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FACIL:50-250 Turkey Point Plant, Unit 3, Florida Power and Light C 05000250
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SUBJECT: Provides addl rept summarizing surveillance testing of hoop tendons inspected during Unit 3 twentieth yr insp.

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SEP 14 1992

L-92-262

Stewart D. Ebneter
Regional Administrator
U. S. Nuclear Regulatory Commission
101 Marietta Street, N.W., Suite 2900
Atlanta, Georgia 30323

Dear Mr. Ebneter:

Re: Turkey Point Unit 3
Docket No. 50-250
Twentieth Year Tendon Inspection Report
Hoop Tendons Low Lift-Off Force

By letter L-92-223 dated August 5, 1992, Florida Power and Light Company (FPL) committed to submit an additional report summarizing the surveillance testing of all hoop tendons inspected during the Unit 3 Twentieth Year Inspection. In response to this commitment, the attached report is provided.

Should there be any questions, please contact us.

Very truly yours,

T. F. Plunkett
Vice President
Turkey Point Nuclear

TFP/RJT/rt

Attachment

cc: USNRC, Document Control Desk, Washington, D.C.
Senior Resident Inspector, USNRC, Turkey Point Plant

# ATTACHMENT

Florida Power and Light Company
Turkey Point Unit 3

Twentieth Year Tendon Inspection
Hoop Tendons Low Lift-Off Force

# TABLE OF CONTENTS

# LIST OF TABLES AND FIGURES

1.0 PURPOSE/SCOPE

During the performance of the twentieth year tendon surveillance of the Turkey Point Unit 3 containment post-tensioning system, four of five hoop surveillance tendons (13H33, 64H61, 35H52 and 42H32) were found to have a measured normalized lift-off force between the predicted lower limit and 90% of the predicted lower limit. Consequently, in accordance with the requirements of the Turkey Point Plant Technical Specifications 4.6.1.6.1 (a), additional lift-off measurements on a tendon located below and a tendon located above (13H32 & 13H34, 64H60 & 64H62, 35H51 & 35H53, and 42H31 & 42H33) the subject tendons were taken. In each case, the measured normalized lift-off force in these adjacent tendons was between the predicted lower limit and 90% of the predicted lower limit. The normalized lift-off force for the fifth hoop surveillance tendon (51H18) was above the predicted lower limit. There were also two hoop tendons (13H29 and 42H9) which due to physical inaccessibility were exempt from the full surveillance requirements in accordance with Technical Specifications (Reference 4.2), Section 4.6.1.6.1. The normalized lift-off forces for these tendons were above the predicted lower limit. Two engineering evaluations (References 4.9 and 4.10) were performed to address the low lift-off forces for tendons 13H33, 64H61, 35H52, and 42H32. These evaluations provided the basis for Special Reports which were submitted to the NRC (Reference 4.32).

In addition, to determine the probable cause of the low lift-off forces measured on the Unit 3 hoop tendons, an evaluation of the post-tensioning system design parameters for the Turkey Point Nuclear Power Plant was performed. The focus of this evaluation was to identify the most probable design parameter(s) or variable(s) that would affect and ultimately cause the low lift-off forces on hoop tendons. The surveillance and design parameters reviewed included: the methods used for measuring lift-off forces and equipment accuracy, temperature effects, tendon wire steel relaxation, concrete creep and shrinkage, spatial location of the hoop tendons that experienced low lift-off forces, and the assumption that time-dependent tendon force losses actually vary with the logarithm of time.

This engineering evaluation addresses the following:

- The probable cause for low lift-off force in the Unit 3 containment hoop tendons.
- The length of time after the Initial Structural Integrity Test (ISIT) that the post-tensioning system hoop tendons will continue to satisfy the Turkey Point design basis requirements.
- The long term recommendations relative to low lift-off force in the Unit 3 containment hoop tendons.

## 2.0 ENGINEERING EVALUATION

### 2.1 Background

The Turkey Point Unit 3 containment is a post-tensioned, reinforced concrete structure comprised of a vertical cylinder with a shallow dome and supported on a conventional reinforced concrete foundation base slab. A reinforced concrete ring girder is located at the interface of the vertical cylinder and the dome. The vertical cylinder wall is provided with a system of vertical and hoop tendons. Vertical tendons are anchored at the top surface of the ring girder and at the bottom of the base slab. Each hoop tendon is anchored at alternate vertical buttresses nominally 120 degrees apart. Three groups of dome tendons, each oriented at 120 degrees with respect to each other, are anchored at the vertical face of the dome ring girder.

The tendon surveillance program for the Turkey Point Nuclear Plant Unit 3 containment structure post-tensioning system has been performed at one, three, and five years after the containment Initial Structural Integrity Test (ISIT) and every five years thereafter. Three dome, five hoop, and four vertical tendons were selected for the twentieth year tendon surveillance on a random basis. In accordance with the Technical Specifications (Reference 4.2) tendons which were previously inspected in earlier surveillances were excluded from the random selection. The lift-off data for the Turkey Point twentieth year tendon surveillance was obtained in accordance with the requirements of References 4.5 and 4.6.

The measured normalized lift-off forces for all four vertical and all three dome surveillance tendons exceeded the predicted lower limit.

Wires were removed for inspection from hoop tendon 64H61, vertical tendon 34V11, and dome tendon 3D8. The visual inspection of the tendon wires revealed no abnormal wire corrosion. The results of tensile testing of the removed tendon wires revealed that, for each sample, the ultimate tensile strength, yield strength, and the elongation at ultimate tensile strength exceeded the required minimum ultimate strength of 240 ksi, the minimum yield strength of 192 ksi, and the minimum elongation of 4 percent in accordance with the requirements of ASTM A421-65 "Standard Specification for Uncoated Stress-Relieved Wire for Prestressed Concrete".

Grease samples were removed from each surveillance tendon. The visual inspection of the sheath filler samples revealed no abnormal grease discoloration. In addition, the chemical analyses of grease samples were within the acceptance limits.

Also, the concrete at the tendon anchorage area adjacent to the bearing plates for all hoop surveillance tendons was inspected. This inspection revealed that the width of the cracks did not exceed 0.01 inches which is the acceptance limit specified in Section IWL-3221.3(d) of ASME Code, Section XI (Reference 4.8).

The following are the predicted lower limit (PLL) and the minimum required prestress force at the anchorage for hoop tendons:

Twentieth Year Predicted Lower Limit = 6.63 kips/wire
(Reference 4.6)

Minimum Required Prestress Force = 6.29 kips/wire
at Anchorage for Hoop Tendons
(Reference 4.3)

The following summarizes the results of the surveillance on hoop tendons.

| Tendon | Measured Normalized Lift-Off Force (kips/wire) | | Percentage of PLL |
|---|---|---|---|
| 13H32 | 6.58 | | 99.2% |
| 13H33 | 6.26 | | 94.4% |
| 13H34 | 6.48 | | 97.7% |
| Average (Buttress 1-3) | 6.44 | kips/wire | 97.1% |
| 64H60 | 6.36 | | 95.9% |
| 64H61 | 6.32 | | 95.3% |
| 64H62 | 6.14 | | 92.6% |
| Average (Buttress 6-4) | 6.27 | kips/wire | 94.6% |
| 35H51 | 6.32 | | 95.3% |
| 35H52 | 6.39 | | 96.4% |
| 35H53 | 6.39 | | 96.4% |
| Average (Buttress 3-5) | 6.37 | kips/wire | 96.1% |
| 42H31 | 6.23 | | 94.0% |
| 42H32 | 6.20 | | 93.5% |
| 42H33 | 6.47 | | 97.6% |
| Average (Buttress 4-2) | 6.30 | kips/wire | 95.0% |
| 51H18 | 6.66 | kips/wire | 100.5% |
| 42H9 (exempted) | 7.09 | | 106.9% |
| 13H29 (exempted) | 6.71 | | 101.2% |

Note: In accordance with the Technical Specifications (Reference 4.2), for the exempted tendons, the lift-off force was measured at the accessible end only which may not be representative of the average force in the subject tendon. Therefore, the exempted tendons are not considered in calculating the overall average tendon force and are included in this report for information only.

The overall average tendon force for all 13 hoop tendons (excluding the exempted tendons) is as follows:

| Tendon | Average Measured Normalized Lift-Off Force (kips/wire) | Percentage of PLL |
|---|---|---|
| 13H32, 13H33, 13H34<br>64H60, 64H61, 64H62<br>35H51, 35H52, 35H53<br>42H31, 42H32, 42H33<br>and 51H18 | 6.37 | 96.1% |

2.2 Probable Cause for Low Lift-Off Force

A review of the Turkey Point tendon surveillance programs relative to the methods used to measure the lift-off forces and equipment accuracy and calibration was performed. Lift-off measurements were performed by qualified personnel using calibrated gages and rams to ensure accurate measurements. The jacking rams and gages used for the twentieth year surveillance were calibrated before and after the surveillance to ensure stability of equipment calibration. Calibration of the test apparatus is traceable to the National Institute of Standards and Technology (NIST).

