## ArevaEPRDCPEm Resource

**From:** WELLS Russell (AREVA) [Russell.Wells@areva.com]
**Sent:** Wednesday, March 30, 2011 6:20 PM
**To:** Tesfaye, Getachew
**Cc:** CORNELL Veronica (EXTERNAL AREVA); BREDEL Daniel (AREVA); COLEMAN Sue (AREVA); BENNETT Kathy (AREVA); DELANO Karen (AREVA); HALLINGER Pat (EXTERNAL AREVA); ROMINE Judy (AREVA); RYAN Tom (AREVA); WILLIFORD Dennis (AREVA)
**Subject:** Draft Revised Response to U.S. EPR Design Certification Application RAI No. 412, FSAR Ch. 3, Question 03.07.02-74
**Attachments:** RAI 412 Question 03.07.02-74 Response US EPR DC - DRAFT.pdf

Getachew,

Attached is a revised draft response for RAI No. 412, FSAR Ch 3, Question 03.07.02-74 in advance of the May 12, 2011 final response date.

Let me know if the staff has questions or if the draft response can be sent as a final response.

*Sincerely,*

*Russ Wells*
*U.S. EPR Design Certification Licensing Manager*
***AREVA NP, Inc.***
*3315 Old Forest Road, P.O. Box 10935*
*Mail Stop OF-57*
*Lynchburg, VA 24506-0935*
*Phone: 434-832-3884 (work)*
*434-942-6375 (cell)*
*Fax: 434-382-3884*
*Russell.Wells@Areva.com*

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**From:** WELLS Russell (RS/NB)
**Sent:** Tuesday, March 22, 2011 5:35 PM
**To:** 'Tesfaye, Getachew'
**Cc:** CORNELL Veronica (External RS/NB); BENNETT Kathy (RS/NB); DELANO Karen (RS/NB); ROMINE Judy (RS/NB); RYAN Tom (RS/NB)
**Subject:** Response to U.S. EPR Design Certification Application RAI No. 412, FSAR Ch. 3, Supplement 6

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 412 on June 24, 2010. On August 27, 2010, AREVA NP submitted Supplement 1 to provide an INTERIM response to Question 03.07.02-73. AREVA NP submitted a revised schedule for Question 03.07.02-74 in Supplement 2 and Supplement 3 on September 15, 2010, and November 15, 2010, respectively. On January 27, 2011, AREVA NP submitted Supplement 4 to provide a revised schedule for Question 03.07.02-74. On February 11, 2011, AREVA NP submitted Supplement 5 to provide a revised schedule for Question 03.07.02-73.

The schedule for Question 03.07.02-74 is being revised to allow AREVA NP additional time to address NRC comments. The schedule for the remaining question is unchanged.

The schedule for a technically correct and complete response to the remaining questions is provided below.

| Question # | Interim Response Date | Response Date |
|---|---|---|
| RAI 412 — 03.07.02-73 | August 29, 2010 (Actual) | May 12, 2011 |
| RAI 412 — 03.07.02-74 | N/A | May 12, 2011 |

*Sincerely,*

*Russ Wells*
*U.S. EPR Design Certification Licensing Manager*
***AREVA NP, Inc.***
*3315 Old Forest Road, P.O. Box 10935*
*Mail Stop OF-57*
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*Phone: 434-832-3884 (work)*
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**From:** BRYAN Martin (External RS/NB)
**Sent:** Friday, February 11, 2011 3:06 PM
**To:** 'Tesfaye, Getachew'
**Cc:** DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
**Subject:** Response to U.S. EPR Design Certification Application RAI No. 412, FSAR Ch. 3, Supplement 5

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 412 on June 24, 2010. On August 27, 2010, AREVA NP submitted Supplement 1 to provide an INTERIM response to Question 03.07.02-73. AREVA NP submitted a revised schedule for Question 03.07.02-74 in Supplement 2 and Supplement 3 on September 15, 2010, and November 15, 2010, respectively. On January 27, 2011, AREVA NP submitted Supplement 4 to provide a revised schedule for Question 03.07.02-74.

The schedule for Question 03.07.02-73 has changed. The schedule for the remaining question is unchanged.

The schedule for a technically correct and complete response to the remaining questions is provided below.

| Question # | Interim Response Date | Response Date |
|---|---|---|
| RAI 412 — 03.07.02-73 | August 29, 2010 (Actual) | May 12, 2011 |
| RAI 412 — 03.07.02-74 | N/A | March 23, 2011 |

Sincerely,

Martin (Marty) C. Bryan
U.S. EPR Design Certification Licensing Manager
AREVA NP Inc.
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Martin.Bryan.ext@areva.com

**From:** BRYAN Martin (External RS/NB)
**Sent:** Thursday, January 27, 2011 11:47 AM
**To:** 'Tesfaye, Getachew'
**Cc:** DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
**Subject:** Response to U.S. EPR Design Certification Application RAI No. 412, FSAR Ch. 3, Supplement 4

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 412 on June 24, 2010. On August 27, 2010, AREVA NP submitted Supplement 1 to provide an INTERIM response to Question 03.07.02-73. AREVA NP submitted a revised schedule for Question 03.07.02-74 in Supplement 2 and Supplement 3 on September 15, 2010, and November 15, 2010, respectively.

The schedule for Question 03.07.02-74 is being revised to allow additional time for AREVA NP to address NRC comments. The schedule for the remaining question is unchanged.

The schedule for a technically correct and complete response to the remaining questions is provided below.

| Question # | Interim Response Date | Response Date |
|---|---|---|
| RAI 412 — 03.07.02-73 | August 29, 2010 (Actual) | February 17, 2011 |
| RAI 412 — 03.07.02-74 | N/A | March 23, 2011 |

Sincerely,

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U.S. EPR Design Certification Licensing Manager
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**From:** BRYAN Martin (External RS/NB)
**Sent:** Monday, November 15, 2010 4:45 PM
**To:** 'Tesfaye, Getachew'
**Cc:** DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB); 'Miernicki, Michael'
**Subject:** Response to U.S. EPR Design Certification Application RAI No. 412, FSAR Ch. 3, Supplement 3

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 412 on June 24, 2010. On August 27, 2010, AREVA NP submitted Supplement 1 to provide an INTERIM response to Question 03.07.02-73. AREVA NP submitted a revised schedule for Question 03.07.02-74 in Supplement 2 on September 15, 2010.

The schedule for Question 03.07.02-74 is being revised to allow additional time for AREVA NP to address NRC comments. The schedule for the remaining question is unchanged.

The schedule for a technically correct and complete response to the remaining questions is provided below.

| Question # | Interim Response Date | Response Date |
|---|---|---|
| RAI 412 — 03.07.02-73 | August 29, 2010 (Actual) | February 17, 2011 |
| RAI 412 — 03.07.02-74 | N/A | January 28, 2011 |

Sincerely,

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**From:** BRYAN Martin (External RS/NB)
**Sent:** Wednesday, September 15, 2010 9:42 AM
**To:** 'Tesfaye, Getachew'
**Cc:** DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
**Subject:** Response to U.S. EPR Design Certification Application RAI No. 412, FSAR Ch. 3, Supplement 2

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 412 on June 24, 2010. On August 27, 2010, AREVA NP submitted Supplement 1 to provide an INTERIM response to Question 03.07.02-73.

The schedule for Question 03.07.02-74 is being revised to allow additional time for AREVA NP to interact with the NRC. The schedule for the remaining question is unchanged.

The schedule for a technically correct and complete response to the remaining questions is provided below.

| Question # | Interim Response Date | Response Date |
|---|---|---|
| RAI 412 — 03.07.02-73 | August 29, 2010 (Actual) | February 17, 2011 |
| RAI 412 — 03.07.02-74 | N/A | December 13, 2010 |

Sincerely,

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**From:** BRYAN Martin (External RS/NB)
**Sent:** Friday, August 27, 2010 5:13 PM
**To:** 'Tesfaye, Getachew'
**Cc:** DELANO Karen (RS/NB); ROMINE Judy (RS/NB); BENNETT Kathy (RS/NB); CORNELL Veronica (External RS/NB)
**Subject:** Response to U.S. EPR Design Certification Application RAI No. 412, FSAR Ch. 3, Supplement 1-INTERIM

Getachew,

AREVA NP Inc. (AREVA NP) provided a schedule for a technically correct and complete response to RAI 412 on June 24, 2010.

The attached file, "RAI 412 Supplement 1 Response US EPR DC - INTERIM.pdf" provides a technically correct and complete INTERIM response to 1 of the remaining 2 questions, as committed.

