Fold & Form PVC Liners
Sewer & Culvert Rehabilitation

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IPEX
Committed to Excellence

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Agenda

- Overview of existing rehab technologies
- Fold and Form PVC Liners
  - Manufacturing
  - Installation
  - Case Studies
  - Performance Standards
  - Structural Design
  - QC & Certifications
  - Benefits / Summary

Deteriorated Sewer Infrastructure

- **D-** is the grade ASCE gave US Wastewater infrastructure
- 10 Billion gallons of raw sewage discharge through SSO's annually[1]
- Main Cause – broken/cracked or blocked pipes and joints

[1] *Source:Local Government Expenditures on Sewer and Water (1991-2005), 2007, http://www.usmayors.org/urbanwater/07expenditures.pdf .*

Culvert Hazards

- Culverts in poor condition can lead to dangerous sinkholes

- Corrugated Steel Pipe (CSP) allows infiltration of water and soil

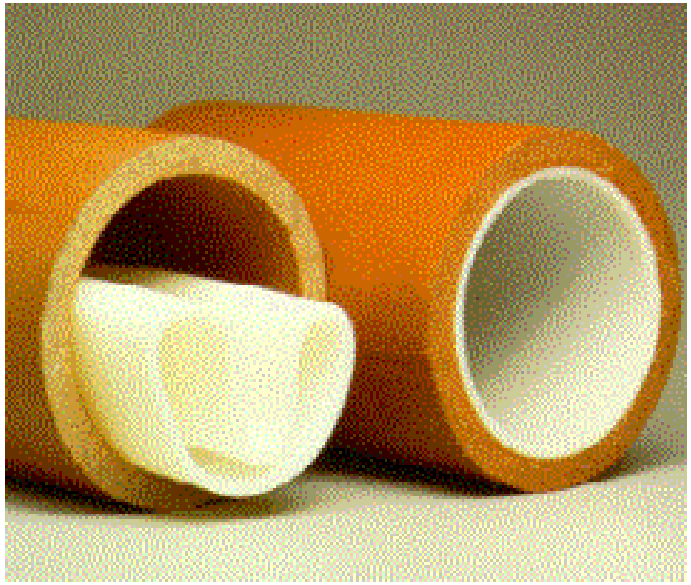
Trenchless Pipeline Rehabilitation

Trenchless rehab is typically far less expensive than the dig-up and replace option, and far less disruptive to the public.

- **Fold & Form Pipe (FFP)**
- Spot Repairs
  - Grouting / Root control
- Pipe Bursting
- Sliplining
  - HDPE
  - Fusible PVC^{tm}
- Cured in Place (CIPP)
  - Steam/Hot Water
  - UV
- Geopolymer Spray-On

