Aegion's Pressure Pipe Technologies

December 8, 2016

AEGION®

Stronger. Safer. Infrastructure.®

Pipeline Infrastructure

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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Pressure Pipe Capabilities

- Rehabilitation
- Structural or Semi-Structural design
- ANSI/NSF 61 certified
- New construction
- Minimally disruptive

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Aegion's products/processes

Cured-in-place pipe (CIPP)

Tight-fit HDPE

Carbon/glass fiber (FRP)

Fusible PVC®

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Insituform - Cured-In-Place Pipe

- Developed in 1971 by Insituform, cured-in-place pipe (CIPP) is a trenchless technology
  - Initially used in sewers
  - InsituMain® CIPP uses modified properties to make it suitable for the drinking water market
  - End product is a joint less, pipe-within-a-pipe that protects against spills, breaks and pipe leakage
- 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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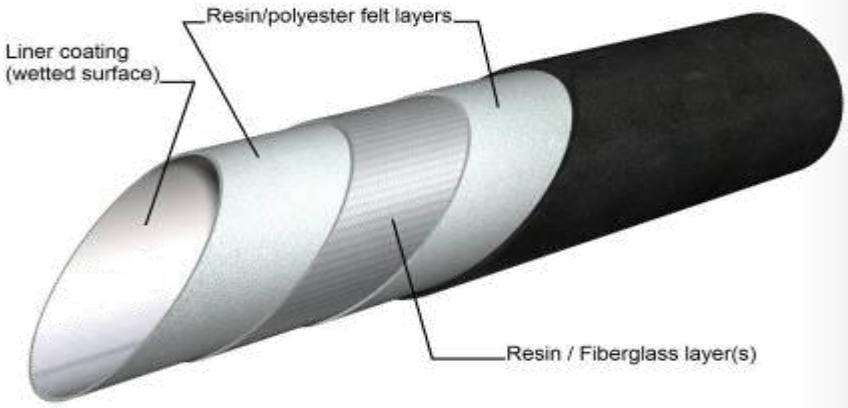
CIPP Fiber-reinforced composite structure

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



Diameter range	6” to 72”
Effluent temperature	Up to 130°F
Internal pressure capability	Up to 250 psi (safety factor of 4)
Bends	Up to 45°
Host pipe material	All materials
Mechanical properties	Exceeds ASTM F1216 and ASTM F1743

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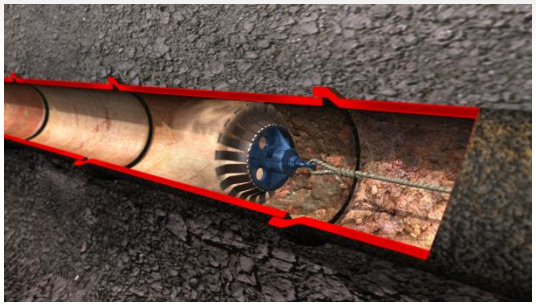
InsituMain® CIPP installation



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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West Palm Beach 48” Force Main project

- 5,800 LF of 48-inch PCCP
- Location: Near Canal and Country Club
  - High-end residential area
- Operating pressure: 30 psi
- Solution: InsituMain® Class IV fully-structural CIPP
- Completed six sections; averaged about 1000’, longest shot 1145’
- Tube delivered to the site wetted
- Completed late summer, 2016

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West Palm Beach 48” Force Main project – Installation Site

West Palm Beach 48” Force Main project – Completed Liner Shot

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West Palm Beach 48” Force Main project – Connected and Tested

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United Pipeline Systems - HDPE (Thermoplastic) Lining Systems

- **Tight-fit or Close-fit** (not slipline)
  - Custom engineered & manufactured
  - Maximizes flow over standard IPS
  - Installed by compression or deformation
  - Allows flexibility for challenging installations
  - Usually <1” of “gap” is all that is needed
  - 2” to 54” diameter
- **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
  - > DR32.5, up to DR 17
  - Sections of host can be removed
  - Solves internal and external corrosion

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HDPE Lining 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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Tite Liner® system in Valley Forge allows for new pipeline in environmentally sensitive area

- 30-inch force main traveling directly through Valley Forge National Historic Park along the Schuylkill River
- Over 40 years old
  - 3 separate failures precipitated need for repair/replacement
- 18,000 linear feet
- Aegion's Tite Liner® system was chosen to rehabilitate the pipeline
- Worked closely with CH2M Hill and general contractor, PACT, to complete the project
- Completed in 6 months
- Pressure tested at 60 psi

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TYFO - Carbon/Glass Fiber (FRP) Systems

- High-strength, lightweight, low profile characteristics provides a less intrusive value engineering solution; adds minimal weight/area and **maintains hydraulics**
- Installed without removal and replacement of many existing obstacles…**trenchless**
- Small project site footprint…**low impact and rapid installation**
- Proven **long term durability** and excellent resistance to corrosion
- Can be applied onto **complex shapes** (tees, elbows, etc.)

Independent/stand alone or an interactive/composite system

Diameter range	36” & Above
Effluent temperature	Up to 150°F
Internal pressure capability	Up to 450 psi
Bends	Any
Host pipe material	All materials
Mechanical properties	Specifically designed as conditions require

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Capabilities of internal or external wrapping with FRP

- Restore pipeline **to original hydrostatic pressure capacity**
- Accommodate **increased internal pressure 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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Installation of Tyfo® Fibrwrap® system allows pipe to withstand operating and transient pressures as well as gravity loads

- Washington Suburban Sanitary Commission discovered numerous sections of its 66-inch pipeline had broken pre-stressed wires and were structurally unsound
- WSSC determined traditional remove and replace method was not practical
- Tyfo® Fibrwrap® system allowed for a shortened construction schedule, minimal curing time and immediate return to service

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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® Available Sizes for Pressure Pipeline and Conduit Applications
Fusible C-900®, Fusible C-905® and FPVC®

Type	Sizes (Nominal OD)	DIPS or IPS or Schedule	Dimension Ratios (DR)	Uses	Color
Fusible C-900®	4" – 12"	DIPS	DR 14, 18, 25	Potable Water AWWA C900	Blue
Fusible C-905®	14" – 36"	DIPS	DR 14, 18, 21, 25, 32.5, 41	Potable Water AWWA C905	Blue
FPVC®	4" – 36"	DIPS, IPS, or Schedule	DR 14,17,18, 21, 25, 26, 32.5, 41 and Sch.80	Non-Potable Water or Potable Water Applications not in C900/C905 Dimensions	Blue, Purple, Green, White, Grey

* Not all diameters are extruded to all listed DR's.