The following table indicates the respective pages in the response document, "RAI 412 Supplement 1 Response US EPR DC- INTERIM.pdf," that contain AREVA NP's response to the subject questions.

| Question # | Start Page | End Page |
|---|---|---|
| RAI 412 — 03.07.02-73 | 2 | 2 |

The schedule for a technically correct and complete response to the remaining questions is provided below.

| Question # | Interim Response Date | Response Date |
|---|---|---|
| RAI 412 — 03.07.02-73 | August 29, 2010 (Actual- August 27, 2010) | February 17, 2011 |
| RAI 412 — 03.07.02-74 | N/A | September 20, 2010 |

Sincerely,

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**From:** BRYAN Martin (EXT)
**Sent:** Thursday, June 24, 2010 2:00 PM
**To:** 'Tesfaye, Getachew'
**Cc:** DELANO Karen V (AREVA NP INC); ROMINE Judy (AREVA NP INC); BENNETT Kathy A (OFR) (AREVA NP INC); VAN NOY Mark (EXT); CORNELL Veronica (EXT); RYAN Tom (AREVA NP INC); GARDNER George Darrell (AREVA NP INC)
**Subject:** Response to U.S. EPR Design Certification Application RAI No. 412, FSAR Ch. 3

Getachew,

Attached please find AREVA NP Inc.'s response to the subject request for additional information (RAI). The attached file, "RAI 412 Response US EPR DC.pdf" provides a schedule since a technically correct and complete response to the 2 questions is not provided.

The following table indicates the respective pages in the response document, "RAI 412 Response US EPR DC.pdf" that contain AREVA NP's response to the subject questions.

| Question # | Start Page | End Page |
|---|---|---|
| RAI 412 — 03.07.02-73 | 2 | 2 |
| RAI 412 — 03.07.02-74 | 3 | 3 |

A complete answer is not provided for 2 of the 2 questions. The dates provide are based upon the civil/structural re-planning activities and revised RAI response schedule presented to the NRC during the June 9, 2010, Public Meeting, and to allow time to interact with the NRC on the responses.

Prior to submittal of the final RAI response, AREVA NP will provide an interim RAI response that includes:

(1) a description of the technical work (e.g., methodology)
(2) U.S. EPR FSAR revised pages, as applicable

The schedule for a technically correct and complete response to these questions is provided below.

| Question # | Interim Response Date | Response Date |
|---|---|---|
| RAI 412 — 03.07.02-73 | August 29, 2010 | February 17, 2011 |
| RAI 412 — 03.07.02-74 | N/A | September 20, 2010 |

Sincerely,

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**From:** Tesfaye, Getachew [mailto:Getachew.Tesfaye@nrc.gov]
**Sent:** Friday, May 28, 2010 8:11 AM
**To:** ZZ-DL-A-USEPR-DL
**Cc:** Chakravorty, Manas; Hawkins, Kimberly; Miernicki, Michael; Patel, Jay; Colaccino, Joseph; ArevaEPRDCPEm Resource
**Subject:** U.S. EPR Design Certification Application RAI No. 412(4744), FSAR Ch. 3

Attached please find the subject requests for additional information (RAI). A draft of the RAI was provided to you on May 25, 2010, and on May 27, 2010, you informed us that the RAI is clear and no further clarification is needed. As a result, no change is made to the draft RAI. The schedule we have established for review of your application assumes technically correct and complete responses within 30 days of receipt of RAIs. For any RAIs that cannot be answered within 30 days, it is expected that a date for receipt of this information will be provided to the staff within the 30 day period so that the staff can assess how this information will impact the published schedule.

Thanks,
Getachew Tesfaye
Sr. Project Manager
NRO/DNRL/NARP
(301) 415-3361

**Hearing Identifier:** AREVA_EPR_DC_RAIs
**Email Number:** 2782

**Mail Envelope Properties** (1F1CC1BBDC66B842A46CAC03D6B1CD41042B956E)

**Subject:** Draft Revised Response to U.S. EPR Design Certification Application RAI No. 412, FSAR Ch. 3, Question 03.07.02-74
**Sent Date:** 3/30/2011 6:20:21 PM
**Received Date:** 3/30/2011 6:21:32 PM
**From:** WELLS Russell (AREVA)

**Created By:** Russell.Wells@areva.com

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| **Files** | **Size** | **Date & Time** |
|---|---|---|
| MESSAGE | 12908 | 3/30/2011 6:21:32 PM |
| RAI 412 Question 03.07.02-74 Response US EPR DC - DRAFT.pdf | 598164 | |

**Options**
**Priority:** Standard
**Return Notification:** No
**Reply Requested:** No
**Sensitivity:** Normal
**Expiration Date:**
**Recipients Received:**

**Response to**

**Request for Additional Information No. 412 (4744), Revision 0**
**Question 03.07.02-74, Revision 2**
**5/28/2010**

**U.S. EPR Standard Design Certification**
**AREVA NP Inc.**
**Docket No. 52-020**
**SRP Section: 03.07.02 - Seismic System Analysis**
**Application Section: 03.07.02**

**QUESTIONS for Structural Engineering Branch 2 (ESBWR/ABWR Projects) (SEB2)**

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**Question 03.07.02-74:**

**RAI from Audit 4/26-30, 2010**

As part of the staff review of the SSI analysis of the Nuclear Island (NI) Common Basemat Structure, AREVA was asked to describe how seismic fluid-structure interaction was considered for those structures containing water in the NI (e.g., the IRWST, the spent fuel pool, etc.). AREVA stated that the entire mass of water is treated as a lumped mass which is added to the mass of the structure in which it is contained. In general the staff was satisfied with the method described but to ensure the analysis and design of the NI meets the requirements of GDC 2 for earthquake design and that the loads due to the seismic response of the water have been properly determined, the staff requests that AREVA provide the following information regarding fluid/structure interaction:

1. Describe how the contained water is modeled in the seismic analysis of the NI;
2. If convective loads are ignored, provide the basis for not considered them:
3. Justify the freeboard is sufficient to accommodate sloshing in the IRWST;
4. Provide the basis for water level assumptions when determining the effects of sloshing;
5. If they exist, describe the effect of sloshing loads; and,
6. Evaluate potential overspill in Spent Fuel Pool.

Provide the basis for not considering a seismic hydrodynamic impact load on the bottom of the spent fuel pool, the IRWST, or any other significant pool or tank in the NI, due to the response of the water from an earthquake acting in the vertical direction.

**Response to Question 03.07.02-74:**

1. Hydrodynamic loads are developed using the method provided in TID-7024 (Reference 1), Chapter 6 and Appendix F for the Nuclear Island (NI) pools in Table 03.07.02-74-1 and the Essential Service Water Building (ESWB). Attachment 1 demonstrates the development of hydrodynamic loads, natural frequencies and hydrodynamic forces on the pool walls, and slab for the spent fuel pool (SFP).

   The impulsive effects are affected by the flexibility of the walls and slab, but the convective effects are insensitive to flexibility. For the impulsive load, the natural frequencies of individual pool walls and floors are calculated by considering the impulsive mass effect and the in-structure response spectra (ISRS). Seven percent damping is used to determine the corresponding accelerations. For the convective mode, the natural frequency of sloshing water is determined using TID-7024, Equation 6.8, and the corresponding acceleration is based on 0.5 percent damping. Damping associated with sloshing is approximately 0.5 percent ( see TID-7024, Section 6.6). Damping associated with the impulsive mode is primarily motion of the supporting structure, which is seven percent for the NI reinforced concrete structure. The ISRS at pool wall mid-elevation determines the corresponding accelerations for the entire pool wall.

   Figure 03.07.02-74-1 to Figure 03.07.02-74-3 show the hydrodynamic forces in a pool resulting from a horizontal earthquake, and represented by a combination of:

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- Impulsive ($P_0$) and convective ($P_1$) forces acting on the pool walls.
- Impulsive ($P_{b0}$) and convective ($P_{b1}$) forces acting on the pool slab.

For each pool, the impulsive and convective pressures are calculated for the horizontal (X and Y) direction in 3.28 feet (1 meter) increments (see Table 03.07.02-74-1). The total pressure is obtained by adding the convective pressure to the impulsive pressure at each increment.

The hydrodynamic pressure on the slab and walls resulting from a vertical earthquake are calculated in accordance with ASCE 4-98, Equation 3.5-7, using the fluid mass density multiplied by the vertical zero peak acceleration (ZPA) as a function of water depth below the surface. The vertical ZPA of pool slabs is less than 1 g for the eight soil cases. No water mass impact on the pool slab resulting from vertical seismic excitation is expected.

