FRANKLIN RESEARCH CENTER

DIVISION OF ARVIN/CALSPAN

MASONRY WALL DESIGN (B-59)

FLORIDA POWER AND LIGHT COMPANY
ST. LUCIE UNIT 1

TER-C5506-244

TECHNICAL REPORT

20TH & RACE STREETS PHILADELPHIA PA 19103 TWX 710-670-1889 TEL (215) 448-1000

TECHNICAL EVALUATION REPORT

NRC DOCKET NO. 50-335

NRC TAC NO. 42900

NRC CONTRACT NO. NRC-03-81-130

FRC PROJECT C5506

FRC ASSIGNMENT 6

FRC TASK 244

MASONRY WALL DESIGN (B-59)

FLORIDA POWER AND LIGHT COMPANY
ST. LUCIE UNIT 1

TER-C5506-244

Prepared for

Nuclear Regulatory Commission
Washington, D.C. 20555

FRC Group Leader: V. N. Con
NRC Lead Engineer: N. C. Chokshi

June 17, 1985

Prepared by:	Reviewed by:	Approved by:
A. K. Le	Vu Ngoc Con	O Pierfagno
Principal Author	Group Leader	Department Director
Date: 6-17-85	Date: 6-17-85	Date: 6-17-85

FRANKLIN RESEARCH CENTER
DIVISION OF ARVIN/CALSPAN
20th & RACE STREETS, PHILADELPHIA, PA 19103

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 and procedures 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, Florida Power and Light Company provided the NRC with documents [2, 3, 4] describing the status of masonry walls at St. Lucie Nuclear Plant Unit 1. The information in these documents was reviewed, and a request for additional information was sent to the Licensee [5], to which the Licensee responded [6]. Additional questions [7] were sent to the Licensee, to which it has also responded [8].

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

A total of 204 masonry walls were inspected by the Licensee, and 90 walls were identified as safety-related. Reference 4 identified two additional safety-related walls in the reactor building; each wall was qualified through analysis. Of the 92 safety-related walls, 65 walls were reinforced vertically. All walls are reinforced horizontally. Wall construction includes both stacked and running bond.

The masonry wall types and materials for the St. Lucie plant are given below.

Wall Types

Total number of walls	204
Safety-related walls	92
Number of safety-related walls for which missing clip angles were replaced	14
Number of walls requiring modification	3
Number of walls requiring reinforcement of top edge support	20

Wall Functions Shielding, partition

Construction Materials

Mortar	C270 Type S
Masonry unit	C90 Grade N
Reinforcing steel	A615 Grade 40
Structural steel (supporting angles, embedments)	A 36

Three walls were qualified using the yield line theory; however, as indicated in Responses 5 and 5.8 of Section 3.1, due to small overstresses of the rebar, these walls can be accepted without relying on the yield line theory.

2. EVALUATION CRITERIA

The basic documents used for guidance in this review were the criteria developed by the Structural Geotechnical Engineering Branch (SGEB) of the NRC (attached as Appendix A to this report), the Uniform Building Code [9], and ACI 531-79 [10].

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 Final Safety Analysis Report (FSAR) for the plant. Allowable stresses are specified in Reference 10, 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 [6, 8] to the requests for additional information [5, 7]. The Licensee's criteria [2] 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 Licensee reevaluated the masonry walls using the following criteria:

- Allowable stresses are consistent with ACI 531-70 [10]
- Load combinations are according to the FSAR
- The working stress design method and yield line theory are used. Of 92 safety-related walls, 3 were qualified by yield line theory (However, the discussion given in Responses 5 and 5.8 indicated that these walls can be accepted without relying on the yield line theory.)
- The following damping values are used:

  For OBE, 2% for uncracked walls and 4% for cracked reinforced walls
  For SSE, 2% for uncracked walls and 5% or 7% for cracked reinforced walls

- The walls are modeled as plates spanning vertically (free vertical edges)
- The typical analytical procedure is summarized below:

  - determine wall boundary conditions
  - develop finite element model
  - use modal analysis (ANSYS computer program) to evaluate stress results
  - compare computed stresses with allowables.

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 response to the requests for additional information follows.

Question 1

Indicate the number of walls of the stack bond type and provide a sample calculation to obtain moment and shear stresses of a typical stack bond wall.

