November 3, 2010

MEMORANDUM TO: ACRS Members

FROM: Christopher L. Brown, Senior Staff Engineer
Reactor Safety Branch A, ACRS

SUBJECT: CERTIFICATION OF THE MINUTES OF THE ACRS **OPEN** ESBWR SUBCOMMITTEE MEETING, SEPTEMBER 23 AND 24, 2010, ROCKVILLE, MARYLAND

The minutes of the subject meeting were certified on October 28, 2010, as the official record of the proceedings of that meeting. A copy of the certified minutes is attached.

Attachment: As stated

cc w/o Attachment: E. Hackett
C. Santos

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

MEMORANDUM TO: Christopher Brown, Senior Staff Engineer
ACRS

FROM: Michael Corradini, Chairman
ESBWR Subcommittee

SUBJECT: CERTIFICATION OF MINUTES OF THE ACRS OPEN ESBWR SUBCOMMITTEE MEETING, SEPTEMBER 23 AND 24, 2010, ROCKVILLE, MARYLAND

I hereby certify, to the best of my knowledge and belief, that the minutes of the subject meeting on September 23 and 24, 2010, are an accurate record of the proceedings for that meeting.

/RA/ 10/ 28 /10
Michael Corradini, Date
ESBWR Subcommittee Chairman

Certified by: M. Corradini
Certified: October 28, 2010

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
MINUTES OF ACRS ESBWR SUBCOMMITTEE MEETING
SEPTEMBER 23 AND 24, 2010
ROCKVILLE, MARYLAND

INTRODUCTION

The Advisory Committee on Reactor Safeguards (ACRS) Subcommittee on the ESBWR met in room T-2B1 at the Headquarters of the U.S. Nuclear Regulatory Commission (NRC), located at 11545 Rockville Pike, Rockville, Maryland, on September 23 and 24, 2010. The Subcommittee was briefed by representatives of NRC's Office of New Reactor Licensing (NRO) on select portions of SERs for Chapters 3, 4, 9, 6, and 7 of the ESBWR DCD.

The Subcommittee planned to gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee of the ACRS at a later date.

The Chairman for this ACRS Subcommittee was Dr. Michael Corradini. Mr. Christopher Brown was the ACRS staff cognizant engineer for this topic and served as the Designated Federal Official for this meeting. This meeting was open to public attendance and no proprietary information was discussed. The Subcommittee received no written comments or requests for time to make oral statements from any members of the public concerning the subject of this meeting. The meeting convened at approximately 8:30am.

The detailed agenda identifying the specific presentation topics comprising this meeting can be found in Attachment 1. Both during and following the scheduled presentations, the speakers responded to specific questions and comments from the ACRS Subcommittee members. The scope of the questions, comments, and answers thereto, and the speaker's responses thereto, have been captured in the verbatim meeting transcript. As a result of Member questions and comments, and speaker responses (answers) thereto – so-called 'Qs and As', a number of follow-up actions were identified for further discussion at subsequent Subcommittee meetings. These follow-up actions will be tracked by the ACRS staff.

ACRS Subcommittee meeting transcripts can be found at the following NRC Internet website location*: http://www.nrc.gov/ reading-rm/doc-collections/acrs/tr/subcommittee/*.

ATTENDEES:

The following list of Individuals (and their affiliations) attending this meeting was compiled using both the sign-in sheets and the Subcommittee meeting transcript.

ACRS Members

M. Corradini, Subcommittee Chairman
J. S. Armijo
S. Abdel-Khalik
J. Stetkar

T. Kress, Consultant
G. Wallis, Consultant

ACRS Staff

C. L. Brown, Designated Federal Official	C. Santos
K. D. Weaver, ACRS staff	

NRC Staff

A. Cubbage, NRO	D. Misenhimer
S. Chakrabarti	M Norato
K. Hawkins	A. Hsia
J. Dixon-Herrity	D. Galvin
A. Pal	D. Terao
L. Wheeler	S. Lee
A. Stibbs	D. Shum
R. Hernandez	G. Thomas
E. Sastre	J. Gilmer
P. Yarsky	J. Donoyhue
C. Harbuck	J. Ashcraft
H. Li	T. Fredetie
D. Zhang	J. Zhao
K Nguyen	

General Electric-Hitachi (GEH) Staff

P. Campbell	R. Kingston
J. Deaver	T. Enfinger
J. Cascone	K. Keithline
W. Bird	W. Marquino
A. Beard	B. Johnson

J. Smith

R. Morante

P. Sekerak

M. Arcaro

J. Braverman

S. Hambric

Y. Wong

SCHEDULED PRESENTATIONS:

The committee meeting focused on select portions of Chapters 3, 4, 9, 6, and 7 with open items resolved by staff review of GEH RAI responses. No significant issues were identified. There were a couple of topics that the subcommittee discussed with GEH and the staff to clarify key points.

