Sengupta, Abhijit

From: Miller, Craig L [Craig.Miller@pgnmail.com]
Sent: Saturday, January 16, 2010 12:53 PM
To: Portmann, Rick; Lake, Louis; Thomas, George; Ghosal, Partha S.; Carrion, Robert; 'nausdj@ornl.gov'
Cc: Williams, Charles R.
Subject: Failure Mode 6.2 for Review and Comment
Attachments: FM 6.2.pdf; FM 6.2 Exhibit 1 Subsection IWL.pdf; FM 6.2 Exhibit 2 Wire Material from DBD11-2-1.pdf; FM 6.2 Exhibit 3 Strain along Wire.pdf; FM 6.2 Exhibit 3 Strain along Wire.pdf; FM 6.2 Exhibit 4 Wire Surveillances.pdf; FM 6.2 Exhibit 5 Wire Testing-1.pdf; FM 6.2 Exhibit 6 atlas 947613_0001.pdf

2 page 14 pages 1 page 2 pages 1 page 1 page 10 pages 1 page

Mr. Lake and others,

Attached for your review is the draft of FM 6.2 and its exhibits. If you have any questions, please contact Charles Williams or myself.

Thank you,

Craig Miller

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SUBSECTION IWL
REQUIREMENTS FOR CLASS CC CONCRETE COMPONENTS OF LIGHT-WATER COOLED PLANTS

ARTICLE IWL-1000
SCOPE AND RESPONSIBILITY

IWL-1100 SCOPE

(a) This Subsection provides the rules and requirements for preservice examination, inservice inspection and repair of the reinforced concrete and the post-tensioning systems of Class CC components, herein referred to as concrete containments as defined by CC-1000.

(b) The rules and requirements of this Subsection do not apply to the following:

(1) steel portions not backed by concrete;

(2) shell metallic liners;

(3) penetration liners extending the containment liner through the surrounding shell concrete.

IWL-1200 ITEMS SUBJECT TO EXAMINATION

IWL-1210 EXAMINATION REQUIREMENTS

The examination requirements of this Subsection shall apply to concrete containments.

IWL-1220 ITEMS EXEMPT FROM EXAMINATION

The following items are exempt from the examination requirements of IWL-2000:

(a) tendon end anchorages that are inaccessible, subject to the requirements of IWL-2521.1;

(b) portions of the concrete surface that are covered by the liner, foundation material, or backfill, or are otherwise obstructed by adjacent structures, components, parts, or appurtenances.

ARTICLE IWL-2000
EXAMINATION AND INSPECTION

IWL-2100 INSPECTION

Examinations shall be verified by an Inspector.

IWL-2200 PRESERVICE EXAMINATION

Preservice examination shall be performed in accordance with the requirements of IWL-2500.

IWL-2210 EXAMINATION SCHEDULE

Preservice examination shall be completed prior to initial plant startup.

IWL-2220 EXAMINATION REQUIREMENTS

IWL-2220.1 Concrete

(a) Preservice examination shall be performed in accordance with IWL-2510.

(b) The preservice examination shall be performed following completion of the containment Structural Integrity Test.

IWL-2220.2 Unbonded Post-Tensioning Systems. The following information shall be documented in the preservice examination records. This information may be extracted from construction records.

(a) Date on which each tendon was tensioned.

(b) Initial seating force in each tendon.

(c) For each tendon anchorage, the location of all missing or broken wires or stands and unseated wires.

(d) For each tendon anchorage, the location of all missing or detached buttonheads or missing wedges.

(e) The product designation for the corrosion protection medium used to fill the tendon duct.

IWL-2230 PRESERVICE EXAMINATION OF REPAIRS AND MODIFICATIONS

(a) When a concrete containment or a portion thereof is repaired or modified during the service lifetime of a plant, the preservice examination requirements shall be met for the repair or modification.

(b) When the repair or modification is performed while the plant is not in service, the preservice examination shall be performed prior to resumption of service.

(c) When the repair or modification is performed while the plant is in service, the preservice examination may be deferred to the next scheduled outage.

IWL-2300 VISUAL EXAMINATION, PERSONNEL QUALIFICATION, AND RESPONSIBLE ENGINEER A92

IWL-2310 VISUAL EXAMINATION AND PERSONNEL QUALIFICATION

(a) VT-1C visual examinations are conducted to determine concrete deterioration and distress for suspect areas detected by VT-3C, and conditions (e.g., cracks, wear, or corrosion) of tendon anchorage and wires or strands. Minimum illumination, maximum direct examination distance, and maximum procedure demonstration lower case character height shall be as specified in IWA-2210 for VT-1 visual examination.

(b) VT-3C visual examinations are conducted to determine the general structural condition of concrete surfaces of containments by identifying areas of concrete deterioration and distress, such as defined in ACI 201.1 R-68. The minimum illumination, maximum direct examination distance, and maximum procedure demonstration lower case character height shall be as specified in IWA-2210 for VT-3 visual examination.

(c) The Owner's written practice shall define qualification requirements for concrete examination personnel in accordance with IWA-2300. Limited certification in accordance with IWA-2350 may be used for examiners limited to concrete.

IWL-2320 RESPONSIBLE ENGINEER

The Responsible Engineer shall be a Registered Professional Engineer experienced in evaluating the in-service condition of structural concrete. The Responsible Engineer shall have knowledge of the design and Construction Codes and other criteria used in design and construction of concrete containments in nuclear power plants.

The Responsible Engineer shall be responsible for the following:

(a) development of plans and procedures for examination of concrete surfaces;

(b) approval, instruction, and training of concrete examination personnel;

(c) evaluation of examination results;

(d) preparation of repair procedures;

(e) submittal of report to the Owner documenting results of examinations and repairs.

IWL-2400 INSERVICE INSPECTION SCHEDULE

IWL-2410 CONCRETE

(a) Concrete shall be examined in accordance with IWL-2510 at 1, 3, and 5 years following the completion of the containment Structural Integrity Test CC-6000 and every 5 years thereafter.

(b) The 1, 3, and 5 year examinations shall commence not more than 6 months prior to the specified dates and shall be completed not more than 6 months after such dates. If plant operating conditions are such that examination of portions of the concrete cannot be completed within this stated time interval, examination of those portions may be deferred until the next regularly scheduled plant outage.

(c) The 10 year and subsequent examinations shall commence not more than 1 year prior to the specified dates and shall be completed not more than 1 year after such dates.

IWL-2420 UNBONDED POST-TENSIONING SYSTEMS

(a) Unbonded post-tensioning systems shall be examined in accordance with IWL-2520 at 1, 3, and 5 years following the completion of the containment Structural Integrity Test and every 5 years thereafter.

(b) The 1, 3, and 5 year examinations shall com-

mence not more than 6 months prior to the specified dates and shall be completed not more than 6 months after such dates. If plant operating conditions are such that examination of portions of the post-tensioning system cannot be completed within this stated time interval, examination of those portions may be deferred until the next regularly scheduled plant outage.

(c) The 10 year and subsequent examinations shall commence not more than 1 year prior to the specified dates and shall be completed not more than 1 year after such dates.

IWL-2421 Sites With Two Plants

(a) For sites with two plants, the examination requirements for the concrete containments may be modified if both containments utilize the same prestressing system and are essentially identical in design, if post-tensioning operations for the two containments were completed not more than 2 years apart, and if both containments are similarly exposed to or protected from the outside environment.

(b) When the conditions of IWL-2421(a) are met, the inspection dates and examination requirements may be as follows.

(1) For the containment with the first Structural Integrity Test, all examinations required by IWL-2500 shall be performed at 1, 3, 10, 20, and 30 years. Only the examinations required by IWL-2524 and IWL-2525 need be performed at 5, 15, 25, and 35 years.

(2) For the containment with the second Structural Integrity Test, all examinations required by IWL-2500 shall be performed at 1, 5, 15, 25, and 35 years. Only the examinations required by IWL-2524 and IWL-2525 need be performed at 3, 10, 20, and 30 years.

