PNWS-AWWA
2026 Section Conference

May 6-8 I Tacoma, WA



What happens **NEXT** is happening **NOW**.

OCSAN
ORANGE COUNTY SANITATION DISTRICT

CDM Smith

Advanced Construction Lessons Learned: Large-Diameter Pressure Cured-in-Place Pipe (CIPP) Lining

Speakers

- Cindy Preuss, P.E., CDM Smith Inc.
- Alberto Acevedo, P.E., CDM Smith Inc.

With support from

- Rich Leon, P.E., Orange County Sanitation District
- Marianne Kleine, P.E., Orange County Sanitation District
- Chris Ott, P.E., CDM Smith Inc.



Presentation Outline

- Orange County Sanitation District (OC San) Project 7-65 overview
- Design basis and criteria
  - Industry standards, guidelines, and practices for CIPP
  - Overview construction acceptance
- Construction quality control
  - Submittal review challenges
  - Ultimate outcomes and takeaways

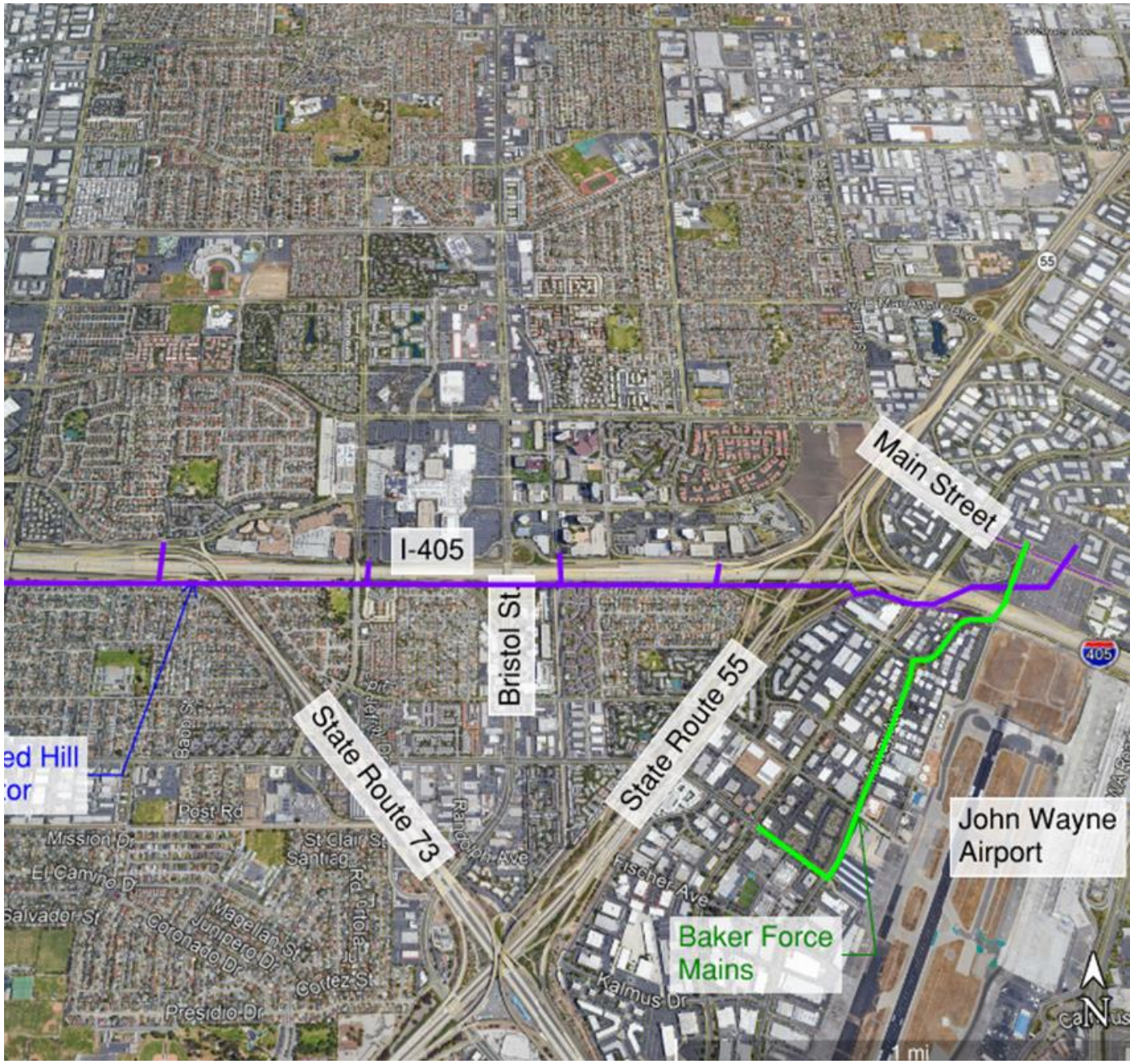


OC San 7-65 Project Location



Project Overview

- Pump station improvements
- Large-diameter gravity and pressure CIPP rehabilitation
  - 8,600 LF of 30- to 33-inch gravity sewers
  - 5,900 LF of 42-inch parallel sewer force mains
- Awarded in 2023
- All CIPP rehabilitation work now completed

