# TECHNICAL EVALUATION REPORT

# MASONRY WALL DESIGN

NORTHERN STATES POWER COMPANY

PRAIRIE ISLAND NUCLEAR GENERATING PLANT UNITS 1 AND 2

NRC DOCKET NO. 50-282, 50-306

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FRC TASK 247


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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 a technical evaluation of the Licensee response to IE Bulletin 80-11 [1] with respect to compliance with the Nuclear Regulatory Commission (NRC) masonry wall criteria. In addition, if the 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 (PGE) 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, Northern States Power Company submitted to the NRC letters with attachments dated July 8, 1980 [2] and November 4, 1980 [3] describing the status of masonry walls at Prairie Island Nuclear Generating Plant Units 1 and 2. The information in these letters was reviewed, and requests for additional information were sent to the Licensee on August 12, 1982 [4] and January 3, 1983 [5]. The Licensee responded to these requests on September 23, 1983 [6] and April 14, 1983 [7].

The Prairie Island plant has approximately 275 single-wythe or double-wythe walls. The Licensee identified 121 walls as safety-related in both Units 1 and 2 according to IE Bulletin 80-11. In general, the masonry walls were designed as partition walls or shield walls. Most masonry walls are vertically reinforced walls. Some are partially grouted and others are fully grouted.

Masonry wall types and materials for the Prairie Island Nuclear Generating Plant Units 1 and 2 are given below:

Wall Types:

| | |
|---|---|
| Total number of walls | 275 |
| Safety-related walls | 121 |
| Walls requiring modifications | 28 |

Wall functions: Partition, shielding

Construction Materials:

Hollow masonry units - ASTM C90-66T, Grade U-1

Solid masonry units - ASTM C145-66T, Grade U-1

Horizontal reinforcement - Dur-O-Wal truss or approved equal

Vertical reinforcement - ASTM A615-68, Grade 40

Mortar - ASTM C476, Type PL with the following constituents unless otherwise specified:

Lime - ASTM C207, Type S hydrated, or quick lime slaked to form lime putty conforming to ASTM C5

Portland Cement - ASTM C150, Type I or ASTM C175, Type IA

Sand - ASTM C144, well graded from coarse to fine.

## 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 (attached as Appendix A to this report), the Uniform Building Code [8], and ACI 531-79 [9].

In general, 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 FSAR for the plant. Allowable stresses are specified in Reference 9 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] and subsequent responses [6, 7] to the requests for additional information [4, 5]. The Licensee's criteria [3] were evaluated with regard to design and analysis methods, loads and load combinations, allowable stresses, construction specifications, materials, and relevant test data. The Licensee's responses to the requests for additional information were also reviewed.

## 3.1 EVALUATION OF LICENSEE'S CRITERIA

The Licensee performed the reevaluation of the masonry walls using the following criteria:

- The design allowables are based on ACI 531-79 [9].
- Load combinations are according to the Final Safety Analysis Report (FSAR).
- The working stress method of analysis is used.
- The transverse earthquake forces acting on the walls are computed by the spectral approach. The following criteria are used:
  - 2% damping is used for uncracked reinforced walls under operating basis earthquake (OBE) and design basis earthquake (DBE) for most of the walls.
  - 5% damping is used for cracked reinforced walls under OBE and DBE for a few walls.
  - Spectral acceleration is selected for the walls by varying the computed fundamental frequency by 10% to account for the variability of material and construction.
  - Peak acceleration is selected as a representative acceleration for the walls when the fundamental period is on the steep gradient of an acceleration vs. period curve for the floor.
  - The loads of the equipment and piping attached to the wall are considered in the analysis.
  - Story drift loads are computed using the maximum horizontal relative displacement of the walls.

- The walls are modeled as beams or plates. The end conditions are considered as being fixed, simply supported, or free.

- Joint reinforcement (Dur-O-Wal) was used to qualify three reinforced walls.

The Licensee responded to all questions in the request for additional information. These responses are reviewed below.

Request 1

Indicate whether the walls are stack bond or running bond. If any stack bond wall exists, provide sample calculations to obtain moment and shear stress of a typical wall.

Response 1

The Licensee confirmed that all masonry walls evaluated in response to IE Bulletin 80-11 are built with the running bond pattern. The Licensee's response has resolved the concern of stack bond construction at the Prairie Island plant.

