Pressure Pipe Technologies

Tuesday December 4th,2018

Procrastinators Workshop

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AEGION®

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Agenda

- Aegion Pressure Pipe Rehabilitation Portfolio
  - Insituform – Insitumain – Pressure CIPP
  - Tyfo Fibrwrap
  - Underground Solutions – Fusible PVC
  - United Pipeline Systems – Tite Liner

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Infrastructure Solutions

- Water & wastewater pipeline rehabilitation
- Structural strengthening

Corrosion Protection

- Pipeline corrosion prevention
- Oil, gas and mining

Energy Services

- Facility maintenance services

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Aegion's products/processes

Insituform — Cured-in-place Pipe (CIPP)

United — Tight-Fit HDPE

FIBRWRAP® — Carbon/Glass Fiber (FRP)

Underground Solutions® — Fusible PVC

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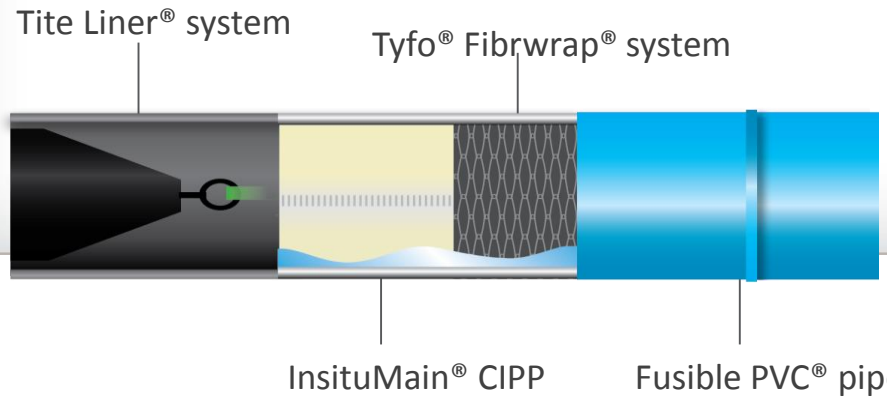
Our Portfolio – Summary

AEGION PRESSURE PIPE CAPABILITIES

Product	Applications							Diameter	Max. Continuous Install Length	Max. Pressure	AWWA Classification		Bends
	Potable Water	Wastewater	Irrigation/ Raw Water	Fire Suppression	Industrial	Electric/ Fiber	Casing				Class III	Class IV	
InsituMain®	X	X	X	X	X			06" - 72""	1,200'	250 psi	X	X	up to 45°
Tite Liner®	*X	X	X	X	X	X		02" - 52"	5,000'	140 psi	X	X	up to 11.25°
Tyfo® Fibrwrap®	X	X	X	X	X			30" & Above	Unlimited	450 psi	X	X	Any
Fusible PVC®	X	X	X	X	X	X	X	04" - 36"	7,000'	305 psi		X	N/A

Note: Pipe size and operating temperature may limit maximum pressure for a given application

** To be evaluated on a case by case basis*



InsituMain® – Slight bends or offsets

Tite Liner – Long, straight runs

Tyfo® Fibrwrap® – Limited or problematic access

Fusible PVC® – Decreased capacity (sliplining), increased capacity (pipe bursting)

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Cured-in-place Pipe (CIPP)

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What is cured-in-place pipe?

- Developed in 1971 by Insituform, cured-in-place pipe (CIPP) is a trenchless technology
  - Started in gravity sanitary and storm sewers
  - Most common trenchless technology
  - Evolved into small diameter low pressure applications
  - Now utilized in medium to large diameter at higher pressures

- The InsituMain® system is suitable for the following applications:
  - Distribution and transmission mains
  - Cooling water lines
  - Fire water mains
  - Industrial pressure applications
  - Sewage force mains

Over 25,000 miles of CIPP have been installed by Insituform crews around the world

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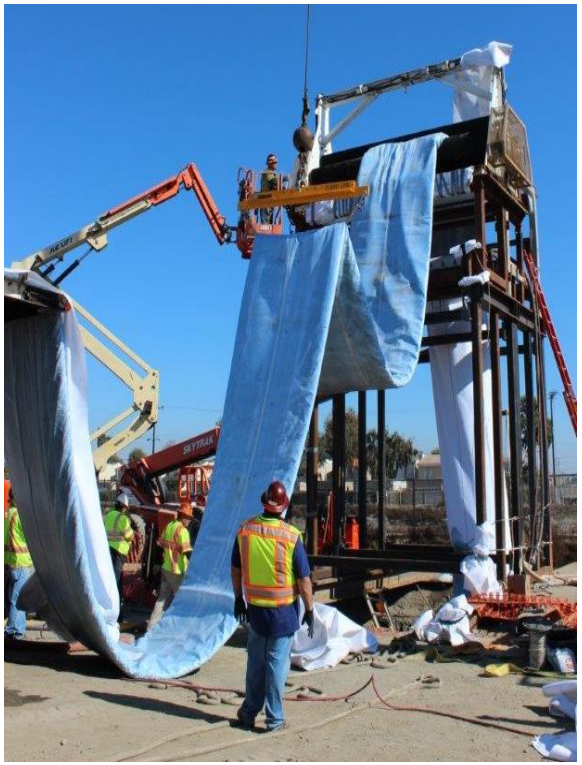
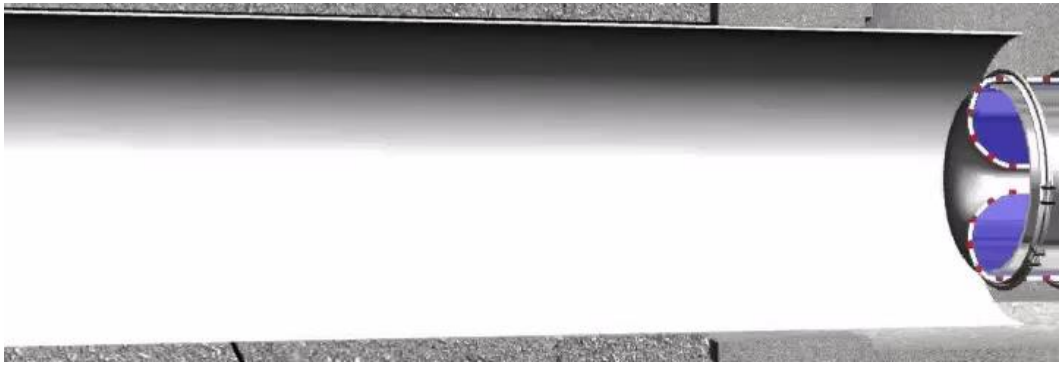
What is InsituMain CIPP?