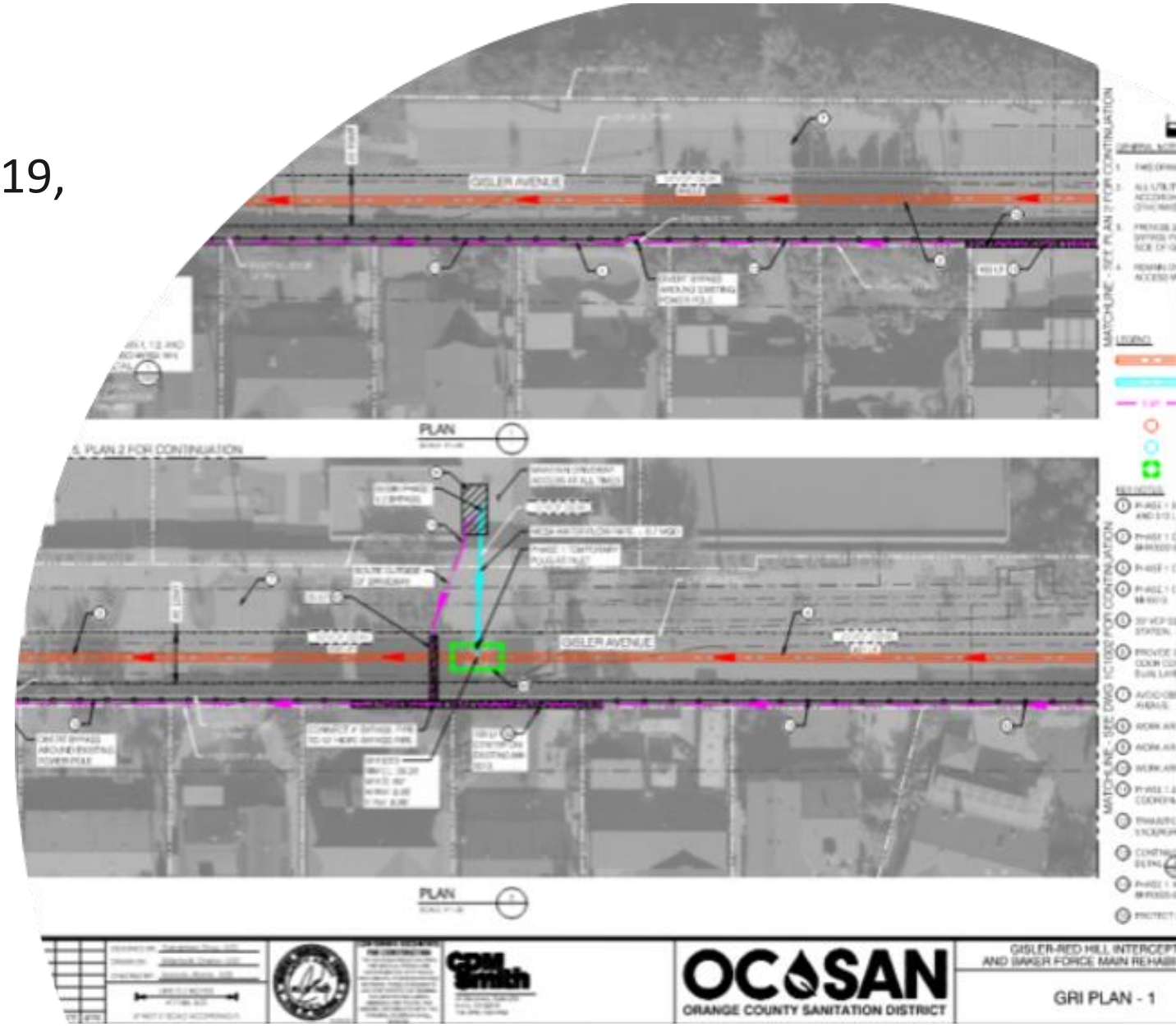




Large-Diameter Pressure CIPP: Design Basis and Criteria

Project Design Criteria

- Design per ASTM F1216 or ASTM F2019, Appendix X1
- Fully deteriorated
- 1 percent ovality; -9 psig vacuum
- 50-year design life
- Vinyl ester resin
- 7,000 psi flexural strength
- 350,000 psi Flex Mod
- 6,500 psi tensile strength





Industry Standards, Guidelines, and Practices for CIPP

Relevant Industry Organizations

- ASTM – American Society for Testing and Materials
- AWWA – American Water Works Association
- NASSCO – National Association of Sewer Service Companies
- NASTT - North American Society for Trenchless Technology

ASTM Standard Practices/Specifications

F1216-24a -22

Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube

F2019-22 -22

Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Pulled in Place Installation of Glass Reinforced Plastic Cured-in-Place (GRP-CIPP) Using the UV-Light Curing Method

F1743-25 -22

Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP)

D618-21 -21

Standard Practice for Conditioning Plastics for Testing

D3567-22 -22

Standard Practice for Determining Dimensions of "Fiberglass" Pipe and Fittings

D5813-25 -18

Standard Specification for Cured-In-Place Thermosetting Resin Sewer Piping Systems

Legend: - ## = year of most recent version - ## = version governing project design

ASTM Standard Test Methods

D790-17 -17 Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials	**D3039-17** -17 Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials	**D903-25** -17 Standard Test Method for Peel or Stripping Strength of Adhesive Bonds
D2990-17 -17 Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics	**D638-22** -22 Standard Test Methods for Tensile Properties of Plastics	**D5035-24** -19 Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)

Legend: - ## = year of most recent version - ## = version governing project design

NASSCO Guidelines and Practices

- Performance Specification Guidelines for CIPP-21
- Inspector training certification program (ITCP) manual-18
- Technical advisory committee (TAC)
- Pressure pipe committee

AWWA Standard (Pressure CIPP)

- C623-22 (first edition): Cured-In-Place Pipe (CIPP) Rehabilitation of Pressurized Potable Water Pipelines, 4 In. (100 mm) and Larger

Legend: - ## = year of most recent version

NASTT Good Practices

- 8-hour Cured-In-Place Pipe (CIPP) Good Practices Course and Manual-04
- Cured-In-Place Pipe (CIPP) Good Practices Guidelines-15



Overview Construction Acceptance: Main Criteria



Visual appearance



Curing results



Flat plate testing results

SUBMITTALS

Hydrostatic testing results

Commissioning

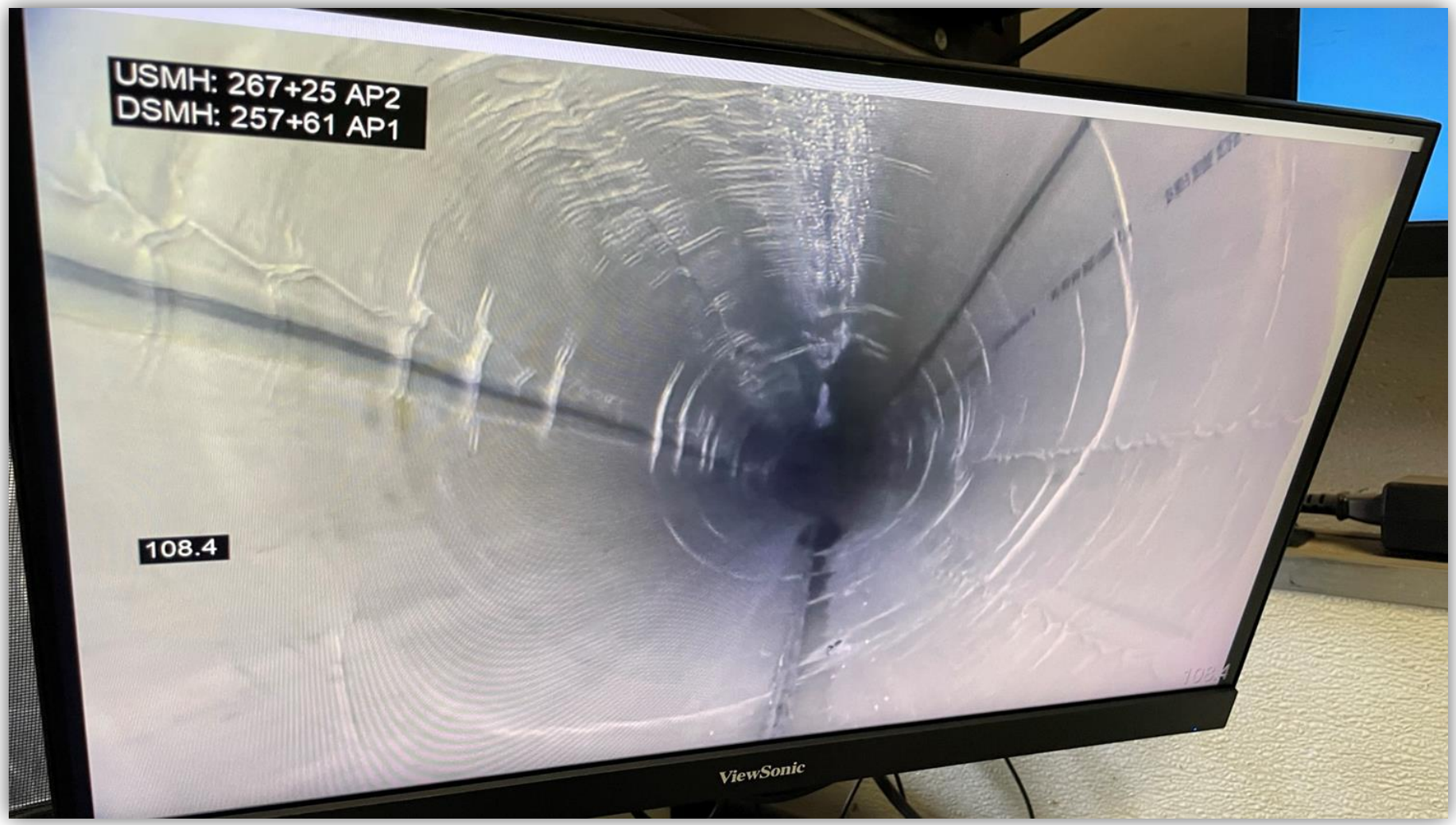


Large-Diameter Pressure CIPP: Construction Quality Control



Submittal Review Challenges

Visual Appearance



Contract Specification Requirements



Visual appearance



Curing results



Flat plate testing results

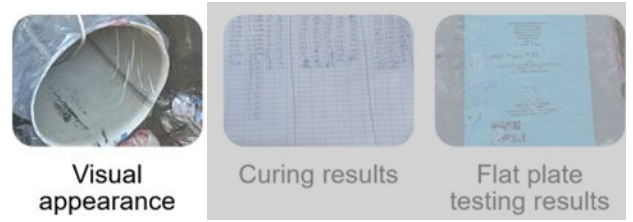
D. For GFR-CIPP continuous liner segments between closure spool assembly limits:

1. Test Method: Post liner installation visual inspection by closed circuit television (CCTV)

B. Confirm fit and finish meet the visual classification standards of ASTM D5813 and that the liner is free of excess wrinkling or other feature that reasonably may compromise its functional or structural performance design objective. The finished lining shall be continuous over the entire length and free from visual defects such as foreign inclusions, pinholes and delaminations. Other defects, such as lifts, folds, fins or wrinkles shall only be acceptable if it can be proven that the reinforcing fabric is not present in this defect. The lining shall be impervious and free of any leakage from the pipe to the surrounding ground or from the ground to the inside of the lined pipe.

