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September 17, 2001
5928-01-20224

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

SUBJECT: Additional Information - TMI Unit 1 25th Year Reactor Building Tendon Surveillance Report

Three Mile Island, Unit 1 (TMI Unit 1)
Operating License No. DPR-50
NRC Docket No. 50-289

On February 25, 2000, pursuant to Technical Specification 4.4.2.1.6.a, AmerGen submitted the results from tests and inspections of the pre-stressed post tensioned reinforced concrete reactor containment building conducted 25 years after the initial structural integrity test. Topical Report (TR) No. 136, Revision 0, "25th Year Tendon Surveillance (Period 7)" was submitted as Attachment 2 to that letter.

In a conference call on March 7, 2001, the NRC questioned the approach of applying normalizing forces to the individual as found tendon lift-off forces when plotting the vertical, hoop, and dome tendon forces vs. time trend plots in Attachment 1 to the TR. In response to the NRC's request enclosed is TR No. 136, Revision 1, in which the normalizing forces have been removed. The conclusions of the report are unchanged.

There are no new regulatory commitments established by this submittal. If you have any questions or require additional information, please do not hesitate to contact us.

Very truly yours,

Michael P. Gallagher

Michael P. Gallagher
Director, Licensing & Regulatory Affairs
Mid-Atlantic Regional Operating Group

Enclosure: 1) Three Mile Island Unit No. 1, 25th Year Reactor Building Tendon Surveillance (Period 7), Topical Report No. 136, Revision 1, July 31, 2001

cc: H. J. Miller, Administrator, USNRC Region I
J. D. Orr, USNRC Senior Resident Inspector, TMI Unit 1
T. G. Colburn, USNRC Senior Project Manager, TMI Unit 1
File No. 00052

A001

Three Mile Island Unit No. 1

25TH YEAR REACTOR BUILDING TENDON SURVEILLANCE (PERIOD 7)

Topical Report No. 136
Revision 01

Originator: John J. Piazza, P.E. / Date: 7-31-01
PA License No. PE-042110-R

Originator: Howard T. Hill, P.E. / Date: 24 JUL 01
Calif Civil Cert. No. C22265

Reviewer: Jonq T. Liu / Date: 07-31-01

Design Verification Required? Yes X No ____ If Yes, DV No. V-1101-153-045

Design Verification Engineer: Jonq T. Liu / Date: 07-31-01

Exhibit 2 (Typical), EP-001T, Revision 1

AmerGen	**DOCUMENT NO.** TR 136

TITLE **25th Year Reactor Building Tendon Surveillance (Period 7)**

REV	SUMMARY OF CHANGE	APPROVAL	DATE
00	Initial Issuance		
01	TMI-1's past practice of applying the normalizing force to Figures 1, 2, and 3 of Section 5.4, "Tendon Force Trends" has been questioned by the reviewer. The reviewer has indicated that TMI is an outlier in the industry, as TMI-1 applies the normalizing force to its individual as-found tendon lift-off forces when plotting the vertical, hoop, and dome tendon forces vs. log of time trend plots. As such, TMI-1 has concurred with the reviewer's request to remove the normalizing force for plotting the force vs. time trend plots, and resubmit the report and all affected portions therein for AMERGEN resubmittal to NRC. Also, TMI-1 has revised Figures 4, 5 & 6 (Control Tendon Trends) to show measured force rather than normalized force. This revision includes several editorial corrections in addition to the substantive changes described. As a result of this change, Attachment 1 to this report has been revised, and supercedes in its entirety, Revision 00. All other portions of the report remain unaffected by this change.	Howard T Hill (signed) J T Liu (signed) John J Piazza (signed)	24 JUL 01 07/31/01 7-31-01

25TH YEAR REACTOR BUILDING TENDON SURVEILLANCE (PERIOD 7)

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25TH YEAR REACTOR BUILDING TENDON SURVEILLANCE (PERIOD 7)

1.0 Purpose

1.1 Pursuant to Technical Specification 4.4.2.1.6, this report provides the US Nuclear Regulatory Commission results obtained during the recently performed 25th Year Tendon Surveillance.

1.2 This report also serves to provide the Engineering Evaluation Report required by 10CFR50.55a and ASME XI IWL-3300, when examination results do not meet the acceptance standards of ASME XI IWL-3100 and IWL-3200.

1.3 The ISI Summary Report (IWA-6000) required by 10CFR50.55a, wherein an abstract of the conditions found are noted, and the corrective measures recommended and taken are described, were provided under separate cover. The IWA 6210, NIS-1 and 2 submittal, was provided via reference 6.12.

1.4 During the 20th Year surveillance, the plant was in its mid cycle operating run. As such, access to areas over the Main Steam Relief Valves could not be obtained to perform crack mapping of two (2) of the nine (9) dome tendons. As committed to in our submittal of April 7, 1995 (Letter no. C311-95-2166), in Topical Report 093, those results are being submitted along with the 25th year results (See Attachment 2).

2.0 Work Performed

2.1 All work was performed in accordance with TMI-1 Procedure 1301-9.1, Rev. 14, "RB Structural Integrity Tendon Surveillance" which is compliant with the requirements of ASME XI IWL 1992 edition with the 1992 addenda, and R.G. 1.35 Revision 3, except as follows: Pursuant to 10CFR50.55a(a)(3)(ii), relief was requested from performing the code specified VT-1C and VT-3C illumination and distance requirements of IWL-2310 (a) and (b) along with IWA-2210 and Table IWA-2210-1 Visual Examination of concrete surfaces. The subject relief request was submitted by TMI-1 via Reference 6.13, and is identified as RR-7.

Physical examinations of the pre-stressed post tensioned reinforced concrete containment commenced on 8/27/99 and completed on 10/26/99. The surveillance was considered complete on 12/1/99 upon completion of grease sample analyses.

2.1.1 Visual examinations (VT-1, VT-1C, and VT-3C) to ASME XI IWL 1992 edition with the 1992 addenda, for accessible exterior surfaces of containment and unbonded post-tensioning system were performed. Concrete examinations were performed in accordance with IWL-2510. In addition, grease leakage exams were conducted of the general containment surface in accordance with 10CFR50.55a(b)(2)((ix)(D)(3).

2.1.1.1 Twenty nine (29) vertical tendons were refilled/topped off with grease as they exhibited oil/grease leakage through the RB exterior concrete (shrinkage cracks) in the Upper Tendon Access Gallery. Identification of the specific vertical tendons affected is listed in Table B, attached.

2.1.1.2 All surfaces of the outdoor exterior concrete containment surface were solvent cleaned to remove historic grease leak remnants for baseline purposes and ready grease leakage identification.

2.1.1.3 As part of the grease leakage mitigation effort, remnant grease was removed from the external surfaces of tendon end caps on buttress H24 from Elev. 322' to Elev. 360'+ to determine which, if any, end caps were leaking.

2.1.2 For Inspection Period 7, twelve (12) tendons specified in Enclosure 2, of TMI-1 Procedure 1301-9.1, were surveilled/inspected, i.e. four (4) vertical, five (5) hoop, and three (3) dome tendons. Selection was based on IWL-2521. Listing is attached as Table A, herein.

2.1.2.1 Tendon force measurements were performed in accordance with IWL-2522, and for retensioned tendons, elongations were documented and compared with the limits specified in 10CFR50.55a(b)(2)((ix)(C) and Regulatory Guide 1.35 Rev. 3.

2.1.2.2 Tendon wire sample examination and testing were performed in accordance with IWL-2523.

2.1.2.3 Tendon anchorage areas including bearing plates, anchorheads, buttonheads, shims and the concrete extending outward a distance of 2 feet from the bearing plate edge were examined in accordance with IWL-2524. In addition, free water examination was documented in accordance with IWL-2524.2.

2.1.3 Samples for examination of corrosion protection medium and free water were taken in accordance with IWL-2525, and analyzed in accordance with IWL-2525.2. Corrosion protection medium water content was compared to the acceptance limit stated in 10CFR50.55a(b)(2)((ix)(D)(1).

2.1.4 Removal and replacement of corrosion protection medium was documented in accordance with IWL-2526.

2.1.5 The dome tendons that showed evidence of concrete cracks during earlier surveillances in the area immediately adjoining the baseplate were inspected and crack mapping performed in accordance with Procedure 1301-9.1.

2.1.6 All accessible grease caps were visually examined for leakage and for grease cap deformations in accordance with 10CFR50.55a(b)(2)((ix)(A).

2.1.6.1 Grease leakage mitigation was performed in the Lower Tendon Access Gallery of the vertical tendon end caps listed in attached Table E. These vertical tendons also had grease sampling/testing performed.

2.1.6.2 End cap gasket repairs were performed in accordance with applicable portions of Procedure 1410-Y-83 where active grease leakage was observed. Table D and F attached hereto sets forth those end caps, which required gasket replacement to mitigate grease leakage.

2.1.6.3 Tendon End Caps modifications were performed in accordance with TMI-1 Procedure 1410-Y-83, Revision 4, "RB Tendon End Cap Installation". Table C attached hereto sets forth those end caps, which required modification.

3.0 Evaluation of Results

3.1 As required by IWL-2510 all exterior concrete surfaces of containment were examined, except those areas exempted by IWL-1220(b). At TMI-1, inaccessible areas include interior surfaces of the concrete containment covered by the steel liner, foundation material, backfill, or are otherwise obstructed by adjacent structures, components, parts, or appurtenances. All concrete surfaces were VT-3C examined in order to detect, describe, and locate evidence of concrete deterioration and distress conditions defined in ACI 201.1R-92 and were found to be acceptable. Where areas with potentially unacceptable indications were identified, a VT-1C examination in accordance with IWL-2310 was performed. Acceptance criteria applied for concrete surface indications are published in ACI 349.3R-96 Section 5.1. Indications meeting the acceptance limits of ACI 349.3R-96 Section 5.1 were considered acceptable without further Engineering Evaluation. Areas noted as not meeting ACI 349.3R-96 Section 5.1, were evaluated not to require repair at this time. These areas are discussed in the following sections:

3.1.1 The VT-1C examination of the RB exterior concrete surface area immediately above the Fuel Handling Building Roof between buttresses 3 and 4 revealed spider like cracking. These areas are approximately 80 square inches and 240 square inches in area, respectively. Neither of the areas has cracks greater than .015" (ACI 349.3R-96), however, "surface widening" on the order of .1" to .2" maximum does exist. These wider surface cracks are of no structural significance. However, they will be reexamined during Period 8 Tendon Surveillance to ensure they are stable.

3.1.2 The SE quadrant of the RB exterior above the ring girder has an area where the cosmetic grout cover has fallen off and the underlying rebar is exposed. This is an original construction condition. The rebar in this area has only 1" of cover. ACI 318 requires minimum of 2" of cover. The condition examined in the field does not indicate any active degradation mechanism. No loss of structural integrity or safety function of containment is realized by this finding. However, the area will be reexamined during Period 8 Tendon Surveillance to ensure it has remained stable.

3.1.3 A VT-1C examination of the RB exterior concrete surface area noted a number of locations at and above the ring girder where cosmetic grout overlay was loose and had fallen off. Loose grout was removed and all areas where grout had become dislodged, or was removed, were examined. This condition is of no structural consequence. The underlying concrete was examined and found not to be significantly weathered or deteriorating. No concrete cracks were found where the grout cover had come loose. If the condition does not remain stable, consideration for repair of the grout cover will be exercised during Period 8 Tendon Surveillance, after reexamination.

3.1.4 During conduct of the VT-1C examination of the RB exterior concrete surface, a number of concrete spalls were noted at non-safe guards component supports. These spalls are inconsequential. The concrete structure remains unaffected with regards to structural integrity, and will still perform its safety function. No active degradation mechanisms were found. These areas will be monitored and reexamined during Period 8 Tendon Surveillance. Consideration for repair will occur at that time.

3.1.5 A construction joint above the ring girder between D320NE and D321NE was identified as having a crack width of .018" (exceeds ACI 349.3R-96 crack width of .015"). No active degradation mechanism such as freeze-thaw cycling was evident for the area in question. The crack is less than 32" in length and the containment structure will still perform its safety function without compromise to structural integrity. However, this area will be monitored/reexamined during Period 8 Tendon Surveillance to ensure the crack is stable.

3.1.6 As required by 10CFR50.55a(b)(2)((ix)(D)(3), grease leakage exams of the general containment surface were conducted. During that exam, twenty-nine (29) hairline cracks < .010" in width and varying from 3' to 12' in length were mapped as part of the IWL examination. This is a condition that has existed since original plant construction. The cracks are located in the upper TAG of the Intermediate Building. Table B provides a listing of the affected vertical tendons. The tendon contractor was directed to clean the cracks of grease/oil to ascertain the degree of leakage. Active leakage does exist; it consists primarily of oils separated from the original Viconorust 2090P and 2090P2 grease, and is minor in nature.

All 29 vertical tendons were topped off with 2090P4 grease to ensure full cover of the end anchorage. (Refer to Section 3.2.7.4 for discussion on grease additions). The upper Tendon Access Gallery is an enclosed area and not exposed to weathering or the environment. No compromise to concrete strength is realized due to leakage of the oils through the cracks. NUREG/CR-6598, "An investigation of Tendon Sheathing Filler Migration into Concrete" describes the phenomena in detail and addresses effects of Viconorust series grease leakage through concrete. This NUREG and ACI 515-1R-79, "A Guide to the Use of Waterproofing, Dampproofing, Protective, and Decorative Barrier Systems for Concrete" serve as the basis for concluding that there is no impact on concrete properties. The Viconorust 2090 series corrosion protection medium contains no fatty oils which could be detrimental to concrete engineering properties and performance. The Mechanical/Structural Engineer shall perform continued monitoring of the grease leakage as part of Repetitive Preventive Maintenance Task No. 9641. An internal report will be filed annually as part of that task for grease leak trending purposes.

3.1.7 All surfaces of the outdoor exterior concrete containment surface were solvent cleaned to remove historic grease leak remnants. These old grease leak stains were removed for baseline examination, and for purposes of improving future grease leak identification.

3.1.8 As part of the grease leakage mitigation effort, remnant grease was removed from the external surfaces of tendon end caps on buttress H24 from Elev. 322' to Elev. 360'+ to determine which end caps were leaking. Further evaluation of the buttress, two months after completion of the cleaning, revealed that no active grease leakage exists. It is apparent that the remnant grease was the result of grease spillage from past tendon work. Regardless, Mechanical/Structural Engineer shall perform monitoring of the grease leakage as part of Repetitive Preventive Maintenance Task No. 9641 to ensure no future leakage is occurring.

3.2 As required by ASME XI, IWL Table IWL-2521-1, sampling criteria, four (4) vertical, five (5) hoop, and three (3) dome tendons were examined in accordance with ASME XI IWL.

3.2.1 Table A provides the listing of tendons sampled.

3.2.2 Measured tendon forces in the inspection sample tendons met the acceptance standard of IWL-3221.1. Attachment 1 summarizes the results, procedures utilized, group mean forces, force trends, and elongation.

3.2.3 As required by IWL-3221.2, the sample wire obtained from each detensioned tendon (one per group) was examined and found to be free of physical damage, and had ultimate strength and elongation measurement results meeting/exceeding the minimum specified values.

3.2.4 The tendon anchorage areas were examined and met the requirements of IWL-3221.3 with one exception. A crack in the concrete surface adjacent to the bearing plate of H46-37 exceeded .01" in width. The measured width was .013" wide and 2.5" long. The crack was monitored/measured, prior to, during, and after tendon lift-off. No change in the crack size was detected. The crack will be reexamined during the 30th Year surveillance to ensure that no active degradation mechanism is present.

