Design & construction considerations for TT pipeline renewal

ICTIS: Instituto Colombiano de Tecnologías de Infraestructura Subterránea

AUGUST 22, 2016

BAMI-I
Buried Asset Management Institute - International

Louisiana Tech University
Trenchless Technology Center

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- Professor, Louisiana Tech University
- Director, Trenchless Technology Center (TTC)
- Chair, Buried Asset Management Institute-International (BAMI-I)

Historical Overview of CIPP

- HISTORY OF CIPP
  - ✓ CIPP lining process was invented by **ERIC WOOD**, the founder of INSITUFORM TECH, and first used to line a VICTORIAN BRICK EGG SEWER IN HACKNEY, LONDON, ENGLAND in 1971.
  - ✓ Designed for **50+years additional service life**
  - ✓ Lab tests proved excellent material performance of the first project by BODYCOTE MATERIALS TESTING LTD. In 2001. 30-year samples proved **the strength of the lining has improved over the years**

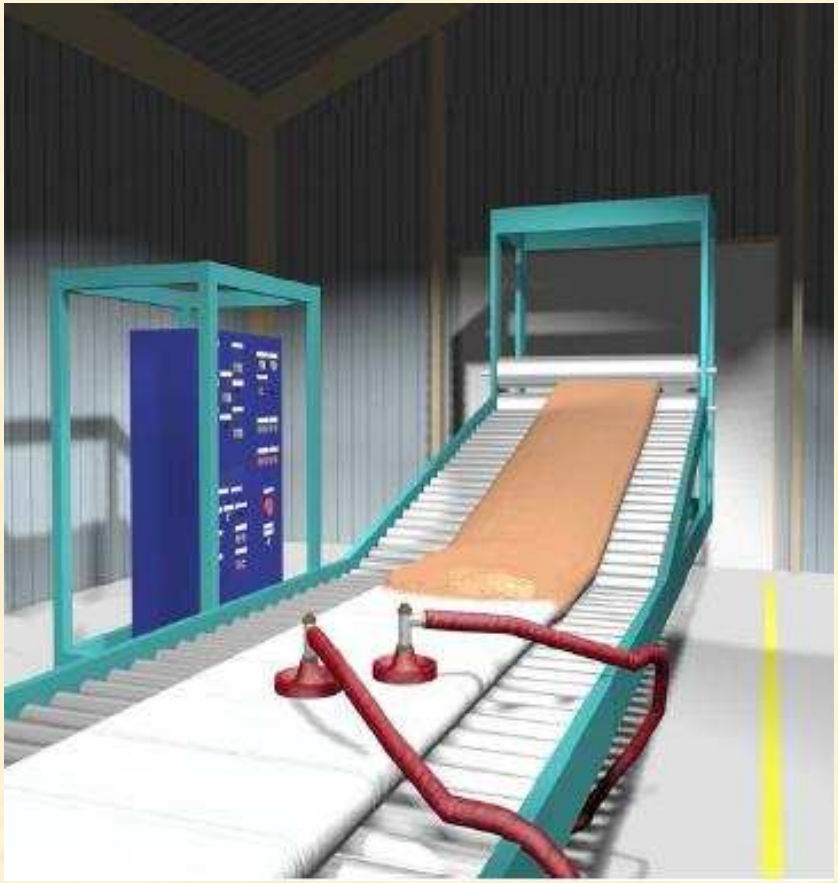
CURED-IN-PLACE PIPE

- CIPP – Materials
  - Resins
    - Polyester
    - Vinyl Ester
    - Epoxy
    - Silicate
  - Polymerization process activated by initiators

Styrene during polymerization

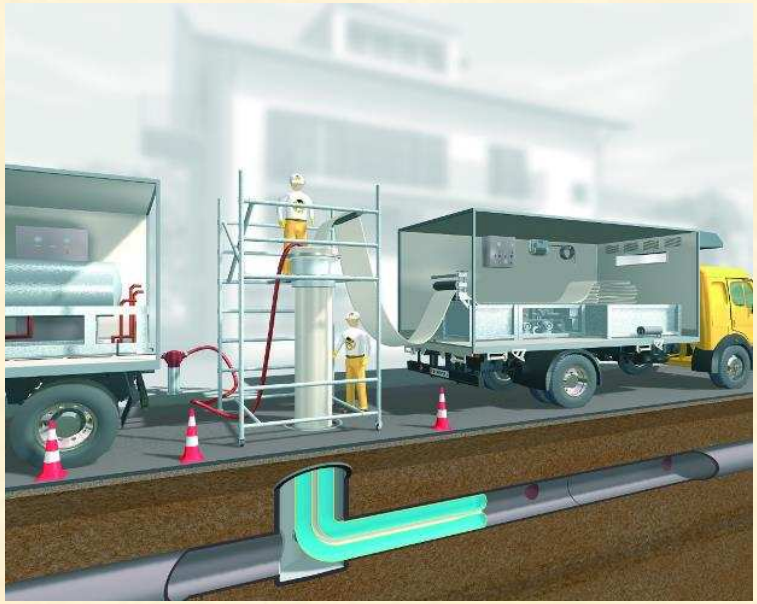
CURED-IN-PLACE PIPE

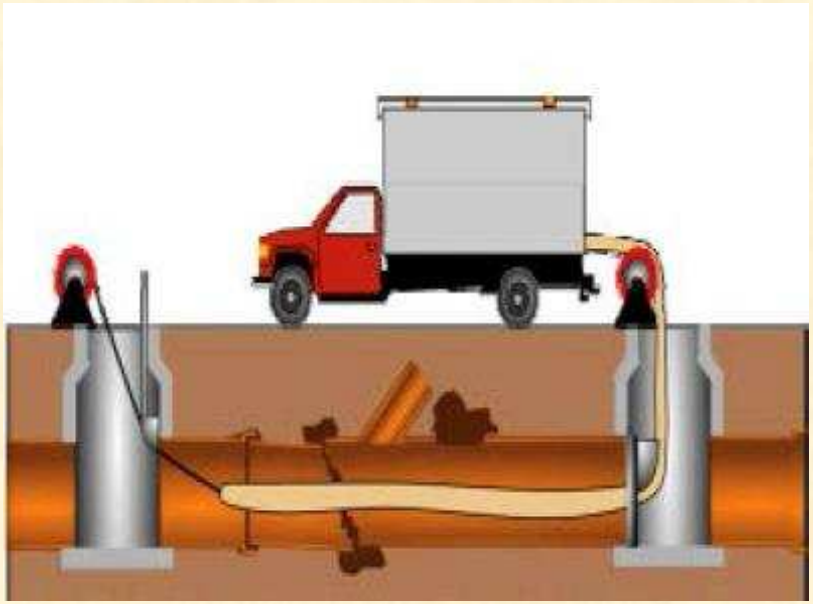
- CIPP – Preparation
  - Resin will be impregnated into the tube liner.
  - Mostly done in factory and process is controlled by negative pressure pump.
  - Resin can be impregnated near construction fields due to:
    - Size
    - Quantity
    - Logistics
    - **Temperature must be controlled**



CURED-IN-PLACE PIPE

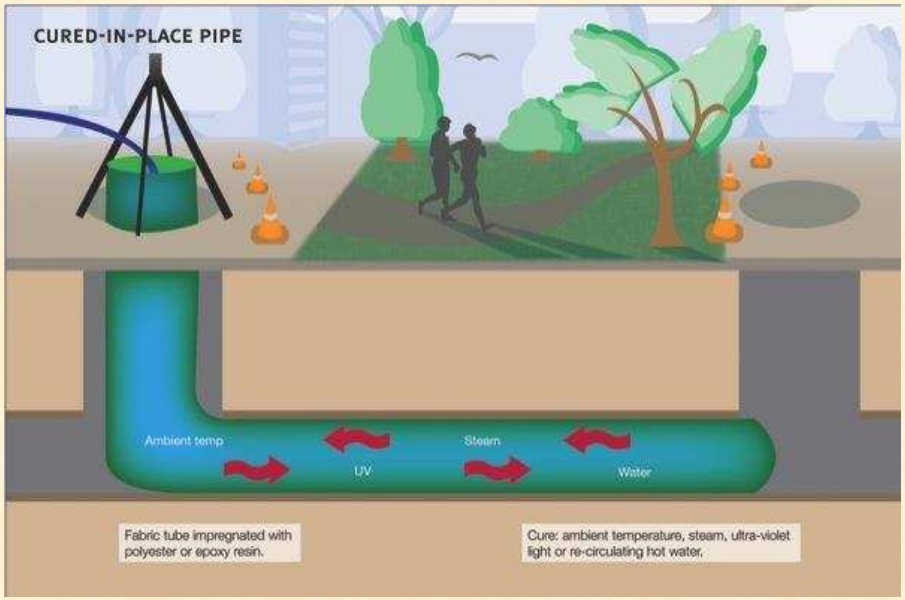
- CIPP – Installation
  - A typical CIPP is installed using inversion technique.
    - Hydrostatic pressure
    - Air pressure
  - Pulled in place is also a common method for CIPP installation





CURED-IN-PLACE PIPE

- CIPP – Curing
  - Curing process is initiated by hot water, steam, air, or UV
    - Temperature varies depending on the resin design



CURED-IN-PLACE PIPE

- CIPP – Cutting
  - Cooled liner must not shrink more than minimum allowable
  - Any annular space shall be filled with suitable materials
  - Cutting is a critical part of curing process
  - Cutting should start after appropriate cooling process and draining

VeriCure

CIPP Curing Monitoring System

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Presentation Outline

1. CIPP lining business = very competitive
2. Conventional practice:
   a. Temperature measurement is one area of real weakness
   b. Heat sinks unknown
   c. Leads to under/overcooking
   d. Lack of knowledge = failure to adequately control costs
   e. Quality control is fragile
3. Fiber optics – new technology for reducing risk = improving margins & quality
4. Fiber optic installation and operation
5. Cost and implementation

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CIPP Process

Complex mix of equipment, chemistry, crew knowledge/capability and time

Looking for an edge:

1. Equipment –
   - Boiler capacity, BTUs
   - Cutters – faster, better robots
   - Hoses, shooters

2. Temperature monitoring
   - Conventionally rudimentary

3. Foreman/crew knowledge
   - Only as good as the temperature intelligence they have

CIPP Cure:
Overcoming Heat Sinks

Achieving kick target

- Target temps 150-160 F
- Cool down controlled to avoid tensile failure
- **Temperature monitoring with two data points**

Poor temperature intelligence leads to over and under-cooking

Pipeline Renewal TECHNOLOGIES

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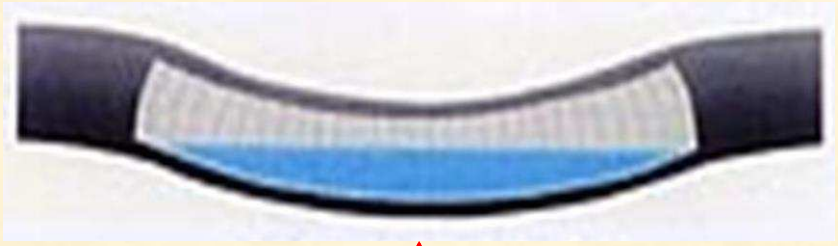
Heat Sinks – where are they?

Pre-bid and pre-project meetings don't often review ground water issues with pipe to be relined.

- Sags and Low Spots
- Moving Ground Water
- Protruding Service Connections
- Lack of Circulation
- Stratification of Heating medium
- Creating adequate BTUs (boiler capacity)

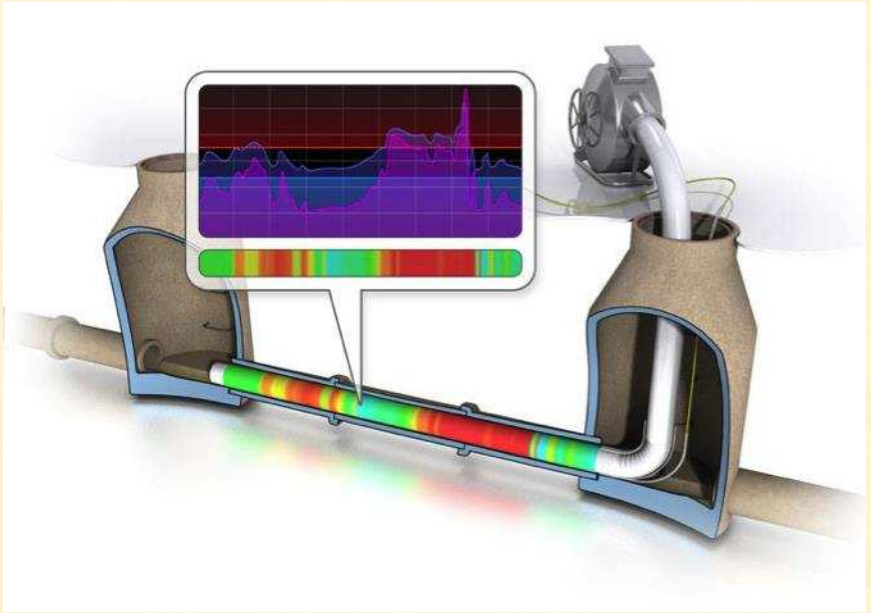


Sag – typical heat sink

Business paradox: Contractor rarely knows about heat sinks that can ruin a good installation

What is VeriCure?

VeriCure is a system that uses patented laser technology, specialized fiber optic probes and intuitive software to monitor temperature during CIPP cure. Compared to other methods, VeriCure offers:



- Continuous coverage ***in real time***
- Laser pings cable, reads oscillation of heated fiber optic molecules
- Increased resolution and detail = ***lifts can't hide***
- Crews watch graphics for real time temperature profiles of cure

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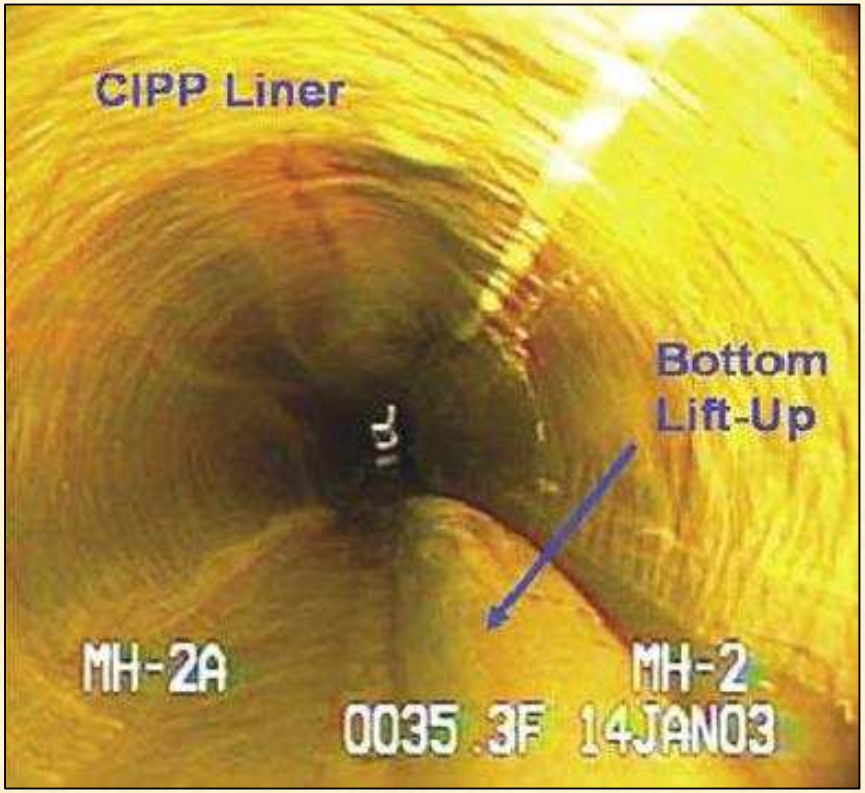
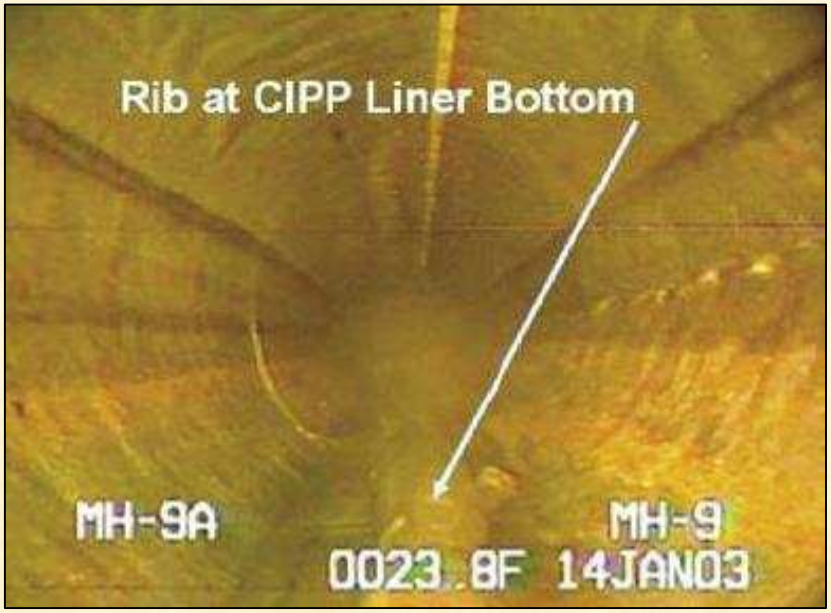
Failure to overcome heat sinks = Lifts

- Soft liner with no or poor cross linking
- Immediate or delayed





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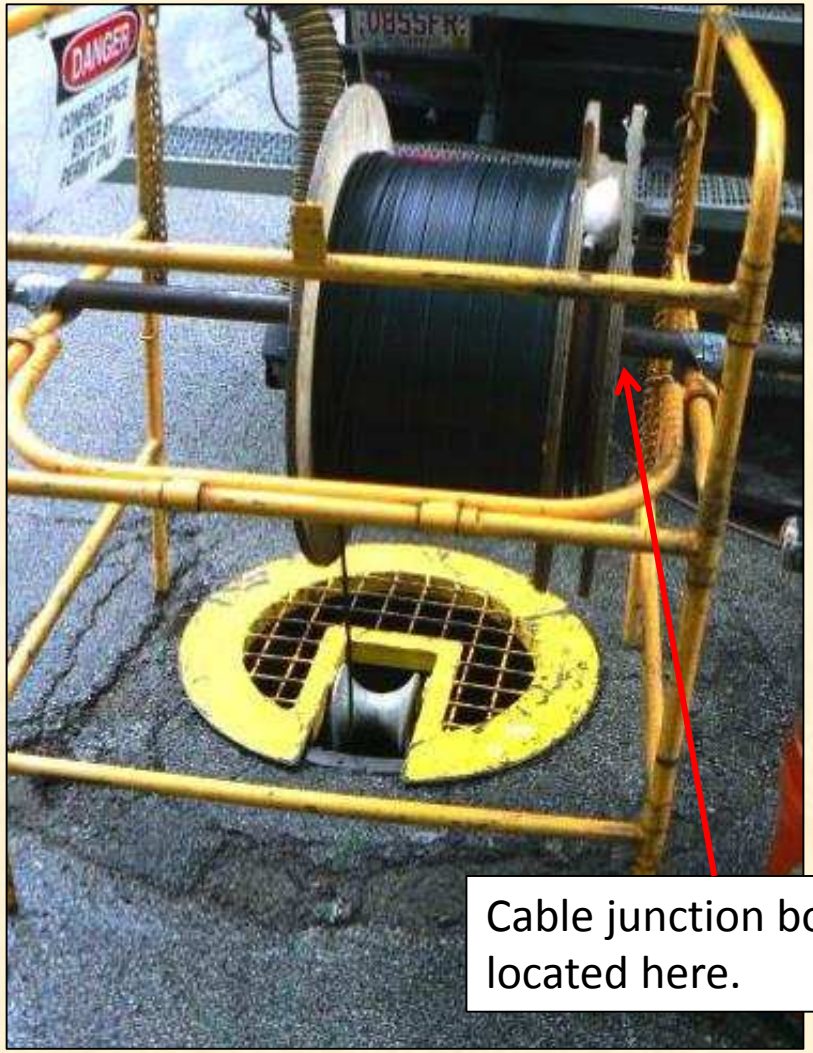
Fiber Optic Deployment & Operation

Technology

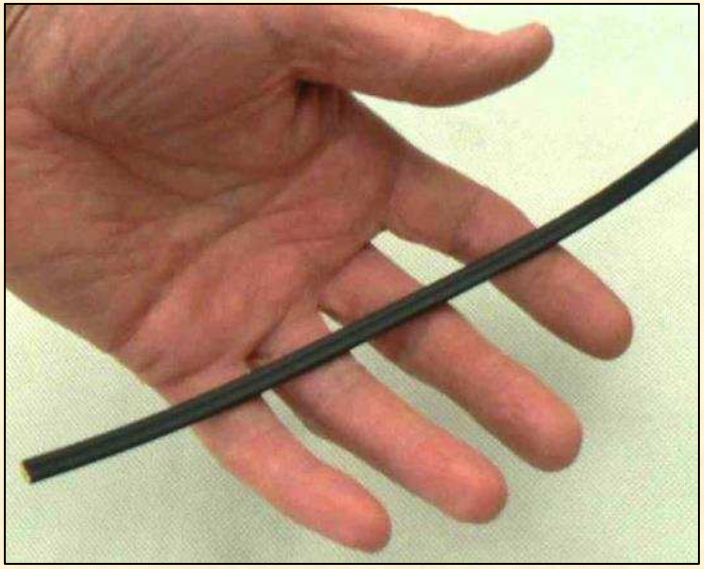
- Cable is spooled in 6,400 ft lengths or
- Pre-cut for project
- Cable junction box is housed inside reel
- Connector cable attaches to junction box then to control unit



Reliable & Unobtrusive Measurement

VeriCure probes are especially suited to the harsh conditions and dimensional constraints of CIPP relining:

- No electronics (intrinsically safe; heat and moisture tolerant)
- Just 3mm in diameter; no flow disturbance
- Compact spool for easy deployment
- Tolerates bending/flexing
- EMI/RF issues
- Cable marked every foot



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Installation

Lay Vericure fiber-optic cable between manhole before inverting or pulling in resin impregnated CIPP liner

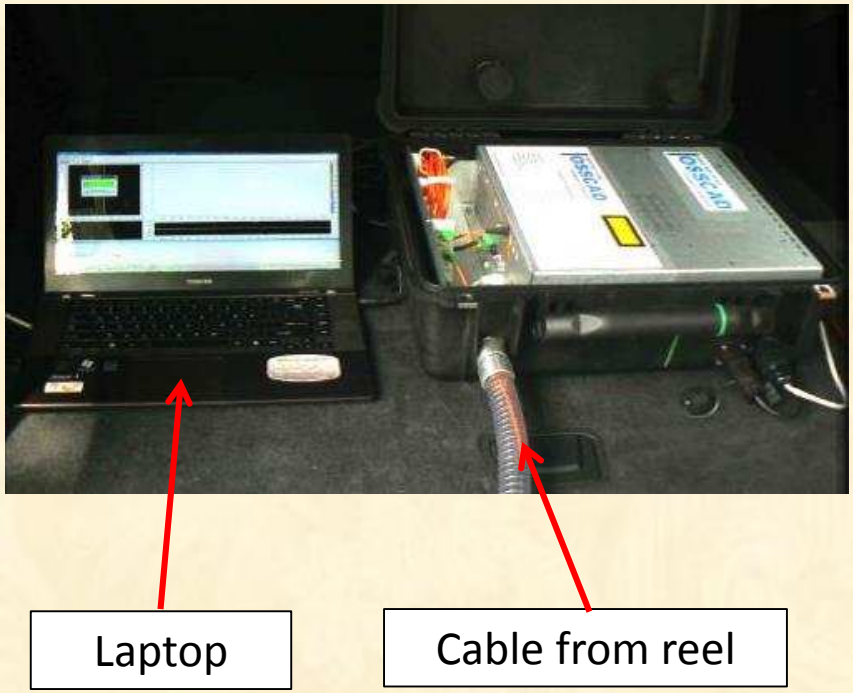
Connect to control unit

Control Unit

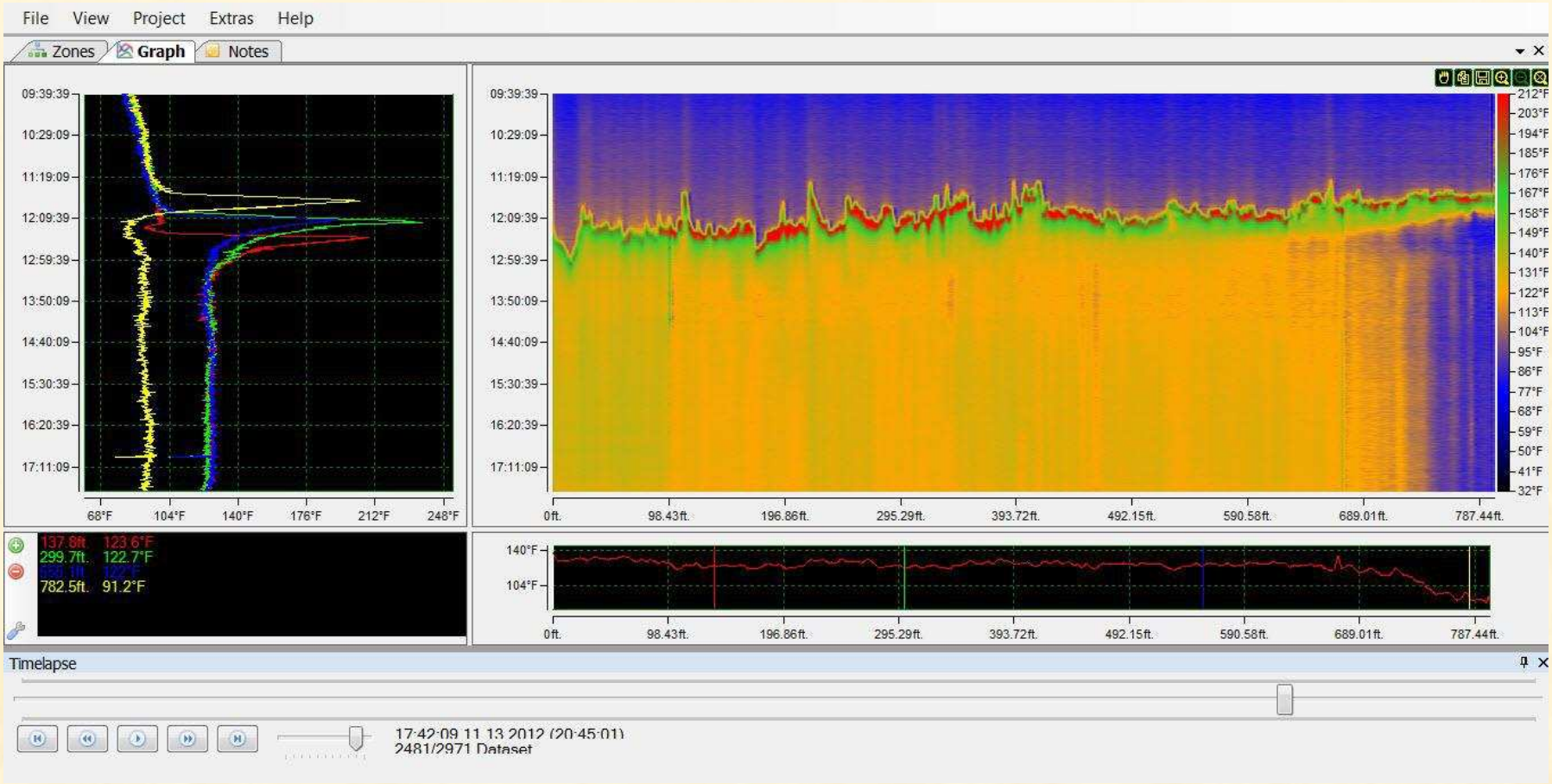
VeriCure's control unit collects data, outputs reports in real time

- Indicators showing completion of cure, post cure and cool-down
- Jog controls for historical analysis
- Easy setup of parameters like cure temp, dwell time and cool rate

- Graphic reporting to document Success.



