2010 Augmented Reactor Building (IWL) In-Service Inspection

(Following the 1R18 Steam Generator Replacement)

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1. PURPOSE, INTRODUCTION AND BACKGROUND

1.1 Purpose

This topical report documents the results of the Three Mile Island Unit 1 2010 Augmented Reactor Building (IWL) In-Service Inspection. This augmented in-service inspection (ISI), also referred to herein as a surveillance or ISI, is a one year follow-up inspection after the repair and replacement activities creating and closing a containment opening for the T1R18 Steam Generator Replacement (SGR) Project.

1.2 Background Information

Measurements, examinations, and tests on randomly selected tendons have been done on a regular basis throughout the life of the plant. The surveillance completed prior to this augmented ISI was the Period 9 surveillance performed from 2009 into early 2010 and was documented in Topical Report No. 203.

On June 27, 2007 Three Mile Island was issued License Amendment No. 259 which allowed a one time deferral of the next Type A containment integrated leak rate test (ILRT) to "prior to the startup from T1R18 refueling outage". T1R18 was the refueling outage during which the SGR was completed. In the associated Safety Evaluation Report by the Office of Nuclear Reactor Regulation the NRC staff recommended augmenting the tendon surveillance program following the SGR. The process established in Subsection IWL of the 2001 Edition of the ASME Code, Section XI (2002 Addenda), was suggested by the NRC staff as an acceptable methodology.

TMI's current containment ISI interval is conducted under the requirements of the 1992 Edition with 1992 Addenda of the ASME Section XI Code (Ref 7.3) as incorporated by reference in 10 CFR 50.55a. The 1992 Edition with 1992 Addenda of the code does not address augmented surveillance requirements following a containment repair or replacement activity. The 2001 Edition with 2002 Addenda and later editions of the code include paragraphs which stipulate requirements for an augmented surveillance following repair or replacement activities of a concrete containment structure or pre-stressing system.

This (TMI 2010) augmented surveillance was conducted in accordance with the requirements of the 2004 Edition of the code with no Addenda (Ref 7.4), referred to herein as the ASME Code. The 2004 Edition of the code with no Addenda is effectively the same as the 2002 Addenda and thus the 2004 Edition was utilized for the basis of this augmented surveillance. The inspection and acceptance criteria between the 2004 Edition and the 1992 Edition with 1992 Addenda of ASME Section XI were compared and consolidated so that the requirements of the 1992 Edition with 1992 Addenda would be maintained in accordance with the stations IWE/IWL In-Service Inspection Basis Document (Ref 7.1) and 10 CFR 50.55a (Ref 7.2). The scope of this augmented

surveillance and evaluation of the inspection requirements is identified in Attachment 8.1.

1.2.1 Steam Generator Replacement Project Containment Opening

The steam generator replacement at Three Mile Island commenced in October 2009 with refueling outage T1R18. During this outage, containment tendons were de-tensioned and/or removed from the containment structure supporting the creation of a construction opening in the containment wall. A rectangular area of concrete was removed from the containment wall and the inner steel containment liner was cut out of the opening. This rectangular opening was located between buttresses 4 and 5. Prior to the removal of concrete, vertical and hoop tendons which routed through the opening were cut out and discarded while a selection of tendons adjacent to the opening was de-tensioned.

Following the steam generator replacement the steel liner was repaired, new tendons were installed, and a concrete patch was poured restoring the containment wall. The new tendons and adjacent tendons were re-tensioned after the concrete patch was cured. The scope of these SGR affected tendons can be found in section 2.2 of Attachment 8.1.

1.3 Section Introduction

The remainder of this topical report is divided into the following sections:

Section 2, Summary of Work Performed and Inspection Results, is a synopsis of the surveillance activities and findings.

Section 3, Post-Tensioning System Examinations and Tests, describes measurements, tests and examinations performed on post-tensioning system components, tabulates the results, and includes evaluations of conditions that do not meet acceptance criteria.

Section 4, Containment Surface Examinations, describes the examination process and scope, discusses examination findings, and includes evaluations of conditions that do not meet acceptance criteria. Containment surface examinations performed to satisfy the Topical Report 203 commitments are also covered in this section.

Section 5, Repairs and Follow-Up Examinations, is a summary list of required repair work and re-examinations of damaged / deteriorated areas to be done during the 40th year surveillance.

Section 6, Conclusions, summarizes overall conclusions regarding containment integrity as demonstrated by the ISI.

Section 7, References, identifies the documents that govern the performance of the ISI and that are otherwise cited in this report.

2. SUMMARY OF WORK PERFORMED AND INSPECTION RESULTS

The work performed during the 2010 augmented surveillance and the results of these examinations and tests are summarized in 2.1 and 2.2 below.

2.1 Work Performed

The 2010 augmented surveillance consisted of testing and visual examination of randomly selected sample tendons from the population of SGR affected tendons (SGR verticals and SGR hoops).

This surveillance also consisted of a visual examination of the concrete repair patch of the containment, adjoining concrete to the repair, and the anchorage areas around the SGR affected tendons.

Additionally, extent of condition testing and additional tendon inspections were performed in response to a degraded condition identified during work activities.

2.1.1 Post-Tensioning System Testing and Examination

The following post-tensioning tendons were randomly selected for testing and examination. The initial sample size, two tendons in each group (SGR verticals and SGR hoops), meets the 4% per group sampling requirements of the ASME Code, IWL-2521. The basis and methodology of this random selection can be found in Attachments 8.1 and 8.2.

- SGR Vertical Tendons: V118, V134
- SGR Hoop Tendons: H46-39, H46-41

Two vertical tendons, V117 and V119, were added to the surveillance scope for limited (visual only) examination as a result of a degraded conditions identified in V118 (Attachment 8.3).

Examinations and tests of the four sample tendons consisted of the following activities with exceptions as noted:

- Collection of corrosion protection medium (CPM) samples from each end of each tendon and laboratory tests on these to determine water content, concentration of corrosive ions and reserve alkalinity
- Inspection and quantification of any free water contained in the anchorage end caps

- Visual examination of end anchorage hardware (button heads, anchor heads, shims and bearing plates) and concrete within two feet of the bearing plate including the two added scope tendons

- Measurements of end anchorage force using the feeler gauge pull out method described in Surveillance Procedure 1301-9.1

- De-tensioning of one tendon in each group and extracting a specimen wire for visual examination and tensile tests

- Re-tensioning of the de-tensioned tendons with measurements of elongations at several loads

- Refilling tendon ducts and end caps with CPM (quantities of CPM removed and replaced measured and documented) including the two added scope tendons

Additionally all SGR tendon end anchorage covers were examined for damage and CPM leakage. The bottom ends of all vertical tendons were examined for CPM leakage as well.

Examinations and tests were performed in accordance with Surveillance Procedure 1301-9.1 (Ref 7.7), which incorporates the applicable requirements of the 1992 Edition (with 1992 Addenda) of the ASME Boiler and Pressure Vessel Code, Section XI, Sub-Section IWL (Ref 7.3), and the additional requirements specified in 10 CFR 50.55a(b)(2)(viii) (Ref 7.2) as well as the applicable requirements of the 2004 Edition of the ASME code (Ref 7.4). The surveillance procedure also incorporates the applicable requirements of the plant's UFSAR (Ref 7.5).

2.1.2 Containment Surface Examination

The concrete construction opening patch, adjoining concrete, and concrete around the end anchorages of the SGR tendons was visually examined using the VT-3C procedure defined in paragraph IWL-2310 of the 1992 Edition with 1992 Addenda of the ASME Code. This examination was performed directly (without optical aids) and remotely using binoculars. The tendon anchorage end caps and bearing plates of the SGR tendons were examined at the same time.

The concrete was examined for evidence of cracking, spalling, efflorescence, and other types of damage / deterioration as identified in ACI 201.1R and ACI 349.3R. This examination was also focused on the concrete repair patch and the adjoining concrete.

Bearing plates were examined for detached or missing coatings and corrosion.

Topical Report No. 203, section 5.2, specifies that detailed examination of the construction opening patch will include a visual of the new concrete perimeter and corners for evidence of shrinkage cracks / separation. This was performed by direct

examination from a hanging platform using the VT-1C detailed visual examination procedure defined in IWL-2310 of the 1992 Edition with 1992 Addenda of the ASME Code.

The last examination performed as specified in Topical Report No. 203 was for evidence and the effects of ground water seepage in the tendon gallery. This was performed by the Responsible Professional Engineer by direct examination.

2.1.3 Extent of Condition Testing and Additional Tendon Inspections

Two broken wires were identified during the as-found visual examination of Tendon V118. Extent of condition testing in the form of a mechanical continuity test of all remaining wires in this tendon was performed and a failure analysis of the wires was conducted. Additionally, the anchorage caps of the two adjacent tendons, V117 and V119 were removed and a visual examination was performed.

The two broken wires were removed from V118 and tensile tested in addition to a specimen wire removed for testing.

The extent of condition testing and additional examinations was developed and prescribed by the Responsible Professional Engineer in accordance with IWL-2320, IWL-3222, and IWL-3300 of the ASME code.

2.2 Inspection Results

The results of the 2010 Augmented Reactor Building In-Service Inspection are summarized below.

2.2.1 Post-Tensioning System

The results of the post-tensioning system examination, measurements and tests met prescriptive acceptance criteria with one exception which was shown to be acceptable by additional testing, examination, and evaluation. A listing of specific results follows.

- All tendon forces were above the predicted values.
- Elongations measured during re-tensioning of de-tensioned tendons were within 10% of previously measured values.
- End anchorage hardware items were free of active corrosion. All anchorage hardware items were free of cracking and distortion.
- The as found button head conditions were as documented during the previous examinations for all examined tendons except for V118. Two button heads were

protruding on the shop end of V118. Further investigation revealed the two wires were broken just below the shop anchorhead.

- The tensile strength and elongation (at failure) of all wire test samples, including the two broken wires from V118, exceeded the minimum required values.

- The results of the wire continuity tests on V118 and examination of the adjacent tendons, V117 and V119, found no further damage or broken wires. Evaluation of the condition found V118 acceptable without repair.

- Water content, corrosive ion concentration and reserve alkalinity of all corrosion protection medium samples met acceptance criteria.

- Concrete adjacent to end anchorages of the surveillance tendons was free of cracks over 0.01 inches wide.

- The differences between the quantities of CPM removed and the quantities replaced in all tendons (including V117 and V119) were all within 10% of the net duct volume.

- All SGR Tendon end anchorage covers were free of damage and none showed signs of significant grease leakage.

2.2.2 Containment Surface

The concrete repair patch had no signs of structural degradation and no cracks were found in the patch or the adjoining original concrete after detailed inspection. The VT-1C examination was performed directly from a hanging platform without the need for optical aids.

The buttress, base mat, and dome trench areas around the SGR tendon anchorages were free of damage / deterioration except for effectively unchanged previously reported conditions.

Water seepage through the tendon gallery outer wall was unchanged from what was observed during the 35th year surveillance.

3. POST-TENSIONING SYSTEM TESTS AND EXAMINATIONS

The following tests and examinations were performed on sample tendons to assess the continuing quality and integrity of the repaired and replaced portions of the post-tensioning system:

- Measurement of tendon end anchorage force
- Measurement of tendon elongation during re-tensioning
- Visual examination of post-tensioning system components and concrete adjacent to bearing plates to detect accumulation of free water, corrosion, deformation, cracking, wire breakage, and wire button head failure
- Measurement of wire test specimen strength and elongation at failure
- Chemical analysis of CPM to determine water content, reserve alkalinity, and concentration of corrosive ions
- Measurement and comparison of CPM removed and replaced
- Visual examination of all SGR tendon end anchorage covers to detect damage and corrosion protection medium leakage.

All but the last of the above tests and examinations involved a small sample of the SGR tendon population. All SGR tendon end anchorage covers were examined.

Due to an un-acceptable condition identified in tendon V118, additional tendons and examinations beyond those already identified were added to the surveillance. The above mentioned tests and examinations apply only to the initial selection of tendons described below. Tendons V117 and V119 were selected for an expanded scope inspection and were subjected to visual examination only. All additional scope tendons, tests, inspections, and acceptability of V118 are described in section 3.10.

Tendons initially selected for tests and examinations were randomly picked from a population that included all tendons in the two SGR tendon groups, vertical and hoop. An additional constraint on tendon selection was added. In both vertical and hoop groups of SGR tendons some tendons were replaced with new tendons and some were re-used and re-tensioned. At least one new and one re-tensioned tendon from each of the two groups were selected for examination. The selection basis is documented in Attachment 8.1 and the random selection process is described in Attachment 8.2. The selection included the following:

- New Vertical Tendon: V134
- Re-Tensioned Vertical Tendon: V118[1]
- New Hoop Tendon: H46-39[1]
- Re-Tensioned Hoop Tendon: H46-41

One tendon from each group (vertical and hoop) was selected for de-tensioning and removal of a specimen wire for testing. Of the two tendons selected for specimen wire testing, an additional constraint requiring one wire be from a re-tensioned tendon and the other be from a new tendon was imposed as described in Attachment 8.1.

