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Energy Systems

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DCP/NRC1000
NSD-NRC-97-5287
Docket No.: 52-003

August 21, 1997

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: T. R. QUAY

SUBJECT: AP600 RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

Dear Mr. Quay:

Enclosed is the Westinghouse revised response to an NRC request for additional information (RAI) pertaining to the AP600 fuel-coolant interactions. Specifically, the revised response to RAI 720.387 is provided. The OITS number associated with this RAI is 5292. The response was revised, per an NRC request during a telecon, to add the values assigned to variables used in the equation presented in the response.

This revised response closes, from the Westinghouse perspective, the RAI. The Westinghouse status column in the OITS will be changed to "Action N." The NRC should review the response and inform Westinghouse of the status to be designated in the "NRC Status" column of the OITS.

Please contact Cynthia L. Haag on (412) 374-4277 if you have any questions concerning this transmittal.

Brian A. McIntyre

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

jml

Enclosure

E004/1

cc: J. M. Sebrosky, NRC (Enclosure)
N. J. Liparulo, Westinghouse (w/o Enclosure)

Enclosure to Westinghouse
Letter DCP/NRC1000

August 21, 1997

RESPONSE REVISION 1

Question 720.387

The deterministic evaluation of ex-vessel fuel coolant interactions (Appendix B to Revision 9 of the PRA) indicates that the impulse loads from ex-vessel steam explosions would fail the reactor cavity floor and wall structures, but that the embedded steel liner will stay intact. The evaluation also indicates that containment vessel integrity will not be compromised by the displacement of the RPV due to the impulse loading. Please submit additional details regarding the calculation of containment vessel strains referenced in Section B.3.2.1 and the calculation of maximum lift of the RPV referenced in Section B.3.2.2.

Response

As described in Appendix B, which presents the discussion of the ex-vessel severe accident phenomena, the reactor pressure vessel and the containment vessel dynamic response was defined using time history analyses. These structures were subjected to the dynamic impulse steam blast impulse loadings simulated by triangular pulse loadings. The models used were equivalent one-degree of freedom dynamic models. The equations of motion are defined in the reference given below:

> Timoshenko, S, D.H. Young, and W. Weaver, Jr, Vibration Problems in Engineering, J. Wiley & Sons, Fourth Edition, 1974.

They are provided below:

$$x = \frac{Q_1}{k}\left(\frac{t}{t_1} - \frac{\sin pt}{pt_1}\right) \qquad (0 \le t \le t_1)$$

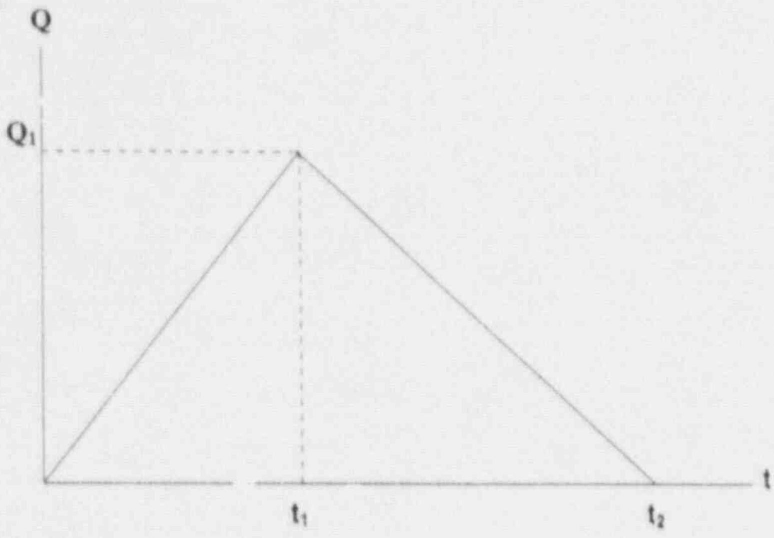
$$x = \frac{Q_1}{k}\left[\frac{t}{t_1} - \frac{\sin pt}{pt_1} - \frac{t_2(t-t_1)}{t_1(t_2-t_1)} + \frac{t_2 \sin p(t-t_1)}{pt_1(t_2-t_1)}\right] \qquad (t_1 \le t \le t_2)$$

$$x = \frac{Q_1}{k}\left[-\frac{\sin pt}{pt_1} + \frac{t_2 \sin p(t-t_1)}{pt_1(t_2-t_1)} - \frac{\sin p(t-t_2)}{p(t_2-t_1)}\right] \qquad (t_2 \le t)$$

where:

p = forced circular frequency

and the other terms are defined in the figure below:



