And the *Polyurea* Goes Round & Round:
Robotic Sprayed-in-Place Pipelining

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We Are In Trouble!!

- In the US alone, it is estimated that over $1 trillion will be required over the next 25 years just to restore buried potable water lines due to age / deterioration
- In EU, infrastructure is must older and in worse conditions
- Above does not include all the burried “chemical pipelines” also affected

References:

Buried No Longer: Confronting America’s Water Infrastructure Challenge, AWWA, 2012.

State of Technology Review Report on Rehabilitation of Wastewater Collection and Water Distribution Systems, EPA, 2012.

So what do we do to repair????

Conventional Methods

- Dig up / Replace
  - Very large “foot-print” / disruption
  - Very expensive
  - Not practical in many locations

Conventional Methods

- Dig up / Replace
- Pipe Bursting / Jacking
  - Large “foot-print” for access
  - Use of steel, PE or PVC pipe
  - Covers lateral connections

Conventional Methods

- Dig up / Replace
- Pipe Bursting / Jacking
- Cementicious Linings
  - Economical advantage
  - Not for aggressive (high acidic) applications
  - Will crack over time / movement
  - Potential erosion issues

Conventional Methods

- Dig up / Replace
- Pipe Bursting / Jacking
- Cementicious Linings
- CIPP: Cured-in-Place Pipelining
  - Epoxy or vinyl ester impregnated sock
  - Covers lateral intrusion, must be cleared
  - Not good for various pipe diameters in “run”
  - Annular space

SIPP: Sprayed-in-Place Pipe

- Dig up / Replace
- Pipe Bursting / Jacking
- Cementicious Linings
- CIPP: Cured-in-Place Pipelining
- SIPP: Sprayed-in-Place Pipelining
  - Epoxy, Polyurethane or ***Polyurea***
  - Lateral tie-ins remain cleared
  - Accommodates various pipe diameters
  - No annular space

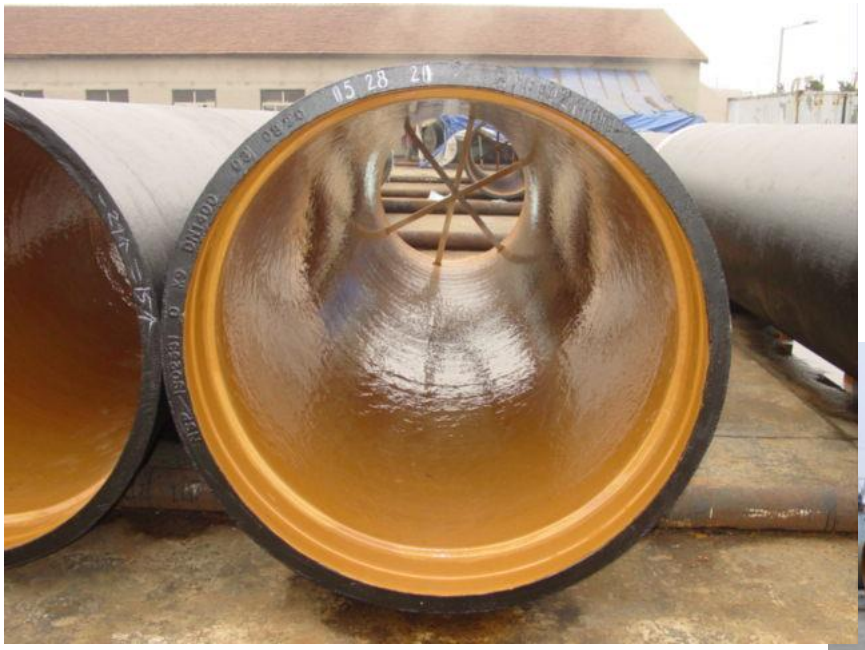
Spray PUA Lined Pipe

- Pipe Rotation / lance spray head
- Simple “robotic head”
- Limited to pipe joint sections
- Difficult in bends and elbows