3.1 Tendon End Anchorage Forces

Tendon end anchorage forces were measured using the liftoff technique described in Surveillance Procedure 1301-9.1 (Attachment 8.4). Forces were measured at both ends of hoop tendons and only at the shop (top) end of vertical tendons.

Acceptance criteria cover individual tendon forces and current group mean forces. These forces and associated criteria are discussed in the following paragraphs.

TMI Technical Specification 4.4.2.1.6 states that this report will include a section dealing with trends for the rate of pre-stress loss as compared to the predicted rate for the duration of plant life (after an adequate number of surveillances have been completed). Additionally, paragraph IWL-3221.1 of the ASME Code requires that the pre-stressing forces for each type of tendon be trended such that predicted tendon forces will not be less than the minimum design pre-stress forces at the next examination. Because this is the first surveillance of the SGR tendons and a single data set is not sufficient to perform force projections, no such projections are made in this report.

3.1.1 Individual Tendon Forces

Lift-off tests are performed on inspection sample tendons per IWL-2522 of the ASME Code. The accuracy and calibration of the force measurements are within 1.5% of the guaranteed ultimate tensile strength (GUTS) of the tendon. Tendon force measurement equipment calibrations are listed in Appendices C and F of Attachment 8.7.

Table 3-1 lists the measured end anchorage forces, the predicted forces, and the lower acceptance limits, as found on procedure 1301-9.1 Data Sheet 1 (for each tendon) in Appendix A of Attachment 8.7. The time dependant force predictions are documented in Calculation C-1101-153-E410-046 (Ref 7.10). The lower acceptance limits defined in

[1] These tendons were selected for the removal of a specimen wire.

paragraph IWL-3221.1 of the ASME Code are equal to 95% of the forces predicted for the individual tendons.

Table 3-1 Tendon End Anchorage Forces

Tendon ID	Tendon End	End Lift-Off Force (kips)	Average Lift-Off Force (kips)	Predicted Force (kips)	95% of Predicted Force (kips)
H46-39	Shop / BT 6	1354.4	1372.7	1316	1250
	Field / BT 4	1391.1			
H46-41	Shop / BT 6	1342.9	1356.8	1314	1248
	Field / BT 4	1370.7			
V118	Shop / Top	1365.3	1365.3	1340	1273
	Field / Bottom	N/A			
V134	Shop / Top	1341.7	1341.7	1332	1265
	Field / Bottom	N/A			

As shown in the table, all tendon forces are above the lower acceptance limits and are actually above the predicted levels.

3.1.2 Group Mean Forces

The mean forces in each group of tendons must be equal to or greater than the minimum required force for the group as stated in IWL-3221.1 of the ASME Code. The minimum required mean force values from Reference 7.9 are:

- Vertical Tendons: 1,033 KIP
- Hoop Tendons: 1,108 KIP

As seen in Table 3-1, all individual tendon forces are well above these minimum values and thus the group mean is acceptable.

3.1.2.1 Group Mean Forces and Projected Group Mean Force calculations for SGR Tendons

It is important to note that the SGR tendons will not be included in group mean force calculations for future surveillances. Future surveillances will include tendons which were not de-tensioned by the SGR. These original tendons were initially tensioned to forces between 70 and 74% of GUTS (Guaranteed Ultimate Tensile Strength) prior to commercial operation in 1974. The SGR tendons were tensioned to forces between 70 and 73% of GUTS in the year 2010. The present forces in these original tendons are appreciably lower than those of the SGR tendons.

The local pre-stress in areas of the containment located far from the SGR opening patch has little to no influence from the higher SGR tendon forces because the SGR tendons are contiguous and not evenly distributed in the containment structure. A mathematical mean pre-stress that includes SGR tendon forces is not representative of the local containment pre-stress in areas far from the SGR opening patch. These areas which have lower pre-stress than the SGR opening patch are the limiting cases for determining if the minimum required pre-stress in the containment structure is met. The appropriate (conservative) approach for assessing if the containment structure is maintaining the minimum required (design) pre-stress is to not include the SGR tendon forces in group mean pre-stress calculations.

The same argument applies to calculating group mean force projections. SGR tendon pre-stress will not be included in the force projections.

Additionally, the SGR tendon pre-stress means and projections do not need to be calculated conditional to the following: SGR tendons continue to meet individual pre-stress acceptance criteria, and the group mean forces and projections of the original tendons continue to meet the minimum required values.

If SGR tendons fail to meet individual pre-stress criteria or group mean forces / force projections of the original tendons fail to meet the minimum required values the issue(s) will be entered into the corrective action process and the need to compute SGR tendon mean forces and / or projections will be assessed.

3.2 Tendon Elongations and Re-Tensioning

One tendon in each group was de-tensioned to allow removal of a wire for testing. Elongations were measured during the subsequent re-tensioning and compared to the previous values to verify that tendons were intact and that there were no obstructions to tendon motion within the ducts. Following the elongation measurements at overstress force (OSF, nominally 80% of GUTS) each tendon was seated, in accordance with ASME code requirements, at a force between that predicted for the time of the surveillance and 70% of GUTS.

Tendons V118 and H46-39 were de-tensioned for wire removal.

3.2.1 Elongations

Elongations measured during the previous tensioning and re-tensioning are normalized to account for differences between the Pre-tension Forces (PTF) / Overstress Forces (OSF) applied during the previous SGR tensioning and those applied during the 2010 surveillance as well as for differences in the number of wires (one was removed for testing prior to re-tensioning, and two more were removed from V118). Normalizing SGR and surveillance values in this manner allows direct comparison of elongations regardless of differences in PTF values, OSF values, and the number of wires.

Normalized elongations are expressed as inches per kip per wire (inch-wire / kip). This method of computing and comparing tendon elongations meets the requirements of IWL-3221.1 of the ASME Code and 10 CFR 50.55a(b)(2)(viii)(C).

Elongations are acceptable if:

$$10\% \geq dR = \left|(\Delta n_2 - \Delta n_1) / \Delta n_1\right| * 100\%$$

Where

Δn_1 is the normalized elongation determined for the previous stressing

Δn_2 is the normalized elongation determined for re-tensioning

dR is the percent difference of normalized elongation

Pertinent data documented for SGR tendon tensioning and the 2010 surveillance re-tensioning are tabulated for each of the sample tendons below. These tabulations also list the calculated normalized elongation rates. SGT stressing data is as listed on the SGT tendon stressing data sheets (Attachment A of Ref 7.10). 2010 surveillance re-tensioning data is as listed on procedure 1301-9.1 Data Sheet 4 (for each tendon) and can be found in Appendix A of Attachment 8.7.

Table 3-2 Tendon Stressing Elongation Data					
	Parameter	Tendon			
		H46-39	V118 (10/26/10)	V118 (10/27/10)	Units
SGR Tensioning	F_{osf}	1588.6	1581.9		kips
	d_{osf}	16.9	17.8		inches
	F_{ptf}	200.0	199.2		kips
	d_{ptf}	6.3	3.8		inches
	Δd_1	10.6	14		delta inches
	Wires	169	169[2]		Number of Wires
	Δn_1	1.29	1.71		in-wire/kip
2010 Surveillance Tensioning	F_{osf}	1577.4	1558.7	1558.7	kips
	d_{osf}	17.6	18.5	18.5	inches
	F_{ptf}	198.3	195.8	195.8	kips
	d_{ptf}	7.4	5	4.5	inches
	Δd_2	10.2	13.5	14	delta inches
	Wires	168	166	166	Number of Wires
	Δn_2	1.24	1.64	1.71	in-wire/kip
	dR	-3.88	-4.09	0.00	Percent Difference

In the above table: F_{osf} is overstress force, ~ 80% GUTS
d_{osf} is overstress reference distance
F_{ptf} is pre-tension force, ~ 200 kip
d_{ptf} is pre-tension reference distance
Δn is normalized elongation
$\Delta n = \Delta d$ * (# of wires) / ($F_{osf} - F_{ptf}$)

Tendon V118 was re-tensioned twice during the 2010 surveillance. The first re-tensioning was on 10/26/11 and resulted in shop end shim stack height taller than the end cap. The tendon was de-tensioned and re-tensioned the next day transferring some of the shims from the shop end to the field end. Both re-tensioning had acceptable elongations. The change between the 10/26 and 10/27 elongations can be accounted for as a re-distribution of the tendon's 'twist' inside the tendon duct. This is expected and further documented in a technical evaluation (Attachment 8.3).

All changes in elongations, adjusted for effective wires, met the acceptance criteria of less than 10% change from the previous stressing.

[2] It should be noted that the SGR as-left inspection of tendon V118 indicated 169 seated and effective wires. The elongation data presented in the PSC report (Attachment 8.7) computes the elongation assuming 167 effective wires at the time of the SGR re-tensioning. This is because consideration was given to both scenarios. All elongation results are acceptable regardless of either number of effective wires assumed at the time of the SGR.

3.2.2 Re-Tensioning

After elongations at OSF were measured tendons were re-seated at forces between those predicted for the time of the surveillance and 70% of GUTS as specified in IWL-2523.3 of the ASME Code. Final lock-off forces, as documented in procedure 1301-9.1 Data Sheet 1 (for each tendon) and found in Appendix A of Attachment 8.7, are listed below with the applicable lower and upper limits.

Table 3-3 Tendon Re-Tensioning Data

Tendon	Effective Wires	Predicted Force (kip)	Lock-Off Force (kip)	70% GUTS (kip)
H46-39	168	1316	1327.8	1385.4
V118 (10/26/11)	166	1340	1355.9	1369.3
V118 (10/27/11)			1341.7	

As shown above, all final lock-off forces are between the specified limits and acceptable.

3.3 End Anchorage Condition

Sample tendon end anchorages were visually examined for evidence of corrosion, physical damage, missing button heads, and unseated button heads per IWL-2524.1 of the ASME Code. In addition, the concrete surrounding the anchorage was examined out to a distance of two feet beyond the bearing plate edge to detect cracks >0.01 inches in width, spalls, and other indications of damage / deterioration.

Except for Tendon V118, the examinations uncovered no indications of unacceptable conditions. Examination results and acceptance criteria are listed below. Acceptance criteria are derived from ACI 201.1 and ACI 349.3R (Ref 7.14 and 7.11)

3.3.1 Corrosion

- Acceptance Criterion

  No evidence of active corrosion

- Examination Results

  No corrosion was found on wires[3], button heads, stressing washers, or shims of the initial selection of tendons. Minor inactive corrosion was noted on the bushing, anchorhead, and shims or V119 with no pitting.

[3] Short segments of some wires are visible when tendons were de-tensioned for specimen wire removal.

3.3.2 Physical Damage

- Acceptance Criterion

  No cracks or deformations in anchor heads, shims, or bearing plates.

- Examination Results

  No cracks or deformation were found.

3.3.3 Missing Button Heads

- Acceptance Criterion

  No missing button heads not previously documented (no specific criterion is set for button heads that detach during surveillance operations).

- Examinations Results

  No missing button heads were found which were not previously documented.

3.3.4 Unseated Button Heads

- Acceptance Criterion

  No unseated button heads not previously documented (no specific criterion is set for button heads that are unseated following re-tensioning).

- Examination Results

  Two unseated button heads were found during as found inspection of V118. This condition was immediately documented in the corrective action program. Additional inspections, tests, and the disposition of this condition are discussed in section 3.10.

  No other unseated button heads were found during as found inspections.

3.3.5 Concrete within Two Feet of Bearing Plates

- Acceptance Criterion

  No concrete cracks wider than 0.01 inches.

- Examination Results

  No cracks wider than 0.01 inches were found.

Examination data sheets are ER-AA-335-018 Attachment 5, ER-AA-335-018 Attachment 6, and 1301-9.1 Enclosure 6 Data Sheet 4, and can be found in Appendix A of Attachment 8.7. All conditions were reviewed and met acceptance criteria or were evaluated as acceptable.

3.4 Specimen Wire Test Results

A specimen wire was removed from one tendon in each group for examination and strength testing. Each wire was visually examined over its entire length for corrosion, pitting, and physical damage. Test samples were cut from near each end and near the middle of each specimen wire. These three samples per specimen wire were diametrically measured and tested to determine yield strength, tensile strength and elongation at failure per IWL-2523.2 of the ASME Code and ASTM A370 (Ref 7.16).

The visual examinations showed that both specimen wires were free from corrosion, physical damage, and wire diameters were within acceptable limits. As a result there was no need to cut an additional test specimen from the most corroded section of wire as specified in the surveillance procedure.

Tensile testing was performed by Exova Materials Testing Laboratory. The test data can be found in Appendix A of Attachment 8.7.

Tensile strength of all 6 test specimens exceeded the specified lower limit of 240 ksi (the Guaranteed ultimate Tensile Strength, or GUTS) and elongations at failure all exceeded the lower limit of 4% for 0.25 inch ASTM A421 (Ref 7.15) steel wire. The results of the tests tabulated below.

All wire tests and examination results met acceptance criteria per IWL-3221.2 of the ASME Code.

