TECHNICAL EVALUATION REPORT

MASONRY WALL DESIGN (B-59)

PUBLIC SERVICE ELECTRIC AND GAS COMPANY

SALEM GENERATING STATION UNITS 1 AND 2

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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 AND SCOPE

The purpose of this review is to provide a technical evaluation of the Licensee's response to Items 2 and 3 of the Nuclear Regulatory Commission's (NRC) IE Bulletin 80-11, "Masonry Wall Design" [1], which required licensees to present reevaluation criteria with justifications and to submit a written report upon completion of the reevaluation program. The evaluation included a review of any Licensee-proposed modifications of masonry walls and the proposed methods, procedures, and repair schedules.

1.2 PLANT-SPECIFIC BACKGROUND

In response to IE Bulletin 80-11, Public Service Electric and Gas Company provided the NRC with documents [2-10, 16] describing the status of masonry walls at the Salem Generating Station Units 1 and 2. Based on the information provided by the Licensee [2-10, 16] and the related NRC documents [11-15], a review of the status of masonry walls at this plant was conducted, and it was determined that some aspects required clarification. Therefore, a telephone conference call was arranged in September 1982 to request the Licensee's clarification. The Licensee has responded to this recent request, and through this response [20] and the earlier responses [7, 9], the Licensee has addressed all the items in the requests for information issued by the NRC. References 9 and 30 indicate that the Licensee has completed the following actions required by the NRC [13] for considering operation above 5% power:

"a. Submit the information requested during the November 20, 1980, meeting,

b. Complete the wall capacity strengthening program,

c. Confirm that the proposed remedial actions do not preclude the option of implementing additional modifications which would, if dictated by future staff review, render the masonry wall design to meet the zero tensile stress requirements under OBE and SSE conditions,

Prior to startup following the first refueling, PSE&G shall resolve the difference between the staff criteria and that of the licensee's

to the satisfaction of the staff and implement the required fixes that might result from such a resolution."

There are nine safety-related masonry walls in Salem Unit 1 and eight in Unit 2. The Licensee has indicated [20] that, with the exception of two walls in Unit 1 and one in Unit 2, all the walls meet the NRC criteria. The Licensee has performed field tests [7, 9] for all of the walls analyzed except for the walls in the controlled facilities building, which have been adequately modified.

The following materials were used in the masonry wall construction, and their properties were used in the analysis [7, 9]:

1. Masonry units - "Waylite" concrete block manufactured to ASTM C-90.
2. Mortar ASTM C-270, type M - field tests of mortar joints were performed.
3. Core fill - normally used block mortar or cement grout. Where field inspection revealed empty block cores, these cores were filled with 5-Star Grout if the wall stresses exceeded the Licensee's criteria allowables.
4. Structural steel - steel used in original construction or to strengthen the masonry walls as a corrective action is ASTM A-36 material.
5. Dur-O-Wall truss-type masonry reinforcing (manufacturer's standard product).
6. Reinforcing steel - ASTM A15, intermediate grade, deformed bars as per ASTM 305.
7. Expansion anchors, such as WEJ-IT, or approved equal.
8. Phillips RED-HEAD Anchors, or approved equal cast into concrete.

The functions of the masonry walls at Salem Units 1 and 2 are shielding, fire protection, security, and weather protection. None of these walls are load-bearing structural walls, nor are they part of the lateral load-resisting system.

2. EVALUATION CRITERIA

The basic documents used for guidance in this review were the "SGEB Criteria for Safety-Related Masonry Wall Evaluation" [17] (attached as Appendix A to this report), developed by the Structural and Geotechnical Engineering Branch (SGEB) of the NRC; the Uniform Building Code [18]; and ACI-531-79 [19].

In general, the materials, testing, analysis, design, construction, and inspection of safety-related concrete masonry walls should conform to the SGEB criteria [17]. For operating plants, the loads and load combinations for qualifying the masonry walls should conform to the appropriate specifications in the FSAR for the plant. Allowable stresses and the appropriate increase factors for abnormal and extreme environmental loads are given in Reference 17.

3. TECHNICAL EVALUATION

This evaluation is based on the Licensee's earlier response [2-6] and subsequent responses [7-10, 16, 20] to the requests for additional information. The Licensee's criteria were evaluated with regard to design and analysis methods, loads and load combinations, allowable stresses, construction specifications, materials, and relevant test data. In addition, the Licensee's modifications and response to the request for additional information has been evaluated.

3.1 EVALUATION OF LICENSEE CRITERIA

The Licensee has reevaluated the masonry walls using the following criteria [7, 9]:

- Allowable stresses for analysis of masonry walls were based on ACI 531-79 Code specifications [19]. However, the increase factors for abnormal loads in the Licensee's criteria are higher (1.67) than those in the SGEB criteria [17].
- Loads and load combinations used were those specified in the plant Safety Analysis Report.
- The working stress method is used for all of the walls analyzed, and the walls were assumed to be unreinforced.
- A 2% damping for operating basis earthquake (OBE) and 5% for design basis earthquake (DBE) were assumed.
- In general, walls are not subject to missile impact, jet impingements, pipe whip, or pressurization loads, and the walls in the controlled facilities room are free also from loads due to pipe reaction and thermal loads.

