ENCLOSURE

FLORIDA POWER & LIGHT COMPANY

ENGINEERING EVALUATION OF
TURKEY POINT UNITS 3 & 4 CONTAINMENT STRUCTURE

TABLE OF CONTENTS

1.0 Purpose / Scope

During the performance of the twentieth year tendon surveillance of the Turkey Point Units 3 and 4 containment structure post-tensioning systems, a number of measured normalized tendon lift-off forces were below their corresponding calculated predicted lower limit (PLL). Evaluation of the twentieth year surveillance results concluded that the probable cause for the low tendon lift-off forces was due to an increased tendon wire steel relaxation loss caused by average tendon temperatures higher than originally considered. The evaluations also concluded that the containment post-tensioning system will provide sufficient prestress force to maintain Turkey Point licensing basis requirements through the twentieth-fifth year tendon surveillance. The evaluations recommended that a structural re-analysis of the containment structure be performed to determine the minimum required prestress forces, and to establish that the containment structure will continue to meet the licensing basis requirements through the end of the licensed plant life (see Attachment 2 for additional detail). A containment structure re-analysis was successfully completed in 1994.

Purpose/Scope

The purpose of this document is to summarize Florida Power & Light Company's activities from the twentieth Year Tendon Surveillances through the completion of the 1994 Containment Structure Re-analysis, and to evaluate the effects of the re-analysis on the safe operation of Turkey Point Units 3 and 4. Accordingly this document provides the following:

1. Summaries of the background information and events leading up to the containment re-analysis, including:

    a. Description of the containment structure.

    b. Description of the current Tendon Surveillance Program.

    c. The twentieth year tendon surveillance tendon lift-off force results.

    d. The engineering evaluations performed to evaluate the results of the twentieth year tendon surveillance programs, including the results and the evaluation performed for the determination of the most probable cause of the twentieth year surveillances low tendon lift-off forces. (see Attachment 1)

    e. The significant activities/events that have occurred between the twentieth year tendon surveillance and the completion of the containment structural re-analysis.

2. An evaluation/summary of the methodology and results of the containment structural re-analysis including the determination of new minimum required tendon prestress forces for each tendon group. (see Attachment 2)

3. An evaluation/summary of the analysis of existing surveillance data versus the minimum required prestress force, for determination of the capability of the containment structure to continue to meet the licensing basis requirements through the end of the licensed plant life.

2.0 Background

Containment Structure Description

Each containment building for Turkey Point Units 3 and 4 is a post-tensioned, reinforced concrete structure comprised of a vertical cylinder with a shallow dome supported on a conventional reinforced concrete foundation base slab. The vertical cylinder wall is provided with a system of vertical and hoop tendons. Vertical tendons are anchored at the top surface of a concrete ring girder and at the bottom of the base slab. At the base, a tendon gallery is provided for access to tendon anchorages. Each hoop tendon is anchored at alternate vertical buttresses nominally 120 degrees apart. Tendons in the dome consist of three groups of tendons oriented at 120 degrees, with respect to each other, and are anchored at the vertical face of the dome ring girder.

Tendon Surveillance Program

The tendon surveillance program for the Turkey Point Units 3 and 4 containment structure post-tensioning systems have been performed at one, three, five, ten, fifteen and twenty years after the containment Initial Structural Integrity Test (ISIT). Additional surveillances are required to be performed every five years for the life of the plant. The Turkey Point Tendon Surveillance Program requires surveillance of 12 randomly selected undisturbed tendons (5 hoop, 4 vertical and 3 dome) at each surveillance.

Twentieth Year Surveillance Tendon Lift-off Force Results

During the performance of the twentieth year tendon surveillance, the measured normalized lift-off forces for a number of randomly selected surveillance tendons (two of five hoop tendons, one of three dome tendons, and one of four vertical tendons in Unit 4, and four of five hoop tendons in Unit 3) were below the predicted lower limit (PLL). In accordance with the Turkey Point Plant Technical Specifications and to further investigate the extent and probable cause of the low lift-off conditions, additional lift-off measurements were taken on tendons adjacent to the tendons that lifted off below the PLL. The measured lift-off force in fifteen of the eighteen adjacent tendons that were tested were also found to be below the PLL (one dome tendon and two vertical tendons in Unit 4 tested above the PLL).

Twentieth Year Tendon Surveillances Engineering Evaluations

In accordance with the Turkey Point Plant Technical Specifications, engineering evaluations (references 5.4 through 5.7 and 5.9 through 5.12) were prepared to address the low lift-off force measurements determined in the twentieth year surveillances.

The reference 5.6 and 5.11 engineering evaluations concluded that the most probable cause for the low lift-off forces was an increased tendon wire steel relaxation loss caused by average tendon wire temperatures higher than originally considered. (NOTE: Attachment 1 to this evaluation provides a synopsis of the root cause evaluation / investigation.) Considering this higher steel relaxation loss rate, references 5.6 and 5.11 also concluded that the Units 3 and 4 containment post-tensioning system would provide sufficient prestress force to maintain Turkey Point licensing basis requirements at least through the twentieth-fifth year tendon surveillance period. In addition, references 5.6 and 5.11 recommend that a structural

2.0 Background (Cont.)

re-analysis of the containment structure and the post-tensioning system be performed to determine a new minimum required prestress force and to establish that the containment structure post-tensioning system will meet the licensing bases requirements through the end of the licensed plant life.

The reference 5.10 engineering evaluation was prepared to provide documentation for reconstitution of the licensing basis for containment design pressure. Reference 5.10 concluded that the licensing basis containment design pressure is 55 psig as established in the original Turkey Point Safety Evaluation Report (SER).

Additional Related Activities After the Twentieth Year Surveillances

Following the completion of the twentieth year surveillances, FPL met with the NRC in Rockville, Maryland on January 11, 1993. FPL presented details of the twentieth year tendon surveillance results, discussed engineering evaluations performed during the surveillances, including the root cause evaluation of the low lift-off forces, and presented the proposed long term action plan for addressing the low lift-off tendon forces. (Note: The structural re-analysis was initiated in April of 1993.)

On January 25, 1993, the NRC requested additional information to support a review of the twentieth year tendon surveillances. By FPL letter L-93-174 (reference 5.15), FPL issued the requested information to the NRC.

A proposed license amendment (PLA) was prepared (reference 5.17) to revise the Turkey Point Technical Specification reference to maximum containment design pressure from 59 to 55 psig (reference 5.13). The PLA was submitted for NRC approval on May 21, 1993. The NRC approved the license amendment and issued Amendment Nos. 160 (Unit 3) and 154 (Unit 4), and associated a Safety Evaluation Report (SER) for the licensing amendments (reference 5.16), on March 30, 1994.

FPL met with the NRC in Rockville, Maryland on September 29, 1994, to discuss the containment re-analysis program preliminary results and methodology. FPL described the re-analysis methodology including analytical assumptions, method of modeling, models used, load combinations used, etc. In addition, FPL presented the preliminary results of the re-analysis.

3.0 Engineering Evaluation

3.1 Containment Structure Design Licensing Bases Requirements

The design criteria for the containment structure are included in Appendix 5B of the Updated Final Safety Analysis Report (UFSAR). Section B.1 of Appendix 5B of the UFSAR states:

> "Integrity of the containment structure under extraordinary circumstances and its performance at various loading stages are the main considerations in establishing the containment structural design criteria:
>
> The two basic criteria are:
>
> a) The integrity of the liner plate shall be maintained under all loading combinations, and,
>
> b) The structure shall have a low-strain elastic response such that its behavior will be predictable under all design loadings.
>
> The strength of the containment structure at working stresses and over-all yielding is compared with various loading combinations to ensure safety."

Section 5.1.1 of the UFSAR states:

> "The containment structure completely encloses the reactor coolant system to minimize release of radioactive material to the environment should a failure of the coolant system occur. The structure provides adequate biological shielding for both normal operation and the hypothetical accident conditions.
>
> The principal design basis for the structure is that it should be capable of withstanding, without loss of integrity, the peak pressure resulting from any size pipe break including the maximum hypothetical accident (MHA)."

Section 5.1.1 of the UFSAR also states:

> "The containment structure is licensed and designed to withstand a pressure of 55 psig and 283^{o}F. The original transient analysis calculated a peak accident pressure of 49.9 psig and a peak accident temperature of 276^{o}F. ...; and the higher 55 psig licensed containment design pressure is considered the nominal structural design pressure, thus allowing a margin of 10% over the calculated peak accident analysis pressure."

The peak accident pressure in containment remains as 49.9 psig and as noted in Section 2.0 "Background", the 55 psig licensing basis containment design pressure has been approved by the NRC in Licensing Amendment 160/154 (Reference 5.16) for Turkey Point Units 3 & 4.

The containment structure is designated as a Class I structure in Appendix 5A of the UFSAR. The original containment structural analysis results are documented in Section 5.0 of the UFSAR. The results of the 1994 containment structure re-analysis is summarized within this evaluation and documented in references 5.18 and 5.29.

3.2 "1994 Containment Structure Re-analysis" - Failure Modes and Effects Analysis

The containment structure re-analysis effort has been evaluated for potential failure modes to determine any possible impact on nuclear safety. The re-analysis has been performed utilizing the existing design bases included in the UFSAR. The results of the re-analysis have shown that for the 1994 re-analysis minimum required prestress forces, the concrete and the reinforcing steel stresses, and the liner plate strains in all areas of the structure will remain within the allowables specified in the UFSAR. In addition, the 1994 containment re-analysis does not require any physical modifications to the containment structure, its post-tensioning system, or any other structures, systems or components (SSCs). As such, no new failure modes that could impact nuclear safety are created, and the probability of occurrence and consequences of previously analyzed failures have not been increased by the re-analysis.

3.3 "1994 Containment Structure Re-analysis" - Evaluation of the Effect on Plant Restrictions

The 1994 containment structure re-analysis is strictly an analytical effort to determine a new minimum required prestress force in three groups of tendons (hoop, dome, and vertical), and does not require any physical modifications to, nor does it affect, the containment structure, its post-tensioning system, or any other SSCs. As such the re-analysis has been performed with no restriction on the operating mode of Turkey Point Units 3 and 4, and the re-analysis does not impose any restrictions on the operation of either Turkey Point Unit 3 or 4.

3.4 "1994 Containment Structure Re-analysis" - Evaluation of the Effect on Technical Specifications

The containment structure re-analysis has been performed utilizing the existing design bases and does not affect any existing Technical Specifications. The re-analysis effort has no adverse effect on the containment structure, its post-tensioning system, or plant safety. Therefore, the containment structure re-analysis does not require any change to the Technical Specifications.

3.5 Summary/Evaluation of the Methodology and Results of the 1994 Containment Structure Re-analysis

Methodology

Details of the methodology used for performance of the 1994 Containment Structure re-Analysis are provided in Attachment 2 of this evaluation. In general, the re-analysis methodology included the following:

* Development of a new 3D model of the containment structure including base slab, major penetrations, soil-structure interface, etc.

* Use of material properties, design loads, load combinations, acceptance criteria, etc., as stated in the UFSAR.

* Performance of a baseline analysis to establish correlation of the new model/analysis results with the original model/analysis results.

* Performance of a final analysis/calculation using the new model.