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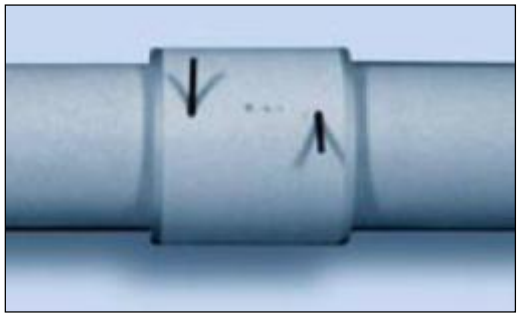
Alternative Restrained PVC Joints Limit Applications

Conventional Gasketed Restrained PVC Connections 12” Example

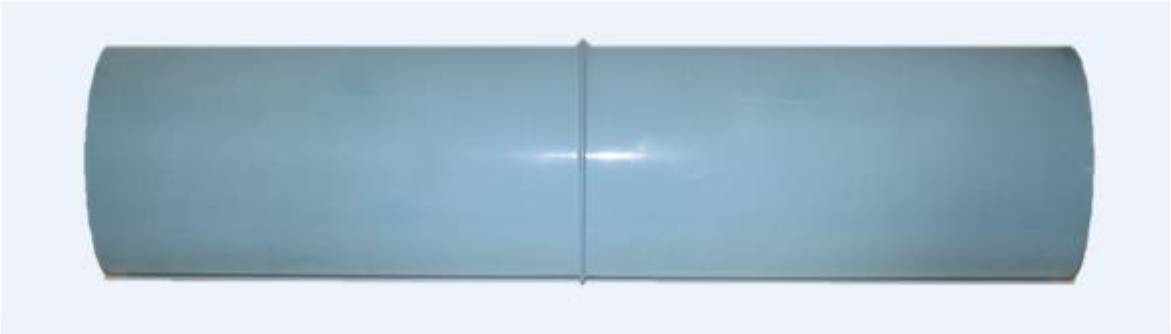
Barrel = 13.2”
Bell = 16.75”
Restraining Hardware = 19.45”

Bulldog™ Restraint
Barrel = 13.2”
Bell = 16.13” DR 18, 16.97” DR 14



Certa-Lok™
Barrel = 13.2”
Bell = 15.83”

Fusible C-900®, Fusible C-905®, FPVC® Low Profile Restrained Joint



Barrel and Fused Joint Have Consistent O.D. = 13.2”

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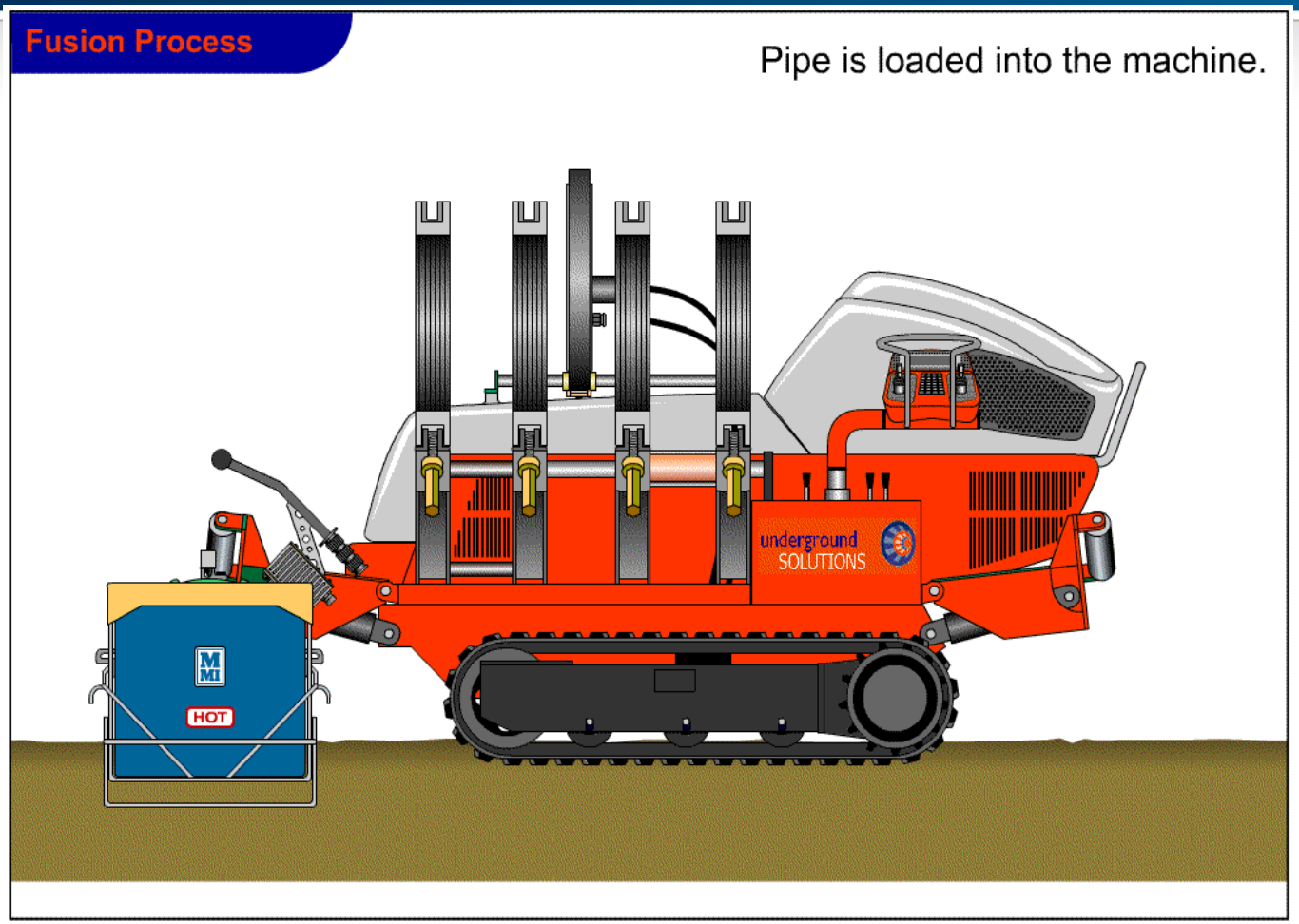
The Underground Solutions® PVC Fusion Process: Utilizes Industry Standard Fusion Equipment