Response 1

The Licensee indicated 65 walls were constructed using stack bond construction. The walls are vertically reinforced with eight No. 4 bars at 4-ft intervals and horizontally reinforced with Dur-O-Wal every course. The walls are fully grouted. The top support is restrained by clip angles on both sides, and the bottom support is restrained by dowel action. Typical construction details are illustrated in Figure 1. A sample calculation was provided for wall 34. Wall 34 is 16 ft high, 17 ft long, and 12 in thick, and was reinforced by eight No. 4 bars at 4-ft intervals. The seismic accelerations are:

- Horizontal OBE 0.125 g
- Horizontal SSE 0.25 g
- Vertical SSE 0.24 g

Attachment loads varied from 75 lb to 400 lb.

The results of a finite element analysis are listed below:

Type of Stress (SSE)	Calculated Stress	Licensee Allowable*
Shear at base	4.6 psi	51 psi
Axial-compression	20 psi	396 psi
Flexural-compression	148 psi	765 psi
Tension (steel reinforcement)	12,000 psi	36,000 psi

A review of the calculation indicated that the Licensee's approach is technically adequate. Therefore, the Licensee's response is considered satisfactory and in compliance with the SGEB criteria.

*The Licensee allowable satisfies the SGEB allowable as discussed in Response 4.

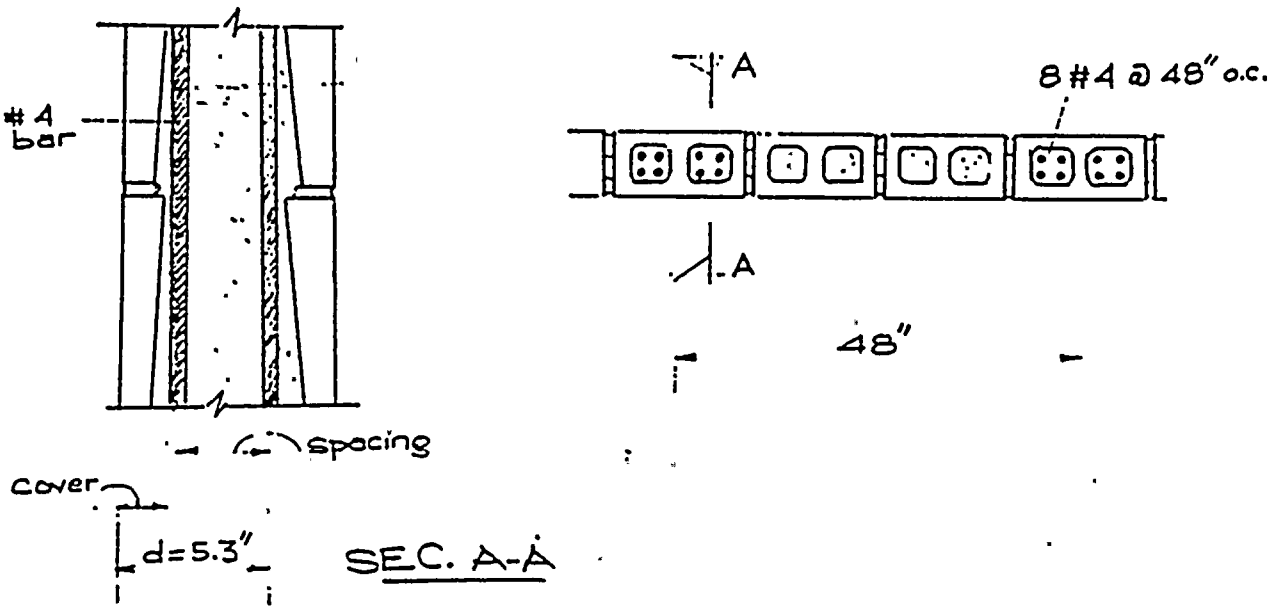


Figure 1. Typical Construction Details

Question 2

The Licensee is required to provide a sample calculation to indicate how the effect of higher modes of vibration is considered in the analysis.

Response 2

In this response, the Licensee indicated that the reevaluation of all walls was performed by finite element computer program ANSYS using modal analysis and that a minimum of 12 modes was considered in the analysis. Therefore, it is concluded that the higher modes of vibration have been adequately considered in the analysis and that the Licensee's response is in compliance with the SGEB criteria.

Question 3

With respect to Table 1 of Reference 2, justify by any existing test data the values for allowable shear and tension of collar joints.

Response 3

The Licensee confirmed that collar joints have not been used in the evaluation of the walls.

The Licensee's response has resolved this concern.

