6.1 Uneven Force Distribution along the Tendon due to Duct Friction

Description:

The tendon force varies along the length of the tendon, with a maximum force at the jacking locations and a decreasing force towards the center of the tendon. These variations can lead to non-uniform pre-stress levels in the concrete material.

The load F(x) at position x along the tendon is approximated by (FM 6.1 Exhibit 1 is the CR3 Design Basis Document 11 Rev.6 and contains numerical values): $F(x) = F(0) \exp(-\mu\alpha - K s)$, where F(0) = Load at the jacking point, μ = Angular friction coefficient, α = Total angle change (rad), typically $\mu = 0.16$, K = Wobble friction coefficient, typically K = 0.0003, and s = Length of tendon "straight" portion (ft). When K and/or μ are too high, the concrete is locally subjected to a higher pre-stress.

This issue has been somewhat reduced after issuance of RG 1.107 "Qualifications for cement grouting for pre-stressing tendons in containment structures" and RG 1.90 "In-service inspection of pres-stressed concrete containment structures with grouted tendons" led to using petroleum greases rather than grout for corrosion protection of highly stressed tendons (FM 6.1 Exhibit 2 is a 1982 paper by H. Ashar and D.J. Naus on the topic).

Around penetrations, tendon curvatures are larger and friction losses are more important (FM 6.1 Exhibit 10 is an excerpt from the original Gilbert calculation on tendon force friction losses around the equipment hatch penetration).

The higher localized stresses can cause local micro-fracturing or local enhanced creep rates.

Data to be collected and Analyzed:

1. Compare the shop and field lift-off data collected during containment IWL inspections (FM 6.1 Exhibit 3 displays the shop and field measurement data for the various surveys and FM 6.1 Exhibit 4 is a summary of all these data);

2. Draw expected tendon force along the 120' long tendons (FM 6.1 Exhibit 5 is a curve of the force along a hoop tendon drawn using the equation and numerical values in the above description);

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3. Review grease losses in tendon sleeves (FM 6.1 Exhibit 6 displays the field measurement for grease losses for the various surveys and FM 6.1 Exhibit 7 is a summary of all these data);

4. Compare shims being used at the shop and field ends (FM 6.1 Exhibit 9 displays the shim thicknesses used at the shop and field ends as observed during surveillance 8 (last surveillance to date));

Verified Supporting Evidence:

a. Differences of 2-3% between the shop and field lift-off data are expected. CR3 surveillance data show much larger differences, up to 8% in survey 2 tendon 53H44, up to 12% in survey 4 tendon 13H40, up to 18% in survey 5 tendon 46H30, up to 20% in survey 6 tendon 42H33, up to 11% in survey 7 tendon 62H02, and up to 12% in survey 8 tendon 13H37 (FM 6.1 Exhibit 3 and FM 6.1 Exhibit 4);

b. The friction contributes to an un-even load distribution (FM 6.1 Exhibit 5). In particular around penetrations, the variation in the tendon force is large. For example, the difference between T1 = 172 ksi and T4 = 135 ksi (page 1 of 3 in FM 6.1 Exhibit 10) is equivalent to 25% variation;

c. Observations made by PSC personnel show the forces required to move the tendons out of the sleeves are much larger than the weight of the tendons (FM 6.1 Exhibit 8);

Verified Refuting Evidence:

a. The maximum force on a tendon running from buttress (n) to buttress (n+2) corresponds to the minimum force on a tendon running from buttress (n+1) to buttress (n+3). On average, the forces balance each other and the pre-stresses are relatively constant in various areas of the concrete.

Discussion:

The shim heights for the hoop tendons are very even between the shop and field ends as observed during IWL surveillance #8 (FM

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6.1 Exhibit 9 outlines the values). This indicates that the different lift-off values recorded at the shop and field ends (FM 6.1 Exhibit 3 and FM 6.1 Exhibit 4) are NOT due to installation issues. Additionally, grease losses are limited (FM 6.1 Exhibit 6 and FM 6.1 Exhibit 7) and cannot explain some of the tendon forces asymmetries.

We must note that a tendon running from buttress (n) to buttress (n+2) will have a maximum force at buttresses (n) and (n+2) (jacking points) and a minimum force at buttress (n+1) (its center) while a tendon running from buttress (n+1) to buttress (n+3) will have a maximum force at buttresses (n+1) and (n+3) (jacking points) and a minimum force at buttress (n+2) (its center). Overall, the tendons will compensate and the average pre-stress is the same everywhere.

Friction forces are particularly important around penetrations where the curvature of the tendons can be much larger. These local pre-stress gradients are in practice handled by adding high amounts of steel reinforcement in these regions of the concrete structure.

Conclusion:

The differences between shop and field lift-off measurements are high at CR3.
The uneven force along the tendons did not initiate the delamination.

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	PARAMETER	SOURCE	REASON
2.	Capacity of liner to resist additional prestress limited to 1.2 x f_y = 36 ksi.	G/C, Inc. Struc. Calc. FC 1.01.7/8 and 9.	The liner undergoes the same deformation as the concrete shell. Its resistance to such deformation is limited by its yield strength which is assumed to be 20% greater than the guaranteed minimum liner yield strength.
3.	Limit concrete tensile stress due to membrane loads to 200 psi.	G/C, Inc. Struc. Calc. FC 1.01.7/9.	ACI 318-63, Sec. 2605 limits tensile stress in unreinforced concrete to 1 $3\sqrt{f'c}$ Reinforcement provided to carry discontinuity stresses; prestressing system carries membrane stresses.
4.	Design anchorage zones for: a. bearing b. spalling c. tensile splitting d. transfer of unbalanced tendon forces	1. Analysis and design of tendon anchorage zones, GAI Report 1730, 1970. 2. G/C, Inc. Struc. Calcs. FC 1.01.7/56a through FC 1.01/7/57 and FC 1.01.8/52 through FC 1.01.8/55. 3. G/C, Inc. Struc. Calc. FC 1.01.7/16. 4. G/C, Inc. Struc. Calcs. FC 1.01.3/303-315.	Extremely high stresses in the anchorage zone require special consideration.
5.	Design parameters a. coefficient of tendon friction, 0.16 b. wobble coefficient, 0.0003	FSAR Sec. 5.2.5.2.1.1.c (for reference only). G/C, Inc. Struc. Calc. FC 1.01.7/16.	Friction and wobble coefficients were specified by Prescon for the BBRV multi-wire tendon system. Tests have shown the friction coefficient to be closer to 0.08 but use of 0.16 is conservative. The 0.0003 wobble coefficient is still representative of industry practice.
	c. max. allowable stress in tendon - less than 70% of minimum guaranteed ultimate strength.	G/C, Inc. Struc. Calc. FC 1.01.7/16.	As required by Section 2606 of ACI 318-63.
6.	Draping around major openings - establish forces radial to opening.	G/C, Inc. Struc. Calcs. FC 1.01.15/1 through FC 1.01.15/46 and FC 1.01.16/1.	A draping pattern was required which allowed tendons to pass around openings, but such that the radial pressure exerted in a direction toward the opening was minimal.

H 1/1*

Overview of the Use of Prestressed Concrete in U.S. Nuclear Power Plants

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Abstract

The containment system of a nuclear power plant provides a key part of the overall plant's engineered-safety features. The structure serves as the final barrier against release of any radioactive fission products to the environment and consideration of public safety is one of the primary criteria in providing such a barrier.

Originally the containment was envisioned as a static pressure envelope fabricated of steel and which would adequately contain the fission products released from the primary system during any credible accident scenario. As the size of the nuclear power plants increased, the costs of fabricating containment structures from stress-relieved steel plate became significant and it became advantageous to fabricate the containments of concrete. In addition to economic advantages, the concrete containments could be fabricated in virtually any size (thickness) and shape, they generally utilize indigenous materials for their construction, and they exhibit a ductile mode of failure (leak before break) which is predictable and observable. The paper outlines the extent of the use of prestressed concrete containments in nuclear power plants. However, the accident at Three Mile Island has changed the design parameters associated with the containment. In addition to containing the radioactivity during a postulated maximum LOCA, future containment designs should also provide for pressures generated during degraded core accidents. The change might give a slight edge to the application of prestressing in containment design.

The evolution of large size prestressing systems in the United States and abroad has been the result of the need to resist high pressures with the minimum number of tendons. Furthermore, corrosion inhibiting materials evolved simultaneously with the use of large size prestressing tendons. Cement grout and organic-petrolatum-based compounds needed to be specially formulated to assure thorough penetration through the tendon elements. Early in the development of prestressed concrete containments extensive dialogue occurred between the Nuclear Regulatory Commission (known then as the Atomic Energy Commission) and the industry relative to the use of portland cement grout as a corrosion inhibitor. Concern by the regulators relative to the inability to inspect the prestressing tendons to insure their structural integrity resulted in the issuance of two regulatory guides (RGs) by the NRC: (1) "Qualifications for Cement Grouting for Prestressing Tendons in Containment Structures (RG 1.107)" and (2) "Inservice Inspection of Prestressed Concrete Containment Structures with Grouted Tendons (RG 1.90)." According to some observers this action eventually eliminated any incentives for the use of grouted tendons in prestressed concrete containments.

In the United States it is required that the condition and functional capability of the ungrouted post-tensioning systems of prestressed concrete nuclear power plant containments be periodically assessed. This is accomplished, in part, systematically through an inservice tendon inspection program which must be developed and implemented for each containment. An overview of the essential elements of the inservice inspection requirements is presented and the effectiveness of these requirements is demonstrated through presentation of some of the potential problem areas which have been identified through the periodic assessments of the structural integrity of containments. Also, a summary of major problems which have been encountered with prestressed concrete construction at nuclear power plant containments in the United States is presented; that is, dome delamination, cracking of anchorheads, settlement of bearing plates, etc. The paper will conclude with an assessment of the overall effectiveness of the prestressed concrete containments.

DATA SHEET 6

PRESTRESS FORCE CONFIRMATION TEST

DOME TENDONS

INSPECTION PERIOD #1

RAM #

TENDON I.D. (1)	LOCATION (2)	PREVIOUS FORCE (kips) (3)	EXPECTED LIFT-OFF FORCE (kips) (4)		LIFT-OFF CONDITION: GAGE PRESS. (Ksi) (5)	FORCE (kips) (6)	FORCE AVG. OF 2 ENDS (kips) (7)	WIRE FORCE (8)	SHIM THICKNESS (in.) PREVIOUS (9)	SHIM THICKNESS (in.) ORIGINAL (10)	LOCK-OFF: GAGE PRESS. (Ksi) (11)	FORCE (kips) (12)	FINAL SHIM THICKNESS (in.) (13)	REACTOR BLDG TEMP °F INT. (14)	REACTOR BLDG TEMP °F EXT. (15)	DATE INSP. (16)	INSP. BY INITIALS (17)
1. D-177	[illegible]	[illegible]	133[illegible]	3	7.6	1612	1570	9,355	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	92°	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		5	7.3	1516			[illegible]	[illegible]	7.2	1516	[illegible]				
2. D-215	[illegible]	[illegible]	133[illegible]	3	7.6	1612	1634	10,086	7	7	[illegible]	[illegible]	[illegible]	92°	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		5	7.7	1635.5			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
3. D-221	[illegible]	[illegible]	133[illegible]	5	7.4	1534	1511	9,270	[illegible]	[illegible]	7.0	1534	[illegible]	115°	71°	[illegible]	[illegible]
4. D-228	[illegible]	[illegible]	133[illegible]	3	6.5	1361.5	1534	9,350	7	7	[illegible]	[illegible]	7	100°	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		5	7.2	1516			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
5. D-234	[illegible]	[illegible]	133[illegible]	3	7.0	1450	1513	9,331	7	7	7.0	[illegible]	7	113°	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		5	7.3	1516			7	7	7.2	[illegible]	7				
6. D-[illegible]	[illegible]	[illegible]	133[illegible]	3	6.4	1347.5	1562	9,583	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	110°	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]		5	7.45	1577			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
	[illegible]	[illegible]		3	7.1	1502			[illegible]	[illegible]	7.1	[illegible]	[illegible]				

NOTE A:
FORCE CALCULATION: (1) Force @ Lift-off = Jack Pressure x Jack Piston Area
OR: (2) Determine force from calibration curve

NOTE B:
Reactor Building internal temperature will be read using CI-274-TE or CI-275-TE (temperature read at Johnson Panel 11-B)

NOTE C:
Wire Force (Column 8) is defined as follows:

$$W.F. = \frac{\text{Column 7}}{163 - \text{Column 4 of Data Sheet 1}}$$

NOTE D:
Expected lift-off force (column 4) is defined as follows: No. of effective wires at installation (or previous inspection) X Avg. predicted ..fe force shown on Fig. 1 at time of inspection.

LEGEND

LOCATION: 1 to 6 Number of buttress nearest to end of tendon.
SHIM THICKNESS: Clear distance between bearing plate and stressing washer.
PREVIOUS: At time of installation or previous surveillance.
ORIGINAL: At time of starting current surveillance.

Contractor Review by: _____ Date: _____

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

DATA SHEET 7

PRESTRESS FORCE CONFIRMATION TEST

VERTICAL TENDONS

INSPECTION PERIOD #1

RAM #

TENDON I.D. (1)	LOCATION (2)	PREVIOUS FORCE (kips) (3)	EXPECTED LIFT-OFF FORCE (kips) (4)		LIFT-OFF CONDITION: GAGE PRESS. (Ksi) (5)	FORCE (kips) (6)	FORCE AVG. OF 2 ENDS (kips) (7)	WIRE FORCE (8)	SHIM THICKNESS (in.) PREVIOUS (9)	SHIM THICKNESS (in.) ORIGINAL (10)	LOCK-OFF: GAGE PRESS. (Ksi) (11)	FORCE (kips) (12)	FINAL SHIM THICKNESS (in.) (13)	REACTOR BLDG TEMP °F INT. (14)	REACTOR BLDG TEMP °F EXT. (15)	DATE INSP. (16)	INSP. BY INITIALS (17)
1. 12V20	T	1615	1499.6	5	8.2	1785	1785	10,951	T 9" B 4"	T 15" B 4"	8.2	1785	T 15" B 4"	111°	65°	12/12/77	[illegible]
2. 23V15	T	1615	1490.4	5	7.3	1589.5	1587.5	9,751	T 13" B 4"	T 13" B 4"	7.3	1589.5	T 13" B 4"	102°	62°	12/12/77	[illegible]
3. 34V6	T	1615	1499.6	3	7.5	1590	1590	9,755	T 14½" B 4"	T 14⅜" B 4"	7.7	1634	T 14⅜" B 4"	102°	41°	12/6/77	[illegible]
4. 45V3	T	1639	1499.6	3	7.9	1678	1678	10,294	T 14" B 4"	T 14" B 4"	7.9	1678	T 14" B 4"	103°	63°	12/4/77	[illegible]
5. 56V1	T	1690 / 1780 *	1499.6	5	7.9	1718.5	1718.5	10,543	T 14" B 4"	T 14" B 4"	7.7	1675.5	T 14" B 4"	107°	66°	12/3/77	[illegible]

*NOTE:

TWO ACTUAL LIFT-OFF PRESSURES WERE REPORTED IN TENDON HISTORY FOR 56V1

NOTE A:
FORCE CALCULATION: (1) Force @ Lift-off = Jack Pressure x Jack Piston Area
OR: (2) Determine force from calibration curve

NOTE B:
Reactor Building internal temperature will be read using CI-274-TE or CI-275-TE (temperature read at Johnson Panel 11-B)

NOTE C:
Wire Force (Column 8) is defined as follows:

$$W.F. = \frac{\text{Column 7}}{163 \times \text{Column 4 of Data Sheet 2}}$$

NOTE D:
Expected lift-off force (column 4) is defined as follows: No. of effective wires at installation (or previous inspection) X Ave. predicted wire force shown on Fig. 2 at time of inspection.

LEGEND
LOCATION: T or B - top or bottom (vertical tendon).
SHIM THICKNESS: Clear distance between bearing plate and stressing washer.
PREVIOUS: At time of installation or previous surveillance.
ORIGINAL: At time of starting current surveillance.

Contractor Review by: _____ Date: _____

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

DATA SHEET 1 A

PRESTRESS FORCE CONFIRMATION TEST

VERTICAL TENDONS

INSPECTION PERIOD #1

RAM #

TENDON				LIFT-OFF CONDITION						LOCK-OFF			REACTOR BLDG TEMP °F		DATE INSP.	INSP. BY
I.D.	LOCATION	PREVIOUS FORCE (kips)	EXPECTED LIFT-OFF FORCE (kips)	CAGE PRESS. (Ksi)	FORCE (kips)	FORCE AVG. OF 2 ENDS (kips)	WIRE FORCE	SHIM THICKNESS (in.) PREVIOUS	SHIM THICKNESS (in.) ORIGINAL	CAGE PRESS. (Ksi)	FORCE (kips)	FINAL SHIM THICKNESS (in.)	INT.	EXT.		INITIALS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. 12V19	T	1640	1499.6	5	7.3	1587.5	1587.5	9.737	T 13 3/8"	13 3/4"	LIFT-OFF	ONLY	—	—	—	—
2. 12V21	T	1651	1472	5	7.5	1632.5	1632.5	10.203	T 13"	13"	LIFT-OFF	ONLY	—	—	—	—
3. —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4. —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5. —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

NOTE A:
FORCE CALCULATION: (1) Force @ Lift-off = Jack Pressure x Jack Piston Area
OR: (2) Determine force from calibration curve

NOTE B:
Reactor Building internal temperature will be read using CI-274-TE or CI-275-TE (temperature read at Johnson Panel 11-B)

NOTE C:
Wire Force (Column 8) is defined as follows:

$$W.F. = \frac{\text{Column 7}}{163 \times \text{Column 4 of Data Sheet 2}}$$

NOTE D:
Expected lift-off force (column 4) is defined as follows: No. of effective wires at installation (or previous inspection) X Ave. predicated wire force shown on Fig. 2 at time of inspection.

LEGEND
LOCATION: T or B - top or bottom (vertical tendon).
SHIM THICKNESS: Clear distance between bearing plate and stressing washer.
PREVIOUS: At time of installation or previous surveillance.
ORIGINAL: At time of starting current surveillance.