No evidence of cracking in the anchor heads, shims or bearing plates was noted. No evidence of active corrosion, broken or unseated wires or detached buttonheads not previously identified, was observed. The acceptance criteria of Procedure 1301-9.1 were met for end anchorage examinations.

No free water was observed in any of the base scope sampled tendons. However, vertical tendon V86, examined due to as-found field conditions, did have free water in its bottom end cap. See Section 3.2.7.2 for further discussion regarding V86.

3.2.5 The corrosion protection medium sampling results were obtained and analyzed in accordance with Table IWL-2525.1. With a single exception, the grease samples obtained met the requirements of IWL-3221.4, i.e. reserve alkalinity, water content (10% acceptance standard per 10CFR50.55a(b)(2)((ix)(D)(1), and soluble ion concentrations of all samples met the acceptance limits of Table IWL-2525-1, except for V164 (field end/bottom). One of two grease sample results for V164 (field end/bottom) indicated nitrates exceeding 10 PPM. Nitrate concentration was determined to be 10.3 PPM. However, the back-up grease sample obtained, and later tested, resulted in acceptable nitrates concentration of <.5 PPM. The tendon materials of construction are of carbon steels and are immersed in a corrosion inhibiting grease medium.

In addition, as V164 was the vertical tendon scheduled to be detensioned, it's wire was pulled. No evidence of wire pitting/corrosion was observed, nor was any cracking in the anchor heads, shims or bearing plates noted. Furthermore, no evidence of active corrosion, broken or unseated wires or detached buttonheads not previously identified, was observed. However, in order to ensure that the nitrate concentration noted is stable, an additional grease sample will be obtained from V164 (field end) during the 30th Year Surveillance.

3.2.6 As has been the trend in past surveillances, the dome tendon crack mapping revealed that the cracks were stable with neither evidence of growth nor active degradation mechanism present. The table of those dome tendon ends examined, where crack mapping was performed, is presented in Table G.

3.2.7 All tendon grease end caps were accessible and visually examined for active grease leakage, and for cap deformations in accordance with 10CFR50.55a(b)(2)((ix)(A). All vertical tendon shop (top) end caps were accessed by removing the hold-down bolts securing the deck cover plates. All others were directly accessible. Tendon end cap modifications, end cap gasket replacements, and general grease mitigation were employed. Employing these corrective measures mitigated all active grease leakage. Tables C, D, E, and F provide a listing of tendon ends repaired for grease leakage mitigation.

3.2.7.1 None of the tendon end caps showed any evidence of end cap deformations.

3.2.7.2 V86 vertical tendon (shop end/top) was found with a 1" gap between its end cap and base plate due to excessive past shimming of the shop end (top) anchor head. This condition did not allow the end cap gasket to be compressed, and allowed passage of water into the tendon duct void. This deviation has existed since the 1st Year Surveillance. It was not discovered at an earlier time because the deck cover plates require removal in order to gain access to the shop end (top) of the vertical tendon end caps. As part of the resolution to this non-conformance, the Licensed Professional Engineer responsible for overall conduct of the tendon surveillance and Section XI IWL exams requested the following actions be performed on V86 in accordance with Procedure 1301-9.1:

1) Drain tendon of grease and secure grease sample for testing
2) Perform an ASME Sec. XI - IWL exam of both tendon ends
3) Confirm lift-off and detension
4) Remove a sample wire and test
5) Retension and adjust shim stack to permit end cap reinstallation
6) Install replacement end cap gaskets and reinstall end caps
7) Blow out all moisture and grease with dry air
8) Regrease tendon void

V86 was drained of its grease, free water collected, and grease samples obtained. Grease sampling of V86 revealed the requirements of IWL-3221.4 were met. Reserve alkalinity, water content (10% acceptance standard per 10CFR50.55a(b)(2)((ix)(D)(1)), and soluble ion concentrations of both tendon end samples met the acceptance limits of Table IWL-2525-1. However, free water of approximately 2.5 gallons was drained from the field end (bottom) of the vertical tendon. Free water pH was determined to be 11.67. Lift-off of V86 was conducted. V86 was then detensioned, and a sample wire secured. Measured tendon force met the acceptance standard of IWL-3221.1. VT-1 visual exam showed no evidence of cracking in the anchor heads, shims or bearing plates. No evidence of active corrosion, broken or unseated wires or detached buttonheads not previously identified, was observed.

The wire sample from V86 was examined and found to be free of physical damage, and had ultimate strength and elongation meeting/exceeding the minimum specified values. V86 was then retensioned, moisture and grease removed, and the tendon duct void regreased with 2090P4. In order to ensure grease voids were filled, and as settling is likely to occur, V86 will be topped off with grease during the 30th Year Tendon Surveillance.

3.2.7.3 Since V86 was found with standing water, as a cautionary investigative measure, further grease sampling was directed for V19, V83, V126 and V139. These vertical tendons had also exhibited active leakage at the shop end (top). The grease samples were obtained in the Lower Tendon Access Gallery (bottom end). Reserve alkalinity, water content (10% acceptance standard per 10CFR50.55a(b)(2)((ix)(D)(1)), and soluble ion concentrations of both tendon end samples met the acceptance limits of Table IWL-2525-1. No free water was observed in any of these four sampled tendons.

3.2.7.4 As discussed in Section 3.1.6 of this report - the 29 vertical tendons exhibiting grease leakage through hairline cracks in the concrete exterior surface, were refilled with grease. TMI-1 had committed to add grease to vertical tendons which exhibited grease leakage through vertical hairline cracks in the upper TAG, and to those which exhibited grease can leakage in the lower TAG. That commitment was made in response to NRC Inspection Report 50-289/98-03. During grease filling of some of the vertical tendons, it was determined that the amount of grease required to fill the tendon net duct volume exceeded the 10% absolute difference requirement cited in 10CFR50.55a(b)(2)((ix)(D)(2). A number of vertical tendons exceeded the 1301-9.1 administrative procedural limit of 4 gallons.

Note: The 4 gallon administrative limit established for grease voiding is conservatively selected based on actual tendon net duct volume, i.e. the net duct volume for the vertical tendons is 120 gallons, with the 10% absolute difference requirement (10CFR50.55a(b)(2)((ix)(D)(2)) being 12 gallons. Similarly the hoop tendon net duct volume is 111 gallons yielding the 10% absolute difference requirement being 11 gallons. Finally, the dome tendon net duct volume is based on the shortest and longest duct length and is 76 gallon and 97 gallon, respectively, i.e. 8 gallon minimum, and 10 gallon maximum.

Note: Tendon grease removal/replacement is documented on Data Sheet 11 of Procedure 1301-9.1, and Section 2 Table XIII of the 25th Year Report No. 464 (Attachment 3, attached hereto).

In order to provide further assurance that the vertical tendons are not experiencing corrosion due to incomplete grease inventory, a random sample of eight (8) "virgin" vertical tendons had their end caps removed. The eight tendons represented 5% of the vertical tendon inventory of 166 and had not been inspected since original installation. The tendons sampled were V8, V35, V57, V80, V94, V110, V143 and V156. The following instruction was provided to the tendon contractor:

1) Remove the shop end (top) vertical tendon end cap of the eight random sampled tendons listed above.
2) Obtain a grease sample for testing of each sampled vertical tendon in accordance with Procedure 1301-9.1.
3) Perform an ASME Sec. XI - IWL exam of the sampled vertical tendon end anchorage in accordance with Procedure 1301-9.1.
4) Replace end cap gasket and reinstall end cap in accordance with Procedure 1301-9.1.
5) Top-off all 166 vertical tendons not worked during this surveillance period with new 2090P4 grease. Record all pertinent grease data in Procedure 1301-9.1.

A VT-1 visual exam of randomly sampled V8, V35, V57, V80, V94, V110, V143 and V156 showed no evidence of cracking in the anchor heads, shims or bearing plates. No evidence of active corrosion, broken or unseated wires or detached buttonheads, not previously identified, was observed. In addition, the grease sample results resulted in reserve alkalinity, water content (10% acceptance standard per 10CFR50.55a(b)(2)((ix)(D)(1),), and soluble ion concentrations of the randomly sampled tendons meeting the acceptance limits of Table IWL-2525-1. No free water was observed in these eight (8) sampled vertical tendons. The end cap gaskets were replaced. All 166 vertical tendons were topped off with new grease. Results are as follows:

The net duct volume at TMI-1 for the vertical tendons is 120 gallons, with the 10% absolute difference requirement, 10CFR50.55a(b)(2)((ix)(D)(2), being 12 gallons.

Of the 166 vertical tendons topped-off with grease, eight (8) vertical tendons had amounts of grease required to fill the tendon net duct volume exceeding the 10% absolute difference requirement cited in 10CFR50.55a(b)(2)((ix)(D)(2). This represents approximately 5% of the vertical tendon population.

The average grease difference amount required to fill the tendon net duct volume was found to be 6.6 gallons for the 166 vertical tendons.

V79 required the greatest amount of grease at 29 gallons. This tendon had shown no evidence of end cap or tendon duct leakage.

The apparent cause of the excessive grease addition is due to vertical tendon duct grease voiding and contraction inherent during/after initial greasing, or from incomplete initial filling, and not due to grease leakage. The tendon grease has a relatively high coefficient of thermal expansion. Inherent in the initial filling of vertical tendons (bottom up), pumping of the grease adds the potential for grease voiding (air pockets) due to the orientation of the tendon (vertical), and configuration of the tendon within the tendon duct.

To date TMI-1 has experienced little to no corrosion on the tendon anchor heads, button heads, baseplates, or sampled wires of vertical tendon components. There is no reason to believe that corrosion is occurring in the 8 vertical tendons, which exceeded the 12-gallon requirement.

4.0 Follow-Up Examinations to be Performed Next Surveillance (30 Year)

4.1 Re-examine the RB exterior concrete surface area immediately above the Fuel Handling Building Roof between buttresses 3 and 4, i.e. spider like cracking approximately 80 square inches and 240 square inches in area, respectively. None of the cracks are greater than .015", however, "surface widening" on the order of .1" to .2" maximum does exist. Inspect during Period 8 Tendon Surveillance to ensure they are stable.

4.2 Re-examine the SE quadrant of the RB exterior above the ring girder. An area where the cosmetic grout cover has fallen off and underlying rebar is exposed exists. This is an original construction disparity. Rebar has only 1" of cover. ACI 318 requires minimum of 2" of cover. The area will be reexamined during Period 8 Tendon Surveillance to ensure there is no active degradation mechanism.

4.3 Re-examine the RB exterior concrete surface area at and above the ring girder, where cosmetic grout overlay was found loose and had fallen off. The underlying concrete was examined and found not to be significantly weathered or deteriorating. No concrete cracks were found where the grout cover had come loose. If the condition does not remain stable, consideration for repair of the grout cover will be exercised during Period 8 Tendon Surveillance, following reexamination.

4.4 Re-examine the RB exterior concrete surface area where a number of concrete spalls were noted at non-safe guards component supports. No active degradation mechanisms were found. These areas will be monitored and reexamined during Period 8 Tendon Surveillance. Consideration for repair will occur at that time.

4.5 Re-examine the construction joint above the ring girder between D320NE and D321 NE. Area was identified as having a crack width of .018" (exceeds ACI 349.3R-96 crack width of .015"). No active degradation mechanism such as freeze-thaw cycling was evident in the area in question. Monitor/reexamine during Period 8 Tendon Surveillance to ensure the crack is stable.

4.6 Continued monitoring of the tendon end cap grease leakage shall be performed as part of Repetitive Preventive Maintenance Task No. 9641. An internal report will be filed annually as part of that task for grease leak trending purposes.

4.7 Re-examine the crack in the concrete adjacent to the bearing plate of H46-37. Exceeded .01" in width. The measured width was .013" wide and 2.5" long. Re-examine during the 30th Year surveillance to ensure that no active degradation mechanism is present.

4.8 Re-sample V164 field end (bottom). Sample results indicated nitrates exceeding 10 PPM. Nitrate level was determined to be 10.3 PPM. However, the back-up grease sample obtained, and later re-tested, resulted in acceptable Nitrates at <.5 PPM. In order to ensure that the nitrate levels noted are stable, an additional grease sample will be obtained from V164 (field end) during the 30th Year Surveillance.

4.9 Top-off V86 with 2090P4 grease, in order to ensure grease voids are filled. Perform during the 30th Year Tendon Surveillance.

5.0 Conclusions

5.1 Based on the examination results, and evaluations presented herein, it is concluded that the pre-stressed post-tensioned containment system is in good condition. Structural integrity of containment remains above established acceptance limits set forth in 10CFR50.55a, and ASME Section XI IWL, or where departures were found, were shown to be acceptable. The system shows no evidence of significant degradation and will continue to perform its required safety function.

6.0 References

6.1 ACI 201.1R-92 and ACI 201.1R-68, "Guide for Making a Condition Survey of Concrete In Service."

6.2 ACI 318-63, "Building Code Requirements for Reinforced Concrete."

6.3 ACI 349.3R-96 Section 5.1, "Evaluation of Existing Nuclear Safety Related Concrete Structures."

6.4 NUREG/CR-6598, "An investigation of Tendon Sheathing Filler Migration into Concrete."

6.5 TMI-1 Procedure 1301-9.1, "RB Structural Integrity Tendon Surveillance", Revision 14.

6.6 TMI-1 Procedure 1410-Y-83, "RB Tendon End Cap Installation", Revision 5.

6.7 Precision Surveillance Corporation Report No. 463, "20th Year Physical Surveillance of the Three Mile Island Unit 1 Containment Building," (Tendon Surveillance Crack Mapping Results (Attachment 2).

6.8 Precision Surveillance Corporation Report No. 464, Twenty-Fifth Year Physical Surveillance of the Three Mile Island Unit 1 Containment Building (Attachment 3).

6.9 NRC Safety Evaluation Review of Twentieth Year Tendon Surveillance, Three Mile Island Unit 1, Docket No. 50-289, dated August 28, 1997.

6.10 GPU Nuclear Topical Report No. 093, letter No. C311-95-2166, dated April 7, 1995, T. G. Broughton to USNRC.

6.11 USNRC Integrated Inspection Report 50-289/98-03, dated September 4, 1998, Michele Evans to James W. Langenbach.

6.12 TMI-1 ISI Summary Report, letter No. 1920-99-20679, dated January 14, 2000, John Cotton to USNRC.

6.13 AmerGen Energy letter to USNRC, letter No. 5928-00-20013, dated January 28, 2000, John Cotton to USNRC (see TMI-1 Relief Request RR-7).