The design of the NI uses the dynamic model, superstructure static model, and basemat model. In the superstructure static finite element model (FEM), seismic loads are applied statically in six directions (east, west, north, south, up, and down) and the square root of the sum of the squares (SRSS) method is used for combining directional seismic loads as described in the Response to RAI 376, Question 03.08.03-24. In each direction, a set of hydrodynamic pressure loads are simultaneously applied on the walls and slab. As shown in Figure 03.07.02-74-3, when the earthquake moves toward the east, the east wall is pushed outward, the west wall is pulled inward, the east half slab is pushed downward, and the west half slab is pulled upward. The application of hydrodynamic loads accounts for the rotational effects of water motion. For SFP rack loads, see the Response to RAI 335, Question 03.08.04-10.

For U.S. EPR pools, the water does not impact slabs in a vertical earthquake because the vertical ZPAs are less than 1 g. One-hundred percent water mass was used in the slab vertical pressure and wall horizontal pressure calculation (see Attachment 1, Table 03.07.02-74-A13).

The dynamic soil structure interaction (SSI) time history model develops the ZPAs for the static model. In the dynamic model, fluid mass on the pool walls and slab is included based on tributary mass contribution (i.e., 1/2 of water mass added to each wall and total water mass added to the slab). For the SFP, the total fuel/racks assembly mass is added to the slab in addition to the fluid total mass, conservatively neglecting racks occupying volume.

The basemat model develops loads on the basemat. The hydrodynamic mass applied to the basemat model is identical to the mass applied in the dynamic model. Table 03.07.02-74-4 provides the water weight, impulsive weight and force, convective weight and force, total hydrodynamic weight (impulsive plus convective), and other relevant parameters. The ratio between hydrodynamic weight and water weight is approximately equal to one. The water weight applied to the dynamic model is approximately the same as the calculated hydrodynamic weight based on TID-7024, except for surge pools. For the surge pools, the actual water level is less than the dynamic model in Table 03.07.02-74-4. The additional water weight of the surge pools in the dynamic model is approximately 0.07 percent of the total NI weight (concrete plus water), and is negligible.

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There is no water in the reactor pool during operation. The reactor pool has no mass in the dynamic model and no loads in the static model.

U.S. EPR FSAR Tier 2, Sections 3.8.3 and 3.8.4 will be revised to describe the hydrodynamic load analysis methodology.

2. Convective loads are included in the hydrodynamic loads for the static FEM, as described in the Response to Item 1. Figure 03.07.02-74-1 and Figure 03.07.02-74-2 show the total hydrodynamic wall pressure distributions for SFP, including impulsive and convective pressures. The contribution from convective mode to the total hydrodynamic load is negligible for the ESWB pool, SFP and other NI pools, except for smaller or shallow pools such as the surge pool and in-containment refueling water storage tank (IRWST). Table 03.07.02-74-1 shows the wall frequencies and pressures for NI pools.
3. See the Response to Item 4.
4. The freeboard values ($d_0$) are determined using the analyzed water levels in Table 03.07.02-74-3. The maximum water levels in the pools are checked against the analyzed water levels and the difference is negligible as shown in Table 03.07.02-74-3.
5. Sloshing height ($d_{max}$) is calculated in accordance with TID-7024, Equation 6.11, and compared to the available freeboard ($d_0$) for each pool to determine if water spillage in an open pool or ceiling impact in a covered pool occurs. The enveloped 0.5 percent damping ISRS for the entire building floor were previously used to calculate the sloshing height and hydrodynamic wall pressures. These wall pressures are applied to the static model for critical section design. A refined analysis, specific to individual pool walls and slabs, using 0.5 percent damping ISRS, was performed and resulted in smaller accelerations. The refined analysis results, in Table 03.07.02-74-2, show that no spillage in open pools and no ceiling impact in covered pools occur.
6. See the Response to Item 5.
7. See the Response to Item 1.

**FSAR Impact:**

U.S. EPR FSAR Tier 2, Section 3.8.3.4.4 and Section 3.8.4.4.1 will be revised as described in the response and indicated on the enclosed markup.

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**Table 03.07.02-74-1—Wall Frequencies and Hydrodynamic Average Pressures**

| Nuclear Island Pools | Pool Size | | | Hydrodynamic Mode | Wall Frequency (Hz) | | Average Wall Pressure (psf) | |
|---|---|---|---|---|---|---|---|---|
| | Lx (ft) | Ly (ft) | h (ft) | | X | Y | X | Y |
| Spent Fuel Pool (Open) | 51.67 | 29.36 | 45.60 | Impulsive | 33 | 19 | 1255 | 1303 |
| | | | | Convective | 0.22 | 0.3 | 34 | 24 |
| Emergency Feedwater Pool 2 and 3 (Enclosed) | 21.33 | 27.23 | 26.90 | Impulsive | 17 | 21 | 627 | 819 |
| | | | | Convective | 0.35 | 0.31 | 24 | 39 |
| Emergency Feedwater Pool 1 and 4 (Enclosed) | 28.21 | 22.97 | 26.90 | Impulsive | 19 | 16 | 802 | 1021 |
| | | | | Convective | 0.30 | 0.34 | 32 | 36 |
| Surge Pool 2 and 3 (Enclosed) | 8.2 | 11.48 | 10.09 | Impulsive | 58 | 76 | 355 | 344 |
| | | | | Convective | 0.56 | 0.47 | 30 | 54 |
| Surge Pool 1 and 4 (Enclosed) | 10.5 | 13.12 | 6.89 | Impulsive | 130 | 144 | 159 | 171 |
| | | | | Convective | 0.49 | 0.43 | 57 | 79 |
| In-containment Refueling Water Storage Pool (Enclosed) | 35.43 | 82.68 | 12.37 | Impulsive | 30 | 117 | 250 | 250 |
| | | | | Convective | 0.24 | 0.24 | 55 | 55 |
| Reactor Pool (Open) | 23.29 | 76.44 | 41.67 | Impulsive | 25 | 54 | 1098 | 926 |
| | | | | Convective | 0.33 | 0.18 | 18 | 52 |

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**Table 03.07.02-74-2—Sloshing Height Based on Updated Accelerations**

| Nuclear Island Pools | Direction | Convective Acceleration $S_a$ (g) | Sloshing Height $d_{max}$ (ft) | Free-board $d_o$ (ft) | If $d_{max} > d_o$, Overspill or Ceiling Impact? |
|---|---|---|---|---|---|
| Spent Fuel Pool (Open) | X | 0.05 | 1.17 | 1.64 | No Overspill |
| | Y | 0.09 | 1.28 | | |
| Emergency Feedwater Pool 2 and 3 (Enclosed) | X | 0.11 | 1.18 | 1.64 | No Ceiling Impact |
| | Y | 0.09 | 1.19 | | |
| Emergency Feedwater Pool 1 and 4 (Enclosed) | X | 0.09 | 1.23 | 1.64 | No Ceiling Impact |
| | Y | 0.11 | 1.27 | | |
| Surge Pool 2 and 3 (Enclosed) | X | 0.36 | 2.85 | 8.29 | No Ceiling Impact |
| | Y | 0.27 | 2.24 | | |
| Surge Pool 1 and 4 (Enclosed) | X | 0.24 | 1.66 | 3.60 | No Ceiling Impact |
| | Y | 0.21 | 1.66 | | |
| In-containment Refueling Water Storage Pool (Enclosed) | X & Y | 0.05 | 0.79 | 6.17 | No Ceiling Impact |
| Reactor Pool (Open) | X | 0.10 | 1.15 | 1.64 | No Overspill |
| | Y | 0.03 | 1.00 | | |

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**Table 03.07.02-74-3—Normal and Maximum Water Level of Pools**

| Nuclear Island Pools | Analyzed Water Level (ft) | Max. Water Level (ft) | Difference (ft) |
|---|---|---|---|
| Spent Fuel Pool (Open) | 62.34 | 62.66 | 0.33 |
| Reactor Pool (Open) | 62.34 | 62.66 | 0.33 |
| In-containment Refueling Water Storage Pool (Enclosed) | -7.81 | -7.71 | 0.10 |
| Emergency Feedwater Pool 2 and 3 [1] (Enclosed) | 26.90 | 26.90 | 0.00 |
| Emergency Feedwater Pool 1 and 4 [1] (Enclosed) | 26.90 | 26.90 | 0.00 |
| Surge Pool 2 and 3[2] (Enclosed) | 78.97 | 78.97 | 0.00 |
| Surge Pool 1 and 4[2] (Enclosed) | 75.79 | 75.79 | 0.00 |

Notes:

1. For emergency feedwater pools, the maximum water level at overflow pipe elevation was conservatively used to calculate the pool loads.
2. Maximum required surge volume for surge tanks is 925 $ft^3$. The water level analyzed is based on a volume of 950 $ft^3$ (normal and maximum water levels).