The values assigned to the variables in the above equations are:

Q_1 = 607777 * K,

where: P = max pressure = 1.75E8 Pa or 25725 psi
Force = P*Area = 25725 (23625.9) = 607777 kips

K = 0.0 to 9539601 k/in., range of stiffness calculated based upon F,
where $K = (2*p*F)^2*W/386.4$

F = 0.001 to 300 Hz
W = 1037.445 kips (weight of RPV minus the weight of the internals)

t_2 = 0.004 seconds
t_1 = 0.002 seconds
p = 1884.96 rad/sec circular frequency

As stated in Appendix B, a 13 foot length was used for the containment vessel steel. This is considered the minimum length that could be subjected to a tensile strain. It is based on half of the length associated with the cracked concrete as shown in Figure 720.387-1. Each side of the 26 foot length is assumed conservatively to be stretched by the full deflection of the failed concrete ~~B~~. Six inches is an upper bound deflection value that is applicable to the range of AP600 soil stiffnesses . Results are shown in Figure 720.387-2. The percentage upper bound strain or elongation is calculated below:

μ = [6/(13 x 12)] x 100

μ = 3.8%

Therefore, the containment vessel strain, which is less than 4 percent, is much less than the ultimate strain capacity associated with the containment vessel material which is 22 percent or greater of elongation. The percent elongation is obtained from tests for SA537 Class 2 material used for the containment and materials with similar chemical properties. Test data was available for 389 tests.

The controlling steam blast impulse loading is best approximated by a triangular pulse (shown above) having a duration of 0.004 seconds. The calculation of the maximum displacement of the reactor pressure vessel follows the same time history dynamic formulation as described for the triangular impulsive load until time t is greater than t_2. The results at time t_2 are used to calculate the maximum displacement since this formulation does not account for gravity effects. The potential energy associated with mass M as it is lifted to its maximum height is equated to the difference between the kinetic energy defined using the maximum velocity (approximately at time t_2) and the strain energy of the piping. Shown in Figure 720.387-3 is a plot of the reactor pressure vessel (RPV) uplift obtained from this analysis as a function of system frequency. The system stiffness is defined by the reactor coolant piping. As the piping plastically deforms, the frequency decreases. A lower bound frequency of 1 hertz is considered. This results in an uplift of six feet. Even if the piping Instantaneously failed, which is not expected, the uplift would still be around 22 feet. As seen in Figure 720.387-4, the reactor pressure vessel will not leave the refueling canal area.

PRA Revision: None.

Figure 720.387-1
Containment Vessel Steel Subjected to Elongation
Due to Ex-Vessel Severe Accident

