UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
CAROLINA POWER AND LIGHT COMPANY	)	Docket Nos. 50-400 OL
	)	50-401 OL
(Shearon Harris Nuclear Power	)	
Plant, Unit 1)	)	

AFFIDAVIT OF DEAN SHAH

New York

State of New York

Dean Shah, being duly sworn according to law, deposes and says as follows:

I. INTRODUCTION:

1. My name is Dean Shah. My business address is Ebasco Services Incorporated, Two World Trade Center, New York, NY 10048. I am a Senior Mechanical Engineer working for the Shearon Harris Nuclear Power Plant project, employed by Ebasco Services Incorporated. A description of my professional experience and qualifications is attached hereto as Exhibit A.

2. I make this affidavit in support of applicants Motion of Summary Disposition of Eddleman 45 (Water Hammer). This affidavit addresses water hammer concerns, specifically for Main Steam (MS), Main Feedwater (MFW) and Auxiliary Feedwater (AFW) and Emergency Core Cooling (ECCS) systems in response to the issues raised in Eddleman's Contention No. 45. In my present position I am directly

I. <u>INTRODUCTION</u>: (Cont'd)

2. (Cont'd)

responsible for the design of these systems and I personally have performed or directed the performance of water hammer analysis for these systems. Therefore, I have personal knowledge of the matters stated herein and believe them to be true and correct to the best of my knowledge and belief.

3. The contention reads: SHNPP design cannot comply with the results of the Plant Water Hammer Experience Report, PWR SG Feedwater, ECCS and Main Steam System water hammer events evaluation (including systems effect) and potential resolutions now being prepared by the NRC, and the CR and NUREG reports on the water hammer question.

4. Water hammer concerns related to SHNPP Emergency Core Cooling System (ECCS), the Steam Generator, the Main Feedwater and Feedwater bypass systems are addressed in the separate affidavit of Mr Robert W Carlson of Westinghouse Electric Corporation.

5. The NRC Staff has reviewed information on water hammer events obtained primarily from licensing event reports and information requests to licensees. The results of this review are summarized in NRC document NUREG-0927 (Rev. 1) "Evaluation of Water Hammer

I. INTRODUCTION: (Cont'd)

5. (Cont'd)

Occurrence in Nuclear Power Plants, Technical Findings Relevant to Unresolved Safety Issue A-1". This document also provides key insight into means to minimize further water hammer occurrences. Based on this evaluation the Staff has also noted that the PWRs are less susceptible to water hammer occurrence and none of the reported water hammer occurrences have resulted in any radioactive release or placed a plant in a faulted or emergency condition.

II. PURPOSE:

6. The purpose of my affidavit is (a) to describe the design of the SHNPP MS, FW AFW and ECCS systems relevant to water hammer, (b) to show that design and analysis of these systems is consistent with the Staff's resolution of Unresolved Safety Issue A-1, (c) to show that design features are provided to minimize water hammer, (d) to show that piping and supports are designed to withstand anticipated water hammer loads and (e) to show that there are no significant safety concerns associated with water hammer for these systems.

III. DEFINITION OF WATER HAMMER:

7. The definitions of water hammer types listed below are used in this affidavit:

a) Water hammer: Water hammer is the change in the pressure of a fluid in a closed conduit caused by a rapid change in the fluid velocity. This pressure change is the result of the conversion of kinetic energy into pressure (compression waves) or the conversion of pressure into kinetic energy (rarefaction waves).

b) Anticipated Water Hammer: An anticipated water hammeris one resulting from a component performing in the manner for which it has been designed and affecting the system in its expected manner. The pressure waves resulting from turbine stop-valve closure are an example of an anticipated event.

c) Unanticipated Water Hammer: An unanticipated water hammer is one that would not be expected from a component of system operating in the manner for which it was designed.

IV. DESIGN AND ANALYSIS FEATURES OF THE MAIN STEAM SYSTEM:

System Description:

8. The Main Steam (MS) system supplies steam from the steam generators to the turbine generator and various system components. The system consists of main steam piping, power-operated relief valves, safety valves, turbine stop valves, main steam isolation valves, main steam isolation bypass valves and various instrumentations.