- Thermosetting resin impregnated felt tube with glass reinforcing material
  - AWWA Class IV material
  - Tight fitting material that maximizes flow
  - End product is a joint less, pipe-within-a-pipe that protects against corrosion, build-up, and leakage
  - NSF 61 certified





Over 600,000 feet of CIPP pressure pipe have been installed by Insituform crews

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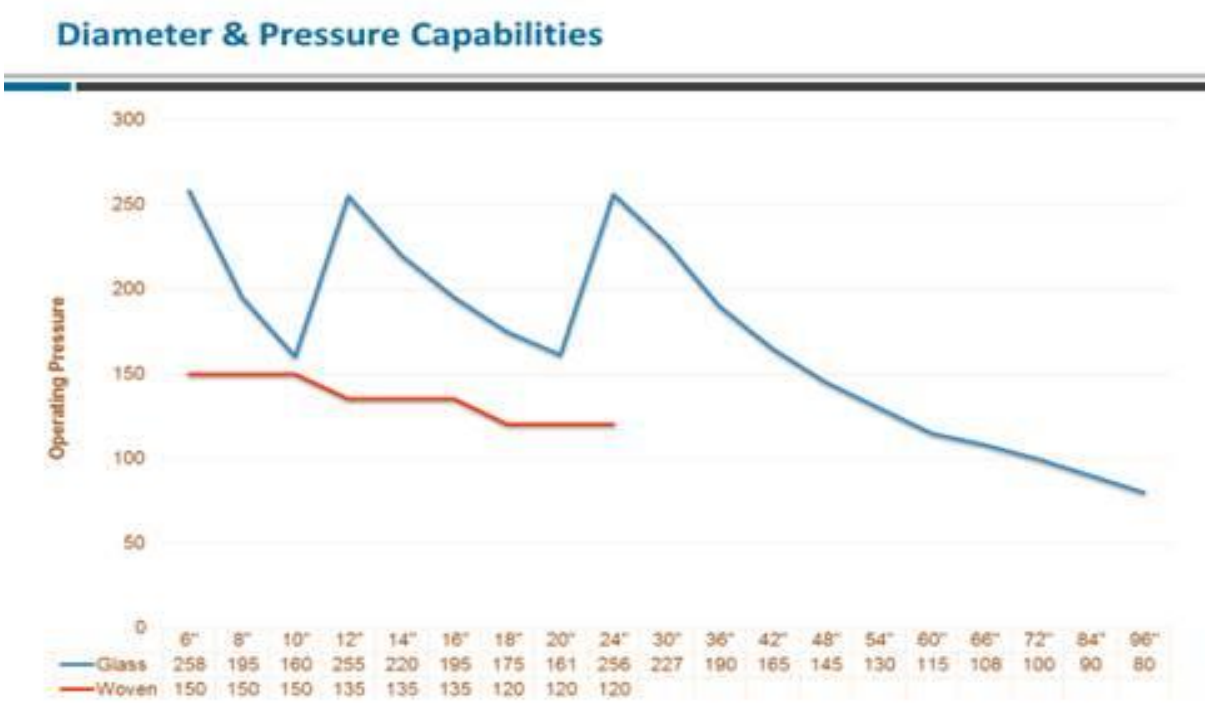
Applications

Potable water | Raw water | Reclaimed | Sanitary water | Industrial (fire & process water)

Technical Envelope

- Diameter = 6” to 96”
- Max. Operating Pressure = >250 psi
- Bends = up to 45^{o}
- Effluent Temp. = up to 150^{o} F
- Physical Properties = exceed ASTM F1216 / AWWA M28

Glass Vs. Woven



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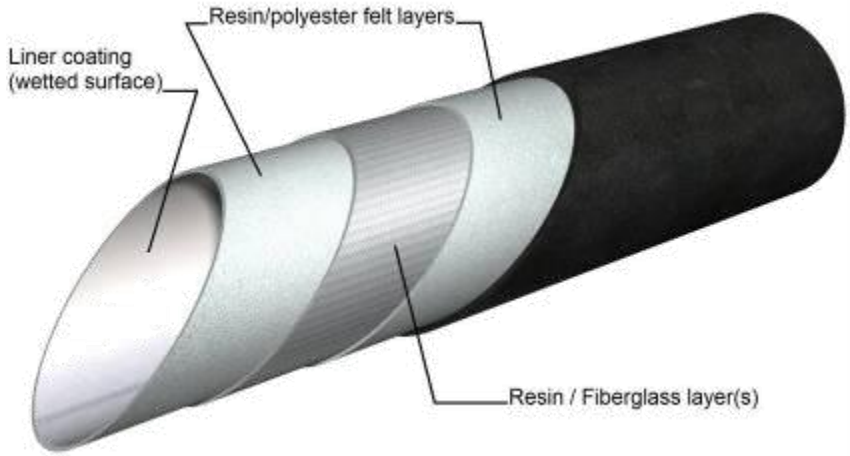
InsituMain® CIPP composite structure

- Polyester felt/epoxy structure
  - Provides for external load capacity
  - Layer thickness can be varied depending on loading conditions
- Fiberglass/epoxy structure
  - Provides high tensile strength
  - Number of layers vary depending on diameter and internal pressure
- PP/TPU coating
  - Water contact surface
  - Coating also provides water barrier for installation processes



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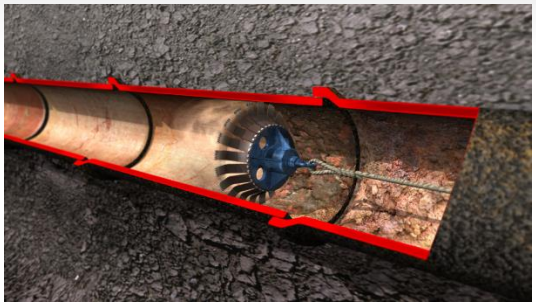
InsituMain® CIPP installation



Step 1:
If required, setup bypass and excavate pits to provide access to the existing pipeline. Clean the pipeline and inspect using closed circuit TV (CCTV).

Step 2:
Install the InsituMain system liner into the host pipe using water pressure. After curing with hot water, the pipe is cooled and the ends are cut. Following hydrostatic pressure testing, post-installation CCTV inspections are also completed.

Step 3:
Reconnect lined sections to the existing system using standard pipe fittings. Finally, restore excavation pits and remove temporary bypass, if applicable.

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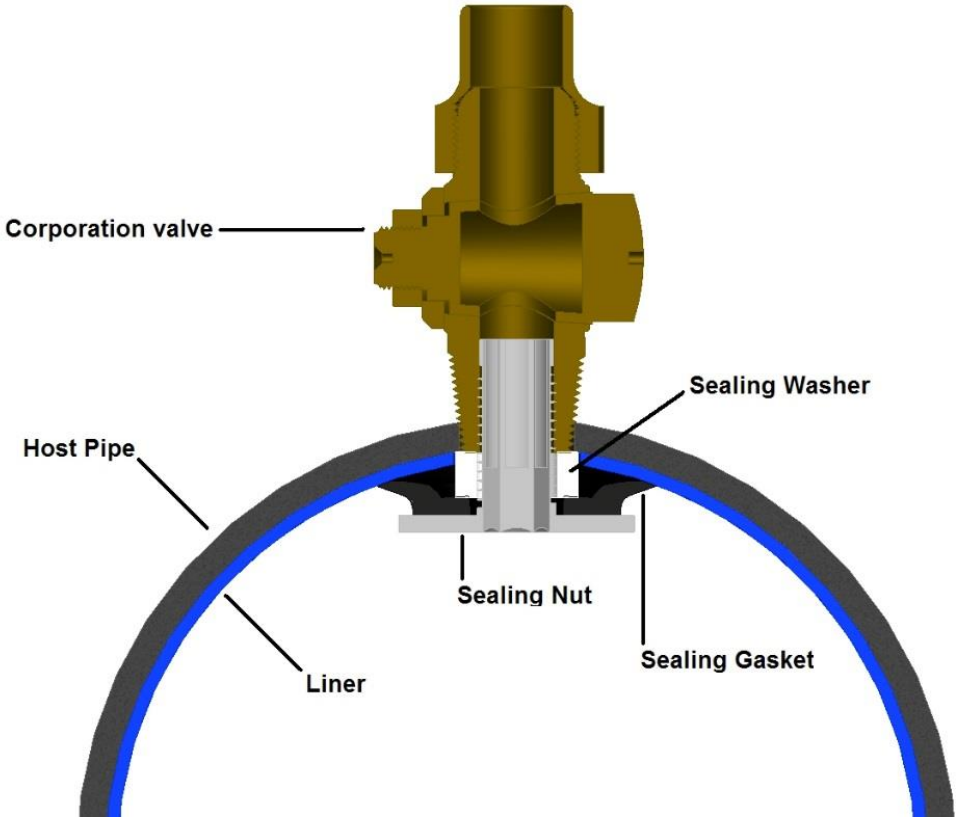
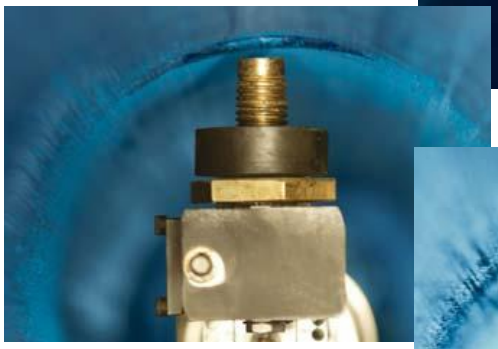
Service Connections - Mechanical

