Hope Creek Circulating Water Pipeline 2013 Carbon Fiber Upgrade

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Background- Hope Creek Generating Station

- Located in Salem, NJ
- Station consists of 1,268 MW boiling water reactor (BWR)
- Circulating Water System consists of 144in PCCP
- Pipelines have been inspected for the past 8 years and distressed pipes have been identified

Background- PCCP Deterioration

- Cracking of Outer Mortar
- Corrosion or Embrittlement of Wires
- Wires Break
- Mortar Coating Delaminates
- Concrete Core Delaminates
- Core Cracks
- Failure

Background- Project Details

Project Scope:

- Carbon fiber reinforced polymer (CFRP) composite lining of seven (7) sections of 144-in PCCP during the October 2013 outage

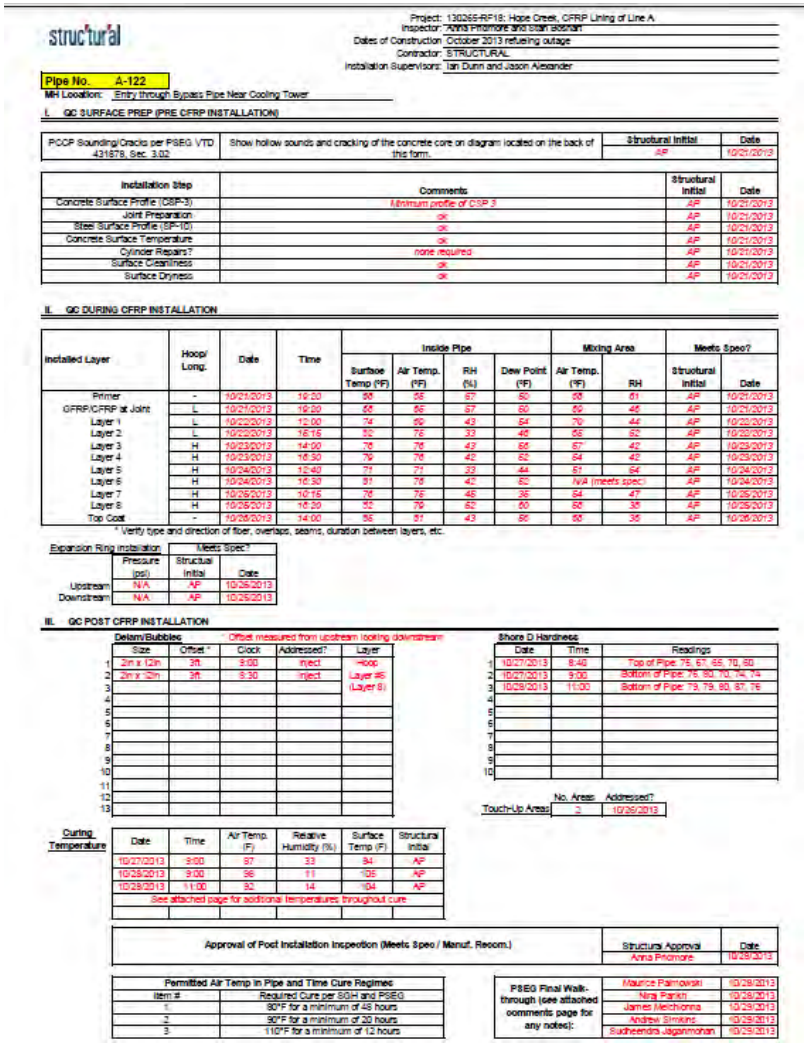
Unique Project Challenges:

- Removal of muck and construction of access through cooling tower basin
- Single point of entry to complete all in-pipe activities
- Construction of 2-tiered access within the 144-inch diameter pipeline
- Changes in elevation and slope conditions within scope area
- Removal of a pre-existing carbon fiber system

QA/QC Program:

- 3rd party Quality Control inspector
- Full time Quality Assurance manager
- Multiple owner representatives

Background- Quality Control Program



structural

Project: 130265-RF18: Hope Creek, CFRP Lining of Line A
Inspector: Anna Fromore and Stan Bosman
Dates of Construction: October 2013 refueling outage
Contractor: STRUCTURAL
Installation Supervisors: Ian Dunn and Jason Alexander