IWL-2500 EXAMINATION REQUIREMENTS

Examination shall be performed in accordance with the requirements of Table IWL-2500-1.

A92 IWL-2510 EXAMINATION OF CONCRETE

(1) Concrete surface areas, including coated areas, except those exempted by IWL-1200(b), shall be VT-3C visual examined for evidence of conditions indicative of damage or degradation, such as defined in ACI 201.1 R-68, in accordance with IWL-2310(b). Selected areas, such as those that indicate suspect conditions, shall receive a VT-1C examination in accordance with IWL-2310(a).

(b) The examination shall be performed by, or under the direction of, the Responsible Engineer.

(c) Visual examinations may be performed from floors, roofs, platforms, walkways, ladders, ground surface, or other permanent vantage points, unless temporary close-in access is required by the inspection plan.

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IWL-2520 EXAMINATION OF UNBONDED POST-TENSIONING SYSTEMS

IWL-2521 Tendon Selection

(a) Tendons to be examined during an inspection shall be selected on a random basis except as noted in IWL-2521(b) and (c). The population from which the random sample is drawn shall consist of all tendons which have not been examined during earlier inspections. The number of tendons to be examined during an inspection shall be as specified in Table IWL-2521-1.

(b) One tendon of each type (as defined in Table IWL-2521-1) shall be selected from the first year inspection sample and designated as a common tendon. Each common tendon shall be examined during each inspection. A common tendon shall not be detensioned unless required by IWL-3300. If a common tendon is detensioned, another common tendon of the same type shall be selected from the first year inspection sample.

(c) If a containment with a stranded post-tensioning system is constructed with a predesignated number of detensionable tendons, one tendon of each type shall be selected from among those which are detensionable. The remaining tendons shall be selected from among those which cannot be detensioned.

IWL-2521.1 Exemptions. The following requirements shall apply to tendon anchorages that are not accessible for examination because of safety or radiological hazards or because of structural obstructions.

(a) After the process of randomly selecting tendons to be examined, any inaccessible tendons shall be designated as exempt and removed from the sample.

(b) Substitute tendons shall be selected for all tendons designated as exempt. Each substitute tendon shall be selected so that it is located as close as possible to

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TABLE IWL-2500-1
EXAMINATION CATEGORIES

EXAMINATION CATEGORY L-A, CONCRETE							
Item No.	Parts Examined	Test or Examination Requirement	Test or Examination Method	Acceptance Standard	Extent of Examination	Frequency of Examination	Deferral of Examination
L1.10	Concrete Surface						
L1.11	All Areas	IWL-2510	Visual, VT-3C	IWL-3210	IWL-2510	IWL-2410	NA
L1.12	Suspect Areas	IWL-2510	Visual, VT-1C	IWL-3210	IWL-2510	IWL-2410	NA

EXAMINATION CATEGORY L-B, UNBONDED POST-TENSIONING SYSTEM							
Item No.	Parts Examined	Test or Examination Requirement	Test or Examination Method	Acceptance Standard	Extent of Examination	Frequency of Examination	Deferral of Examination
L2.10	Tendon	IWL-2522	IWL-2522	IWL-3221.1	IWL-2521	IWL-2420	NA
L2.20	Wire or Strand	IWL-2523	IWL-2523.2	IWL-3221.2	IWL-2523.1	IWL-2420	NA
L2.30	Anchorage Hardware and Surrounding Concrete	IWL-2524	Visual, VT-1 and VT-1C	IWL-3221.3	IWL-2524.1	IWL-2420	NA
L2.40	Corrosion Protection Medium	IWL-2525	IWL-2525.2(a)	IWL-3221.4	IWL-2525.1(a)	IWL-2420	NA
L2.50	Free Water	IWL-2525	IWL-2525.2(b)		IWL-2525.1(b)	IWL-2420	NA

TABLE IWL-2521-1
NUMBER OF TENDONS FOR EXAMINATION

Inspection Period	Percentage[1,2] of all Tendons of Each Type[3]	Required Minimum[1] Number of Each Type	Maximum Required Number of Each Type
1st year	4	4	10
3rd year	4	4	10
5th year	4	4	10
10th year	2	3	5
15th year	2	3	5
20th year	2	3	5
25th year	2	3	5
30th year	2	3	5
35th year	2	3	5

NOTES:
(1) Fractional tendon numbers shall be rounded to the next higher integer. Actual number examined shall not be less than the minimum required number and need not be more than the maximum required number.
(2) The reduced sample size listed for the 10th year and subsequent inspections is applicable only if the acceptance criteria of IWL-3221.1 are met during each of the earlier inspections.
(3) A tendon type is defined by its geometry and position in the containment; e.g., hoop, vertical, dome, helical, and inverted U.

the exempted tendon, and shall be examined in accordance with IWL-2520.

(c) Each exempted tendon shall be examined in accordance with IWL-2524 and IWL-2525 to the extent that the end anchorages of the exempt tendon are accessible either during operation or at an outage.

IWL-2522 Tendon Force Measurements

(a) The prestressing force in all inspection sample tendons shall be measured by lift-off or an equivalent test.

(b) Equipment used to measure tendon force shall be calibrated in accordance with a calibration procedure prior to the first tendon force measurement and following the final tendon force measurement of the inspection period. Accuracy of the calibration shall be within 1.5% of the specified minimum ultimate strength of the tendon. If the post-test calibration differs from the pretest calibration by more than the specified accuracy tolerance, the results of the examination shall be evaluated.

IWL-2523 Tendon Wire and Strand Sample Examination and Testing

IWL-2523.1 Tendon Detensioning and Sample Removal. One sample tendon of each type shall be completely detensioned. A single wire or strand shall be removed from each detensioned tendon.

IWL-2523.2 Sample Examination and Testing

(a) Each removed wire or strand shall be examined over its entire length for corrosion and mechanical damage. The examination shall determine the location of most severe corrosion, if any. Strand wires shall be examined for wedge slippage marks.

(b) Tension tests shall be performed on each removed wire or strand: one at each end, one at mid-length, and one in the location of the most corroded area, if any. The following information shall be obtained from each test:

(1) yield strength
(2) ultimate tensile strength
(3) elongation

IWL-2523.3 Retensioning. Tendons that have been detensioned shall be retensioned to at least the force predicted for the tendon at the time of the test. However, the retensioning force shall not exceed 70% of the specified minimum ultimate tensile strength of the tendon based on the number of effective wires or strands in the tendon at the time of retensioning.

IWL-2524 Examination of Tendon Anchorage Areas

IWL-2524.1 Visual Examination. A VT-1 visual examination in accordance with IWA-2211 shall be performed on the tendon anchorage hardware, including bearing plates, anchorheads, wedges, buttonheads, shims, and the concrete extending outward a distance of 2 ft from the edge of the bearing plate. The following shall be documented:

(a) concrete cracks having widths greater than 0.01 in.;

(b) corrosion, broken or protruding wires, missing buttonheads, broken strands, and cracks in tendon anchorage hardware;

(c) broken wires or strands, protruding wires and detached buttonheads following retensioning of tendons which have been detensioned.

IWL-2524.2 Free Water Documentation. The quantity of free water contained in the anchorage end cap as well as any which drains from the tendon during the examination process shall be documented.