VeriCure software – 3 dimensional view of liner cure



No guessing about cure -
Crews watch graph to determine that target temperatures have been achieved.

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Benefits of fiber optic temperature profiling

Removes cure uncertainty

- Foreman has great information
- Cook only as required
- Eliminates under/over cooking

Operational benefits

- Reduces unnecessary crew & fuel costs related to over cooking
- Savings: $500+ per hour
- Time savings = additional lining per
- Week
- Quality assurance tool for inspectors and agency

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Operational benefits, cont.

Business benefits:

1. Improves crew efficiency
2. Increases crew utilization
3. Sharper pencils for competitive bidding
4. Greatly educes rework – lifts, delaminations, dig ups
5. Builds management confidence

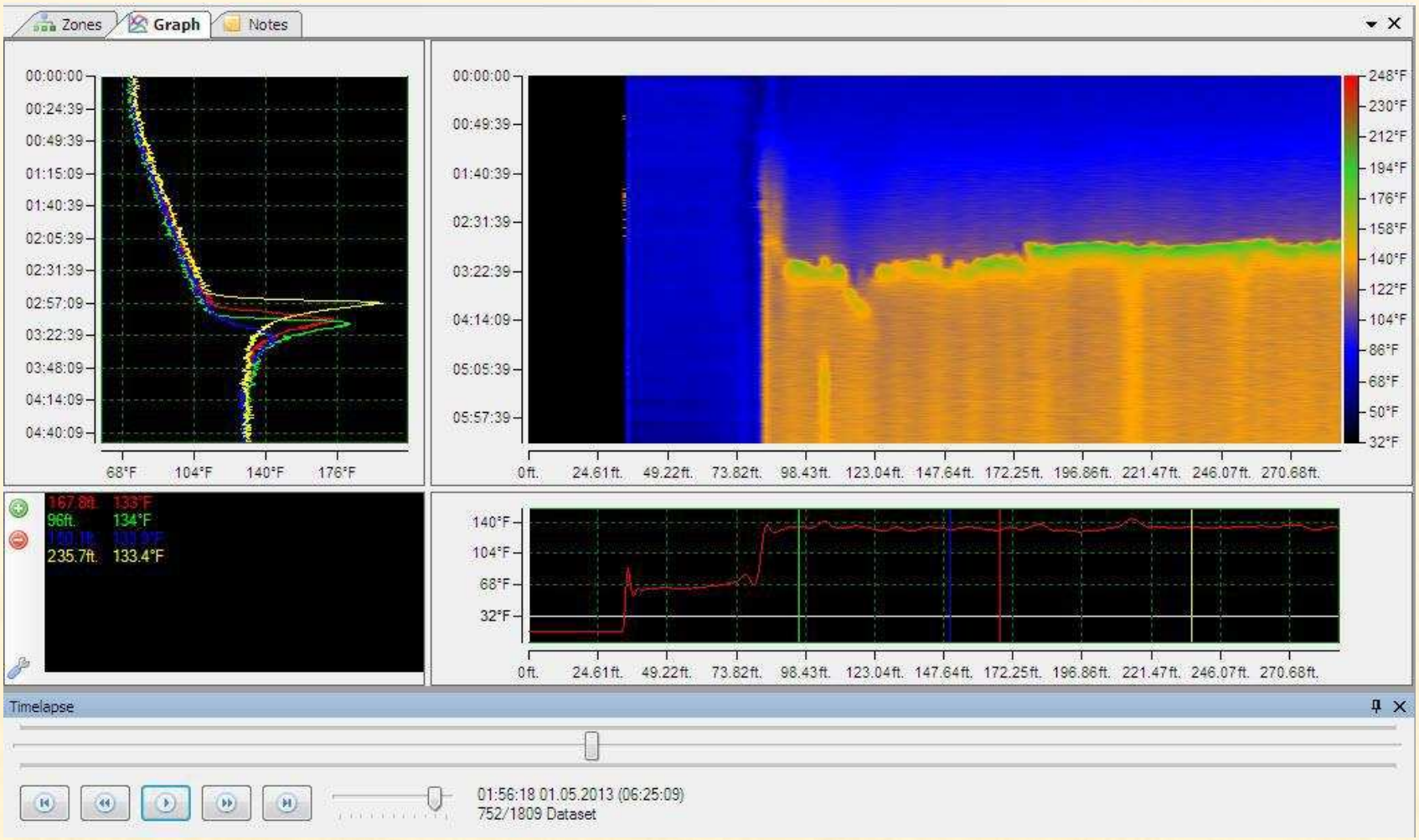
Bottom line: Better project control and less post lining rework = better margins

Contractor Costs & Implementation

Operational costs:

- Cable: 1,950m spools – approx. $6.60/m
- or Pre-cut for job - >$6.60/m (slightly more)
- Controller – rental @ $1,500/week or
- outright purchase @ $60K
- Training/certification: $1,250/day 2 weeks
- advanced notice; $2,000 less than 2 weeks notice

CIPP-Centric Data Presentation



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Resource Optimization

Because VeriCure tells you exactly when CIPP cure goes exothermic, and when post cure and cool-down are complete, you can save resources by avoiding:

- Overcooking
  - Wasted fuel - $30-50/hour
  - Wasted crew time
  - Inconvenience owner's customers

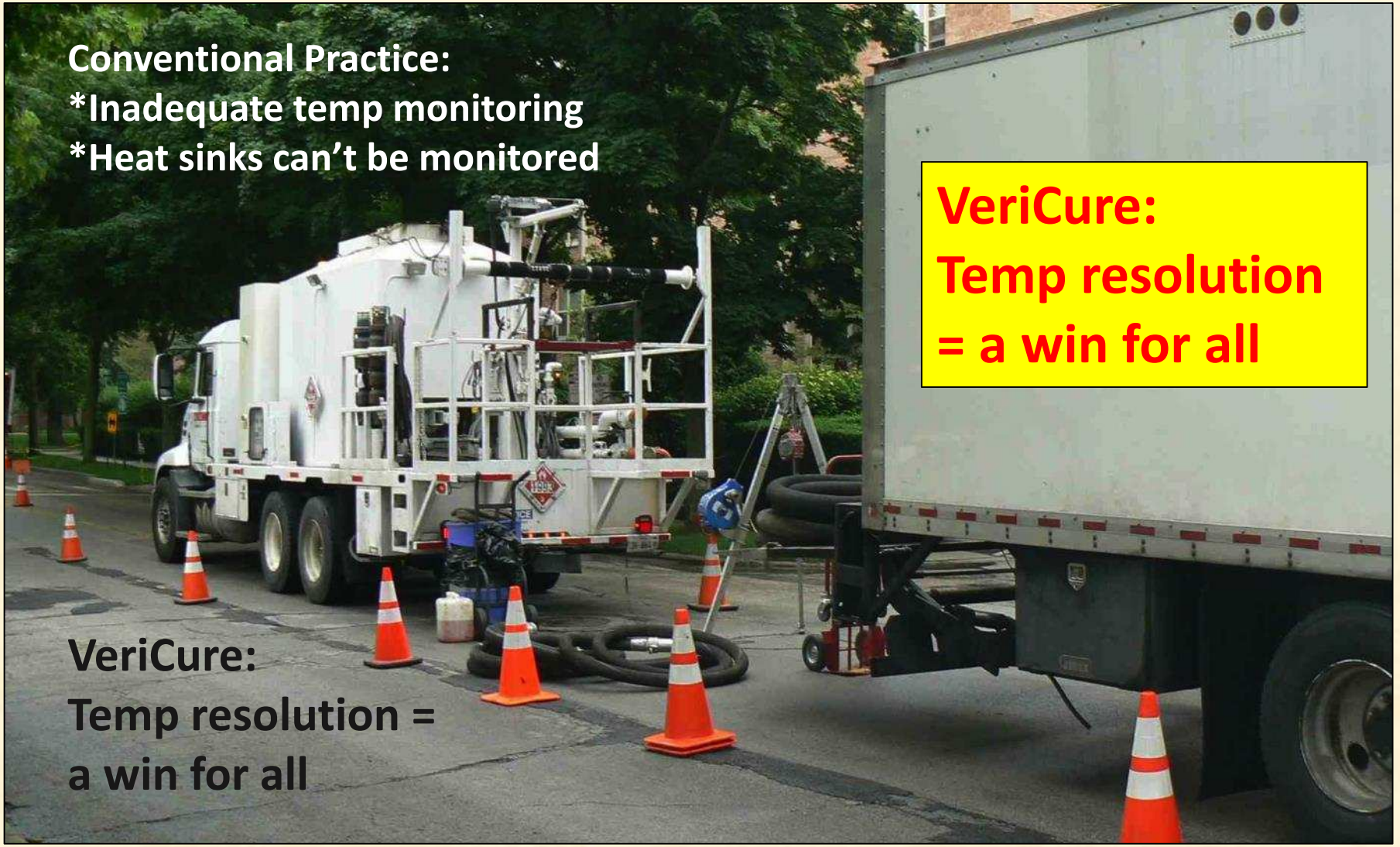
- Undercooking
  - Expensive repairs
  - Risk of failure

Quality Assurance

The data from VeriCure documents that storm and sewer lines have been rehabilitated to specification, and will perform as intended without costly:

- Lifts
- Delamination
- Over-tensioning
- Environmental contamination

Summary



Pipeline Renewal TECHNOLOGIES

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Reliability

How reliable is this technology?

This technology is relied upon extensively in punishing, mission critical applications such as:

- Oil/gas
- Aerospace
- Concrete - layered installations for dams and skyscrapers

Installation history

- 10 states
- Dozen contractors
- 8” – 102” (200mm to 2,590mm)

When to use VeriCure?

Does this get used on every line?

Our results show that the conditions causing longitudinal temperature variance are hard to predict, regardless of line size. That said, we believe the design engineer should determine when continuous temperature monitoring should be used.

Small pipe considerations:

* Known ground water infiltration
* Adjacent to bodies of water: streams, rivers, lakes or oceans
* Storm drain influences

VeriCure Technology

- The internal reflectance of optical fiber changes predictably with temperature.
- Measuring the reflectance (or backscatter) of laser light pulsed through this fiber yields temperature readings accurate to within 0.1°F.
- Correlating transit time of laser pulse to the speed of light allows you to pinpoint the position of measurements

Does the probe compromise liner strength?

Our probes measure less than 3mm diameter. If a liner cannot accommodate dimensional variations on this scale, the industry has much bigger problems.

Introduction to New Generation PVC Liner for Sewer, Storm Drain, Water Main, Gas Main & Other Suitable Utility Rehabilitation

About DynaLiner LLC

- Formed in Birmingham Alabama in 2013
- Mission - Be the premier supplier of PVC Folded/Formed pipeline rehabilitation products in the world.
- Supply products of consistent high quality to the pipeline rehabilitation market and to provide outstanding technical and product support to our installers.
- New company but the principals and founders have decades of experience both in manufacturing and installing PVC liners
- Close affiliation with a manufacturer, who has over the past two decades manufactured Folded/Formed PVC pipe lining products for several companies

General Properties of DynaLiner

- Liner is chemical resistant
- Completely non-toxic, not harmful to the environment
- Passed testing for NSF-61 certification
- No chemicals required – in shop or on the job site
- Much smaller installation footprint and uses less energy to install than other PVC or CIPP liner systems
- Uses low pressure steam for initial preparation as well as the later inflation/profile conforming process
- Low pressure process – minimize general hazards and potential damage to host pipe during installation
- Quickest installation time compare to all or most competitors
- Manufactured under full quality controlled environment in modern precision facility to meet engineer's design specifications

About DynaLiner's Technology

- DynaLiner is a PVC Folded/Formed pipeline rehabilitation system
- Custom PVC compound that was developed specifically for use in pipeline rehabilitation.
- Key advantages of this revolutionary compound is its ability to allow heat to transfer through the material more quickly than other products currently on the market
- The enhanced heat transfer characteristics of the DynaLiner material allows for:
  - ✓*Larger diameters (up to 36") than other similar products*
  - ✓*Faster processing time*
  - ✓*Greater ability of the liner to conform to pipeline irregularities*
  - ✓*The ability to accommodate reasonable variations in pipeline diameter*

About DynaLiner's Technology

- DynaLiner is extruded in a factory in the same manner as conventional PVC Pipe
- While still hot, the extruded pipe is folded into either a "C" or "H" shape prior to being wrapped on a coil
- The length of each coil is determined by the needs of each individual project
- Manufactured in a controlled environment, the physical properties of the liner are verified prior to shipment
- The liner's final physical properties are not affected by the installation process
- When properly installed, it provides a continuous, structural PVC pipe between sewer manholes, water valves etc.
- The finished liner will be molded tightly and conforming to the internal cross sectional profile of original host pipe.

Lining with PVC Liner

- The liner shall be fabricated to size which, when installed will fit the internal circumference of the pipe as specified by the Engineer;
- Allowance for circumferential expansion during installation shall be made;
- Minimum liner length shall span the distance from the inlet to the outlet of the pipe to be lined;
- Minimum wall thickness of the liner shall be determined by design calculations of a Professional Engineer;
- The supplied liner shall meet all the requirements for cell classification 32333, as defined in Specifications ASTM D-1784 complying with the minimum physical properties required

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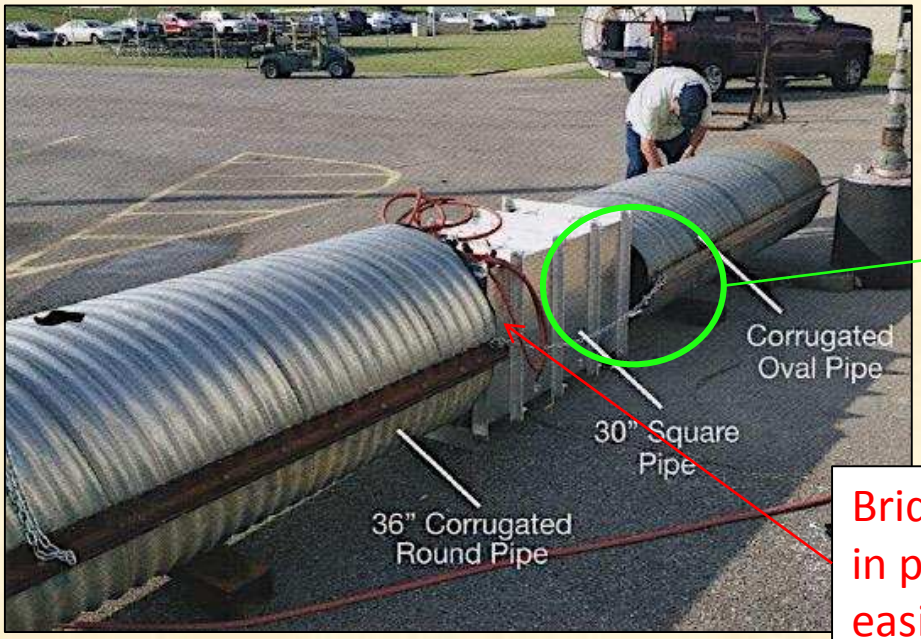
DynaLiner's Physical Properties in compliance with cell classification and ASTM standards

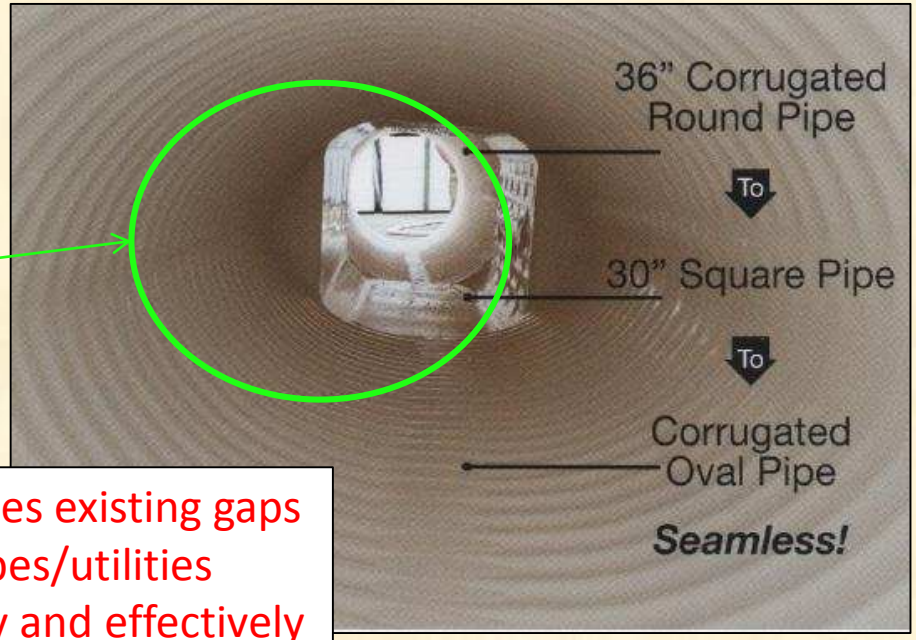
Coefficient of Linear Thermal Expansion	ASTM-E831	3.76×10^{-5}	in./in/°F
Tensile Strength	ASTM-D638	5000	psi
Tensile Modulus	ASTM-D638	320,000	psi
Flexural Strength	ASTM-D790	8,000	psi
Flexural Modulus	ASTM-D790	350,000	psi
Specific Gravity	ASTM-D792	1.35	
IZOD Impact	ASTM-D256	0.90	ft./lb/in

Unique Properties of

New Generation DynaLiner PVC Liner

Liner molds seamlessly to deviations of internal diameter or changes physical cross sectional shapes of utility being rehabilitated

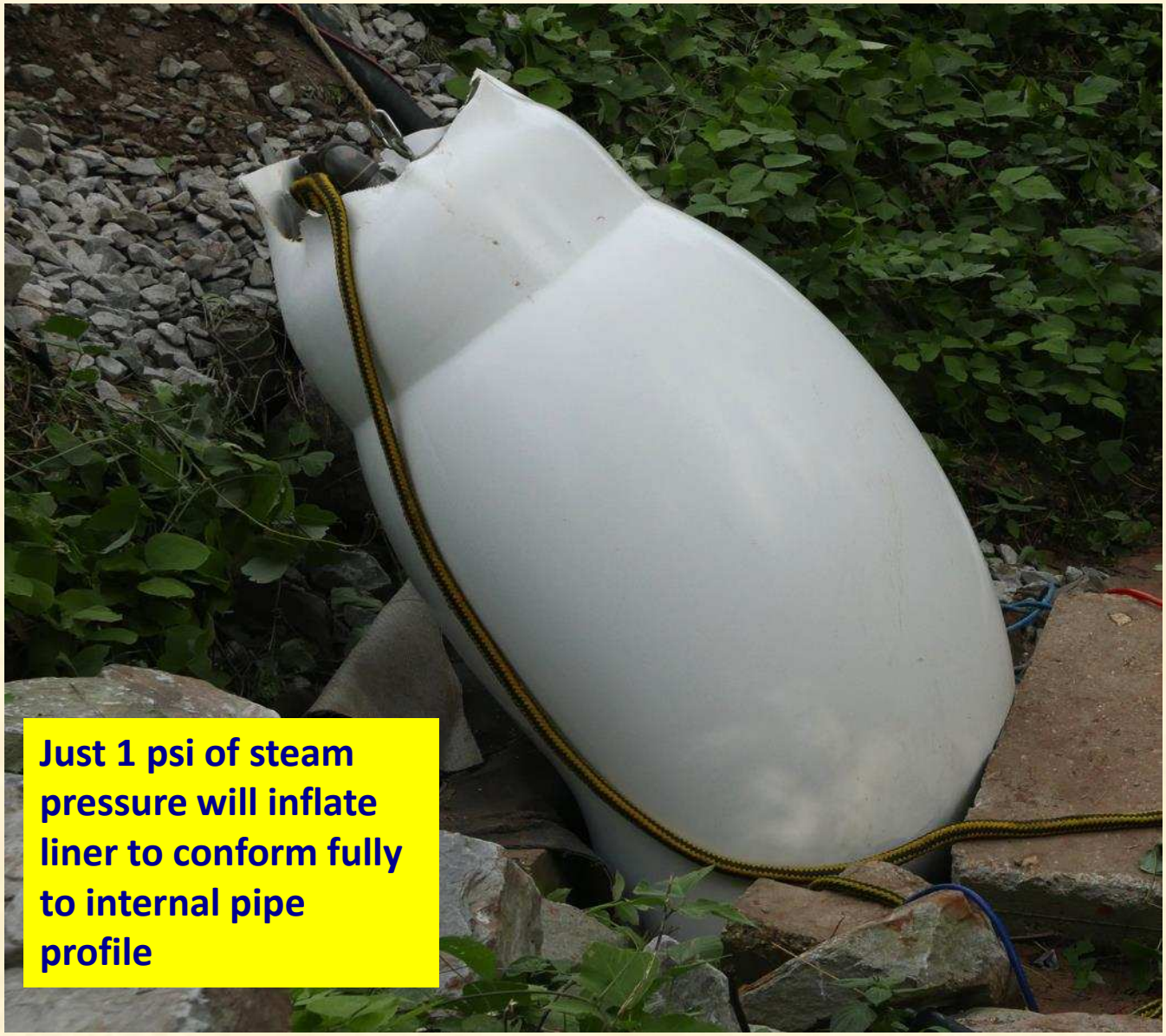




Bridges existing gaps in pipes/utilities easily and effectively

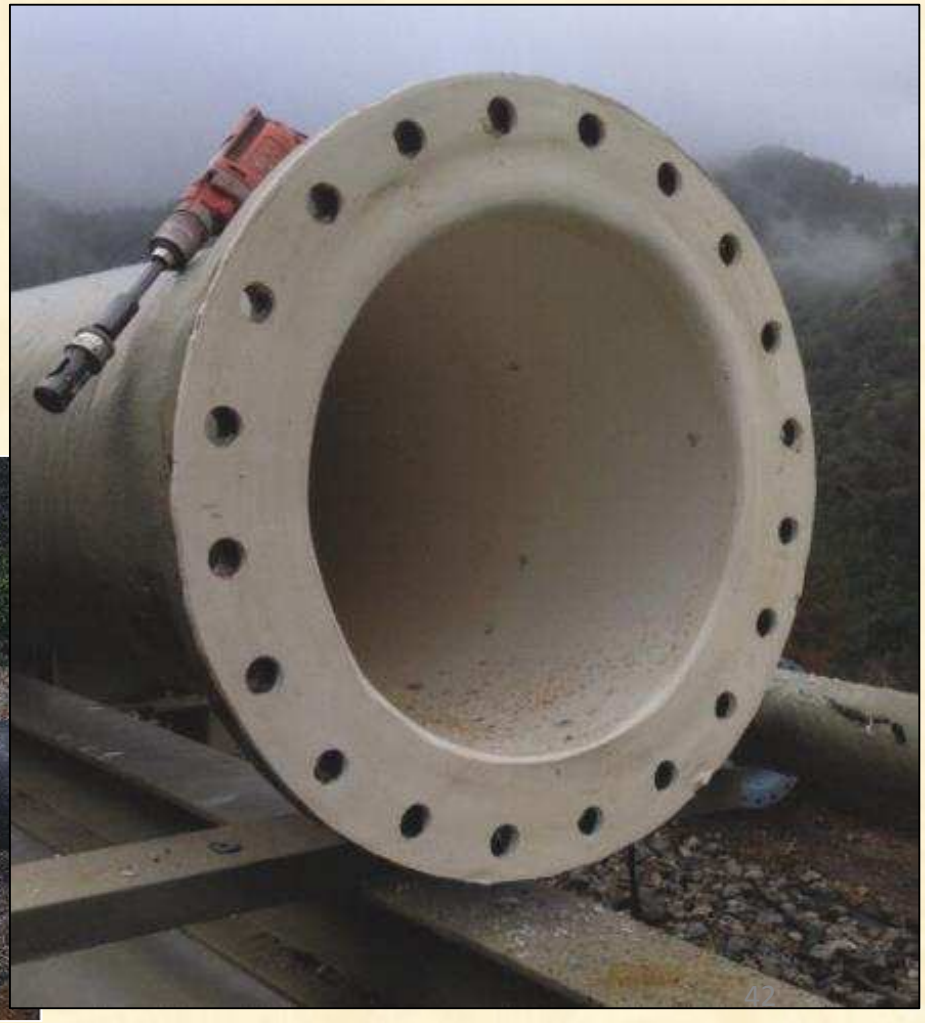
DynaLiner able to confirm to round, square, oval and the spirals of corrugated pipe

Relatively easy installation process



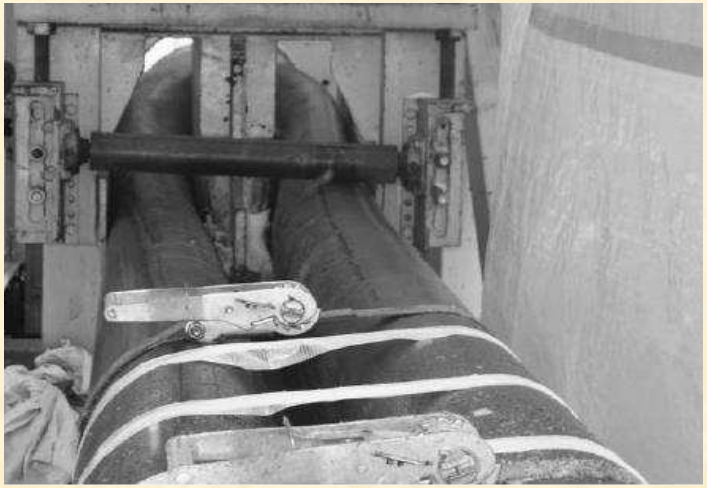
Liner's seamless mold ability is suitable to lining bends and elbows and other suitable fittings along pipeline.

DynaLiner has successfully lined water, gas and other pipelines with flanged end connections….forming flange mating surface for 100% zero annulus free lining



Close-Fit Pipe

- Can be used for both structural and nonstructural
- Reduces the cross-sectional area of the new pipe before it is installed.
- After placement, liner expands to its original size and shape at the jobsite, just to provide a close fit with the existing pipe and for pressure (more common) and gravity applications.



A semi-structural close-fi t pipe going through diameter reduction process (Najafi, 2010).

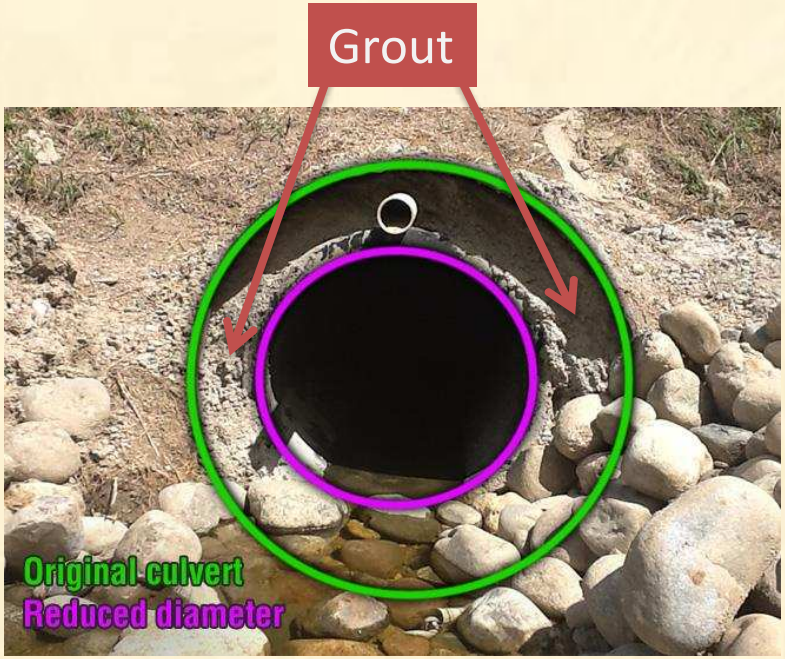
Thermoformed Pipe

- After insertion, the liner is heated (thermoform) to conform to the existing pipe dimensions with a close fit.