* Performance of a thermal crack analysis to refine/optimize analysis results.

* Determination of the new minimum required prestress values for each tendon group (hoop, dome and vertical).

Analysis

The containment structure has been re-analyzed for all design basis requirements and loading combinations defined in UFSAR Appendix 5B. The results of the 1994 re-analysis define/conclude (reference 5.29) that the concrete and the reinforcing steel stresses, and the liner plate strains, in all areas of the structure, remain within the allowables specified in the UFSAR, while using the "new" calculated minimum required prestress forces defined below.

The 1994 containment structure re-analysis including results, is documented in detail in references 5.19 through 5.31. Per reference 5.29, the re-analysis has determined new minimum required prestressing forces for each of the three tendon groups (hoop, dome and vertical).

The 1994 re-analysis minimum required average prestress forces for each of the three tendon groups are as follows:

Hoop Prestress Force = 590 kips/ft

Dome Prestress Force = 313 kips/ft

Vertical Prestress Force = 250 kips/ft

The tendon force and tendon wire force (based on a 90 wire tendon) corresponding to the minimum required average prestress forces calculated in the 1994 re-analysis are as follows:

TENDON GROUP	MINIMUM REQUIRED AVERAGE PRESTRESS FORCE (kips/ft)	TENDON FORCE (kips)	WIRE FORCE (kips/wire)
HOOP	590	491.6	5.46
DOME	313	531	5.90
VERTICAL	250	522	5.80

3.6 Evaluation of Containment Structure to Meet Licensing Basis Requirements through the end of the plant life.

Based on the minimum required prestress forces determined in the re-analysis, it has been concluded, per reference 5.30, that the containment post-tensioning system will provide sufficient prestress force to maintain Turkey Point licensing basis requirements through the currently licensed plant life (July 2012 - Unit 3 and April 2013 - Unit 4).

3.7 "1994 Containment Structure Re-analysis" - Evaluation of the Effect on Plant Safety

The 1994 containment structure re-analysis is strictly an analytical effort to determine a new minimum required prestress force in three groups of tendons (hoop, dome, and vertical), and does not require any physical modifications to the containment structure, its post-tensioning system, or any other SSCs.

As stated above, the containment structure is a Class I structure and its analysis and design are governed by the criteria included in Appendix 5B of the UFSAR.

The results of the "1994 Containment Structure Re-analysis" are defined in Section 3.5 of this evaluation. The 1994 re-analysis concludes that for all UFSAR load cases and combinations, the containment structure remains within the allowables specified in the UFSAR.

Based on the evaluation above, the 1994 containment structure re-analysis does not impact plant nuclear safety.

Based on the evaluation above, the 1994 Containment Structure Re-analysis does not have an adverse effect on plant safety, security, or operation, does not constitute an unreviewed safety question, and does not require changes to the Technical Specifications. Therefore, prior NRC approval is not required.

4.0 Conclusion

This engineering evaluation has determined that "The 1994 Containment Structure Re-analysis" maintains the licensing design bases requirements, does not impact nuclear safety, safe plant operation, or Plant Technical Specifications, and does not impose any plant restrictions.

The containment structure has been re-analyzed for all design basis requirements and loading combinations defined in UFSAR Appendix 5B. The results of the 1994 re-analysis define/conclude that the concrete and the reinforcing steel stresses, and the liner plate strains, in all areas of the structure, remain within the allowables specified in the UFSAR, while using the "new" calculated minimum required prestress forces. In addition, based on the minimum required prestress forces determined in the re-analysis, it has been concluded that the containment post-tensioning system will provide sufficient prestress force to maintain Turkey Point licensing basis requirements through the currently licensed plant life (July 2012 for Unit 3 and April 2013 for Unit 4).

5.0 References

5.1 Turkey Point Units 3 and 4, Updated Final Safety Analysis Report (UFSAR) Revision 11, dated November 1993.

5.2 Turkey Point Technical Specifications Updated Through Amendment 171/165, effective January 11, 1995.

5.3 Stand Alone Safety Evaluation JPN-PTN-SECJ-92-004, "Unit 3 Twentieth Year Containment Tendon Surveillance", Revision 0.

5.4 Engineering Evaluation JPN-PTN-SECJ-92-019, "Unit 3 Twentieth Year Tendon Surveillance Hoop Tendons Low Lift-Off Force", Revision 1.

This evaluation was used as the basis for the "Special Report" issued to the USNRC under Letter L-92-203, dated July 10, 1992.

5.5 Engineering Evaluation JPN-PTN-SECJ-92-023, "Unit 3 Twentieth Year Tendon Surveillance Low Lift-Off Force on Hoop Tendon 42H32", Revision 0.

This evaluation was used as the basis for the "Special Report" issued to the USNRC under Letter L-92-223, dated August 5, 1992.

5.6 Engineering Evaluation JPN-PTN-SECJ-92-024, "Unit 3 Twentieth Year Tendon Surveillance Extent and Cause of Low Lift-Off Force on Hoop Tendons", Revision 0.

This evaluation was used as the basis for the "Special Report" issued to the USNRC under Letter L-92-262, dated September 14, 1992.

5.7 Engineering Evaluation JPN-PTN-SECJ-92-027, "Unit 3 Twentieth Year Tendon Surveillance Final Report", Revision 0.

5.8 Stand Alone Safety Evaluation JPN-PTN-SECJ-92-021, "Unit 4 Twentieth Year Containment Tendon Surveillance", Revision 0.

5.9 Engineering Evaluation JPN-PTN-SECJ-92-039, "Unit 4 Twentieth Year Tendon Surveillance - Low Lift-Off Force on Hoop Tendon 13H54 and Dome Tendon 1D40", Revision 0

This evaluation was used as the basis for the "Special Report" issued to the USNRC under Letter L-92-330, dated December 4, 1992.

5.10 Engineering Evaluation JPN-PTN-SECJ-92-041, "Unit 4 Twentieth Year Tendon Surveillance - Low Lift-Off Force on Hoop Tendon 35H38", Revision 0.

This evaluation was used as the basis for the "Licensee Event Report 251-92-009" issued to the USNRC under Letter L-92-344, dated December 17, 1992.

5.11 Engineering Evaluation JPN-PTN-SECJ-92-042, "Unit 4 Twentieth Year Tendon Surveillance, Extent and Probable Cause of Low Lift-Off Force on Hoop and Dome Tendons", Revision 0.

This evaluation was used as the basis for the "Special Report" issued to the USNRC under Letter L-93-002, dated January 25, 1992.

5.0 References (Cont.):

5.12 Engineering Evaluation JPN-PTN-SECJ-93-004, "Unit 4 Twentieth Year Tendon Surveillance Final Report", Revision 0.

5.13 Engineering Evaluation JPN-PTN-SECJ-93-008, "No Significant Hazards Evaluation Related to Containment Design Pressure Technical Specifications and Updated FSAR Changes", Revision 0.

5.14 Engineering Evaluation JPN-PTN-SECJ-93-013, "Units 3 and 4 Twentieth Year Tendon Surveillance - Use of Alternate Test Methods for the Chemical Analysis of Sheath Filler", Revision 0.

5.15 Letter, T. F. Plunkett (FPL) to USNRC, concerning "Containment Tendon Surveillance Program", L-93-174, dated August 10, 1993.

5.16 USNRC Safety Evaluation Report for Turkey Point Units 3 and 4 Technical Specifications Amendment 160 and 154, dated March 30, 1994.

5.17 Letter, T. F. Plunkett (FPL) to USNRC, concerning "Proposed License Amendments Maximum Containment Pressure", L-93-133, dated May 21, 1993.

5.18 Stand Alone Safety Evaluation JPN-PTN-SECJ-94-027, "Units 3 & 4 Containment Structure Re-analysis", Revision 0.

5.19 Calculation C-SJ599-01, "3-D Finite Element Model for Turkey Point Containment Building", Rev. 0.

5.20 Calculation C-SJ599-02, "Determination of Containment Thermal Loadings for Input into BSAP Finite Element Computer Program", Rev.0.

5.21 Calculation C-SJ599-03, "Determination of Containment Prestress Loadings for Input into BSAP Finite Element Computer Program", Rev.0.

5.22 Calculation C-SJ599-04, "Baseline Analysis of Turkey Point Containment Building", Rev. 0.

5.23 Calculation C-SJ599-05, "Software Modification and Calculation of Prestress Loads on Containment Shell", Rev. 0.

5.24 Calculation C-SJ599-06, "Design Loads and Load Combinations for Turkey Point Containment Structure Re-Analysis", Rev. 0.

5.25 Calculation C-SJ599-07, "Turkey Point Containment Confirmatory Analysis Results", Rev. 0.

5.26 Calculation C-SJ599-08, "Turkey Point Containment Structure Analysis Refined Thermal Crack Analysis for Containment Shell", Rev. 0.

5.27 Calculation C-SJ599-09, "Turkey Point Containment Stress Allowables", Rev. 0.

5.28 Calculation C-SJ599-10, "Turkey Point Containment Structure - Equipment Hatch BSAP Modeling and Loading", Rev. 0.

5.0 References (Cont.):

5.29 Calculation No. C-SJ599-11, "Containment Structure Final Analysis Results for all Load Combinations", Revision 0.

5.30 Calculation No. C-SJ599-12, "Turkey Point Containment Structure Tendon Surveillance Lift-Off Force Requirements", Revision 0.

5.31 Calculation C-SJ599-13, "Turkey Point Containment Structure Personnel Hatch and Thrust Beam Area BSAP Model & Loading", Rev. 0.