Overall Summary of ESBWR Subcommittee Meeting (September 23, 2010)

1. GEH was asked to confirm that the Seismic Category II and Seismic Category NS structures, which are in close proximity to Seismic Category I structures, are designed to Seismic Category I requirements. It was demonstrated that the Seismic Category II and Seismic Category NS structures, which are in close proximity to Seismic Category I structures, are designed to SSE requirements. The gaps between the structures are large enough to preclude impact during SSE event.

2. GEH was asked to Confirm that the Seismic Category I structures meet the sliding stability requirements of the SRP 3.8.5. Justify use of static coefficient of friction beneath the basemat and along the vertical surfaces of the walls. Justify use of full passive pressure at the side of the vertical surfaces of the walls in the sliding resistance. How did GEH consider other potential sliding interfaces in addition to soil shear failure (i.e., basemat to concrete mudmat, concrete to soil)? In response, GEH indicated that Seismic Category I structures meet the sliding stability requirements of the SRP 3.8.5. Static coefficient of friction of 0.7 beneath the basemat and a reduced coefficient of friction of 0.5 for the vertical surface of the wall is adequate to provide sliding stability. Additional reinforcement was added to the vertical walls to resist the passive pressure. GEH added requirements to increase the friction resistance between the basemat, mudmat and soil.

Overall Summary of ESBWR Subcommittee (September 24, 2010)

GEH provided revised decay heat calculation and associated analysis using bounding bounding total decay power curve to show water remains over active fuel and all thermal requirements are met. GEH Illustrated how OE experience applied to ESBWR design for spent fuel uncovery and gas accumulation in FAPCS. GEH described Aux System RTNSS functions and robustness of system design. They also described PSWS, RCCWS, NICWS design overview, and the Instrument Air / Service Air System Overview.

OPENING REMARKS AND OBJECTIVES:

Dr. Michael L. Corradini, Chairman of the ACRS ESBWR Subcommittee, convened the meeting at 8:30 a.m.

Ms. Amy Cubbage, the NRO Acting Branch Chief and lead PM responsible for the ESBWR DCD review, also made an opening statement.

INDIVIDUAL SUMMARY OF CHAPTER PRESENTATIONS:

Based on committee discussion, the subcommittee did not identify any substantive concerns that were specific to the ESBWR. NRC staff has produced appropriate RAIs and the open items associated with these have been adequately closed by the GEH responses for these chapters.

Chapter 3: Design of Structures, Components, Equipment, and Systems

Chapter 3 is a very comprehensive chapter. It covers the basic design bases of essentially every significant part of the plant, from major buildings to individual components. Later chapters build on this information, describing how various systems work together under normal operating conditions and how they respond to accidents, and how this response is assured by procedures, testing, etc.

Seismic events are a particular concern since they affect every component of every system located in every structure.

The following NRC RAIs were discussed in this portion of the meeting: 1) 3.8-79 - seismic II/I issue & seismic gaps between structures, 2) 3.8-94 - soil-bearing capacity and enveloping floor response spectra, 3) 3.8- 96 - stability analysis of the structure due to sliding, 4) 3.8-107 – in view of significant nonlinear behavior of the containment structure due to thermal loading, the staff questioned the appropriateness of combining results from thermal analysis with elastically calculated results for other loads, 5) 3.8-120- reactor shield wall material, and 6) 3.8-125- impact of spent fuel rack on spent fuel pool structure

GEH staff presented each of these RAI's and their responses. NRC staff stated that they had performed five design audits to review design reports and calculations, and that they had performed confirmatory analysis of the nuclear island foundation base mat. The NRC staff stated that the majority of the review questions required additional technical information which resulted in significant enhancement of the DCD content, and that all issues identified during their review have been resolved.

For Section 3.9 – Seismic Category I Structures, the following NRC RAIs were discussed in this portion of the meeting: 1) 3.9-75- use of terms prototype and non-prototype in DCD Tier 2, Section 3.9.9.1 and NEDE-33259P, 2) 3.9-96-preoperational flow-induced vibration testing for the first ESBWR plant, 3) 3.9-81- demonstrate that there is no significant dynamic amplification of loads on reactor internals as a result of postulated break in main steam and feedwater line, and 4) 3.9-177-availability of design reports and design specifications.

The NRC staff stated that all open items identified were resolved.

For Section 3.12 – Piping Design, the following NRC RAIs were discussed in this portion of the meeting: 1) 3.12-3-Independent Support Motion Response Spectrum, 2) 3.12-17-provide justification that meets the provision of NUREG-0484, and3) 3.12-27-load combination of seismic anchor movement and seismic inertia response

The NRC staff stated that all open items identified were resolved.

Chapter 4: Reactor Design

Chapter 4 includes discussion of the fuel system (fuel rods and fuel assemblies), the nuclear design, the associated thermal-hydraulic design, reactor materials, and the functional design of the control rod drive system.

