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ADDITIONAL INFORMATION FOR IMPACT RESPONSE OF THE RESTART SAFETY RODS (U)

by

W. W. F. Yau

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

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WESTINGHOUSE SAVANNAH RIVER COMPANY

INTER-OFFICE MEMORANDUM

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cc: D. L. McIntosh, 773-A
J. D. Spencer, 773-A
A. J. Garrett, 773-A
T. L. Capeletti, 773-41A
D. T. Rankin, 773-A
J. C. Marra, 773-A
D. R. Leader, 773-A
J. M. Morrison, 773-56A
R. N. Lutz, 773-56A
F. R. Utsch, 773-A
N. C. Iyer, 773-A
SRL Records, 773-A (4)

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Reviewing Official: (Name and Title)

Date:

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TO: E. W. HOLTZSCHEITER, 773-A

FROM: W. W. F. YAU, 773-A
(5-1726)

ADDITIONAL INFORMATION FOR IMPACT RESPONSE OF THE RESTART SAFETY RODS - (U)

Introduction

WSRC-RP-91-677 studied the structural response of the safety rods under the conditions of brake failure and accidental release. It was concluded that the maximum impact loading to the safety rod is 6020 pounds based on conservative considerations that energy dissipation attributable to fluid resistance and reactor superstructure flexibility. The staffers of the Defense Nuclear Facility Safety Board reviewed the results and inquired about the extent of conservatism. By request of the RESTART team, I reassessed the impact force due to these conservative assumptions. This memorandum reports these assessments.

Authorized Derivative Classifier

Summary

When a safety rod plunges into a pool of heavy water at 60°C, it drags a thin layer of heavy water with it. The amount of heavy water moving with the safety rod is estimated to be 1.5 pounds. Consideration of energy dissipation due to fluid viscosity reduces the impact force by 540 pounds, or 9%. The reactor superstructure is more than 10,000 times heavier than a safety rod. Consideration of inelastic collision between them shows that energy dissipation due to superstructure motion is in the order of 10^{-4}, or negligibly small.

Discussion

A flat plate moving in a viscous fluid in the plane of the plate drags a layer of the fluid with it, and the thickness is estimated by $\delta = 2(\nu\tau)^{1/2}$, where ν is the kinematic viscosity of the fluid, and τ is the duration of motion, (p. 64, Viscous Flow Theory, Vol. 1, S. I. Pai, Van Nostrand, 1956). For heavy water at 60°, $\nu = 0.514\ (10)^{-5}$ ft²/sec. The time duration is solved from the equation of motion for a safety rod plunging to a depth y,

$$w - \rho A y = \frac{w}{g}\frac{d^2y}{dt^2}$$

where w = 27.2 pounds is the rod weight, ρ = 64 lb/ft³ is the weight density of heavy water, A = 0.694 in² is the rod cross-sectional area, g = 32.2 ft/sec² is the gravitational acceleration, and t is the time variable. It can be shown that

$$y = \frac{v_0}{\lambda}\sin\lambda t + \frac{1}{2}gt^2, \qquad \lambda^2 = \rho g A/w$$

is a solution satisfying the initial conditions of zero depth and velocity v_0 = 38.08 fps (WSRC-RP-91-677). The time duration is obtained by setting y = L = 20 ft, the length of the safety rod, and solve for the time t = τ = 1.114 sec.

The amount of heavy water stuck on the rod is

$$W' = 2\pi\rho DL(\nu\tau)^{1/2}$$
$$= 2\pi(64)\frac{0.94}{12}(20)\left[0.514(10)^{-5}(1.114)\right]^{1/2}$$
$$= 1.50 \text{ lb}$$

where D = 0.94 in. is the rod diameter. The energy dissipated during the travel is U = 0.5 W'L = 15 ft-lb. By reducing the amount of energy available for tube deformation by 15 ft-lb, it can be shown at the maximum elongation of the housing tube is

$$\Delta'_{max} = 0.3811 \text{ in}$$

The impact force is proportional to the elongation, so the modified impact force considering the effect of water resistance is

$$F' = F\Delta'_{max}/\Delta_{max} = 5480 \text{ lb}$$

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