Attachment 1

TECHNICAL EVALUATION REPORT

MASONRY WALL DESIGN

PHILADELPHIA ELECTRIC COMPANY

PEACH BOTTOM ATOMIC POWER STATION UNITS 2 AND 3

NRC DOCKET NO. 50-277, 50-278

NRC TAC NO. —

NRC CONTRACT NO. NRC-03-81-130

FRC PROJECT C5506

FRC ASSIGNMENT 6

FRC TASK 233

Prepared by

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

Prepared for

Nuclear Regulatory Commission
Washington, D.C. 20555

Author: S. Triolo, V. N. Con

FRC Group Leader: V. N. Con

Lead NRC Engineer: N. C. Chokshi

September 12, 1984

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

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Prepared by:	Reviewed by:	Approved by:
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Date: 9-12-84	Date: 9-12-84	Date: 9-12-84

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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 the 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 plans repair work on masonry walls, the planned methods, procedures, and repair schedules are 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, Philadelphia Electric Company provided the NRC with documents describing the status of masonry walls at Peach Bottom Station Units 2 and 3 [2, 3, 4[]. These documents were reviewed, and a request for additional information was sent to the Licensee on March 10, 1982. The Licensee responded to this request on May 26, 1982 [9]. Additional

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

questions were sent on February 7, 1984 [10], to which the Licensee has also responded [11].

A total of 86 walls have been identified as safety-related. All of them are reinforced. The functions of the masonry walls at Peach Bottom Units 2 and 3 and the number of walls in each category are indicated in Reference 2 as follows:

Shielding	35 walls
Partition	2 walls
Fire resistance	49 walls
Total	86 walls

These walls are located in the radwaste building, turbine building, reactor building, emergency cooling tower, and circulating water pump structure. Priorities for wall reevaluation were determined based on the following factors [2]:

a. the number of safety-related systems on the walls or in their proximity

b. the weight of the loadings to which the walls are subject

c. the criticality of the walls in terms of height, length, and thickness.

Concrete masonry walls are not used as shear walls at Peach Bottom Atomic Power Station. Wall thickness range from 8 in to 48 in. Vertical reinforcements have been placed in single wythe walls and in the exterior wythes of multiple wythe walls. In shield walls, all cells are grouted, whereas in partition and fire walls, only the cells containing reinforcement are grouted. Horizontal reinforcements and bond beams are provided at intervals. At the base of the walls, restraint is provided by steel angles bolted to the floor or by expansion bolts projecting into the block cells at the same spacing as the vertical reinforcing. In addition, where required, horizontal restraints are provided at the sides and tops of the walls. There are four safety-related walls that required modification. Modifications typically consist of improvements to the restraints at the top of walls.

The materials used in the construction of the masonry walls were specified as follows:

o Concrete block	ASTM Specification C90-66, Grade U-1
o Mortar	ASTM Specification C-270, type N, minimum compressive strength 750 psi at 28 days
o Grout (concrete)	Minimum compressive strength 2000 psi at 28 days
o Reinforcing steel	ASTM Specification A-615, Grades 40 and 60
a. vertical reinforcing	Deformed bars from #4 to #8, spaced at 24 in to 32 in.
b. horizontal reinforcing	Bond beam reinforcing with #4 or #5 deformed bars spaced at 40 in (2 or 4 bars per beam). Also, ladder-type reinforcing is placed in horizontal joints, spaced at 16 in.
o Masonry ties	In multiple wythe walls, #10 gage ties placed at a spacing of 48 in horizontally and vertically.

Adequate inspection was performed during construction. Documentation of the tests and inspection is maintained in the project file. Test of materials conducted during construction confirmed that the values used for concrete block, mortar, grout, and rebar were conservative [3].

The Licensee has relied upon the energy balance 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 reinforced 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 the energy balance technique to masonry walls in nuclear power plants is questionable [12]. In a subsequent meeting, consultants of utility companies presented their rebuttals [13] and requested that they be treated on a plant-by-plant basis.