The NRC staff provided a list of the topical reports that they had approved and stated that the ESBWR fuel assembly and control blade design was acceptable.

Staff indicated that the ESBWR fuel assembly and control blade design to be acceptable and meets regulatory requirements including applicable GDCs. Analyses and testing demonstrated a conservative design.

Chapter 9 Auxiliary Systems

The ESBWR application classifies the auxiliary systems into five categories: fuel storage and handling; water systems; process auxiliaries; heating, ventilation, and air conditioning (HVAC) systems; and other auxiliaries.

The GEH staff provided a brief discussion and overview of the following
1) Spent fuel pool decay heat calculation and associated analysis.
2) Spent fuel uncover – operating experience considerations
3) Gas accumulation

The staff's briefing on Chapter 9 covered staff's review of spent fuel storage and fuel and auxiliary pools cooling system (FAPCS)- sections 9.1.2 and 9.1.3. Additional discussion related to the August 16, 2010 ACRS Subcommittee in which an issue related to NEDO-33373; basis for the heat loads used in the SFP thermal-hydraulic. GEH calculations for decay heat were determined to be non-conservative. The updated SFP heat load for the full core offload and discharged fuel decay uses end of fuel cycle and is determined to be more conservative. Staff indicated that gas accumulation that could enter a system and result in component or system damage was adequately addressed. Refueling cavity bellows seal (RCBS) postulated failures were adequately addressed. RTNSS 'B' and 'C' functions are highly reliable and meet single failure criteria and are subject to enhanced design, quality, reliability, and availability provisions. Also, the Subcommittee heard staff's review of Plant Service Water System (PSWS), Reactor Component Cooling Water System (RCCWS), and Nuclear Island Chilled Water System (NICWS) Sections 9.2.1. 9.2.2 and 9.2.7 and staff's presentation of Thermal-Hydraulic Analysis for ESBWR Fuel Racks (NEDO-33373).

Chapter 7 Digital I & C

The instrumentation, logic and control system for the ESBWR provides a centralized set of equipment for plant protection, safety monitoring, and control. This system, called the

Distributed Control and Information System (DCIS), is divided into two subsystems, the Q-DCIS, which is the safety-related portion of the system, and the N-DCIS, which is non-safety-related.

Staff evaluated the safety of the ESBWR I&C system design and finds the design to be safe and in compliance with applicable regulations. The I&C design follows safe design principles, including 1) independence, 2) determinism, 3) redundancy, 4) diversity, 5) defense-in-depth. The staff found that the I&C system design provides sufficient independence in compliance with IEEE-603 (10 CFR 50.55a(h)) and GDC 21. Staff indicated that diverse and independent diverse protection system (DPS) is provided as a defense-in-depth feature to cope with an unlikely scenario of a primary system malfunction (CCF or multiple independent failures). It was reported that the DCD contains adequate control logic design information for the staff to make a reasonable safety assurance finding. Information described in the DCD will be used to develop logic diagrams. Logic diagrams are produced and used during the I&C development life-cycle process. Logic diagrams are finalized during the hardware/software design specification phase of the I&C system development lifecycle.

Chapter 6 Engineered Safety Features

GEH Submitted the CONTAIN 2.0 analysis as the design basis calculation for the CRHA analysis. GOTHIC analysis was submitted to demonstrate mixing in MCR. A first principle calculation was submitted as an alternate method of demonstration of passive heat removal In addition, an ITAAC was added to update and validate design basis calculations with as-built building dimensions, thermal properties, and exposed surface areas, heat loads, and environmental assumptions. Staff reviewed CONTAIN 2.0 analysis of CRHA and RB, CRHA GOTHIC analysis results, applicant's first principles calculation and performed confirmatory calculations.

The staff determined that CONTAIN model has some conservative assumptions. GOTHIC demonstrates convective mixing is expected. Highest averaged temperature in the occupied zone observed in GOTHIC model. Staff's sensitivity studies approached CONTAIN result when most inputs were matched. The small differences between the 3 different model's temperature results are small and considered inconsequential. Agreement in model results support use of CONTAIN. CONTAIN Methodology made Tier 2*. ITAAC added for verification of heat stress conditions using site specific environmental data and as built heat sink information. Staff concludes that supplemental analyses support the use of CONTAIN for demonstration of performance of CRHA passive cooling features for the ESBWR.

The staff discussed heat up profiles for three models; GEH CONTAIN 2.0, NRC GOTHIC, and NRC First Principles Model (FPM). Additionally, details of the Tech Spec Surveillance on Control Room Habitability Area (CRHA) heat sink temperatures and how assumptions used in the Reactor Building heat up calculation are assured. Staff conclusion is that there is no benefit to reconcile models further. Studies support use of CONTAIN. GEH's initial conditions are appropriately conservative. Staff noted that differences in model results are small.