The least squares straight lines, fitted through the stressing ram calibration data points, for pre-surveillance and post-surveillance calibration are within 2% of the calibration data points and meet the acceptance criteria as required in Technical Requirements Document 21701-539-CP-1 (Reference 4.6). In addition, the two calibrations of the rams were very stable at the jacking pressures corresponding to the lift-off forces obtained. The feeler shim method was used in the twentieth year surveillance to determine when tendon lift-off occurs. This method results in accurate and repeatable tendon lift-off measurements. Therefore, it was determined that equipment calibration or method of measurement was not the cause for the low lift-off forces that occurred on the hoop tendons.

A review of the spatial location of the hoop tendons with low lift-off forces indicated no significant or unusual physical attributes, such as large penetrations or construction openings, causing secondary bends in the tendons, that could affect the performance of the tendons (Reference 4.12).

The behavior of the long term time-dependent losses such as concrete creep and shrinkage and tendon wire steel relaxation were reviewed to determine if the original design assumption of a log-linear reduction with time was appropriate. Based on a review of the available test results (Reference 4.13), published technical literature (Reference 4.14) and Regulatory Guide 1.35.1 (Reference 4.11), the use of a log-linear reduction of tendon force with time due to concrete creep and shrinkage and tendon wire steel relaxation was appropriate as an original design assumption.

The previous surveillance reports were reviewed (References 4.15 through 4.25) relative to internal containment temperature recorded during each surveillance. This review determined that the internal containment temperatures averaged approximately 114 °F and 109 °F for Units 3 and 4, respectively, compared with an average ambient outdoor temperature of 85 °F for Unit 3 and 82 °F for Unit 4. This resulted in a steady state temperature gradient through the containment building wall. Considering a linear thermal gradient across the containment wall, it was determined that at the location of the hoop tendons (approximately 9 inches from the exterior concrete surface), the steady state temperature of the tendons would be approximately 90 °F.

Further investigations indicated that tendon wire steel relaxation loss varies significantly over a small range of temperature (References 4.13 and 4.14). Based on test results conducted for Ginna and V. C. Summer Nuclear Power Plants, raising the temperature of the tendon wires from 68 °F to 90 °F increases the relaxation losses from approximately 8% to 14%, for the 40 year life of the plant (References 4.13 and 4.26). In addition, based on the original relaxation test performed for Turkey Point tendon wires, a temperature of 90 °F to 100 °F corresponds to a tendon wire steel relaxation rate of 11.5% to 12% (Reference 4.31). The original design of Turkey Point post-tensioning system used 8% tendon wire steel relaxation (UFSAR, Section 5.1.4.4, Reference 4.1). Considering this information, a calculation (Reference 4.27) was prepared to predict the hoop tendon forces at the fifteenth and twentieth years (varying tendon wire steel relaxation). This data was compared with the hoop tendons lift-off forces measured during the fifteenth year and twentieth year surveillance. As a result of this calculation which used the UFSAR losses for creep and shrinkage, the measured lift-off forces for undisturbed hoop tendons (tendons which were inspected only one time) correlate with the predicted lift-off forces at an increased tendon wire steel relaxation loss rate of approximately 11.5 % (Figures 4 and 4A). This result suggested that review of other time-dependent losses (creep and shrinkage) was prudent.

A review of the total time-dependent losses specified in the UFSAR Section 5.1.4.4, "Prestress Losses", indicated that concrete shrinkage loss used in the original design was based on 100 x $10^{-6}$ in/in strain which is consistent with the industry data and Regulatory Guide 1.35.1 (Reference 4.11) recommendation. Due to the low magnitude of the concrete shrinkage loss (3.0 ksi) and the fact that the majority of this loss occurs within the first year, variation of shrinkage loss and its effect on the prestress force loss was considered minimal. It was also noted that the design magnitude of concrete creep loss for each of the tendon groups was specified at 19.2 ksi based on a level of concrete compressive stress of 1500 psi. Concrete creep is a stress dependent parameter and would vary with the level of compressive stress in the concrete. As stated in UFSAR Table 5.1.4-1, allowable concrete compressive stress was limited to 1500 psi and therefore, 19.2 ksi is considered a conservative and maximum magnitude of creep

loss. The compressive concrete stress in each direction, corresponding to the tendon groups (vertical, dome and hoop), is directly related to the prestress force existing in each tendon group. To more accurately define the compressive concrete stress level and magnitude of creep for each tendon group, the average of sustained concrete compressive stress for each direction (vertical, dome and hoop) was calculated. Creep losses of 18.5, 9.1, 17.3 ksi were determined for the hoop, vertical and dome tendons, respectively. A calculation varying tendon wire steel relaxation losses for temperature and retensioning conditions and magnitude of creep loss for the state of compressive stress in the concrete for each tendon group was prepared to predict lift-off forces at the fifteenth and twentieth years. This data was then compared with the measured lift-off forces from the fifteenth and twentieth year surveillances (Reference 4.27). The following summarizes the observations made as a result of this evaluation (Table 1). For the graphical presentation, refer to Figures 5 through 7.

a) The results of the undisturbed tendons (except Unit 3 dome tendons as discussed below) correlate (within 2.5%) with the predicted forces at 12% tendon wire steel relaxation loss rate.

b) The measured lift-off forces for the Unit 3 dome tendons are higher than the predicted lift-off forces and do not correlate within the expected range. A review of the Unit 3 dome history revealed that all dome tendons were retensioned after the Unit 3 dome concrete repair in 1971 (the original tensioning of dome tendons was performed in 1970). The retensioning occurred on concrete that had cured for approximately one additional year. Based on the known properties of concrete, concrete creep rate decreases with increase in concrete age prior to the application of loads (Reference 4.28). Therefore, the high lift-off forces for the Unit 3 dome tendons are considered to be due to the complete retensioning of the dome tendons during the concrete dome repair and increased concrete age prior to retensioning of the dome tendons.

c) As shown in Table 1, for a 10% relaxation loss rate for disturbed tendons (tendons that were inspected more than one time and were retensioned in previous surveillance programs), the measured lift-off forces of all tendon groups (except Unit 3 dome tendons) provide a consistent trend and correlate within approximately 4% of the predicted lift-off forces, which is a reasonable range of expected differences for ram and gage calibration and for other factors. Although exhibiting greater tendon wire steel relaxation than the original design value of 8%, the relaxation rate of disturbed tendons is seen to be somewhat lower than that of the undisturbed tendons, which is consistent with industry findings (References 4.26, 4.29, and 4.30).

In summary, it can be reasonably stated that with the exception of the Unit 3 dome tendons which are believed to have reduced creep losses due to increased concrete age prior to

retensioning, all the measured lift-off forces from the fifteenth and twentieth year surveillance correlate well with the predicted lift-off forces if the tendon wire steel relaxation losses are taken as 12% for undisturbed tendons and 10% for disturbed tendons. The increased tendon wire steel relaxation losses of 12% and 10% are indicative of a higher temperature experienced by the tendons. Finally, using 12% tendon wire steel relaxation loss rate, as shown in Figure 8, it was estimated that the prestress force in the Unit 3 hoop tendons will not fall below the calculated minimum required prestress force at the anchorage (6.29 kips/wire) until 35 years after the ISIT.

## 2.3 Evaluation and Plant Specific Results

Post-tensioning systems experience time-dependent losses due to creep and shrinkage of concrete and relaxation of tendon wires. The losses are reflected in the form of a reduction in the prestressing level of the tendons and lower lift-off readings. Due to material characteristics and behavior, most of the time-dependent losses occur during the first few years after initial stressing of the tendon. Therefore, a plot of stress level against time would follow a curve which would have a high rate of losses (steep slope) during the first few years and minimal change thereafter.

This behavior is experienced with all prestressing systems and has been demonstrated in the industry by the results of monitoring programs which have been performed on these systems. Future losses may also be projected by performing a log-linear regression analysis to establish a loss trend using the data from earlier surveillance programs.