IWL-2525 Examination of Corrosion Protection Medium and Free Water

IWL-2525.1 Samples

(a) Samples of the corrosion protection medium shall

TABLE IWL-2525-1
CORROSION PROTECTION MEDIUM ANALYSIS

Characteristic	Test Method	Acceptance Limit
Water content	ASTM D 95	In course of preparation
Water soluble chlorides	ASTM D 512 [Note (1)]	10 ppm maximum
Water soluble nitrates	ASTM D 992 [Note (1)]	10 ppm maximum
Water soluble sulfides	APHA 427 [Note (1)] (Methylene blue)	10 ppm maximum
Reserve alkalinity (Base number)	ASTM D 974 Modified [Note (2)]	[Note (3)]

NOTES:
(1) *Water Soluble Ion Tests.* The inside (bottom and sides) of a one (1) liter beaker, approx. OD 105 mm, height 145 mm, is thoroughly coated with 100 ±10 grams of the sample. The coated beaker is filled with approximately 900 ml of distilled water and heated in an oven at a controlled temperature of 100°F (37.8°C) ±2°F for 4 hours. The water extraction is tested by the noted test procedures for the appropriate water soluble ions. Results are reported as PPM in the extracted water.
(2) *ASTM D 974 Modified.* Place 10 g of sample in a 500 ml Erlenmeyer flask. Add 10 cc isopropyl alcohol and 5 cc toluene. Heat until sample goes into solution. Add 90 cc distilled water and 20 cc $1NH_2SO_4$. Place solution on a steam bath for ½ hour. Stir well. Add a few drops of indicator (1% phenolphthalein) and titrate with 1NNaOH until the lower layer just turns pink. If acid or base solutions are not exactly 1N, the exact normalities should be used when calculating the base number. The Total Base Number (TBN), expressed as milligrams of KOH per gram of sample, is calculated as follows:

$$TBN = \frac{[(20)\ (N_A) - (B)\ (N_B)]\ 56.1}{W}$$

where

B=milliliters NaOH
N_A=normality of H_2SO_4 solution
N_B=normality of NaOH solution
W=weight of sample in grams

(3) The base number shall be at least 50% of the as-installed value, unless the as-installed value is 5 or less, in which case the base number shall be no less than zero. If the tendon duct is filled with a mixture of materials having various as-installed base numbers, the lowest number shall govern acceptance.

be taken from each end of each tendon examined. Free water shall not be included in the samples.

(b) Samples of free water shall be taken where water is present in quantities sufficient for laboratory analysis.

IWL-2525.2 Sample Analysis

(a) Corrosion protection medium samples shall be thoroughly mixed and analyzed for reserve alkalinity, water content, and concentrations of water soluble chlorides, nitrates, and sulfides. Analyses shall be performed in accordance with the procedures specified in Table IWL-2525-1.

(b) Free water samples shall be analyzed to determine pH.

IWL-2526 Removal and Replacement of Corrosion Protection Medium

The amount of corrosion protection medium removed at each anchorage shall be measured and the total amount removed from each tendon (two anchorages) shall be recorded. The total amount replaced in each tendon shall be recorded and differences between amount removed and amount replaced shall be documented.

ARTICLE IWL-3000
ACCEPTANCE STANDARDS

IWL-3100 PRESERVICE EXAMINATION

IWL-3110 CONCRETE SURFACE CONDITION

IWL-3111 Acceptance by Examination

The condition of the surface is acceptable if the Responsible Engineer determines that there is no evidence of damage or degradation sufficient to warrant further evaluation or repair.

IWL-3112 Acceptance by Evaluation

Items with examination results that do not meet the acceptance standards of IWL-3111 shall be evaluated as required by IWL-3300.

IWL-3113 Acceptance by Repair

Repairs required to reestablish acceptability of an item shall be completed as required by IWL-3300. Acceptable completion of the repair shall constitute acceptability of the item.

IWL-3120 UNBONDED POST-TENSIONING SYSTEM

The condition of the unbonded post-tensioning system is acceptable if it met the requirements of the construction specification at the time of installation.

IWL-3200 INSERVICE EXAMINATION

IWL-3210 CONCRETE SURFACE CONDITION

IWL-3211 Acceptance by Examination

The condition of the concrete surface is acceptable if the Responsible Engineer determines that there is no evidence of damage or degradation sufficient to warrant further evaluation or repair.

IWL-3212 Acceptance by Evaluation

Items with examination results that do not meet the acceptance standards of IWL-3211 shall be evaluated as required by IWL-3300.

IWL-3213 Acceptance by Repair

Repairs to reestablish the acceptability of an item shall be completed as required by IWL-3300. Acceptable completion of the repair shall constitute acceptability of the item.

IWL-3220 UNBONDED POST-TENSIONING SYSTEMS

IWL-3221 Acceptance by Examination

IWL-3221.1 Tendon Force. Tendon forces are acceptable if:

(a) the average of all measured tendon forces, including those measured in IWL-3221.1(b)(2), for each type of tendon is equal to or greater than the minimum required prestress specified at the anchorage for that type of tendon;

(b) the measured force in each individual tendon is not less than 95% of the predicted force unless the following conditions are satisfied:

(1) the measured force in not more than one tendon is between 90% and 95% of the predicted force;

(2) the measured forces in two tendons located adjacent to the tendon in IWL-3221.1(b)(1) are not less than 95% of the predicted forces; and

(3) the measured forces in all the remaining sample tendons are not less than 95% of the predicted force.

IWL-3221.2 Tendon Wire or Strand Samples. The condition of wire or strand samples is acceptable if:

(a) samples are free of physical damage;

(b) sample ultimate tensile strength and elongation are not less than minimum specified values.

IWL-3221.3 Tendon Anchorage Areas. The condition of tendon anchorage areas is acceptable if:

(a) there is no evidence of cracking in anchor heads, shims, or bearing plates;

(b) there is no evidence of active corrosion;

(c) broken or unseated wires, broken strands, and detached buttonheads were documented and accepted during a preservice examination or during a previous inservice examination;

(d) cracks in the concrete adjacent to the bearing plates do not exceed 0.01 in. in width.

IWL-3221.4 Corrosion Protection Medium. Corrosion protection medium is acceptable when the reserve alkalinity, water content, and soluble ion concentrations of all samples are within the limits specified in Table IWL-2525-1.

IWL-3222 Acceptance by Evaluation

Items with examination results that do not meet the acceptance standards of IWL-3221 shall be evaluated as required by IWL-3300.

IWL-3223 Acceptance by Repair or Replacement

Repairs or replacements to reestablish acceptability the condition of an item shall be completed as required by IWL-3300. Acceptable completion of the repair or replacement shall constitute acceptability of the item.

IWL-3300 EVALUATION

IWL-3310 EVALUATION REPORT

Items with examination results that do not meet the acceptance standards of IWL-3100 or IWL-3200 shall be evaluated by the Owner. The Owner shall be responsible for preparation of an Engineering Evaluation Report stating the following:

(a) the cause of the condition which does not meet the acceptance standards;

(b) the acceptability of the concrete containment without repair of the item;

(c) whether or not repair or replacement is required and, if required, the extent, method, and completion date for the repair or replacement;

(d) extent, nature, and frequency of additional examinations.

IWL-3320 REVIEW BY AUTHORITIES

The Engineering Evaluation Report shall be subject to review by the regulatory and enforcement authorities having jurisdiction at the plant site.

ARTICLE IWL-4000
REPAIR PROCEDURES

IWL-4100 GENERAL

IWL-4110 SCOPE

This Article provides rules and requirements for repair of concrete containments.

IWL-4120 REPAIR/REPLACEMENT PROGRAM

(a) Repairs shall be performed in accordance with the Repair/Replacement Program required by IWA-4140.

(b) Repairs shall be completed in accordance with the Repair Plan of IWL-4200.

(c) The Repair/Replacement Program shall address concrete material control.

IWL-4200 REPAIR PLAN

The Repair Plan shall be developed under the direction of a Responsible Engineer (IWL-2500).

IWL-4210 CONCRETE REPAIR

(a) The Repair Plan shall specify requirements for removal of defective material.

(b) The affected area shall be visually examined to assure proper surface preparation of concrete and reinforcing steel prior to placement of repair material.

(c) When removal of defective material exposes reinforcing steel, the reinforcing steel shall receive a VT-1 visual examination. Reinforcing steel is acceptable when the Responsible Engineer determines that there is no evidence of damage or degradation sufficient to warrant further evaluation or repair. When required, reinforcing steel shall be repaired in accordance with IWL-4220. Repair of exposed-end anchors of the post-tensioning system shall be in accordance with IWL-4230.

(d) Repair material shall be chemically, mechanically, and physically compatible with existing concrete.