Table 3-4 Specimen Wire Tensile Test Results

Tendon	Sample Number	Approximate Sample Location	Diameter (in)	Yield Strength (ksi)	Ultimate Strength (ksi)	Elongation at Failure (%)
H46-39	1	Shop End	0.250	236.2	267.0	5.1
	2	Middle	0.250	238.6	269.9	5.6
	3	Field End	0.250	233.2	267.4	4.6
V118	1	Shop End	0.250	212.9	247.3	4.5
	2	Middle	0.250	207.0	246.2	5.9
	3	Field End	0.250	208.5	246.6	5.4

3.5 Corrosion Protection Medium Test Results

A sample of corrosion protection medium (CPM) was collected from each end of each sample tendon per IWL-2525 of the ASME Code. Laboratory tests were performed on these samples to determine the characteristics listed (with acceptance limits) below.

Table 3-5 Corrosion Protection Medium Test Results

Tendon	End	Characteristic				
		Chlorides (ppm)	Nitrates (ppm)	Sulfides (ppm)	Water Content (% weight)	Base Number / Reserve Alkalinity (mg KOH/g)
H46-39	Shop	<0.50	<0.50	<0.500	<0.10	73.6
	Field	<0.50	<0.50	<0.500	<0.10	71.2
H46-41	Shop	<0.50	<0.50	<0.500	<0.10	74
	Field	<0.50	<0.50	<0.500	<0.10	71.3
V118	Shop	<0.50	<0.50	<0.500	0.19	68.1
	Field	<0.50	<0.50	<0.500	<0.10	65.1
V134	Shop	<0.50	<0.50	<0.500	<0.10	70.8
	Field	<0.50	<0.50	<0.500	<0.10	63.3
Acceptance Limits		<10	<10	<10	<10	>17.5

CPM tests were performed by Suburban Laboratories, Inc. The laboratory results can be found in Appendix B of Attachment 8.7. As shown in the table, all test results meet the acceptance criteria per IWL-3221.4 of the ASME Code.

3.6 Corrosion Protection Medium Removal / Replacement

When CPM was removed from the tendon sheaths, the quantity removed and the quantity later replaced were documented. The difference in these quantities provides the information to assess the acceptability of both the level of CPM fill prior to removal and the level following replacement. If the amount replaced is significantly less than the amount removed, the level is low and must be increased. If the amount replaced is significantly greater than the amount removed, the reason for the difference (initial fill or leakage over time) must be determined and the situation corrected.

All tendons which were visually examined had CPM removed and replaced. This includes the two added scope tendons, V117 and V119.

Quantities of CPM removed and replaced are shown in Table 3-4. All differences (absolute values) are less than 10% of the net duct volume limits specified in 10 CFR 50.55a(b)(2)(viii)(D)(2) and IWL-3221.4 of the ASME Code, and are acceptable.

Table 3-6 Corrosion Protection Medium Quantities Removed and Replaced

Tendon	End	Grease Removed (Gallons)		Grease Replaced (Gallons)		Difference (Gallons)	Duct Volume (Gallons)	% Difference
		End	Total	End	Total			
H46-39	Shop	1	2.5	2.65	5.74	3.24	115.26	2.8
	Field	1.5		3.09				
H46-41	Shop	0.75	2.25	2.21	4.86	2.61	114.86	2.3
	Field	1.5		2.65				
V117	Shop	3	4	6.19	6.19	2.19	129.86	1.7
	Field	1		N/A				
V118	Shop	5.5	11.5	12.39	12.39	0.89	129.61	0.7
	Field	6		N/A				
V119	Shop	2	3	4.42	4.42	1.42	129.6	1.1
	Field	1		N/A				
V134	Shop	7	8	8.85	8.85	0.85	131.62	0.6
	Field	1		N/A				

3.7 Free Water Accumulation

End anchorages were examined for evidence of free water accumulation per IWL-2524.2 of the ASME Code. No free water was found at any of the anchorages examined.

3.8 Tendon End Anchorage Cover Examination

Tendon end anchorage covers (grease caps) of the SGR tendons were examined as specified in 10 CFR 50.55a(b)(2)(viii)(A) for damage / deformations and CPM leakage. Only SGR tendon grease caps were examined as all accessible grease caps are examined each five year surveillance.

All covers examined were in sound condition and free of deformations. There was no evidence of corrosion on the covers and no significant CPM leakage was observed.

3.9 Topical Report No. 203 Examination and Test Commitments

The only Post Tensioning System Test and Examination commitment made in the previous inspection report (Topical Report 203, 35th year tendon surveillance, Ref 7.12) was, "Tendons, anchorage hardware, sample wires, and CPM will be examined / tested as required by the 2001 Edition with 2002 Addenda of the ASME Boiler and Pressure Vessel Code, Section XI, Sub-Section IWL." Containment structure and CPM leakage examination commitments made in Topical Report 203 are discussed in Section 4.

As discussed in section 1.2 of this Topical Report and documented in Attachment 8.1, the 2004 Edition with no Addenda of the ASME code was implemented in substitution of the 2001 Edition with 2002 Addenda.

3.10 Two Damaged Wires in Tendon V118

Upon initial visual examination of the shop (top) end anchorage hardware of tendon V118, two button heads were slightly protruding. This condition was immediately documented in the corrective action process.

Further investigation revealed that the two buttonheads were protruding because the wires were broken four inches down where the wire exits the shop end anchorhead.

The full description and detailed evaluation of this event is captured in Attachment 8.3, which includes the failure analysis report and documents the acceptability of the condition without repair. The highlighted events, overview, and overall disposition of the condition are presented below.

3.10.1 Extent of Condition Testing

Extent of condition testing was conducted which included the following:

- Examination of tendon V118 for signs of damage on the other wires
- Verifying mechanical continuity of all the remaining wires in tendon V118
- Removing the two broken wires from the tendon
- Examining the broken wires for corrosion
- Sending the wire fractures to a materials testing lab for a failure analysis
- Sending intact sample lengths from the two broken wires to a materials testing lab for tensile testing

3.10.2 Increased Surveillance Tendon Scope

In addition to the testing of tendon V118, the scope of the surveillance was increased to include a VT-1 examination of the anchorage hardware of the two adjacent tendons, V117 and V119. The examinations of V117 and V119 focused on looking for indications of broken wires or other degradation.

3.10.3 Results from the Extent of Condition Testing

The location of the fractures along the length of the two broken wires was at the interface of the shop anchorhead and the first shim. The wires were physically damaged at the fracture with a slight bend and shiny areas worn into the wires' surfaces. These two broken wires were located in the periphery of the anchorhead where wires are most vulnerable to contact with an external object.

Upon removal from the tendon, both ends of the two fractured wires were examined for corrosion with none found along the entire length of the wires and the fracture surfaces. The only indications on the wires were a slight bend at the fractures and worn shiny spots in the metal at the fractures.

Using the methodology described in Attachment 8.3, all the remaining wires in tendon V118 were individually verified to be mechanically continuous. None of the wires had any signs, both visually and after mechanical testing, of degradation.

The fractured wires were sent to Exelon Powerlabs for a failure analysis and tensile testing of the wires. The failure analysis indicated that the wires failed under shearing and that the bend and other indentations in the metal adjacent to the wire fractures would act as a stress riser and a source of shearing forces. All tensile tests returned acceptable results showing no degradation of the wires' material properties.

3.10.4 Results of the Increased Surveillance Scope Tendon Examinations

The end caps were removed from tendons V117 and V119 and a VT-1 examination was performed on the anchorage hardware on both the shop and field ends. No conditions indicative of broken or damage wires existed and all conditions noted were previously documented and without change.

3.10.5 Disposition of Tendon V118 without Repair

The results of the extent of condition testing indicate that the remaining wires in tendon V118 have no degradation and are fully capable of carrying their design forces. The 169 wire tendon, now reduced to 166 wires (the 2 broken wires and a third, specimen wire, were removed for tensile testing), is still capable of carrying the design pre-stress for a vertical tendon. Evaluation of the acceptability of up to 5 in-effective wires in a vertical tendon is evaluated in Attachment 8.6. Additionally, the as found pre-stress during this surveillance was acceptable with the broken wires and the elongation data of V118

during its re-stressing was also acceptable. Based on this data and discussion provided in Attachment 8.3, V118 is acceptable without repair.

3.10.6 Extent of the Condition to other Tendons

The fractured wires in tendon V118 were most likely initiated by an external event which physically damaged the wires. The damage which created a stress riser in the wires would have led to wire fracturing either during or after when the tendon was re-tensioned from the SGR. The inspection of the two adjacent tendons and the other three surveillance tendons had no signs of damage indicative of broken wires. It is concluded that the broken wires are an isolated event and there is no common cause which would affect the remainder of the pre-stressing system.

4. CONTAINMENT SURFACE EXAMINATIONS

Containment surface examinations were limited to areas affected by the SGR opening per IWL-2410(d) of the ASME Code. A 100% visual examination of the containment surface is not required per the 2004 edition of the ASME code for this augmented surveillance. The 1992 edition with 1992 addenda of the code requires a 100% examination every five years. The last full examination was performed during the 35th year surveillance (Ref. 7.12) and the next full examination will be performed during the 40th year surveillance thus meeting the code requirements.

All conditions discussed in the following sections are acceptable with very few requiring review per ACI 349.3R (Ref 7.11). All examination data sheets were reviewed by the responsible professional engineer and the ANII and all indications were acceptable with review.

Examination data sheets can be found in Appendix H of Attachment 8.7.

4.1 Containment Wall between Buttresses 5 and 6

The entire containment face between buttresses 5 and 6 (including the SGR opening patch) was examined using the VT-3C methodology. The overall concrete surface shows no evidence of damage or degradation other than non-structural degradation of grout patches in several areas.

There are small shrinkage cracks at the concrete surface. All cracks were less than 0.040 inches in width and are acceptable after review (per Ref. 7.11). All surface examination results were reviewed by the responsible professional engineer and the ANII and were all deemed acceptable upon review. No conditions were found which required evaluation. All conditions were reported with no change from the previous conditions.

4.2 SGR Opening Patch

The SGR opening patch and the adjoining concrete was subjected for a detailed visual examination using the VT-1C methodology. The results of this examination found that the patch is structurally sound and stable. No cracks or other degradation were found in the patch or adjoining concrete. The visual examination data sheet and a hand sketch of the patch by the VT-1C examiner can be found in Appendix H or Attachment 8.7.

4.3 Buttresses 4, 5, 6 and 1

The four buttresses which anchor SGR hoop tendons were examined using the VT-3C methodology. Cracks were less than 0.010 inches in width and require no further evaluation. Other conditions noted were degraded grout patches, minor oil stains. All conditions noted were previously reported with no change and are acceptable.

4.4 Dome Area Tendon Trench

The tendon trench on the building dome houses the top ends of vertical tendons. The trench was examined using the VT-3C methodology over the areas from tendon V113 to V157, the SGR vertical tendons. No cracks were reported. The only observations made were a spall in the trench, and bearing plates with corrosion, all of which were previously reported, repaired, and stable.

All conditions noted were previously reported with no change.

4.5 Tendon Gallery Base Mat

The tendon gallery base mat anchors the bottom ends of vertical tendons. The base mat was examined using the VT-3C methodology over the areas from tendon V113 to V157. Cracks were less than 0.015 inches in width and require no further evaluation. Other conditions noted were efflorescence, exposed rebar, abandoned tendon trumpets, bearing plates with corrosion that are repaired and stable, and an exposed embed plate with active corrosion and pitting less than 0.010 inches. All conditions noted were previously reported with no change and are acceptable.

4.6 Topical Report 203 Examinations and Commitments

Two follow-up containment examinations were prescribed in previous inspection report (Topical Report 203, 35th year tendon surveillance, Ref 7.12). The first was a detailed VT-1C examination of the SGR opening patch and adjoining concrete which was performed and discussed above. The second was a tendon gallery examination for evidence of CPM leakage and the effects of ground water seepage.

In addition to the VT-3C examinations discussed above, the responsible professional engineer performed an examination of the walls, ceiling and floor of the tendon gallery for indications of ground water seepage as well as leakage of corrosion protection medium (CPM) from tendon end caps (Attachment 8.5). The examination concluded there is no reason to expect a significant change in the level of ground water seepage between now and the next 5 year surveillance and that the tendon end gasket repair work has eliminated all the significant CPM leaks observed at the start of the 35th year surveillance.

5. REPAIRS AND FOLLOW-UP EXAMINATIONS

5.1 Repairs

The results of the surveillance show that no repair to either the concrete or post-tensioning system is necessary at the present time. The two broken wires in tendon V118 were evaluated as acceptable without repair (Attachment 8.3).

5.2 Follow-Up Examinations during the 40th Year Surveillance

There are no new follow-up examinations as a result of this augmented surveillance. The follow-up examinations specified during the 35th year surveillance in Topical Report 203 (Ref. 7.12) shall be completed during the 40th year surveillance.