Pipe No. A-122
MH Location: Entry through Bypass Pipe Near Cooling Tower

I. QC SURFACE PREP (PRE CFRP INSTALLATION)

PCCP Sounding/Cracks per PSEG VTD 431878, Sec. 3.02	Show hollow sounds and cracking of the concrete core on diagram located on the back of this form.	Structural Initial	Date
		AP	10/25/2013

Installation Step	Comments	Structural Initial	Date
Concrete Surface Profile (CSP-3)	Minimum profile of CSP 3	AP	10/21/2013
Joint Preparation	ok	AP	10/21/2013
Steel Surface Profile (SP-10)	ok	AP	10/21/2013
Concrete Surface Temperature	ok	AP	10/21/2013
Cylinder Repairs?	none required	AP	10/21/2013
Surface Cleanliness	ok	AP	10/21/2013
Surface Dryness	ok	AP	10/21/2013

II. QC DURING CFRP INSTALLATION

Installed Layer	Hoop/ Long.	Date	Time	Inside Pipe: Surface Temp (°F)	Air Temp. (°F)	RH (%)	Dew Point (°F)	Mixing Area: Air Temp. (°F)	RH	Meets Spec? Structural Initial	Date
Primer	-	10/21/2013	10:20	66	68	67	60	66	61	AP	10/21/2013
GFRP/CFRP at Joint	L	10/21/2013	10:20	66	66	67	60	66	46	AP	10/21/2013
Layer 1	L	10/22/2013	12:00	74	69	43	54	70	44	AP	10/22/2013
Layer 2	L	10/22/2013	16:15	80	76	33	46	68	35	AP	10/22/2013
Layer 3	H	10/23/2013	14:00	76	76	42	64	67	42	AP	10/23/2013
Layer 4	H	10/23/2013	16:30	79	76	42	62	64	42	AP	10/23/2013
Layer 5	H	10/24/2013	12:40	71	71	33	44	61	64	AP	10/24/2013
Layer 6	H	10/24/2013	16:30	81	76	42	62	N/A (meets spec)		AP	10/24/2013
Layer 7	H	10/25/2013	10:15	76	76	48	36	64	47	AP	10/25/2013
Layer 8	H	10/25/2013	16:20	82	79	62	60	66	38	AP	10/25/2013
Top Coat	-	10/26/2013	14:00	86	81	43	66	66	36	AP	10/26/2013

* Verify type and direction of fiber, overlaps, seams, duration between layers, etc.

Expansion Ring Installation	Meets Spec* Pressure (psi)	Structural Initial	Date
Upstream	N/A	AP	10/26/2013
Downstream	N/A	AP	10/26/2013

III. QC POST CFRP INSTALLATION

Delam/Bubbles (Offset measured from upstream looking downstream)

	Size	Offset *	Clock	Addressed?	Layer
1	2in x 12in	3ft	9:00	Inject	Hoop
2	2in x 12in	3ft	8:30	Inject	Layer #5 (Layer 6)
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					

Shore D Hardness

	Date	Time	Readings
1	10/27/2013	8:40	Top of Pipe: 75, 67, 65, 70, 60
2	10/27/2013	9:00	Bottom of Pipe: 75, 80, 70, 74, 74
3	10/28/2013	11:00	Bottom of Pipe: 79, 79, 80, 87, 76
4			
5			
6			
7			
8			
9			
10			

	No. Areas	Addressed?
Touch-Up Areas	2	10/26/2013

Curing Temperature

Date	Time	Air Temp. (F)	Relative Humidity (%)	Surface Temp (F)	Structural Initial
10/27/2013	9:00	87	33	84	AP
10/28/2013	9:00	86	11	105	AP
10/28/2013	11:00	82	14	104	AP
See attached page for additional temperatures throughout cure					

Approval of Post Installation Inspection (Meets Spec / Manuf. Recom.)	Structural Approval	Date
	Anna Fromore	10/28/2013

Permitted Air Temp in Pipe and Time Cure Regimes: Item #	Required Cure per SGH and PSEG
1	90°F for a minimum of 48 hours
2	90°F for a minimum of 20 hours
3	110°F for a minimum of 12 hours

