UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

July 22, 1985

Docket Nos. 50-213/50-245
LS05-85-07-028

Mr. John F. Opeka, Senior Vice President
Nuclear Engineering and Operations
Connecticut Yankee Atomic Power Company
and Northeast Nuclear Energy Company
Post Office Box 270
Hartford, Connecticut 06141

Dear Mr. Opeka:

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION - MASONRY WALL DESIGN

Re: Haddam Neck Plant and Millstone Nuclear Power Station, Unit No. 1

By separate letters, dated November 4, 1980, Northeast Utilities (NU) provided their responses to IE Bulletin 80-11, Masonry Wall Design for the Haddam Neck Plant and Millstone Unit 1. By letter dated December 3, 1982, NU provided responses to requests for additional information (RAI) for both the Haddam Neck Plant and Millstone Unit 1. The staff contractor has reviewed your submittals and responses to the RAI and has concluded that the enclosed additional information is required to complete its review. Attachment 1 contains RAI for the Haddam Neck Plant and Attachment 2 contains RAI for Millstone Unit 1. Attachment 3 is provided for reference and describes the staff position on arching action theory to qualify unreinforced masonry walls.

In order to expedite the review schedule, we suggest that a site visit/audit meeting be arranged in late September or early October, 1985 to review calculations and discuss the responses to the enclosed RAI. We anticipate that both Millstone Unit 1 and Haddam Neck units can be discussed at the same meeting given the similarity of the responses to the IE Bulletin. The project managers for Haddam Neck and Millstone Unit 1 will be working with your staff to arrange the technical meeting and the subsequent site visits.

Ex-27 SE01 '1,

The reporting and/or recordkeeping requirements contained in this letter affect fewer than ten respondents; therefore, OMB clearance is not required under PL 96-511.

Sincerely,

Original signed by:

John A. Zwolinski, Chief
Operating Reactors Branch #5
Division of Licensing

Attachments:
As stated

c w/attachments:
See next page

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Mr. John F. Opeka
Connecticut Yankee Atomic Power Company
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Haddam Neck Plant &
Millstone Nuclear Power Station,
Unit No. 1

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ATTACHMENT 1

REQUEST FOR ADDITIONAL INFORMATION
MASONRY WALL DESIGN, IE BULLETIN 80-11
HADDAM NECK PLANT
DOCKET NO. 50-213

1. In Response 17 of Reference 1, Connecticut Yankee Atomic Power Company (CYAPCo) indicated that the seismic evaluation of masonry walls used estimated floor spectra based on the Interim Seismic Design Ground Spectrum and that this criterion was later compared to the SEP floor response spectra. Provide the conclusions that were drawn from this comparison and clarify whether the SEP spectra were actually used.

2. With respect to Attachment 2 in Reference 1, explain how the wall attachment weights were determined. Indicate why these forces are divided by the area of the entire wall.

3. With respect to Attachment 5, Section 5.1 (Appendix A) in Reference 1, CYAPCo indicates that allowable stresses can be increased by 33% for OBE seismic loadings. However, the SGEB criteria, Section 3(a), expressly forbid the increase of allowable stress when wind or seismic loads (OBE) are involved. CYAPCo should identify the walls that require an increase in allowable stress for OBE load combinations in order to be qualified. Also, provide the actual percentage increase in allowable stress that is needed to qualify these walls.

4. In Response 11 of Reference 1, CYAPCo indicated that all allowable stresses were increased by a factor of 1.67 for load cases involving SSE. The SGEB criteria permit increase factors of only 1.3 for masonry shear and tension normal to the bed joint and 1.5 for tension parallel to the bed joint. CYAPCo should identify those walls which would not qualify if the SGEB factors were used and provide the percentages by which the SGEB factored allowables are exceeded.

5. Identify the total number of walls that required modifications in order to be qualified under the SGEB criteria (2). Also, indicate how many of these are unmortared walls.