6. CONCLUSIONS

The following conclusions are based on and supported by evaluation of the surveillance results:

- The force in each individual sample tendon exceeds the lower acceptance limit (95% of the predicted value).
- Elongations measured during re-tensioning of de-tensioned tendons are as expected and are within 10% of previously measured values.
- All examined wire buttonheads are seated and meet acceptance criteria (as left).
- The difference between quantities of CPM removed from sample tendons and quantities replaced were all within 10% of net duct volume showing that tendon duct fill was adequate both as-found and as-left.
- Corrosion protection medium samples meet specified limits on absorbed water content and concentrations of corrosive ions. The samples also meet the specified lower limit on reserve alkalinity.
- No free water was detected at tendon end anchorages; therefore it is concluded that water intrusion is not a problem.
- Tendon wire samples meet the specified lower limits on ultimate strength and elongation at failure.
- Concrete surrounding sample tendon bearing plates is free of damage, deterioration, and cracks that exceed 0.010 inches in width.
- End anchorage hardware items were free of active corrosion. All anchorage hardware items were free of cracking, distortion, and damage.
- Concrete surfaces are free of damage and degradation. Spalling of grout patches, as noted in various areas, has no structural significance. The few concrete cracks that exceed the threshold acceptance criteria of 0.010 inches in width are less than 1 foot long and are of no structural significance.
- The SGR opening patch is structurally sound without cracking and is adherent to the adjoining concrete.
- The SGR tendon end caps are free of damage and any indications of tendon anchorage failure.
- SGR tendon end caps are not leaking CPM to any significant degree and no corrective action is required at this time.

- The broken wires identified in tendon V118 were evaluated to be caused by an external event that physically damaged the affected wires. The damage is isolated to the affected wires in V118.

- Per evaluation, tendon V118 is acceptable without repair.

- Overall, the repair of the containment structure and post-tensioning system from the SGR is successful with no deficiencies.

7. REFERENCES

7.1 Basis Document: **TMI-1-ISI-BASIS-5** Revision 3, FIRST INTERVAL 10 YEAR INSERVICE INSPECTION PROGRAM ISI, **IWE/IWL** FOR THREE MILE ISLAND NUCLEAR STATION, UNIT 1 (TMI-1)

7.2 United States Code of Federal Regulations, Title 10, Part 50, Sub-part 50.55a (10 CFR 50.55a)

7.3 ASME Boiler and Pressure Vessel Code (1992 Edition with Addenda through 1992), Section XI, Sub-Sections IWA and IWL

7.4 ASME Boiler and Pressure Vessel Code (2004 Edition with no Addenda), Section XI, Sub-Section IWL

7.5 TMI – Unit 1 FSAR Section 5.7.5, Rev. 20

7.6 TMI – Unit 1 Technical Specification Sections 3.19.1 & 4.4.2.1

7.7 TMI – Unit 1 Surveillance Procedure 1301-9.1, RB Structural Integrity Tendon Surveillance, Revision 22

7.8 TMI – Unit 1 EER JO # 162193, RX Building Tendons, Minimum Required Prestressing Forces

7.9 TMI – Unit 1 Calculation C-1101-153-E410-028, RX Building Tendons, Minimum Required Prestressing Forces, Revision 0

7.10 TMI – Unit 1 Calculation C-1101-153-E410-046, TMI-1 Reactor Building / Post-Tensioning System In-Service Inspection Program / Tendon Force Prediction

7.11 ACI 349.3R-96, Evaluation of Existing Nuclear Safety-Related Concrete Structures, Published by the American Concrete Institute

7.12 Topical Report No. 203, 35th Year Reactor Building Tendon Surveillance (Period 9), Revision 0

7.13 Exelon Procedure ER-AA-335-018, Detailed General VT-1 VT-1C VT-3 and VT-3C Visual Examination of ASME Class MC and CC Containment Surfaces and Components, Revision 5

7.14 ACI 201.1R-92, Guide for Making a Condition Survey of Concrete in Service, Part 1, Published by the American Concrete Institute

7.15 ASTM A421 / A421M, Standard Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete, Published by the American Society for Testing and Materials

7.16 ASTM A370, Standard Test Methods and Definitions for Mechanical Testing of Steel Products, Published by the American Society for Testing and Materials

7.17 1040851-02, TMI-1 Reactor Building Augmented Examination Requirements for Tendons Affected by SGRP Activities

7.18 1129072-02, Evaluation of Two Broken Tendon Wires on Tendon V118 as Found During the 2010 Augmented Reactor Building (IWL) In-Service Inspection

7.19 TM-N1063-500, Final Report for the Three Mile Island Unit 1 – 2010 Augmented IWL Surveillance

8. ATTACHMENTS

8.1 TMI-1 Reactor Building Augmented Examination Requirements for Tendons Affected by SGRP Activities

9 pages

8.2 Selection of Sample Tendons for the 2010 Augmented Reactor Building (IWL) In-Service Inspection

3 pages

8.3 Evaluation of Two Broken Tendon Wires on Tendon V118 as Found During the 2010 Augmented Reactor Building (IWL) In-Service Inspection

p. 8	Attachment A -	VT-1 exam data sheets of the as-found top anchorhead of V118
p. 10	Attachment B -	Wire continuity test procedure and results
p. 12	Attachment C -	Exelon Powerlabs report on the fractured wires
p. 18	Attachment D -	Tendon V118 elongation rate graph and brief summary

18 pages

8.4 TMI – Unit 1 Surveillance Procedure 1301-9.1, RB Structural Integrity Tendon Surveillance, Revision 22

87 pages

8.5 Tendon Gallery Examination for Water Seepage and Corrosion Protection Medium Leakage

1 page

8.6 Passport AR 00982006 A02, Evaluation of Unseated Tendon Wire Buttonheads

3 pages

8.7 Final Report for the Three Mile Island Unit 1 – 2010 Augmented IWL Surveillance, Revision 0

p. 29	Appendix A -	Surveillance Data Sheets
p. 162	Appendix B -	Laboratory Analysis of Sheathing Filler
p. 173	Appendix C -	Jack Calibrations
p. 194	Appendix D -	PSC Surveillance Procedures
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p. 508	Appendix G -	Correspondence
p. 513	Appendix H -	General Exterior Concrete Exam

523 pages

Technical Evaluation

TMI-1 Reactor Building
Augmented Examination Requirements
For
Tendons Affected by SGRP Activities

Prepared by: Howard T. Hill, P. E. Date: 26 May 10

Reviewed by: Evan Johnson Date: 5/26/2010

Approved by: Thomas Geyer Date: 5/26/10

1. Reason for Evaluation / Scope

This technical evaluation provides input for the Tendon Surveillance Program for augmented examination of Reactor Building pre-stressing tendons affected by Steam Generator Replacement Project (SGRP) activities.

Steam generator replacement work included making an opening in the Reactor Building concrete wall, steel plate liner, and the associated replacement or de-tensioning / re-tensioning of 30 hoop and 45 vertical tendons. The creation and restoration of the opening constitutes a Repair / Replacement (R & R) activity as defined by ASME Section XI, which specifies that R & R work be periodically examined under the Reactor Building in-service inspection (ISI) program to ensure continuing integrity.

TMI-1 will perform the first of these augmented tendon examinations in late 2010 (during the 1st Reactor Building ISI interval) as recommended by the USNRC in License Amendment No. 259, which states that the requirements contained in the 2001 Edition (with Addenda through 2003) of ASME Section XI comprise an acceptable basis for the initial examination activity. This examination will conform, with the exception discussed in a later part of this evaluation, to this Edition / Addendum of Section XI.

Subsequent augmented examinations will conform to the code of record for the applicable Reactor Building in-service inspection interval. This evaluation covers examinations through the 2nd ISI interval which extends from 20 April 2011 through 19 April 2021. Examinations during this interval will follow the 2004 Edition (no Addenda) of Section XI.

The 2002 Addendum to Section XI, and later code editions, contain specific requirements for augmented examination of post-tensioning system tendons affected by R & R work. The augmented examination requirements in the 2002 Addendum and those in the 2004 Edition, which are effectively the same, are the basis for the program as described in this evaluation.

TMI-1 Surveillance Procedure 1301-9.1 provides detailed instructions for in-service examination of Reactor Building concrete and tendons as required by 10CFR50.55a and ASME Section XI, Sub-Section IWL. Augmented examinations will also be done under this procedure. This technical evaluation develops the programmatic requirements that are specific to the seventy-five (75) tendons affected by SGRP work. These requirements will be incorporated into Procedure 1301-9.1 under 01040851-04 so that the entire in-service examination of Reactor Building concrete and tendons can be performed under a single document.

Acceptance criteria applicable to the augmented examinations are not fully addressed in Sub-Section IWL. This technical evaluation develops comprehensive criteria for inclusion in Procedure 1301-9.1.

Repair of the post-tensioning system is not within the scope of this Technical Evaluation. This evaluation addresses only examination. Any repairs that are required as a result of examination findings will be done in accordance with Section XI.

The examination requirements addressed in this evaluation apply only to the Reactor Building pre-stressing tendons and associated anchorages. No other plant components are considered herein.

This technical evaluation covers only the examination requirements that will be a part of the 1st and 2nd Reactor Building ISI intervals. Subsequent updates to the program will be performed in accordance with the requirements in the applicable future amendments to 10CFR50.55a.

2. Detailed Evaluation

TMI-1 will examine the tendons affected by the SGRP work in accordance with the requirements of the 2004 Edition[1] (no Addenda) of the ASME Boiler and Pressure Vessel Code, Section XI, Sub-Section IWL. These requirements are summarized below.

IWL-2521.2(a) states that tendons affected by R & R activities shall be selected at random and examined in accordance with Table IWL-2521-2.

IWL-2521.2(b) states that any randomly selected tendon which is inaccessible for full examination shall be designated as exempt and replaced in the sample by the nearest accessible tendon included in the population affected by the R & R activity. It further requires visual examination of the exempt tendon anchorages per IWL-2524 and sampling / testing of corrosion protection medium (and free water, if found) per IWL-2525 to the extent that this can be done.

Table IWL-2521-2 lists the following requirements.

- An initial examination between 9 and 15 months following the completion of the R & R activity and subsequent examinations as specified by IWL-2420, which defines the schedule for tendons not impacted by the SGRP work.

[1] Section XI requirements pertinent to this technical evaluation and the augmented examination program are essentially the same in both the 2001 Edition (with Addenda through 2003) and the 2004 Edition.

- A sample size of 4% of the affected tendons in each group (vertical and hoop) for the first two examinations and, if the results are acceptable, 2% subsequently, with all percentage samples rounded up to the next whole number of tendons.

- All tests and examinations listed in Table IWL-2500-1 Category L-B which include lift-off force measurement, end anchorage visual examination, wire testing and corrosion protection medium (and free water if found) testing.

- Completion, during the next regularly scheduled outage, of all tests / examinations deferred due to plant operating conditions.

Implementation of these requirements under the program is detailed in the following paragraphs.

2.1 Examination Schedule

The SGRP R & R activity ended with the 17 January 2010 examination that followed completion of the post-repair pressure test. The first augmented examination will be done between 17 October 2010 and 17 April 2011. This satisfies the table IWL-2521-2 requirement that this examination be performed 9 to 15 months after the R & R completion date.

Subsequent examinations of tendons affected by the SGRP work will be concurrent with the regularly scheduled Reactor Building in-service inspections during fall outages in 2013, 2019, 2023, 2029 and 2033, unless changes to the plant fuel cycle or regulatory requirements alter this schedule.

2.2 Examination Scope

The SGRP work affected 30 of 330 hoop tendons and 45 of 166 vertical tendons. Twenty two hoops and ten verticals were replaced with new tendons; the remainder were de-tensioned and subsequently re-tensioned as summarized below.

- New Vertical Tendons (10): V131 through V140
- Re-tensioned Vertical Tendons (35): V113 through V130 & V141 through V157
- New Hoop Tendons (22): H46-30 through H46-39 & H51-28 through H51-39
- Re-tensioned Hoop Tendons (8): H46-28, H46-29, H46-40, H46-41, H46-42, H51-40, H51-41 & H51-42

2.2.1 Examination Sample Selection

Sampling requirements applicable to the first examination, to the second examination and to the subsequent examinations differ as addressed below.

(a) First Examination

The sample for the first examination will consist of 2 verticals (4% of 45 rounded up) and at least 2 hoops (4% of 30 rounded up). These will be selected by random draw subject to the following conditions.

- The first examination will be performed while the plant is in operation and the Buttress 1 ends of the H51 tendons are inaccessible for safety reasons. If an H51 sub-group tendon is selected by random draw, it will be treated as exempt per IWL-2521.1 and replaced with the corresponding H46 sub-group tendon (or the nearest thereto if already selected for examination) and:
    - Examined during the fall 2011 outage as specified in Table IWL-2521-2 Note 4 or;

- Examined during the regularly scheduled surveillance in the fall of 2013, in which case an additional H-46 sub-group tendon will be randomly selected and added to the first examination sample[2].

- The overall examination sample (vertical and hoop considered together) must include at least one new tendon and at least one re-tensioned tendon. The population from which the final sample tendon is drawn will be limited to new or re-tensioned tendons if necessary to meet this requirement.

The procedure used to make the random selection will be documented on a data form to be added to Procedure 1301-9.1.

(b) Second Examination

The sample for the second examination will consist of any tendons deferred from the first examination as well as 2 verticals and 2 hoops selected by random draw from a population that excludes those in the first examination sample.