(e) When detensioning of prestressing tendons is required for repair of the concrete surface adjacent to the tendon, the Repair Plan shall require the following:

(1) selection of repair material to minimize stress and strain incompatibilities between repair material and existing concrete;

(2) procedures for application of repair material;

(3) procedures for detensioning and retensioning of prestressing tendons.

(f) The Repair Plan shall specify requirements for in-process sampling and testing of repair material.

IWL-4220 REPAIR OF REINFORCING STEEL

Damaged reinforcing steel shall be repaired by any method permitted in the original Construction Code or in Section III, Division 2, with or without removal of the damaged reinforcing steel.

IWL-4230 REPAIR OF THE POST-TENSIONING SYSTEM

(a) Weld repair of bearing plates and shim plates of the post-tensioning system shall meet the applicable requirements of IWA-4000. The corrosion protection medium shall be restored following the repair.

(b) Procedures for detensioning and retensioning of prestressing tendons shall be specified in the Repair Plan.

IWL-4300 EXAMINATION

The repaired area shall be examined in accordance with IWL-2000 to establish a new preservice record and shall meet the acceptance standards of IWL-3000.

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ARTICLE IWL-5000
SYSTEM PRESSURE TESTS

IWL-5100 SCOPE

This Article provides requirements for pressure testing concrete containments following repair or replacement.

IWL-5200 SYSTEM TEST REQUIREMENTS

IWL-5210 GENERAL

A containment pressure test shall be performed following repair or replacement unless any of the following conditions exist:

(a) The Engineering Evaluation Report (IWL-3310) demonstrates that the structural integrity of containment in the existing unrepaired condition has not been reduced below that required by the original design criteria.

(b) The repair or replacement affects only the cover concrete external to the outermost layer of structural reinforcing steel or post-tensioning tendons.

(c) The repair or replacement involves only exchange of post-tensioning tendons, tendon anchorage hardware, shims, or corrosion protection medium.

IWL-5220 TEST PRESSURE

The pressure test shall be conducted at the design basis accident pressure, P_a.

IWL-5230 LEAKAGE TEST

If the repair or replacement penetrated the containment metallic liner, or otherwise breached containment leak-tight integrity, a leakage rate test shall be conducted as required by IWE-5000.

IWL-5240 SCHEDULE OF PRESSURE TEST

If the repair or replacement is performed with the plant shutdown, the pressure test shall be conducted prior to resumption of operation. If the repair or replacement is performed with the plant in operation, the pressure test may be deferred until the next scheduled integrated leak-rate test.

IWL-5250 TEST PROCEDURE AND EXAMINATIONS

The pressure test shall be conducted in accordance with a detailed procedure prepared under the direction of the Responsible Engineer. The surface of all containment concrete placed during repair or replacement operations shall be examined by VT-1 examination prior to start of pressurization, at test pressure, and following completion of depressurization. Extended surface examinations, additional examinations during pressurization, other examinations, and measurements of structural response to pressure shall be conducted as specified by the Responsible Engineer.

IWL-5260 CORRECTIVE MEASURES

If the surface examinations of IWL-5250 cannot satisfy the requirements specified by the Responsible Engineer, the area shall be examined to the extent necessary to establish requirements for corrective action. Repairs shall be performed in accordance with IWL-4000, and pressure testing shall be repeated in accordance with IWL-5200, prior to returning the containment to service.

IWL-5300 REPORT

A pressure test report shall be prepared under the direction of the Responsible Engineer. This report may be an addition to a previously-prepared Engineering Evaluation Report (IWL-3310). The report shall describe pressure test procedures and examination results and shall state whether or not the repair or replacement is acceptable. If the repair or replacement is not acceptable, the report shall specify corrective measures.

ARTICLE IWL-7000
REPLACEMENTS

IWL-7100 GENERAL REQUIREMENTS

IWL-7110 SCOPE

(a) This Article provides rules and requirements for reinstallation and replacement of post-tensioning system items for concrete containments.

(b) Grease caps and installation screws are exempt from the requirements of this Article.

IWL-7120 REPLACEMENT PROGRAM

The following items, as applicable, shall be contained in the Replacement Plan:

(a) requirements for removal of items that are to be replaced;

(b) surface preparation required prior to installation of replacement items;

(c) examinations required prior to installation of replacement items;

(d) detensioning and retensioning requirements for tendons affected by installation of replacement items;

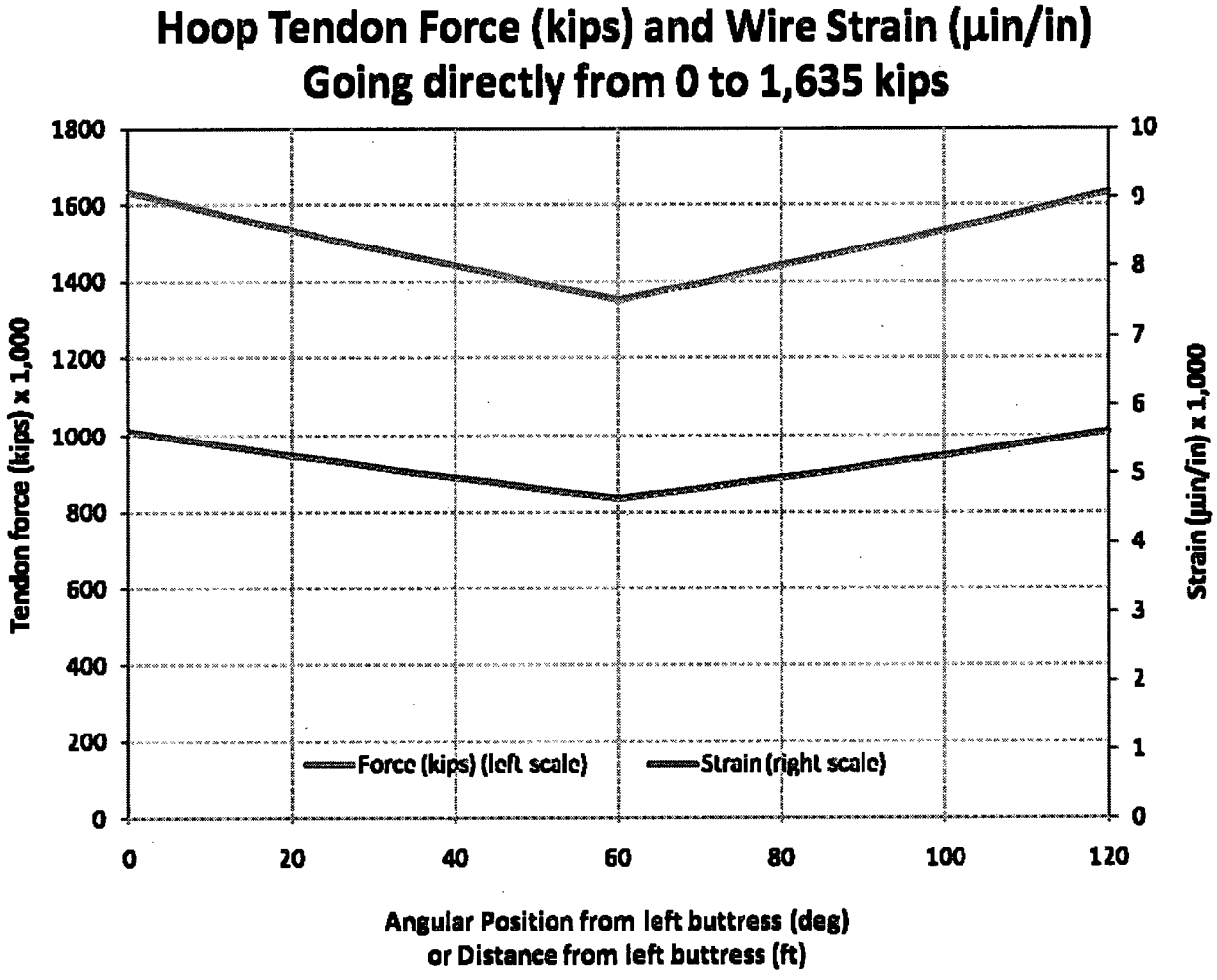
(e) requirements and procedures applicable to installation of replacement items;

(f) in-process sampling and testing requirements to be performed during installation of replacement items.