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**Table 03.07.02-74-4—Seismic Load Comparisons for Nuclear Island Pools**

| Nuclear Island Pools[1] | W (kips)[2] | Impulsive Mode | | Convective Mode | | $W_0+W_1$ (kips)[7] | $(W_0+W_1)/W$[8] | SASSI Weight/$W_0+W_1$[9] | $W_1/W_0$[10] | $P_1/P_0$[11] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $W_0$ (kips)[3] | $P_0$ (kips)[4] | $W_1$ (kips)[5] | $P_1$ (kips)[6] | | | | | |
| **X-Direction Seismic** | | | | | | | | | | |
| Spent Fuel Pool | 4448 | 3416 | 3416 | 1318 | 92 | 4734 | 1.06 | 0.97 | 0.39 | 0.03 |
| Emergency Feedwater Pool 2&3 | 1005 | 872 | 959 | 210 | 36 | 1081 | 1.08 | 0.99 | 0.24 | 0.04 |
| Emergency Feedwater Pool 1&4 | 1121 | 889 | 1022 | 308 | 40 | 1197 | 1.07 | 0.99 | 0.35 | 0.04 |
| Surge Pool 2&3 | 61 | 53 | 84 | 13 | 7 | 66 | 1.08 | 1.36 | 0.25 | 0.09 |
| Surge Pool 1&4 | 61 | 40 | 28 | 24 | 11 | 64 | 1.05 | 1.46 | 0.59 | 0.38 |
| IRWST | 2330 | 926 | 500 | 1410 | 113 | 2336 | 1.00 | 1.06 | 1.52 | 0.23 |
| Reactor Pool | 4770 | 4429 | 7397 | 702 | 112 | 5132 | 1.08 | 0.00 | 0.16 | 0.02 |
| **Total** | | **10625** | **13406** | **3985** | **411** | **14610** | | | | |
| **Y Direction Seismic** | | | | | | | | | | |
| Spent Fuel Pool | 4448 | 4038 | 6461 | 755 | 113 | 4793 | 1.08 | 0.96 | 0.19 | 0.02 |
| Emergency Feedwater Pool 2&3 | 1005 | 808 | 969 | 267 | 45 | 1075 | 1.07 | 0.99 | 0.33 | 0.05 |
| Emergency Feedwater Pool 1&4 | 1121 | 953 | 1620 | 252 | 55 | 1205 | 1.08 | 0.99 | 0.26 | 0.03 |
| Surge Pool 2&3 | 61 | 47 | 55 | 18 | 9 | 65 | 1.06 | 1.37 | 0.39 | 0.17 |
| Surge Pool 1&4 | 61 | 34 | 24 | 28 | 12 | 63 | 1.03 | 1.48 | 0.83 | 0.49 |
| IRWST | 2330 | 403 | 217 | 1807 | 36 | 2210 | 0.95 | 1.12 | 4.49 | 0.17 |
| Reactor Pool | 4770 | 2762 | 1795 | 2163 | 102 | 4925 | 1.03 | 0.00 | 0.78 | 0.06 |
| **Total** | | **9045** | **11141** | **5290** | **372** | **14336** | | | | |

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Notes:

Column 1 Nuclear Island Pools

Column 2: Actual water weight

Column 3: Impulsive weight, $W_o$ (TID-7024, Eq. 6.1)

Column 4: Impulsive force, $P_o$ (TID-7024, Eq. 6.4)

Column 5: Convective weight, $W_1$ (TID-7024, Eq. 6.5)

Column 6: Convective force, $P_1$ (TID-7024, Eq. 6.8-6.10)

Column 7: Hydrodynamic Weight = Impulsive weight + Convective Weight

Column 8: Static Weight Ratio = Hydrodynamic Weight / Actual Pool Water weight

Column 9: Dynamic Weight Ratio = Weight in SASSI Model/ Hydrodynamic Weight (no water in RP during operation)

Column 10: Convective Mass Ratio = Convective Weight / Impulsive weight

Column 11: Convective Load Ratio = Convective Load / Impulsive Load

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**Figure 03.07.02-74-1—Impulsive and Convective Wall Pressure Distributions in the X direction**