Water Hammer Events and System Evaluation:

9. In NUREG-0927 the NRC reports that water hammer in PWR MS system is of low safety significance. The reported water hammers and relief valve discharge incidents resulted in either no damage or minor support damage. No events occurring in the MS lines have been severe enough to cause piping damage.

10. Various water hammer events and their causes can be compared with SHNPP MS system as follows:

    a) Most of the water hammer events occurring in the MS systems were caused by rapidly closing valves. The Staff in NUREG-0927 recommends that the system should be designed to withstand the resulting water hammer.

10. (Cont'd)

The MS for SHNPP has been analyzed for fast acting main steam stop valve and turbine stop valve closing transients. Piping and supports have been designed to accommodate dynamic water hammer loads from these transients.

Also to minimize water hammer, automatic drain pots are provided at the appropriate locations to collect and discharge any steam condensation in the system. This drainage feature incorporates automatic level control valve stations, which operate on receipt of level signal from drain pots located upstream of the level control valves. This provision of draining condensate prevents formation of water slugs and minimizes water hammer events.

b) The cause of one of the reported events was steam admission into partially warmed steam line during heat up. For SHNPP MS system a small bypass valve around the main steam stop valve has been provided for slow warmup to prevent steam hammer during startup of cold lines.

IV. DESIGN AND ANALYSIS FEATURES OF THE MAIN STEAM SYSTEM: (Cont'd)

10. (Cont'd)

c) The cause of another reported event was high reaction forces resulted from relief valve actuation. SHNPP main steam piping and supports are designed to accommodate dynamic reaction forces resulting from valve actuation. This analysis is consistent with the criteria set forth in NRC Regulatory Guide 1.67.

11. Based on the above discussion, I conclude that the MS system for SHNPP is designed to minimize steam hammer and also analyzed to withstand the consequences of the anticipated steam hammer.

V. DESIGN AND ANALYSIS FEATURES OF THE FEEDWATER SYSTEM:

System Description:

12. The Feedwater (FW) system pumps condensate from the low-pressure heaters to the steam generators. The FW system consists of FW pumps, FW heaters, FW control valves, FW control bypass valves, FW isolation valves, FW isolation bypass valves, FW check valves, associated piping and instrumentation. The FW control valves

V. DESIGN AND ANALYSIS FEATURES OF THE FEEDWATER SYSTEM: (Cont'd)

12. (Cont'd)

control feedwater flow rate based on various input signals. FW bypass control valves are used for flow control under low flow conditions. AFW lines are connected to the bypass line of the MFW system. The AFW lines are part of the AFW system described in the next section.

Water Hammer Events and System Evaluation:

13. In NUREG-0927 the NRC reports that the significance of water hammer for FW system is moderate. The major cause of non-SGWH events in PWR feedwater systems have been FW control valve instability. These reported events related to FW water hammer can be compared with SHNPP FW system as follows:

a) FW control (FCV) valve instability was shown to be a predominant cause of water hammer events in the FW system reported cases. The FW control valve instability resulted from design deficiencies such as over-sizing of the valve and unbalanced valve trim. Generally, the NSSS vendor supplies and specifies FCVs. The AE designs the remainder of the condensate/feedwater system, from the condensate pumps to the

13. (Cont'd)

steam generator. Failure to verify FCV compatibility with the feedwater system has resulted in several designs in which the FCV is incompatible with the remainder of the feedwater system. The most common incompatibility has been valve oversizing. The incompatibility problem can be greater for systems containing a motor-driven feed pump, because such systems have very high FCV pressure drops at reduced plant loads. The high pressure drops at low flows tend to decrease valve stability.

The major cause of water hammer events in the PWR feedwater system due to feedwater control valve (FCV) instability has been corrected for SHNPP by trimming the feedwater pump impeller and by the following changes to the FCV:

(i) The valve full open C_v was lowered
(ii) The valve flow characteristic was changed to a modified equal percentage characteristic.

