ATTACHMENT 1

TECHNICAL EVALUATION REPORT

MASONRY WALL DESIGN

DUKE POWER COMPANY

OCONEE NUCLEAR STATION UNITS 1, 2, AND 3

NRC DOCKET NO. 50-269, 50-270, 50-287

NRC TAC NO. 42904, 42905, 42906

NRC CONTRACT NO. NRC-03-81-180

FRC PROJECT C5506

FRC ASSIGNMENT 6

FRC TASK 232

Prepared by

Franklin Research Center
20th and Race Streets
Philadelphia, PA 19103

Author: V. N. Con, A. K. Le

FRC Group Leader: V. N. Con

Prepared for

Nuclear Regulatory Commission
Washington, D.C. 20555

Lead NRC Engineer: N. Chokshi

February 2, 1984

Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000

8402070447 XA

61pp

TECHNICAL EVALUATION REPORT

MASONRY WALL DESIGN

DUKE POWER COMPANY

OCONEE NUCLEAR STATION UNITS 1, 2, AND 3

NRC DOCKET NO. 50-269, 50-270, 50-287

NRC TAC NO. 42904, 42905, 42906

NRC CONTRACT NO. NRC-03-81-180

FRC PROJECT C5506

FRC ASSIGNMENT 6

FRC TASK 232

Prepared by

Franklin Research Center
20th and Race Streets
Philadelphia, PA 19103

Author: V. N. Con, A. K. Le

FRC Group Leader: V. N. Con

Prepared for

Nuclear Regulatory Commission
Washington, D.C. 20555

Lead NRC Engineer: N. Chokshi

February 2, 1984

Prepared by:	Reviewed by:	Approved by:
Vu Ngoc Con	A. K. Le	[signature]
Principal Author		Department Director
Date: 2-2-84	Date: 2-2-84	Date: 2-2-84

Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000

CONTENTS

FOREWORD

This Technical Evaluation Report was prepared by Franklin Research Center under a contract with the U.S. Nuclear Regulatory Commission (Office of Nuclear Reactor Regulation, Division of Operating Reactors) for technical assistance in support of NRC operating reactor licensing actions. The technical evaluation was conducted in accordance with criteria established by the NRC.

1. INTRODUCTION

1.1 PURPOSE OF REVIEW

The purpose of this review is to provide technical evaluations of licensee responses to IE Bulletin 80-11* [1] with respect to compliance with the Nuclear Regulatory Commission (NRC) masonry wall criteria. In addition, if a licensee has planned repair work on masonry walls, the planned methods and procedures are to be reviewed for acceptability.

1.2 GENERIC ISSUE BACKGROUND

In the course of conducting inspections at the Trojan Nuclear Plant, Portland General Electric Company determined that some concrete masonry walls did not have adequate structural strength. Further investigation indicated that the problem resulted from errors in engineering judgment, a lack of established procedures and procedural details, and inadequate design criteria. Because of the implication of similar deficiencies at other operating plants, the NRC issued IE Bulletin 80-11 on May 8, 1980.

IE Bulletin 80-11 required licensees to identify plant masonry walls and their intended functions. Licensees were also required to present reevaluation criteria for the masonry walls with the analyses to justify those criteria. If modifications were proposed, licensees were to state the methods and schedules for the modifications.

1.3 PLANT-SPECIFIC BACKGROUND

In response to IE Bulletin 80-11, Oconee Nuclear Station provided the NRC with letters and attachments describing the status of masonry walls at Oconee Nuclear Station [2, 3, 4]. On the basis of information supplied by the Licensee, the status of the masonry walls at this plant was reviewed. As a result of this review, a list of questions was sent to the Licensee [5], to which the Licensee has responded [6].

*Numbers in brackets indicate references, which are cited in Section 5.

A total of 299 masonry walls have been identified as safety-related walls at Oconee Nuclear Power Station [6]. The functions of the masonry walls are listed below:

1. partitions
2. in-fill panels
4. fire barriers
5. radiation barriers.

The walls are single- and multi-wythe (97% are single-wythe) and are constructed of hollow or grouted concrete blocks. All masonry walls are nonstructural. Typical arrangements of these walls are shown in Appendix B. Appendix C outlines the construction details.

Materials used in construction are as follows:

Concrete Blocks	ASTM C-90, $f_m' = 1000$ psi
Mortar	ASTM C-270, $m_o = 750$ psi
Joint Reinforcement	ASTM A-82, $f_y = 70{,}000$ psi.

A total of 82 walls have been qualified using the arching theory (further discussion of this theory is provided in Response 7 of Section 3.1). The remaining walls have been qualified by the working stress design method.

The Licensee reported that no modification was required. However, some modifications were instituted only to provide an added margin of safety for several walls that are generally taller than normal and/or experience greater seismic acceleration than other walls in the plant.

The Licensee has relied upon the arching action technique to qualify some masonry walls. NRC, FRC, and FRC's consultants (Drs. H. Harris and A. Hamid of Drexel University) have conducted an exhaustive review of this subject based on submittals provided by the Licensee and published literature and 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 and FRC's staff and consultants could explain why the applicability of arching theory of masonry walls in nuclear power plants is questionable [7]. In a subsequent meeting on January 20, 1983, consultants of utility companies presented their rebuttals [8] and requested that they be treated on a plant-by-plant basis.

In accordance with the above request, NRC, FRC, and consultants visited Oconee Nuclear Power Station on May 25-27, 1983 to examine the field conditions of unreinforced masonry walls in the plant and to gain first-hand knowledge of how arching theory is applied to actual walls. Extensive review and discussion took place during this visit, with particular emphasis on the arching theory. Further discussion on this subject is provided in Section 3.1. As a result of this audit meeting, a list of action items was sent to the Licensee [9], to which the Licensee has responded [10, 11].

2. REVIEW CRITERIA

The basic documents used for guidance in this review were the criteria developed by the Structural and Geotechnical Engineering Branch (SGEB) of the NRC (included as Appendix A to this report), the Uniform Building Code [12], and ACI 531-79 [13].

The materials, testing, analysis, design, construction, and inspection of safety-related concrete masonry walls should conform to the SGEB criteria. For operating plants, the loads and load combinations for qualifying the masonry walls should conform to the appropriate specifications in the Final Safety Analysis Report (FSAR) for the plant. Allowable stresses are specified in Reference 13, and the appropriate increase factors for abnormal and extreme environmental loads are given in the SGEB criteria (Appendix A).

3. TECHNICAL EVALUATION

This technical evaluation is based on the Licensee's earlier submittals [2, 3, 4], and subsequent responses [6, 10, 11] to the NRC requests for additional information [5, 9]. The Licensee's criteria were evaluated with regard to design and analysis methods, loads and load combinations, allowable stresses, construction specifications, materials, and any relevant test data.

3.1 EVALUATION OF LICENSEE'S CRITERIA

The Licensee has evaluated the masonry walls using the following criteria:

- Allowable stresses were based on ACI 531-79 [13].
- Both the working stress design method and arching theory were used to qualify the walls. Of 299 safety-related walls, 82 have been qualified by arching theory.
- Loads and load combinations were those specified in the plant FSAR.
- A critical damping value of 2% was used for both operating basis earthquake (OBE) and safe shutdown earthquake (SSE).
- A test program was conducted to verify the assumed values used for masonry and mortar strength.
- The typical analytical procedure is summarized below:
  - Determine wall boundary conditions.
  - Calculate the wall's fundamental frequency using either a one-way or two-way action assumption.
  - Obtain inertial loading from the floor response spectra.
  - Compare computed stresses with the allowable values in ACI 531-79.

The Licensee's criteria [3] and responses [6, 10, 11] have been reviewed by FRC and its consultants. In addition, an audit visit was conducted by NRC, FRC, and FRC's consultants on May 25-27, 1983 to gain first-hand knowledge about the actual walls' conditions in the plant and how their conditions are reflected in the analysis. During this audit, each item of the Licensee's responses dated June 15, 1982 [6] was reviewed. The applicability of arching theory was discussed. Several key calculations were also reviewed. As a result of this audit a list of action items was sent to the Licensee [9] to which the Licensee has responded [10, 11].

Following is the review of the Licensee's responses [6, 10, 11]. [Note: questions arising from the audit meeting on May 25-27, 1983 [9] will be identified.]

Question 1

In Reference 3, the Licensee states that the final reevaluation report will include the detailed justification for the criteria used. Provide this detailed justification for review.

Response 1

It should be noted that in Reference 3, the Licensee only briefly stated the design criteria without providing detailed justification for each item in the design criteria. In this response, the Licensee provided the appropriate detailed justification for the criteria used, which is summarized below:

Governing Code: ACI 531-79 was selected as the governing code.

Loads and Load Combinations: Design loadings for masonry walls at the Oconee plant are those specified in the Oconee Final Safety Analysis Report, Section 5.7.

Materials: The properties of the mortar were assumed to be the lowest grade mortar permitted under the governing code. In addition, a test program was conducted to verify the assigned values for material properties. Further discussion of the test results is given in Response 8.

Analysis and Design: Steps taken in the analysis of the masonry walls are briefly described below:

- Appropriate boundary conditions are chosen dependent upon the wall configuration.

- The natural frequency of the wall is determined by considering either one-way or two-way action.

- Inertial loading is specified from the floor response spectrum.

- Seismic inertial and attachment loads are applied to the wall and the resulting distribution of shear and bending moment is calculated and checked against the code allowables.

The Licensee's justification for the design criteria is technically adequate and satisfactory.

Question 2

Provide a table showing the actual stresses and the allowable stresses of analyzed walls.

Response 2

The Licensee provided a table (see Appendix E) illustrating the resultant stresses along with the appropriate code allowables for all safety-related masonry walls. According to this table, 41 walls have been qualified relying on an increase factor greater than 1.3 for tension normal to bed joint (varies between 1.47 and 1.67). Further discussion of the increase factor will be given in Response 10.

Other than the increase factor for tension normal to the bed joint, all stresses are found to be satisfactory and in compliance with SGEB criteria.

Question 3

With reference to Section 5.1.2 of Reference 3, justify the assumed 12 psi allowable shear stress in collar joints. Also provide any existing test data and discuss the applicability to the Oconee masonry walls.

Response 3

The Licensee stated that the collar joint shear stress allowables are not addressed in the governing code and that 12 psi is considered to be a conservative estimate. During an audit meeting on May 25-27, 1983, several calculations were checked, and the resulting collar joint shear stress was much less than 12 psi. (It can be seen from Appendix E that the maximum calculated shear stress is 2.25 psi.) Furthermore, as specified by other plants, the test results obtained from a number of 3/8-in collar joints at the Trojan Nuclear Plant indicated that 12 psi is an appropriate value. In view of this, the Licensee's response is satisfactory and in compliance with the SGEB criteria.