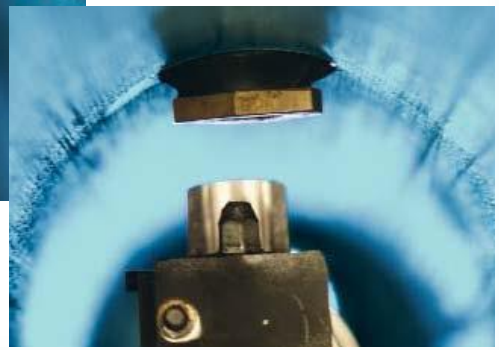
- Robotic reinstatement of service connections
  - Up to 1” in diameter
  - Up to 2” in diameter (2018)
- Reduces/Eliminates need for costly excavations
- Does not rely on host pipe for water tightness



Service Connections - Mechanical

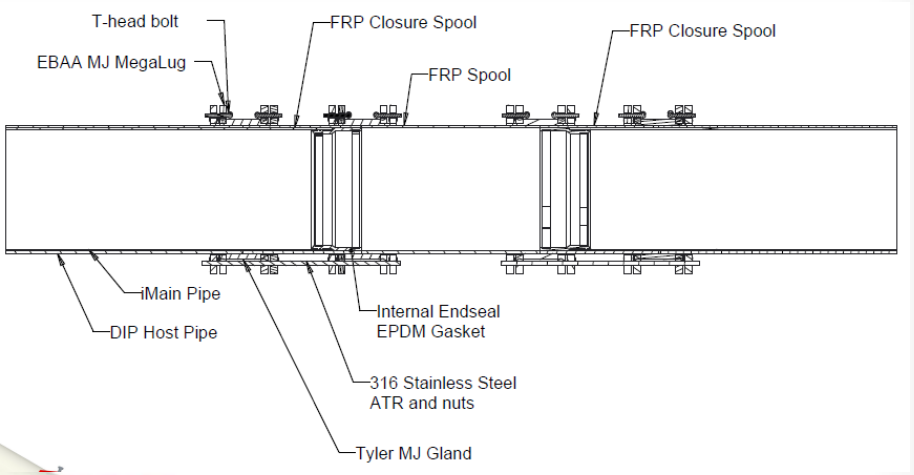
- Step 1 – reverse threading (internal) of protruding service
- Step 2 – plugging of existing service connection
- Step 3 – locating and drilling of the existing service (after lining)
- Step 4 – installation of mechanical connection

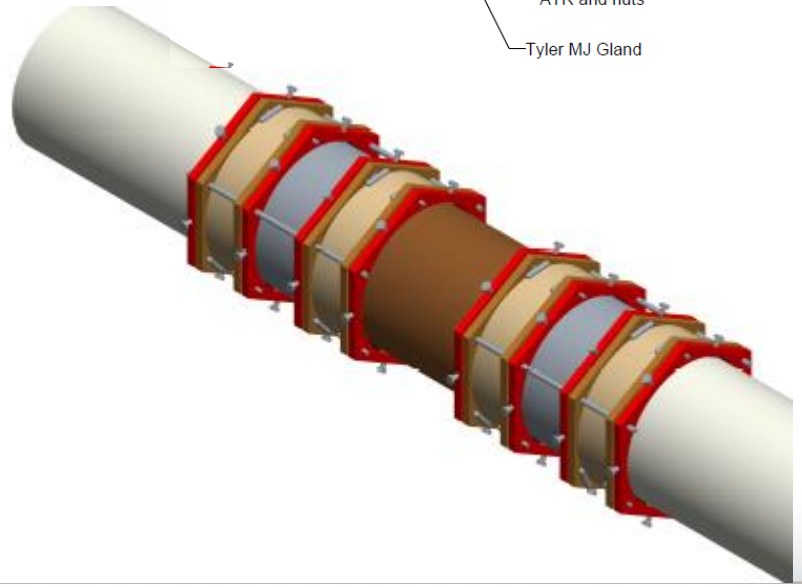




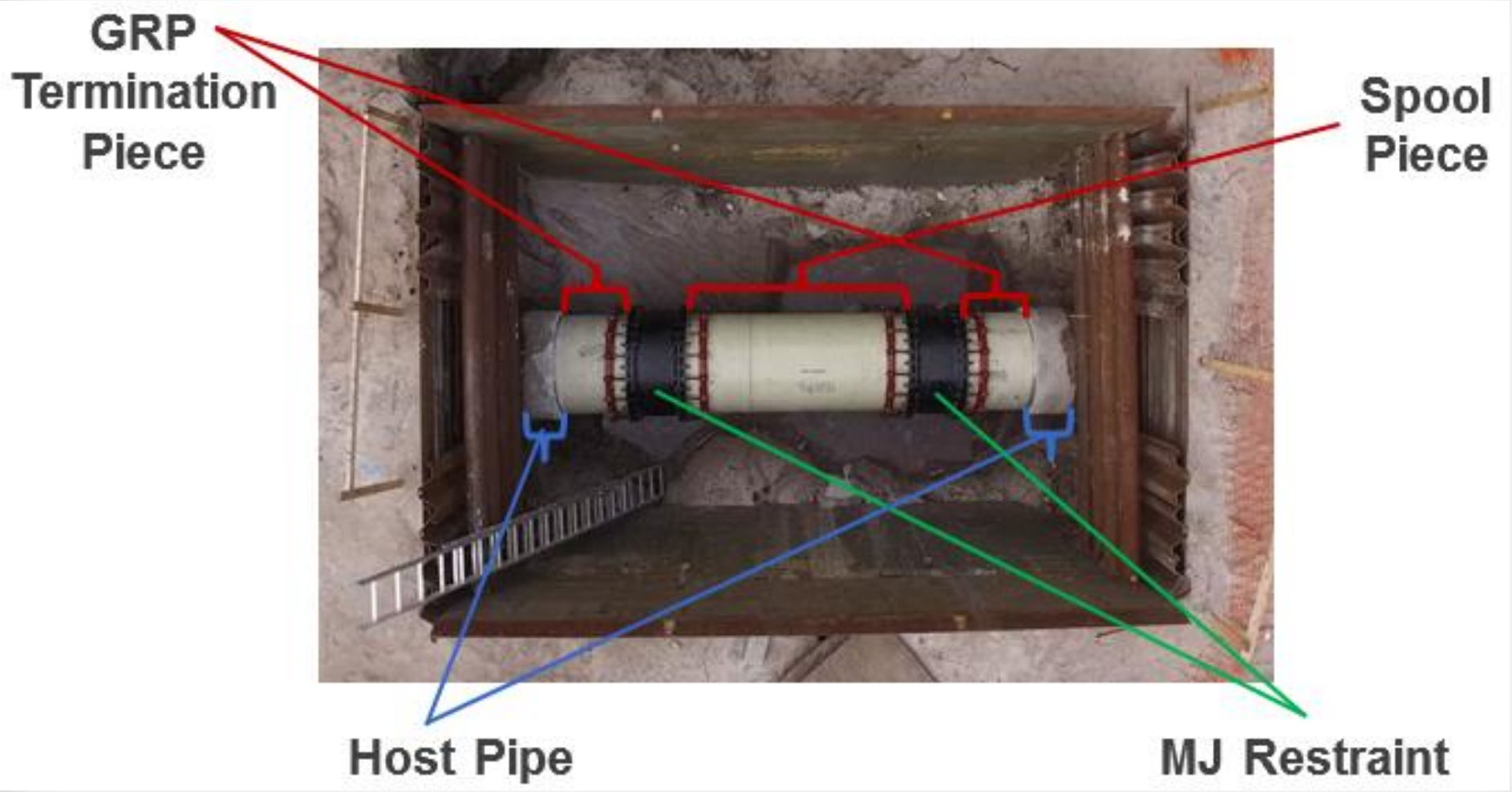
End Termination - FRP

- Precast FRP composite pipe
  - Interior abraded and primed with bonding agent
  - CIPP inserted through FRP and cured to obtain a watertight bond
- Eliminates need to connect back to the host pipe
- Promotes the use of standard mechanical joint fittings