Request 2

According to Attachment A, Section 2.5 of Reference 3, the masonry walls in the hydrogen room and those around the elevator shaft were designed as shear walls. Indicate whether these shear walls are safety-related. If yes, have they been analyzed?

Response 2

The Licensee stated that the masonry walls around the hydrogen room were originally designed as bearing walls, but they are not safety-related walls. The walls around some of the elevator shafts were classified as safety-related walls, but they are not shear walls. The Licensee confirmed that these safety-related walls were reanalyzed per the criteria of Reference 3.

Therefore, none of the safety-related walls are shear walls. This has resolved the concern.

Request 3

Provide test results of the compressive strength of masonry block, mortar, and grout.

Response 3

The Licensee provided test results of masonry block and mortar. The test results of five samples indicated that the compressive strength of masonry block ranged from 2750 psi to 3480 psi, thus meeting ASTM Specification C90-66T, Grade U-1 Hollow Concrete Masonry Units, which requires a minimum strength of 1600 psi for individual units and 2000 psi for the average of five units. However, the Licensee used 1350 psi for compressive strength of masonry block in the analysis. The test results of two samples demonstrated mortar compressive strengths of 2370 psi and 2380 psi, thus meeting the ASTM-C476 Type PL specified strength of 1600 psi at 7 days. For the same sample at 28 days, the tested compressive strengths of 3830 psi and 3930 psi also met the ASTM-specified strength of 2500 psi.

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

Request 4

Indicate how earthquake forces in three directions were considered in the analysis.

Response 4

The Licensee indicated that Prairie Island masonry walls were designed and analyzed for the two-dimensional seismic forces, i.e., north-south combined with vertical earthquake and east-west combined with vertical earthquake. The masonry wall computed stresses due to each component of the earthquake are conservatively added by an absolute sum method. This procedure indicated that the effects of in-plane seismic loads were included in the analysis.

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

Request 5

Regulatory Guide 1.61 allows 4% damping for the OBE and 7% damping for the safe shutdown earthquake (SSE). Section 3.2.2 of Reference 3 specifies a damping value of 5% for both OBE and SSE conditions. Justify this value for the OBE condition.

Request 5.3 (Request 3 in Reference 5)

Regulatory Guide 1.61 allows 4% damping for the OBE. In the Response No. 5 the Licensee used 5% damping for OBE and indicated that the ratios of floor response spectral accelerations for 4 and 5 percent damping are less than 1.33. Indicate the number of walls qualified by 5% damping (OBE) and state whether these walls can be qualified if 4% damping is used.

Responses to Requests 5 and 5.3

The Licensee confirmed that six walls were qualified as reinforced concrete block walls with 5% damping for OBE and SSE. For SSE, the computed stresses were taken as twice the values of OBE, and the allowables for SSE were increased by a factor of 1.5, which complied with the SGEB criteria except for shear carried by masonry and masonry tension perpendicular to bed joint, which will be discussed in Response 10.

The OBE accelerations were multiplied by 2.0 to determine SSE design accelerations. The increase factors for OBE and SSE allowables are 1.0 and 1.5, respectively. These load factors and allowable factors result in the following stress equations:

For OBE: 1.0 (actual OBE stress) $\leq$ 1.0 (code allowable stress for OBE).

However for SSE: 2.0 (actual OBE stress) $\leq$ 1.5 (code allowable stress for OBE).

Hence: 1.33 (actual OBE stress) $\leq$ 1.0 (code allowable stress for OBE).

The effect of the increase factor of 1.5 for the allowable stress for SSE is the same as using a load factor of 2.0/1.5 = 1.33 with no increase in the

allowable stress. The SSE conditions therefore governed the wall design. From this point of view, the Licensee justified the use of 5% damping for OBE for the six walls in question by comparing the ratio of 4% and 5% damping floor response spectral accelerations and found that this response ratio is less than 1.33, which is the allowed increase factor in the governing SSE case. It should be noted that for cracked reinforced walls, the Licensee used 5% damping for SSE, which is more conservative than the damping ratio of 7% specified in Regulatory Guide 1.61. Therefore, the Licensee's responses are considered adequate and meet the intent of the SGEB criteria.

Request 6

Provide sample calculations to indicate how the effects of higher modes of vibration are considered in the analysis.