Question 4 (Audit meeting, May 25-27, 1983, Reference 9)

With reference to Section 6.1.4 of Reference 3, provide justification for the boundary conditions and indicate whether adequate shear transfer mechanisms exist at supported boundaries. [Note: the concern is whether the mortar joint alone at the boundary is able to transfer shear.]

Response 4

The Licensee stated that masonry walls were surveyed and the boundary conditions were determined. The selected boundary conditions are typically simple and/or free. Furthermore, as a result of the audit meeting on May 25-27, 1983, the Licensee provided the computation of the boundary shear stress in Reference 11. The worst-case maximum shear stress is 23.7 psi as compared to the 58.1 psi allowable. Typically, the calculated shear stress is less than 15 psi. It should be noted that the boundary shear stress was calculated based on an assumed value of f_m' of 1000 psi, which is considerably smaller than that obtained on the basis of a test of masonry samples removed from the Oconee plant (see Response 8 for further details). In addition, the assumed thickness for the face shell was 1 1/4 in, which results in a conservative area for the fire-rated blocks which have a minimum face shell thickness of 1 3/4 in.

Based on the information provided by the Licensee, it is judged that the Licensee's response is technically adequate and in compliance with the SGEB criteria.

Question 5

With reference to Section 6.1.2 of Reference 3, indicate the number of modes considered and provide detailed modal anlysis.

Response 5

With regard to the effects of higher modes of vibration, the Licensee provided a typical calculation illustrating the negligible contribution of higher modes to the response of the wall. The examined wall is 18 ft long and 14 ft tall, simply supported on all sides. A modal analysis was performed using STRUDL DYNAL program. The results of the first three modes extracted from the solution indicated that the first mode of vibration contributed close to 100% of the total response.

For all practical purposes, the first mode should adequately cover the total responses of the walls. It has been found, in many cases of other plants, that the first mode usually contributes 95% or more to the total responses. Therefore, it can be concluded that the Licensee's approach is satisfactory and in compliance with the SGEB criteria.

Question 6 (Audit meeting, May 25-27, 1983, Reference 9)

> With reference to page 5 of Reference 4, justify the use of average floor spectra instead of the envelope for seismic analysis.

Response 6

To justify the use of average response spectra between the floors, the Licensee indicated that a value of 2% critical damping used for both OBE and SSE should compensate for unconservative estimates of acceleration based on the average response spectra.

The Licensee has reviewed all applicable spectra, and the results show that, for 2% critical damping, the typical reduction in peak acceleration is between 12% to 15% when average spectra are used and the maximum reduction was 26%. However, a review of response spectra for 5% damping (note that SGEB criteria allow up to 7%, but the Oconee plant does not have response spectra higher than 5%) shows that increasing the damping value from 2% to 5% reduces the peak acceleration by approximately 35% in all cases. If response spectra for 7% damping were available, further reduction in peak acceleration would be expected. Since low damping was used in the analysis and based on the results given by the Licensee, it is concluded the Licensee's assessment is technically adequate and meets the intent of the SGEB criteria.

Question 7 (Audit meeting, May 25-27, 1983, Reference 9)

> In Reference 3, the Licensee indicates that the arching theory has been used to qualify some masonry walls. The NRC, at present, does not accept the application of this technique to masonry walls in nuclear power plants in the absence of conclusive evidence to justify this application. The Licensee is requested to indicate the number of walls which have been analyzed by this technique and to provide resulting stresses and displacements.
>
> The following areas need technical verification before any conclusion can be made about the arching theory:
>
> o Explain how the arching theory handles cyclic loading, especially when the load is reversed.
>
> o Provide justification and test data (if available) to validate the applicability of the arching theory to the masonry structures at Oconee Nuclear Power Station, with particular emphasis on the following areas:
>
> a. nature of the load,
> b. boundary conditions,
> c. material strength, and
> d. size of the test wall.
>
> o If hinges are formed in the walls, the capability of the structures to resist in-plane shear force would be diminished, and shear failure might take place. This in-plane shear force would also reduce the out-of-plane stiffness. Explain how the effect of this phenomenon can be accurately determined.

Response 7

The Licensee indicated that arching analysis was employed for walls well confined in a relatively stiff reinforced concrete frame. With regard to technical verification, the Licensee referred to tests performed by Gulkan et al. [14, 15, 16] (usually referred to as the Berkeley tests) and McDowell et al. [17] and claimed that the loading types in [14, 15, 16] are very similar to actual seismic loading. The Licensee also stated that, in the Berkeley tests, it was observed that arching action did occur in some test panels.

NRC staff, FRC, and FRC's consultants have conducted an exhaustive review of available information on this subject and of licensees' responses to determine the technical adequacy of the methodology. In addition, the results of the audit meeting with Oconee personnel on May 25-27, 1983 indicated that there are no test data available which are directly applicable to the walls in the plant.

According to Attachment 1 of Reference 6 the following walls have been qualified by arching action:

0457 0463 0464 0481 0507 0005 0006 0019 0020 0041 0049 0050 0062 0063 0064 0079 0080 0081 0091 0093 0094 0104 0108 0109 0123 1001 1004 1005 1201 1205 1211 1216 1400 1414 1231 1232 1233 1236 1237 1238 1239 1243 1245 1248 1255 1261 1270 1297 1303 1306 1315 1317F 1321F 0001F 0002F 0202 0223 0224 0228 0232 0269 1100 1101 1159 0600 0615 0628 0809 0811 0836 0838 0848F 0719 0061 0062.

In addition, Reference 10 indicated that wall 1215 was reanalyzed by arching action and six more unidentified walls were also reanalyzed by arching action. In all, 82 walls have been qualified by arching action.

FRC and its consultants have issued their evaluation and assessment of the use of arching action in masonry walls [7, 18]. The Structural and Geotechnical Engineering Branch (SGEB) has issued a position statement regarding this subject which will be addressed in their Safety Evaluation Report.

Question 8

> Reference 3 indicated that a test program was conducted to determine the prism strength and mortar strength and that test results confirmed the chosen values. The Licensee is requested to submit the test results (i.e., test procedures, results of individual block strength, and prism strength).

Response 8

The test program was conducted by the Licensee to confirm masonry and mortar strength. The tests were conducted in accordance with ASTM C140 for the masonry units and ASTM E447 for the masonry prisms. Samples were removed from the walls for testing. Test results are given in Tables 1 and 2.

Test results in Table 2 show that block type I has the lowest strength with a minimum compressive strength of 1450 psi and a maximum of 2040 psi. Based on Section 2404 of the Uniform Building Code [12], the compressive strength can be deduced from the test results and could be 1812 psi (125% of the minimum test value), which is significantly higher than the assumed value of f_m' = 1000 psi used in the analysis. With respect to the mortar strength, the results of the individual block tests shown in Table 1 and of the prism tests shown in Table 2 evidently indicate that the mortar strength is likely to be higher than the assumed value of 750 psi. Based on this information, it can be concluded that the assumed values for masonry and mortar strength used in the analysis are conservative and in compliance with the SGEB criteria.

Question 9

With reference to Section 5.2.1(b) of Reference 3, indicate whether the 5% damping is applied to the operating basis earthquake (OBE) as well as the safe shutdown earthquake (SSE). If 5% damping is applied to the OBE, justify this deviation from the SGEB criteria which specify 4% damping for the OBE.

Response 9

The Licensee stated that a 5% damping value was not applied to OBE. A 2% damping value was used for both OBE and SSE. Further details on this subject were given in Response 6.

The response is technically adequate and in compliance with the SGEB criteria.

Question 10

With reference to Sections 5.1.1 and 5.1.5 of Reference 3, justify the proposed 67% increase in allowable stresses for the SSE, thermal effects, and displacement loads. For factored loads, the SGEB criteria suggest 50% increase in allowable stresses for the reinforcement shear and masonry tension parallel to the bed joint and 30% increase in allowable stresses for masonry shear and tension normal to the bed joint.

Table 1. Results of Individual Block Tests

Block Type*	Compressive Strength Net Area (psi)
I	2980
I	3110
I	2930
I	2280
I	2730
I	3740
I	3630
I	3060
I	3070
I	3820
II	3420
II	3640
III	2510
III	3290
III	3120
III	3230
IV	5590
IV	5020
IV	4150
IV	4480
IV	4500
IV	3980
IV	4250
IV	4600
IV	4470

*Block types are as follows:
Type I: Non-fire-rated Block
Type II: Fire-rated Block
Type III: Fire-rated Block
Type IV: Fire-rated Block

Table 2. Results of Prism Tests

Block Type*	Compressive Strength Net Area (psi)
I	2040
I	1930
I	2030
I	1450
II	1540
III	2000
III	1800
IV	2910
IV	2980
IV	2440

*Block types are as follows:
Type I: Non-fire-rated Block
Type II: Fire-rated Block
Type III: Fire-rated Block
Type IV: Fire-rated Block

Response 10

Review of Appendix E indicated that the only increase factor greater than the SGEB factor is tension normal to bed joint. As previously discussed in Response 2, for tension normal to the bed joint, an increase factor which varies between 1.47 and 1.67 (as opposed to 1.3 by the SGEB criteria) has been used to qualify 41 masonry walls. However, the Licensee stated that the test results illustrated that the chosen values for the mortar and prism strength are conservative. Information regarding the test results was given in Response 8. By correlating the in-place properties determined by tests with the chosen values, the actual increase in allowable stresses is much less than the 1.67 assumed increase factor. In fact, if the test values were used, the actual increase factor would be in compliance with the SGEB criteria. In addition, a critical damping of 2% (as opposed to 7% as specified in the SGEB criteria) was used, which should result in a conservative estimate for stress calculation. Because of this, it is concluded that the Licensee's assumption meets the intent of the SGEB criteria.

Question 11

With reference to Section 5.1.3 of Reference 3, justify the formula used for allowable stress in grout core tension. [Note: in Reference 3 the Licensee specified $2.5\sqrt{f'c}$ as the allowable stress in grout core tension].

Response 11

With respect to the formula $2.5\sqrt{f'c}$ used for allowable stress in grout core tension, the Licensee referred to a value of $7.5\sqrt{f'c}$ for the modulus of rupture of concrete given in ACI 318-71, and a factor of safety of 3 is applied to obtain $2.5\sqrt{f'c}$. Because the formula is for plain concrete, it is judged that the value used by the Licensee is adequate and satisfactory.