Internal and External Bead Removal is Optional – friction losses are negligible ('C'-factor of 150) and are significantly less than mechanically joined pipe (i.e. for 8" DR18 with 1,000 gpm in a length of 1000 LF, flow loss is 0.173 gpm and a head loss of 0.013 ft) and pipe tensile strength is not impaired (extra material in bead)

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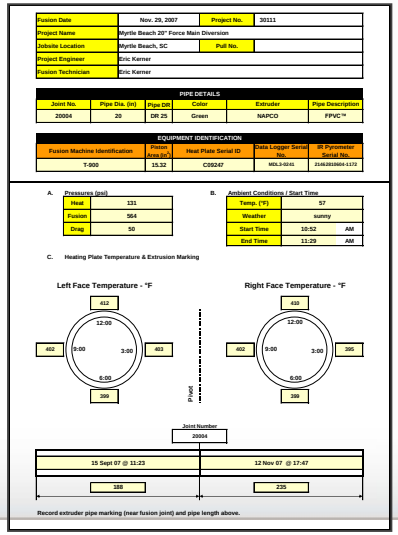
The Fusible PVC® Fusion Process Is Tightly Controlled

- 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	21462810604-1172

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

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

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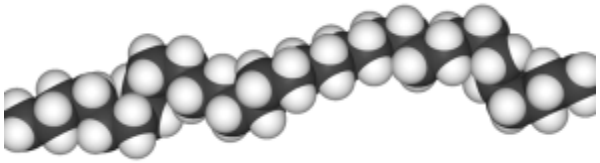
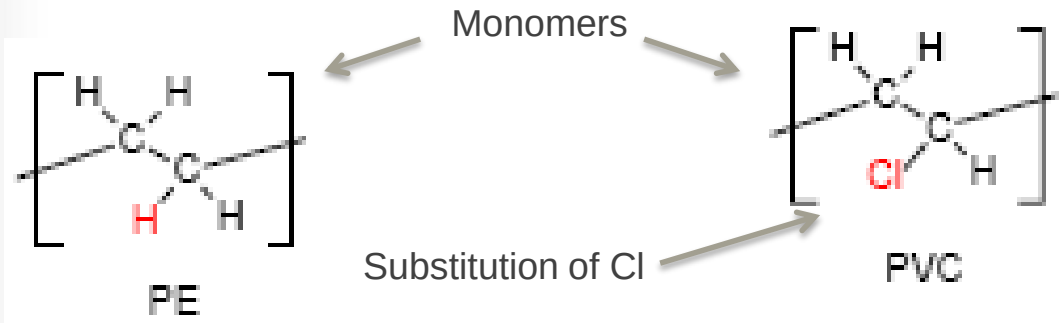
Molecular Structures Drive Differences between PVC and HDPE

HDPE

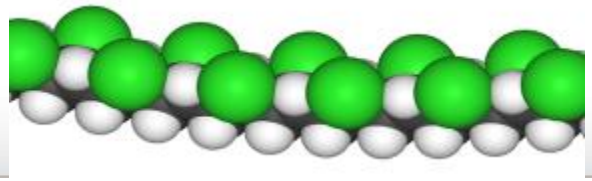


Similar structures except that on each monomer (repeated unit in the polymer chain) a Hydrogen atom is replaced with Chlorine atom



The uniformity of the linear chains allow HDPE to pack closely together resulting in a highly crystalline material

PVC



The Cl – C bond is more polar than H-C bond. The Cl atom does not allow for as efficient packing creating an amorphous structure

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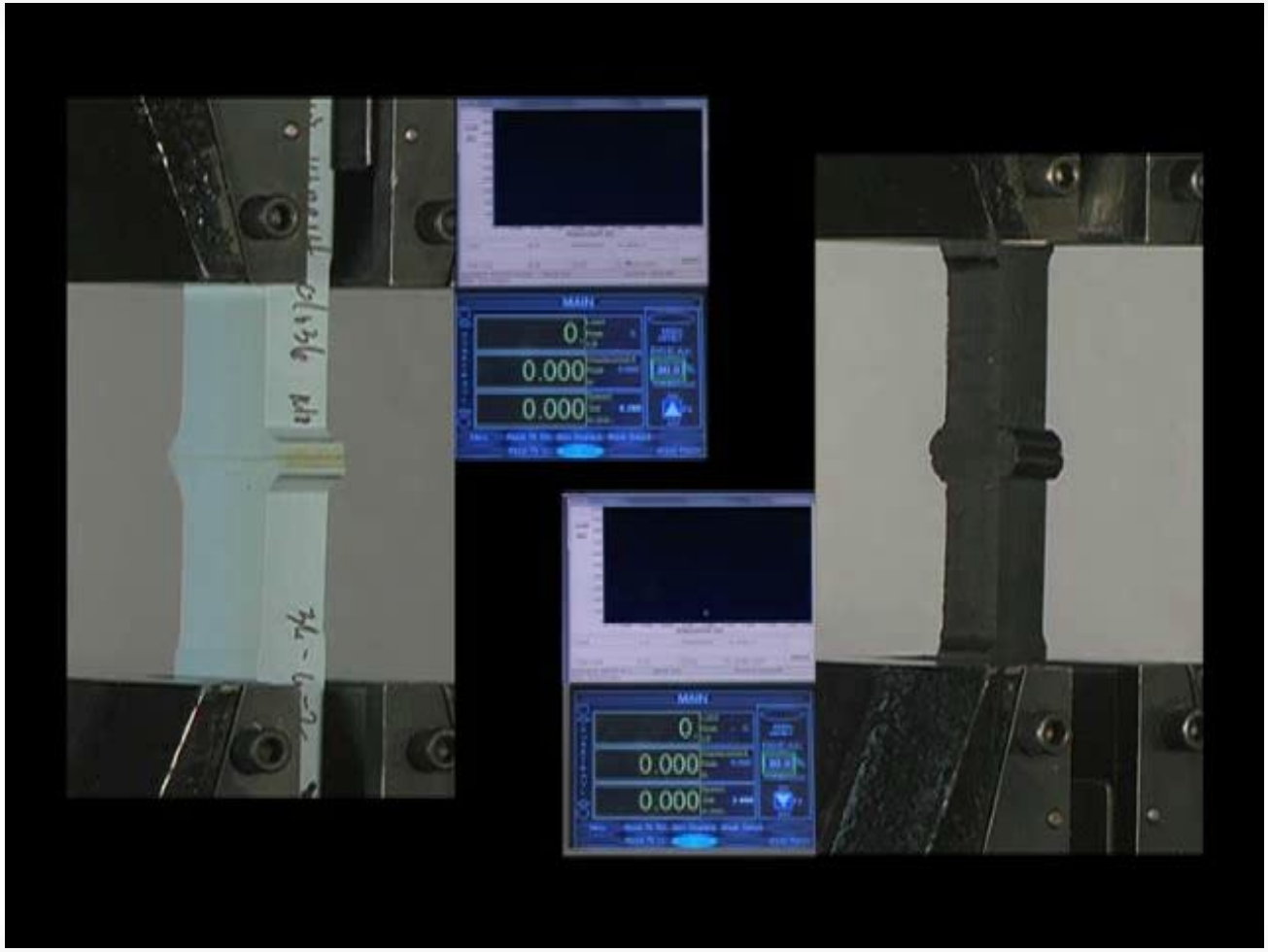
Molecular Structure Affects Tensile Strength and Deformation