C. There shall be no wrinkling or folding of the glass fiber layers in the liner. If an area of the finished liner is deemed to exhibit this condition, it shall be thoroughly investigated; and, if found to truly be in this condition, the subject areas shall be removed and replaced.

Wrinkles and Folds



Why so many wrinkles?

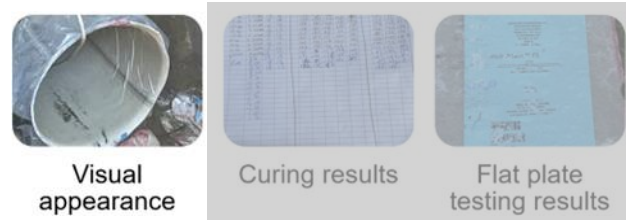
- Liner sizing for tight fit within the pipe
- Minor ovality (x≠y)
- Interaction with the pre-liner
- Thermoplastic polyurethane versus felt/fiberglass layer properties



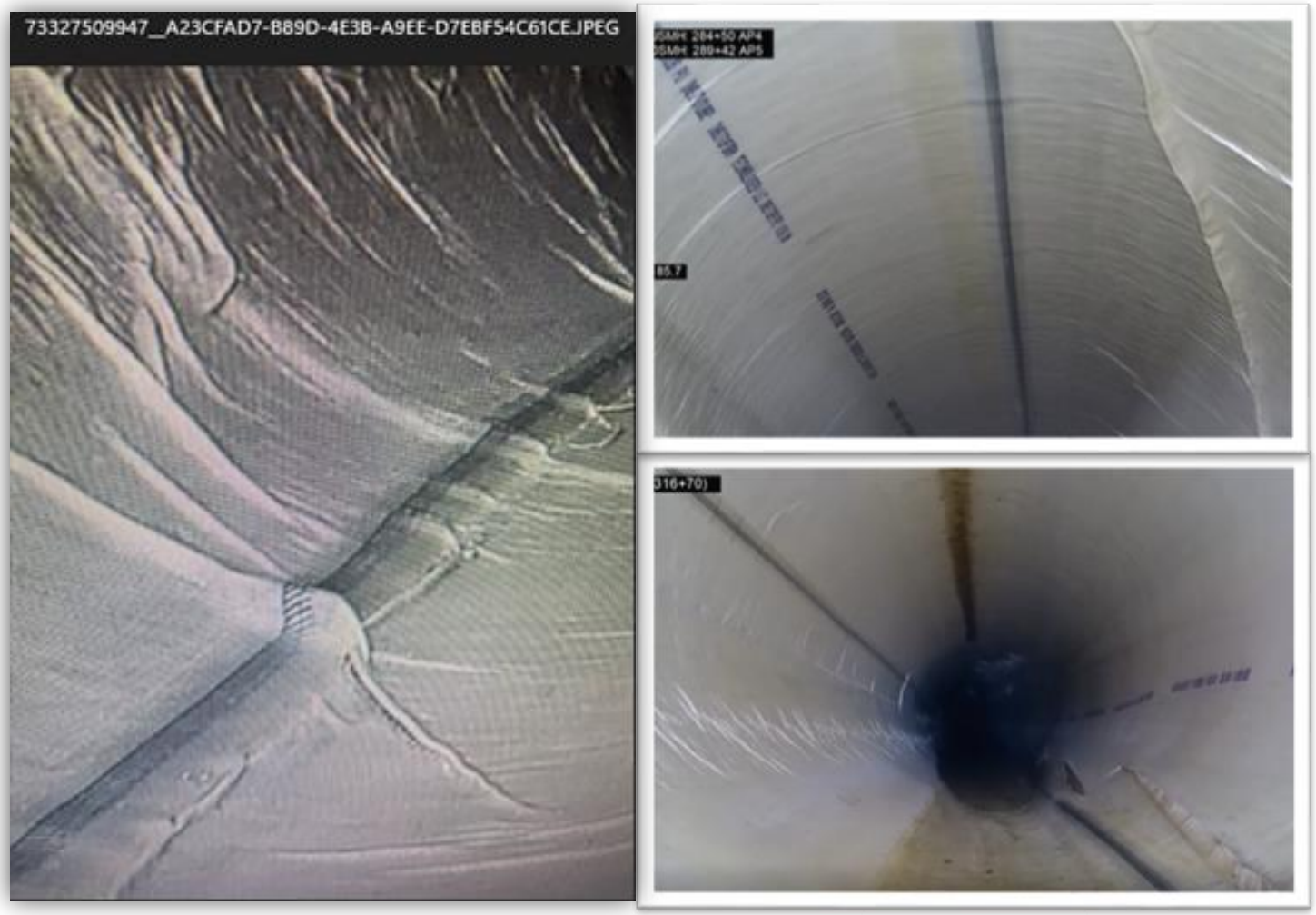




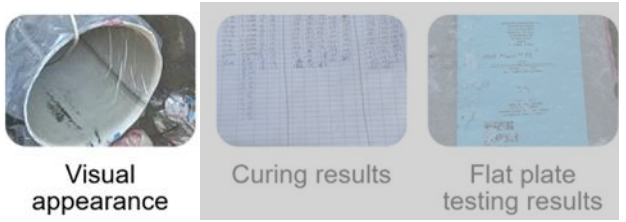
Wrinkles and Folds



- Usual concerns:
  - ~~Flow obstruction/debris accumulation~~
  - Damage to new liner (pipe) where it protrudes because of sharp material in flow
- Pressure pipe concerns:
  - Impedance of load transfer through the pipe



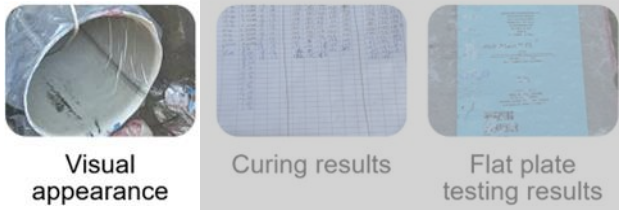
Submittal Response – Example 1



Concern	Action
Adverse impacts on hydraulics	Take measurements to determine height relative to pipe cross section



Submittal Processing and Disposition







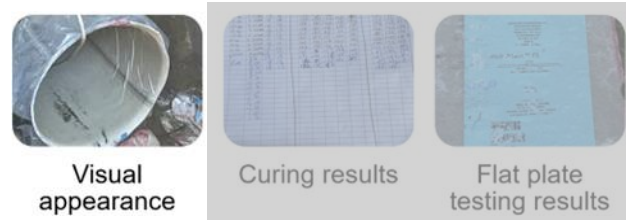








Submittal Processing and Disposition



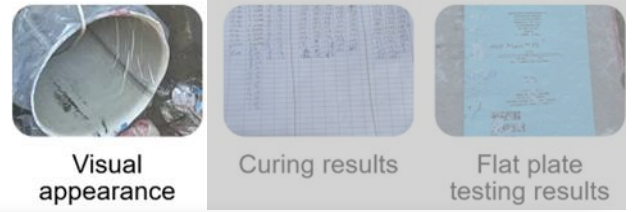
Concern	Action	Outcome	Disposition
Adverse impacts on hydraulics	Take measurements to determine height relative to pipe cross section	Some fold/fin measurements equaled or exceeded industry standards	Relatively low risk being outside highest velocity flow area