5.32 Bechtel letter NOPS 94-820, dated December, 1994.

Figure 1

Comparison of Surveillance Data to PUL and PLL

20th Year Lift-Off Data for Hoop Tendons

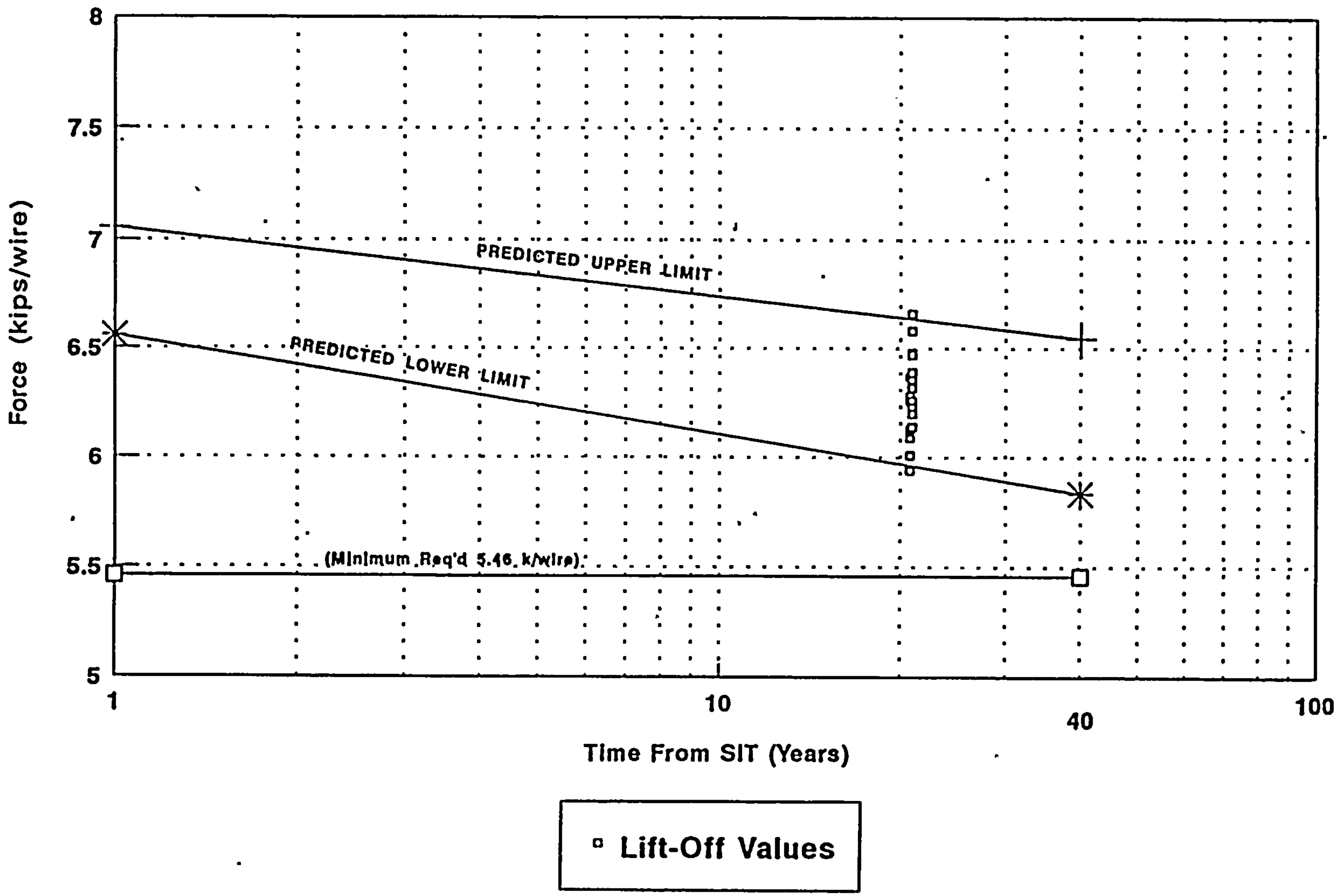


Figure 2

Comparison of Surveillance Data to PUL and PLL

20th Year Lift-Off Data for Dome Tendons

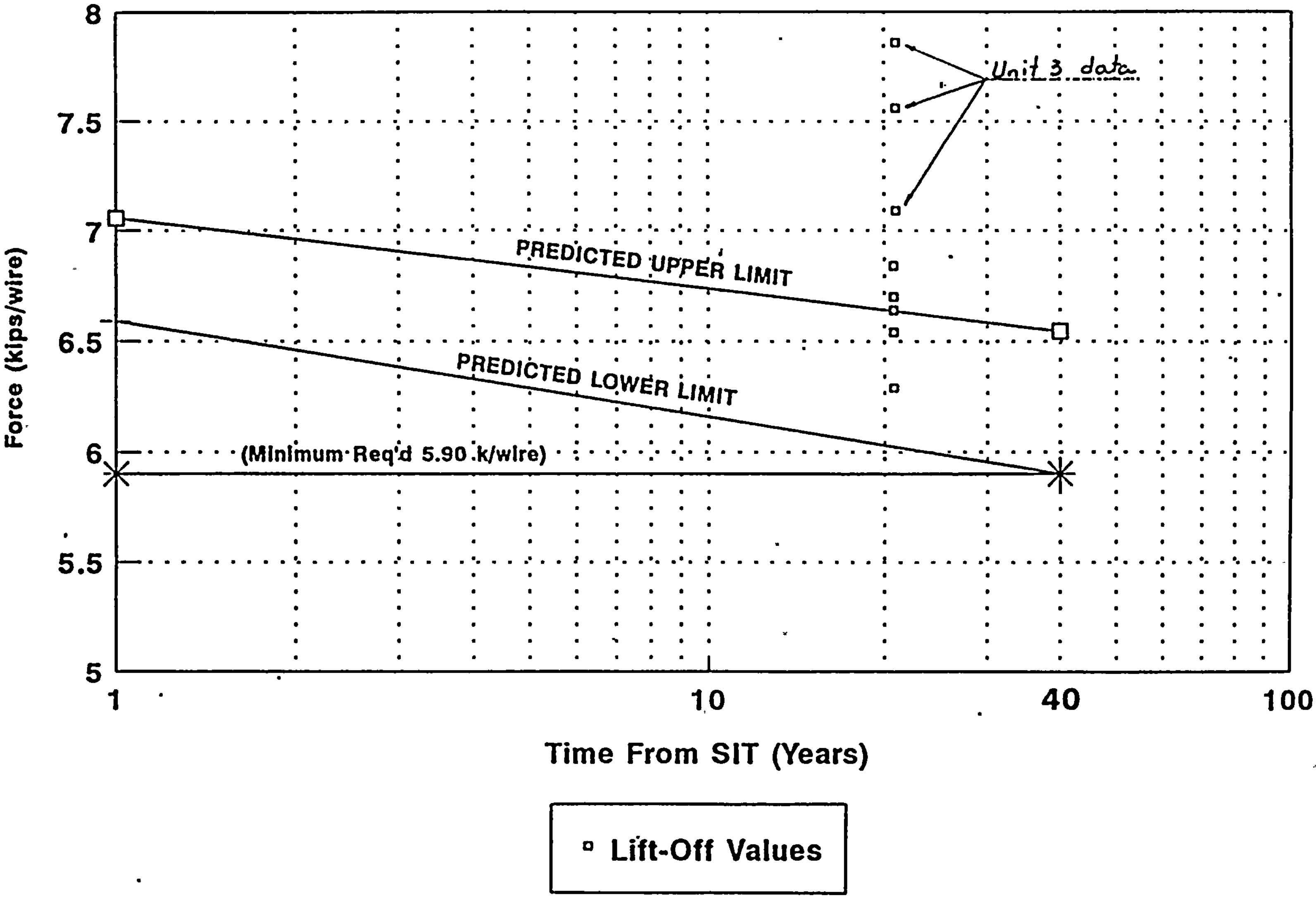
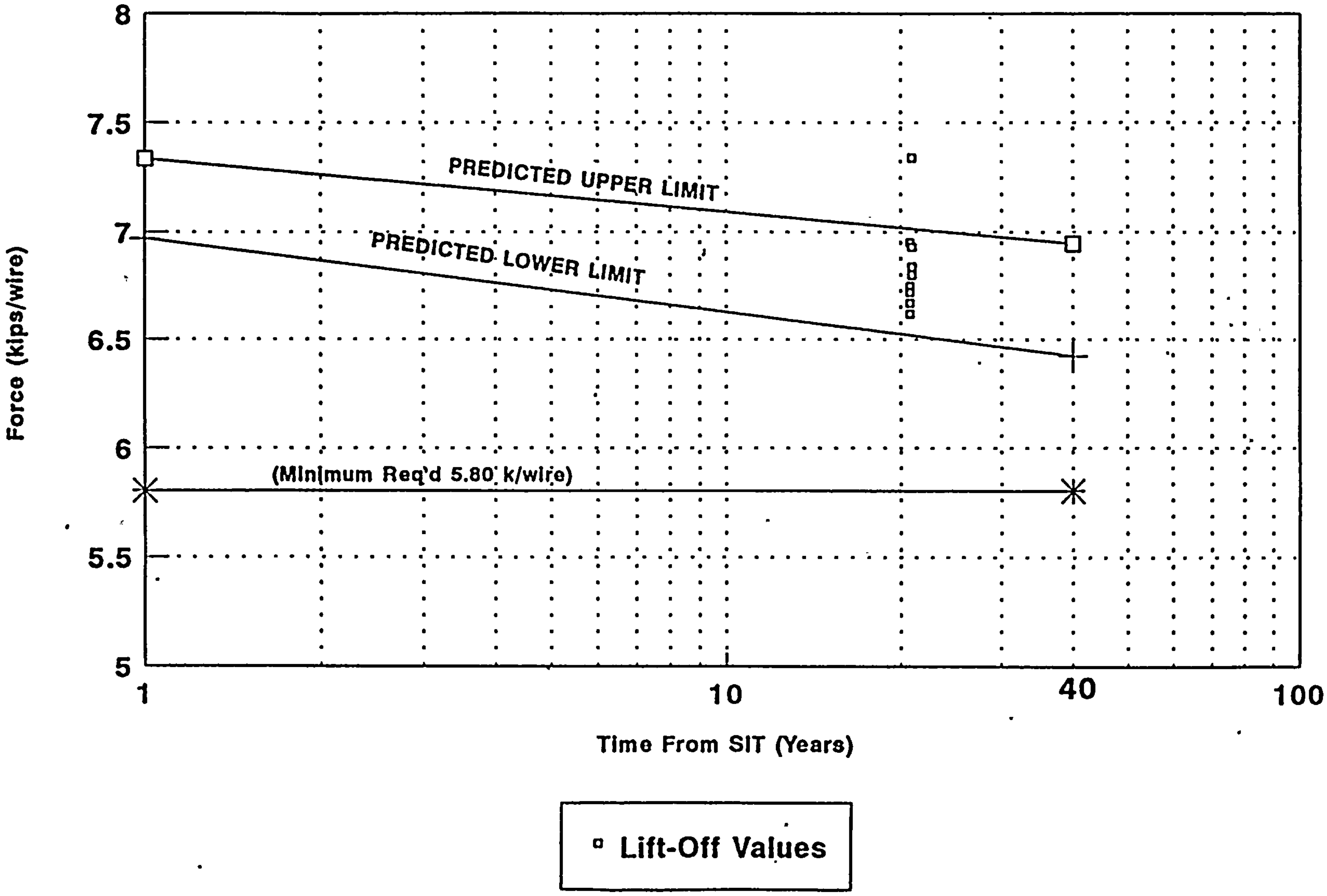


Figure 3

Comparison of Surveillance Data to PUL and PLL

20th Year Lift-Off Data for Vertical Tendons



ATTACHMENT 1

SYNOPSIS OF THE TURKEY POINT UNITS 3 & 4 TWENTIETH YEAR TENDON SURVEILLANCE LOW LIFT-OFF TENDON FORCE ROOT CAUSE EVALUATION / INVESTIGATION

SYNOPSIS OF THE TURKEY POINT UNITS 3 AND 4 20TH YEAR TENDON SURVEILLANCE LOW TENDON LIFT-OFF FORCE ROOT CAUSE EVALUATION/INVESTIGATIONS

I. Purpose

The purpose of this document is to summarize the methodology and evaluation performed for the determination of the most probable cause of the low tendon lift-off forces found during the performance of the twentieth year tendon surveillance of the Turkey Point Units 3 and 4 containment structure post-tensioning systems. Engineering Evaluations JPN-PTN-SECJ-92-024 (reference 4) and JPN-PTN-SECJ-92-042 (reference 7) have documented the most probable cause analysis in detail. This report does not provide any new data or evaluations; it summarizes the effort and provides a synopsis of the investigations described in references 4 and 7. The focus of this report will be on the time dependent losses (creep, shrinkage, and wire steel relaxation) and the effects of temperature on the magnitude of each loss.