*** Note: 1st digital readout is load, 2nd is displacement**

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PVC Pipe has Many Mechanical Property Advantages over HDPE

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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Bending differences

- HDPE is More Flexible Than PVC…

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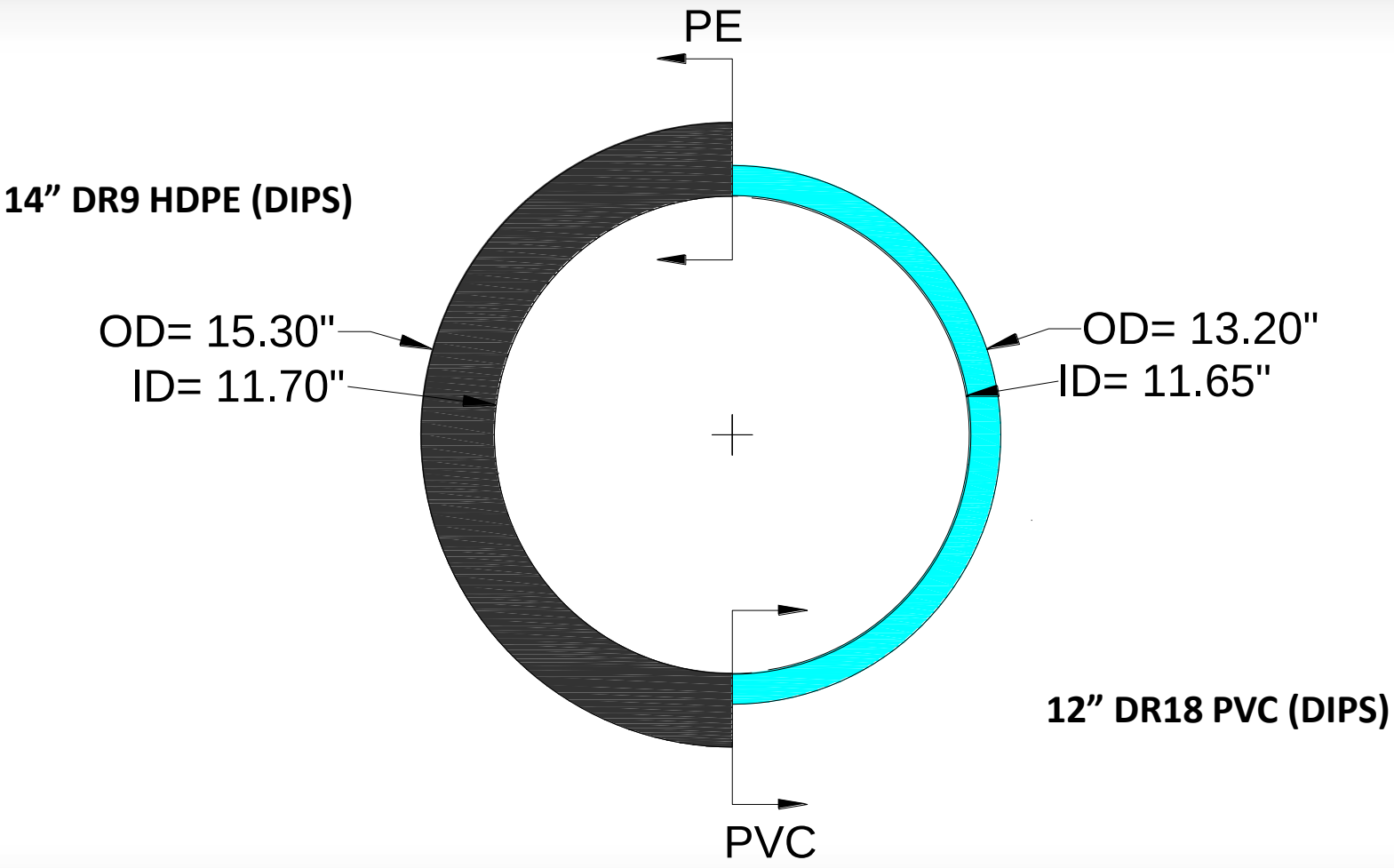
PVC is Stronger and Requires Less Wall Thickness



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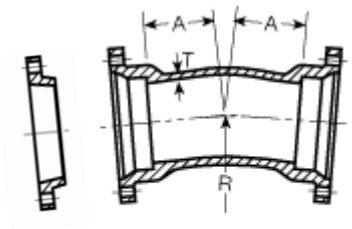
Industry Standard Connections with Fusible PVC® Pipe

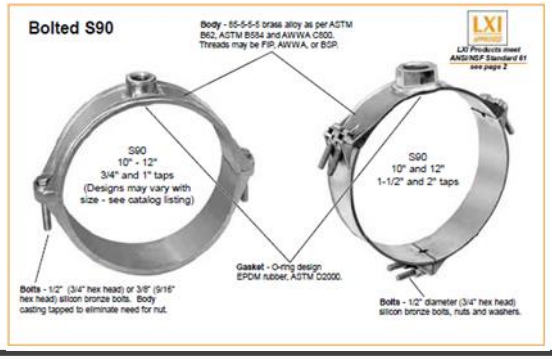
Connecting to Fittings

Mechanical Joint Fittings:



MJ and MJ

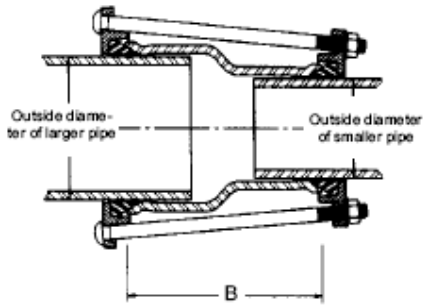
Tapping:



