

2018 KEPIC-Week

Containment Post Tensioning System(CPTS)

[Strand Damage Assessment]

2018.08.30, Rev.0 Nuclear BG

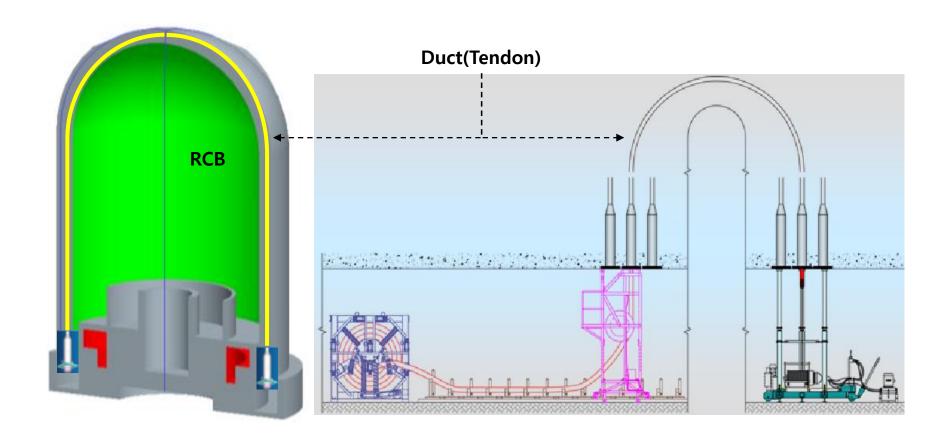
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1. CPTS(Containment Post Tensioning System)

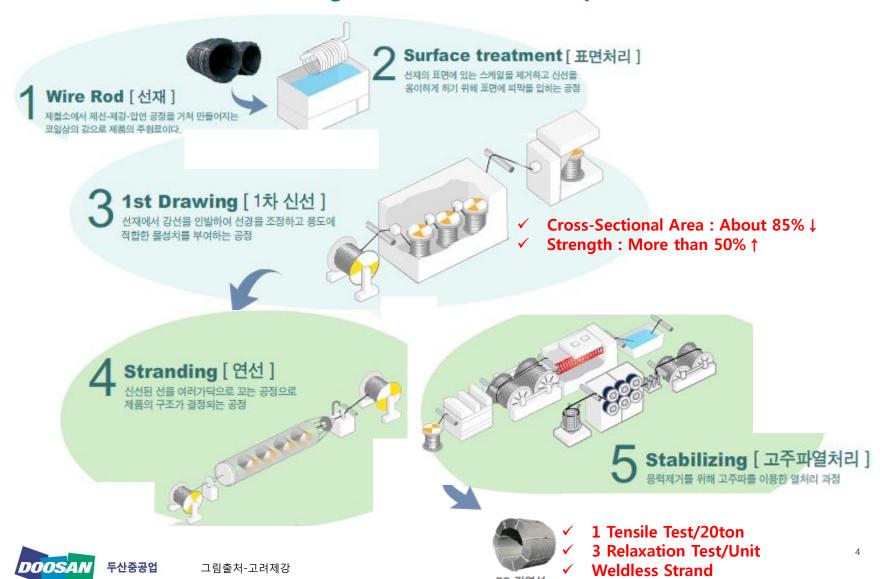
To prevent cracks in concrete by applying compressive stress in advance to the structure by tensioning the strands(tendon) inside the reactor building concrete





2. Strand and Tendon Fabrication (1/3)

Strand - Continuous drawing and stabilization to prevent local defects



2. Strand and Tendon Fabrication (2/3)

Tendon - 0.5" x 55 Strands(OPR1000), 0.6" x 42 Strands(APR1400)

Wire rod x 7 ea



Twisting (7 Wires)



Strand (0.6 in Diameter)





















Strand x 42 ea

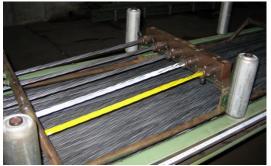


Parallel strands



Tendon (0.6 in x 42)









2. Strand and Tendon Fabrication (3/3)

Tendon(Vertical & Horizontal) - Pulled into the duct as complete tendon



















3. Strand Damage Issue

Damaged packaging and scratches on strands in tendon package delivered to the site







4. Technical Specification/Code/Standard (1/2)

The quantitative guideline or acceptance criteria for the strand damage assessment is necessary