42" West Baker Force Main	
Wrinkles Measurements on CIPP Installation from AP2 to AP3	
Distance (Ft.)	Measurement (Inch.)
866'	1 3/4"
843'	1 1/4"
840'	Picture
755'	3/4" to 1 1/8"
682'	Picture
625'	1 1/8"
622'	1 1/8"
577'	1"
549'	3/4"
502'	1 1/4"
440'	1 1/2"

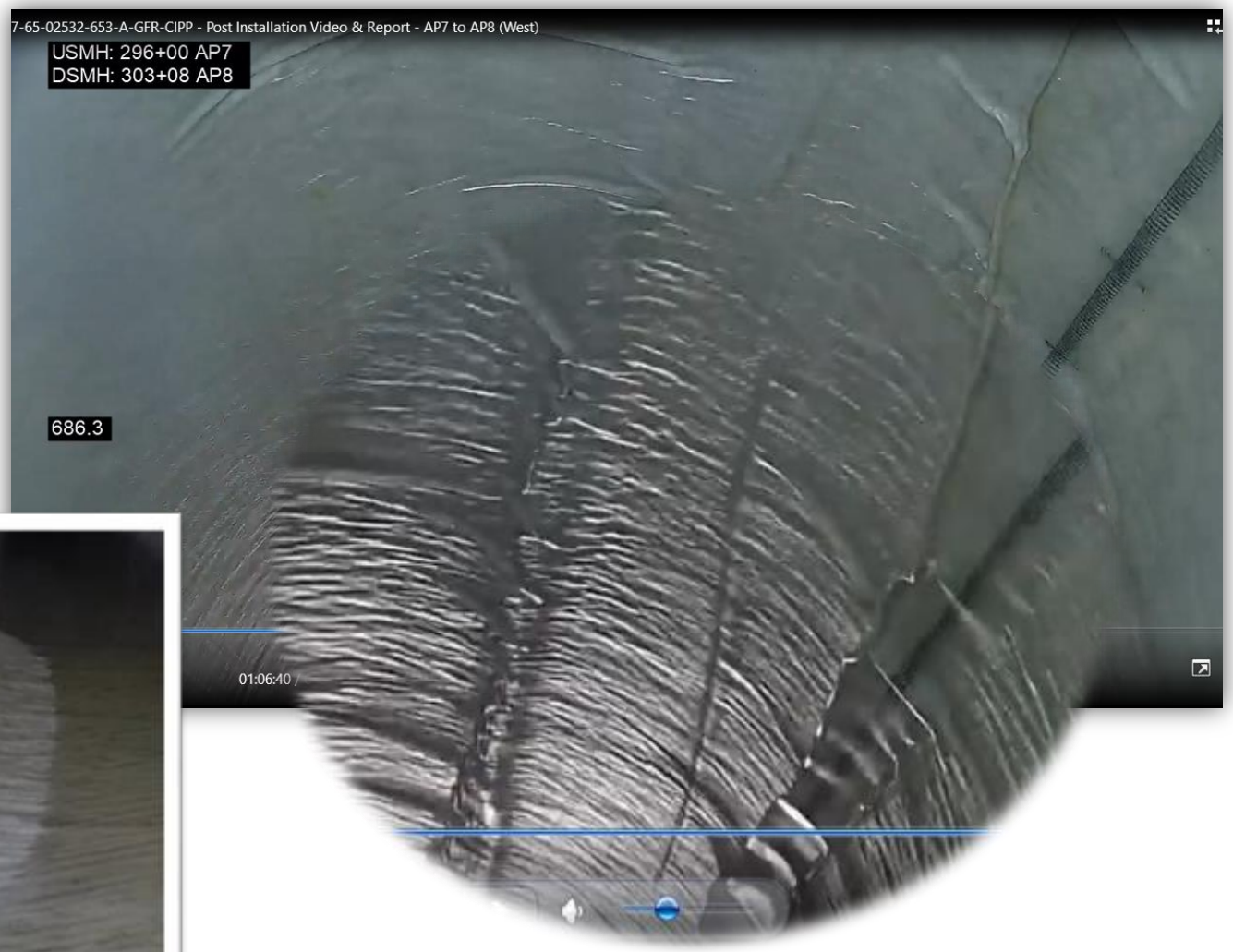
Industry guidance on allowable measurements for wrinkles:

- Outside flow line: 5% of nominal diameter (NASSCO)
- Lower 1/3 of pipe or flow line: 3% of nominal diameter, circumferentially oriented (NASSCO)
- Thickness no more than 2 times coated layer (TPU) thickness for pressure (NASSCO)
- Less than 2% of nominal diameter (AWWA C623)

Submittal Response – Example 2



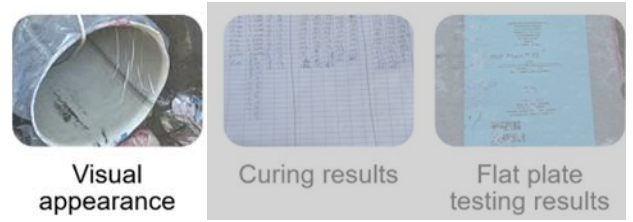
Concern	Action
Impedance of load transfer because of glass in wrinkles	Inspect wrinkles/folds to see if there is glass in them







Submittal Processing and Disposition



Concern	Action	Outcome	Disposition
Impedance of load transfer because of glass in wrinkles	Inspect wrinkles/folds to see if there is glass in them	Close up inspection and photos show “no glass present”	Defer to flat plate and require attestation from installer (ours are untrained eyes)



RE: OCSD – Wrinkles Discussion

To Whom It May Concern:

The purpose of this letter is to address the wrinkles seen in the OCSD installations post CCTV videos. Upon review of the videos and close-up photos, the wrinkles are within the coated felt layers and not in the reinforcing component of the iMain® CIPP Liner. Furthermore, these wrinkles have no structural impact on the installed liner and will not impact the pressure capacity of the liner. Based on research and development

Examples of Glass Reinforcement in Wrinkles

Figure 1 below shows examples of wrinkles within the reinforcing layers. This can be used to compare any wrinkles found in past and future installations.

