February 6, 2003

MEMORANDUM TO: Marsha Gamberoni, Deputy Director
New Reactor Licensing Project Office
Office of Nuclear Reactor Regulation

FROM: Lawrence J. Burkhart, AP1000 Project Manager ***/RA/***
New Reactor Licensing Project Office
Office of Nuclear Reactor Regulation

SUBJECT: JANUARY 21, 2003, TELEPHONE CONFERENCE CALL SUMMARY

On Tuesday, January 21, 2003, a telephone conference call was held with Westinghouse Electric Company (Westinghouse) representatives and Nuclear Regulatory Commission (NRC) staff to discuss issues associated with the structural design portion of the AP1000. The purpose of the call was to further discuss information that Westinghouse shared with the staff at a meeting in November 2002 (see meeting summary under ADAMS Accession No. ML030150537). A list of call participants is included as Attachment 1.

The following is a summary of the background of the relevant issues and the discussions held on January 21, 2003.

<u>Nuclear Island Modeling Issues</u>

During the meeting in November 2002, the NRC staff requested Westinghouse to select a simple shear wall section from its Nuclear Island (NI) dynamic model in order to compare the lateral deflection of the selected wall predicted by the computer analysis against the result of hand calculation. The information presented by Westinghouse during the meeting in November 2002 did not compare satisfactorily and consequently, the NRC staff requested a call with Westinghouse representatives. In preparation for the call, the NRC staff sent information on January 9 and 15, 2003, via electronic mail to Mr. Michael Corletti of Westinghouse regarding the desired topics for discussion at the January 21, 2003, telephone conference call (see Attachments 2 and 3). Several days prior to the conference call on January 21, 2003, Westinghouse provided the results of computer analysis and hand calculation of another simple model (see Attachment 4). The NRC staff reviewed the latest information and determined that the comparison of results from the latest model is acceptable. However, this did not completely address all of the NRC staff's concerns (as discussed below).

During the telephone conference call the NRC staff and Westinghouse representatives discussed several errors in one of the calculations reviewed at the November 2002 meeting. Although the length of the model shear wall was 51 feet (ft.), it was taken as 37.1 ft. in the hand calculation (as discussed in Attachments 2 and 3). The NRC staff conveyed to the Westinghouse staff that the calculation of shear wall stiffness needs to consider reduction of stiffness. The Westinghouse staff agreed to review the references provided by the NRC on stiffness reduction of shear walls, and to respond in the future. The stiffness reduction of the shear wall structure, virtually the entire NI model, would affect the design loads on the critical sections of the NI and the location of resonant frequencies on the in-structure response spectra.

Given that the AP1000 NI model is very complex and was developed through the collaborative efforts of consultants from Switzerland, Spain, Italy, Japan and two entities in the United States, the NRC staff is concerned about the process used by Westinghouse to ensure the adequacy of the structural model for use in the design of structures, systems, and components (SSCs). The requirement regarding reasonable assurance of the quality of the design of SSCs stems from general design criterion (GDC) No. 1, "Quality Standards and Records," of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50. The importance of ensuring the appropriateness of analytical assumptions made (including the size and type of finite elements used to develop the dynamic model) is emphasized in the design control criteria of Appendix A to Part 50 which states that "[m]easures shall be established for the identification and control of design interfaces and for coordination among participating design organizations. These measures shall include the establishment of procedures among participating design organizations for the review, approval, release, distribution, and revision of documents involving design interfaces. The design control measures shall provide for verifying or checking the adequacy of design, such as by the performance of design reviews, by the use of alternate or simplified calculational methods, or by the performance of a suitable testing program. The verifying or checking process should be performed by individuals or groups other than those who performed the original design, but who may be from the same organization." To address this issue, the NRC staff highlighted the need for a peer review of the NI design model during the November 2002 meeting and reiterated the same position at the January 21, 2003, telephone conference call. The NRC staff believes that a peer review of the complex NI model of the AP1000 is especially important in the light of the fact that Westinghouse did not consider the stiffness reduction of the shear walls.

Westinghouse agreed to inform the NRC staff of its intentions regarding how Westinghouse plans to address the issues of (1) peer review of its AP1000 design models and (2) stiffness reduction of shear wall models.

Docket No. 52-006

Attachment: As stated

sections of the NI and the location of resonant frequencies on the in-structure response spectra.

