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for ESBWR Fuel Racks,"
November 2007

Non-Proprietary Version

HITACHI

3901 Castle Hayne Road
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November 2007

Licensing Topical Report

DYNAMIC, LOAD-DROP AND THERMAL-HYDRAULIC ANALYSES FOR ESBWR FUEL RACKS

David G. Davenport

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eDRF-0000-0077-6501

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This document is the result of the technical contributions from many individuals and organizations in addition to the authors of this document. At Equipos Nucleares, S. A., significant contributions to the development of these analyses were provided by Luis Costas, Marisa Crespo, and Alfonso Alvarez.

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1.0 DYNAMIC LOAD ANALYSIS FOR SPENT FUEL RACKS IN THE SPENT FUEL POOL

1.1 Introduction

1.1.1 Purpose

The purpose of this document is to present the structural analysis of Spent Fuel High Density Fuel Storage Racks (FSR) for the Spent Fuel Storage Pool located in the Fuel Building (FB) of the ESBWR.

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1.1.2 Scope

The scope of this document covers the design principles, load analysis and justification of the structural configuration of the FSR.

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1.2 Input Data

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1.3 Summary of Results

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1.4 ANALYSIS SUMMARY

Section 1.4.1 presents a brief description of the FSR.

Section 1.4.2 presents the properties of the FSR materials.

Section 1.4.3 indicates the applicable design code to analysis of the FSR.

Section 1.4.4 presents the assumptions adopted in the analysis of the FSR.

Section 1.4.5 gives a detailed description of the FSR model. A detail Finite Element Model (FEM) is developed for the FSR in order to analyze stresses, reactions and displacements.

Section 1.4.6 describes the different load cases which apply to the FSR analysis.

Section 1.4.7 presents the load combinations applied for the FSR analysis.

Section 1.4.8 presents the analysis procedure description for the FSR.

Section 1.4.9 gives the allowable stress limits used in the FSR analysis.

1.4.1 Spent Fuel Storage Rack Description

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1.4.2 Material

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1.4.3 Design Code

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1.4.4 Assumptions

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1.4.5 FSR Analysis Model

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1.4.5.1 Structural Consideration on the Borated Plates

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1.4.6 Analysis Loads

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1.4.6.1 Dead Weight + Buoyancy (D)

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1.4.6.2 Fuel Handling Loads (P_f)

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1.4.6.3 Differential Temperature Induced Loads (T_o, T_a)

[[

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1.4.6.4 Safe Shutdown Earthquake (SSE)

[[

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1.4.6.5 Safety Relief Valve Discharge (SRVD)

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1.4.6.6 Loss of Coolant Accident (LOCA)

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1.4.7 Load Combinations

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1.4.8 Analysis Methodology Description

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1.4.9 Stress Limits

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1.5 Results of the Analysis

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1.5.1 Displacements Results

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1.5.2 Plate Stress Results

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1.5.2.1 10 mm Thick Enveloping Plate

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1.5.2.2 5 mm Thick Upper Level Plates

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1.5.2.3 20 mm Thick Base Plate Stiffener Plates

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1.5.2.4 20 mm Thick Base Plate and 60 mm Thick Bolted Support Plates

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1.5.3 Bolt Stress Results

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1.6 Conclusions

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1.7 References

1. ASME Boiler & Pressure Vessel Code, Section II Materials, Part A Ferrous Material Specifications, 2001 Edition with Add. 2003
2. ASME Boiler & Pressure Vessel Code, Section II Materials, Part D Properties (Customary), 2001 Edition with Add. 2003
3. ASME Boiler & Pressure Vessel Code, Section III Rules for Construction of Nuclear Facility Components, Division 1, Subsection NF, Supports, 2001 Edition with Add. 2003
4. ASME Boiler & Pressure Vessel Code, Section III Rules for Construction of Nuclear Facility Components, Division 1, Appendices, 2001 Edition with Add. 2003
5. Regulatory Guide 1.92. Combining Modal Responses and Spatial Components in Seismic Response Analysis
6. Sarpkaya: Mechanics of Wave Forces on Off-Shore Structures
7. ANSYS 10.0 Documentation (User Manual, Theoretical Manual)
8. ASME B1.13M-2001 Metric Screw Threads: M Profile
9. ROARK'S Formulas for Stress & Strain