The minimum average dry bulb temperature for 0% exceedance minimum temperature day and maximum high humidity average wet bulb globe temperature index for 0% exceedance maximum wet bulb temperature day were also discussed. Staff reviewed the need for a reactor building heat sink temperature LCO similar to control building heat sink temperature LCO 3.7.2, "CRHAVS."

SUBCOMMITTEE FOLLOW-UP ACTIONS/SIGNIFICANT ISSUES/COMMENTS

See attached (none).

BACKGROUND MATERIALS PROVIDED TO THE SUBCOMMITTEE PRIOR TO THIS MEETING:

1. Memoranda from David Matthews, transmitting “Final Safety Evaluation Reports Chapters 1 – 22,” (ML102850502 package)

2. Letter to U.S. Nuclear Regulatory Commission, transmitting “Transmittal of ESBWR DCD Markups to Tier 1 and Chapter 2, 3, and 19 Related to GEH Internal Corrective Actions and Discussions with the NRC,” (ML102730795) 09/24/2010.

3. Letter to U.S. Nuclear Regulatory Commission, transmitting “ESBWR Design Control Document, Tier 2 Chapter 7 and Tier 1 Changes to Respond to ACRS Remarks,” (ML102700297) 09/23/2010.

4. Letter to U.S. Nuclear Regulatory Commission, transmitting “ESBWR Design Control Document, Revision 7, Tier 1 and Tier 2,” (ML1013401430 and ML101340380) 03/29/2010.

5. Letter to R.W. Borchardt, transmitting “Interim Letter 6: Chapters 7 and 14 of the NRC Staff’s Safety Evaluation Report with Open Items Related to the Certification of the ESBWR Design,” (ML083460306) 12/22/2008.

6. Letter to R.W. Borchardt, transmitting “Interim Letter 4: Chapter 3 of the NRC Staff’s Safety Evaluation Report with Open Items Related to the Certification of the ESBWR Design,” (ML081930777) 07/21/2008.

7. Letter to R.W. Borchardt, transmitting “Interim Letter 3: Chapters 4, 6, 15, 18, and 21 of the NRC Staff’s Safety Evaluation Report with Open Items Related to the Certification of the ESBWR Design,” (ML081330447) 05/23/2008.

8. Letter to Dale E. Klein, transmitting “Digital Instrumentation and Control System Interim Staff Guidance,” (ML081050636) 04/29/2008.

1. Meeting Agenda
2. Sign-In Sheets
3. Follow-up items
4. Presentation Materials
5. Consultant Report

ACRS Meeting of the Subcommittee on ESBWR
Rockville, MD
Thursday, September 23, 2010

Cognizant Staff Engineer: Christopher L. Brown (301)-415-7111, Christopher.Brown@nrc.gov

Item	Topic	Presenter(s)	Time
1	Opening Remarks and Objectives	**Dr. Michael L. Corradini, ACRS**	8:30 – 8:35 a.m.
2	Staff Opening Remarks	**Amy Cubbage, NRO**	8:35 – 8:40 a.m.
3	**Chapter 3** - Design of Structures Components Equipment Section 3.9 RAIs	GEH – Jerry Deaver, Sujit Niogi, Wayne Marquino (Phone support: Dave Hamon, Taylor Blake, Tom Walker, Antonio Barrett)	8:40 – 9:10 a.m.
4	**Chapter 3** Section 3.9 RAIs	NRO – David Misenhimer (PM), Yuken Wong, Tuan Le	9:10 – 9:40 a.m.
5	**Chapter 3** Section 3.8 RAIs	GEH – Jerry Deaver, Sujit Niogi, Wayne Marquino (Phone support: Dave Hamon, Taylor Blake, Tom Walker, Antonio Barrett)	9:40 – 10:15 a.m.
	Break		10:15 – 10:30 a. m.
6	**Chapter 3** Section 3.8 RAIs	NRO – David Misenhimer (PM) Samir Chakrabarti	10:30 a.m. – 11:00 p.m.
7	**Chapter 3** Section 3.12 RAIs	GEH – Jerry Deaver, Sujit Niogi, Wayne Marquino (Phone support: Dave Hamon, Taylor Blake, Tom Walker, Antonio Barrett)	11:00 – 11:30 a.m.
8	**Chapter 3** Section 3.12 RAIs	NRO – David Misenhimer (PM), Kaihwa Hsu	11:30 – 12:00 a.m.
	Lunch		12:00 – 1:00 p.m.
9	**Chapter 4** Reactor	NRO – Bruce Bavol (PM), Jim Gilmer	1:00 – 1:30 p.m.
10	**Chapter 9** Auxiliary Systems	GEH –Mike Arcaro, Jerry Deaver (Phone support: Mike Arcaro, Dave Davenport, John Gels, John Stryhal)	1:30 – 3:00 p.m.
	Break		3:00 p.m. – 3:15 p.m.
11	**Chapter 9** Auxiliary Systems	NRO –Dennis Galvin (PM), Larry Wheeler, David Shum, James Gilmer, John Segala, Samuel Lee	3:15 – 4:45 p.m.
12	Committee Discussion	**Dr. Corradini, ACRS**	4:45 p.m.
	Adjourn		5:00 p.m.