Fold & Form Pipe (FFP) Overview

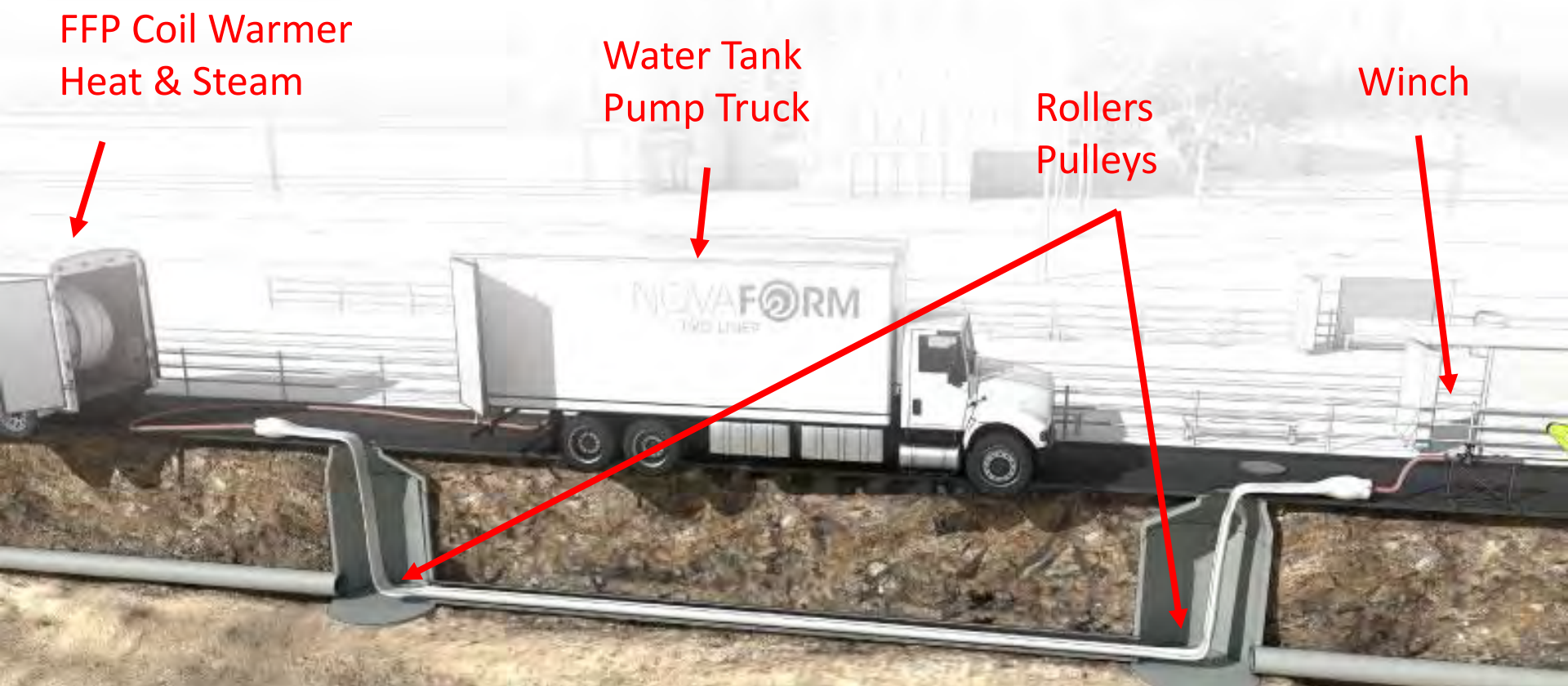
- PVC or PE thermoplastic liners
- Extruded pipe is folded into a U or H profile while still warm
- Coiled onto large reels and cooled to ambient temperature
- Reheated on-site until pliable
- Pulled into the host pipe
- Ends are plugged and it is filled with steam and air to expand and reform the circular pipe
- Snug fitting liner pipe cools and hardens



FFP Install Set-Up

Small Footprint:

- Sewer MH to MH – occupies single traffic lane
- Culvert – typically no lane closures



FFP - Manufacturing

Manufacturing

PVC pipe is extruded

Manufacturing

While still warm, the pipe is folded into a U or H profile shape

Manufacturing

While still warm, the pipe is folded into a U or H profile shape

Manufacturing

The warm, folded pipe is coiled onto large reels & cools to ambient

FFP – Installation

Installation – Step 1

Host Pipe Prep

- Bypass control if needed
- Roots cut out
- Offset joints fixed
- Groundwater infiltration points grouted (heat sink)
- Debris removed
- Large voids under pipe inverts should be filled (gravel, grout, cement)

Installation – Step 2

Reel of coiled FFP is steam heated until pliable

Installation – Step 2

Reel of coiled FFP is steam heated until pliable (inner and outer surfaces)

Installation – Step 3

A cable is sent down a manhole, through the host pipe and up a different manhole, where it is connected to a pull head fashioned on the FFP

Installation – Step 3

A winch and rollers/pulleys pull the pliable FFP through sewer/culvert

Installation – Step 3

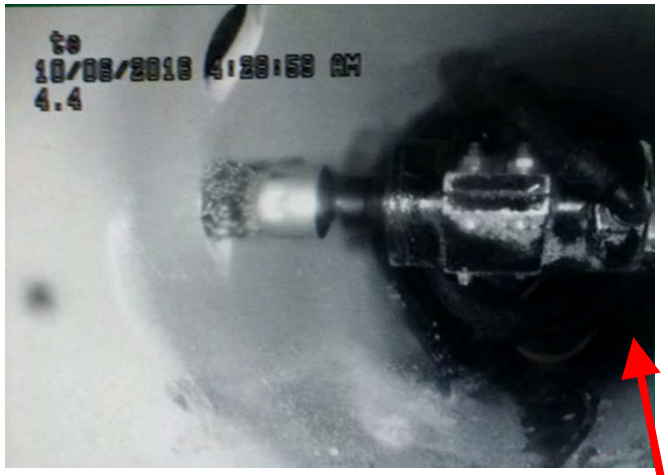
A winch and rollers/pulleys pull the pliable FFP through sewer/culvert

