4-20-81

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
HOUSTON LIGHTING & POWER COMPANY	)	Docket No. 50-466
	)	
(Allens Creek Nuclear Generating Station, Unit No. 1)	)	
	)	

DIRECT TESTIMONY OF KAMRAN MOKHTARIAN
ON BEHALF OF HOUSTON LIGHTING & POWER COMPANY
ON DOHERTY CONTENTION NO. 9-CONTAINMENT BUCKLING

Q. Please state your name and place of employment.

A. My name is Kamran Mokhtarian. I am employed by Chicago Bridge & Iron Company. My business address is 800 Jorie Boulevard, Oak Brook, Illinois.

Q. Please describe your professional qualifications.

A. A statement of my background and qualifications is attached as Exhibit KM-1.

Q. Why have you prepared this testimony?

A. The purpose of this testimony is to address Doherty's Contention No. 9 which alleges that the Applicant's steel containment shell will not be strong enough to resist buckling under the design loads. Doherty's Contention No. 9 alleges:

> That Intervenor's health and safety interests are inadequately protected because Applicant's steel containment shell is not strong enough by design to resist dynamic and static loads which may plausibly occur in the life of the atomic plant.

The only specific basis stated in the contention for the above allegations are four observations on containment vessel bucking evaluation methods paraphrased from a preliminary (Jan. 1978) report of an NRC consultant, namely:

(1) Adequate experimental data for determining design criteria did not exist.

(2) Computer programs for determining building loads do not predict experimental buckling results very well.

(3) That the ASME Section III Buckling Criteria Regulatory Guide 1.57 NE-3224 (sic) "permits designers to select the method which yields a buckling stress which is least conservative."

(4) Until more test data is obtained to study the effects of imperfections, asymmetric loading, load interaction, dynamic and nonlinear effects, a conservative factor of safety such as 3 should be used."

Q. Will you describe how the containment for Allens Creek is being designed?

A. The steel containment vessel for ACNGS, as specified in Subsection 3.8 of the PSAR, is being designed in accordance with the requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Section III, Subsection NE. Chicago Bridge & Iron Company (CBI) is designing the steel containment vessel and its appurtenances for the ACNGS. The Applicant, through Ebasco, has prepared the design specification required by Paragraph NA-3250 of the ASME Code for use by CBI in their design of the ACNGS steel containment vessel and its appurtenances. This design specification establishes the minimum requirements for the design of the vessel. These requirements include the identification of the load definitions and the establishment of appropriate load combinations and related acceptance criteria to be employed in assessing structural stability and buckling capacity.

CBI is performing the required analyses and design activities to configure the steel containment vessel which will comply with the Applicant's design specification. CBI upon completion of their ongoing design activities, will prepare and submit to the Applicant a Certified Stress Report in accordance with Article NA-3350 of the ASME Code.

Q. How does this design process account for buckling?

A. The PSAR Table 3.8-2 outlines the buckling criteria in use for ACNGS. This criteria is based on the classical linear theory with reductions applied to account for imperfections in vessel geometry and other differences between theoretical and actual load capacities.

Basically, the method used on ACNGS for the buckling evaluation is the following:

1. The containment vessel is mathematically modeled using Kalnins' Shells of Revolution Program which has been verified as producing results for axisymmetric shells comparable to those of finite element programs recommended in NUREG/CR-0793. The Kalnins' Program is based on linear theory. The loads, as specified for ACNGS, are imposed on this mathematical model of the containment vessel in accordance with the specified loading combinations. The program has capabilities for axisymmetric and nonaxisymmetric stress

analyses of axisymmetric shell structures.

2. For the buckling analysis, the maximum compressive stresses at any azimuth are assumed to act uniformly all the way around, resulting in a conservative analysis.

3. The maximum stresses resulting from the sum of the static and dynamic loads will be compared to critical buckling stresses using the specified stress interaction equations which include the appropriate factors of safety.

This method of analysis accounts for the amplification factors on stresses due to dynamic loadings. These resulting stresses, however, are treated as equivalent static stresses for comparison with critical buckling stresses. This is a conservative approach, since a structure can withstand stresses due to dynamic loadings that are equal to or, in many cases, greater than critical stresses from statically applied loadings.

The buckling capacity of the shell is based on linear bifurcation (classical) analyses reduced by capacity reduction factors which account for the effects of imperfections and nonlinearity in geometry and boundary conditions and by plasticity reduction factors which account for nonlinearity in material properties.

In addition to the above reduction factors, factors of safety are employed in the assessment of structural stability. A factor of safety of 2.75 is applied wherever the critical buckling stresses are in the elastic range. The safety factor is linearly reduced from 2.75 to 2.0 between the proportional limit and the yield stress of the material. Where the critical stresses approach the yield strength of the material, material deformation becomes the controlling factor rather than buckling.

In addition to meeting the requirements of PSAR Table 3.8-2, the design of ACNGS containment vessel will meet the requirements of ASME Code Case N-284, titled "Metal Containment Shell Buckling Methods," issued August 25, 1980.

Q. What do you understand to be the basis for Mr. Doherty's contention?

A. Mr. Doherty filed, as a basis for his contention on containment buckling, his summary of a preliminary progress report submitted to the NRC Staff in January, 1978, by International Structural Engineers, Inc. (ISE). ISE was under a consulting contract with the NRC to study containment buckling analysis. The preliminary report included a number of preliminary observations which were cited by Mr. Doherty as criticisms of the present predictive methods used for buckling evaluation of containment vessels. ISE's final report was published as NUREG/CR-0793, "Buckling Criteria and Application of Criteria to Design of Steel Containment Shell" (May, 1979).