PARAMETER	SOURCE	REASON
Flexible Conduit - Used around penetrations in wall of containment. - Minimum 22 gauge - 5 1/4" O.D. - 5" I.D.		Flexible conduit specified in order to permit economical and efficient field fabrication and fitting.
Schedule 40 Conduit Used in foundation mat and containment dome. - ASTM A53-70, Type E or S Steel pipe Grade A for mat Grade B for dome	See "Conduit (General)" on Page 5 for the Source of requirements cited on this page.	Structural design material to ensure that dome conduit system is capable of supporting the dome liner under concrete placement loads. This conduit is, therefore, load carrying such that Grade B material (fy = 60 ksi) is specified. In the base mat the schedule 40 conduit (pipe) is the transition material between the trumpet in the base mat and the rigid conduit in the cylindrical wall. This pipe is not required to carry structural load, such that Grade A material (fy = 48 ksi) is considered adequate.
Tendon Wire ASTM A421-65 Type BA	Tendon wire is specified in G/C, Inc. Specification SP-5583 and is listed here for reference only.	Steel conforming to ASTM A421 is the standard material specified throughout the industry for use as a buttonheaded tendon wire. The steel used for this project is the Japanese equivalent of that material.
f_y = 240 ksi		Exceptionally high strength is required in order to develop the required level of prestress.
- Relaxation = 4%	See "Tendon Wire" on Page 6 for the Source of the requirement cited on this page.	Relaxation is a loss of stress when a wire is prestressed and maintained at a constant strain for an extended time. The degree to which this happens varies with the steel and is, therefore, specified by the steel supplier. That value must be known in order to evaluate the effective prestress over the life of the plant.

PARAMETER	SOURCE	REASON
Tendons - 163 wire Area - 9.723 in^2	G/C, Inc. Specification SP-5583 (for reference only).	The tendon comprised of 163 - 7mm wires is approximately equivalent to the 170-0.25 in. wire tendons typically being utilized in the industry at the time of plant design. See page 19 for a summary of prestress forces in each of the three tendon groups.
Anchorage Components Bearing plate - ASTM A533 - Grade B - Class 2 Shims - Modified Armco VNT or like material Stressing End Washer - Alloy steel forging	Prescon Shop Drawings. PEERE # 0987	Utilized on the basis of recommendations from Prescon Corp., the supplier of the prestressing system.
Tendon Grease Shop application: Visconorust 3001A Field application: Visconorust 2090P Visconorust 2090P-2	G/C, Inc. Specification SP-5583 (for reference only).	Visconorust 3001A was the state-of-the-art tendon grease for the prevention of corrosion of prestressing wires. The 3001A material was used as a shop-applied coating. The 2090P and 2090P-2 were used to field coat the inside of the conduit as well as to serve as a bulk filler after tendon installation. Other Visconorust formulations compatible with those noted are used during outages when tendon surveillance is carried out.
Foundation Bearing Material	The basic source for all criteria relating to foundation design parameters is: Woodward-Clyde & Assoc., "Summary of Foundation Investigation Evaluation and Construction for Crystal River Unit 3."	

Tendon Force and Wire Strain along the Tendon



TENDON WIRE TEST RESULTS

Page 34

INSPECTION PERIOD ONE.

	TENDON WIRE (1) SAMPLE NO.	LOCATION (2) FROM END OF WIRE	YIELD (3) STRESS (ksi)	ULTIMATE STRESS (ksi)	PERCENT ELONGATION	COMMENT
	DOME					
1.						
2.						
3.						
	VERTICAL					
1.	45V3	6-12 Ft	228.2	251.7	Over 4%	Accept
2.	45V3	30-37 FT	227.8	252.1	Over 4%	Accept
3.	45V3	175-181 FT	229.7	255.0	Over 4%	Accept
	HOOP					
1.						
2.						
3.						

SP-182

NOTES:
(1) See Steps 6.2.5.1 and 6.2.5.3.
(2) The end starts from the end of zero length as indicated on Data Sheet 4.
(3) The yield stress is defined as the stress at 1% elongation, i.e., 192,000 psi minimum.

Prepared by: _____ Date: _____

Contractor Review by: _____ Date: _____

F.P.C. Approval by: _____ Date: _____

Date 11/14/77

[redacted]

DATA SHEET 5

TENDON WIRE TEST RESULTS

INSPECTION PERIOD #2

TENDON WIRE SAMPLE NO. (1)	LOCATION FROM END OF WIRE (2)	YIELD STRESS (ksi) (3)	ULTIMATE STRESS (ksi)	PERCENT ELONGATION	COMMENTS
DONE D208					
1. SHOP	0	215	263	6.25	N/A
2. MIDDLE	60	225	264	8.13	N/A
3. FIELD	120	211	252	6.88	N/A
VERTICAL 56V1					
1. SHOP	0	213	251	8.75	N/A
2. MIDDLE	75	216	254	8.13	N/A
3. FIELD	150	217	253	9.38	NO HANDLING MARKS WITHIN GAGE LENGTH
HOOP 13H32					
1. SHOP	0	223	253	8.75	N/A
2. MIDDLE	150	219	249	6.25	N/A
3. FIELD	300	226	257	6.25	N/A

NOTES:
(1) See Steps 6.2.5.1 and 6.2.5.3.
(2) The end starts from the end of zero length as indicated on Data Sheet 4.
(3) The yield stress is defined as the stress at 1% elongation, i.e., 192,000 psi minimum.

Prepared by: W.A. Jemian Date: 28 JUNE 80

Contractor Review by: BJ Raffensperger Date: 7-25-80

F.P.C. Approval by: _____ Date: _____

3. Laboratory analysis on twenty-two samples of the filler grease disclosed that the grease was free of unacceptable nitrate, chloride, sulfide or water contamination.

3.4 Tendon Lift-Off Force

1. Lift-off force measurements were made on ten horizontal, plus six dome, plus three upper vertical tendon ends. All lift-off measurements were within the procedure specified acceptance criteria. Refer to Table 1.

   One end lift-off measurement was used for the vertical tendons.

3.5 Tendon Detensioning/Retensioning and Wire Tests

1. Broken, damaged or slipped wires were not noted during wire inspection operations on surveillance tendons 13H40, 56V2 and D105. None of the surveillance tendons exhibited lift-off forces above or below the procedure specified maximum or minimum. The ±3% (of initial) lift-off criteria was met and was deemed acceptable.

2. The visual inspection of the three removed tendon wires showed no significant signs of corrosion or damage. There were minor handling marks from the extraction tool.

3. Three wire samples were removed. The samples were measured, tagged and wrapped. They were then sent to Professional Service Industries, (PSI), Pittsburgh, Pennsylvania for testing. The samples were cut into three coupons (one at each end and at mid-length) and subjected to breaking tests per ASTM 421. The wire coupons showed tensile strengths in excess of 240 ksi minimum required.

4. The "as found" elongation for the three surveillance tendons differed from the "proportioned" original elongation. Horizontal tendon 13H40 "shop-end" was 7.2% above; dome tendon D105 "field-end" was 17.8% above; and vertical tendon 56V2 was 9.5% below the respective proportioned original elongations. The procedure specified acceptable criteria is ± 5%. See Table 2.