The evaluation of Turkey Point Plant specific data was performed to determine the length of time that the structural integrity of the Unit 3 containment post-tensioning system hoop tendons will remain in compliance with the design basis requirements. This evaluation consisted of performing statistical regression analyses to determine the most conservative trend for prestress loss. The results from the first year through the twentieth year surveillance programs were reviewed to determine the possible trend in loss of prestress force exhibited by the hoop tendons. Two different groups of tendons were identified: a) tendons which were inspected only one time (undisturbed tendons) and b) tendons that were inspected more than one time and were restressed in previous surveillance programs (disturbed tendons). The Turkey Point Technical Specifications (Reference 4.2) required a total random selection process of surveillance tendons in the Unit 3 twentieth year surveillance program. During the surveillance programs prior to the twentieth year surveillance, the Technical Specifications identified specific tendons to be inspected. These tendons were inspected in every surveillance, resulting in a disturbed hoop tendon population in the third year through fifteenth year surveillance. The Unit 3 fifteenth

year surveillance however included one randomly selected hoop tendon in addition to the pre-selected tendons. This resulted in undisturbed hoop tendons inspected during the first, fifteenth, and twentieth year surveillance with the most undisturbed tendons inspected in the twentieth year surveillance. Considering the above information and the fact that the lift-off forces for disturbed tendons experience more variation than the undisturbed tendons which are more representative of the total tendon population, the following regression analyses were performed to examine the various conditions to determine the predicted prestress force loss rate:

a) Statistical regression analysis was performed on all hoop tendons (total population) inspected during the first through twentieth year surveillance programs. The results of this analysis revealed that the prestress force in the hoop tendons will remain above the minimum design prestress force for 40 year life of the plant (See Figure 1 for plot of regression analysis). However, this result was not considered to be totally representative of the entire hoop tendon population since the available lift-off data for the third year through fifteenth year was for the disturbed tendons.

b) Statistical regression analysis was performed on the undisturbed hoop tendons inspected during the first through twentieth year surveillance programs. Review of the first year data indicates that approximately 70% of the total time dependent loss occurred in the first year which is consistent with the industry observations and assumptions used in the design of the post-tensioning systems based on known material behavior. The results of this analysis revealed that the prestress force in the hoop tendons will remain above the minimum design prestress force for 36 years after ISIT (See Figure 2 for plot of regression analysis). Although the undisturbed tendon lift-off data was limited to only first, fifteenth and twentieth year, this estimate is considered the most reasonable and representative of the total hoop tendon population.

c) Based on review of the total tendon population data, there is an apparent trend of loss in prestress force from the third year through twentieth year. However, the third year data has shown an increase in lift-off force with respect to the measured first year data which is not consistent with behavior of post-tensioning systems and may be a result of retensioning in the first year surveillance. Despite this inconsistency, a statistical regression analysis was performed on all hoop tendons (total population), excluding the first year surveillance data (See Figure 3 for plot of regression analysis). This analysis is considered conservative as it produced the steepest loss trend, which in turn resulted in the shortest predicted time period (26 years after ISIT) that the prestress force in hoop tendons remains above the minimum design prestress force.

Based on the most conservative results (Section 2.3 c) of the regression analyses (documented in Reference 4.4), it is concluded that the Unit 3 hoop tendons will provide sufficient prestress force to maintain Turkey Point design basis requirements until 1997 (i.e., twenty-six years after Unit 3 ISIT date).

3.0 <u>CONCLUSION</u>

3.1 Based on the preceding engineering evaluation, it was determined that tendon wire steel relaxation loss increases with the increase in temperature experienced by the tendon. It was also determined that the measured Unit 3 containment internal temperature during surveillances averaged 114 °F which results in hoop tendon temperature of approximately 90 °F, which corresponds to higher tendon wire steel relaxation losses than those used in the original design. Therefore, the probable cause for the low lift-off forces measured for the Unit 3 Turkey Point containment hoop tendons was the increased tendon wire steel relaxation loss occurring at a higher tendon temperature (approximately 90 °F).

Based on the results of this evaluation, it is estimated that a 12% tendon wire steel relaxation loss rate should be used to predict the undisturbed tendon lift-off forces in future surveillances. It is also concluded that creep loss calculated based on the average sustained concrete compressive stress should be used to more accurately predict the tendon lift-off forces in each group (hoop, vertical, and dome) in future surveillances.

3.2 Based on the results of the regression analyses and the determination of predicted lift-off forces using a 12% tendon wire steel relaxation, the Unit 3 hoop tendons will provide sufficient prestress force to maintain Turkey Point design basis requirements until 1997 (i.e., twenty-six years after Unit 3 ISIT date). This date is based on the most conservative regression analysis (see Section 2.3 c and Figure 3). As noted in Section 2.3 b, the regression analysis performed on the undisturbed hoop tendons inspected from the first through twentieth year surveillance (see Section 2.3 b and Figure 2) is considered the most reasonable and representative of the total hoop tendon population. Based on this analysis (Section 2.3 b), the Unit 3 hoop tendons will provide sufficient prestress force to maintain Turkey Point design basis requirements through the twenty-fifth year tendon surveillance (including the 25% extension of the surveillance interval allowed by Technical Specification Section 4.0.2), i.e., October 1997.

Florida Power and Light Company will continue to evaluate both the containment post-tensioning system and the methodology associated with performing the tendon surveillance inspection.

## 4.0 REFERENCES

4.1 Turkey Point Units 3 and 4 Updated Final Safety Analysis Report (UFSAR), Revision 9, dated July 1991, Section 5.0

4.2 Turkey Point Units 3 and 4 Technical Specifications, Amendment 151/146

4.3 Bechtel Calculation No. C-SJ539-05, "Evaluation of the Fifteenth Year Tendon Surveillance Lift-Off Forces", Revision 0

4.4 Bechtel Calculation No. C-SJ539-06, "Evaluation of Low Lift-Off Force in Hoop Tendons - Unit 3 Twentieth Year Tendon Surveillance", Revision 0

4.5 Turkey Point Plant Procedure 0-SMM-51.2, "Containment Tendon Inspection", dated May 22, 1992

4.6 Bechtel Technical Requirements Document 21701-539-CP-1, Revision 3 for Unit 3 Twentieth Year Tendon Surveillance

4.7 Regulatory Guide 1.35, "In-service Inspection of Ungrouted Tendons in Prestressed Concrete Containment", Revision 3, dated July 1990

4.8 ASME Code 1989, Section XI - Division 1, Article IWL-3000, "Acceptance Standards"

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

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

4.11 Regulatory Guide 1.35.1, "Determining Prestressing Forces For Inspection Of Prestressed Concrete Containment", dated July 1990

4.12 Prescon Drawings 3P21 to 3P26 and 3P52 to 3P57 for Horizontal Tendon Placement

4.13 Relaxation Tests on 1/4 Inch Prestressing Wire, by R. G. Slutter, Report No 200.79.100.5, dated January 21, 1982, from Fritz Engineering Laboratory at Lehigh University

4.14 Modern Prestressed Concrete, Second Edition, by J. R. Libby

4.15 Unit 3 First Year Tendon Surveillance Inspection Report, dated August 1973

4.16 Unit 3 Second Year Dome Inspection Report, dated October 1973

4.0 REFERENCES (Cont.)

4.17 Unit 3 Third Year Tendon Surveillance Inspection Report, dated March 1975

4.18 Unit 3 Fifth Year Surveillance Report, Revision 1, dated September 13, 1978

4.19 Unit 3 Tenth Year Surveillance Report, dated July 1982

4.20 Turkey Point Unit 3, Containment Structure Post-Tensioning System Fifteenth Year Surveillance Report, dated November 11, 1988

4.21 Unit 4 First Year Tendon Surveillance Inspection Report, dated August 1973

4.22 Unit 4 Third Year Tendon Surveillance Inspection Report, Revision 2, dated September 8, 1978

4.23 Unit 4 Fifth Year Surveillance Report, dated September 8, 1978

4.24 Unit 4 Tenth Year Surveillance Report, dated July 1982

4.25 Turkey Point Unit 4, Containment Structure Post-Tensioning System Fifteenth Year Surveillance Report, dated November 11, 1988

4.26 V. C. Summer Unit 1 Nuclear Station Reactor Building Containment Third Period Surveillance Tendon Forces, Gilbert/Commonwealth Report No. 2610, dated January 13, 1986

4.27 Calculation No. C-SJ539-09, Revision 0

4.28 Reinforced Concrete Structures, by R. Park and T. Paulay

4.29 Ginna Nuclear Power Station Containment Vessel Tendons Stress Relaxation Properties of Retensioned Wires, Gilbert/Commonwealth Report No. 2499, dated December 1983

4.30 Inservice Inspection Forces Measured In Retensioned Tendons by J. F. Fulton of Gilbert/Commonwealth, and C. A. Forbes of Rochester Gas & Electric Corporation

