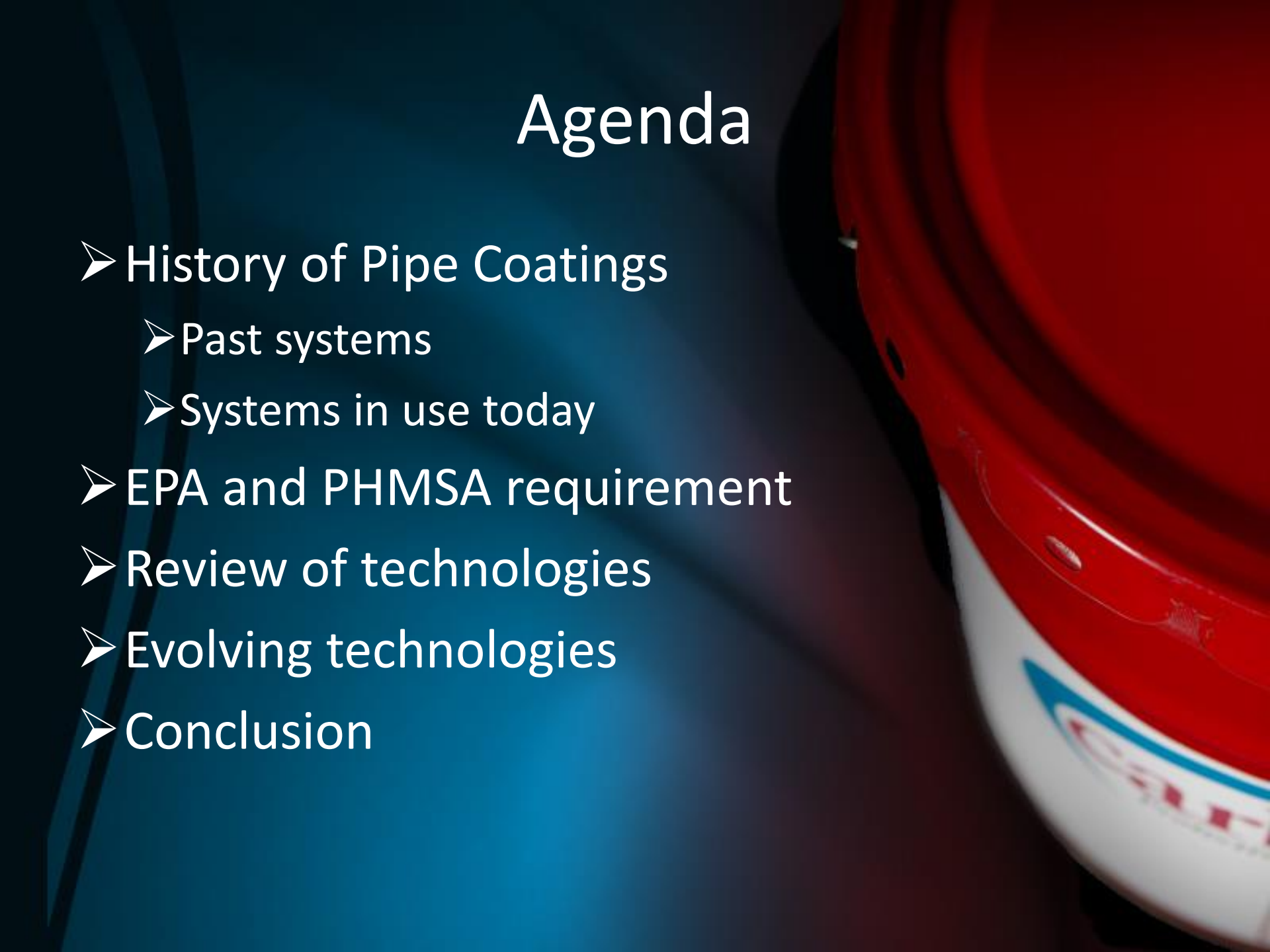
Evolution of Pipeline Coatings Below Grade Service