Response 6

The Licensee's response indicated that seismic loads for typical walls were applied as uniform loads on the entire wall. The spectral accelerations corresponding to the fundamental mode of vibration were used to determine the seismic loads. Also, the criteria for reevaluation of masonry walls at Prairie Island Nuclear Plant [3] indicated that peak acceleration of the floor response spectra was used. Based on these conservative measures and for all practical purposes, the fundamental mode should adequately cover the total responses of the walls. It has been found, in many cases at 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.

Request 7

Indicate whether load combinations not involving loads due to thermal gradient, wind, operating pressure, accident pressure, pipe rupture, etc., are according to FSAR specifications. Also justify the use of a factor of 2/3 for the load combination in Section 7.3.2 of Reference 3.

Response 7

The Licensee confirmed that all load combinations used for the reevaluation of masonry walls are in accordance with the Prairie Island FSAR. Also, the Licensee explained that the factor of 2/3 for the load combination in Section 7.3.2 of Reference 3 is equivalent to an increase of the allowable stresses for the load combinations involving SSE load by 50%, which is consistent with the Prairie Island FSAR. However, in Responses 10 and 5.2 on page 12 of this report, the Licensee stated that all masonry block walls have been reevaluated based on the SGEB allowed increase factors and that all walls are found to be in compliance with the criteria. This response and Responses 10 and 5.2 resolve any concern over the factor of 2/3 for the load combination in Section 7.3.2 of Reference 3.

Request 8

Provide sample calculations for block pullout analysis.

Response 8

The Licensee stated that no major pipe thrust or other heavy loads are attached to any of the safety-related masonry walls. The sample calculation was provided for an 8-in single-wythe wall with the following conditions:

- hollow block, 8 in by 8 in by 16 in
- total net area is 242 $in^2$
- horizontal seismic force is 600 lb
- attached load on wall is 400 lb.

The calculated shear stress was found to be 3.72 psi, which is much smaller than the available shear stress of 33 psi. The Licensee's response is adequate and in compliance with the SGEB criteria.

Request 9

According to Section 7.4.4.3, Attachment A of Reference 3, a limit of 25 psi has been used for tension between wythes of multi-wythe walls in composite action. Justify this value by any existing test data. Also,

provide and justify by any existing test data the value for allowable collar joint shear stress. Provide sample calculations illustrating the analysis of multi-wythe walls in composite action.

Response 9

In response to this request, the Licensee provided justification in the following subsections:

1. Tension Between Block and Fill:

   The Licensee indicated that multi-wythe walls for the Prairie Island plant are solid grouted. The bond between the block and grout is expected to be the same as the bond between block and mortar. ACI 531-79 allows 40 psi for tension normal to bed joint for mortar of 2000 psi. Moreover, the Licensee referred to tests of tensile bond strength of concrete blocks to grout fill conducted by Northwest Testing Lab for Portland General Electric's Trojan Nuclear Power Plant. The specified compressive strength for blocks was 2000 psi and for grout fill was 3000 psi. These test results indicated average tensile bond strength between blocks and grout to be 194 psi. However, the Licensee indicated that the maximum computed tensile stresses between blocks and fill materials is less than 3 psi.

2. Collar Joint Shear Stress

   In response to this request to provide and justify by existing test data the value for allowable collar joint shear stress, the Licensee did not refer to any test. Instead, the ACI 531-79 allowable shear stress of $1.1\sqrt{f'm}$ was mentioned. For the Prairie Island plant, this allowable shear stress is equivalent to 43 psi. However, the Licensee used a more conservative value of 10 psi as the allowable collar joint shear stress. Moreover, the maximum computed value of collar joint shear stress for multi-wythe walls is less than 5 psi including SSE loads.

3. Sample Calculation

   A sample calculation was provided for an 18-in double-wythe solid grouted wall with the following conditions:

   - span is 15 ft, both ends simply supported
   - attached load on wall is 200 lb, rigidly attached
   - OBE is 0.094 g
   - wall is uncracked.

The sample calculated collar joint shear stresses were found to be 1 psi for OBE and 2 psi for SSE, both of which are smaller than the allowable shear stress of 10 psi.

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

Request 10

Provide any increase factors that may have been used for allowable stresses under abnormal conditions. If they are higher than those factors listed in the SGEB criteria (Appendix A), provide justification. The SGEB factors are listed below by type of stress.

| | |
|---|---|
| Axial or flexural compression | 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 the bed joint | 1.5 |
| Shear carried by masonry | 1.3 |
| Masonry tension perpendicular to the bed joint | |
| Reinforced masonry | 0 |
| Unreinforced masonry | 1.3 |

Request 5.2 (Request 2 in Reference 5)

In Response No. 10, the Licensee indicated that, for factored load cases, an increase factor of 1.5 has been used for shear carried by masonry and tension perpendicular to the bed joint. The SGEB criteria allow only 1.3. The Licensee is requested to identify the number of affected walls and the corresponding increase factor used for each wall. The Licensee is also requested to identify sources of conservatism used in the analysis, which can be claimed to justify the use of the higher increase factor.