Question 12

Provide details of proposed wall modifications with sample drawings and explain, using sample calculations, how these modifications will rectify the wall deficiencies. Also, provide a status report for the proposed wall modifications.

Response 12

The Licensee's response indicated that the modifications have been instituted to provide an added margin of safety for several of the walls that are generally taller than normal and/or experience greater seismic acceleration and that there are no modifications to bring the walls' responses within the Licensee's acceptance criteria.

The Licensee has provided a typical modification in which steel beams have been placed horizontally to reduce the vertical span and hence reduce the bending moment of the wall. (See Appendix D for a schematic representation of wall modification.)

Since no actual modification was needed to bring the wall within the design allowable, it is concluded that the concern has been resolved satisfactorily.

Question 13 (Audit meeting, May 25-27, 1983, Reference 9)

> Assess the influence of hairline cracks observed in two wall panels (-0633, -1215) on the wall qualification calculations.

Response 13

A vertical crack in wall 0633 was observed at the boundary of the concrete column and masonry wall. This wall was previously qualified by two-way flexure. Subsequent to the original qualification, a cable tray support attachment was removed from the wall. A reanalysis of the wall considering one-way vertical span was done, and the calculated stress level was within the SGEB acceptance criteria.

Diagonal hairline cracks were observed in wall 1215. This wall was originally qualified by two-way flexure. The wall has been reanalyzed and qualified by arching action. Discussion on arching action was given in Response 7.

The Licensee's response is considered adequate and satisfactory. However, with regard to arching action, it can be seen from Response 7 that wall 1215 is not acceptable. This issue will be addressed by the NRC in their Safety Evaluation Report.

<u>Question 14</u> (Audit meeting, May 25-27, 1983, Reference 9)

Conduct a field surveillance of safety-related masonry walls at Oconee to identify existing cracks so that their influence can be assessed.

<u>Response 14</u>

The Licensee conducted the requested field surveillance to assess the influence of cracks on the masonry walls. There are 62 walls with hairline cracks (including the two walls in Response 13). The 62 walls were originally qualified as follows:

21 walls qualified by one-way flexure
26 walls qualified by two-way flexure
15 walls qualified by arching action.

To assess the influence of cracks, the cracked area was considered ineffective in resisting tension in the reanalysis. The results of the reevaluation showed that four walls previously qualified by two-way flexure are now qualified by arching action and one wall previously qualified by one-way flexure is now qualified by arching action. The remaining walls were qualified by the same techniques previously used. The results are summarized below:

21 walls qualified by one-way flexure
20 walls qualified by two-way flexure
21 walls qualified by arching action.

Other than walls qualified by arching action (see further discussion in Response 7), the remaining walls are considered to be structurally adequate and in compliance with the SGEB criteria.

<u>Question 15</u> (Audit meeting, May 25-27, 1983, Reference 9)

Justify neglecting out-of-plane drift for a generic panel by using a sample calculation.

<u>Response 15</u>

With respect to the effect of out-of-plane drift effect, the Licensee provided a sample calculation to justify neglecting its effect. A generic panel was selected for this investigation. Both simple-support and fixed-end conditions were assumed, and the results illustrated that the tensile stress in the pinned walls is greater than in the fixed-end wall. (The maximum bending stress in the fixed-end case is 10.3 psi, as compared to 11.25 psi for the pinned-end case.)

From the information above, it is judged that the Licensee is justified in neglecting the out-of-plane drift effect.

Question 16 (Audit meeting, May 25-27, 1983, Reference 9)

> Check walls qualified on the basis of dur-o-wall joint reinforcing to determine if allowable masonry stresses are satisfied neglecting such joint reinforcing.

Response 16

The Licensee stated that, in the process of upgrading certain masonry walls to achieve added margin of safety, seven masonry walls were replaced. The new walls were constructed of hollow core masonry with M [illegible] mortar. C10x15.3 channels were anchored to the concrete columns and W[illegible] beams were installed vertically between the supporting concrete frame; 3/[illegible] heavy duty joint reinforcement was placed in every horizontal bed joint.

A reanalysis was performed for these walls neglecting the effects of the joint reinforcement. The first of these procedures assumes that the wall spans horizontally between the steel members. All masonry walls were found to be acceptable by the SGEB criteria for horizontal bending stresses when the Dur-O-Wal joint reinforcement is neglected.

In the second method, the wall was modeled by the finite element scheme. This method includes the effect of vertical span bending being induced in the wall by the deflection of the steel beams. Again, the results showed that, when neglecting the effect of the Dur-O-Wal joint reinforcement, both horizontal and vertical bending stresses satisfied the SGEB criteria.

Therefore, it is concluded that these walls are structurally adequate and in compliance with the SGEB criteria.

Question 17 (Audit meeting, May 25-27, 1983, Reference 9)

Provide a detailed discussion with regard to the adequacy of the masonry missile shield in the reactor building as discussed in the May 27 meeting.

Response 17

With respect to missile impact, the Licensee identified two walls as being subject to possible missile strike. The Licensee also provided five types of missiles with highest calculated penetration, as follows:

Missile 1: Core flood line, missile class III, 14-in CV bonnet and assembly

Missile 2: Core flood line, missile class III, 14-in PO valve bonnet and assembly

Missile 3: RV outlet line to LP system, missile class III, 10-in EMO valve bonnet and assembly

Missile 4: Primary pump seal water return to HP system, missile class III, 3-in EMO valve bonnet and assembly

Missile 5: Letdown cooler inlet and outlet lines, missile class III, 1-1/2-in EMO valve bonnet and assembly.

All of the missiles are from piping systems. The analysis for missile impact follows the method presented in the Oconee FSAR (Section 3.5, Missile Protection). According to this method, the maximum penetration calculated for Missile 1 above is 1.38 ft and for Missiles 2 through 5 is between 1.28 ft and 1.37 ft. Hence, they do not fully penetrate the missile shields, whose thickness is about 5 ft.

Since the block wall in this case is solid and only 3.4 ft high and the thickness of the missile shield is much greater than the penetration depth, the Licensee's response is considered to be adequate and satisfactory.

3.2 EVALUATION OF LICENSEE'S APPROACH TO WALL MODIFICATIONS

As previously indicated in Section 3.1, all walls have been qualified either by the working stress design method or by arching action. No actual modification was required. However, the Licensee instituted some modifications to provide an added margin of safety for several walls that are generally taller than normal and/or experience greater seismic acceleration.

4. CONCLUSIONS

A detailed study was conducted to provide a technical evaluation of the masonry walls at the Oconee Nuclear Power Station. Based on the SGEB criteria, the Licensee's submittals and additional information provided by the Licensee have been reviewed and the following conclusions have been reached.

The Licensee's criteria have been found technically adequate and in compliance with the SGEB criteria except for the following areas:

- Higher stress increase factors were used for tension normal to the bed joint (1.67 as opposed to 1.3 by the SGEB criteria) to qualify 41 masonry walls (see Response 10 for further details). However, a test program was conducted, and the test results illustrated that, if the masonry and mortar strength based on the test results were used, the actual increase factor would be in compliance with the SGEB criteria. In addition, a critical damping of 2% (as opposed to 7% as specified in the SGEB criteria) was used, which should result in a conservative estimate for stress calculation. Therefore, it can be concluded that the Licensee's increase factors are technically adequate and meet the intent of the SGEB criteria.

- With regard to arching theory, the following walls are affected: 0457, 0463, 0464, 0481, 0507, 0005, 0006, 0019, 0020, 0041, 0049, 0050, 0062, 0063, 0064, 0079, 0080, 0081, 0091, 0093, 0094, 0104, 0108, 0109, 0123, 1001, 1004, 1005, 1201, 1205, 1211, 1216, 1400, 1414, 1231, 1232, 1233, 1236, 1237, 1238, 1239, 1243, 1245, 1248, 1255, 1261, 1270, 1297, 1303, 1306, 1315, 1317F, 1321F, 0001F, 0002F, 0202, 0223, 0224, 0228, 0232, 0269, 1100, 1101, 1159, 0600, 0615, 0628, 0809, 0811, 0836, 0838, 0848F, 0719, 0061, 0062, 1215, and six unidentified walls mentioned in Response 7. As previously discussed in Response 7, the NRC does not accept the use of arching action in qualifying the walls, and this issue will be addressed in its Safety Evaluation Report.

5. REFERENCES

1. IE Bulletin 80-11
Masonry Wall Design
NRC
May 8, 1980

2. W. O. Parker
Letter to J. P. O'Reilly, NRC
Subject: Response to IE Bulletin 80-11, Masonry Wall Design
Oconee Nuclear Station
July 7, 1980

3. W. O. Parker
Letter to H. R. Denton, NRC
Subject: Response to IE Bulletin 80-11, Masonry Wall Design
Oconee Nuclear Station
December 29, 1981

4. W. O. Parker
Letter to H. R. Denton, NRC
Subject: Response to IE Bulletin 80-11, Masonry Wall Design
Oconee Nuclear Station
July 13, 1981

5. J. F. Stolz (NRC)
Letter to W. O. Parker (Oconee Nuclear Station)
Subject: Request for Additional Information Regarding Masonry Wall Design (IE Bulletin 80-11)
March 15, 1982

6. W. O. Parker
Letter to H. R. Denton (NRC)
Subject: Submittal of Information Regarding Masonry Wall Design (IE Bulletin 80-11), Oconee Nuclear Station
June 15, 1982

7. H. G. Harris and A. A. Hamid, "Applicability of Arching Theory to Unreinforced Block Masonry Walls Under Earthquake Loading," Department of Civil Engineering, Drexel University, August 1982

8. Computech Engineering Services, Inc., URS/Blume and Associates, and Bechtel Power Corporation, "Rebuttal to 'Applicability of Arching Theory to Unreinforced Block Masonry Walls Under Earthquake Loading' by Harris and Hamid," January 1983

9. J. F. Stolz (NRC)
Letter to H. B. Tucker (Oconee Nuclear Station)
Subject: Request for Additional Information Regarding Masonry Wall Design (IE Bulletin 80-11)
July 20, 1983

10. H. B. Tucker
Letter to H. R. Denton (NRC)
Subject: Submittal of Information Regarding Masonry Wall Design (IE Bulletin 80-11)
Oconee Nuclear Station, September 7, 1983

11. H. B. Tucker
Letter to H. R. Denton (NRC)
Subject: Submittal of Information Regarding Masonry Wall Design (IE Bulletin 80-11)
Oconee Nuclear Station, October 20, 1983