Contractor Review by: _____ Date: _____

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

DATA SHEET 8

PRESTRESS FORCE CONFIRMATION TEST

HOOP TENDONS

INSPECTION PERIOD 7-1-1

TENDON I.D. (1)	LOCATION (2)	PREVIOUS FORCE (kips) (3)	EXPECTED LIFT-OFF FORCE (kips) (4)		LIFT-OFF CONDITION GAGE PRESS. (Ksi) (5)	FORCE (kips) (6)	FORCE AVG. OF 2 ENDS (7)	WIRE FORCE (8)	SHIM THICKNESS (in.) PREVIOUS (9)	ORIGINAL (10)	LOCK-OFF GAGE PRESS. (Ksi) (11)	FORCE (kips) (12)	FINAL SHIM THICKNESS (in.) (13)	REACTOR BLDG TEMP °F INT. (14)	EXT. (15)	DATE INSP. (16)	INSP. BY INITIALS (17)
1. 13H10	5-1	1595	1475.4	3	7.1	1502	1524	9,351	7	7	7.15	1513	7	107°	71°	[illegible]	[illegible]
				5	7.1	1502.5			7¼	7¼	7.1	1502.5	7¼				
2. 13H19			1474.4	3	7.15	1557	1495	9,224	6⅛	6¼	7.1	1502	6⅞	109°	53°	[illegible]	[illegible]
				5	6.5	1431.5			6¼	6¼	6.6	1452	6¼				
3. 13H31			1435.4	3	7.1	1557	1605.5	9,850	6⅛	6¼	7.3	1557	6⅛	95°	51°	[illegible]	[illegible]
				5	7.6	1654			5⅞	5¾	7.4	[illegible]	5¾				
4. 13H47			1434.4	3	7.45	1610	1556	9,351	6⅛	7¼	7.4	1615	7¼	93°	49°	[illegible]	[illegible]
				5	7.5	1612.5			6	6	7.4	[illegible]	6				
5. 13H49			1434.4	3	7.5	1616	1573.5	9,650	7	7	7.4	1576	7	105°	59°	[illegible]	[illegible]
				5	7.45	1557			5¾	5¾	7.1	1502.5	5¾				
6. 14H21			1435.4	5	6.7	1453.5	1502	9,217	5⅞	5¾	6.7	1451.5	5¾	106°	40°	[illegible]	[illegible]
				3	7.2	1546			5⅞	5⅞	7.2	1554	5⅞				
7. 14H37			1434.4	5	6.85	1471	1473	8,975	6¾	6¾	6.7	1451.5	6¾	104°	54°	[illegible]	[illegible]
				3	6.8	1415			6	6	6.8	1422	6				
8. 14H43			1435.4	5	6.5	1411.5	1457	8,940	7	7	6.5	1413.5	7	104°	62°	[illegible]	[illegible]
				3	7.1	1503			6⅞	6¾	6.45	[illegible]	6¾				
9. [illegible]			1434.4	5	6.5	1415.5	1424	8,982	7⅛	7¼	6.6	1411	7¼	111°	74°	[illegible]	[illegible]
				3	7.15	1571			6¼	6¼	7.0	1522	6¼				
10. 5H-1			1434.4	5	6.7	1457.5	1474	9,044	5⅞	5¾	6.7	1455.5	5⅞	107°	63°	12/15/77	[illegible]
				5	6.8	1491			6¾	7	7.1	1522.5	7				

NOTE A:
FORCE CALCULATION: (1) Force @ Lift-off = Jack Pressure x Jack Piston Area
OR: (2) Determine force from calibration curve

NOTE B:
Reactor Building internal temperature will be read using CI-274-TE or CI-275-TE (temperature read at Johnson Panel 11-B)

NOTE C:
Wire Force (Column 8) is defined as follows:

$$W.F. = \frac{\text{Column 7}}{163 \times \text{Column 4 of Data Sheet 3}}$$

NOTE D:
Expected lift-off force (column 4) is defined as follows: No. of effective wires at installation (or previous inspection) X Ave. predicted wire force shown on Fig. 3 at time of inspection.

LEGEND

LOCATION: 1 to 6 - Number of buttress nearest to end of tendon.

SHIM THICKNESS: Clear distance between bearing plate and stressing washer.

PREVIOUS: At time of installation or previous surveillance.

ORIGINAL: At time of starting current surveillance.

Contractor Review by: _____ Date: _____

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

DATA SHEET 6

PRESTRESS FORCE CONFIRMATION TEST

DOME TENDONS

INSPECTION PERIOD #2

TENDON				LIFT-OFF CONDITION						LOCK-OFF			REACTOR BLDG TEMP °F		DATE INSP.	INSP. BY	
I.D.	LOCATION	PREVIOUS FORCE (kips)	EXPECTED LIFT-OFF FORCE (kips)	GAGE PRESS. (Ksi)	FORCE (kips)	FORCE AVG. OF 2 ENDS (kips)	WIRE FORCE	SHIM THICKNESS (in.) PREVIOUS	SHIM THICKNESS (in.) ORIGINAL	GAGE PRESS. (Ksi)	FORCE (kips)	FINAL SHIM THICKNESS (in.)	INT.	EXT.		INITIALS	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1. D331	1	—	—	6.8	1454	1460.6	9.07	6	6	LIFT OFF		6	71	76	4-24-80	DCS	161
	5	—		6.9	1467			6 3/4	6 3/4	ONLY		6.75					
2. D323	1	—	—	7.2	1512	1525.5	9.47	7	7	LIFT OFF		7	74	78	4-28-80	DCS	161
	5	—		7.1	1507			6 3/4	6 3/4	ONLY		6.76					
3. D208	3	—	—	7.6	1623	1593.5	9.89	6 3/4	6 3/4	7.6	1623	6.75	72	81	4-29-80	DCS	161
	1	—		7.3	1564			6 5/8	6 5/8	7.3	1564	6.625					
4. D140	5	—	—	7.3	1551	1587	9.73	6 5/8	6 5/8	LIFT OFF		6.625	74	77	4-30-80	DCS	163
	3	—		7.6	1623			6 1/8	6 1/8	ONLY		6.125					
5. D122	5	—	—	7.6	1628	1646.5	10.1	7 1/4	7 1/4	LIFT OFF		7.25	71	82	5-2-80	DCS	163
	3	—		7.8	1665			7	7	ONLY		7					
6. —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
	—	—		—	—			—	—	—	—	—					

NOTE A:
FORCE CALCULATION: (1) Force @ Lift-off = Jack Pressure x Jack Piston Area
OR: (2) Determine force from calibration curve

NOTE B:
Reactor Building internal temperature will be read using CI-274-TE or CI-275-TE (temperature read at Johnson Panel 11-B)

NOTE C:
Wire Force (Column 8) is defined as follows:

$$W.F. = \frac{\text{Column 7}}{16) - \text{Column 4 of Data Sheet 1}}$$

NOTE D:
Expected lift-off force (column 4) is defined as follows: No. of effective wires at installation (or previous inspection) X Ave. predicted wire force shown on Fig. 1 at time of inspection.

LEGEND

LOCATION: 1 to 6 Number of buttress nearest to end of tendon.
SHIM THICKNESS: Clear distance between bearing plate and stressing washer.
PREVIOUS: At time of installation or previous surveillance.
ORIGINAL: At time of starting current surveillance.

Contractor Review by: [signature] Date: 7-25-80

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

DATA SHEET 2

PRESTRESS FORCE CONFIRMATION TEST

VERTICAL TENDONS

INSPECTION PERIOD #2

Only 1 lift off!

TENDON I.D. (1)	LOCATION (2)	PREVIOUS FORCE (kips) (3)	EXPECTED LIFT-OFF FORCE (kips) (4)	LIFT-OFF CONDITION: GAGE PRESS. (Ksi) (5)	FORCE (kips) (6)	FORCE AVG. OF 2 ENDS (kips) (7)	WIRE FORCE (8)	SHIM THICKNESS (in.) PREVIOUS (9)	SHIM THICKNESS (in.) ORIGINAL (10)	LOCK-OFF: GAGE PRESS. (Ksi) (11)	FORCE (kips) (12)	FINAL SHIM THICKNESS (in.) (13)	REACTOR BLDG TEMP °F INT. (14)	REACTOR BLDG TEMP °F EXT. (15)	DATE INSP. (16)	INSP. BY INITIALS (17)	
1. 34V1	T	—	—	7.4	1569	1569	9.625	T 13 1/8 B 4	T 13 1/8 B 4	LIFT-OFF ONLY		T 13 1/8 B 4	71	80	3/27/80	DCS	163
2. 23V5	T	—	—	7.5	1580	1580	9.693	T 14 1/2 B 4	T 14 1/2 B 4	LIFT-OFF ONLY		T 14 1/2 B 4	71	80	3/28/80	DCS	163
3. 12V12	T	—	—	7.8	1718	1718	10.607	T 15 3/8 B 4	T 15 3/8 B 4	LIFT-OFF ONLY		T 15 3/8 B 4	72	81	4/3/80	DCS	162
4. 56V1	T	—	—	7.7	1707	1707	10.472	T 14 B 4	T 14 B 4	7.7	1707	T 14 B 4	70	84	4/2/80	DCS	163
5. 56V20	T	—	—	7.6	1630	1630	10.0	T 15 B 4	T 15 B 4	LIFT-OFF ONLY		T 15 B 4	70	81	4/1/80	DCS	163

162, 1 remove

Force/wire = 10.54 K

NOTE A:
FORCE CALCULATION: (1) Force @ Lift-off = Jack Pressure x Jack Piston Area
OR: (2) Determine force from calibration curve

NOTE B:
Reactor Building internal temperature will be read using CI-274-TE or CI-275-TE (temperature read at Johnson Panel 11-B)

NOTE C:
Wire Force (Column 8) is defined as follows:

$$W.F. = \frac{\text{Column 7}}{163 - \text{Column 4 of Data Sheet 2}}$$

NOTE D:
Expected lift-off force (column 4) is defined as follows: No. of effective wires at installation (or previous inspection) X Ave. predicted wire force shown on Fig. 2 at time of inspection.

LEGEND

LOCATION: T or B - top or bottom (vertical tendon).
SHIM THICKNESS: Clear distance between bearing plate and stressing washer.
PREVIOUS: At time of installation or previous surveillance.
ORIGINAL: At time of starting current surveillance.

Contractor Review by: [signature] Date: 7-25-80

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

DATA SHEET 7

PRESTRESS FORCE CONFIRMATION TEST

VERTICAL TENDONS

INSPECTION PERIOD #2

TENDON				LIFT-OFF CONDITION						LOCK-OFF			REACTOR BLDG TEMP		DATE INSP.	INSP. BY	
								SHIM THICKNESS (in.)					°F				
I.D.	LOCATION	PREVIOUS FORCE (kips)	EXPECTED LIFT-OFF FORCE (kips)	GAGE PRESS. (Ksi)	FORCE (kips)	FORCE AVG. OF 2 ENDS (kips)	WIRE FORCE	PREVIOUS	ORIGINAL	GAGE PRESS. (Ksi)	FORCE (kips)	FINAL SHIM THICKNESS (in.)	INT.	EXT.		INITIALS	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1. 45Y6	T	—	—	7.5	1685	1685	10.40	T 14 3/8 B 4	T 14 3/8 B 4	LIFT-OFF ONLY		T 14 3/8 B 4	72	81	4/11/80	DCS	162
2. 12Y20	T	—	—	8.0	1740	1740	10.67	T 15 B 4	T 15 B 4	LIFT-OFF ONLY		T 15 B 4	71	78	4/11/80	DCS	163
3.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
4.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
5.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

NOTE A:
FORCE CALCULATION: (1) Force @ Lift-off = Jack Pressure x Jack Piston Area
OR: (2) Determine force from calibration curve

NOTE B:
Reactor Building internal temperature will be read using CI-274-TE or CI-275-TE (temperature read at Johnson Panel 11-9)

NOTE C:
Wire Force (Column 8) is defined as follows:

$$W.F. = \frac{\text{Column 7}}{163 - \text{Column 4 of Data Sheet 2}}$$

NOTE D:
Expected lift-off force (column 4) is defined as follows: No. of effective wires at installation (or previous inspection) X Ave. predicated wire force shown on Fig. 2 at time of inspection.

LEGEND

LOCATION: T or B - top or bottom (vertical tendon).
SHIM THICKNESS: Clear distance between bearing plate and stressing washer.
PREVIOUS: At time of installation or previous surveillance.
ORIGINAL: At time of starting current surveillance.

Contractor Review by: [signature] Date: 7-25-80

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

DATA SHEET 6

PRESTRESS FORCE CONFIRMATION TEST

HOOP TENDONS

INSPECTION PERIOD #2

TENDON I.D. (1)	LOCATION (2)	PREVIOUS FORCE (kips) (3)	EXPECTED LIFT-OFF FORCE (kips) (4)	LIFT-OFF CONDITION GAGE PRESS. (Ksi) (5)	FORCE (kips) (6)	FORCE AVG. OF 2 ENDS (kips) (7)	WIRE FORCE (8)	SHIM THICKNESS (in.) PREVIOUS (9)	SHIM THICKNESS (in.) ORIGINAL (10)	LOCK-OFF GAGE PRESS. (Ksi) (11)	LOCK-OFF FORCE (kips) (12)	FINAL SHIM THICKNESS (in.) (13)	REACTOR BLDG TEMP °F INT. (14)	REACTOR BLDG TEMP °F EXT. (15)	DATE INSP. (16)	INSP. BY INITIALS (17)
1. 13H22	1 S	—	—	7.4	1569	1572	9.644	7	7	LIFT-OFF ONLY		7	71	68	4/16/80	DCS
	3 F	—	—	7.5	1575			7 7/8	7 7/8	"	"	7 7/8			4/17/80	
2. 13H32	1 S	—	—	7.6	1591	1610.6	9.94	7 1/2	7 1/2	7.6	1591	7 1/2	72	77	4/17/80	DCS
	3 F	—	—	7.6	1630			7 1/2	7 1/2	7.6	1630	7 1/2				
3. 13H43	1 S	—	—	7.6	1591	1583	9.77	8 1/8	8 1/8	LIFT OFF ONLY		8 1/8	73	80	4/18/80	DCS
	3 F	—	—	7.5	1575			7	7	"	"	7				
4. 51H10	5 F	—	—	7.3	1553	1572	9.76	6 1/4	6 1/4	LIFT OFF ONLY		6 1/4	71	85	5/6/80	DCS
	1 S			7.6	1591			6 3/8	6 3/8	"	"	6 3/8			5/5/80	
5. 51H23	5 F	—	—	7.5	1580	1528	9.37 ✓	7 1/4	7 1/4	LIFT OFF ONLY		7 1/4	72	80	4/24/80	DCS
	1 S			6.9	1476			7 1/4	7 1/4	"	"	7 1/4				
6. 51H37	5 F	—	—	7.6	1591	1566.5	9.73	6 3/4	6 3/4	LIFT OFF ONLY		6 3/4	71	81	4/24/80	DCS
	1 S			7.2	1542			7	7	"	"	7				
7. 53H24	5 F	—	—	7.0	1499	1533	9.41 ✓	6 7/8	6 7/8	"	"	6 7/8	71	82	4/22/80	DCS
	3 S			7.4	1568			6 7/8	6 7/8	"	"	6 7/8			4/22/80	
8. 53H28	5 S	—	—	6.5	1393	1480	8.77 ✓	7	7	"	"	7	70	79	4/22/80	DCS
	3 F			6.9	1467			5 7/8	5 7/8	"	"	5 7/8				
9. 53H44	5 S	—	—	7.5	1553	1621.5	9.95	6 3/4	6 3/4	"	"	6 3/4	73	77	4/22/80	DCS
	3 F			7.9	1620			6 7/8	6 7/8	"	"	6 7/8				
10. 64H42	4 F	—	—	7.0	1492	1547.5	9.49 ✓	7 1/2	7 1/2	"	"	7 1/2	72	77	4/23/80	DCS
	4 S	—	—	7.5	1603			7	7	"	"	7				

NOTE A:
FORCE CALCULATION: (1) Force @ Lift-off = Jack Pressure x Jack Piston Area
OR: (2) Determine force from calibration curve

NOTE B:
Reactor Building Internal temperature will be read using CI-274-TE or CI-275-TE (temperature read at Johnson Panel 11-8)

NOTE C:
Wire Force (Column 8) is defined as follows:

$$W.F. = \frac{\text{Column 7}}{163 - \text{Column 4 of Data Sheet 3}}$$

NOTE D:
Expected lift-off force (column 4) is defined as follows: No. of effective wires at installation (or previous inspectio X Ave. predicted wire force shown on Fig. 3 at time of inspection.

LEGEND
LOCATION: 1 to 6 - Number of buttress nearest to end of tendon.
SHIM THICKNESS: Clear distance between bearing plate and stressing washer.
PREVIOUS: At time of installation or previous surveillance.
ORIGINAL: At time of starting current surveillance.

Contractor Review by: [signature] 7-25-80
F.P.C. Approval by: _____ Date: _____

SUMMARY OF LIFT-OFF FORCES

TABLE 1

CRYSTAL RIVER UNIT 3

TENDON NUMBER	END DESIGNATION	ALLOWABLE LIFT-OFF FORCE (KIPS) MAXIMUM	ALLOWABLE LIFT-OFF FORCE (KIPS) MINIMUM	10TH YEAR SURVEILLANCE LIFT-OFF FORCE (KIPS)	AVERAGE (KIPS)
64H19 64H19	Field Shop	1721	1249	1446 1493	1470
13H20 13H20	Field Shop	1721	1249	1460 1451	1456
51H26 51H26	Field Shop	1721	1249	1334 1487	1411
13H40 13H40	Field Shop	1721	1249	1558 1383	1471
51H41 51H41	Field Shop	1721	1249	1346 1377	1362
D105 D105	Field Shop	1721	1249	1413 1492	1453
D212 D212	Field Shop	1721	1249	1260 1292	1276
D328 D328	Field Shop	1721	1249	1602 1635	1619
12V1 12V1*	Field Shop	1721	1249	1535	1535
34V4 34V4*	Field Shop	1721	1249	1623	1623
56V2 56V2*	Field Shop	1721	1249	1648	1648

*Lift-off occurring at Shop end only

TP417ds

TABLE 1: SUMMARY OF LIFT-OFF FORCES

Tendon Number	Tendon End	Allowable Lift-Off* (Kips) Maximum	Allowable Lift-Off* (Kips) Minimum	Actual Lift-Off (Kips)	Average Lift-Off (Kips)
34V6	Field	1721	1249	N/A	
34V6	Shop	1721	1249	1590	1590
56V15	Field	1721	1249	N/A	
56V15	Shop	1721	1249	1541	1541
61V14	Field	1721	1249	N/A	
61V14	Shop	1721	1249	1587	1587
D215	Field	1721	1249	1579	
D215	Shop	1721	1249	1458	1518
D224	Field	1721	1249	1412	
D224	Shop	1721	1249	1438	1425
D231	Field	1721	1249	1332	
D231	Shop	1721	1249	1337	1335
35H1	Field	1721	1249	1568	
35H1	Shop	1721	1249	1577	1572
42H1	Field	1721	1249	1507	
42H1	Shop	1721	1249	1613	1560
46H21	Field	1721	1249	1427	
46H21	Shop	1721	1249	1423	1425
46H28	Field	1721	1249	1374	
46H28	Shop	1721	1249	1376	1375
46H29	Field	1721	1249	1280	
46H29	Shop	1721	1249	1321	1300
46H30	Field	1721	1249	1371	
46H30	Shop	1721	1249	1138	1382
46H47	Field	1721	1249	1472	
46H47	Shop	1721	1249	1464	1468
62H8	Field	1721	1249	1462	
62H8	Shop	1721	1249	1407	1435

* Allowable values as presented are based on the FPC Tech Spec requirements as required and summarized in SP-182, Rev 10. Additional acceptance criteria for compliance to Reg. Guide 1.35, Rev 3, are summarized in Rev 11 of SP-182 and is applicable. Base, 95% base, and 90% base values required for consideration and performance of inspection activities according to SP-182, Rev 11 are provided in separate tendon curves in Appendix 1. See also Enclosures 44, 45, and 46 for tendon group acceptance criteria.

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

V. TENDON LIFTOFFS AND DETENSIONING

A liftoff is performed on each surveillance tendon to monitor the force exerted by the tendon onto the structure. PSC Procedure SQ 9.0 (Volume 2, Section 9, Appendix F) details the steps to be taken to perform a liftoff. The results are documented on Data Sheet SQ 9.0 and are summarized in Table VIII.

It should be noted that performing a liftoff has only a localized effect on a tendon; therefore, it is acceptable to use the same jacks for both ends of a tendon by executing the liftoff on separate occasions.

Vertical tendon liftoffs were found to be above the base value except for 12V1 which was above 95% of base, and all dome liftoff averages were above the base value.

Horizontal liftoffs revealed two isolated areas 42H30 to 42H36 inclusive and 51H26, 51H27 where average tendon liftoffs were between 90% and 95% of base value. One tendon 42H35 was found to be below 90% and detensioned for continuity test per FPC requirement. This continuity test revealed that all of the wires were continuous, one wire was removed for testing and the tendon restored to base value -0% +6%. All other tendons found between 90 and 95% of base value were subsequently restored per procedure to base value -0% +6%.

These low liftoff results were documented on NCR's -010, 011, 012,.013, and 014 for 42H30 - 36 and NCR 005 for 51H26.

All other tendon liftoffs were either above base value or 95% of base value and therefore acceptable.