In accordance with the above request, NRC, FRC, and consultants visited several nuclear power plants to examine the field conditions of masonry walls in the plant and to gain first-hand knowledge of how the energy balance technique is applied to actual walls. Further discussion on this subject is provided in Section 3.1.

2. EVALUATION 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 (attached as Appendix A to this report), the Uniform Building Code [6], and ACI 531-79 [7].

In materials, testing, analysis, design, construction, and inspection of safety-related concrete masonry structures 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 7, and the appropriate increase factors for abnormal and extreme environmental loads are given in the SGEB Criteria (Appendix A).

3. TECHNICAL EVALUATION

This evaluation is based on the Licensee's earlier responses [2, 3, 4] and subsequent responses [9, 11] to the request for additional information. The Licensee's criteria [4, 9] were evaluated with regard to design and analysis methods, loads and load combinations, allowable stresses, construction specifications, and materials. The Licensee's response to the request for additional information was also reviewed.

3.1 EVALUATION OF LICENSEE'S CRITERIA

- The design allowables are based on ACI 531-79 [7], and the stresses are also checked against Uniform Building Code 1967.
- The load combinations considered are based on the project FSAR.
- Proper construction practices were conducted in building the walls. Appropriate tests were also performed to verify the strength requirements of the walls. Test results indicated that the values used for concrete block, mortar, grout, and rebar were conservative [3].
- The following damping values are used:
  - a. for uncracked sections, 2% for both OBE and safe shutdown earthquake (SSE)
  - b. for cracked sections, 4% for OBE and 7% for SSE.
- Collar joint tension and shear strengths have been conservatively assumed to be zero.
- Joint reinforcement is not relied upon to resist tension.
- The typical analytical procedure is summarized below:
  - determine wall boundary conditions
  - calculate the wall's natural frequency assuming either one-way or two-way action
  - obtain inertial loading from the floor response spectra
  - compare computed stresses with the allowable values in ACI 531-79 [7] and the Uniform Building Code 1967.
- Both working stress and energy balance techniques were used in the analysis. Of 86 total walls, 5 were qualified by the energy balance technique.

Other than those areas identified in Section 4, the Licensee's criteria have been reviewed and found to be technically adequate and in compliance with the SGEB criteria. The review of the Licensee's responses to the requests for additional information follows.

Question 1

With reference to Section 3, Appendix I, part 1 [4], justify the basis for load combinations 7, 8, and 9 which contain dead load (D), jet impingement (P), pressurization load due to line break (P'), and accident temperature load (Ta): 7) 1.05D + 1.25P, 8) 1.05D + 1.0P', 9) 1.05D + 1.0 Ta.

Response 1 [Reference 9]

The load combination 8 (FSAR) considers the combined effect of dead load (D), jet impingement (P), and pressurization (P') due a to high energy line break (HELB). The Licensee stated that one term (1.0P) was inadvertently omitted and the report was revised to reflect the load combination (1.05D + 1.0P' + 1.0P).

The load combination 7 (1.05D + 1.25P) recognizes the impulsive nature of jet impingement load by using a dynamic load factor of 25%. Since the peak pressure in a compartment due to a HELB does not occur at the instant of this impact, the pressurization load is not included in this combination.

The load combination 9 (1.05D + 1.0Ta) considers the accidental temperature stresses. The thermal effects are relatively long term and, by the time the final temperature gradients are established across the wall thickness, the jet impingement and pressurization effects become negligible, and thus are not combined directly.

The Licensee's response is considered adequate and consistent with the SGEB criteria.

Question 2

With reference to Table 1, Appendix I, part 1 [4], justify the increase factors of 1.67 applied to allowable stresses in shear, bond, tension

normal to the bed joint, and tension parallel to the bed joint. The SEB Criteria [5] allow increase factors of only 1.5 for tension parallel to the bed joint and shear in the reinforcement and 1.3 for tension normal to the bed joint and masonry shear.

