Water Pressure Distribution on Pool Door for Research Reactor

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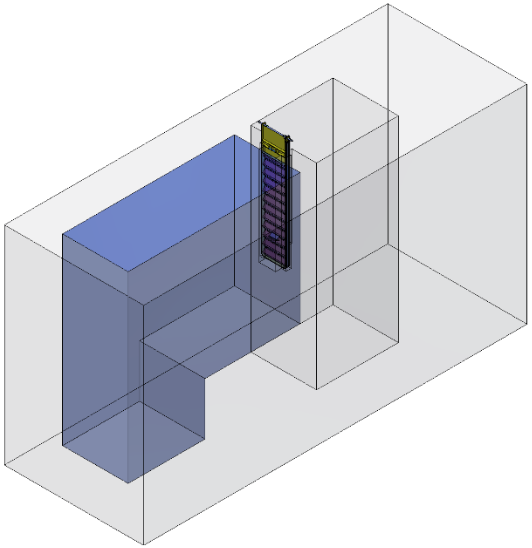
Introduction

- Pool door

- Pool doors are used for maintenance of the research reactor.
- The pool door is installed between the reactor pool and the service pool.
- Reactor pool water is drained but the service pool maintains water level.
- Water pressure on the pool door

: Hydrostatic pressure + Dynamic pressure



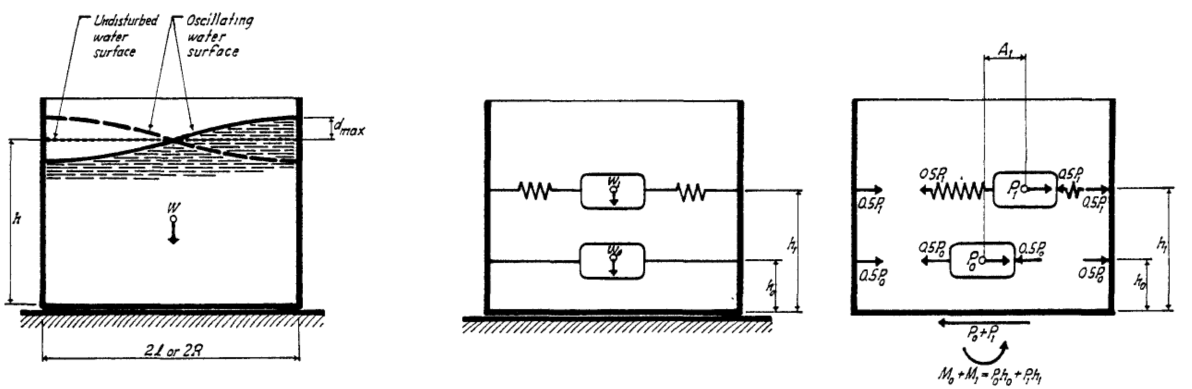
The pool door installed in the research reactor pool gate

TID-7024 Formula (1)

- TID-7024 report "Nuclear Reactors and Earthquakes", U.S. Atomic Energy Commission, 1961
- Chap. 6 Dynamic Pressure on Fluid Containers

- Horizontal dynamic water forces

: impulsive force + convective force



(a) Fluid Motion in Tank

(b) Dynamic Model

(c) Dynamic Equilibrium of Horizontal Forces

TID-7024 Formula (2)

	Impulsive	Convective
Equivalent weight of water	$W_i = 1.15W\frac{H}{L}\tanh\left(0.866\frac{L}{H}\right)$	$W_c = 0.264W\frac{L}{H}\tanh\left(3.16\frac{H}{L}\right)$
Height (from the bottom)	$h_i = 0.375H$	$h_c = H\left(1-\frac{\cosh\left(3.16\frac{H}{L}\right)-1}{3.16\frac{H}{L}\sinh\left(3.16\frac{H}{L}\right)}\right)$
Force	$P_i = \frac{\dot{u}_0 W_i}{g}$ $\dot{u}_0$: zero period acceleration	$P_c = W_c\theta_h \sin\omega t$ Natural frequency of water oscillation $\omega^2 = \frac{3.16g}{L}\tanh\left(3.16\frac{H}{L}\right)$ Angle of free oscillation $\theta_h = 3.16\frac{A_1}{L}\tanh\left(3.16\frac{H}{L}\right)$