The average normalized liftoff for each group, vertical, dome and horizontal, exceeded the minimum required and is acceptable.

After completion of liftoffs, protruding wires were found to tendons 51H26(1), 51H27(2) and 62H46(2). These wires, once removed, were found to have broken behind the anchorhead. No corrosion was found to indicate wire failure due to deterioration and it is suspected that slight tendon head rotation while setting back down sheared the wires against the shims. In all cases the broken wires were on the outer corner edge of the tendon bundle and no gauge movement was noted to indicate failures during liftoff. These wires were probable "pinched" during original installation and additional work on these tendons has broken the wires. NCR's FN604-003,007 and 015 recorded these occurrences.

PSC Precision Surveillance Corporation

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

Florida Power CORPORATION

TABLE VIII: SUMMARY OF DATA SHEETS SQ 9.0 TENDON LIFTOFFS

TENDON	END	EFFECT. WIRES	JACK No.	PRESS.	LIFTOFF	AVE. LIFTOFF	BASE VALUE	95% BASE	90% BASE	NORMALIZING FACTOR	ACCEPT
12V1	SHOP/TOP	162	8833	4390	1471	1471	1530	1453	1377	-9	YES
23V2	SHOP/TOP	163	8778	4820	1609	1609	1482	1408	1333	37	YES
61V21	SHOP/TOP	163	8833	4550	1525	.1525	1482	1408	1334	38	YES
D113	SHOP/ 2	163	8778	4267.5	1424.7	1427	1369	1301	1232	-35	YES
	FIELD/ 6	163	8833	4265	1429						YES
D115	SHOP/ 2	163	8778	4062.5	1356	1380	1347	1280	1213	-12	YES
	FIELD/ 6	163	8833	4190	1404						YES
D212	SHOP/ 1	162	8833	3820	1280	1335	1317	1252	1186	15	YES
	FIELD/ 3	162	8778	4160	1389						YES
D304	SHOP/ 4	163	8778	4810	1605	1598	1397	1327	1258	-64	YES
	FIELD/ 2	162	8833	4748	1591						YES
D311	SHOP/ 4	163	8778	4220	1409.5	1408	1335	1269	1202	0	YES
	FIELD/ 2	163	8833	4200	1407						YES

PSC Precision Surveillance Corporation

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

Florida Power CORPORATION

TABLE VIII: SUMMARY OF DATA SHEETS SQ 9.0 - TENDON LIFTOFFS

TENDON	END	EFFECT. WIRES	JACK No.	PRESS.	LIFTOFF	AVE. LIFTOFF	BASE VALUE	95% BASE	90% BASE	NORMALIZING FACTOR	ACCEPT
42H18	SHOP/ 4	163	8778	4690	1565	1476	1495	1420	1346	-56	YES
	FIELD/ 2	163	8833	4137	1386.5						YES
42H29	SHOP/ 4	163	8778	4500	1502	1448	1445	1373	1300	-7	YES
	FIELD/ 2	163	8833	4160	1394						YES
42H30	SHOP/ 4	163	8778	4355	1454	1389	1469	1396	1322	-32	NO
	FIELD/ 2	163	8833	3950	1324						NO
42H31	SHOP/ 4	163	8778	4100	1369	1338	1460	1387	1314	-21	NO
	FIELD/ 2	163	8833	3900	1307						NO
42H32	SHOP/ 4	163	8778	4320	1442	1355.5	1452	1380	1307	-15	NO
	FIELD/ 2	163	8833	3785	1269						NO
42H33	SHOP/ 4	163	8778	4490	1499	1361	1474	1400	1326	-35	NO
	FIELD/ 2	163	8833	3650	1223						NO
42H34	SHOP/ 4	163	8778	4240	1415	1377.5	1452	1380	1307		NO
	FIELD/ 2	163	8833	4000	1340						NO

PSC Precision Surveillance Corporation

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

Florida Power CORPORATION

TABLE VIII: SUMMARY OF DATA SHEETS SQ 9.0 - TENDON LIFTOFFS

TENDON	END	EFFECT. WIRES	JACK No.	PRESS.	LIFTOFF	AVE. LIFTOFF	BASE VALUE	95% BASE	90% BASE	NORMALIZING FACTOR	ACCEPT
42H35	SHOP/ 4	163	8778	4110	1372	1296.5	1455	1382	1309	-17	NO
	FIELD/ 2	163	8833	3693	1221						NO
42H36	SHOP/ 4	163	8778	4490	1499	1408	1503	1428	1353	-65	NO
	FIELD/ 2	163	8833	3930	1317						NO
42H37	SHOP/ 4	163	8778	4310	1439	1401.5	1452	1379	1306	-14	YES
	FIELD/ 2	163	8833	4070	1364						YES
42H44	SHOP/ 4	163	8778	4510	1505	1471.5	1427	1356	1285	10	YES
	FIELD/ 2	163	8833	4291	1438						YES
51H25	SHOP/ 1	163	8833	4090	1370.5	1363	1401	1331	1261	38	YES
	FIELD/ 5	163	8778	4060	1355.5						YES
51H26	SHOP/ 1	163	8833	4190	1403.5	1320	1514	1438	1363	-75	NO
	FIELD/ 5	163	8778	3705	1237						NO
51H27	SHOP/ 1	163	8833	3787	1269	1265.5	1368	1300	1231	71	NO
	FIELD/ 5	163	8778	3780	1262						NO

PSC Precision Surveillance Corporation

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

Florida Power CORPORATION

TABLE VIII: SUMMARY OF DATA SHEETS SQ 9.0 - TENDON LIFTOFFS

TENDON	END	EFFECT. WIRES	JACK No.	PRESS.	LIFTOFF	AVE. LIFTOFF	BASE VALUE	95% BASE	90% BASE	NORMALIZING FACTOR	ACCEPT
51H28	SHOP/ 1	163	8833	4445	1489.5	1450.5	1518	1442	1367	80	YES
	FIELD/ 5	163	8778	4230	1412						YES
53H2	SHOP/ 5	163	9501	4400	1624	1611	1424	1353	1281	12	YES
	FIELD/ 3	163	9501	4330	1598						YES
53H46	SHOP/ 5	163	8833	4340	1454	1459.5	1472	1399	1325	-35	YES
	FIELD/ 3	163	8778	4390	1465						YES
62H41	SHOP/ 2	163	8778	4230	1412	1426	1422	1351	1280	16	YES
	FIELD/ 6	163	8833	4297.5	1440						YES
62H46	SHOP/ 2	163	8778	4280	1429	1485	1465	1392	1318	-27	YES
	FIELD/ 6	163	8833	4600	1541						YES

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

Florida Power
A Progress Energy Company

V. TENDON LIFTOFFS AND DETENSIONING

A liftoff is performed on each surveillance tendon to monitor the force exerted by the tendon onto the structure. PSC Procedure SQ 9.0 (Volume 2, Section 9, Appendix F) details the steps to be taken to perform a liftoff. The results are documented on Data Sheet SQ 9.0 and are summarized in Table VIII.

It should be noted that performing a liftoff has only a localized effect on a tendon; therefore, it is acceptable to use the same jacks for both ends of a tendon by executing the liftoff on separate occasions.

All dome tendon liftoffs were found to be above base value and acceptable. Vertical tendon liftoffs were found to be above the base value except for 12V01 which was between 90% and 95% of base requiring adjacent tendons to be tested. The adjacent tendons were both between base value and 95% and therefore acceptable. Tendon 12V01 was retensioned to base value -0%,+6% per procedure and left as acceptable. Vertical tendon average (allowing for removal of tendons exhibiting anchorhead rotation) was above the required minimum and acceptable. The low liftoff result for 12V01 was documented on NCR FN750-016.

Horizontal liftoffs revealed one isolated area 46H30 to 46H38 inclusive where tendon liftoffs were between 90% and 95% of base value, one tendon, 46H36, was found to be below 90% of base value . After testing, all the tendons in this area were subsequently restored per procedure to base value -0% +6%. Of the other horizontal tendons tested (6 total) two were found above base value and four were found to be between base value and 95%. After removal of horizontal tendons that exhibited anchorhead rotation, average normalized horizontal liftoffs were above the required minimum and deemed acceptable.

During liftoff, rotation of the anchorhead was noted to tendon D339. During subsequent detensioning (as scheduled) a broken wire was discovered at the field end. This wire, once removed, was found to have broken behind the anchorhead. No corrosion was found to indicate wire failure due to deterioration and it is suspected that the tendon head rotation sheared the wires against the shims. The broken wire was on the outer corner edge of the tendon bundle and no gauge movement was noted to indicate failure during liftoff. This wire was probable "pinched" during original installation and additional work on this tendon resulted in the wire finally breaking. NCR FN750-004 recorded this occurrence.

PSC Precision Surveillance Corporation

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

Florida Power
A Progress Energy Company

TABLE VIII: SUMMARY OF DATA SHEETS SQ 9.0
TENDON LIFTOFFS

TENDON	END	EFFECT. WIRES	JACK No.	PRESS.	LIFTOFF	AVE. LIFTOFF	BASE VALUE	95% BASE	90% BASE	NORMALIZING FACTOR	ACCEPT
12V01	SHOP/TOP	161	8783	4360	1446	1446	1528	1451	1375	-9	NO
12V02	SHOP/TOP	163	8783	4660	1546	1546	1599	1519	1439	-80	YES
23V24	SHOP/TOP	163	8783	4587	1521.8	1521.8	1527	1451	1374	-9	YES
45V14	SHOP/TOP	163	8833	4650	1552	1552	1580	1501	1422	-61	YES
61V08	SHOP/TOP	163	8783	4450	1476	1476	1494	1419	1344	23	YES
46H21	SHOP/ 6	163	8783	4166.6	1381.4	1388	1446	1374	1302	-12	YES
	FIELD/ 4	162	8833	4180	1394.7						
46H29	SHOP/ 6	159	8783	4060	1345.9	1407.1	1427	1356	1284	8	YES
	FIELD/ 4	159	8833	4400	1468.3						
46H30	SHOP/ 6	162	8783	4200	1392.6	1355.6	1442	1370	1298	-8	NO
	FIELD/ 4	161	8833	3953	1318.7						
46H31	SHOP/ 6	163	8783	4073	1350.2	1343.3	1456	1383	1311	-22	NO
	FIELD/ 4	161	8833	4006	1336.5						
46H32	SHOP/ 6	162	8783	4180	1385.9	1366.8	1455	1382	1308	-22	NO
	FIELD/ 4	163	8833	4040	1347.8						

PSC Precision Surveillance Corporation

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

Florida Power
A Progress Energy Company

TABLE VIII: SUMMARY OF DATA SHEETS SQ 9.0 - TENDON LIFTOFFS

TENDON	END	EFFECT. WIRES	JACK No.	PRESS.	LIFTOFF	AVE. LIFTOFF	BASE VALUE	95% BASE	90% BASE	NORMALIZING FACTOR	ACCEPT
46H33	SHOP/ 6	163	8783	4200	1392.6	1357.8	1450	1378	1305	-17	NO
	FIELD/ 4	163	8833	3966	1323.1						
46H34	SHOP/ 6	162	8783	4200	1392.6	1424.7	1521	1445	1369	-86	NO
	FIELD/ 4	163	8833	4366	1456.9						
46H35	SHOP/ 6	163	8783	4240	1405.9	1376.8	1459	1386	1313	-25	NO
	FIELD/ 4	163	8833	4040	1347.8						
46H36	SHOP/ 6	163	8783	4080	1352.5	1343.5	1497	1422	1348	-63	NO
	FIELD/ 4	163	8833	4000	1334.5						
46H37	SHOP/ 6	162	8783	3700	1225.7	1293.45	1414	1343	1272	20	NO
	FIELD/ 4	161	8833	4080	1361.2						
46H38	SHOP/ 6	163	8783	4093	1356.9	1353.4	1459	1380	1307	-19	NO
	FIELD/ 4	162	8833	4046	1349.9						
46H39	SHOP/ 6	163	8783	4146	1374.6	1356.2	1410	1339	1269	23	YES
	FIELD/ 4	163	8833	4010	1337.8						

PSC Precision Surveillance Corporation

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

Florida Power
A Progress Energy Company

TABLE VIII: SUMMARY OF DATA SHEETS SQ 9.0 - TENDON LIFTOFFS

TENDON	END	EFFECT. WIRES	JACK No.	PRESS.	LIFTOFF	AVE. LIFTOFF	BASE VALUE	95% BASE	90% BASE	NORMALIZING FACTOR	ACCEPT
53H16	SHOP/ 5	163	8752	4560	1498.2	1475.4	1496	1422	1347	-63	YES
	FIELD/ 3	163	8783	4380	1452.7						
62H02	SHOP/ 6	163	8752	4473	1469.4	1551.6	1466	1393	1319	-33	YES
	FIELD/ 2	163	8833	4970	1633.9						
62H09	SHOP/ 2	163	8752	4346	1427.3	1431.8	1420	1349	1278	13	YES
	FIELD/ 6	163	8752	4373	1436.3						
D126	SHOP/ NEAR 3	163	8833	4180	1394.7	1376.9	1345	1278	1211	-18	YES
	FIELD/ NEAR 5	163	8783	4100	1359.2						
D212	SHOP/ NEAR 1	162	8783	3813	1263.4	1292.2	1311	1246	1180	15	YES
	FIELD/ NEAR 3	162	8833	3960	1321.1						
D339	SHOP/ NEAR 5	163	8783	4560	1512.8	1507.3	1439	1367	1295	-111	YES
	FIELD/ NEAR 1	163	8833	4500	1501.8						

8.0 TENDON LIFTOFFS

8.1 MONITOR TENDON FORCES

8.1.1 A liftoff is defined as the force required to lift the anchor head off the shim stack and is representative of the force held by that tendon. A liftoff is performed on each physical surveillance tendon to monitor the force exerted by the tendon onto the structure. PSC Procedure SQ 9.0 in Appendix F details the steps taken to perform a liftoff. The results were documented on Data Sheet SQ 9.0 and are summarized in Tables 40 thru 45.

8.1.1.1 It should be noted that performing a liftoff has only a localized effect on a tendon; therefore, it is acceptable to use the same jack for both ends of a tendon by executing the liftoff on separate occasions.

8.1.2 All of the vertical and dome tendon liftoffs were found to be above the minimum design and above 95% Predicted Force as required by IWL-3221.1. Three of the five horizontal surveillance tendons were found to be below 95% Predicted Force but above 90% Predicted Force. The liftoff requirement stated in IWL is:

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.

8.1.3 Based upon the unacceptable horizontal tendon liftoffs, adjacent tendons were monitored for force until an acceptable liftoff reading was obtained on both sides of the selected tendon. 13H36 required testing of 5 adjacent tendons, 46H21 and 62H30 also required testing of five adjacent tendons. Of these tendons, six were above 95%, five were between 95% and 90% and four fell just below 90%. All tendons below 95% were restored to Predicted Force – 0%, + 6% and locked off. The restoration of these tendons is summarized in Table 46.

8.1.4 The average of the As-Found normalized liftoff values was above the minimum requirement, despite the low liftoffs, and deemed acceptable per PSC Procedure SQ9.0 Section 10.4.

8.1.4.1 The average normalized tendon force in Unit 3 for each group and their respective minimum design are:

Vertical Tendon:	Group Average = 1535.2 Kips	Minimum Design = 1149 Kips
Hoop Tendon:	Group Average = 1347.4 Kips	Minimum Design = 1252 Kips
Dome Tendon:	Group Average = 1367.3 Kips	Minimum Design = 1215 Kips

8.1.4.1.1 As depicted above, all group averages are above the required group minimum and are therefore acceptable. The actual values for each tendon and its corresponding group are summarized in Table 47.

8.1.5 Upon completion of the liftoff, a visual verification is performed to identify any changes in the condition of the tendon end. No additional or broken wires were noted during or after liftoffs.

TABLE 40: VERTICALS – SQ9.0 – MONITORING TENDON FORCE

TENDON	END	SHIM STACK HEIGHT (in)	EFFECTIVE WIRES	JACK I.D.	LIFT-OFF (kips)	AALV (kips)	B.V.P.F. (KIPS)	95% B.V.P.F. (KIPS)	90% B.V.P.F. (KIPS)	ADJACENTS REQUIRED	# OF ADJACENTS MONITORED	AS-FOUND ACCEPTANCE
12V01	TOP	14.75	161	8784	1559.95	1559.95	1525	1449	1372	NO	0	YES
	BOT	4.00	158	N/A	N/A							
45V20	TOP	12.50	163	8780	1456.80	1456.80	1507	1432	1357	NO	0	YES
	BOT	4.00	163	N/A	N/A							
61V08	TOP	13.00	163	8784	1505.98	1505.98	1491	1416	1342	NO	0	YES
	BOT	4.00	163	N/A	N/A							
61V17	TOP	12.00	161	8784	1580.18	1580.18	1498	1423	1348	NO	0	YES
	BOT	4.00	163	N/A	N/A							

TABLE 41: HOOPS – SQ9.0 – MONITORING TENDON FORCE

TENDON	END	SHIM STACK HEIGHT (in)	EFFECTIVE WIRES	JACK I.D.	LIFT-OFF (kips)	AALV (kips)	B.V.P.F. (KIPS)	95% B.V.P.F. (KIPS)	90% B.V.P.F. (KIPS)	ADJACENTS REQUIRED	# OF ADJACENTS MONITORED	AS-FOUND ACCEPTANCE
13H36	BT 1	6.50	163	8784	1344.08	1385.23	1484	1410	1336	YES	5	NO
	BT 3	7.25	163	8780	1426.63							
42H46	BT 2	5.75	163	8784	1546.46	1558.63	1456	1383	1310	NO	0	YES
	BT 4	6.00	163	8780	1570.80							
46H21	BT 4	5.75	163	8780	1319.34	1330.02	1441	1369	1297	YES	5	NO
	BT 6	6.00	163	8784	1340.71							
51H34	BT 1	8.00	163	8784	1532.96	1464.70	1487	1413	1339	NO	0	YES
	BT 5	7.00	163	8780	1396.45							
62H30	BT 2	6.75	163	8784	1249.64	1290.84	1413	1342	1272	YES	5	NO
	BT 6	6.75	163	9501	1332.05							

TABLE 42: DOMES – SQ9.0 – MONITORING TENDON FORCE

TENDON	END	SHIM STACK HEIGHT (In)	EFFECTIVE WIRES	JACK I.D.	LIFT-OFF (kips)	AALV (kips)	B.V.P.F. (KIPS)	95% B.V.P.F. (KIPS)	90% B.V.P.F. (KIPS)	ADJACENTS REQUIRED	# OF ADJACENTS MONITORED	AS-FOUND ACCEPTANCE
D129	BT 3	6.25	162	8780	1289.16	1289.64	1287	1223	1159	NO	0	YES
	BT 5	6.00	161	8784	1290.12							
D212	BT 1	6.38	162	8784	1259.76	1277.81	1305	1240	1175	NO	0	YES
	BT 3	6.50	162	8780	1295.87							
D238	BT 4	7.00	163	8780	1527.21	1511.53	1348	1281	1213	NO	0	YES
	BT 6	6.00	163	8784	1495.86							

TABLE 43: 13H36 ADJACENTS – SQ9.0 – MONITORING TENDON FORCE

TENDON	END	SHIM STACK HEIGHT (In)	EFFECTIVE WIRES	JACK I.D.	LIFT-OFF (kips)	AALV (kips)	B.V.P.F. (KIPS)	95% B.V.P.F. (KIPS)	90% B.V.P.F. (KIPS)	ADJACENTS REQUIRED	AS-FOUND ACCEPTANCE
13H33	BT 1	7.00	163	8784	1310.35	1306.46	1366	1298	1229	NO	YES
	BT 3	6.75	163	8780	1302.57						
13H34	BT 1	7.00	163	8784	1350.83	1368.61	1475	1402	1328	YES	NO
	BT 3	7.00	163	8780	1386.39						
13H35	BT 1	6.56	163	8784	1249.64	1244.25	1373	1304	1235	YES	NO
	BT 3	6.38	162	8780	1238.87						
13H37	BT 1	6.88	163	8784	1367.69	1289.87	1368	1299	1231	YES	NO
	BT3	5.75	163	8780	1212.05						
13H38	BT 1	6.50	163	8784	1411.54	1395.05	1444	1372	1300	NO	YES
	BT 3	7.00	163	8780	1378.57						