12. Uniform Building Code
International Conference of Building Officials, 1979

13. ACI 531-79 and ACI 531-R-79
Building Code Requirements for Concrete Masonry Structures
American Concrete Institute, 1979

14. P. Gulkan, R. L. Mayes, and R. W. Clough, "Shaking Table Study of Single Story Masonry Houses, Volume 1 - Test Structures 3 and 4," EERC Report No. 79-22, 1979

15. P. Gulkan, R. L. Mayes, and R. W. Clough, "Shaking Table Study of Single Story Masonry Houses, Volume 2 - Test Structures 3 and 4," EERC Report No. 79-23, 1979

16. R. W. Clough, R. L. Mayes, and P. Gulkan, "Shaking Table Study of Single Story Masonry Houses, Volume 3 - Summary Conclusions and Recommendations," EERC Report No. 79-24, 1979

17. E. L. McDowell, K. E. McKee, and E. Sevin, "Arching Action Theory of Masonry Walls," Paper No. 915, Journal of the Structural Division, ASCE, ST2, March 1956

18. A. A. Hamid, H. G. Harris, and V. Con, "Evaluation of Arching Theory in Unreinforced Masonry Walls in Nuclear Power Plants," Franklin Research Center, June 1983

APPENDIX A

SGEB CRITERIA FOR SAFETY-RELATED MASONRY WALL EVALUATION
(DEVELOPED BY THE STRUCTURAL AND GEOTECHNICAL ENGINEERING BRANCH
[SGEB] OF THE NRC)
July 1981

Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila. Pa. 19103 (215) 448-1000

CONTENTS

1. General Requirements

The materials, testing, analysis, design, construction, and inspection related to the design and construction of safety-related concrete masonry walls should conform to the applicable requirements contained in Uniform Building Code - 1979, unless specified otherwise, by the provisions in this criteria.

The use of other standards or codes, such as ACI-531, ATC-3, or NCMA, is also acceptable. However, when the provisions of these codes are less conservative than the corresponding provisions of the criteria, their use should be justified on a case-by-case basis.

In new construction, no unreinforced masonry walls will be permitted. For operating plants, existing unreinforced walls will be evaluated by the provisions of these criteria. Plants which are applying for an operating license and which have already built unreinforced masonry walls will be evaluated on a case-by-case basis.

2. Loads and Load Combinations

The loads and load combinations shall include consideration of normal loads, severe environmental loads, extreme environmental loads, and abnormal loads. Specifically, for operating plants, the load combinations provided in the plant's FSAR shall govern. For operating license applications, the following load combinations shall apply (for definition of load terms, see SRP Section 3.8.4II-3).

(a) Service Load Conditions

(1) D + L

(2) D + L + E

(3) D + L + W

If thermal stresses due to T_o and R_o are present, they should be included in the above combinations as follows:

(1a) $D + L + T_o + R_o$

(2a) $D + L + T_o + R_o + E$

(3a) $D + L + T_o + R_o + W$

Check load combination for controlling condition for maximum 'L' and for no 'L'.

(b) Extreme Environmental, Abnormal, Abnormal/Severe Environmental, and Abnormal/Extreme Environmental Conditions

(4) $D + L + T_o + R_o + E$

(5) $D + L + T_o + R_o + W_t$

(6) $D + L + T_a + R_a + 1.5\ P_a$

(7) $D + L + T_a + R_a + 1.25\ P_a + 1.0\ (Y_r + Y_j + Y_m) + 1.25\ E$

(8) $D + L + T_a + R_a + 1.0\ P_a + 1.0\ (Y_r + Y_j + Y_m) + 1.0\ E'$

In combinations (6), (7), and (8) the maximum values of P_a, T_a, R_a, Y_j, Y_r, and Y_m, including an appropriate dynamic load factor, should be used unless a time-history analysis is performed to justify otherwise. Combinations (5), (7), and (8) and the corresponding structural acceptance criteria should be satisfied first without the tornado missile load in (5) and without Y_r, Y_j, and Y_m in (7) and (8). When considering these loads, local section strength capacities may be exceeded under these concentrated loads, provided there will be no loss of function of any safety-related system.

Both cases of L having its full value or being completely absent should be checked.

3. Allowable Stresses

Allowable stresses provided in ACI-531-79, as supplemented by the following modifications/exceptions, shall apply.

(a) When wind or seismic loads (OBE) are considered in the loading combinations, no increase in the allowable stresses is permitted.

(b) Use of allowable stresses corresponding to special inspection category shall be substantiated by demonstration of compliance with the inspection requirements of the SEB criteria.

(c) When tension perpendicular to bed joints is used in qualifying the unreinforced masonry walls, the allowable value will be justified by test program or other means pertinent to the plant and loading conditions. For reinforced masonry walls, all the tensile stresses will be resisted by reinforcement.

(d) For load conditions which represent extreme environmental, abnormal, abnormal/severe environmental, and abnormal/extreme environmental conditions, the allowable working stress may be multiplied by the factors shown in the following table:

Type of Stress	Factor
Axial or Flexural Compression[1]	2.5
Bearing	2.5
Reinforcement stress except shear	2.0 but not to exceed 0.9 fy
Shear reinforcement and/or bolts	1.5
Masonry tension parallel to bed joint	1.5
Shear carried by masonry	1.3
Masonry tension perpendicular to bed joint	
for reinforced masonry	0
for unreinforced masonry[2]	1.3

Notes

(1) When anchor bolts are used, design should prevent facial spalling of masonry unit.

(2) See 3(c).

4. Design and Analysis Considerations

(a) The analysis should follow established principles of engineering mechanics and take into account sound engineering practices.

(b) Assumptions and modeling techniques used shall give proper considerations to boundary conditions, cracking of sections, if any, and the dynamic behavior of masonry walls.

(c) Damping values to be used for dynamic analysis shall be those for reinforced concrete given in Regulatory Guide 1.61.

(d) In general, for operating plants, the seismic analysis and Category I structural requirements of FSAR shall apply. For other plants, corresponding SRP requirements shall apply. The seismic analysis shall account for the variations and uncertainties in mass, materials, and other pertinent parameters used.

(e) The analysis should consider both in-plane and out-of-plane loads.

(f) Interstory drift effects should be considered.

(g) In new construction, grout in concrete masonry walls, whenever used, shall be compacted by vibration.

(h) For masonry shear walls, the minimum reinforcement requirements of ACI-531 shall apply.

(i) Special constructions (e.g., multiwythe, composite) or other items not covered by the code shall be reviewed on a case-by-case basis for their acceptance.

(j) Licensees or applicants shall submit QA/QC information, if available, for staff's review.

In the event QA/QC information is not available, a field survey and a test program reviewed and approved by the staff shall be implemented to ascertain the conformance of masonry construction to design drawings and specifications (e.g., rebar and grouting).

(k) For masonry walls requiring protection from spalling and scabbing due to accident pipe reaction (Y_r), jet impingement (Y_j), and missile impact (Y_m), the requirements similar to those of SRP 3.5.3 shall apply. However, actual review will be conducted on a case-by-case basis.

5. References

(a) Uniform Building Code - 1979 Edition.

(b) Building Code Requirements for Concrete Masonry Structures ACI-531-79 and Commentary ACI-531R-79.

(c) Tentative Provisions for the Development of Seismic Regulations for Buildings - Applied Technology Council ATC 3-06.

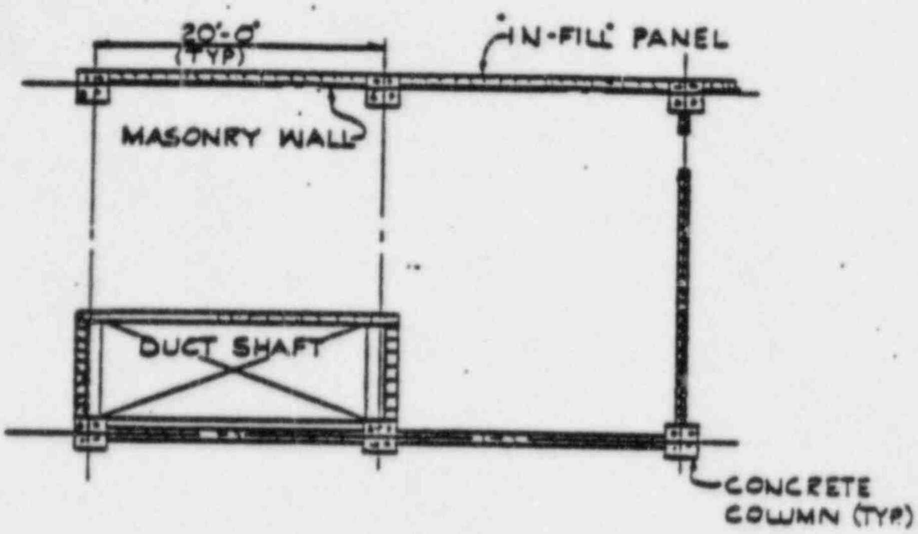
(d) Specification for the Design and Construction of Load-Bearing Concrete Masonry - NCMA August, 1979.

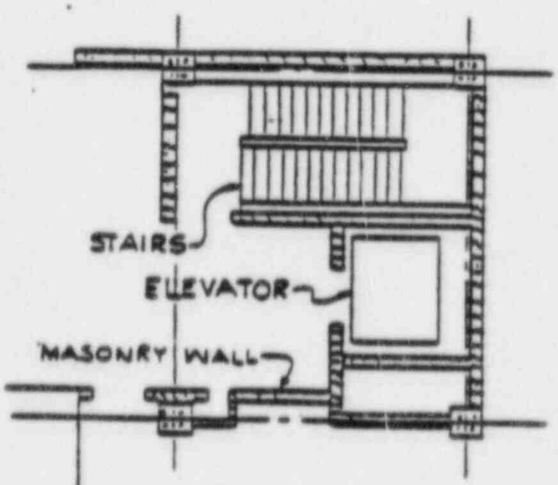
(e) Trojan Nuclear Plant Concrete Masonry Design Criteria Safety Evaluation Report Supplement - November, 1980.