Question 4

With reference to Section V, Table 1 of Reference 2, justify the use of an increase factor of 1.7 for tension normal to bed joint. SGEB criteria [5] allow only 1.3. If the Licensee intends to use any existing test data to justify this increase factor, the Licensee is required to discuss the applicability of these tests to the masonry walls at the plant with particular emphasis on the following: boundary conditions, type of loads, sizes of walls, and type of masonry construction (block type, grouted, or ungrouted).

Response 4

The Licensee referred to the test results from the National Concrete Masonry Association (NCMA) to justify the increase factor of 1.67 for tension normal to bed joint. The Licensee indicated that the average modulus of

rupture for walls built with Type M and S mortar is 88 psi on a net area of hollow units. The safety factor of the 1.67 factored loads is equal to $88/1.67 \times 0.5 \sqrt{m_o} = 2.5$ (where $M_o = 1800$ psi). Similarly, the safety factor for grouted units was found to be 2.34.

However, in Response 12, the Licensee confirmed that none of the walls would be unqualified if the SGEB increase factors were to be used. Therefore, these responses have resolved this concern.

Question 5

a. In Reference 2, the Licensee indicated the "yield-line theory," "plastic design," and "arching analysis" have been used to qualify some of the masonry walls. The NRC, at present, does not accept the application of these methods to masonry walls in nuclear power plants in the absence of conclusive evidence to justify this application. Before any conclusion can be made about these methods, the Licensee is requested to provide any existing test data to justify the use of each technique mentioned above. The applicability of the tests should be discussed for the following areas:

   - Nature of the loads
   - Boundary conditions
   - Materials used
   - Wall sizes
   - Amount and distribution of reinforcement.

b. The Licensee is also requested to indicate the number of walls which were qualified by each method and to provide the resulting stresses and displacements for these walls.

c. Provide a sample calculation illustrating how stresses and displacement were calculated by each method (yield-line theory, plastic design, and arching analysis).

Question 5.8 (Question 5 from Reference 8)

With regard to the nonlinear analysis technique (yield line theory and arching action theory), please note the following information:

a. Arching Action: The NRC position on this issue states that the use of the arching action theory to qualify unreinforced masonry walls is not acceptable; these walls should be repaired so that they can be qualified based on the SGEB criteria. (The NRC position is attached.)

b. Yield Line Theory: This technique is being reviewed and the Licensee will be informed as to whether or not this technique is acceptable upon completion of the review.

Responses 5 and 5.8

The Licensee confirmed that arching action has not been used in the reevaluation.

There are three walls being qualified by the yield line theory. These walls were originally analyzed based on simple support condition at the top, fixed condition at the base, and free along the vertical edges. The top support was restrained by clip angles on both sides. The bottom support was assumed fixed due to the dowels' action. Finite element analysis provided stresses lower than all of the Licensee allowables (see Response 4 for a discussion of the Licensee allowables) except the bond stress of the rebar at the base.

The calculated bond stress was 218 psi, which is higher than the Licensee's allowable of 186 psi. ACI 531-79 [10] allows a bond stress of 160 psi, and for severe environmental loading condition it is judged that an increase factor of 1.3 can be used for the stress allowable which results in an allowable of 208 psi. If this value were used, the calculated bond stress would have exceeded the allowable about 5%, which, for all practical purposes, is small and acceptable. Further discussion regarding this subject is given in Reference 11.

However, due to high bond stress, the Licensee revised the analysis changing the fixed condition to a simple support condition at the base. The revised analysis resulted in a rebar stress of 39 ksi at the midspan, which is higher than the 0.9 Fy (36 ksi) SGEB allowable. Due to the high stress in the rebar, the analysis was further revised relying on the yield line theory. It is judged, however, that the rebar stress exceeded the allowable by only 8%, which, again, for all practical purposes, is acceptable.

Based on the above information, it is judged that the exceeding levels of bond stress and rebar stress were, for all practical purposes, acceptable both in the original and revised analysis. The yield line theory was not needed. It is also noted that the free edge assumption of the vertical sides will result in a conservative estimate.

Question 6

Provide sample drawings of wall modifications, and clarify whether the modified walls were qualified under working stress conditions.

Response 6

The Licensee provided sketches of sample wall modifications and confirmed that all modified walls were qualified under working stress conditions.

According to Reference 3, the modifications include the replacement of missing clip angles, the addition of steel reinforcing members to provide support and to reduce the span length of the wall, and clip angle reinforcement at top edge supports. Appendix B of this report presents the sketch of the typical wall modifications.