Responses 10 and 5.2

In response to Request 10, the Licensee stated that all factors are equal to or less than those factors listed in the SGEB criteria in all cases except for the 1.3 factor permitted for shear carried by masonry and for tension perpendicular to the bed joint. In response to Request 5.2, the Licensee stated that all masonry block walls have been reevaluated in response to this current inquiry and that all walls are found to be in compliance with the reduced factor. The Licensee's response is satisfactory and in compliance with the SGEB criteria.

Request 11

> Indicate whether the walls are subject to impulsive or impactive loads such as missle or jet impingement loads. If so, provide sample calculations showing how they were considered in the analysis.

Response 11

The Licensee stated that masonry walls in the plant are not subjected to impulsive and/or impactive loads such as missile or jet impingement.

This response has resolved the concerns of missile or jet impingement loads for the Prairie Island plant's masonry walls.

Request 12

> Indicate the current status of the modifications and provide detailed drawings of some sample modifications.

Response 12

The Licensee confirmed that engineering and construction of modifications have been completed. Also, a drawing was provided for sample modifications. The Licensee's response has resolved the concern of this request. See the Section 3.2 for further discussion of wall modifications.

Request 5.1 (Request 1 in Reference 5)

In Response No. 5 [6], the Licensee stated that almost all of the masonry walls were analyzed as reinforced walls, but in Response No. 10 [6] it was stated that many walls at the plant were analyzed as unreinforced walls. Explain this discrepancy.

Response 5.1

The Licensee explained that almost all of the masonry walls were analyzed as uncracked reinforced masonry walls. Both responses have the same meaning. An uncracked reinforced wall subject to bending tensile stresses behaves similarly to an unreinforced wall. As long as the tensile stresses remain below the code allowable stresses for the tension in the mortar, the wall remains uncracked and reinforcing steel is not relied upon to resist the tensile stresses.

The Licensee's response is considered adequate and has resolved the concern satisfactorily.

Request 5.4 (Request 4 in Reference 5)

a. Indicate if any joint reinforcement (Dur-O-Wal) was used as a tensile resisting element. If so, provide the number of affected walls.

b. The primary function of joint reinforcement is to control cracks associated with thermal or moisture expansion or contraction. Provide technical basis (i.e., test data) to substantiate its use as a tensile resisting element.

c. Provide verification to assure proper bonding between the reinforcement and mortar and proper anchorage of joint reinforcement at the boundary.

Response 5.4

a. All safety-related walls have Dur-O-Wal joint reinforcement. Most walls were qualified without relying upon the horizontal reinforcement to resist tensile stresses. Only three walls rely on Dur-O-Wal to carry the tensile stress. These are Walls 3, 27, and 36.

b. The Licensee indicated that the allowable design stresses for joint wire reinforcement as detailed in Section 10.2 of ACI-531 were used.

The Licensee also stated that the Uniform Building Code, 1982 Edition allows the use of joint reinforcement as a principal steel to carry design tension stresses.

c. Verification was obtained by examination of the quality assurance inspection checklist for masonry wall construction. The walls were inspected during construction and found to be in compliance with the design specifications.

A review of both vertical and horizontal reinforcement for the three walls mentioned above indicated that they meet the minimum requirements for reinforcement as specified in ACI 531-79 [9]. In addition, the Licensee confirmed that the working stress allowables for joint wire reinforcement specified in Section 10.2 of ACI 531-79 [9] were used for all loading conditions.

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

## 3.2 EVALUATION OF LICENSEE'S APPROACH TO WALL MODIFICATIONS

The Licensee concluded through its reevaluation program that 28 of the 121 safety-related masonry walls at the Prairie Island plant do not meet the reevaluation criteria and need field modification. In all cases, failure of the walls is due to postulated earthquake loads.

The Licensee has proposed two types of modification:

a. changing the existing free edge condition of the wall to a simply supported edge condition in the transverse direction. This is accomplished by attaching steel members to the ceiling and/or side walls and by columns on both sides of the masonry wall.

b. introducing additional supports to reduce the span. This is accomplished by installing structural members on one side of the wall at appropriate intermediate locations.