ACRS Notes:

- During the meeting, 301-415-7360 should be used to contact anyone in the ACRS Office.
- Presentation time should not exceed 50 percent of the total time allocated for a given item. The remaining 50 percent of the time is reserved for discussion.
- Thirty five (35) hard copies (2 B&W slides per page) of each presentation or handout should be provided to the Designated Federal Official 30 minutes before the meeting.
- 10 full page colored copies for the ACRS members and the court reporter.

- One (1) electronic copy of each presentation should be emailed to the Designated Federal Official 1 day before the meeting. If an electronic copy cannot be provided within this timeframe, presenters should provide the Designated Federal Official with a CD containing each presentation at least 30 minutes before the meeting.

ACRS Meeting of the Subcommittee on ESBWR
Rockville, MD
Friday, September 24, 2010

Item	Topic	Presenter(s)	Time
1	Opening Remarks and Objectives	**Dr. Michael L. Corradini, ACRS**	8:30 – 8:35 a.m.
2	Staff Opening Remarks	**Amy Cubbage, NRO**	8:35 – 8:40 a.m.
3	**Chapter 7** Instrumentation and Control Systems	GEH – Skip Butler, Peter Yandow, Ira Poppel (Phone support: Romeo El Daccache, Ron Swetnam, Paul Primavera)	8:40 – 10:45 a.m.
	Break		10:45 - 11:00 a. m.
4	**Chapter 7** Instrumentation and Control Systems	GEH – Skip Butler, Peter Yandow, Ira Poppel (Phone support: Romeo El Daccache, Ron Swetnam, Paul Primavera)	11:00 – 12:00 p.m.
	Lunch		12:00 – 1:00 p.m.
5	**Chapter 7** Instrumentation and Control Systems	NRO –Dennis Galvin (PM), Hulbert Li, Joe Ashcraft, Dinesh Taneja, Ian Jung	1:00 – 2:00 p.m.
6	**Chapter 6** Engineered Safety Features (Section 6.4) & Chapter 9 (Section 9.4)	GEH – Mike Arcaro, Wayne Marquino (Phone Support: Mike Sulva, Antonio Barrett, Jesus Diaz-Quiroz, MD Alamgir)	2:00 – 3:30 p.m.
	Break		3:30 – 3:45 p.m.
7	**Chapter 6** Engineered Safety Features (Section 6.4) & Chapter 9 (Section 9.4)	NRO –Dennis Galvin (PM), Jim O'Driscoll, Brad Harvey, Craig Harbuck, John McKirgan	3:45 – 5:15 p.m.
8	Committee Discussion	**Dr. Corradini, ACRS**	5:15 – 5:30 p.m.
	Adjourn		5:30 p.m.

ACRS Notes:

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CONSULTANT'S REPORT. ESBWR SUBCOMMITTEE MEETING, ROCKVILLE, MD. OCTOBER 20-22, 2009

Graham Wallis October 26, 2009

I attended this meeting and heard presentations by GEH and the staff. Previously I had reviewed the responses to most of the RAIs that formed the basis for the presentations.

1. ***Seismic design of PCCS and ICS RH.***

The main issue concerned the modeling of the water in the RH pools and its interaction with the RH structures.

For the overall "stick" model, the water is treated as fixed to the walls of the tanks for the impulsive loads, which probably dominate. This appears to be a standard approach and is reasonable. There was some confusion about whether the mass of the metal structure of the heat exchanger was included. It was stated on some slides that it was ignored, while verbally it was claimed that it was included. Since this mass is about 1/10 of the water mass it probably has a small effect. If it were important, the analysis could get quite complicated. The mass is attached to the floor, but sways relative to it, so the acceleration force has to be computed from the motion of the metal, which is not the same as the motion of the floor or of the walls. In addition, the "added mass" effects create a reaction on the walls due to the motion of the metal structure relative to the water in the pool. These effects could be included in a more complete "stick" model.

For the analysis of the motion of the internal structures, and the resulting stresses, the model appears to add an amount of "added mass", equal to the mass of displaced water volume, to the cylinders in the heat exchanger and its headers. There are three problems with this approach.

The *first* involves the concept itself. The added mass is not stuck to the tubes, but is a reaction from the fluid due to the relative acceleration between the structure and the water surrounding it. If the water and the tubes move together there is no relative motion and no added mass effect. The effect should be treated as an interaction force proportional to relative acceleration, not a force proportional to the acceleration of the structure itself, as appears to be the case in the GEH model. A large added mass does not make the structure more reluctant to move, because of added inertia, but drags it along with the water. So the whole structure moves together with the floor and stresses due to bending are reduced.