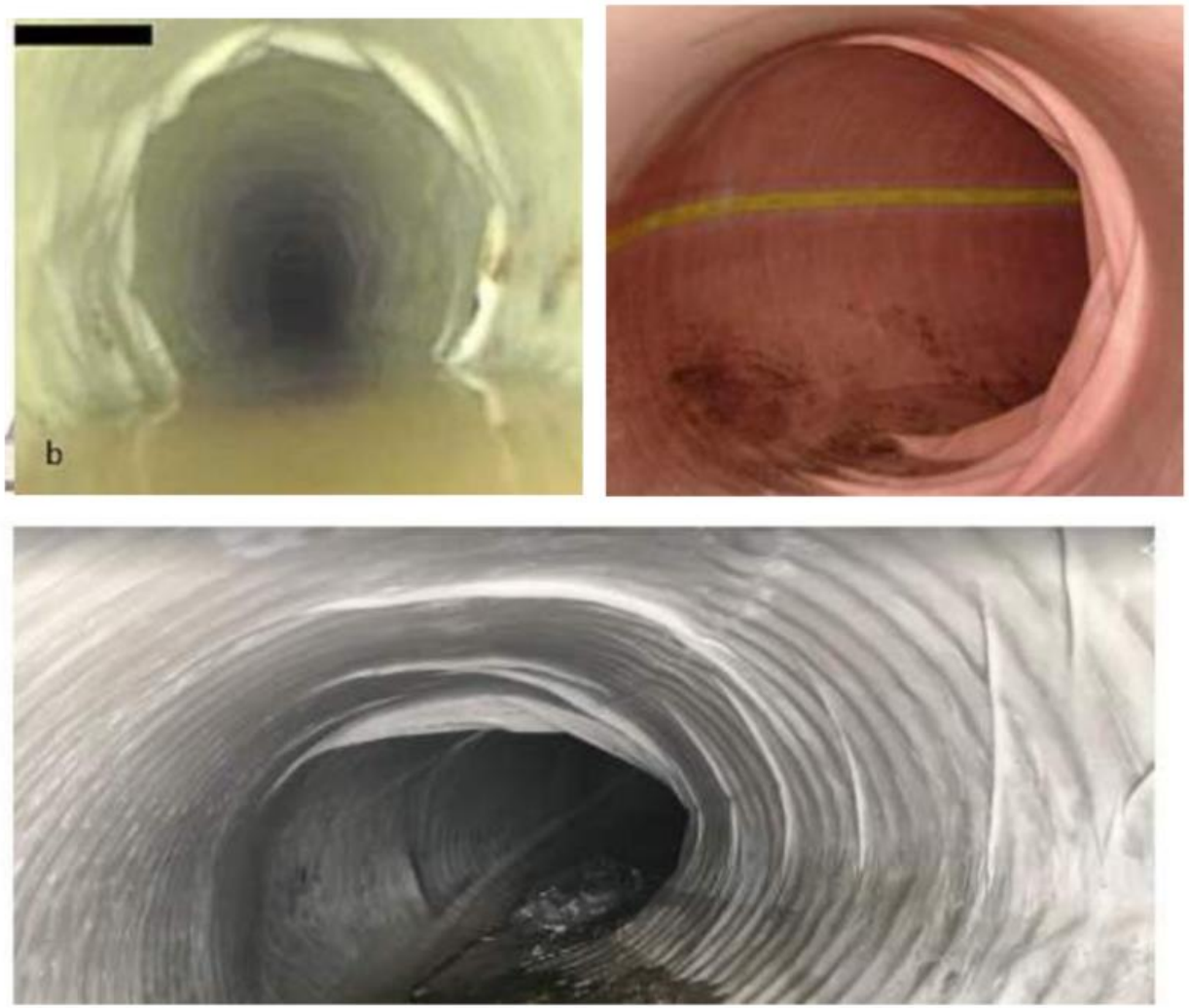


Figure 1 – Sample of Wrinkles with Glass Reinforcing

vs.

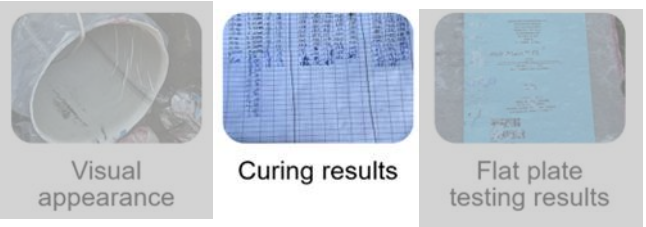


Figure 2 - Project 7-65 Wrinkles

Curing Results

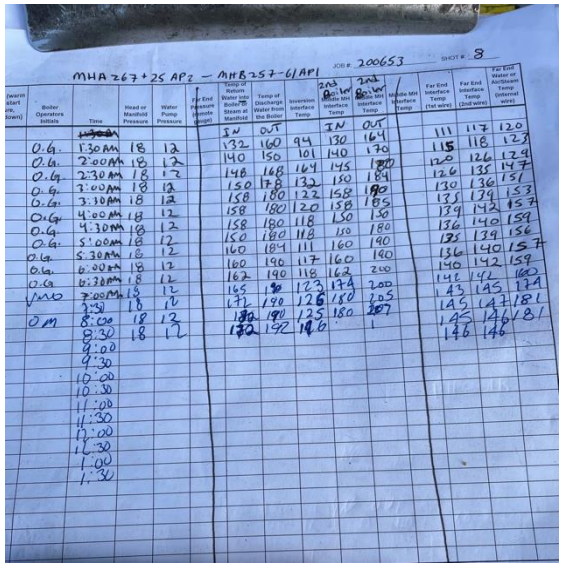


Contract Specification Requirements



F. Curing log, including temperatures, pressures, and times during the curing process to document that a proper cure has been achieved. Curing log is to be submitted immediately after the curing is complete for each line segment that is rehabilitated.

B. The heat source shall be fitted with suitable monitors to gauge the temperature of the incoming and outgoing heat supply. A temperature monitoring system placed in the invert of the host pipe and running the full length of the reach being cured shall be employed to confirm in real time that the required temperature for complete curing is achieved at all points in the liner.

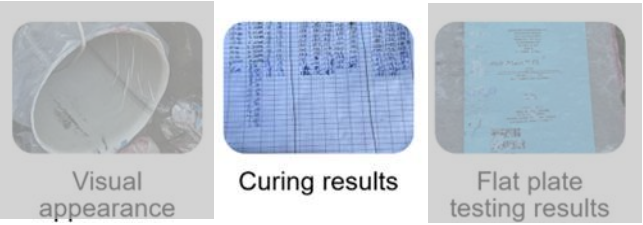








Curing Temperature Examinations



Component 1: Wet out log curing recommendations from resin manufacturer

Cure Schedule

Thermocouple Verification & Placement:

Daily Verification: Fill at least 8 oz. cup with ice & add water. Place & hold thermowire in ice water for at least 30 seconds without touching sides or bottom of cup. Document the S/N's and temperature readings below for every thermobox. If the temperature reading is outside of the range 0°C/32°F +/- 5° then discard the thermobox.

Placement: Place 2 thermowires at the far end and 1 in ***all*** other accessible manholes to measure interface temps (at 6 o'clock position).
Place 1 thermowire inside the tube at the far end (i.e. attach to condensate rod) to measure internal air/steam or water temp.

Water cure: If ANY of these temps can not be reached, contact the General Superintendent or Operations Manager.

1) Start cure time when the far end & return water temp is >= 180°F(82°C) ***and*** the minimum of all interface temps is: 140 °F 60 °C
2) Hold the cure time for: 6.0 hour(s) while maintaining these minimum temps.

Steam Cure: If ANY of these temps can not be reached, contact the General Superintendent or Operations Manager.

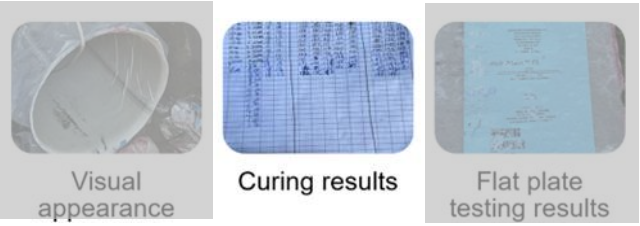
1) Start cure time when far end steam/air mixture is >=210°F(99°C) ***and*** the minimum of all interface temps is: 130 °F 54 °C
2) Hold the cure time for: 7.0 hour(s) while maintaining these minimum temps.

Extend Cure (water or steam) times for the following conditions:

1) Extend cure time for 1 hour for every 10 deg below the min interface. *For any interface below 115° F(46° C), the OM must determine next steps with engineering input.*
2) Extend the cure time for 1 hour when sags or dips are present.
3) Extend the cure time by 50% for deep installs (>12ft/3.7m) and when adding water to AISC.

Cool Down: For **steam cure,** maintain recommended head and cool down until all interface temps are ≤ 100°F/40°C.
For **water cure,** maintain recommended head and cool down until the internal water temp is ≤ 100°F/40°C.