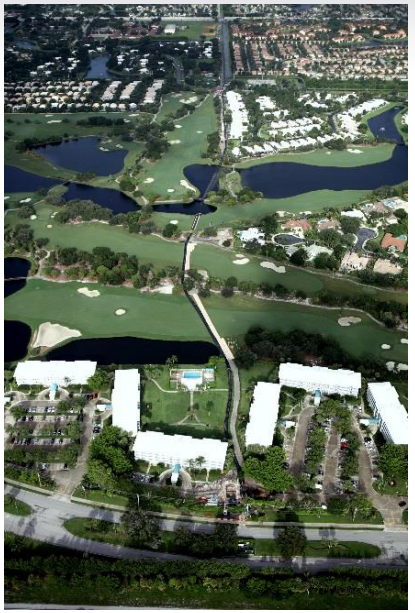


End Termination - FRP



West Palm Beach Force Main

- Owner: West Palm Beach, FL
- Pipe Type: Sanitary Sewer
  - Material: PCCP
  - Diameter: 48”
  - Length: 5,700 LF
  - Pressure: 25 psi operating; 55 psi test
- Deteriorated force main that ran underneath country club & condo building, and along canal/high end residential property
- Why CIPP?
  - Minimal diameter reduction
    - iMain Design Thickness of 18mm or 0.71” x 2 = less than 1.5” diameter loss on 48” host (0.3% reduction)



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El Dorado Springs Canyon Water Main

- Owner: Lafayette, CO
- Pipe Type: Potable Water
  - Material: Steel
  - Diameter: 12”
  - Pressure: 145 psi
- Summary: The project commenced after catastrophic flooding plagued the city and surrounding towns. During post-flood inspection, the pipeline was found to contain pitting and holes potentially compromising its structural integrity. The InsituMain Class IV (NSF 61 certified) system was designed and successfully installed in order to provide a new 50-year pipeline.

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Newport Beach Force Main

- Owner: Orange County, CA
- Pipe Type: Sanitary Sewer
  - Material: Steel
  - Diameter: 24” – 36”
  - Pressure: <50 psi
- Summary: The Newport Beach force main is a critical component in OCSD’s collection system infrastructure serving more than 15,000 acres of land. At over 50 years of age, this pipeline was in desperate need of repair or replacement. InsituMain, because of its limited disruption to the community, was chosen to rehabilitate this long stretch of pipeline.

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Questions?

What current projects might be a good fit for a gravity or pressure pipe cured in place solution?

Carbon/Glass Fiber (FRP)

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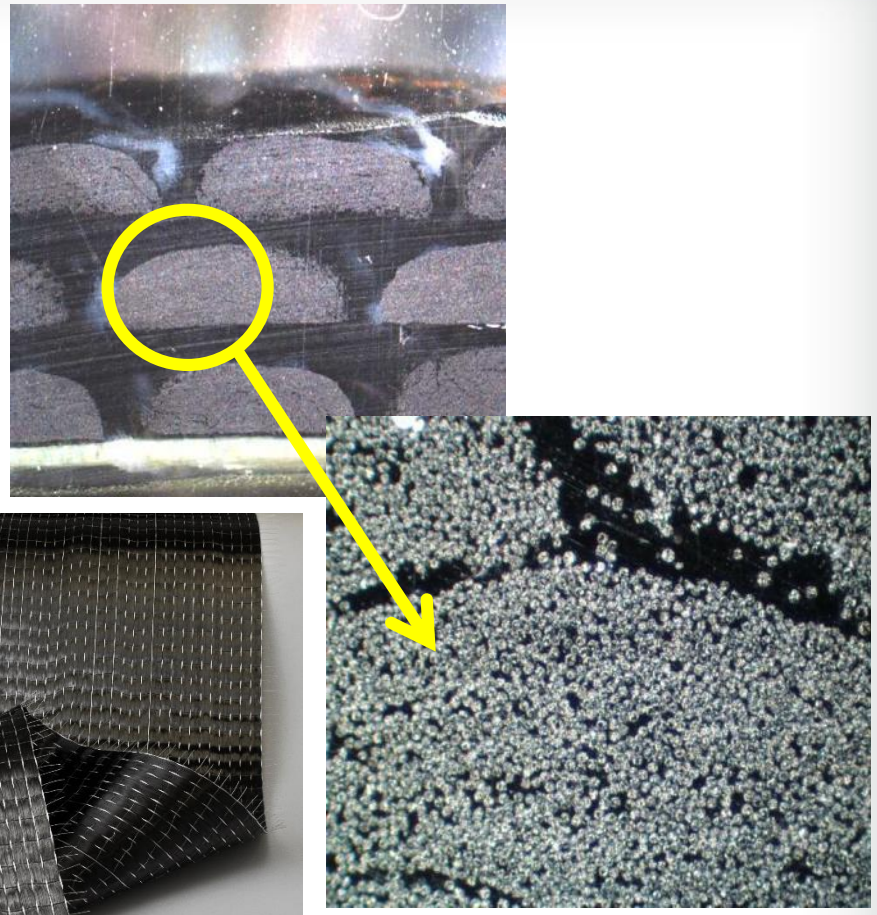
Tyfo FRP materials

- Composite structure
  - Polymer Matrix = Epoxy
    - Bonds filaments to share loads
  - Reinforcement = Carbon and/or Glass
    - Continuous Strands
- Excellent strength to weight ratio
- Directional Strength
- Non isotropic
  - Complex shapes



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When does the Tyfo® Fibrwrap® system make sense?

Diameter range:

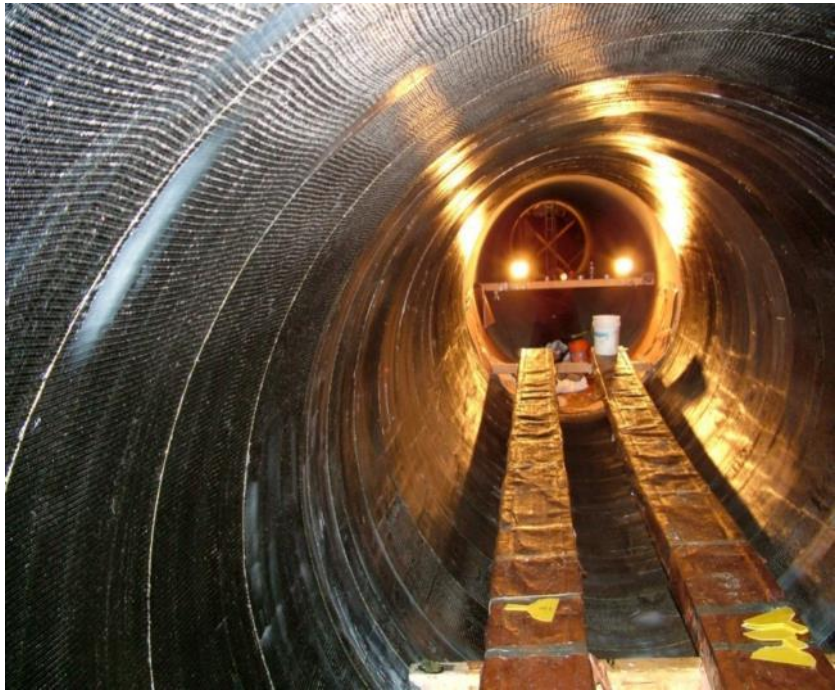
- Large-diameter pipe (internal)
  - 36” to ≥ 216”
- Small-diameter pipe (external)
  - Less than 36”