V. DESIGN AND ANALYSIS FEATURES OF THE FEEDWATER SYSTEM: (Cont'd)

13. (Cont'd)

The above changes will provide smooth and effective flow control and will minimize water hammer related to unstable control valve operation. A small bypass control valve to the FCV has been provided to further provide stable operation at a low power level.

b) One of the reported events resulted from steam bubble collapse.

To minimize bubble collapse water hammer, design recommendations provided by Westinghouse have been incorporated in the SHNPP FW system. The piping arrangement has been designed to minimize the volume of feedwater piping external to the steam generator which could pocket by steam using the shortest possible horizontal run of inlet piping to the steam generator nozzle. This is accomplished by providing a downward elbow welded directly to each steam generator feedwater nozzle. This arrangement minimizes slug formation and thereby feedline slugging type water hammer.

13. (Cont'd)

c) In addition the FW system has been analyzed for anticipated water hammer due to FW isolation and FW control valve closure. Piping and supports are designed to accommodate dynamic loads from this analysis.

The FW system has also been analyzed for various unanticipated water hammer transients which include feedline check valve slam following a line break and bubble collapse pressure transient. This analyses are performed to assure that at least two out of the three SGs will be available for plant safe shutdown.

Traditional design features such as vents at high points and drains at low points are provided to minimize water hammer.

14. Based on the above discussion, I conclude that the SHNPP FW system is designed to minimize water hammer and is analyzed to withstand waterhammer loads as applicable.

VI. DESIGN AND ANALYSIS FEATURES OF THE AUXILIARY FEEDWATER SYSTEM:

System Description:

15. The Auxiliary Feedwater (AFW) system serves as a backup system for supplying feedwater to the secondary side of the SG at times when main feedwater is not available. The system provides an alternate to the Feedwater system during start-up, hot standby, and cooldown. The AFW system consists of two motor driven pumps and one turbine drive pump with associated valves, piping, controls and instrumentation. The water supply to the pump is from the condensate storage tank which is located at higher elevation than the pumps.

Water Hammer Events and System Evaluation:

16. Various design features have been provided for SHNPP AFW system to minimize water hammer in this system.

17. To minimize the potential for the interaction of steam and cold water in the bypass piping as a result of leaking check valves the following design features have been provided:

17. (Cont'd)

a) A 90° elbow directed vertically downward, at the SG auxiliary feedwater nozzle has been provided.

b) Temperature sensors on the bypass piping have been provided to monitor any steam backleakage from steam generator into the feedwater bypass line. This will minimize the potential for bubble collapse water hammer.

Temperature sensors are also provided on the auxiliary feedwater piping to monitor any leakage into the Auxiliary Feedwater system from the Main Feedwater system. This will minimize the potential of water hammer and AFW pump steam binding events as described in the NRC IE Information Notice No. 84-066, 1/25/74.

The above temperature sensors will indicate any leakage in pipe by measuring the increased temperature or by differences in temperatures between the sensors mounted along the pipe. The presence of the leakage will provide alarm in the Control Room for operator's appropriate action.

VI. DESIGN AND ANALYSIS FEATURES OF THE AUXILIARY FEEDWATER SYSTEM: (Cont'd)

c) The feedwater bypass line has also been analyzed for water hammer transients similar to the Main Feedwater system.

d) The steam supply line to the auxiliary feedwater turbine has been designed to slope in the direction of the steam flow and drain pots have been provided for proper drainage of any steam condensation.

VII. DESIGN AND ANALYSIS FEATURES OF THE EMERGENCY CORE COOLING SYSTEM:

18. Westinghouse is responsible for the actual design of the Emergency Core Cooling System (ECCS). Westinghouse provides design information to Ebasco in order that Ebasco can prepare the piping layout drawings (which are subject to Westinghouse review and concurrence). The design recommendations related to water hammer which are identified in Mr R W Carlson's affidavit in paragraphs 47 and 48 have been implemented in the SHNPP ECCS.