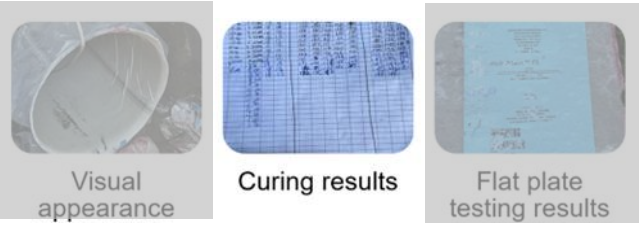
Curing Temperature Examinations



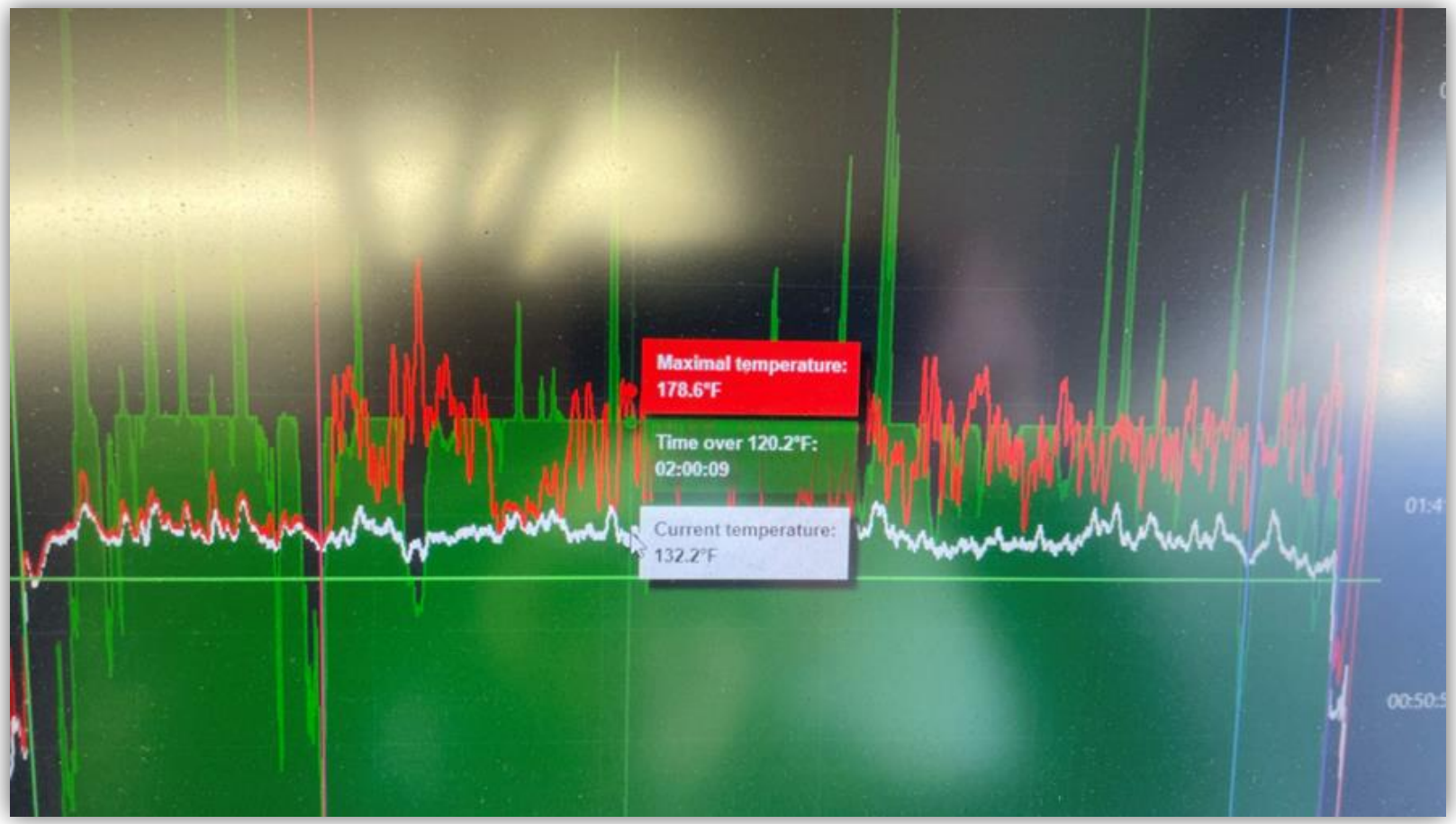
Component 2: Temperature readings from thermocouples at each end

Step (warm up, start cure, cooldown)	Boiler Operators initials	Time	Head or Manifold Pressure	Water Pump Pressure	Far End Pressure (remote gauge)	Return Water into Boiler or Steam at Manifold	Temp of Discharge Water from the Boiler	Inversion Interface Temp	Middle MH Interface Temp	Middle MH Interface Temp	Middle MH Interface Temp	Far End Interface Temp (1st wire)	Far End Interface Temp (2nd wire)	Water or Air/Steam Temp Internal wire)
	C.R	9:00	11	14		186	204	134				88	88	162
	C.R	9:30	11	14		186	203	128				99	99	181
	C.R	10:00	11	14		188	206	128				115	115	188
	C.R	10:30	11	14		188	206	132	start exotherm			130	130	186
	C.R	11:00	11	14		186	204	132				180	180	186
	C.R	11:30	11	14		186	190	133				159	153	189
	LO	12:00	11	14		190	190	135				155	155	191
	LO	12:30	11	14		189	190	137				155	155	195
	LO	01:00	11	14		189	180	136				154	154	193
	LO	01:30	11	14		190	190	135				156	155	190
	CH	02:00	11	14		191	191	135				155	155	193
						190	190	136				155	155	190

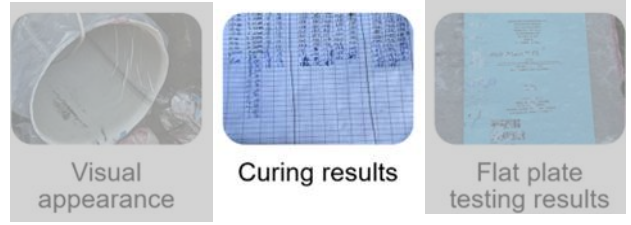
Curing Temperature Examinations



Component 3: Continuous temperature sensor (VeriCure) monitoring results

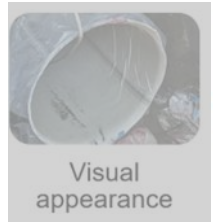


Temperature Reporting Discrepancies



Concern	Action	Outcome	Disposition
Cure schedule temperature documentation may not meet wet out log recommendations	Inquire with installer for significant disparities in hold times/temperatures	Live results are basis for decisions	Defer to installer; require attestation; await other QA/QC submittals