4.31 Turkey Point Wire Relaxation Test, dated March 1, 1968

4.32 FPL Letter L-92-233, dated August 5, 1992 (Re: Hoop Tendons Low Lift-off Force)

## TABLE 1
## TABULATED MEASURED VS. PREDICTED LIFT-OFF FORCES FOR HOOP, VERTICAL, AND DOME TENDON GROUPS

12% STEEL RELAXATION LOSS RATE FOR UNDISTURBED TENDONS
10% STEEL RELAXATION LOSS RATE FOR DISTURBED TENDONS

### UNIT 3

| | | 15TH YEAR | | 20TH YEAR | |
|---|---|---|---|---|---|
| | | UNDISTURBED (KIPS/WIRE) | DISTURBED (KIPS/WIRE) | UNDISTURBED (KIPS/WIRE) | DISTURBED (KIPS/WIRE) |
| HOOP | MEASURED | 6.48 | 6.83 | 6.37 | N/A |
| | PREDICTED (1) | 6.42 | 6.56 | 6.38 | 6.52 |
| | % DIFFERENCE | +0.93% | +4.12% | −0.16% | N/A |
| VERTICAL | MEASURED | 6.91 | 6.73 | 6.98 | N/A |
| | PREDICTED (1) | 6.84 | 6.98 | 6.81 | 6.96 |
| | % DIFFERENCE | +1.02% | −3.58% | +2.50% | N/A |
| DOME | MEASURED | N/A | 7.2 | 7.5 | N/A |
| | PREDICTED (1) | 6.47 | 6.61 | 6.43 | 6.58 |
| | % DIFFERENCE | N/A | +8.9% | +16.6% | N/A |

### UNIT 4

| | | 15TH YEAR | |
|---|---|---|---|
| | | UNDISTURBED (KIPS/WIRE) | DISTURBED (KIPS/WIRE) |
| HOOP | MEASURED | 6.43 | 6.31 |
| | PREDICTED (1) | 6.42 | 6.56 |
| | % DIFFERENCE | +0.16% | −3.81% |
| VERTICAL | MEASURED | N/A | 7.08 |
| | PREDICTED (1) | 6.84 | 6.98 |
| | % DIFFERENCE | N/A | +1.43% |
| DOME | MEASURED | N/A | 6.67 |
| | PREDICTED (1) | 6.47 | 6.61 |
| | % DIFFERENCE | N/A | +0.91% |

NOTES:
1. PREDICTED WIRE FORCE IS BASED ON 12% RELAXATION LOSS (@40 YEARS) FOR UNDISTURBED TENDONS AND 10% RELAXATION LOSS FOR DISTURBED TENDONS. CREEP LOSSES ARE BASED ON ACTUAL SUSTAINED CONCRETE STRESSES.