Based on the review of modification techniques and the fact that all modified walls were qualified under the SGEB criteria, it is concluded that the Licensee's response is satisfactory and in compliance with the SGEB criteria.

Question 7

The Licensee reported that one of the walls missing top supporting angles was inaccessible during normal plant operation, and that it would be repaired during the 1981 refueling outage. Indicate the current status of this wall, as well as the status of modifications of the other walls.

Response 7

The Licensee confirmed that modification to the one wall which was inaccessible during normal operation was completed during the 1981 outage and that modifications to other walls have been completed. As indicated in Response 6, the modification techniques have been reviewed and found acceptable.

Question 8

Provide a sample calculation illustrating how stresses were calculated for a multi-wythe wall.

Response 8

The Licensee provided a sample calculation for a multi-wythe wall which is 15 ft high, 9 ft 3 in long, and 2 ft 10 in thick (two 12-in-thick wythes and one 10-in-thick wythe). The wall was modeled as plate elements; the top and the bottom of the wall are simply supported. The two sides of the wall are free. The wall was analyzed as a single wythe wall.

The results of the sample calculation are listed below.

Type of Stress (SSE)	Calculated Stress	Licensee Allowable*
Shear at base	14 psi	51 psi
Axial-compression	19 psi	396 psi
Flexural-compression	111 psi	765 psi
Tension - 12-in block (steel reinforcement)	31,000 psi	36,000 psi
Tension - 10-in block (steel reinforcement)	23,730 psi	36,000 psi

A review of the Licensee's sample calculation indicated that the Licensee's approach is technically adequate and in compliance with the SGEB criteria.

Question 9

Provide a sample drawing of a finite element model to illustrate how openings and attachments were considered in the model.

Response 9

In this response, the Licensee provided the sketch of the finite element model of walls 34 and 35. The wall is 16 ft high, 17 ft long, and 12 in

*The Licensee allowable satisfies the SGEB allowable as discussed in Response 4.

thick. The finite elements used to model the wall have dimensions that vary from 2 ft to 4 ft. This model depicted the walls with the opening 5 ft high and 6 ft 4 in wide in the mid-bottom area of the wall. The wall has been qualified, and the results were presented in Response 1. The sample calculation in Response 1 indicated that the attachment weights have been considered and accounted for as added masses at appropriate finite element nodes.

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

Question 10

Indicate the critical damping value used for the operating basis earthquake (OBE). Justification should be given if it is higher than 4% as specified in Regulatory Guide 1.61.

Response 10

The Licensee provided the following damping values which the Licensee stated have been used in the analysis.

- For OBE, 2% for uncracked walls and 4% for cracked reinforced walls
- For SSE, 2% for uncracked walls and 7% for cracked reinforced walls.

However, the Licensee stated that the largest damping value available from the orginal St. Lucie Unit 1 floor response spectra curves is 5%; therefore, these curves were used in lieu of 7% damping curves for SSE. In cases where the 5% curves could not be used to qualify the wall, the applicable 7% sampling curves were generated specifically for this analysis and used in accordance with the criteria.

Since these damping values are within those specified in Regulatory Guide 1.61, the Licensee's response is satisfactory and in compliance with the SGEB criteria.

Question 11 (Question 1 of Response 8)

With reference to the reinforcement in masonry walls, the ACI 531-79 Code [10] 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 horizontal, 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 joint reinforcement is used to resist tension, it should follow the working stress design method, which limits its allowable to 30 ksi. Please clarify whether this requirement has been satisfied. If this requirement is not satisfied, identify all affected walls along with the calculated stress value for each wall.

Indicate if there is any wall that has only joint reinforcement (horizontal reinforcement), no vertical reinforcement, and may have been qualified using the tensile resistance of the joint reinforcement. It should be noted that the NRC, at present, does not approve the use of joint reinforcement to qualify this type of wall. Indicate all walls belonging to this category.

Response 11

The Licensee provided the reinforcement ratio of vertical and horizontal reinforcement for 8-in, 10-in, and 12-in thick walls, which indicated that the reinforced single- and multi-wythe masonry walls at St. Lucie Plant Unit 1 meet the minimum reinforcement criteria of the ACI 531-79 Code [10].