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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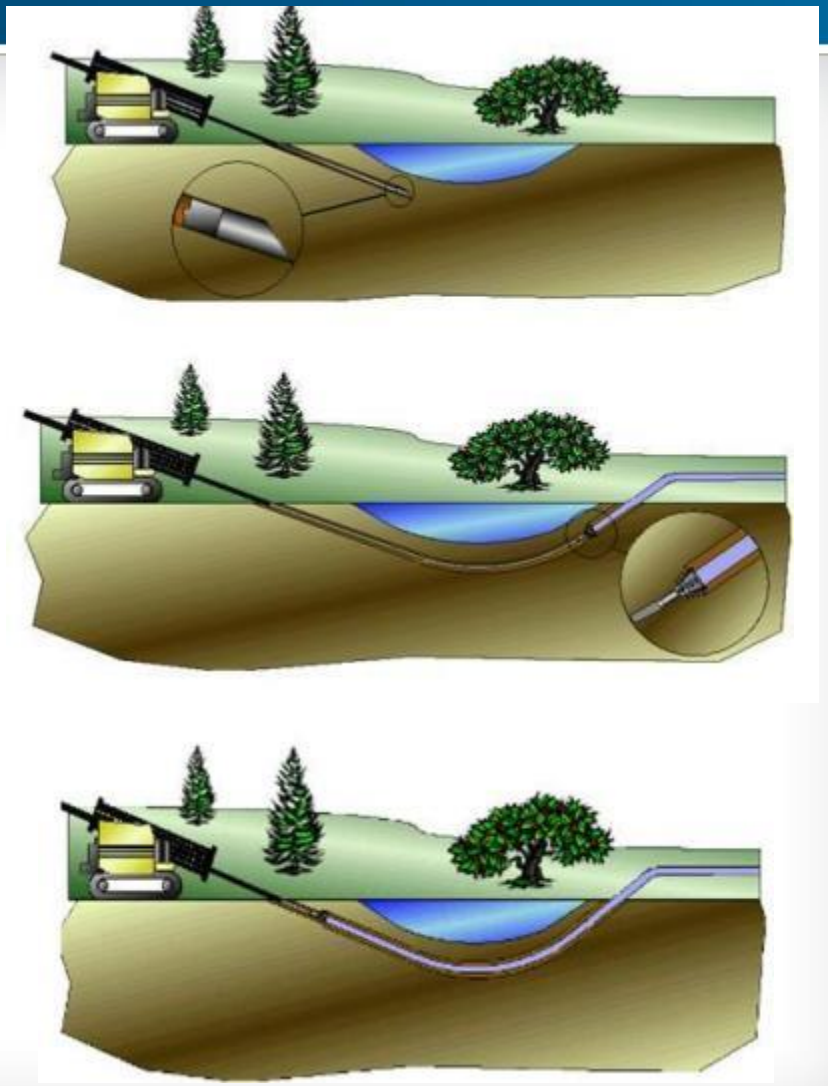
HDD Trenchless Installation Method

Horizontal Directional Drilling

- Guided pilot hole is drilled along a bore path
- Drilling fluids are injected into the hole to stabilize and lubricate
- Back reamer is used to enlarge the pilot hole
  - Multiple passes are required to accommodate pipe OD
  - Drilled bore hole is typically enlarged to 1.5 x OD of new pipe
  - Fusible PVC® is pulled through the bore hole



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Horizontal Directional Drilling with Fusible PVC® Pipe

Horizontal Directional Drilling

Client: Ohio Army National Guard – Ravenna, OH

- Camp Ravenna Joint Military Training Center utility extension to enhance facility readiness
- Design-Build - 52,850 feet – 10 miles of pipe
  - 12-inch DR 18 Fusible C900® water main pipe
  - 8-inch DR-18 Fusible PVC® force main pipe

- Consultant: CT Consultants
- Prime Contractor: Rock Industries
- HDD Contractor: Speer Bros, Inc.
- Fusion: Speer Bros, Inc & UGSI

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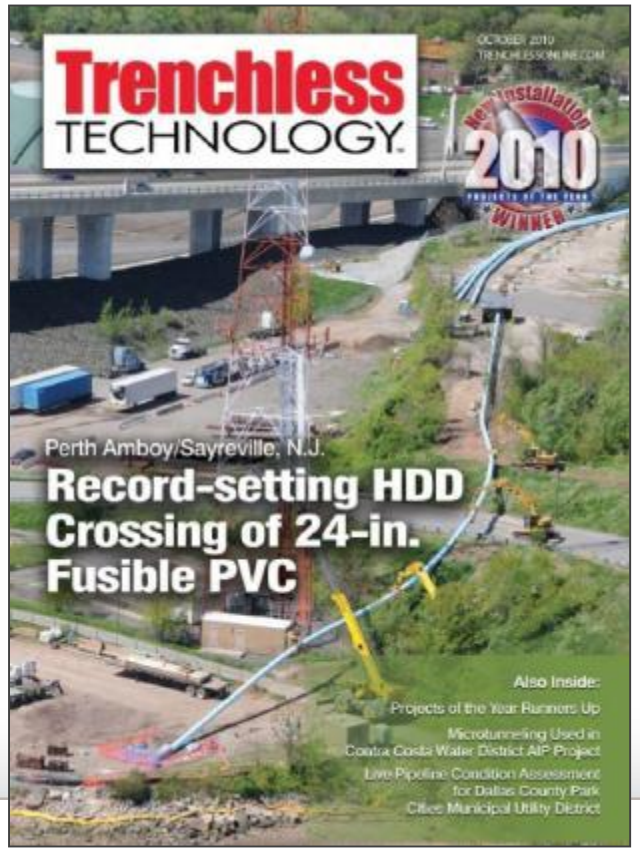
HDD - Raritan River, New Jersey

Horizontal Directional Drilling

Client: Middlesex Water – Perth Amboy, NJ



- 5,400 LF of 24” DR 18 Fusible C905® pipe
- Longest unassisted pull of thermoplastic pipe in the water & wastewater industry
- 3 intermediate fusions during pull-in (~1,300 LF each)
- “Trenchless Technology Project of the Year 2010”