Response 2 [Reference 9]

The Licensee stated that the reevaluation of block walls has been based on steel tension reinforcement resisting all tension normal and parallel to the bed joint, and that the increase factor of 1.67 was not used for tension, shear, or bond.

The Licensee's response is considered adequate and satisfies the SGEB criteria.

Question 3

With reference to Section 5.2.4, Appendix I, part 1 [4], justify the increase factor of 1.67 proposed for allowable in-plane strains.

Response 3 [Reference 9]

The Licensee stated that the allowable strain for a confined wall was based on the equivalent compression strut model with a factor of safety of 3.0 against crushing.

The increase factor of 1.67 has been used for abnormal and/or extreme environment conditions, which are credible but highly improbable. The effect is to reduce the factor of safety against crushing from 3.0 to 1.8, which is considered sufficient for such conditions. It has been found in other plants that this increase factor is judged to be reasonable based on various test programs performed at the Earthquake Engineering Research Center, University of California, Berkeley. The response is adequate and satisfactory.

Question 4

In Section 5.4, Appendix I [4], two approaches are given for determining the modulus of rupture: the first used 6 f'_c or 0.8 times modulus of rupture as determined by test; the second used 2.4 times the code-allowable flexural tensile stress. Justify these two approaches.

Response 4 [Reference 9]

The Licensee stated that, in the first method, a 20% variation in modulus of rupture was assumed and a lower bound modulus of rupture was obtained by applying a reduction factor of 0.80 to the ACI Code Value of $7.5\sqrt{f'_c}$.

The Licensee stated that the second approach, given in Section 5.4, was not used in the masonry wall reevaluation. It this approach, the modulus of rupture is obtained by applying a factor of safety of 3 to the code allowable flexural tensile stress, and then reducing it by 20% to arrive at a lower bound value.

The Licensee's response is satisfactory and consistent with the SGEB criteria.

Question 5

> Justify the use of alternative acceptance criteria of Section 6.0, Appendix I, part 1, since it is the NRC's position that energy balance techniques and the arching theory should not be used in the absence of conclusive evidence of their applicability to masonry structures in nuclear power plants.

Response 5 [Reference 9]

The Licensee gave a theoretical justification for the energy balance technique and used it to qualify five walls with an alternative acceptance criteria (see Response 13). According to Reference 9, the following walls were qualified by the energy balance technique: 68.2, 68.3, 532.1, 532.2, and 532.3. 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. FRC and its consultants have issued their evaluation and assessment of the use of the energy balance technique for masonry walls [12]. The Structural and Geotechnical Engineering Branch (SGEB) has issued a position statement regarding this subject which will be addressed in its Safety Evaluation Report.

Question 6

With reference to Section 7.1.2, Appendix I, part 1 [4], provide sample calculations to indicate how the effects of higher modes of vibration are accounted for.

Response 6 [Reference 9]

The Licensee showed analytically that the contribution of higher modes to the seismic response of the masonry walls is small relative to the fundamental mode, and can be neglected in the evaluation of wall deflections, moments, shears, etc.

The above is demonstrated with an example of an undamped simply supported beam. Using the square root of the sum of the squares (SRSS) method of combining modal responses, the contribution of higher modes to the response is less than 1% of the fundamental mode response. Using the more conservative absolute sum (ABS) method of combining responses, the contribution of higher modes is less than about 5%.

The Licensee's response is considered adequate and in compliance with the SGEB criteria.

Question 7

With reference to Section 7.1.4, Appendix I, part 1 [4], justify the use of average floor acceleration instead of the envelope of the floor response spectra.