Table A
Period 7 Selected Base Scope Tendons

VERTICAL TENDON	HOOP TENDON	DOME TENDON
V32	H13-50 *	D102 *
V40	H35-33	D104 **
V114	H46-37	D225
V164 *	H51-43	D313
-	H62-26	-

* Tendons detensioned
** Exempt tendon examined in accordance with IWL-2521.1.(c)

Table B
Vertical Tendons Exhibiting Sheathing Filler Migration into Concrete Surface

V1	V17	V31	V54	V135	V153
V3	V21	V32	V59	V137	V155
V5	V23	V41	V131	V138	V159
V6	V26	V46	V132	V139 *	V162
V13	V28	V51	V134	V140	-

* Main Gasket of V139 (Shop End/Top) Replaced

Table C
Tendon End Cap Modifications (Includes Gasket Replacement)

H24-51	H51-4	H62-10
H26-4	H51-13	H62-13
H26-52	H51-14	H62-14
H26-53	H53-11	H62-15
H31-18	H53-13	D145SE
H31-46	H53-25	D147SE
H31-51	H53-44	D317SE
H31-55	H53-48	-

Table D
Grease Leakage Mitigation
Tendon End Cap Gasket Replacements

H13-12
H13-13
H13-21
H15-13
D202NE
D336NW

Table E
Vertical Tendon Field (Bottom) End Cap Grease Leakage Mitigation with Grease Sampling *

V72, V73, V74, V75, V76, V136, V146

* Tendon Contractor Examination Yielded Minor Fastener or Drain Plug Tightening – Grease Leakage Mitigated

Table F
Vertical Tendon Shop (Top) End Cap Grease Leakage Mitigation
Gasket Replacements

V19, V83, V86, V126, V139

Table G
Dome Tendon Crack Mapping

D103NE, D118SW, D203NE, D218SE, D225NW, D249SE, D313SE, D329SW, D334NW

ATTACHMENT 2
Topical Report No.136
Revision 00

Dome Crack Mapping Results
Deferred from 20th Year Tendon Surveillance Report (Period 6)

The following Precision Surveillance Corporation (PSC) report, entitled "20th Year Physical Surveillance of the Three Mile Island Unit 1 Containment Building, Post Tensioning Surveillance Report," Engineering File No. 463, presents the findings from the 20th year surveillance inspections of two (2) of the nine (9) dome tendons that were deferred due to the potential risk of personnel injury in performing the inspections during plant operation. The 20th Year Reactor Building Tendon Surveillance was performed while the plant was in its mid cycle operating run and crack mapping in the vicinity of dome tendons D-103 (NE end) and D-334 (NW end) were not inspected due to the proximity of these tendons to the main steam exhaust vents. The April 7, 1995 GPU Nuclear submittal of the 20th Year Tendon Surveillance test results committed to inspect these tendons during the TMI-1 Cycle 11 Refueling (11R) Outage in the fall of 1995 and if the results were essentially the same, the data would be filed in the document control system and the results would be included with the 25th Year Tendon Surveillance Report.

This attachment provides the results from the September 1995 (20th Year) inspections of dome tendons D-103NE and D-334NW where, as has been the trend in past surveillances, the dome tendon crack mapping revealed that the cracks were stable with no evidence of growth, nor active degradation mechanism present. (Refer to Attachment 3 for the recent 25th Year results for dome tendon crack mapping).

ATTACHMENT 1
TENDON FORCE AND ELONGATION
SURVEILLANCE RESULTS & EVALUATION

Tendon force and elongation are discussed in the following sections. The first summarizes results. The second describes the procedures used to measure tendon force and elongation. The third, fourth, fifth and sixth sections provide detailed discussions of, respectively, individual tendon force, group mean force, force trends and elongation.

All surveillance activities, including force and elongation measurements, were performed in accordance with the detailed instructions provided by TMI-1 Surveillance Procedure 1301-9.1, Revision 14. This procedure incorporates the applicable requirements as set forth in the following documents.

- USNRC Regulatory Guide 1.35, Revision 3.
- Subsection IWL of ASME Boiler & Pressure Vessel Code Section XI, 1992 Edition with Addenda through 1992.
- 10CFR50.55a as amended effective 09 September 1996.
- TMI-1 Technical Specification Section 4.4.2.1

This report includes information as required by the above listed documents. Acceptance limits on current & trended tendon forces and on tendon elongation are as provided by the following.

- Subsection IWL of ASME Boiler & Pressure Vessel Code Section XI, 1992 Edition with Addenda through 1992 (generic lower limits on individual tendon forces).
- Gilbert / Commonwealth Calculation DC-5390-225.01-SE dated 26 April 1994 (numerical limits on individual tendon forces).
- TMI-1 FSAR Par. 5.7.5.2.3.f, Update 15 (lower limits on current and trended tendon group mean forces).
- 10CFR50.55a as amended effective 09 September 1996 (generic limits on tendon elongation).

Other documents used as sources for data and information presented in the following sections are identified at the appropriate points in the text. All documents relevant to the preparation and content of the following sections are included in the References listing.

As discussed in Section 5, tendon forces documented in the reports covering the 10th, 15th & 20th Year Surveillances are adjusted to provide a correct basis for trending. As a result, there are numerous differences between the forces documented in those earlier reports and those used to compute trends in this report. Addendum sheets will be added to the 10th, 15th and 20th Year Surveillance reports to clarify this issue. The addendum sheets will refer to this report for correct force values and an explanation of the adjustments.

1. Summary of Results & Conclusions

Forces were determined for 4 vertical, 5 hoop and 3 dome tendons. One tendon in each group was detensioned (for removal of a sample wire) and the elongations of these tendons were measured during subsequent retensioning. Current & trended forces and elongations meet all applicable acceptance criteria as stated below.

- All individual tendon forces are above the minimum required values listed in Gilbert / Commonwealth Calculation DC-5390-225.01-SE.

- Current normalized group (vertical, hoop & dome) mean forces are above the currently applicable minimum required values listed FSAR Par. 5.7.5.2.3.f and the proposed minimum required values discussed in Subsections 4.3 & 5.3(c) below.

- Vertical, hoop and dome tendon group mean forces projected to March 2005 (the latest date for completion of the next surveillance as stipulated in Reference 2) using log-linear trends based on all accumulated surveillance data are acceptable. Projected forces are above both current and proposed minimum required values. Measured (not normalized) forces are used to construct trends.

- Statistical bounds on vertical, hoop and dome tendon group mean forces determined for March 2005 using the 10th through 25th Year Surveillance results are acceptable. These bounds, determined at the 95% confidence level, are above both current and proposed minimum required values. Measured (not normalized) forces are used to construct the statistical lower bounds.

- All tendon elongations are within the generic acceptance limits specified in 10CFR50.55a.

The results of the 25th Year Surveillance provide positive assurance that containment prestressing forces are adequate to ensure continuing structural integrity at the required level at least until March 2005 (by which time the next surveillance must be complete per the requirements of Reference 2).

2. Force and Elongation Measurement Procedures

Tendon forces are determined by the feeler gage pull out method in accordance with the instructions given in Reference 7 (Rev. 14) and summarized below.

- Couple a jack to the tendon stressing washer.
- Pressurize the jack until jacking force is sufficient to open a small (just over 0.030 in.) gap in the shim stack.
- Insert a 0.030 in. feeler gage into each side of the shim stack between the stressing washer and the outboard shim pair.
- Reduce jacking force to about 100 kip.
- Slowly increase jacking force until both feeler gages can be moved (which verifies that the shim stack is unloaded) and record jack pressure. The force corresponding to this pressure (computed using jack calibration constants) is called the liftoff force.
- Repeat the above two steps until three consecutive liftoff forces fall within a 25 kip range.
- Calculate end (shop or field) anchorage force as the average of the above three consecutive jacking forces.
- Compute tendon force as the mean of the shop and field (if determined) end forces. Vertical tendon forces are determined by jacking only at the upper (shop) end.

Elongation is determined during retensioning of all tendons that are detensioned. Detailed instructions for retensioning and elongation measurement are provided in Reference 7 (Rev. 14) and summarized below.

- Couple jacks at the upper end (verticals) or both ends (hoops & domes) of the tendon.
- Increase the force applied by each jack to a nominal level of 1 kip per wire to eliminate tendon slack.
- Measure and record the extension of each jack.
- Increase the force applied by each jack a nominal 80% of tendon ultimate strength in three approximately equal steps.
- Measure and record the extension of each jack at each of the above force levels.
- Compute elongation at each end as the difference between final and initial jack extensions.
- Compute tendon elongation as the sum of the individual end elongations.

3. Individual Tendon Force

As noted in the Summary above, all individual tendon forces exceed the minimum acceptable values. The minimum acceptable force level applicable to an individual tendon is 95 % of the force predicted for that tendon at the time of measurement. This acceptance limit is the same as that given in Subsection IWL of the ASME Boiler & Pressure Vessel Code, which is incorporated by reference into 10CFR50.55a (per amendment effective 9 Sep 96). Predicted forces (Base Levels) for the tendons included in the 25th Year Surveillance were determined in a 1994 calculation prepared by Gilbert / Commonwealth (Reference 11).

Forces determined for individual tendons and the corresponding acceptance limits (lower limits) are listed in Table 1 below. The tendon force listed is the mean of the shop and field end values (hoop & dome tendons; vertical tendon forces are measured only at the shop end). End forces are computed as the average of first three consecutive liftoff force measurements that fall within a 25 kip range. Liftoff is the point at which both sides of the shim stack are verified loose by the feeler gage withdrawal method. The feeler gage withdrawal method, the liftoff procedure and the computation of tendon force are defined in detail in Reference 7 (Rev. 14). All liftoff and other data documented during the surveillance are included in Attachment 3 (the surveillance contractor report).

Table 1
Tendon Forces, Acceptance Limits & Margins

Tendon	Shop End Force, kip (Note 1)	Field End Force, kip (Notes 1 & 2)	Tendon Force, kip (Note 3)	Lower Acceptance Limit, kip (Note 4)	Margin, kip (Note 5)
V32	1193.0	N/A	1193	1132	+61
V40	1202.0	N/A	1202	1128	+74
V114	1189.3	N/A	1189	1100	+89
V164	1181.0	N/A	1181	1165	+16
H13-50	1183.0	1135.0	1159	1042	+117
H35-33	1180.7	1158.0	1169	1080	+89
H46-37	1134.3	1123.0	1129	1022	+107
H51-43	1176.0	1163.3	1170	1116	+54
H62-26	1133.0	1138.3	1136	1064	+72
D102	1276.0	1284.0	1280	1053	+227
D225	1118.0	1090.3	1104	1027	+77
D313	1110.0	1129.0	1120	1052	+68

Notes:

1. Rounded to nearest 0.1 kip.
2. Vertical tendon forces measured at upper (shop) end only.
3. Shop end force (vertical tendons) or mean of shop & field end forces (hoop & dome tendons); rounded to the nearest kip.
4. Lower Acceptance Limit is 95% of the Base Level as computed in Reference 11.
5. Margin is tendon force less lower acceptance limit. Positive margin denotes acceptance.

4. Normalization and Group Mean Tendon Force

As noted in the summary above, and as discussed in detail in Subsection 4.2, the mean normalized forces calculated for the vertical, hoop and dome tendon samples are all acceptable.

The primary purpose of measuring tendon forces is to ensure that time dependent force loss is not excessive and that the mean levels of prestressing force in the structure are not below the specified minima. The mean levels of prestressing forces are considered to be acceptable if the averages of normalized sample tendon forces (separate averages are computed for vertical, hoop and dome tendons) are not below the specified group minima.

4.1 Normalization

The force at a tendon end anchorage is a function not only of the time dependent losses (concrete creep, concrete shrinkage and tendon stress relaxation), but also of the initial tendon seating force and the elastic shortening occurring during tendon stressing. Time dependent losses should be similar for all tendons in a group although some differences are expected as a result of variations in initial force level, thermal environment, structural stiffness and possible redistribution (of force along the length of a tendon). Initial seating force and elastic shortening loss vary significantly within each tendon group.

For example, the initial average (both ends) seating forces in hoop tendons, as documented in Reference 12 ranged from 1395 kips to 1461 kips. The mean of all initial hoop tendon seating forces was 1435 kips. As a result, the initial average seating force in any randomly selected hoop tendon may vary from 40 kips below the mean to 26 kips above the mean.

The sequential stressing of tendons causes incremental strains in the concrete and in all tendons already stressed. As a result, the forces in all tendons except the last one stressed are affected by stressing sequence. The final elastic (in contrast to time dependent) hoop strain resulting from stressing all hoop tendons is on the order of -0.0005. As a result of this strain, the force in the first tendon stressed decreases by about 120 kips (-0.0005 strain times 30,000 ksi modulus times 8.3 sq. in. area). This decrease is called elastic shortening loss. The last tendon stressed experiences no elastic shortening loss. The mean elastic shortening loss is about 60 kips. As a result, the elastic shortening loss in any randomly selected hoop tendon may be as little as 60 kips below the mean or as much as 60 kips above the mean.

Therefore, as a result of the combination of the above effects, the force in any randomly selected hoop tendon could be as low as 100 (60 + 40) kips below the mean or as high 86 (60 + 26) kips above the mean. However, actual variations are probably less since the tendons with the extreme initial seating forces are not necessarily at either end of the stressing sequence.

As surveillance samples are small, there is a very low probability that the mean of the forces in the sample tendons is close to the mean force in all tendons. In fact, for hoop tendons, the sample mean could vary from almost 100 kips below to almost 86 kips above the actual group mean. Maximum possible variations for vertical and dome sample means are less but still significant. Individual measured forces can be adjusted to account for the effects of initial seating forces and elastic shortening losses. If this is done, the sample mean can be considered to better represent the group mean. The adjustment process is termed normalization and the adjustment applicable to an individual tendon is called a normalization factor. Computation and application of normalization factors are described in USNRC Regulatory Guide 1.35.1, Determining Prestressing Forces for Inspection of Prestressed Concrete Containments.

Normalization factors applicable to each surveillance tendon were computed by Gilbert / Commonwealth and are documented in References 11 & 12. These factors, which are added to measured tendon forces, are the summation of the following elements.

- The mean initial seating force for all tendons in the group less the initial seating force for tendon in question.
- The mean elastic shortening loss (a negative number) for the group less the elastic shortening loss (also a negative number) computed for the tendon in question.
- Unit load stress relaxation (a negative number) times the sum of the above two elements.

The last of the above elements accounts for the variation in time dependent loss expected as a result of the variation among the forces in the individual tendons at the time that stressing of the group is complete.

All tendon forces are normalized, per the guidance given in Reg. Guide 1.35.1, so that sample means are more representative of group means. Table 2 below lists measured forces (from Table 1), normalizing factors (from Reference 11) and normalized forces. However, while normalized forces are used to determine group means, actual measured forces are used in the trending analysis presented in Section 5.

Table 2
Measured Forces, Normalizing Factors & Normalized Forces

Tendon	Measured force, kip (Note 1)	Normalizing Factor, kip (Note 2)	Normalized force, kip (Note 3)
V32	1193	-7	1186
V40	1202	-1	1201
V114	1189	27	1216
V164	1181	-42	1139
H13-50	1159	25	1184
H35-33	1169	-15	1154
H46-37	1129	46	1175
H51-43	1170	-53	1117
H62-26	1136	2	1138
D102	1280	18	1298
D225	1104	45	1149
D313	1120	19	1139

Notes:

1. Measured forces from Table 1.
2. Normalizing factors from References 11 & 12.
3. Normalized force is sum of measured force and normalizing factor.

4.2 Group Mean Tendon Forces

Normalized forces in individual tendons (from Table 2), group mean forces, minimum required group mean forces and margins are listed in Table 3 below. The minimum required group mean forces are as stated in FSAR Par. 5.7.5.2.3.f (Update 15).

As is shown in the table, the vertical, hoop and dome tendon sample means are all above the respective minimum required values. Therefore mean normalized tendon forces, as determined by the results of the 25th Year Surveillance, are acceptable. The final column of the table lists the margin between current group mean and the minimum required value. A positive margin (all are positive) denotes acceptance.