APPENDIX A

A.1 Figures

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APPENDIX B

B.1 Output Analysis File

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2.0 DYNAMIC LOAD ANALYSIS FOR SPENT FUEL RACKS IN THE BUFFER POOL

2.1 Introduction

2.1.1 Purpose

The purpose of this document is to present the structural analysis of Spent Fuel High Density Fuel Storage Racks (FSR) for the Buffer Pool located in the Reactor Building (RB) of the ESBWR.

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2.1.2 Scope

The scope of this document covers the design principles, load analysis and justification of the structural configuration of the FSR.

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2.2 Input Data

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2.3 Summary of Results

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2.4 ANALYSIS SUMMARY

Section 2.4.1 presents a brief description of the FSR.

Section 2.4.2 presents the properties of the FSR materials.

Section 2.4.3 indicates the applicable design code to analysis of the FSR.

Section 2.4.4 presents the assumptions adopted in the analysis of the FSR.

Section 2.4.5 gives a detailed description of the FSR model. A detail Finite Element Model (FEM) is developed for the FSR in order to analyze stresses, reactions and displacements.

Section 2.4.6 describes the different load cases which apply to the FSR analysis.

Section 2.4.7 presents the load combinations applied for the FSR analysis.

Section 2.4.8 presents the analysis procedure description for the FSR.

Section 2.4.9 gives the allowable stress limits used in the FSR analysis.

2.4.1 SPENT FUEL STORAGE RACK DESCRIPTION

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2.4.2 MATERIALS

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2.4.3 DESIGN CODE

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2.4.4 ASSUMPTIONS

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2.4.5 FSR ANALYSIS MODEL

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2.4.5.1 Structural Considerations on the Borated Plates

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2.4.6 ANALYSIS LOADS

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2.4.6.1 Dead Weight + Buoyancy (D)

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2.4.6.2 Fuel Handling Loads (P_f)

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2.4.6.3 Differential Temperature Induced Loads (To, Ta)

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2.4.6.4 Safe Shutdown Earthquake (SSE)

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2.4.6.5 Safety Relief Valve Discharge (SRVD)

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2.4.6.6 Loss of Coolant Accident (LOCA)

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2.4.7 Load Combinations

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2.4.8 ANALYSIS METHODOLOGY DESCRIPTION

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2.4.9 STRESS LIMITS

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2.5 RESULTS OF THE ANALYSIS

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2.5.1 Displacement Results

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2.5.2 Plate Stress Results

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2.5.2.1 10 mm Thick Enveloping Plate

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2.5.2.2 7 mm Thick Upper Level Plates

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2.5.2.3 20 mm Thick Base Plate Stiffener Plates

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2.5.2.4 20 mm Thick Base Plate and 60 mm Thick Bolted Support Plates

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2.6 Bolt Stress Results

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2.7 Conclusions

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2.8 References

1. ASME Boiler & Pressure Vessel Code, Section II Materials, Part A Ferrous Material Specifications, 2001 Edition with Add. 2003
2. ASME Boiler & Pressure Vessel Code, Section II Materials, Part D Properties (Customary), 2001 Edition with Add. 2003
3. ASME Boiler & Pressure Vessel Code, Section III Rules for Construction of Nuclear Facility Components, Division 1, Subsection NF, Supports, 2001 Edition with Add. 2003
4. ASME Boiler & Pressure Vessel Code, Section III Rules for Construction of Nuclear Facility Components, Division 1, Appendices, 2001 Edition with Add. 2003
5. Regulatory Guide 1.92. Combining Modal Responses and Spatial Components in Seismic Response Analysis
6. Sarpkaya: Mechanics of Wave Forces on Off-Shore Structures
7. ANSYS 10.0 Documentation (User Manual, Theoretical Manual)