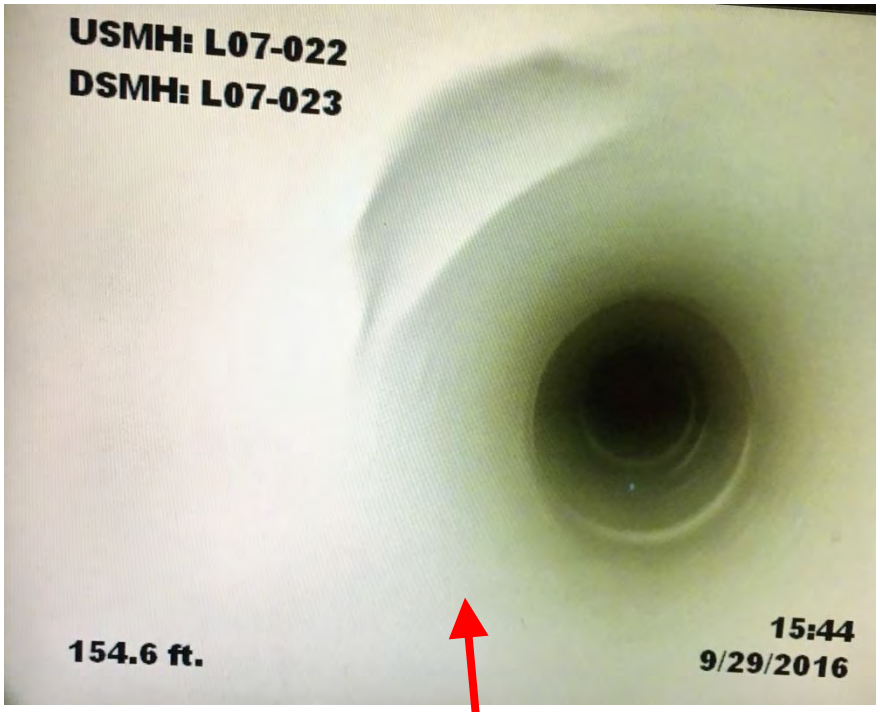
Installation – Step 4

- Both ends are plugged
- Pressurized steam expands it in place
- Pipe is cooled and hardens

Installation – Step 5

FFP is trimmed at Manholes and laterals are cut out robotically





8” DIP Sanitary
360’ MH to MH

8” VCP Sanitary
240’ MH to MH

FFP - Case Studies

FFP – Case Study 1A (Leamington)

- 18” CSP Culvert, 75’ pull - 18” Liner Used
- Liner expansion: 13%, Finished DR66

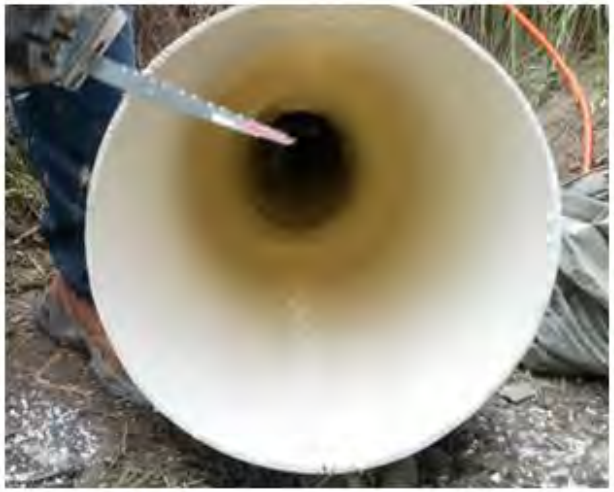
FFP – Case Study 1B (Leamington)

15” CSP Culvert, 70’ pull

12” Liner Used

Liner expansion: **36%**,

Finished DR66



FFP – Case Study 2

Liner expansion: 10%, Finished DR35

FFP – Case Study 2

- Host Pipe
  - 8” RCP Sanitary sewer
  - 300’ MH to MH, passed through MH at 200’
  - 8’ Depth of Bury
- FFP Pipe
  - 8” DR 27.5, 350’ long
- Ambient Temperature
  - 26 to 35°F

FFP – Case Study 3 (Tillsonburg)

16” CSP Culvert, 60’ MH to road side
Liner expansion: 14%, Finished DR47

FFP – Case Study 4 (Tecumseh)