The reinforcement ratio of various wall thicknesses is listed as follows:

Wall Thickness	Reinforcement	Requirement Ratio	ACI Minimum Ratio Requirements
1ft-0 in	Vertical (8-#4 at 4'-0)	0.0029	0.0007
	Horizontal (2-3/16" Rod + 1 No. 9 wire)	0.008	0.0007
	Total Combined Area	0.0030	0.0020
10 in	Vertical(8-#4 at 4'-0)	0.0035	0.0007

Wall Thickness	Reinforcement	Requirement Ratio	ACI Minimum Ratio Requirements
10 in	Horizontal (2-3/16" Rod + 1 No. 9 wire)	0.0010	0.0007
	Total Combined Area	0.0036	0.0020
8 in	Vertical (8-#4 at 4'-0)	0.0044	0.0007
	Horizontal (2-3/16" Rod + 1 No. 9 wire)	0.0012	0.0007
	Total Combined Area	0.0046	0.0020

The Licensee confirmed that the joint reinforcement used to resist tension in the walls has been evaluated according to the working stress design method with the allowable limited to 30 ksi.

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

Question 12 (Question 2 of Reference 8)

With respect to the increase factors for factored load cases [6], please identify all walls that would not be qualified if the SGEB criteria were to be used. Identify the percentage of exceedance for each case. The Licensee is advised to explain all conservative measures (if any) used in the analysis to justify a higher increase factor.

Response 12

The Licensee confirmed that none of the walls would be unqualified if the SGEB increase factors were to be used.

The Licensee's response has resolved the concern.

Question 13 (Question 3 of Reference 8)

In Response 1 of Reference 6, the Licensee indicated that the number of stack bond walls is 65. Please provide the following information:

a. Clarify whether all of these 65 walls are safety-related.

b. Section 10.3.2 of ACI 531-79 [10] states, "where masonry is laid in stack bond, the tensile strength of masonry, grout, and mortar shall not be used in vertical continuous joints, and the shear strength of masonry, grout, and mortar shall not be utilized to transfer concentrated loads across vertical continuous joints." Please identify all walls that may have been qualified without complying with the above restrictions. Also, provide the technical basis and justification for not complying with the above restrictions.

Response 13

In this response, the Licensee confirmed that all of the 65 stack bond walls are safety-related.

With regard to the compliance with the stack bond restrictions, the Licensee stated that all walls evaluated comply with the ACI 531-79 Code [10]. All stack bond walls are reinforced both vertically and horizontally. The vertical reinforcement is the main reinforcement of the wall, while the purpose of the horizontal (joint) reinforcement is to distribute the load to the main vertical steel.

The Licensee's response has resolved these concerns.

Question 14 (Question 4 of Reference 8)

With reference to Response 4 and the sample calculation in Attachment E [6], please clarify the following:

The moment of inertia for the cracked section of blocks 16 x 11 5/8 and 16 x 9 5/8 on pages 3 and 4 of Attachment E [6] is higher than that for the uncracked section as given on page 1 of the same attachment. Please explain why the moment of inertia for each block is greater for the cracked section compared to its uncracked section.

On page 2 of Attachment E [6], it appears that the moment of inertia of transformed section for the multi-wythe wall was calculated based on the composite section. If this is the case, the calculation is not consistent with Response 3 of Reference 6, in which walls were not analyzed by composite section. Please clarify this point. If needed, provide any explanation necessary to make the sample calculation understandable.

Response 14

With regard to the moment of inertia for the cracked and uncracked sections, the Licensee indicated that the differences were due to using a unit block for the uncracked section and using an entire wall cross section which is 9 ft 3 in long for the cracked section for calculating the moment of inertia. The Licensee also provided the proper values to be compared which indicated that the cracked moment of inertia is in fact less than that for the uncracked section.

For the composite section of multi-wythe walls, the Licensee confirmed that the strength of collar joint was not relied upon in the qualification of multi-wythe wall. The Licensee also indicated that, because all concrete block walls were filled with cement mortar, composite behavior was considered for the first iteration in order to more correctly represent the behavior of the uncracked wall. The transformed moment of inertia thus determined is then used for calculation of the cracking moment and the first iteration frequency. The calculation of the moment of inertia of the cracked section, subsequent frequency iterations, and all stress distributions were based on the assumption of independent action of the individual wythes.

The Licensee's response is considered adequate and acceptable.

3.2 EVALUATION OF LICENSEE'S APPROACH TO WALL MODIFICATIONS

There are 37 safety-related masonry walls that require modifications which include the replacement of missing clip angles, addition of structural steel members to provide support and to reduce the span length of the wall, and reinforcement of top edge supports.