Spray PUA Lined Pipe

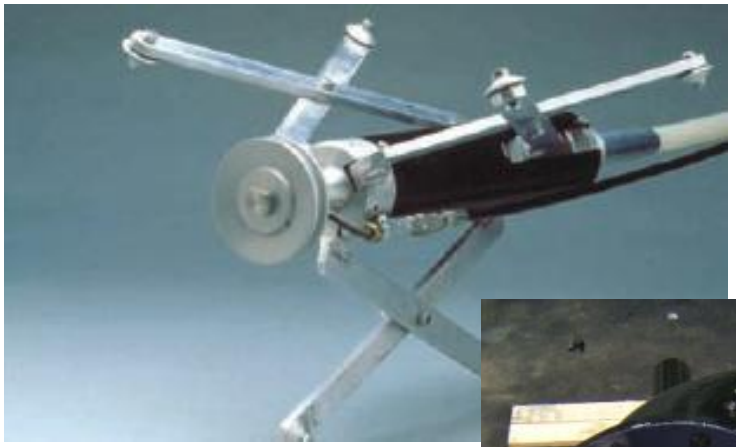
- Pipe rotation

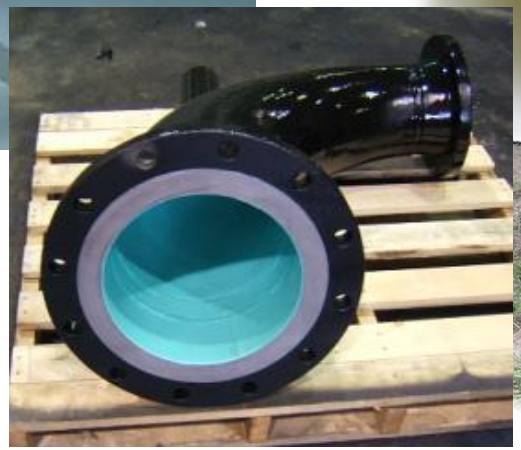
Spray PUA Lined Pipe



Spray PUA Lined Pipe

- Simple “robotic head”
  - “Clemco” based equipment





But wait a minute……

How do you rotate the pipe once installed?

What about the joint areas????

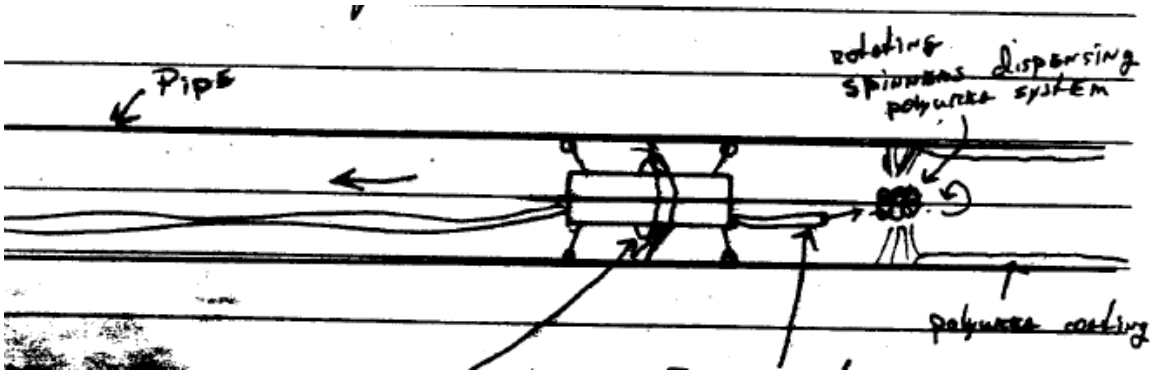
So how do you line “in-place” pipe with Polyurea Spray?

- Hand spray application
  - Pipe must be large enough to enter, or have *really small* spray applicators

Armco Culverts, Australia, 1999.

Background / History

- First disclosed in 1989
  - AL 8824 Patent Suggestion, Texaco Chemical Company



- Subsequent work in UK in mid 90's
  - Shot independent streams of ISO component and Resin component, mixed on "spinner"

Background / History

- First “spinner” application in 1992
  - PUA dispensed from impingement mix spray gun on spinning disk
  - Used in some manhole lining work
  - Limits entrance in confined space