II. Background

During the performance of the twentieth year tendon surveillance of the Turkey Point Units 3 and 4 containment structure post-tensioning systems, the measured normalized lift-off forces for a number of randomly selected surveillance tendons (two of five hoop tendons, one of three dome tendons, and one of four vertical tendons in Unit 4, and four of five hoop tendons in Unit 3) were below the predicted lower limit (PLL). In accordance with the Turkey Point Plant Technical Specifications and to further investigate the extent and probable cause of the low lift-off conditions, additional lift-off measurements on adjacent tendons were taken. The measured lift-off force in the adjacent tendons (with the exception of one dome tendon and two vertical tendons in Unit 4) were also found to be below the PLL. Consequently, in accordance with the Turkey Point Plant Technical Specifications, engineering evaluations (references 2 through 7) were prepared to address the low lift-off conditions.

Evaluations and calculations were performed to establish the root cause of the higher than expected losses. It was concluded that the most probable cause for the low lift-off forces measured during the twentieth year tendon surveillance was an increased tendon wire steel relaxation loss caused by average tendon temperatures higher than originally considered. This analysis was documented in Calculation C-SJ539-09 (reference 8) and the results were summarized in references 4 and 7. References 4 and 7 also concluded that the Unit 3 and Unit 4 containment post-tensioning systems will provide sufficient prestress force to maintain Turkey Point licensing basis requirements at least through the twentieth-fifth year tendon surveillances. This finding prompted the recommended action to re-analyze the containment structure post-tensioning system to determine the minimum required prestress force and to establish that the containment structure post-tensioning system is acceptable through the end of the licensed plant life. Subsequent to the twentieth year tendon surveillances, Florida Power and Light Company (FPL) implemented an action plan for the containment post tensioning system which included a re-analysis of the containment structure. Furthermore, in January 1993, this information was presented to the NRC during a presentation by FPL.

III. Root Cause Analysis of Accelerated Tendon Force Losses

The Turkey Point Updated Final Safety Analysis Report (UFSAR), Section 5.1.4.4 and Appendix 5B (Section B.1.8) defines the following prestress losses for the post-tensioning system, which are consistent with industry standards:

a) Seating Loss
b) Concrete Elastic Shortening Loss
c) Concrete Shrinkage Loss
d) Frictional Loss
e) Concrete Creep Loss
f) Tendon Wire Relaxation Loss

The seating loss [as stated in Section 5.1.4.4 of the UFSAR, there is no seating loss for the Turkey Point anchor system - Berkemeier, Brandestini, Ros and Vogt (BBRV) system], elastic shortening loss and frictional loss are immediate (short term) losses which occur upon tendon stressing operation and lock-off. The concrete shrinkage and creep, and tendon wire steel relaxation are time dependent (long term) losses which occur during the life of the structure.

The magnitude of the original tendon seating force, as discussed in the UFSAR, Page 5.1.4-11, was selected such that after elastic losses, the <u>average</u> anchor stress will be approximately 0.7 f_{pu} (f_{pu} = wire ultimate tensile strength). Therefore, Calculation C-SJ539-09 (reference 8) examined all of the assumed long term losses documented in the UFSAR, which have also been the basis for previous surveillances.

The concrete and shrinkage losses are dependent on the properties of the concrete mix. In addition, both creep and tendon wire relaxation are dependent on the state of stress of the material. Also, creep and relaxation are known to increase with higher temperatures. The following summarizes the information and investigation relative to each time dependent loss and the associated influencing factors:

<u>Temperature</u>

Calculation C-SJ539-09 (reference 8) was prepared using meteorological and plant operation data to establish the average inside and outside containment temperatures which were then used to determine average temperatures at the tendon locations. Based on the resulting average wall gradient, tendon temperatures for the dome, hoop, and vertical tendon groups were determined to be approximately 90°F.

<u>Creep</u>

The Turkey Point UFSAR Appendix 5D includes concrete test reports conducted by the University of California (Berkeley) using site-specific concrete mix proportions and aggregates. Creep tests were performed for two different test conditions; 70°F and 100°F at a constant stress of 1500 psi. The test results were reported as creep strains (in/in) per psi of applied concrete stress. Test results were extrapolated from the test end date (180 days) to 40 years. As stated in Section 5.1.4.4 of the UFSAR, the actual creep loss used to predict tendon force considered a 40 year creep strain of 0.433×10^{-6} in/in per psi corresponding to 100°F test results (The creep strain corresponding to 70°F, as shown in Appendix 5D of the UFSAR, is 0.34×10^{-6} in/in per psi). Therefore, it was concluded that concrete creep, which is known to be influenced by higher temperatures, had already been conservatively calculated using

site-specific concrete testing conducted at 100°F. The creep strain of 0.433×10^{-6} in/in per psi results in a final tendon stress loss of 19.2 ksi for a sustained concrete stress of 1500 psi. In addition, Calculation C-SJ539-09 determined that the concrete compressive stress for both the hoop and dome tendon groups is at similar level (approximately 1500 psi) and is approximately double that of the vertical tendon group. Therefore, the creep loss value for vertical tendons was taken as 50% of the value of hoop or dome tendons.

Shrinkage

Shrinkage loss was taken as 3 ksi. This loss corresponds to a strain of 100×10^{-6} in/in which is consistent with the industry standards and Regulatory Guide 1.35.1 (reference 14) recommendations. Furthermore, as noted in the UFSAR, this value was reasonable considering that the concrete had aged a year or more before the tendons were stressed. Shrinkage losses are less than 25% of the other time dependent losses. Therefore, any variance in the estimation of losses due to shrinkage was judged to be minimal and to not be a potential root cause for accelerated tendon force losses.

Steel Wire Relaxation

The original long-term steel wire relaxation losses were estimated in the UFSAR to be 8% (of 0.65 f_{pu})). Based on the original tendon wire tests conducted by Shinko Company, the supplier of the tendon wires, it was determined that this value is appropriate for ambient wire temperatures of 68°F (reference 10). However, the original wire tests were also conducted for higher temperatures of 125°F and 250°F. These wire tests indicated that steel wire relaxation increases at higher temperatures. Additional research into other operating nuclear plants with post-tensioned containments which had experienced low tendon lift-off tests (V.C. Summer and Ginna) also confirmed that higher tendon wire temperatures of 90°F could result in relaxation values up to 14% (references 11 and 12). Based on the results of the original tendon wire tests using higher ambient temperatures, it was determined that for average tendon wire temperatures of 90°F, relaxation values of approximately 12% could be expected.

IV. Tendon Surveillance Lift-off Data Evaluation

Calculation C-SJ539-09 used a trial and error data correlation approach, varying the assumed relaxation rate, until a good match was achieved with the lift-off test data from the fifteenth and twentieth year tendon surveillances.

Calculation C-SJ539-09 was originated to determine the probable cause of the twentieth year surveillance Unit 3 hoop tendon low lift-off results, before the completion of the Unit 4 surveillance. Therefore, only data through the fifteenth year surveillance were available for Unit 4.

A good correlation was obtained using 12% relaxation for the Units 3 and 4 hoop tendons and the Unit 4 dome tendons. However, in order to understand the behavior of the vertical tendons and the Unit 3 dome tendons, additional research was required. The relatively high Unit 3 dome lift-off values were attributed to the later restressing operation

performed as a result of the Unit 3 dome concrete repair. For vertical tendons, examination of the assumed UFSAR losses determined that a single creep value was used for all three groups. Concrete for both the hoop and dome tendon groups are at similar stress level (approximately 1500 psi), and is approximately double that of the vertical tendon direction. Since the same higher concrete creep losses were also assumed for the vertical tendons, the effects of the accelerated steel relaxation losses were somewhat offset by the overestimation of vertical tendon creep losses. Calculation C-SJ539-09 recalculated creep losses for the vertical tendon group (based on the appropriate lower concrete stress) and combined it with the shrinkage and higher relaxation losses. The analysis concluded that 12% steel relaxation was the most appropriate value. This conclusion was documented in Engineering Evaluation JPN-PTN-SECJ-92-024 (reference 4) as the most probable cause for the low tendon lift-off forces. Later, Engineering Evaluation JPN-PTN-SECJ-92-042 (reference 7) compared Unit 4 lift-off data using the higher 12% relaxation figure and found that the lift-off data for the Unit 4 hoop, dome and vertical tendon groups correlated well to the predicted values (within 3.5%).

Predicted Tendon Forces

In accordance with the recommendations of references 4 and 7, 12% (of 0.65 f_{pu}) steel relaxation has been used to generate the new Predicted Upper Limit (PUL) and Predicted Lower Limit (PLL) tendon force curves for future tendon surveillances (i.e., twentieth-fifth year and beyond) in Calculation C-SJ599-12 (reference 9). The variable nature of the predicted losses has been included by introducing tolerance factors on each of the losses in accordance with Regulatory Guide 1.35.1 (reference 14). The factors are: $\pm$20% for concrete shrinkage, +25% and -15% for concrete creep, and $\pm$15% for steel relaxation. In addition, the following changes were made to the originally assumed UFSAR loss values:

- The higher steel relaxation loss of 12% was used.
- 40 year concrete creep value for the vertical tendons was taken as 50% of the creep value of the hoop or dome tendons. The values used are 19.2 ksi (unchanged from the original UFSAR) for hoop and dome and 9.6 ksi for vertical tendons.

The curves generated by this methodology are documented in Calculation C-SJ599-12 (reference 9) and are also included as part of this document for reference. As shown, use of the higher value of steel relaxation and considering the creep loss corresponding to the actual sustained stress on the concrete, the resulting tolerance bands created by using the RG 1.35.1 variance technique correlated quite well with the actual data collected in the most recent surveillance. Therefore, it is concluded that the time dependent loss values considered for the new PUL and PLL curves are appropriate.

V. Conclusions

As outlined above, all of the classical long-term losses which are known to influence tendon performance were considered when determining the root cause of the accelerated tendon losses discovered in the twentieth year surveillance. Furthermore, no other losses were discovered in the research which was considered to have potential for causing the larger losses that the Turkey Point containment post-tensioning system was experiencing. The most probable cause of the higher losses was determined to be higher tendon temperatures which resulted in higher steel relaxation. Concrete creep, which is also known to be influenced by higher temperatures, had already been conservatively calculated using site-specific concrete testing conducted at 100°F. As a further demonstration of the accuracy of the new values used, plots of the tolerance band created by the PUL and PLL curves were superimposed with actual surveillance data from the most recent surveillance. These plots show very good agreement with the data demonstrating that the magnitude of the time dependent losses for three tendon groups and the new PUL and PLL curves for the remaining tendon surveillances are reasonable.

VI. References

1. Turkey Point Units 3 and 4, Updated Final Safety Analysis Report (UFSAR), Revision 11, dated November 1993.

2. Engineering Evaluation JPN-PTN-SECJ-92-019, "Unit 3 Twentieth Year Tendon Surveillance Hoop Tendons Low Lift-Off Force", Revision 1.

3. Engineering Evaluation JPN-PTN-SECJ-92-023, "Unit 3 Twentieth Year Tendon Surveillance Low Lift-Off Force on Hoop Tendon 42H32", Revision 0.