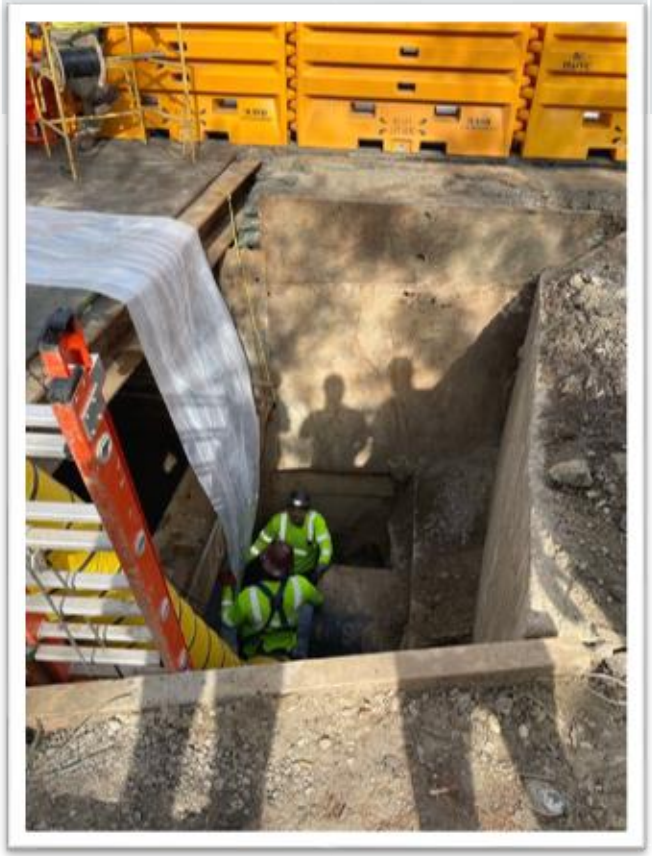
Temperature Reporting Discrepancies


Visual appearance

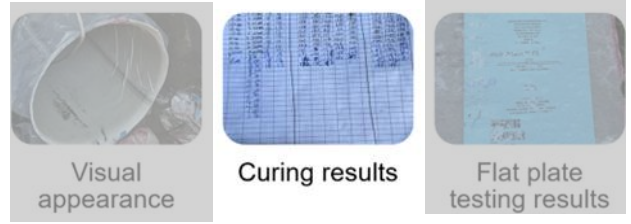

Curing results


Flat plate testing results

Concern	Action	Outcome	Disposition
Thermocouple readings ≠ Vericure reports	Inquire with installer	Preliner skews Vericure sensor readings	Defer to end thermocouples



Temperature Reporting Discrepancies



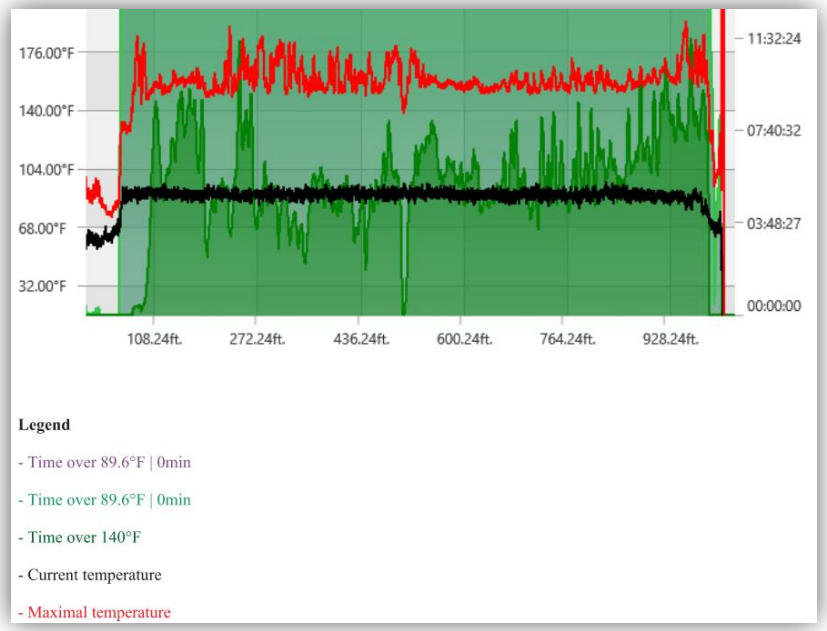
Concern	Action	Outcome	Disposition
Vericure reports missing input parameters	Require installer to populate input parameters	3D graph proves exotherm reached	Require input parameters populated for future shots

General information

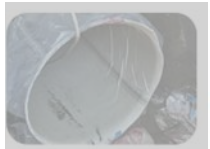
Holding	1039.76ft.
First measurement	3/21/2024 11:52:13 AM
Last measurement	3/23/2024 6:28:14 PM

Temperatures

Cure temperature	158.0°F
Overheat temperature	248.0°F
Heatinput	89.6°F, 0min
Heatinput	89.6°F, 0min



Temperature Reporting Discrepancies


Visual appearance


Curing results


Flat plate testing results

Concern

Temperature targets not reached through length

Cure Schedule

Thermocouple Verification & Placement:

Daily Verification: Fill at least 8 oz. cup with ice & add water. Place & hold thermowire in ice water for at least 30 seconds without touching sides or bottom of cup. Document the S/N's and temperature readings below for every thermobox. If the temperature reading is outside of the range 0°C/32°F +/- 5° then discard the thermobox.

Placement: Place 2 thermowires at the far end and 1 in *all* other accessible manholes to measure interface temps (at 6 o'clock position). Place 1 thermowire inside the tube at the far end (i.e. attach to condensate rod) to measure internal air/steam or water temp.

Water cure: If ANY of these temps can not be reached, contact the General Superintendent or Operations Manager.

1) Start cure time when the far end & return water temp is >= 180°F(82°C) *and* the minimum of all interface temps is: 140 °F 60 °C

2) Hold the cure time for: 6.0 hour(s) while maintaining these minimum temps.

Steam Cure: If ANY of these temps can not be reached, contact the General Superintendent or Operations Manager.

1) Start cure time when far end steam/air mixture is >=210°F(99°C) *and* the minimum of all interface temps is: 130 °F 54 °C

2) Hold the cure time for: 7.0 hour(s) while maintaining these minimum temps.

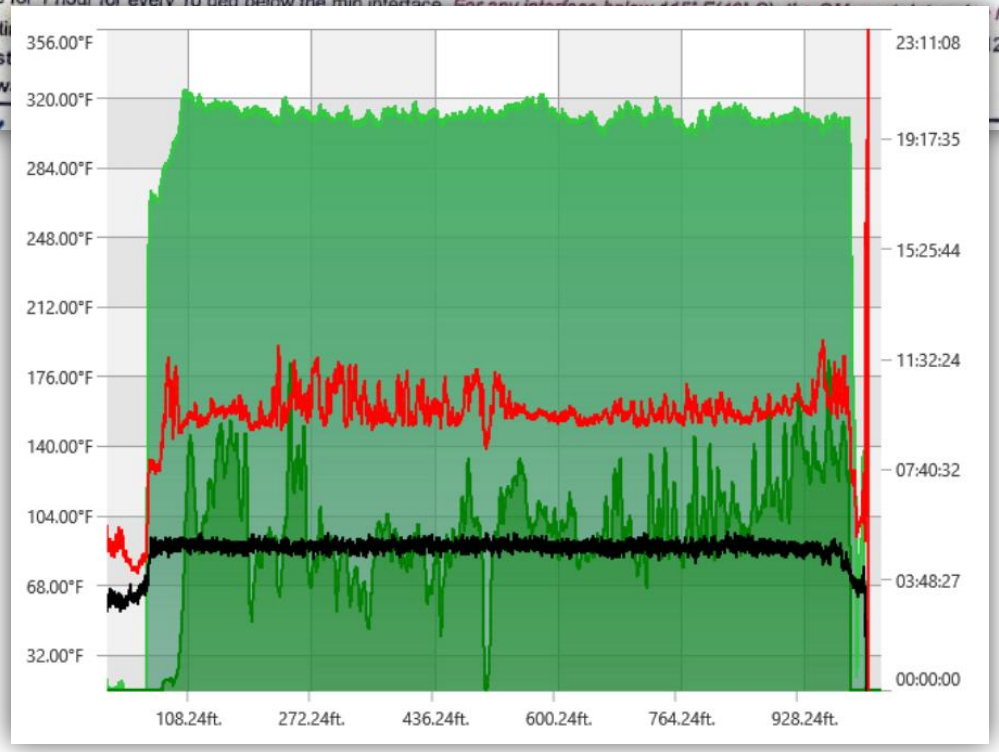
Extend Cure (water or steam) times for the following conditions:

1) Extend cure time for 1 hour for every 10 deg below the min interface. *For any interface below 115°F(46°C) the GM is to be contacted for next steps with engineering input.*

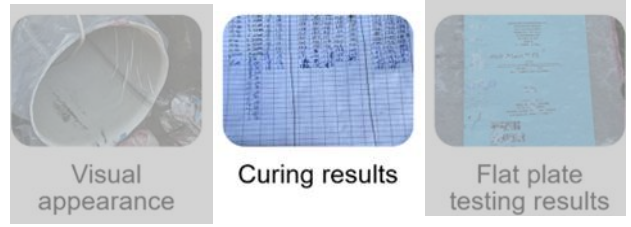
2) Extend the cure ti … (2ft/3.7m) and when adding water to AISC.