TABLE 44: 46H21 ADJACENTS – SQ9.0 – MONITORING TENDON FORCE

TENDON	END	SHIM STACK HEIGHT (in)	EFFECTIVE WIRES	JACK I.D.	LIFT-OFF (Kips)	AALV (Kips)	B.V.P.F. (KIPS)	95% B.V.P.F. (KIPS)	90% B.V.P.F. (KIPS)	ADJACENTS REQUIRED	AS-FOUND ACCEPTANCE
46H19	BT 4	7.00	163	8780	1352.87	1358.61	1402	1332	1262	NO	YES
	BT 6	7.50	163	8784	1364.35						
46H20	BT 4	6.75	160	8780	1269.04	1298.13	1467	1394	1321	YES	NO
	BT 6	7.25	163	8784	1327.22						
46H22	BT 4	5.75	163	8780	1315.98	1311.48	1488	1412	1337	YES	NO
	BT 6	6.38	163	8784	1306.98						
46H23	BT 4	6.00	161	8780	1336.10	1329.97	1425	1354	1283	YES	NO
	BT 6	5.75	163	8784	1323.85						
46H24	BT 4	6.75	163	8780	1419.92	1425.85	1472	1398	1325	NO	YES
	BT 6	7.50	163	8784	1431.78						

TABLE 45: 62H30 ADJACENTS – SQ9.0 – MONITORING TENDON FORCE

TENDON	END	SHIM STACK HEIGHT (in)	EFFECTIVE WIRES	JACK I.D.	LIFT-OFF (Kips)	AALV (Kips)	B.V.P.F. (KIPS)	95% B.V.P.F. (KIPS)	90% B.V.P.F. (KIPS)	ADJACENTS REQUIRED	AS-FOUND ACCEPTANCE
62H29	BT 2	6.50	163	8780	1366.28	1369.63	1421	1350	1279	NO	YES
	BT 6	6.38	163	9501	1372.98						
62H31	BT 2	6.25	163	8780	1269.04	1269.04	1475	1401	1328	YES	NO
	BT 6 *	6.00	163	N/A	N/A						
62H32	BT 2	7.00	163	8780	1332.75	1332.75	1455	1382	1310	YES	NO
	BT 6 *	6.50	163	N/A	N/A						
62H33	BT 2	6.19	163	8780	1242.22	1313.39	1461	1388	1315	YES	NO
	BT 6	6.50	162	8784	1384.56						
62H34	BT 2	7.00	163	8780	1393.10	1378.71	1432	1360	1289	NO	YES
	BT 6	6.75	162	8784	1364.32						

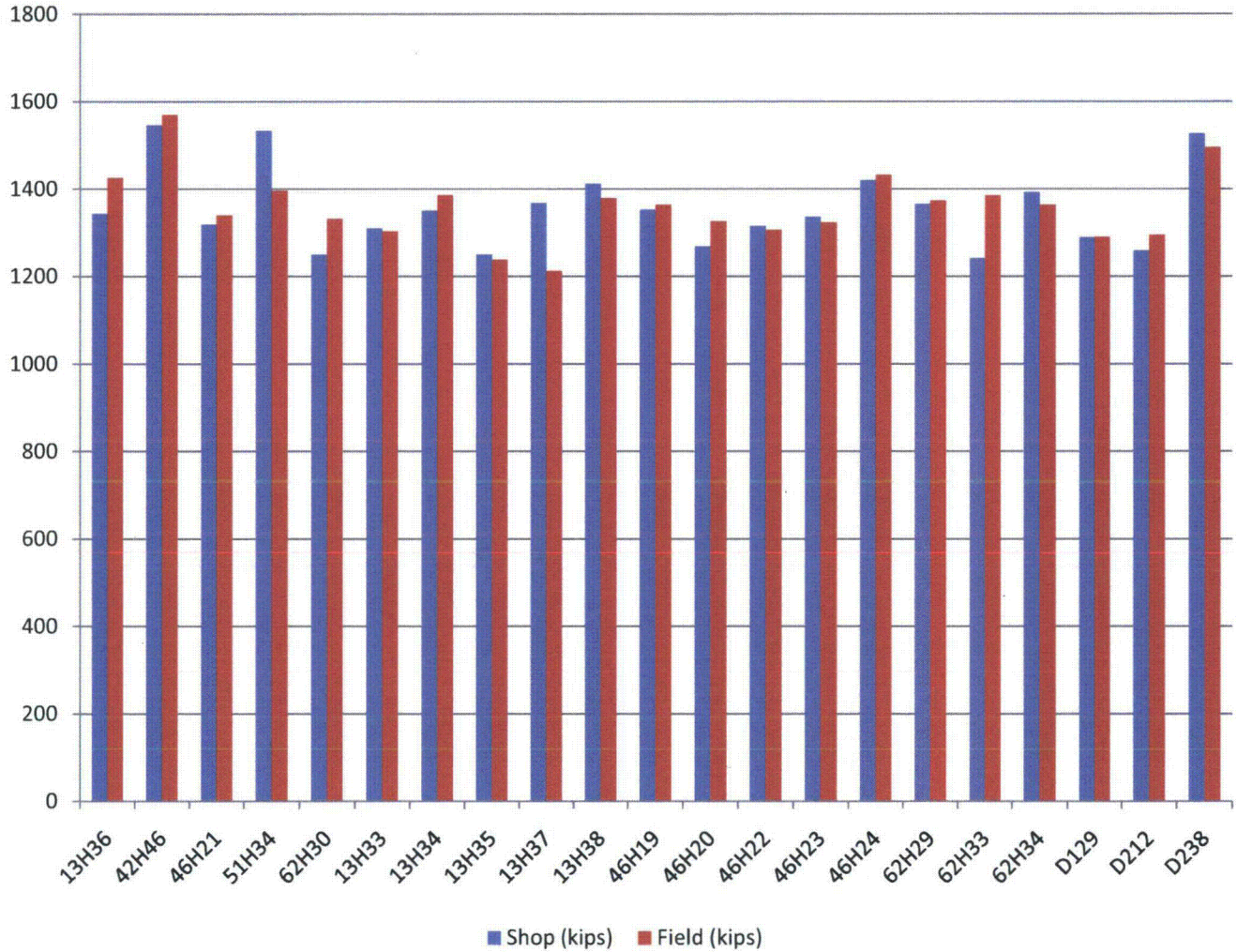
* TENDON NOT ACCESSABLE AT BUTTRESS 6.

TABLE 46 ADJACENTS - TENDON FORCE RESTORATION

TENDON	END	AS-FOUND LIFTOFF			RESTORATION			B.V.P.F. (KIPS)	% VARIATION ABOVE B.V.P.F	ACCPETABLE ?
		JACK	LIFT-OFF (kips)	AALV (kips)	JACK	LIFT-OFF (kips)	AALV (kips)			
13H34	BT 1	8784	1350.83	1368.61	8784	1479.00	1508.13	1475	+2.2%	YES
	BT 3	8780	1386.39		8780	1537.27				
13H35	BT 1	8784	1249.64	1244.25	8784	1411.54	1417.40	1373	+3.2%	YES
	BT 3	8780	1238.87		8780	1423.27				
13H36	BT 1	8784	1344.08	1385.23	8784	1546.46	1555.27	1484	+4.8%	YES
	BT 3	8780	1426.63		8780	1564.09				
13H37	BT 1	8784	1367.69	1289.87	8784	1394.68	1415.68	1368	+3.5%	YES
	BT 3	8780	1212.05		8780	1436.69				
46H20	BT 4	8780	1269.04	1298.13	8780	1486.98	1494.79	1467	+1.9%	YES
	BT 6	8784	1327.22		8784	1502.61				
46H21	BT 4	8780	1319.34	1330.02	8780	1503.74	1501.49	1441	+4.2%	YES
	BT 6	8784	1340.71		8784	1499.24				
46H22	BT 4	8780	1315.98	1311.48	8780	1567.45	1538.40	1486	+3.5%	YES
	BT 6	8784	1306.98		8784	1509.35				
46H23	BT 4	8780	1336.10	1329.97	8780	1486.98	1481.30	1425	+4.0%	YES
	BT 6	8784	1323.85		8784	1475.62				
62H30	BT 2	8784	1249.64	1290.84	8780	1443.39	1467.71	1413	+3.9%	YES
	BT 6	9501	1332.05		9501	1492.04				
62H31	BT 2	8780	1269.04	1269.04	8780	1486.98	1486.98	1475	+0.8%	YES
	BT 6 *	N/A	N/A		N/A	N/A				
62H32	BT 2	8780	1332.75	1332.75	8780	1497.04	1497.04	1455	+2.9%	YES
	BT 6 *	N/A	N/A		N/A	N/A				
62H33	BT 2	8780	1242.22	1313.39	8780	1486.98	1494.79	1461	+2.3%	YES
		8784	1384.56		8784	1502.61				

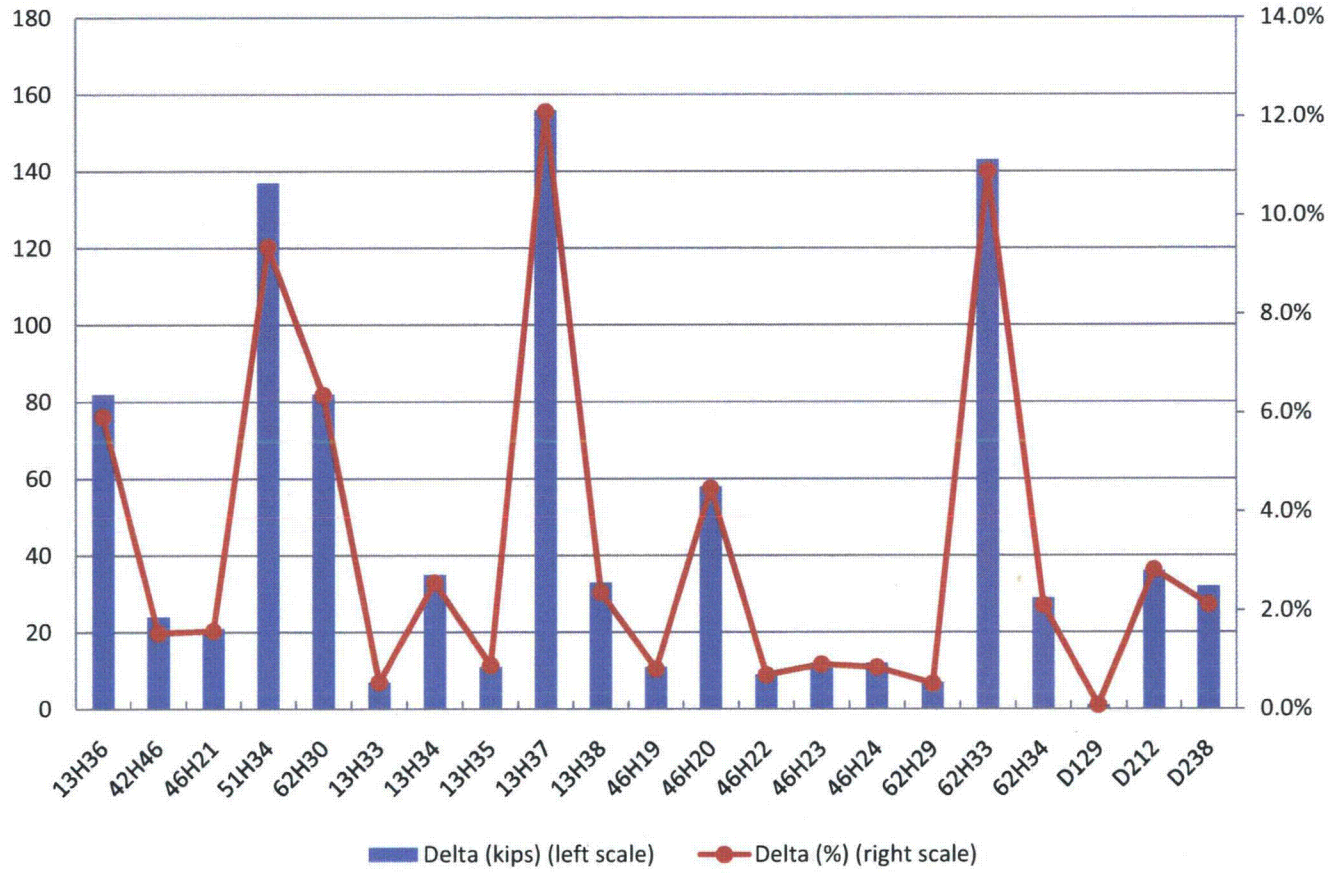
* TENDON NOT ACCESSABLE AT BUTTRESS 6 – RESTORATION ONE END ONLY.

Tendon Lift-off Forces (Survey 8)



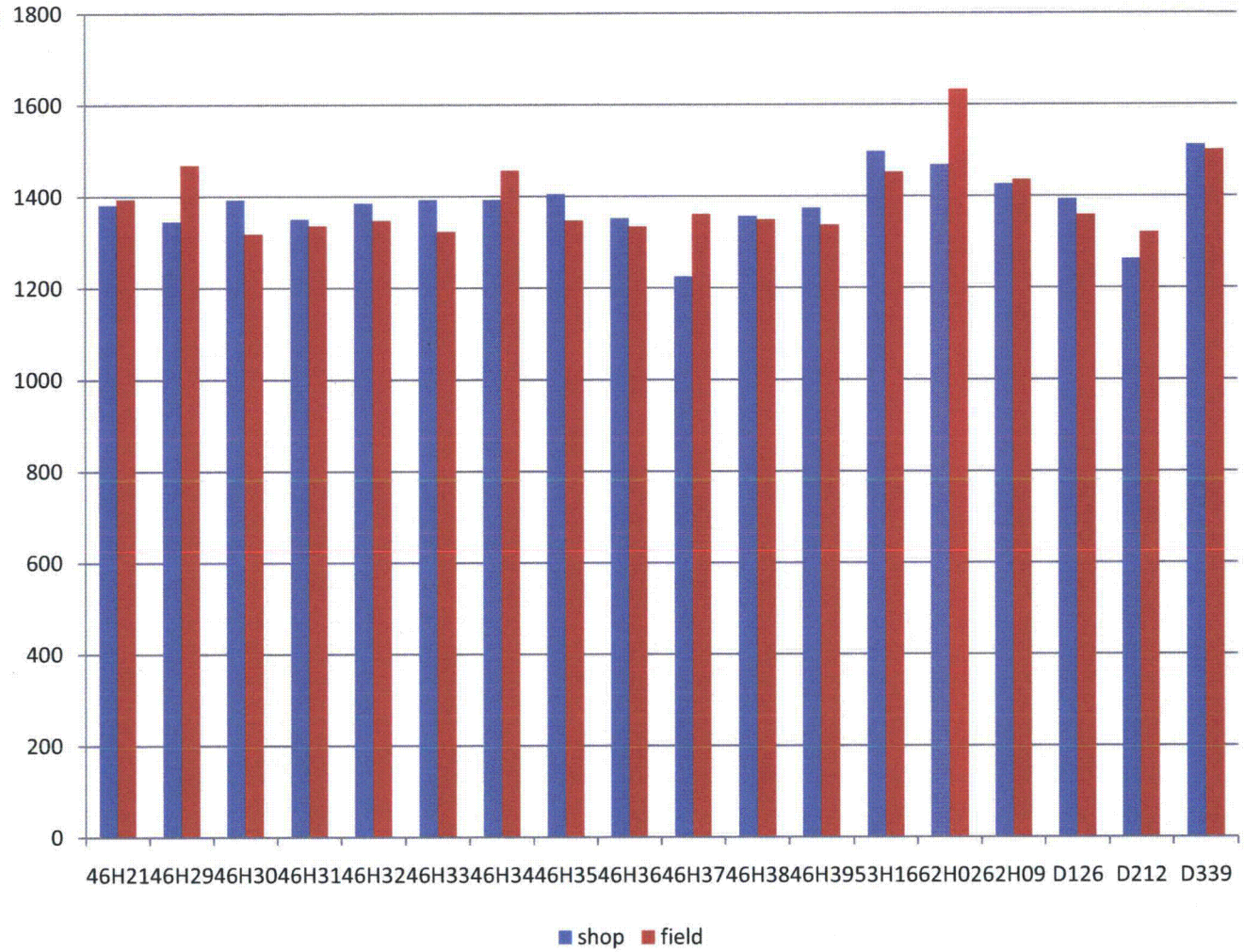
Lift-off forces measured at the Shop end (blue) and at the Field end (red)

Tendon Lift-off Force Asymmetry (Survey 8)



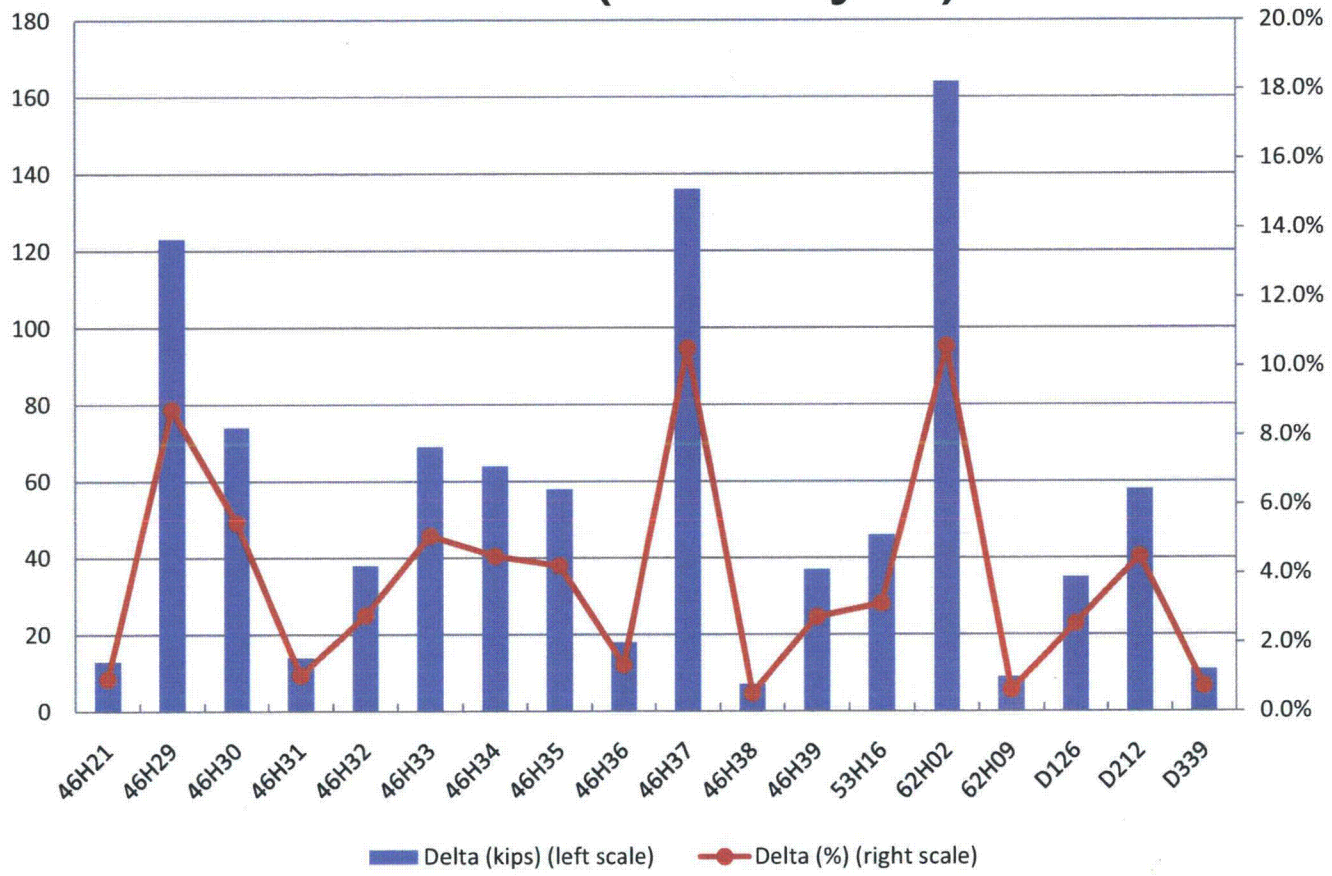
Delta = Difference between lift-off forces at Shop and Field ends