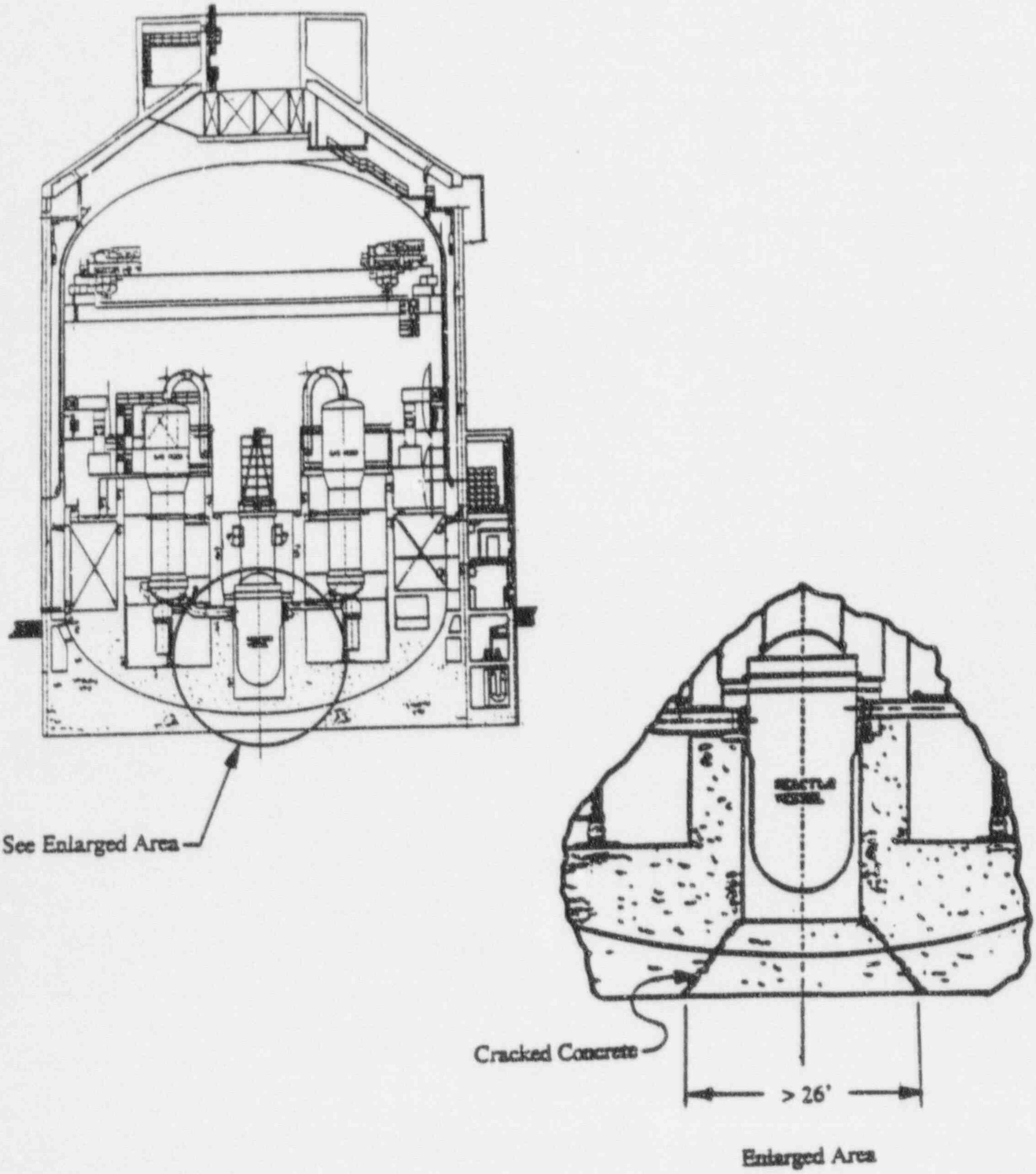


Figure 720.387-2

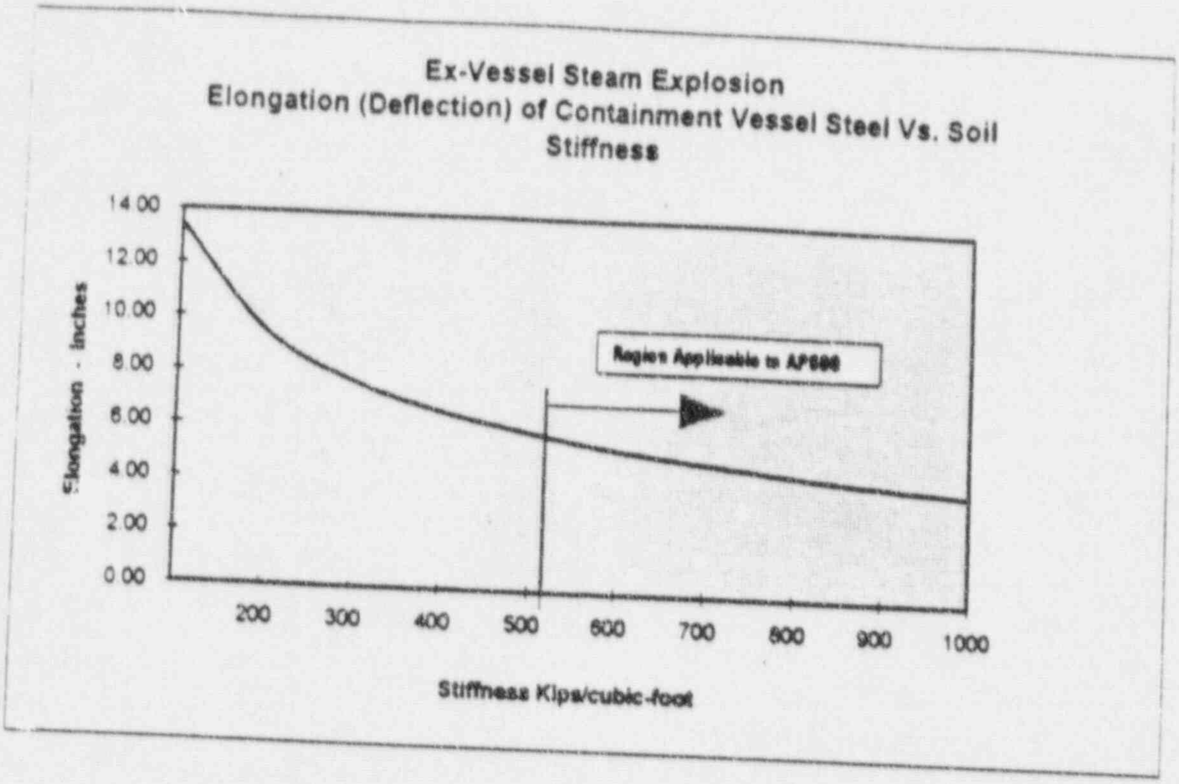


Figure 720.387-3