8. ASME B1.13M-2001 Metric Screw Threads: M Profile
9. ROARK'S Formulas for Stress & Strain

APPENDIX C

C.1 FIGURES

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APPENDIX D

D.1 OUTPUT ANALYSIS FILE

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3.0 DYNAMIC LOAD ANALYSIS FOR NEW FUEL RACKS IN THE BUFFER ROOL

3.1 Purpose

The purpose of this document is to present the structural analysis of New Fuel Storage Racks (FSR) for the Buffer Pool located in the Reactor Building (RB) of the ESBWR.

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3.2 Scope

The scope of this document covers the design principles, load analysis and justification of the structural configuration of the FSR.

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3.3 Summary of Results

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3.4 Analysis Summary

Section 3.4.1 presents a brief description of the FSR.

Section 3.4.2 presents the properties of the FSR materials.

Section 3.4.3 indicates the applicable design code to analysis of the FSR.

Section 3.4.4 presents the assumptions adopted in the analysis of the FSR.

Section 3.4.5 gives a detailed description of the FSR model. A detail Finite Element Model (FEM) is developed for the FSR in order to analyze stresses, reactions and displacements.

Section 3.4.6 describes the different load cases which apply to the FSR analysis.

Section 3.4.7 presents the load combinations applied for the FSR analysis.

Section 3.4.8 presents the analysis procedure description for the FSR.

Section 3.4.9 gives the allowable stress limits used in the FSR analysis.

3.4.1 New Fuel Storage Rack Deescription

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3.4.2 Materials

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3.4.3 Design Code

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3.4.4 Assumptions

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3.4.5 FSR Analysis Model

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3.4.6 Analysis Loads

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3.4.7 Dead Weight + Buoyancy (D)

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3.4.7.1 Fuel Handling Loads (P_f)

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3.4.7.2 Differential Temperature Induced Loads (T_o, T_a)

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3.4.7.3 Safe Shutdown Earthquake (SSE)

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3.4.7.4 Safety Relief Valve Discharge (SRVD)

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3.4.7.5 Loss of Coolant Accident (LOCA)

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3.4.8 Load Combinations

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3.4.9 Analysis Methodology Description

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3.4.10 Stress Limits

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3.5 Results of the Analysis

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Table3-7b Acceleration for Missing Masses						
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3.5.1 Displacements Results

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3.5.2 Plate Stress results

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3.5.2.1 8 mm Thick Channel Plate

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3.5.2.2 12 mm Thick Door Plates

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3.5.2.3 10 mm and (10+8) mm Assembly Grid Plates

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3.5.2.4 Axis and Hinge Plates

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3.5.2.5 15 mm Thick Support-base Stiffener Plates

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3.5.2.6 15 mm Thick Folded Base Plate and (15+15) mm Thick Bolted Support Plates

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3.5.3 Bolt Stress Results

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3.6 Conclusions

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3.7 References

1. ASME Boiler & Pressure Vessel Code, Section II Materials, Part A Ferrous Material Specifications, 2001 Edition with Add. 2003
2. ASME Boiler & Pressure Vessel Code, Section II Materials, Part D Properties (Customary), 2001 Edition with Add. 2003
3. ASME Boiler & Pressure Vessel Code, Section III Rules for Construction of Nuclear Facility Components, Division 1, Subsection NF, Supports, 2001 Edition with Add. 2003
4. ASME Boiler & Pressure Vessel Code, Section III Rules for Construction of Nuclear Facility Components, Division 1, Appendices, 2001 Edition with Add. 2003
5. Regulatory Guide 1.92. Combining Modal Responses and Spatial Components in Seismic Response Analysis
6. Sarpkaya: Mechanics of Wave Forces on Off-Shore Structures
7. ANSYS 10.0 Documentation (User Manual, Theoretical Manual)
8. ASME B1.13M-2001 Metric Screw Threads: M Profile
9. ROARK'S Formulas for Stress & Strain

APPENDIX E

E.1 FIGURES

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APPENDIX F

F.1 Output Analysis File

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4.0 LOAD-DROP (IMPACT) ANALYSIS

4.1 Introduction

Load drop analysis is required in the design of high density racks for new and spent fuel elements. The fuel consists of General Electric (GE) boiling water reactor (BWR) fuel elements, within the context of the project known as the Economic Simplified Boiling Water Reactor (ESBWR).