Tendon Lift-off Forces (Survey 7)



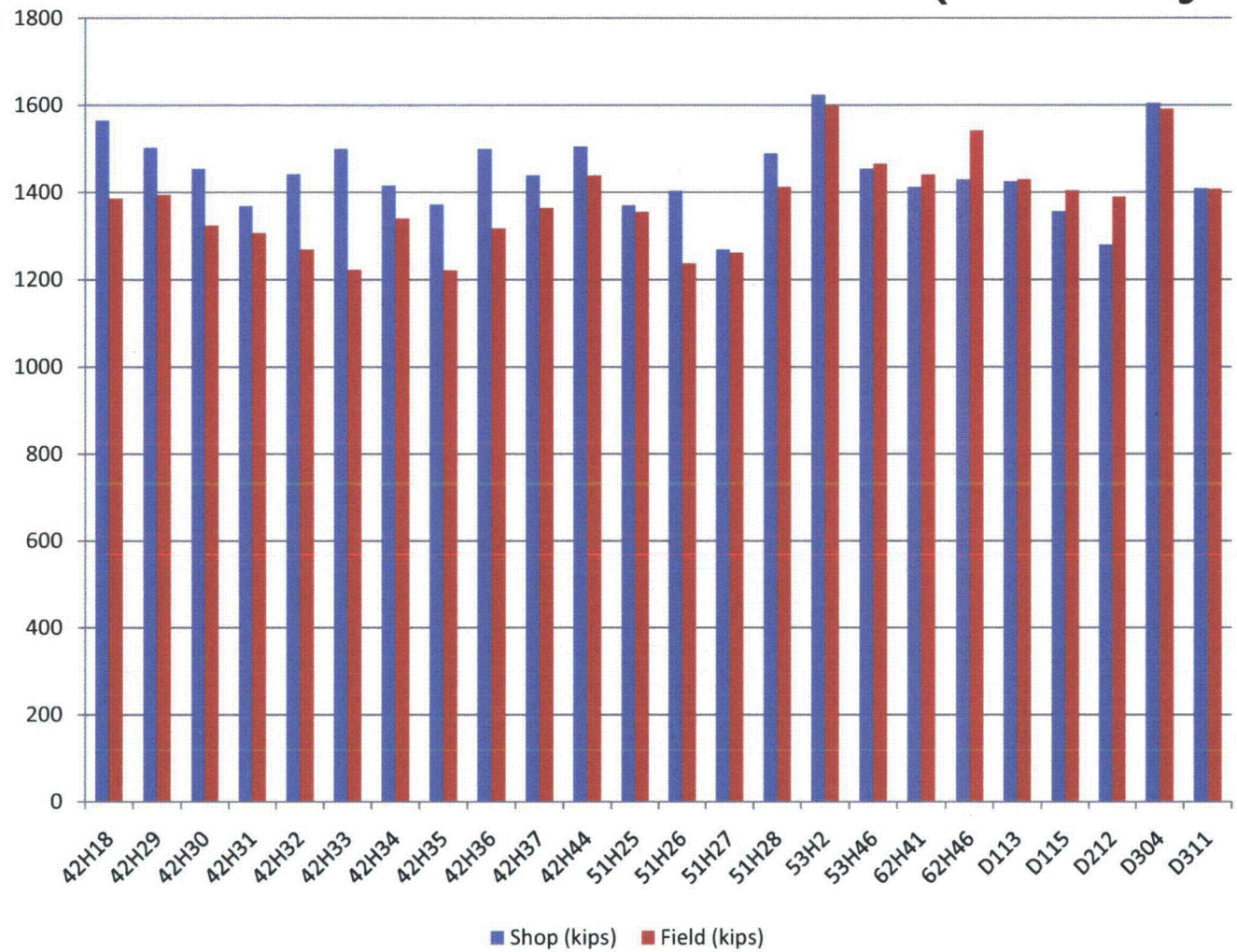
Lift-off forces measured at the Shop end (blue) and at the Field end (red)

Tendon Lift-off Force Asymmetry (Survey 7)



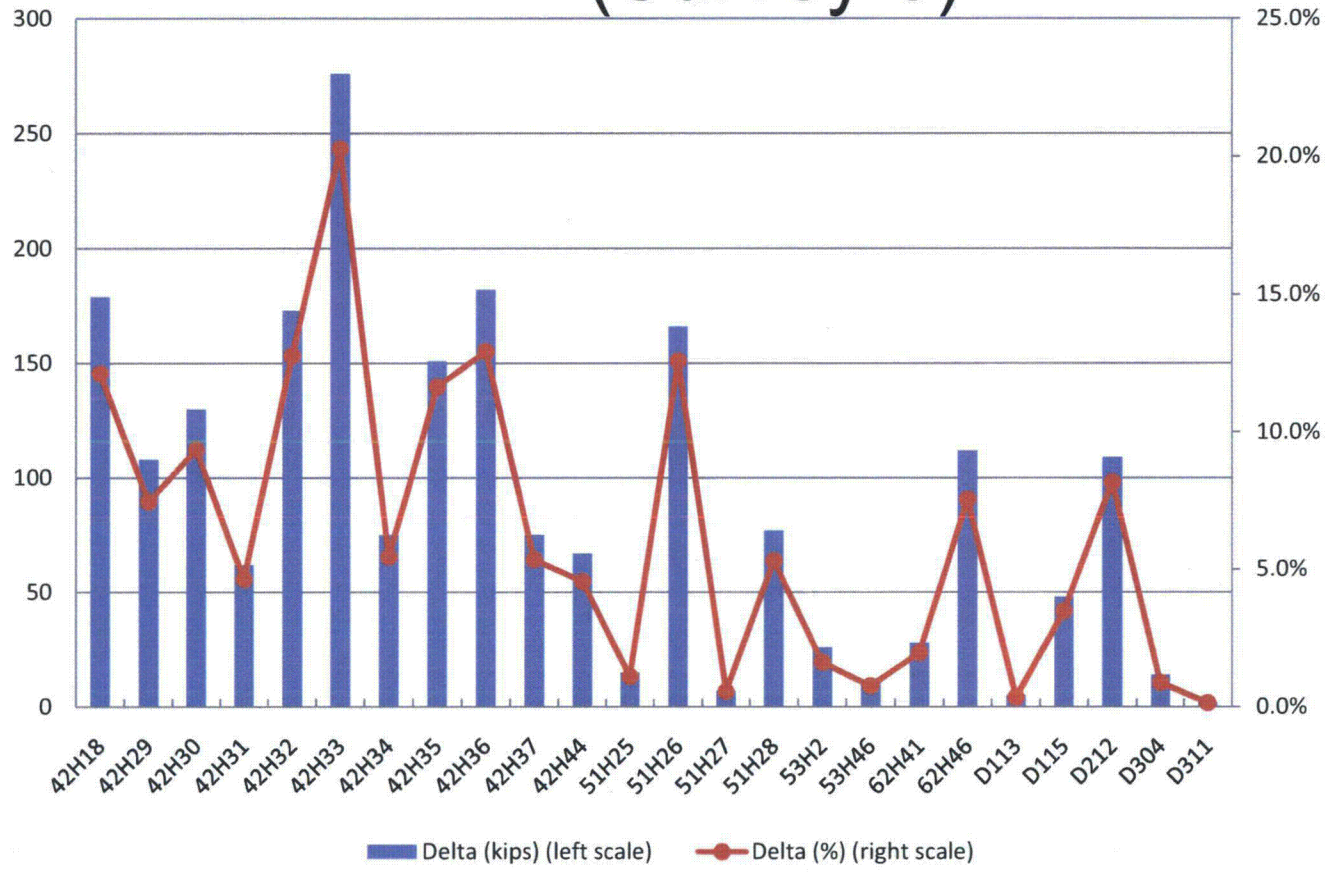
Delta = Difference between lift-off forces at Shop and Field ends

Tendon Lift-off Forces (Survey 6)



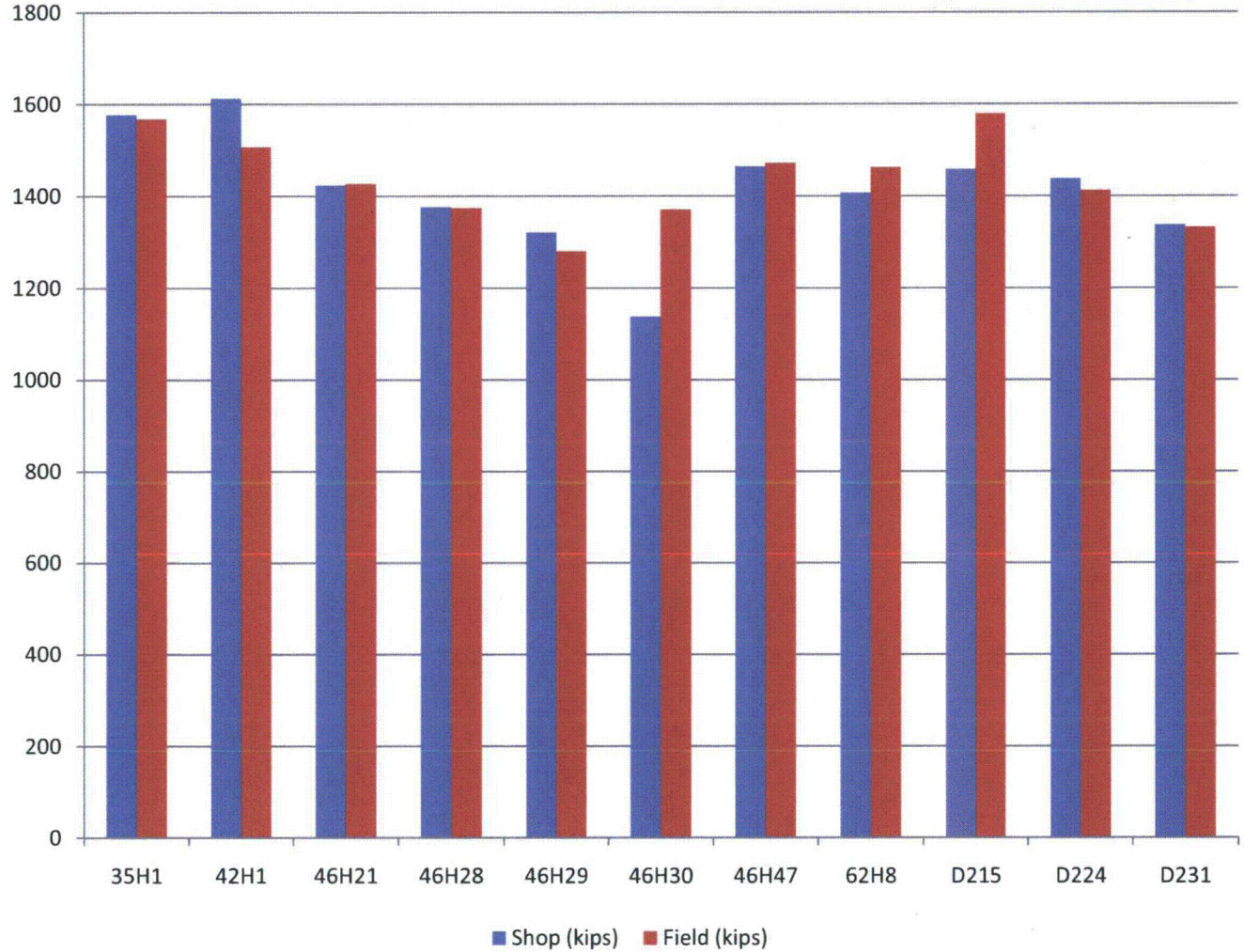
Lift-off forces measured at the Shop end (blue) and at the Field end (red)

Tendon Lift-off Force Asymmetry (Survey 6)



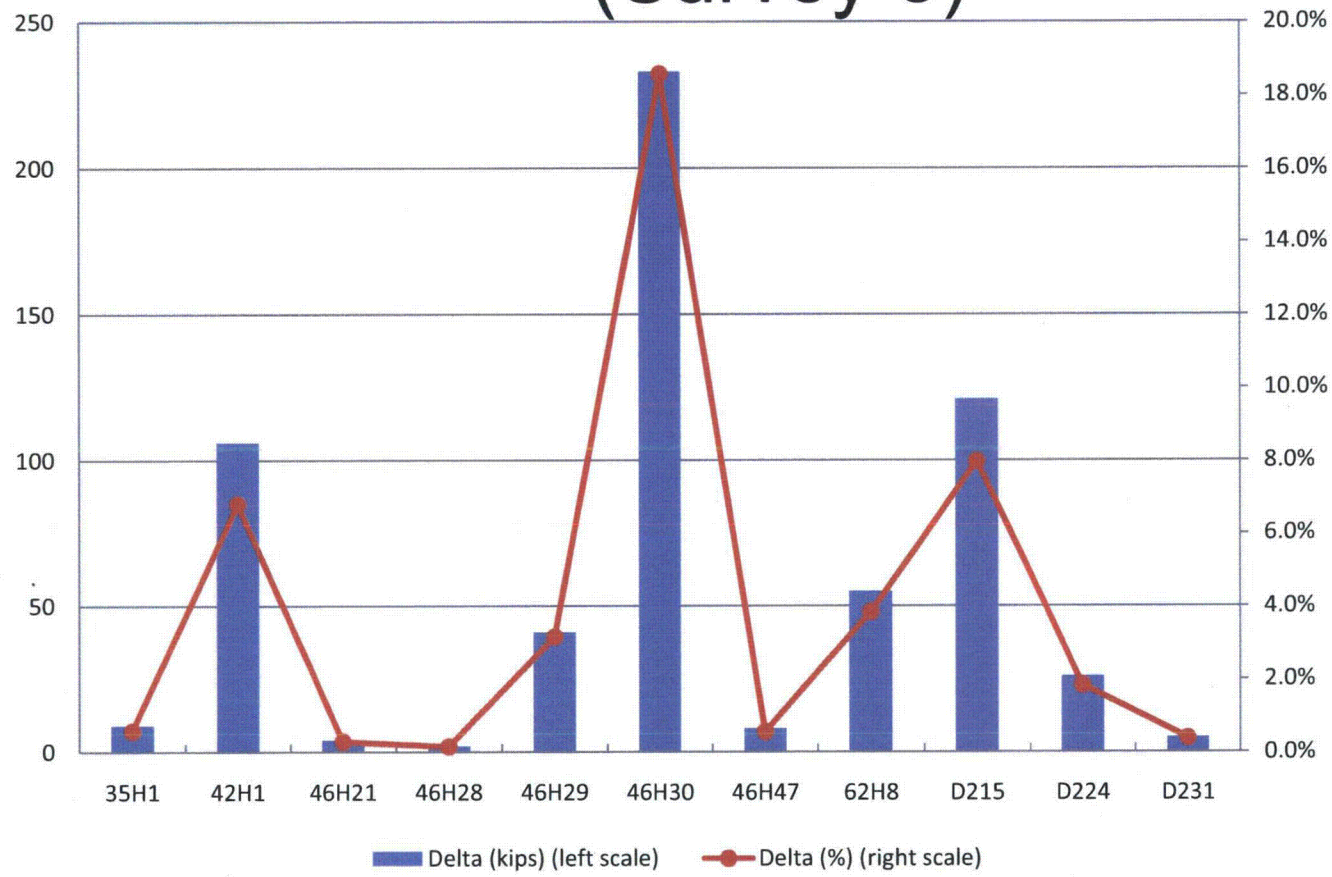
Delta = Difference between lift-off forces at Shop and Field ends

Tendon Lift-off Forces (Survey 5)



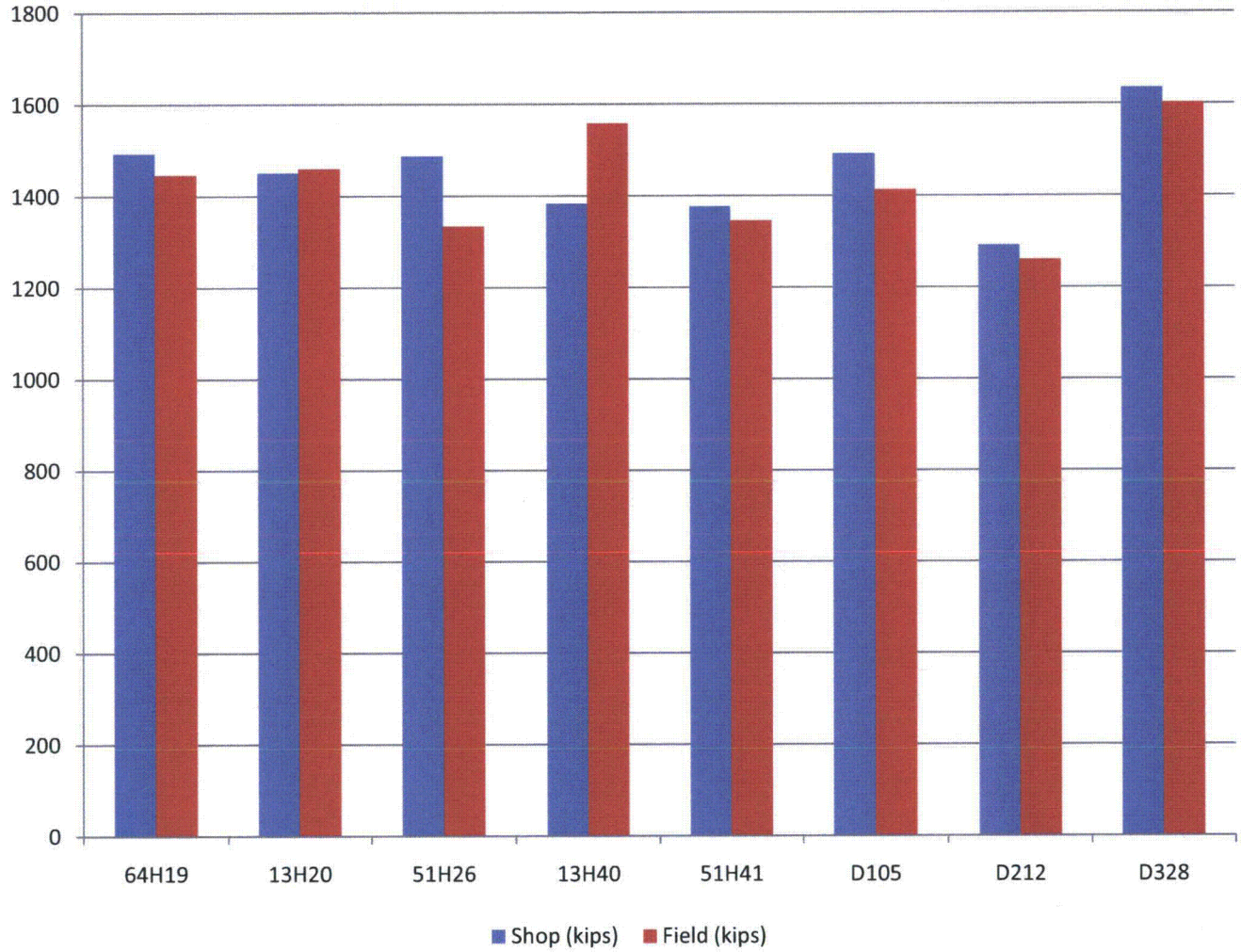
Lift-off forces measured at the Shop end (blue) and at the Field end (red)

