Applications
    - Steam Generator (Severe accident)
  - CFD Validation
    - PWR 17x17 Zirconium Fire (SNL)
    - Panda SETH Tests (Jets/Stratification/Mixing in Containment) (PSI)
    - T-Junction (Hot and Cold Fluids) First OECD/CFD WG Benchmark Exercise
- Summary

Introduction

- Use of CFD for the solution of thermal/hydraulic problems in Nuclear Reactor Safety (NRS) applications is growing:

✓ Reduce uncertainty in the prediction of important phenomena like boron dilution, Dry cask PCT, thermal striping and others.

✓ The availability of robust CFD software and high speed computing.

- USNRC reviews applicant's CFD analysis as well as performs additional CFD for confirmation.
- USNRC validates CFD methods when deemed necessary.
- Growing awareness that CFD can be difficult to apply reliably.
- CFD is a knowledge-based activity despite the availability of CFD software.

CFD Best Practices Activities

- USNRC is looking for ways to implement BPG for application reviews.
- NRC is an active member in the OECD/CSNI 3 CFD Writing Groups:
  - WG1: Provide guidelines for the application of CFD to NRS
    "Best Practice Guidelines for the use of CFD in NRS Applications"
  - WG2: Evaluate the existing assessment basis, and fill the gaps.
    "Assessment of CFD Codes for Nuclear Reactor Safety Problems"
  - WG3: Summarize the extensions to CFD for 2-Phase NRS.
- USNRC is working with DOE on the NE-CAMS program: support the development of CFD quality test data for CFD validation.
- USNRC is part of the ASME V&V 30 Writing Group.

4

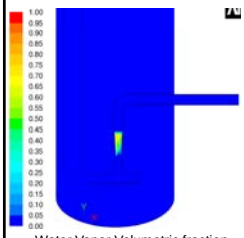
CFD Workshop (CFD4NRS-3)

- USNRC and OECD sponsored and organized Workshop. (September 14-16, 2010).
- The program consisted of about 80 technical papers and 20 posters.
- 30% increase with respect to the previous XCFD4NRS held in Grenoble in 2008 and 70% increase as compared to CFD4NRS held in Garching in 2006.
- Confirms that there is a real need for such workshops.
- Among the Topics included were containment, advanced reactors, multiphase flows, flow in the bundle, fire analysis, dry cask's flow and thermal analysis, mixing flows and pressure thermal shock (PTS).

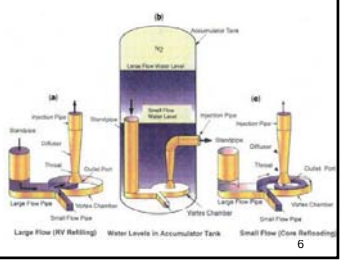
5

US APWR Licensing Support

- To investigate the performance of an advanced accumulator.
- Multi-Phase modeling was used (cavitation)
- CFD model was validated using ½ scale experimental data.
- Examine possible scale effects.



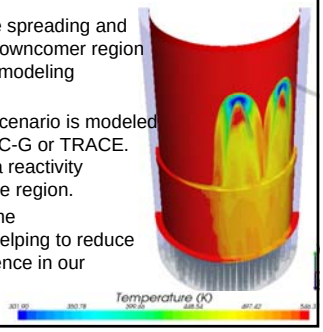
Water Vapor Volumetric fraction



6

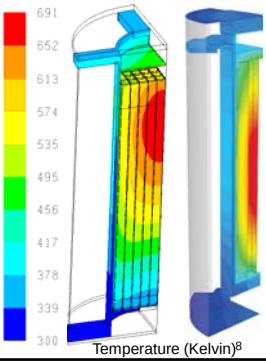
ESBWR Licensing Support

- Inadvertent **actuation** of the isolation condenser system (ICS).
- CFD provided a prediction of the spreading and mixing of cold water jets in the downcomer region for confirmation of system code modeling approach.
- This Inadvertent ICS actuation scenario is modeled with system codes such as TRAC-G or TRACE. Unmixed cold water can cause a reactivity excursion upon entering the core region.
- CFD is used to confirm the plume spreading/mixing assumptions helping to reduce uncertainty and increase confidence in our regulatory decisions



