Underground Solutions®

Introductory Capabilities Presentation

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Underground Solutions: Bringing Innovation to the Underground Infrastructure Market

- Fastest growing underground infrastructure product-line in North America since 2004
  - Leak free, restrained joint pipe systems
  - Trenchless installation modes that reduce contractor costs
  - Rehabilitation capabilities for difficult high pressure water pipe applications
  - "Trenchless Project of the Year 2010 & 2013" – Trenchless Technology magazine
  - 41 technical project papers involving Fusible PVC presented at "No Dig"
- Over 6,000 successful projects installed to date with ~ 2,000 miles or 10,000,000 LF in service
  - In 50 states, Canada, Latin America, New Zealand, Australia
  - Over 4,000 HDD's (horizontal directional drills) completed
  - Over 10,000 separate pull-in instances (HDD, Slipline, Pipe Burst, Open-Cut)
  - In service installations dating to 2003
- Pipe meets relevant industry pipe standards
  - AWWA C900, C905, C605, NSF-61, NSF-14, PPI-TR2, ASTM Cell Classification 12454, ASTM 1674
  - Utilizes standard PVC and ductile iron fittings
  - Available in all water industry configurations

Underground Solutions has Developed Fusible PVC® Pipe to Deliver Greater Value than Alternatives

Fusible PVC® Improves Installation and Long Term Operating Costs
• **Lower Installation Costs for Rehabilitation and New Installations**
Horizontal Directional Drilling, Sliplining, Pipe Bursting, Open-Cut
• **Mechanical and Chemical Advantages Over Other Thermoplastic Pipe**
Higher Tensile Strength – Longer pull-ins for trenchless installations
Higher Pressure Capacity for PVC – Favorable ID/OD comparison to other plastic pipe means downsizing of pipe OD with savings
Chemical Compatibility – Resistance to hydrocarbon permeation
Chemical Compatibility – Resistance to water disinfectant degradation
• **Restrained Joint System – No Dimensional Compromise with Regard to Pipe OD**
• **Use of Standard PVC and DI Fittings Drives Down Project and Maintenance Costs**

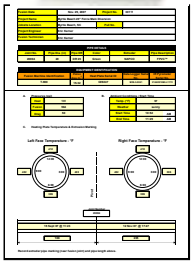
Fusible PVC® Pipe Products Cover Water, Wastewater, Reclaimed Water and Raw Water: Fusible C-900®, Fusible C-905® and FPVC®

Pipe 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.

Fusible C-900®, Fusible C-905® and FPVC ®: Fusion Process is Tightly Controlled

- Qualified fusion technicians are trained and retrained 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
- Fusion conditions logged by technician and "as-built" fusion joint record can be provided for the owner



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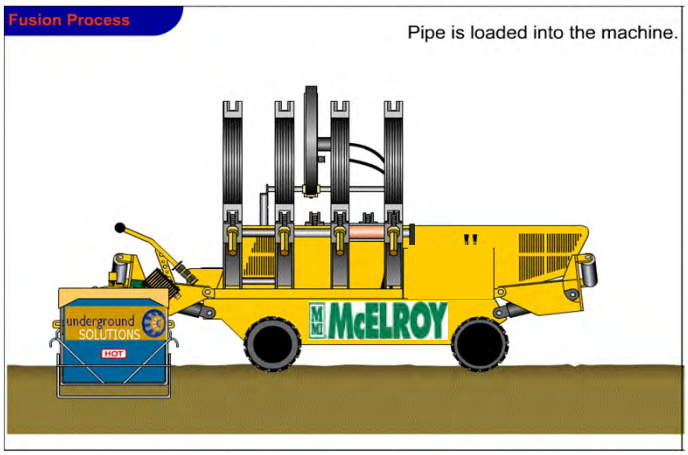
The Underground Solutions® PVC Fusion Process: Utilizes Industry Standard Fusion Equipment