4. Engineering Evaluation JPN-PTN-SECJ-92-024, "Unit 3 Twentieth Year Tendon Surveillance Extent and Cause of Low Lift-Off Force on Hoop Tendons", Revision 0.

5. Engineering Evaluation JPN-PTN-SECJ-92-039, "Unit 4 Twentieth Year Tendon Surveillance - Low Lift-Off Force on Hoop Tendon 13H54 and Dome Tendon 1D40", Revision 0.

6. Engineering Evaluation JPN-PTN-SECJ-92-041, "Unit 4 Twentieth Year Tendon Surveillance - Low Lift-Off Force on Hoop Tendon 35H38", Revision 0.

7. Engineering Evaluation JPN-PTN-SECJ-92-042, "Unit 4 Twentieth Year Tendon Surveillance, Extent and Probable Cause of Low Lift-Off Force on Hoop and Dome Tendons", Revision 0.

8. Calculation C-SJ539-09, "Probable Cause Analysis for Low Lift-Off Forces on Hoop Tendons" Revision 1.

9. Calculation C-SJ599-12, "Turkey Point Containment Structure, Tendon Surveillance Lift-Off Requirements", Revision 0.

10. Test Results for Turkey Point Wire Relaxation Tests, dated March 1, 1968 (see Appendix 1 of FPL letter L-93-174 to USNRC, dated August 10, 1993).

11. Relaxation Tests on 1/4 Inch Prestressing Wire, by R. G. Slutter, Report Number 200.79.100.5, dated January 21, 1982, from Fritz Engineering Laboratory at Lehigh University (see Appendix 1 of FPL letter L-93-174 to USNRC, dated August 10, 1993).

12. Excerpt from V. C. Summer Unit 1 Nuclear Station Reactor Building Containment Third Period Surveillance Tendon Forces,

    Gilbert/Commonwealth Report Number 2610, dated January 13, 1986 (see Appendix 1 of FPL letter L-93-174 to USNRC, dated August 10, 1993).

13. Test results of Inservice Inspection Forces Measured in Retensioned Tendons by J. F. Fulton of Gilbert/Commonwealth, and C. A. Forbes of Rochester Gas and Electric Corporation (see Appendix 1 of FPL letter L-93-174 to USNRC, dated August 10, 1993).

14. Regulatory Guide 1.35.1, "Determining Prestressing Forces for Inspection of Prestressed Concrete Containments", July 1990.

ATTACHMENT 2

FLORIDA POWER & LIGHT COMPANY

TURKEY POINT UNITS 3 & 4 UFSAR

APPENDIX 5H

1994 CONTAINMENT STRUCTURE RE-ANALYSIS

TURKEY POINT UNITS 3 AND 4

TABLE OF CONTENTS

TABLES

FIGURES

APPENDIX 5H

1994 CONTAINMENT STRUCTURE RE-ANALYSIS TURKEY POINT UNITS 3 AND 4

5H.1 GENERAL

This appendix documents the results of the containment re-analysis relative to the determination of the minimum prestressing requirements for each tendon group. The containment re-analysis was completed in 1994.

5H.2 BACKGROUND

The tendon surveillance programs for the Turkey Point Units 3 and 4 containment structure post-tensioning systems have been performed at one, three, and five years after the containment Initial Structural Integrity Test (ISIT), and every five years thereafter. During the performance of the 20th year tendon surveillance, the measured normalized lift-off forces for a number of randomly selected surveillance tendons (two of five hoop tendons, one of three dome tendons, and one of four vertical tendons in Unit 4, and four of five hoop tendons in Unit 3) were below the predicted lower limit (PLL). In accordance with the Turkey Point Plant Technical Specifications and to further investigate the extent and probable cause of the low lift-off conditions, additional lift-off measurements on adjacent tendons were taken. The measured lift-off force in the adjacent tendons (with the exception of one dome tendon and two vertical tendons in Unit 4) were also found to be below the PLL. Consequently, in accordance with the Turkey Point Plant Technical Specifications, engineering evaluations (References 1 through 6) were prepared to address the low lift-off conditions.

References 3 and 6 evaluated the low lift-off forces and concluded that the most probable cause for the low lift-off forces measured during the 20th year tendon surveillances were due to an increased tendon wire steel relaxation loss caused by average tendon temperatures higher than originally considered. Considering this higher steel relaxation loss rate, these evaluations also concluded that the Units 3 and 4 containment post-tensioning systems will provide sufficient prestress force to maintain Turkey Point licensing basis requirements at least through the 25th year tendon surveillance.

References 3 and 6 also recommended a structural re-analysis of the containment structure and the post-tensioning system to determine a new minimum required prestress force and to establish the time period that the containment post-tensioning system will provide sufficient prestress force to maintain the Turkey Point licensing basis requirements.

5H.2.1 Original Containment Analysis

The original containment structural analysis results are documented in UFSAR, Section 5.0.

In the original containment analysis/design, the containment base slab was designed as a conventional reinforced concrete structure. The containment re-analysis as described in this appendix does not include a new evaluation of the base slab since the base slab is not affected by the post-tensioning system. However, the base slab was included in the containment re-analysis model to provide a realistic boundary condition for the model. Therefore, the original base slab design/analysis, as summarized in UFSAR, Sections 5.1.3, 5.1.4 and Table 5.1.4-1, Sheet 6 remains unchanged. In addition, certain load conditions (e.g., initial prestressing and initial structural integrity test condition) and evaluations (e.g., buttress anchorage zone stress evaluation) were not included in the 1994 re-analysis. The UFSAR, Section 5.0 has been annotated in all areas where the 1994 re-analysis has modified the original analysis.

5H.3 CONTAINMENT RE-ANALYSIS

5H.3.1 MODEL DESCRIPTION

A three dimensional (3-D) finite element model using Bechtel's Structural Analysis Program (BSAP), is used for the re-analysis of the containment structure. The 3-D model consists of the cylindrical wall (including buttresses), ring girder, dome, base slab, and the major penetrations (equipment hatch and the personnel hatch). A plate element is used in the 3-D model to represent the shell (including buttresses and major penetrations), dome, ring girder, and the base slab. This element is a thin quadrilateral and/or triangular element that has both membrane and bending properties. The formulation of this element is based on the thin shell and small deflection theory. The base slab is modeled as a circular foundation including a central hole with appropriate boundary conditions representing the centerline of the reactor pit walls. The soil-structure interaction is accounted for by introducing the soil springs at each node of the base slab. Refer to Figures 5H-1 through 5H-4 for the geometric plots of the 3-D model. The development of the 3-D model is documented in Reference 7.

5H.3.2 MATERIAL PROPERTIES

The material properties used in the 3-D model are as follows:

Modulus of Elasticity of Concrete (E_c) = 1.5 x 10^6 psi

Concrete Poisson's Ratio = 0.17

Coefficient of Thermal Expansion (α_c)= 5.0 x 10^{-6} per ^oF

These values are consistent with the information included on page 5.1.3-2 which were used in the original design basis analysis of the Turkey Point containment structure.

The soil properties are based on the 1988 seismic survey conducted at the Turkey Point site for the EDG enhancement project (Reference 19). The properties for each soil layer used in the re-analysis are as follows:

Soil Layer	Poisson's Ratio	Shear Modulus
Limerock Fill	0.256	7380 ksf
Miami Oolite	0.253	18620 ksf

For the Fort Thompson formation, consistent with the original analysis, 0.22 and 4×10^6 psi was used for the Poisson's ratio and the Young's modulus, respectively.

Detailed explanation of the 3-D model material properties is documented in Reference 7.

5H.3.3 DESIGN LOADS AND LOAD COMBINATIONS:

The design loads and the load combinations used in the re-analysis of the containment structure are in accordance with the requirements of Appendix 5B "Containment Structure Design Criteria". All load combinations included in Appendix 5B for the design load and the yield conditions have been evaluated in the re-analysis of the containment structure. Reference 12 documents the load conditions and the load combinations that have been considered in the analysis.

5H.3.4 METHOD OF ANALYSIS & STRESS ALLOWABLES

The working stress method (elastic analysis) is applied to the load combinations for design load, as well as yield load conditions. The design assumption of straight line variation of stresses is maintained under yield conditions. This method of analysis is consistent with the original design basis for the Unit 3 and Unit 4 containment structures as outlined in Appendix 5B.

The stress allowables used for evaluation of the critical sections of the containment structures are in accordance with Appendix 5B. This is documented in Reference 15.

5H.3.5 BASELINE ANALYSIS

A baseline analysis was performed to demonstrate correlation between the results of the 1994 3-D BSAP finite element analysis and the original Turkey Point containment axisymmetric analysis (Refer to Page 5.1.3-1). The results of the baseline analysis demonstrate good correlation between the 1994 BSAP 3-D analysis and the original axisymmetric analysis specified in the isostress plots in the UFSAR, Section 5.0. In addition, the baseline analysis for the pressure load case was compared to classical closed form solutions with good correlation. It was concluded that the 3-D finite element model accurately predicts the state of

stress in the containment structures. The baseline analysis has been documented in Reference 10.

5H.3.6 THERMAL CRACK ANALYSIS

As stated in Section 5.1.3.1, the thermal loading used in the original design was based on Figure 5.1-8 "Design Thermal Gradient Across Containment Wall". Also, as stated in Page 5.1.3-3, a temperature of 283°F was used for liner plate in the original design. The thermal loading used in the re-analysis of the containment structure is consistent with the original criteria. In addition, the occurrence of a higher containment bulk temperature (i.e., from 120°F to 125°F) as stated in Pages 14.3.4-16 and 14.3.4-22 has been considered in the re-analysis. The thermal loading for the 3-D model is documented in Reference 8.

Consistent with the original analysis, the thermal crack analysis outlined on Pages 5.1.3-7 through 5.1.3-9 has been used to determine the stresses in reinforcing steel and concrete due to thermal loading. This method of analysis is based on the equilibrium of normal forces acting on the section under consideration. The concrete and reinforcing steel stresses from the primary loads are added to the thermal stresses to determine the total stresses.

For load combination 1.05D + F + 1.5P + T_a, an additional refined thermal crack analysis has been performed for the critical mid-height section of the shell to determine the effects of thermal loading and concrete cracking on the overall state of stress in the shell. The ALGOR SuperSap computer program is used in the refined thermal crack analysis. The finite element analysis used a two dimensional (2-D) model which includes a section of the shell halfway between the adjacent buttresses (a 60° segment of the containment). This 2-D model is primarily used to capture the behavior of the shell in the hoop direction. Two models, one with and one without buttresses, were used to study the effects of the buttress in cracking analysis. There are 10 layers of elements representing concrete thickness in the shell area. In addition, there is one element representing the liner plate. The reinforcing steel and the hoop tendons are also modeled as truss elements. By modeling the hoop tendons, the effects of pressurization (increase in tendon force due to internal pressure loading) is directly captured. Roller type boundary conditions have been used for this model to allow the boundary nodes to displace in the radial direction. The modeling and the method of analysis are documented in Reference 14. Figure 5H-5 depicts the finite element models used in the refined thermal cracking analysis.