Agenda

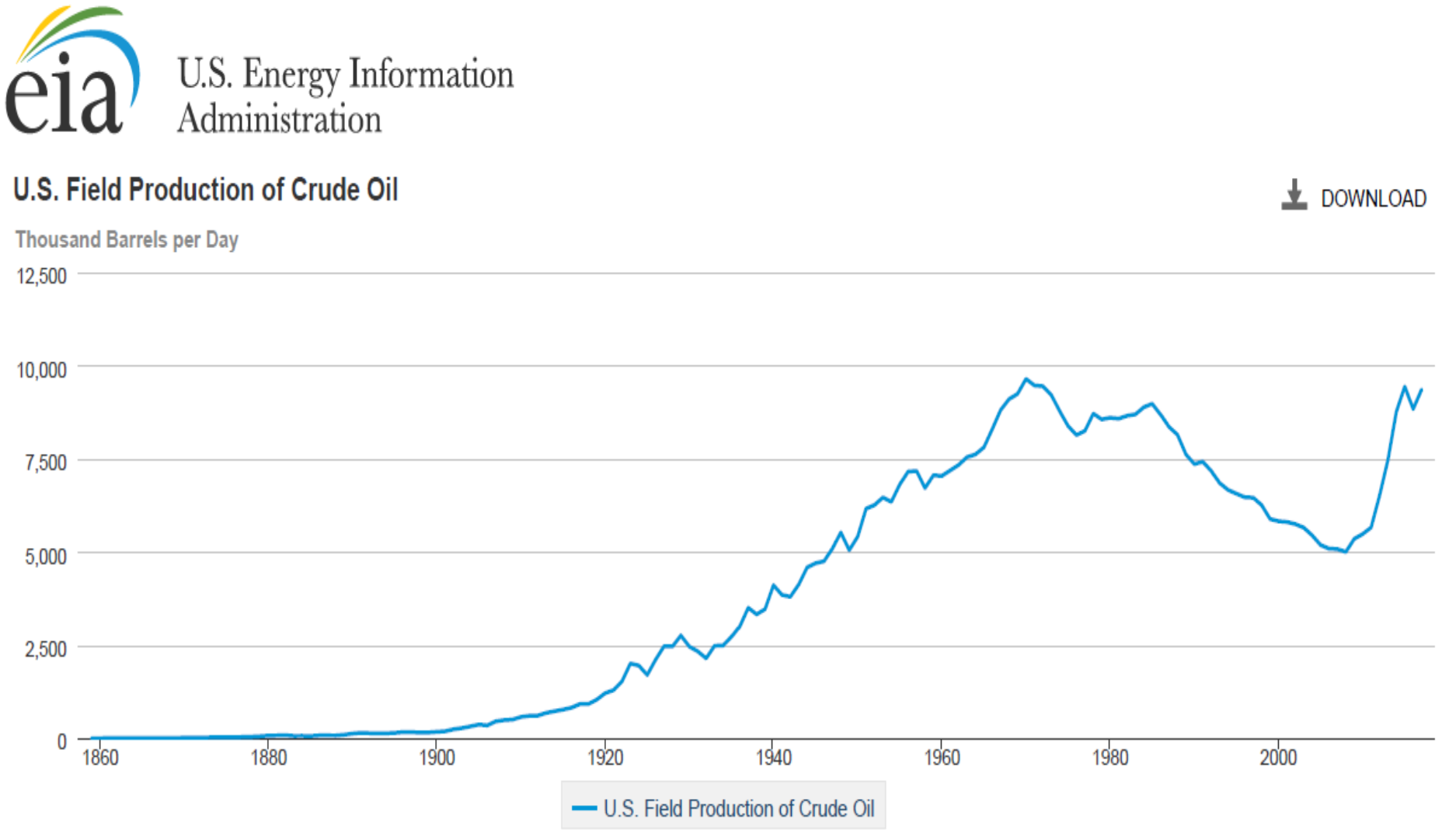
- History of Pipe Coatings
  - Past systems
  - Systems in use today
- EPA and PHMSA requirement
- Review of technologies
- Evolving technologies
- Conclusion