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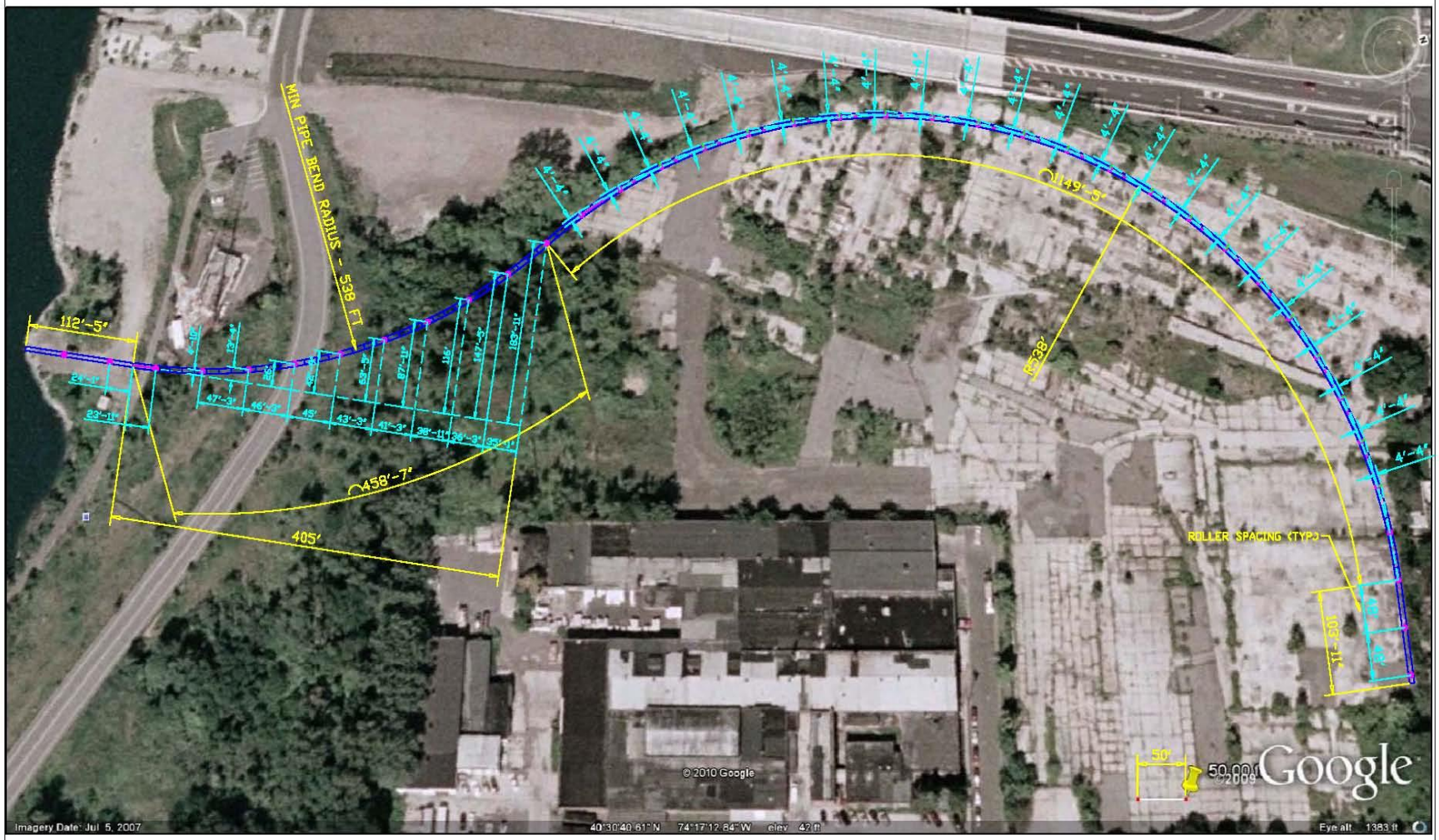
Pipe String Layout



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HDD with Fusible PVC™ in Monessen, PA

Horizontal Directional Drilling

Intermediate Fusion Example

- 1,200’ pull-in required with 800 LF of allowable laydown area
- Pulled majority of 800’ run then fused on 400’ tail piece

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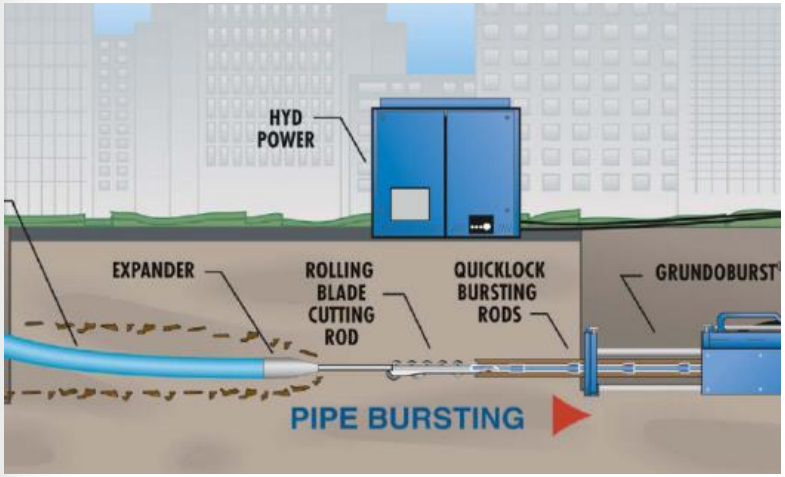
Fusible PVC® pipe is a Proven for Potable Water Pipe Bursting

Pipe Bursting Process:



Fusible PVC® Advantages for Pipe Bursting

- PVC pipe is a common, accepted small diameter water pipe material:
  - Same fittings, taps, and connections
  - Same labor skillset
  - Same operation and maintenance requirements
- Reduced upsize bursting effort required compared to similar ID/Pressure HDPE