The overall examination sample must include at least one new tendon and at least one re-tensioned tendon. The population from which the final sample tendon is drawn will be limited to new or re-tensioned tendons if necessary to meet this requirement.

The tendons to be included in the second examination sample will be selected following the completion of the initial examination. The procedure used to make the random selection will be documented on the data form cited in (a) above.

(c) Subsequent Examinations

If acceptance criteria are met in both the first and second examinations, the samples for subsequent examinations will consist of 1 vertical (2% of 45 rounded up) and 1 hoop (2% of 30 rounded up) selected by random draw from a population that excludes those previously examined. The overall examination sample may include any combination of new and re-tensioned tendons.

If acceptance criteria are not met in either the first or second examination, the requirements in (b) above will continue to apply until the results of two

[2] This option is not in compliance with Table IWL-2521-2 Note 4 which specifically requires that tendons declared inaccessible for operational reasons be examined during the next regularly scheduled outage. It is presented as a reasonable alternative that requires an expanded sample in exchange for additional deferral of randomly selected inaccessible tendons.

consecutive examinations are acceptable, at which time the preceding paragraph will apply.

The tendons to be included in each subsequent examination sample will be selected following the completion of the prior examination. The procedure used to make the random selection will be documented on the data form cited in (a) above.

2.2.2 Documenting Tendons Examined

SGRP scope tendons will be identified on a master tracking list that must be added to Procedure 1301-9.1 under 01040851-06.
This tracking list will be updated following the completion of each examination to identify all tendons that have been examined and removed from the population from which future examination samples are to be drawn.

2.2.3 Examinations

Each examination will consist of all visuals and tests identified in Table IWL-2500-1, Category L-B as follow.

- Visual examination of end anchorage hardware including anchor head, button heads, shims and bearing plate for evidence of corrosion, cracks and distortion.
- Examination of concrete surrounding the bearing plate for evidence of crack development, spalling and other types of damage / deterioration.
- Collection and testing of corrosion protection medium samples for water content, contaminants and reserve alkalinity as specified in Table IWL-2525-1.
- Collection and testing of any free water found in the anchorage area.
- Measurement of lift-off force.
- Testing of wires extracted from one vertical and one hoop tendon. For the first two examinations, one wire must be a new wire and one must be an original wire.

2.3 Acceptance Criteria

Acceptance criteria for individual SGRP scope tendons are the same as those for regular surveillance sample tendons. These criteria, which conform to the requirements of IWL-3220, are identified in Procedure 1301-9.1.

Sub-Section IWL does not address combining the SGRP scope tendons and regular surveillance sample tendons for determining group mean lift-off force. Since the SGRP scope tendons were seated at 70% - 73% of specified minimum ultimate tensile strength and since time dependent losses in these tendons will be small, measured anchorage forces are expected to remain relatively high throughout the operating lifetime of the plant. Therefore, including the measured anchorage forces in the vertical and hoop group means would probably introduce a non-conservative bias into the computed values.

For the above reason, measured forces in SGRP scope tendons will not be included in either the normalized mean computations or the trend analyses.

Acceptance criteria applicable to measured forces in individual tendons are based on expected (predicted) values. SGRP scope tendon predicted forces are computed and tabulated in Calculation C-1101-153-E410-046 (in course of preparation). This calculation is tracked under 01040851-03.

2.4 Examination Personnel, Measuring & Test Equipment and Procedures

Requirements for examination personnel training / certification, control of measuring & test equipment and examination procedures applicable to the SGRP scope tendons are the same as those that apply to regular surveillance sample tendons and that are currently addressed in Procedure 1301-9.1.

2.5 Removal / Replacement of Corrosion Protection Medium

Procedures and criteria covering the removal / replacement of corrosion protection medium and evaluation of the quantities documented are the same for both SGRP scope tendons and regular surveillance sample tendons. These are addressed in Procedure 1301-9.1.

3. Conclusions / Findings

This technical evaluation defines a program. Conclusions and findings do not apply.

4. References

References used in the preparation of this technical evaluation are listed below.

4.1 Code of Federal Regulations, Title 10, Part 50, Paragraph 50.55a, *Codes and Standards*, Current Amendment.

4.2 ASME Boiler and Pressure Vessel Code, Section XI, *In-Service Inspection*, 2001 Edition with Addenda through 2003.

4.3 ASME Boiler and Pressure Vessel Code, Section XI, *In-Service Inspection*, 2004 Edition (no Addenda).

4.4 Calculation 38455-CALC-C-005, *Containment Opening Analysis and Design for Temporary Opening and Restoration*, Revision 6.

4.5 TMI-1 Surveillance Procedure 1301-9.1, *RB Structural Integrity Tendon Surveillance*, Current Revision.

4.6 Amergen Energy Company, LLC / Docket No. 50-289 / Three Mile Island Nuclear Station, Unit No. 1 / Amendment to Facility Operating License, *Amendment No. 259 / License No. DPR-50.*

4.7 TMI-1 Calculation C-1101-153-E410-046, *TMI-1 Reactor Building / Post-Tensioning System In-Service Inspection Program / Tendon Force Prediction*, (in course of preparation).

Selection of Sample Tendons for the 2010 Augmented Reactor Building (IWL) In-Service Inspection

The selection of sample tendons for the 2010 Augmented Tendon Surveillance consists of 4% of the following tendon populations:

- SGR Affected Hoop Tendons – H46-28 to H46-42, H51-28 to H51-42
- SGR Affected Vertical Tendons – V113 to V157

Two tendons in each group are to be selected for surveillance testing. One tendon in each group is to be selected for specimen wire removal and additional testing. In addition to the selection requirements imposed in the 2004 Edition (no Addenda) of the ASME Boiler and Pressure Vessel Code, Section XI, Subsection IWL, the following restraints were placed on the selection:

- Each group consists of both new and re-tensioned tendons. The random selection from each group must contain at least one new and one re-tensioned tendon
- Of the two tendons selected for specimen wire removal and additional testing (one from each group), at least one such tendon must be a new tendon and the other a re-tensioned tendon.

To make the selection, each tendon per group was assigned a unique number in the following spreadsheet and the tendon identifier coded with a trailing hyphen or without, representing a new SGR tendon or a re-tensioned SGR tendon respectively. A random number generator was configured to generate a number between one and forty-five and was used to pick the first vertical tendon. If a number corresponding to a hyphen coded (new) tendon is first generated and selected, then subsequent numbers will be generated until the first number corresponding to a non-hyphen coded (re-tensioned) tendon makes the second vertical tendon selection. Likewise if a non-hyphen coded (re-tensioned) tendon is selected upon the first number generated, then subsequent numbers will be generated until the first number corresponding to a hyphen coded (new) tendon makes the second vertical tendon selection.

The same procedure described above was also used to make the surveillance tendon selection for the hoop group with random numbers limited to between one and thirty.

Next the two selected vertical tendons were assigned the unique numbers one or two (in the Wire # column of the attached spreadsheet). The random number generator was configured to produce a number one or two. The associated tendon selected in this process is assigned to have a specimen wire removed and additional testing. If the selected vertical tendon in this step is a hyphen coded (new) tendon, then the hoop tendon selected for specimen wire removal and additional testing will be the non-hyphen coded (re-tensioned) tendon, and vice versa.

The selection made based on the results of the random numbers generated is:

- V118, re-tensioned SGR tendon selected for specimen wire removal
- V134, new SGR tendon
- H46-39, new SGR tendon selected for specimen wire removal
- H46-41, re-tensioned SGR tendon

Attached is the spreadsheet listing all the SGR tendons by group and hyphen coded by new / re-tensioned tendons. Each tendon per group had a unique number used for the initial selection. The two selected tendons in the vertical group were assigned a second number, unique to each tendon in this second numbering sequence. Tendons whose unique numbers are dark orange colored were selected for examination. Tendons whose designator is bolded were those selected for specimen wire removal and additional testing.

The light coloring in the legend labeled "Nearest Substitute" was intended to be used if a H51-XX tendon was selected. This is because those tendons are inaccessible during the time of this schedule surveillance due to their location above the MSSV's and a nearest substitute would need to be designated from the H46-XX group if one were selected. No H51-XX tendons were randomly selected and thus nearest substitutes were not needed.

SGR Random Sample Selection

Wire #	Number	Tendon	Number	Tendon
	1	V113	1	46-28
	2	V114	2	46-29
	3	V115	3	46-30-
	4	V116	4	46-31-
	5	V117	5	46-32-
1	6	**V118**	6	46-33-
	7	V119	7	46-34-
	8	V120	8	46-35-
	9	V121	9	46-36-
	10	V122	10	46-37-
	11	V123	11	46-38-
	12	V124	12	**46-39-**
	13	V125	13	46-40
	14	V126	14	46-41
	15	V127	15	46-42
	16	V128	16	51-28-
	17	V129	17	51-29-
	18	V130	18	51-30-
	19	V131-	19	51-31-
	20	V132-	20	51-32-
	21	V133-	21	51-33-
2	22	V134-	22	51-34-
	23	V135-	23	51-35-
	24	V136-	24	51-36-
	25	V137-	25	51-37-
	26	V138-	26	51-38-
	27	V139-	27	51-39-
	28	V140-	28	51-40
	29	V141	29	51-41
	30	V142	30	51-42
	31	V143		
	32	V144		
	33	V145		
	34	V146		
	35	V147		
	36	V148		
	37	V149		
	38	V150		
	39	V151		
	40	V152		
	41	V153		
	42	V154		
	43	V155		
	44	V156		
	45	V157		

= Randomly Selected

= Nearest Substitute

No hyphen = SGR Affected Tendon

With hyphen = SGR Replaced Tendon

Post Containment Repair/Restoration Augmented Exam		New SGRP Tendons for Inspection	Re-Tensioned SGRP Tendons for Inspection	New SGRP Tendon for Wire Removal	Re-Tensioned SGRP Tendon for Wire Removal
Tendon Location	Vertical	V134	V118		V118
	Horizontal	H46-39	H46-41	H46-39	

Evaluation of Two Broken Tendon Wires on Tendon V118 as Found During the 2010 Augmented Reactor Building (IWL) In-Service Inspection

Preparer:	Evan Johnson	Date: 2/14/11
Co-Preparer:	Howard T. Hill, P.E.	Date: 2/14/11
Reviewer:	Gene Navratil	Date: 2/14/11
Approver:	Tom Geyer	Date: 2/22/11

Copies to be forwarded to: Dan Fiorello, Heather Malikowski, and Hien Do

1. Reason for Evaluation and Scope

The purpose of this technical evaluation is to evaluate the acceptability of two broken tendon wires on tendon V118 as found during the 2010 Augmented Reactor Building (IWL) In-service Inspection. The extent of condition and wire sample results are also documented and evaluated in this document. This evaluation is required per ASME XI 2004 ed. with no addenda and is prepared per such requirements.

Broken wires in small numbers do not adversely affect a tendon's ability to hold its required pre-stress. This has already been evaluated in the past for up to five broken/in-effective wires in a 169 wire tendon (Ref 4.5). The as left condition of tendon V118 is 166 effective wires and requires no further evaluation. This evaluation is limited to the extent of condition for un-expected discovery of two broken wires in tendon V118.

2. Detailed Evaluation

This evaluation has been prepared IAW Exelon Procedure CC-AA-309-101. A technical task risk and rigor assessment and pre-job brief has been conducted IAW Exelon Procedure HU-AA-1212. This evaluation screened as having a risk ranking of 1 (lowest risk ranking) and as such, the existing review process required in CC-AA-309-101 is adequate.

This evaluation is developed using inspection data inputs from the reactor building in-service inspection contractor (Precision Surveillance Corporation), an Exelon Powerlabs failure analysis report, and first hand accounts of the events from the preparer and co-preparer. All data sheets and reports have been reviewed by the preparer, co-preparer, and, where applicable, an authorized nuclear in-service inspector (ANII).

During the scheduled visual inspection of vertical tendon V118 for the 2010 Augmented Reactor Building (IWL) In-service Inspection, the as-found VT-1 exam documented two of the 169 tendon wire buttonheads (ends) were not fully seated on the top (shop) end tendon anchorhead (Attachment A). The initial observations of the VT-1 examiner were that the buttonheads were protruding ~0.1 inches above the anchorhead seating surface and that the two buttonheads appeared to be slightly oversized.

Per ASME XI 2004 ed. with no addenda, broken or unseated wires are not an acceptable condition and shall be evaluated (IWL-3221.3, IWL-3222). This report will evaluate the cause of the condition, applicability of the condition to other tendons and any other plants at the same site, acceptability of the containment without repair of the item, the necessity for repair or replacement, and the extent, nature, and frequency of additional examinations (IWL-3310).

The following investigation plan and disposition was developed by the Responsible Engineer (Howard T. Hill) in accordance with IWL-2320, IWL-3222, and IWL-3300 of ASME XI 2004 ed. with no addenda, and TMI Procedure 1301-9.1.

IR 1129072 was written to document this recordable indication (per ER-AA-335-018) and the recommended actions were to perform a mechanical continuity test of the two wires after the tendon had been de-tensioned to verify whether they were broken or not broken.