PSEG Final Walk-through (see attached comments page for any notes):		
	Maurice Palmowski	10/28/2013
	Nina Parikh	10/28/2013
	James Melchionna	10/28/2013
	Andrew Simkins	10/28/2013
	Sudheendra Jagannmohan	10/28/2013

Multiple QA/QC Personnel

- 3rd Party inspector
- Full time Quality Assurance Manager
- Multiple Owner Representatives

Documentation for each stage of implementation

- Material verification
- Surface preparation
- Mixing and saturation
- CFRP liner installation
- End details and special detailing
- Top coat
- Final cure

Unique Project Challenges

- Cooling water tower basin filled with muck
- De-mucking required prior to access into the pipeline
- Quantity of muck unknown prior to start of outage
- Specialty scaffolding required to bring materials and personnel from staging area into basin

Unique Project Challenges

- Materials, personnel, and ventilation equipment all routed through a single point of entry
- Main access to the circulating water pipe required navigation through a butterfly valve
- Substrate had buildup of existing epoxy (remainder of failed carbon fiber lining system), sometimes over 1/2in thick
- Exact condition of substrate unknown prior to removal of coating

Key Project Step: Surface Preparation

Project Step:

- Surface preparation performed using Sponge Blasting to minimize airborne particulates and to avoid utilizing a separate surface preparation method for end joint details

QC Documentation:

- All prepared concrete substrates achieved a minimum surface profile of ICRI CSP 3
- All substrates cleaned and dried prior to installation of CFRP system

Key Project Step: Surface Preparation

Project Step:

- CFRP lining system terminates into the steel substrate to ensure water tightness

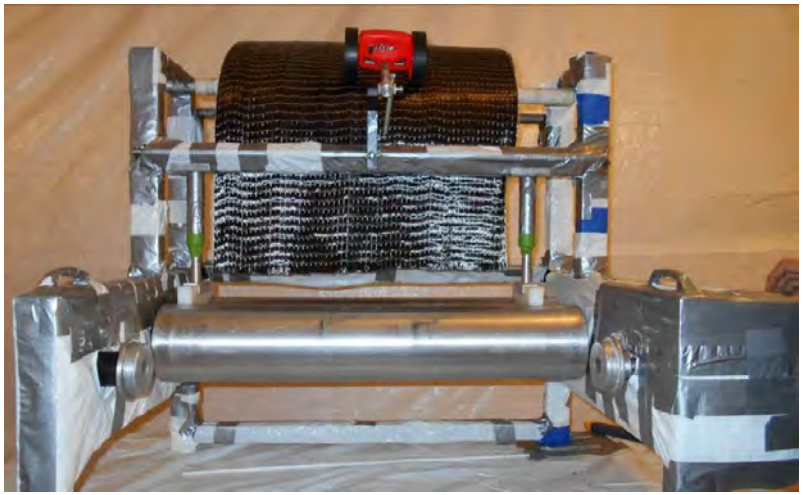
***QC Documentation*:**

- All prepared steel surfaces achieved a near white metal blast SP10 and a minimum surface roughness of 2 mils
- All substrates cleaned and dried prior to installation of CFRP system

Unique Project Challenges

- Extensive pitting and concrete patches observed on prepared substrate
- Additional details identified that were not shown on drawings
- Specialty detailing to accommodate thermowell was designed after construction began

Key Project Step: Mixing and Saturation



Project Steps:

- Materials arrive on site in premeasured containers for part A and B components
- Designated mixing region is an isolated area to avoid material contamination
- Mechanical saturator ensures consistent application of epoxy to carbon fiber

QC Documentation:

- Lot numbers of fabrics and epoxies are documented
- Gap between saturator rollers measured and calibrated using weigh test
- Weigh test verifies ratio of fabric to epoxy is within tolerance (1:1 for carbon fiber fabric, 0.8:1 for glass fiber fabric ±10%)