The *second* involves the effect of the tube arrangement and pitch on the added mass. For a single cylinder in a large volume of water the added mass for motion perpendicular to the axis is indeed equal to the mass of water displaced. When several cylinders side-by-side move perpendicular to the line through their centers the added mass is increased. (If there are many of them and they touch, the added mass is huge). If the cylinders are in line with the direction of motion, the slipstream effects reduce the added mass. For an array, the effective added mass can be calculated as the sum of the effects of all the tubes on each other. I have several papers on this subject, particularly for the case of spheres in an array. Rather than working out the full solution it may be sufficient for GEH to run sensitivity studies on the effect of using different added mass coefficients. Looking at the fairly open array, I would estimate that a factor of two up and down would suffice. If this brings the predicted stresses significantly closer to the allowable limit, or over it, more complete analysis might be justified.

The *third* effect is the influence of walls. If a cylinder is moved towards a nearby wall, the fluid that would be set in motion towards the wall cannot penetrate the wall. It is diverted sideways, eventually flowing along the floor and ceiling, and creates a pressure on the wall. The total kinetic energy of the fluid due to the motion of the cylinder is increased by the motion of the "external inertia" and so is the added mass. In the case of a wide array moving toward a wall, the displacement of fluid by the cylinders causes the fluid to flow back through the array, driven by a pressure gradient that acts on the cylinders as part of the "added mass effect". This pressure gradient also creates a force on the container walls. The added mass in a closed container can be many times what it is in a large volume of fluid. The details of the motion can get quite complicated. I suspect that this may be a larger effect in the present situation than the effect of the array mentioned above as the *second* effect. It should act to make the structure move in phase with the water and may reduce the stresses due to bending. Again, sensitivity studies could help to resolve this issue.

GEH also discussed a "sloshing" mode that has a frequency an order of magnitude less than the inertial mode. The water sloshes to and fro like water in a bathtub, the restoring force being gravity rather than reaction from the walls and attachments. The added mass also has an effect that influences the coupling between the motion of the water and the motion of the structure, but if the amplitude of the motion is large enough, drag forces may have a larger impact. It appeared at the presentation that GEH had not computed effects on the structure, in response to Dr. Armijo's question. I do not understand the statement on one of the GEH slides: "since dynamic loads are combined by SRSS (not phase coherent), any stress increase from sloshing becomes negligible". The proper response should be to compute the force on the structure due to the relative motion of the water and show what stresses result. I would expect them to be small, as the perturbed pressures set up in the water are of order 1psi. GEH's "Sloshing force" in their slide is actually a pressure. No forces were reported.

I have not seen the details of the sloshing analysis. The pressure on the wall at the surface is said to be 1.39psi, corresponding to lifting the edge of the surface by almost three feet. We were told that the ceiling is close to the surface, so probably this motion is constrained by the proximity of that solid surface. If the water filled the tank completely up to the ceiling, there would be no sloshing at all.

Recommendations

a. Develop a more realistic treatment of added mass effects, including sensitivity studies. I suspect that this will reduce the stresses on the structure, but there could be surprises.

b. Make a quantitative estimate of forces on the structure due to sloshing. Clear up the influence of the proximity of the ceiling.

2. *Pipe break hazard analysis.*

GEH presented the results of FLUENT computations that were benchmarked against experimental results for an impinging jet with subsonic speeds of Mach 0.5 and 0.9. The pulsation frequency was successfully predicted for the Mach 0.9 case.

While these comparisons are interesting, they would seem to have little to do with the actual problem, in which an underexpanded jet achieves a Mach number of about 4 and suffers a large shock wave on its way to the surface.

GEH also presented a 2-D model of the actual ESBWR case. A shock is predicted, but it seems to be too far from the wall. Several other details of the flow are odd (for example, the appearance of a Mach 3 bubble for fluid that has already has its stagnation pressure reduced by a factor of seven or so by the shock. There are also strange effects near corners, which may be due to the modeling by a 2-D slice that does not let the flow escape sideways).

The Committee raised questions about the ability of FLUENT to model this situation. I do know of FLUENT solutions to combustion problems that appear quite realistic at relatively low supersonic Mach numbers. They show the usual shock diamond pattern. To validate the approach GEH should find examples of successful predictions at higher Mach numbers in restricted spaces. Some CFD models of the Marviken experiments may be useful.

It appears that GEH's development of an adequate analysis is at a preliminary stage. They plan 3-D modeling, which is appropriate. 2-D modeling of a slice is far from reality. Arguing that it is conservative is not sufficient, because the phenomena may be qualitatively different for the 3-D problem, perhaps producing fluctuating pressures or unsteady jet motion, for example, when the 2-D method does not. The final model should include impact at an angle and realistic boundary conditions around the computational zone. Since a jet producing Mach 4 suffers a very strong shock that reduces the centerline pressure on the impact surface (but not the overall force, due to momentum change), there may be larger local pressures created at lower Mach numbers, later in the transient.