Force in the tendon was next measured per the planned inspection prior to de-tensioning. The tendon pre-stress met acceptance criteria having a pre-stressing force slightly greater than predicted (Ref. 4.6 & 4.8).

The tendon was detensioned after the pre-stress measurement. A wire pulling assembly was connected to the two protruding buttonheads one at a time and was pulled with a force less than the yield strength of the wire to verify the wires' mechanical continuity.

Both buttonheads pulled out of the anchorhead with ~4" of wire up to fractures in the wires. The breaks in the two wires had nearly identical fracture characteristics and were located where the wire exits the ~4" thick anchorhead. Both fracture ends of the two 4" wire stubs showed visible indications of external damage in the form of a slight bend and a shiny spot where mechanical contact was made with the wires during some past event. No corrosion was observed. Both wires were located in "corner" positions on the same side of the top (shop) anchorhead (see page 2 of Attachment A) and are most vulnerable to external mechanical damage in these positions within the tendon. IR 1129648 documented the discovery of the broken wires.

The tendon was next pulled up to inspect the break on the remaining length of the wires in the tendon and to examine the other 167 wires for signs of damage. The mating broken ends of the two wires were observed to have similar indications to the fractured area on the 4" pieces removed. The remaining wires did not appear to have any damage over all observable areas above or below the top (shop) anchorhead and no corrosion was observed.

The remaining 167 wires were each checked for mechanical continuity. This was done one of two ways. The first was to allow the detensioned tendon wires to protrude from the bottom (field) anchorhead several inches. A buttonhead at the top end is then attached to the wire pulling assembly and the wire is pulled until a lower buttonhead is observed to retract into the tendon. The lower buttonhead is then marked as a continuous wire. This method was performed for some of the wires until it became too difficult to connect the wire pulling assembly to the upper buttonheads. This difficulty comes from the need to hand pry the buttonheads up from the top (shop) anchorhead against the weight of the hanging tendon wire.

The remaining wires were tested by attaching the wire pulling assembly to each wire from the bottom side and pulling on the wire to a force of 5500 – 6000 lbf. The assumption of this test is that a continuous wire will (approximately) linearly elongate up to the maximum force which was applied while measured with a dynamometer. A non-continuous wire is expected to pull out with a force much less than 5500 lbf. For this testing, TMI M&TE Dynamometer #0002788915 was used and is documented in the

PIMS Work Order R2319507 Activity 02 (Ref. 4.8). All of the 167 wires were found to be mechanically continuous per this testing (Attachment B).

During the manipulation of the tendon and wires, one of the lower ends of the two broken wires partially fell out of the bottom (field) anchorhead and was removed by hand. The lower end of the other broken wire was found during the mechanical continuity test. The wire was pulled out of the tendon from the bottom with a recorded maximum force of ~100 lbf. These events provide validity that a wire holding 5500 lbf is continuous.

The removed broken wires were each cut into 46 four foot lengths plus the broken 4" ends. Each of the 46 segments (per wire) was tagged with a piece of red tape labeled with: an incremental number, a black dot or absence of (differentiating the two wires), and an arrow pointing to the bottom (field) buttonhead direction of the wires (marking the up/down orientation of the wire segments). Samples from both ends and the center of each wire were sent to Exelon Powerlabs for a failure analysis of the wire breaks and a material strength test of the wires IAW ASTM A370, the test specification for the ASTM A421 0.25" diameter round wires. The Powerlabs failure analysis report (Attachment C) concluded:

"All tensile test results for Load @ 1%, Breaking Load & % Elongation, were in accordance with 0.250" diameter wire spec ASTM A421acceptance criteria.

The two V-118 broken wires had fractured surfaces indicative of both shearing forces and ductile overload. Circumferential indentations and slight bending was observed adjacent both wire fractures; most likely from where the wire exits the anchor head. This location would be characterized, as a geometric stress riser as well as a source for shearing forces synergistic with the mechanical notch would significantly contribute to premature wire failure.

Another unconfirmed possible contributing factor would be if the overall effective wire length was slightly shorter than the others within the tendon, hence under a greater share of the total load."

All test samples of the broken wires met the specifications for the material and showed no signs of degradation of the material properties. The broken sections of wire exhibited signs of external mechanical damage and the fracture surfaces indicated shearing forces and ductile overload. The mechanical damage to the wires, in the form of slight bending and circumferential indentations, acts as a stress riser and a source of shearing.

The relative positions of the two broken wires in the upper anchorhead can be observed in page 2 of Attachment A. The wire locations in the extreme corners of an anchorhead are most likely to expose the wires to mechanical contact with the anchorhead, shims, bearing plate, or other external objects. A wire damaging event could have happened during original tendon installation or during de-tensioning or re-tensioning activities during the Steam Generator Replacement Project (SGRP). It is plausible that these two corner wires could have been damaged without the event affecting any of the other wires

in the tendon. Additionally, the visual inspection of the tendon wires exiting the top anchorhead did not have any signs of damage besides the two broken wires.

In addition to testing the broken wires and verifying the continuity of the remaining wires in tendon V118, additional examinations included removing the end caps from the two adjacent tendons, V117 and V119, and performing a VT-1 exam to verify the absence of any protruding buttonheads or other indications of broken wires. V117, V119, and the other randomly selected surveillance tendon's as found exams matched the documented as-left condition from the SGRP with no indications of broken wires not previously documented. No other additional examinations for the extent of condition were performed.

At the conclusion of the tendon wire testing, a sample wire (3rd wire) was removed from V118 for the planned materials testing per IWL-2523. V118 was then re-tensioned with 166 effective wires in accordance with the site surveillance procedure and IWL-2523.3. V118 was re-tensioned twice because after the first tensioning, the shim stack on the top (shop end) was taller than the end cap could fit. The tendon was de-tensioned, some shims re-distributed to the bottom (field end), and then re-tensioned for a second time. Both times the tendon was tensioned to an acceptable force and the tendon elongation rate was well within the acceptance criteria of <10% difference from previous tensioning (Attachment D).

3. Conclusions

The conclusions presented herein are based on assumptions that the inspection inputs are valid and accurate. It is possible that these wires have been broken since plant construction and the very minor buttonhead protrusion not identified until this surveillance. However, due to the ease of which the lower end of the broken wire fell from the lower anchorhead and the disturbance the tendon experienced from the SGRP, it is most probable that the wires were damaged during SGRP re-stressing of the tendon.

It is concluded that the broken wires are an isolated event affecting only the two broken wires in V118 and was most likely caused by external mechanical damage to the wires assumed to have occurred during the SGRP. The acceptable material properties of the wire samples, Exelon Powerlabs analysis of the fractures, positions of the broken wires at the anchorhead corners (most vulnerable to external mechanical damage), verified mechanical continuity of the remaining wires, acceptable tendon stressing at the conclusion of the surveillance, and the lack of any other indications on either of the neighboring tendon's additional examinations or any other surveillance tendon's examinations support this conclusion.

Tendon V118 is acceptable with the remaining 166 effective wires and the previous evaluation presented in Reference 4.5 justifies acceptability of the tendon and containment without any repairs to V118. Per the Responsible Engineer, there is no need to repair or replace any tendon wires. V118 was left with all buttonheads fully seated, and tensioned to a force between the predicted force at the time and 70% of the

guaranteed ultimate tensile strength of the tendon adjusted for effective wires per IWL-2523.3. The additional examinations concluded with the inspection of the two adjacent tendons (V117 and V119) and materials testing of the broken wires and no further extent of condition examinations are required (IWL-3310(e)).

4. References

4.1 ASME XI 2004 Ed.
4.2 10 CFR 50.55a
4.3 ASTM A370 and ASTM A421
4.4 TMI procedure 1301-9.1 Rev. 21, RB Structural Integrity Tendon Surveillance
4.5 Passport AR 00982006 A02
4.6 C-1101-153-E410-046, TMI-1 Reactor Building Post-Tensioning System In-Service Inspection Program Tendon Force Prediction
4.7 Exelon Procedure ER-AA-335-018 Rev. 005, Detailed General VT-1 VT-1C VT-3 VT-3C Visual Examination of ASME Class MC and CC Containment Surfaces and Components
4.8 TMI PIMS Work Order R2139507 (2010 Augmented ASME IWL Inspection)

5. Attachments

Attachment A[1]	VT-1 exam data sheets of the as-found top anchorhead of V118
Attachment B[1]	Wire continuity test procedure and results
Attachment C	Exelon Powerlabs report on the fractured wires
Attachment D	Tendon V118 elongation rate graph and brief summary

1: It should be noted that the depictions of the broken wire locations between Attachment A and B are different. This is because Attachment A depicts the top (shop) anchorhead and Attachment B depicts the bottom (field) anchorhead. During plant construction, the tendons were delivered (from the fabrication shop) with the wires threaded and button-headed through the shop end anchorhead. The tendon is then pulled through the building's tendon ducts, and the bottom (field) anchorhead is installed in the field. There is no correlation between a wire's position in the shop and field anchorheads.

ATTACHMENT 5
ASME IWL (Class CC) Containment Tendon Anchorage
Detailed Visual or VT-1 Visual Examination NDE Report
Page 1 of 1

Station: TMI | Unit: 1 | Date: 10-19-2010 | Report No: N/A

WO No(s): R21295-07 | Tendon Anchorage No: V-118 | Tendon End: ☒ Shop ☐ Field

Location: (Tunnel) Gallery, Buttress | Elevation: 456'-2" | Bearing Plate I.D: unable to locate.

Bearing Plate I.D: Unable to locate | Anchor Head I.D: 793 | Bushing I.D: 578

Exam Type: ☐ DV ☒ VT-1 | Type Of Exam: ☒ Direct ☐ Remote

☒ As Found Exam ☐ As Left Exam Following Retensioning Of Tendons Which Have Been Detentioned

Design Drawing(s): TMI 1-0016 | Visual Aids: None

M&TE Used: Steel Rule R-22 Cal Due 2-24-11 ☒ Test Card | UTC or Serial No: N/A | Cal Due Date: N/A

Illumination Used: Spot Light | Illumination Verified: Date 10-19-10 | Time 12:30 PM

Special / Specific Instructions:

Component / Item Number and Description	RESULTS NI	RI TYPE	IO	Explanation / Notes (Sketch Shall Be Attached Depicting Location Of All Missing, Protruding, Unseated Wires)
V-118 Tendon Anchorage Shop/Top end.		C		2 protruding wires. Both protruding .100". See enclosure 6 Data sheet 4.
			O	These wires appear to be slightly oversized.

Results Legend
NI - No Indications RI - Recordable Indication IO - Information Only

Recordable Indication Type Codes

A	Missing Wires	H	Cracks	O	Other (Explain)
B	Missing Button Heads	I	Pitting		
C	Protruding / Unseated Wires	J	Nicks, Gouges, Mechanical Damage		
D	Broken Wires	K	Uneven Shim Stack		
E	Active Corrosion	L	Excessive Shim Gaps		
F	Other Corrosion	M	Gasket Seating Surface Damage		
G	Evidence Of Free Water (Quantify)	N	Surface Discontinuities, Deflections		

Supplemental Information: ☒ Yes ☐ No ☒ Sketch ☒ Photo ☐ Video ☐ Other (Describe)

Results Acceptable ☒ Yes ☐ No

EXAMINER/EVALUATOR (Print & Sign) Timothy C. Gibson | LEVEL II | DATE 10-19-10

STATION/ADMIN REVIEW (Print & Sign) Evan Johnson Sr | DATE 10/26/2010

This section to be completed only if Examiner/Evaluator notes RI or Unacceptable condition.

RI or Unacceptable results Acceptable ☐ Yes ☐ No NO RI

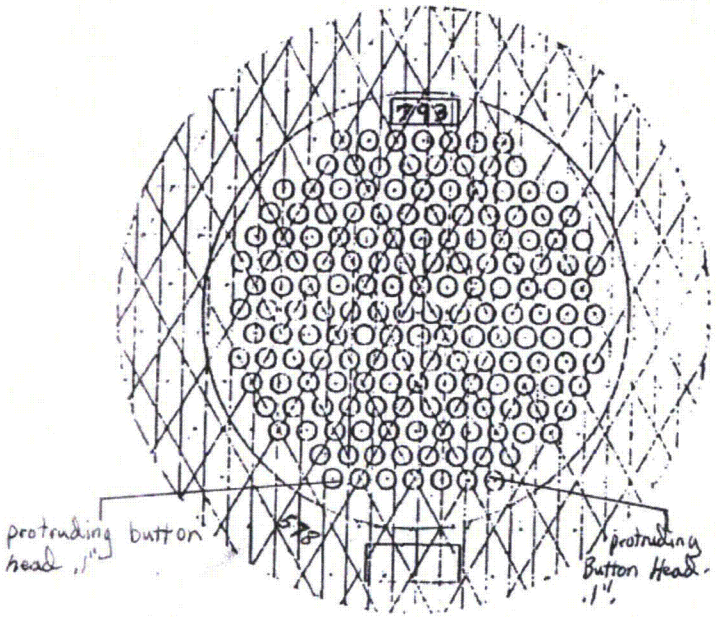
Additional Actions (Action Request, Work Order, Issue Report, etc. initiated for Corrective Action)

LEVEL III or RI REVIEW (as applicable) (Howard Hill) | DATE 29 Oct 10

ANII REVIEW (as applicable) Joseph A Shelby | DATE 11-4-10

Page 1 of 1

ENCLOSURE 6
Data Sheet 4
Tendon Buttonhead Inspection
AS Found Inspection



RB Tendon Surveillance

COMMENT: Shim Stack Hieght - 16.3"
(4,4,4,1,1,2)

No noted corrosion.