# Unit 3 Hoop Tendons Regression Analysis
# Total Tendon Population
# 1st Year Through 20th Year

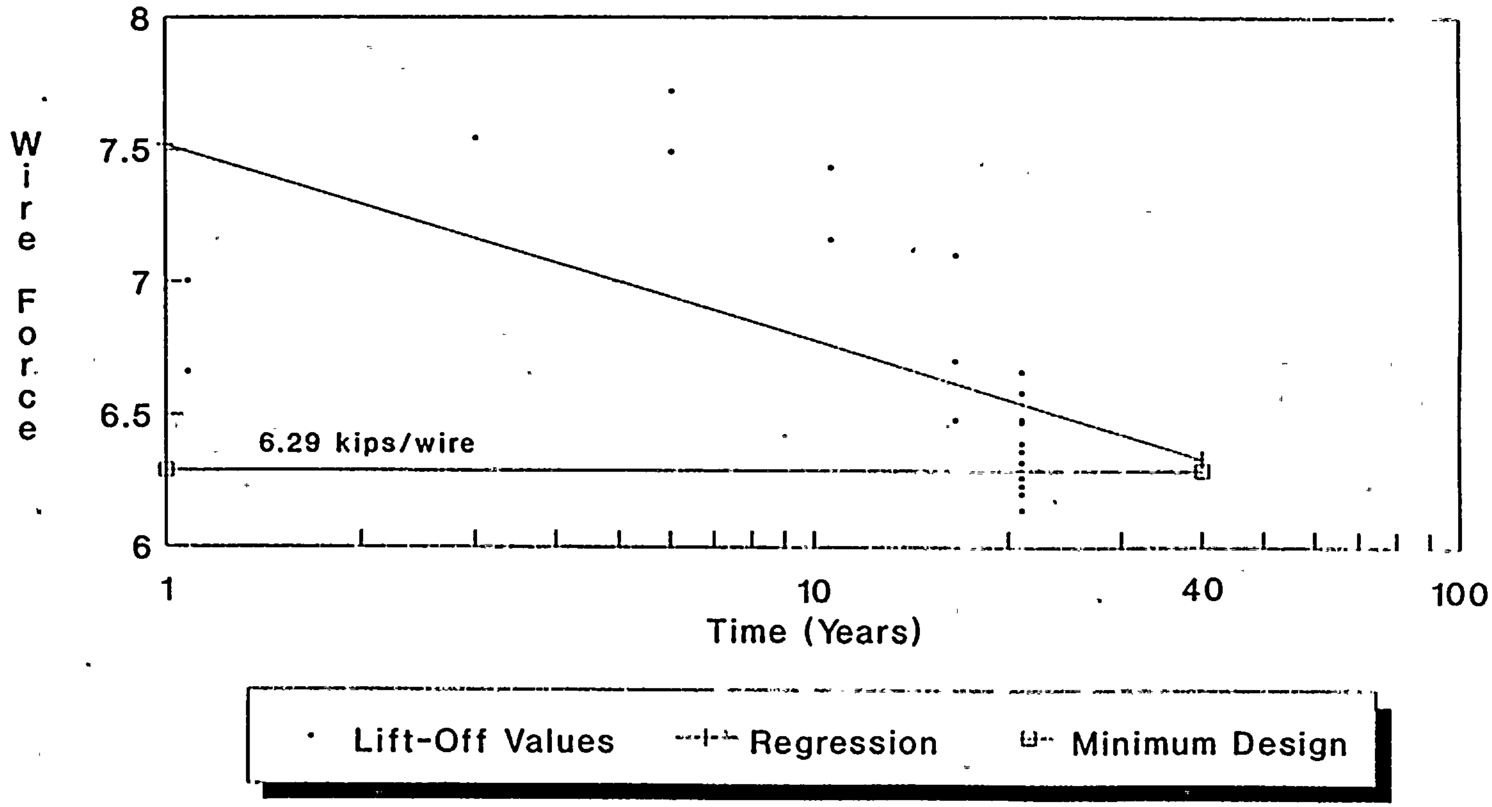


Figure 1

# Unit 3 Hoop Tendons Regression Analysis
## Undisturbed Tendons
## 1st Year Through 20th Year

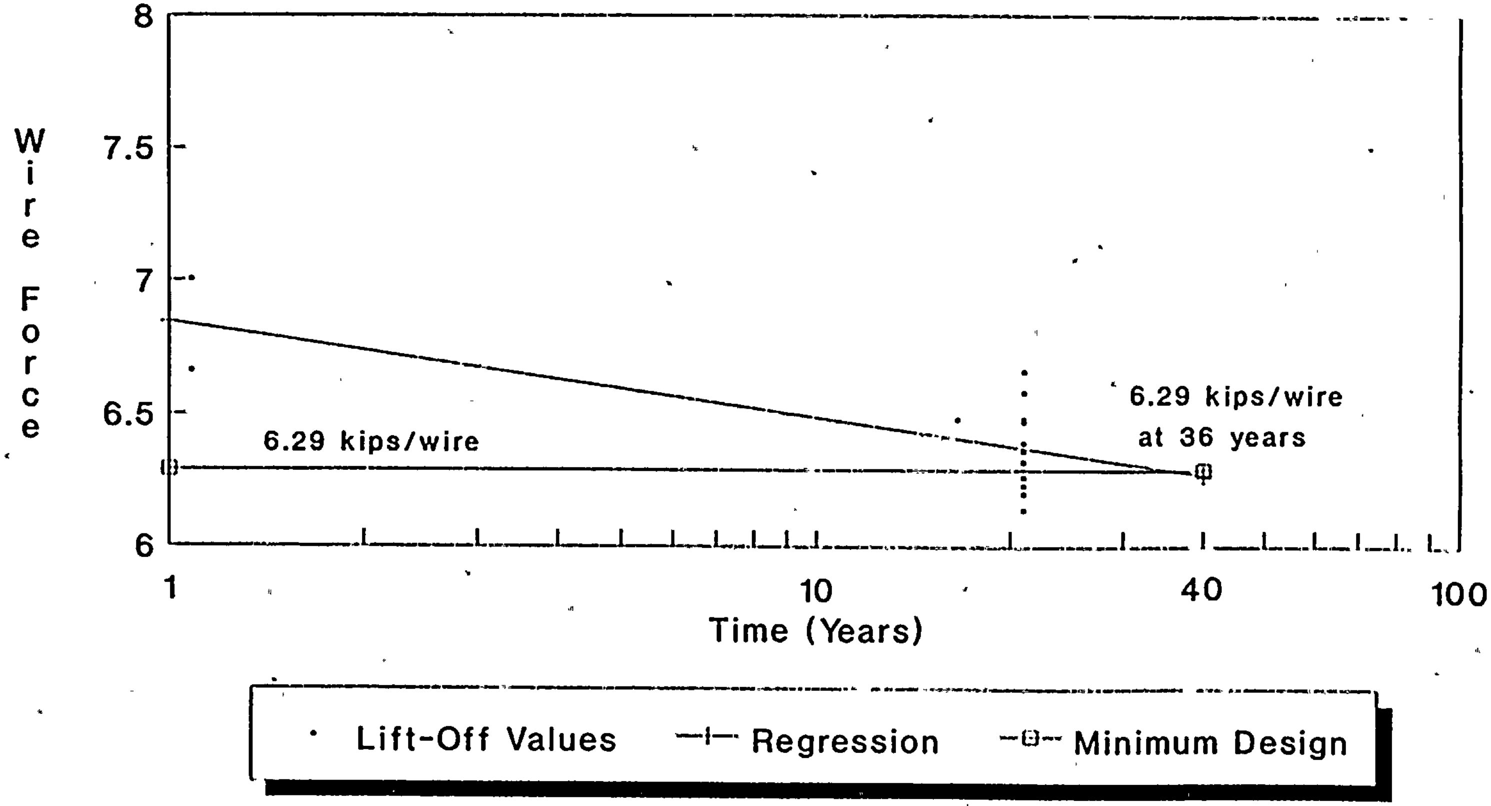


Figure 2

# Unit 3 Hoop Tendons Regression Analysis
## Total Tendon Population
## 3rd Year Through 20th Year

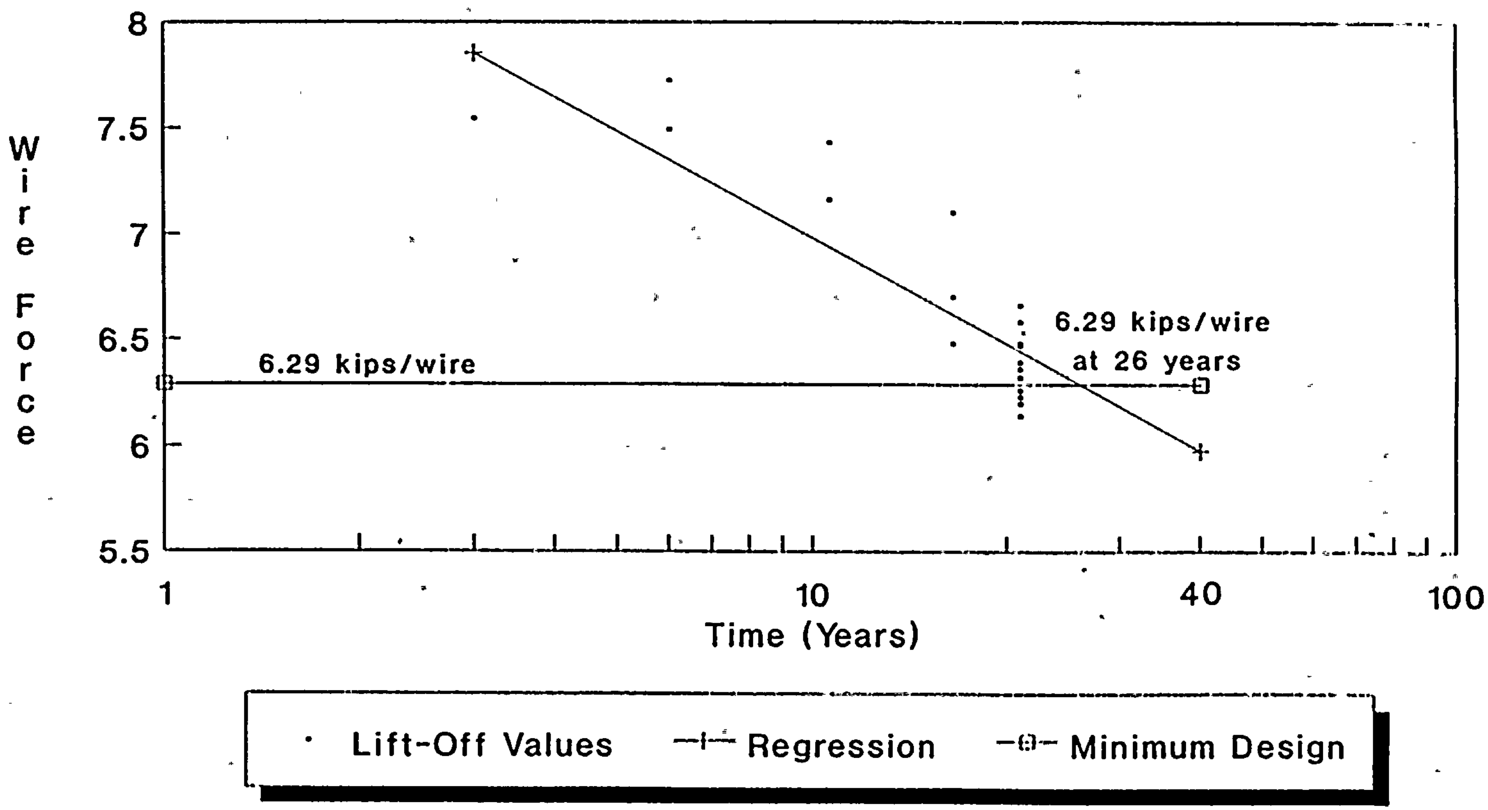


Figure 3

# 15TH YEAR HOOP TENDON WIRE FORCE FOR VARIOUS STEEL RELAXATION PERCENTAGES

NOTE: 15th year Predicted Wire Forces are for FSAR specified concrete creep and shrinkage losses