CFD Analysis for Dry Cask Applications

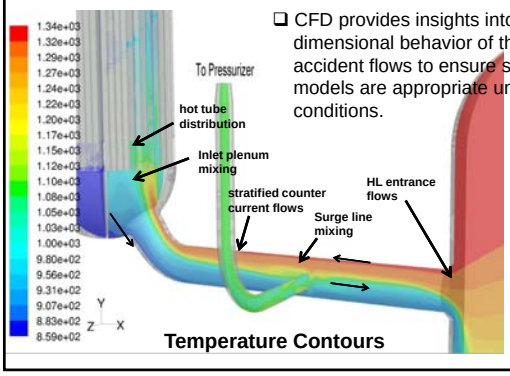
- CFD is used to review licensing application findings.
  - ❖ Vacuum Drying.
  - ❖ Transportation.
  - ❖ Normal Storage.
- Through sensitivity and validation we put forth CFD BPG for Dry Cask Applications.



Temperature (Kelvin)[8]

Severe Accident CFD

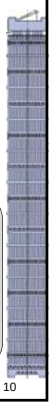
- CFD provides insights into the three-dimensional behavior of the severe accident flows to ensure system code models are appropriate under these conditions.



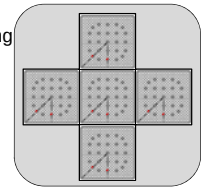
Temperature Contours

Validation

PWR 17x17 Zirconium Fire



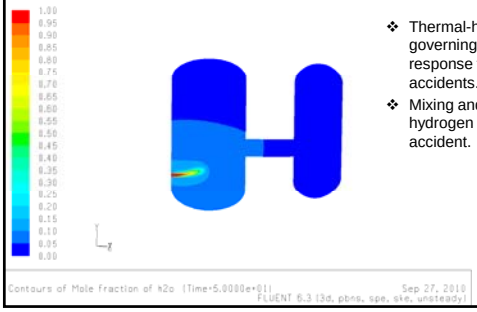
- Provide prototypic thermal hydraulic and zirc-fire data for accident code validation under air flow conditions associated with:
  - Spent fuel pool complete loss of inventory accident
  - Late phase core melt progression
  - Complete loss of water during refueling
  - Dry cask storage (Pre-ignition data)
- CFD will be used to perform Pre-test (Blind) and Post comparison to ensure code adequacy.
- 12 OECD countries are participating.



10

Panda SETH1 Tests

- Containment Analysis Validation Using SETH1 Panda Test.

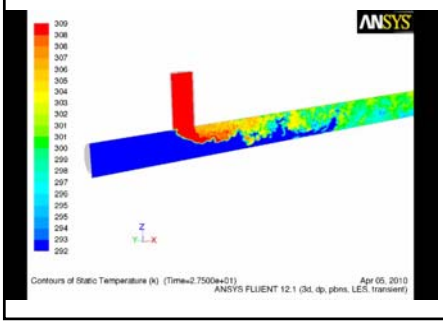


- Thermal-hydraulic processes governing the containment response to postulated accidents.
- Mixing and distribution of hydrogen following a severe accident.

11

T-Junction

- T-Junction Validation Using OECD/CSNI/CFD-WG 1st Benchmark Exercise.



- Mixing of hot and cold flows at a pipe junction results in downstream temperature fluctuations.
- Lead to a high-cycle thermal fatigue and cracking in the piping.

12

Summary

- CFD is used to reduce uncertainty and increase confidence in our regulatory decisions.
- USNRC uses CFD to review and confirm applicant's analyses.
- USNRC validates CFD prior to any new application.
- USNRC is part of many working group on the CFD BPG and implementations. (OECD/NEA/CSNI, DOE/NE-CAMS, V&V 30).
- USNRC is in process of finding a best way to include CFD BPG in application reviews.

13