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 1000gpm in a length of 1000LF, 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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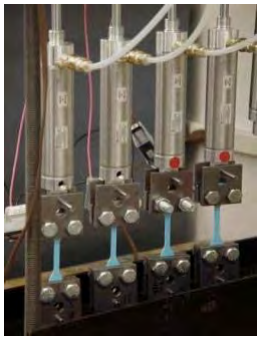
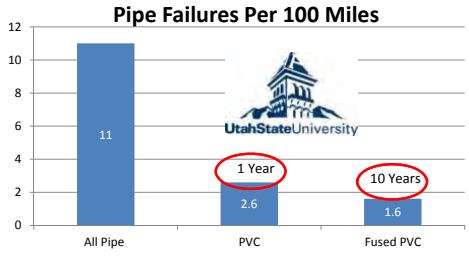
Thousands of Hours and Thousands of Individual Sample Tests by Independent Sources have Verified Mechanical Properties of UGSI Fusible PVC® Pipe

- Tensile Strength – >1,000 fused samples verify fused joint strength ~ 7,000 psi ultimate tensile strength or typically 95-105% of the un-fused pipe strength (within the variability found in commercial PVC pipe)
- 1000 Hour Sustained Pressure Test - per ASTM D1598 at 500 psi (DR18) for 10x the ASTM threshold of 1,000 hours – UGSI test duration was 10,000 hours – fused and un-fused pipe
- 1,000,000 Cycle Pressure Test – (94-188 psi for DR18) demonstrating cyclic surge on a fused joint system per ASTM F1674 – simulating a severe duty cycle (3.5 million completed)
- 5000 Hour Scratch/Pressure Test – Gouge depths of 5-10% on samples under 500psi (DR18) pressure were successfully tested (pipe and fused joint)



The Exceptionally Low Failure Rate of Fusible PVC® Pipe Confirms System Reliability Over Time versus other Pipe Materials

- **Over 1,000 miles in service in the United States**
- **A failure rate of ~ 1.6 per 100 miles (528,000 feet) of installed pipe (over a *ten-year* period)**
  - **Includes tapping and joint failures by licensees**
- **Very low compared to 11 failures per 100 miles over a *one-year* period for all pipe materials***



Utah State University (USU), Water Main Break Rates, April 2012.

Note – USU break rates do not include joint leaks and tapping failures, however those types of failures are included in the "Fused PVC" rate

Alternative Restrained PVC Joints Limit Applications

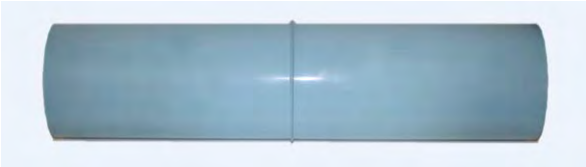
Conventional Gasketed & Restrained PVC to PVC Connections 12" Example

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

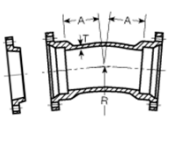


Barrel and Fused Joint Have Consistent O.D. = 13.2"

Connections with Fusible PVC® Pipe can be Easily Accomplished with Industry Standard Couplings and Fittings

Connecting to Fittings

Mechanical Joint Fittings:



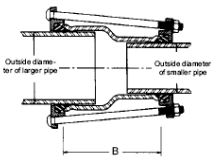
MJ and MJ

Flanged Joint Fittings:

Connecting to Pipe

Same Piping Size:

Different Piping Size:



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

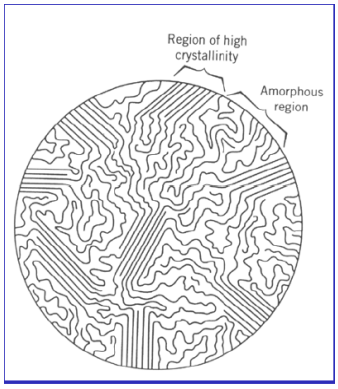
Thermoplastic pipes are composed of large hydrocarbon polymers whose behavior is largely dictated by morphology, temperature and chemical structure

Amorphous polymer

Amorphous Polymer chains are arranged randomly and even at low temperatures do not organize or become crystalline (PVC)

Semi-crystalline polymer

Semi-Crystalline Polymer chains organize more readily due to more simple geometry or chemical structure – crystalline regions and amorphous regions (HDPE)



Callister 2003

Thermoplastic materials exist in various states or phases over a range of temperatures (Glassy, Rubbery, Flow) where the materials behave very differently