Q. Would you discuss each of the observations made in the consultant's preliminary report which Mr. Doherty cites?

A. Those preliminary observations as paraphrased and cited by Mr. Doherty in his contention are quoted and responded to in the following four paragraphs:

1. "Adequate Experimental data for determining design criteria did not exist."

Over the past decade a systematic collection has been made by CBI of several hundred technical papers known to contain experimental data on shell buckling. These tests include stiffened and unstiffened shells subjected to a variety of loads or loading combinations. Several of these tests have been performed on models fabricated with procedures representative of those used on containment vessels.

The final consultant's report recognized the fact that adequate experimental data does exist for shells subjected to axisymmetric static loadings. The concern seemed to remain that there may be a lack of data for shells subjected to dynamic asymmetric loadings. This concern will be conservatively accounted for in the methods employed in design and analysis of ACNGS containment vessel. The specified dynamic loadings will be applied to a mathematical model of the vessel. A shells of revolution program having dynamic analysis capabilities will be used. The resulting stresses, which include the effects of dynamic amplification factors, will then be used as equivalent static stresses for buckling evaluation of the vessel.

The asymmetric stress effects are also conservatively treated by applying the maximum stress around the entire azimuth as an axisymmetric (uniform) stress. The final consultants' report recommends this procedure as a conservative approach.

2. "Computer programs for determining buckling loads do not predict experimental buckling results very well."

It is well recognized that the results of computer programs based upon classical theory must be modified to predict the buckling capacity of imperfect shells. For the ACNGS vessel, the classical buckling values are reduced by knockdown and plasticity reduction factors, which conservatively account for the difference between the theoretical elastic buckling value for a perfect shell and the critical buckling capacity of a fabricated shell.

Both the preliminary and the final consultants' reports endorsed this approach as the preferred method of arriving at the critical buckling loads.

3. "That the ASME Section III Buckling Criteria Regulatory Guide 1.57, NE-3224 (sic), permits designers to select the method which yields a buckling stress which is least conservative."

The classical linear buckling analysis with reductions based on test results, which is the buckling evaluation method used for ACNGS vessel, is the method preferred and recommended by the consultants. This approach, outlined in previous paragraphs, is the most widely used approach for shell buckling evaluation. Applicant does not intend to perform any buckling evaluation for the ACNGS vessel using either of the other two methods permitted.

4. "Until more test data is obtained to study the effects of imperfections, asymmetric loading, load interaction,

dynamic and nonlinear effects, a conservative factor of safety such as 3 should be used."

The final consultants' report recognized that imperfections, asymmetric loadings, load interactions, dynamic loadings, and nonlinear effects can all be treated in a conservative manner, and that a safety factor of 2.0 will be adequate. As the final consultants' report states, "It is felt that a safety factor of 2 is sufficient to achieve a conservative design for all states of stress, if applied to reduction factors obtained as the minimum of experimentally obtained data." This recommendation of the consultants' Report is consistent with the buckling criteria of the ASME Code Case N-284, the requirements of which will be met for this vessel.

Q. Would you summarize your opinions concerning Mr. Doherty's contention?

A. The four (4) observations cited by Mr. Doherty's contention have either been superceded in whole or in part by their own authors in the final consultant's report to the NRC (NUREG/CR-0793, May, 1979) or they are well accounted for in the design of the ACNGS containment vessel. The method of analysis employed for the design of the ACNGS containment vessel will result in a conservative prediction of stresses and the buckling evaluation method employed will produce a safe and conservative design.

Exhibit KM-1

EDUCATION AND PROFESSIONAL QUALIFICATIONS

KAMRAN MOKHTARIAN

RESIDENCE:	BUSINESS:
442 Claremont Court	Chigago Bridge & Iron Co.
Downers Grove, Illinois 60516	800 Jorie Blvd.
	Oak Brook, Illinois 60521

EDUCATION:

B.S. Degree in Civil Engineering, Cleveland State University, 1963

M.S. Degree in Structural Mechanics, Northwestern University, 1964

Graduate level courses at Illinois Institute of Technology

EXPERIENCE:

Employed by Chicago Bridge & Iron Co. from 1964 to present.

August 1964-August 1965 - Design Engineer: Working on design of vacuum chambers and pressure vessels.

August 1965-June 1966 - Field Engineer: Working on fabrication and construction of tanks and vessels in an oil refinery.

June 1966-August 1967 - Design Engineer: Working on design and analysis of nuclear reactor vessels.

August 1967-May 1972 - Group Leader: Having responsibility for stress analysis of nuclear reactor vessels and preparation of ASME Code Stress Reports.

May 1972-Sept. 1975	- Supervisor of Stress Analysis: Having responsibility for complete design and analysis of nuclear structures. Supervising groups of engineers performing heat transfer analysis, fatigue and fracture analysis, shell and finite element analysis, and buckling analysis. Reviewing and certifying complete Code design and stress reports.
Sept. 1975-July 1977	- Project Engineer: Having overall engineering responsibility for design and analysis of the containment vessel for the Clinch River Breeder Reactor Project. Helped develop buckling criteria to be used for the design of that vessel.
July 1977-To Date	- Design Supervisor: Having responsibility for design of various nuclear structures. Supervising groups of engineers working on design and analysis of various containment vessels. Helped with developing buckling criteria to be used for design of Mark III containment vessels. Helped with

the development of and authored portions of the ASME Code Case N-284, titled "Metal Containment Shell Buckling Design Methods".

PROFESSIONAL REGISTRATION:

Registered Professional Engineer in State of Ohio

HONOR SOCIETIES:

Tau Beta Pi

Pi Mu Epsilon

PUBLICATIONS:

"Hotspot Flexure of Plate on Circular Support", Journal of the Engineering Mechanics Division of ASCE, June 1968