- Both PVC and PE can be used for this method, but PVC is more common.

SLIP LINING

- Oldest of all trenchless techniques
- Involves inserting a new smaller diameter pipe into an existing pipe
- Simplest trenchless process
- PVC and HDPE are the most commonly used pipe materials
- Annular space must be grouted
  - Selecting the right grout may be a challenge



SLIP LINING

Different pipe sizes can be rehabilitated using sliplining

From easy to complex projects, slip lining is a very versatile technique

Modified Slip lining

Methods in which pipe sections or plastic strips are installed in close-fit inside existing pipe and the annular space is grouted.

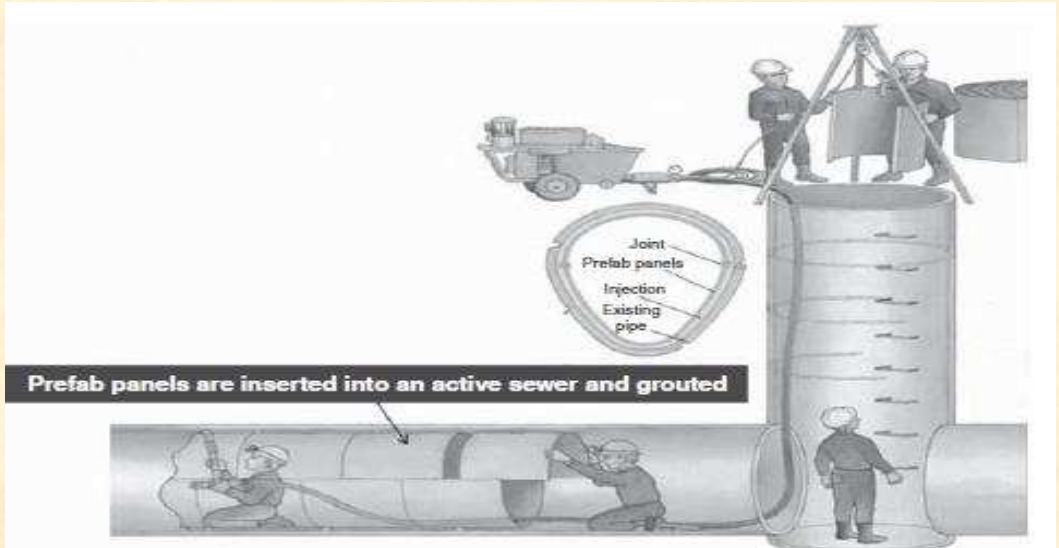
Two variations of modified sliplining method:

- Panel lining (PL),
- Spiral Wound Process (SWP).

Modified Slip lining

Panel lining (PL)

- It can be used to structurally renew large-diameter (more than 48 in. or worker-entry) pipes.
- It can accommodate different shapes, such as noncircular pipelines.
- The main type of material for this method is fiberglass.

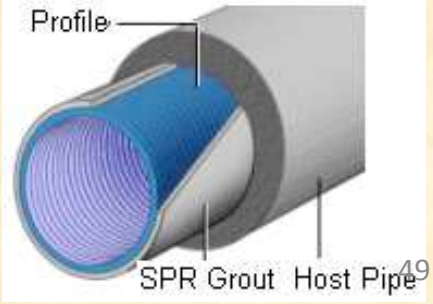


Panel lining method (Najafi, 2010)

Modified Slip lining

Spiral Wound

- Rigid PVC and PE profile which is spirally wound into an existing pipeline.
- Successive wraps of profile are locked together and the annular space is grouted.
- Ranging form 12 to 180 inches



Modified Slip lining

Strengths of Spiral Wound

- Truly trenchless technology
- Custom pipe shape, diameters and wall thickness
- Can negotiate bends and cross sectional transition
- Can be installed in live line
- Longitudinal slope adjustment is possible

Example of Non-Circular Spiral Wound

- Project Background 2004
  - Hyperion treatment plant, directly south of LAX airport
  - Host: 156” x 63” x 222’
  - Rehabilitated: 147” x 57” x 222’
  - Project started on September ’04
  - 4 weeks with crew of 8

Step 1: Pipe Cleaning

Step 2: Assemble Machine

Step 3: Winding

Step 4: Support Jack

Step 5: Head Wall

Step 6: Grouting

Step 7: Remove Supports

Step 8: Secondary Grouting

Step 9: Clean Up

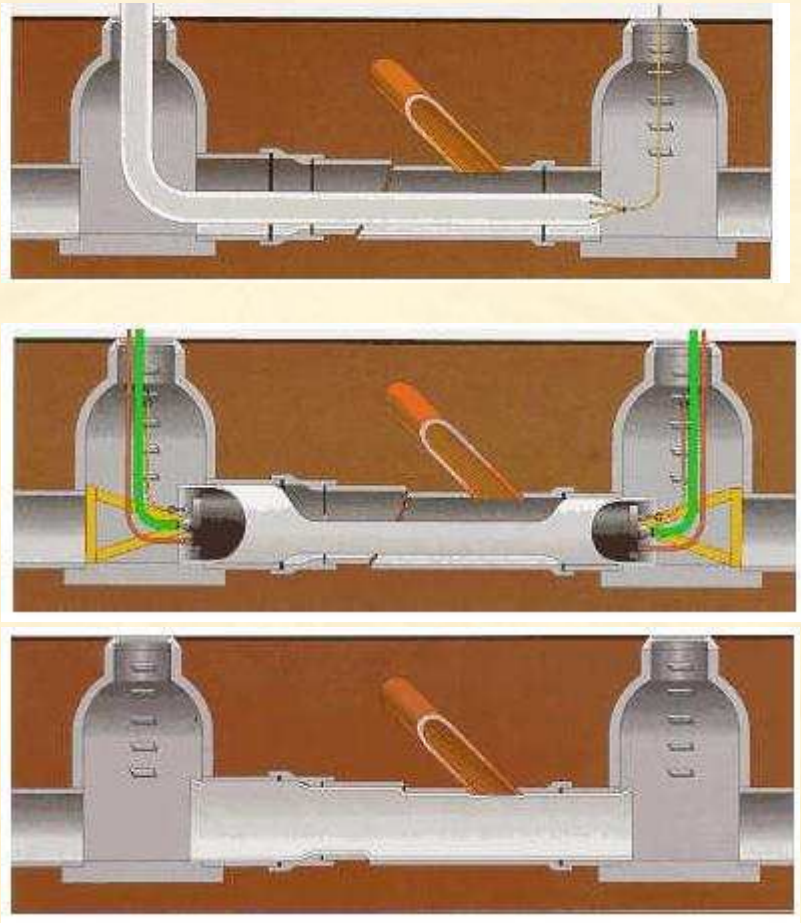
Finished Product

FOLD & FORMED

- Manufactured in a folded shape
- Thermoformed inside the pipe
- Polyvinyl Chloride (PVC) as preferred material
- Noxious, styrene or caustic chemicals are inexistent
- Some manufacturers:
  - AM-LINER II
  - EX Method
  - Instituform Technologies, Inc. NuPipe
  - Ultraliner

FOLD & FORMED

- Similar to CIPP but no felt or resin
- Pull into place
- Introduce Heat to Cure
- Cool down
- Robotic Service Lateral Reinstatement



FOLD & FORMED

- Installation Process
  - Material pulled into place from truck thru manhole. Normally, no pre-heating required
  - Once in place, ends are plugged and steam lines attached
  - Cured by steam

FOLD & FORMED

- Finishing
  - Service laterals robotically re-instated (openings cut out) by technician in TV truck.
  - Finished cut-out similar to Cured-in-Place liner

Forest Parkway Culvert Rehabilitation

Presentation Overview

- Project Background
- Challenges
- Summary Results
- Questions

Service Population:
280,000

Water/Sewer/Storm
Customers: 77,000

Utility for the County and 6 Cities:

- Forest Park
- Lake City
- Morrow
- Riverdale
- Jonesboro
- Lovejoy


NORTH
AMERICA
Stormwater
500 miles
Water
1500 miles
Sanitary
1400 miles

Forest Parkway Culvert Rehabilitation

Project Background

- Approximately 220 lf of 66-inch diameter corrugated metal pipe
- Culvert initially surveyed in 2011 and scheduled for CIPP
- ROW segment CIPP
- Extent of Service issues delayed response
- Authorized as an Emergency RFP
- Deterioration/movement continued during project work

Forest Parkway Culvert Rehabilitation

Project Challenges

- Extent of Service – Utility/Public Safety
- Dynamic collapse/sinkhole – depth/building
- Deflections
- Public Works – RFP – Trenchless – responsiveness

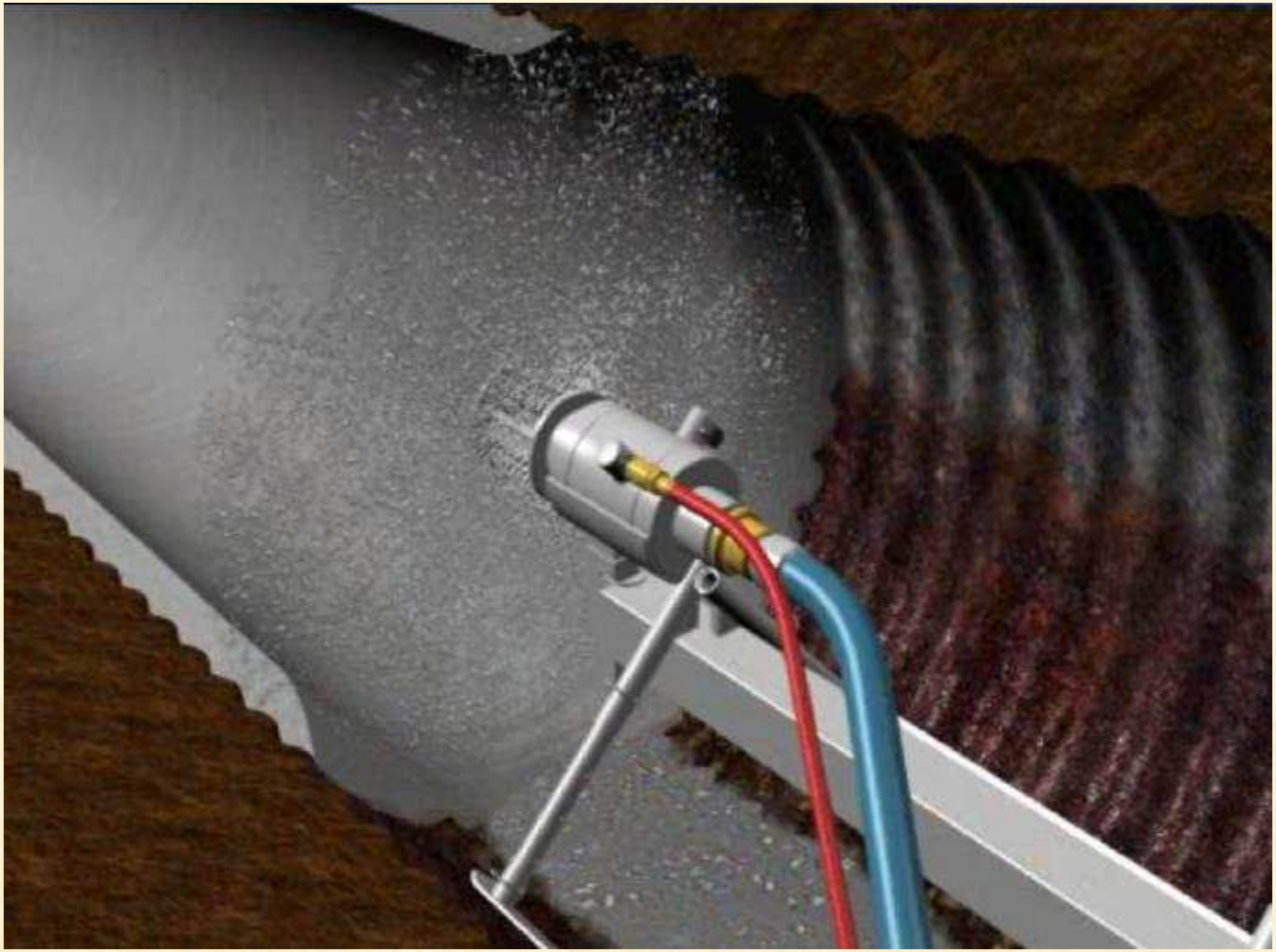
Forest Parkway Culvert Rehabilitation

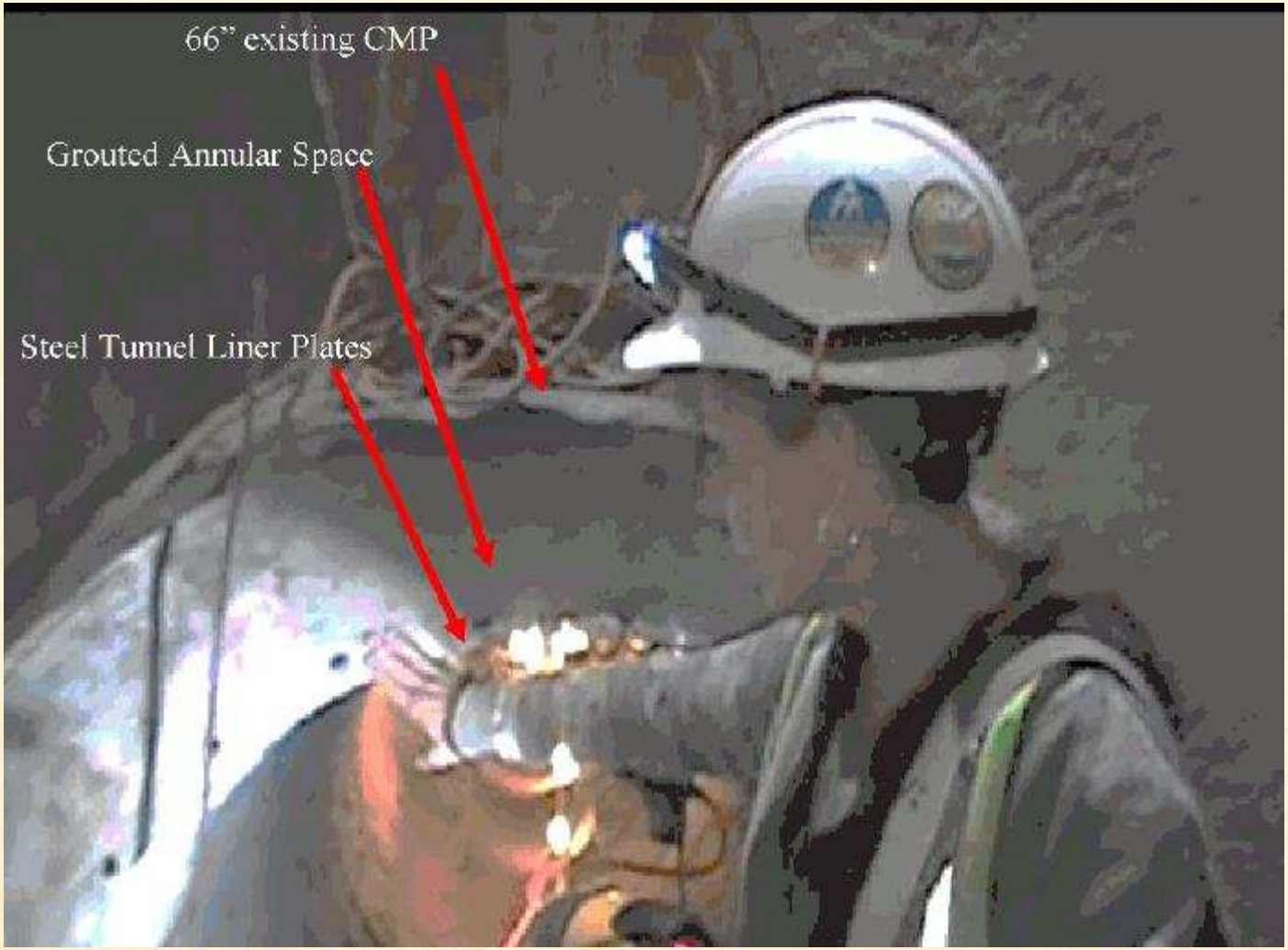
RFP Summary

	Contractor RP	Contractor RC Option 1	Contractor RC Option 2	Contractor RC Option 3	Conractor S	**UAM Option 1**	UAM Option 2
Quals & Exp	16.50	10.80	13.20	16.50	16.50	**16.50**	15.60
References	14.80	0.00	2.40	14.00	14.80	**13.60**	13.60
Approach	11.00	10.86	11.00	10.71	11.86	**13.43**	12.43
Costs	11.19	16.57	14.45	11.68	20.24	**28.71**	30.00
Final Score	53.49	38.23	41.05	52.89	63.40	**72.24**	71.63
Ranking	4	7	6	5	3	**1**	2
	$607,688	**$410,306**	**$470,594**	**$582,081**	**$335,962**	**$236,820**	**$226,645**

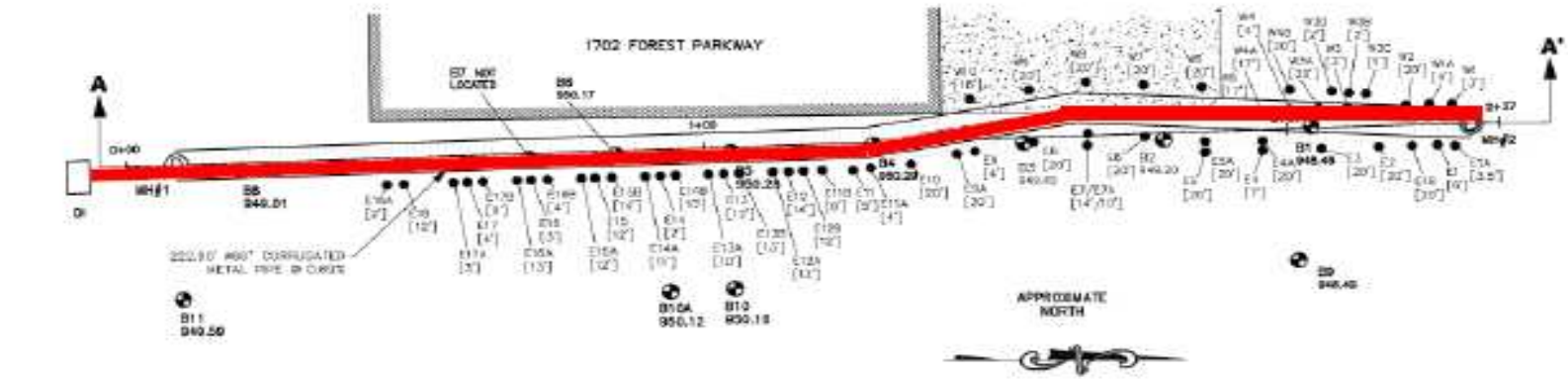
Forest Parkway Culvert Rehabilitation

"Quality Water, Quality Service"



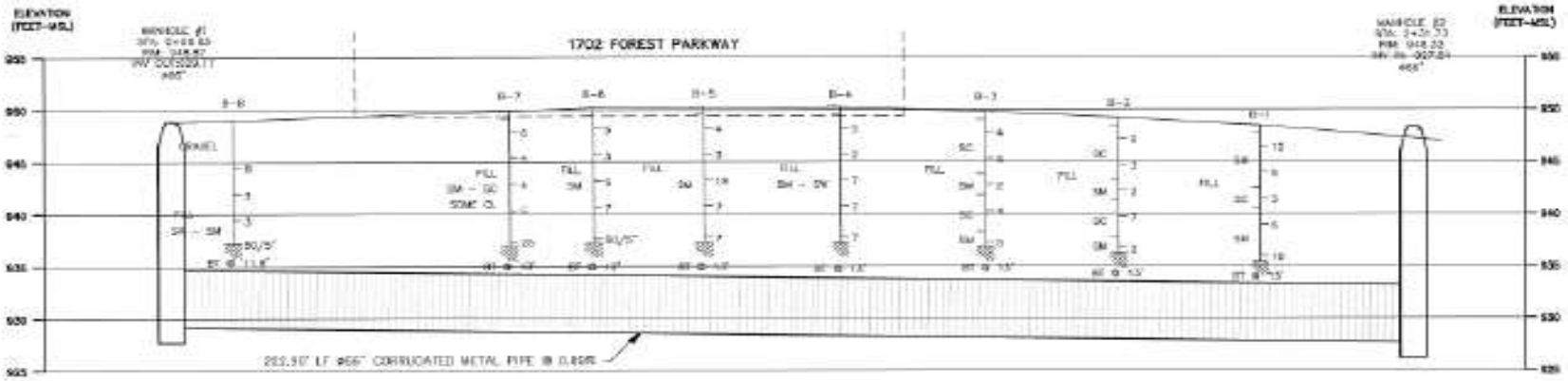

66" existing CMP
Grouted Annular Space
Steel Tunnel Liner Plates


Bobcat



GROUT INJECTION POINT PLAN

SCALE: 1" = 20' (HORIZONTAL)

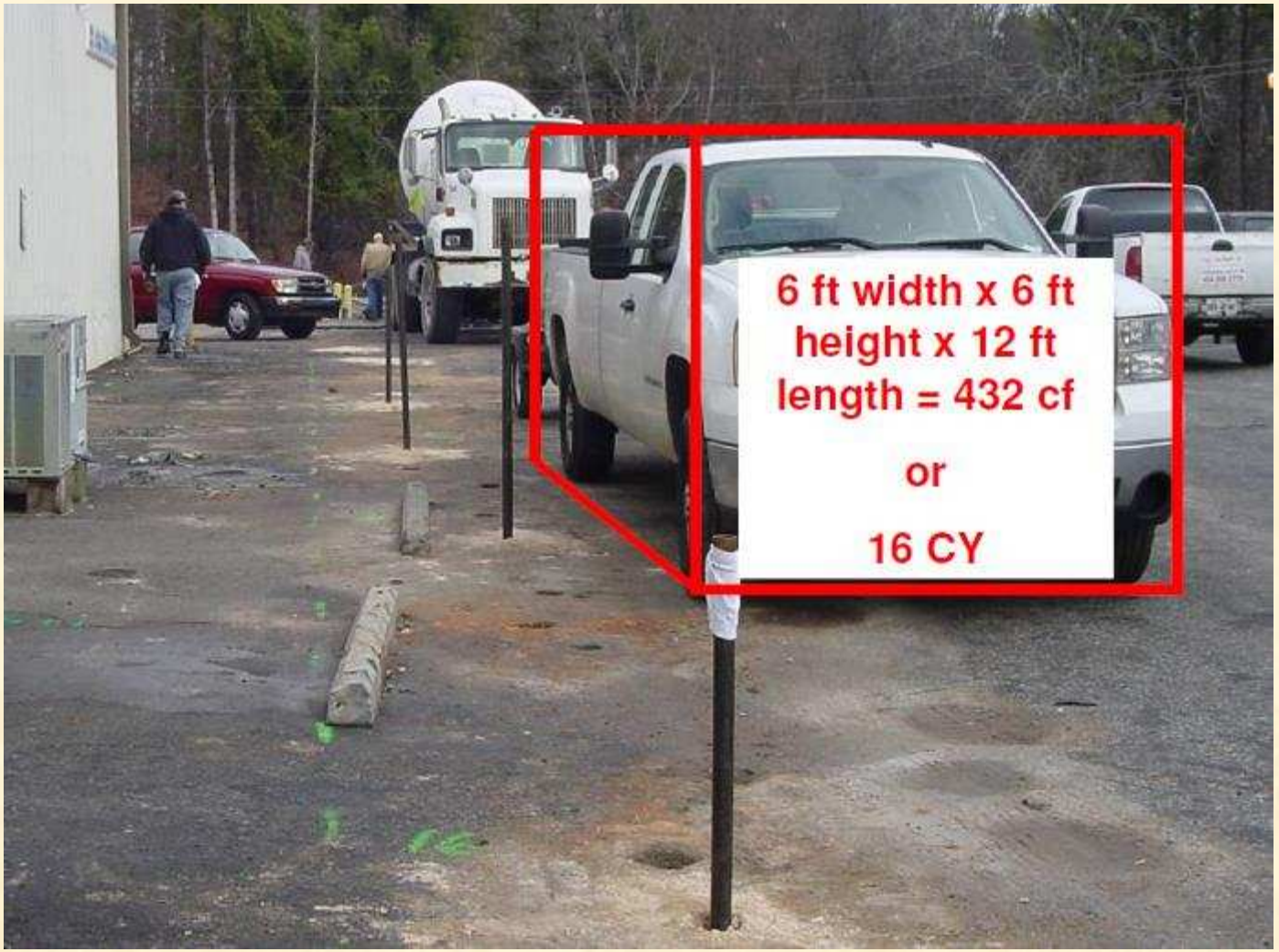


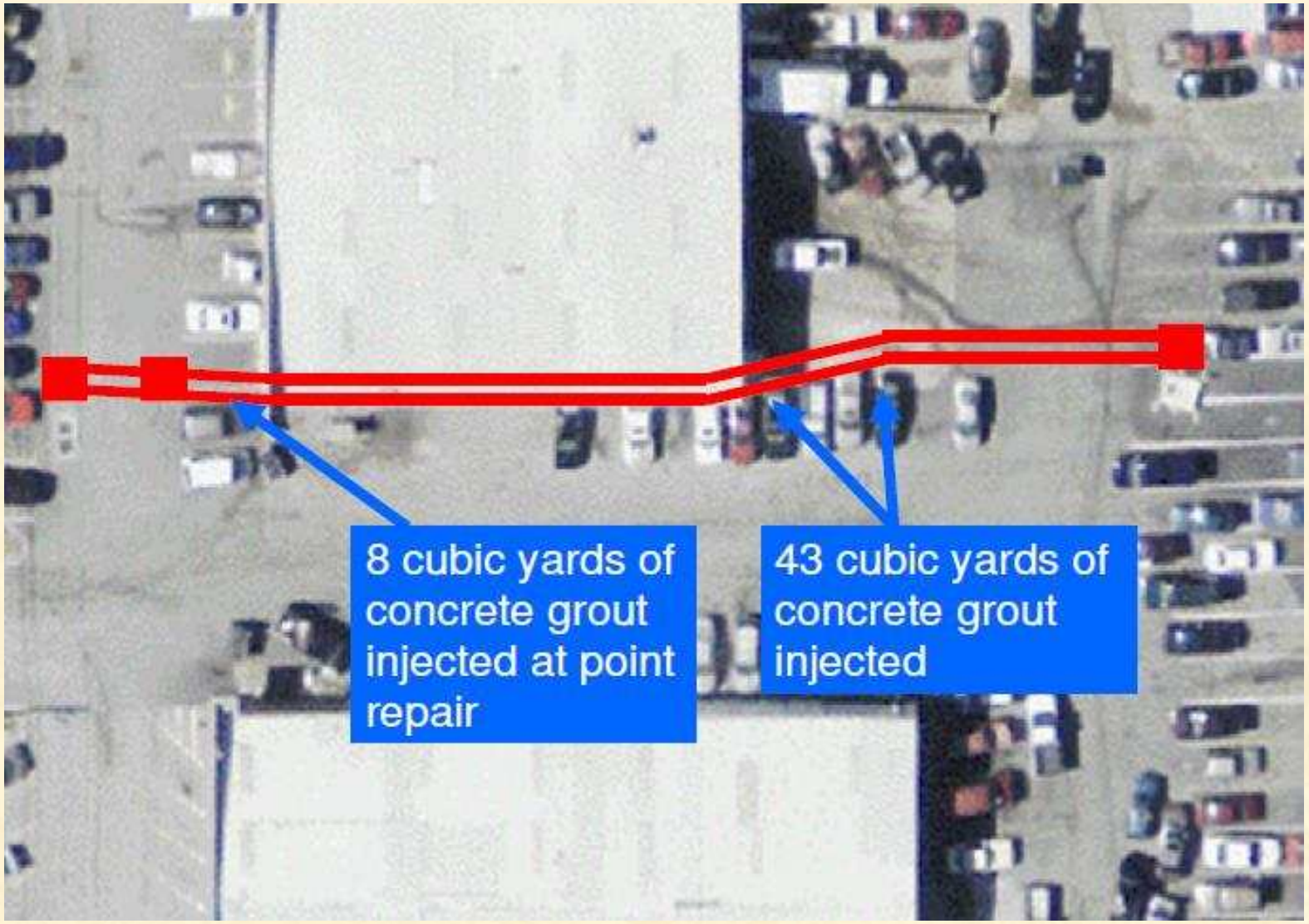
CULVERT PROFILE A-A'

SCALE: 1" = 10' (VERTICAL) 1" = 20' (HORIZONTAL)

GEOSYSTEMS
ENGINEERING, INC.