In general, except for the increase factors, the Licensee's criteria are in compliance with the SGEB criteria [17]. The Licensee has responded to all of the questions in the requests for additional information. These responses are incorporated in References 7, 9, and 20 and are found to be technically adequate as explained below.

In Reference 20, the Licensee has indicated that, with the exception of three walls (wall No. 9 in Unit 1, wall No. 2-9 in Unit 2, and wall No. 14 in

Unit 1), all safety-related masonry walls in Salem Units 1 and 2 meet the SGEB criteria [17]. Hence, the concern regarding higher increase factors in the Licensee's criteria applies only to these three walls.

With regard to wall No. 9 and wall No. 2-9, which are walls between the control equipment room and corridor and between the janitor's closet and maintenance room, the Licensee has indicated [20] that the mortar stress in the joints for DBE is 8% above the SGEB criteria (although well below the Licensee's criteria). Since a conservative damping value of 5% has been assumed and a lower bound value of Young's modulus has been used, the Licensee has satisfied the intent of the criteria; the Licensee's approach is technically adequate.

With regard to wall No. 14 (walkway and truck bay), the Licensee indicates [20] the following corrective actions: Many bracing members have been added to reduce the stress to the extent that the Licensee's criteria are satisfied as shown in Table 1. Since only the lower section of the wall does not meet the SGEB criteria, the Licensee has proposed to install a wire mesh structure for the lower section of the wall in order to protect safety-related structures in its vicinity. The Licensee's approach provides adequate protection since the upper section of the wall is fully supported by a steel beam and the wire mesh is adequate to prevent the lower section of the wall from hitting safety-related structures nearby.

Table 1. Summary of Results of Walkway Wall (Wall No. 14)

	Lower Section (Moment Capacity/Actual Moment)		Upper Section (Moment Capacity/Actual Moment)	
	Licensee's Criteria	SGEB Criteria	Licensee's Criteria	SGEB Criteria
Horizontal Span	1.82	1.42	8.19	6.37
Vertical Span	1.10	0.85	2.17	1.68

Notes: From the results, it is seen that the lower section of wall No. 14 is weaker in the vertical span. The Licensee will be installing protective netting to prevent the lower section of this wall from collapsing onto safety-related structures in its vicinity. Since the upper section of the wall is fully supported by a steel beam, the Licensee's approach is adequate.

3.2 EVALUATION OF LICENSEE APPROACH TO WALL MODIFICATIONS

The Licensee has provided details of wall modifications in Reference 20 and in Appendix D of References 7 and 9. Modifications have been proposed for all of the safety-related masonry walls except two which meet the SGEB criteria without modifications (one each in Units 1 and 2). These modifications primarily consist of attaching structural steel (wide flanges, angles, and channels) to the faces of the existing walls. The Licensee's approach to wall modifications is satisfactory since confirmatory analyses [20] have shown that all of the walls except two in Unit 1 and one in Unit 2 meet the SGEB criteria. Wall No. 9 (Unit 1) and wall No. 2-9 (Unit 2) indicated stresses which are 8% higher than the SGEB criteria allowables. However, these walls have been analyzed using a conservative value for damping and a lower bound value for the modulus of elasticity, and therefore no modification is required; the Licensee's approach is considered adequate. Wall No. 14 (Unit 1) does not itself carry any safety-related component but is in the vicinity of the refueling water storage tank and the auxiliary feedwater storage tank. Therefore, braces were added to this wall to bring the stresses within the Licensee's criteria allowables, as shown in Table 1. Though this does not satisfy the SGEB criteria allowables (because of the lower increase factors), the following considerations eliminate any safety-related concerns:

1. The Licensee has used a conservative value for damping and a lower bound value for the modulus of elasticity.

2. In order to preclude the possibility of the wall collapsing onto safety-related structures, the Licensee is committed to install a wire mesh cargo netting by June 1983 [20]. Because of this netting, the lower section of the wall can tip outside only until it encounters the net's restraint and then fall vertically into a pile at the base of the wall. The upper section of the wall is fully supported by a steel beam.

In Reference 20, the Licensee also has committed to corrective actions with regard to steel framing of the walkway. The walkway and truck bay structure will be physically cut at the point at which the foundation conditions change in order to preclude warping of the structures due to possible seismic motion. Since there will be a structural steel frame on both

sides of this cut, the structural integrity of the walkway and truckbay walls will be maintained. The Licensee had committed to installing this modification by August 1, 1983. The Licensee's approach is considered technically adequate.