Background / History

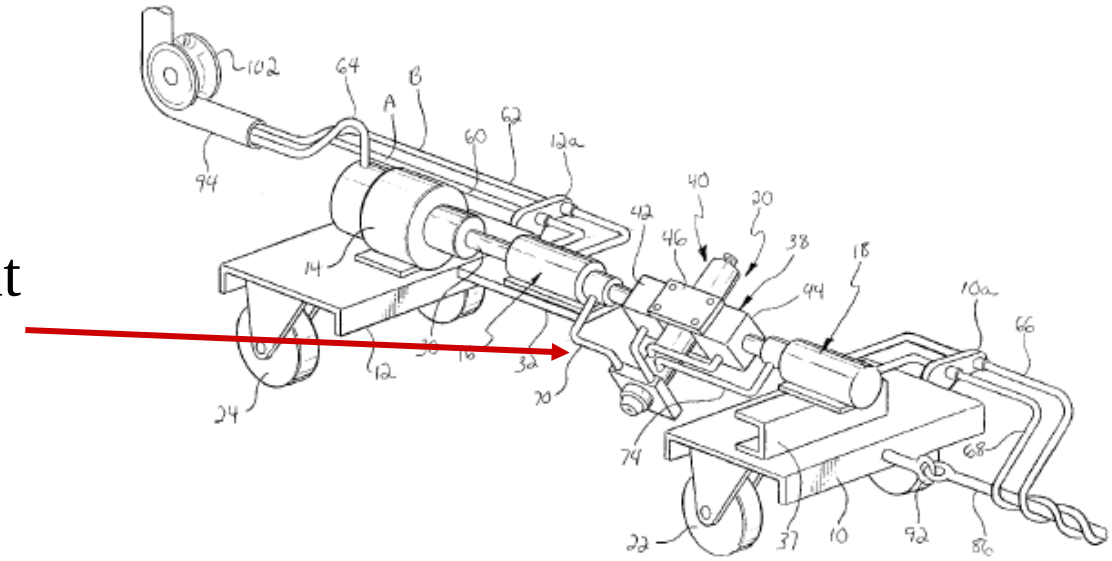
- First Commercial Use – 1995
  - Southern Underground
  - Waste water pipeline
    - Houston, Texas
  - Not a 360° coverage / bottom bare
  - Large diameter / ride-on unit

ICI Polyurethanes Review, Vol 6, No 8, October 1996

Background / History

- "Spinning" spray gun technique
  - Great concept for fast set
  - Minimum diameter 60 cm (24 inch)
  - Wheels track in fresh material

Rotating impingement mix gun



US Patent 6,632,475

Current Robotic Technology

- "Spinning" disk / cup
  - Premixed system dispensed and broadcast off
  - High RPM disk or "cup" - up to 30,000 rpm's
  - Oscillation / reciprocation simulates "hand spray"
  - Segmented "head" for bends and 90°

US Patent's 6,986,813; 7,338,687; 7,591,901; 7,682,655

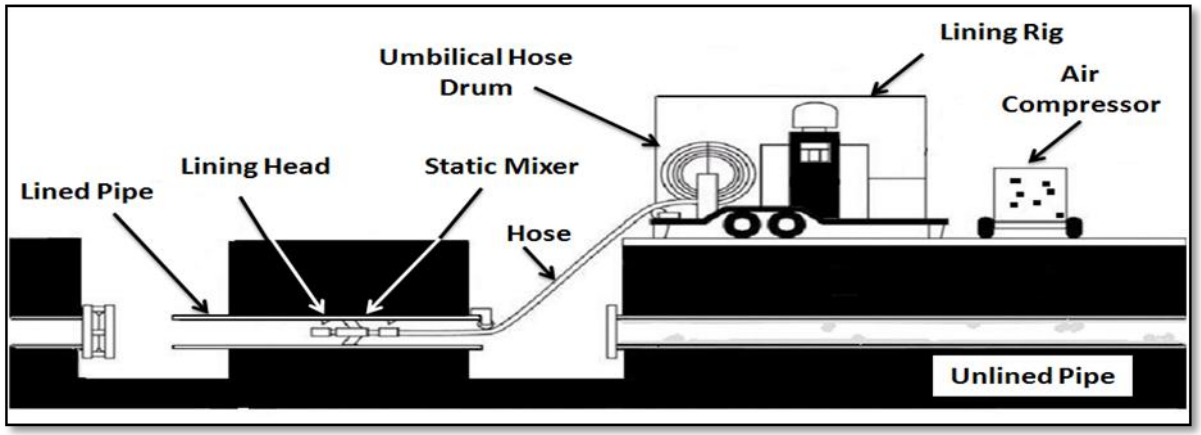
Current Robotic Technology

- Static Mix / Hollow Cone Spray
  - Spray pattern not perpendicular, double run

Adjustable from 25 – 60+ cm (10 – 24”) via skid

Current Robotic Technology

- Typical installation diagram
  - Surface preparation is similar setup
  - CCTV's observe real-time installation
  - Automatic hose real controls speed / application film build