6. In Response 8 of Reference 1, CYAPCo stated that one wall at the Haddam Neck plant was analyzed using the "arching action" technique. Identify this wall. The NRC position on this issue states that the use of the arching action theory to qualify unreinforced masonry walls is not acceptable. These walls should be repaired so they can be qualified based on the SGEB criteria (2). (The NRC position is provided as Attachment 3).

7. Identify whether any QA/QC records are available to ensure conformance of masonry construction to design drawings and specifications.

REFERENCES

1. W. G. Counsil
   Letter with attachments to R. A. Clark (NRC)
   Subject: Request for Additional Information on IE Bulletin 80-11, Masonry Wall Design
   Northeast Utilities
   December 3, 1982
   Enclosure I

2. SGEB Criteria for Safety-Related Masonry Wall Evaluation
   Developed by the Structural and Geotechnical Engineering Branch (SGEB) of the NRC
   July 1981

ATTACHMENT 2

REQUEST FOR ADDITIONAL INFORMATION
MASONRY WALL DESIGN, IE BULLETIN 80-11
MILLSTONE NUCLEAR POWER STATION UNIT 1
DOCKET NO. 50-245

1. In Response 10 of Reference 1, Northeast Nuclear Energy Company (NNECO) indicated that the seismic evaluation of masonry walls used the floor accelerations of the original design multiplied by a factor of 5 (Response 6) and that this criterion would be compared with the SEP floor response spectra. Provide a summary of this comparison and the conclusions drawn from it and clarify whether the SEP spectra were actually used.

2. Identify the 24 walls that have been qualified by arching action. The NRC position on this issue states that the use of the arching action theory to qualify unreinforced masonry walls is not acceptable. These walls should be repaired so that they can be qualified based on the SGEB criteria (3). (The NRC position is enclosed as Attachment 3).

3. Identify the number of walls that required modifications in order to be qualified under the NNECO reevaluation criteria, and specify how many of these can be qualified under the SGEB criteria (3) design method after modification.

4. Exhibit C-2 in Attachment 2 of Reference 2 lists the allowable shear stress for reinforced walls in flexure as $1.1\sqrt{f'm}$; this agrees with ACI 531-79. However, the revised Exhibit C-2 in Attachment 6 of Reference 1 lists the allowable value for out-of-plane shear as $1.5\sqrt{f'm}$. Explain why this value was chosen for reinforced walls.

5. Exhibit C-2 in attachment 2 of Reference 1 indicated that an increase factor of 1.5 for allowable masonry shear stress was used for reinforced walls. If a basic allowable of $1.5\sqrt{f'm}$ was used (as suggested by Exhibit C-2 [1]) and an increase factor 1.5 was applied to it, that would be equivalent to applying an increase factor of about 2 to the basic allowable found in ACI 531-79, which is $1.1\sqrt{f'm}$. The SGEB criteria [3], however, allow an increase factor of only 1.3 for masonry shear. Indicate whether the maximum shear stress in the reinforced walls still meets the SGEB criteria, which is based on ACI 531-79. If any walls would not qualify, provide the percentages by which the SGEB allowables are exceeded.

6. Indicate whether any walls at the Millstone Unit 1 were built without mortar. If so, the walls must be modified so that loose blocks do not impact safety-related equipment. Provide some sample sketches or drawings of this type of modification if applicable to this plant.

7. Identify whether any QA/QC records are available to ensure conformance of masonry construction to design drawings and specifications.