CMW, Lakewood, CO – Over 30 miles of Potable Water Pipe Bursting

Pipe Bursting

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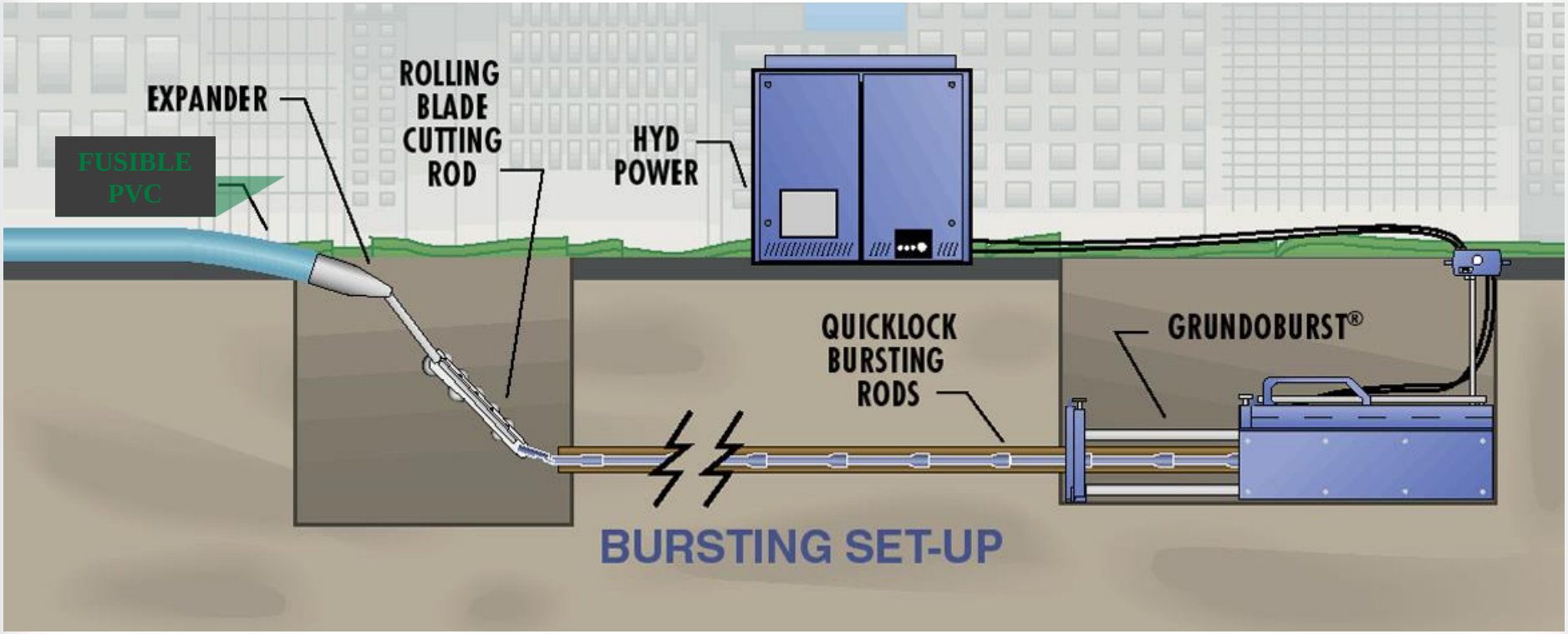
Pull Back



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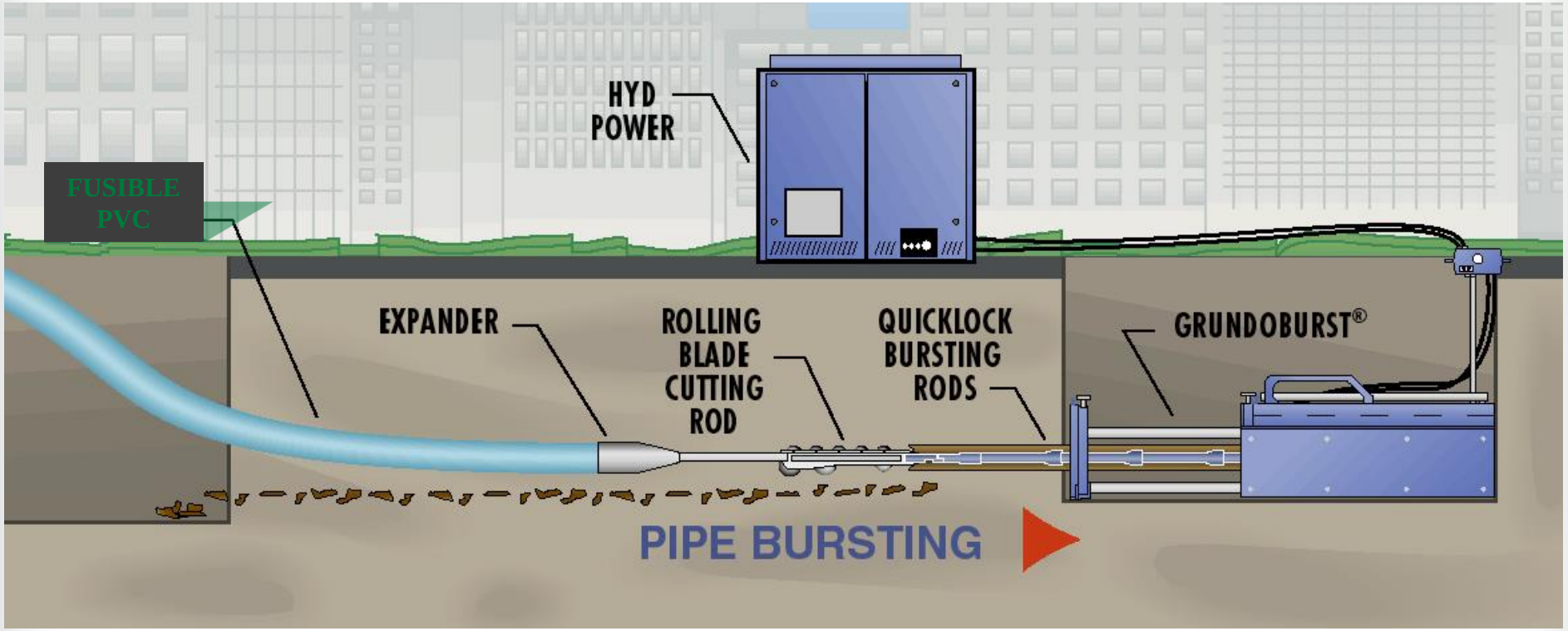
Pipe Insertion



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Insertion

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Pipe Bursting with Fusible C-900® for Potable Water

Pipe Bursting

Client: City of Dearborn Heights

- 3 Pipe Burst/HDD projects Completed to Date
- 4th Project to start in April 2016
- Replacement of Existing 6” and 8” CI with 8” and 12” Fusible C-900®