All modifications were scheduled to be implemented by April 10, 1981. In Response 12 of Section 3.1, the Licensee confirmed that engineering and construction of modifications have been completed.

The modified walls are listed in Table 1 below.

Table 1. Walls Requiring Modifications

| Floor Level | Wall Identification No. | Type of Modification |
|---|---|---|
| 695 ft | 28, 31, 37, 39, 40, 48 | Change free edge of the walls to a simple support |
| 715 ft | 23, 83, 90 | Change free edge of the walls to a simple support |
| 735 ft | 1, 2, 3, 4, 5, 27, 34, 35, 36, 37 | Change freee edge of the walls to a simple support |
| 755 ft | 1 | Change free edge of the walls to a simple support |
| 715 ft | 25, 26 | Reduce span of the wall by introducing additional support(s) |
| 735 ft | 6, 8, 38, 39 | Reduce span of the wall by introducing additional support(s) |
| 755 ft | 2, 3 | Reduce span of the wall by introducing additional support(s) |

Most of the walls were provided with supports on both faces, with the exception of a few walls which were supported only on one face of the wall. However, thrubolts and special types of support configurations were used to restrain the walls in the transverse direction. Details 3, 5, and 11 of drawings in Appendix B show the details of the wall supports either on top of or on the sides of the wall.

For those walls to which additional supports were introduced to reduce the span, thrubolts were used at either the top or the edge of the wall support to provide seismic restraint of the wall (similar to the configuration in Detail 5 in Appendix B) in the transverse direction. All of these walls are reinforced and connected to the floor with dowels. Along the supported beam, expansion bolts were used on alternate locations on the near side and far side of the supported beam web (see Details 18A, 9A, 10 of drawings in Appendix B).

The review of modification drawings as described above indicates that the modifications are adequate and that the modified walls satisfy the SGEB criteria with regard to the allowables.

# 4. CONCLUSIONS

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

The Licensee's criteria are in compliance with the SGEB criteria except for the following cases:

- The damping value for the OBE case is 5% as opposed to 4%. However, in Response 5 on page 7, it was shown that for the six affected walls, the ratio of 4% and 5% damping floor response spectral accelerations is less than 1.33, which is the allowed load increase factor (without an increase in the code allowable stress for OBE) in the governing SSE case. Therefore, the Licensee's criteria are still considered to meet the intent of the SGEB criteria.

- A higher stress increase factor was used for shear carried by masonry and tension normal to bed joint (1.5 as opposed to 1.3 by the SGEB criteria). However, the Licensee has reevaluated all masonry walls and found that they are in compliance with the SGEB criteria.

The Licensee's approach to wall modifications has been reviewed and is judged to be adequate and in compliance with the SGEB criteria.

## 5. REFERENCES


1. IE Bulletin 80-11
   "Masonry Wall Design"
   NRC, 08-May-81

2. D. E. Gilberts
   Letter to J. G. Keppler, NRC. Subject: Prairie Island Nuclear Generating Plant - Response to IE Bulletin 80-11, Items 1, 2a, and 3
   Northern States Power Co., 08-Jul-80

3. D. E. Gilberts
   Letter to J. G. Keppler, NRC. Subject: Prairie Island Nuclear Generating Plant - Response to IE Bulletin 80-11, Item 2b
   Northern States Power Co., 04-Nov-80

4. R. A. Clark (NRC)
   Letter to Northern States Power Company. Subject: Additional Information Required by IE Bulletin 80-11
   August 12, 1982

5. R. A. Clark (NRC)
   Letter to Northern States Power Company. Subject: Additional Information Required by IE Bulletin 80-11
   January 3, 1983

6. D. Musolf
   Letter to Director Region III, NRC. Subject: Prairie Island Nuclear Generating Plant - Response to Request for Additional Information Related to Masonry Wall Design (IE Bulletin 80-11)
   Northern States Power Co., 23-Sep-82

7. D. Musoft
   Letter to Director Region III, NRC. Subject: Prairie Island Nuclear Generating plant - Additional Information Related to Masonry Walls and Action Required by IE Bulletin 80-11
   Northern States Power Co., 14-Apr-83

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

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

APPENDIX A

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

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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.