VIII. COMPUTER CODE:

19. To calculate the forcing functions for water hammer transients, RELAP 5 and WHAMMOC II computer codes have been used. The RELAP 5 code, developed by EG&G for NRC as described in NUREG/CR1826, EGG 2070 Draft, Revision 2, September 1981, has been used for valve closing type transients. It is my understanding that the RELAP 5 code is used extensively by the industry for this type of the analysis. The WHAMMOC II developed by Ebasco has been used for feedline snapping pressure transient analysis. RELAP 5 developed by EG&G was implemented and tested by Ebasco on Ebasco's computer system and has undergone extensive experimental verification. Similarly, WHAMMOC has undergone experimental verification.

IX. CONCLUSION:

20. In summary, numerous design and engineering measures have been taken to minimize the potential of water hammer. These measures are consistent with the Staff's recommendation described in NUREG-0927, Revision 1.

In my judgement, the issues of water hammer in the FW, MS, AFW, and ECCS is not a safety concern for SHNPP.

Dean Shah

Subscribed and sworn to before me
this 24th day of May, 1984

Hugh T. McCarthy
Notary Public

My commission expires on

HUGH T. McCARTHY
Notary Public, State of New York
No. 31-2601970
Qualified in New York County
Commission Expires March 30, 1985

DEAN SHAH
SENIOR MECHANICAL ENGINEER
EXPERIENCE SUMMARY

Employed with Ebasco Serivces Incorporated, which engineers design and construct power plants. I am Lead Systems Engineer for the Shearon Harris Nuclear Power Plant in the Mechanical Engineering Department, responsible for engineering and design of all balance of plant (BOP) Systems including Main Steam, Feedwater and Auxiliary Feedwater systems. As a Lead Systems Engineer, I am responsible of providing technical assistance and direction to other engineers in the group. Responsibilities include preparing BOP systems design basis documents, design calculations for sizing pipes, pumps, and other mechanical components of the systems, selection and sizing the valves. I have prepared sections of design specification to identify piping analysis requirements including water hammer analysis.

I am also responsible for interpretation and implementation of NRC I&E Bulletins, SRPs, Regulatory Guides and NSSS Vendor requirements related to BOP systems. I have written and reviewed FSAR sections and have replied to NRC questions.

I also oversee the technical matters related to pipe rupture and jet impingement analysis.

My eleven (11) years experience include a number of positions in Applied Mechanics group where I have performed pipe stress analysis of nuclear power plant pipelines as per ASME B&PV Code Section III, Power Piping Code B31.1 and other Licensing requirements. I have personally performed or directed the performance of piping thermal expansion analysis, dynamic seismic analysis and water hammer analysis for various systems including Main Steam, Feedwater and Auxiliary Feedwater systems for the Shearon Harris project. I have also reviewed restraints and support design and load combination criteria.

DEAN SHAH

REPRESENTATIVE EXPERIENCE

Client	Project	Size	Fuel	Position
Carolina Power & Light Company	Shearon Harris Unit Nos. 1-4	960 MW Each	Nuclear (PWR)	Lead
Japan Atomic Power Company	Tokai No. Unit 2	1100 MW	Nuclear (BWR)	Support
Public Service Company of Colorado	Fort St. Vrain	330 MW	Nuclear (HTGR)	Support
Virginia Electric Power Company	Surry Unit No.2	934 MW	Nuclear (PWR)	Support
Toyko Electric Power Company	Fukushima Unit 6	1100 MW	Nuclear (BWR)	Support
Power Authority Of The State Of New York	Indian Point Unit 3	1000 MW	Nuclear (PWR)	Lead

EMPLOYMENT HISTORY

Ebasco Services Incorporated, New York, N.Y.; 1974-Present

- o Senior Engineer, 1978 - Present
- o Engineer, 1975 - 1978
- o Associated Engineer 1974 - 1975

Stone & Webster Engineering Corp., Boston, Mass; 1973-1974

- o Stress Analyst

Warner & Swasey, Co.; Worcester, Mass; 1972-1973

- o Designer

EDUCATION

Worcester Ploytechnic Institute - MSME - 1973

REGISTRATIONS

Professional Engineer - New York

DEAN SHAH

PROFESSIONAL AFFILIATIONS

ASME - Member
Have participated in Special Working Group - Dynamic Analysis ASME (Section III).