REFERENCES

1. W. G. Counsil
   Letter with attachments to R. A. Clark (NRC)
   Subject: Request for Additional Information on IE Bulletin 80-11, Masonry Wall Design
   Northeast Utilities
   December 3, 1982
   Enclosure II

2. W. G. Counsil
   Letter to B. H. Grier, NRC
   Subject: Millstone Nuclear Power Station, Unit 1 - IE Bulletin 80-11, Masonry Wall Design
   Northeast Utilities
   November 4, 1980
   A01021

3. SGEB Criteria for Safety-Related Masonry Wall Evaluation
   Developed by the Structural and Geotechnical Engineering Branch (SGEB) of the NRC
   July 1981

ATTACHMENT 3

SGEB Staff Position on Use of Arching Action Theory to Qualify Unreinforced Masonry Walls in Nuclear Power Plants

INTRODUCTION

Unreinforced hollow block masonry walls have a very limited capacity under the action of out-of-plane loads. Higher resistance could be developed by creating large in-plane clamping forces, thereby forming a three hinged arch mechanism after mid-span and support flexural cracking has occurred. The most important conditions for the arching mechanism to develop are the existence of rotational restraint at the boundaries and the prevention of gross sliding of the wall at support sections. Some of the licensees have relied on the development of this arching mechanism (referred to herein as 'arching action theory') to qualify unreinforced masonry walls in their plants.

The staff and their consultants have reviewed the basis provided by licensees to justify the use of arching action theory to qualify the unreinforced masonry walls. The staff met with a group of licensees representing approximately eleven utilities and twenty two units on November 3, 1982 and January 20, 1983 to discuss this issue. Further, a

site visit and detailed review of design calculations were conducted by the staff and consultants to gain first-hand knowledge of field conditions and the application of arching action theory in qualifying in-place masonry walls. Based on the information gained through the above activities, the staff has formulated the following position on the acceptability of the use of arching action theory to qualify unreinforced masonry walls in operating nuclear power plants. The staff's technical basis for the position is discussed in the attached report.

POSITION

The use of arching action theory to qualify unreinforced masonry block walls is not acceptable. Therefore, the licensee shall fix the walls currently qualified by the use of arching action theory such that they meet the staff acceptance criteria based on the working stress approach.

ENCLOSURE TO ATTACHMENT

EVALUATION OF ARCHING THEORY IN UNREINFORCED MASONRY WALLS IN NUCLEAR POWER PLANTS

Prepared by

Ahmed A. Hamid[1]

Harry G. Harris[1]

Vu Con[2]

June 1983

1. Department of Civil Engineering, Drexel University
2. Nuclear Engineering Department, Franklin Research Center

INTRODUCTION

In response to IE Bulletin 80-11, a total of 16 nuclear power plants have indicated that the arching action technique has been employed to qualify some unreinforced masonry walls. Based on the review of submittals provided by the licensees and published literature, Franklin Research Center (FRC) staff and FRC consultants have concluded that the available data in the literature do not give enough insight for understanding the mechanics and performance of unreinforced masonry walls under cyclic, fully reversed dynamic loading. As a result, a meeting with representatives of the affected plants was held at the NRC on November 3, 1982 so that the NRC, FRC staff, and FRC consultants could explain why the applicability of arching theory to masonry walls in nuclear power plants is questionable [1]. In a subsequent meeting on January 20, 1983, consultants of utility companies presented their rebuttals [2] and requested that they should be treated on a plant-by-plant basis. In accordance with their requests, the NRC staff has started the process of evaluating each plant on an individual basis. In this process, the NRC, FRC staff, and consultants have initiated visits to various nuclear plants to examine the field conditions of unreinforced masonry walls in the plants and to gain first-hand knowledge on how the arching theory is applied to actual walls. Key calculations have been reviewed with regard to the arching theory.

EVALUATION OF ARCHING THEORY

Test of unreinforced concrete masonry walls were recently conducted by Agbabian Associates, S. B. Barnes and Associates, and Kariotis and Associates [3] (this joint venture work is designated as ABK). Based on the visit to Oconee Nuclear Station, the results of the ABK tests, and all relevant information submitted by the licensees including the rebuttals given by the licensees in the January 20, 1983 meeting, the NRC, FRC staff, and consultants have made the following evaluations:

1. The design methodology used at various nuclear plants was developed by McDowell et al. [4] in 1956 for solid brick walls under static monotonic loading. No test data are available to check the adequacy of hollow block masonry under cyclic, fully reversed dynamic loading.