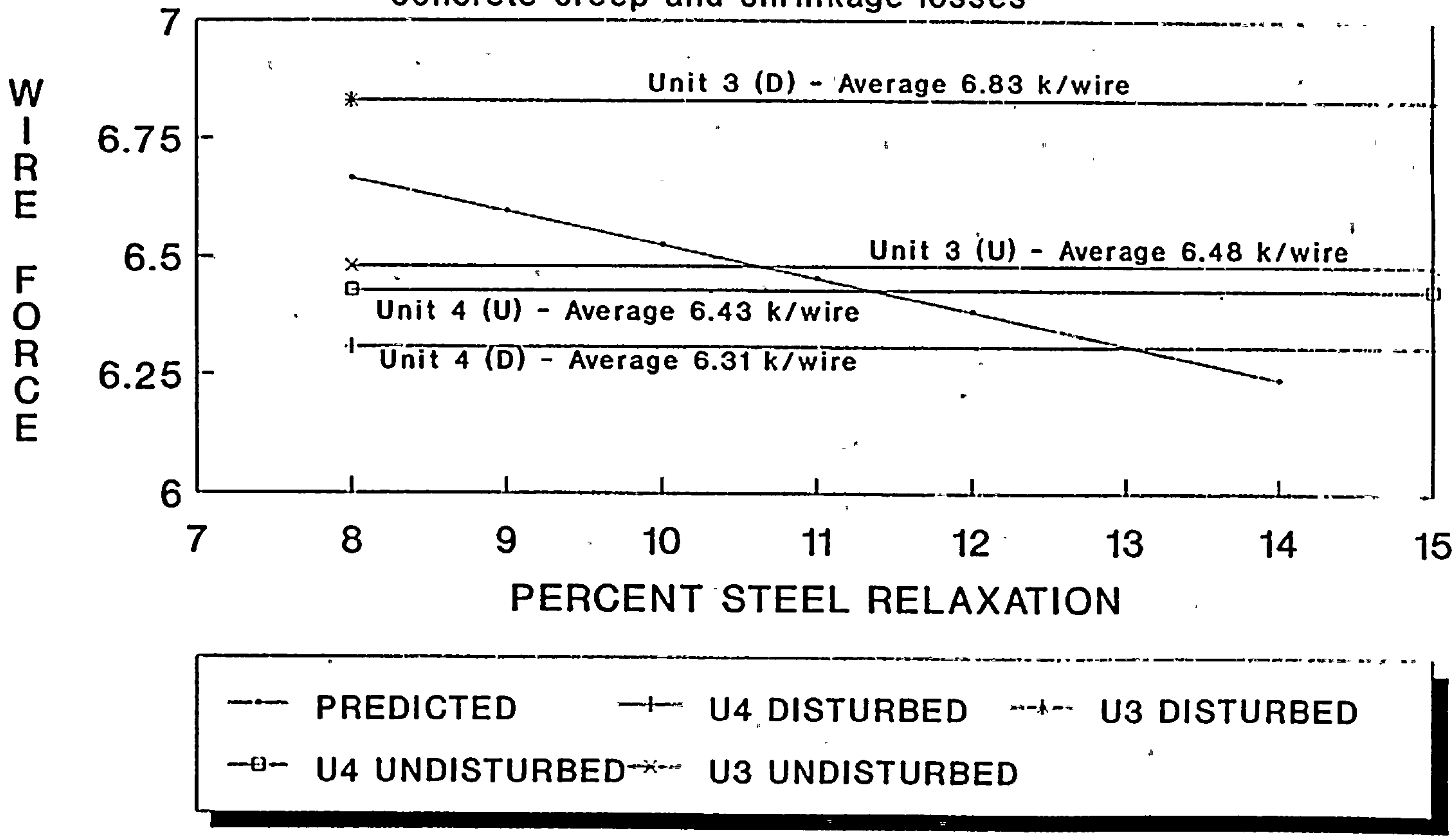


FIGURE 4

# 20TH YEAR HOOP TENDON WIRE FORCE FOR VARIOUS STEEL RELAXATION PERCENTAGES

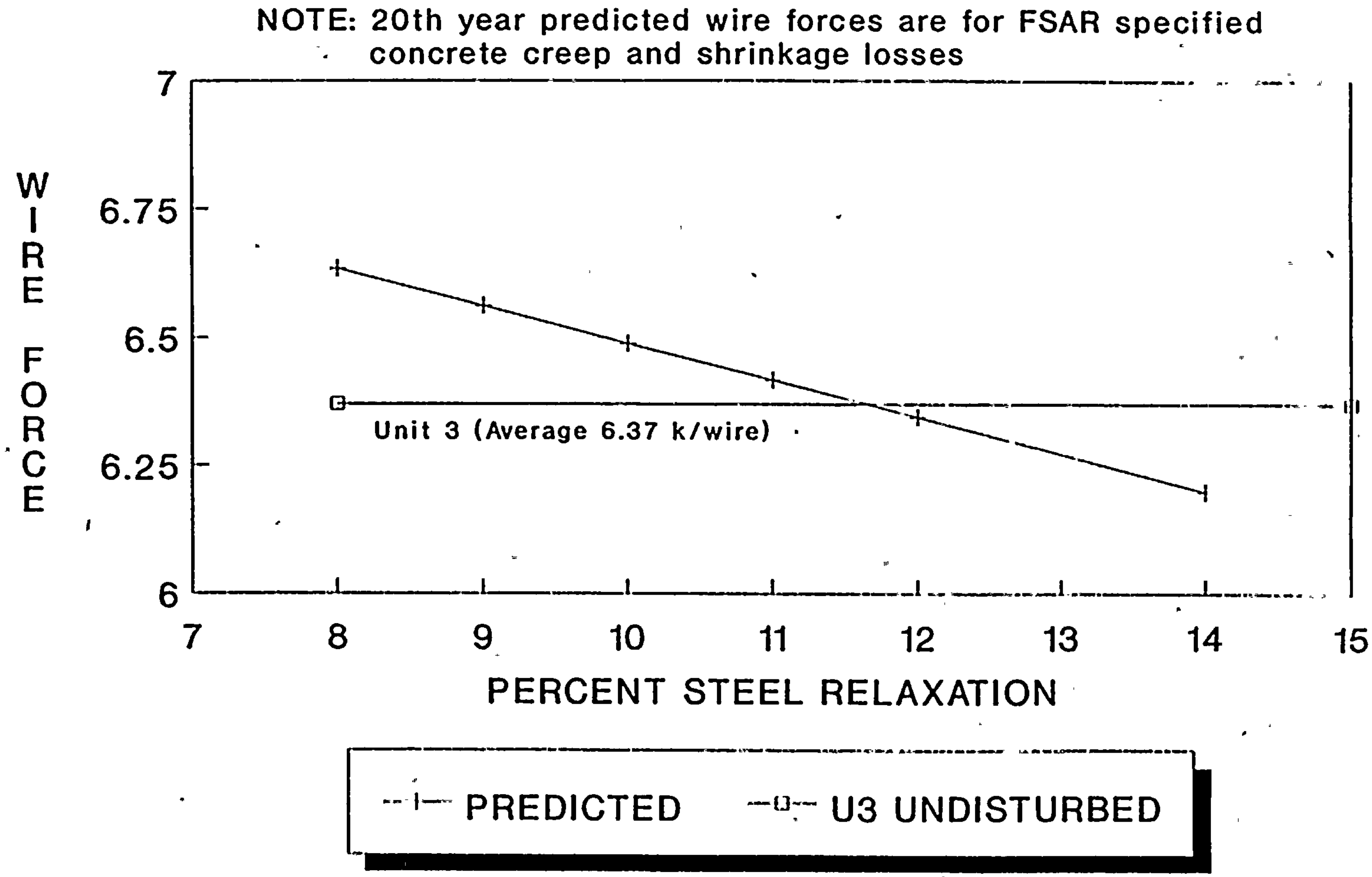


FIGURE 4A

# 15TH YEAR HOOP TENDON WIRE FORCE FOR VARIOUS STEEL RELAXATION PERCENTAGES

NOTE: 15th year predicted wire forces are based on magnitude of creep calculated based on average sustained compressive force.

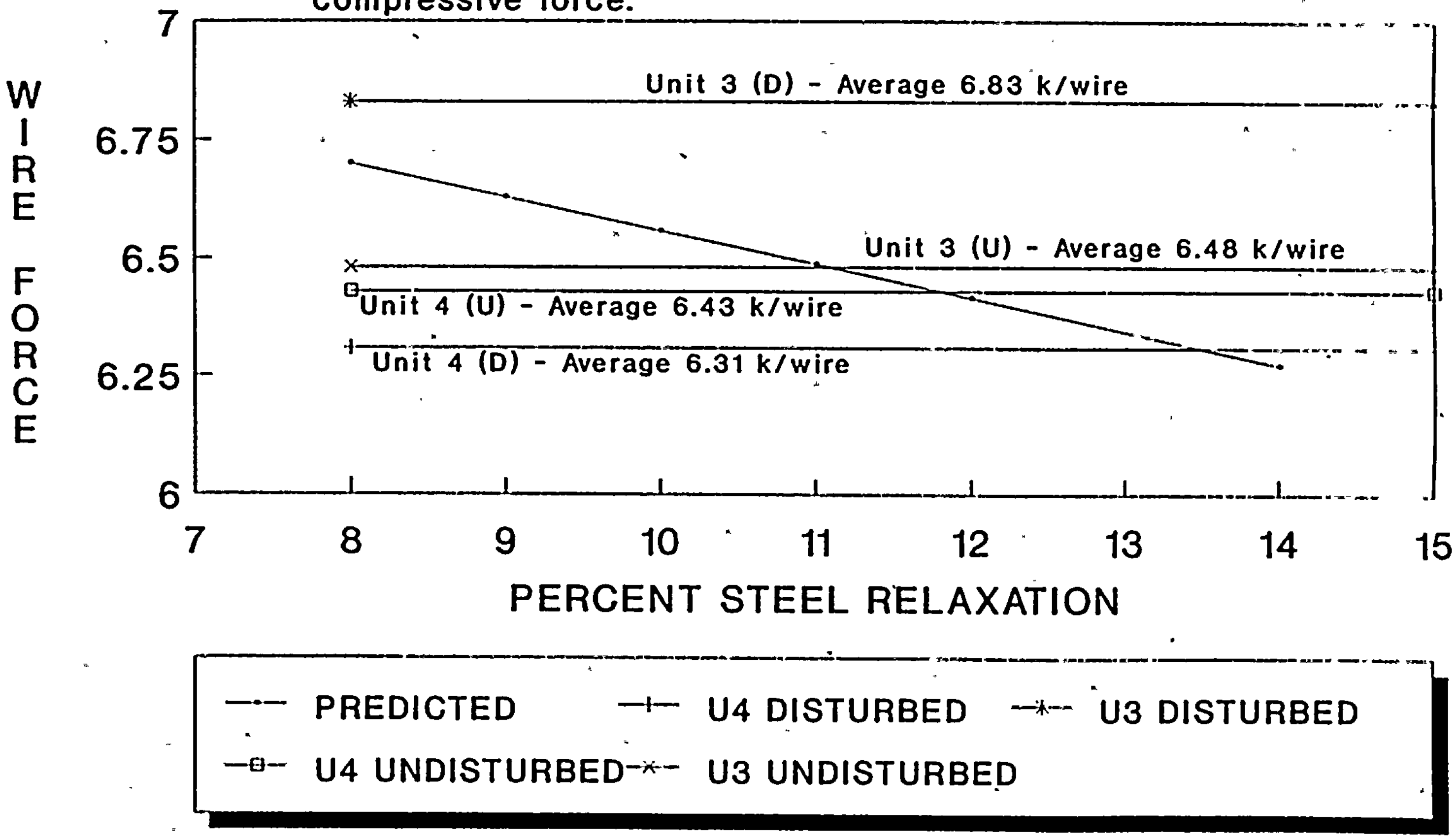


FIGURE 5

# 20TH YEAR HOOP TENDON WIRE FORCE FOR VARIOUS STEEL RELAXATION PERCENTAGES

NOTE: 20th year predicted wire forces are based on magnitude of creep calculated based on average sustained compressive force.