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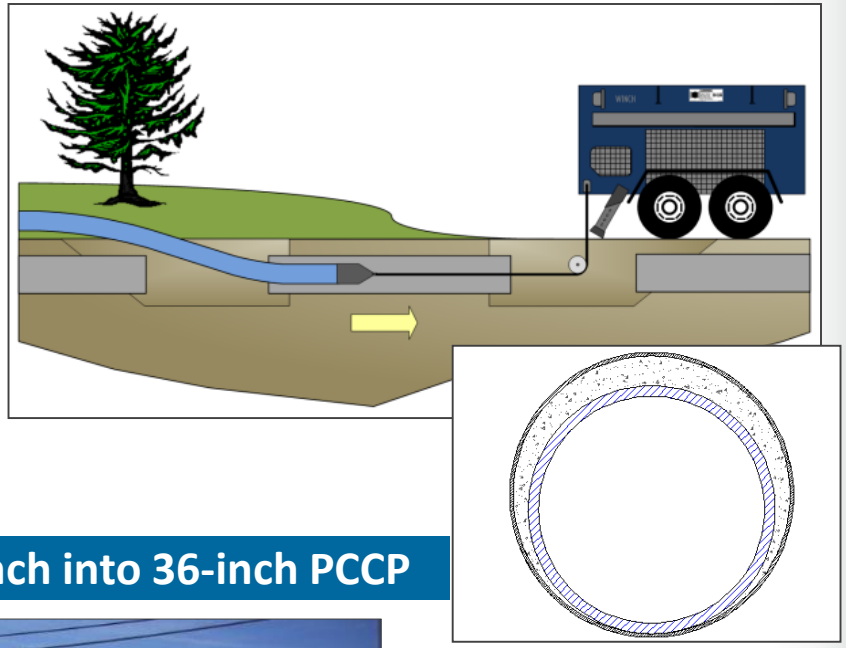
Fusible PVC® Maximizes Flow for Structural Slipline Installations

Fusible PVC® 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

Sliplining Process:



Newport, RI – Emergency Forcemain Slipline – 30-inch into 36-inch PCCP

Sliplining

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Sliplining - Harrisburg, PA

Sliplining

Client: United Water

- 3,510 linear feet of Fusible C-900®
- Host Pipe – 16” cast iron
- 12” DR 18 for water line under the Susquehanna River

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Cleaning

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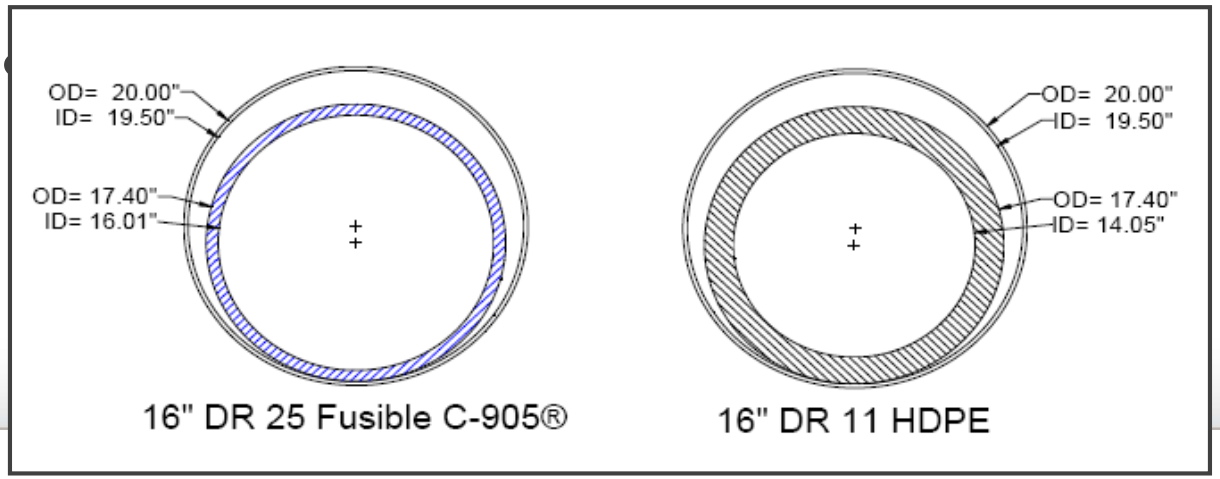
Cleaning Final Inspection

Sliplining with Fusible C-905® Pipe

Sliplining

Client: Andersen AFB, Guam

- 25,000 LF of 16” Fusible C-905® via Slipline
- Provides 80% of base water supply
- Host Pipe – 18”-20” Riveted Steel



Sliplining with Fusible C-905®

Sliplining

Client: City of Hamilton, OH

4,500’ of 20” Fusible C-905® Rehabs Existing 24” Steel Line along Rt. 4

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Sliplining

City of Hamilton - Consideration's

- Maximize flow capacity of existing 24" main and design for a max operating pressure of 150 PSI.
- 20" DR-25 Fusible C-905® was selected
  - Max Operating Pressure 165 PSI with 2.0 SF
  - Max allowable pull force for insertion 157,500 lbs. with 2.5 SF
  - 21.6" OD able to fit comfortably inside 24" ID host pipe
  - Final ID of new fused PVC line 19.8"
  - 2,100' single pull achieved

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Summary of Aegion Pressure Pipe Capabilities

AEGION PRESSURE PIPE CAPABILITIES

Product	Applications							Diameter	Thickness	Max Continuous Install Length	Max. Temp.	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""	5mm - 28.5mm +/-	1,200'	130°F	250 psi	X	X	up to 45°
Tite Liner®	*X	X	X	X	X	X		02" - 52"	DR 9 - DR 41	5,000'	140°F	140 psi	X	X	up to 11.25°
Tyfo® Fibrwrap®	X	X	X	X	X			30" and above	4mm - 20mm	Unlimited	150°F	450 psi	X	X	Any
Fusible C-900®	X	X	X	X	X	X	X	04" - 12"	DR 14, 18, 21, 25	7,000'	140°F	305 psi		X	N/A
Fusible C-905®	X	X	X	X	X	X	X	14" - 36"	DR 14, 18, 21, 25, 32.5	7,000'	140°F	305 psi		X	N/A
Fusible PVC®	X	X	X	X	X	X	X	04" - 36"	SCH40 or SCH80	7,000'	140°F	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*

AEGION®

Aegion's experience and technologies allow us to partner with customers to determine the best solution for their challenges

- 30,000 miles of installed pipe around the world
- Professional engineers involved in every project
- Mobile installation crews
- 80+ years of combined experience in rehabilitation
- Industry-leading safety record
- Certified to ISO 9001:2008 standards

Questions?

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