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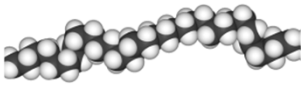
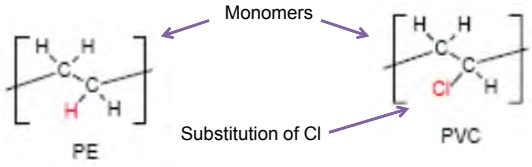
Molecular Structures Drive Differences in Polymer Chain Packing which Results in Material Properties Differences

HDPE

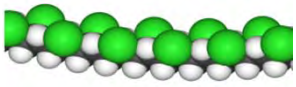


Similar structures except that on each monomer (repeated unit in the polymer chain) a Hydrogen atom is replaced with Chlorine atom



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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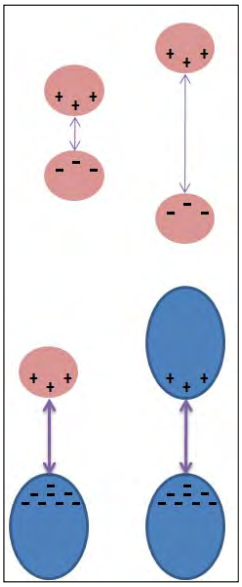
Bonding : van der Waal Forces



Dispersion Forces
Strength is proportional to the distance between the atoms (magnets)
Attraction due to temporary dipoles formed from electron movement within each atom
Occur in Both HDPE and PVC

Dipole – Dipole
Chlorine atoms more electronegative than hydrogen (stronger magnet)
Carbon - Chlorine bond is a permanent dipole (polar).
Polar bonds are attracted to opposite charges in other PVC chains.
Occurs only in PVC

Hydrogen Bonding
The bond between Polar Chlorine atoms and hydrogen atoms from another chain on average are 10-20X stronger than solely dispersion forces – Hydrogen to Hydrogen seen in HDPE
Occurs only in PVC

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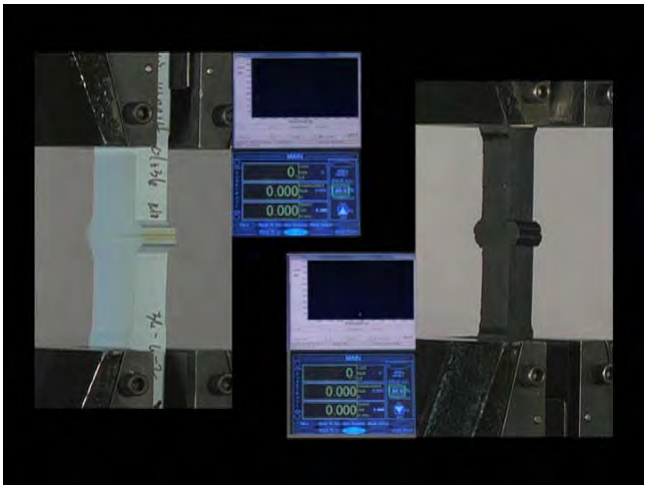
Deformation in Thermoplastics: Chemical Structure Affects Strength and Deformation – Tensile Strength



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

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PVC Pipe has Many Mechanical Property Advantages over HDPE Thermoplastic Pipe that Often Result in Economic Savings

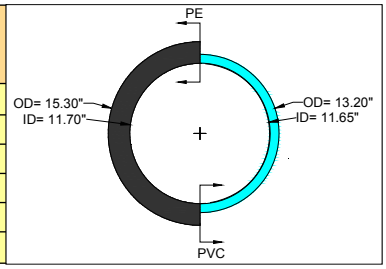
Property	Specification	PVC	HDPE 3408/3608[1]	HDPE 4710[2]
Tensile Strength psi	ASTM D638	7,000	3,000	3,500
Specific Gravity	ASTM D1505	1.40	0.94	0.95
ASTM D3350 Cell Class	ASTM D3350	NA[3]	345464	445574
Hydrostatic Design Basis At 73° F, psi	ASTM D2837	4,000	1,600	1,600
Modulus of Elasticity psi (Short 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