INSPECTED BY
CONTRACTOR FOREMAN _____ Date _____
VERIIFIED BY
COGNIZANT QV INSPECTOR [signature] Date 12-19-10
COGNIZANT MECH/STRUCT ENGINEER [signature] Date 29 OCT 10
REVIEWED BY

INSPECTION PERIOD 35 H.

Tendon # V-118
END: FIELD ____ (1 piece washer)
SHOP X (2 piece washer)

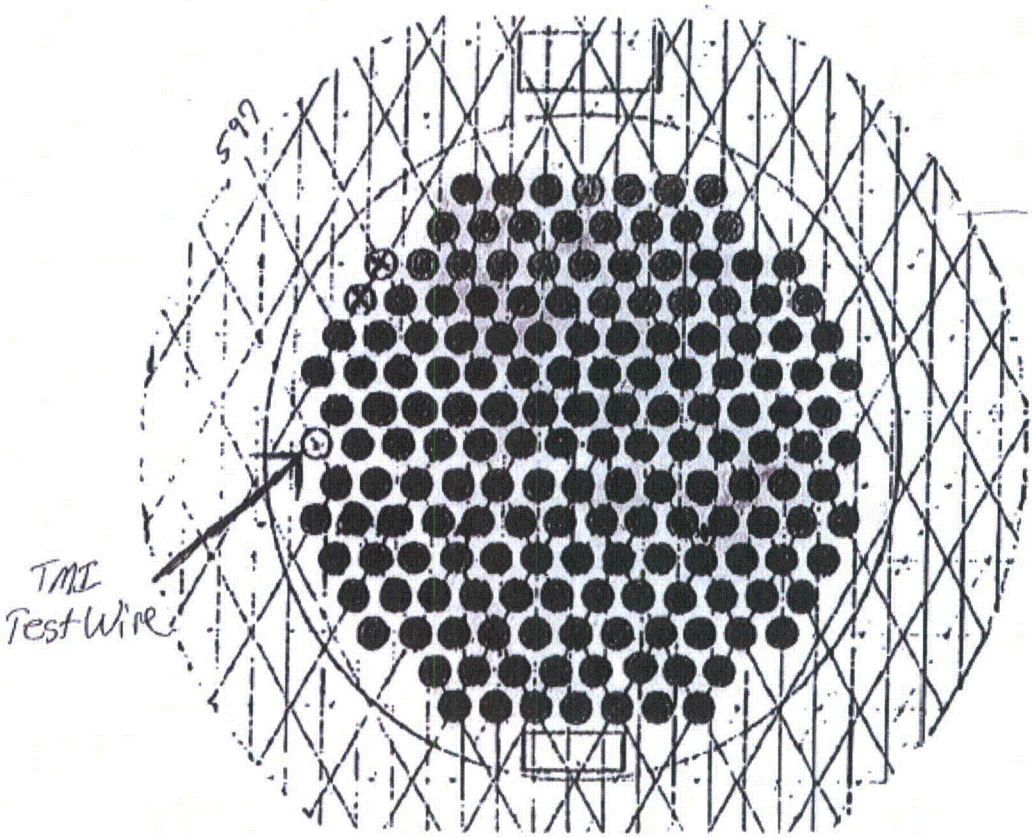
TMI-1 2010 Augmented Tendon Surveillance
Wire Continuity Test Data Sheet 1 of 2
(Use for Verifying Continuity of Vertical Wires by Pulling at the Bottom End)

Tendon Number V-118 / Date 10-25-2010 / Signature [illegible]

Dynamometer ID No. 0002288915 / Cal due Date 11-09-2010 / Accuracy MFR. Specs.

Data Sheet 1 Instructions:

1. Connect pulling device with in-line dynamometer to each wire in sequence.
2. Increase pulling force until dynamometer indicates between 5,500 and 6,000 lb. DO NOT EXCEED A PULLING FORCE OF 6,000 LB.
3. If pulling force will not reach 5,500 lb, wire is broken. Remove in one piece and store against inside wall of the tendon gallery. Record on Data Sheet 2 the maximum pulling force applied to the removed wire.
4. If continuity is verified, blacken the appropriate circle in the anchor head sketch below.
5. If wire is broken and removed, mark the appropriate circle with an 'X '.
6. If wire is removed for a surveillance test sample, mark the appropriate circle with a single slash.
7. Identify the short test wire with an arrow pointing to the appropriate circle.



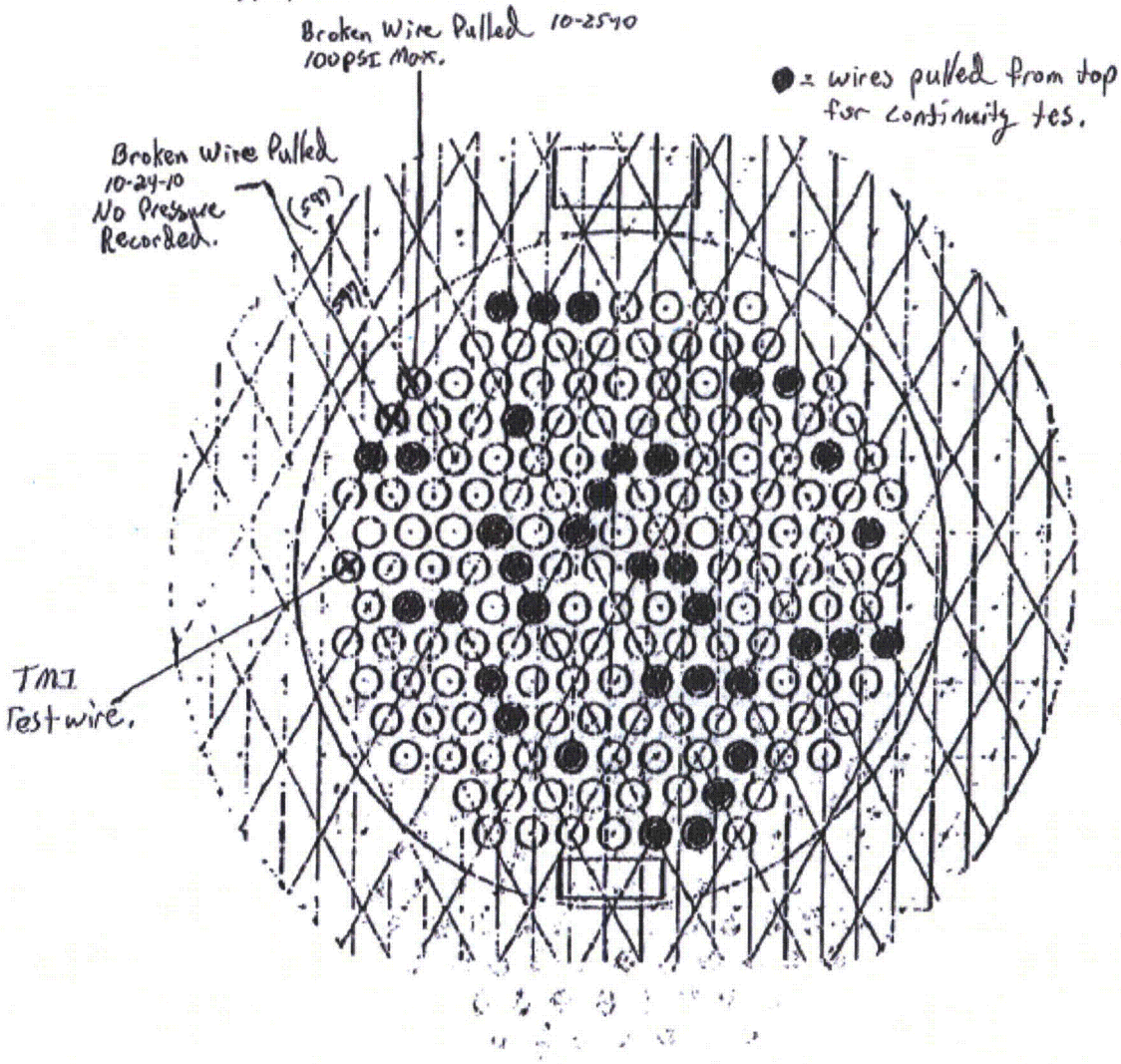
TMI-1 2010 Augmented Tendon Surveillance
Wire Continuity Test Data Sheet 2 of 2
(Use for Verifying Continuity of Vertical Wires by Pulling at the Bottom End)

Tendon Number V-118 / Date 10-25-10 / Signature [signature]

Dynamometer ID No. 0002-78915 / Cal due Date 11-09-2010 / Accuracy MFRS. SPECS.

Data Sheet 2 Instructions:

1. On the diagram below, identify each removed wire by marking the appropriate circle with an 'X'.
2. For each wire removed, record the maximum applied pulling force adjacent to the anchor head diagram. Draw an arrow from the recorded force to the appropriate marked circle.



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To: **Evan Johnson, Three Mile Island Station**

From: **R. John Diletto, (610)380-2427**
john.diletto@ExelonPowerLabs.com

Project Number: **TMI-18793**

Subject: **Material and Failure Evaluation of Two Wires in Tendon V118 Found Protruding in the Upper Anchor Head, Oct 2010 Buttonhead Inspection Ref WO: R2139507, Three Mile Island**

Date: **January 5, 2011**

DESCRIPTION

COMPONENT FAILURE & INITIAL INVESTIGATIONS:
Two corner wires were found not fully seated in the anchor head. The wires were pulled from tendon with little effort. There are 169 wires per tendon, each approximately 184" long. The anchor head, approximately 4" thick, is hydraulically lifted and shimmed to achieve a tensile stress of 83% of the tendon design maximum tensile strength. No corrosion was reported during the inspection and removal.

REQUESTED WORK AND SPECIAL INSTRUCTIONS:
The 0.25" diameter high strength steel wire samples need to be tested IAW ASTM A370 as specified in the wire spec ASTM A421. The analysis should also investigate the cause of the break.

CONCLUSIONS

All tensile test results for Load @ 1%, Breaking Load & % Elongation, were in accordance with 0.250" diameter wire spec ASTM A421acceptance criteria.

The two V-118 broken wires had fractured surfaces indicative of both shearing forces and ductile overload. Circumferential indentations and slight bending was observed adjacent both wire fractures; most likely from where the wire exits the anchor head. This location would be characterized, as a geometric stress riser as well as a source for shearing forces synergistic with the mechanical notch would significantly contribute to premature wire failure.

Another unconfirmed possible contributing factor would be if the overall effective wire length was slightly shorter than the others within the tendon, hence under a greater share of the total load.

The Exelon PowerLabs Quality System meets **10CFR50 Appendix B, 10CFR21, ANSI N45.2, ANSI/NCSL Z540-1, and NQA 1.**
Exelon PowerLabs is **ISO 9001:2000 Registered (8734)**
and **ISO/IEC 17025 Accredited (2044.01/02).**

TEST PLAN

1. Photo document the as-received tendon wires.
2. Perform tensile tests on each wire at the top, mid and lower segments. Reference ASTM A412 for acceptance criteria.
3. Perform Stereoscopic examination and photo documentation.
4. Perform electron microscopy exam on both fractures.

STATEMENT OF QUALITY

Testing was performed with standard equipment that have accuracies traceable to nationally recognized standards, or to physical constants, by qualified personnel, and in accordance with the **Exelon** PowerLabs Quality Assurance Program.