The cracking of the concrete is established by the criterion in Appendix 5B which states that the principal concrete tension due to combined membrane tension, membrane shear, and flexural tension due to bending moments or thermal gradients is limited to $6(f'c)^{0.5}$. The cracking of the concrete is accomplished by introducing a very small modulus of elasticity in the hoop direction. The cracking analysis is carried out in successive analyses as follows:

5H.3.6 THERMAL CRACK ANALYSIS (cont)

a) The first analysis considers an uncracked concrete condition. In this analysis, the concrete elements with stresses in the hoop direction exceeding the Appendix 5B limit are considered cracked.

b) The second analysis includes the material properties for the cracked elements determined in the first cycle.

Based on the results of the first analysis, the second analysis was performed with all layers of concrete cracked. The reinforcing steel and tendon stresses, and the liner strain were found to be within the established UFSAR allowable limits. The results of the refined thermal crack analysis are documented in Reference 14.

5H.3.7 MAJOR PENETRATIONS EVALUATION

The 3-D finite element model includes a refined mesh at the equipment hatch and the personnel hatch locations to capture the behavior of the shell in the vicinity of these large penetrations. By modeling the penetrations in the 3-D model, the need for a local model and defining the boundary conditions and the loads at the boundaries of the local model is eliminated. Also, the effects of the shell curvature will be captured.

The thickened shell at the equipment hatch area has been taken into account by specifying the appropriate element thicknesses. In addition, the deflection of the hoop and vertical tendons around the equipment hatch and the personnel hatch has been considered in the modeling by applying the appropriate nodal loads and element pressure loads.

The modeling of the equipment hatch and the personnel hatch is documented in References 16 and 18, respectively. Refer to Figures 5H-3 and 5H-4 for the geometric plots of the finite element mesh for the equipment and personnel hatches.

5H.4 SUMMARY OF RESULTS

Tables 5H-1A and 5H-1B include the most critical reinforcing steel stress summary as a result of the containment re-analysis. The information presented in these tables are given for representative elements in the 3-D model away from the major penetrations. The elements range from the base/shell junction to the vicinity of dome apex as shown in Figure 5H-2. The results are tabulated for all design and yield loading combinations stated in Appendix 5B. The reinforcing steel and concrete stresses, and liner strains were found acceptable for all design basis loading conditions.

In addition, the stresses in reinforcing steel and concrete, and liner plate strains in the localized areas around the major penetrations were found acceptable for all design basis loading conditions.

These results are based on the following final minimum required average prestress forces:

Hoop Prestress Force = 590 kips/ft

Dome Prestress Force = 313 kips/ft

Vertical Prestress Force = 250 kips/ft

The tendon forces and tendon wire forces (based on a 90 wire tendon) corresponding to these average prestress values are as follows:

TENDON GROUP	FINAL REQUIRED AVERAGE PRESTRESS FORCE (kips/ft)	TENDON FORCE (kips/tendon)	WIRE FORCE (kips/wire)
HOOP	590	491.6	5.46
DOME	313	531	5.90
VERTICAL	250	522	5.80

The methodology and results of the 1994 containment structure re-analysis are documented in Reference 17.

H5.5 REFERENCES

1. Engineering Evaluation JPN-PTN-SECJ-92-019, "Unit 3 20th Year Tendon Surveillance Hoop Tendons Low Lift-Off Force", Revision 1.

2. Engineering Evaluation JPN-PTN-SECJ-92-023, "Unit 3 20th Year Tendon Surveillance Low Lift-Off Force on Hoop Tendon 42H32", Revision 0.

3. Engineering Evaluation JPN-PTN-SECJ-92-024, "Unit 3 20th Year Tendon Surveillance, Extent and Probable Cause of Low Lift-Off Force on Hoop Tendons", Revision 0.

4. Engineering Evaluation JPN-PTN-SECJ-92-039, "Unit 4 20th Year Tendon Surveillance - Low Lift-Off Force on Hoop Tendon 13H54 and Dome Tendon 1D40", Revision 0.

5. Engineering Evaluation JPN-PTN-SECJ-92-041, "Unit 4 20th Year Tendon Surveillance - Low Lift-Off Force on Hoop Tendon 35H38", Revision 0

6. Engineering Evaluation JPN-PTN-SECJ-92-042, "Unit 4 20th Year Tendon Surveillance, Extent and Probable Cause of Low Lift-Off Force on Hoop and Dome Tendons", Revision 0.

7. Calculation No. C-SJ599-01, "3-D Finite Element Model for Turkey Point Containment Building".

8. Calculation No. C-SJ599-02, "Determination of Containment Thermal Loading for Input into BSAP Finite Element Computer Program".

9. Calculation No. C-SJ599-03, "Determination of Prestress Loads on the Containment Structure for Input into BSAP Finite Element Computer Program".

10. Calculation No. C-SJ599-04, "Baseline Analysis of Turkey Point Containment Building".

11. Calculation No. C-SJ599-05, "Software Modifications and Calculation of Prestress Loads on Containment Shell".

12. Calculation No. C-SJ599-06, "Design Loads and Load Combinations for Turkey Point Containment Structure Re-Analysis".

13. Calculation No. C-SJ599-07, "Confirmatory Analysis of Turkey Point Containment Structure for Load Case 1.05D+1.5P+F+Ta".

14. Calculation No. C-SJ599-08, "Refined Thermal Crack Analysis for Containment Shell".

15. Calculation No. C-SJ599-09, "Stress Allowables for Analysis of Turkey Point Containment Structure".

16. Calculation No. C-SJ599-10, "Turkey Point Containment Structure - Equipment Hatch BSAP Modeling and Loading.

H5.5 REFERENCES: (cont)

17. Calculation No. C-SJ599-11, "Turkey Point Containment Structure Final Analysis Results for all Load Combinations".

18. Calculation No. C-SJ599-13, "Turkey Point Containment Structure - Personnel Hatch and Thrust Beam Area BSAP Model and Loading".

19. Geotechnical Investigations and Foundation Analysis for Diesel Building Addition, Report No. FLO 53-20E.5000, Revision 0.

TABLE 5H-1A
Rebar Stress Summary
Most Critical Stresses at Representative Section of Containment
For Load Combinations 1, 2, or 3 (WSD)
(BSAP Analysis, With Post-Processing)

Working Stress Design (WSD) Load Combinations are in accordance with Section B.1.5 of Appendix 5B:
(1) D + F + L + To (2) D + F + L + P + Ta + E (3) D + F + L + 1.15P

Element Number	MOST CRITICAL REBAR STRESSES — Larger of (Primary) or (Thermal + Primary) Evaluations — Hoop Rebar (XX) (Inside Face)	Hoop Rebar (XX) (Outside Face)	Meridional Rebar (YY) (Inside Face)	Meridional Rebar (YY) (Outside Face)
11	NOT-CRITICAL	NOT-CRITICAL	-11.590 (1)	27.738 (1)
1733	NOT-CRITICAL	NOT-CRITICAL	-11.034 (1)	21.311 (1)
53	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
95	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
137	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
179	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
221	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
263	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
305	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
347	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
389	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
431	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
473	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
515	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
557	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
599	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
641	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
683	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
725	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
767	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
809	NOT-CRITICAL	NOT-CRITICAL	-0.464 (2)	12.720 (2)
851	NOT-CRITICAL	NOT-CRITICAL	-1.926 (2)	17.200 (2)
893	NOT-CRITICAL	NOT-CRITICAL	- 1.413 (2)	22.846 (1)
935	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
977	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1019	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1061	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1103	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1145	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1187	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1229	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1271	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1313	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1355	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL

Notes
a) Rebar Stresses for Sections not cracking under any of the Load Combinations are entered as "NOT-CRITICAL"
b) Numbers shown in parentheses with stress entry indicate governing Loading Combination.

REBAR ALLOWABLE STRESSES, ksi	
Rebar size	WSD, LC's 1-3
< #11, Fy=40ksi	20.0
#11 or larger, Fy=60 ksi	30.0

TABLE 5H-1B
Rebar Stress Summary
Most Critical Stresses at Representative Section of Containment
For Load Combinations 4, 5, 6, 7, or 8 (USD)
(BSAP Analysis, With Post-Processing)

Ultimate Strength Design (USD) Load Combinations are in accordance with Section B.1.6 of Appendix 5B:
(4) 1.05D + 1.5P + Ta + F
(5) 1.05D + F + 1.25P + Ta + 1.25E
(6) 1.05D + F + 1.25H + R + To + 1.25E
(7) D + F + P + Ta + H + E'
(8) D + F + H + R + E' + To

Element Number	MOST CRITICAL REBAR STRESSES Larger of (Primary) or (Thermal + Primary) Evaluations Hoop Rebar (XX) (Inside Face)	Hoop Rebar (XX) (Outside Face)	Meridional Rebar (YY) (Inside Face)	Meridional Rebar (YY) (Outside Face)
11	N/A	17.296 (8)	-18.281 (6)	28.440 (8)
1733	N/A	13.484 (7)	-20.269 (6)	21.825 (8)
53	N/A	20.874	20.868	15.811 (7)
95	N/A	(Note d)	19.635 (7)	17.092 (7)
137	N/A	(Note d)	10.717	25.576
179	N/A	(Note d)	18.902 (7)	26.624
221	N/A	(Note d)	12.325 (7)	24.966
263	N/A	(Note d)	N/A	24 614
305	N/A	(Note d)	N/A	24.060
347	N/A	(Note d)	N/A	24.547
389	N/A	(Note d)	N/A	25.369
431	N/A	(Note d)	N/A	26.195
473	N/A	(Note d)	N/A	27.012
515	N/A	(Note d)	N/A	27.814
557	N/A	28.166	N/A	28.596
599	N/A	28.359	N/A	20.523
641	N/A	29.002	9.222	19.379
683	14 479	28.101	9.329	19.942
725	15.326	29.379	9.026	21.073
767	20.503	35.602	6.299	20.522
809	18.684	34.225	5.328	23.088
851	14 060	29.754	7.243	25.304
893	-12.476 (8)	21.065	11.308	25.225
935	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
977	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1019	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1061	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1103	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL	NOT-CRITICAL
1145	-3.989 (5)	13.188	9.250	19.250
1187	3.805	24.186	8.336	32.918
1229	9.814	29.765	11.170	36 439
1271	13 013	31.061	13 155	34.925
1313	14 364	30.681	14.237	32.473
1355	14 784	30.128	14.829	31.101

Notes

a) Rebar Stresses for Sections not cracking under any of the Load Combinations are entered as "NOT-CRITICAL"

