



UNITED STATES  
NUCLEAR REGULATORY COMMISSION

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November 26, 1996

Mr. Nicholas J. Liparulo, Manager  
Nuclear Safety and Regulatory Activities  
Nuclear and Advanced Technology Division  
Westinghouse Electric Corporation  
P.O. Box 355  
Pittsburgh, Pennsylvania 15230

SUBJECT: FEEDWATER LINE WATER HAMMER ISSUE FOR THE WESTINGHOUSE AP600  
ADVANCED REACTOR DESIGN

Dear Mr. Liparulo:

By letter dated November 4, 1996, the Nuclear Regulatory Commission (NRC) staff provided our technical position on three issues in the Civil Engineering and Geosciences Branch (ECGB) review area. In recent conversations regarding that letter, Westinghouse requested additional information on the probability of a water hammer event and the application of leak-before-break (LBB) on feedwater lines to better understand the staff's conclusion. As requested, provided below is a discussion of the probability of a water hammer event on feedwater lines. It is our understanding that Westinghouse is preparing more detailed analysis to justify the application of LBB to feedwater lines.

Water hammer is not a rare event. In work for the NRC Office of Research by a professor at the Massachusetts Institute of Technology, a review of historical water hammer information taken from a 1992 EPRI report was provided (D. A. VanDuyne, W. Yow, and J. W. Sabin, "Water Hammer Prevention, Mitigation and Accommodation. Vol. I: Plant Water Hammer Experience," EPRI Report NP-6766, July 1992). Of the 123 pressurized water reactor (PWR) water hammer events listed, 27 occurred in the feedwater system. Using a rough calculation of the number of effective full power years of PWR operating experience in the United States, it was estimated that the probability of occurrence of a feedwater system water hammer is about 1 event per plant over its operational lifetime. The staff believes it is difficult to determine the magnitude of the water hammer loads that might be experienced on the AP600 feedwater lines, except in a conservative, bounding sense. Water hammer is not a "normal" occurrence, and, in general, results from either a mechanical malfunction or human error. The magnitude of water hammer loads is a complex function of a number of mechanical and thermal-hydraulic factors, including system configuration and fluid (water and steam) temperatures and pressures at the time of such an event; given that water hammers (and the conditions that cause them) are abnormal occurrences, it is not practical to try to analyze the range of potential water hammer loads. However, if one assumes that cold water is introduced into the feedwater system in the most unfavorable manner, and comes in contact with saturated steam at or near secondary side operating pressure, the aforementioned "conservative, bounding analysis" indicates that water hammer pulses as high as 20,000 psi could result; the actual loads would probably be somewhat less.

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Mr. Nicholas J. Liparulo

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The staff does not believe that a finding that feedwater line water hammer is of "extremely low" probability can be justified and it appears that potential water hammer loads could be extremely high. Under the rules of the broadened scope of General Design Criteria (GDC)-4, for a piping system to be eligible for LBB, the probability of pipe rupture must be demonstrated to be extremely low by demonstrating adequate design consideration of several potentially direct and indirect pipe failure mechanisms, one of which is water hammer. Westinghouse has incorporated features in the AP600 design that could reduce but not necessarily eliminate the occurrence of a water hammer. As stated in our November 4, 1996, letter, since the potential for water hammer cannot be ruled out, and Westinghouse has not provided a quantitative analysis demonstrating an extremely low probability of this event, the staff has concluded that the criteria in GDC-4, i.e. the probability of pipe rupture due to water hammer is extremely low, has not been met. The staff concludes that application of LBB to the feedwater line for the AP600 is unacceptable.

If you have any questions regarding this matter, you can contact me at (301) 415-8548.

Sincerely,

original signed by:

Diane T. Jackson, Project Manager  
Standardization Project Directorate  
Division of Reactor Program Management  
Office of Nuclear Reactor Regulation

Docket No. 52-003

cc: See next page

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Mr. Nicholas J. Liparulo  
Westinghouse Electric Corporation

Docket No. 52-003  
AP600

cc: Mr. B. A. McIntyre  
Advanced Plant Safety & Licensing  
Westinghouse Electric Corporation  
Energy Systems Business Unit  
P.O. Box 355  
Pittsburgh, PA 15230

Mr. Ronald Simard, Director  
Advanced Reactor Programs  
Nuclear Energy Institute  
1776 Eye Street, N.W.  
Suite 300  
Washington, DC 20006-3706

Mr. John C. Butler  
Advanced Plant Safety & Licensing  
Westinghouse Electric Corporation  
Energy Systems Business Unit  
Box 355  
Pittsburgh, PA 15230

Ms. Lynn Connor  
Doc-Search Associates  
Post Office Box 34  
Cabin John, MD 20818

Mr. M. D. Beaumont  
Nuclear and Advanced Technology Division  
Westinghouse Electric Corporation  
One Montrose Metro  
11921 Rockville Pike  
Suite 350  
Rockville, MD 20852

Mr. James E. Quinn, Projects Manager  
LMR and SBWR Programs  
GE Nuclear Energy  
175 Curtner Avenue, M/C 165  
San Jose, CA 95125

Mr. Sterling Franks  
U.S. Department of Energy  
NE-50  
19901 Germantown Road  
Germantown, MD 20874

Mr. Robert H. Buchholz  
GE Nuclear Energy  
175 Curtner Avenue, MC-781  
San Jose, CA 95125

Barton Z. Cowan, Esq.  
Eckert Seamans Cherin & Mellott  
600 Grant Street 42nd Floor  
Pittsburgh, PA 15219

Mr. S. M. Modro  
Nuclear Systems Analysis Technologies  
Lockheed Idaho Technologies Company  
Post Office Box 1625  
Idaho Falls, ID 83415

Mr. Ed Rodwell, Manager  
PWR Design Certification  
Electric Power Research Institute  
3412 Hillview Avenue  
Palo Alto, CA 94303

Mr. Frank A. Ross  
U.S. Department of Energy, NE-42  
Office of LWR Safety and Technology  
19901 Germantown Road  
Germantown, MD 20874

Mr. Charles Thompson, Nuclear Engineer  
AP600 Certification  
NE-50  
19901 Germantown Road  
Germantown, MD 20874