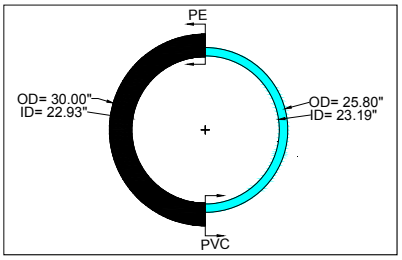
1. HDPE 3408/3608 also referred to as PE80
2. HDPE 4710 also referred to as PE100
3. PVC Pipe Cell Class per ASTM D1784 (12454)
4. PPI – PE Handbook – Long Term Modulus of Elasticity is 28,200 psi
5. Carollo Engineers 2008, Choi 2008, Chung 2008, Fumire 2008, Rozental 2008, Castegnetti 2007, Audouin 2007, Dear 2006,
6. Lundback 2005, Hassinen 2004
7. Water Research Foundation (formerly AWWA Research Foundation 2008)

When Designing for Flow, Fusible PVC® Pipe Requires less OD (Pipe Volume) and Weight for a Given ID (Flow) than HDPE

Example: Fixed I.D., Fixed Pressure Class

12" ID	12" PVC DR 18 SF = 2.0	14" PE DR 9 SF = 2.0	PVC % Advantage
OD (inches)	13.20	15.30	16%
Volume per Foot (ft^3)	0.95	1.28	34%
Wall Thickness (inches)	0.73	1.80	90%
ID (inches)	11.65	11.70	-0.5%
Pressure Rating (PSI)	235	200	15%
Weight (lbs./ft.)	19.05	31.64	70%



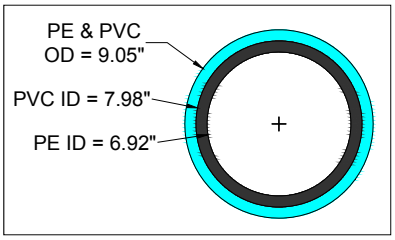


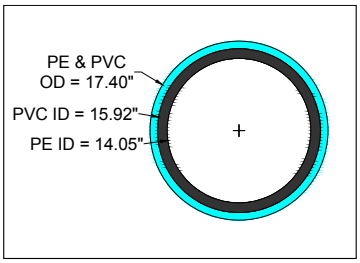
24" ID	24" PVC DR 21 SF = 2.0	30" PE DR 9 SF = 2.0	PVC % Advantage
OD (inches)	25.80	30.00	16%
Volume per Foot (ft^3)	3.63	4.91	35%
Wall Thickness (inches)	1.23	3.33	171%
ID (inches)	23.19	22.93	1%
Pressure Rating (PSI)	200	200	0%
Weight (lbs./ft.)	61.49	121.62	98%

Fusible PVC® Pipe Delivers 20-30% More Cross-Sectional Flow Area than HDPE for a Given OD

Example: Fixed O.D., Fixed Pressure Class

8" Pipe	8" PVC DR 18 SF = 2.0	8" PE DR 9 SF = 2.0	% PVC Advantage
OD (inches)	9.05	9.05	-
Wall Thickness (inches)	0.51	1.01	98%
ID (inches)	7.98	6.92	13%
Flow Area (inches^2)	50.01	37.61	25%
Pressure Rating (PSI)	235	200	15%
Weight (lbs. / ft.)	8.75	11.07	27%





16" Pipe	16" PVC DR 25 SF = 2.0	16" PE DR 11 SF = 2.0	% PVC Advantage
OD (inches)	17.4	17.4	-
Wall Thickness (inches)	0.69	1.68	141%
ID (inches)	15.92	14.05	12%
Flow Area (inches^2)	199.06	155.04	22%
Pressure Rating (PSI)	165	160	3%
Weight (lbs. / ft.)	23.70	34.29	45%

For gravity sewer, reducing gaskets is a better system, long term

- Provides a monolithic pipeline between connections to solve very common problems
  - Over insertion/deflection, differential settlement, differential deflection, and root intrusion
  - A new segmented pipeline has an allowable leakage rate
- Economic benefits of eliminating potential leak points for the life of the line
  - Reduce Inflow and Infiltration (I&I)
  - What is the net present value of that additional flow over the life of the pipeline?