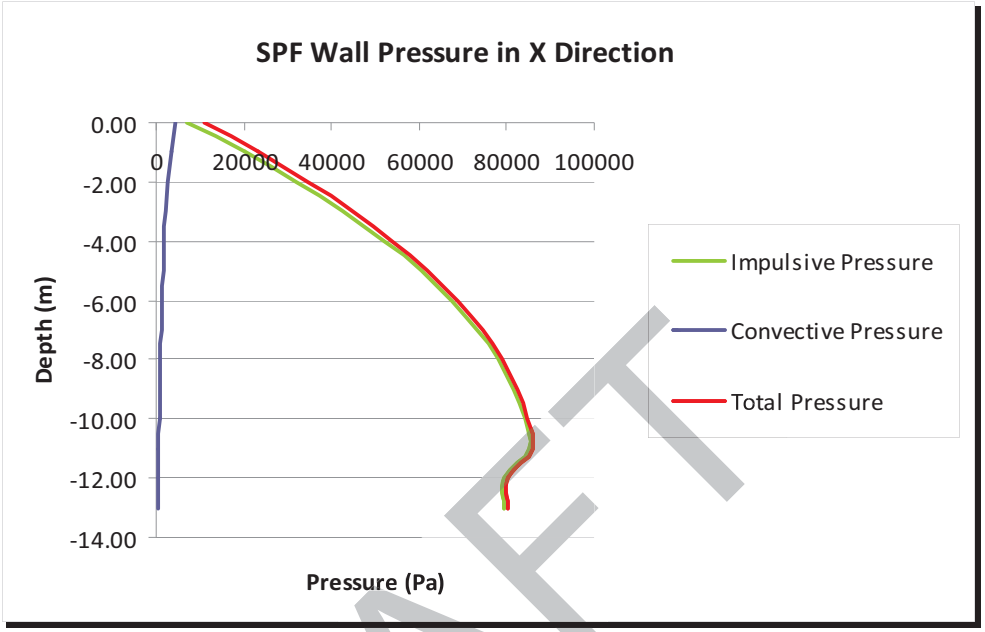


**Figure 03.07.02-74-2—Impulsive and Convective Wall Pressure Distributions in the Y direction**

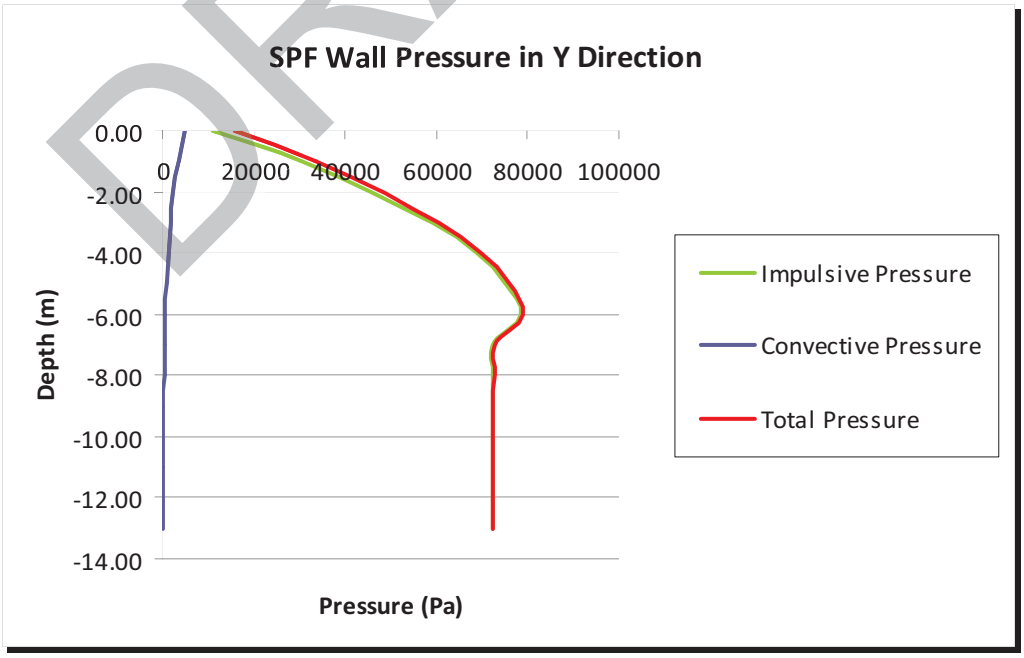


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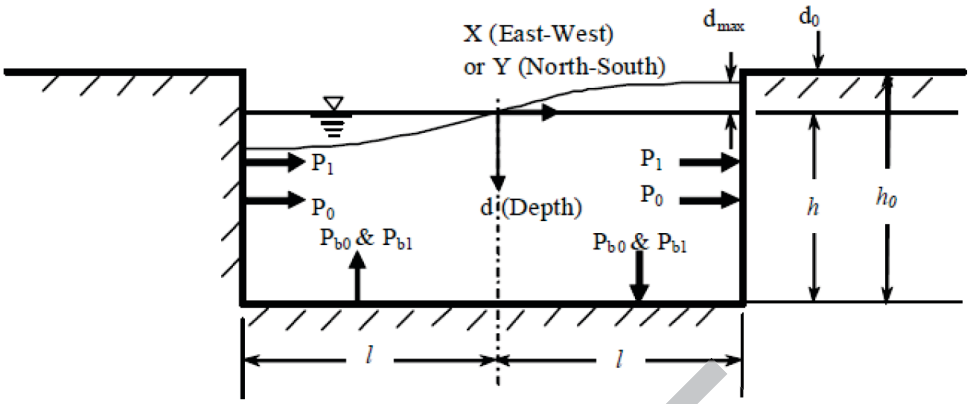
**Figure 03.07.02-74-3—Hydrodynamic Pressure in Pool due to Horizontal Acceleration**

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# Attachment 1 - Spent Fuel Pool Example

Accelerations ($a_X$, $a_Y$, and $a_Z$) for the impulsive mode are based on the localized seven percent damping ISRS specific to the SFP walls/slabs. These accelerations are smaller compared to the accelerations from the enveloped ISRS of the entire Fuel Building (FB) floor. These principles apply to the convective mode accelerations, as discussed in Item 5 of this response, which used localized 0.5 percent damping ISRS. The lower accelerations were used in the sloshing height calculation as described in Item 5 of this response.

The higher accelerations from the enveloped FB ISRS were used in calculating the hydrodynamic loads in this Attachment 1, Section 1.2 to Section 1.4, and applied to the static model used for design of critical sections. The higher accelerations ($a_X$, $a_Y$, and $a_Z$) from the enveloped FB ISRS are 1.0 g, 1.6 g, and 1.44 g, respectively.

## 1.0 Hydrodynamic Load in Spent Fuel Pool

According to TID-7024 (Reference 1), the horizontal acceleration of fluid in a tank or pool generates hydrodynamic forces acting outward on one side of the pool and inward on the other side. The seismically-induced fluid motion developed in a pool is represented by a combination of impulsive force, $P_0$, and convective force, $P_1$, acting on the pool walls and the combination of impulsive force, $P_{b0}$, and convective force, $P_{b1}$, acting on the pool slab, as shown in Figure 03.07.02-74-3.

In order to use TID-7024, Equation 6.4 or Equation F.47 to obtain impulsive pressures on pool walls and slab, the natural frequencies of the walls and slab are required for finding the corresponding accelerations.

The hydrodynamic pressure on the pool walls and slab resulting from vertical seismic acceleration ($a_Z$) is calculated using a similar formula to that used for hydrostatic calculation as follows:

$$P_z = \rho_{water}\, a_Z\, d$$

## 1.1 Natural Frequencies of Spent Fuel Pool

### East or West Wall

According to TID-7024, impulsive force, $P_0$, is created by a portion of the fluid, of weight $W_0$, acting as if it were rigidly connected to the walls. The impulsive equivalent water mass associated with one wall at X = –*l* or X = +*l* is determined with TID-7024, Equation 6.1 for total weight calculation:

$$W_0 = W \times \frac{\tanh\left(\sqrt{3}\,\frac{l}{h}\right)}{\sqrt{3}\,\frac{l}{h}} \qquad \text{TID-7024, Equation 6.1}$$

Where W = total weight of fluid.

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$$w_0 = \rho_{\text{water}} l \times \frac{\tanh\left(\sqrt{3}\frac{l}{h}\right)}{\sqrt{3}\frac{l}{h}} = 1279\ psf$$

Where $l = L_X/2 = 51.67/2 = 25.84$ ft, $\rho_{water} = 64.3$ pcf, and $h = 45.6$ ft.

The total weight per unit wall area for frequency calculation is:

$w = w_0 + \rho_{concrete}(t) = 1279+150\times4.1 = 1894$ psf

Where t = 4.1 ft (minimum wall thickness of east or west wall.

Reference 2, Table 36, Case 16 (the edges simply supported) is used to find natural frequency of the walls, where "a" is the short edge of the plate and "b" is the long edge.

The maximum unsupported span of either east or west wall is 21.65 ft. Therefore, a = 21.65 ft (the length of unsupported span), b ≈ h = 45.6 ft (the unsupported height of the pool), and the lowest natural frequency of the east or west wall is:

$K_1 = \pi^2[1+(a/b)^2] = \pi^2\ [1+(21.65/45.6)^2] = 12.09$

$E_c = 57000(f'_c)^{0.5} = 57000(6000)^{0.5} = 4.42\text{x}10^6$ psi $= 6.36\text{x}10^8$ psf

$D = E_c t^3/[12(1-\nu^2)] = (6.36\text{x}10^8)(4.1)^3/[12(1-0.17^2)] = 3.76\text{x}10^9$ lb-ft

Natural frequency, $f = \frac{K_1}{2\pi}\sqrt{\frac{Dg}{wa^4}} = \frac{12.09}{2\pi}\sqrt{\frac{(3.76\times10^9)\times32.2}{1894\times21.65^4}} = 33Hz$

Using ISRS near the mid-height of pool water, the maximum acceleration in the X direction for seven percent damping ratio at 33 Hz is:

$a_X = .81g$

**North or South Wall**

The impulsive equivalent water mass associated with one wall at Y = –*l* or Y = +*l* is determined using TID-7024, Equation 6.1 as follows:

$$w_0 = \rho_{\text{water}} l \times \frac{\tanh\left(\sqrt{3}\frac{l}{h}\right)}{\sqrt{3}\frac{l}{h}} = 859\ psf$$

Where $l = L_Y/2 = 29.36/2 = 14.68$ ft, $\rho_{water} = 64.3$ pcf, and $h = 45.6$ ft.

The total weight per unit wall area for frequency calculation is:

$w = w_0 + \rho_{concrete}(t) = 859+150\times5.9 = 1745$ psf

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Where t = 1.8m = 5.9 ft

With a = h = 45.6 ft and b = $L_X$ = 51.67 ft, the lowest natural frequency of the north or south wall is:

$K_1 = \pi^2[1+(a/b)^2] = \pi^2\ [1+(45.6/51.67)^2] = 17.56$

$D = E_c t^3/[12(1-\nu^2)] = (6.36\text{x}10^8)(5.9)^3/[12(1-0.17^2)] = 1.12\text{x}10^{10}$ lb-ft

Natural frequency, $f = \frac{K_1}{2\pi}\sqrt{\frac{Dg}{wa^4}} = \frac{17.56}{2\pi}\sqrt{\frac{(1.12\times10^{10})\times32.2}{1745\times45.6^4}} = 19Hz$

Using ISRS approximately at the mid-height of the SFP water, the maximum acceleration in the Y direction for seven percent damping ratio at 19 Hz is:

$a_Y$ = 1.13g

**Pool Slab**

The flexibility of the pool slab is considered when generating vertical response spectra. The ZPA for the pool slab at Elevation +12.1 ft in the Z direction is:

$a_Z$ = 0.45g

## 1.2 Hydrodynamic Pressure of Spent Fuel Pool due to Seismic Load in X Direction

**East or West Wall**

As illustrated in TID-7024, Section 6.5 for slender tanks with *h* > 1.5*l*, the impulsive pressures, $P_0$, has to be further divided into two zones. The upper portion of water with a depth of 1.5*l* is in fluid motion, and TID-7024, Equation F.47 is used to find impulsive pressures, $P_0$, as a function of water depth below the surface (d):

$$P_0 = \rho \dot{u}_0 h\left[\frac{d}{h} - \frac{1}{2}\left(\frac{d}{h}\right)^2\right]\sqrt{3}\tanh\left(\sqrt{3}\frac{l}{h}\right) \text{ for d = 0 to 1.5}l$$

Where $\dot{u}_0$ = $a_X$ = 1.0g, *l* = 25.84 ft, and *h* = 38.76 ft.