Cool Down: For st… For w…

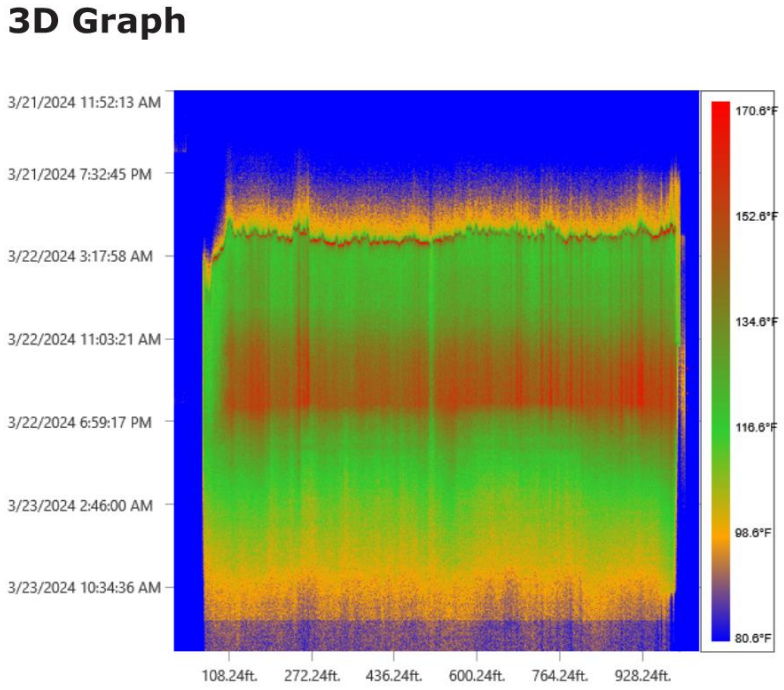




Temperature Reporting Discrepancies



Concern	Action	Outcome	Disposition
Temperature targets not reached through length	Request installer justify their disposition for a complete cure	3D graph proves exotherm reached	Exotherm ≠ complete cure. Defer to installer; require attestation



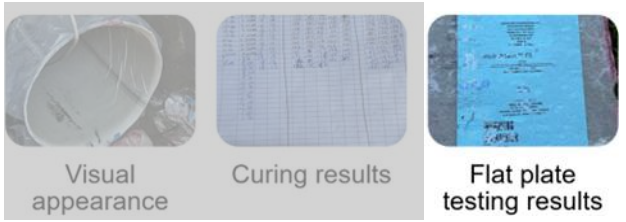


Flat Plate Sample Testing

POWER OF COMMUNITY

CWEA

Contract Specification Requirements



Minimum Physical Properties of the GFR-CIPP

EASTER PROPERTY SYSTEM	ASTM TEST METHOD	EPOXY SYSTEM
Flexural Strength	D790	7,000 psi
Flexural Modulus (initial)	D790	350,000 psi
Flexural Modulus (50-year)	D2990	175,000 psi
Tensile Strength (initial)	D638	6,500 psi
Tensile Strength (50-year)	D2990	4,000 psi

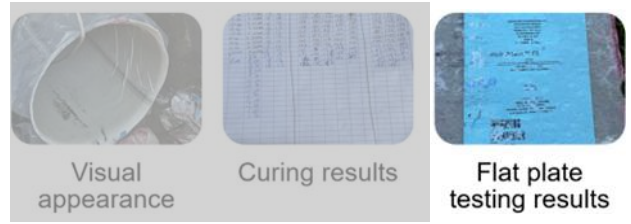
Confined samples for testing to conform the CIPP flexural strength, flexural modulus and thickness in accordance with the requirements of ASTM D5813, D790 and ASTM D3567 for each liner installed.

E. Samples shall be conditioned and prepared in accordance with ASTM D618 and ASTM D5813 to ensure consistency in laboratory results.

F. Flexural testing shall be in accordance with ASTM D790, latest version, with only the structural portion of the GFR-CIPP being tested.

G. Tensile testing shall be in accordance with ASTM D638, latest version, with only the structural portion of the GFR-CIPP being tested.

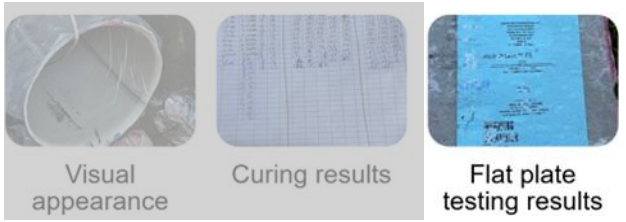
Flat Plate Samples – Required Tests



- Liner thickness
  - ASTM D3567: Standard Practice for Determining Dimensions of “Fiberglass” Pipe and Fittings
- Tensile strength
  - ASTM D638: Standard Test Method for Tensile Properties of Plastics
  - ASTM D3039: Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials
- Flexural strength
- Flexural modulus



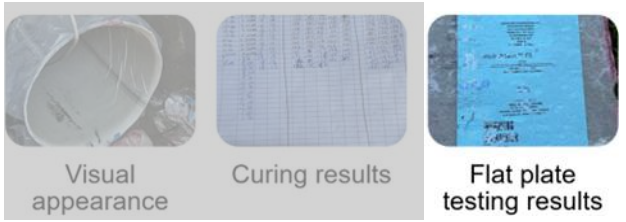
Flat Plate Sample Thickness Testing



Concern	Action	Outcome	Disposition
Thickness greater than design (>10%)	Confirm hydraulics are not compromised (internal hydraulic model check)	Hydraulics acceptable	Accepted



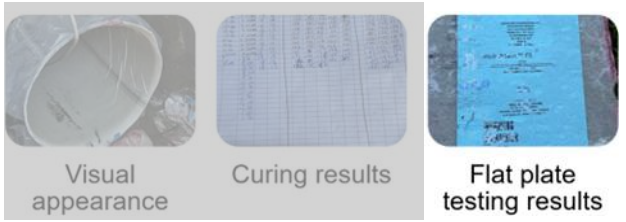
Flat Plate Sample Tensile Strength Testing



Concern	Action	Outcome	Disposition
Sample thickness exceeds max allowed for tensile testing per ASTM D638 (≤14mm)	Request to machine down samples >14mm per ASTM requirements	Machining compromises reinforcement and thus strength results; no issue testing on full thickness	ASTM methods based on plastics vs. composites; check ASTM D3039 testing protocol



Flat Plate Sample Tensile Strength Testing



Concern	Action	Outcome	Disposition
ASTM D3039 pertains to balanced/ symmetric fiber matrix vs. anisotropic materials	Reinforced tube is anisotropic; inquire with lab as to directional testing protocol	Tested in both directions per D638; went with strongest	No standard directly applies to project materials; defer to engineering judgement



Ultimate Outcomes and Takeaways

Acceptance Contingencies

- Stand-alone submittal results are not enough for resolution
- Deferred dispositions are pending
  - Other submittal results (perhaps two of three).
  - Hydrostatic testing results
    ("if any issues, won't pass")
  - Attestation/documentation by manufacturer/installer (CYA)
  - Commissioning (last box to check)
  - Warranty

During the warranty period, any defects that will affect the integrity or strength of the liner, collect solids, or reduce hydraulic flow capabilities of the product shall be repaired at the CONTRACTOR'S expense in a manner mutually accepted by the ENGINEER and the CONTRACTOR.



Takeaways

- Know that industry standards are outpaced by technology
- Prepare for results that are not black and white
  - Apply holistic approach
  - Use engineering judgement
- Ensure expectations are understood by all
  - Contractor may not appreciate how documentation (versus unsupported claims) translates to confidence





Q & A

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Thank you