Table 3
Normalized Tendon Forces, Group Means & Margins

Tendon Group	Tendon	Normalized Force, kip (Note 1)	Minimum Required Group Mean Force, kip (Note 2)	Margin, kip (Note 3)
Vertical	V32	1186		
	V40	1201		
	V114	1216		
	V164	1139		
	Vertical Tendon Sample Mean = 1186		1010	+176
Hoop	H13-50	1184		
	H35-33	1154		
	H46-37	1175		
	H51-43	1117		
	H62-26	1138		
	Hoop Tendon Sample Mean = 1154		1121	+33
Dome	D102	1298		
	D225	1149		
	D313	1139		
	Dome Tendon Sample Mean = 1195		1040	+155

Notes:

1. Normalized forces from Table 2.
2. Minimum required values from FSAR Par. 5.7.5.2.3.f (Update 15).
3. Normalized force mean less minimum required. Positive margin denotes acceptance.

4.3 Proposed Minimum Required Group Mean Forces

As discussed in 5.3(c), TMI-1 recently recalculated the minimum required mean forces for all three tendon groups. This calculation is documented in EER JO # 162193 with appended calc C-1101-153-E410-028. These recalculated minima, which are proposed for future use, are listed for information below along with the vertical, hoop and dome sample means. All sample means exceed the proposed minima by significant margins.

Tendon Group	Sample Mean, kip	Proposed Minimum, kip	Margin, kip
Vertical	1186	1033	153
Hoop	1154	1108	46
Dome	1195	1064	131

5. Tendon Force Adjustment and Group Mean force Trends

As noted in the summary above, vertical, hoop and dome tendon mean forces trended to Year 31 (March 2005, the latest date for completion of the next surveillance as stipulated in Reference 2) are above the minimum required values listed in FSAR Par. 5.7.5.2.3.f. Statistically determined lower bounds (lower 95% confidence limits or LCL's) on mean forces at Year 31 are also above minimum required levels. These minimum required mean force levels are:

- 1010 kips for vertical tendons.
- 1121 kips for hoop tendons.
- 1040 kips for dome tendons.

Log-linear trends are computed using adjusted (as applicable) tendon forces measured during the 1st through 25th Year Surveillances. Lower 95% confidence limits on mean forces at Year 31 are computed using forces determined during the 10th through 25th Year Surveillances only. Early (1st, 3rd & 5th Year Surveillances) results are not used in the statistical computation since the early reports do not provide sufficient information to allow positive interpretation of the forces documented therein (the method of measuring liftoff is not identified).

Force adjustment and trend computations are discussed in the following subsections.

5.1 Force Adjustment

The 10th, 15th & 20th Year Surveillances were performed per the requirements of Revisions 4, 6, & 9, respectively, of TMI Surveillance Procedure 1301-9.1 (Reference 7). These revisions defined the following process for determining tendon force.

- After coupling the stressing jack to the anchor head, pressurize the jack until there is a small (just over 0.030 in.) gap in the shim stack.
- Insert two 0.030 in. feeler gages approximately 180^{o} apart between the anchor head and the shim stack or between the bearing plate and the shim stack.
- Reduce jacking force to about 100 kip.
- Increase jacking force and record pressures at which the 1st and 2nd feeler gages can be withdrawn.
- Compute liftoff force as the average of the forces calculated from the jack pressures recorded in the previous step.
- Continue the above process until at least three consecutive sets of measurements meet the following criteria.
    - The difference between the forces (in a given set of measurements) at which the 1st and 2nd feeler gages can be withdrawn does not exceed 40 kips.
    - The average forces (average of the forces at which the 1st and 2nd feeler gages can be withdrawn) fall within a 25 kip band.

- Compute end force as the mean of the first three consecutive liftoff forces meeting the above criteria.

- Compute tendon force as the average of the two end (shop and field) forces or as the single end force if jacking is done at only one end.

Liftoff is more correctly defined as the jacking force at which the 2nd feeler gage can be withdrawn. Since this force is generally higher than that at which the 1st gage can be withdrawn, the above process tends to yield an underestimate of tendon force. Revision 14 to Surveillance Procedure 1301-9.1 (the revision used during the 25th Year Surveillance) incorporates the corrected definition of liftoff and eliminates the requirement to record the force at which the first feeler gage can be withdrawn.

Tendon forces reported for the 25th Year Surveillance are correct in that lift off force is computed using the correct process. Those reported for the 10th, 15th & 20th Year Surveillances may be incorrect since, as discussed above, these are generally based on underestimates of liftoff force.

In order to provide a consistent basis for force trending, the tendon forces documented in the 10th, 15th & 20th Year Surveillance reports (References 16, 17 & 18, respectively) are adjusted to reflect the correct liftoffs as defined in Revision 14 to Surveillance Procedure 1301-9.1. The adjustment consists of simply redefining liftoff force as the force at which the second feeler gage can be removed. This force is recorded for all liftoff operations documented in the subject reports.

The 1st, 3rd & 5th Year Surveillances were conducted under Revision 1 to USNRC Regulatory Guide 1.35. The requirements outlined in this early document are considerably less detailed than those in the current revision (Revision 3). Also, many of the requirements given in Revision 1 are significantly changed in Revision 3.

The TMI-1 tendon surveillance procedure (Reference 7) has changed in parallel with regulatory requirements and, from the 10th Year Surveillance forward, has provided much more detailed instructions for measuring and documenting liftoff forces. As a result, all data and related information needed to adjust the 10th, 15th & 20th Year Surveillance tendon forces are available in the applicable reports.

The procedure revisions applicable to the first three surveillances allow the use of several liftoff measurement methods and provide no details on the implementation of these. The reports covering these surveillances (References 13, 14 & 15) do not identify the method(s) used. Therefore, the tendon forces reported for these earlier surveillances cannot be adjusted. However, the Log-linear trend computations use the results of all surveillances since this is the conventional basis for trend presentation. The more meaningful statistical (LCL) determinations of lower bound mean forces at Year 31 use only the 10th through 25th Year Surveillance results for the reason previously mentioned. The 25th Year Surveillance results are not adjusted since these are obtained using the correct procedure for liftoff determination.

Force adjustments are documented in Tables 4, 5 and 6. The forces at which the 2nd feeler gage can be removed are extracted from the Data Sheet 24 copies included in the subject reports.

These tables also list the previously recorded (in the subject reports) tendon forces and the differences between those and the adjusted forces.

Adjusted forces are generally determined using the same data sets as were used to compute the previously documented forces. However, in several cases, it was necessary to perform more than three liftoff trials before meeting the criteria imposed by the earlier procedure revisions. In these cases, discussed below, adjusted forces are based on different data sets.

During the initial lift off of V84 (10th Year Surveillance), the anchor head rotated and ejected shims. The shim stack was reset, which may have caused some change to the distribution of force in the tendon, and three more liftoff forces were measured. These subsequent liftoff forces were noticeably higher than the first. To ensure a consistent and conservative approach, the adjusted force is based on only the initial liftoff measurement. As a result, the adjusted force is 14 kips below the previously reported force. For all other tendons, the adjusted force is equal to or greater than that previously reported:

Eight liftoff measurements were made at the shop end of H35-23 (20th Year Surveillance). Only the final three satisfied the procedure criterion requiring 3 consecutive measurements with 1st & 2nd feeler gage pull out forces differing by not more than 40 kips. The adjusted shop end force is based on the first 3 measurements.

Seven liftoff measurements were made at the shop end of H62-26 (20th Year Surveillance) for the same reason as above. However, in this case, the shim stack was reset following the 4th measurement and the final three were used to compute shop end force. The adjusted shop end force is based on the first 3 measurements.

Five liftoff measurements were made at the field end of H62-49 (20th Year Surveillance), again for the same reason as above. The shim stack was reset following the 2nd measurement and the final three were used to compute field end force. The adjusted field end force is based on the first 3 measurements.

Tendon D218 was detensioned / retensioned during the 5th Year Surveillance. It was included in the 15th Year Surveillance as a substitute for D318 which is over a main steam vent valve discharge line and could not be safely examined with the plant in operation (as it was during this surveillance). Since D218 was previously detensioned / retensioned, it should not be included in trend or LCL calculations. This tendon is listed in the 15th Year Surveillance table for information but the adjusted force is not used in determining the dome group trend or LCL.

Table 4
10^{th} Year Surveillance - Adjusted Tendon Force, Previously Reported Force & Difference

Tendon	Shop End Liftoff Force, kip, at 2^{nd} Feeler Gage Withdrawal	Mean Shop End Force, F_s, kip (Note 1)	Field End Liftoff Force, kip, at 2^{nd} Feeler Gage Withdrawal (Note 2)	Mean Field End Force, F_f, kip (Note 1)	Adjusted Tendon Force, F_n, kip (Note 3)	Previously Reported Tendon Force, F_o, kip (Note 4)	$\Delta F = F_n - F_o$, kip (Note 5)
V14	1244		N/A				
	1240		N/A				
	1244	1242.7	N/A	N/A	1243	1243	0
V30	1190		N/A				
	1190		N/A				
	1198	1192.7	N/A	N/A	1193	1193	0
V32	1190		N/A				
	1187		N/A				
	1210	1195.7	N/A	N/A	1196	1196	0
V84	*1189		N/A				
	1202		N/A				
	1202		N/A				
	1206	1189.0*	N/A	N/A	1189	1203	(-)14
V160	1189		N/A				
	1194		N/A				
	1194	1192.3	N/A	N/A	1192	1192	0
H13-35	1215		1179				
	1206		1175				
	1198	1206.3	1175	1176.3	1191	1184	7
H13-36	1198		950				
	1194		940				
	1185	1192.3	930	940.0	1066	1064	2
H13-37	1173		1199				
	1160		1199				
	1164	1165.7	1199	1199.0	1182	1175	7
H24-26	1181		1169				
	1181		1159				
	1189	1183.7	1159	1162.3	1173	1172	1

* The anchor head rotated and ejected shims during the initial liftoff measurement. See discussion in text.

Notes:

1. Mean (rounded to the nearest 0.1 kip) of the first three consecutive liftoff measurements falling within a 25 kip band.
2. Vertical tendon liftoff measured only at top (shop) end.
3. For vertical tendons $F_n = F_s$; for hoop & dome tendons, $F_n = (F_s + F_f) / 2$. F_n is rounded to the nearest kip.
4. Tendon force documented in the 10^{th} Year Surveillance Report.
5. Increase in tendon force resulting from use of the revised procedure (per discussion in text) to determine liftoff force.

Table 4 (cont'd)
10th Year Surveillance - Adjusted Tendon Force, Previously Reported Force & Difference

Tendon	Shop End Liftoff Force, kip, at 2nd Feeler Gage Withdrawal	Mean Shop End Force, F_s, kip (Note 1)	Field End Liftoff Force, kip, at 2nd Feeler Gage Withdrawal (Note 2)	Mean Field End Force, F_f, kip (Note 1)	Adjusted Tendon Force, F_n, kip (Note 3)	Previously Reported Tendon Force, F_o, kip (Note 4)	$\Delta F = F_n - F_o$, kip (Note 5)
H35-26	1143		1172				
	1147		1169				
	1139	1143.0	1165	1168.7	1156	1153	3
H62-26	1122		1169				
	1118		1172				
	1118	1119.3	1172	1171.0	1145	1138	7
H62-30	1135		1175				
	1135		1172				
	1126	1132.0	1169	1172.0	1152	1146	6
D133	1080		1130				
	1092		1130				
	1080	1084.0	1130	1130.0	1107	1100	7
D225	1135		1118				
	1130		1113				
	1143	1136.0	1113	1114.7	1125	1117	8
D314	1301		1286				
	1293		1291				
	1288	1294.0	1282	1286.3	1290	1286	4

Notes:

1. Mean (rounded to the nearest 0.1 kip) of the first three consecutive liftoff measurements falling within a 25 kip band.
2. Vertical tendon liftoff measured only at top (shop) end.
3. For vertical tendons $F_n = F_s$; for hoop & dome tendons, $F_n = (F_s + F_f) / 2$. F_n is rounded to the nearest kip.
4. Tendon force documented in the 10th Year Surveillance Report.
5. Increase in tendon force resulting from use of the revised procedure (per discussion in text) to determine liftoff force.

Table 5
15th Year Surveillance - Adjusted Tendon Force, Previously Reported Force & Difference

Tendon	Shop End Liftoff Force, kip, at 2nd Feeler Gage Withdrawal	Mean Shop End Force, F_s, kip (Note 1)	Field End Liftoff Force, kip, at 2nd Feeler Gage Withdrawal (Note 2)	Mean Field End Force, F_f, kip (Note 1)	Adjusted Tendon Force, F_n, kip (Note 3)	Previously Reported Tendon Force, F_o, kip (Note 4)	$\Delta F = F_n - F_o$, kip (Note 5)
V19	1191		N/A				
	1187		N/A				
	1183	1187.0	N/A	N/A	1187	1186	1
V21	1196		N/A				
	1196		N/A				
	1196	1196.0	N/A	N/A	1196	1185	11
V22	1175		N/A				
	1171		N/A				
	1168	1171.3	N/A	N/A	1171	1169	2
V23	1175		N/A				
	1175		N/A				
	1175	1175.0	N/A	N/A	1175	1175	0
V50	1216		N/A				
	1212		N/A				
	1212	1213.3	N/A	N/A	1213	1209	4
V83	1196		N/A				
	1196		N/A				
	1196	1196.0	N/A	N/A	1196	1193	3
V84	1175		N/A				
	1175		N/A				
	1175	1175.0	N/A	N/A	1175	1169	6
V85	1179		N/A				
	1179		N/A				
	1179	1179.0	N/A	N/A	1179	1179	0
H24-29	1116		1038				
	1105		1038				
	1103	1108.0	1035	1037.0	1072	1068	4

Notes:

1. Mean (rounded to the nearest 0.1 kip) of the first three consecutive liftoff measurements falling within a 25 kip band.
2. Vertical tendon liftoff measured only at top (shop) end.
3. For vertical tendons $F_n = F_s$; for hoop & dome tendons, $F_n = (F_s + F_f) / 2$. F_n is rounded to the nearest kip.
4. Tendon force documented in the 15th Year Surveillance Report.
5. Increase in tendon force resulting from use of the revised procedure (per discussion in text) to determine liftoff force.

Table 5 (cont'd)
15th Year Surveillance - Adjusted Tendon Force, Previously Reported Force & Difference

Tendon	Shop End Liftoff Force, kip, at 2nd Feeler Gage Withdrawal	Mean Shop End Force, F_s, kip (Note 1)	Field End Liftoff Force, kip, at 2nd Feeler Gage Withdrawal (Note 2)	Mean Field End Force, F_f, kip (Note 1)	Adjusted Tendon Force, F_n, kip (Note 3)	Previously Reported Tendon Force, F_o, kip (Note 4)	$\Delta F = F_n - F_o$, kip (Note 5)
H24-30	1178		1103				
	1174		1103				
	1174	1175.3	1103	1103.0	1139	1135	4
H24-31	1124		1107				
	1124		1107				
	1120	1122.7	1103	1105.7	1114	1108	6
H24-51	1136		1154				
	1132		1154				
	1128	1132.0	1150	1152.7	1142	1140	2
H46-34	1187		1170				
	1183		1170				
	1183	1184.3	1170	1170.0	1177	1172	5
H62-13	1091		1087				
	1083		1090				
	1091	1088.3	1087	1088.0	1088	1087	1
H62-26	1129		1134				
	1121		1134				
	1121	1123.7	1129	1132.3	1128	1122	6
D145	1228		1212				
	1228		1212				
	1228	1228.0	1212	1212.0	1220	1220	0
D218*	1116		1183				
	1116		1175				
	1116	1116.0	1179	1179.0	1148	1148	0
D347	1187		1187				
	1175		1174				
	1196	1186.0	1178	1179.7	1183	1181	2

* Tendon previously detensioned/retensioned. See discussion in text.