Pressure range:

- Up to 400+ psi
- Vacuum pressure (to 14.7 psi)

External loads:

- Earth cover
- Traffic loads
- Water table
- General surcharge



Designed as either an independent/stand alone or an interactive/composite system

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Tyfo® Fibrwrap® system installation

Capabilities of internal/external wrap with Tyfo® Fibrwrap® system

- Restore pipeline to original or increased hydrostatic pressure capacity/requirements
- Re-establish flexural loading capabilities
- Restore original external loading capacity of pipeline
- Upgrade external loading capability due to higher live load/traffic requirements
- Provide watertight rehabilitation at joints/couplings or transition zones

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Tyfo® Fibrwrap® Installation

- Location = Tampa, FL
- Affluent Harbour Island Community
- Owner evaluated numerous technologies
  - Open Cut
  - Slip lining
  - CIPP
  - Directional Drilling
  - Tyfo FRP
- One entry point

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Tight-Fit HDPE

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United's Tite Liner® system

- **Tight-fit or Close-fit** (not slipline)
  - Custom engineered & manufactured
  - Maximizes flow over standard IPS
  - Installed by compression or deformation
  - Usually <1" of "gap" is all that is needed
- **Non-structural liners**
  - Liner relies on host pipe
  - Thin-wall; < DR32.5
  - Eliminates leaky joints and/or internal corrosion
- **Structural liners**
  - For use where host pipe is NOT structurally sound
  - Typically DR 32.5 to DR 17
  - Solves internal and external corrosion

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Installation methods

Radial Compression

- Diameter is temporarily reduced by radial compression
- Timing is important as the liner will begin to grow back once tension is released
- Can be used for structural or non-structural
- Entire liner section is installed in a single and continuous “pull”

Elastic Deformation

- Achieves significant cross sectional reduction
- Wall thickness limitations—maximum w.t. of 1” is limitation
- Not suitable for structural loading
- “Fuse and fold” method facilitates small worksite footprint
- Only moderate collapse resistance
- Re-rounded after installation

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Ideal project characteristics

- Maximum flow is a high priority
- Long installation sections are possible (>300’)
- Host pipe has a consistent ID
- Kicked joint deflection </= 3 degrees
- Available access points
- Pressure sewer or raw water mains
- Diameter range of 8 inches to 54 inches
- Typical operation pressure </= 125 psi (DR 17)
- Available access points, and room to string liner




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Fusible PVC

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Underground Solutions – Fusible PVC Pipe Systems

- **Fusible PVC® Pipe – Leak free, restrained joint, PVC pipe system**
  - Trenchless installations that reduce contractor costs
  - Rehabilitation capabilities for pressure pipe applications
- **Over 10,000,000 feet in service**
  - In 50 states, Canada, Latin America, New Zealand, Australia
  - Over 10,000 Projects (HDD, Slipline, Pipe Burst, Open-Cut)
- **Pipe meets relevant industry pipe standards**
  - AWWA C900, C605, NSF-61, PPI-TR2, ASTM Cell Class 12454
  - Utilizes standard waterworks fittings

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Fusible PVC Pipe Applications

Horizontal Directional Drilling

- **55% of UGSI Fusible PVC® pipe installed by directional drilling techniques**
  - Pulls of over 7,000 ft accomplished with 30” pipe

Sliplining

- **25% of UGSI Fusible PVC® pipe installed in slip lining applications**
  - Pull of over 7,000 ft accomplished with 14” pipe

Pipe Bursting

- **5% of UGSI Fusible PVC® pipe installed in pipe bursting applications**
  - Pulls of over 2,000 ft accomplished with 8” and 10” pipe

Open-Trench/ Direct Bury

- **15% of UGSI Fusible PVC® pipe installed in direct-bury applications**

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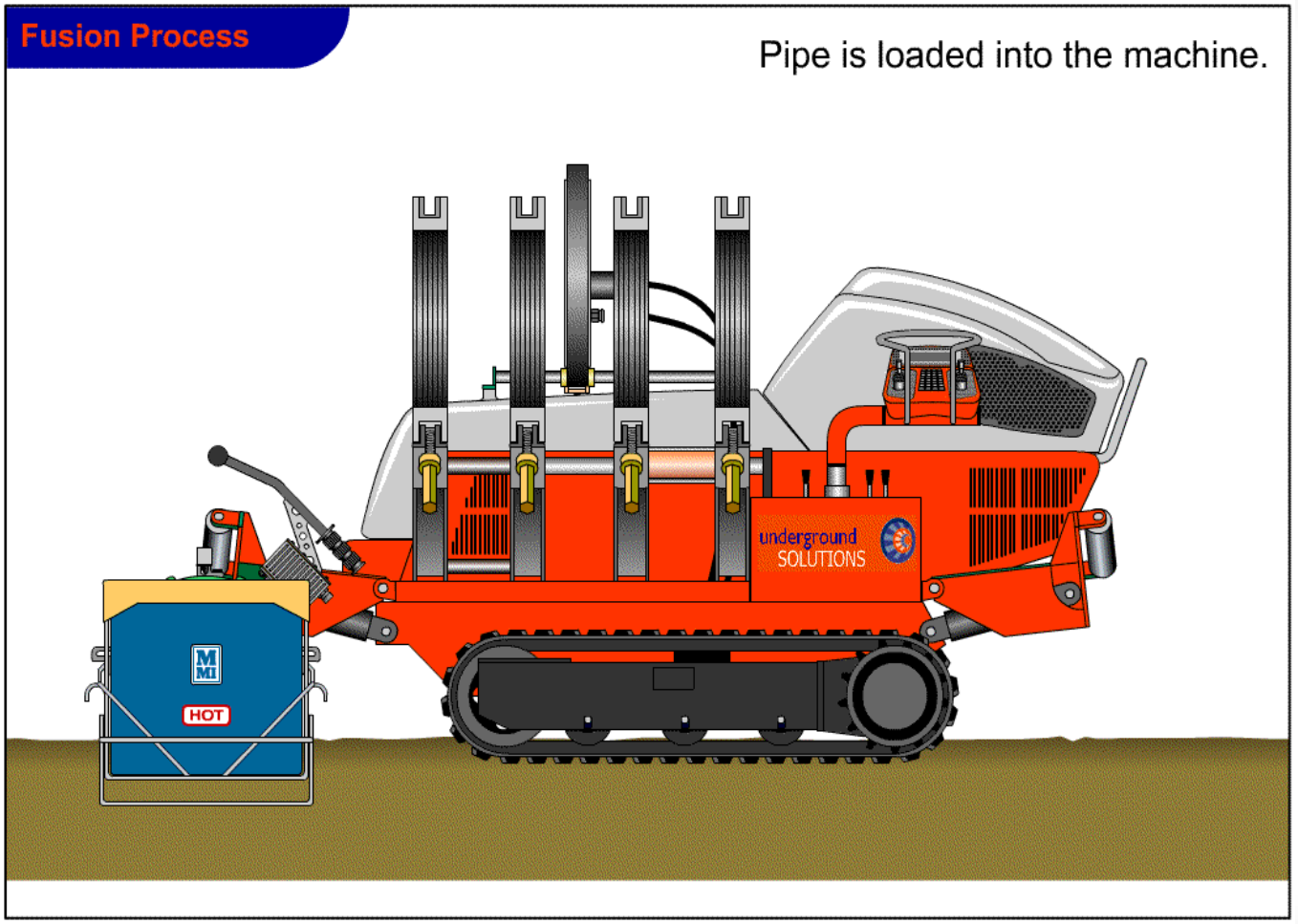
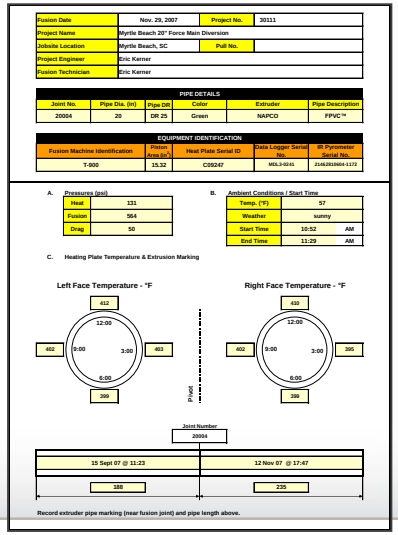
Fusible PVC Fusion Process