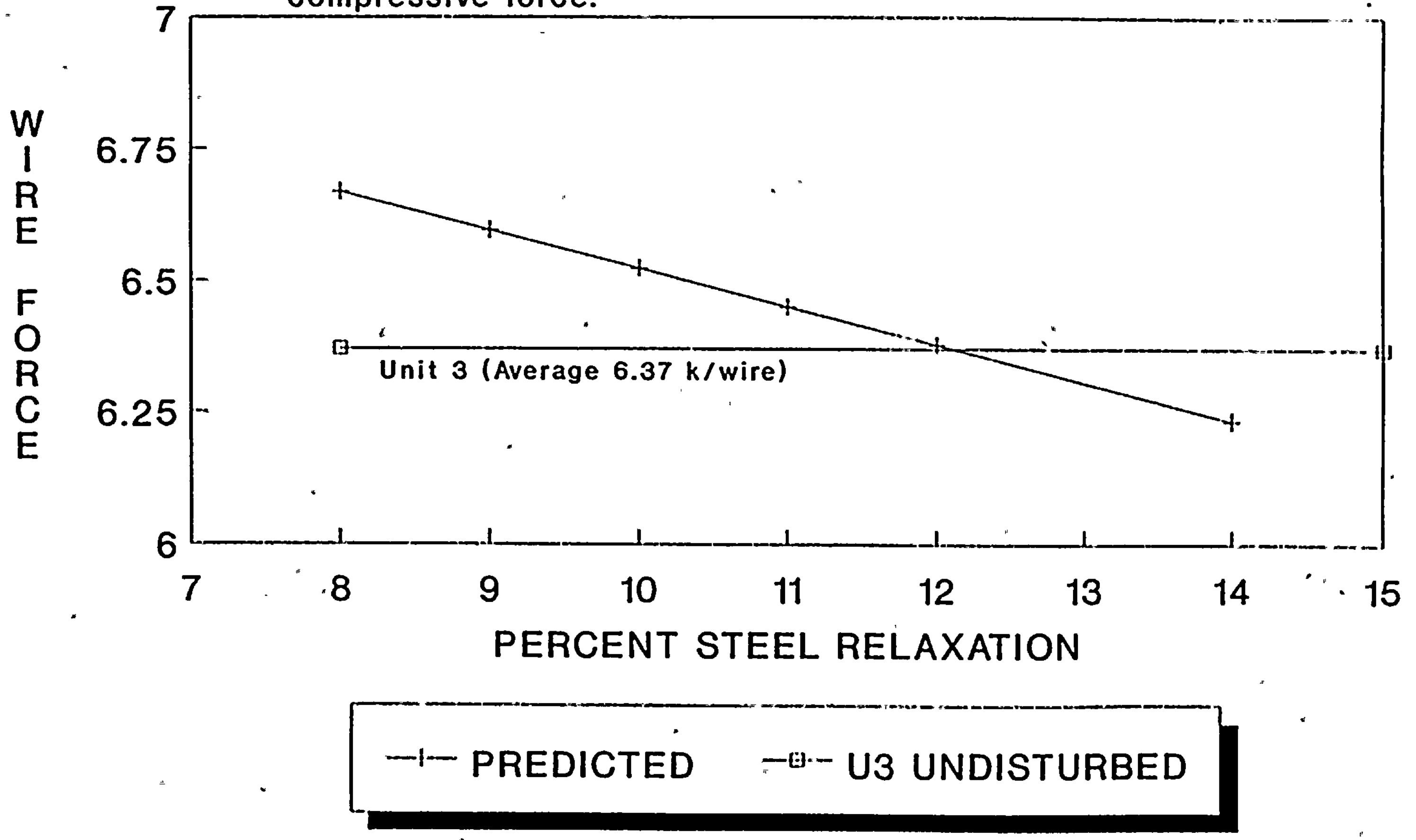


FIGURE 5A

# VERTICAL TENDON WIRE FORCES FOR VARIOUS STEEL RELAXATION PERCENTAGES

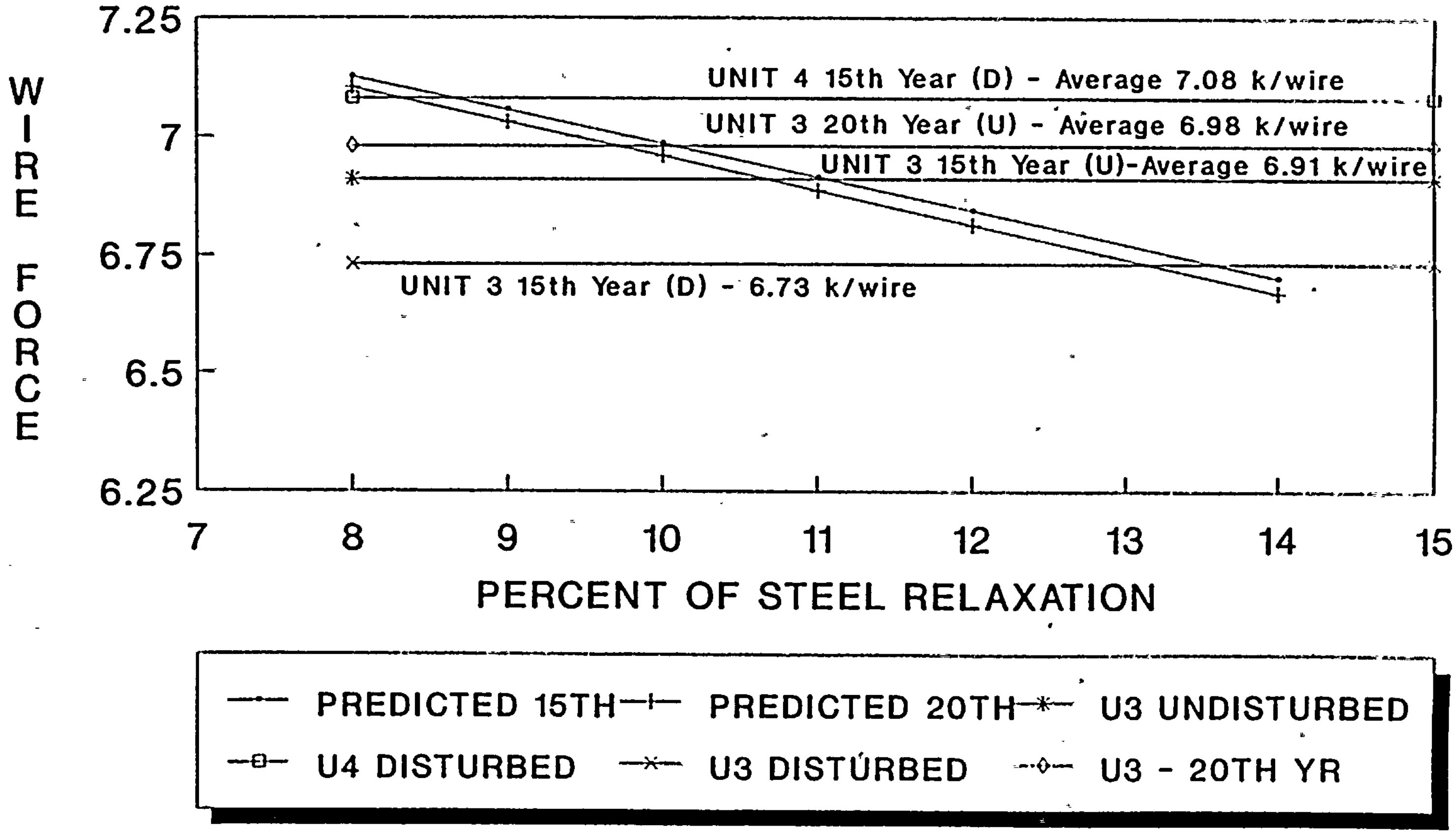


FIGURE 6

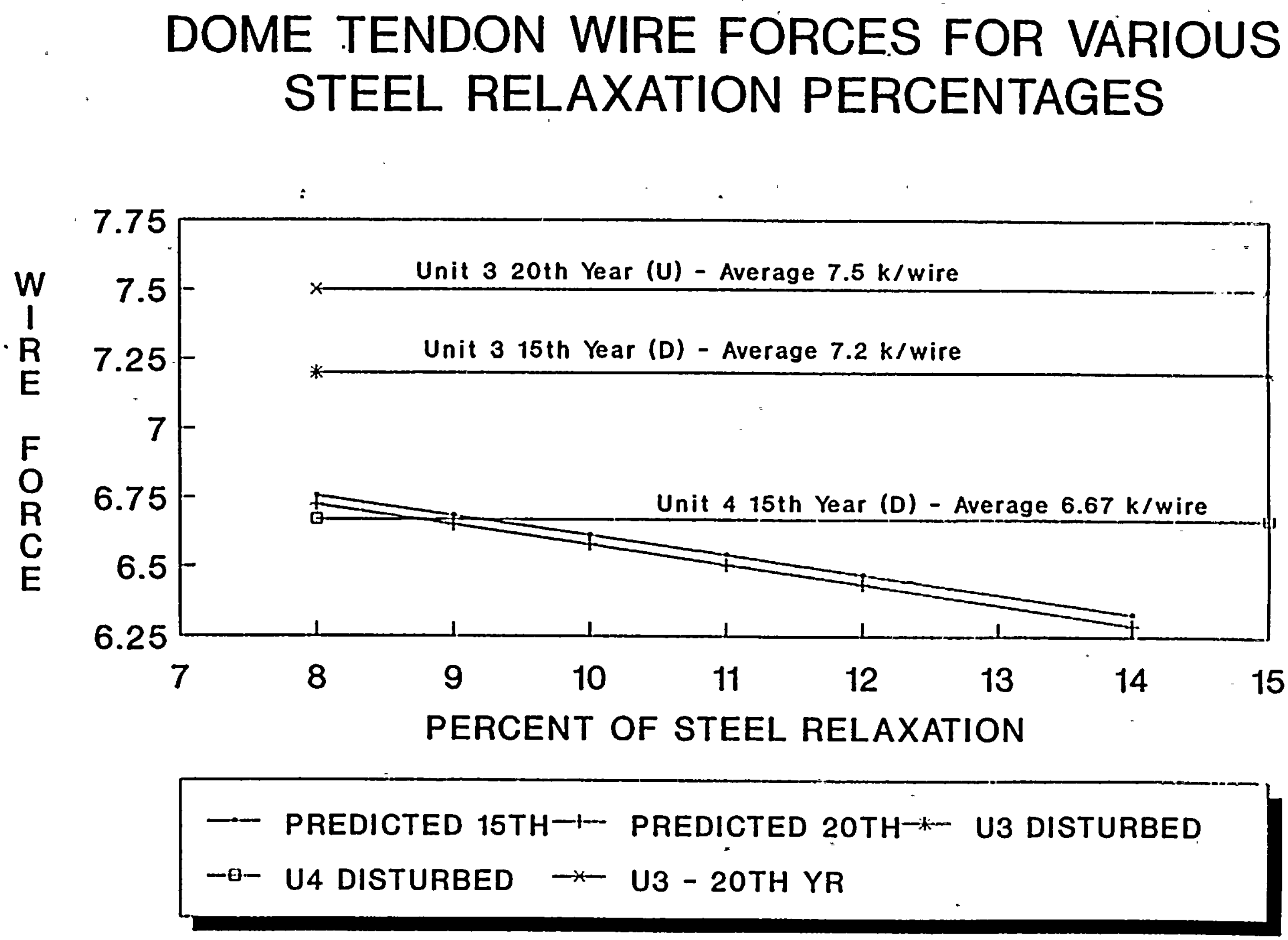
DOME TENDON WIRE FORCES FOR VARIOUS STEEL RELAXATION PERCENTAGES
WIRE FORCE
7.75
7.5
7.25
7
6.75
6.5
6.25
Unit 3 20th Year (U) - Average 7.5 k/wire