15” CSP Storm, 108’ CB to CB

Liner expansion: 11%, Finished DR41

FFP – Case Study 5 (Mississauga)

36” CSP Culvert, 220’ pull

Liner expansion: 24%, Finished DR68

30” Liner Used

FFP – Case Study 6 (Lambton)

- 24” CSP Culvert, 140’ CB to CB
- Liner expansion: 13%, Finished DR66

FFP – Standards

FFP – Two Material Choices

	ASTM F1504	**ASTM F1871**
Flexural Strength	9,000 psi	6,100 psi
Modulus (E)	400,000 psi	230,000psi
Heat Deflection Temp	140 °F	115°F
Re-heating Method	Steam in & out	Steam out
Size Range	4” to 15”	4” to 18”

- Higher stiffness permits deeper burial
- Lower stiffness is easier to negotiate bends in the host pipe

- *NovaForm available in up to 30” (ASTM F1504)*

Structural Design

- Design theory is that of a “Close Fit Liner”
  - Use **ASTM F1947 Appendix X1** for F1504 liner
  - Use ASTM F1867 Appendix X1 for F1871 liner
  - Same design methods currently used for CIPP liners: ASTM F1216 Appendix X1 (-07a, -07b or -09)

- Calculate:
  - Buckling Pressure using loading on the pipe
  - Deflection, Ring Bending, Minimum Stiffness

Structural Design

- Design parameters:
  - Liner dimensions and physical properties
  - Existing (host) pipe characteristics:
    - Fully or Partially Deteriorated Pipe
    - Ovality
  - Soil characteristics: Density and Modulus
  - Loading conditions:
    - Soil depth to pipe crown
    - Groundwater depth to pipe crown
    - Live Loading (HS-20, R.R.)

Structural Design – Liner Comparison

The material properties used for the 4 liner types in Tables 1-4 are:

Liner Type	Flexural Modulus Short-term	Flexural Strength Short-term	Long-term Retention (5 year)
CIPP Regular	2,420 MPa 350,000 psi	31 MPa 4,500 psi	50%
CIPP Reinforced	8,000 MPa 1,150,300 psi	150 MPa 21,7580 psi	65%
PVC F/F ASTM 1871	1,586 MPa 230,000 psi	42.1 MPa 6,100 psi	50%
PVC F/F ASTM 1504	2758 MPa 400,000 psi	62.1 MPa 9,000 psi	50%

Structural Design – Existing Pipe

Existing Pipe Parameters

Design Condition	Fully Deteriorated
Inside Diameter	As stated in the form of tender
Depth to invert	4m*
Water table below surface	1m
Ovality	3%**
Soil Density	1925 kg/m3 (unless otherwise known)
Soil Modulus	4.8 MPa (unless otherwise known)
Live Load	H20 of 110MPa

* Sewer greater than 4m in-depth will have site specific designs. (SSD)
** Sewer greater than 3% ovality will have site specific designs. (SSD)

Structural Design - Comparison

Wall Thickness and corresponding DR of FFP required for given conditions

TABLE 1: Water Table: 0 m below ground surface; Ovality 3%

Existing Pipe Condition	Pipe Size	Invert Depth	CIPP Regular	CIPP Reinforced	PVC F/F ASTM 1871	PVC F/F ASTM 1504
Fully Deteriorated	300 mm	2.0 m	4.9 mm DR 61	3.0 mm DR 100	5.6 mm DR 54	4.7 mm DR 64
Fully Deteriorated	600 mm	2.5 m	10.0 mm DR 60	6.2 mm DR 97	11.5 mm DR 52	9.6 mm DR 63
Fully Deteriorated	900 mm	3.0 m	15.5 mm DR 58	9.6 mm DR 94	17.9 mm DR 50	14.9 mm DR 60
Fully Deteriorated	1200 mm	4.0 m	23.0 mm DR 52	14.2 mm DR 85	26.5 mm DR 45	22.0 mm DR 55
Partially Deteriorated	300 mm	2.0 m	4.2 mm DR 71	3.0 mm DR 100	4.8 mm DR 63	4.0 mm DR 75
Partially Deteriorated	600 mm	2.5 m	9.0 mm DR 67	6.0 mm DR 100	10.3 mm DR 58	8.6 mm DR 70
Partially Deteriorated	900 mm	3.0 m	14.3 mm DR 63	9.0 mm DR 100	16.4 mm DR 55	13.7 mm DR 66
Partially Deteriorated	1200 mm	4.0 m	20.9 mm DR 57	12.9 mm DR 93	24.0 mm DR 50	20.0 mm DR 60