The lower portion of water (below 36.76 ft) is assumed to move as a completely constrained fluid in calculating the impulsive pressure as follows:

$$P_0 = \rho \dot{u}_0 l$$

Based on these equations, the impulsive pressures at 3.28 ft increments along the height of the wall are calculated and shown in Table 03.07.02-74-A1.

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Convective force, $P_1$, is created by a portion of the fluid moving as if it were a solid oscillating mass flexibly connected to the walls with a maximum sloshing height of $d_{max}$, as shown in Figure 03.07.02-74-3. The natural frequency of sloshing fluid is determined by TID-7024, Equation 6.8:

$$\omega^2 = \frac{1.58g}{l}\tanh\left(\frac{1.58h}{l}\right) = 1.95$$

$$f = \frac{\omega}{2\pi} = 0.22Hz$$

Where g = 32.2 ft/sec$^2$, $l$ = 25.84 ft, and $h$ = 45.6 ft.

The maximum acceleration in the X direction for 0.5 percent damping ratio at 0.22 Hz for Elevation +48.5 ft is:

$S_{a1}$ = 0.05g

$d_{max}$ of water surface is estimated by TID-7024, Equation 6.11:

$$d_{max} = \frac{0.527l}{\left(\frac{g}{\omega^2\theta_h l} - 1\right)\left(\tanh\frac{1.58h}{l}\right)} = 1.17 \text{ ft} < d_0 = 1.64 \text{ ft}$$

Where $\theta_h = \frac{1.58A_1}{l}\left(\tanh\frac{1.58h}{l}\right) = 0.05$ rad TID-7024, Equation 6.9.

$A_1$ (max displacement) = $S_{a1}/\omega^2$.= (0.05)(32.2)/1.95 = 1.95 ft=0.826 ft.

To find convective pressures, $P_1$, at X= $-l$ or X= $+l$, as a function of water height above the pool bottom, (h-d), TID-7024, Equation F.62 is used. To find the maximum value of $P_1$, the sin$\omega$t is set equal to one and, consequently, removed from the equation as follows:

$$P_1 = \rho\frac{l^2}{3}\sqrt{\frac{5}{2}}\frac{\cosh\frac{1.58(h-d)}{l}}{\sinh\frac{1.58h}{l}}\omega^2\theta_h$$

Based on the $P_1$ equation, the convective pressures at 3.28 ft increments along the height of wall are calculated and shown in Table 03.07.02-74-A2.

Table 03.07.02-74-A3 shows the total hydrodynamic pressures on the East or West wall, which are obtained by adding the results from Table 03.07.02-74-A1 and Table 03.07.02-74-A2.

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**Pool Slab**

The pressure on the pool bottom ($P_{b0}$) produced by the impulsive force ($P_0$) in the X direction is obtained using TID-7024, Equation F.48, expressed as a function of distance from the centerline of the pool (X):

$$P_{b0} = \rho \dot{u}_0 h \frac{\sqrt{3}}{2} \frac{\sinh \frac{\sqrt{3}X}{h}}{\cosh \frac{\sqrt{3}l}{h}}$$

Where $\dot{u}_0$ = $a_X$ = 1.0g, $l$ = 25.84 ft, and $h$ = 45.6 ft.

Based on the $P_{b0}$ equation, the impulsive pressures at 3.28 ft increments from the centerline of the pool bottom are calculated and shown in Table 03.07.02-74-A4.

The pressure on the pool bottom ($P_{b1}$) produced by the convective force ($P_1$) in the X direction is obtained using TID-7024, Equation F.74, expressed as a function of distance from the centerline of the pool (X):

$$P_{b1} = \frac{1}{2}\sqrt{\frac{5}{2}}\rho l^2 \omega^2 \theta_h \left[\frac{X}{l} - \frac{1}{3}\left(\frac{X}{l}\right)^3\right] \frac{\sin \omega t}{\sinh \sqrt{\frac{5}{2}}\frac{h}{l}}$$

Where $\theta_h = 1.58 \frac{A_1}{l} \tanh\left(\frac{1.58h}{l}\right)$ TID-7024, Equation 6.9

$A_1 = S_{a1}/\omega^2$

By setting the $\sin\omega t$ to one, substituting $\theta_h$, and $A_1$, TID-7024, Equation F.74 for $P_{b1}$ can be rewritten as follows:

$$P_{b1} = \frac{1}{2}\sqrt{\frac{5}{2}}\rho l^2 \left[\frac{X}{l} - \frac{1}{3}\left(\frac{X}{l}\right)^3\right] \frac{1.58\frac{S_{a1}}{l}}{\cosh \frac{1.58h}{l}}$$

Where $S_{a1}$ = 0.07g.

Based on the $P_{b1}$ equation, the convective pressures at 3.28 ft increments from the centerline of the pool bottom are calculated and shown in Table 03.07.02-74-A5.

Table 03.07.02-74-A6 shows the total vertical pressure on the pool slab resulting from impulsive and convective pressures in the X direction, which is obtained by adding the results from Table 03.07.02-74-A4 and Table 03.07.02-74-A5.

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## 1.3 Hydrodynamic Pressure of Spent Fuel Pool due to Seismic Load in Y Direction

### North or South Wall

As illustrated in TID-7024, Section 6.5 for slender tanks with $h > 1.5l$, the impulsive pressures, $P_0$, has to be further divided into two zones. The upper portion of water with a depth of $1.5l$ is considered to be in fluid motion, and TID-7024, Equation F.47 is used to find impulsive pressures, $P_0$, as a function of water depth below the surface (d):

$$P_0 = \rho \dot{u}_0 h \left[ \frac{d}{h} - \frac{1}{2}\left(\frac{d}{h}\right)^2 \right] \sqrt{3} \tanh\left(\sqrt{3}\frac{l}{h}\right) \text{ for d = 0 to } 1.5l$$

Where $\dot{u}_0$ = $a_y$ = 1.6g, $l$ = 14.68 ft, and $h$ = 1.5$l$ = 22.02 ft.

The lower portion of water (below 22.02 ft) is assumed to move as a completely constrained fluid in calculating the impulsive pressure using:

$$P_0 = \rho \dot{u}_0 l$$

The calculated impulsive pressure at 3.28 ft increments along the height of the wall are shown in Table 03.07.02-74-A7. For convective pressure calculation, the natural frequency of sloshing fluid is found by TID-7024, Equation 6.8:

$$\omega^2 = \frac{1.58g}{l} \tanh\left(\frac{1.58h}{l}\right) = 3.47$$

$$f = \frac{\omega}{2\pi} = 0.30Hz$$

Where g = 32.2 ft/sec$^2$, $l$ = 14.68 ft, and $h$ = 45.6 ft.

The maximum acceleration in the Y direction for 0.5 percent damping ratio at 0.30 Hz for Elevation +48.5 ft is:

$S_{a1}$ = 0.09g

$d_{max}$ of water surface is estimated by TID-7024, Equation 6.11:

$$d_{\max} = \frac{0.527l}{\left(\frac{g}{\omega^2 \theta_h l} - 1\right)\left(\tanh\frac{1.58h}{l}\right)} = 1.28 \text{ ft} < d_0 = 1.64 \text{ ft}$$

where $\theta_h = \frac{1.58A_1}{l}\left(\tanh\frac{1.58h}{l}\right)$ = 0.09 TID-7024, Equation 6.9

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$A_1 = S_{a1}/\omega^2 .= (0.09)(32.2)/3.47 = 0835$ ft

Convective pressures at 3.28 ft increments along the height of wall are calculated using the following equation, and Table 03.07.02-74-A8 shows the results:

$$P_1 = \rho \frac{l^2}{3}\sqrt{\frac{5}{2}}\frac{\cosh\frac{1.58(h-d)}{l}}{\sinh\frac{1.58h}{l}}\omega^2\theta_h$$ TID-7024, Equation F.62

Table 03.07.02-74-A9 shows the total hydrodynamic pressures on the South or North wall, which are obtained by combining the results from Table 03.07.02-74-A7 and Table 03.07.02-74-A8.

**Pool Slab**

The pressure on the pool bottom ($P_{b0}$) produced by the impulsive forces in the Y direction is obtained using TID-7024, Equation F.48, expressed as a function of distance from the centerline of the pool (Y):

$$P_{b0} = \rho \dot{u}_0 h \frac{\sqrt{3}}{2}\frac{\sinh\frac{\sqrt{3}Y}{h}}{\cosh\frac{\sqrt{3}l}{h}}$$

Where $\dot{u}_0$ = $a_Y$ = 1.6g, $l$ = 14.68 ft, and $h$ = 45.6 ft.