Response 7 [Reference 9]

The Licensee showed analytically that the use of the average response spectra is more appropriate than the conservative approach of using the envelope of the floor response spectra. Using an example of an undamped simply supported beam, it is shown that the absolute maximum modal displacement response is less than or equal to the value obtained by using the average of spectral values corresponding to the two supports. Also, the use of the average response spectra is considered satisfactory in view of the conservative

method of determining response: the peak acceleration is used if the lower bound frequency falls on the low frequency side of the peak and, if the lower bound frequency falls on the high frequency side, its corresponding acceleration is used. The Licensee's response is satisfactory and adequate.

Question 8

In Section 7.2, Appendix I, part 2 [4], the following formulae were given to estimate the localized moment per unit length in a plate due to concentrated loads:

M_L = 0.4P and, for loads close to an unsupported edge
M_L = 1.2P where P is the concentrated load.

Justify the application of these formulae to masonry walls and indicate how walls with openings were analyzed.

Response 8 [Reference 9]

The Licensee stated that computer programs using finite element models were employed for the analysis of walls with concentrated loads and openings and that the formulae in question were not used in the reevaluation of masonry walls.

Since these formulae were not used, this question is considered to be resolved.

Question 9

Provide brief descriptions for the analytical approaches used for single wythe and multiple wythe walls.

Response 9 [Reference 9]

The Licensee outlined the analytical approach as follows:

1. The single wythe concrete masonry walls are first evaluated by considering one-way action.

2. For the cases found inadequate in (1), a more refined analysis considering plate action is performed using available plate theories.

3. For boundary conditions and for loading not covered by available plate theories, and for walls with openings, analysis is performed using finite element computer programs.

4. Neglecting collar shear strength, the multiple wythe walls are treated as an assemblage of single wythe walls and analyzed accordingly.

5. For seismic analysis of multiple wythe walls, additional inertia due to the unreinforced interior wythes is imposed on the reinforced exterior wythes.

6. Alternate acceptance criteria (energy balance technique) are used to demonstrate functional capability of walls that have stresses in excess of the allowable limits.

Except for the use of alternate acceptance criteria in item 6, the Licensee's analytical approach is considered adequate and in compliance with the SGEB criteria.

Response 5 addresses the use of alternate acceptance criteria.

Question 10

With regard to seismic analysis, indicate how the equipment loads were accounted for and how the earthquake forces in horizontal and vertical directions were considered.

Response 10 [Reference 9]

The Licensee stated that the weights of equipment and pipes were considered distributed over the wall height, but the seismic reactions of Class I pipes were considered as concentrated loads. Since the masonry walls are nonbearing, vertical seismic effects are insignificant except for the pipes and equipment on brackets causing local moments. These local moments were combined with out-of-plane inertia effects. The Licensee's response is considered adequate and in compliance with the SGEB criteria.

Question 11

Provide details of proposed wall modifications and indicate, using sample calculations, how these modifications will correct the wall deficiencies.

Response 11 [Reference 9]

According to the Licensee response, the wall modification improves the support condition at the top of the wall by connecting the two wythes. Before wall modification, mechanical connection of the top 6 X 4 angle was only to a 4-in wythe through 1/2-in diameter expansion bolts. A 1/2-in plate has been welded to the top angle and anchored to the 8-in wythe with 5/8-in diameter expansion bolts. The details of the wall modifications are given in Appendix B.

The Licensee's response is considered adequate and satisfies the SGEB criteria.

Question 12

Provide a status report of the proposed wall modifications.

Response 12 [Reference 9]

In this response, the Licensee stated that all modifications have been completed.

Question 13

Provide the results of the wall analysis indicating the walls that do not qualify under the working stress criteria.

Response 13 [Reference 9]

The Licensee stated that the energy balance technique was used to qualify five walls (68.2, 68.3, 532.1, 532.2, 532.3). Alternate acceptance criteria were used, making certain that a displacement of 2 times the calculated value would not affect the function of the safety-related system attached to the walls. As previously discussed in Response 5, the Structural and Geotechnical Engineering Branch (SGEB) of the NRC has issued a position statement regarding this subject which will be addressed in its Safety Evaluation Report.