Structural Design - Comparison

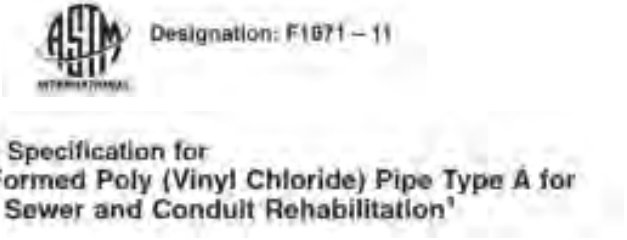
Wall Thickness and corresponding DR of FFP required for given conditions

TABLE 4: Typical for CSP Culverts; Water Table at Crown; Ovality 4%

Existing Pipe Condition	Pipe Size	Invert Depth	CIPP Regular	CIPP Reinforced	PVC F/F ASTM 1871	PVC F/F 1504
Fully Deteriorated	300 mm	2.0 m	4.5 mm DR 67	3.0 mm DR 100	5.1 mm DR 59	4.3 mm DR 70
Fully Deteriorated	600 mm	2.5 m	8.9 mm DR 67	6.0 mm DR 100	10.2 mm DR 59	8.5 mm DR 71
Fully Deteriorated	900 mm	3.0 m	13.3 mm DR 68	9.0 mm DR 100	15.3 mm DR 59	12.7 mm DR 71
Fully Deteriorated	1200 mm	4.0 m	19.2 mm DR 63	12.0 mm DR 100	22.1 mm DR 54	18.4 mm DR 65
Partially Deteriorated	300 mm	2.0 m	3.0 mm DR 100	3.0 mm DR 100	3.0 mm DR 100	3.0 mm DR 100
Partially Deteriorated	600 mm	2.5 m	6.0 mm DR 100	6.0 mm DR 100	6.7 mm DR 90	6.0 mm DR 100
Partially Deteriorated	900 mm	3.0 m	9.9 mm DR 91	9.0 mm DR 100	11.4 mm DR 79	9.5 mm DR 95
Partially Deteriorated	1200 mm	4.0 m	14.5 mm DR 83	12.0 mm DR 100	16.7 mm DR 72	13.9 mm DR 86

QC Testing

- Each Coil
  - QC tests include acetone immersion, heat reversion tests, and dimensional checks
- Every Production Run
  - Impact, Stiffness, Flattening, Flexural Modulus
  - Sample lengths are taken and expanded to mimic in-field expansion; min. 1 per production run


Designation: F1871 – 11

Standard Specification for
Folded/Formed Poly (Vinyl Chloride) Pipe Type A for
Existing Sewer and Conduit Rehabilitation[1]

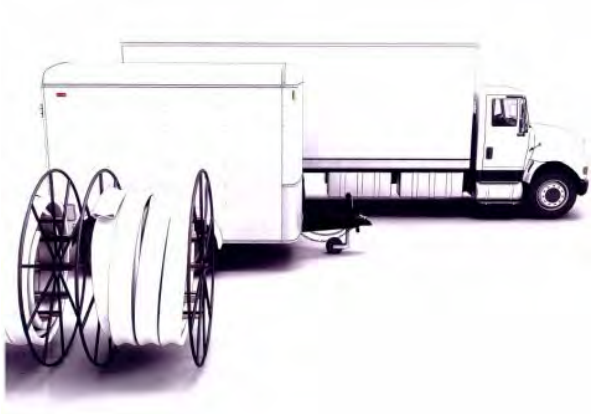
Certifications

NovaForm in sizes 6” – 15” is 3rd party certified by the CSA organization to comply with ASTM F1504.

FFP – Benefits / Summary

- **Odor free installation - Steam / Heat**
- **Styrene / Chemical free installation**
- Small installation footprint
- Fast installation
- Factory manufactured:
  - QA/QC in controlled environment
  - 3rd party certified
  - Material properties available **BEFORE** installation
- Finished product like “stick pipe” (SDR 35)
- Improved hydraulics: ***Mannings = 0.009***
- Chemical resistant & corrosion-proof
- 50+ year service life
- Over 20M ft installed world-wide

Thank you!



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