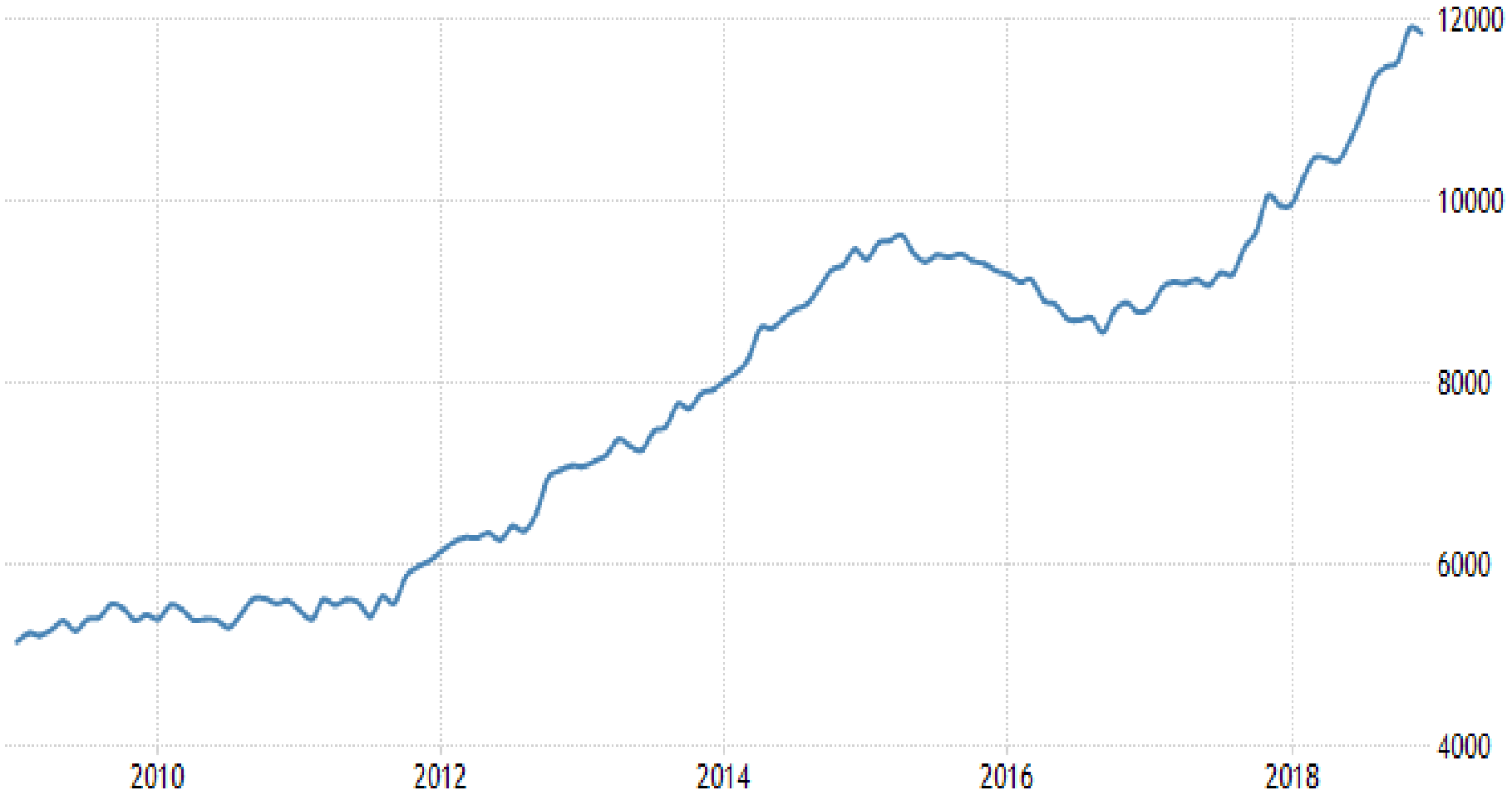
Early Pipelines

- First oil pipeline was 109 miles and 6 inches in diameter built in 1879
- Since the late 1920s most all pipes were welded steel pipes
- Buried pipes had corrosion problems
- Pipes needed corrosion protection

US Crude Oil Production from Beginning to 2014



Crude Oil Production 2010 to 2019



SOURCE: TRADINGECONOMICS.COM | U.S. ENERGY INFORMATION ADMINISTRATION

1930 to 1950

- First major coating used on steel pipe was a Bituminous Enamel (Coal Tar or Asphalt)
- Applied in a hot process along with reinforcement mesh (Fiberglass or Felt)
- Could be finished with Kraft Paper wrapped around the exterior
- Used till 1950s

1950s

- Coal tar pitch was mixed with epoxy resin system to create coal tar epoxy
- Coal tar epoxy has excellent resistance to water penetration
- Some use of wax coatings
- First hot applied tape systems
- Went from hot to cold applied tape coatings using butyl rubber as adhesives
- Two layer polyolefin coating