Tendon Lift-off Force Asymmetry (Survey 5)



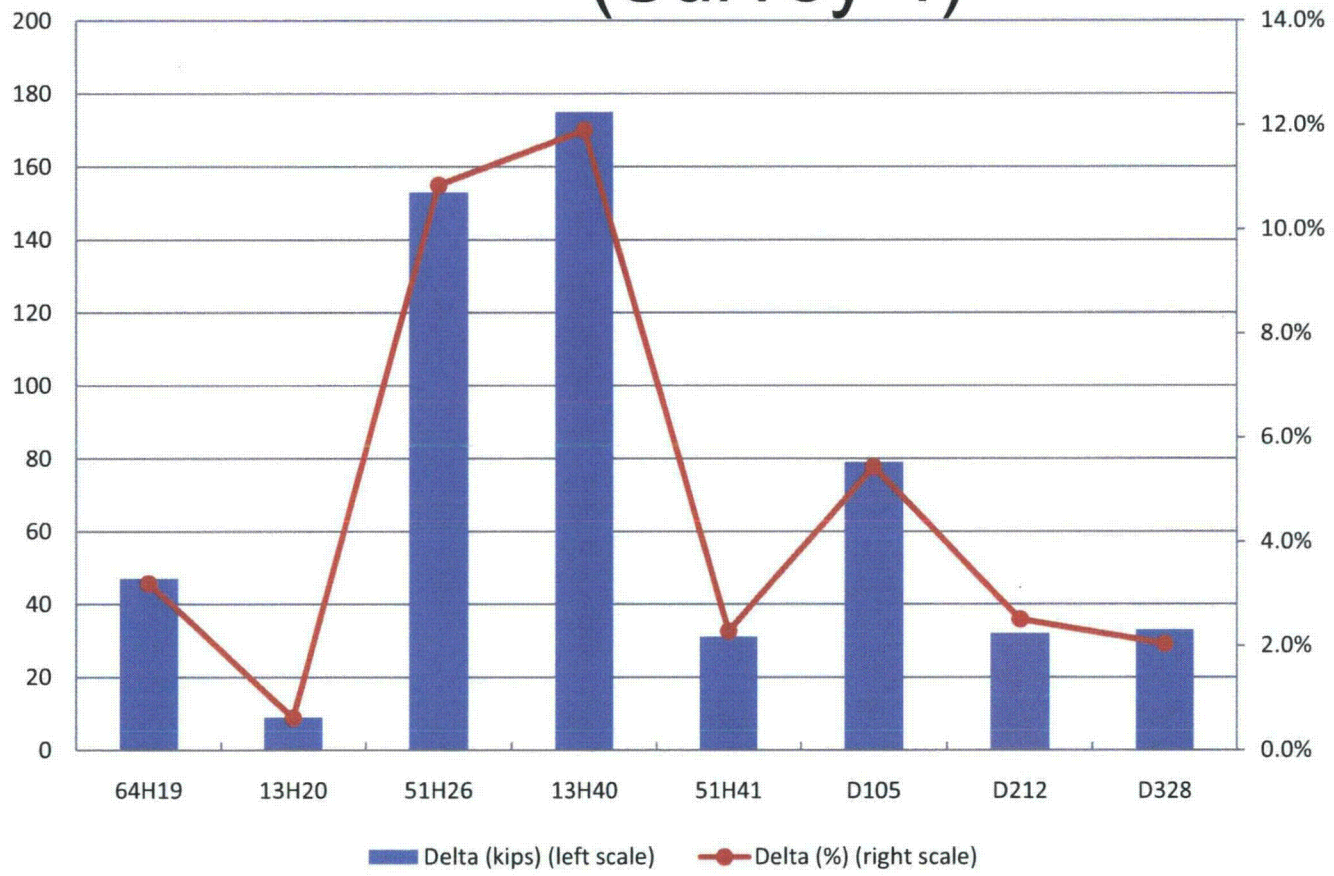
Delta = Difference between lift-off forces at Shop and Field ends

Tendon Lift-off Forces (Survey 4)



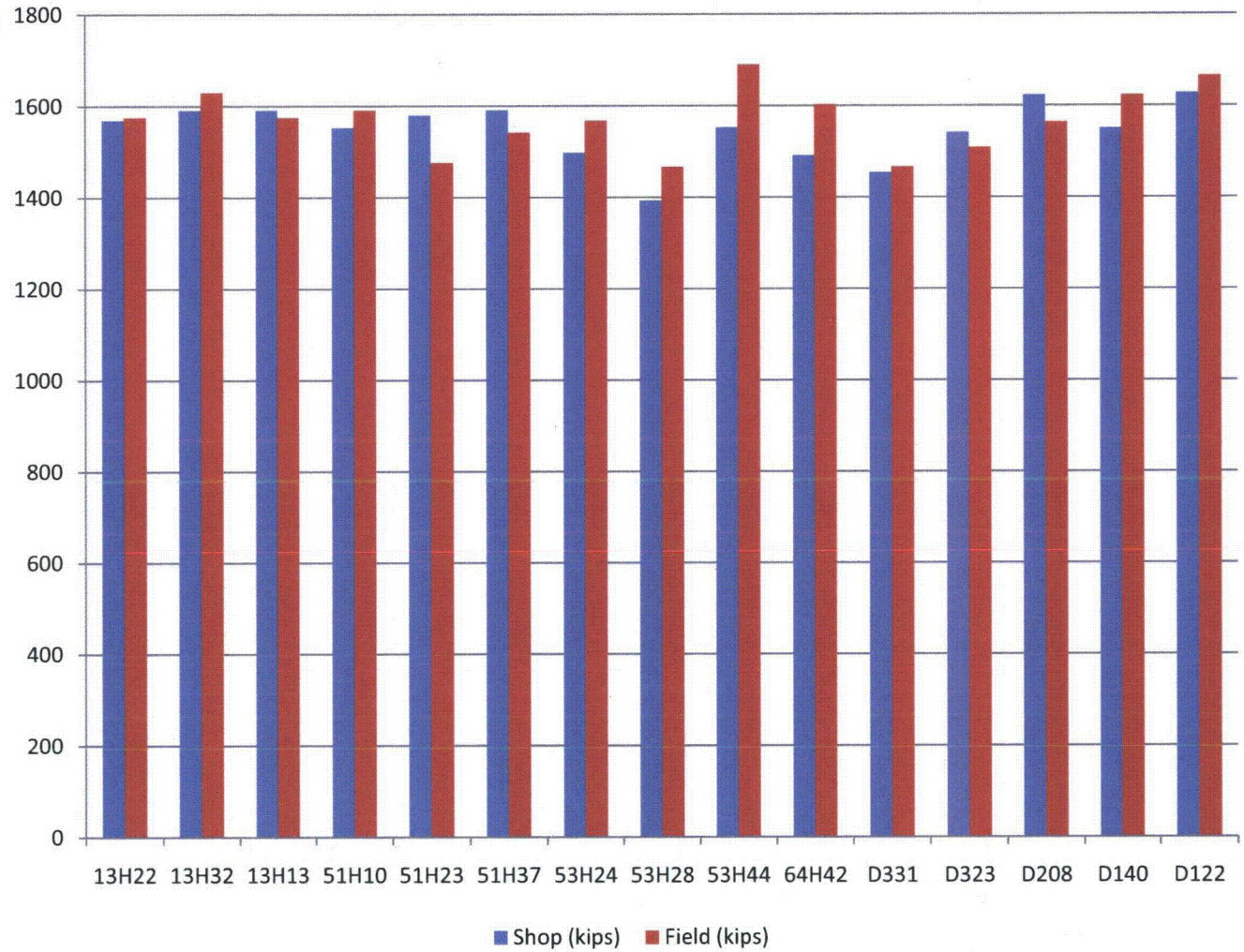
Lift-off forces measured at the Shop end (blue) and at the Field end (red)

Tendon Lift-off Force Asymmetry (Survey 4)



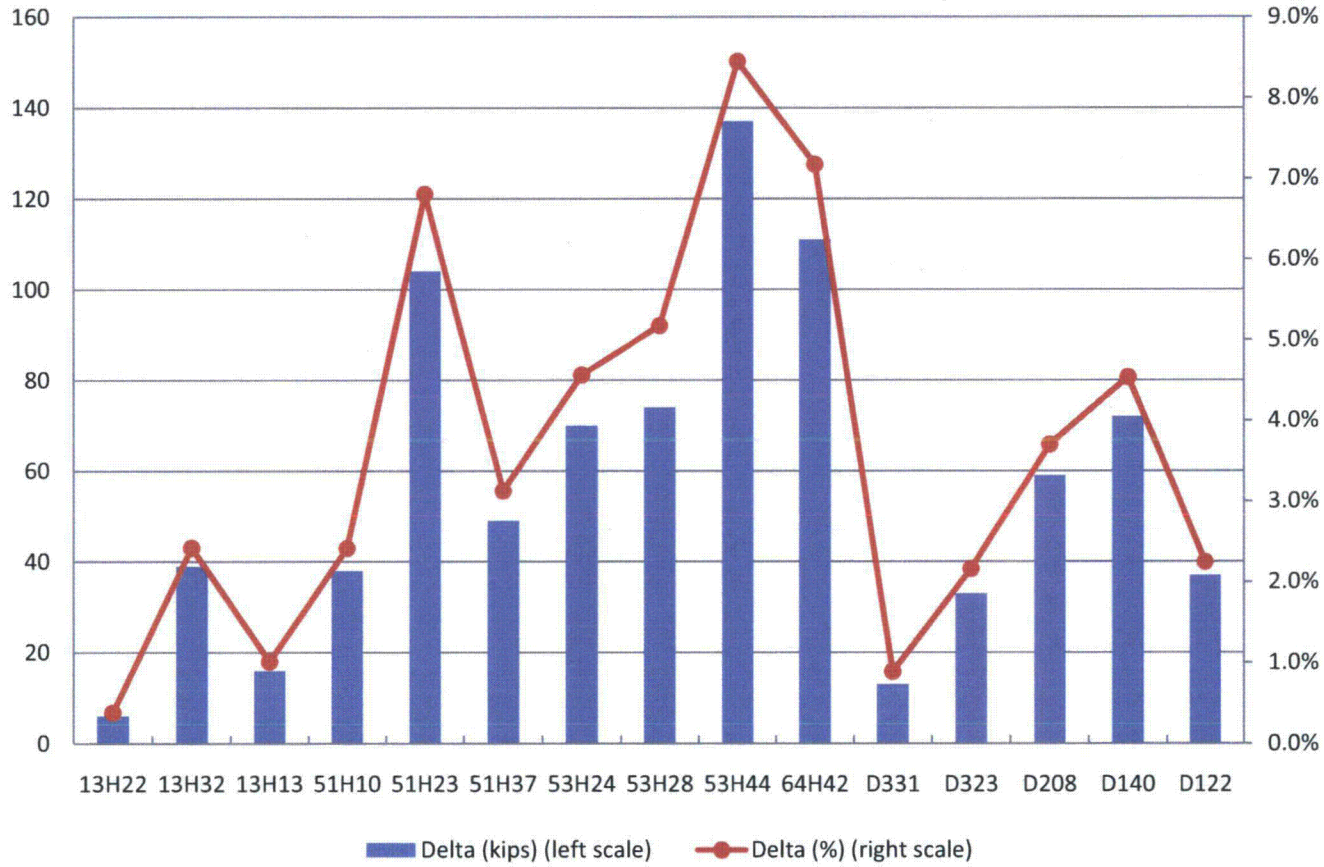
Delta = Difference between lift-off forces at Shop and Field ends

Tendon Lift-off Forces (Survey 2)



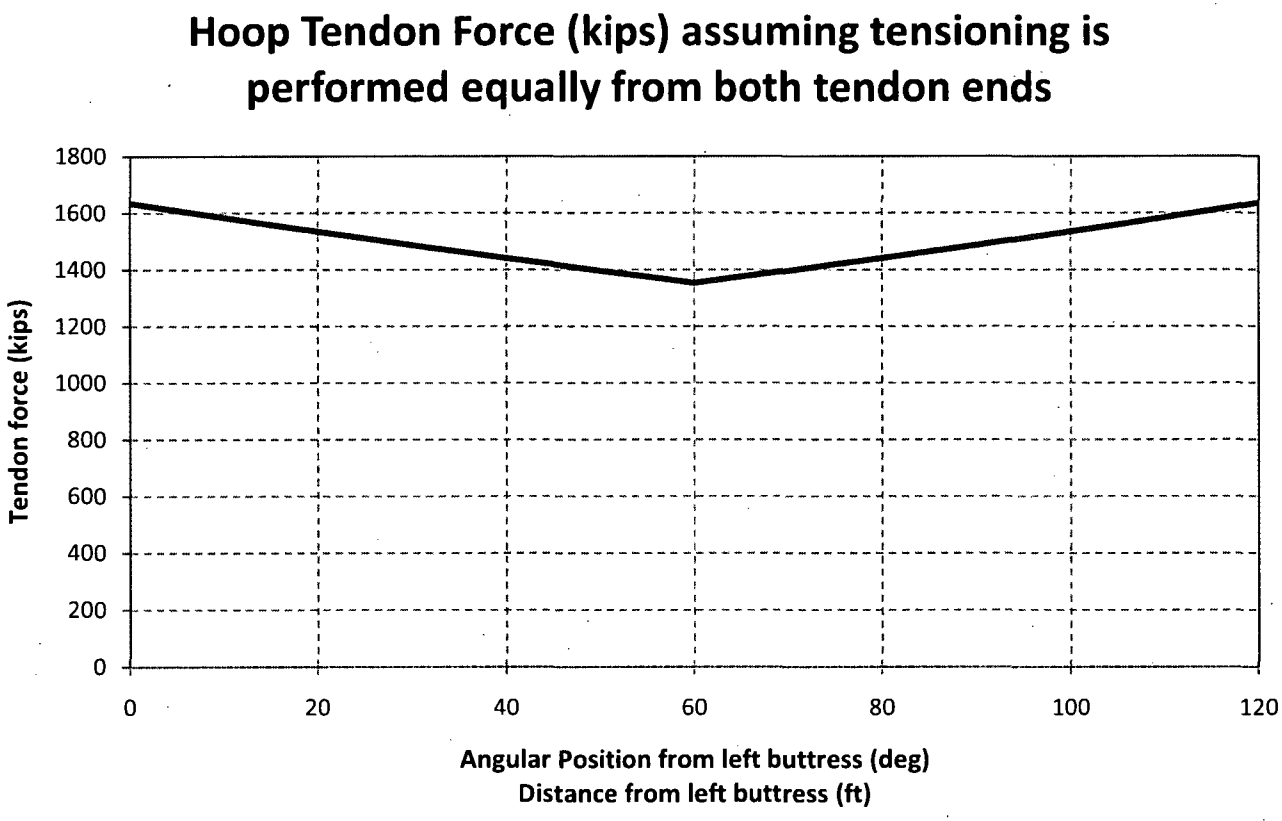
Lift-off forces measured at the Shop end (blue) and at the Field end (red)

Tendon Lift-off Force Asymmetry (Survey 2)



Delta = Difference between lift-off forces at Shop and Field ends

Force Along Hoop Tendon



GREASE REMOVAL AND REPLACEMENT

TABLE 4

Crystal River
Unit 3

TENDON NUMBER	END DESIGNATION	GREASE REMOVED (gals.)	GREASE REPLACED (gals.)	NET DIFFERENCE :
12V1	Field + Shop	29.9	34.0	4.1 Gallons
34V4	Filed + Shop	12.9	17.9	5.0
56V2	Field + Shop	89.9	92.9	3.0
D105	Field + Shop	11.0	34.0	23.0
D212	Field + Shop	4.0	16.0	12.0
D328	Field + Shop	8.0	16.0	8.0
13H20	Field + Shop	2.0	21.1	19.1
13H40	Field + Shop	4.0	24.5	20.5
H26	Field + Shop	2.0	21.1	19.1
51H27 *	Field + Shop	1.0	5.0	4.0
51H41	Field + Shop	2.0	25.6	23.6
64H19	Field + Shop	2.0	16.8	14.8

* Unsealed in error.

TP420Ads

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

TABLE 5: SUMMARY OF GREASE REMOVAL AND REPLACEMENT

TENDON	GREASE REMOVED (GALLONS)	GREASE REPLACED (GALLONS)	NET DIFFERENCE *
34V6	30	71.5	41.5
56V15	96	116	20
61V14	64	82	18
D215	19	51	32
D224	38	51	13
D231	40	51	11
35H1	02	22	20
42H1	02	22	20
46H21	04	19	15
46H28	3.5	19	15.5
46H29	07	22	15
46H30	04	17	13
46H47	04	24	20
62H8	02	22	20

* Acceptance Criteria: Net difference shall not exceed 4 gallons. Please refer to the applicable NCR where it is noted that final evaluation and disposition of acceptance criteria is deferred to Gilbert Commonwealth (to be addressed in their engineering report).