Recommendations

a. Prepare a more complete and realistic analysis.

b. Search for experimental validation under similar conditions.

GEH also performed a blast wave analysis for a steam line break inside the shield wall. The method used a 2-D slice, which is far from the actual case and is likely to overestimate the forces by order(s) of magnitude. A realistic analysis would be preferable. Otherwise the approach appears acceptable.

3. Steam Dryer Methods

GEH solves the Helmholtz equation to obtain the acoustic response in the dryer from which the loads on the structure are derived. The acoustics are driven by inputs from the four steam lines, which can be determined from transducer measurements on the walls.

This method has been developed from extensive modeling efforts based on behavior of the Quad Cities and Dresden dryers. I have not studied the details of the analysis. The NRC consultants gave quite a convincing presentation in support of the approach, which appears to be the best available. I doubt if it can be improved upon at this stage. I understand that the dryer and steam line will be instrumented and readings will be used to diagnose the response of the system as it is brought up to power.

The staff's evaluation is reasonable.

4. ***Non-condensable gas in GDCS line***

The issue appears to have been overblown. The only way that noncondensables can accumulate in the line is if the block valve near the GDCS tank is closed and they are trapped between it and the squib valve. If this line is full of water when the valves are closed, there will be no room for gas to form, but some might come out of solution when the squib valve opened, if they had been stored at an elevated pressure. The gases would have to have been left behind in some erroneous maintenance operation. The staff needs to evaluate if such a scenario needs consideration, and if there is a possibility of common cause human error repeating the mistake in all of the drain lines.

GE performed several analyses using extreme and probably impossible starting conditions. For instance, they considered the line to be full of noncondensables after a LOCA and then ran TRACG to show that they would vent to the GDCS pool in about 70 seconds before the squib valve was opened. In this case the noncondensables would have vented to the GDCS pool long before the event initiated and would not be there. The lines are designed to promote venting in the desired directions. With the squib valve closed, the condition would be that there was no net flux in the line and the volumetric countercurrent flow of gas towards the GDCS tank would be the same as the volumetric flow of liquid out of it. Countercurrent flow would be limited by CCFL. This is the assumption made by GEH.

The truly worst case, which is hard to imagine ever being set up, would be for the block valve at the GDCS tank to be closed, with noncondensables trapped beneath it, and then opened later, after the squib valves had fired. Depending on how the gas came to be there (during maintenance) its pressure could be above or below the water pressure, so it might expand when released. To open the valve the operators would have to enter containment and this would take time. By the time the valve was opened, the RPV would have depressurized so much that the gases would probably be swept out by the large velocity of the water.

If the block valve could be operated from the control room, which would require redesign and is unlikely as it introduces the possibility of inadvertent closure, then it would have to be calculated if the gases would flow towards or away from the RPV initially. The reduced hydrostatic head due to the gases might make the liquid velocity inadequate to move them towards the RPV and they would start to vent to the GDCS tank. This would increase the hydrostatic driving head and the flow would eventually reverse. This would also be encouraged by the rapid depressurization of the RPV. Gases would be swept out increasingly rapidly as their contribution to the buoyancy in the line opposing their motion decreased. This is the "worst scenario" that could be analyzed if the staff insisted upon it.

GEH also showed that adequate cooling could be performed with a much reduced total GDCS flow and that there was considerable time available before any overheating would occur even in the most extreme case.

Recommendation

Forget the matter. There is no problem unless the block valves are left closed and even then there would have to be some major error for the maintenance crew to leave gas in the line. Having the block valves closed causes a major problem in preventing GDCS flow which overwhelms any consideration of the perturbations in the resulting scenario that any gas might cause.

5 GDCS Check Valve

We have learned that details in the design can have important effects. It was therefore useful to hear about this valve and the standards and tests that apply to it. I have no further comments.

6 TRACE confirmatory calculations of an AOO

It was good to see TRACE/PARCS being used. The results resemble the TRACG predictions, with some deviations. Particularly, the temperature at the core inlet is different by several degrees.

The staff commented that they decide whether or not such calculations "confirm" by how they feel about the comparisons. This was an unfortunate statement. Feelings should have nothing to do with regulatory decisions. What matters is how much the deviations may influence decision criteria or other important safety parameters.

The next day, Joe Staudenmeier showed us predictions of MCPR using the TRACE outputs in the Biasi correlation. This rapid response by the staff to our request was impressive. The agreement with GEH's GEXL was quite good. Over part of the time the two TRACE values, computed using different assumptions about chimney voids, bracketed the GEXL values. The minimum Biasi MCPR was about 1.17 compared with GEH's value of 1.24. This may not be cause for concern, though a difference of about twice that much might be. It would be useful for the staff to develop some rationale about how large a deviation is considered to be important. Is there some criterion about how low the MCPR is allowed to be during an AOO?