Current Robotic Technology

- Robotic Pipe-Lining Rehabilitation
  - Technology introduced in 2000, but slow to start
  - Robotic Spray-In-Place Pipe (SIPP)
  - Up to 200 meters in-place, 2.5 cm to 2.5 m diameter
  - Municipal or Chemical plant use
  - High pressure rating
    - 76 mm dia hole, 6 mm thickness, > 2.8 MPa pressure hold
  - Can line multiple diameters in-line, bends and elbow's
  - Class IV Structural capabilities

Types of *Polyurea*

	"standard"	Semi-Structural	Fully Structural
Flexural Modulus, MPa	~ 345	~ 690	> 1725
kpsi	~ 50	~ 100	> 250
Tensile strength, MPa	~ 13 – 20	~ 20 – 34	~ 28 - 41
kpsi	2 – 3	3 – 5	4 - 6
Elongation, %	400	250	< 20
Hardness	50	58	65
Gel time, sec	6 to 8	6 to 8	6 to 8*

- relative unlimited applied film thickness

* One supplier example is actually 60 sec gel / modified aliphatic / aromatic PUA, limited film thickness

Types of *Polyurea*

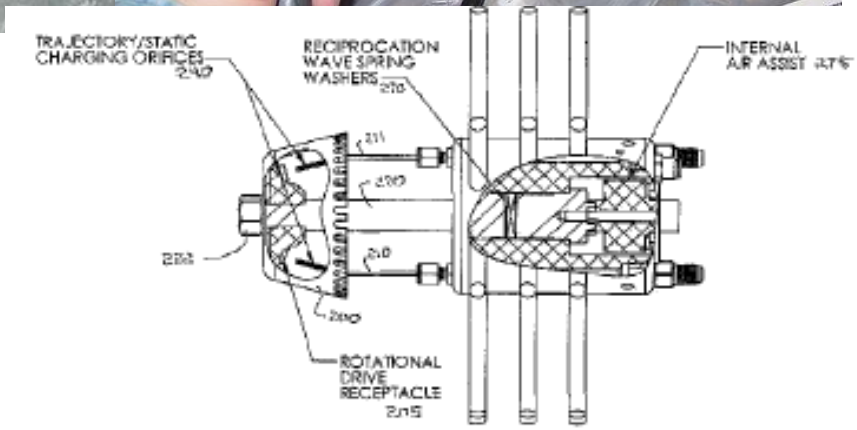
Industry Uses	"standard"	Semi-Structural	Fully Structural
Potable water	yes	yes	yes
Wastewater	yes	yes	yes
Process water / salt	yes	yes	yes
Power generation	yes	yes	yes
Chemical plants	conditional	yes	yes
Low pressure steam	no	yes	yes
Oil sands	yes	yes	no
Mining / processing	conditional	yes	no
Deteriorated pipe	no	conditional	yes

Recent Advancements

- Electrostatic Deposition
  - Uses a slower set PUA system
  - Designed for smaller diameter pipe
    - Down to 2.5 cm (1-inch) diameter
  - Insures complete, uniform coverage
  - Can be adapted to large diameter pipe for fast set PUA systems

Recent Advancements

- Electrostatic Deposition
  - Based on self generating charge equipment



- US Patented work:
  - 7,992,514 and 8,109,231

Industry Standards

- **ASTM International**
  - Work Group WK23937 (F 36), Standard Practice for Renewal of Existing Potable Water Pipes by Spray in Place Pipe – Polyurea and Polyurethane Coatings
    - Calculation for required applied thickness based on material properties and pipe diameter

- **ASCE: American Society of Civil Engineers**
  - Manual of Practice 28: Methods for Renewal of Potable Water Pipes

Conclusion

Polyurea is sound solution for pipeline rehabilitation work: State-of-the-Art

- Proven, not experimental
- Conforms to pipe interior surface / no annulus
- Fast set allows rapid return to service
- Thickness builds in single run
- No solvents, minimized fire issues
- Various industrial projects in-process now ***Around the Globe***!