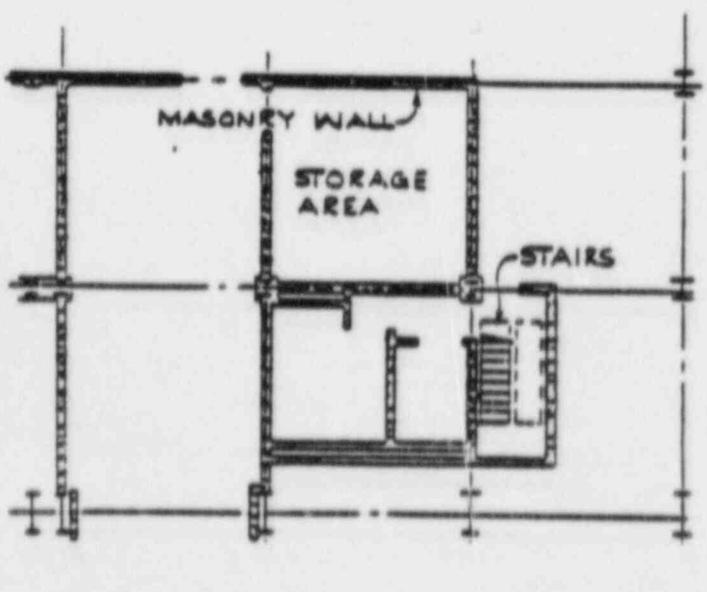
APPENDIX B

TYPICAL ARRANGEMENT OF MASONRY WALLS

Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila. Pa. 19103 (215) 448-1000


20'-0"
(TYP)
IN-FILL PANEL
MASONRY WALL
DUCT SHAFT
CONCRETE
COLUMN (TYP)

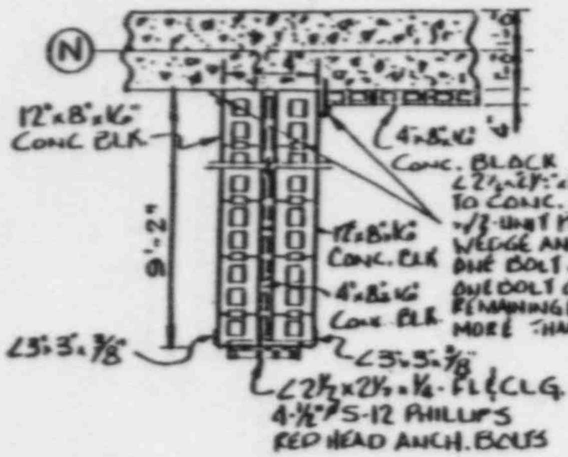

STAIRS
ELEVATOR
MASONRY WALL


MASONRY WALL
STORAGE
AREA
STAIRS

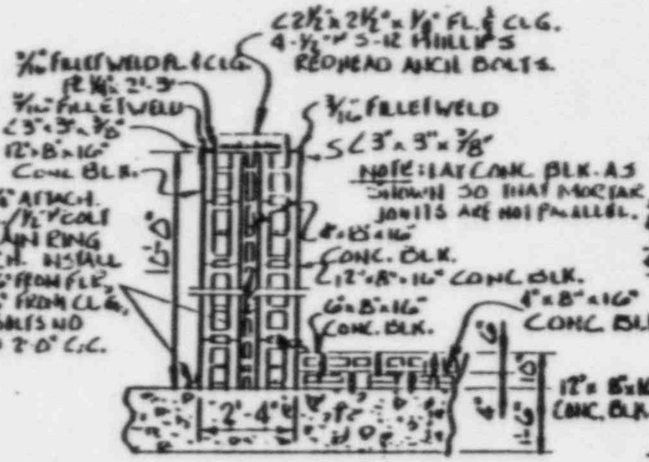
APPENDIX C

TYPICAL WALL DETAILS

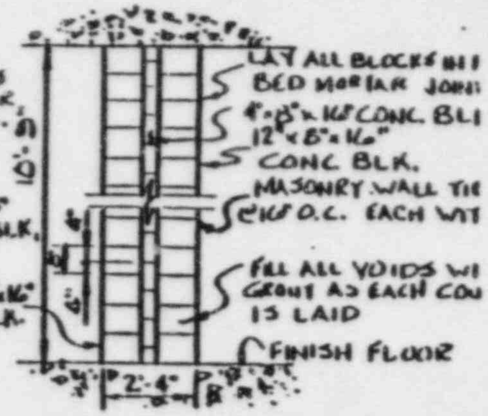
Franklin Research Center
A Division of The Franklin Institute
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000