4. CONCLUSIONS

A detailed study was performed to provide a technical evaluation of the masonry walls at Salem Generating Station Units 1 and 2. Review of the Licensee's criteria and additional information provided by the Licensee led to the conclusions given below.

A review of the information presented in References 7 and 9 for reevaluation of the masonry walls, along with the additional information provided by the Licensee [20], indicates compliance with the SGEB criteria except for minor deviations with respect to the proposed increase factors for allowable tension normal to the bed joint. However, the results of the wall analysis indicate that stresses are within the allowables (with SGEB increase factors) except in the case of three walls, wall Nos. 9, 2-9, and 14. In the case of wall Nos. 9 and 2-9, the overstress, as compared to the SGEB allowables, is only about 8%; this does not warrant any wall modifications due to conservatism in using a low (5%) damping value and a lower bound value of modulus of elasticity. In the case of wall No. 14 (walkway and truck bay), the Licensee's approach has brought the stresses to within their criteria allowables and any concern due to the higher increase factors is eliminated by the conservatism in the Licensee's analytical approach (low damping) and by the proposed structural netting to prevent possible wall collapse onto safety-related structures.

The Licensee's criteria are considered technically adequate and meet the intents of the SGEB criteria [17].

The Licensee's modifications are considered adequate based on sketches of wall modifications, which are provided in Reference 20 and in Appendix D of References 7 and 9. The protective netting designed by the Licensee for wall No. 14 is adequate since only the lower section of this wall is overstressed as compared to SGEB criteria allowable, as shown in Table 1 and the upper section of the wall is fully supported by a steel beam.

The Licensee has committed to complete all modifications by January 1981, as indicated in References 7 and 9, and all additional modifications by August 1983.

5. REFERENCES

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   "Masonry Wall Design"
   NRC, 08-May-81

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   Letter to B. H. Grier, NRC. Subject: NRC IE Bulletin 80-11, Masonry Wall Design - Salem Generating Station Unit 1
   Public Service Electric & Gas, 02-Jul-80

3. R. L. Mittl
   Letter to F. J. Miraglia, NRC. Subject: Masonry Wall Design - IE Bulletin 80-11, Salem Nuclear Generating Station Unit 2
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4. Computech Engineering Services, Inc.
   Criteria for the Re-Evaluation of Concrete Masonry Walls Salem Nuclear Generating Station; Draft
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   P8060/08

5. H. G. Berrick
   Salem Generating Station Units 1 and 2 - Design Change Request
   Public Service Electric & Gas, 15-Nov-80
   2EC1049, pkg. 1

6. F. P. Librizzi
   Letter to B. H. Grier, NRC. Subject: Reportable Occurence 80-56/01T, Salem Generating Station Unit 1
   Public Service Electric & Gas, 24-Nov-80

7. Salem Generating Station Unit 1 - Report on Re-Evaluation of Masonry Walls
   Public Service Electric & Gas, 28-Nov-80

8. H. J. Midura
   Letter to B. H. Grier, NRC. Subject: Reportable Occurrence 80-56/01X-1, Salem No. 1 Unit Licensee Event Report
   Public Service Electric & Gas, 01-Dec-80

9. Salem Generating Station Unit 2, Report on Re-Evaluation of Masonry Walls
   Public Service Electric & Gas, 03-Dec-80

10. F. W. Schneider
    Letter to B. Grier, NRC. Subject: IE Bulletin 80-11, Masonry Wall Design - Salem Generating Station Unit 2
    Public Service Electric & Gas, 10-Dec-80

11. J. Kerrigan
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USNRC, 11-Dec-80

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USNRC, 30-Dec-80

13. H. R. Denton
Memo, Subject: Consideration of Full Power Operating License for Salem Nuclear Generating Station, Unit 2, including pages 3-3 to 3-9 of attachment (Masonry Walls)
USNRC, 30-Dec-80

14. F. P. Schauer
Memo for J. P. Knight, NRC. Subject: IE Bulletin 80-11 - Design Review Meeting of First Group Operating Plant Masonry Walls
USNRC, 07-Jan-81

15. R. L. Tedesco
Letter to R. L. Mittl, PSE&G. Subject: Request for Information - Masonry Walls, Salem Unit 2
USNRC, 08-Jan-81

16. R. A. Uderitz
Letter to B. H. Grier, NRC. Subject: Reportable Occurrence 80-56/01X2, Supplemental Report
Public Service Electric & Gas, 00-Mar-81

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

18. Uniform Building Code
Internal Conference of Building Officials, 1979

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

20. E. A. Liden
Letter to S. A. Varga, NRC
Subject: Additional Information - NRC IE Bulletion 80-11
08-Dec-82

APPENDIX A

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

APPENDIX A

SGEB CRITERIA FOR SAFETY-RELATED MASONRY WALL EVALUATION
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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.