The Fusible PVC® Fusion Process Is Tightly Controlled

- Qualified fusion technicians are trained and re-trained every year by Underground Solutions
  - Initial 3 day course
- Fusion equipment must meet minimum company standards to be approved for PVC fusion
- Data loggers record critical fusion data for each joint
  - Provide real time feedback on joint integrity
  - Provide record of entire project for proof of system integrity
  - Joint data reviewed off-line as well by QA/QC
- Fusion conditions logged by technician and “as-built” fusion joint record is developed for owner as necessary



Fusion Date	Nov. 29, 2007	Project No.	30111
Project Name	Myrtle Beach 20" Force Main Diversion		
Jobsite Location	Myrtle Beach, SC	Pull No.	
Project Engineer	Eric Kerner		
Fusion Technician	Eric Kerner		

PIPE DETAILS

Joint No.	Pipe Dia. (in)	Pipe DR	Color	Extruder	Pipe Description
20004	20	DR 25	Green	NAPCO	FPVC™

EQUIPMENT IDENTIFICATION

Fusion Machine Identification	Fusion Area (in²)	Heat Plate Serial ID	Data Logger Serial No.	IR Pyrometer Serial No.
T-900	15.32	C09247	MDL3-0241	21662810604-1172

A. Pressures (psi)

Heat	131
Fusion	564
Drag	50

B. Ambient Conditions / Start Time

Temp. (°F)	57	
Weather	sunny	
Start Time	10:52	AM
End Time	11:29	AM

C. Heating Plate Temperature & Extrusion Marking

Left Face Temperature - °F

Right Face Temperature - °F

Joint Number: 20004

15 Sept 07 @ 11:23	12 Nov 07 @ 17:47
388	235

Record extruder pipe marking (near fusion joint) and pipe length above.

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Fusible PVC Pipe Mechanical Property Advantages

Property	Specification	PVC	HDPE 3408/3608[1]	HDPE 4710[2]
Tensile Strength psi	ASTM D638	7,000	3,000	3,500
Specific Gravity	ASTM D1505	1.40	0.94	0.95
ASTM D3350 Cell Class	ASTM D3350	NA[3]	345464	445574
Hydrostatic Design Basis At 73° F, psi	ASTM D2837	4,000	1,600	1,600
Modulus of Elasticity psi (Short Term)	ASTM D638	400,000	110,000[4]	130,000[4]
Hardness (Rockwell R)	ASTM D785	117	52	NA
Coefficient of Linear Expansion In./In. deg F	ASTM D696	0.3×10^{-4} .36"/ 100'/ 10°F	1.2×10^{-4} 1.44"/ 100'/ 10°F	1.2×10^{-4} 1.44"/ 100'/ 10°F
Water Disinfectant Induced Oxidation[5]		Highly Resistant	Low Resistance	Low Resistance
Hydrocarbon Permeation[6]		Highly Resistant	Highly Permeable	Highly Permeable

1. HDPE 3408/3608 also referred to as PE80
2. HDPE 4710 also referred to as PE100
3. PVC Pipe Cell Class per ASTM D1784 (12454)
4. PPI – PE Handbook – Long Term Modulus of Elasticity is 28,200 psi

5. Carollo Engineers 2008, Choi 2008, Chung 2008, Fumire 2008, Rozental 2008, Castegnetti 2007, Audouin 2007, Dear 2006,
6. Lundback 2005, Hassinen 2004
7. Water Research Foundation (formerly AWWA Research Foundation 2008)

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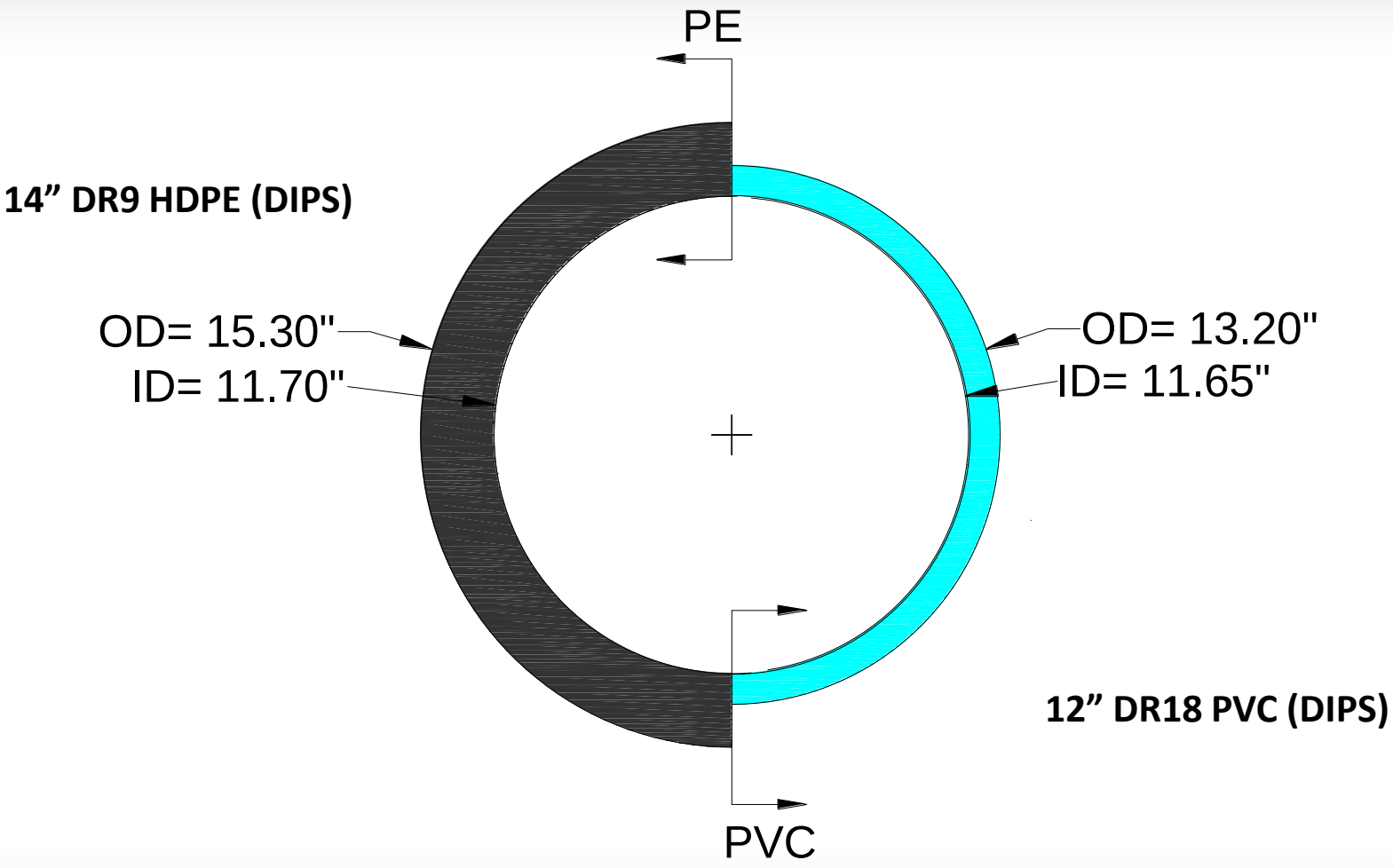
PVC is Stronger and Requires Less Wall Thickness