Question 14

Indicate whether the door modifications and vent installations recommended by Bechtel [4] pertain to walls 68.1 to 68.4; if they do not, provide a complete description of the problem, including wall identification and proposed modification.

Response 14 [Reference 9]

The Licensee affirmed that the door modifications and vent installations recommended by Bechtel [4] to alleviate the effects of tornado depressurization inside the computer room pertained to the walls 68.1 to 68.4. Further details concerning this subject are given is Section 3.2 of this report.

The response is satisfactory.

REVIEW OF ADDITIONAL REQUESTS [10] AND RESPONSES [11]

Question 1

With regard to Response No. 2 of Reference 9, it is noted that the SGEB criteria (developed by the Structural and Geotechnical Engineering Branch of the NRC) specify that no increase factor is allowed for load combinations including OBE loads. In view of this, the Licensee is requested to provide the following information:

a. If no increase factor is used, indicate whether the walls can still be qualified for load combinations including OBE loads. It is recommended that some worst cases could be reviewed to obtain this information.

b. If the walls cannot be qualified, the Licensee is advised to explain all conservative measures used in the analysis to justify the proposed increase factor and also to identify all affected walls and the actual increase factor used in each wall.

Response 1 [Reference 11]

In response to this request, the Licensee stated that for worst cases the walls can be qualified for load combinations containing OBE loads without using the 1.3 increase factor.

This response is satisfactory and in compliance with the SGEB criteria.

Question 2

Indicate whether any wall is subjected to tornado and other impulsive loads (i.e., jet impingement). If so, provide a typical calculation for each case (with necessary explanation to make the calculation understandable).

Response 2 [Reference 11]

The Licensee responded that some walls are subjected to tornado and/or jet impingement loads and has provided a sample calculation for such a wall (wall 406.9) illustrating the analytical approach for these loads. Basically, a static, finite element computer analysis (STRUDL) was used to calculate horizontal and vertical moments in the wall and wall reactions for each load combination. The loads considered included tornado depressurization, jet impingement (with a 1.25 dynamic load factor). This approach is adequate and satisfactory.

Question 3

With reference to the reinforcement in masonry walls, the ACI-531-79 Code [7] specifies that the minimum area of reinforcement in a wall in either direction, vertical or horizontal, shall be 0.0007 (0.07%) times the gross cross-sectional area of the wall and that the minimum total area of steel, vertical and horizonal, shall not be less than 0.002 (0.2%) times the gross cross-sectional area. In view of this, clarify whether the reinforced walls at this plant meet the above requirements. It should be noted that the horizontal reinforcement is installed to satisfy the minimum reinforcement requirement for a reinforced wall.

If the joint reinforcement is used to resist tension, it should follow the working stress design method which limits its allowable to 30 ksi. The Licensee is requested to clarify if this requirement has been satisfied. If this requirement is not satisfied, identify all affected walls along with the calculated stress value for each wall.

Response 3 [Reference 11]

In this response, the Licensee stated that the minimum reinforcement requirements of the ACI-531-79 Code [7] have been met and that joint reinforcement has not been used to resist tension.

This response satisfies the SGEB criteria.

3.2 EVALUATION OF LICENSEE'S APPROACH TO WALL MODIFICATIONS

The Licensee indicated [9] that 77 walls were qualified in accordance with the conventional working stress criteria. In addition, five walls were qualified by the alternative acceptance criteria (energy balance technique). The remaining four walls required some minor modification since the collar joint tensile strength and shear strength were conservatively assumed to be zero. The modified walls are:

Serial No.	Group No.	Wall No.	Modification Status
1	11	418.10	Completed
2	11	418.11	Completed
3	11	102.8	Completed
4	11	102.9	Completed

The Licensee indicated that the purpose of the modifications to these walls was to improve support conditions at the top of the walls by connecting the two wythes. This was accomplished by welding small 1/2-in plates at regular intervals to the existing restraint (a 6 x 4 angle), which was already bolted to the top of one wythe. The new plates were then bolted to the top of the second wythe, thus connecting the wythes. Refer to Appendix B for sketches of a typical modification.