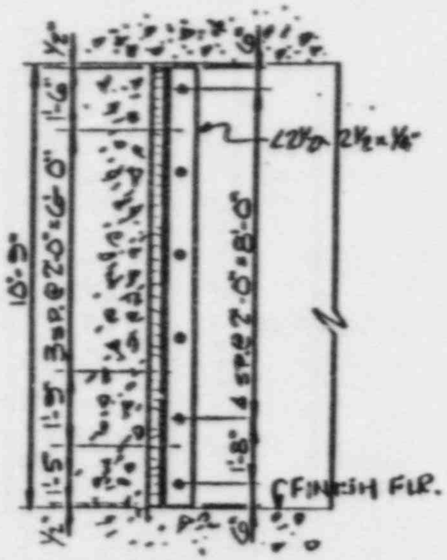
HORIZONTAL WALL SECTION



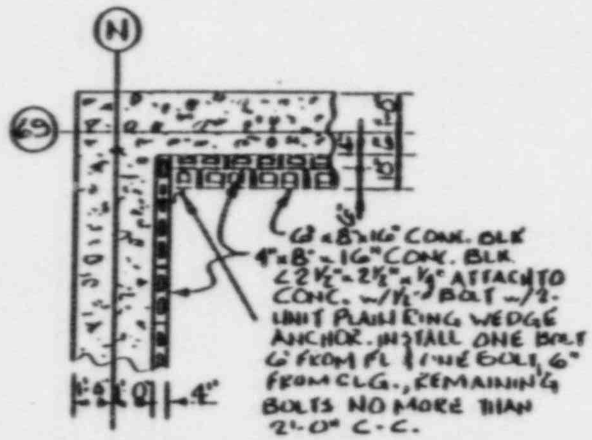
HORIZONTAL WALL SECTION



VERTICAL WALL SECTION



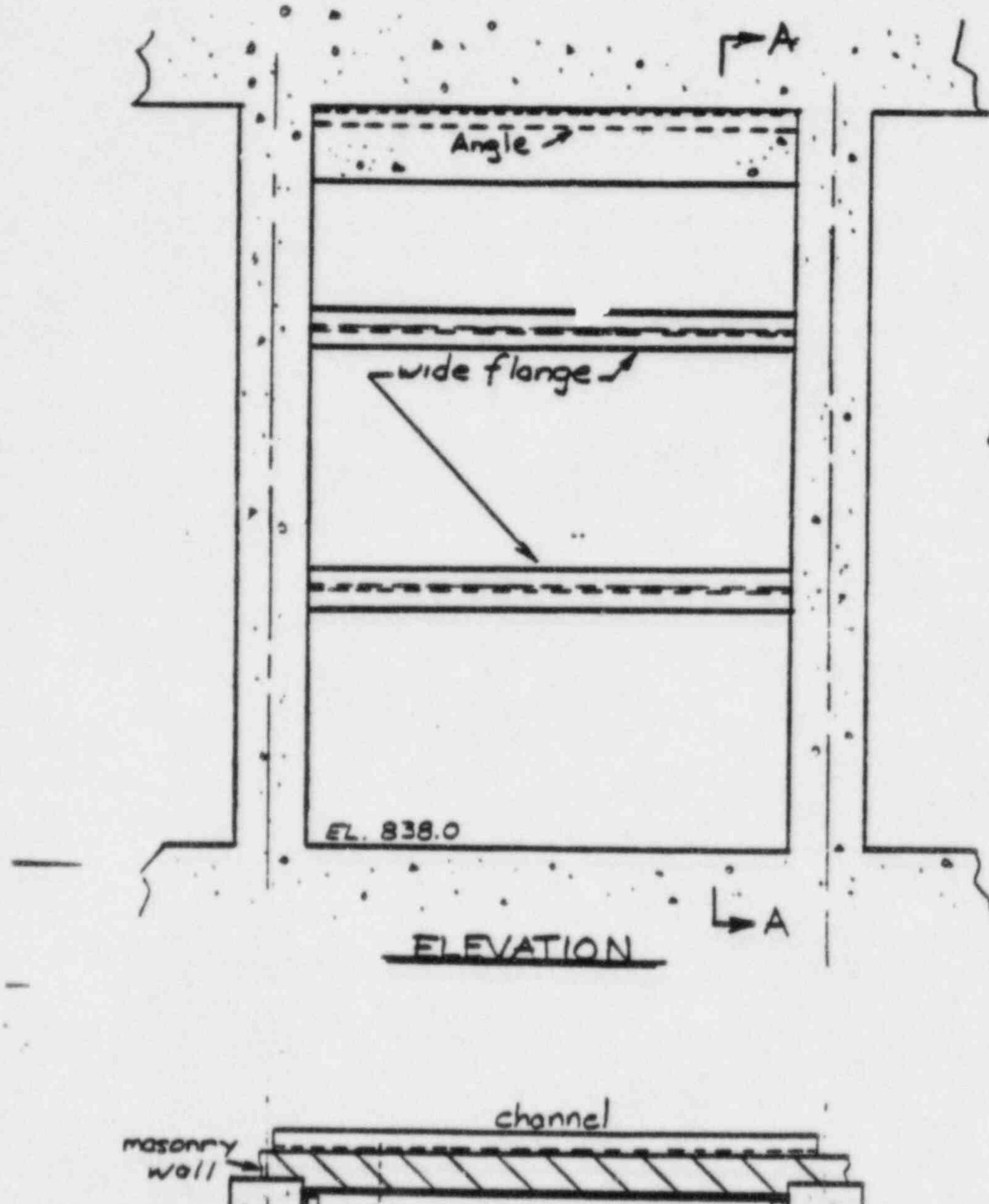
VERTICAL WALL SECTION



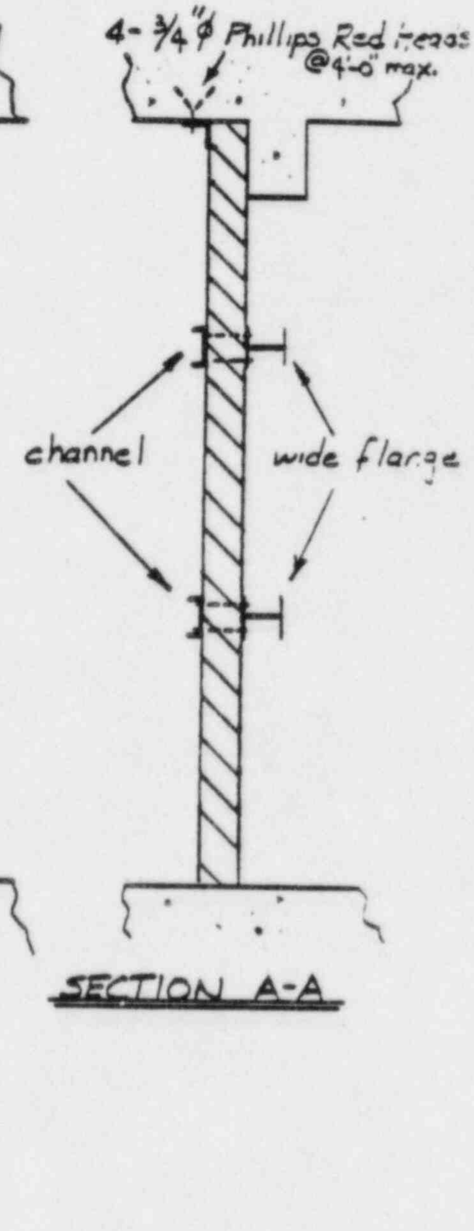
HORIZONTAL WALL SECTION

APPENDIX D

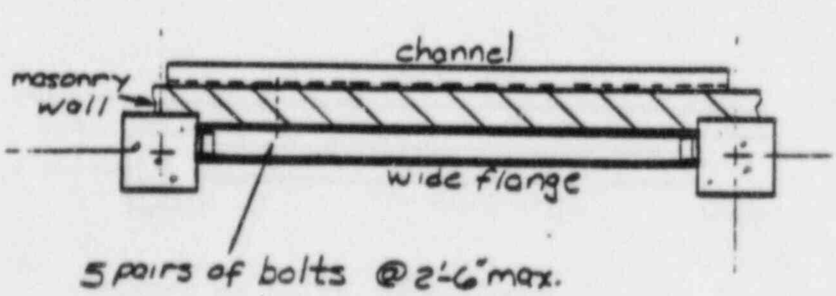
SCHEMATIC REPRESENTATION OF WALL MODIFICATIONS



ELEVATION



SECTION A-A



PLAN

APPENDIX E

MASONRY WALL DATA SUMMARY

Note: The allowable stresses given in this Appendix are based on the Licensee's design criteria.

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-13	1165			12.1	23.4		3.5	58.1		
	1166			12.1	23.4		3.5	58.1		
	1167			12.1	23.4		3.5	58.1		
	1168			12.1	23.4		3.5	58.1		
0-15	0005									No NSR Equip. in Proximity Zo
	0006									No NSR Equip. in Proximity Zo
	0007									No NSR Equip. in Proximity Zo
	0013									Proximity Zone Modified
	0014									Proximity Zone Modified
	0017									Proximity Zone Modified
	0023	10.3 in-kips	62 in-kips				13.6	58.1		Reinforced Wall
	0024	16 in-kips	51 in-kips				11.2	58.1		Reinforced Wall
0-15A	1172									Proximity Zone Modified
	1178									Proximity Zone Modified
	1179									Proximity Zone Modified
	1180									Proximity Zone Modified
	1186									Proximity Zone Modified
0-15B	1604									No NSR Equip. in Proximity Zo
	1608									Proximity Zone Modified
	1609									Proximity Zone Modified
	1611									No NSR Equip. in Proximity Zo
	1612									No NSR Equip. in Proximity Zo
	1613									No NSR Equip. in Proximity Zo
0-18A	1165	6.4	45.1				4.9	58.1	0.81	
	1166									No NSR Equip. in Proximity Zo

Franklin Research Center
A Division of The Franklin Institute

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-303G	1444	31.0	45.1				7.7	58.1		
	1447	31.0	45.1				7.7	58.1		
	1448	31.0	45.1				7.7	58.1		
	1449	31.0	45.1				7.7	58.1		
	1450	31.0	45.1				7.7	58.1		
	1451	31.0	45.1				7.7	58.1		
	1458	31.0	45.1				7.7	58.1		
0-304A	0402					29.51	9.0	58.1		
	0404			13.6	23.4		9.1	58.1		
	0406	4.1	45.1	14.4	23.4		9.6	58.1		
	0407	7.8	45.1	12.3	23.4		9.2	58.1		
	0413			4.1	23.4		14.4	58.1		
	0414					11.64	16.2	58.1		
	0415					2.83	6.8	58.1		
	0416					12.7	18.3	58.1		
	0418	9.3	45.1	13.5	23.4		25.8	58.1		
	0419	13.9	45.1	18.7	23.4		31.8	58.1		
	0420	8.6	45.1	10.8	23.4		22.4	58.1		
	0421	4.5	45.1	3.5	23.4		17.1	58.1		
	0422	12.6	45.1	12.4	23.4		35.1	58.1		
	0423					6.3	15.9	58.1		
	0424					3.71	47.0	58.1		
	0425	20.7	45.1				10.5	58.1		
	0426			13.5	23.4		11.0	58.1		
	0427					1.83	40.9	58.1		
	0431					6.25	24.8	58.1		
	0454									No HSR Equip. in Proximity Zo:
	0455			9.5	23.4		3.8	58.1		

Franklin Research Center
A Division of The Franklin Institute

ATTACHMENT I

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-304A	0456			4.4	23.4		1.9	58.1		
	0457					16.04	12.7	58.1		
	0458			9.3	23.4		3.7	58.1		
	0459	4.8	45.1	3.7	23.4		12.8:	58.1		
	0460			10.1	23.4		3.9	58.1		
	0461	15.1	45.1	21.5	23.4		38.5	58.1		
	0162	14.4	45.1	18.6	23.4		37.5	58.1		
	0463					11.6	16.5	58.1		
	0464					19.8	18.3	58.1		
	0472			23.4	23.4		7.9	58.1		
	0481					5.82	32.6	58.1		
	0482	17.1	45.1	22.9	23.4		21.9	58.1		
	0193	3.7	45.1	2.1	23.4		20.6	58.1		
	0484	38.0	45.1	22.9	23.4		25.7	58.1		
	0487	8.1	45.1	18.5	23.4		16.3	58.1		
	0502			20.3	23.4		31.4	59.1		
	0505			1.8	23.4		0.6	58.1		
	0507					3.2	33.6	58.1		
	0509	7.7	45.1	14.3	23.4		20.0	58.1		
	0511			10.2	23.4		3.3	58.1		
	0515			2.6	23.4		0.9	58.1		
	0516	3.8	45.1	2.0	23.4		16.0	58.1		
0-304B	0005					4.48	29.6	58.1		
	0006					3.82	34.4	58.1		
	0007	14.6	45.1	18.5	23.4		7.7	58.1		
	0019					25.9	7.7	58.1		
	0020					29.0	7.1	58.1		
	0041					15.65	2.7	60.6		
	0042	3.0	68.1	4.8	44.8		2.7	60.6		
	0044									Structural Framework Supporting Wal
	0049					15.05	14.6	58.1		

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-304B	0050					9.28	20.7	58.1		
	0052	13.6	45.1	20.1	23.4		8.4	58.1		
	0053	10.3	45.1	15.9	23.4		11.4	58.1		
	0056	12.0	45.1	16.8	23.4		7.8	58.1		
	0062					2.99	42.4	58.1		
	0063					2.56	43.1	58.1		
	0064					3.65	35.1	58.1		
	0065	2.2	45.1	5.2	23.4		31.8	58.1		--
	0079					4.7	26.4	58.1		
	0080					7.64	15.3	58.1		
	0081					9.72	20.3	58.1		
	0090									Structural Framework Supporting Wall
	0091					14.69	13.6	58.1		
	0093					14.69	13.6	58.1		
	0094					14.69	13.6	58.1		
	0104					3.31	33.2	58.1		
	0108, 0109					3.31	33.2	58.1		
	0123					15.64	12.8	58.1		
0-305A	1000	16.7	45.1	23.0	23.4		22.0	58.1		
	1001					9.40	22.3	58.1		
	1002	10.4	45.1	17.3	23.4		45.2	58.1		
	1003	9.2	45.1	19.3	23.4		34.2	58.1		
	1004					4.92	47.2	58.1		
	1005					4.74	24.0	58.1		
	1006	10.2	45.1	12.3	23.4		28.8	58.1		
	1007	17.8	45.1	22.8	23.4		14.1	58.1		
	1008			0.7	23.4		1.5	58.1		
	1010	11.5	45.1	6.5	23.4		11.0	58.1		
	1012	11.1	68.1	11.8	44.8		7.8	60.6		
	1013	4.6	45.1	3.2	23.4		35.9	58.1		
	1017	3.3	45.1	0.9	23.4		19.0	58.1		

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-305A	1018			11.9	23.4		4.0	58.1		
	1019			22.4	23.4		5.0	58.1		
	1024	19.3	68.1	27.5	44.8		7.1	60.6		
	1025			16.0	44.8		1.5	60.6		
	1026			22.4	23.4		5.0	58.1		
	1028	8.6	45.1	10.0	23.4		9.4	58.1		
	1029			21.7	23.4		3.2	58.1		
	1030			9.6	23.4		3.8	58.1		
	1031			12.8	23.4		4.0	58.1		
	1032			19.2	23.4		9.9	58.1		
	1033, 1034			1.7	23.4		1.3	58.1		
	1036	17.5	45.1	15.5	23.4		9.6	58.1		
	1038	7.2	45.1	7.6	23.4		10.4	58.1		
	1039			20.2	23.4		6.1	58.1		
	1009	6.1	45.1	5.8	23.4		4.4	58.1		
	1011, 1016	7.1	45.1	9.7	23.4		5.2	58.1		
0-305B	1200	7.44	45.1	13.63	23.4		9.9	58.1		
	1201					13.93	15.3	58.1		
	1202	7.44	45.1	13.63	23.4		9.8	58.1		
	1203	7.53	45.1	12.98	23.4		13.6	58.1		
	1205					8.9	21.0	58.1		
	1206	3.6	45.1	6.2	23.4		13.8	58.1		
	1207	8.3	45.1	12.3	23.4		12.5	58.1		
	1208	10.2	45.1	14.8	23.4		14.2	58.1		
	1209			9.9	23.4		3.8	58.1		
	1210	7.78	68.1	15.85	44.8		3.8	60.6		
	1211					13.93	7.9	60.6		
	1212	11.9	68.1	18.9	44.8		4.7	60.6		
	1213	7.74	68.1	14.6	44.8		3.8	60.6		
	1214	8.86	45.1	13.4	23.4		15.9	58.1		
	1215	7.44	45.1	13.6	23.4		8.4	58.1		