◆ Technical Specification

- ➤ 4.05 : Tendon type(0.6 in X 42 Strands)
- ➤ 4.06 : Tendon fabrication(ASTM A416-270-Low Relaxation)
- ➤ 4.06 : Tendon replacement(Damage or Pitting)
- ➤ 4.09 : Broken strands(1 Strand/1 Tendon, 2 Strands/5 Tendons)
- ➤ 4.11 : Transportation/Storage/Handling(NAQ-1-II-2.2-C)

♦ KEPIC SNB(ASME SEC-III DIV-2 CC)

- > 2420 : Permitted material(ASTM A416/A421/A722/A779), Testing(Tensile/Relaxation)
- ➤ 4430 : Tendon fabrication
- > 4450 : Tendon installation(Construction specification)

◆ ASTM & Procedure

- > ASTM A416 : Strand diameter/Grade/Type, Tensile & Relaxation test
- ➤ Supplier's Installation Manual(1.1.8): Transportation/Storage/Handling(NAQ-1-II-2.2-C), No rusting inducing pitting



4. Technical Specification/Code/Standard (2/2)

PTI M50.3-12, 11.5 : Picture 1,2 and 3 acceptable(no pitting)

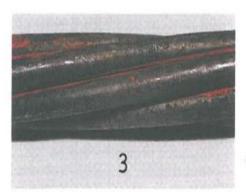


Photo 3. Strand surface before cleaning

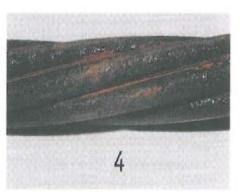


Photo 4. Strand surface before cleaning

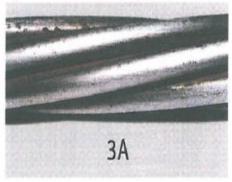


Photo 3A. Strand surface after cleaning

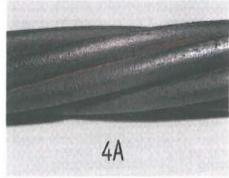


Photo 4A. Strand surface after cleaning

11.5 — Acceptance criteria

Formation of light rust on the strand surface shall not be detrimental. The following test shall be used to determine the acceptability of strand for installation in the ducts.

Use a Scotch Brite Cleaning Pad No. 96—made by 3M—or its equivalent, made from synthetic, nonmetallic material. Hand-clean a strand sample longitudinally with a new pad using moderate pressure. Refer to Fig. 11.1 for evaluation. Based on Pictures 1A, 2A, and 3A, levels of rust shown in Pictures 1, 2, and 3 are acceptable. Picture 4A shows pitting visible to the unaided eye. Hence, rust levels corresponding to Picture 4 are cause for rejection.



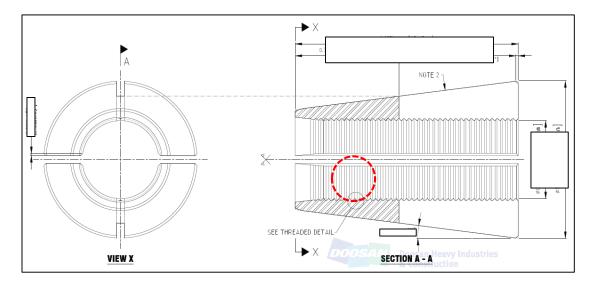


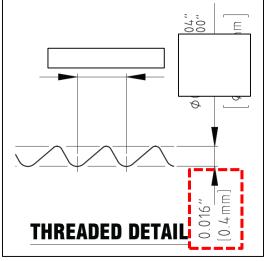
5. System Qualification Test for SKN 3&4 (1/3)

System qualification test satisfied for strand damage up to 0.4mm deep

- **♦** VSL(DOOSAN) Wedge: Thread Depth 0.4mm
- ◆ Qualification tests(KEPIC SNB-2460) @ strand damage 0.4mm deep
 - ➤ Static Tensile Test: 100% Fpu(2 Times, LST & Ambient)
 - ➤ Low Cycle Dynamic Tensile Test: 80%~40% Fpu(50 Cycle)
 - ➤ High Cycle Dynamic Tensile Test: 66%~60% Fpu(500,000 Cycle)





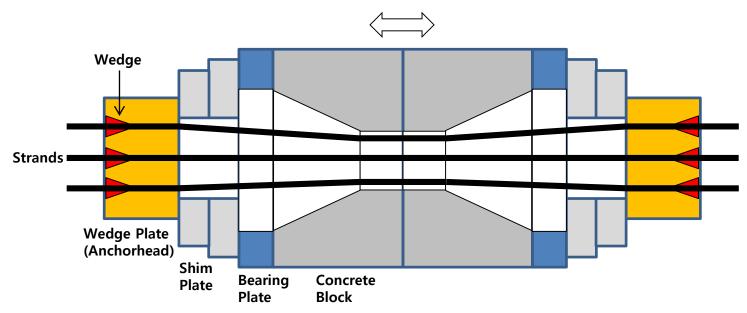




5. System Qualification Test for SKN 3&4 (2/3)

System qualification test satisfied for strand damage up to 0.4mm deep

Static Tensile Test (Ambient & -34°C, 100% of Full Size) (100% MUTS)