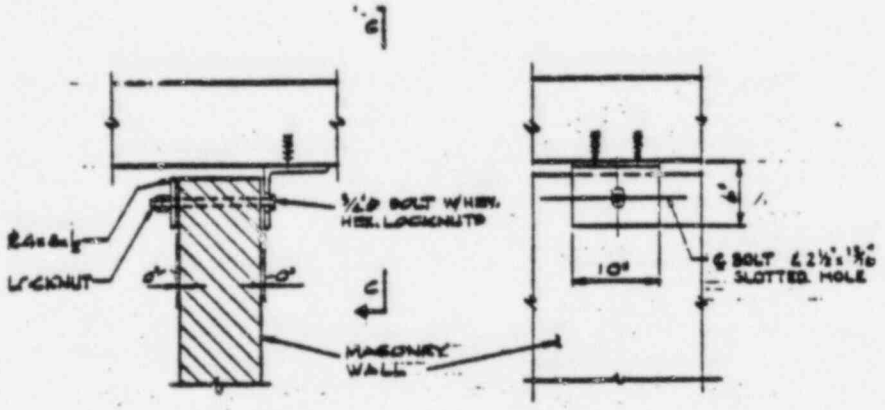
(d) Specification for the Design and Construction of Load-Bearing Concrete Masonry - NCMA August, 1979.

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

# APPENDIX B

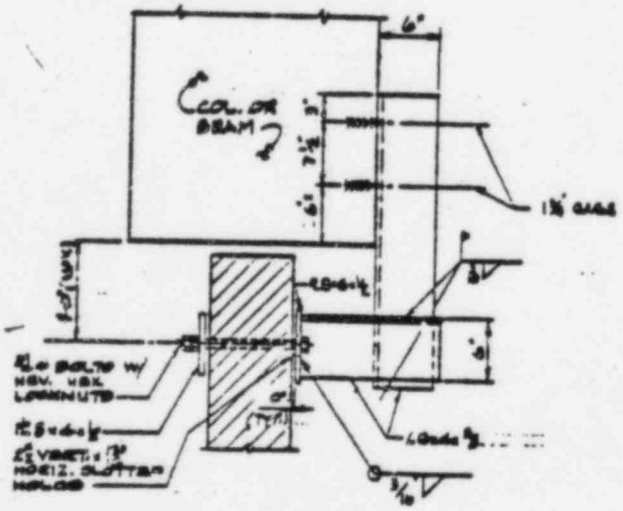
## SKETCHES OF WALL MODIFICATIONS

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




DETAIL-5

SECTION C-C

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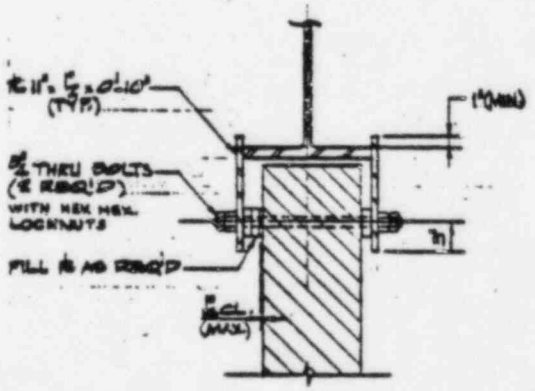