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<u>Distribution</u>:
<u>Hard Copy</u>
NRLPO R/F
LBurkhart
JLyons
MGamberoni

<u>E-mail</u>

PUBLIC	T. Cheng	J. Segala
R. Borchardt	G. Imbro	J. Colaccino
J. Williams	K. Manoly	J. Starefos
J. Moore, OGC	G. Bagchi	
R. Weisman, OGC		

ACCESSION NUMBER: ML030280305-Pkg. *See previous concurrence

OFFICE	NRLPO/PM	EMEB/SC*	NRLPO/DD
NAME	LBurkhart:cn	KManoly	MGamberoni
DATE	2/5/03	2/4/03	2/5/03

OFFICIAL RECORD COPY

cc:

Mr. W. Edward Cummins
AP600 and AP1000 Projects
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

Mr. H. A. Sepp
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230

Lynn Connor
Doc-Search Associates
2211 SW 1ST Ave - #1502
Portland, OR 97201

Barton Z. Cowan, Esq.
Eckert Seamans Cherin & Mellott, LLC
600 Grant Street 44th Floor
Pittsburgh, PA 15219

Mr. Ed Rodwell, Manager
Advanced Nuclear Plants' Systems
Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94304-1395

Charles Brinkman, Director
Washington Operations
Westinghouse Electric Company
12300 Twinbrook Parkway, Suite 330
Rockville, MD 20852

Mr. R. Simard
Nuclear Energy Institute
1776 I Street NW
Suite 400
Washington, DC 20006

Mr. Thomas P. Miller
U.S. Department of Energy
Headquarters - Germantown
19901 Germantown Road
Germantown, MD 20874-1290

Mr. David Lochbaum
Nuclear Safety Engineer
Union of Concerned Scientists
1707 H Street NW, Suite 600
Washington, DC 20006-3919

Mr. Paul Gunter
Nuclear Information & Resource Service
1424 16th Street, NW., Suite 404
Washington, DC 20036

Mr. Tom Clements
6703 Guide Avenue
Takoma Park, MD 20912

Mr. James Riccio
Greenpeace
702 H Street, NW, Suite 300
Washington, DC 20001

Mr. James F. Mallay, Director
Regulatory Affairs
FRAMATOME, ANP
3315 Old Forest Road
Lynchburg, VA 24501

Mr. Ed Wallace, General Manager
Project Management
Lake Buena Vista Bldg., 3rd Floor
1267 Gordon Hood Avenue
Centurion 0046
Republic of South Africa
PO Box 9396 Centurion 0046

Mr. Vince Langman
Licensing Manager
Atomic Energy of Canada Limited
2251 Speakman Drive
Mississauga, Ontario
Canada L5K 1B2

Mr. Gary Wright, Manager
Office of Nuclear Facility Safety
Illinois Department of Nuclear Safety
1035 Outer Park Drive
Springfield, IL 62704

Dr. Gail H. Marcus
U.S. Department of Energy
Room 5A-143
1000 Independence Ave., SW
Washington, DC 20585

Mr. Edwin Lyman
Nuclear Control Institute
1000 Connecticut Avenue, NW
Suite 410
Washington, DC 20036

Mr. Jack W. Roe
SCIENTECH, INC.
910 Clopper Road
Gaithersburg, MD 20878

Patricia Campbell
Winston & Strawn
1400 L Street, NW
Washington, DC 20005

Mr. David Ritter
Research Associate on Nuclear Energy
Public Citizens Critical Mass Energy
  and Environmental Program
215 Pennsylvania Avenue, SE
Washington, DC 20003

Mr. Michael M. Corletti
Passive Plant Projects & Development
AP600 & AP1000 Projects
Westinghouse Electric Company
P. O. Box 355
Pittsburgh, PA 15230-0355

JANUARY 21, 2003
TELEPHONE CONFERENCE CALL SUMMARY
LIST OF PARTICIPANTS

Nuclear Regulatory Commission

Larry Burkhart
Thomas Cheng
Goutam Bagchi
Carl Constantino (NRC Contractor)
Tom Tsai (NRC Contractor)

Westinghouse

Mike Corletti
Ed Cummins
Richard Orr

Attachment 1

AP 1000 Finite Element Analysis of a Shear Wall

Background:

NRC staff from the Division of Engineering (DE) assisted by its consultants and the Nuclear Regulatory Commission (NRC) Project Manager from the New Reactors Licensing Project Office (NRLPO) conducted a design and analysis review in the building foundation and structures area during November 12-15, 2002, at the Westinghouse Energy Center in Monroeville, PA. The purpose of the meeting was to discuss issues associated with the seismic and structural design for the AP1000 design certification including requests for additional information (RAIs) that were sent to Westinghouse via letter dated September 19, 2002.

Westinghouse has developed a complex finite element model (FEM) for the Auxiliary and Shield Building consisting of over 12,000 elements. The development of the FEM is a multinational effort involving Spain (Initec), Japan (Obayashi), Italy (Ansaldo), Switzerland (NOK), Westinghouse (USA) and a consultant from USA (Lapay). The control and coordination of these interfaces will need to be reviewed in depth by Westinghouse and the other participating organizations.

In order to determine the adequacy of the model, the NRC staff requested that Westinghouse take a simple concrete shear wall and apply some lateral load at the top of the shear wall FEM and obtain the deflection from an ANSYS run. The objective was that the staff will verify how closely the ANSYS results match the number that will be generated by simple hand calculation. Westinghouse did this and provided the staff with a three page document that contained the ANSYS result and some hand calculation assuming uncracked section. The results are as follows:

ANSYS Deflection = $2.06X10^{-4}$ Ft.
Hand Calculation Deflection = $1.92X10^{-4}$ Ft.