Spectral Acceleration Approach

- Mutual relationships of pseudo values: displacement, velocity and acceleration

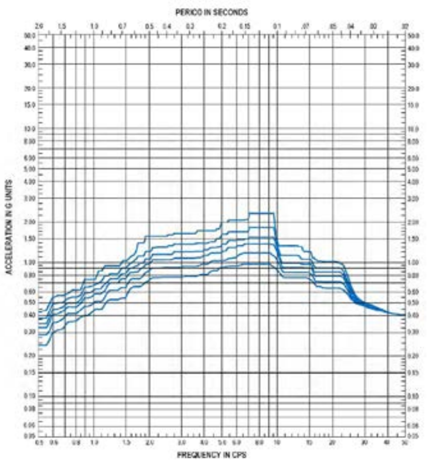
$$A_1 = S_D = \frac{S}{\omega} = \frac{S_A}{\omega^2}$$

- S_A is the spectral acceleration for the natural frequency of water, ω.
- Angle of free oscillation can be obtained from S_A .

$$\theta_h = \frac{\omega^2}{g} A_1 = \frac{\omega^2}{g} \frac{S_A}{\omega^2} = \frac{S_A}{g}$$

- Convective force can be obtained from S_A and geometry of pool.

$$P_c = \frac{S_A W_c}{g} \sin \omega t$$



FRS curve of research reactor building

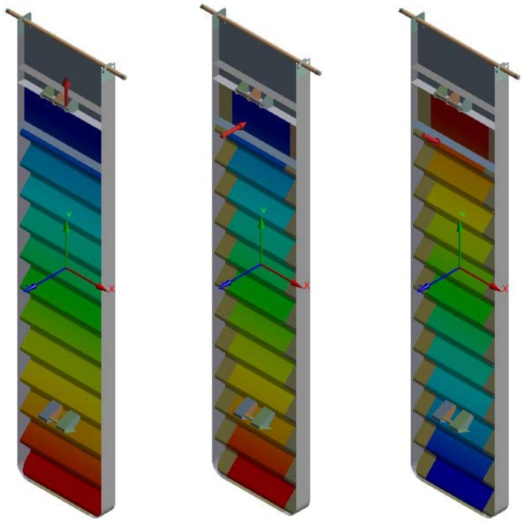
ACI 350.3 Formula (1)

- ACI 350.3 standards, "Seismic Designs of Liquid-Containing Concrete Structures and Commentary", American Concrete Institute, 2006
- Impulsive and convective forces are essentially same as those in TID-7024. Only importance and modification factors are adopted.

	Impulsive	Convective
Force	$P_i = C_i I \frac{W_i}{R_i}$	$P_c = C_c I \frac{W_c}{R_c}$
Response modification factor	$1.5 \le R_i \le 3.25$	$R_c = 1.0$
Vertical distribution	$P_{iy} = \frac{P_i}{H^2}\left[2H - 3h_i - (3H - 6h_i)\frac{y}{H}\right]$	$P_{cy} = \frac{P_c}{H^2}\left[2H - 3h_c - (3H - 6h_c)\frac{y}{H}\right]$
Horizontal distribution	$p_{iy} = \frac{P_{iy}}{B}$	$p_{cy} = \frac{P_{cy}}{B}$

Water Pressure Distribution

- Water pressure acts on one side of the pool door.
- Impulsive and convective pressures are negligible in slot of the pool gate.



hydrostatic *impulsive* *convective*

Water pressure distributions

Location	Pressure (kPa)			
	Hydrostatic	Impulsive	Convective	Total
Pool Surface	0	3.86	12.8	16.7
Door Bottom	58.8	27.0	3.01	88.8

Structural Analysis Results

- Load combinations

1) Normal condition: Dead load + Hydrostatic pressure + Gasket air pressure

2) Extreme environmental condition: Static loads + Impulsive pressure + Convective pressure + SSE loads

- Structural Analysis

- Responses to the load conditions are calculated through FEM analysis using ANSYS.

- The maximum von-Mises stress occurs at the bottom.

	Static	Impulsive	Convective	SSE	Total
Max. Stress (MPa)	82.6	31.7	48.0	2.6	93.6
Stress Distribution