Franklin Research Center
A Division of The Franklin Institute

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-305B	1216					16.64	13.7	58.1		
	1217	7.44	45.1	13.6	23.4		12.4	58.1		
	1218	10.9	45.1	13.7	23.4		10.7	58.1		
	1219	2.44	45.1	4.1	23.4		8.1	58.1		
	1220			15.1	23.4		9.3	58.1		
	1222	18.8	45.1	18.1	23.4		17.1	58.1		
	1224			15.9	23.4		5.1	58.1		
	1225	10.5	45.1	10.6	23.4		14.5	58.1		
	1226	9.8	68.1	17.0	44.8		4.8	60.6		
	1227	12.7	68.1	19.7	44.8		2.8	60.6		
	1228	9.7	68.1	17.9	44.8		3.7	60.6		
	1229	9.72	68.1	17.81	44.8		3.8	60.6		
0-306A	[illegible]					2.73	55.8	58.1		
	1402			4.6	23.4		3.1	58.1		
	1407	31.5	45.1				3.7	58.1		
	1408	10.6	45.1	5.7	23.4		35.7	58.1		
	1410	7.9	45.1	2.2	23.4		3.5	58.1		
	1411	13.6	45.1	9.6	23.4		24.9	58.1		
	1412	8.3	45.1	3.7	23.4		29.3	58.1		
	1413			7.3	23.4		4.7	58.1		
	1414					2.83	58.7	58.1		
	1417									No NSR Equip. in Proximity Zon
	1421			10.7	23.4		6.7	58.1		
	1422	9.7	45.1				4.2	58.1		
	1423	0.4	45.1				0.6	68.1		
	1424	10.4	45.1	5.4	23.4		41.8	58.1		
	1425	2.4	45.1				1.7	58.1		
	1426	22.0	45.1	18.3	23.4		36.5	58.1		
	1427	11.4	45.1				4.5	58.1		

Franklin Research Center
A Division of The Franklin Institute

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-306B	1230	14.4	45.1	10.4	23.4		46.4	58.1		
	1231					2.73	41.5	58.1		
	1232					2.53	36.7	58.1		
	1233					3.48	42.9	58.1		
	1234	10.6	45.1	5.4	23.4		37.4	58.1		
	1235	11.6	45.1	5.4	23.4		47.8	58.1		
	1236					4.94	39.6	58.1		
	1237					2.19	45.2	58.1		
	1238					3.26	12.2	60.6		
	1239					2.95	20.5	60.6		
	1240			10.1	23.4		4.5	58.1		
	1241	7.8	45.1	3.72	23.4		32.6	58.1		
	1242	27.2	68.1	34.1	44.8		16.1	60.6		
	1243					3.48	42.9	58.1		
	1244									No NSR Equip. in Proximity Zc
	1245					2.75	41.6	58.1		
	1246	15.4	45.1	11.8	23.4		44.7	58.1		
	1247	7.8	45.1	3.72	23.4		32.6	58.1		
	1248					9.3	46.5	58.1		
	1249			13.4	23.4		3.4	58.1		
	1250	15.2	45.1	9.7	23.4		33.3	58.1		
	1251	11.9	45.1				10.5	58.1		
	1252	24.2	45.1	16.5	23.4		25.3	58.1		
	1253	30.8	68.1	42.7	44.8		16.2	60.6		
	1254	31.1	68.1	42.8	44.8		15.6	60.6		
	1255					2.61	16.9	60.6		

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-307A	0518			17.3	23.4		6.9	58.1		
	0519	115 in-kips	168 in-kips				6.4	58.1		Reinforced Wall
	0522									Proximity Zone Modified
	0523	1.4	45.1				1.8	58.1		
	0525									No NSR Equip. in Proximity Zon
	0527	31.5	45.1				5.7	58.1		
	0528									No NSR Equip. in Proximity Zon
	0529			16.7	23.4		15.5	58.1		
	0530									Proximity Zone Modified
	0531									Proximity Zone Modified
	0532			18.5	23.4		10.6	58.1		
	0533									No NSR Equip. in Proximity Zon
	0534			21.7	23.4		8.3	58.1		
	0535			9.5	23.4		16.9	58.1		
	0536	26.0	45.1				10.6	58.1		
	0537									No NSR Equip. in Proximity Zo
	0541									No NSR Equip. in Proximity Zo
	0544									No NSR Equip. in Proximity Zo
	0545									No NSR Equip. in Proximity Zo
	0546									Proximity Zone Modified
	0550	24.2	45.1	11.4	23.4		7.1	58.1		
	0557	35.6	45.1	17.2	23.4		26.2	58.1		
	0558	124 in-kips	168 in-kips				6.4	58.1		Reinforced Wall
	0559			17.3	23.4		6.9	58.1		
	0563	37.9	45.1				11.6	58.1		
	0564	32.2	45.1				10.7	58.1		
	0566	44.1	45.1				24.7	58.1		
	0571									Proximity Zone Modified
	0578	18.3	45.1	3.6	23.4		4.9	58.1		
	0579			18.9	23.4		10.6	58.1		

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-307A	0580			21.7	23.4		8.3	58.1		
	0581									No NSR Equip. in Proximity Zone
	0586	20.6	45.1				5.6	58.1		
	0588									Proximity Zone Modified
	0589									Proximity Zone Modified
	0600F									Proximity Zone Modified
	0598	17.0	45.1	11.2	23.4		8.5	58.1		
	0556, 0597									Proximity Zone Modified
0-307B	1042									Proximity Zone Modified
	1043									Proximity Zone Modified
	1044	30.7	68.1				2.9	60.6		
	1045									Proximity Zone Modified
	1046									Proximity Zone Modified
	1047									Proximity Zone Modified
	1048	25.9	68.1	10.5	44.8		2.9	60.6		
	1049									Proximity Zone Modified
0-308A	1258	14.5	45.1	14.7	23.4		9.8	58.1		
	1261					15.07	12.31	58.1		
	1267			0.09	23.4		0.84	58.1		
	1269			12.2	23.4		4.3	58.1		
	1270					7.34	14.6	58.1		
	1277			15.9	23.4		5.1	58.1		
	1278	6.54	45.1	11.4	23.4		10.6	58.1		
	1279			12.9	23.4		15.1	58.1		
	1280	3.11	45.1	5.73	23.4		18.6	58.1		
	1281			14.8	23.4		4.8	58.1		
	1282			11.2	23.4		3.32	58.1		
	1289			16.2	23.4		4.6	58.1		
	1290			14.8	23.4		4.8	58.1		
	1291			3.6	23.4		0.7	58.1		
	1292			12.4	23.4		10.1	58.1		

Franklin Research Center
A Division of The Franklin Institute

ATTACHMENT 3

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-308B	1296	25.2	68.1	32.5	44.8		3.2	60.6		
	1297					12.4	8.0	60.6		
	1298			18.5	23.4		5.1	58.1		
	1302			15.6	23.4		7.1	58.1		
	1303					6.67	26.1	58.1		
	1305			28.9	44.8		2.4	60.6		
	1306					6.24	34.8	58.1		
	1307	1.8	68.1	16.0	44.8		3.7	60.6		
	1308			36.0	44.8		2.9	60.6		
	1309			36.0	44.8		2.9	60.6		
	1310			40.3	44.8		2.6	60.6		
	1312			32.5	44.8		1.8	60.6		
	1313			36.3	44.8		2.9	60.6		
	1314			36.3	44.8		2.9	60.6		
	1315					4.86	10.5	60.6		
	1317F					3.27	15.3	60.6		
	1318F	19.7	68.1	22.1	44.8		10.8	60.6		
	1319F	20.3	68.1	23.1	44.8		10.8	60.6		
	1320F	18.0	68.1	18.9	44.8		10.8	60.6		
	1321F					2.74	16.3	60.6		
	1322F	19.7	68.1	22.1	44.8		10.5	60.6		
	1323F	19.7	68.1	22.5	44.8		10.5	60.6		
	1324F	20.5	68.1	24.4	44.8		10.5	60.6		
	1327F	21.1	68.1	27.0	44.8		11.2	60.6		
	1328F			2.3	44.8		0.8	60.6		
	1335F			34.0	44.8		5.6	60.6		
	1336F			21.3	44.8		2.0	60.6		

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-308C	1324									No NSR Equip. in Proximity Zone
	1325									No NSR Equip. in Proximity Zone
	1236									No NSR Equip. in Proximity Zone
	1327									No NSR Equip. in Proximity Zone
	1328									No NSR Equip. in Proximity Zone
	1329									No NSR Equip. in Proximity Zone
	1331									No NSR Equip. in Proximity Zone
	1332									No NSR Equip. in Proximity Zone
	1333									No NSR Equip. in Proximity Zone
	1335									No NSR Equip. in Proximity Zone
	1336									No NSR Equip. in Proximity Zone
0-364	0001F	34.8	45.1				6.8	58.1		
	0002F	34.7	45.1				7.7	58.1		
	0003F	33.8	45.1				7.6	58.1		
0-384	0001F	29.1	45.1	17.2	23.4		10.7	58.1		
	0002F	8.5	45.1	12.5	23.4		10.5	58.1		
	0003F	29.1	45.1	17.2	23.4		10.7	58.1		
	0004F	8.5	45.1	12.5	23.4		10.5	58.1		
0-460	0001F					2.28			1.5	
	0002F					2.28			1.5	
0-1013	1167			12.5	23.4		3.6	58.1		
	1170			12.5	23.4		3.6	58.1		
0-1015	1652									Proximity Zone Modified
	1654									Proximity Zone Modified
	1668									Proximity Zone Modified
	1671									Proximity Zone Modified

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-1015A	1066									Proximity Zone Modified
	1067									Proximity Zone Modified
0-2015	1684									Proximity Zone Modified
	1728									Proximity Zone Modified
0-2015A	1076									Proximity Zone Modified
0-2018	1463	17.5	45.1				7.2	58.1	2.25	
0-2303B	1162			21.7	23.4		5.6	58.1		
0-2304A	0200	14.5	45.1	22.0	23.4		34.8	58.1		
	0201	11.4	45.1	22.0	23.4		29.9	58.1		
	0202					3.42	31.0	58.1		
	0203	12.9	45.1	22.6	23.4		17.8	58.1		
	0204	16.6	45.1	22.4	23.4		6.5	58.1		
	0205	13.5	45.1	23.8	23.4		15.6	58.1		
	0206			20.9	23.4		4.4	58.1		
	0207			13.2	23.4		3.5	58.1		
	0223					9.7	18.9	58.1		
	0224					5.2	27.5	58.1		
	0227	9.33	45.1	18.33	23.4		16.5	58.1		
	0228					6.92	25.6	58.1		
	0229	8.3	45.1	14.6	23.4		17.5	58.1		
	0230			2.6	23.4		0.9	58.1		
	0231			18.3	23.4		5.1	58.1		
	0232									No HSR Equip. in Proximity Zo
	0239					8.6	17.3	58.1		