5. System Qualification Test for SKN 3&4 (3/3)

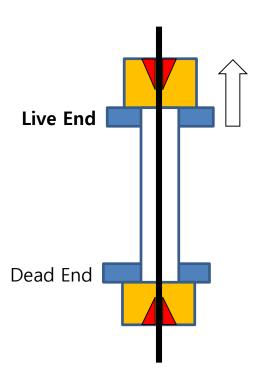
System qualification test satisfied for strand damage up to 0.4mm deep

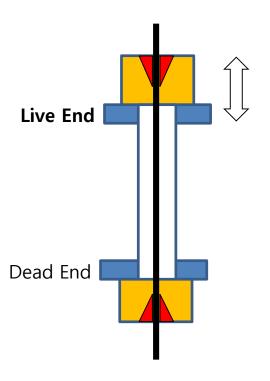
Dynamic Tensile Test

(10% of Full Size, 500,000@60~66% MUTS)

Dynamic Tensile Test

(10% of Full Size, 50@40~80% MUTS)

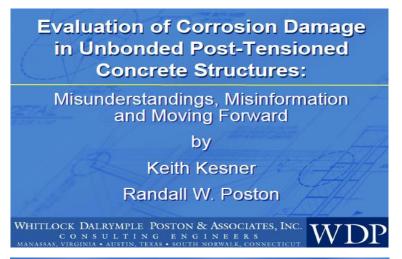


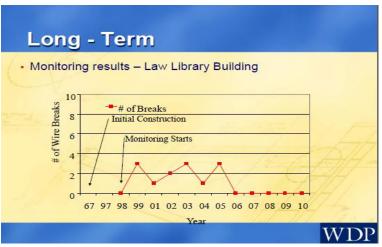




6. PTI 2010 Conference Data (1/2)

No strength loss for strand pitting up to 0.5mm deep





Corrosion Assessment Ultimate Load Testing % GUTS Assembly (kip) - Loss of strength 40.6 98.3 39.8 96.4 - Comparison with 36.0 87.2 101.9 analysis results 39.0 94.4 - Comparison with code 39.2 94.9 40.6 98.3 requirements 41.0 99.3 40.2 97.3 36.2 41.0 40.3 97.6 13 40.2 40.2 97.3 39.7 Average

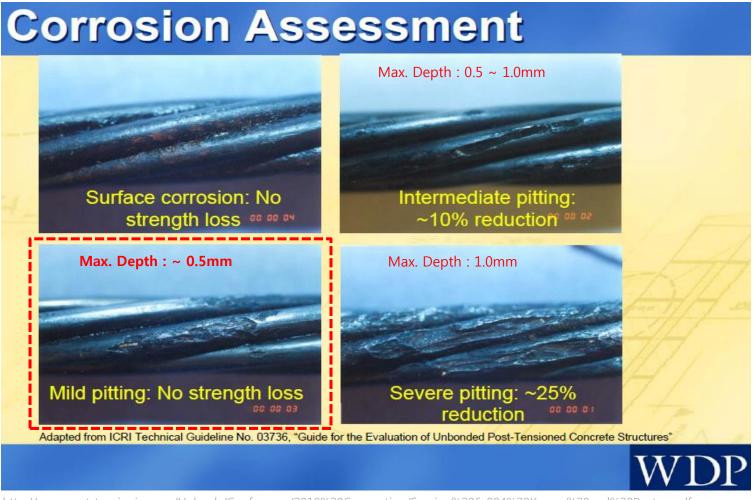
Corrosion Assessment						
Law School Library – 56 Tendons extracted						
Category	%	Max. pit depth (in.)	Ultimate Strength (kips)	% GUTS		
Failure	3	-	-	13 7 /		
Severe	52	0.04 in.	31.7	77 ///		
Intermediate	11	0.02 - 0.04 in	37.2	90		
Mild / None	34	0.02 in.	40.3	97		
Total	100%		1,2/	4/4		

http://www.post-tensioning.org/Uploads/Conference/2010%20Convention/Session%206_004%20Kesner%20and%20Poston.pdf