Crystal River Unit 3 Post-Tensioning System:
5th In-Service Tendon Surveillance Test Report: Revision 0

TABLE 7: SUMMARY OF TENDON WIRE TENSILE TEST RESULTS

TENDON NUMBER	WIRE SAMPLE LOCATION	YIELD STRENGTH (ksi @ 1% Ext)	ULTIMATE TENSILE STRENGTH (ksi)	PERCENT ELONGATION	LOCATION OF WIRE FAILURE (in)
D231 RANDOM WIRE	SHOP	219.0	243.0	6.3	1.0 *
	CENTER	219.0	239.0	6.4	5.3 *
	FIELD	221.0	244.0	6.2	0.5 *
46H47 RANDOM WIRE	SHOP	226.0	251.0	8.5	0.3 *
	CENTER	225.0	252.0	7.8	0.3 *
	FIELD	227.0	253.0	8.1	4.5 *
56V15 RANDOM WIRE	SHOP	212.0	244.0	7.8	8.5 *
	CENTER	216.0	243.0	6.5	2.0 *
	FIELD	212.0	243.0	8.7	8.5 *
56V15 NON TENSION WIRE	SHOP	220.0	245.0	8.5	7.5 *
	CENTER	216.0	243.0	7.9	1.6 *
	FIELD	215.0	243.0	8.6	2.0 *
46H29 RANDOM WIRE	SHOP	227.0	253.0	7.4	0.2 *
	CENTER	226.0	253.0	7.1	0.2 *
	FIELD	229.0	254.0	7.5	3.0 *
46H29 BROKEN WIRE 1 OF 3	SHOP	217.0	242.0	8.3	7.8 *
	CENTER	217.0	242.0	8.7	0.5 *
	FIELD	214.0	242.0	8.5	8.5 *
46H29 BROKEN WIRE 2 OF 3	SHOP	221.0	253.0	8.5	8.8 *
	CENTER	227.0	252.0	8.5	8.9 *
	FIELD	227.0	252.0	8.5	3.3 *
46H29 BROKEN WIRE 3 OF 3	SHOP	222.0	245.0	7.8	8.5 *
	CENTER	219.0	242.0	8.7	8.5 *
	FIELD	215.0	240.0	7.5	0.5 *
ACCEPTANCE CRITERIA		204.0 (min)	240.0 (min)	4.0 (min)	N/A

* Distance From Moving Jaw

Crystal River Unit 3 Post-Tensioning System:
5th In-Service Tendon Surveillance Test Report: Revision 0

TABLE 7: SUMMARY OF TENDON WIRE TENSILE TEST RESULTS

TENDON NUMBER	WIRE SAMPLE LOCATION	YIELD STRENGTH (ksi @ 1% Ext)	ULTIMATE TENSILE STRENGTH (ksi)	PERCENT ELONGATION	LOCATION OF WIRE FAILURE (in)
D231 RANDOM WIRE	SHOP	219.0	243.0	6.3	1.0 *
	CENTER	219.0	239.0	6.4	5.3 *
	FIELD	221.0	244.0	6.2	0.5 *
46H47 RANDOM WIRE	SHOP	226.0	251.0	8.5	0.3 *
	CENTER	225.0	252.0	7.8	0.3 *
	FIELD	227.0	253.0	8.1	4.5 *
56V15 RANDOM WIRE	SHOP	212.0	244.0	7.8	8.5 *
	CENTER	216.0	243.0	6.5	2.0 *
	FIELD	212.0	243.0	8.7	8.5 *
56V15 NON TENSION WIRE	SHOP	220.0	245.0	8.5	7.5 *
	CENTER	216.0	243.0	7.9	1.6 *
	FIELD	215.0	243.0	8.6	2.0 *
46H29 RANDOM WIRE	SHOP	227.0	253.0	7.4	0.2 *
	CENTER	226.0	253.0	7.1	0.2 *
	FIELD	229.0	254.0	7.5	3.0 *
46H29 BROKEN WIRE 1 OF 3	SHOP	217.0	242.0	8.3	7.8 *
	CENTER	217.0	242.0	8.7	0.5 *
	FIELD	214.0	242.0	8.5	8.5 *
46H29 BROKEN WIRE 2 OF 3	SHOP	221.0	253.0	8.5	8.8 *
	CENTER	227.0	252.0	8.5	8.9 *
	FIELD	227.0	252.0	8.5	3.3 *
46H29 BROKEN WIRE 3 OF 3	SHOP	222.0	245.0	7.8	8.5 *
	CENTER	219.0	242.0	8.7	8.5 *
	FIELD	215.0	240.0	7.5	0.5 *
ACCEPTANCE CRITERIA		204.0 (min)	240.0 (min)	4.0 (min)	N/A

* Distance From Moving Jaw

20TH YEAR SURVEILLANCE OF THE POST-TENSIONING SYSTEM AT THE CRYSTAL RIVER NUCLEAR PLANT UNIT 3

VI. WIRE INSPECTION AND TESTING

One wire was scheduled for removal from each detensioned tendon for visual inspection and tensile testing. PSC Procedure SQ 10.3 outlines the details involved with the wire testing and the data was recorded on Data Sheets SQ 10.2 and SQ 10.3 with the results summarized in Table X.

All wire diameters were within the acceptance criteria of 0.27559 $\pm$ 0.002". The corrosion condition of all samples was level 1 - "bright metal; no visible oxidation" and the Ultimate Strength exceeded the minimum strength criteria of 240,000 psi (240 ksi) for all wire samples tested.

20TH YEAR SURVEILLANCE OF THE POST-TENSIONING SYSTEM AT THE CRYSTAL RIVER NUCLEAR PLANT UNIT 3

Florida Power CORPORATION

TABLE X: SUMMARY OF DATA SHEETS SQ 10.2 & 10.3 - VISUAL INSPECTION AND TENSILE TESTING OF WIRE

TENDON	SAMPLE No.	CORROSION LEVEL	SAMPLE LOCATION (FT)	DIAMETER (IN)	YIELD STRENGTH (PSI)	ULTIMATE STRENGTH (PSI)	ACCEPTABLE
61V21	1	1	20 - 29	0.275	210,770	249,197	YES
	2	1	90 - 99	0.275	210,251	251,793	YES
	3	1	170 - 179	0.275	209,212	242,966	YES
D304	1	1	20 - 29	0.2755	213,614	244,138	YES
	2	1	60 - 69	0.2755	213,614	241,552	YES
	3	1	100 - 109	0.2755	217,236	250,864	YES
42H35	1	1	20 - 29	0.276	210,286	241,219	YES
	2	1	70 - 79	0.276	210,802	246,375	YES
	3	1	140 - 149	0.276	212,864	253,077	YES
51H26	1	1	10 - 19	0.2745	210,512	254,293	YES
	2	1	70 - 79	0.2745	209,990	248,560	YES
	3	1	140 - 149	0.2745	216,766	243,869	YES
51H26	1A	1	10 - 19	0.2745	215,202	250,645	YES
	2A	1	70 - 79	0.2745	214,160	253,251	YES
	3A	1	146 - 155	0.2745	220,415	257,942	YES
62H41	1	1	20 - 29	0.2755	211,545	247,760	YES
	2	1	70 - 79	0.2755	213,614	245,173	YES
	3	1	140 - 149	0.2755	214,390	241,552	YES

VI. WIRE INSPECTION AND TESTING

One wire was scheduled for removal from each detensioned tendon for visual inspection and tensile testing. PSC Procedure SQ 10.3 outlines the details involved with the wire testing and the data was recorded on Data Sheets SQ 10.2 and SQ 10.3 with the results summarized in Table X.

All wire diameters were within the acceptance criteria of 0.27559" $\pm$ 0.002". The corrosion condition of all samples was level 1 - "Bright metal, no visible oxidation", or level 2 - "Metal reddish brown color; no pitting". Also, the ultimate strength exceeded the minimum strength criteria of 240,000 psi (240 ksi) for all samples tested.