All the racks have to withstand a number of operational and accidental loads. The present report is concerned with the effects of postulated impacts, as arising from the accidental drop of fuel elements onto the various racks during operations at the plant.

4.1.1 Object

The object of the work consists of evaluating the performance of the ESBWR racks when they are subjected to postulated accidental impacts from fuel elements. There are two types of racks to be considered: racks for spent fuel and racks for fresh fuel.

In the case of the spent fuel racks, the dropped mass may impact the upper part of the rack, in which case the distortions caused should not affect criticality (i.e. should not reach the active zones of the elements stored in adjoining cells); also, fuel cells other than those directly involved in the impact should not be affected by the accident. Alternatively, the dropped mass may not interact with the upper part of the rack, but enter a cell and proceed all the way to the bottom plate, which should then be capable of successfully arresting the falling mass.

In the case of the fresh fuel racks, the dropped mass may impact the upper part of the short wall of the cell, an accident that should not affect the walls separating contiguous elements. Alternatively, it could continue to impact the bottom plate, which should be capable of successfully arresting the falling mass.

4.1.2 Scope

In order to carry out the evaluations mentioned, the necessary data was first acquired and critically assessed. When the value of a parameter could vary over a range, conservative assumptions have been incorporated to evaluate the postulated accidents.

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As mentioned earlier in relation with spent fuel racks, a dropped element may fall through to the bottom of a cell and impact the base plate of the rack; alternatively, it may be arrested at the top of the storage cells by impact against the upper part of the cell walls. Both possible alternatives have been considered in the present work. [[

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4.1.3 Layout of Report

The report is organized as follows:

Section 4.2 describes the problems under consideration, including the geometry and behavior of the falling fuel element and the two types of storage racks, as well as the accident conditions.

The next two sections are dedicated to studying the impacts on spent fuel racks. Section 4.3 is concerned with impacts against the base plate, while Section 4.4 deals with the impacts taking place against the upper part of the rack.

Section 4.5 discusses the impacts against fresh fuel racks, including both the case in which the dropped element impacts the top of the wall and that in which it continues falling through the interior of one of the storage cells to reach the bottom plate.

The conclusions and recommendations derived from the work conducted are presented in Section 4.6.

The appendix contains the list of bibliographic references mentioned in the text of the report.

4.2 DESCRIPTION OF THE PROBLEM

4.2.1 The Fuel Element and Handling Tool

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4.2.2 Spent Fuel Racks

4.2.2.1 Description

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4.2.2.2 Postulated Accidents

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4.2.3 Fresh Fuel Racks

4.2.3.1 Description

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4.2.3.2 Postulated Accidents

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4.3 SPENT FUEL RACKS: IMPACTS ON THE BASE PLATE

4.3.1 Introduction

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4.3.2 Impact above a leg

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4.3.3 Impact between legs

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4.4 SPENT FUEL RACKS: IMPACTS AT THE TOP OF THE CELLS

4.4.1 Introduction

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4.4.2 Impacts on Cell Walls

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4.4.2.1 Walls Slotted Below

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4.4.2.2 Walls Slotted Above

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4.4.3 Impacts on Cell Contacts

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4.5 FRESH FUEL RACKS

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4.5.1 Impact on the base plate

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4.5.2 Impact on the wall

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4.6 CONCLUSIONS

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4.7 References

1. ASME - American Society of Mechanical Engineers (1977) "ASME Section III. Boiler and Pressure Vessel Code".

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5.0 THERMAL-HYDRAULIC ANALYSIS

5.1 Introduction

The purpose of this analysis is to determine the maximum peak temperatures that will be reached within the spent fuel pool in the ESBWR nuclear power station.