Key Project Step: Adhesion Testing

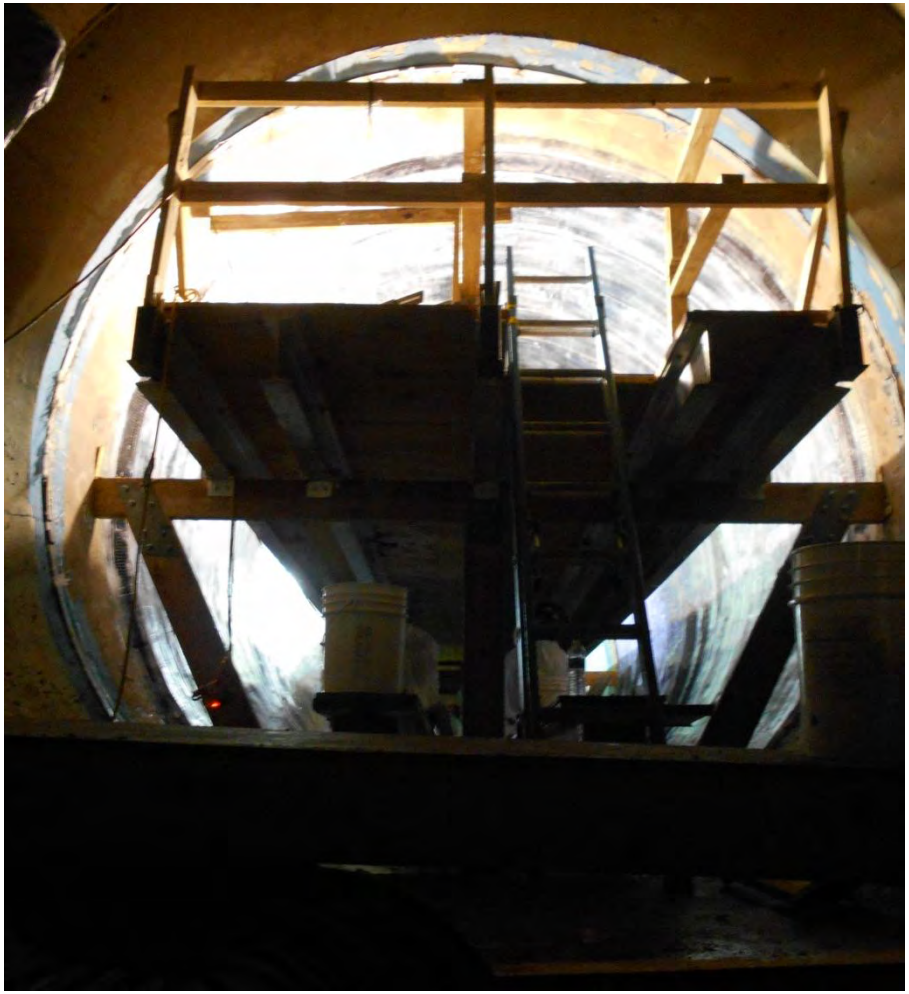
Project Step:

- Surface preparation is verified by performing an adhesion test per ASTM D4541 on an adjacent section of prepared pipe

QC Documentation:

- A minimum of three (3) test pulls performed at three separate test regions
- Failure mode documented
- Minimum pull-off test of 200 psi required

Unique Project Challenges



Project required custom built two-tiered engineered scaffold for the following requirements:

- Live load of 25 psf
- 30 ft spans
- Changes in vertical slope midway through span
- Specialty connection designs required by PSEG safety dept
- All materials required to fit through limited access into the pipes

Key Project Step: End Joint Details

Project Steps:

- Epoxy mortar in joint region used to create a sloped transition for the CFRP
- Glass layer installed in direct contact with steel substrate to create a dielectric barrier between the CFRP and steel
- All layers of longitudinal and circumferential CFRP installed onto the main pipe are also installed into the joint

QC Documentation:

- Slope of epoxy mortar verified (2:1 slope)
- Air temperature, and surface temperature documented (min of 40°F)
- Humidity in pipe monitored (min of 5°F above dew point)

Key Project Step: CFRP Installation

Project Steps:

- Unidirectional mechanically saturated carbon fiber fabric installed in both longitudinal and circumferential directions
- CFRP design serves as stand alone system to resist 100psi internal pressure and -14.7 psi vacuum pressure without reliance on host pipe

QC Documentation:

- Air temperature, surface temperature, and humidity during installation documented
- Alignment of CFRP layers observed (maximum of 5 degree misalignment)
- Minimum development length of 12in in fiber direction