Reducing Inflow and Infiltration saves money on treatment and operations

- Wet weather flow can be 2 to 10 times greater than dry weather flows.
- Significant cost to collect and treat wet weather flows.
- Design Criteria accounts for I&I – City and County of Honolulu
  - Base Sanitary for Neighborhood Business = 3,200 gallons per acre (80 gallons per capita per day x 40 capita per acre)
  - Wet Weather for Neighborhood Business
    - 2,750 gallons per acre per day for sewer laid below normal ground water table
    - 1,250 gallons per acre per day for sewer laid above normal ground water table

Industry Accepted Allowable Leakage for Newly Installed Gasketed Gravity Sewer

200 gallons per inch-diameter per mile = 24 hour leak rate

24" B&S Gravity Sewer = 5,160 gallons per day per mile

- Leakage will be zero gallons per day per mile for a gasketless system

Direct Bury with Fusible PVC® for Sanitary Sewer Pipe Schofield Barracks, HI

Open-Trench/ Direct Bury

Client: Aqua Engineers & the US Army DPW

- More than 100,000' of gravity sewer pipe installed to address current and future Inflow and Infiltration
- Installation Methods – Open Cut, Pipe Burst, Slipline and HDD
- Estimated $1.5M saved by reducing WWTP treatment operating costs

Pipe Bursting, Open Cut and Utilidor Placement with Fusible PVC® Pipe for Potable Water and Sanitary Sewer Pipelines

Pipe Bursting/Open Cut

Client: NAVFAC Marianas, Apra Harbor

- 30,000' LF potable water and Fusible PVC®
- Bursting through Dresser Couplings – Grundoburst equipment from TT Technologies
- Manhole to Manhole pipe burst/open cut runs
- Pipe alignment in groundwater
- Provide Zero leakage vs. conventional B&S pipe
  - 200 gal/Inch OD Pipe/mile/day

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Horizontal Directional Drilling

Horizontal Directional Drilling Considerations

- Insertion trench is configured to meet bend radius of the pipe
- 6,400 ft 16" DR18 pulled in a single continuous drill operation
- Care taken to prevent drill mud, etc. from entering pipe with capping attachment
- Bend radius of drill stem usually dictates alignment (almost always less bend than Fusible PVC®)
- No relaxation period required – immediate connections possible
- Higher density of Fusible PVC® pipe reduces buoyant forces to reduce pull-in forces
- Longer pull-ins – recommend water ballasting and rollers to reduce drag
- For equivalent wall thicknesses, HDPE only supports 40% of the PVC pull force

30" HDD Bore in Hillsborough, FL 2012

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Horizontal Directional Drilling with Fusible PVC® Pipe

Horizontal Directional Drilling

Client: NAVFAC Hawaii – Pearl Harbor

- Phase I - 3,500 LF of 24" DR 18 Fusible C905® pipe
- Pearl City to Ford Island - Pearl Harbor Crossing
- Replacement of deteriorated cast iron
- Phase II - 3,800 LF of 24" DR 18 Fusible C905® pipe from Ford Island to Pearl Harbor - 2015

Horizontal Directional Drilling with Fusible PVC® Pipe

Horizontal Directional Drilling

Client: Andersen AFB, Guam

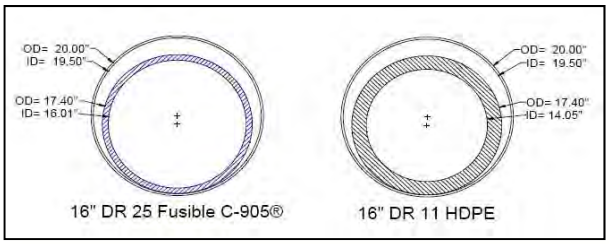
- 2012-2013 Clear Rinse Facility
- Provide casing and new high pressure water delivery system
- Multiple Water, Sewer and Conduit Crossings under runway
- Open Cut potable water and sanitary sewer lines

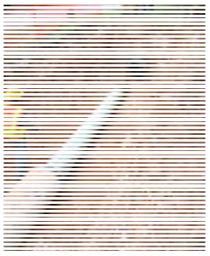
Sliplining with Fusible C-905® Pipe

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
- Fusible PVC® provided 30% more flow area than the HDPE pipe specified