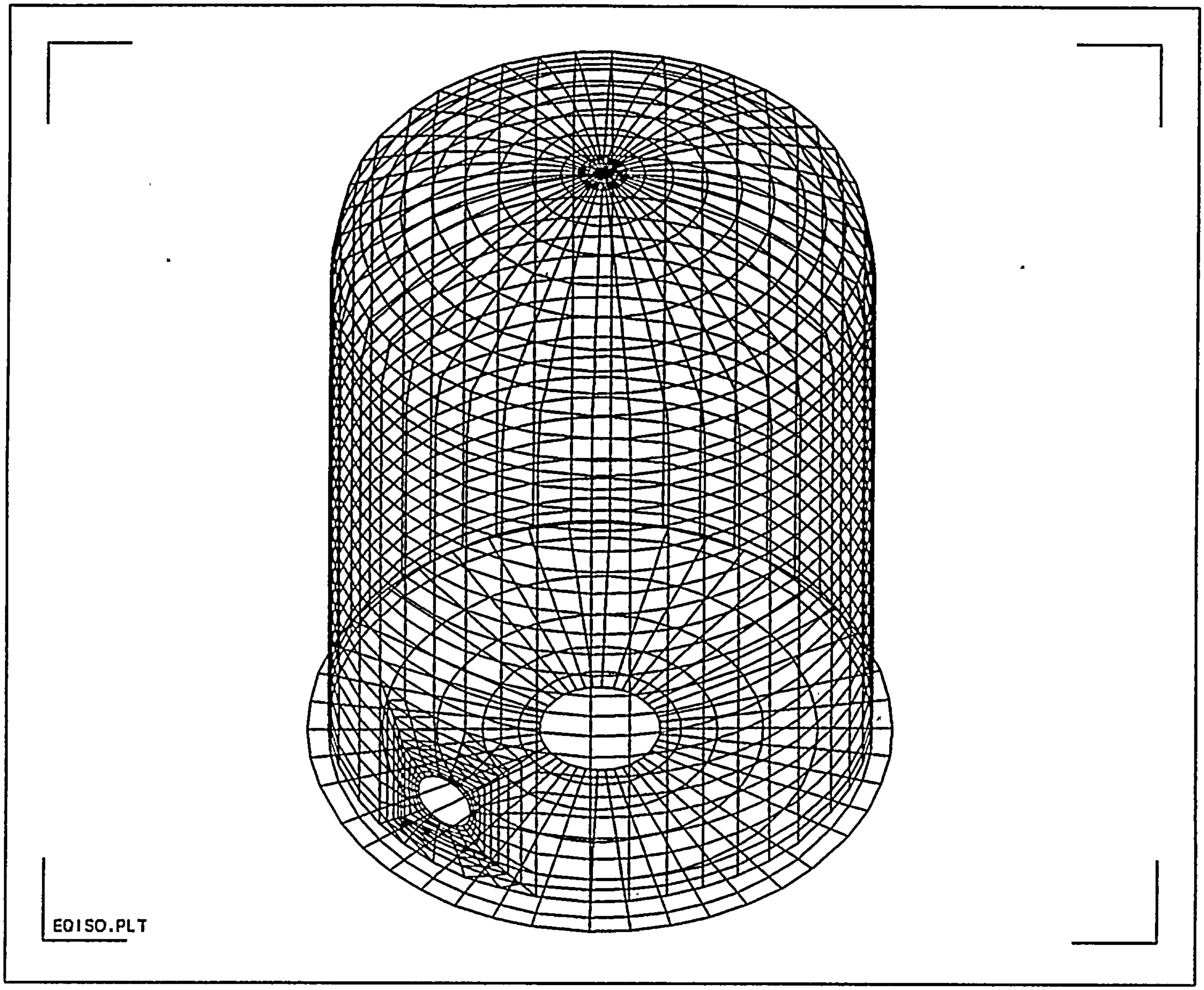
b) Numbers shown in parentheses with stress entry indicate governing Loading Combination. For cases with no load combination shown, governing Load Combination is (4).

c) "N/A" entry denotes: no inside face rebar exists.

d) Maximum hoop outside face rebar stress per refined thermal analysis for this area was determined to be 29.9 ksi.

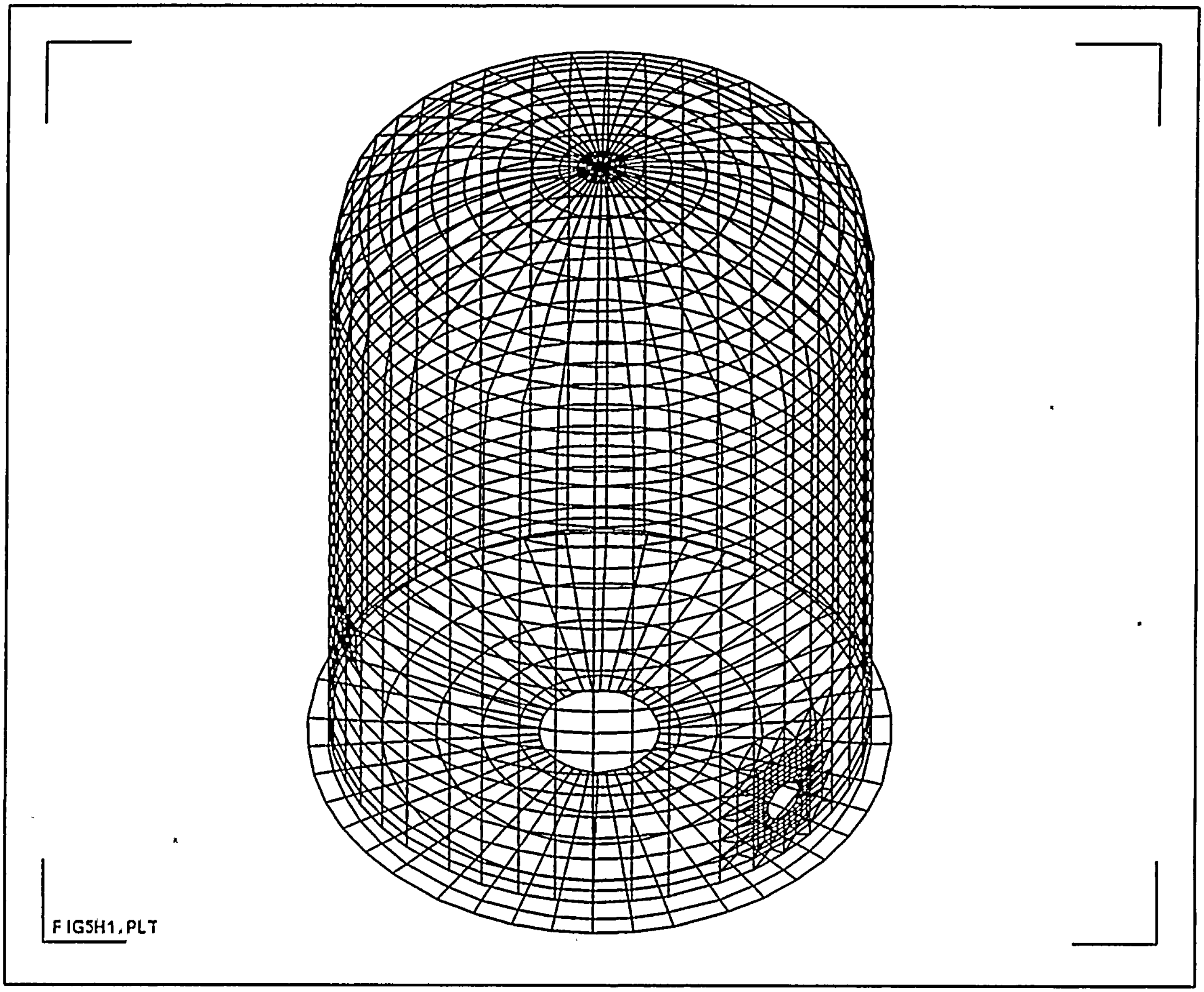
REBAR ALLOWABLE STRESSES, ksi	
Rebar size	USD, LC's 4-8
< #11, Fy=40ksi	36 0
#11 or larger, Fy=60 ksi	54 0

[illegible]