Notes:

1. Mean (rounded to the nearest 0.1 kip) of the first three consecutive liftoff measurements falling within a 25 kip band.
2. Vertical tendon liftoff measured only at top (shop) end.
3. For vertical tendons $F_n = F_s$; for hoop & dome tendons, $F_n = (F_s + F_f) / 2$. F_n is rounded to the nearest kip.
4. Tendon force documented in the 15th Year Surveillance Report.
5. Increase in tendon force resulting from use of the revised procedure (per discussion in text) to determine liftoff force.

Table 6
20th Year Surveillance - Adjusted Tendon Force, Previously Reported Force & Difference

Tendon	Shop End Liftoff Force, kip, at 2nd Feeler Gage Withdrawal	Mean Shop End Force, F_s, kip (Note 1)	Field End Liftoff Force, kip, at 2nd Feeler Gage Withdrawal (Note 2)	Mean Field End Force, F_f, kip (Note 1)	Adjusted Tendon Force, F_n, kip (Note 3)	Previously Reported Tendon Force, F_o, kip (Note 4)	$\Delta F = F_n - F_o$, kip (Note 5)
V32	1207		N/A				
	1211		N/A				
	1211	1209.7	N/A	N/A	1210	1204	6
V78	1304		N/A				
	1304		N/A				
	1309	1305.7	N/A	N/A	1306	1289	17
V126	1207		N/A				
	1220		N/A				
	1199	1208.7	N/A	N/A	1209	1205	4
H24-40	1137		1129				
	1133		1129				
	1133	1134.3	1129	1129.0	1132	1128	4
H35-23	1233		1178				
	1222		1171				
	1226	1227.0	1171	1173.3	1200	1184*	16
H35-47	1195		1191				
	1191		1191				
	1191	1192.3	1191	1191.0	1192	1182	10
H62-26	1157		1169				
	1149		1169				
	1151	1152.3	1169	1169.0	1161	1146**	15
H62-49	1180		1156				
	1180		1149				
	1180	1180.0	1135	1146.7	1163	1145**	18

* Based on the last 3 of 8 liftoff measurements (adjusted force based on first 3). See discussion in text.

** Based on final 3 liftoffs (adjusted force based on first 3). See discussion in text.

Notes:

1. Mean (rounded to the nearest 0.1 kip) of the first three consecutive liftoff measurements falling within a 25 kip band.
2. Vertical tendon liftoff measured only at top (shop) end.
3. For vertical tendons $F_n = F_s$; for hoop & dome tendons, $F_n = (F_s + F_f) / 2$. F_n is rounded to the nearest kip.
4. Tendon force documented in the 20th Year Surveillance Report.
5. Increase in tendon force resulting from use of the revised procedure (per discussion in text) to determine liftoff force.

Table 6 (cont'd)
20th Year Surveillance - Adjusted Tendon Force, Previously Reported Force & Difference

Tendon	Shop End Liftoff Force, kip, at 2nd Feeler Gage Withdrawal	Mean Shop End Force, F_s, kip (Note 1)	Field End Liftoff Force, kip, at 2nd Feeler Gage Withdrawal (Note 2)	Mean Field End Force, F_f, kip (Note 1)	Adjusted Tendon Force, F_n, kip (Note 3)	Previously Reported Tendon Force, F_o, kip (Note 4)	$\Delta F = F_n - F_o$, kip (Note 5)
	1166		1165				
D141	1162		1165				
	1164	1164.0	1161	1163.7	1164	1161	3
	1119		1124				
D225	1115		1124				
	1117	1117.0	1124	1124.0	1120	1114	6
	1191		1214				
D248	1191		1214				
	1187	1189.7	1214	1214.0	1202	1188	14

Notes:

1. Mean (rounded to the nearest 0.1 kip) of the first three consecutive liftoff measurements falling within a 25 kip band.
2. Vertical tendon liftoff measured only at top (shop) end.
3. For vertical tendons $F_n = F_s$; for hoop & dome tendons, $F_n = (F_s + F_f) / 2$. F_n is rounded to the nearest kip.
4. Tendon force documented in the 20th Year Surveillance Report.
5. Increase in tendon force resulting from use of the revised procedure (per discussion in text) to determine liftoff force.

5.2 Tabular Summary of Adjusted Forces

The adjusted (as applicable) vertical, hoop and dome tendon forces are summarized in Tables 7, 8 & 9, respectively, which follow. Forces for the 1st, 3rd & 5th Year Surveillances are as shown in the applicable reports listed in Section 7, References. Adjusted forces for the 10th, 15th & 20th Year Surveillances are from Tables 4, 5 & 6. Those for the 25th Year Surveillance, which required no adjustment, are from Table 2,

The time since the Structural Integrity Test (SIT) shown in the second column of these tables is determined by the number of months from Mar 74 (when the SIT was performed) to the month including the midpoint the surveillance in question. The surveillance midpoint is considered to be the date midway between the initial and final as-found liftoff dates. Time in years is the number of months divided by 12 and rounded to the nearest 0.1.

Table 7
Summary of Adjusted Vertical Tendon Forces

Surveillance Year	Time since SIT, Years	Tendon	Adjusted Force, kip
1	1.2	V16	1348
		V27	1285
		V61	1306
		V86	1285
		V158	1306
3	3.6	V24	1283
		V48	1275
		V72	1258
		V97	1258
		V119	1209
5	6.2	V18	1274
		V31	1147
		V55	1211
		V105	1253
		V138	1211
10	11.2	V14	1243
		V30	1193
		V32	1196
		V84	1189
		V160	1192
15	15.6	V19	1187
		V21	1196
		V22	1171
		V23	1175
		V50	1213
		V83	1196
		V84	*
		V85	1179
20	20.6	V32	1210
		V78	1306
		V126	1209
25	25.5	V32	1193
		V40	1202
		V114	1189
		V164	1181

* V84 was selected as a sample tendon for the 15th Year Surveillance. However, since the V84 shim stack was reset during the 10th Year Surveillance, it is not a valid sample tendon for any subsequent surveillance. Therefore, 15th Year Surveillance data for this tendon is not listed in the table and is not used in trend computations.

Table 8
Summary of Adjusted Hoop Tendon Forces

Surveillance Year	Time since SIT	Tendon	Adjusted Force, kip
1	1.2	H13-28	1261
		H13-34	1273
		H13-46	1260
		H24-21	1267
		H24-47	1280
		H35-10	1259
		H35-28	1282
		H51-12	1293
		H62-10	1272
		H62-16	1253
3	3.6	H24-19	1105
		H24-48	1194
		H35-11	1242
		H35-29	1219
		H46-24	1225
		H46-28	1206
		H51-13	1217
		H62-11	1163
		H62-47	1113
		H62-53	1177
5	6.2	H24-20	1253
		H24-28	1243
		H24-49	1191
		H35-16	1221
		H46-30	1243
		H46-32	1253
		H51-11	1243
		H62-10	*
		H62-28	1243
		H62-51	1222
10	11.2	H13-35	1191
		H13-36	1066
		H13-37	1182
		H24-26	1173
		H35-26	1156
		H62-26	1145
		H62-30	1152
15	15.6	H24-29	1072
		H24-30	1139
		H24-31	1114
		H24-51	1142
		H46-34	1177
		H62-13	1088
		H62-26	1128

* H62-10 was selected as a sample tendon for the 5th Year Surveillance. However, since H62-10 was detensioned/retensioined during the 1st Year Surveillance, it is not a valid sample tendon for any subsequent surveillance Therefore, 5th Year Surveillance data for this tendon is not listed in the table and is not used in trend computations.

Table 8 (cont'd)
Summary of Adjusted Hoop Tendon Forces

Surveillance Year	Time since SIT	Tendon	Adjusted Force, kip
20	20.6	H24-40	1132
		H35-23	1200
		H35-47	1192
		H62-26	1161
		H62-49	1163
25	25.5	H13-50	1159
		H35-33	1169
		H46-37	1129
		H51-43	1170
		H62-26	1136

Table 9
Summary of Adjusted Dome Tendon Forces

Surveillance Year	Time since SIT	Tendon	Adjusted Force, kip
1	1.2	D101	1252
		D116	1259
		D201	1278
		D220	1253
		D301	1269
		D316	1259
3	3.6	D130	1252
		D148	1226
		D202	1273
		D219	1226
		D334	1247
		D348	1226
5	6.2	D131	1180
		D147	1180
		D203	1159
		D218	1137
		D336	1221
		D346	1169
10	11.2	D133	1107
		D225	1125
		D314	1290
15	15.6	D145	1220
		D218	*
		D347	1183
20	20.6	D141	1164
		D225	1120
		D248	1202
25	25.5	D102	1280
		D225	1104
		D313	1120

* D218 was selected as a sample tendon for the 15th Year Surveillance. However, since D218 was detensioned/retensioned during the 5th Year Surveillance, it is not a valid sample tendon for any subsequent surveillance. Therefore, 15th Year Surveillance data for this tendon is not listed in the table and is not used in trend computations.

5.3 Tendon Force Trends

Figures 1, 2 & 3 are, respectively, plots of vertical, hoop and dome tendon forces vs. the log of time since the Structural Integrity Test (SIT). The SIT date is selected as the starting point for time since both Regulatory Guide 1.35 and Subsection IWL use this date as the basis for scheduling post-tensioning system in-service inspections. The logarithmic scale is used for the horizontal axis since time dependent losses (concrete creep, concrete shrinkage and tendon stress relaxation) are generally postulated to follow exponential relationships. Therefore, tendon force is expected to decrease in a relatively linear fashion with the log of time (but, in fact, does not as discussed below). The numerical data used to construct the plots is that listed in Tables 7, 8 & 9. The plotted forces are not normalized.

The plots include trend lines and lines representing minimum required mean tendon force. The trend lines, provided only for information as discussed in (c) below, are constructed using the method of least squares (a statistical procedure described in Reference 20 or any standard statistics text). The minimum required mean tendon force levels are those listed in FSAR Par. 5.7.5.2.3.f, Update 15.

All of these plots are similar in two major respects. First, the tendon force data is quite scattered. Second, the rate of decrease (kips / log time) in tendon forces appears to be substantially less in later years than in earlier years. The significance of these plot aspects is discussed below.

(a) Data Scatter

The magnitude of the scatter of the individual tendon forces about the fitted trend lines is on the order of the overall decrease in mean forces (based on trend line slopes) over the 24 year period covered by the data. As a result, the 'true' (in the statistical sense) trends have a high probability of deviating significantly from those represented by the fitted lines. Therefore, even if the 'true' trends were known to follow a log-linear relationship, the fitted lines could not be considered accurate representations of those trends.

When scatter is relatively large, as is typically the case when measured tendon forces are plotted, statistically determined bounds are generally used to used to define a confidence interval for the 'true' trend. Lower bounds on projected tendon forces are computed later in this Subsection. The procedure used to compute these bounds is described in Reference 20.