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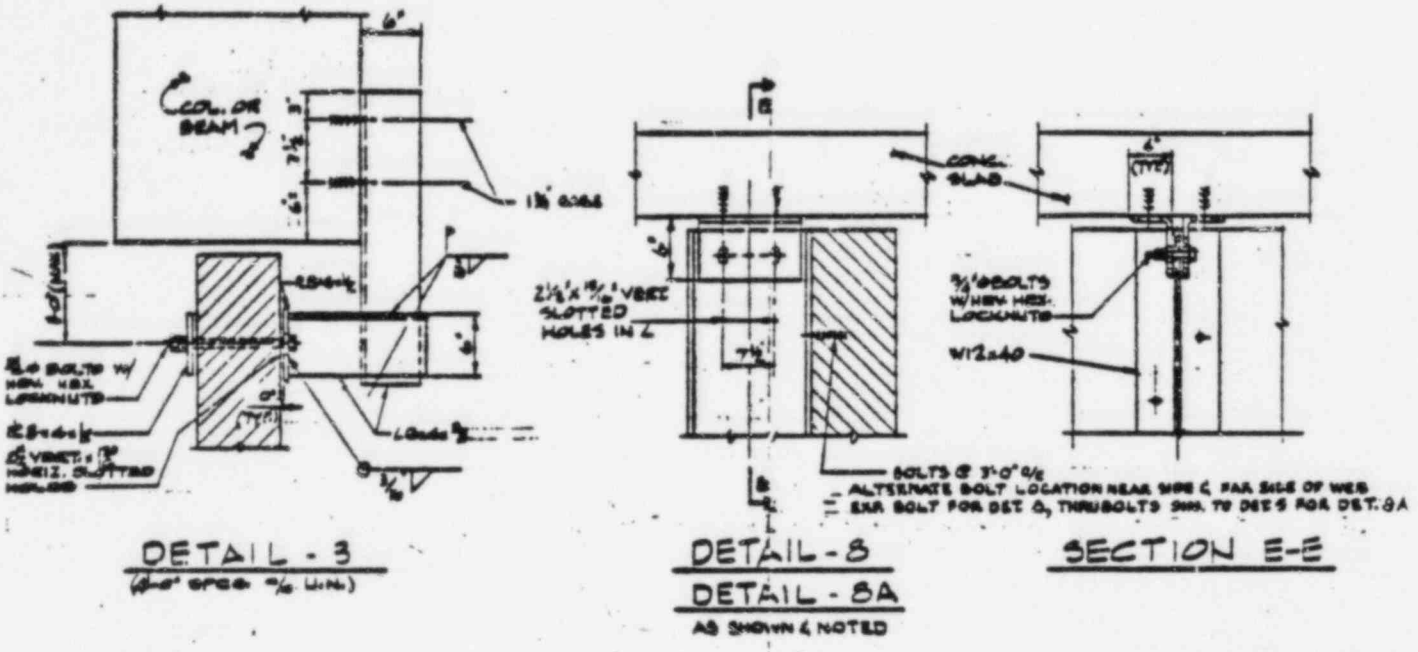
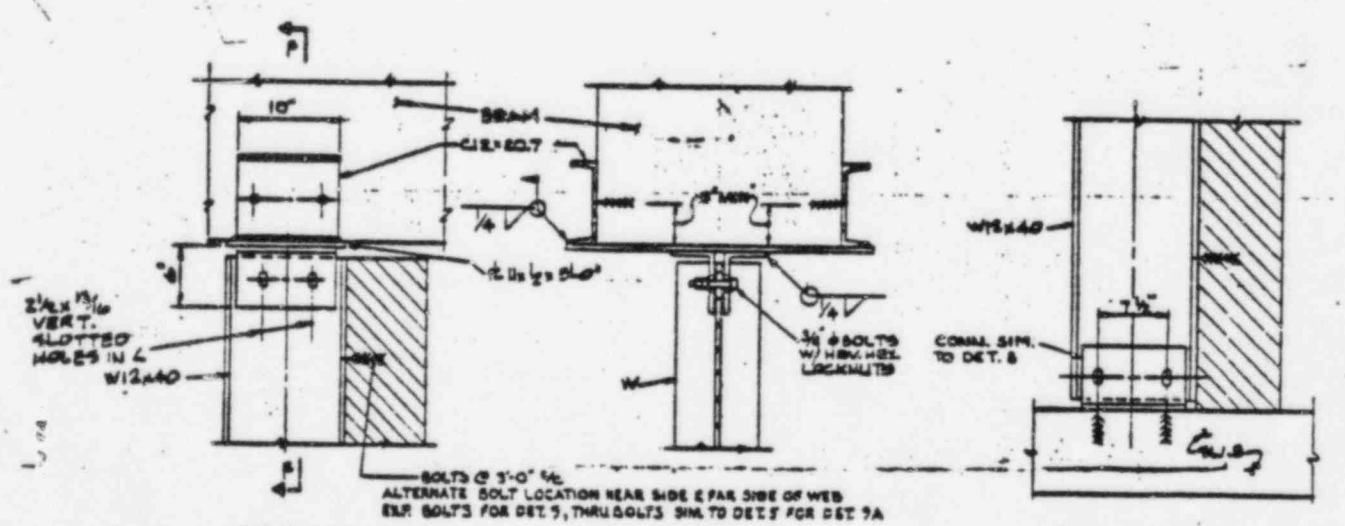



DETAIL - 3

DETAIL - 8

DETAIL - 8A

AS SHOWN & NOTED




DETAIL - 9

DETAIL - 9A

DETAIL-10