Appendix B of this report presents the sketch of the typical masonry wall modification.

A review of the Licensee's approach to wall modifications indicated that the modified walls satisfied the SGEB criteria.

4. CONCLUSIONS

A detailed study was performed to provide a technical evaluation of the masonry walls at St. Lucie Unit 1. 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.

With regard to the yield line theory, the discussion provided in Responses 5 and 5.8 of Section 3.1 indicated that the three affected walls can be accepted without relying on the yield line theory. The exceeding percentages of the bond stress (original analysis) and the rebar stress (revised analysis) were 4% and 8%, respectively. For all practical purposes, these percentages are considered to be small and acceptable; therefore, the yield line theory was not actually needed. It is also noted that the free edge assumption of the vertical sides results in a conservative estimate.

Section 3.2 indicated that 37 walls have been modified, that the Licensee's approach to wall modification is judged to be satisfactory, and that the modified walls were considered to be structurally adequate and in compliance with the SGEB criteria.

5. REFERENCES

1. IE Bulletin 80-11
   Masonry Wall Design
   NRC, May 8, 1981

2. R. E. Uhrig, FPL
   Letter to J. P. O'Reilly, NRC.
   Subject: IE Bulletin 80-11,
   Reevaluation of Masonry Walls at St. Lucie Unit 1 - Final Report (Attached)
   Florida Power & Light Co., February 11, 1981
   L-81-45

3. A. D. Schmidt, FPL
   Letter to J. P. O'Reilly, NRC.
   Subject: Reportable Occurrence, 335-61-03, St. Lucie Unit 1, January 23, 1981
   Florida Power & Light Co., March 20, 1981
   PRN-LI-81-138

4. R. E. Uhrig, FPL
   Letter to J. P. O'Reilly, NRC.
   Subject: Addendum A to Final Report on IE Bulletin 80-11, November 9, 1981 (Attached)
   Florida Power & Light Co., December 7, 1981

5. R. B. Clark, NRC
   Letter to R. E. Uhrig, FPL.
   Subject: St. Lucie Unit 1 IE Bulletin 80-11, Masonry Wall Design - Request for Additional Information
   August 5, 1982

6. R. E. Uhrig, FPL
   Letter to R. B. Clark, NRC
   Subject: St. Lucie Unit 1 IE Bulletin 80-11, Request for Additional Information
   Florida Power & Light Co.
   October 4, 1982

7. J. R. Miller, NRC
   Letter to J. W. Williams, Jr., FPL
   Subject: St. Lucie Unit 1 - IE Bulletin 80-11, Masonry Wall Design - Request for Additional Information
   February 29, 1984

8. J. W. Williams, Jr., FPL
   Letter to J. R. Miller, NRC
   Subject: St. Lucie Unit 1 - IE Bulletin 80-11, Masonry Block Wall
   Florida Power & Light Co.
   June 14, 1984

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

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

11. A. A. Hamid
"Review of Design of Masonry Walls in St. Lucie Nuclear Power Plant,"
Franklin Research Center, February 1985

APPENDIX A

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

FRANKLIN RESEARCH CENTER
DIVISION OF ARVIN/CALSPAN
20th & RACE STREETS, PHILADELPHIA, PA 19103

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.