Figure 1
Vertical Tendon Force Trend

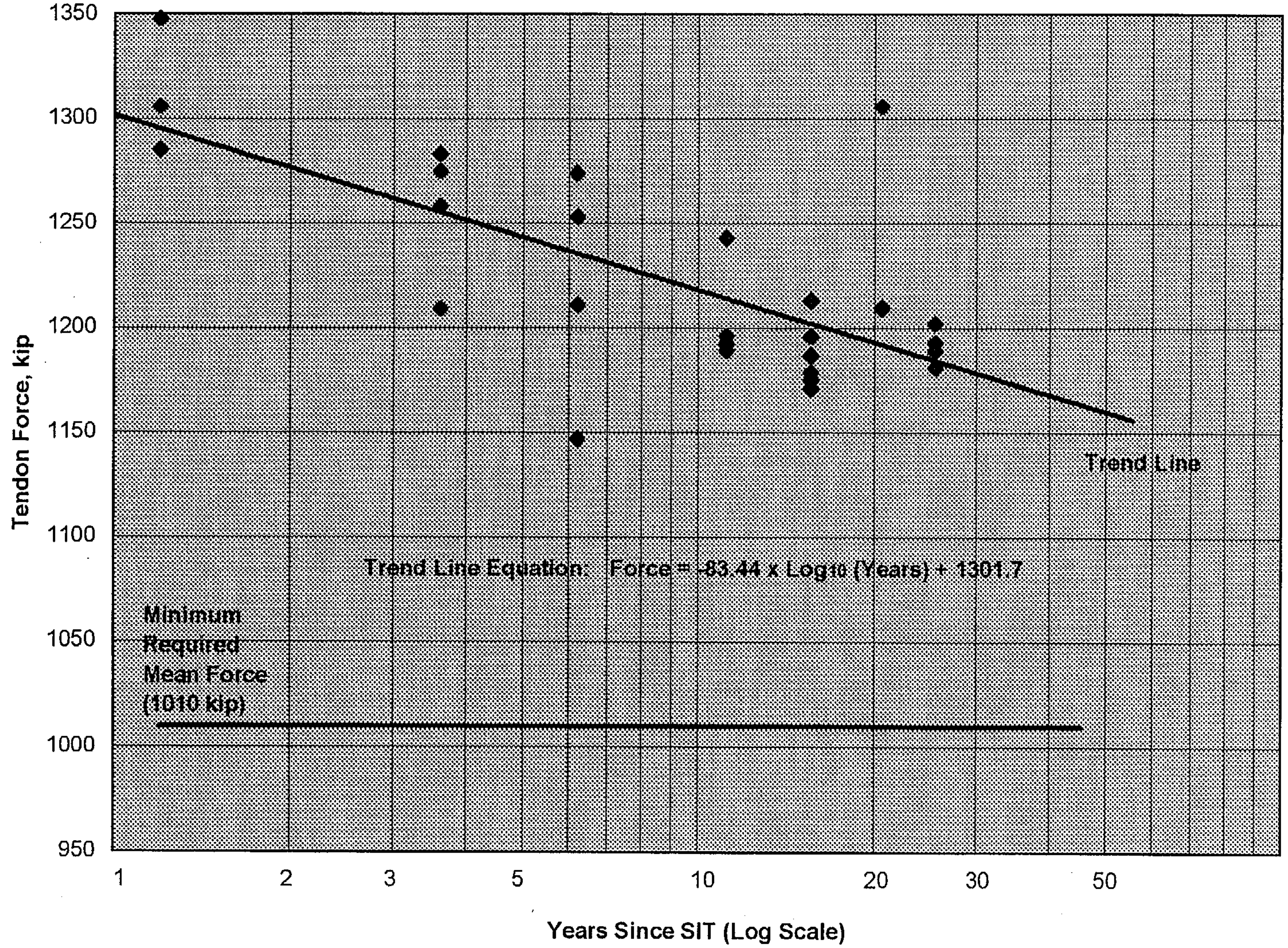


Figure 2
Hoop Tendon Force Trend

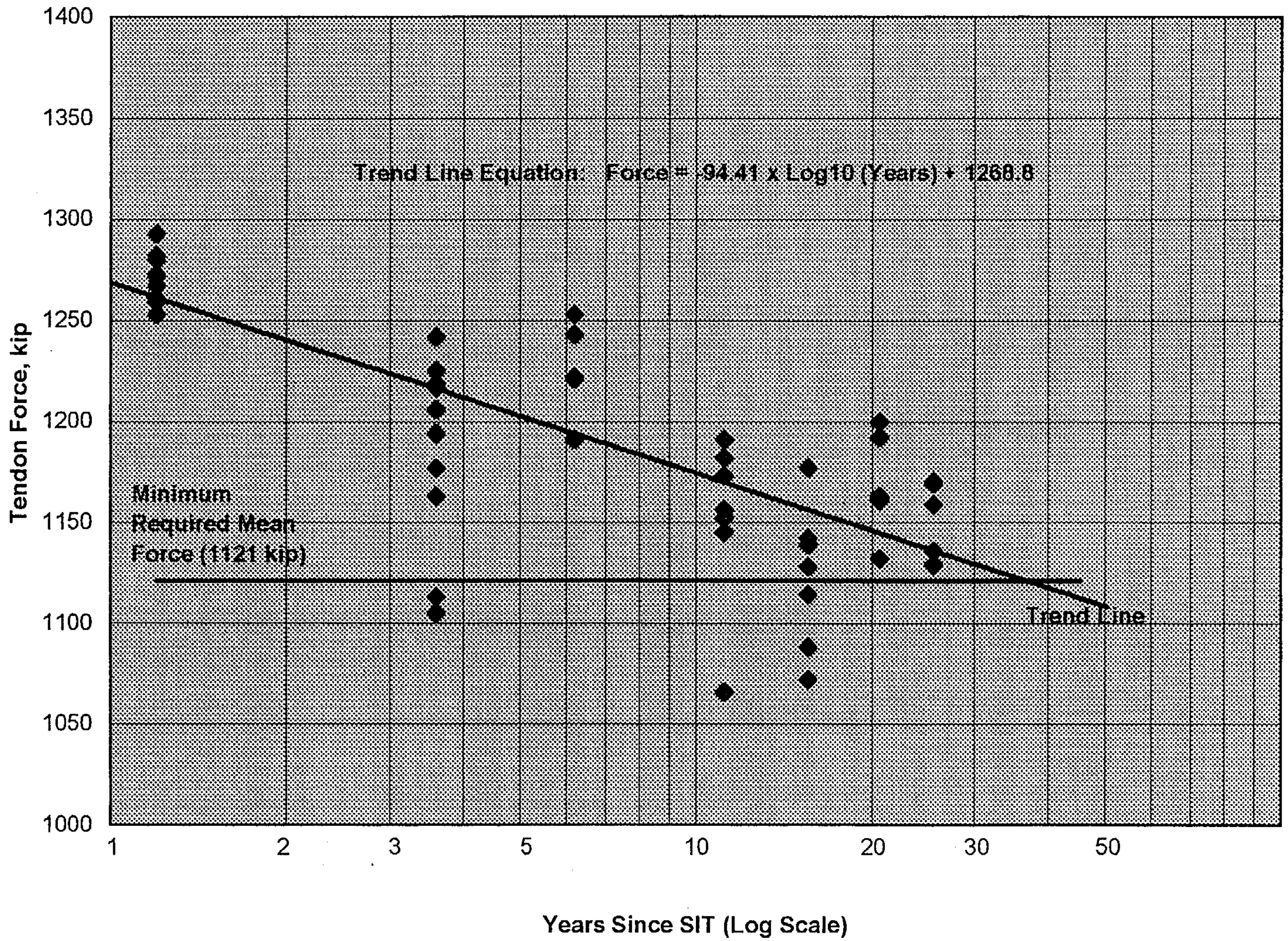
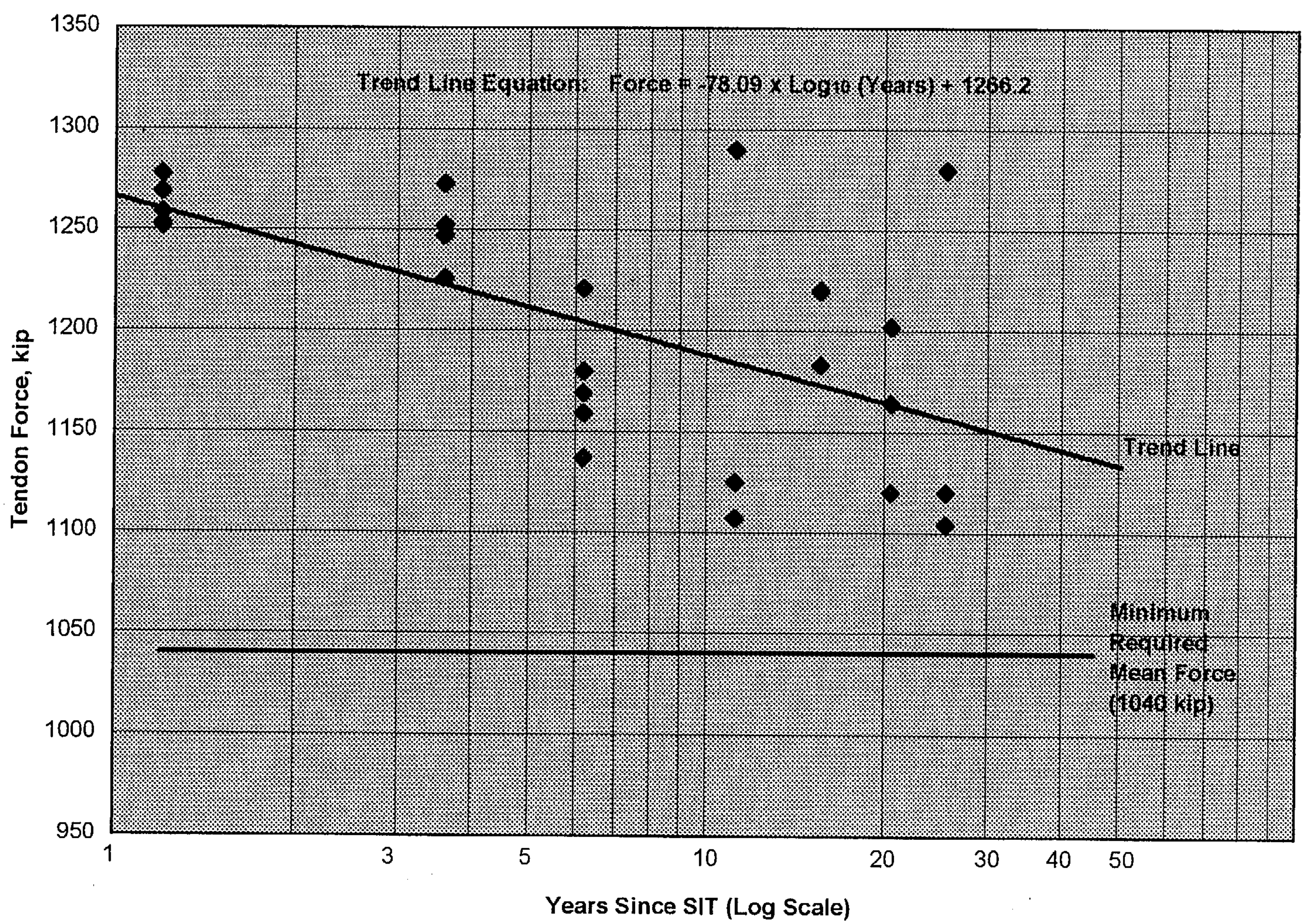


Figure 3
Dome Tendon Force Trend



(b) Data Trends

A visual examination of data plotted in Figures 1, 2 & 3 can easily lead to the conclusion that the decrease in tendon force is not linear with the logarithm of time. In all three plots, the rate of change of force appears to decrease as the logarithm of time increases. As a result, the trend lines shown on the plots exaggerate the rates of loss in later years (and provide underestimates of the loss rates in early years).

Various curves (exponential and other) could be fitted to the data. Any such curve (which can bend to conform to the data trend) will fit the data better than a straight line in the sense that the variance about the curve will be less than that about the line. However, no such curve will be particularly meaningful since the scatter of the data is so large.

For this reason, specific non-linear relationships between tendon force and the logarithm of time are not considered in this report. Instead, the 'true' trend (an undefined curvilinear relationship) is considered to be closely approximated by a linear relationship over the log time interval from 11 years to 31 years (the latest time for completion of the next surveillance per IWL requirements). Lower bound forces at Year 31 are then computed for a 95% confidence level.

The above procedure and the results are described in subsequent paragraphs. The 11 year (Surveillance Year 10) data is used as the starting point for the linear approximation. This is done since 11 to 25 years (the final data are for Year 25) covers only one fourth of the overall logarithmic interval from 1 to 25 years and there is no marked curvilinear trend to the data over 11 to 25 year time span. The 11 to 25 year interval is still significant since it includes 60% of the total (linear) time spanned by the surveillance data. Also, procedures and results from Surveillance Year 10 forward are fully documented, which ensures a consistent basis for all data used in the linear analysis. Linear extrapolating to 31 years is reasonable since the Log time increment from 25 to 31 years is only one fourth of the Log time span from 11 to 25 years.

(c) Overall Linear Trends

For the reasons discussed above, the trend lines shown on Figures 1, 2 & 3 are provided for information only. However, this type of log-linear trending is, despite the drawbacks, an accepted method for establishing the future levels of tendon group mean forces. Therefore, the trends shown are discussed below.

Figures 1 & 3 show that all vertical and dome tendon forces measured to date are well above the minimum required mean forces specified in FSAR Par. 5.7.5.2.3.f (Update 15). In addition, the trend lines remain well above the applicable minima for many decades after the current TMI-1 operating license expires. It can, therefore, be concluded that the mean levels of force in the vertical and dome tendon groups will not fall below the respective minima prior to the next surveillance or, in fact, prior to any surveillance performed during the period of validity of the current operating license.

Figure 2 shows the mean hoop tendon force falling below the 1121 kip minimum some time after Year 35. The computed crossover is at 36.8 years per the trend line equation, Force = 1268.8 – 94.41 Log (Years), where Log is the symbol for a base 10 logarithm. Further, at Year 31 (the latest date for completion of the next surveillance per IWL) the computed hoop tendon mean force is 1128 kip. This projected force is 7 kips above the 1121 kip minimum.

In anticipation that the 25th Year Surveillance hoop tendon sample mean force could be marginal, TMI-1 recently recalculated the minimum required mean forces for all three tendon groups. This calculation (as documented in EER JO # 162193 with appended calc C-1101-153-E410-028) was considerably more detailed than the original design calculation. It was done to ensure an easily auditable basis for acceptance limits should the mean force levels be close to those limits.

The recalculated minimum required group mean forces differ somewhat from those determined by the original design calculation and currently specified as acceptance limits in FSAR Par. 5.7.5.2.3.f (Update 15). It is expected that the current FSAR acceptance limits will be replaced with the new values. However, since this FSAR change must be submitted to and reviewed by the NRC, it could not be completed in time to apply to the 25th Year Surveillance. Nonetheless, it is reasonable to compare the surveillance results to the proposed new minimum required mean forces. Therefore, the proposed values are listed below for information and reference.

The original and proposed minimum required mean forces are listed in Table 10 below.

Table 10
Minimum Required Group Mean Forces per Original Design & New Calculations

Tendon Group	Minimum Required Mean Force, kip	
	Original Design Calculation	New Calculation (for Information & Reference Only)
Vertical	1010	1033
Hoop	1121	1108
Dome	1040	1064

The newly calculated minimum required vertical and dome group mean forces are somewhat greater than those given in the original design calculation and specified in the FSAR. However, even if the new values are used in Figures 1 & 3, the conclusions regarding trend, as stated above, remain unchanged. Also, the current sample means are still well above the revised minima.

The newly calculated minimum required mean hoop force is 13 kips below the originally determined value. As a result, the Year 31 margin based on the new minimum increases from 7 kips to 20 kips. Also, the trend line intersects the new minimum at 50.5 years instead of 36.8 years. Therefore, if the new minimum is applied, hoop tendon mean force trend appears acceptable with ample margin until well beyond the completion deadline for the 30th Year Surveillance.

In summary, it can be concluded that tendon force trends determined by the above conventional approach are acceptable and allow continued plant operation at least until the results of the 30th Year Surveillance are in hand. This conclusion applies for both currently specified and newly calculated acceptance limits.

(d) Statistical Limits on Trended Forces

The conventional approach discussed in (c) above is open to the following technical challenges.

- Close examination of Figures 1, 2 & 3 leads to the conclusion that the rate of tendon force loss decreases as the logarithm of time increases. This suggests that an exponential (or similar) curve would fit the data better than a straight line.

  The least squares fit method can be used to fit any type of curve to a given set of data. The method itself does not determine the type of curve that provides the best fit. The choice of curve must be made by the individual(s) applying the method. The choice can be made based on the appearance of the data or on basic engineering principles.

In the present case, it is concluded that a straight line is not the best curve to represent the change in tendon force with the logarithm of time. Engineering principles may suggest the use of a linear fit. However, the time span covered by the surveillance data is about 24 years. The tests performed on the concrete and steel specimens to establish time dependent material properties (creep, shrinkage and stress relaxation) were completed in a year or less. It is possible that time dependent material properties are not the same in the long and short term. Therefore, the appearance of the data rather than material properties determined by short term tests should guide the selection of curve type.

- The 10th through 25th Year Surveillance data are supported by extensive and complete documentation covering the measurement of liftoff forces. As a result, there is a high degree of assurance that the tendon forces determined during these surveillance years are accurately measured and have a common basis (after the adjustments discussed in Subsection 5.1).

  Documentation covering the first three surveillances is less complete and does not describe the procedure used to determine liftoff force. As a result, there is no assurance that the tendon forces reported for these surveillances conform to the same basis (verification, by the feeler gage method, that both sides of the shim stack are loose) as those reported for the 10th through 25th Year Surveillances.

  Therefore, tendon forces reported for the first three surveillances could introduce errors of unknown magnitude into trend computations. For this reason the 1st, 3rd & 5th Year Surveillance results should not be used in the computation of future force levels.

- The data plotted in Figures 1, 2 & 3 exhibit a relatively high degree of scatter. As a result, the 'true' (in the statistical sense) trend has a relatively high probability of differing significantly from that represented by any fitted line. Since a fitted line has little practical significance when scatter is large, the 'true' trend of scattered data is generally defined by statistically derived bounds.

The statistical bound approach is developed in Section 12.2 of Reference 20 and should be covered in the curve fitting (or regression analysis) section of any similar statistics text . When this approach is used, the value of the dependent variable (in this case, tendon force) is not defined as a specific function of the independent variable (in this case, log time). It is, instead, defined by its probability of falling within (or above or below) computed limits.

The statistical bound approach is currently applied to one aspect of containment safety by 10CFR50, Appendix J. This regulation requires (by a reference to ANSI/ANS 56.8) that containment leakage rate be reported at the upper 95% confidence limit. Thus, the leakage rate reported is neither the 'true' rate, which is unknown, nor the rate determined by the slope of the fitted line. It is, rather, a rate which the 'true' rate has only a 5% probability of exceeding. Or, in other words, there is a 95% probability that the 'true' rate will not exceed the computed upper 95% confidence limit.

Application of the statistical bound approach requires only two assumptions. First, the nature (linear, exponential or other) of the 'true' trend must be specified. Second, the dependent variable is assumed to be normally distributed about the 'true' trend. The first assumption is not a significant limitation if the trend can be approximated as a linear function over some time segment of interest. The second assumption is generally valid if the deviations of the dependent variable are the result of random variations in various uncontrolled parameters.