6. PTI 2010 Conference Data (2/2)

No strength loss for strand pitting up to 0.5mm deep





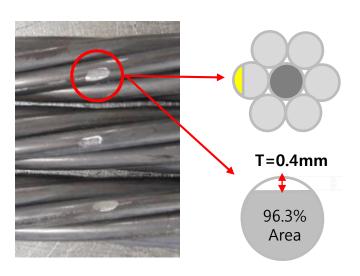
7. Tensile Test for Damaged Strand – 1 Wire (1/3)

1 outer wire damaged(0.4mm deep) - Tensile test satisfied

◆ Actual tensile test result by KISWIRE(30-OCT-2017)

> Strand Size: 0.6in-270-Low Relaxation, 260.7kN

➤ Wire Size(Nominal Diameter) : 5.XX(Center Wire), 5.XX(Outer Wire)



No.	Tensile(kN)	Results
	260.70	Normal strand - 272.49kN
1	261.89	1 wire broken(damaged section)
2	267.65	1 wire broken(gripper section)
3	265.66	1 wire broken(damaged section)

Specimen(damaged)



7. Tensile Test for Damaged Strand – 1 Wire (2/3)

1 outer wire damaged(0.4mm deep) – Tensile test satisfied





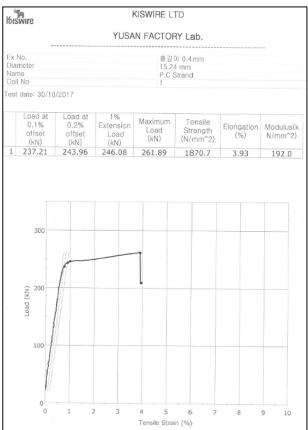


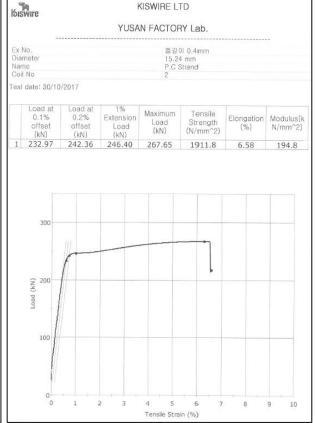




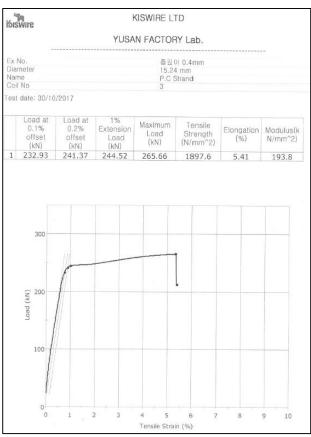
7. Tensile Test for Damaged Strand – 1 Wire (3/3)

1 outer wire damaged(0.4mm deep) - Tensile test satisfied





KISWIRE LTD





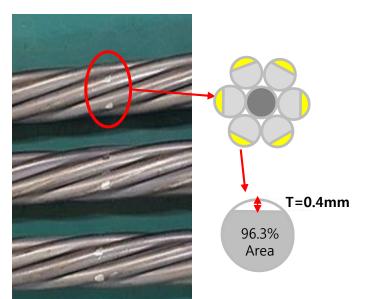
8. Tensile Test for Damaged Strand – 6 wires (1/3)

6 outer wires damaged(0.4mm deep) - Tensile test satisfied

◆ Actual tensile test result by KISWIRE(27-DEC-2017)

> Strand Size: 0.6in-270-Low Relaxation, 260.7kN

➤ Wire Size(Nominal Diameter) : 5.XX(Center Wire), 5.XX(Outer Wire)



No.	Tensile(kN)	Results
	260.70	Normal strand - 272.49kN
1	270.65	1 wire broken(damaged section)
2	270.78	1 wire broken(damaged section)
3	268.30	1 wire broken(damaged section)

Specimen(damaged)



8. Tensile Test for Damaged Strand – 6 wires (2/3)

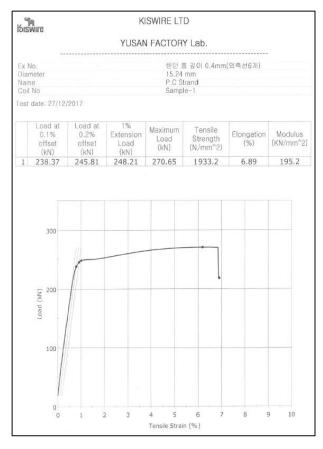
6 outer wires damaged(0.4mm deep) - Tensile test satisfied

