LOCA/SRV

SUBMERGED STRUCTURE LOADS

METHODOLOGY

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I. INTRODUCTION

During a postulated LOCA event or SRV discharge, water clearing, air expulsion and steam condensation in the Mark II suppression pool will create induced fluid motion which in turn may produce loads on the submerged structures. In order to evaluate these hydrodynamic loads, analytical models are utilized to predict velocity and acceleration in the entire flow field. The subsequent calculation of the total drag loads due to both standard and acceleration drag is carried out for each submerged structure as follows: (See DFFR (Ref. 1) and NEDE-21730 (Ref. 2))

$$\text{Standard drag} = F_s = \frac{C_d A_x \rho U|U|}{2g_c} \quad (1)$$

$$\text{Acceleration drag} = F_a = \frac{C_m \rho \forall \dot{U}}{g_c} \quad (2)$$

Where C_d = Standard Drag Coefficient

A_x = Structure's Area Normal to the Flow Direction

ρ = Water Density

U = Fluid Velocity

g_c = Acceleration Constant

C_m = Inertia Coefficient

$\forall$ = Structure Volume

$\dot{U}$ = Fluid Acceleration

In the process of computing the loads, the NRC Acceptance Criteria (Ref. 3) concerning the unsteady flow effect, interference effect, equivalent uniform flow, bubble asymmetric effect, etc. are addressed and considered whenever they are needed.

The approaches to the calculation of submerged structure loads for Shoreham plant are described in detail below.

II. LOCA SUBMERGED STRUCTURE LOADS

In this section, the methods used to predict the hydrodynamic loads associated with water jet, air bubble charging, pool swell, fallback, condensation oscillation and chugging in the LOCA event are discussed.

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A. LOCA Water Jet Loads

Shoreham adopts the NRC Acceptance Criteria to calculate the LOCA water jet loads. First, the vent clearing transient is determined using Shoreham response to NRC Question 020.58 part (2). Based on NEDE-21472 (Ref. 4), DFFR and NEDE-21730, the jet front location, velocity and acceleration are calculated. The potential function from the NRC Acceptance Criteria is used to predict the induced velocity and acceleration in the flow field by the method of NEDE-21471 (Ref. 5). The standard drag and acceleration drag are then calculated in accordance with Eqs (1) & (2). For a structure which is fully engulfed or not fully submerged inside the jet boundary, the procedure outlined in NEDE-21730 is used to calculate the drag forces.

B. LOCA Air Bubble Charging Loads

Based on NEDE-21471, NEDE-21730 and DFFR, the air bubble charging loads are calculated. The following steps are taken to compute the loads:

(1) Use NEDE-21471 to determine the bubble source strength, the induced velocity and acceleration in the flow field.

(2) Use procedure in NEDE-21730 and DFFR to determine the drag loads.

(3) NRC Acceptance Criteria are addressed according to Ref. 6.

C. Pool Swell Loads

NEDE-21544-p (Ref. 7), DFFR, NEDE-21730 and NRC Acceptance Criteria are used to develop the forcing functions on structures in the pool swell zone. Major steps taken are as follows:

(1) Use NEDE-21544 and DFFR to evaluate the pool water slug velocity, acceleration and elevation time histories.

(2) Use DFFR and NEDE-21730 to calculate the standard drag and acceleration drag loads.

(3) Use NRC Acceptance Criteria (Section III.B.3.C.1) to calculate the impact loads.

(4) Use Ref. 6 to address the NRC concerns about lift force.

D. Pool Fallback Loads

The fallback loads on structures are computed based on the velocity and acceleration time histories of a free falling fluid slug. The procedure outlined in DFFR and NEDE-21730 is used to evaluate the fallback loads on structures located between the vent exit and the maximum pool swell height.

E. Condensation Oscillation Loads

Condensation oscillation produces an effective unsteady source at the vent exit analogous to the LOCA air bubble source and can also be expected to generate submerged structure loads. Once the source strength is defined, the same basic approach and fundamentals that are applied to the LOCA air bubble load calculation can be utilized to compute loads.

Shoreham uses basically the approaches of G.E. documents: NEDO-21669 (Ref. 8), NEDE-23617-P (Ref. 9), 4T Application Memo (Ref. 10), NEDE-21471, DFFR and NEDE-21730 with the following features:

(1) Based on analytical hydrodynamic models in NEDO-21669 and NEDE-23617-P, the source is defined as follows:

(a) A point source is located at each vent (downcomer) tip.