Key Project Step: CFRP Final Cure

Project Step:

- After top coat is installed, final cure of CFRP system is performed at elevated temperature

QC Documentation:

- Air temperature, surface temperature, and humidity during CFRP cure recorded
- Shore D hardness values throughout pipe recorded to document progression of cure
- Degree of cure testing performed to verify degree of cure achieved for CFRP system

Key Project Step: CFRP Tensile Test Panels

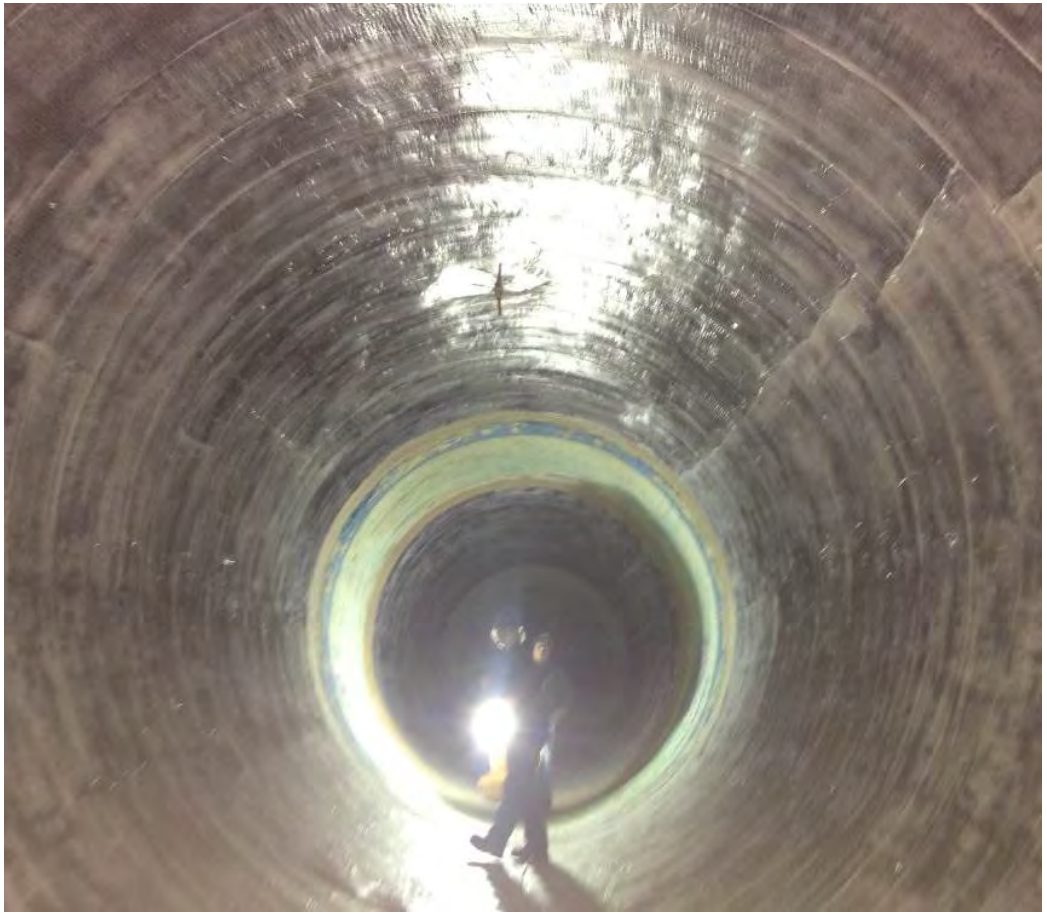
Project Step:

- During each shift of CFRP installation, two test panels are fabricated

QC Documentation:

- Air temperature and humidity during CFRP test panel fabrication are recorded
- Lot numbers for carbon fiber fabric documented
- Once panels cure, they are sent off to 3rd party test facility for tensile tests per ASTM D3039

Key Project Step: Final Walkthrough



Project Step:

- After final cure is completed and scaffolding is removed, a final Quality walkthrough and FME check with all QA/QC personnel is performed

QC Documentation:

- Final walkthrough is signed off on by:
  - 3rd party Inspector
  - Structural QC Inspector
  - PSEG Engineering Team
  - PSEG System Owner