25TH YEAR SURVEILLANCE OF THE POST-TENSIONING SYSTEM AT THE CRYSTAL RIVER NUCLEAR PLANT UNIT 3

Florida Power
A Progress Energy Company

TABLE IX: SUMMARY OF DATA SHEETS SQ 10.2 & 10.3 - VISUAL INSPECTION AND TENSILE TESTING OF WIRE

TENDON	SAMPLE No.	CORROSION LEVEL	SAMPLE LOCATION (FT)	DIAMETER (IN)	YIELD STRENGTH (PSI)	ULTIMATE STRENGTH (PSI)	ACCEPTABLE
45V14	1	2	20 - 29	.275	226,477	267,691	YES
	2	2	90 - 99	.275	224,249	266,020	YES
	3	2	170 - 179	.275	228,148	265,184	YES
53II16	1	1	10 - 19	.275	227,312	272,146	YES
	2	1	70 - 79	.275	231,211	266,298	YES
	3	1	140 - 149	.275	233,160	272,703	YES
D339	1	1	20 - 29	.275	230,097	265,463	YES
	2	1	50 - 59	.275	231,489	257,944	YES
	3	1	90 - 99	.275	230,097	265,184	YES

9.0 WIRE INSPECTION AND TESTING

9.1 One tendon from each group (Vertical, Hoop, Dome) was completely detensioned. A single wire was removed from each detensioned tendon for inspection and testing. Each removed wire was examined over its entire length for corrosion and mechanical damage. Three samples from each wire were tested for diameter, yield strength, ultimate tensile strength and elongation. PSC Procedures SQ 10.2 and SQ 10.3 outline the details and acceptance criteria pertaining to the wire removal and testing. All data was recorded on Data Sheets SQ 10.2 and SQ 10.3 and the results summarized in Table 48.

9.1.1 All wire diameters were within the acceptance criteria of 0.2756 ± 0.002".

9.1.2 The corrosion level for all of the test wires were:

1 - Bright metal; no visible oxidation.

9.1.3 No mechanical damage was noted on any of the wires.

9.1.4 The yield strength of the wires tested exceeded the minimum acceptance criteria of 192,000 psi at 1% elongation. The lowest recorded yield strength was 225,678 psi.

9.1.5 The Ultimate Strength of the wires tested exceeded the minimum strength criteria of 240,000 psi on all samples. The lowest recorded ultimate strength was 257,305 psi.

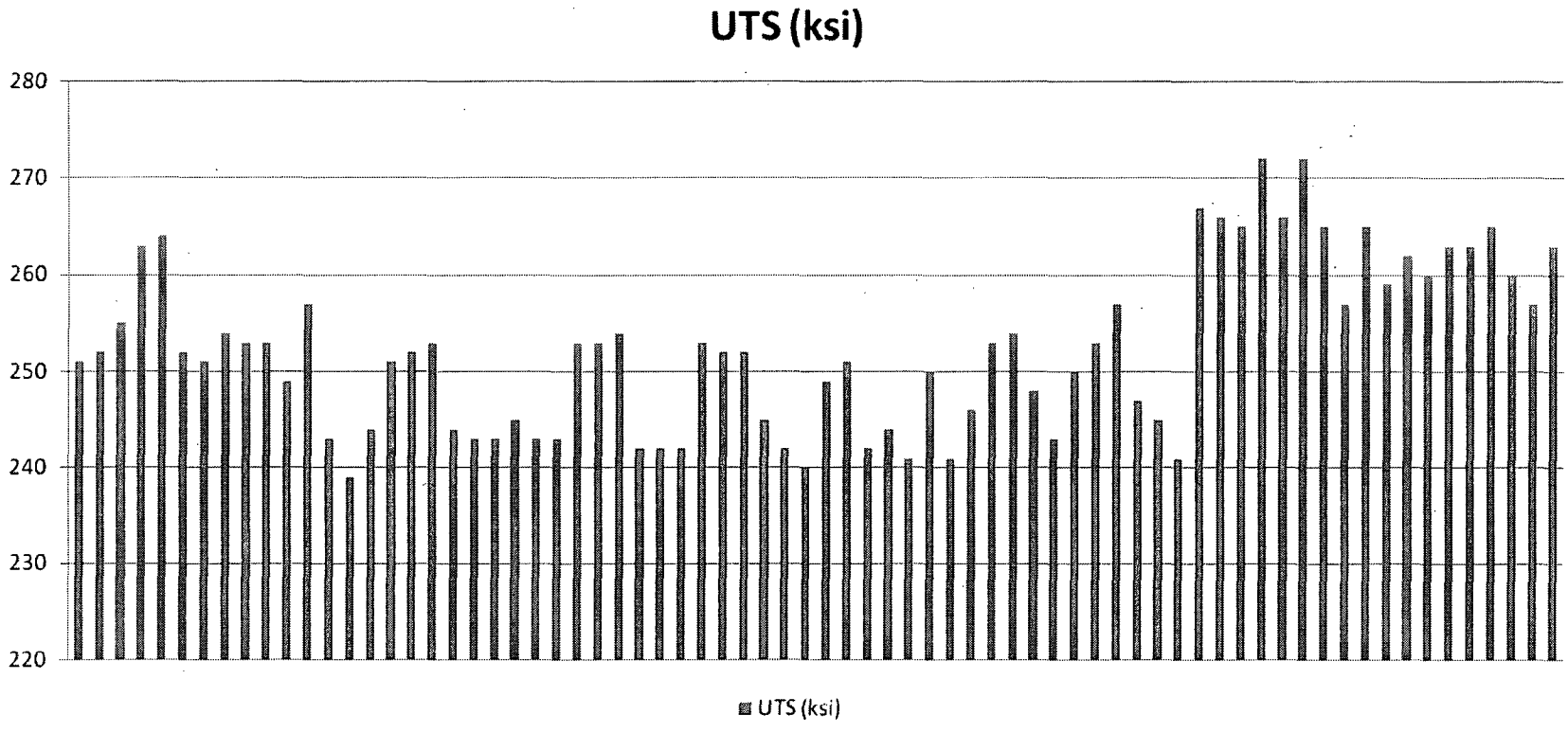
9.1.6 The percent elongation at sample failure exceeded the required minimum of 4.0% on all samples tested. The recorded elongation on the samples varied from 4.5% to 5.3%.

TABLE 48: SQ10.2 & SQ10.3 – VISUAL INSPECTION AND TENSILE TESTING OF WIRE

TENDON	SAMPLE NUMBER	CORROSION LEVEL	SAMPLE LOCATION (ft)	DIAMETER (in.)	YIELD STRENGTH (ksi)	ULTIMATE STRENGTH (ksi)	ELONGATION (%)	ACCEPT?
51H34	1	1	10'-20'	276	227.805	259.164	4.6	YES
	2	1	70'-80'	.276	226.210	262.353	5.1	YES
	3	1	140'-150'	.276	225.678	260.227	4.8	YES
61V17	1	1	10'-20'	.275	230.535	263.194	4.6	YES
	2	1	90'-100'	.275	229.464	263.194	5.0	YES
	3	1	170'-180'	.275	230.000	265.871	5.3	YES
D238	1	1	10'-20'	.275	230.000	260.517	4.7	YES
	2	1	50'-60'	.275	229.464	257.305	4.5	YES
	3	1	100'-110'	.275	228.393	263.194	5.0	YES

Wire Testing

All tested wires passed the Ultimate Tensile Strength requirement of 240ksi



TEST REPORT
"SAMPLE (S): CUSTOMER SUPPLIED"

ATLAS
TESTING LABORATORIES, INC.
ATLASLABS@ATT.NET
9820 SIXTH STREET • RANCHO CUCAMONGA, CA 91730 • 909-373-4130 FAX 909-373-4132

WF
PERFORMANCE IMPROVEMENT INT'L
ATTN: DR. MOSTAFA MOSTAFA
2111 S. EL CAMINO REAL ST.302
OCEANSIDE, CA. 92054

PAGE 1 OF 1
DATE 12/09/09
ATL# 947613
PO# 5718
MAT'L: STEEL

ID: #12 & #13

MECHANICAL PROPERTIES:

	Actual Size	Actual Area	YIELD STRENGTH Load/ Pounds	YIELD STRENGTH Pounds Sq. inch	TENSILE STRENGTH Load/ Pounds	TENSILE STRENGTH Pounds Sq. inch	Elongation in.64"	Elongation %	Reduced Dimension	Reduction of Area %
12-1	.160	.0201	4,720	234,800	5,280	262,700	.09	14.1	.118	45.6
12-2	.161	.0204	4,680	229,400	5,220	255,900	.10	15.6	.117	47.2
13-1	.162	.0206	4,900	237,900	5,420	263,100	.10	15.6	.125	40.5
13-2	.161	.0204	4,700	230,400	5,200	254,900	.08	12.5	.125	39.7