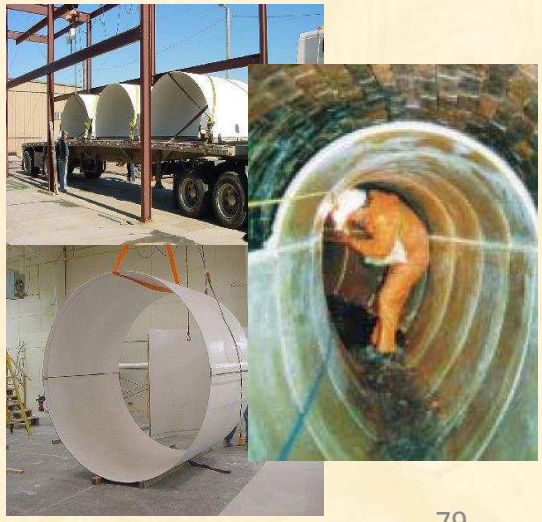
GROUTING SKETCH


6 ft width x 6 ft
height x 12 ft
length = 432 cf
or
16 CY


8 cubic yards of concrete grout injected at point repair
43 cubic yards of concrete grout injected

Structural Panels

- Man entry procedure where one piece or multi sectional panels are custom formed and fitted together in sewers to form a full segment
- Annular space between structural panel and host pipe is filled with grout to complete the installation
- Ranging form 12 to 240 inches
- Standards: BS5480, DN9000

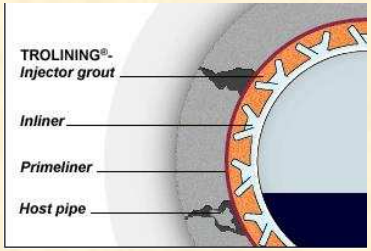


Strengths of Structural Panels

- Could be truly trenchless
- Custom pipe shape and size
- Can negotiate bends and cross sectional transition
- Can provide full and independent structural integrity

Grout In Place Polyethylene Lining

- Single liner with anchors on the outside of the HDPE sheet
- Additional HDPE flat liner to create a defined annular space for grouting
- Annular space is then grouted
- Reinforcing bars or mesh can be included to increase structural integrity
- Ranging form 8 to 160 inches



Strengths of Polyethylene Grouting

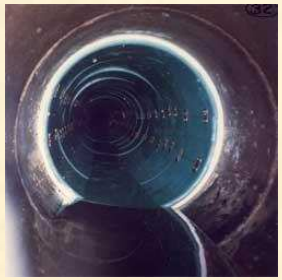
- Truly trenchless technology
- Custom pipe shape and size
- Can negotiate bends and cross sectional transition

Structural Sleeve

- More for point repair then rehabilitation of whole lining
- Structural sleeves is used to cover the damaged area
- Annular space is then grouted
- Ranging form 16 to 216 inches

Strengths of Structural Sleeves

- Truly trenchless technology
- Round, tear-drop, horse-shoe, oval pipe
- Rapid installation: Repair takes approximately 20 minutes with a crew of 2
- Recommended in emergency situation when rapid response is essential



GeoPolymer Products

GeoSpray Overview

GeoSpray™ geopolymer is a high performance fiber reinforced mortar specifically designed for structural rehabilitation.

This high strength, ultra-low porosity material is made from natural mineral polymers and recycled industrial waste streams.

GeoSpray is designed for use through multiple application techniques including pouring, placing, trowelling, spraying, or centrifugal casting.

GeoSpray can be used to rehabilitation of pipes and structures in Civil Infrastructure, Gas & Oil and Chemical industries.

GeoPolymer Products

GeoSpray Overview

Engineered

- High flexural and bond strength.
- High early and ultimate strength.
- Adapts to any shape, including bends, curves, and angles.

Sustainable

- Lower greenhouse gas emissions.
- 50%+ of raw materials come from recycled industrial by-products.
- Locally manufactured.

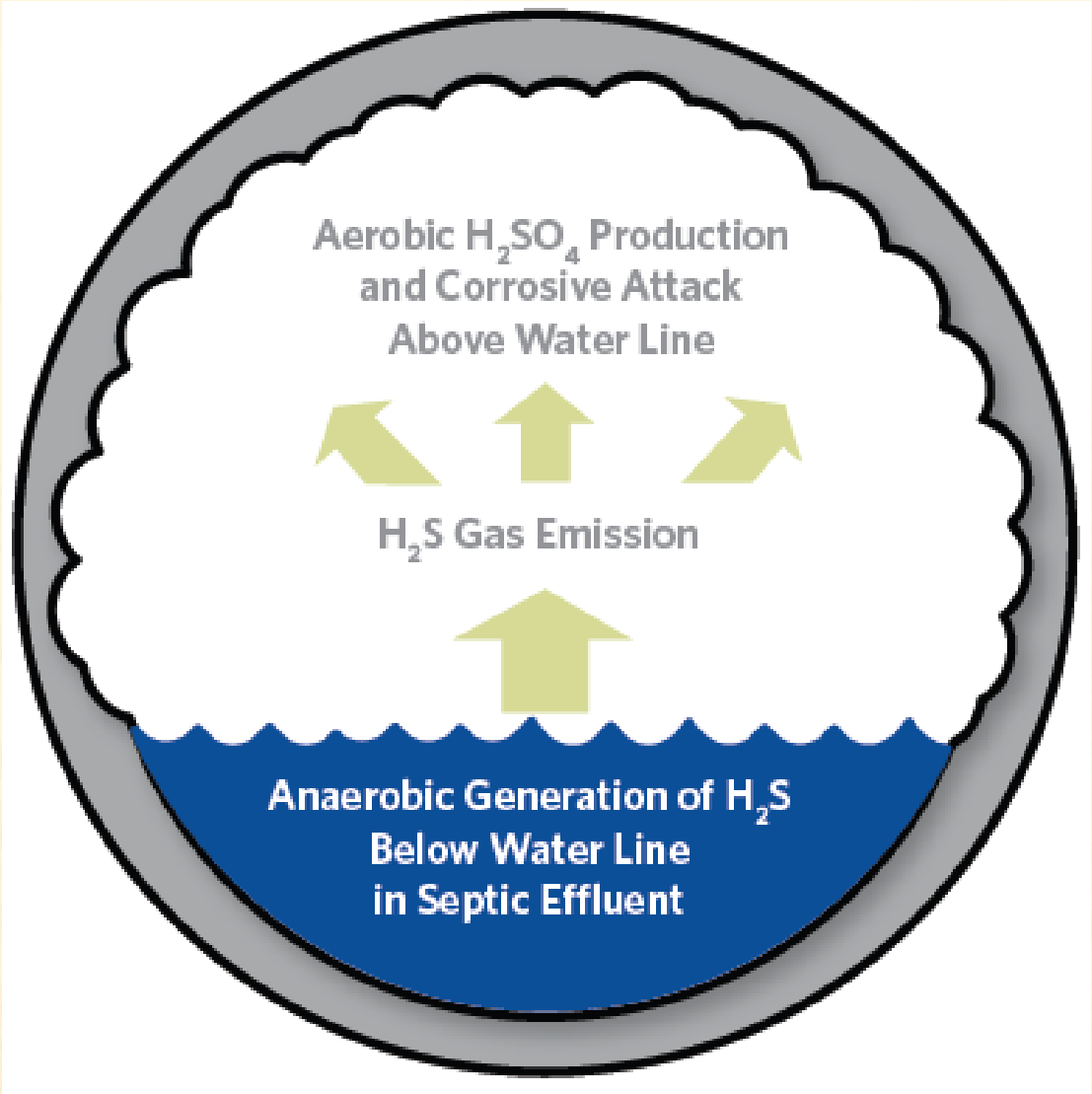
Lower Total Cost

- Generally lower installation and operating costs compared with alternative methods (SPR/CIPP/Slipline).
- Less disruption to the community
- Faster installation.

Safe

- Styrene FREE.
- Contains no leachable toxins.
- Passed – EPA TCLP Toxicity Characteristic Leaching Procedure.

GeoPolymer Advantages
Corrosion Resistance



Microbial-Induced-Corrosion (MIC) Mechanism

GeoPolymer Advantages

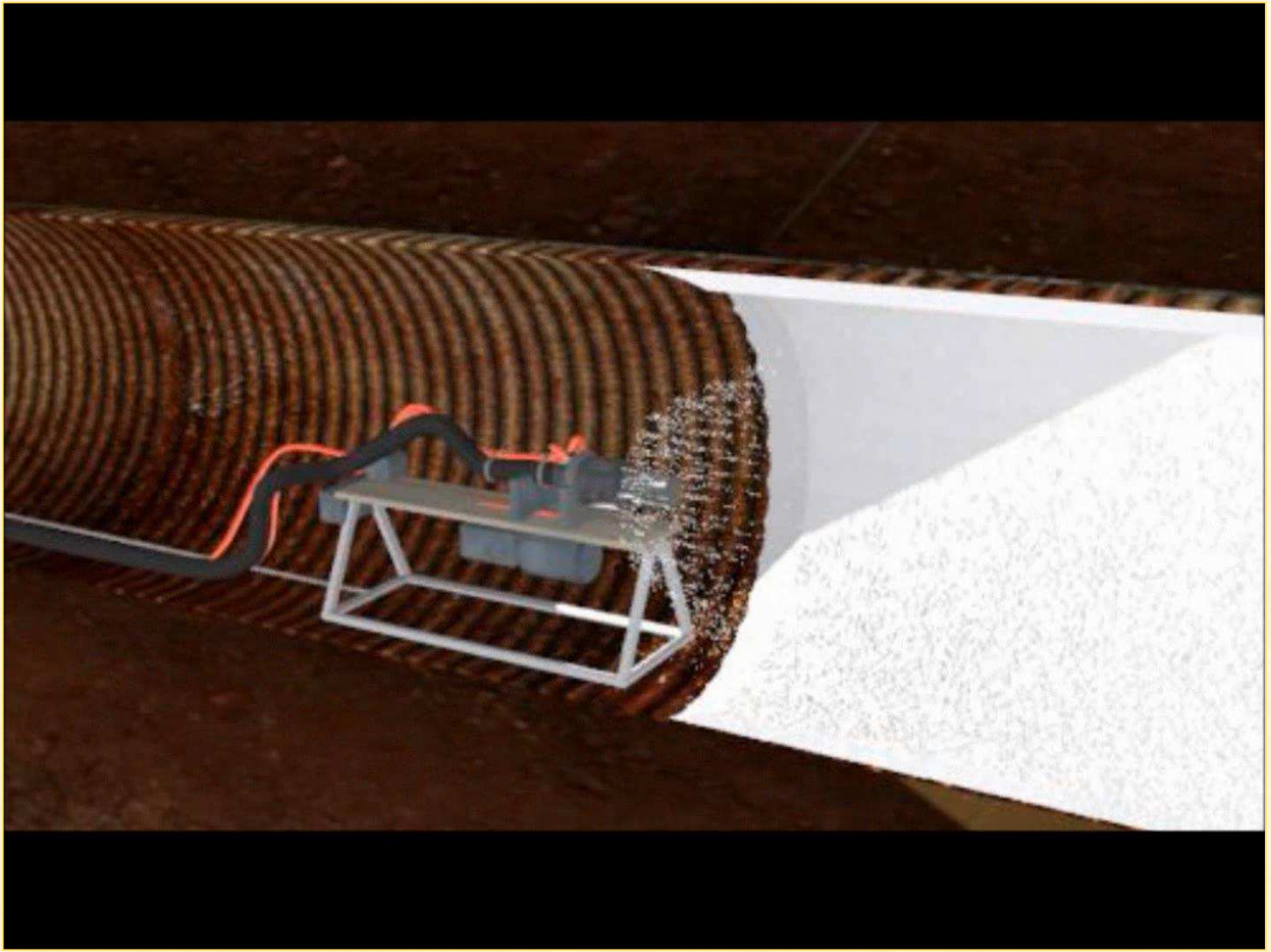
Corrosion Resistance

The Advantage

- The chemical make-up of GeoSpray™AMS makes it *inherently acid resistant* to the MIC mechanism found in many sewer environments.
- Geopolymers (dependent on the exact formulation) will contain greatly reduced concentrations of $Ca(OH)_2$ (calcium hydroxide) essentially the acid corrosion mechanism found in many typical cements.
- In addition to the base geopolymer chemistry, GeoSpray™AMS includes an added layer of chemical protection from the proprietary PostCoat that creates an additional glass-like chemically resistant surface.

Structural Rehabilitation

Application Process



Structural Rehabilitation

Centrifugal Casting

Centrifugal Casting of GeoSpray

- Rapidly distributes material within the pipe's internal circumference
- Forms a strong, low permeability, cement mortar lining
- Depending upon design & thickness, creates a "pipe within a pipe" and does not rely on the integrity of the host structure
- While not generally required it is compatible with most common reinforcement technologies

GeoPolymer Advantages

Effective and Efficient

- Lower total system cost than alternative methods
  - Installation + ongoing operating costs
- Point of failure repair
- Less risk exposure from weather
- Less disruptive to the community
  - Less cost associated with road closures, non-productive labor, traffic delays, impact to local business, etc.
- More quickly implemented
  - Less cure/set-up time

GeoPolymer Advantages

Application Flexibility

Shape

- Non-round, elliptical, egg shaped
- Manholes, wet-wells, junction boxes

Length

- Short lines, culverts, point repair
- Longer sewer and storm segments

Diameter

- From 36 inches to 180 inch
- Varying diameter in a single run

Ovality

- Ovality greater than 10%
- Box culverts and structures

GeoPolymer Advantages

Application Flexibility

Angles

- Bends, curves, and change in elevation

Laterals

- Monolithically tied to structure

Host pipe material

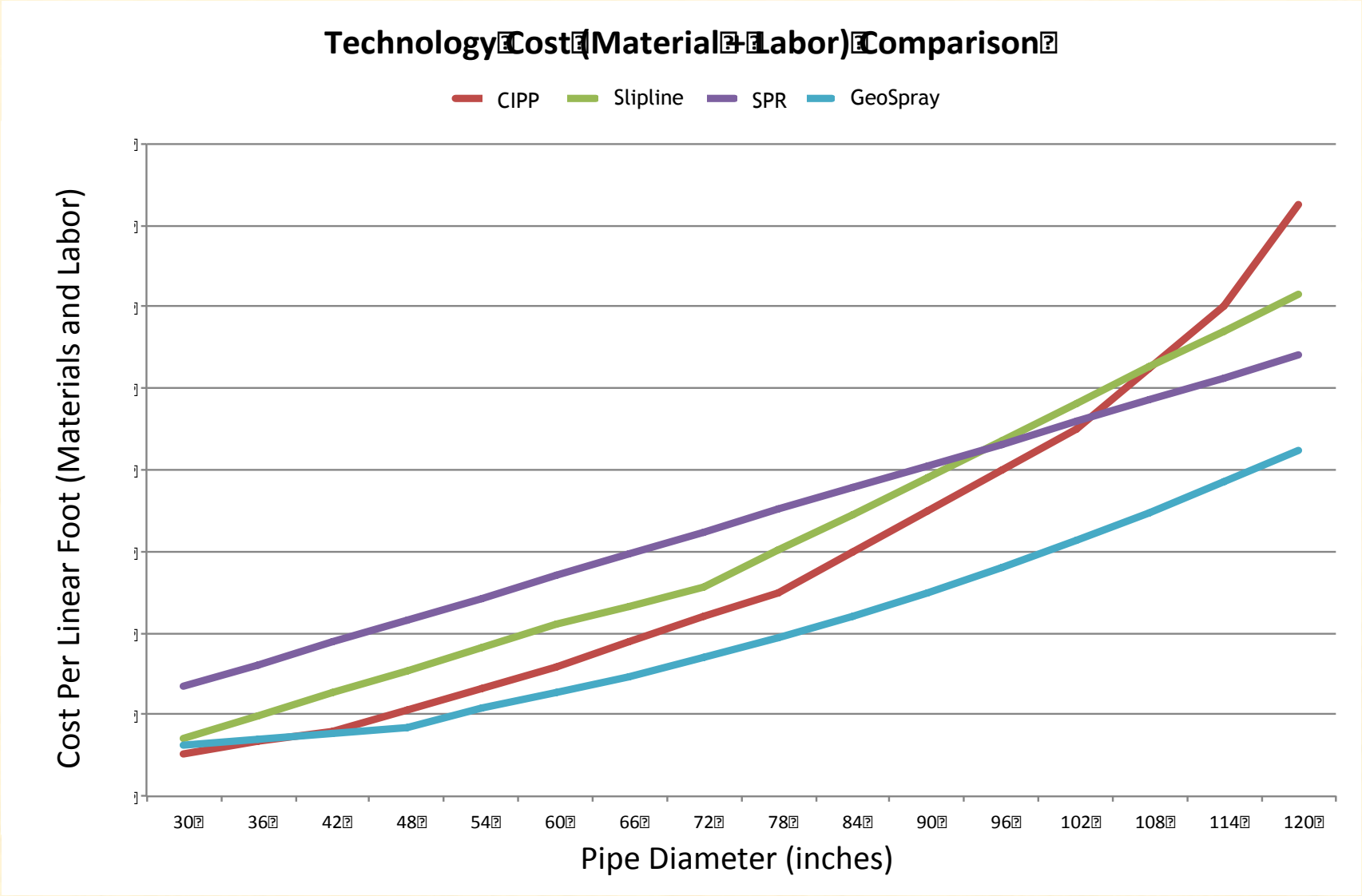
- Brick, Rock, Concrete
- Corrugated Metal or Cast Iron

Host pipe condition

- Slightly to fully deteriorated

Trenchless Technologies

Simple Cost Estimations

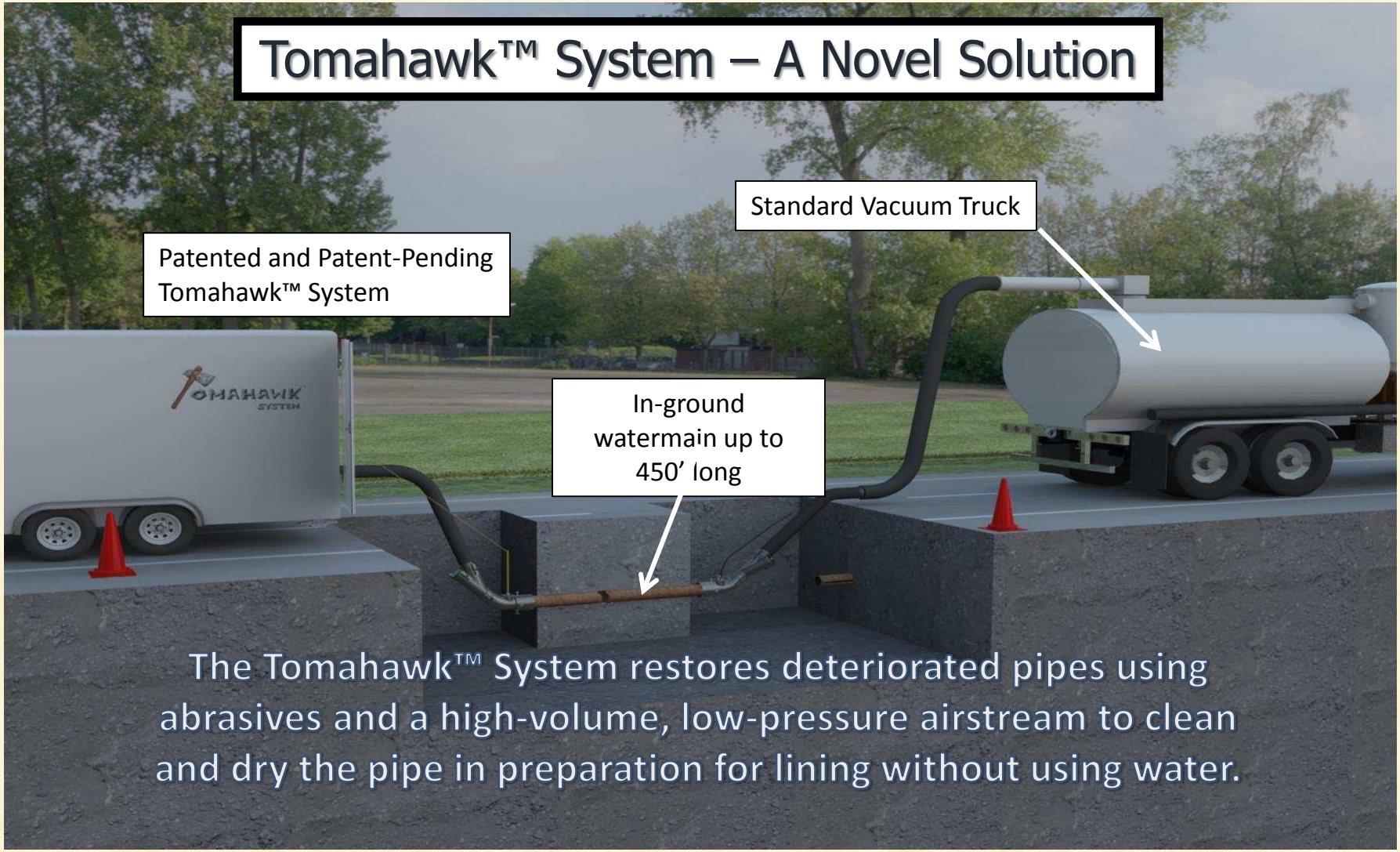


Innovation

PARADIGM SHIFT:

- If you could:
  - Clean and inspect pipes 50% faster,
  - Dry them for 100% superior liner bond,
  - Not use a drop of water,
  - Reduce waste generation by 98%,
  - NOT damage your pipes or services,
  - Capture all waste in a closed, filtered system; and
  - Meet NACE surface preparation standards,
- …would this technology be of interest?

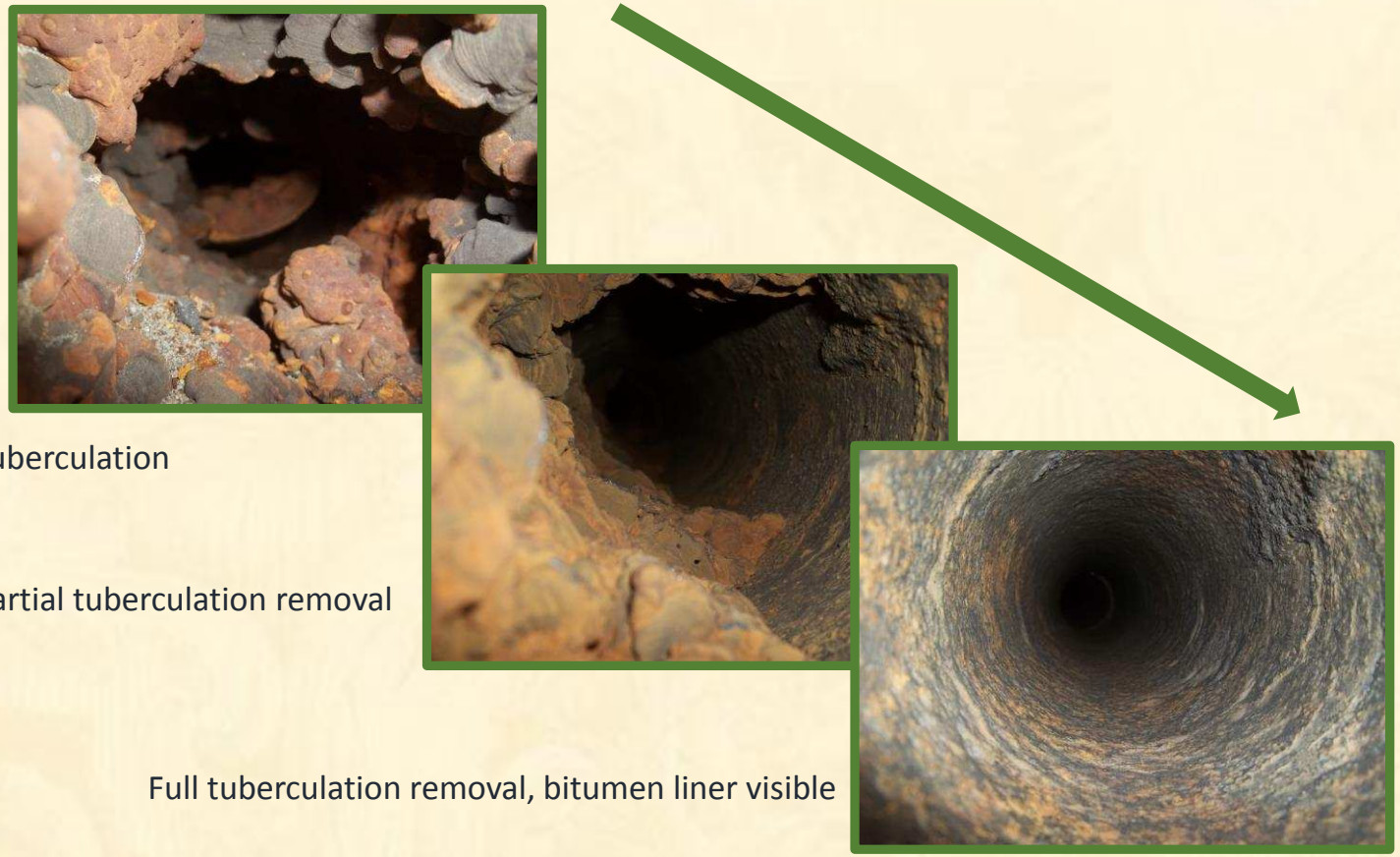
Tomahawk™ System – A Novel Solution



The Tomahawk™ System restores deteriorated pipes using abrasives and a high-volume, low-pressure airstream to clean and dry the pipe in preparation for lining without using water.