In a letter dated June 4, 1981 [8], the Licensee indicated that four walls (68.1 to 68.4) were identified as unstable under the effects of tornado depressurization and cardox injection. These are the computer room walls in the cable spreading room. To prevent wall failure due to tornado, the computer room walls have been blocked open. A permanent design modification to install vents in the walls at each end of the computer room was to be completed as soon as possible. According to the response to Question 12 in Reference 9, all wall modifications have been completed.

Through an analysis performed on the modified walls, the Licensee verified that the modified walls satisfy the SGEB criteria. The Licensee's modification methods have been reviewed and are judged to be adequate.

4. CONCLUSIONS

A detailed study was performed to provide a technical evaluation of the masonry walls at Peach Bottom Atomic Power Station. Review of the Licensee's criteria and additional information provided by the Licensee led to the conclusions given below.

The criteria used for reevaluation of the masonry walls, along with the additional information provided by the Licensee, indicate that the Licensee's criteria are in compliance with the SGEB criteria except for the use of the energy balance technique to qualify five walls in which stress due to out-of-plane loads exceeded the allowable working stress; the five walls are 68.2, 68.3, 532.1, 532.2, and 532.3. As stated in Response 5, FRC and its consultants have issued an evaluation of this technique [12]. The SGEB has also issued a position statement which will be addressed in its Safety Evaluation Report.

Section 3.2 indicated that four walls have been structurally modified, that the Licensee's approach to wall modifications is judged to be satisfactory, and that the modified walls were structurally adequate and in compliance with the SGEB criteria.

5. REFERENCES

1. "Masonry Wall Design"
   USNRC, 08-May-80
   IE Bulletin 80-11

2. S. L. Daltroff
   Letter to B. H. Grier, NRC. Subject: Response to IE Bulletin 80-11, Peach Bottom Atomic Power Station
   Philadelphia Electric Co., 02-Jul-80

3. S. L. Daltroff
   Letter to B. H. Grier, NRC. Subject: Interim Response to Item 2b of IE Bulletin 80-11 - Peach Bottom Atomic Power Station
   Philadelphia Electric Co., 03-Nov-80

4. S. L. Daltroff
   Letter with attachment to B. H. Grier, NRC. Subject: IE Bulletin 80-11 - Reevaluation of Concrete Masonry Walls for Peach Bottom Atomic Power Station
   Philadelphia Electric Co., 04-May-81

5. Interim Criteria for Safety-Related Masonry Wall Evaluation
   USNRC, 00-July-81
   SRP 3.8.4

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

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

8. M. J. Cooney
   Letter to B. H. Grier, NRC. Subject: Licensee Event Report Narrative Description and Transmittal of LER
   Philadelphia Electric Co., 04-June-81
   LER 2-81-32/1T-0

9. J. W. Gallagher
   Letter with Attachment to J. F. Stolz (NRC)
   Subject: IE Bulletin 80-11 for Peach Bottom Atomic Power Station Units 2 and 3
   Philadelphia Electric Co., 26-May-82

10. J. F. Stolz
    Letter to E. G. Bauer, Jr. (PECO)
    Subject: Masonry Wall Design, IE Bulletin 80-11
    7-Feb-84

11. Letter with Attachment to J. F. Stolz (NRC)
Subject: IE Bulletin No. 80-11, Masonry Wall Design for Peach Bottom Atomic Power Station Units 2 and 3
Philadelphia Electric Co., 21-Mar-84

12. H. G. Harris and A. A. Hamid
"Applicability of Energy Balance Technique Reinforced Masonry Walls"
Department of Civil Engineering, Drexel University
August 1982

13. Computech Engineering Services, Inc., URS/Blume and Associates, and Bechtel Power Corporation
"Rebuttal to 'Applicability of Energy Balance Technique to Reinforced Masonry Walls' by Harris and Hamid"
February 1983

