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SANDIA REPORT

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Analysis of Spent Fuel Pool Flow Patterns Using Computational Fluid Dynamics: Supplement – Thermal Plume Response

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Executive Summary

In 2001, United State Nuclear Regulatory Commission (NRC) staff performed an evaluation of the potential accident risk in a spent fuel pool (SFP) at decommissioning plants in the United States [NUREG-1738]. The study was prepared to provide a technical basis for decommissioning rulemaking for permanently shutdown nuclear power plants. The study described a modeling approach of a typical decommissioning plant with design assumptions and industry commitments; the thermal-hydraulic analyses performed to evaluate spent fuel stored in the spent fuel pool at decommissioning plants; the risk assessment of spent fuel pool accidents; the consequence calculations; and the implications for decommissioning regulatory requirements. It was known that some of the assumptions in the accident progression in NUREG-1738 were necessarily conservative, especially the estimation of the fuel damage. Furthermore, the NRC desired to expand the study to include accidents in the spent fuel pools of operating power plants. Consequently, the NRC has continued the spent fuel pool accident research by applying best-estimate computer codes to predict the severe accident progression following various postulated accident initiators. The present report is a supplement to a two part three-dimensional computational fluid dynamics (CFD) study to examine the flow patterns above, through, and around the spent fuel racks during accident conditions. In Part 1 of the CFD study [Chiffelle, 2003], the response of the spent fuel pool and surrounding refueling room in a reactor building of a boiling water reactor to a complete loss-of-coolant inventory accident is examined.

Ex. 5

In Part 2 of the CFD study [Ross, 2003], the flow patterns in accidents with partial water filled conditions are examined.

Ex. 5

Ex. 5

Table of Contents

List of Figures

Analysis of Spent Fuel Pool Flow Patterns Using Computational Fluid Dynamics: Supplement – Thermal Plume Response

1. Introduction

Ex. 5

The present report is a supplement to two other three-dimensional CFD reports that examined the flow patterns above, through, and around the spent fuel racks during accident conditions. In Part 1 of the CFD study [Chiffelle, 2003], the response of the spent fuel pool and surrounding refueling room in a reactor building of a boiling water reactor to a complete loss-of-coolant inventory accident is examined.

Ex. 5

In Part 2 of the CFD study [Ross, 2003], the flow patterns in accidents with partial water filled conditions were examined.

Ex. 5

2. Description of Model

Ex. 5

Ex. 5

Flow drag within the fuel assemblies is included by a Reynolds number correlation of the following form:

f = friction factor = 100/Re Ex. 2 *

Re = Reynolds number = $(\rho\ v\ h_{D)}) / \mu$

h_D = Hydraulic diameter = Ex. 2 *

The constant factor accounts for orifice and other velocity-squared frictional pressure drops [Chiffelle, 2003]. The drag relationship was specified by dividing the laminar flow coefficient by α, and the turbulent coefficient by α^2, where α is the porosity. These corrections allow the correct flow rate which is calculated for a given buoyant force. Ex. 2

Natural circulation of air through the assemblies is allowed by including a gap between the bottom plate of the spent fuel racks and the floor of the SFP. Typically, cool air will flow down the side walls and other empty regions adjacent to the racks, turn and transverse underneath the fuel racks, and finally turn upwards through the fuel assemblies. Ex. 2

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[3] The color code for the figure is pool walls (light green), surrounding concrete floor (dark green), and fuel subassembly walls (purple).

6. References

Chiffelle, R., et al., "Analysis of Spent Fuel Pool Flow Patterns Using Computational Fluid Dynamics: Part 1 – Air Cases," Sandia National Laboratories, Informal Report, April 2003.

Collins, T. E., and Hubbard, G., "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants," NUREG-1738, February, 2001.

Ex. 5

Ross, K. W., et al., "Analysis of Spent Fuel Pool Flow Patterns Using Computational Fluid Dynamics: Part 2 – Partial Water Cases," Sandia National Laboratories, Informal Report, April 2003.

Ex. 5

Wagner, K. C., et al., "Evaluation of Spent Fuel Pool Accident Response to a Complete Loss-of-Coolant Inventory Using MELCOR 1.8.5," Sandia National Laboratories, Informal Report, January 2003.