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Project review and approval is electronically authenticated in Exelon PowerLabs project record.

cc: Fleet Dist

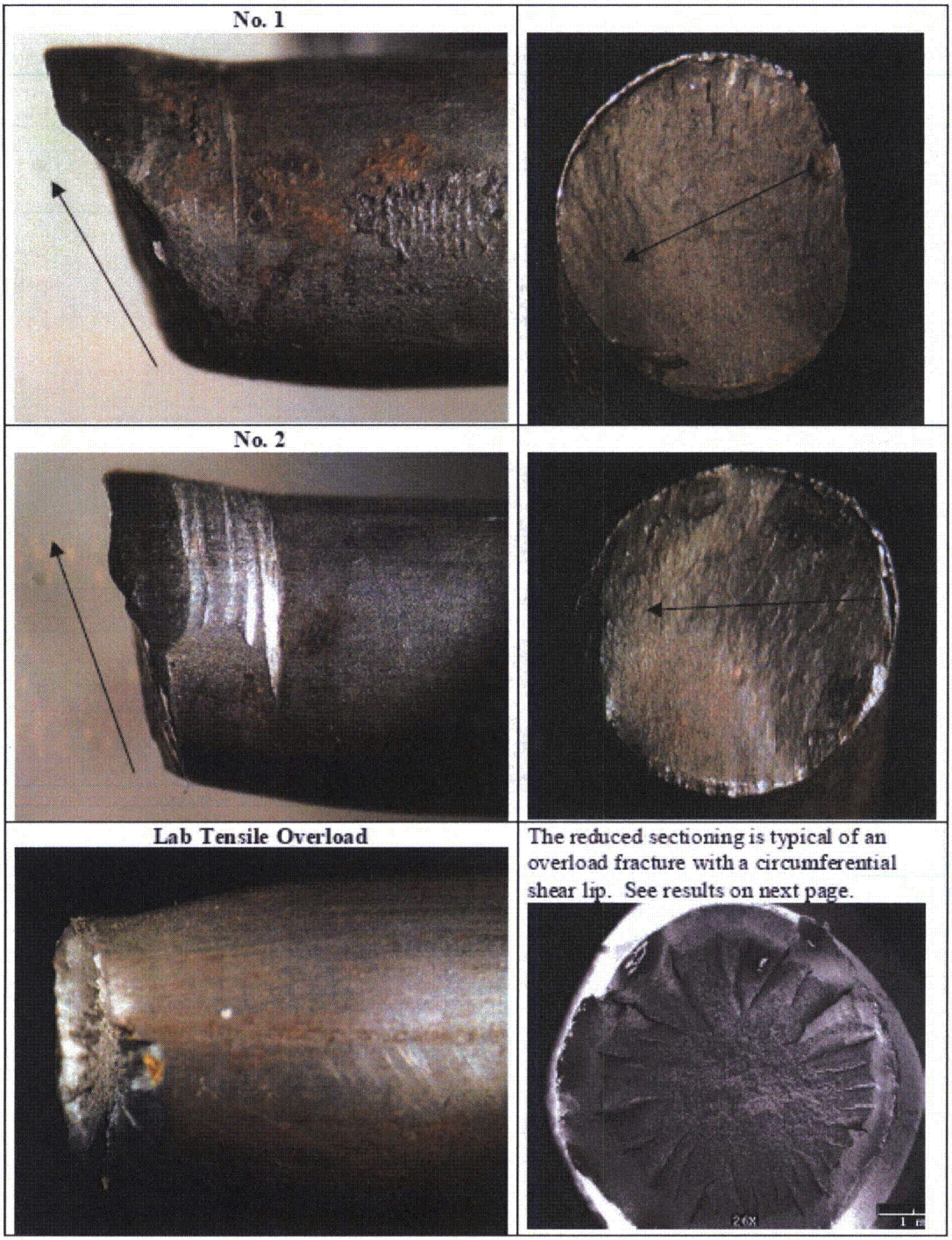
OBSERVATIONS and DATA

Figure I. Photographs of the As-Received V-118 Tendon Wires Nos. 1 and 2

	V-118 Tendon Wire No. 1 The wire length No. 46 fracture was located approximately 4" from the upper (roof) end and most likely where the wire exits the anchor head. Wire length No. 1 was at ground level and length No. 23 was approximately mid-length.
	V-118 Tendon Wire No. 2 The wire length No. 46 fracture was located approximately 4" from the upper (roof) end and most likely where the wire exits the anchor head. Wire length No. 1 was at ground level and length No. 23 was approximately mid-length.

Figure II. Side & End View Photographs of the Fractured Tendon Wires Nos. 1 and 2

Wire Nos. 1 & 2 both exhibited circumferential scoring and lateral deformation adjacent the fracture suggestive of a shearing force. The arrows in the photos below denote the direction of fracture.

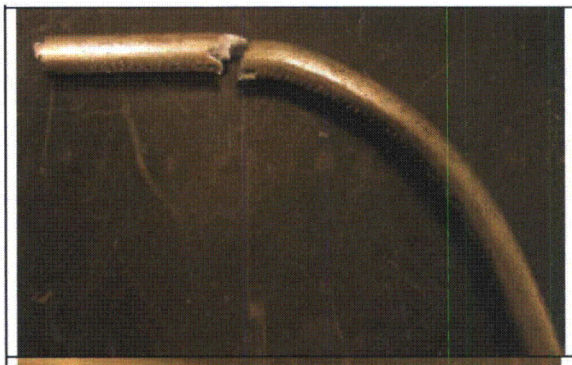
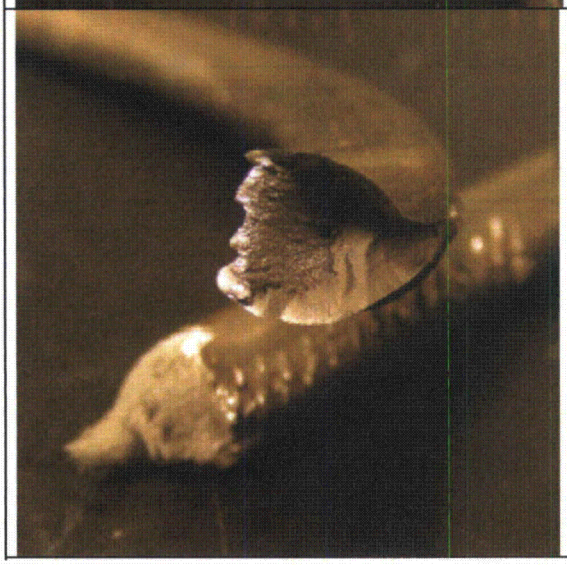


Tensile Testing in accordance with ASTM A421

	Load @ 1%	Breaking Load	Final Gage	% Elongation
Wire 1	Lbf.	Lbf.	Inches	
1	10,600	12,275	10.57	5.7%
23	10,650	12,275	10.55	5.5%
45	10,500	12,150	10.60	6.0%
Wire 2				
1	10,650	12,200	10.525	5.25%
23	10,700	12,175	10.540	5.45%
45	10,775	12,200	outside gage	
45 re-do	10,750	12,150	10.50	5.0%
Acceptance	**>10,016**	**>11,784**		**>4.0%**

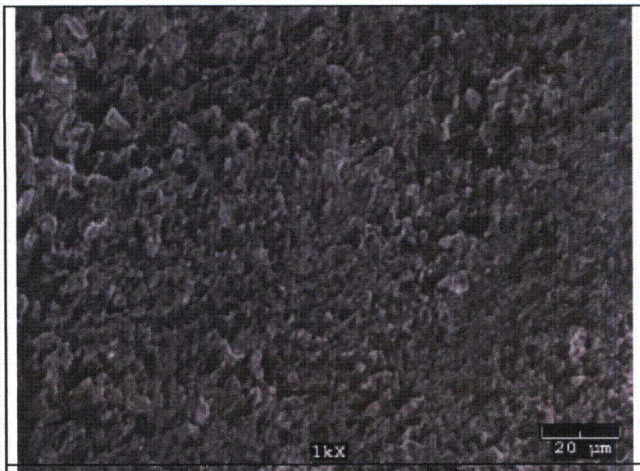
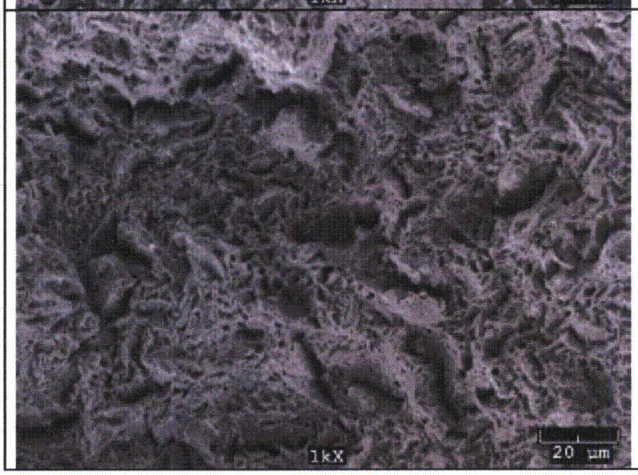
All tensile results were iaw 0.250" diameter wire.

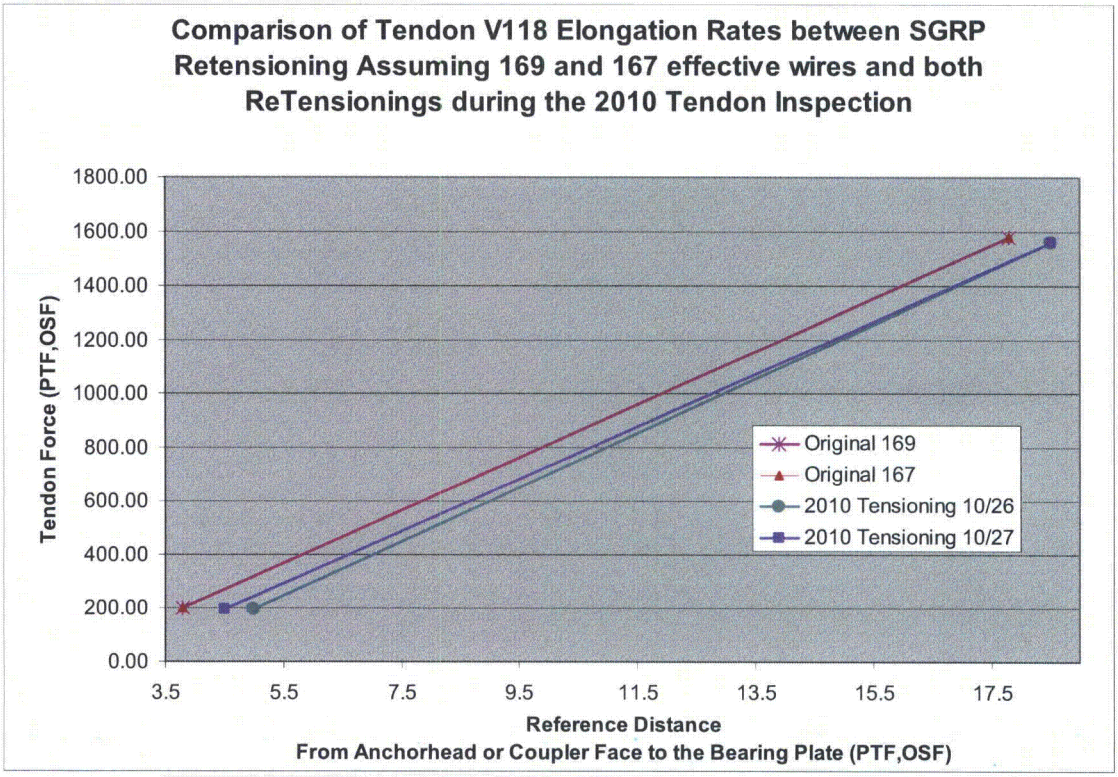
Figure III. Lab Notched Bending Fracture

	A short wire length was horizontally positioned and the vise jaws were tightly closed vise to induce surface scoring. The wire was repositioned vertically and the free end was bent approximately 60-degrees when rapid fracture occurred.
	The fracture initiated at one of the surfaces indentations. The fracture surface had a fibrous appearance, characteristics of ductile overload accompanied by shear lips at both neutral quadrants. There was no necking down as in the lab tensile overload test.

Electron Microscopy

Figure IV. Fractographs of the Tendon Wires Nos. 1 and 2 and the Lab Fracture

	No. 1 Ball End Fracture The fracture appearance exhibited an aged ductile surface. Magnification: 1000X
	No. 2 Ball End Fracture The fracture appearance exhibited an aged ductile surface. Magnification: 1000X
	The tensile test fracture surface was as-expected for a ductile overload failure. Magnification: 1000X



	SGRP Tensioning (assuming 169 effective wires)	SGRP Tensioning (assuming 167 effective wires)	2010 Tensioning 10/26	2010 Tensioning 10/27	
# of Wires	169	167	166	166	
PTF Force	199.20	199.20	195.81	195.81	kip
PTF Dist	3.8	3.8	5.0	4.5	inch
OSF Force	1581.90	1581.90	1558.73	1558.73	kip
OSF Dist	17.8	17.8	18.5	18.5	inch
Diff Force	1382.70	1382.70	1362.92	1362.92	kip
Diff Dist	14.0	14.0	13.5	14.0	inch
Elong Rate	**1.711**	**1.691**	**1.644**	**1.705**	inch-wire/kip
Elongation Rate % change from SGRP 169			**3.909**	**0.350**	%
Elongation Rate %change from SGRP 167			**2.758**	**0.844**	%
Elongation Rate %change from 10/26				**3.704**	%

The acceptance criterion for allowable change in elongation rate is <10% change from the last tensioning per IWL-3221.1. The variations observed here are normal and expected. The change in elongation rate from 10/26 to 10/27 can be explained as a re-distribution of the tendon's twist. The 169 wire bundle in the tendon duct has a twist to distribute the elongation of the wires more evenly when a tendon is routed through a curved duct. The twist distribution was altered when the wires were pulled individually and subsequent de- and re-tensioning will re-distribute the twist and result in a larger elongation rate as observed here. In this case, the vertical tendon V118 has no curvature in its duct and the wire twist is of little to no importance other than its effect on elongation rate.