7 GE14E core design

The staff concluded that the initial core design has substantial cold shutdown margin.

The maximum enthalpy rise of 10 cal/gm in a control rod drop accident is remarkably low and far from the criterion of 150 cal/gm. I have no further comment.

8 GE14E CPR correlation

We had long discussions about this rather arcane field in previous meetings. I do not have the expertise to comment.

9 FW Temperature operating domain

This was an enlightening presentation. Varying the FW temperature provides more flexibility during maneuvering and helps protect the fuel. Explanations and responses to questions helped to develop confidence in the approach. The reasoning behind the choice of domains, valve block and scram limits appeared reasonable and justified.

The staff explained their acceptance of the method on the basis of quantitative changes in CPR following events starting from various points on the operating diagram. These have similar margin to the regulatory criteria. Stability may be challenged at the SP1 limit, so SP1M is chosen as the lowest feedwater temperature allowed at full power in order to stay away from inducing instability. Since the stability boundary is somewhat dependent on the fuel loading and time in cycle, backup is provided by oscillation detection systems.

The staff's decision to accept the approach appears reasonable.

10 Chimney stability etc

Jose March-Leuba discussed several items about which the ACRS had previously asked questions.

Nodalization in the chimney was varied to the point where the Courant Number was close to one. This improved the authenticity of the void response, but had no significant effect on stability.

Chimney entrance effects were evaluated by referring to the Dodewaard experience and to a paper by Dubrovskii. It was concluded that inlet effects are over after about a meter of height in the chimney and they have little effect on the overall buoyancy force.

There may still be some issues about these effects. The Dodewaard experience seems, from the RAI response, to include void fractions up to 0.5, whereas those in the ESBWR may range from 0.7 to 0.85 across the core outlet. The Dubrowskii tests also were restricted to void fractions below 0.5. The steam velocities in those tests were limited to 1m/s and the water velocities to 0.39 m/s. In the ESBWR the comparable values are over 3m/s for steam and over 1m/s for the water (according to my recollection from the meeting. There may be some mistake, as the relative velocity seems too high for the churn-turbulent regime. It would be worthwhile to check). Therefore the flow regime in the ESBWR could differ from those in the cited experience.

Regarding flow regime, one might expect void fractions greater that 0.8 to lead to the annular regime, for which entrance effects are known to be much larger than in the bubbly or churn-turbulent regimes. GEH's criterion for annular flow in the chimney was said at the meeting to be a steam velocity exceeding 5m/s. This is based on an ancient and tentative correlation by Wallis, which gives 5.4m/s according to the RAI response and is also to be found in the TRACG code description. (It is a bit odd that GEH uses a Kutateladze Number, involving surface tension, for its CCFL correlation but uses the parameters j_f^* and j_g^*, which only involve inertia and gravitational effects, for both the transition to annular flow and the prediction of void fraction in annular flow via Ishii's approach, which I think is designed to be compatible with a CCFL correlation based on j_f^* and j_g^*. One would expect the CCFL correlation to be compatible with the annular flow methods, since it is presumably the prevention of liquid downflow in a film that leads to upwards cocurrent flow). In the Ontario Hydro tests, transition to annular flow was reported at a vapor velocity of 5.5m/s at a void fraction of 0.7; this probably provides more secure confirmation of the flow regime.

The quoted *residence time in the chimney* of 10 seconds appears too long. What is important for stability considerations is the void fraction residence time and it is comparable with the residence time of the vapor. With a velocity of over 3m/s (correct?) the vapor residence time in the chimney is between 2 and 3 seconds. This is perhaps not far enough away from the frequency of neutronic/void fraction oscillations in the core at around 1Hz for the chimney response to be neglected. However, analysis of the entire loop does show that the core response dominates.

Perturbations introduced into the chimney did not lead to amplification and instability, according to the code.

The ACRS previously raised questions about the *GENESIS tests* of a natural circulation loop designed to copy the ESBWR. Loop oscillations did occur in that facility, which was electrically heated. TRACG was used to duplicate those results successfully. The oscillations disappear when the electrical heating is replaced by neutronic heating with void feedback. This resolves the issue.

Jose reviewed RAI responses showing that instability would not occur *after an ATWS* but that small oscillations might occur after a turbine trip and they are attenuated flowing FW runback. These meet SAFDL criteria.

11 I & C

This is not my field. Like John Stetkar I have some uneasiness about accepting a design at a high level. We have learned over several years of reviewing thermal/hydraulic phenomena in the ESBWR that the details of the final design matter. Perhaps I and C design is different. However, lacking details at this stage imposes considerable burden on the staff to perform an in depth review at the ITAAC stage, beyond what would normally be accomplished by inspection.