Tomahawk™ System Process

Cleaning progression……



Tuberculation

Partial tuberculation removal

Full tuberculation removal, bitumen liner visible

Preparation progression……

Bitumen liner being removed

Partial liner and graphitic corrosion removal

Fully prepared for liner bonding

Tomahawk Value Proposition:

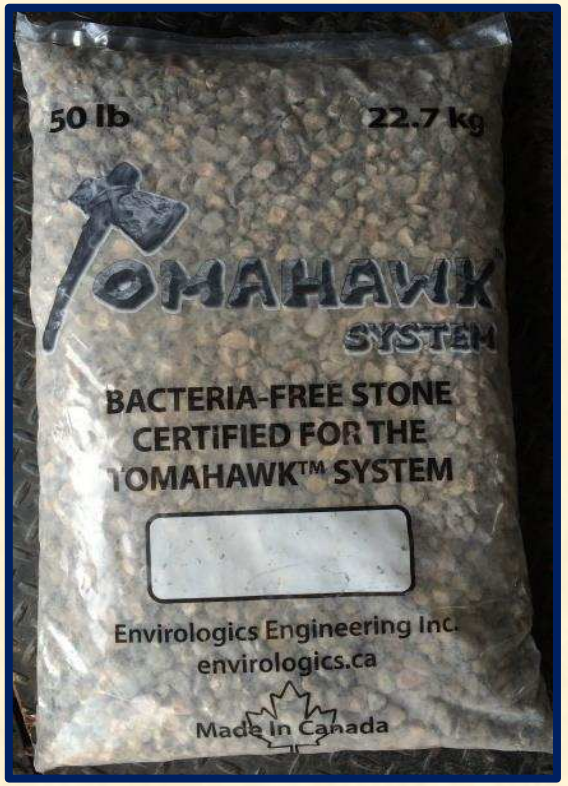
- ✓ Cleans pipe to bare metal (4” – 12”)
- ✓ Waterless, dust-free process
- ✓ Dries the pipe for best bond
- ✓ No damage to pipe or service connections
- ✓ Very fast (enables same-day return to service)
- ✓ Used on metallic, AC, & concrete pipes
- ✓ Reduced construction footprint


TOMAHAWK SYSTEM
MWD
MSD
✓ Trenchless water main rehab
✓ Minimal disruption to local residents
✓ Dry, dust free process
✓ Small footprint vs dig and replace
✓ No service bypass present

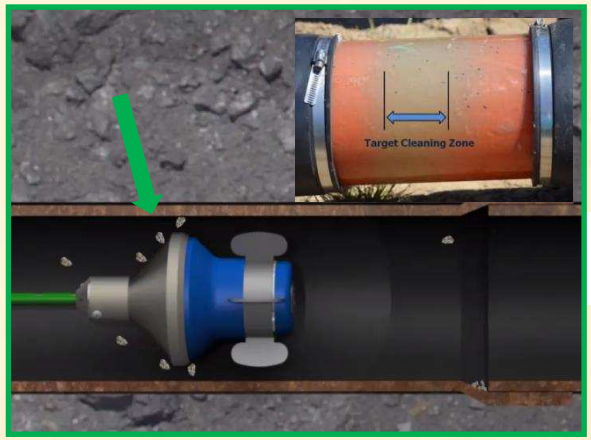
Reduced Project Footprint

Abrasives: Stone

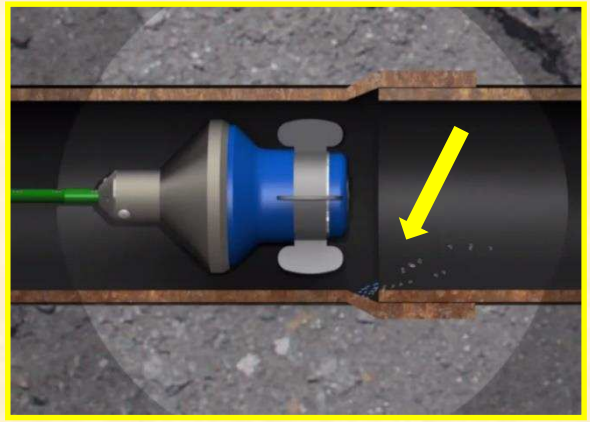
- Various calibers used
- Stone is triple-washed and dried at high temperature
- Verified bacteria free



Concurrent Cleaning, Drying and Inspection



Inspect and target clean along pipe, at joints, around service connections for improved liner bond



Inspect and draw trapped water and debris from joints, crevices and service connections

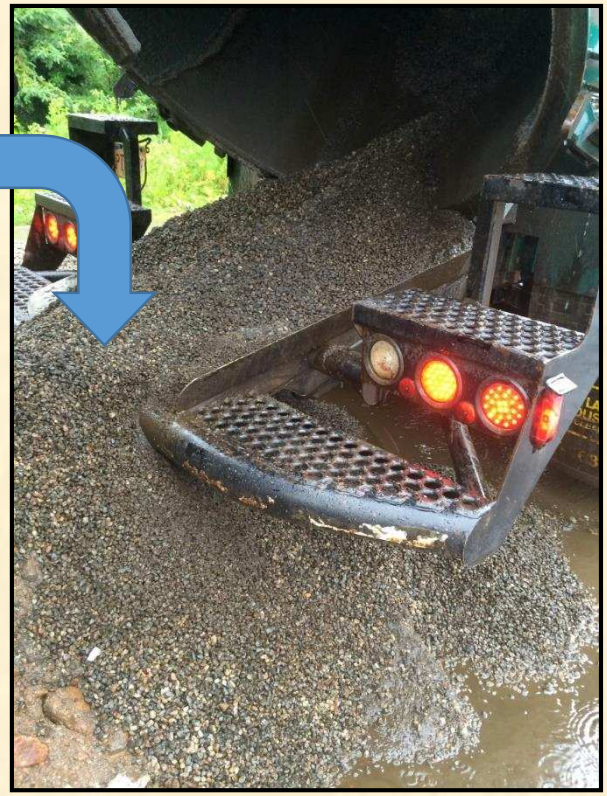
Waste Capture

- Cleaning process uses closed loop
- Dust, debris and cleaning stone are 100% captured, maintaining a dry, clean and safe worksite

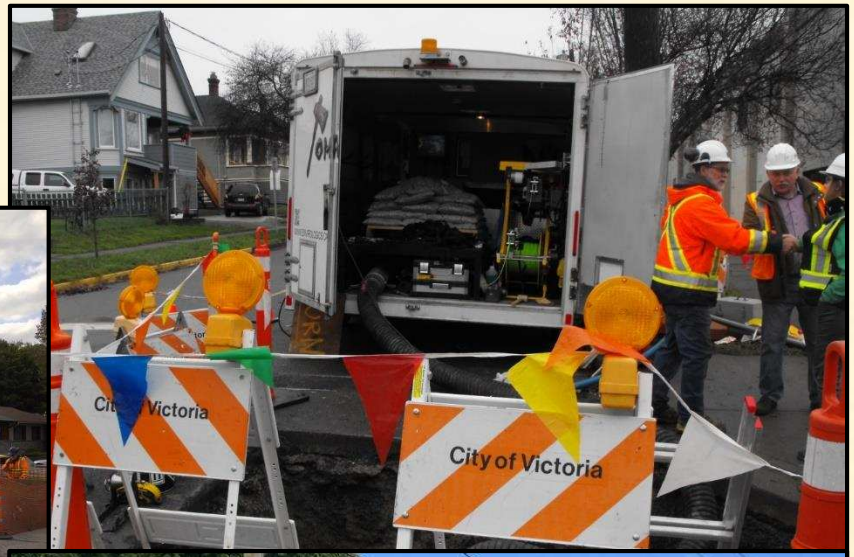
- Eliminates the sensory impacts (visual, smell) of the waste released from aging, fouled water mains
- Minimizes cost and provides ease of disposal

Dry Versus Wet Waste:

- Stone and debris captured by vac truck after cleaning 6 pipe sections
- Represents 30 to 50% of average truck capacity
- **Result:** Less waste by volume means vac truck can stay on-site working for much longer periods

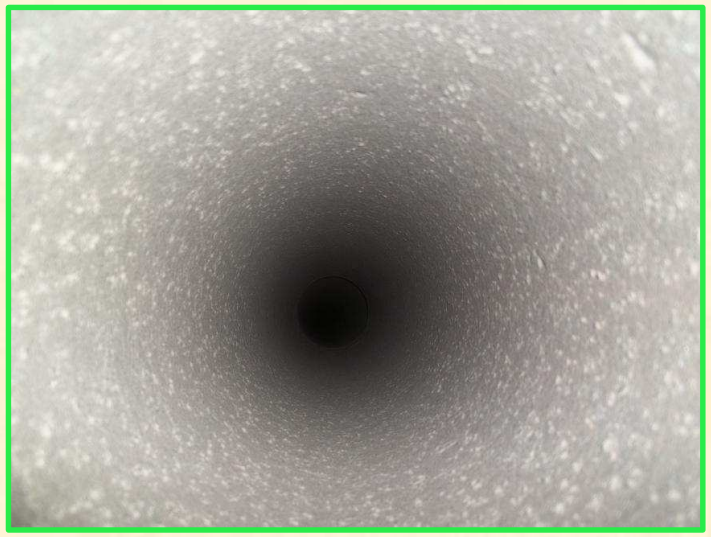


Cleaning Results



Corrosion and Coal Tar Liner Removed

Before



After

Tuberculation Removed From Unlined Pipe

Before

After

Tuberculation Removed From Unlined Pipe

Before

After

Tuberculation and bitumen removed from water main using the Tomahawk™ System followed by a 3M™ Scotchkote™ Pipe Renewal Liner 2400 application

Achievements:

- Improved water quality
- Hydraulic capacity restored
- Reduced power consumption to pump water
- Decades of additional service

Tomahawk Cleaning – Street View

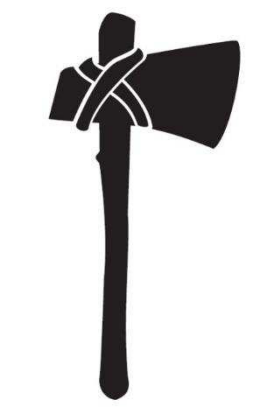
Trenchless Watermain Rehabilitation - Tomahawk™ Cleaning
150mm - 120 meter long watermain - cleaned and prepared for lining in 2 hours

Click here to view video

Projects Completed

- Napanee, ON
- Peterborough, ON
- Cambridge, ON
- St. John, NB (2)
- Moline, IL
- Waterloo, ON
- Montreal, QC
- Quebec City, QC
- Victoria, BC
- Vancouver, BC

Proven Capability



- Cleans up to 135m (450 feet)
- Accommodates 40% sectional tuberculation
- Cleans 45° elbows
- Highest quality cleaning/preparation amongst cleaning methods

In-Development: Tomahawk Airborne Lining

Tomahawk Airborne Lining

Pressure Water Pipes:

- Low cost, NSF61, non-structural barrier coat lining system for metallic pipes
- AWWA M28, Class I coating to prevent future interior corrosion, deposit build-up and water quality problems
- Large percentage of pipes require barrier protection only

Above: 6” tuberculate pipe
Below: cleaned and lined
Photos by Envirologics

Tomahawk Lining Process – In-Pipe View

Video of lining process as viewed from a Tee looking towards the mainline

Distributive body removed from video as patent is pending

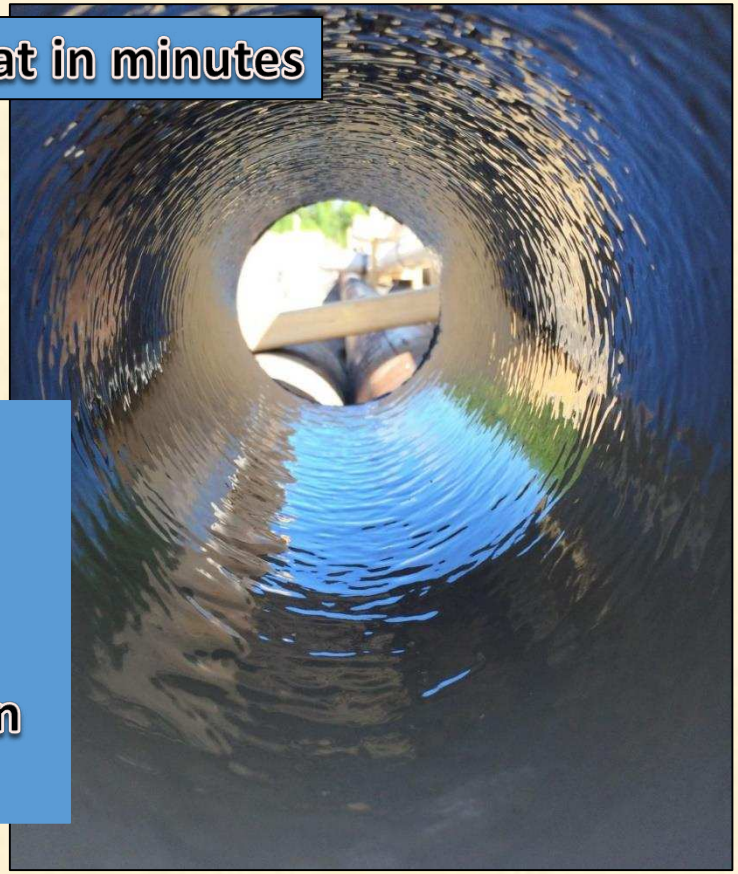
Water main before cleaning - inspection video

Water main after Tomahawk cleaning and lining - inspection video

Tomahawk Airborne Lining

Clean then apply barrier coat in minutes

TOMAHAWK SYSTEM



Low cost barrier coat to:

- Extend pipe life
- Restore flow capacity
- Improve water quality
- Encapsulate lead found in pipe and joints

Photos by Envirologics


PipeMedic

PipeMedic® FRP Technologies

Three Fiber Reinforced Polymer (FRP) systems for repair of sewer pipes and Force Mains:

- Wet Layup
- StifPipe®
- InfinitPipe®

Wet Layup

- Carbon or glass fabric saturated with epoxy resin and applied to the interior or exterior surface of the pipe
- Each layer is only 1.3mm thick
- For internal repairs:
  - Applied by hand in larger dia. pipes or
  - Applied with a packer in smaller pipes
- Can be used for spot or full length repair

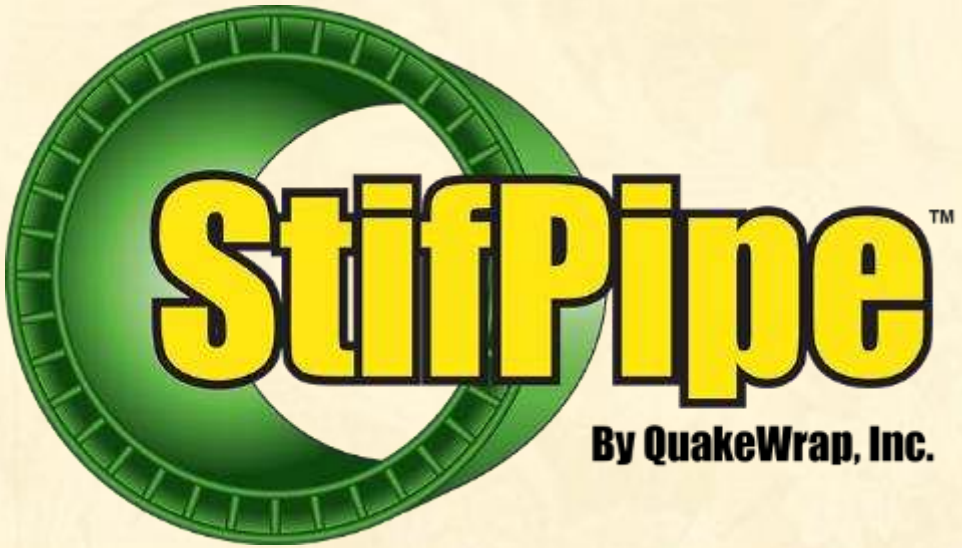
QuakeWrap® Wet Layup FRP Products

42” (1070 mm) Curved Steel Pipe Carrying Hot Air
Encina Wastewater Authority Carlsbad, CA

96” (2440mm) Fiberglass Sewer Pipe DC Sewer, Washington DC

- **Newly installed pipe was defective and required repair with Carbon FRP**
- **Fabric was saturated using saturating machine shown below and taken inside the pipe for installation**

Small (200mm) Diameter Pipe Repair Using a Carrier or Packer


StifPipe™
By QuakeWrap, Inc.

StifPipe® (Patented Technology)

- Lightweight pipe manufactured to any shape and size locally by your trained crew
- Used to slip-line existing pipes
- Good for spot repair or longer lengths
- Structural solution that can serve as a Class IV liner (resisting all external loads and internal pressure)

Manufacturing Process






Repair of 48”(1220mm) Force Main
Avalon Pumping Station, Los Angeles, CA

- **Seven steel pipes were severely corroded.**
- **StifPipe® segments were designed to resist internal pressure**
- **Annular space was only 4mm to maximize flow through repaired pipes.**

Available in All Shapes & Sizes

StifPipe® can be manufactured to any shape and size to minimize loss of flow capacity

Repair of Corroded Culvert with StifPipe®

Gillies Road Culvert

Cairns, QLD

Gillies Road Culvert

Cairns, QLD

Gillies Road Culvert

Cairns, QLD


InfinitPipe™
By QuakeWrap, Inc.

Onsite-Manufactured InfinitPipe®

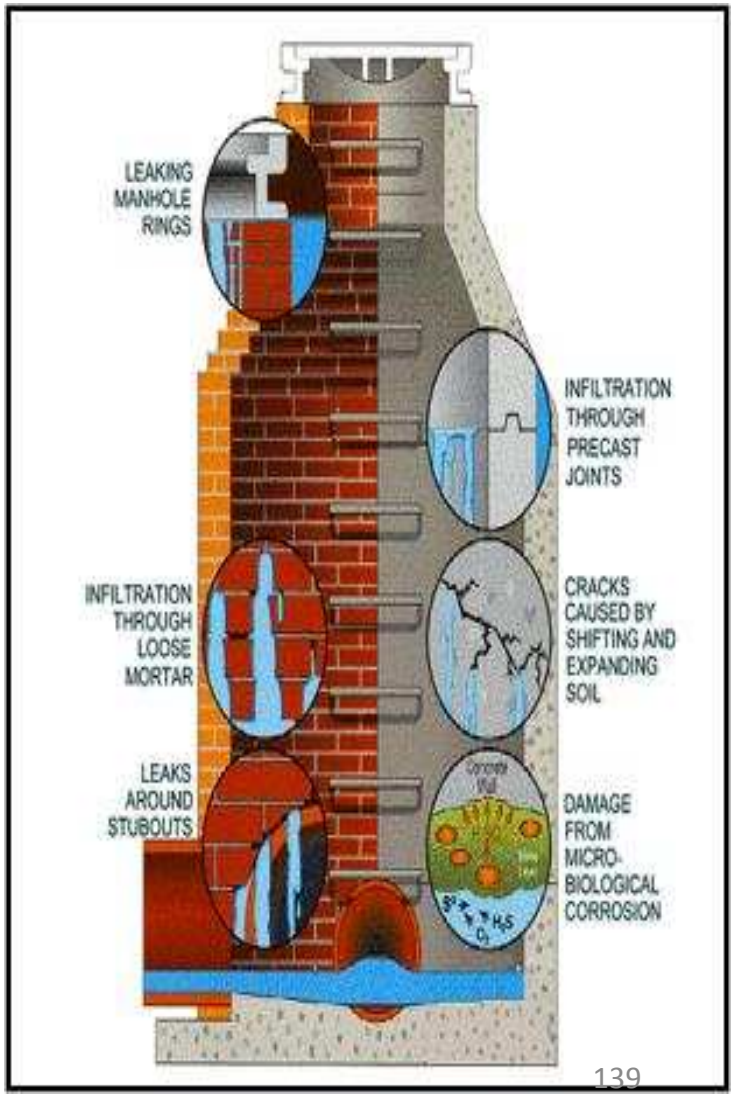
MANHOLES

- Why renew Manholes?
  - Control I&I
  - Reduce treatment costs
  - Stop leaks & erosion
  - Less wear on the system

http://trenchlessonline.com/pix/stories/FS-0408-ManholeAssess-2.jpg

Typical Causes of Manhole Decay

- **Corrosion**
  - sulfide rich effluent
  - warm/humid environment
  - long retention times
- **Infiltration**
  - leaks through joints or missing mortar
  - cracks caused by shifting soils
  - leaks around pipes
- **Fatigue**
  - traffic loading
  - groundwater loading
  - temperature variation
  - shifting and expanding soils
- **Concrete Quality**



The Need for Manhole Assessment / Rehabilitation

- U.S. wastewater collection system contains more than…

  20 million manholes

- 4 million are 50 years old or older
- 5 million are 30 to 50 years old
- The **EPA** estimates that approximately **3.5 million (17%)** of these manholes are suffering from serious decay and in need of immediate rehabilitation or replacement
- These 3.5 million manholes represent a rehab or replacement cost of over 5 billion dollars

The Need for Manhole Assessment / Rehabilitation – cost of not doing it

- Public Safety – streets / manholes caving in

- I and I costs
  - EPA estimates that 25% to 60% of all flow in sewers is I and I.
  - 10 MGD plant = $3K to $8K per day treatment costs (more than $1 million per year)
  - Wasted Ground Water
  - Energy Use
  - May require plant expansion

Source – Trenchless Technology 'Attacking Manhole I/I'

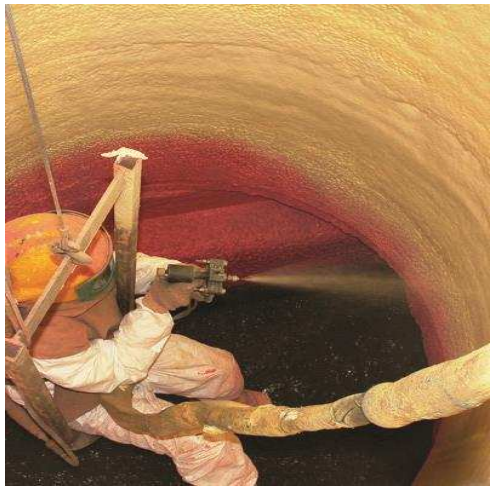
The Need for Manhole Assessment
I and I Sources

- I and I – 3 sources
    - Main lines – largest contribution
    - Laterals – tied +/- with manholes
    - Manholes – tied +/- with laterals
- Cost to fix
    - Manholes – lowest cost

Source – Trenchless Technology 'Attacking Manhole I/I'

Condition Assessment / Manhole Inspection Programs

- Manhole Inspection and Rehabilitation – ASCE Manual 92
- Manhole Assessment & Certification Program (MACP)- NASSCO
- JEA Condition Assessment Program - In House Case Study


ASCE Manual 92

This manual presents current and complete inspection and grading protocol that offers logical step-by-step guidance for maintaining and improving the health of these systems. This new addition presents the primary components that allow agencies to accurately identify and evaluate the condition of manholes and make informed decisions for rehabilitation materials and techniques.

Some of the topics in this edition include:

- ❑Safety
- ❑Manhole inspection
- ❑Manhole rehabilitation methods
- ❑Cost-effectiveness analysis of rehabilitation methods
- ❑Construction inspection and quality control

NASSCO – MACP

Manhole Assessment and Certification Program

NASSCO has developed two inspection protocols to better meet the needs of utility owners. The level 1 inspection provides basic condition assessment information to evaluate the general condition of a manhole. The purpose of the level 2 inspection is to gather detailed information to fully document all defects, determine condition of the manhole, and provide the specific information needed corrective action.

Additional information, including upcoming classes may be found at

nassco.org

Condition Assessment / Manhole Inspection Programs
In-house program example – JEA (Jacksonville Electric Authority)

Jacksonville Electric Authority was established in 1895. Became an independent authority in 1968.

Water and wastewater systems established in 1880. Absorbed by JEA in June of 1997 because of poor conditions such as overflows, collapsing manholes, etc. JEA had the ability to bond.

2009 – started a 5 year program to evaluate 54,000 plus manholes.

Data captured on InfoNet – modeling / condition assessment software.
Condition assessment maps were developed.
Developed own condition assessment form and system.
Inspections were performed.
Information was combined with historical cleaning maps,
Future re-inspections were performed by cleaning crews.

Products for Manhole Rehabilitation

A sampling from the June 2011 Report on…
Currently Available Products and Techniques for Manhole Rehabilitation
Trenchless Technology Center - Louisiana Tech University

- Cementitious Coatings / Linings
- Polymer BASED Coatings / Linings
- Preformed Manhole Inserts
- Cured in Place Liners (CIP)

Cementitious Coatings / Linings

- Advantages
  - Initially Economical
  - Good productivity
  - Structural repair capability if polymer cement
  - Tolerant to surface wetness
- Limitations
  - Limited corrosion protection
  - Cure time can be an issue
  - Can create a cold joint
  - Inspection frequency
  - Life Expectancy
  - Life Cycle Cost – Medium to High

Polymer Based Coatings / Linings

- Advantages
  - Corrosion resistant
  - May add strength to the host manhole
  - Competitive price
  - Effective for eliminating Infiltration
  - Life Expectancy
  - Life cycle cost – Low to Medium
- Limitations
  - Some sensitive to surface wetness
  - Can be expensive if applied thick

Preformed Manhole Inserts

- Advantages
  - Good corrosion protection
  - Structural repair
  - Life expectancy
  - Life Cycle Costs – Low to Medium
- Limitations
  - Low productivity
  - Requires excavation(may weaken the pavement structure)
  - Upper portions (chimney and ring)
  - Only down to the bench
  - Can be expensive vs. cost to replace and coat

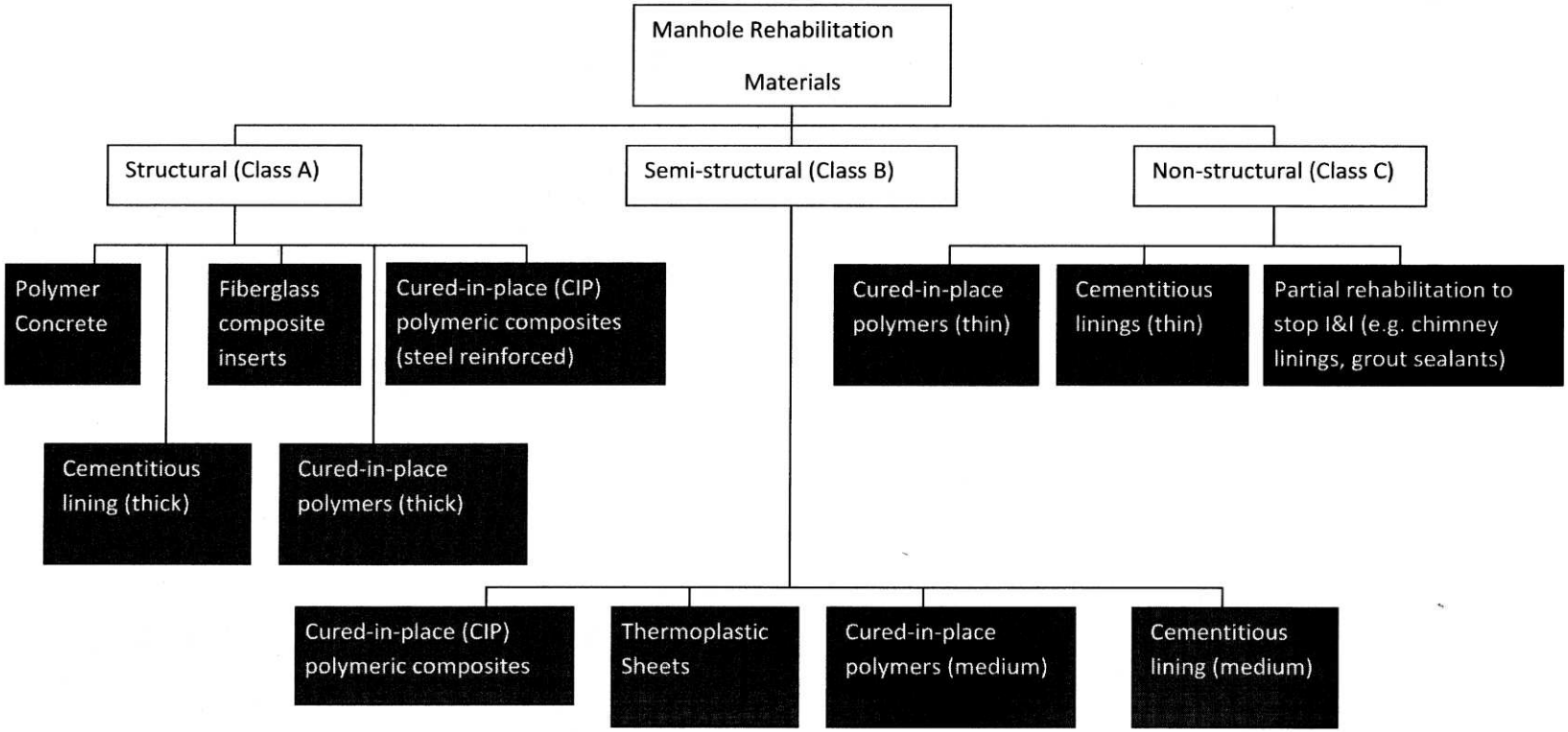


Figure 8-1. Manhole Rehabilitation Material Classification Based on Structural Capabilities.