APPENDIX A

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

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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 considereing 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

SKETCHES OF WALL MODIFICATIONS

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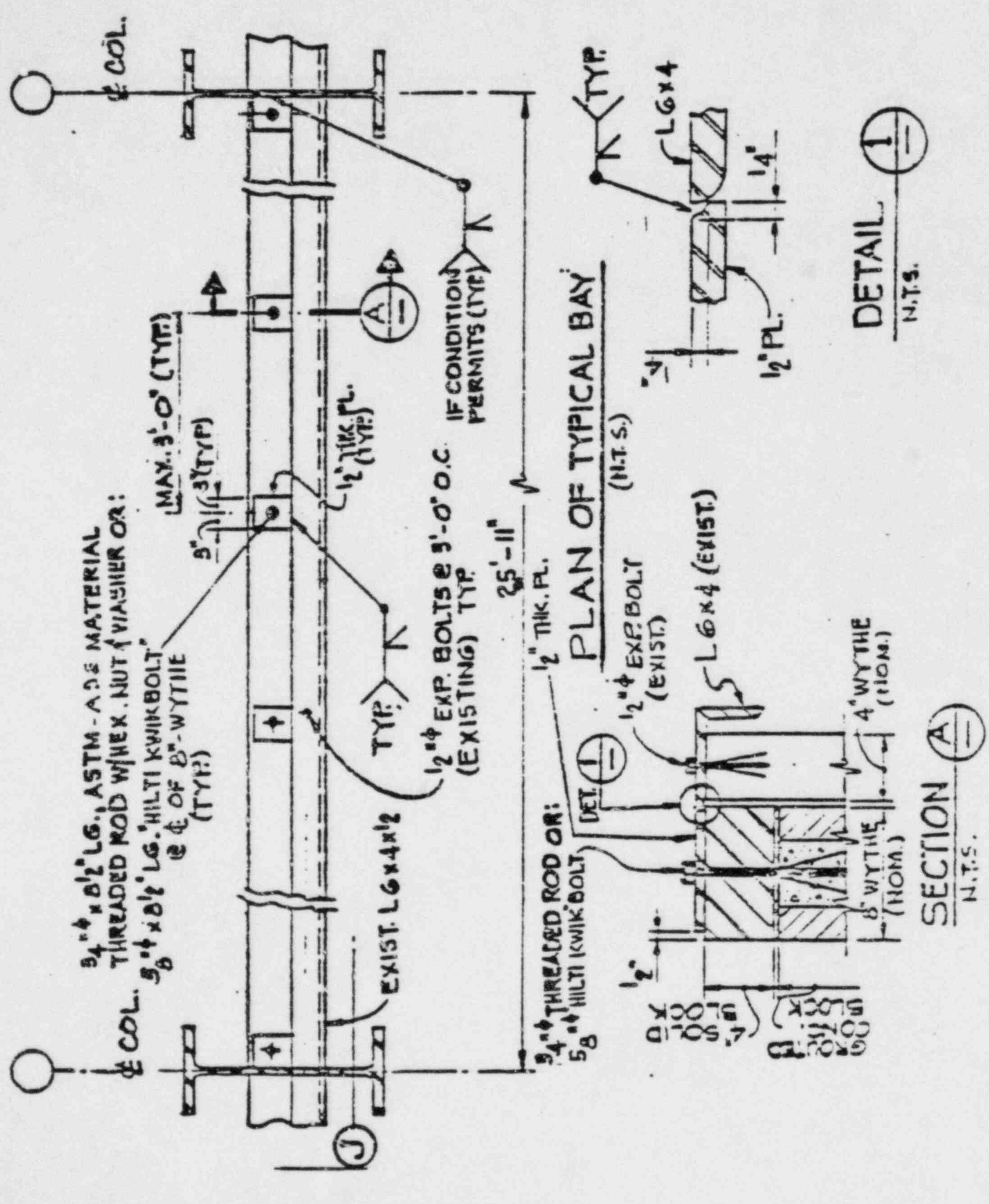
The Benjamin Franklin Parkway, Phila., Pa. 19103 (215) 448-1000