(b) The source strength, $\dot{S}$, is derived from full scale single vent data of the 4T test facility, and is related to the wall pressure as follows:

$$\dot{S} = \frac{P\ wall}{\rho\ f\ (r)} \qquad (3)$$

Where P wall = 4T wall pressure at tank bottom center

ρ = Fluid Density

f (r) = Transfer factor determined by the method of images and 4T geometry.

According to the 4T Application Memo, the bounding wall pressure in Eq. (3) is used. The pressure history is considered to be sinusoidal with an amplitude of ± 5 psi and a possible frequency range of 2 to 7 Hertz.

(2) After the source strength is defined, the worst combination of phasing (out - of - phase) for all vents is considered to calculate the submerged structure loads in accordance with the analysis and procedure outlined in NEDE-21471, DFFR and NEDE-21730.

(3) Interference effect, unsteady flow effect, and equivalent velocity and acceleration are incorporated to comply with NRC Acceptance Criteria.

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F. Chugging Loads

Essentially the same methodology used in the load definition for condensation oscillation is adopted to compute the chugging loads. All documents mentioned in II. E. plus the Shoreham response to NRC Question 020.75 form the design bases for load generation. The key difference from condensation oscillation is described as follows:

(1) Chug source strength is based on the 4T Application memo with the maximum source being that resulting in the +20 psi, -14 psi amplitude wall pressure. The frequency range used for chugging loads is 20 through 30 Hz.

(2) When considering the influence of more than one vent, source amplitude is reduced by using a source amplitude multiplier versus number of vents function based on the asymmetric wall pressure distribution. (see Figure 020.75-1)

III. SRV SUBMERGED STRUCTURE LOADS

In this section, the methodology adopted to predict SRV submerged structure loads related to the water jet and air bubble oscillation is discussed.

A. SRV Water Jet Loads

According to the NRC Acceptance Criteria, the SRV water jet loads may be neglected for those structures located outside of a sphere circumscribed about the quencher arms. Shoreham's zone of influence as defined by the NRC Acceptance Criteria is a sphere with radius of 5.328 ft. However, as proposed by the Mark II Lead Plant Owners, the zone of influence of SRV water jet is modified from a sphere to a cylinder tangent to the sphere. Although the jet loads are expected to be small, the loads on structures inside the modified cylinder zone of influence are calculated as follows:

(1) Standard drag is calculated from NEDE-23539 (Ref. 11) and NEDE-25090-P (Ref. 12)

(2) The induced acceleration is predicted by the line source method (Ref. 13) The subsequent acceleration drag computation is obtained from DFFR and NEDE-21730.

B. SRV Air Bubble Loads

Shoreham uses a NRC/KWU hybrid method. This methodology includes the following features:

(1) NRC Acceptance Criteria

a. Assume air bubble with radius of 5 feet located at quencher center.

b. Use Mark II submerged structure load calculation methodology in NEDE-21471, DFFR and NEDE-21730.

c. Fulfill the NRC required modifications, such as bubble asymmetric effect, interference effect, etc.

(2) Single exception to the NRC Acceptance Criteria: use KWU specification (Ref. 14) to define the bubble pressure, i.e. bubble pressure is equal to 1.5 KKB (3 KWU-PPL pressure traces)

(3) Application

a. Source strengh is based on the product of bubble radius (5 ft.) and pressure (1.5 KKB)

b. Frequency range is covered by using a time scale factor of 0.8 to 1.8 on KWU pressure time histories. Worst frequency is considered for the structure loads.

c. Use analysis and precedure in NEDE-21471, DFFR and NEDE-21730 to calculate the submerged structure loads.

IV. REFERENCE

1. "Mark II Containment Dynamic Forcing Functions Information Report (DFFR)," NEDO-21061-P, NEDO-21061, Revision 3, Class 1, June 1978, (GE Report)

2. "Mark II Pressure Suppression Containment System Loads on Submerged Structures - An Application Memorandum," NEDE-21730, December 1977. (GE Report)

3. "Mark II Containment Lead Plant Program Load Evaluation Report," USNRC, NUREG-0487, October 1978.

4. "Analytical Model for Liquid Jet Properties for Predicting Forces on Rigid Submerged Structures," NEDE-21472, Sept. 1977. (GE Report)

5. "Analytical Model for Estimating Drag Forces on Rigid Submerged Structures Caused by LOCA and Safety Valve Ramshead Air Discharge," GE Report, NEDE-21471, Sept. 1977.