In the following paragraphs, statistical lower bounds for group mean forces at Year 31 are computed using tendon forces determined during the 10th, 15th, 20th and 25th Year Surveillances. While the overall trend of group mean force is considered to be non-linear, that segment of the trend between Years 11 & 31 can be reasonably approximated as a straight line. The results of the 1st, 3rd & 5th Year Surveillances are not used in the computation for the following two reasons.

- As discussed above, the basis for computing the forces documented in the 1st, 3rd & 5th Year Surveillance Reports is not well defined.
- Also, as discussed above, the overall trend is non-linear. However, if the results of the first 3 surveillances are not considered, it should be possible to closely approximate the remaining segment of the trend as a straight line (this region of the data shows no noticeable curvilinear trend in any of the plots). The length of the Log time interval between Years 11 and 25 (the final data are for Year 25) is, in fact, only one fourth of the length of the total Log time interval from Years 1 to 25. Extrapolating the linear assumption to Year 31 increases the length of the Log time segment by a relatively small amount (Log 25 - Log 11 = 0.357 & Log 31 - Log 11 = 0.450). As a result, if the linear approximation is valid from Years 11 to 25, it should be almost equally valid from Years 11 to 31.

Bounds are computed for Year 31 since the next surveillance (30th Year Surveillance) must be completed by this time. Bounds are computed at the 95% confidence level since this level is applied to numerous nuclear plant safety issues and, in particular, to the reporting of containment leakage rate as discussed earlier. The lower bound at the 95% confidence level is subsequently referred to as the LCL (lower 95% confidence limit).

The LCL on mean tendon force at a time T (with X = Log T) years after the SIT is given by the following expression as developed in Section 12.2 of Reference 20. T is limited to the range of 11 to 31 years in accordance with the assumption that the trend may be approximated by a linear function over this time interval.

$$\text{LCL (kips)} = a + b \times X - t_{0.05} \times s_e \times \sqrt{[1/n + n \times (X - X_m)^2 / S_{xx}]}$$

where (with all summations from 1 to n):

$a = Y_m - b \times X_m$ is the intercept of the least squares fit trend line
$Y_m = (\Sigma Y_i) / n$
$X_m = (\Sigma X_i) / n$
X_i , Y_i are data sets with X = Log (T) and Y = tendon force in kip
T is time in years since the SIT (limited to the range 11 - 31 per linearity assumption)
$b = S_{xy} / S_{xx}$ is the slope of the slope of the least squares fit trend line
$t_{0.05}$ is Student's t statistic[1] for a 95% confidence level and (n-2) degrees of freedom
$s_e = \sqrt{\{[S_{xx} \times S_{yy} - (S_{xy})^2] / [n \times (n - 2) \times S_{xx}]\}}$ is the standard error of estimate
n is the number of data sets used in the LCL calculation
$S_{xx} = n \times \Sigma X_i^2 - (\Sigma X_i)^2$
$S_{yy} = n \times \Sigma Y_i^2 - (\Sigma Y_i)^2$
$S_{xy} = n \times \Sigma (X_i \times Y_i) - (\Sigma X_i) \times (\Sigma Y_i)$

Values of the LCL for the vertical, hoop and dome tendons at Year 31 (March 2005) were computed using a short BASIC algorithm and the data for Surveillance Years 10-25 as compiled in Tables 7, 8 & 9. These LCL values and the corresponding acceptance limits are listed in Table 11

[1] Numerical values for Student's t statistic are given in Table IV of Reference 20 and in many other statistics texts.

below. Both the current (FSAR Par. 5.7.5.2.3.f) and proposed (EER JO # 162193 & Calculation C-1101-153-E410-028) acceptance limits are listed.

Table 11
March 2005 Lower Bound Mean Forces at the 95% Confidence Level

Tendon Group	LCL, kip	Lower Acceptance Limits, kip	
		Current Per FSAR	Proposed (for Information & Reference Only)
Vertical	1177	1010	1033
Hoop	1128	1121	1108
Dome	1085	1040	1064

All lower bound forces are acceptable, using either current or proposed limits, as is shown by the entries in the table.

(e) Control Tendons

All but one of the sample tendons in each group are randomly selected from a population that excludes tendons previously examined. One tendon in each group is retained as a common, or control, tendon. Control tendons are examined during each surveillance (although, in rare instances, plant operating conditions prohibit the examination and require a substitution).

Control tendons are not detensioned unless this is required per IWL-3300, in which case a new control tendon is selected in accordance with the intent of IWL-2521(b). IWL-2521(b) requires control tendons to be selected from the 1st Year Surveillance sample. However, since all sample tendons were detensioned during the 1st, 3rd & 5th Year Surveillances, these cannot be used as control tendons. Therefore, the intent of IWL-2521(b) is followed by selecting control tendons from the 10th Year Surveillance sample.

The current control tendons are V32, H62-26 and D225. V32 was selected as a control tendon during the 20th Year Surveillance to replace previously selected control tendon V84. The force in V84 was found to be below 90% of the base value during the 15th Year Surveillance. As a result, the force in V84 had to be increased to an acceptable level and it could no longer be used as a control tendon. V32 was not examined during the 15th Year Surveillance. Also, D225 was not examined during the 15th Year Surveillance.

Control tendon forces, which are not normalized, are summarized in Table 12 below.

Table 12
Control Tendon Forces (Adjusted as Required), kip

Tendon	Surveillance Year			
	10th	15th	20th	25th
V32	1196	N/A	1210	1193
H62-26	1145	1128	1161	1136
D225	1125	N/A	1120	1104

The tendon forces shown in the table fall within relatively narrow bands. As expected, there is some scatter in the data. The bands are defined primarily by the scatter, which masks the underlying trends. However, since the bands are narrow, it is concluded that the actual trends are such that rates of vertical, hoop and dome tendon force loss are quite low. This reinforces the results of the statistical evaluation performed in (d) above. A similar statistical evaluation of the control tendon data would not be meaningful since there are so few data points.

Figures 4, 5 & 6, which follow, are plots of the vertical, hoop & dome, respectively, control tendon forces. These plots include trend lines and lines representing the predicted base force levels for the tendons. The trend lines are fitted to the log-linear data points by the method of least squares, which is discussed in 5.3. The predicted force lines pass through the Year 10 & Year 40 computed base values tabulated in Reference 11.

These plots confirm the conclusions (stated above) derived from examination of the data presented in Table 12. Vertical and hoop control tendon data are scattered, which obscures the true trends. These trends appear, however, to be relatively flat. The fitted trend lines slope up somewhat, but this is a consequence of scatter and should not be considered representative of true trend directions. Dome control tendon data exhibit relatively little scatter. Therefore, the line fitted to the dome control tendon data may be considered a reasonably good representation of the true trend.

The plotted data indicate that the forces in the control tendons are currently (since Surveillance Year 10) decreasing at rates that are below those predicted. This is consistent with the trends evident in Figures 1, 2 & 3. These show that the current rates of group average force decrease are well below those that would be predicted by extrapolation of the 1st, 3rd, 5th &10th Year Surveillance results.

Figure 4
Vertical Control Tendon (V32) Force Trend

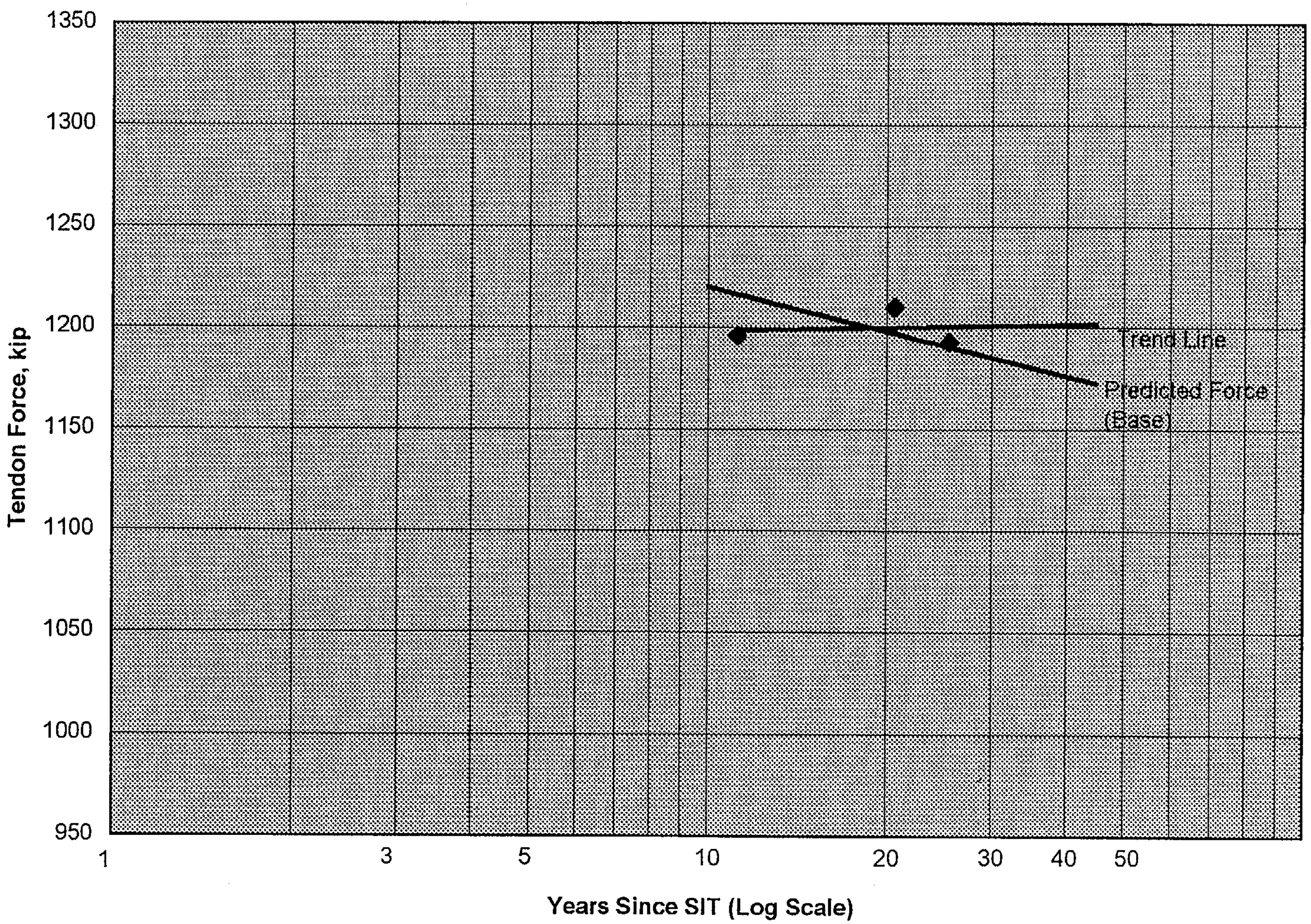


Figure 5
Hoop Control Tendon (H62-26) Force Trend

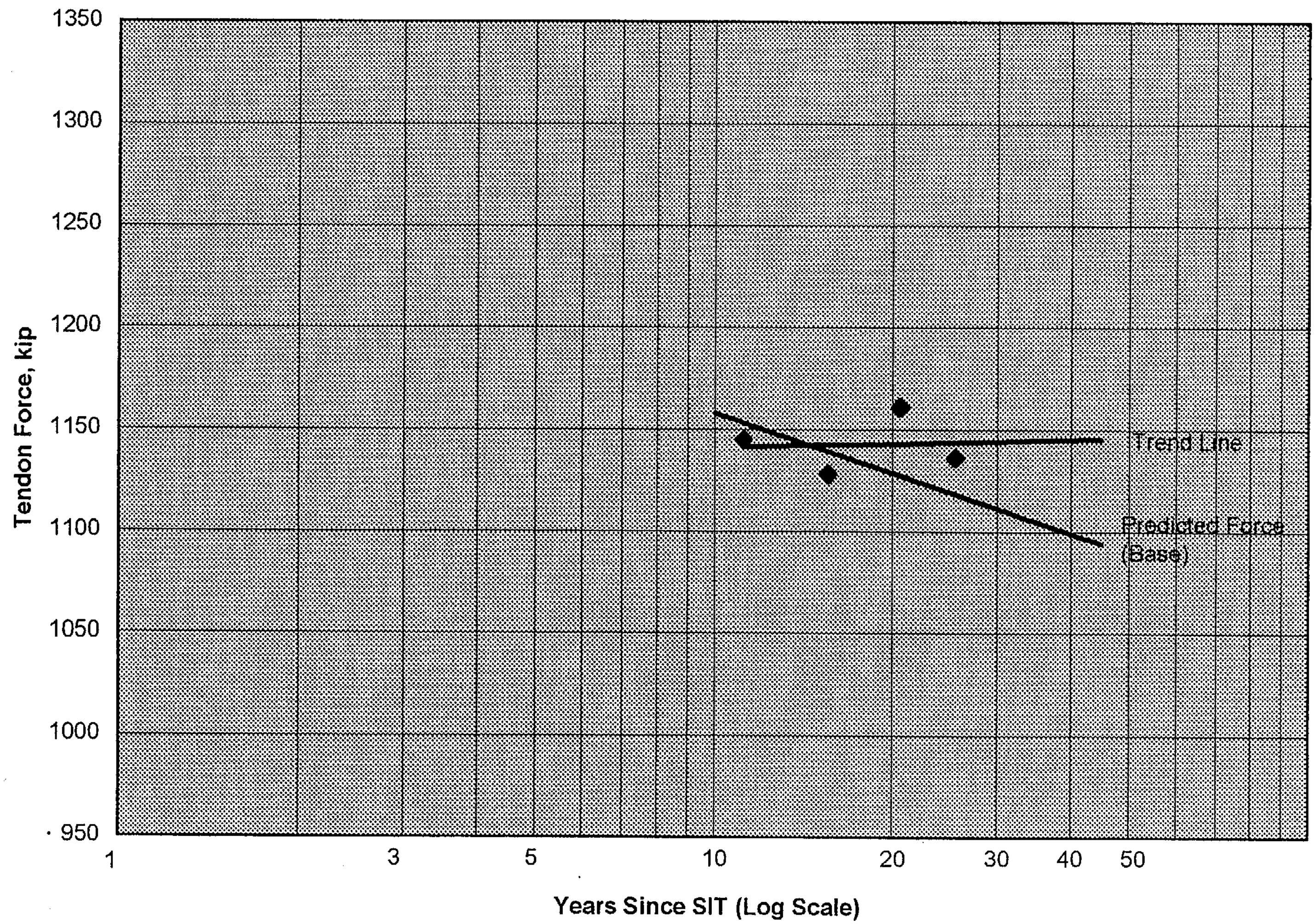
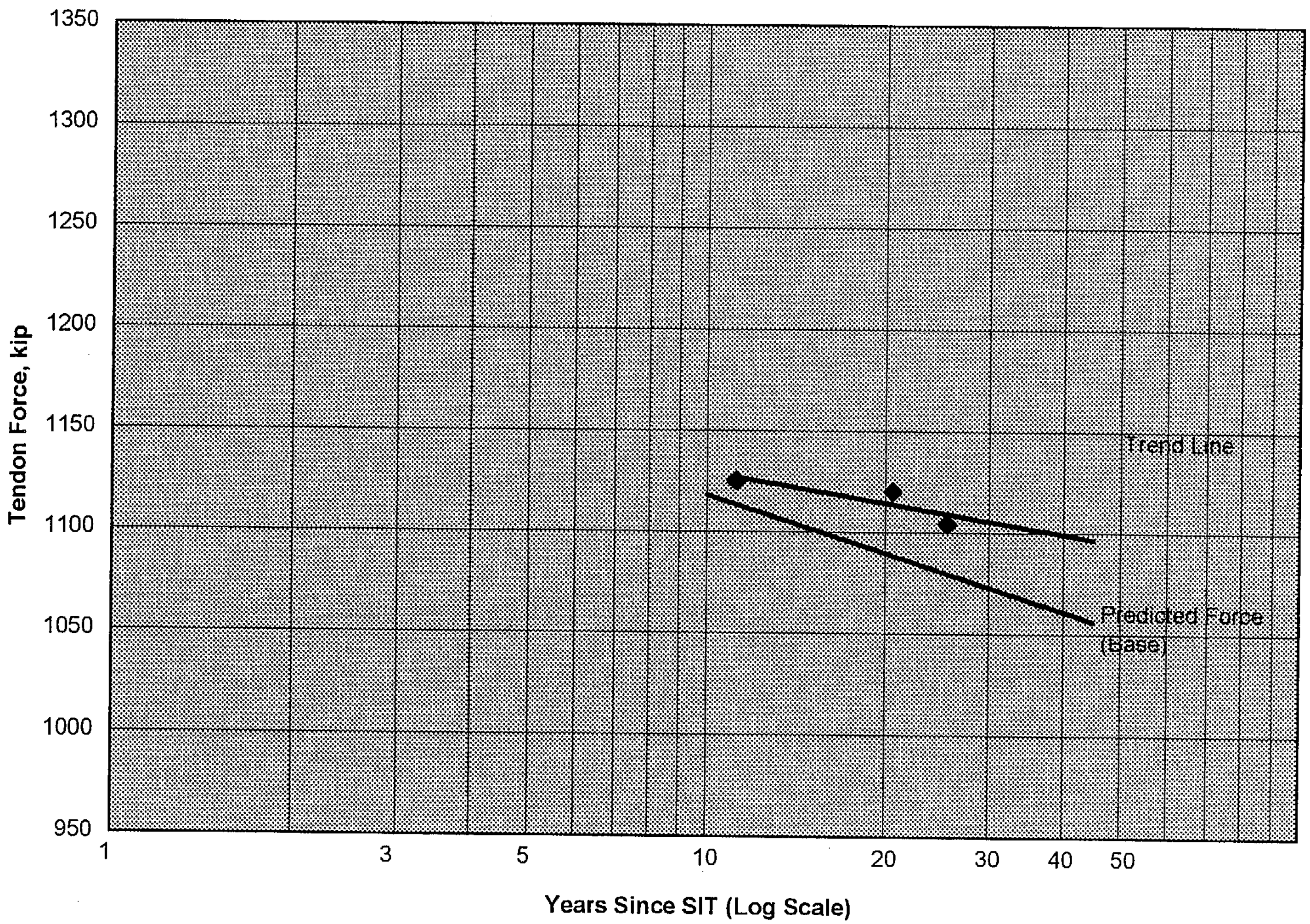