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Important to Design with both DR and Safety Factor

Dimension Ratio - Pressure Class Rating					
PVC		HDPE 3608 / 3408		HDPE 4710	
SF = 2.0		SF = 2.0		SF = 1.59	
DR	Pressure Rating (PSI)	DR	Pressure Rating (PSI)	DR	Pressure Rating (PSI)
DR 14	305	DR 7.3	255	DR 7.3	317
DR 18	235	DR 9	200	DR 9	250
DR 21	200	DR 11	160	DR 11	200
DR 25	165	DR 13.5	128	DR 13.5	160
DR 32.5	125	DR 17	100	DR 17	125
DR 41	100	DR 21	80	DR 21	100

Lower Design Factors Increases Risk of Failure and Lowers Life Expectancy

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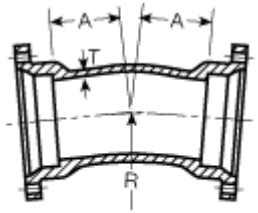
Fusible PVC is Compatible with Standard Fittings

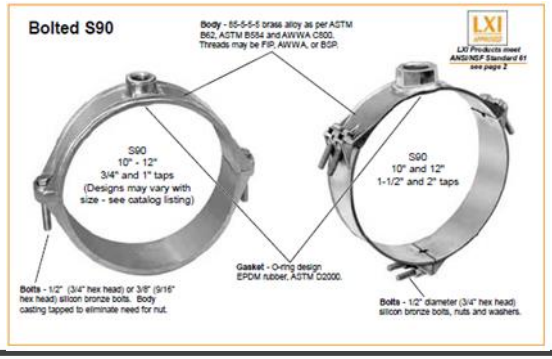
Connecting to Fittings

Mechanical Joint Fittings:



MJ and MJ

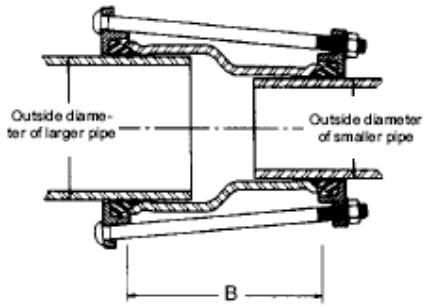
Tapping:



Connecting to Pipe

Same Piping Size:

Different Piping Size:



Pictures from various manufacturers of fittings: JCM, Smith Blair, EBAA Iron, Romac Industries.

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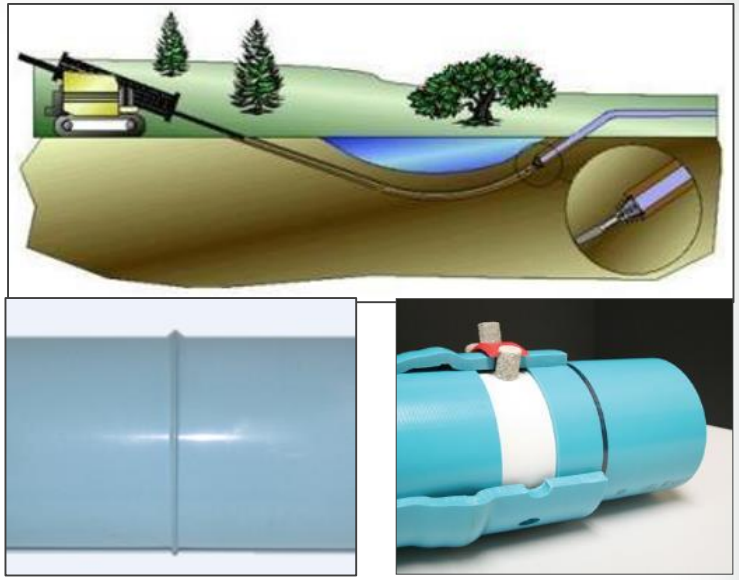
Fusible PVC® pipe and Terrabrute CR® pipe = cost savings for HDD

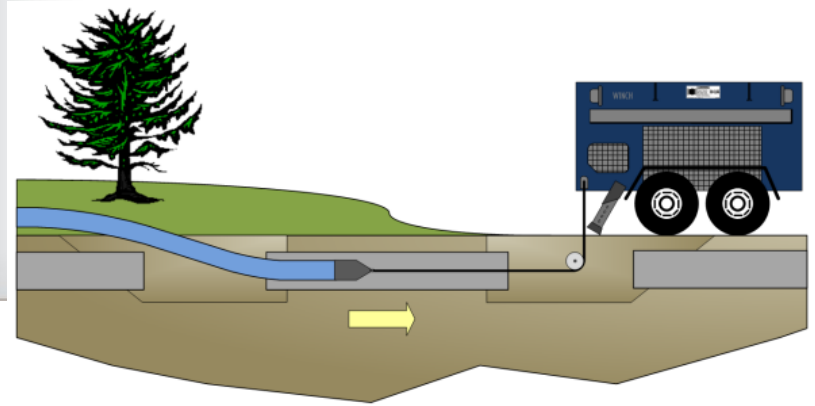
Advantages for HDD installations

- Favorable inner diameter and pressure capacity comparison to HDPE = smaller borehole, less cost
- Continuously fused, gasket-free Fusible PVC® pipe
- Strength to weight ratio allows for longer and deeper installations than HDPE
- Provides capable pipe material for HDD installation falling between steel pipe and HDPE pipe

HDD process:



Sliplining Process:



Fusible PVC® pipe advantages for sliplining

- Utilizes same utility alignment
- Increased flow area for a given host pipe ID compared to similar pressure class HDPE Industry standard connections
- Simple, fast, inexpensive trenchless method

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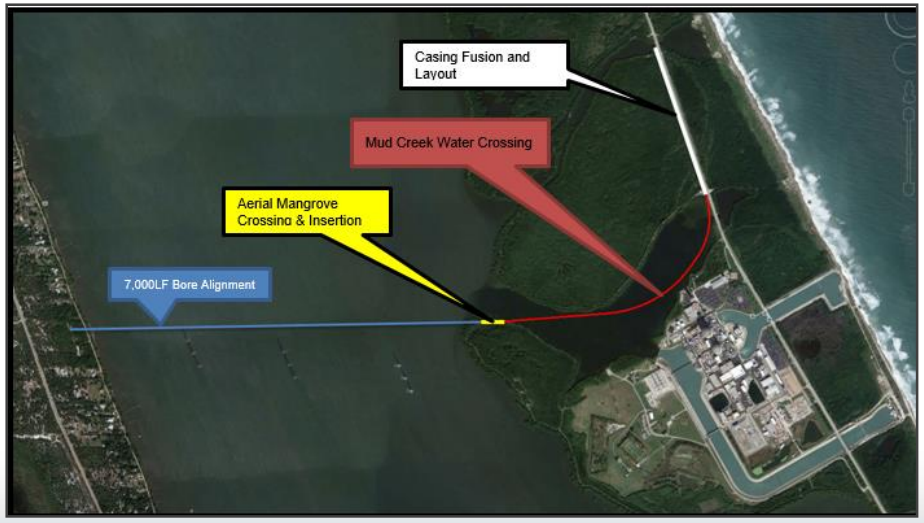
HDD Installation – Florida Power & Light