Discussion:

Upon some scrutiny, it was apparent that the shear wall FEM which consists of a wall with two different thicknesses, one part is three feet thick having 37.1 feet width and 35.5 feet height, and the top part is two feet thick having 37.1 feet width and 53.19 feet height was not properly treated in the hand calculation. The hand calculation had a mistake; it did not account for the moment transfer to the lower part, the thicker wall. The moment transfer causes two additional deflections at the top of the wall, one due to the moment on the thicker wall and the other due to end rotation on the thicker wall multiplied by the height of the thinner wall. When these additional deflections are added, the total deflection becomes $4.51X10^{-4}$ ft. Therefore, the ratio between the hand calculated deflection and the ANSYS deflection assuming uncracked concrete is 2.19. This is a very unfavorable comparison. Westinghouse needs to review the results carefully.

NRC Tests on Concrete Shear Walls:

Seismic tests on scaled shear wall structures were conducted by the Los Alamos National Laboratory (LANL) under the sponsorship of NRC's Office of Nuclear Regulatory Research (RES) and the shear walls exhibited natural frequencies that were lower than those calculated by the gross section properties of uncracked concrete sections even at relatively low levels of shaking, far less than the safe-shutdown earthquake (SSE) level of vibration. This was a surprise to many, including the Review Panel members. After a lot of peer review and detailed investigation by academicians, a paper written by Prof. Sozen (a member of the Review Panel) explained the reasons and made some recommendations for capturing the stiffness of shear walls in modeling their behavior in a seismic motion. The reference to this paper is:
J. P. Moehle, P. Monteiro, H. T. Tang, and M. A. Sozen, "Effects of Cracking and Age on Stiffness of Reinforced Concrete Walls Resisting In-Plane Shear," Proceedings of the Fourth Symposium on Nuclear Power Plant Structures, Equipment, and Piping, North Carolina State University, Raleigh, NC, December 1992, pp. 3.1-3.13. This paper recommends that the shear deformation part should be evaluated using gross uncracked area values, but the flexural properties should be based on cracked section properties.

The most recent guidance on the effective stiffness of reinforced concrete members is given in the proposed (Draft) ASCE Standard, "Seismic Design Criteria For Structures, Systems And Components In Nuclear Facilities," in Section 3.4. Provisions of this Section are excerpted below:

3.4 Modeling and Input Parameters

3.4.1 Effective Stiffness of Reinforced Concrete Members

In lieu of a detailed stiffness calculation, the effective stiffness of reinforced concrete members provided in Table 3.4-1 shall be used in linear elastic static or dynamic analysis. When finite element methods are used, the element stiffness shall be modified using the effective stiffness factor for the dominant response parameter.

Table 3.4-1 Effective Stiffness of Reinforced Concrete Members

Member	**Flexural Rigidity**	**Shear Rigidity**	**Axial Rigidity**
Beams – nonprestressed	$0.5E_cI_g$	G_cA_W	
Beams – prestressed	E_cI_g	G_cA_W	
Columns in compression	$0.7E_cI_g$	G_cA_W	E_cA_g
Columns in tension	$0.5E_cI_g$	G_cA_W	$E_s A_s$
Walls and Diaphrams – uncracked , $f_b<f_{cr}$, $V<V_c$	$0.8E_cI_g$	$0.8G_cA_W$	E_cA_g
Walls and Diaphrams – cracked, $f_b>f_{cr}$, $V>V_c$	$0.5E_cI_g$	$0.5G_cA_W$	E_cA_g

E_c = concrete compressive modulus	A_w = web area	f_{cr} = cracking stress
G_c = concrete shear modulus = $0.4E_c$	A_g = gross area of the concrete section	V = wall shear
E_s = steel modulus	A_s = gross area of the reinforcing steel	V_c = nominal concrete shear capacity
I_g = gross moment of inertia	f_b = bending stress	

Effective Stiffness of Reinforced Concrete Members

Table 3.4-1 is derived from FEMA 356, Table 6-5. For additional information on effective stiffness, consult FEMA 274, Section C6.4.1.2.

Consideration of Realistic Stiffness Properties of Shear walls:

Using the recommendation in the reference in Sozen's paper, the cracked moment of inertia of a shear wall section is 63% of the gross value.

Deflection Calculated by the Recommended Method Considering Concrete Cracking:

Deflection calculated = $6.83x10^{-4}$ ft.

Ratio of recommended deflection considering concrete cracking to the ANSYS deflection provided by Westinghouse assuming uncracked concrete is 3.32.

Finding:

Based on the ratio of 3.32, the calculated natural frequency can be off by 82%.

Recommendation:

Westinghouse should use the criteria in the FEMA documents. These criteria are based on substantial new research.