WERF Conclusions

- Most manhole rehab methods semi-structural
- Fully-structural (standalone) methods not needed for most manholes
- Semi or non-structural could be efficient for I&I removal at lower cost
- Application/surface preparation important. Same type of material …. can be classified as structural, semi-structural or non-structural depending on the thickness and application quality.
- Each manhole different – no silver bullet solution
- Use of decision support tool recommended
- Sound engineering and thorough technical specifications are crucial in implementing a successful project.

What is *SpectraShield?*

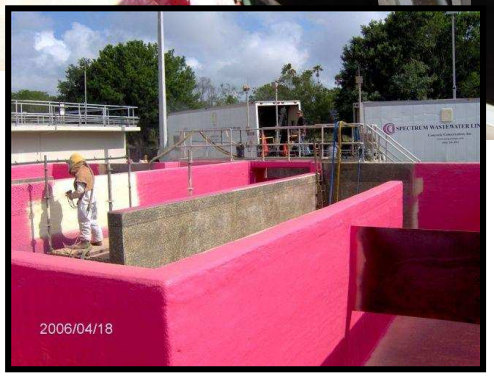
- **A modified polymer 'stress skin panel' liner**
  - Moisture Barrier bonded to substrate (Polyurea)
  - Resurfacing Layer (Polyurethane Foam)
  - Corrosion Barrier (Polyurea)

- **Important Design Features**
  - "Stress-Skin Panel" design
  - Forms a "manhole within a manhole"
  - Renews Structure
  - Flexible (not susceptible to cracking)
  - Mechanical Bond to substrate
  - Stops Infiltration and Exfiltration
  - Prevents Corrosion
  - Trenchless Application
  - Rapid installation (7' deep manhole lined in less than one hour)
  - 10 YEAR Manufacturer and Applicator Warranty

SpectraShield APPLICATIONS

It's not just "manholes"...

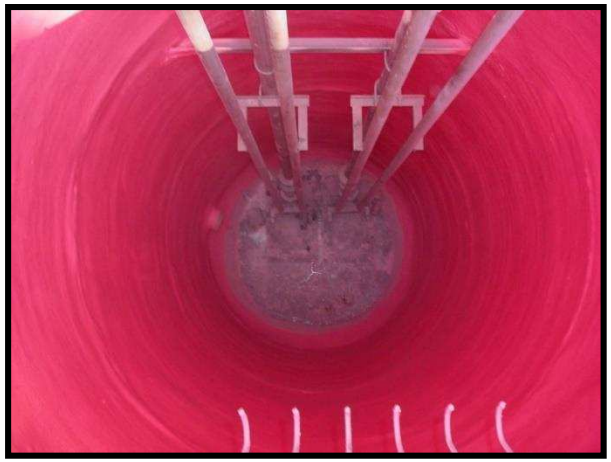
- Box culverts
- Clarifier Weirs
- Contact Chambers
- Package WWTP



SpectraShield APPLICATIONS

It's not just "manholes"...

- **Structures**
  - Manholes
  - Wetwells
  - Headworks
  - Grit Chambers
  - Vaults
  - Digesters
  - EQ Basins
  - Large Diameter Pipe / Culverts



- **What type of Structure materials?**
  - Concrete
  - Brick
  - Steel

SpectraShield Installation Process

- Record Photo of each step.
- Structure Cleaning
- Primer
- First Barrier Layer
- Resurfacing Layer
- Final Barrier Layer

SpectraShield - Cleaned and Prepared Manhole

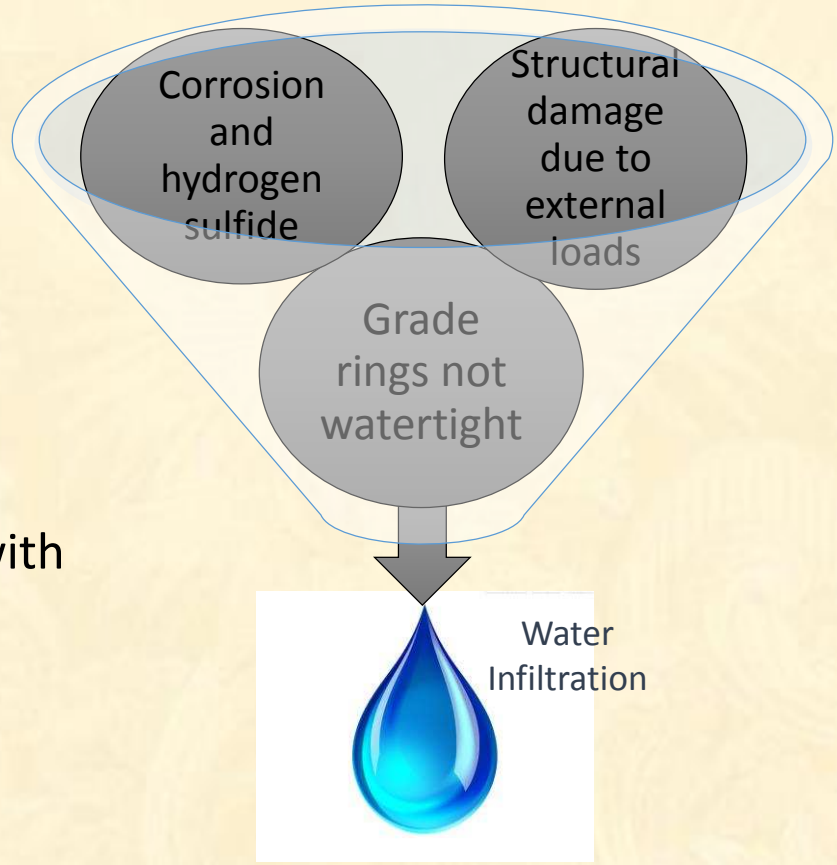
SpectraShield –
First Barrier Layer

SpectraShield – Resurfacing Layer

SpectraShield –
Final Barrier Layer and Completed Manhole

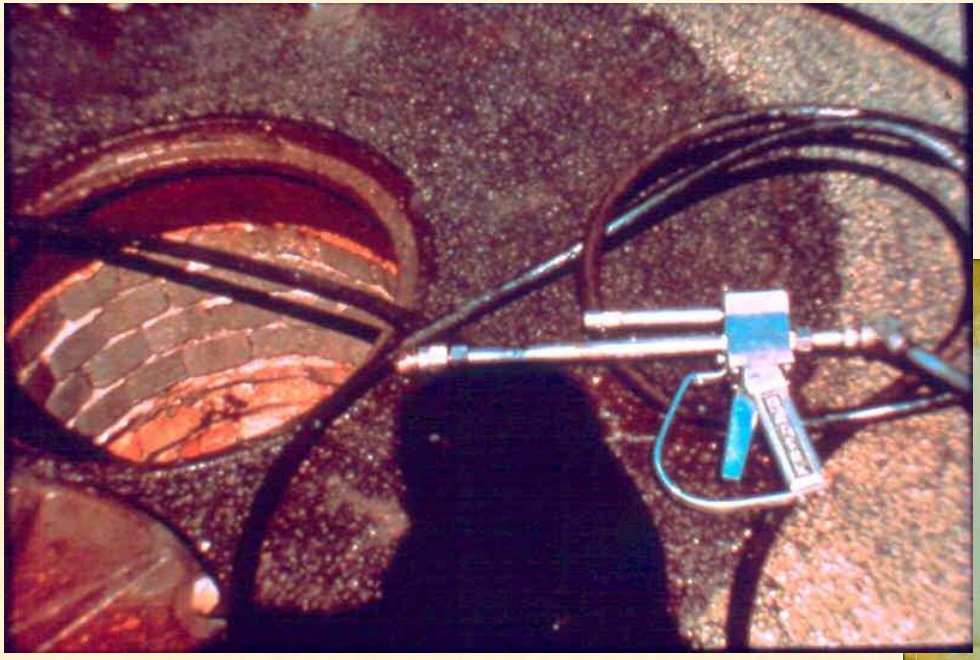
MANHOLES

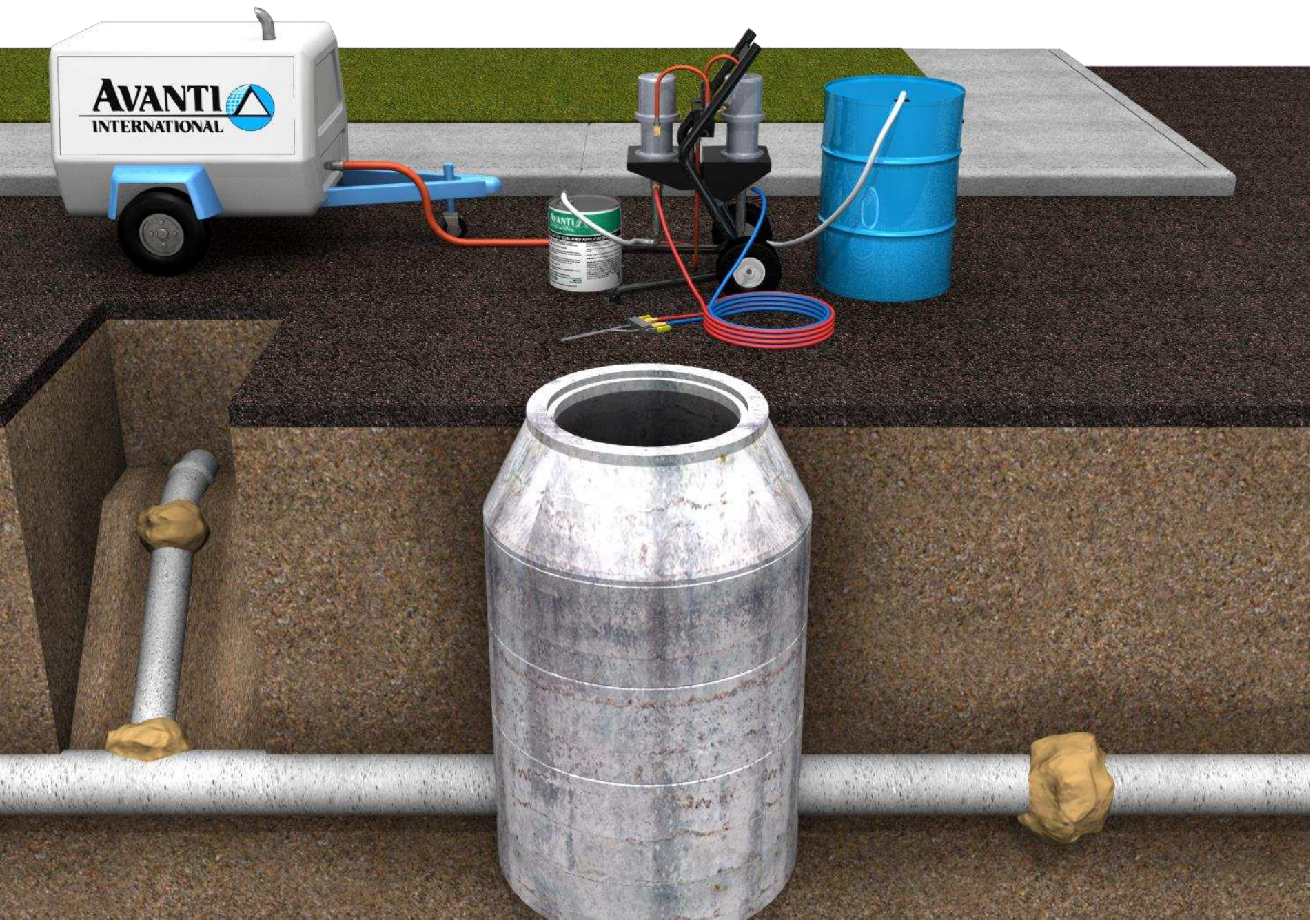
- Solutions
  - Cement Liners
    - Calcium Aluminate mortar
    - Microsilica mortars
  - Epoxy
    - Strong ceramic like exteriors
    - Polyurethane coatings
    - Hot-melt polyurethane (cures with moisture)
  - Liners
    - CIPP
  - Grade rings
    - Hole plugs sealing ring holes
    - Rubber gaskets sealing grade rings

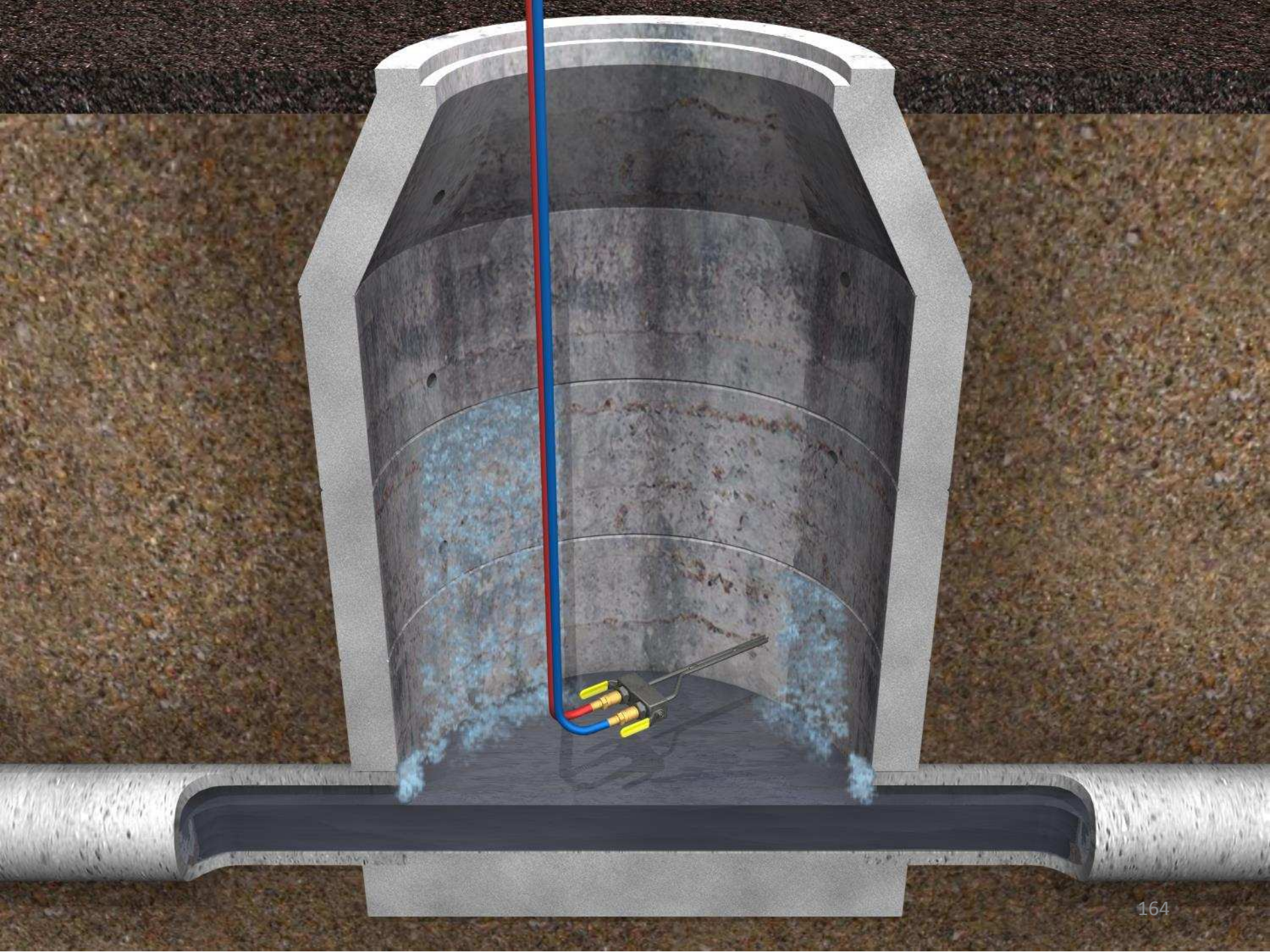


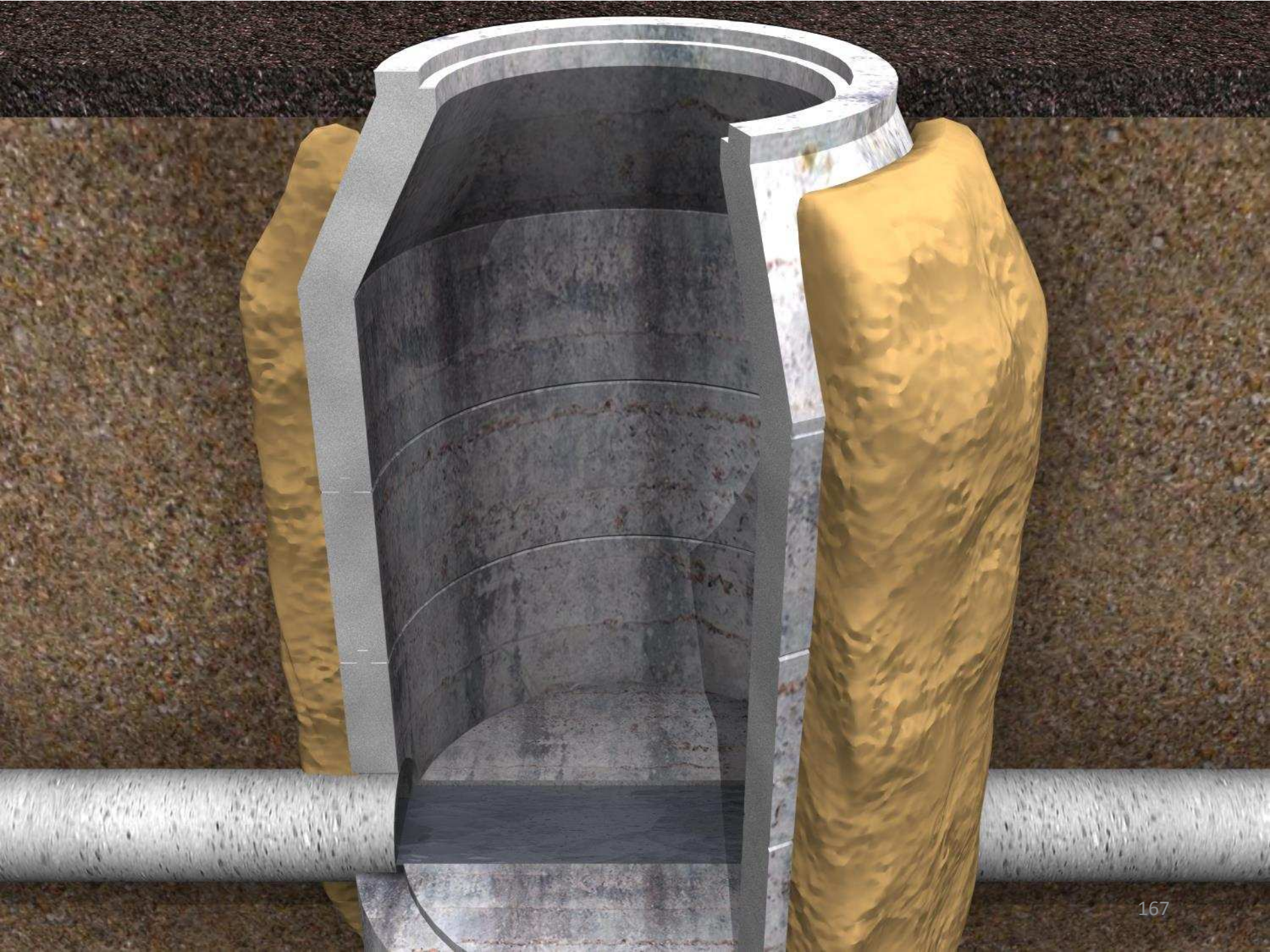
MANHOLES

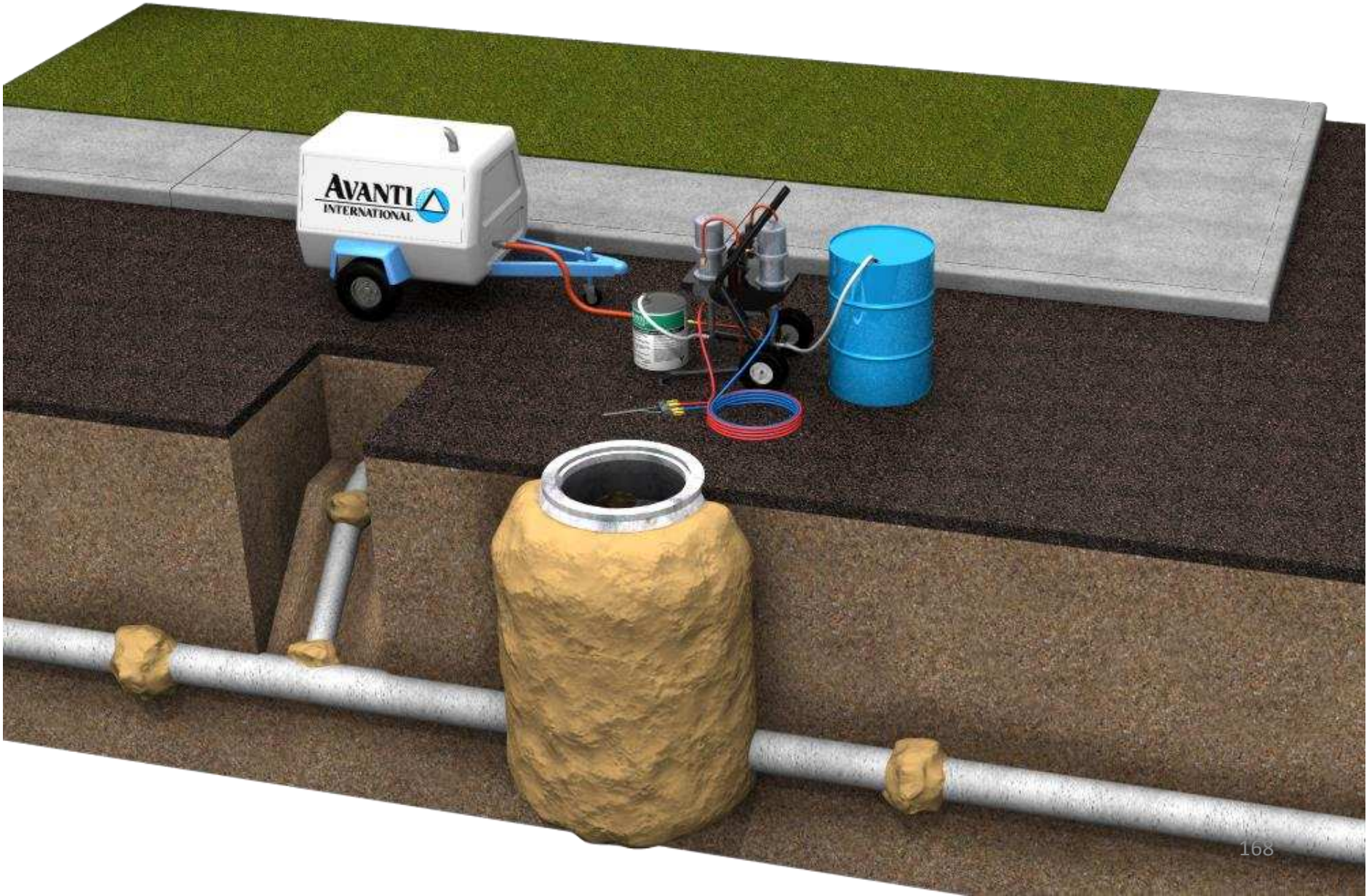
- Chemical injection grouting




AVANTI
INTERNATIONAL



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INTERNATIONAL

MANHOLES

- Reinforced cement liner

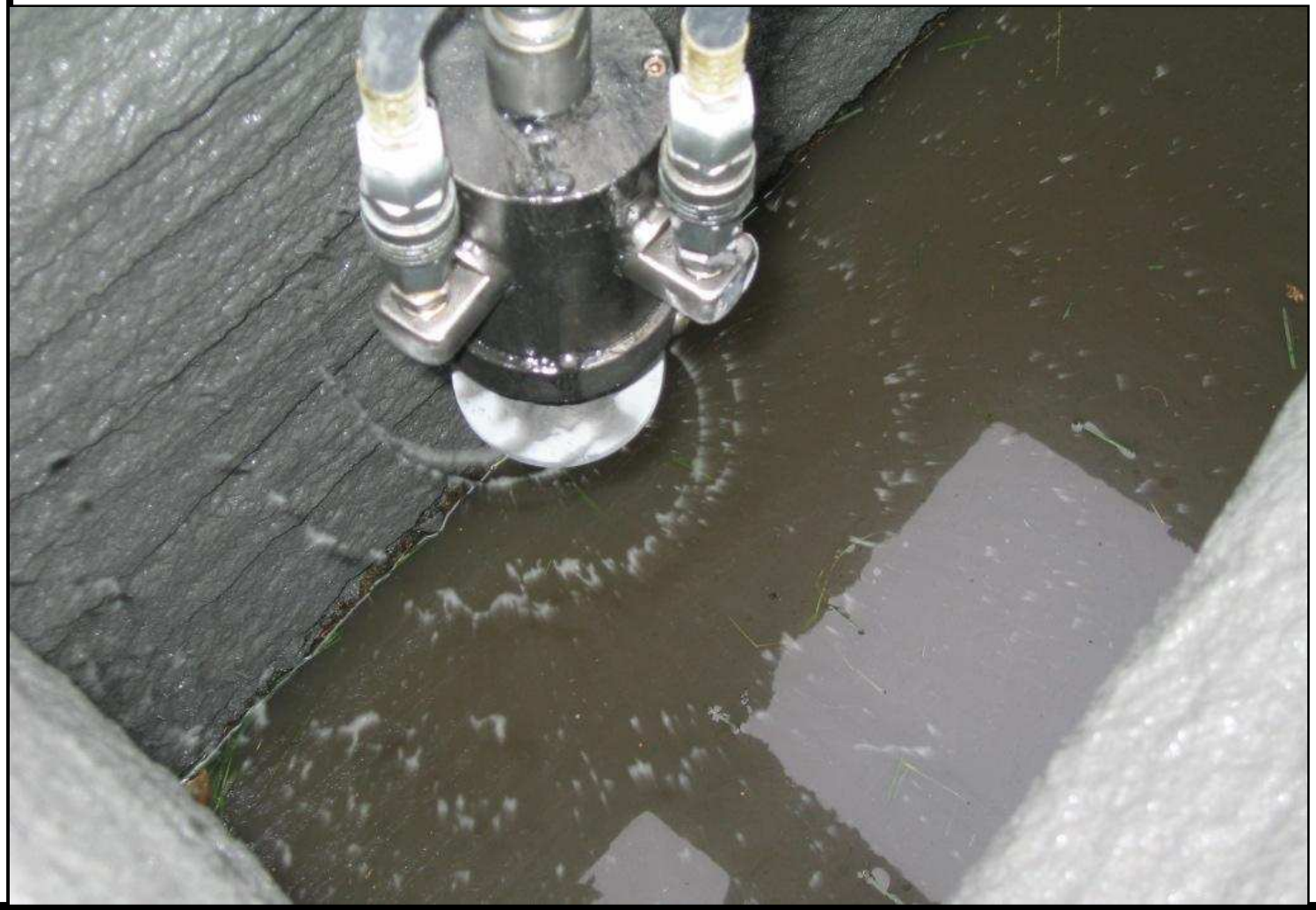
MANHOLES

- Coating

Brick Manhole Missing Mortar Joints

Finished Permacast Liner

Radial Impingement

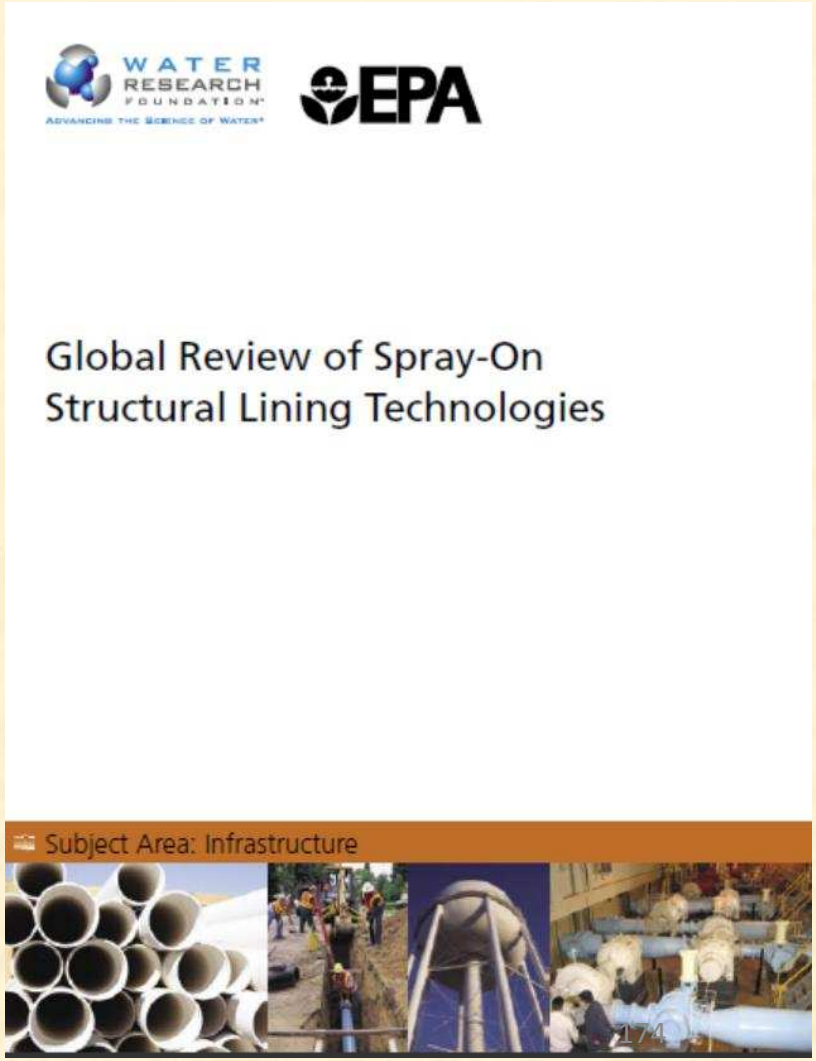


Spray-on Polymeric Coatings used for Rehabilitation of Pressure Pipes

- Polymeric materials used in pressure pipeline rehabilitation, epoxy, polyurethane, and polyurea.