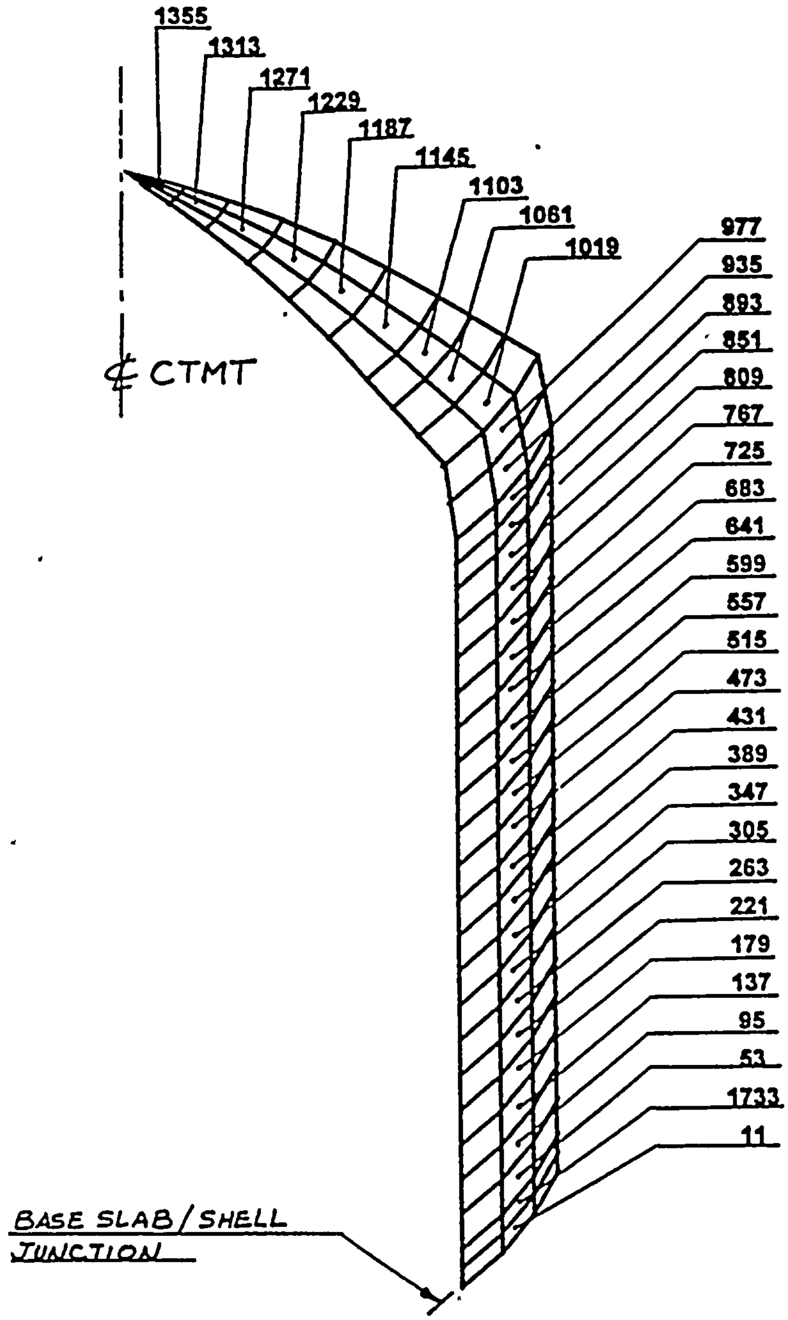
3D FINITE ELEMENT MODEL INCLUDING EQUIPMENT HATCH PENETRATION

FIGURE 5H-1A



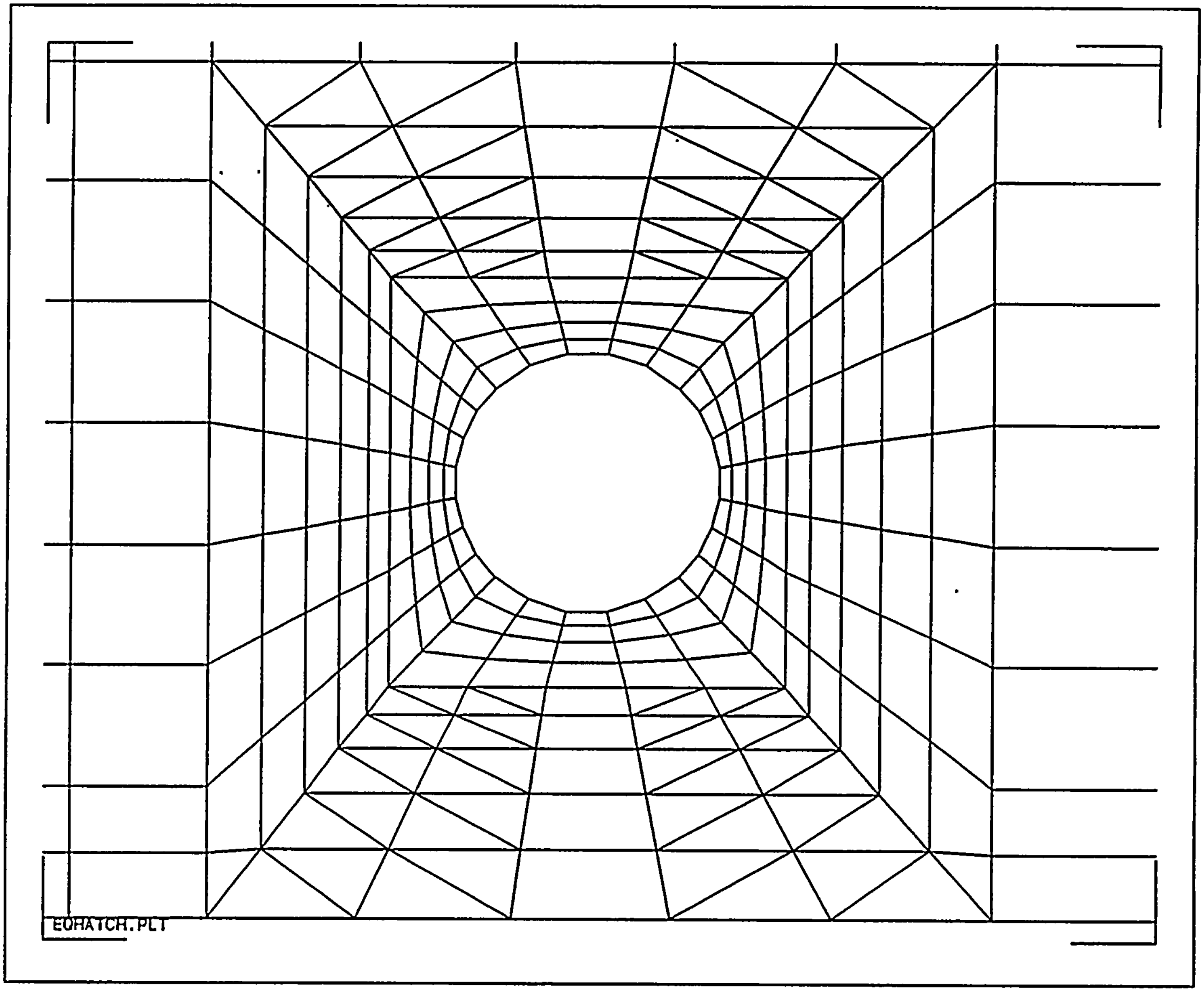
3D FINITE ELEMENT MODEL INCLUDING PERSONNEL HATCH PENETRATION

FIGURE 5H-1B



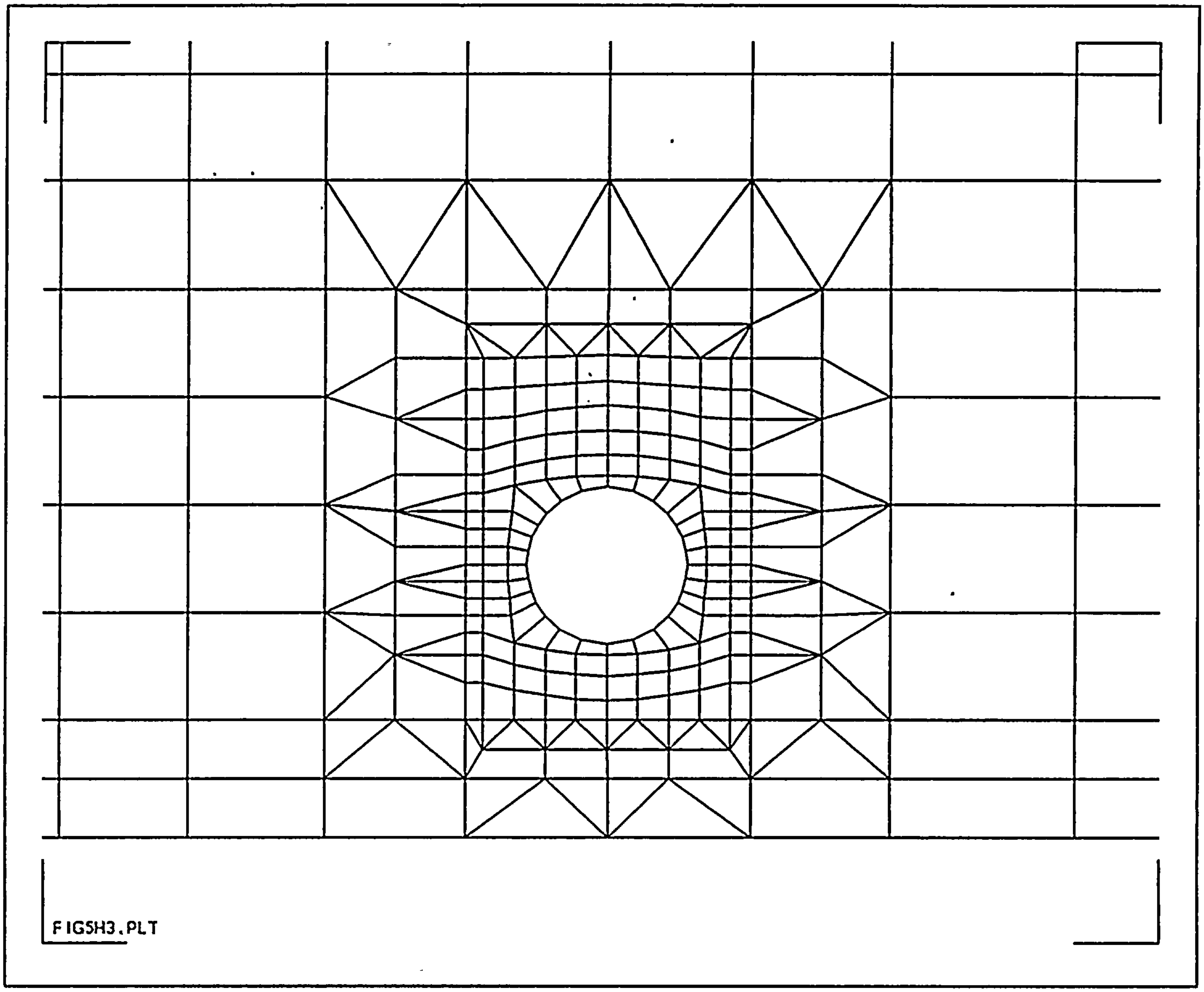
REPRESENTATIVE ELEMENTS IN 3-D MODEL

FIGURE 5H-2



EQUIPMENT HATCH FINITE ELEMENT MESH

FIGURE 5H-3



PERSONNEL HATCH FINITE ELEMENT MESH

FIGURE 5H-4

REFINED THERMAL CRACKING ANALYSIS

FINITE ELEMENT MODELS

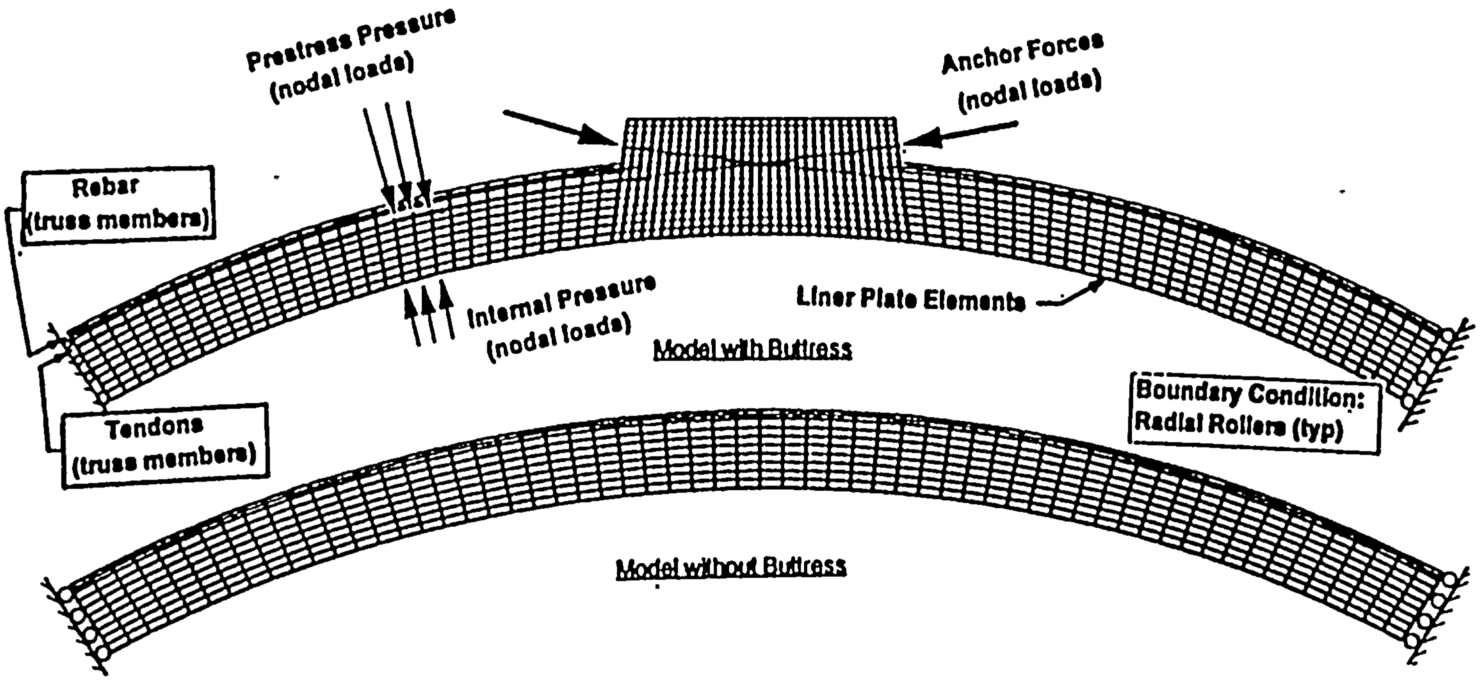


FIGURE 5H-5