2. The only dynamic test data for arched masonry walls are the URS tests [5] for blast loading. This type of loading is not a true representation of earthquake loading because it is not fully reversed and has a decayed nature. Under very short-duration blast loading, masonry walls, which have much lower natural frequencies, would not fully respond to the applied load. In addition, only two walls were tested under cyclic blast loading at URS for arched masonry walls.

3. Extrapolation of test data from solid masonry to hollow block masonry is questionable. Recent test data [6] of eccentrically loaded masonry assemblages showed that the failure mechanism, strain distribution, and overall behavior of hollow masonry are quite different from those of solid or grouted masonry.

4. Hollow block masonry walls are more susceptible to premature web-shear failure or crushing compression failure. Precluding these types of failure is neccesary for the development of the arching mechanism. No data are available at the present time to determine the safety factors against these brittle failures under seismic loading.

5. Recent ABK dynanic tests [3] showed that unreinforced block masonry walls did fail (collapse) under earthquake loads with ground acceleration (effective peak acceleration) of about 0.3g to 0.4g, which is typical for nuclear plants. Also, some walls experienced local crushing at the base before failure by instability, which emphasizes the possibility of premature compression failure of arched walls. It must be noted, however, that the ABK test walls were not restrained at top to develop arching. The effect of boundary conditions could be significant and cannot be evaluated without further testing.

6. Unreinforced block masonry walls are extremely brittle, and flexural failure occurs without warning. The sensitivity of unreinforced masonry to crack development due to temperature and shrinkage is evident. Also, the inherent strength variability indicates the necessity of different safety indexes in ultimate failure analysis.

7. Masonry walls in nuclear plants usually have openings and attachments. Their effects on wall stability under seismic loading are unknown and cannot be rationally evaluated without testing.

8. No test data are available for gapped arching block walls under cyclic loading. In some cases, restrainers are provided around the gap to prevent gross sliding; this repair measure does not necessarily change the wall behavior from gapped arch to rigid arch.

CONCLUSION

A review and evaluation of the available information on the applicability of arching theory to unreinforced masonry walls in nuclear power plants has been presented. NRC, FRC staff, and consultants are firmly convinced that their original position expressed to the licensees in the November 3, 1983 meeting is still valid. It is evident that test data are needed to quantitatively determine the effects of different wall geometries, material properties, and boundary conditions on unreinforced block masonry walls' resistance to earthquake loading. It is recommended that a confirmatory testing program be performed to investigate the applicability of arching theory to unreinforced block masonry walls in nuclear power plants.

REFERENCES

1. Hamid, A. A. and Harris, H. G., "Applicability of Arching Theory to Unreinforced Block Masonry Walls Under Earthquake Loading," Franklin Research Center, Philadelphia, PA
August 1982

2. "Rebuttal to Applicability of Arching Theory to Unreinforced Block Masonry Walls Under Earthquake Loading," Computech Engineering Services, Inc., URS/J. A. Blume & Associates and Bechtel Power Corporation, January 1983

3. "Methodology of Mitigation of Seismic Hazards in Existing Unreinforced Masonry Buildings: Wall Testing, Out-of-Plane," ABK report, El Segundo, CA
1981

4. McDowell, E. L., McKee, M. E., and Sevin, E., "Arching Action Theory of Masonry Walls," ASCE Proceedings, Journal of the Structural Division, ST2
March 1956

5. Gabrielsen, B., Wilton, C., and Kaplan, K., "Response of Arching Walls and Debris from Interior Walls Caused by Blast Loading," Report No. 7030-23, URS Research Company, San Mateo, CA
February 1975

6. Drysdale, R. G. and Hamid, A. A., "Capacity of Concrete Block Masonry Prisons Under Eccentric Compressive Loading," ACI Journal, Proceedings, Vol. 80
March-April 1983