- Depending on the type and hardening agent combined with the resin, the resultant polymer may possess either more rigid or more elastic material properties, also called elastomeric.

The American Water Works Association (AWWA) classify trenchless rehabilitation methods as “non-structural” (Class I), “semi-structural” (Class II and Class III), and “structurally independent” (Class IV) based upon their ability to perform under internal pressure



Spray-on Polymeric Coatings used for Rehabilitation of Pressure Pipes

The semi-structural category further differentiates between coatings with inherent ring stiffness, Class III, versus those that rely on adhesion to the host pipe to be self-supporting, Class I. Polymer coatings are either nonstructural (Epoxy) or semi-structural (polyurethane and polyurea).

Spray-on Polymeric Coatings used for Rehabilitation of Pressure Pipes

The semi-structural coatings can be applied to the pipe wall in multiple layers called “High Build”, which leads to the added ability to bridge gaps in the host pipe and add strength to the system. Depending on the design and application, these may be a Class II or Class III.

The design thickness of a spray-on polymeric lining will be related to

- The maximum operating pressure of the host pipe,
- The material properties of the polymer, and
- The degree of pipe deterioration.

Spray-on Polymeric Coatings used for Rehabilitation of Pressure Pipes

A polymeric lining installed into a deteriorating pressurized host pipe with holes or gaps may fail in three ways:

(1) Punching shear failure,
(2) Biaxial bending failure, and
(3) Tensile failure.

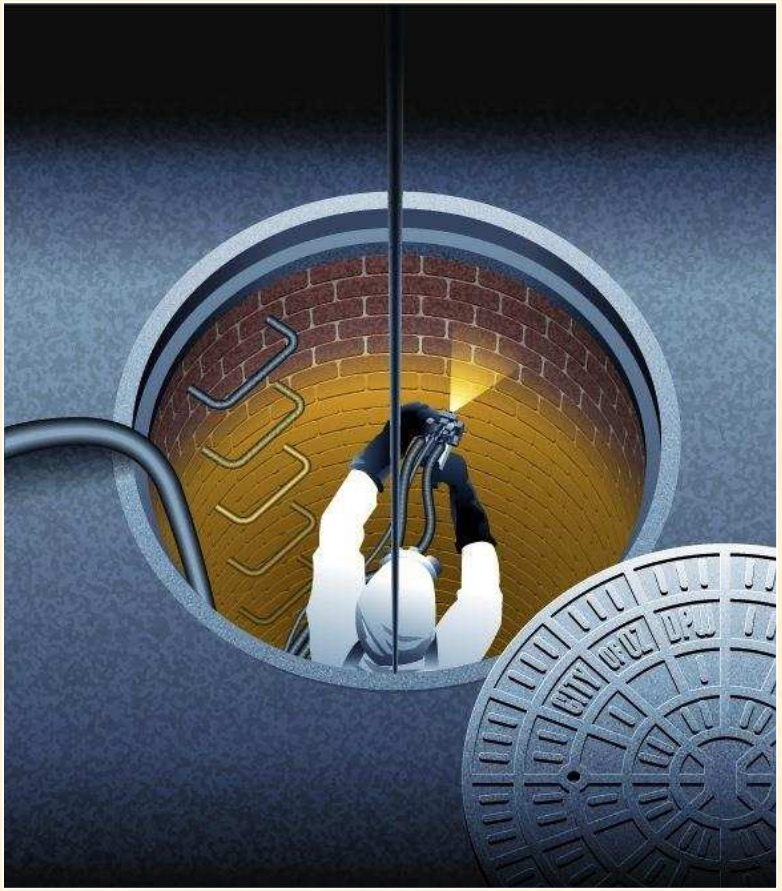
The type of failure that occurs is a function of:

- The lining thickness, t, and
- The size and shape of the deteriorated opening (or diameter of hole), d, of the host pipe.

Polymeric (Polyurethane / Polyurea / Hybrids)

Lining System For Larger Diameter Utilities

Structural or semi structural grade spray applied polymeric lining systems are suitable for water, wastewater and stormwater Infrastructure rehabilitation



- Spray applied polymeric products (polyurethane or polyurea)
- Rigid or Elastomeric
- Quick Curing
  - As fast as 10 second gel time
  - Reinstate flow in 30-60
- Monolithic finish

- Adapts to all shapes and structures
- Most material attains NSF 61 qualified for potable water contact
- Up to 50 year design life

Properties of Structural Grade Polyurethane
(Sprayroq material used as example)

- Technical Properties
  - High Flex Modulus - 735,000 psi Flex Modulus
  - 4% elongation
  - Tensile 7,450 psi
  - Compressive strength - >18,000psi
  - Abrasion – 17.7 mg loss per 1000 cycles
  - Hardness Shore D = 85
  - Pull test yields on concrete = 400-500 psi (substrate failure)
  - "N" Factor .009 (C factor = 155+)

- Chemical Resistance
  - Hydrogen Sulfide
  - Sulfuric Acid to 20%
  - Chlorine to 6%
  - Road salts

- Quick Cure
  - 10 seconds to gel
  - 30-60 Minute Return-to-Service Time
  - 4-6 hrs to full cure

Semi Rigid Polyurethane (Polyurea & Hybrids)

- Technical Properties
  - >75,000 psi Flex Modulus
  - 43% elongation
  - Tensile 2,900 psi
  - N/a
  - Abrasion – 42 mg loss per 1000 cycles
  - Hardness Shore D = 62-68
  - “N” Factor .01 (C factor = 140+)
  - 34% Bio based content

Demonstration of Strength (structural grade polyurethane)

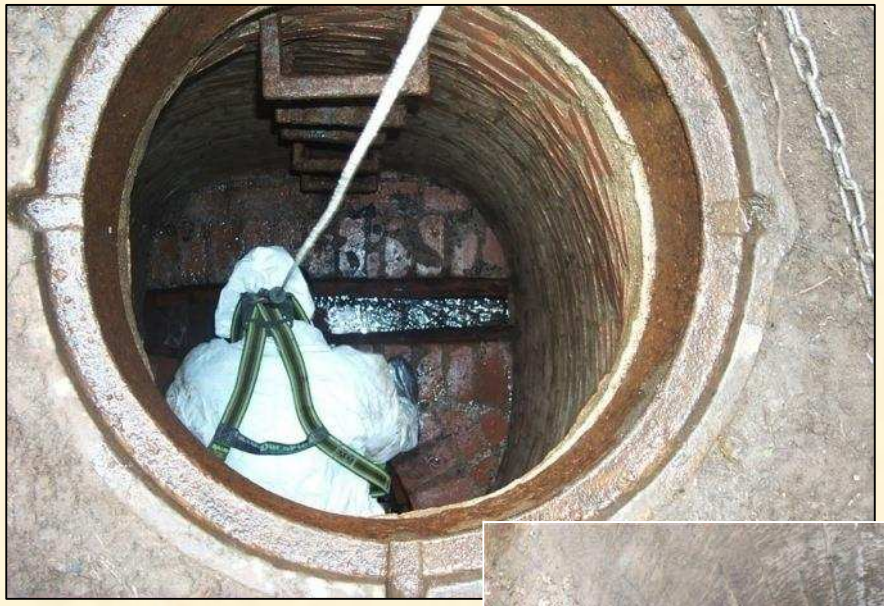
Demonstration of Strength

Typical applications

Water and Wastewater Rehabilitation

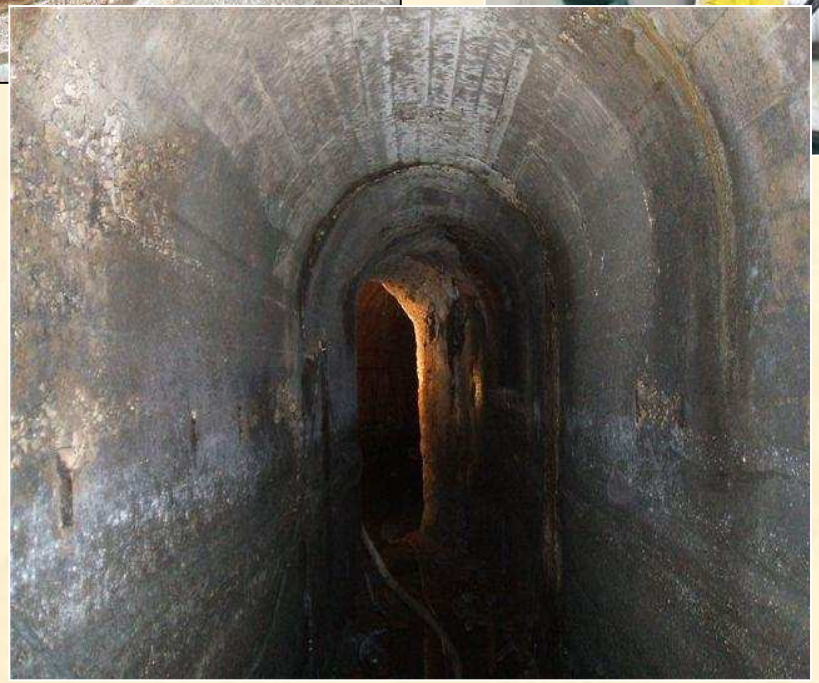
- Wet Wells
- Lift Stations
- Vaults
- Grit chambers
- Separators
- Pipelines (Man entry)
- Tunnels
- Sedimentation tanks
- Secondary Containment

Manholes



Lift Stations

Tunnels

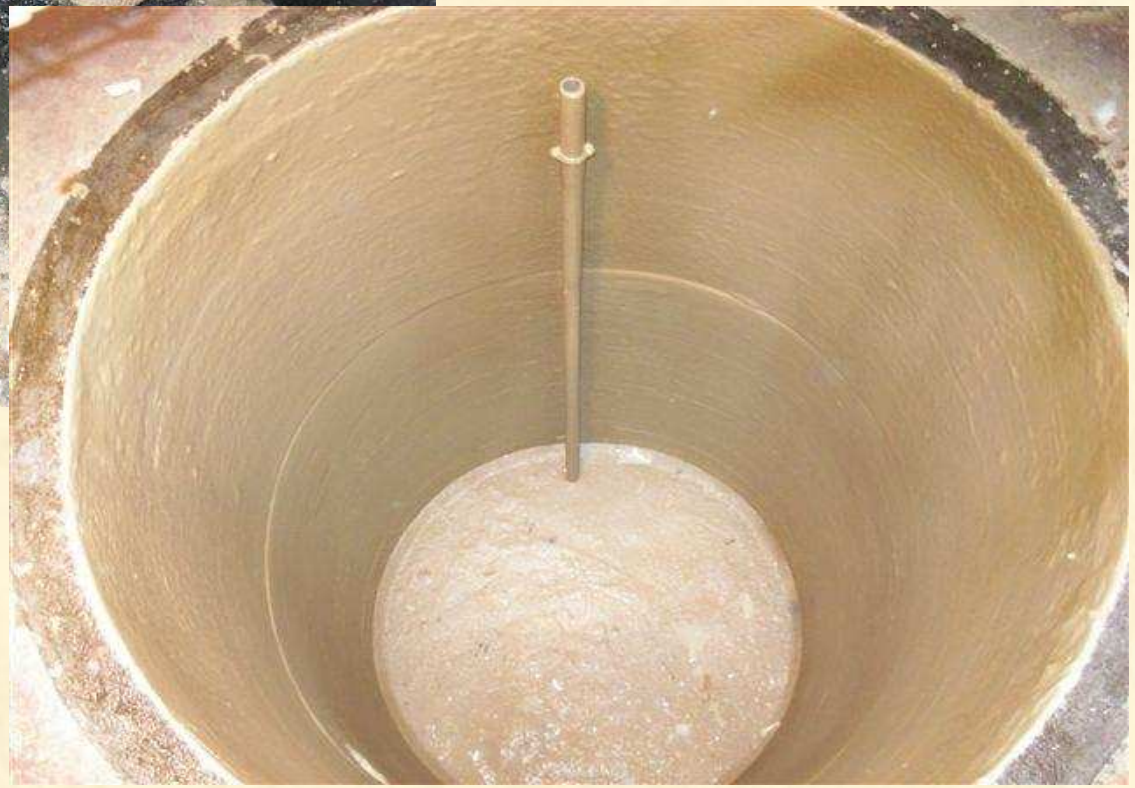


Other Structures

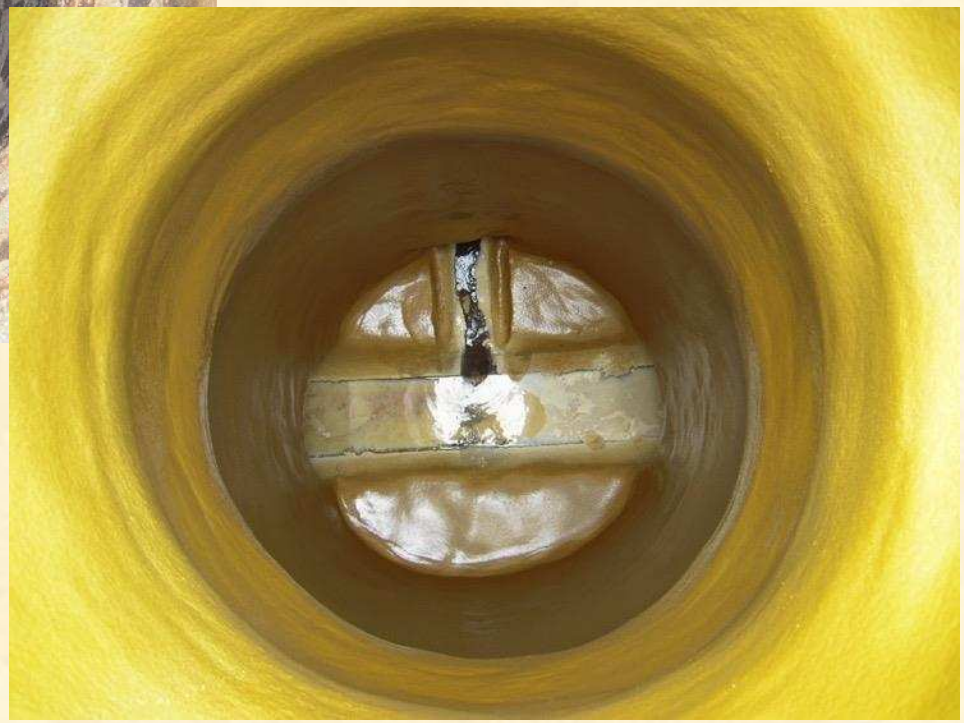
Sample Projects

New Lift Station

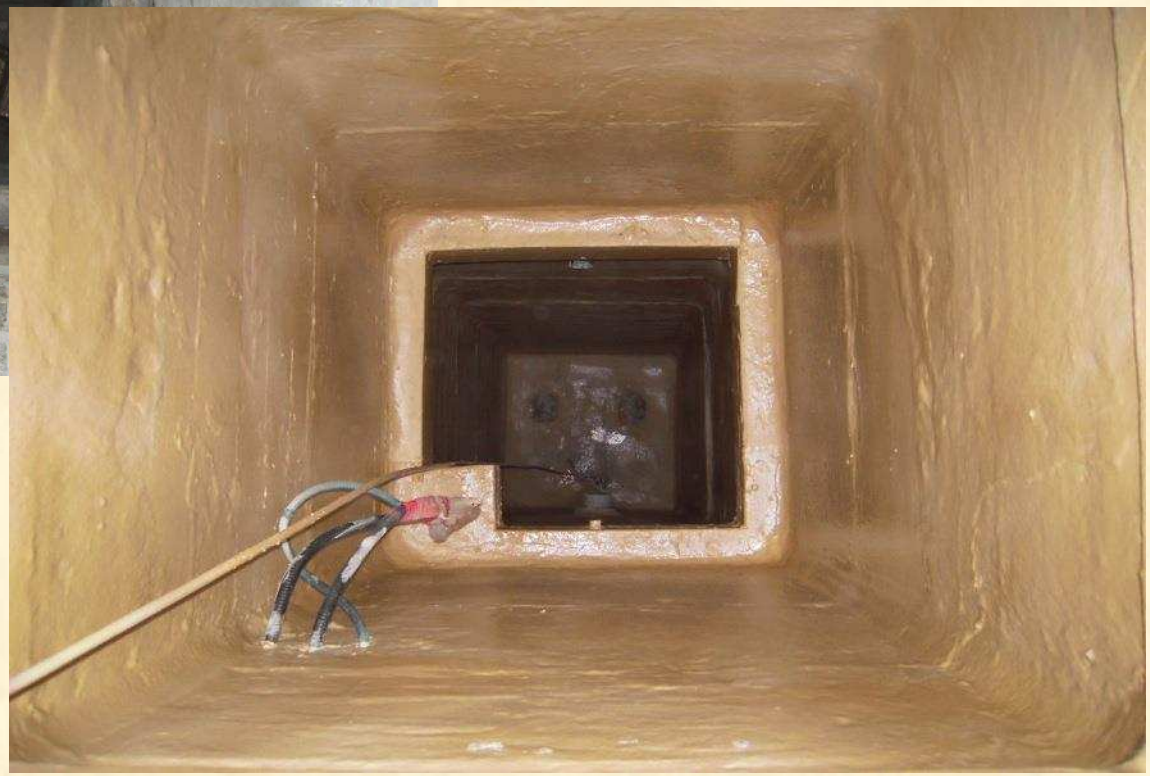
Existing Lift Station Lining



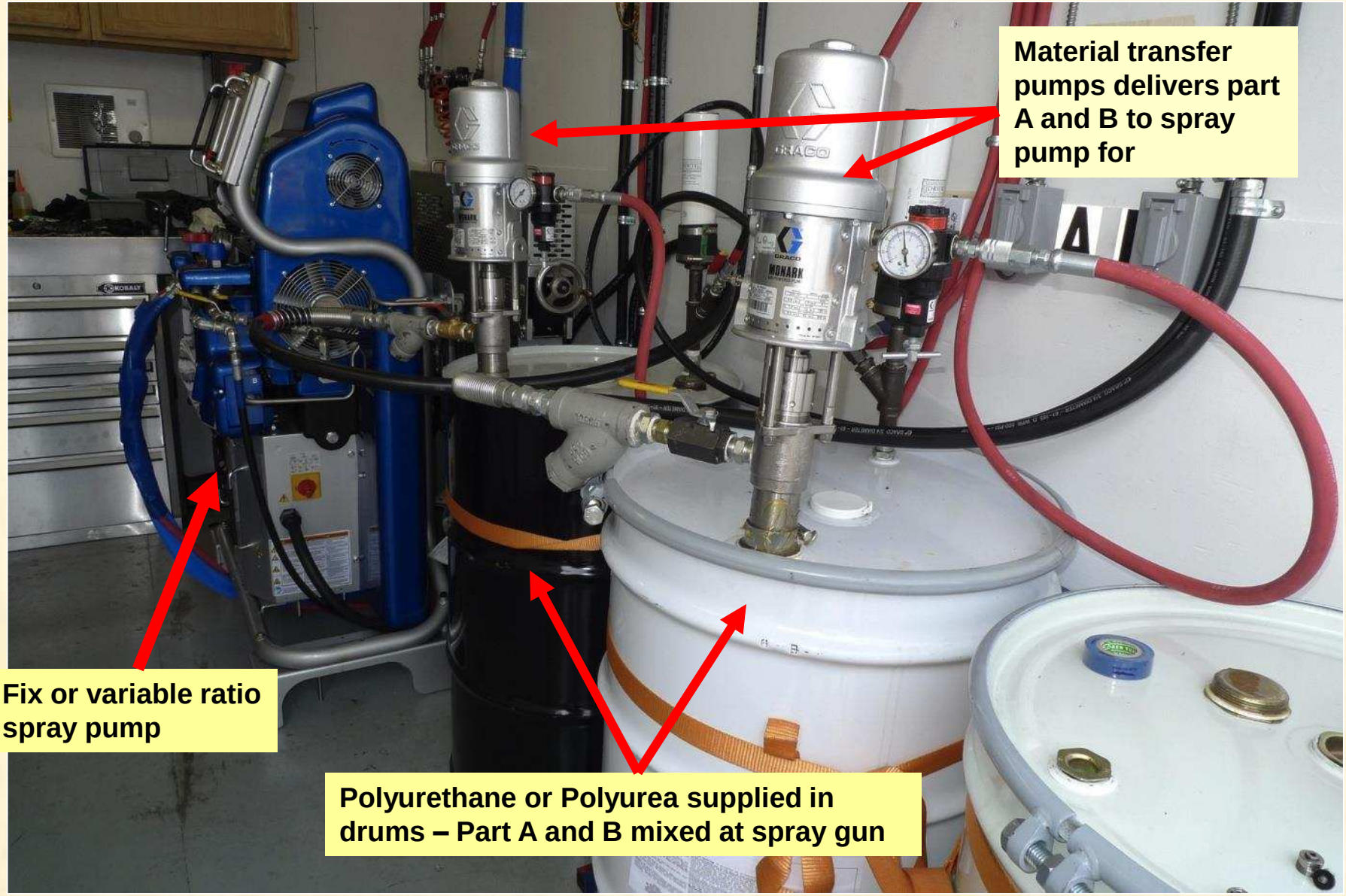
Brick Manhole



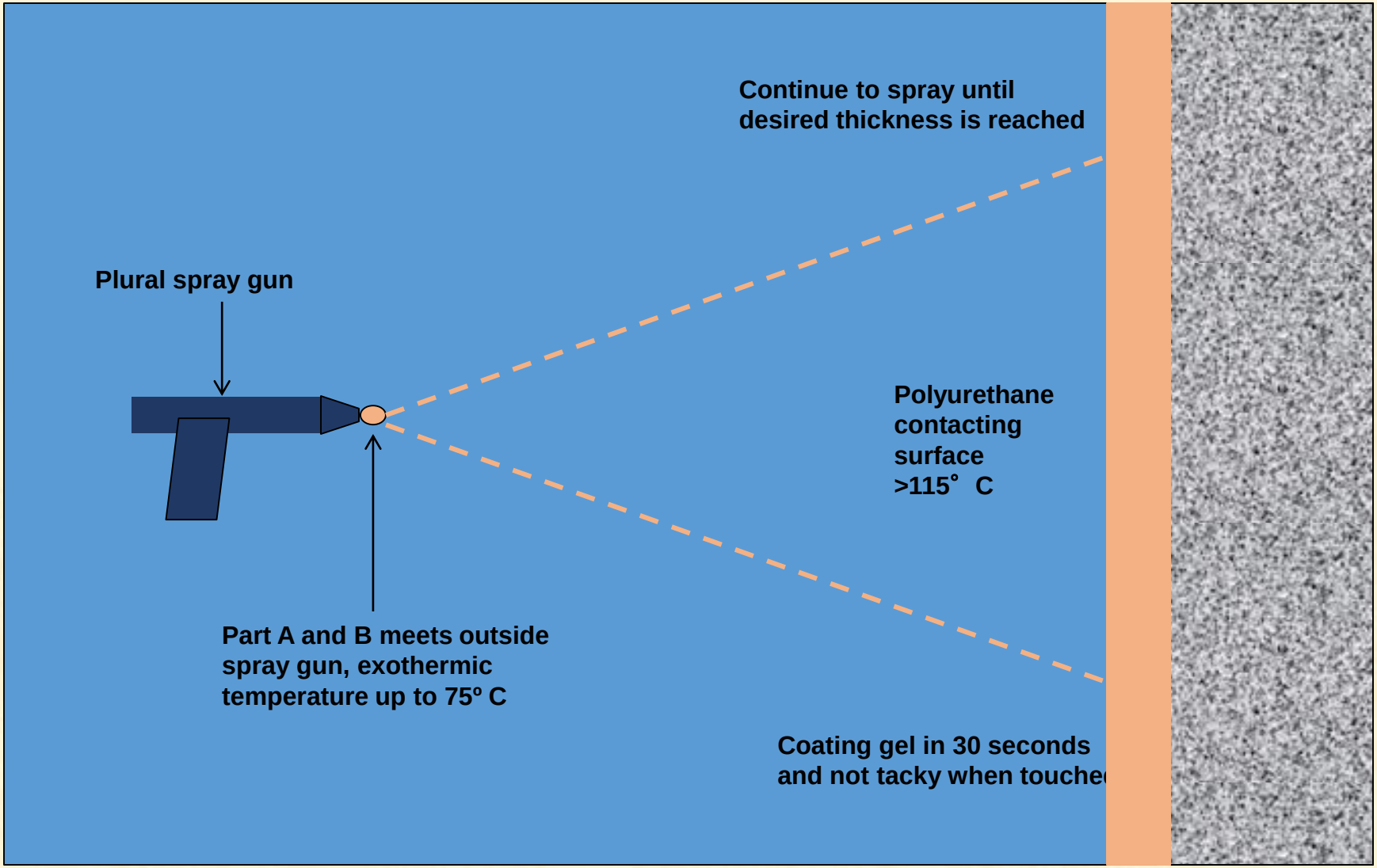
Sump



Spraying on DRY Surface

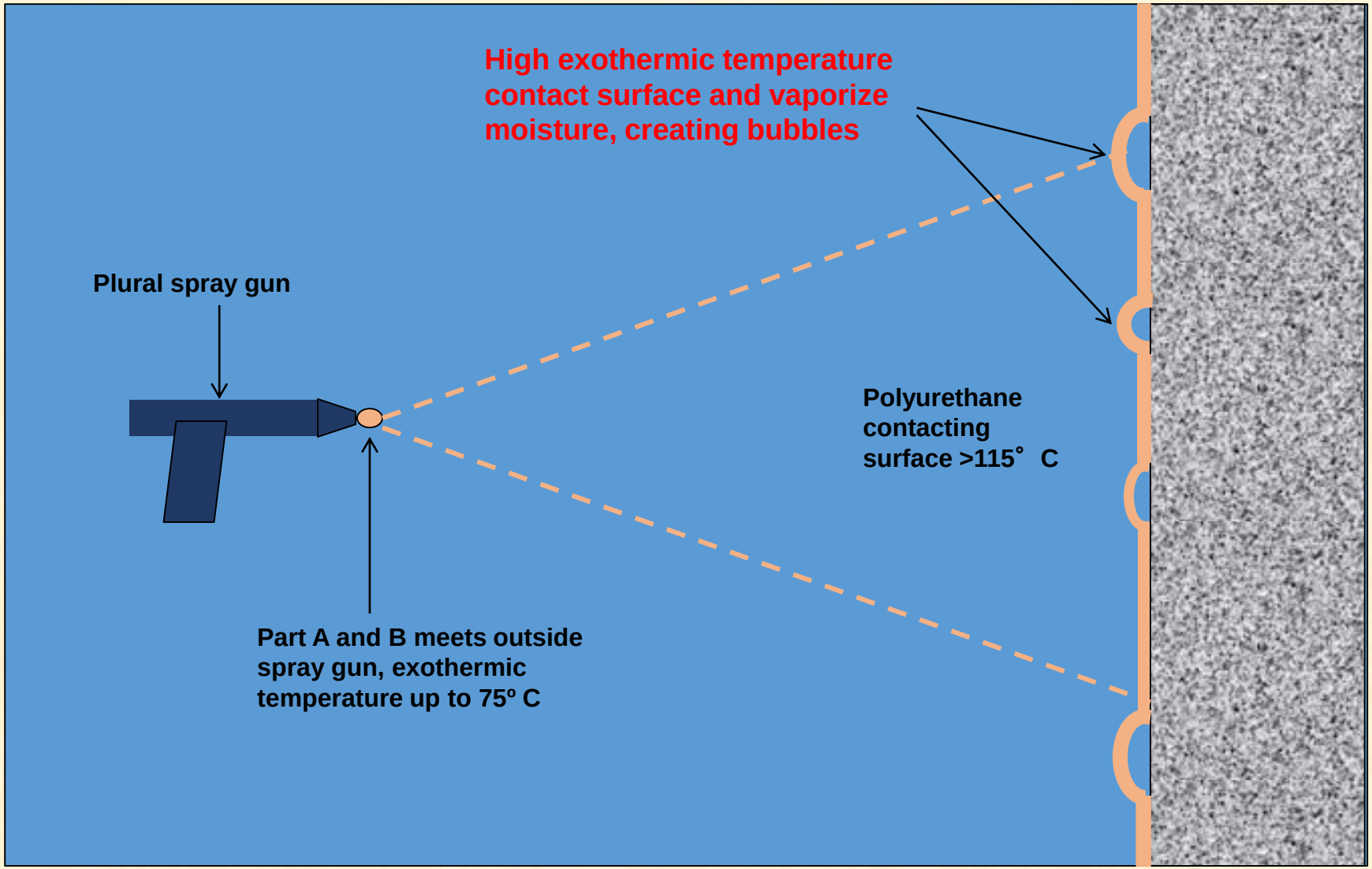

Material transfer pumps delivers part A and B to spray pump for
Fix or variable ratio spray pump
Polyurethane or Polyurea supplied in drums – Part A and B mixed at spray gun