PSC Precision Surveillance Corporation

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

Florida Power CORPORATION

TABLE XII: SUMMARY OF DATA SHEETS SQ 12.1
GREASE LOSS Vs GREASE REPLACEMENT

TENDON	GREASE REMOVED			GREASE REPLACED			DIFF.	NET	%
	SHOP	FIELD	TOTAL (GAL.)	SHOP	FIELD	TOTAL (GAL.)	(GAL.)	VOLUME	
12V1	2.00	36.75	38.75	40.75	0.75	41.50	+2.75	143.46	1.91
23V2	0.75	9.75	10.50	11.50	0.00	11.50	+1.00	142.52	0.70
61V21	0.75	88.50	89.25	20.25	72.50	92.75	+3.50	144.03	2.43
43V04	0.50	0.00	0.50	7.50	0.00	7.50	+7.00	N/A	N/A
D113	4.50	4.00	8.50	6.20	3.50	9.70	+1.20	115.11	1.04
D115	4.50	4.50	9.00	7.00	4.00	11.00	+2.00	117.17	1.71
D212	6.50	4.00	10.50	20.00	4.50	24.50	+14.00	115.55	12.12♦
D304	12.00	7.25	19.25	38.20	0.00	38.20	+18.95	103.68	18.30♦
D311	24.00	4.00	28.00	46.50	3.50	50.00	+22.00	115.12	19.10♦

♦ SEE NCR No. FN604-018, 019, 020

PSC Precision Surveillance Corporation

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

Florida Power CORPORATION

TABLE XII: SUMMARY OF DATA SHEETS SQ 12.1
GREASE LOSS Vs GREASE REPLACEMENT

TENDON	GREASE REMOVED			GREASE REPLACED			DIFF.	NET	%
	SHOP	FIELD	TOTAL (GAL.)	SHOP	FIELD	TOTAL (GAL.)	(GAL.)	VOLUME	
42H18	3.75	2.00	5.75	5.25	5.25	10.50	+4.75	121.40	3.91
42H29	3.50	3.25	6.75	5.25	6.25	11.50	+4.75	121.48	3.91
42H30	3.00	3.00	6.00	7.00	7.00	14.00	+8.00	121.59	6.58 ♦
42H31	2.50	3.00	5.50	5.25	5.75	11.00	+5.50	121.84	4.51
42H32	3.75	2.50	6.25	6.25	4.75	11.00	+4.75	121.36	3.90
42H33	3.00	3.00	6.00	6.25	4.75	11.00	+5.00	120.38	4.15
42H34	3.00	3.00	6.00	6.50	6.25	12.75	+6.75	121.99	5.53 ♦
42H35	3.25	4.50	7.75	4.90	5.30	10.20	+2.45	121.27	2.02
42H36	4.00	4.00	8.00	4.00	5.75	9.75	+1.75	121.62	1.44
42H37	4.50	4.50	9.00	6.20	5.00	11.20	+2.20	120.44	1.83
42H44	4.75	3.50	8.25	5.30	4.90	10.20	+1.95	121.08	1.61
51H25 *	3.50	3.50	7.00	8.00	4.50	12.50	+5.50	120.73	4.56
51H25 **	3.00	4.00	7.00	4.50	4.00	8.50	+1.50	120.73	1.24
51H26	4.50	3.75	8.25	5.25	4.50	9.75	+1.50	121.43	1.24
51H27	3.50	3.25	6.75	5.30	5.70	11.00	+4.25	121.60	3.50
51H28 *	3.50	4.00	7.50	4.50	4.75	9.25	+1.75	120.46	1.45
51H28 **	4.00	4.00	8.00	4.50	4.00	8.50	+0.50	120.46	0.42
53H2	4.50	4.00	8.50	5.75	6.25	12.00	+3.50	121.32	2.88
53H46	3.25	3.50	6.75	6.00	5.25	11.25	+5.25	121.60	4.32
62H41	4.00	4.00	8.00	7.10	5.30	12.40	+4.40	121.37	3.63
62H46	3.50	4.50	8.00	6.25	6.50	12.75	+4.75	121.11	3.92
51H41	N/A	3.50	3.50	N/A	4.00	4.00	+0.50	N/A	N/A

* GREASED 11/18/97
** GREASED 12/18/97

♦ SEE NCR No. FN604-021

PSC Precision Surveillance Corporation

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

Florida Power
A Progress Energy Company

TABLE XI: SUMMARY OF DATA SHEETS SQ 12.1 GREASE LOSS Vs GREASE REPLACEMENT

TENDON	GREASE REMOVED			GREASE REPLACED			DIFF.	NET	%
	SHOP	FIELD	TOTAL (GAL.)	SHOP	FIELD	TOTAL (GAL.)	(GAL.)	VOLUME	
12V01	2.25	105.75	108.00	0.00	115.00	115.00	7.00	139.43	+5.02
12V02	3.00	0.00	3.00	3.50	0.00	3.50	0.50	139.78	+0.36
23V02	2.75	0.00	2.75	4.75	0.00	4.75	2.00	139.85	+1.43
45V14	7.00	102.50	109.50	0.00	118.50	118.50	9.00	140.34	+6.41
61V08	7.00	102.75	109.75	0.00	112.50	112.50	2.75	139.78	+1.97
46H21	3.25	3.25	6.50	3.50	4.00	7.50	1.00	119.96	+0.83
46H29	1.75	1.75	3.50	3.50	2.50	6.00	2.50	119.73	+2.09
46H30	1.75	1.50	3.25	4.50	2.25	6.75	3.50	119.73	+2.92
46H31	1.75	1.75	3.50	3.25	4.50	7.25	3.75	119.73	+3.13
46H32	1.75	1.75	3.50	2.25	3.50	5.75	2.25	119.73	+1.88
46H33	1.75	1.75	3.50	4.50	3.50	8.00	4.50	119.73	+3.76
46H34	1.75	1.75	3.50	2.50	3.50	6.00	2.50	119.73	+2.09
46H35	1.75	1.75	3.50	3.50	2.50	6.00	2.50	119.09	+2.10
46H36	2.25	1.00	3.25	2.50	4.50	7.00	3.75	119.25	+3.14
46H37	1.75	1.00	2.75	3.50	4.00	7.50	4.75	119.93	+3.96
46H38	1.50	1.50	3.00	2.50	4.00	6.50	3.50	119.73	+2.92
46H39	1.75	3.50	5.25	3.00	3.50	6.50	1.25	119.73	+1.04
56H16	2.50	2.00	4.50	3.00	3.50	6.50	2.00	119.53	+1.67
62H02	2.25	2.50	4.75	4.50	5.25	9.75	5.00	119.33	+4.19
62H09	3.00	2.00	5.00	3.50	5.25	8.75	3.75	119.73	+3.13
62H13	2.50	1.50	4.00	4.75	4.50	9.25	5.25	120.59	+4.53
D126	14.50	25.75	40.25	0.00	42.75	42.75	2.50	115.97	+2.16
D212	24.75	22.00	46.75	0.00	62.25	62.25	15.50	113.86	+13.73 *
D339	40.00	15.00	55.00	73.75	0.00	73.75	18.75	100.18	+18.72 **

* ADDRESSED IN FN 750-007

** ADDRESSED IN FN 750-006

10.2 TENDON CAP RESEALING AND GREASING

10.2.1 After completion of all inspections, the anchorage components were hand coated with cold grease to ensure complete coverage. The caps were reinstalled with new gaskets and the results of the grease cap replacement were recorded on Data Sheet SQ 12.0 and are summarized in Tables 50 thru 55.

10.2.2 Upon acceptable cap replacement, the necessary amount of sheathing filler (grease) was added. All of the inspected tendons were refilled within the acceptable limits as stated in the PSC Procedure SQ12.1. The results of the grease replacement were recorded on Data Sheet SQ 12.1 and are summarized in Tables 56 thru 60.

10.2.2.1 The absolute difference between the amount of grease removed/lost and the amount of grease replaced in the subject tendon shall not exceed 10% of the net duct volume per PSC Procedure SQ 12.1. No tendon accepted above 10% of the net duct volume more than was lost, and all refills were acceptable.

TABLE 50: VERTICALS – SQ12.0 – GREASE CAP REPLACEMENT

TENDON	END	BEARING PLATE SURFACE CLEAN AND ACCEPTABLE	ANCHORAGE ASSEMBLY COATED W/ GREASE	CAP FLANGE AND GASKET SEALING SURFACE IS CLEAN AND DRY	NEW GASKET IS BEING USED FOR FINAL INSTALLATION OF GREASE CAP	ANCHORAGE NUTS EVENLY TIGHTENED AND GASKET COMPRESSED	TOUCH-UP OF HARDWARE, CAP OR BEARING PLATE REQUIRED	ACCEPTABLE ?
12V01	TOP	YES	YES	YES	YES	YES	NO	YES
	BOT	YES	YES	YES	YES	YES	NO	YES
45V20	TOP	YES	YES	YES	YES	YES	NO	YES
	BOT	YES	YES	YES	YES	YES	NO	YES
61V08	TOP	YES	YES	YES	YES	YES	NO	YES
	BOT	YES	YES	YES	YES	YES	NO	YES
61V17	TOP	YES	YES	YES	YES	YES	NO	YES
	BOT	YES	YES	YES	YES	YES	NO	YES

TABLE 51: DOMES – SQ12.0 – GREASE CAP REPLACEMENT

TENDON	END	BEARING PLATE SURFACE CLEAN AND ACCEPTABLE	ANCHORAGE ASSEMBLY COATED W/ GREASE	CAP FLANGE AND GASKET SEALING SURFACE IS CLEAN AND DRY	NEW GASKET IS BEING USED FOR FINAL INSTALLATION OF GREASE CAP	ANCHORAGE NUTS EVENLY TIGHTENED AND GASKET COMPRESSED	TOUCH-UP OF HARDWARE, CAP OR BEARING PLATE REQUIRED	ACCEPTABLE ?
D129	BT 3	YES	YES	YES	YES	YES	NO	YES
	BT 5	YES	YES	YES	YES	YES	NO	YES
D212	BT 1	YES	YES	YES	YES	YES	NO	YES
	BT 3	YES	YES	YES	YES	YES	NO	YES
D238	BT 4	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES

TABLE 52: HOOPS – SQ12.0 – GREASE CAP REPLACEMENT

TENDON	END	BEARING PLATE SURFACE CLEAN AND ACCEPTABLE	ANCHORAGE ASSEMBLY COATED W/ GREASE	CAP FLANGE AND GASKET SEALING SURFACE IS CLEAN AND DRY	NEW GASKET IS BEING USED FOR FINAL INSTALLATION OF GREASE CAP	ANCHORAGE NUTS EVENLY TIGHTENED AND GASKET COMPRESSED	TOUCH-UP OF HARDWARE, CAP OR BEARING PLATE REQUIRED	ACCEPTABLE ?
13H36	BT 1	YES	YES	YES	YES	YES	NO	YES
	BT 3	YES	YES	YES	YES	YES	NO	YES
42H46	BT 2	YES	YES	YES	YES	YES	NO	YES
	BT 4	YES	YES	YES	YES	YES	NO	YES
46H21	BT 4	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES
51H34	BT 1	YES	YES	YES	YES	YES	NO	YES
	BT 5	YES	YES	YES	YES	YES	NO	YES
62H30	BT 2	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES

TABLE 53: 13H36 ADJACENTS – SQ12.0 – GREASE CAP REPLACEMENT

TENDON	END	BEARING PLATE SURFACE CLEAN AND ACCEPTABLE	ANCHORAGE ASSEMBLY COATED W/ GREASE	CAP FLANGE AND GASKET SEALING SURFACE IS CLEAN AND DRY	NEW GASKET IS BEING USED FOR FINAL INSTALLATION OF GREASE CAP	ANCHORAGE NUTS EVENLY TIGHTENED AND GASKET COMPRESSED	TOUCH-UP OF HARDWARE, CAP OR BEARING PLATE REQUIRED	ACCEPTABLE ?
13H33	BT 1	YES	YES	YES	YES	YES	NO	YES
	BT 3	YES	YES	YES	YES	YES	NO	YES
13H34	BT 1	YES	YES	YES	YES	YES	NO	YES
	BT 3	YES	YES	YES	YES	YES	NO	YES
13H35	BT 1	YES	YES	YES	YES	YES	NO	YES
	BT 3	YES	YES	YES	YES	YES	NO	YES
13H37	BT 1	YES	YES	YES	YES	YES	NO	YES
	BT 3	YES	YES	YES	YES	YES	NO	YES
13H38	BT 1	YES	YES	YES	YES	YES	NO	YES
	BT 3	YES	YES	YES	YES	YES	NO	YES

TABLE 54: 46H21 ADJACENTS – SQ12.0 – GREASE CAP REPLACEMENT

TENDON	END	BEARING PLATE SURFACE CLEAN AND ACCEPTABLE	ANCHORAGE ASSEMBLY COATED W/ GREASE	CAP FLANGE AND GASKET SEALING SURFACE IS CLEAN AND DRY	NEW GASKET IS BEING USED FOR FINAL INSTALLATION OF GREASE CAP	ANCHORAGE NUTS EVENLY TIGHTENED AND GASKET COMPRESSED	TOUCH-UP OF HARDWARE, CAP OR BEARING PLATE REQUIRED	ACCEPTABLE ?
46H19	BT 4	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES
46H20	BT 4	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES
46H22	BT 4	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES
46H23	BT 4	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES
46H24	BT 4	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES

TABLE 55: 62H30 ADJACENTS – SQ12.0 – GREASE CAP REPLACEMENT

TENDON	END	BEARING PLATE SURFACE CLEAN AND ACCEPTABLE	ANCHORAGE ASSEMBLY COATED W/ GREASE	CAP FLANGE AND GASKET SEALING SURFACE IS CLEAN AND DRY	NEW GASKET IS BEING USED FOR FINAL INSTALLATION OF GREASE CAP	ANCHORAGE NUTS EVENLY TIGHTENED AND GASKET COMPRESSED	TOUCH-UP OF HARDWARE, CAP OR BEARING PLATE REQUIRED	ACCEPTABLE ?
62H29	BT 2	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES
62H31	BT 2	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES
62H32	BT 2	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES
62H33	BT 2	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES
62H34	BT 2	YES	YES	YES	YES	YES	NO	YES
	BT 6	YES	YES	YES	YES	YES	NO	YES

TABLE 56: VERTICALS - SQ 12.1 - GREASE LOSS vs GREASE REPLACEMENT

TENDON	END	GREASE REMOVED (GALLONS)		GREASE REPLACED (GALLONS)		DIFF. (GAL.)	DUCT VOLUME (GAL.)	% DIFF.	ACCEPT
		END	TOTAL	END	TOTAL				
12V01	TOP	2.5	78.5	0	82.19	3.69	143.97	2.56	YES
	BOT	76		82.19					
45V20	TOP	3	88	0	91.04	3.04	144.47	2.10	YES
	BOT	85		91.04					
61V08	TOP	2.5	55	7.08	56.64	1.64	144.12	1.13	YES
	BOT	52.5		49.56					
61V17	TOP	2.5	98.5	1	107.2	8.7	144.74	6.01	YES
	BOT	96		106.2					

Depending on the amount of grease loss during the inspection, grease can be replaced by pouring it back into the grease cap.

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TABLE 57: HOOPS – SQ12.1 – GREASE LOSS vs. GREASE REPLACEMENT

TENDON	END	GREASE REMOVED (GALLONS)		GREASE REPLACED (GALLONS)		DIFF. (GAL.)	DUCT VOLUME (GAL.)	% DIFF.	ACCEPT
		END	TOTAL	END	TOTAL				
13H36	BT 1	2.5	5	3.54	7.08	2.08	121.67	1.70	YES
	BT 3	2.5		3.54					
42H46	BT 2	2.5	5.5	3.09	5.74	0.24	122.57	0.19	YES
	BT 4	3.0		2.65					
46H21	BT 4	2.5	5	3.54	7.08	2.08	122.06	1.70	YES
	BT 6	2.5		3.54					
51H34	BT 1	2.5	5	2.65	6.19	1.19	120.88	0.98	YES
	BT 5	2.5		3.54					
62H30	BT 2	2.5	5.	3.54	7.08	2.08	121.75	1.70	YES
	BT 6	2.5		3.54					

TABLE 58: DOMES – SQ12.1 – GREASE LOSS vs. GREASE REPLACEMENT

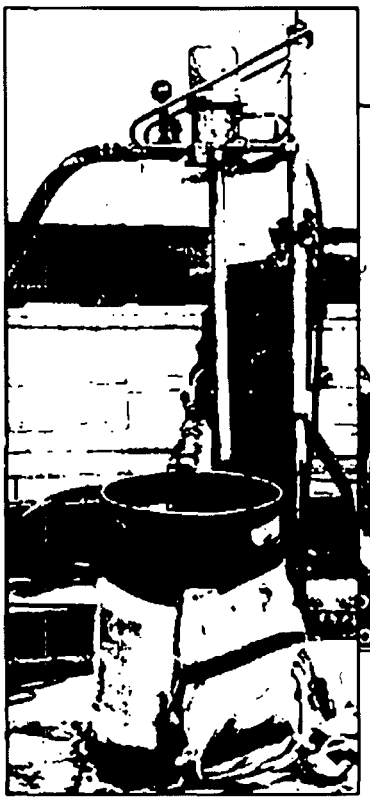
TENDON	END	GREASE REMOVED (GALLONS)		GREASE REPLACED (GALLONS)		DIFF. (GAL.)	DUCT VOLUME (GAL.)	% DIFF.	ACCEPT
		END	TOTAL	END	TOTAL				
D129	BT 3	13.5	36.5	0	39.71	3.21	116.41	2.75	YES
	BT 5	23		39.71					
D212	BT 1	2.5	20	0	23.78	3.78	115.99	3.25	YES
	BT 3	17.5		23.78					
D238	BT 4	62.5	69.5	73.34	73.34	3.84	102.59	3.74	YES
	BT 6	7		0					

TABLE 59: ADJACENTS - SQ124 - GREASE LOSS vs GREASE REPLACEMENT

TENDON	END	GREASE REMOVED (GALLONS)		GREASE REPLACED (GALLONS)		DIFF. (GAL.)	DUCT VOLUME (GAL.)	% DIFF.	ACCEPT
		END	TOTAL	END	TOTAL				
13H33	BT 1	2	4	2.65	5.3	1.3	121.57	1.06	YES
	BT 3	2		2.65					
13H34	BT 1	2	4	2.65	5.3	1.3	121.25	1.07	YES
	BT 3	2		2.65					
13H35	BT 1	2	4	2.65	5.3	1.3	121.77	1.06	YES
	BT 3	2		2.65					
13H37	BT 1	2	4	2.65	5.3	1.3	122.18	1.06	YES
	BT 3	2		2.65					
13H38	BT 1	2	4	2.65	5.3	1.3	121.53	1.06	YES
	BT 3	2		2.65					
46H19	BT 4	2	4	2.21	4.86	0.86	121.25	0.70	YES
	BT 6	2		2.65					
46H20	BT 4	2	4	2.65	5.3	1.3	121.37	1.07	YES
	BT 6	2		2.65					
46H22	BT 4	2	4	2.65	5.74	1.74	122.43	1.42	YES
	BT	2		3.09					
46H23	BT 4	2	4	2.65	5.3	1.3	122.63	1.06	YES
	BT 6	2		2.65					
46H24	BT 4	2	4	2.65	5.74	1.74	121.57	1.43	YES
	BT 6	2		3.09					

TABLE 60 ADJACENTS – SQ121 – GREASE LOSS vs GREASE REPLACEMENT

TENDON	END	GREASE REMOVED (GALLONS)		GREASE REPLACED (GALLONS)		DIFF. (GAL.)	DUCT VOLUME (GAL.)	% DIFF.	ACCEPT
		END	TOTAL	END	TOTAL				
62H29	BT 2	2	4	2.65	5.3	1.3	121.93	1.06	YES
	BT 6	2		2.65					
62H31	BT 2	2	2	2.65	2.65	0.65	122.13	0.53	YES
	BT 6	0		0					
62H32	BT 2	2	2	2.65	2.65	0.65	121.45	0.53	YES
	BT 6	0		0					
62H33	BT 2	2	4.5	2.65	5.3	0.80	122.07	0.65	YES
	BT 6	2.5		2.65					
62H34	BT 2	2	4	2.65	5.3	1.3	121.47	1.07	YES
	BT 6	2		2.65					



If a large amount of grease is lost during the inspection, then grease must be replaced by pressure pumping it back into the tendon duct.

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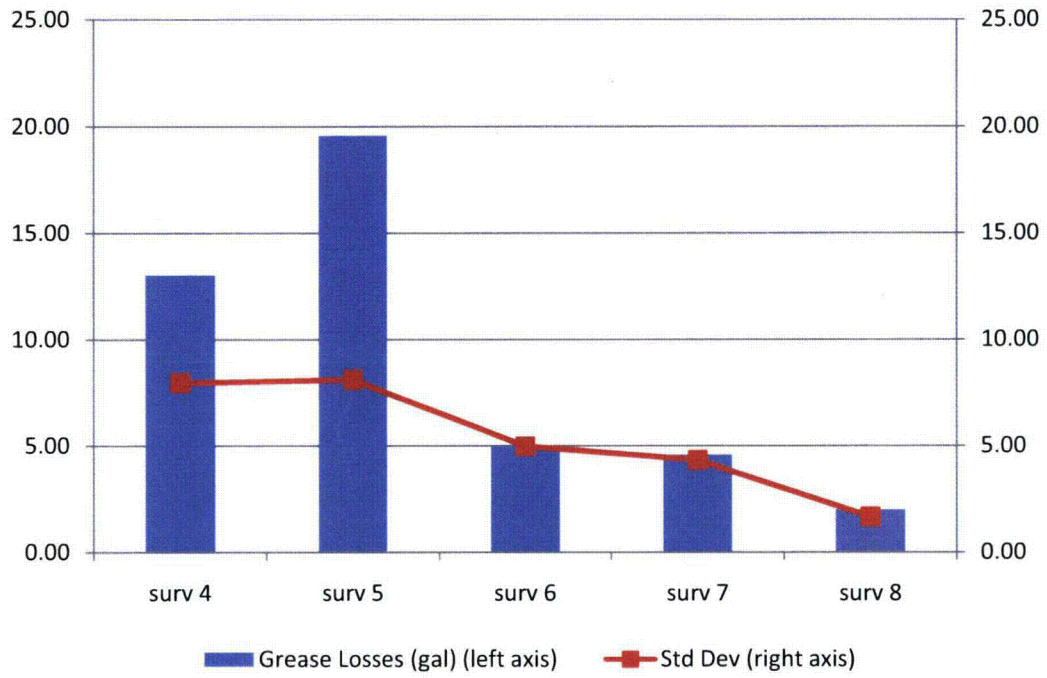
Grease losses from tendon sleeves



Average and standard deviation of grease losses for each surveillance

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Weight of tendons

A. Horizontal tendon

163 wires x pi/4 (7/25.4)^2 in2 = 9.72 in2

9.72 in2 x 130ft x 12 in/ft x 0.283 lb/in3 = 4,291 lbs

B. Vertical tendon

9.72 in2 x 192 ft x 12 in/ft x 0.283 lb/in3 = 6,337 lbs

C. Conclusion

Hoop tendon = 4,300 lbs

Vertical tendon = 6,400 lbs

From: Brian Giometti
To: Portmann, Rick; Christopher Cox
Subject: RE: CR3 Root Cause Team Questions
Date: Tuesday, December 15, 2009 8:24:18 AM

Rick-

I would estimate the maximum force the vertical coiler can pull around 16,000 lb. The horizontals are less.