Based on the $P_{b0}$ equation, the impulsive pressures at 3.28 ft increments from the centerline of the pool bottom are calculated and shown in Table 03.07.02-74-A10.

Convective pressures at 3.28 ft increments from the pool bottom centerline are calculated using the following equation, and Table 03.07.02-74-A11 shows the results:

$$P_{b1} = \frac{1}{2}\sqrt{\frac{5}{2}}\rho l^2\left[\frac{Y}{l} - \frac{1}{3}\left(\frac{Y}{l}\right)^3\right]\frac{1.58\frac{S_{a1}}{l}}{\cosh\frac{1.58h}{l}}$$

Where $S_{a1}$ = 0.15g.

Table 03.07.02-74-A12 shows the total vertical pressure on the pool slab resulting from impulsive and convective pressures in the Y direction, which is obtained by combining the results from Table 03.07.02-74-A10 and Table 03.07.02-74-A11.

## 1.4 Hydrodynamic Pressure of Spent Fuel Pool due to Seismic Load in the Z Direction

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The hydrodynamic pressure resulting from seismic load in the Z direction is calculated using the following formula, and Table 03.07.02-74-A13 shows the results.

$P_z = \rho\ a_Z\ d$

Where $a_Z$ = 1.44g, and d = depth of fluid.

### *1.5 Loading Pit and Transfer Pit*

The loading pit and transfer pit are two small areas adjacent to the SFP and are separated from the SFP with access hatches. When the hatches are open, the loading pit and transfer pit become part of SFP. Instead of developing separate sets of loads for these two small pit areas, it is conservative to apply the loads developed for the larger SFP to the two smaller pool areas.

**For walls:**

The floors of the loading pit and transfer pit are located at Elevations +31.8 ft and +19.5 ft, respectively, which are higher than the floor of the SFP at Elevation +16.7 ft. The hydrostatic and hydrodynamic water pressures on the walls for SFPs is used for the loading pit and transfer pit up to water depths as follows:

Water Height of Loading Pit, $h_1$ = 30.5 ft

Water Height of Transfer Pit, $h_2$ = 42.8 ft

**For slabs:**

The SFP hydrostatic pressures and hydrodynamic pressure resulting from seismic loading in the Z direction near water depths, $h_1$ and $h_2$, is used for the loading pit and transfer pit slabs.

Because the loading pit and transfer pit are located in the SFP corners, maximum values of hydrodynamic pressures resulting from seismic loading in horizontal directions at the SFP slab corner near water depths, $h_1$ and $h_2$, is conservatively used for the loading pit and transfer pit slabs.

**References:**

1. TID-7024, “Nuclear Reactors and Earthquakes”, United States Atomic Energy Commission, 1963
2. Roark’s Formulas for Stress & Strain, 6th edition, McGraw-Hill Book Company, 1989

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**Table 03.07.02-74-A1—Impulsive Pressure on East or West Wall of Spent Fuel Pool in the X Direction**

| Depth (ft) | | d | $P_0$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 145 |
| 3.28 | 6.56 | 4.92 | 418 |
| 6.56 | 9.84 | 8.20 | 666 |
| 9.84 | 13.12 | 11.48 | 888 |
| 13.12 | 16.40 | 14.76 | 1087 |
| 16.40 | 19.68 | 18.04 | 1260 |
| 19.68 | 22.97 | 21.33 | 1408 |
| 22.97 | 26.25 | 24.61 | 1532 |
| 26.25 | 29.53 | 27.89 | 1631 |
| 29.53 | 32.81 | 31.17 | 1706 |
| 32.81 | 36.09 | 34.45 | 1755 |
| 36.09 | 39.37 | 37.73 | 1780 |
| 39.37 | 42.65 | 41.01 | 1661 |
| 42.65 | 45.60 | 44.13 | 1661 |

**Table 03.07.02-74-A2—Convective Pressure on East or West Wall of Spent Fuel Pool in the X Direction**

| Depth (ft) | | d | $P_1$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 88 |
| 3.28 | 6.56 | 4.92 | 72 |
| 6.56 | 9.84 | 8.20 | 59 |
| 9.84 | 13.12 | 11.48 | 49 |
| 13.12 | 16.40 | 14.76 | 40 |
| 16.40 | 19.68 | 18.04 | 33 |
| 19.68 | 22.97 | 21.33 | 28 |
| 22.97 | 26.25 | 24.61 | 23 |
| 26.25 | 29.53 | 27.89 | 20 |
| 29.53 | 32.81 | 31.17 | 17 |
| 32.81 | 36.09 | 34.45 | 15 |
| 36.09 | 39.37 | 37.73 | 13 |
| 39.37 | 42.65 | 41.01 | 12 |
| 42.65 | 45.60 | 44.13 | 12 |

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**Table 03.07.02-74-A3—Total Hydrodynamic Pressure on East or West Wall of Spent Fuel Pool in the X Direction**

| Depth (ft) | | d | $P_{wx}$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 233 |
| 3.28 | 6.56 | 4.92 | 490 |
| 6.56 | 9.84 | 8.20 | 725 |
| 9.84 | 13.12 | 11.48 | 937 |
| 13.12 | 16.40 | 14.76 | 1126 |
| 16.40 | 19.68 | 18.04 | 1293 |
| 19.68 | 22.97 | 21.33 | 1436 |
| 22.97 | 26.25 | 24.61 | 1555 |
| 26.25 | 29.53 | 27.89 | 1651 |
| 29.53 | 32.81 | 31.17 | 1722 |
| 32.81 | 36.09 | 34.45 | 1770 |
| 36.09 | 39.37 | 37.73 | 1793 |
| 39.37 | 42.65 | 41.01 | 1674 |
| 42.65 | 45.60 | 44.13 | 1673 |

**Table 03.07.02-74-A4—Vertical Pressure on Spent Fuel Pool Slab due to Impulsive Force in the X Direction**

| Distance (ft) | | X | $P_{b0}$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 104 |
| 3.28 | 6.56 | 4.92 | 314 |
| 6.56 | 9.84 | 8.20 | 528 |
| 9.84 | 13.12 | 11.48 | 751 |
| 13.12 | 16.40 | 14.76 | 986 |
| 16.40 | 19.68 | 18.04 | 1236 |
| 19.68 | 22.97 | 21.33 | 1505 |
| 22.97 | 25.84 | 24.40 | 1778 |

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**Table 03.07.02-74-A5—Vertical Pressure on Spent Fuel Pool Slab due to Convective Force in the X Direction**

| Distance (ft) | | X | $P_{b1}$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 1 |
| 3.28 | 6.56 | 4.92 | 3 |
| 6.56 | 9.84 | 8.20 | 5 |
| 9.84 | 13.12 | 11.48 | 7 |
| 13.12 | 16.40 | 14.76 | 9 |
| 16.40 | 19.68 | 18.04 | 10 |
| 19.68 | 22.97 | 21.33 | 11 |
| 22.97 | 25.84 | 24.40 | 12 |

**Table 03.07.02-74-A6—Vertical Pressure on Pool Slab due to Hydrodynamic Force in the X Direction**

| Distance (ft) | | X | $P_{sx}$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 105 |
| 3.28 | 6.56 | 4.92 | 317 |
| 6.56 | 9.84 | 8.20 | 534 |
| 9.84 | 13.12 | 11.48 | 759 |
| 13.12 | 16.40 | 14.76 | 995 |
| 16.40 | 19.68 | 18.04 | 1246 |
| 19.68 | 22.97 | 21.33 | 1516 |
| 22.97 | 25.84 | 24.40 | 1790 |

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**Table 03.07.02-74-A7—Impulsive Pressure on North or South Wall of Spent Fuel Pool in the Y Direction**

| Depth (ft) | | d | $P_0$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 226 |
| 3.28 | 6.56 | 4.92 | 629 |
| 6.56 | 9.84 | 8.20 | 964 |
| 9.84 | 13.12 | 11.48 | 1232 |
| 13.12 | 16.40 | 14.76 | 1434 |
| 16.40 | 19.68 | 18.04 | 1568 |
| 19.68 | 22.97 | 21.33 | 1635 |
| 22.97 | 26.25 | 24.61 | 1510 |
| 26.25 | 29.53 | 27.89 | 1510 |
| 29.53 | 32.81 | 31.17 | 1510 |
| 32.81 | 36.09 | 34.45 | 1510 |
| 36.09 | 39.37 | 37.73 | 1510 |
| 39.37 | 42.65 | 41.01 | 1510 |
| 42.65 | 45.60 | 44.13 | 1510 |