Spraying onto DRY surface

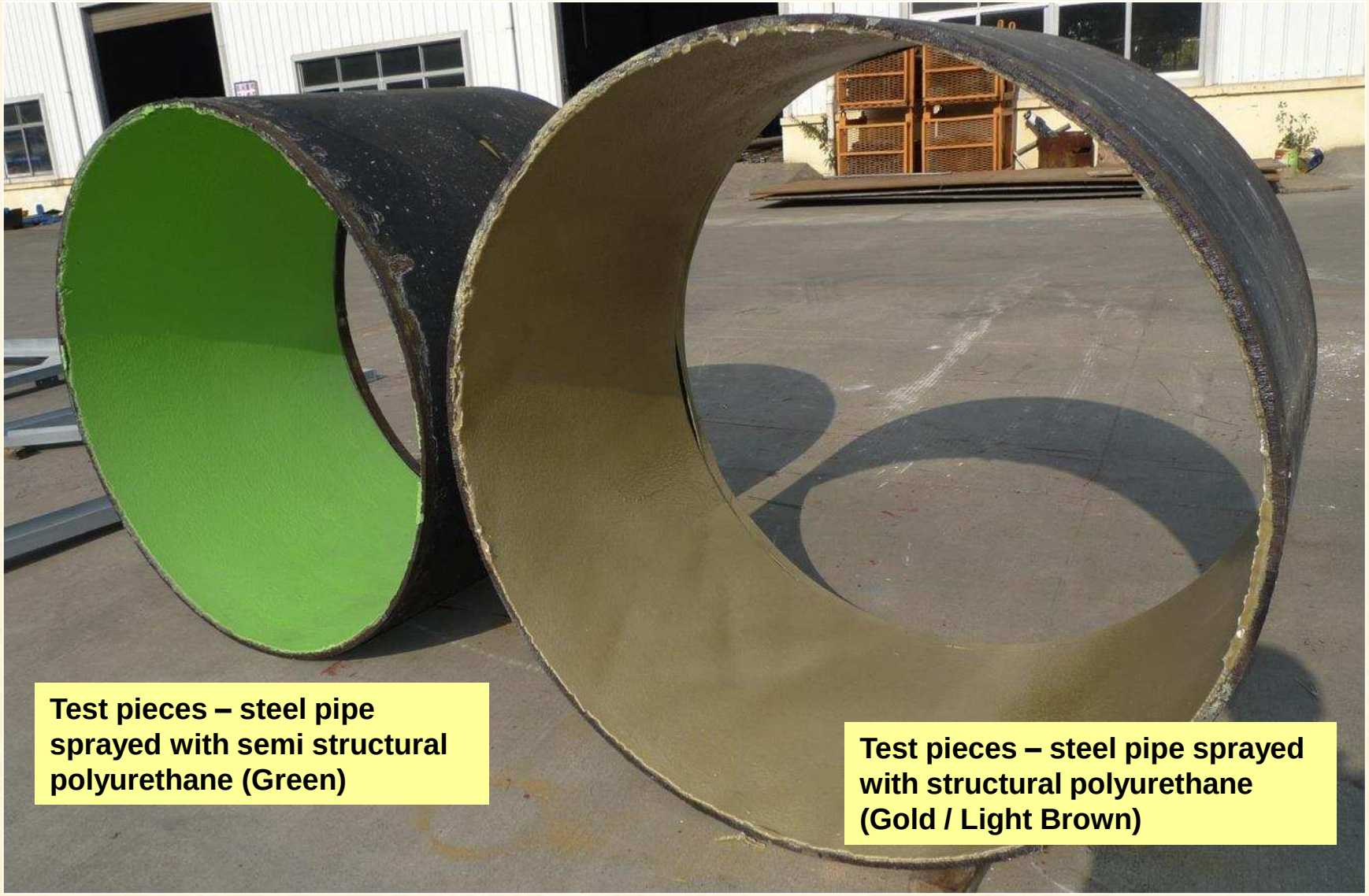


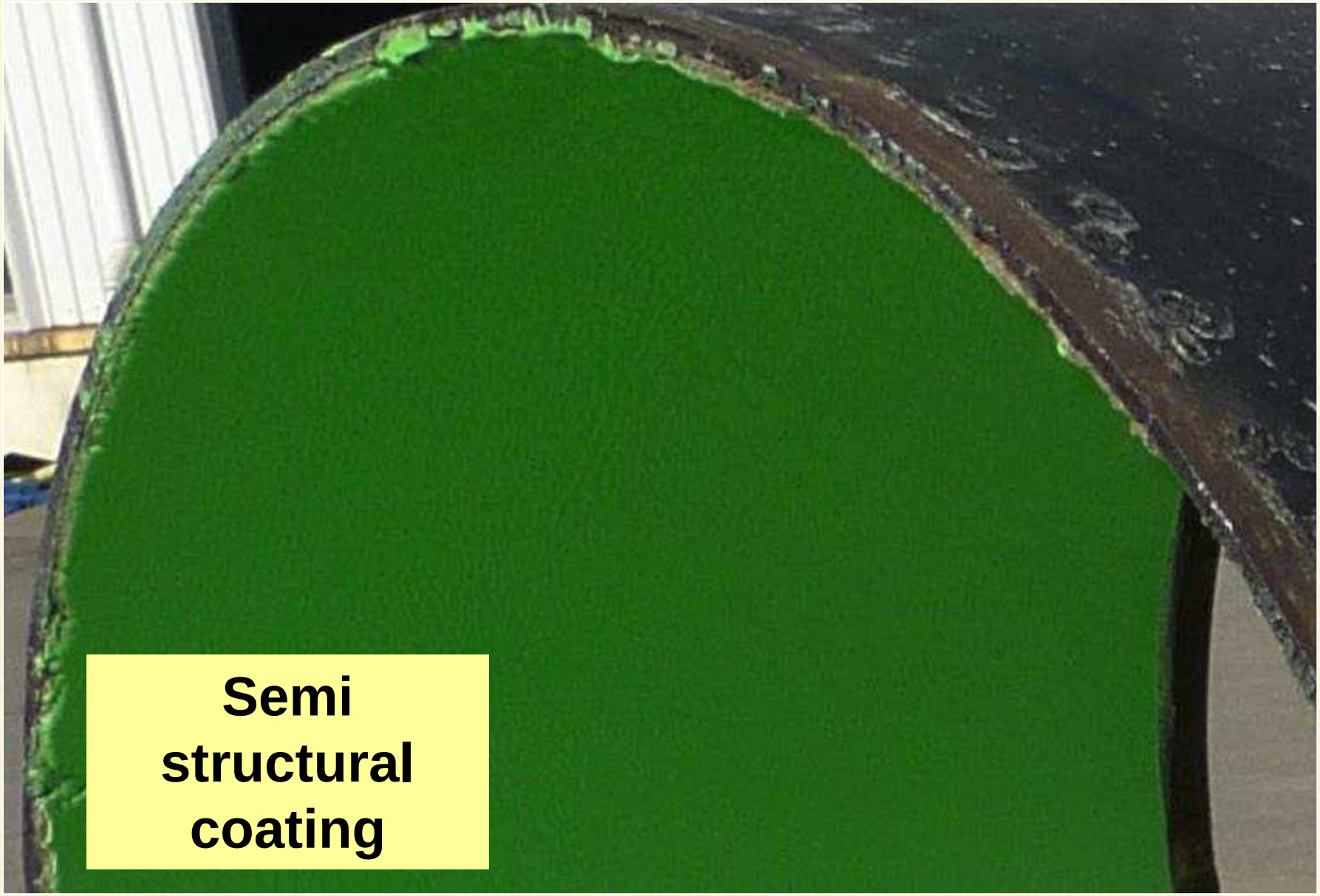
Spraying on Damp or Semi DRY Surface

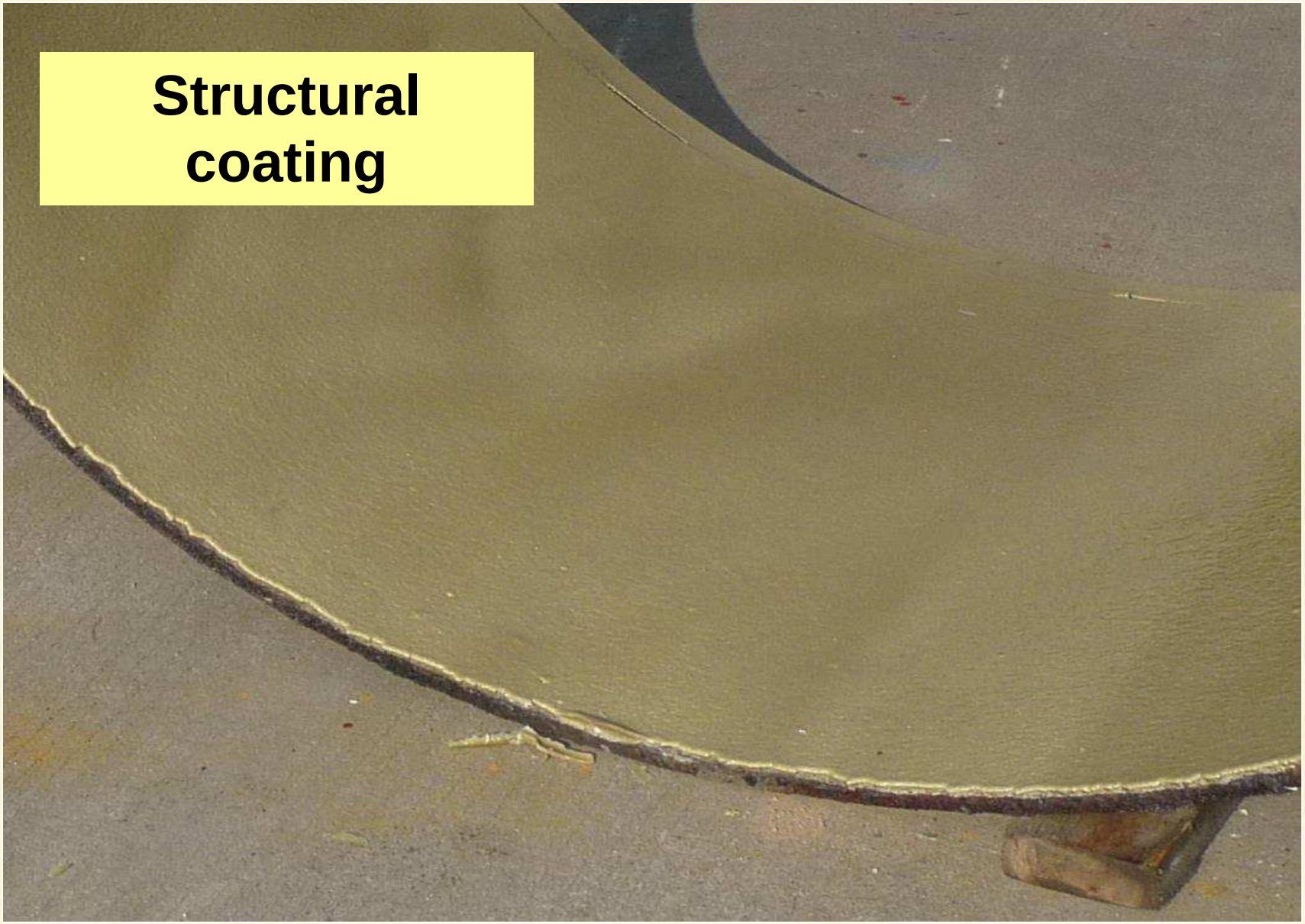
Spraying onto DAMP surface



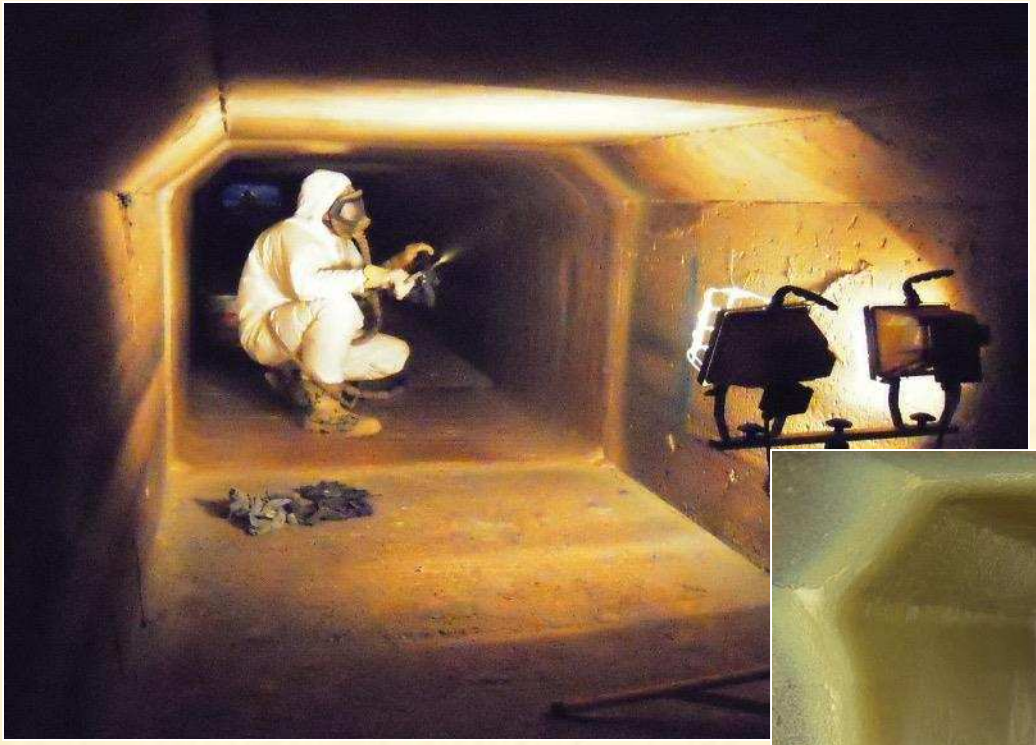

Certified applicator with prepares to spray inside of a 1200mm diameter steel pipe

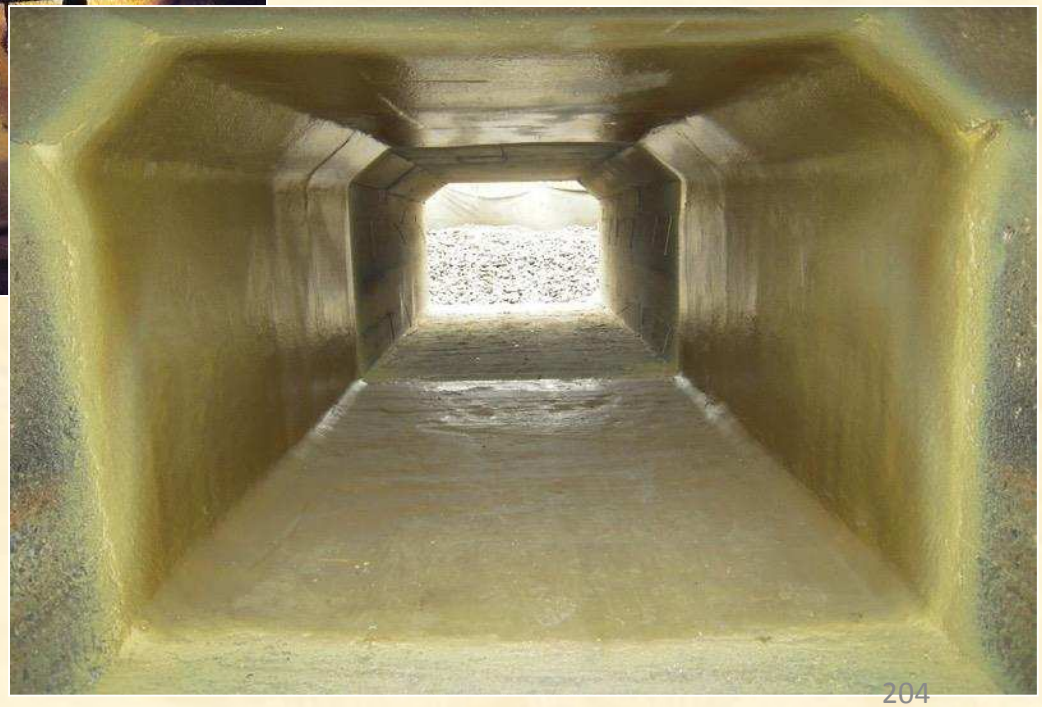

Test pieces – steel pipe sprayed with semi structural polyurethane (Green)
Test pieces – steel pipe sprayed with structural polyurethane (Gold / Light Brown)


Semi
structural
coating

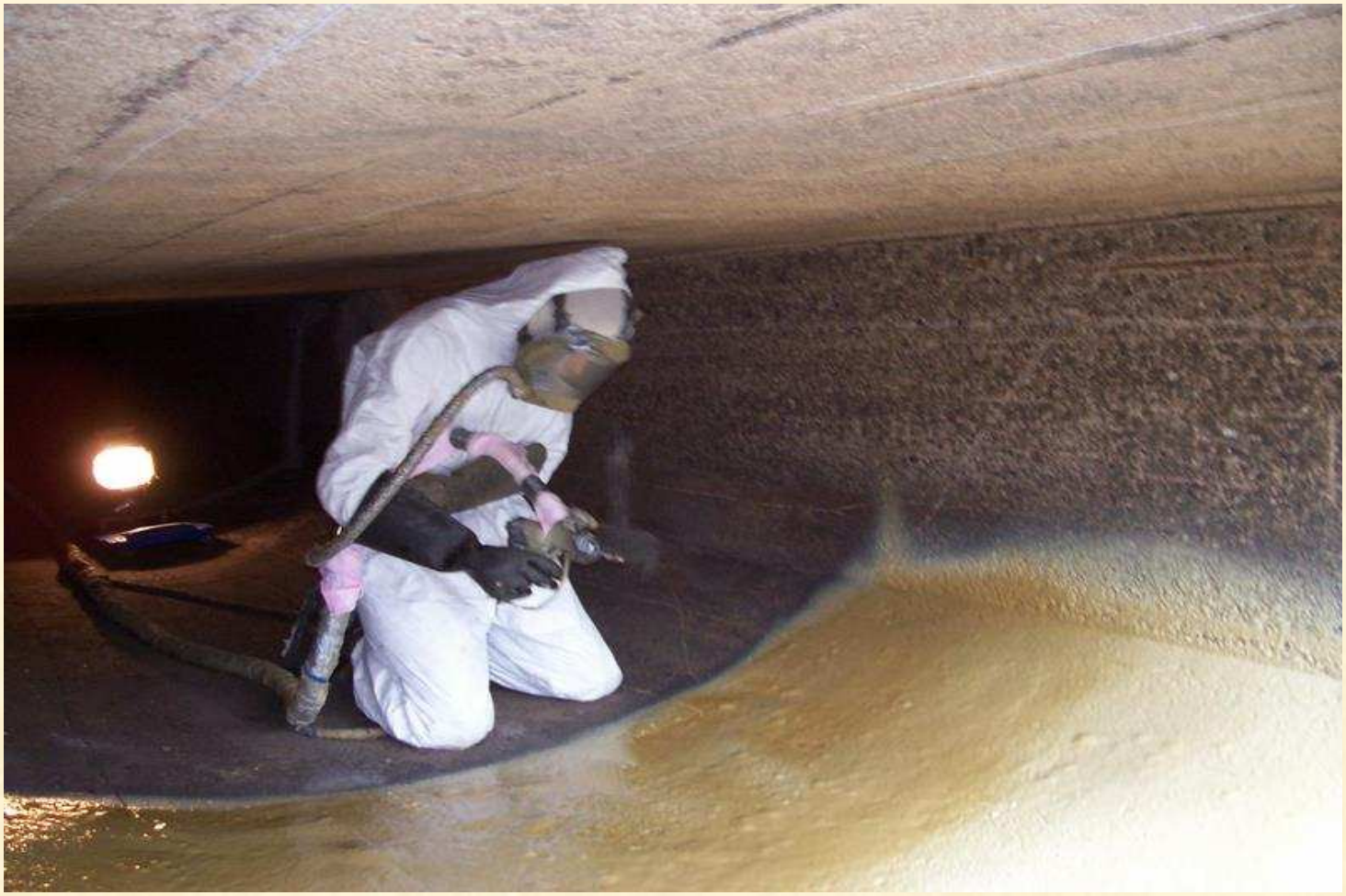

Structural coating

Adapts to any shape or structure





Irregular shaped utilities



Aqueducts and tunnels – Inspection after cleaning and surface repair

Aqueducts and tunnels – Spraying

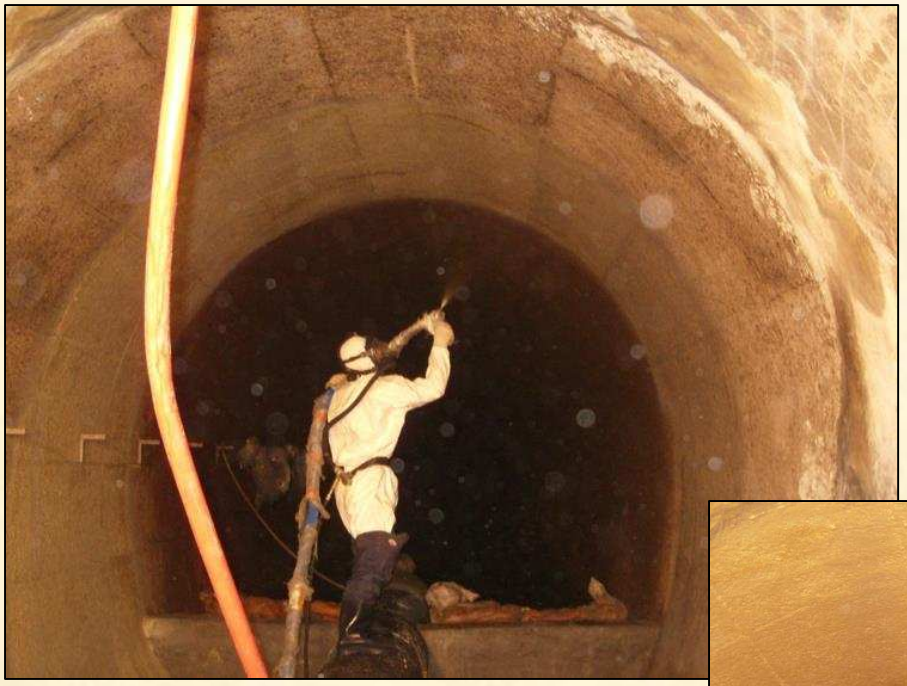
Shenzhen Water Valve Chamber

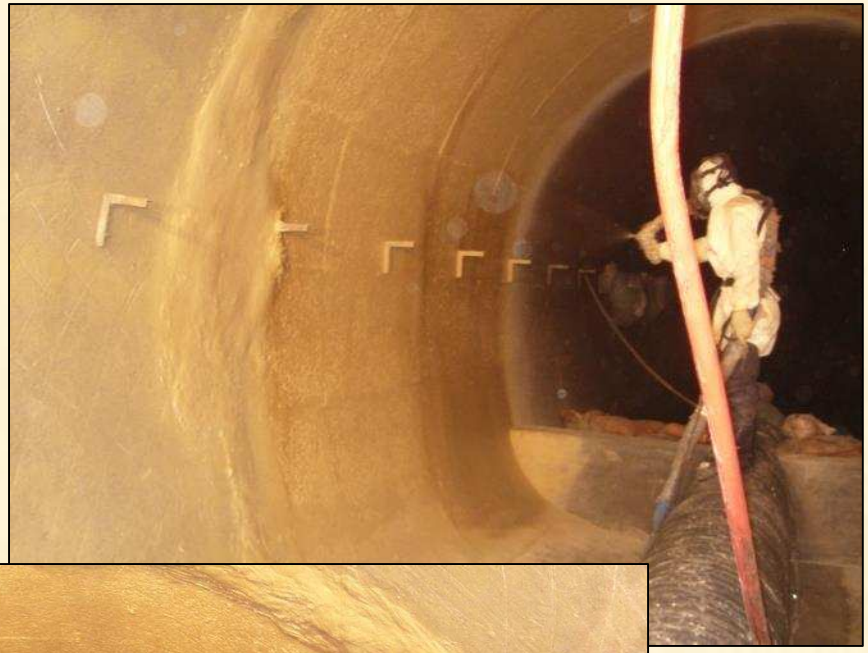
Corrosion Protection

Water valve chamber - preparation

Spraying and finish…..

Shenzhen 4.5m water transmission tunnel





Adhesion Test

Standard ASTM pull test

In Summary:

- Structural & Semi Structural Rehabilitation
- Corrosion Control
- Flow Enhancement

Thanks for your attention!

Questions?

Contact information

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