- 2 -7,020 LF HDD installs of 30” DR21 Fusible PVC Casing
- St. Lucie, FL 230kV Underground Transmission Project
- Design Engineer – Power Engineering, St. Louis, MO
- HDD Contractor - Mears Group, Houston, TX
- 2016 Trenchless Project of the Year



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Perrysburg: 16” Force Main; HDD

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Sliplining Project Considerations

Sliplining

- Video inspection of host pipe – condition, deflections, vertical profiles and stranded appurtenances
- Layout area for fused pipe – as well as entrance pit constraints – possibility for “fuse & pull” or in pit fusion
- Recommended difference between ID of host pipe and OD of Fusible PVC® pipe is about 2”
- Ability to dig out connections before sliplining
- Effect of abrasion on pipe surface – plastic 10% gouge depth before de-rating, steel corrosion coating degradation due to friction
- Traffic management – night activity or “fuse & pull” in tight areas

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City of Hamilton: 20” Water Main; Slipline of Existing 24” Line

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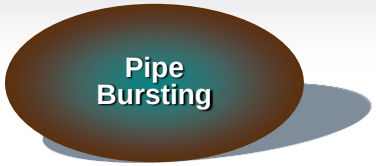
Considerations and Fusible PVC® Pipe



- Ductile iron, cast iron, asbestos-concrete and steel are typical water pressure pipe materials that are burst – high production rates are possible (project in Florida - 500 LF in 1 hour)
- Static hydraulic bursting/splitting method is used vs. pneumatic method (typically used in sewer work)
- High density of Fusible PVC® results in excellent scratch and abrasion resistance
- Isolation of pipe from burst hardware prevents rebound when force changes rapidly

McCandless Twp.:
12” FPVC®; Static pull water main pipe burst

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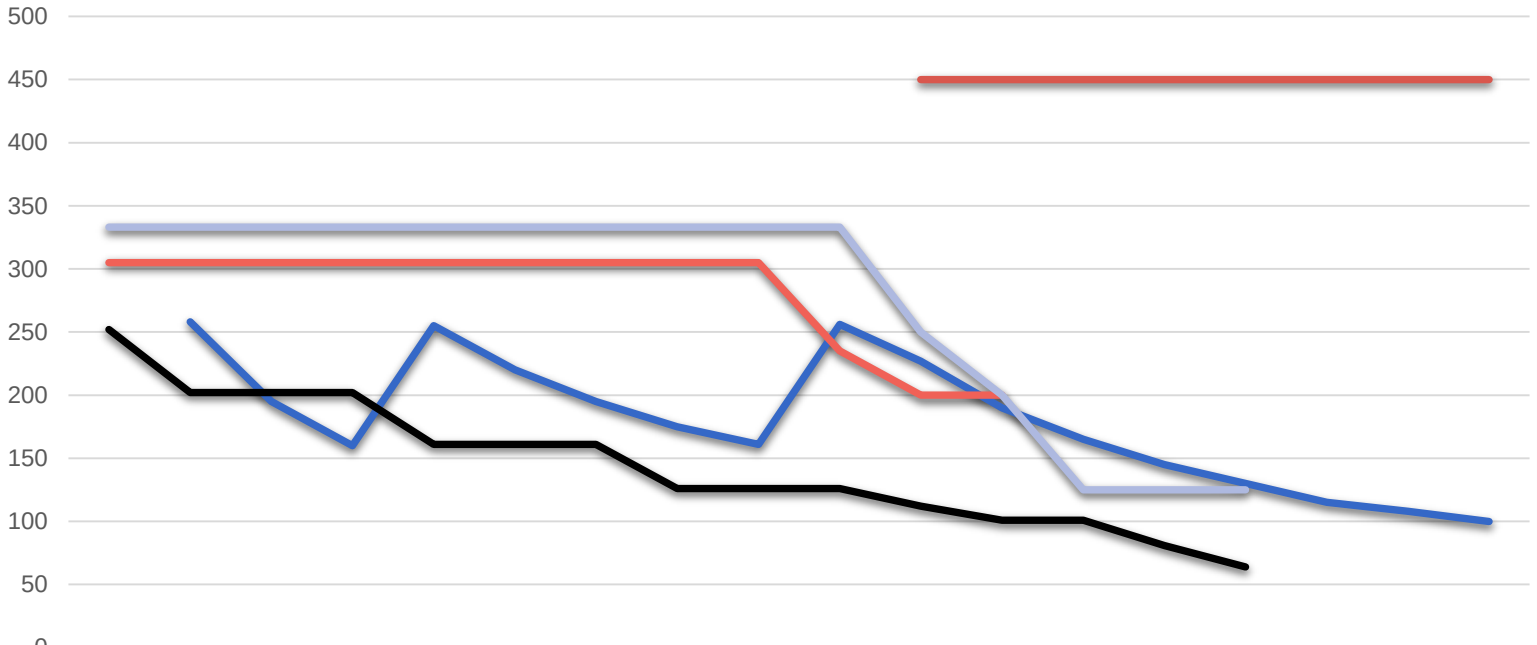
Aegion Pressure Pipe Capabilities

Aegion Product Matrix by Maximum Internal Operating Pressure



	4"	6"	8"	10"	12"	14"	16"	18"	20"	24"	30"	36"	42"	48"	54"	60"	66"	72"
InsituMain		258	195	160	255	220	195	175	161	256	227	190	165	145	130	115	108	100
Fusible PVC	305	305	305	305	305	305	305	305	305	235	200	200						
Tite Liner	252	202	202	202	161	161	161	126	126	126	112	101	101	81	64			
HDPE Slip Lining	333	333	333	333	333	333	333	333	333	333	250	200	125	125	125			
Tyfo											450	450	450	450	450	450	450	450

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Successful Projects in 2017

InsituMain® CIPP

- Fairfax, VA
  - 4,000’ of 36” sewer force main

Tyfo® Fibrwrap® system

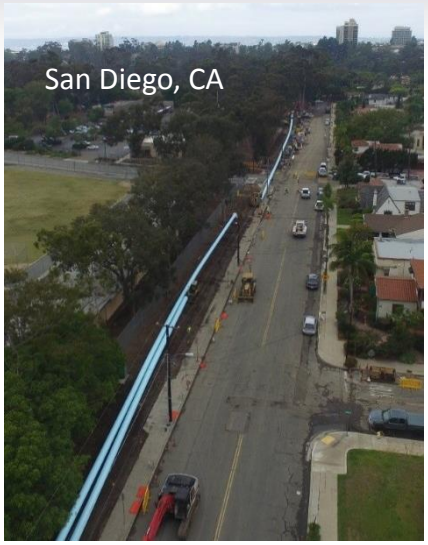
- Tampa, FL
  - 350’ of 54” sewer force main

Tite Liner® system

- Laramie, WY
  - 90,000’ of 20” water main

Fusible PVC® pipe

- San Diego, CA
  - 2,425’ of 24”/30” water main



AEGION®

Aegion's Experience

- >50,000 miles of installed pipe around the world
- Professional engineers involved in every project
- Vertically integrated corporation
- Mobile installation crews
- 50+ years of combined experience
- Industry-leading safety record
- Certified to ISO 9001:2014 standards

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Questions?

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Stronger. Safer. Infrastructure.®