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5.1.1 Acceptance Criteria

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5.2 Calculation Methodology

5.2.1 General Description

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5.2.1.1 Maximum Inlet Temperature Determination

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5.2.1.2 Calculation of the Velocities and Temperatures within the Spent Fuel Pool (SFP)

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5.2.2 Maximum Inlet Temperature Determination

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5.2.2.1 Normal Conditions Case

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5.2.2.2 Abnormal Conditions Case

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5.2.3 Calculation of the Velocities and Temperatures within the Spent Fuel Pool (SFP)

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5.2.3.1 Loss Coefficient Clculation

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An 8% safety factor has been applied to the loss coefficient obtained previously ($K=269.55 Kg^{-1} \cdot m^{-1}$).

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5.2.3.2 Heat Generation Calculation in Each Rack Under the Normal Conditions Case

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5.2.3.3 Heat Generation Calculation in Each Rack Under the Abnormal Conditions Case

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5.2.4 Summary Tables

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5.3 Results

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5.3.1 Temperature Distribution Under Normal Conditions Case

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5.3.2 Temperature Distribution Under Abnormal Conditions Case

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5.3.3 Velocity Distribution Under Normal Conditions Case

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5.3.4 Velocity Distribution Under Abnormal Conditions Case

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5.3.5 Maximum Cladding Temperature

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5.4 Reactor Buffer pool

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5.5 Conclusions

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5.6 References

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7. "Heat Transmission" William H. McAdams. McGraw-Hill Book Company.

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end of document

Total page count 423

MFN 07-607

Enclosure 3

Affidavit

GE Hitachi Nuclear Energy

AFFIDAVIT

I, David H. Hinds, state as follows:

(1) I am the Manager, New Units Engineering, GE Hitachi Nuclear Energy ("GEH"), have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Enclosure 1 of GEH letter MFN 07-607, Mr. James C. Kinsey to U.S. Nuclear Regulatory Commission, entitled *Transmittal of Licensing Topical Report NED-33373P, Revision 0, "Dynamic, Load-Drop and Thermal-Hydraulic Analysis for ESBWR Fuel Racks," November 2007,* dated November 16, 2007. The GEH proprietary information in Enclosure 1, which is entitled *Licensing Topical Report NEDC-33373P, Revision 0, "Dynamic, Load-Drop and Thermal-Hydraulic Analysis for ESBWR Fuel Racks," November 2007 - GEH Proprietary Information,* is delineated by a [[dotted underline inside double square brackets.{3}]]. Figures and large equation objects are identified with double square brackets before and after the object. In each case, the superscript notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination. A non-proprietary version of this information is provided in Enclosure 2, *Licensing Topical Report NEDO-33373, Revision 0, "Dynamic, Load-Drop and Thermal-Hydraulic Analysis for ESBWR Fuel Racks," November 2007 - Non-Proprietary Version.*

(3) In making this application for withholding of proprietary information of which it is the owner, GEH relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret," within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GEH competitors without license from GEH constitutes a competitive economic advantage over other companies;
b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;
c. Information which reveals aspects of past, present, or future GEH customer-funded development plans and programs, resulting in potential products to GEH;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a., and (4)b, above.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GEH, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GEH, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or subject to the terms under which it was licensed to GEH. Access to such documents within GEH is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GEH are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2), above, is classified as proprietary because it identifies detailed GE ESBWR design information for the Spent Fuel Storage Racks. GE utilized prior design information and experience from its fleet with significant resource allocation in developing the system over several years at a substantial cost.

The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GEH asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GEH's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GEH's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GEH.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GEH's competitive advantage will be lost if its competitors are able to use the results of the GEH experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GEH would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GEH of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 16th day of November 2007.

David H. Hinds
GE Hitachi Nuclear Energy