YIELD STRENGTH .2% OFFSET METHOD: ASTM-E8/08 ATE# 503

CHEMICAL ANALYSIS: (% BY WEIGHT)

ELEMENTS	12-A	12-B	13-A	13-B
Carbon	0.82	0.80	0.81	0.79
Manganese	0.84	0.84	0.84	0.84
Phosphorus	0.018	0.018	0.018	0.018
Sulfur	0.015	0.014	0.015	0.014
Silicon	0.21	0.21	0.21	0.21
Chromium	0.05	0.05	0.05	0.05
Nickel	0.03	0.03	0.03	0.03
Molybdenum	0.01	0.01	0.01	0.01
Copper	0.08	0.08	0.08	0.08
Aluminum	0.032	0.031	0.030	0.030

METHOD: ASTM-E415/08, E1019/08 STDS: IARM 31C, NBS 1262B, 63A, 64A, LECO 501-502
ATE# 202, 204

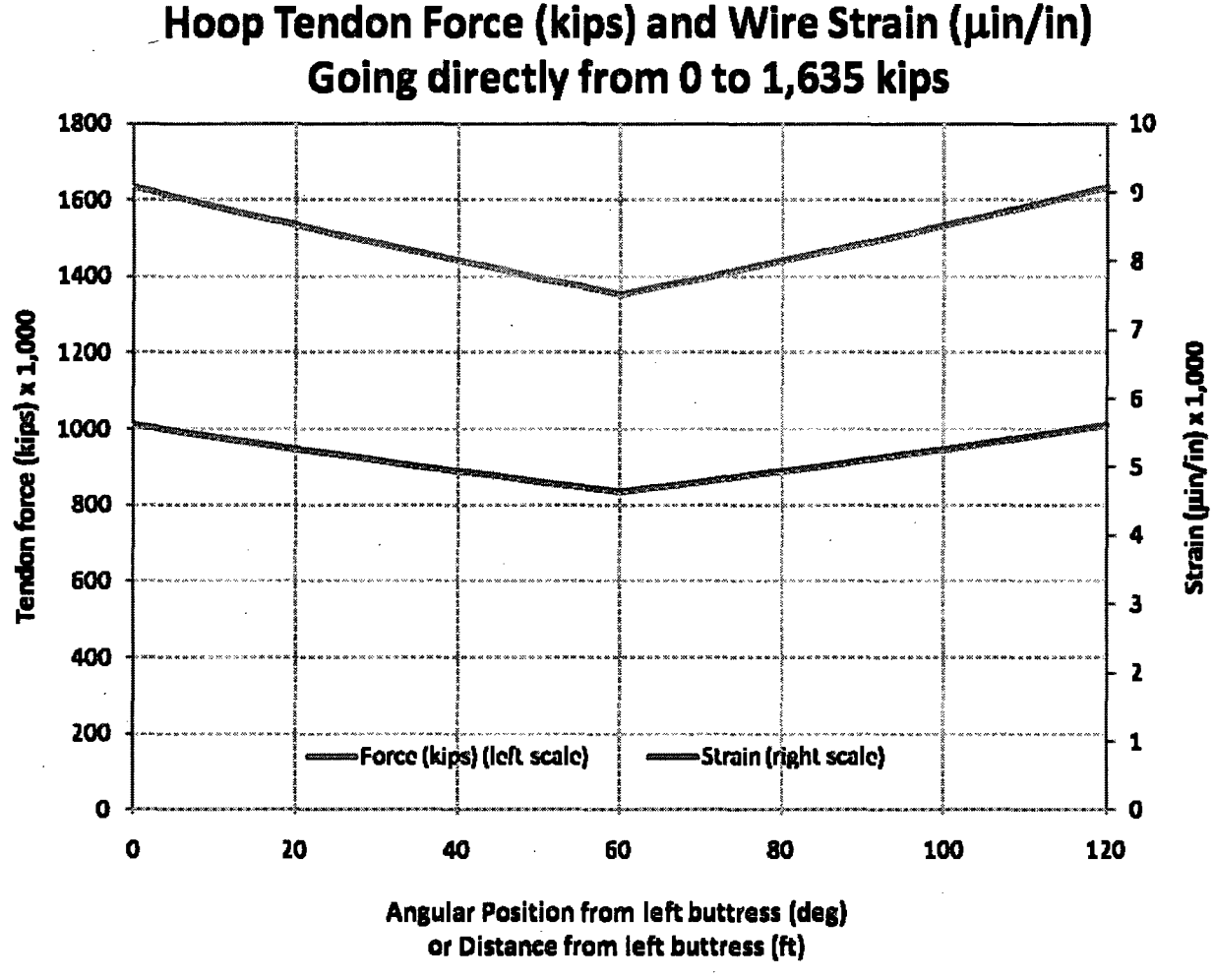
ANALYSIS IDENTIFIED MATERIAL AS: 1080 C/STEEL

REMARKS: Samples tested for information only.

Respectfully Submitted,

LYDIA PADILLA
Quality Control

Tendon Force and Wire Strain along the Tendon



6.2 Inadequate Tendon Wires

Description:
The tendons in a concrete post-tensioned system are made of steel wires. The wires must have a very high tensile strength and must sustain high stress levels for long time periods with minimal stress relaxation. Cold-drawn steel wires are typically used. The wire quality, strength, uniformity, and corrosion are tested during regular surveillances, as described in the ASME Code Section XI, Subsection IWL (FM 6.5 Exhibit 1). Relaxation of the tendon wires leads to reduced pre-stress levels in the concrete. Local strain-hardening (work-hardening) leads to non-uniform force along the tendon and non-uniform pre-stress levels. Tendon wires are ASTM A421-65 high-strength steel with a guaranteed ultimate tensile strength (GUTS) of 240ksi (FM 6.2 Exhibit 2).

Data to be collected and Analyzed:

1. Draw wire elongation variation along the tendon due to friction (FM 6.2 Exhibit 3);
2. Review surveillance data on tendon wires (FM 6.2 Exhibit 4);
3. Analyze wire surveillance data (FM 6.2 Exhibit 5);
4. Test wires recovered from removed tendons (FM 6.2 Exhibit 6);

Verified Supporting Evidence:

a. The strain in the wire is not uniform because the tendon force is not uniform (due to friction) (FM 6.2 Exhibit 3).

Verified Refuting Evidence:

a. Wire material ASTM A421 high-strength steel is the standard material specified in the industry. It is low relaxation and it is not subject to strain hardening / work hardening (FM 6.2 Exhibit 2);
b. Surveillance data on tendon wires show expected strengths and ductilities (FM 6.2 Exhibit 4 and FM 6.2 Exhibit 5);

Draft 1

Discussion:

a. The strain of 5,000 μin/in on a 120 ft wire leads to a displacement of 7.2in. This is consistent with observations made by PSC *personnel*;

b. There are no cyclic stresses imparted to the tendon wires so that the effects of strain hardening / work hardening are further limited;

c. ASTM A421 has chemical requirements on Sulfur (0.050% max) and Phosphorus (0.040 % max) only for carbon steel alloys. The wire material is left to the discretion of the manufacturer to provide the wire physical requirements such as tensile, yield, and elongation. Therefore, a wire chemistry of 1080 carbon steel falls within the ASTM A421 specifications. Based on Atlas Laboratories analysis, the wire meets chemical and mechanical properties of the ASTM A421 requirements;

d. The tendon wires are stretched to 70% GUTS in service. Therefore the maximum possible over-stressing in a local area of a wire is only 30% (above that we would reach the GUTS and the wire would break). There are very few instances of broken wires and all are explained by other factors than over-stressing;

Conclusion:

There are no indications the tendon wires used in CR3 tendons generated the delamination.

Draft 1