Figure 6
Dome Control Tendon (D225) Force Trend



6. Tendon Elongation

Both Regulatory Guide 1.35 (Revision 3) and 10CFR50.55a as amended effective 9 Sep 96 require tendon elongation measured during retensioning to be within 10% of that previously measured. Elongation is measured to ensure that there are neither restrictions in the tendon duct nor a significant number of broken wires.

Elongations of the three tendons (V164, H13-50 and D102) detensioned during the 25th Year Surveillance were measured during retensioning. Attachment 3 documents the elongations measured during retensioning as well as those recorded during construction (the only prior measurements for these tendons). Measurements are summarized in Table 13 below.

Entries in this table are:

- PTF (Pre-Tension Force) is a small force (on the order of 1 kip per wire) applied to ensure that all slack is removed form the tendon and that wires are seated at the face of the stressing washer. The PTF shown is the average of the individual forces applied at the shop and field ends of hoop and dome tendons and is equal to the single force applied at the shop (upper) end of the vertical tendon, which is tensioned only at this end.

- OSF (Over Stress Force) is the maximum load applied to the tendon. It is typically close to 80% of tendon ultimate strength. The OSF shown is the average of the individual forces applied at the shop and field ends of the hoop and dome tendons and is equal to the single force applied at the shop (upper) end of the vertical tendon, which is tensioned only at this end.

- Elongations @ PTF & @ OSF are the sums of the measured distances from the bearing plates to the shop and field (hoop & dome tendons) end jack coupler faces or the single measured distance from the bearing plate to the shop end coupler face (vertical tendon). The separate @ PTF & @ OSF elongations are entered only for the 25th Year Surveillance. Attachment 3 summarizes construction record data and lists only the net elongation (elongation @ OSF less that @ PTF) determined during initial tendon stressing. It does not list the separate @ OSF & @ PTF values. Therefore, for the construction phase, the table lists only the net elongations; the spaces for the separate @ PTF & @ OSF values are marked N/A.

- Net force is the force @ OSF less the force @ PTF.

- Net elongation is the elongation @ OSF less the elongation @ PTF (25th Year Surveillance) or the value reported in Attachment 3 (construction).

For consistency of presentation, all forces are rounded to the nearest kip and all elongations are rounded to the nearest 0.1 inch.

Table 13
Tendon Elongation Summary

Tendon	Phase	Parameter	@ PTF	@ OSF	Net
V164	Construction	Force, kip	210	1479	1269
		Elongation, in	N/A	N/A	12.4
	25th Year Surveillance	Force, kip	168	1584	1416
		Elongation, in	4.9	18.6	13.7
H13-50	Construction	Force, kip	210	1564	1354
		Elongation, in	N/A	N/A	10.6
	25th Year Surveillance	Force, kip	168	1584	1416
		Elongation, in	6.5	17.1	10.6
D102	Construction	Force, kip	210	1472	1262
		Elongation, in	N/A	N/A	6.8
	25th Year Surveillance	Force, kip	168	1584	1416
		Elongation, in	5.4	13.1	7.7

The @ PTF forces applied during construction are uniformly greater (by 42 kips) than those applied during the 25th Year Surveillance. Also, the @ OSF forces applied to the vertical and dome tendons during construction are significantly less (just over 100 kips less) than those applied during the 25th Year Surveillance. As a result, the net forces listed for the construction phase are all less than those listed for the 25th Year Surveillance. To compare net elongations on the same basis, those listed for the construction phase are adjusted for both force differences and the effect of removing a sample wire prior to retensioning. Since elongation is a linear function of jacking force, the adjustment factor is the ratio of the net force applied during the 25th Year Surveillance to the net force applied during construction times the correction factor for the difference in the number of wires. The wire correction factor is 169/168 = 1.006. Table 14 below shows the adjusted construction net elongations and percentage differences between these and the 25th Year Surveillance net elongations.

Table 14
Comparison of Adjusted Elongations

Tendon	Measured Construction Net Elongation, in.	Adjustment Factor (Note 1)	Adjusted Construction Net Elongation, in. (Note 2)	25th Year Surveillance Net Elongation, in.	Percentage Difference (Note 3)
V164	12.4	1416/1269 x 1.006	13.9	13.7	-1%
H13-50	10.6	1416/1354 x 1.006	11.2	10.6	-5%
D102	6.8	1416/1262 x 1.006	7.7	7.7	0%

Notes:

1. Adjustment factor is the ratio of the 25th Year Surveillance net force to the construction net force times 1.006 (correction for removal of one wire during the surveillance).
2. Adjusted construction net elongation is measured construction net elongation times the adjustment factor.
3. Percentage difference is 100 x (SE - CE) / CE

   where: SE is 25th Year Surveillance Net Elongation
   CE is Adjusted Construction Net Elongation

All differences shown in Table 14 are between +10% and -10%. Therefore, per 10CFR50.55a, these are acceptable without further evaluation.

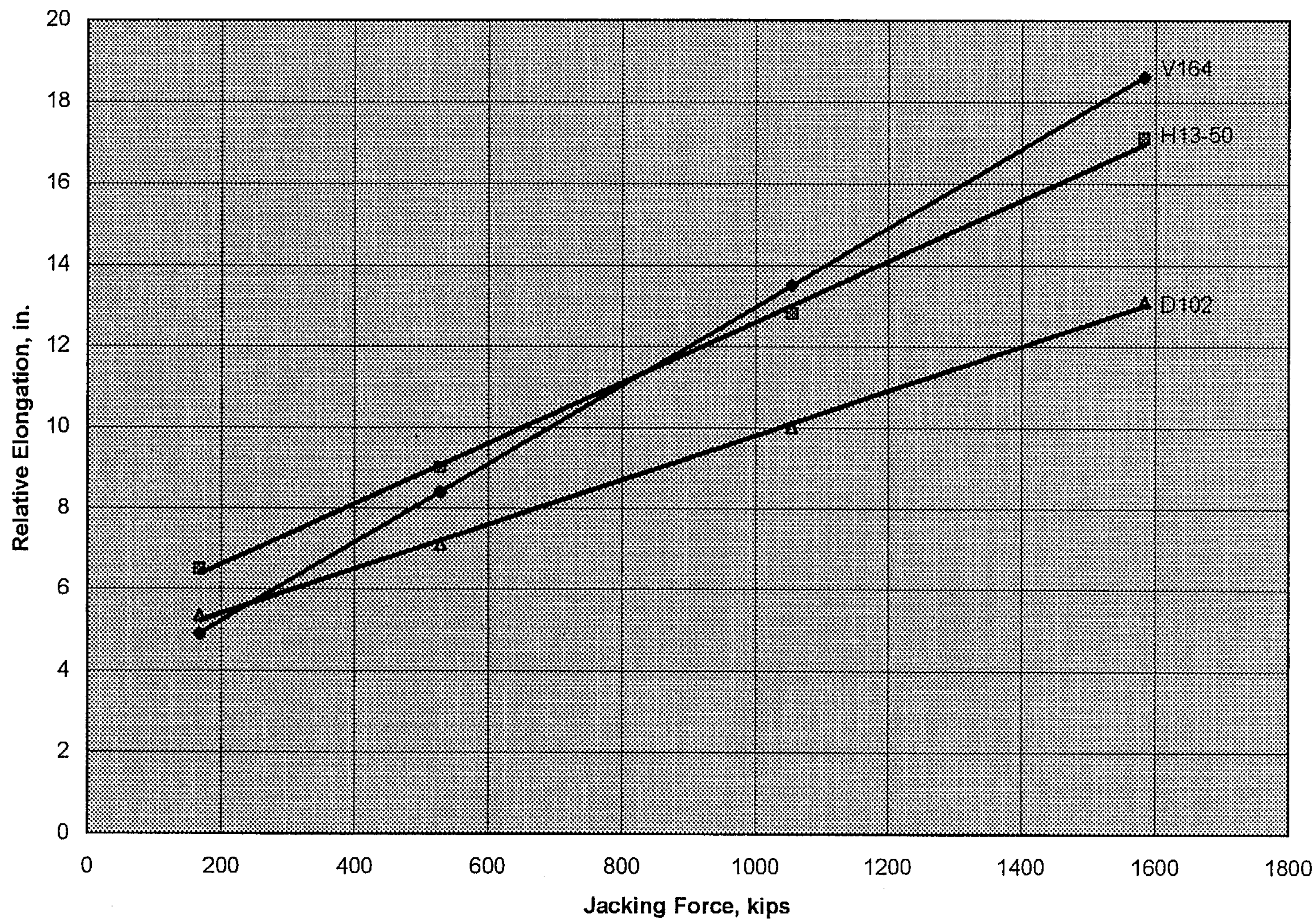
In accordance with the requirements of Reference 3, elongations were measured at two intermediate points between PTF and OSF. This was done to ensure that elongations are linear with force (which is one basis of the containment design calculations). These forces and relative elongations are recorded in Attachment 3 and listed in Table 15 below. Relative elongation is the sum of the distances from the bearing plates to shop and field end coupler faces (hoop & dome tendons) or the distance from the bearing plate to the shop end coupler face (vertical tendon).

Table 15
Incremental Force & Corresponding Relative Elongation Measured During Retensioning

Tendon	Elongation, in.			
	@PTF, 168 kips	@1/3 increment, 528 kips	@2/3 increment, 1055 kips	@OSF, 1583.5 kips
V164	4.90	8.40	13.50	18.60
H13-50	6.50	9.00	12.80	17.10
D102	5.35	7.10	10.00	13.10

Figure 7, which follows, plots the forces and relative elongations tabulated above. A line is fitted to the data for each tendon by the method of least squares (previously discussed). Data points are effectively on the fitted lines which verifies the expected linear relationship between elongation & force.

Figure 7 Tendon Elongation



7. References

The following documents (applicable sections as noted) were used in the preparation of this report and / or are specifically referenced herein.

1. 10CFR50.55a as amended effective 09 Sep 96.

2. ASME Boiler and Pressure Vessel Code (1992 Edition with Addenda through 1992), Section XI, Subsection IWL.

3. USNRC Regulatory Guide 1.35, Inservice Inspection of Ungrouted Tendons in Prestressed Concrete Containments, Revisions 1 & 3.

4. USNRC Regulatory Guide 1.35.1, Determining Prestressing Forces for Inspection of Prestressed Concrete Containments, Jul 90.

5. TMI-1 FSAR Section 5.7.5, Update 15.

6. TMI-1 Technical Specification Sections 3.19.1 & 4.4.2.1.

7. TMI-1 Surveillance Procedure 1301-9.1, Revisions 4, 6, 9 & 14.

8. TMI-1 EER JO # 162193, Rx Building Tendons, Minimum Required Prestressing Forces.

9. TMI-1 Calculation C-1101-153-E410-028, Rx Building Tendons, Minimum Required Prestressing Forces, Revision 0.

10. Deleted

11. Gilbert / Commonwealth Calculation DC-5390-225.01-SE, dated 26 Apr 94.

12. Gilbert / Commonwealth Letter (with attachments) G/C/TMI-1CS/16616, dated 27 Dec 88, Transmitting Tendon Stressing Record Data (ECD C-310055).

13. TMI-1, Reactor Containment Building / First Tendon Surveillance Test / One Year After SIT, GAI Report No. 1880, 29 Sep 75.

14. TMI-1, Second Tendon Surveillance Test of Reactor Containment Building / Three Years After SIT, VSL Corp. Report No. GQL 0204, Dec 77.

15. TMI-1, Containment Building Tendon Surveillance Test Report for Third Period (5 Years After SIT), TDR No. 229, 27 Mar 81.

16. TMI-1, Reactor Building Tendon Surveillance Test / Inspection Period 4 (10 Years), TR No. 025, 27 Aug 85.

17. TMI-1, Reactor Building Fifteen Year Tendon Surveillance Test (Inspection Period 5), Topical Report 069, 2 May 90.

18. TMI-1, Reactor Building Twenty Year Tendon Surveillance Test (Inspection Period 6), Topical Report 093, 22 Mar 95.

19. Deleted

20. Miller, Irwin & John E. Freund, Probability and Statistics for Engineers. Prentice-Hall, Englewood Cliffs, N. J., 1965.

21. 10CFR50, Appendix J.

22. ANSI / ANS-56.8-1987 (& 1994), Containment System Leakage Testing Requirements.