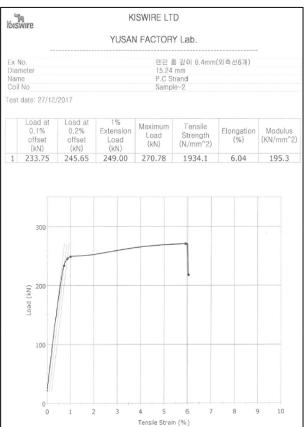


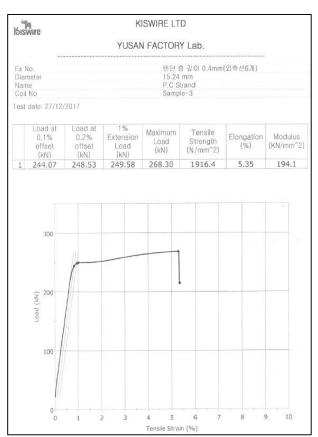


8. Tensile Test for Damaged Strand – 6 wires (3/3)

6 outer wires damaged(0.4mm deep) - Tensile test satisfied







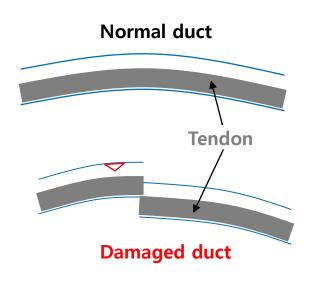


9. Duct Installation Issue (1/3)

Stress concentration and breakage on strand due to kink or dent of duct

[Duct damage and concrete intrusion]



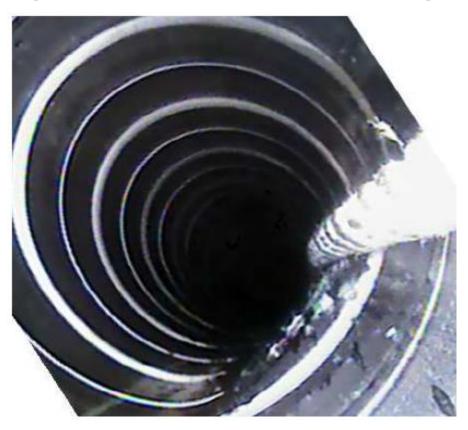


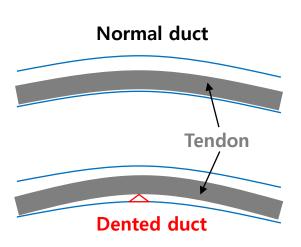


9. Duct Installation Issue (2/3)

Stress concentration and breakage on strand due to kink or dent of duct

[Duct dent due to rebar or concrete]







9. Duct Installation Issue (3/3)

Stress concentration and breakage on strand due to kink or dent of duct

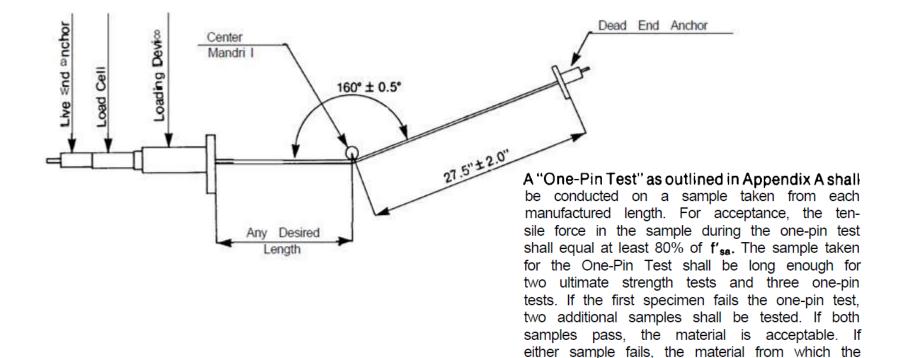


FIGURE A.1 BASIC DETAILS OF PIN TEST DEVICE (FOR STAY CABLE)

sample was taken shall be rejected.

SEE FIGURE A.2 FOR DETAIL OF CENTER MANDRIL

[PTI Recommendations for stay cable design and testing-1986]



10. Conclusion

Acceptance criteria for strand damage – Maximum 0.4mm deep damage

◆ No strength loss for strand damage up to 0.4mm deep

- ➤ APR1400 CPTS System Qualification Tests(0.4mm deep damage)
- ➤ PTI 2010 Conference Data(0.5mm deep pitting)
- ➤ Actual Strand Tensile Test(0.4mm deep damage)

◆ Duct kink or dent is the major causes for strand breakage

- ➤ Video camera inspection results for duct of continuous strand breakage
 - ✓ Abrupt bending of duct
 - ✓ Duct dent due to concrete or rebar
- ➤ No failure of tensile tests for strand samples supplied at site for the last 18 years(More than 12 Reactor Containment Building)