℄ COL.
℄ COL.
3/4"φ x 8 1/2" LG., ASTM-A36 MATERIAL THREADED ROD W/HEX. NUT & WASHER OR:
5/8"φ x 8 1/2" LG. "HILTI KWIKBOLT" @ ℄ OF 8"-WYTHE (TYP.)
EXIST. L6x4x1/2
1/2"φ EXP. BOLTS @ 3'-0" O.C. (EXISTING) TYP.
TYP.
MAX. 3'-0" (TYP.)
3"
3"(TYP.)
1/2" THK. PL. (TYP.)
IF CONDITION PERMITS (TYP.)
25'-11"
PLAN OF TYPICAL BAY
(N.T.S.)
3/4"φ THREADED ROD OR: 5/8"φ HILTI KWIKBOLT
1/2" THK. PL.
1/2"φ EXP. BOLT (EXIST.)
L6x4 (EXIST.)
DET. 1
1/2"
8" WYTHE (HOM.)
4" WYTHE (HOM.)
SECTION A
N.T.S.
L6x4
TYP.
1/2" PL.
1/4"
DETAIL 1
N.T.S.

ENCLOSURE 2

SGEB STAFF POSITON ON USE OF ENERGY
BALANCE TECHNIQUE TO QUALIFY REINFORCED
MASONRY WALLS IN NUCLEAR POWER PLANTS

INTRODUCTION

Under seismic loads, strain energy transfer through elastic response is very small compared to the inelastic response for energy dissipation. Therefore, inelastic non-linear analysis of reinforced masonry walls is an attractive approach. Some of the licensees have relied on a non-linear analysis approach known as "energy-balance technique" to qualify some of the reinforced masonry walls in their plants.

The staff and their consultants have reviewed the basis provided by licensees to justify the use of energy-balance technique to qualify the reinforcd masonry walls. The staff met with a group of licesees representing approximately ten utilities on November 3, 1982 and January 20, 1983 to discuss this issue. Further, site visits and detailed review of design calculations were conducted by the staff and their consultants to gain first-hand knowledge of field conditions and the application of energy-balance technique 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 energy-balance technique to qualify reinforced 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 energy-balance technique or any other non-linear analysis approach is not acceptable to the staff without further confirmation by an adequate test

Attachment 2

program. Therefore, the staff position consists of the following three options. Adoption of any one of the option and successful implementation will constitute a resolution of the issue regarding the qualification of reinforced masonry walls by energy balance technique or other non-linear techniques.

1. Reanalyse walls qualified by the energy-balance technique by linear elastic working stress approach as recommended in the staff acceptance criteria (SRP Section 3.8.4, Appendix A) and implement modifications to walls as needed.

2. Develop rigorous non-linear time-history analysis techniques capable of capturing the mechanism of the walls under cyclic loads. Different stages of behavior should be accurately modeled; elastic uncracked, elastic cracked and inelastic cracked with yielding of the central rebars. Then, a limited number of dynamic tests (realistic design earthquake motion inputs at top and bottom of the wall) should be conducted to demonstate the overall conservatism of the analysis results. In this case, "as built" walls should be constructed to duplicate the construction details of a specific plant.

3. For walls qualified by energy-balance technique, conduct a comprehensive test program to establish the basic non-linear behavioral characteristics of masonry walls (i.e. load-deflection hysteretic behavior, ductility ratios, energy absorption and post yield envelopes) for material properties and construction details pertaining to masonry walls in question. The

behavior revealed from tests should then be compared with that of elastic-perfectly-plastic materials for which the energy balance technique was originally developed. If there are significant differences, then the energy balance technique should be modified to reflect the actual wall behavior.