Unit 3 15th Year (D) - Average 7.2 k/wire
Unit 4 15th Year (D) - Average 6.67 k/wire
7
8
9
10
11
12
13
14
15
PERCENT OF STEEL RELAXATION
PREDICTED 15TH
PREDICTED 20TH
U3 DISTURBED
U4 DISTURBED
U3 - 20TH YR

FIGURE 7

# PREDICTED HOOP TENDON WIRE FORCE FOR 12% STEEL RELAXATION

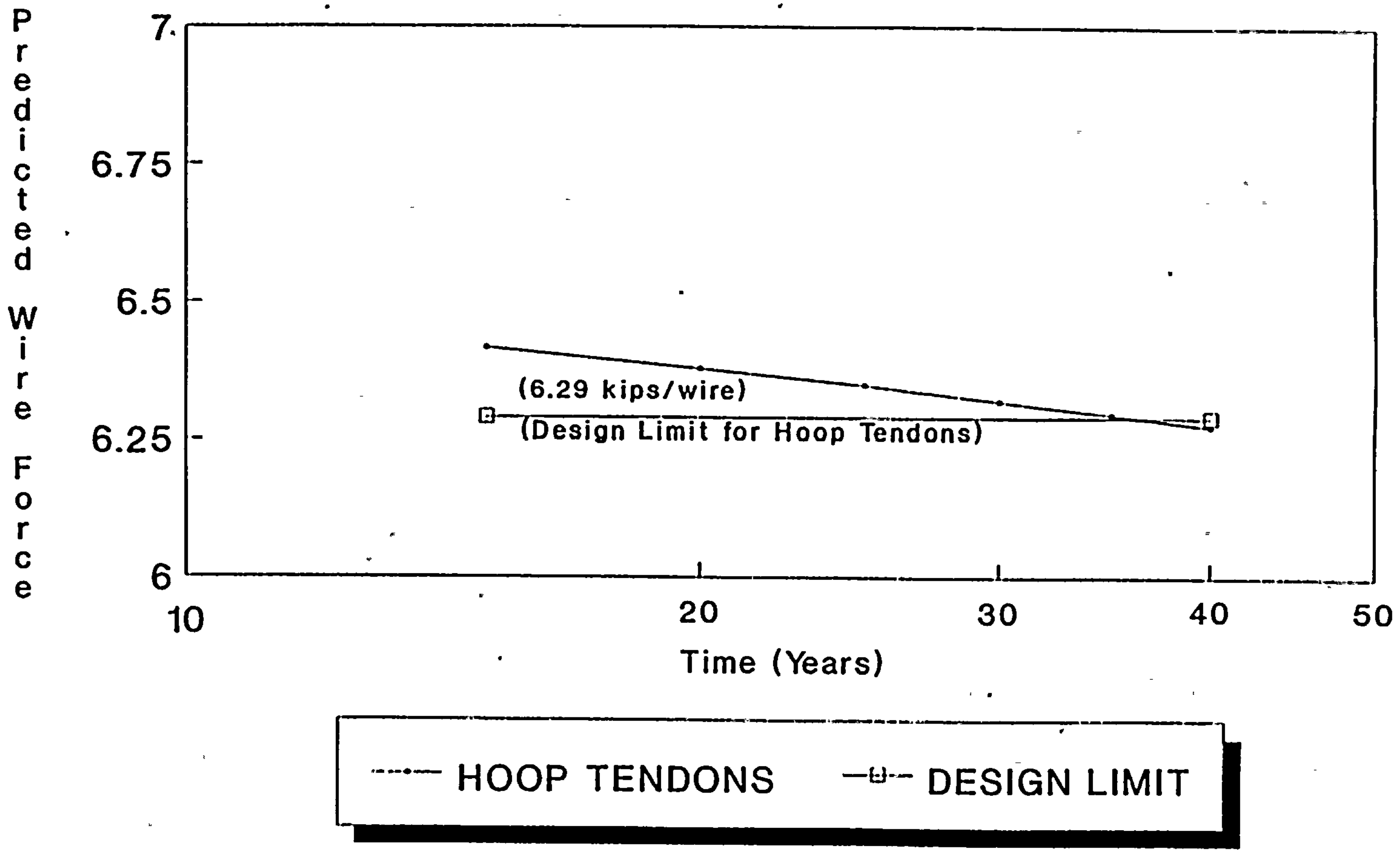


FIGURE 8