RPV Motion Based on a Spring/Mass System
Subjected to an Impulse Load

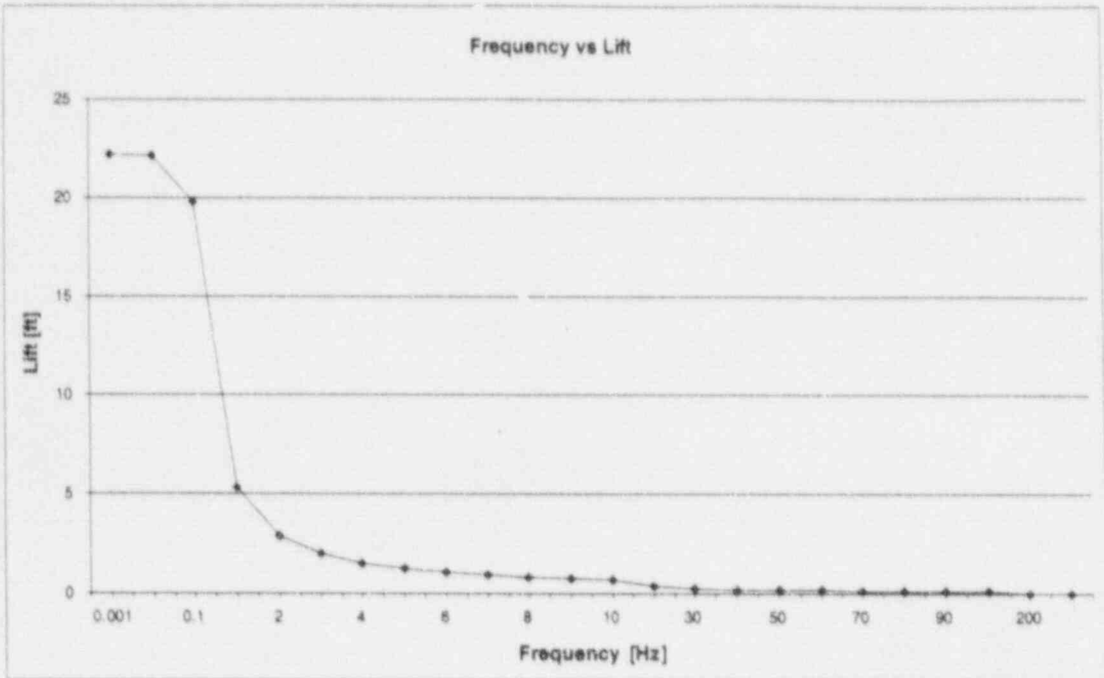


Figure 720.387-4
RPV Elevation Sketch