This is based upon our testing at the shop as well as the fact that the 1st vertical tendon was not able to be broken free from the grease with the coiler. When the crane was used, the operator's computer read 17,000 lb.

Let me know if you need any further clarification.

Brian

From: Portmann, Rick [mailto:Rick.Portmann@pgnmail.com]
Sent: Tuesday, December 15, 2009 6:24 AM
To: Christopher Cox; Brian Giometti
Subject: CR3 Root Cause Team Questions

Christopher / Brian – There were a few more questions that came up last night from the root cause team. I'm not sure where this one question comes up in the scheme of things, but your assistance is appreciated. See below. Thanks, Rick Outage Cell: 352-464-7846

What is the maximum force of the tendon coiler used at CR3?

FW: RCA question about PSC coiler Monday, January 4, 2010 8:12 AM

From: "Holliday, John" <John.Holliday@pgnmail.com>

To: "'patrickberbon@yahoo.com'" <patrickberbon@yahoo.com>

From: Paul Smith [mailto:PSmith@psctendon.com]
Sent: Monday, January 04, 2010 8:26 AM
To: Holliday, John
Subject: RE: RCA question about PSC coiler

John,

Please find below a response to the questions:

1. Hoop tendon length is approximately 155 feet so weight should be approximately 4500lbs.
2. Vertical weight is about right.
3. Max pulling force is 16,000lb when you start pulling but quickly drops.
4. Coiler is designed and built by PSC for PSC and has no operation manual.
5. Estimated coiling rate is more like 30 ft per minute during continuous operation. Coiler stops to allow banding each revolution.

Paul

From: Holliday, John [mailto:John.Holliday@pgnmail.com]
Sent: Sunday, January 03, 2010 9:25 AM
To: Paul Smith
Subject: FW: RCA question about PSC coiler

Paul,
Could you please review and provide responses to the questions below that I received from the Root Cause Team. Thanks.

Regards,
John Holliday

From: Patrick Berbon [mailto:patrickberbon@yahoo.com]

Cc: Portmann, Rick; Williams, Charles R.; Dave Brevig
Subject: RCA question about PSC coiler

Hi John,

We have some more questions on the PSC tendon coiler used at CR3.

- Can you confirm the approximate weight of a hoop tendon is: 9.72 in2 x 130 ft x 0.28 lb/in3 = 4,250 lbs?

- Can you confirm the approximate weight of a vertical tendon is: 9.72 in2 x 192 ft x 0.28 lb/in3 = 6,270 lbs?

- We have an email from Brian Giometti at PSC indicating the maximum pulling force for the coiler is around 16,000 lbs. Can you confirm that?

- Do you have an operation's manual for the coiler? Can we get a copy?

- What is an estimate of the coiling rate? Does 1ft/min make sense?

I appreciate your time.

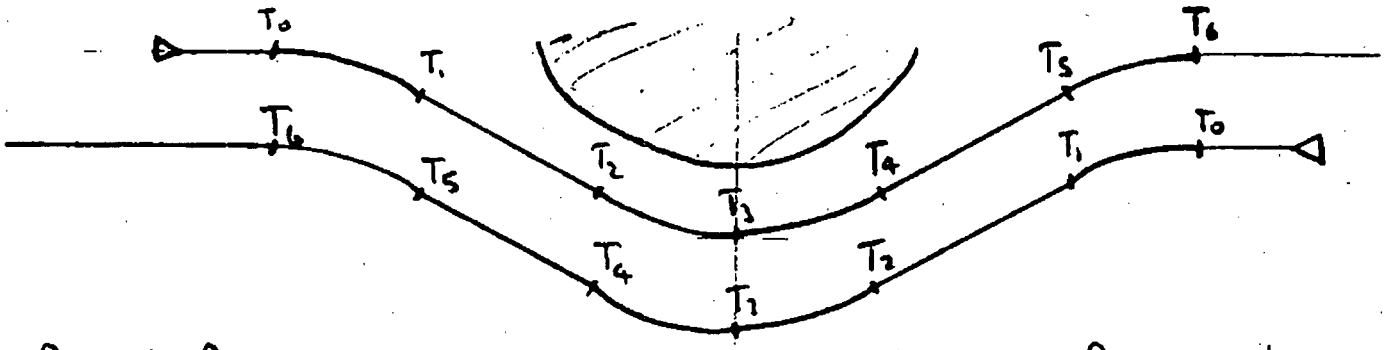
Patrick Berbon, PII Team

8th Surveillance (2007) Tendon Shim Information

8th Surv. Tendon	End #1	Lift-Off KIPS	Shim Height	Stack Make-Up	End #2	Lift-Off KIPS	Shim Height	Stack Make-Up	Lift-Off Ave.	Re-Tensioning Notes	End #1	Lift-Off KIPS	Shim Height	Stack Make-Up	End #2	Lift-Off KIPS	Shim Height	Stack Make-Up	Lift-Off Ave.
D129	Butt. 3	1289.16	6 1/4"	3,1,1,1,1/4	Butt. 5	1290.12	6"	3,3	1289.64										
D212	Butt. 1	1259.76	6 3/8"	3,3,3/8	Butt. 3	1295.87	6 1/2"	3,1,1,1,1/2	1277.81										
D238	Butt. 4	1527.21	6 3/8"	3,3,3/8	Butt. 6	1495.86	7"	3,3,1	1511.53	Re-Tensioned due to Wire Removal Detension.	Butt. 4	1613.8	7"	3, 0.4, 0.5, 3.1	Butt. 6	1519.47	7 1/4"	3, 3, 1, 1/4	1566.6
12V01	Top	1559.95	14 3/4"	3,3,3,3,1,1/2,1/2,1/2,1/4	Bot.	N/A	4"	3,1	N/A										
45V20	Top	1456.8	12"	3,3;3,3	Bot.	N/A	4"	3,1	N/A										
61V08	Top	1505.98	13"	3,3,3,3,1	Bot.	N/A	4"	3,1	N/A										
61V17	Top	1580.18	12"	3,3,3,3	Bot.	N/A	4"	3,1	N/A	Re-Tensioned due to Wire Removal Detension.	Top	1597.1	12 1/2"	3,3,3,3, 1/2	Bot.	N/A	4"	3,1	N/A
13H33	Butt. 1	1310.35	7"	3,1,3	Butt. 3	1302.57	6 3/4"	3,3,3/8, 3/8	1306.46										
13H34	Butt. 1	1350.83	7"	3,1,1,1,1	Butt. 3	1386.39	7"	3,1,1,1,1	1368.61	Re-Tensioned due to low-lift-off <95%	Butt. 1	1479	7 1/2"	3,1,1,1,1, 1/2	Butt. 3	1537.27	7 1/2"	3,1,1,1,1, 1/2	1508.1
13H35	Butt. 1	1249.64	6 9/16"	3,3,3/8,3/16	Butt. 3	1238.87	6 3/8"	3,3, 3/8	1244.25	Re-Tensioned due to low-lift-off <95%	Butt. 1	1411.5	7 1/4"	(Not listed)	Butt. 3	1423 1/4	7"	(Not listed)	1417.4
13H36	Butt. 1	1344.08	6 1/2"	3,1,1,1, 1/4, 1/4	Butt. 3	1426.63	7 1/4"	3,1,1,1,1, 1/4	1385.23	Re-Tensioned due to low-lift-off <95%	Butt. 1	1546.5	7 1/4"	(Not listed)	Butt. 3	1564.09	7 3/4"	(Not listed)	1555.3
13H37	Butt. 1	1367.69	6 7/8"	3,3, 3/8, 1/4, 1/4	Butt. 3	1212.05	5 3/4"	3,1,1, 3/8, 3/8	1289.87	Re-Tensioned due to low-lift-off <95%	Butt. 1	1394.7	7 1/8"	3,3,3/8,1/4,1/4,1/4	Butt. 3	1436.69	6 1/2"	3,1,1,3/8,3/8,1/2,1/4	1415.7
13H38	Butt. 1	1411.54	6 1/2"	3,1,1,1,1/4,1/4	Butt. 3	1378.57	7"	3,1,1,1,1	1395.05										
42H46	Butt. 2	1546.46	5 3/4"	3,3/8,3/8,1,1	Butt. 4	1570.8	6"	3,3	1558.63										
46H19	Butt. 4	1352.87	7"	3,1,1,1,1	Butt. 6	1364.35	7 1/2"	3,3,1,1/4,1/4	1358.61										
46H20	Butt. 4	1269.04	6 3/4"	3,3,1/4,1/2	Butt. 6	1327.22	7 1/4"	3,3,1, 1/4	1298.13	Re-Tensioned due to low-lift-off <90%	Butt. 4	1487	7 1/4"	(Not listed)	Butt. 6	1502.61	7 5/8"	(Not listed)	1494.8
46H21	Butt. 4	1319.34	5 3/4"	3,1,1/2,1/4,1	Butt. 6	1340.71	6"	3,1,1,1/2,1/2	1330.02	Re-Tensioned due to low-lift-off <95%	Butt. 4	1503.7	6 1/8"	(Not listed)	Butt. 6	1499.24	6 3/8"	(Not listed)	1501.5
46H22	Butt. 4	1315.98	5 1/2"	3,1,1,1/2	Butt. 6	1306.98	6 3/8"	3,3, 3/8	1311.48	Re-Tensioned due to low-lift-off <90%	Butt. 4	1567.5	6"	(Not listed)	Butt. 6	1509.35	6 3/4"	(Not listed)	1538.4
46H23	Butt. 4	1336.1	6"	3,1,1,1	Butt. 6	1325.85	5 3/4"	3,1,1,1/2, 1/4	1329.97	Re-Tensioned due to low-lift-off <95%	Butt. 4	1487	6 1/2"	(Not listed)	Butt. 6	1475.62	7 1/8"	(Not listed)	1481.3
46H24	Butt. 4	1419.92	6 3/4"	3,3, 1/2, 1/4	Butt. 6	1431.78	7 1/2"	3,3,1, 1/4, 1/4	1425.85										
51H34	Butt. 1	1532.96	8"	3,3,1, 1/2, 1/2	Butt. 5	1396.45	7"	3,1,1,1,1	1464.7	Re-Tensioned due to Wire Removal Detension.	Butt. 1	1585.8	8 1/2"	3.1,1.25,1.05,3.1,	Butt. 5	1530.56	7 1/2"	3,1,1,1,1, 1/2	1558.2
62H29	Butt. 2	1366.28	6 1/2"	3, 1/2, 3	Butt. 6	1372.78	6 3/8"	3, 3/8, 1,1,1	1369.63										
62H30	Butt. 2	1249.64	6 3/4"	3, 3/8, 3/8, 3	Butt. 6	1332.05	6 3/4"	3,3, 1/2, 1/4	1290.84	Re-Tensioned due to low-lift-off <95%	Butt. 2	1443.4	7 9/16"	(Not listed)	Butt. 6	1492.04	7 1/8"	(Not listed)	1467.7
62H31	Butt. 2	1269.04	6 1/4"	3, 1/4, 3	Butt. 6	InAcc	6"	3,1,1,1	N/A	Re-Tensioned due to low-lift-off <90%	Butt. 2	1487	7"	(Not listed)	Butt. 6	InAcc	N/A	(Not Changed)	N/A
62H32	Butt. 2	1332.75	7"	3,1,3	Butt. 6	InAcc	6 1/2"	3,3, 3/8, 1/8	N/A	Re-Tensioned due to low-lift-off <95%	Butt. 2	1497	7 3/8"	(Not listed)	Butt. 6	InAcc	N/A	(Not Changed)	N/A
62H33	Butt. 2	1242.22	6 3/16"	3, 3/16, 3	Butt. 6	1384.56	6 1/2"	3 1/4, 1/4, 1,1,1	1313.39	Re-Tensioned due to low-lift-off <95%	Butt. 2	1487	6 9/16"	(Not listed)	Butt. 6	4502.61	6 7/8"	(Not listed)	1494.8
62H34	Butt. 2	1393.1	7"	3,3,1	Butt. 6	1364.32	6 3/4"	3,3, 3/8, 3/8	1378.71										

Florida Power Corp	MADE Cliff	GILBERT ASSOCIATES, INC.	
Crystal River	CHK'D. 3-19-70	ENGINEERS AND CONSULTANTS	
Reactor Building	SQ. CP.	READING, PENNA.	
Equip Opening	CP. DFM.	4203-00	1.01.15 / 14
Tendon Drape Pattern	ENG.	WORK ORDER	SIZE DRAWING REV.
	REV. CH. APP. DATE		

Calculate Friction Losses for Tendons.



Radial forces are based on average tendon force between T_2 & T_3 for first tendon, and every alternate tendon. Second and alternate tendons are based on average tendon force between T_4 & T_3

Tendon 53 H-11

① Vertical Curvature $\alpha_{V01} = \alpha_{V23} = \alpha_{V34} = \alpha_{V56} = .4916$ radians

$L_{01} = L_{23}$ etc $= 12.3'$

Horizontal Curvature $\alpha_{H01} = \alpha_{H23} = \frac{12.3}{135\pi} \times 2\pi = .1823$ rad

K=.0003 $\therefore Q_1 = (1 + KL + \mu\alpha) = (1 + 12.3 \times .0003 + .6739 \times .16) = 1.1115$

μ=.16

② $\alpha_{H12} = .5236 - 2 \times .1823 = .1590$ radians

Use $L_{12} = 13.5'$ (scaled from Prescon marked Dwg)
(this figure has little significance to total frictional losses ∴ approximation justified)

$\therefore Q_2 = (1 + KL + \mu\alpha) = (1 + 13.5 \times .0003 + .159 \times .16) = 1.0295$

.8 GTS = 192 KSI

$\therefore T_1 = 192 / 1.1115 = 172.74$ Ksi

$T_2 = 172.74 / 1.0295 = 167.79$ Ksi

$T_3 = 167.79 / 1.1115 = 150.96$ KSI

$T_4 = 150.96 / 1.1115 = 135.81$ Ksi

Ave = 318.75 / 159.37

Florida Power Corp Crystal River Reactor Building Equip Opening Tendon Drape Pattern	MADE Cite CHK'D. 3-19-76 SQ. CF. CF. DFN. ENG. REV. CH. APP. DATE	GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PENNA.	
		4203-00	1.01.15	15
		WORK ORDER	SIZE DRAWING	REV.

Tendon 42H-10

① Vertical Curvature $\alpha_{V01} = \alpha_{V23} = .3694$ radians

$L_{01} = L_{23} = 9.23'$

Horizontal Curvature $\alpha_{H01} = \alpha_{H23} = \frac{9.23}{135} \times 2 = .1367$ rad

$\therefore Q_1 = (1 + KL + \mu\alpha) = (1 + 9.23 \times .0003 + .5061 \times .16) = 1.0837$

② $\alpha_{H12} = .5236 - 2 \times .1367 = .2502$ rad
2734

Use $L_{12} = 17$

$\therefore Q_2 = (1 + KL + \mu\alpha) = (1 + 17 \times .0003 + .2502 \times .16) = 1.0451$

$\therefore T_1 = 192 / 1.0837 = 177.17$ ksi
$T_2 = 177.17 / 1.0451 = 169.53$ ksi
$T_3 = 169.53 / 1.0837 = 156.43$ ksi
$T_4 = 156.43 / 1.0837 = 144.35$ ksi

300.78

Ave = 150.39

Tendon 53H-10

① Vertical Curvature $\alpha_{V01} = \alpha_{V23} = .36361$ radians

$L_{01} = L_{23} = 9.08'$

Horizontal Curvature $\alpha_{H01} = \alpha_{H23} = \frac{9.08}{135} \times 2 = .1345$ rad

$\therefore Q_1 = (1 + 9.08 \times .0003 + .4981 \times .16) = 1.0824$

② $\alpha_{H12} = .5236 - 2 \times .1345 = .2546$ radians
2690

Use $L_{12} = 17'$

$\therefore Q_2 = (1 + 17 \times .0003 + .2546 \times .16) = 1.0458$

$\therefore T_1 = 192 / 1.0824 = 177.38$ ksi
$T_2 = 177.38 / 1.0458 = 169.61$ ksi
$T_3 = 169.61 / 1.0824 = 156.70$ ksi
$T_4 = 156.7 / 1.0824 = 144.77$ ksi

326.31

Ave = 163.15

Florida Power Corp Crystal River Reactor Building Equip Opening Tendon Drape Pattern	MADE CHK CHK'D. 3/19-70 BD. CF. CF. DFN. ENG. REV. CH. APP. DATE	GILBERT ASSOCIATES, INC. ENGINEERS AND CONSULTANTS READING, PENNA.	
		4203-00	1.01.15	16
		WORK ORDER	SIZE DRAWING	REV.

Tendon 42 H-9 & Tendon 53-H-9

Ave $\theta = .2647$ $\quad S = 6.62'$

① Vertical Curvature $\alpha_{V01} = \alpha_{V23} = .2647$ radians

$L_{01} = L_{23} = 6.62'$

Horizontal Curvature $\alpha_{H01} = \frac{6.62}{135} \times 2 = .0982$ rad

$\therefore Q_1 = (1 + KL + \mu\alpha) = (1 + 6.62 \times .0003 + .3629 \times .16) = 1.06$

② $\alpha_{H12} = .5236 - 2 \times .0982 = .3272$ radians

Use $L_{12} = 22'$ (967)

$\therefore Q_2 = (1 + 22 \times .0003 + .3272 \times .16) = 1.059$

$T_1 = 192/1.06 = 181.13$ ksi

$T_2 = 181.13/1.059 = 171.04$ ksi

$T_3 = 171.04/1.06 = 161.36$ ksi

$T_4 = 161.36/1.06 = 152.23$ ksi

313.59

Ave = 156.79

Tendon 42 H-8 & 53H-8 $\quad$ Ave $\theta = .1766$ $\quad S = 4.48'$

① Vert Curv $\alpha_{V01} = \alpha_{V23} = .1766$ radians

$L_{01} = L_{23} = 4.48'$

Hor Curv $\alpha_{H01} = \alpha_{H23} = \frac{4.48}{135} \times 2 = .0664$ rad

$\therefore Q_1 = (1 + 4.48 \times .0003 + .243 \times .16) = 1.0402$

② $\alpha_{H12} = .5236 - 2 \times .0664 = .3908$ rad (1328)

Use $L_{12} = 26$

$\therefore Q_2 = (1 + 26 \times .0003 + .3908 \times .16) = 1.0703$

$T_1 = 192/1.0402 = 184.58$ ksi

$T_2 = 184.58/1.0703 = 172.46$ ksi

$T_3 = 172.46/1.0402 = 165.79$ ksi

$T_4 = 165.79/1.0402 = 159.38$ ksi

338.25

Ave = 169.12