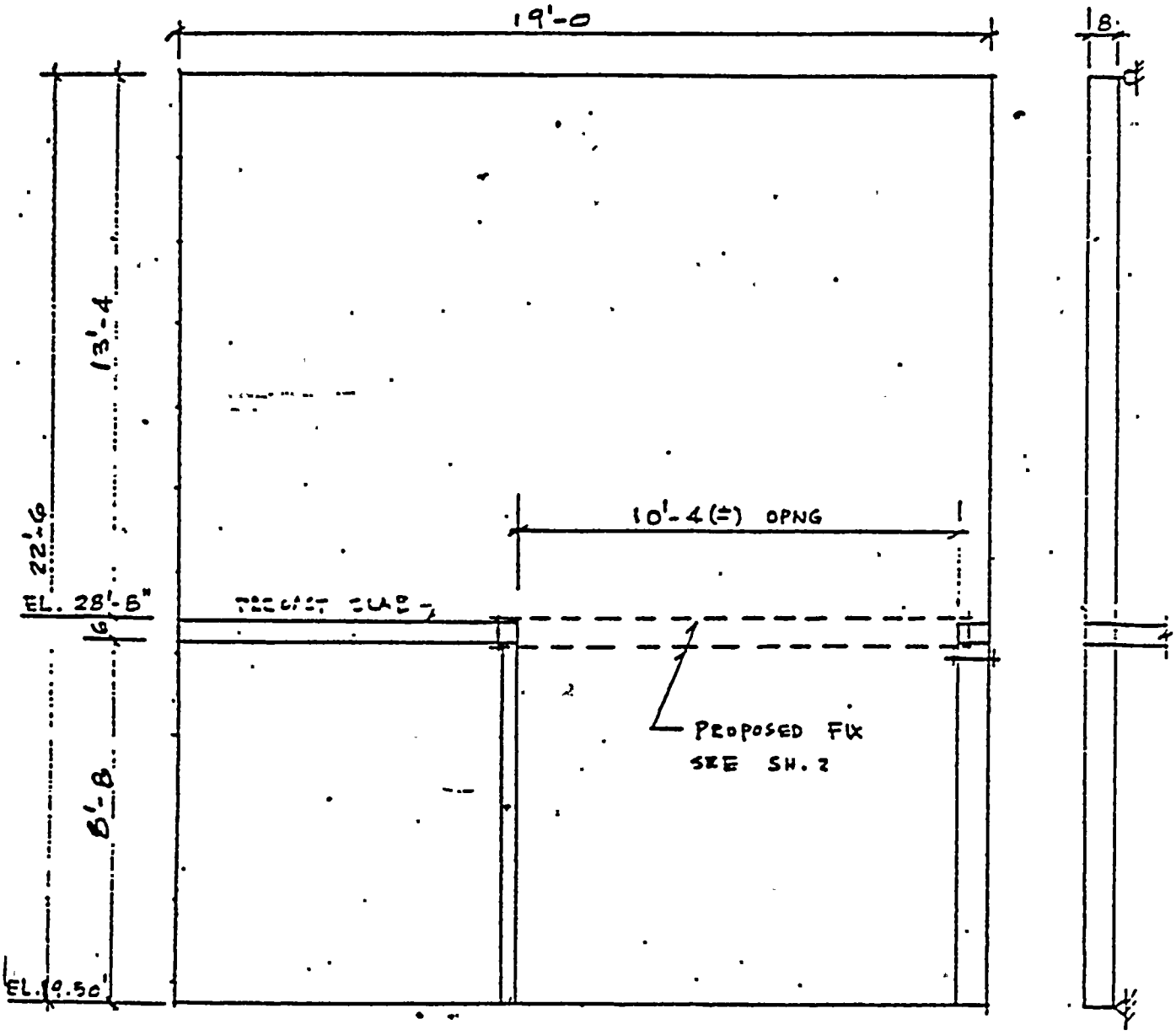
(d) Specification for the Design and Construction of Load-Bearing Concrete Masonry - NCMA August, 1979.