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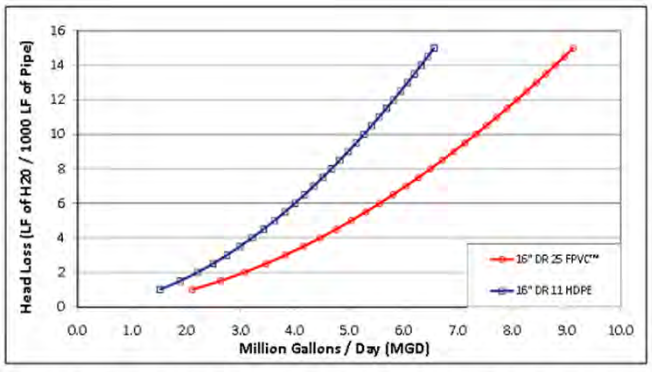
Head Loss Comparison



This chart and table were created using the Hazen-Williams formulas for the flow of water in plastic pressure pipes. A flow coefficient (C) of 150 was used for all calculations.

The table below shows the head loss, pressure change, and fluid velocity for a given flow rate in million gallons per day (MGD).

	16" DR 25 FPVC™				16" DR 11 HDPE			
	Head loss (LF H20 / 1000 LF)	Total Head Loss (LF H20)	Pressure Change (PSIG)	Velocity (LF/s)	Head loss (LF H20 / 1000 LF)	Total Head loss (LF H20)	Pressure Change (PSIG)	Velocity (LF/s)
1 MGD	0.2	0.5	0.2	1.1	0.5	0.9	0.4	1.4
2 MGD	0.9	1.9	0.8	2.2	1.7	3.4	1.5	2.9
3 MGD	1.9	3.9	1.7	3.4	3.5	7.2	3.1	4.3
4 MGD	3.3	6.7	2.9	4.5	6.0	12.3	5.4	5.8
5 MGD	4.9	10.1	4.4	5.6	9.1	18.7	8.1	7.2
6 MGD	6.9	14.2	6.2	6.7	12.7	26.1	11.3	8.6

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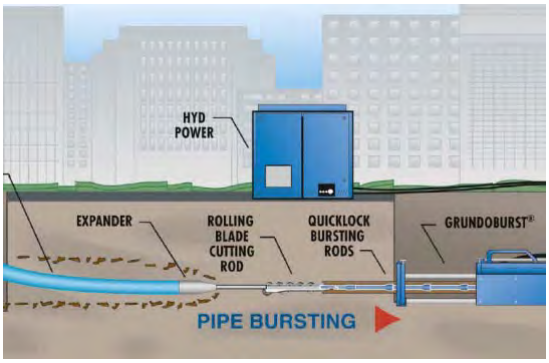
Fusible PVC® Pipe Attached to the Bursting Head and Pulled into the Existing Pipe Alignment

Pipe Bursting

- Static Hydraulic Method is used
- Burst head is pulled through existing line - fracturing or cutting the pipe
- Fractured or split pipe is pushed into the surrounding soil
- New pipe is pulled in immediately behind the burst head
- Typically done in 300 - 500' increments (~1 hour pull-back)
- Utilizes existing alignment – less engineering cost to locate adjacent utilities
- Result in same or larger I.D. (upsizing) as old pipe



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Pipe Bursting with Fusible C-900® Pipe for Potable Water

Pipe Bursting

Client: Travis AFB

- Static Hydraulic Method for 3,240' LF pipe burst of 8" ductile iron and cast iron pipe with 8" Fusible C-900®
- Bursting through Dresser Couplings – Grundoburst equipment from TT Technologies

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Summary: Underground Solutions Fusible PVC® Pipe Lowers Project Costs and Lowers Project Risk

- Fusible C-900®, Fusible C-905® & FPVC® pipe offer advantages over other pipe systems:
  - Tough, reliable thermoplastic material
  - Leak free, fused, restrained joint pipe system
  - Acceptance of standard PVC fittings and methods
- Fused PVC® pipe systems deliver lower costs:
  - High tensile strength allows for longer "pulls" in Sliplining, Pipe Bursting and HDD – superior productivity
  - Lower OD for specified flow (ID) means less spoils disposal and smaller fittings, valves & connections
  - Higher ID for specified OD (i.e. host pipe, bore) – optimal flow when OD constrained (sliplining, pipe bursting)
  - Lower overall project cost possible in open-cut projects due to:
    - Higher production rates
    - Less rework (no bell & spigot)
    - Restrained joint without costly mechanical restraint

Questions?

Underground Solutions, Inc.
Poway, CA

www.undergroundsolutions.com
858-679-9551