6. "Draft Report on Submerged Structure Methodology in Response to the NRC Submerged Structure Acceptance Criteria for Mark II Lead Plants," Submitted to the NRC in May 1979, on Zimmer Docket.

7. "Mark II Pressure Suppression Containment System: An Analytical Model of the Pool Swell Phenomenon," GE Report NEDE-21544-P, December 1976

8. "The Multivent Hydrodynamic Model for Calculating Pool Boundary Loads Due to Chugging - Mark II Containments," GE Report NEDE-21669, June 1977.

9. "Mark II Lead Plant Topical Report Pool Boundary and Main Vent Chugging Loads Justification," GE Report NEDE-23617-P, July 1977.

10. "Mark II Phase I, II and III Temporary Tall Tank Test Application Memorandum," Janurry 1977, Letter from L.J. Sobon (G.E.) to O. Parr (NRC)

11. "Analytical Model for Quencher Water Jet Loads on Rigid Submerged Structures," GE Report NEDE-23539-P, Class III, August 1979 (Draft)

12. "Analytical Model for T-Quencher Water Jet Loads on Submerged Structures," GE Report NEDE-25090-P, Class III, May 1979

13. Shames, I.H., "Mechanics of Fluids," McGraw-Hill Book Company, 1962

14. "Thermo-Hydraulic Quencher Design of the Safety Relief System," Kraftwerk Union Report R14-25/1978, Revision 1, April 1978

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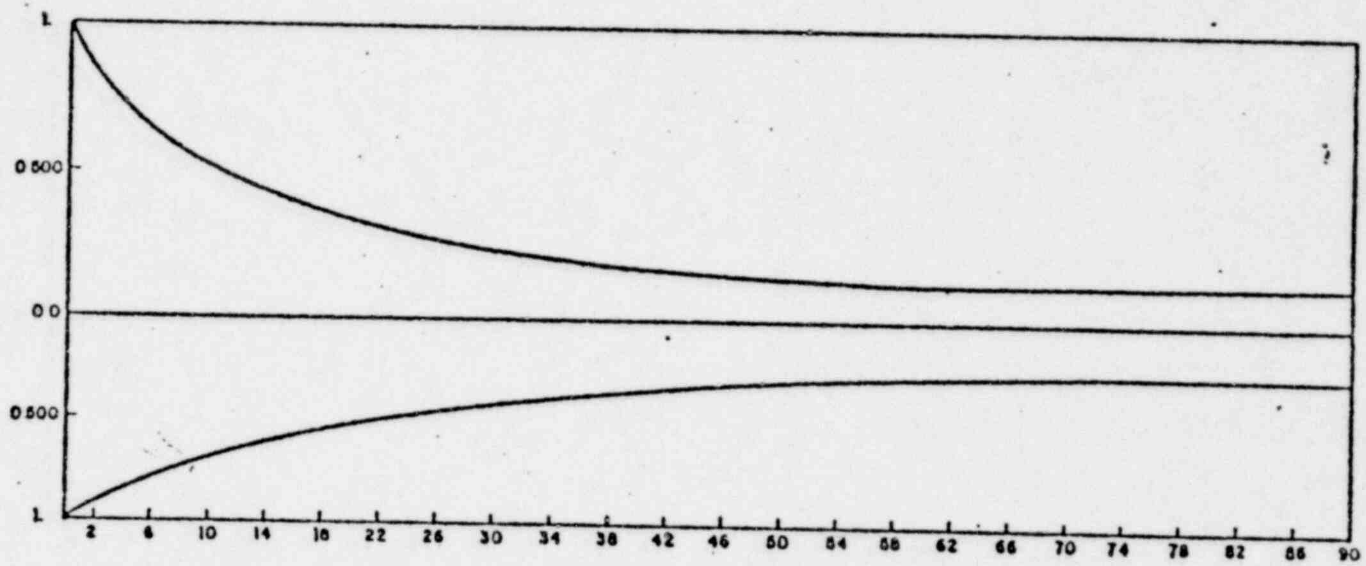

FIG.020.75-1

SOURCE AMPLITUDE MULTIPLIER vs NUMBER OF VENTS

SHOREHAM NUCLEAR POWER STATION-UNIT 1