**Table 03.07.02-74-A8—Convective Pressure on North or South Wall of Spent Fuel Pool in the Y Direction**

| Depth (ft) | | d | $P_1$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 99 |
| 3.28 | 6.56 | 4.92 | 69 |
| 6.56 | 9.84 | 8.20 | 49 |
| 9.84 | 13.12 | 11.48 | 34 |
| 13.12 | 16.40 | 14.76 | 24 |
| 16.40 | 19.68 | 18.04 | 17 |
| 19.68 | 22.97 | 21.33 | 12 |
| 22.97 | 26.25 | 24.61 | 8 |
| 26.25 | 29.53 | 27.89 | 6 |
| 29.53 | 32.81 | 31.17 | 4 |
| 32.81 | 36.09 | 34.45 | 3 |
| 36.09 | 39.37 | 37.73 | 2 |
| 39.37 | 42.65 | 41.01 | 2 |
| 42.65 | 45.60 | 44.13 | 2 |

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**Table 03.07.02-74-A9—Total Hydrodynamic Pressure on North or South Wall of Spent Fuel Pool in the Y Direction**

| Depth (ft) | | d | $P_{wy}$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 325 |
| 3.28 | 6.56 | 4.92 | 698 |
| 6.56 | 9.84 | 8.20 | 1013 |
| 9.84 | 13.12 | 11.48 | 1267 |
| 13.12 | 16.40 | 14.76 | 1458 |
| 16.40 | 19.68 | 18.04 | 1585 |
| 19.68 | 22.97 | 21.33 | 1647 |
| 22.97 | 26.25 | 24.61 | 1519 |
| 26.25 | 29.53 | 27.89 | 1516 |
| 29.53 | 32.81 | 31.17 | 1515 |
| 32.81 | 36.09 | 34.45 | 1514 |
| 36.09 | 39.37 | 37.73 | 1513 |
| 39.37 | 42.65 | 41.01 | 1512 |
| 42.65 | 45.60 | 44.13 | 1512 |

**Table 03.07.02-74-A10—Vertical Pressure on Spent Fuel Pool Slab due to Impulsive Force in the Y Direction**

| Distance (ft) | | Y | $P_{b0}$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 218 |
| 3.28 | 6.56 | 4.92 | 659 |
| 6.56 | 9.84 | 8.20 | 1109 |
| 9.84 | 13.12 | 11.48 | 1577 |
| 13.12 | 14.68 | 13.90 | 1937 |

**Table 03.07.02-74-A11—Vertical Pressure on Spent Fuel Pool Slab due to Convective Force in the Y Direction**

| Distance (ft) | | Y | $P_{b1}$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 0 |
| 3.28 | 6.56 | 4.92 | 1 |
| 6.56 | 9.84 | 8.20 | 1 |
| 9.84 | 13.12 | 11.48 | 2 |
| 13.12 | 14.68 | 13.90 | 2 |

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**Table 03.07.02-74-A12—Total Vertical Pressure on Spent Fuel Pool Slab due to Hydrodynamic Force in the Y Direction**

| Distance (ft) | | Y | $P_{sy}$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 219 |
| 3.28 | 6.56 | 4.92 | 660 |
| 6.56 | 9.84 | 8.20 | 1111 |
| 9.84 | 13.12 | 11.48 | 1579 |
| 13.12 | 14.68 | 13.90 | 1939 |

**Table 03.07.02-74-A13—Hydrodynamic Pressure on Walls and Slab of Spent Fuel Pool due to Seismic Load in the Z Direction**

| Depth (ft) | | d | $P_z$ |
|---|---|---|---|
| from | to | (ft) | (psf) |
| 0.00 | 3.28 | 1.64 | 152 |
| 3.28 | 6.56 | 4.92 | 456 |
| 6.56 | 9.84 | 8.20 | 759 |
| 9.84 | 13.12 | 11.48 | 1063 |
| 13.12 | 16.40 | 14.76 | 1367 |
| 16.40 | 19.68 | 18.04 | 1671 |
| 19.68 | 22.97 | 21.33 | 1975 |
| 22.97 | 26.25 | 24.61 | 2278 |
| 26.25 | 29.53 | 27.89 | 2582 |
| 29.53 | 32.81 | 31.17 | 2886 |
| 32.81 | 36.09 | 34.45 | 3190 |
| 36.09 | 39.37 | 37.73 | 3493 |
| 39.37 | 42.65 | 41.01 | 3797 |
| 42.65 | 45.60 | 44.13 | 4086 |
| Slab | | 45.60 | 4222 |

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Section 3.8.3.6 describes methods used to confirm that concrete properties satisfy design requirements.

*Seismic Structural Damping*

Seismic analysis of RB internal structures uses the following SSE structural damping values recommended by RG 1.61.

| Structure Type | Percent of Critical Damping |
|---|---|
| • Welded Steel | 4 |
| • Bolted Steel, Slip-Critical Connections | 4 |
| • Bolted Steel, Bearing Connections | 7 |
| • Reinforced Concrete | 7 |

*Hydrodynamic Load Analyses*

Hydrodynamic loads are applied to the IRWST and refueling canal walls and floors to account for the impulsive and ~~impactive~~convective effects of water moving and sloshing in the tank as a result of seismic excitation. These loads are considered as part of the seismic SSE loads, and components of these loads in the three orthogonal directions are combined in the same manner as other seismic loads. Methodology consistent with USAEC TID-7024 is used to determine hydrodynamic loadings. The effect of tank structure flexibility on spectral acceleration is included when determining the hydrodynamic pressure on the tank walls for the impulsive mode. The SSE spectra with seven percent damping are used to determine the corresponding impulsive accelerations. For convective mode, the natural frequency of sloshing water is determined and the corresponding acceleration is based on 0.5 percent damping.

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In the static finite element model, hydrodynamic loads are applied statically in each of six directions (east, west, north, south, up, and down). The hydrodynamic loads due to a horizontal earthquake are a combination of impulsive and convective forces simultaneously acting on the pool walls and slabs, accounting for the rotational effects of water motion. The hydrodynamic pressure on the slab and walls due to a vertical earthquake are calculated using the fluid mass density multiplied by the vertical spectral acceleration of each pool slab location as a function of water depth below the surface.

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Design for hydrodynamic loads is within the elastic range of concrete and steel members and elements.

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- Welded Steel 4
- Bolted Steel, Slip Critical Connections 4
- Bolted Steel, Bearing Connections 7
- Reinforced Concrete 7

*Hydrodynamic Loads*

Hydrodynamic loads are applied to the walls and floors of the spent fuel pool and liquid storage tanks in the SBs and in the ESWBs to account for the impulsive and ~~impactive~~convective effects of the water moving and sloshing in the tanks as a result of seismic excitation. These loads are considered as part of the seismic SSE loads, and components of these loads in the three orthogonal directions are combined in the same manner as other seismic loads. The requirements of ASCE Manual No. 58, USAEC TID-7024, and other proven methods are used to determine hydrodynamic loadings. The effect of tank structure flexibility on spectral acceleration is included when determining the hydrodynamic pressure on the tank wall for the impulsive mode. The SSE spectra with seven percent damping are used to determine the corresponding impulsive accelerations. For convective mode, the natural frequency of sloshing water is determined and the corresponding acceleration is based on 0.5 percent damping.

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In the static finite element model, hydrodynamic loads are applied statically in each of six directions (i.e., east, west, north, south, up, and down). The hydrodynamic loads due to a horizontal earthquake are a combination of impulsive and convective forces simultaneously acting on the pool walls and slabs, accounting for the rotational effects of water motion. The hydrodynamic pressure on the slab and walls due to a vertical earthquake are calculated using the fluid mass density, multiplied by the vertical spectral acceleration of each pool slab location as a function of water depth below the surface.

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For the spent fuel pool, the combined rack and hydrodynamic loads including rack sliding/impact loads are applied separately in the static finite element model. The combined loads need to be higher than the whole pool seismic analysis results, considering the rack, fluid, and pool dynamic interaction. The impact, friction, and/or hydrodynamic peak instantaneous loads due to rack rocking/sliding will be considered in a local design for punching shear and bending checks.

Design for hydrodynamic loads is within the elastic range of concrete and steel members and elements.

*Thermal Analysis and Design*

Normal thermal loads ($T_o$) are considered in the analysis and design of other Seismic Category I structures. Abnormal pipe break accident thermal loads ($T_a$) are considered

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