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-2304A	0242									No NSR Equip. in Proximity Zone
	0243									No NSR Equip. in Proximity Zone
	0245									No NSR Equip. in Proximity Zone
	0249									No NSR Equip. in Proximity Zone
	0264	7.2	45.1	6.5	23.4		16.9	58.1		
	0267			5.1	23.4		2.4	58.1		
	0268			3.0	23.4		1.4	58.1		
	0269					8.11	22.4	58.1		
	0270									No NSR Equip. in Proximity Zone
	0273									No NSR Equip. in Proximity Zone
0-2304B	1100					17.65	8.3	58.1		
	1101					17.73	10.4	58.1		
	1107			19.44	23.4		5.51	58.1		
	1111	15.0	45.1	20.5	23.4		28.0	58.1		
	1112	16.24	45.1	21.9	23.4		28.2	58.1		
	1113	16.03	45.1	21.57	23.4		27.2	58.1		
	1142			18.0	23.4		5.1	58.1		
	1143			14.6	23.4		4.3	58.1		
	1146									Structural Framework Supporting Wall
	1147	3.8	45.1	21.9	23.4		13.1	58.1		
	1159					13.63	14.3	58.1		
0-2305A	0600					15.65	12.3	58.1		
	0601	14.9	45.1				15.4	58.1		
	0602	10.0	45.1	14.2	23.4		8.3	58.1		
	0603			22.3	23.4		6.5	58.1		
	0604			21.8	23.4		5.7	58.1		
	0605			8.9	23.4		3.6	58.1		
	0606			18.4	23.4		6.2	58.1		
	0608			12.6	23.4		4.2	58.1		
	0609			17.1	23.4		5.3	58.1		
	0611			7.1	23.4		2.3	58.1		

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 90-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-2305A	0612	22.4	45.1	13.6	23.4		32.2	58.1		
	0613	2.6	45.1				0.8	58.1		
	0614	13.8	45.1	21.5	23.4		38.2	58.1		
	0615					17.3	9.47	58.1		
	0616			15.4	23.4		4.8	58.1		
	0617			6.7	23.4		3.0	58.1		
	0618			14.0	23.4		4.5	58.1		
	0619			18.6	23.4		5.7	58.1		
	0620	4.84	45.1	2.9	23.4		10.0	58.1		
	0621			22.7	23.4		6.4	58.1		
	0622			6.7	23.4		3.0	58.1		
	0623			14.0	23.4		4.5	58.1		
	0726	1.2	45.1				1.0	58.1		
	0727F			5.2	23.4		3.0	58.1		
	0728F			12.6	23.4		4.2	58.1		
	0729F			3.8	23.4		3.2	58.1		
0-2305B	0624	6.5	45.1	10.0	23.4		7.4	58.1		
	0625			22.9	23.4		7.1	58.1		
	0626	5.4	45.1	10.4	23.4		8.6	58.1		
	0627			15.8	23.4		4.9	58.1		
	0628					7.58	24.0	58.1		
	0629	9.1	45.1	14.9	23.4		17.6	58.1		
	0630			16.6	23.4		4.5	58.1		
	0631			29.1	44.8		2.1	60.6		
	0632			27.3	44.8		2.2	60.6		
	0633	35.6	68.1	44.0	44.8		3.1	60.6		
	0634			24.7	44.8		2.0	60.6		
	0636			3.1	23.4		2.4	58.1		
	0637			15.0	23.4		4.9	58.1		
	0638			9.4	23.4		1.1	58.1		
	0639			16.7	23.4		5.3	58.1		
	0725			21.7	23.4		6.0	58.1		

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-2306A	0808	7.6	45.1	5.0	23.4		26.0	58.1		
	0809					4.56	34.1	58.1		
	0810	15.2	45.1	22.7	23.4		26.6	58.1		
	0811					4.93	31.9	58.1		
	0814	6.6	45.1	3.6	23.4		29.8	58.1		
	0816	7.4	45.1	15.0	23.4		36.9	58.1		
	0817	2.3	45.1	10.0	23.4		28.2	58.1		
	0818	10.5	45.1	10.4	23.4		7.3	58.1		
	0823	20.3	45.1	18.8	23.4		52.3	58.1		
	0825	20.3	45.1	18.8	23.4		2.7	58.1		
	0826	6.6	45.1	2.9	23.4		3.3	58.1		
	0828									No NSR Equip. in Proximity Zor
	0830, 0831									No NSR Equip. in Proximity Zor
	0832, 0833									No NSR Equip. in Proximity Zor
0-2306B	0834	17.0	45.1	21.3	23.4		31.5	58.1		
	0835	17.9	45.1	20.9	23.4		31.6	58.1		
	0836					3.66	38.0	58.1		
	0837	17.9	45.1	20.9	23.4		31.7	58.1		
	0838					3.83	44.6	58.1		
	0839	6.0	45.1	2.9	23.4		27.1	58.1		
	0940	23.0	68.1	30.5	44.8		11.4	60.6		
	0842	22.0	68.1	32.4	44.8		11.1	60.6		
	0943	29.5	68.1	35.1	44.8		13.0	60.6		
	0844	31.3	45.1	7.9	23.4		29.0	58.1		
	0945	31.3	45.1	16.9	23.4		29.0	58.1		
	0845	12.0	45.1	19.2	23.4		24.7	58.1		
	0947F									No NSR Equip. in Proximity Zor
	0848F					4.32	11.5	60.6		

Franklin Research Center
A Division of The Franklin Institute

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-2307A	0640									No NSR Equip. in Proximity Zone
	0641									No NSR Equip. in Proximity Zone
	0642	18.2	45.1				6.8	58.1		
	0643	24.5	45.1				3.4	58.1		
	0644	54 in-kips	187 in-kips				6.2	58.1		Reinforced Wall
	0653	16.9	45.1	9.2	23.4		5.8	58.1		
	0654	14.3	45.1				10.0	58.1		
	0655	14.3	45.1				10.0	58.1		
	0656									Proximity Zone Modified
	0657									No NSR Equip. in Proximity Zone
	0658									No NSR Equip. in Proximity Zone
	0665									Proximity Zone Modified
	0666									Proximity Zone Modified
	0667			16.4	44.8		1.6	60.6		
	0668	17.1	68.1	8.8	44.8		4.7	58.1		
	0669									No NSR Equip. in Proximity Zone
	0672									No NSR Equip. in Proximity Zone
	0675									No NSR Equip. in Proximity Zone
	0676	11.9	45.1	11.8	23.4		33.0	58.1		
	0678	28.4					4.5	58.1		
	0679	77.9 in-kips	204 in-kips				26.5	58.1		Reinforced Wall
	0685									No NSR Equip. in Proximity Zone
	0686	14.3	45.1	17.4	23.4		13.7	58.1		
	0688	16.3	45.1				3.3	58.1		
	0689	77.9 in-kips	204 in-kips				26.5	58.1		Reinforced Wall
	0690	12.7	45.1				3.9	58.1		
0-2308A	0704			14.0	23.4		3.7	58.1		
	0705			14.0	23.4		3.7	58.1		
	0705			14.0	23.4		3.7	58.1		
	0707			14.3	23.4		4.3	58.1		
	0708			11.9	23.4		4.1	58.1		
	0709			9.4	23.4		3.3	58.1		

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
0-2308A	0710			11.9	23.4		3.9	58.1		
	0711			22.2	23.4		6.2	58.1		
	0712			20.2	23.4		4.8	58.1		
0-2308B	0714									No NSR Equip. in Proximity Zone
	0715									No NSR Equip. in Proximity Zone
	0716			27.5	44.8		2.1	60.6		
	0717			15.3	44.8		0.4	60.6		
	0718			27.6	44.8		2.1	60.6		
	0719					7.01	24.4	58.1		
	0720			17.1	23.4		5.2	58.1		
	0721			27.8	44.8		2.2	60.6		
	0722			34.9	44.8		2.2	60.6		
	0723			28.9	44.8		2.2	60.6		
	0724			35.9	44.8		2.3	60.6		
	0725F	19.3	68.1	17.1	44.8		10.5	60.6		
	0726F	17.2	68.1	20.3	44.8		10.2	60.6		
	0727F	17.3	68.1	19.5	44.8		10.1	60.6		
	0728F	16.4	68.1	16.8	44.8		11.1	60.6		
	0729F	17.3	68.1	18.6	44.8		11.1	60.6		
	0730F	16.6	68.1	17.5	44.8		11.1	60.6		
	0731F	8.2	68.1	33.02	44.8		11.1	60.6		
0-2308C	1435									No NSR Equip. in Proximity Zone
	1436									No NSR Equip. in Proximity Zone
	1437									No NSR Equip. in Proximity Zone
	1438									No NSR Equip. in Proximity Zone
	1439									No NSR Equip. in Proximity Zone
	1440									No NSR Equip. in Proximity Zone
	1442									No NSR Equip. in Proximity Zone

ATTACHMENT 1

OCONEE NUCLEAR STATION, UNITS 1, 2 AND 3
IEB 80-11 MASONRY WALL DATA SUMMARY

ARCH. DRAWING NUMBER	WALL SEQUENCE NUMBER	HORIZ. STRESS (PSI)	ALLOW. HORIZ. STRESS (PSI)	VERTICAL STRESS (PSI)	ALLOW. VERTICAL STRESS (PSI)	STABILITY FACTOR OF SAFETY	SUPPORT SHEAR STRESS (PSI)	ALLOW. S. SHEAR STRESS (PSI)	COLLAR JOINT SHEAR (PSI)	REMARKS
K-300A	0012			7.3	23.4		2.2	58.1		
	0013			7.3	23.4		2.2	58.1		
	0015			7.3	23.4		2.2	58.1		
	0016			7.3	23.4		2.2	58.1		
K-301A	0057									Proximity Zone Modified
	0061					58.84	9.2	58.1		
	0062					58.84	9.2	58.1		

NOTES:

Modification of wall proximity zone. Structures are erected to alter the proximity zone of the masonry wall such that safety related equipment is no longer within the proximity zone of the all.

A resurveillance of the proximity zones for the masonry walls was conducted. This resurveillance resulted in the finding that many walls previously identified as having safety related equipment nearby actually had no safety related equipment within the proximity zone of the wall.

ATTACHMENT 2

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. (Appendix A of TER, Attachment 1).

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

~~8312070017~~

5pp

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 dymanic 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 Sequndo, 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