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

APPENDIX B

SKETCHES OF WALL MODIFICATIONS

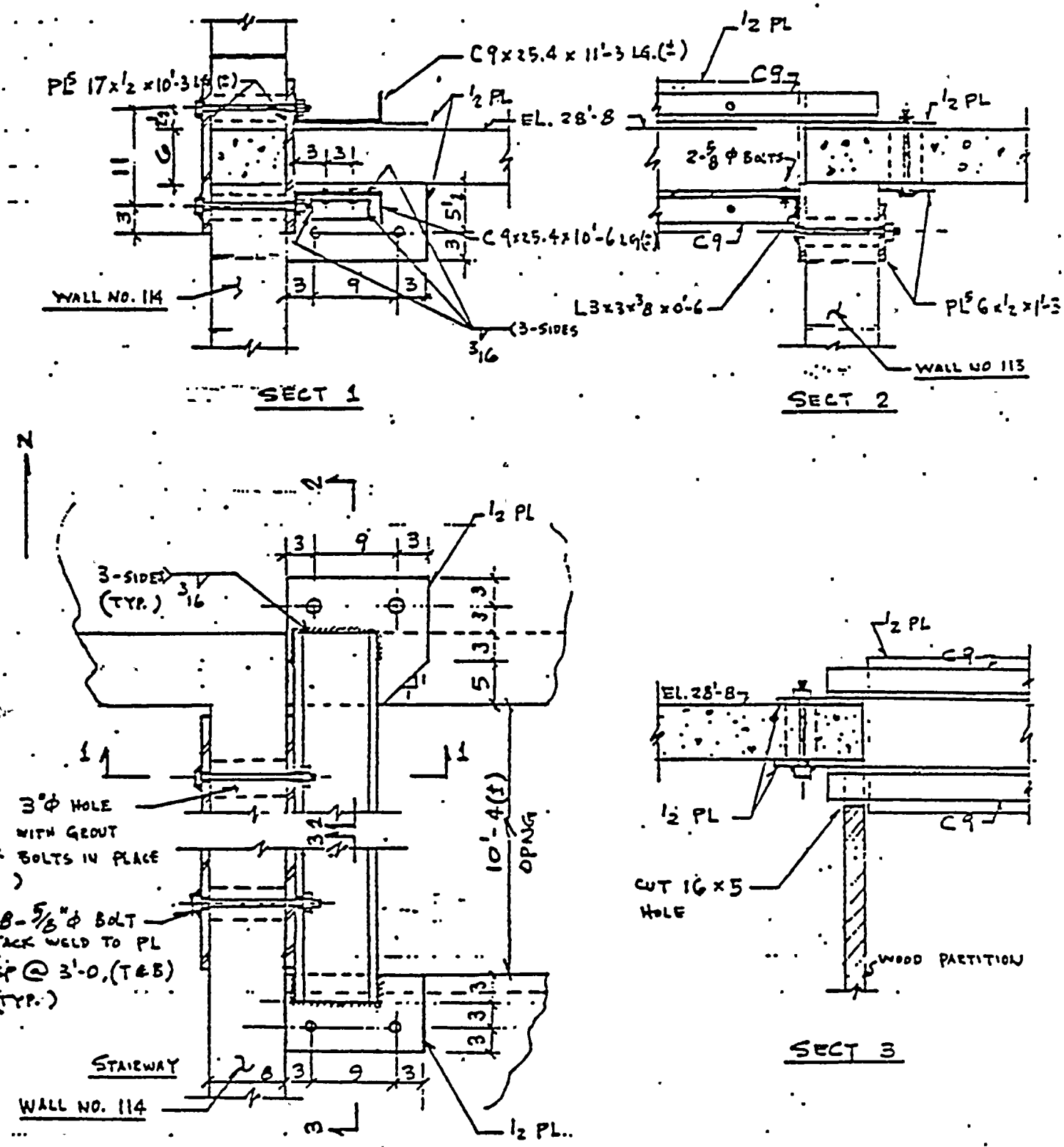
WALL NO. 114 :



ELEVATION (WALL NO. 114)
SCALE 1/4" = 1'-0

UNREINFORCED
NO MORTAR
FILLED-IN

WALL NO 114



PLAN AT EL. 28'-8 (ALL MATERIALS ARE AVAILABLE IN WAREHOUSE)

Mr. J. W. Williams, Jr.
Florida Power & Light Company

St. Lucie Plant

Mr. Jack Shreve
Office of the Public Counsel
Room 4, Holland Building
Tallahassee, Florida 32304

Resident Inspector
c/o U.S. NRC
Senior Resident Inspector
7585 S. Hwy A1A
Jensen Beach, Florida 33457

State Planning & Development Clearinghouse
Office of Planning & Budget
Executive Office of the Governor
The Capitol Building
Tallahassee, Florida 32301

Harold F. Reis, Esq.
Newman & Holtzinger
1615 L Street, N.W.
Washington, DC 20036

Norman A. Coll, Esq.
McCarthy, Steel, Hector and Davis
14th Floor, First National Bank Building
Miami, Florida 33131

Administrator,
Department of Environmental Regulation
Power Plant Siting Section
State of Florida
2600 Blair Stone Road
Tallahassee, Florida 32301

Mr. Weldon B. Lewis, County
Administrator
St. Lucie County
2300 Virginia Avenue, Room 104
Fort Pierce, Florida 33450

Mr. Charles B. Brinkman, Manager
Washington - Nuclear Operations
Combustion Engineering, Inc.
7910 Woodmont Avenue
Bethesda, Maryland 20814

Regional Administrator
USNRC, Region II
Executive Director for Operations
101 Marietta Street N.W., Suite 2900
Atlanta, Georgia 30323

Mr. Allan Schubert, Manager
Public Health Physicist
Department of Health and
Rehabilitative Services
1323 Winewood Blvd.
Tallahassee, Florida 32301