1960s

- Advances in tape technology using polymers like vinyl and polyethylene
- Fusion bond epoxy, FBE is 100% solids powder coating
- Two layer extruded polyethylene system
- Liquid epoxies come in use mostly in the field

1970 to 1980

- Fusion bond epoxy takes place of the older technologies becomes preferred coating system for mainline
- Polyurethane mixed with coal tar forms a rapid curing system
- Three-Layer PE/PP, FBE or liquid epoxy as the first coat, copolymer adhesive intermediate topcoated with polyolefin

History of Coatings for Steel Pipe

- Early 1900's Asphalt/Coal Tar Emulsions
- 1930's Oil-based Coatings Lead containing
- 1960's Fusion Bonded Epoxy (FBE)
- 1960's Two Layer Tape Wrap System
- 1960's Two Layer Extruded Polyethylene Systems
- 1970's Polyurethane Rapid Setting Systems
- 1980's Three Layer Systems (FBE+Adhesive+PP or PE)

History of Girth Weld Coatings

- 1940's Coal Tar Enamel
- 1950's Asphalt, Cold-Applied Tapes, 2 Layer PE
- 1960's Coal Tar Epoxy and Liquid Epoxies
- 1970's Heat Shrinkable Sleeves and FBE
- 1980's Three Layer PE and 100% Solids Epoxies
- 1990's Modified Polyurethane and MLPP

Protection of steel buried pipelines from corrosion is accomplished by the use of protective coatings and cathodic protection.

EPA and PHMSA

- The U.S. EPA requires protective coating and cathodic protection to all buried piping installed or replaced after **August 2002**
- PHMSA, Operators were given until March 31, 2002 or February 18, 2003, depending on their total pipeline mileage, to develop and implement their Integrity Management programs.

REVIEW OF TECHNOLOGIES

Motor Oil is Motor Oil?

- Most of the protecting coating system we will talk about is constantly evolving and improving
  - Higher temperatures
  - Improved physical properties
  - Chemical stability
  - Improved adhesion
  - Resistance to cathodic disbondment

Technology in use today

- Polyolefin (solid) Coatings
  - Tapes
  - Extruded PE
- Powder Coatings
  - Fusion bond epoxy (FBE)
- Liquid Coatings
  - Epoxy
  - Polyurethane

Polyolefin (solid) Coating System

- Two layer system
  - Consist on adhesive or hot melt layer followed by a layer of Polyethylene or Polypropylene.
- Three layer system
  - FBE primer or liquid epoxy primer
  - Adhesive Layer
  - Layer of Polyethylene or Polypropylene

Two Layer Coating System

Advantages

- Low Cost
- Ease of application
- Simple surface preparation

Disadvantages

- Poor shear stress resistance(crosslinking in adhesive can solve issue)

Three Layer System

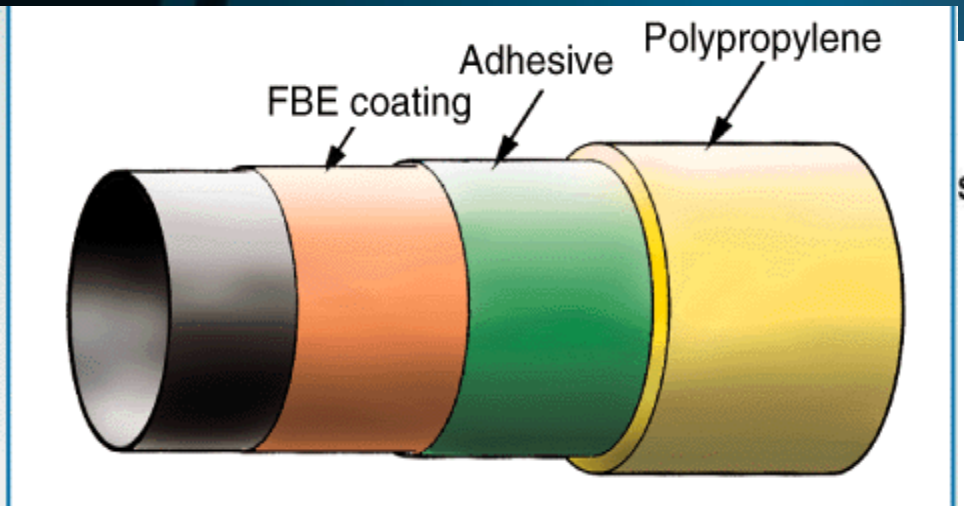
FBE + adhesive layer + PP or PE layer

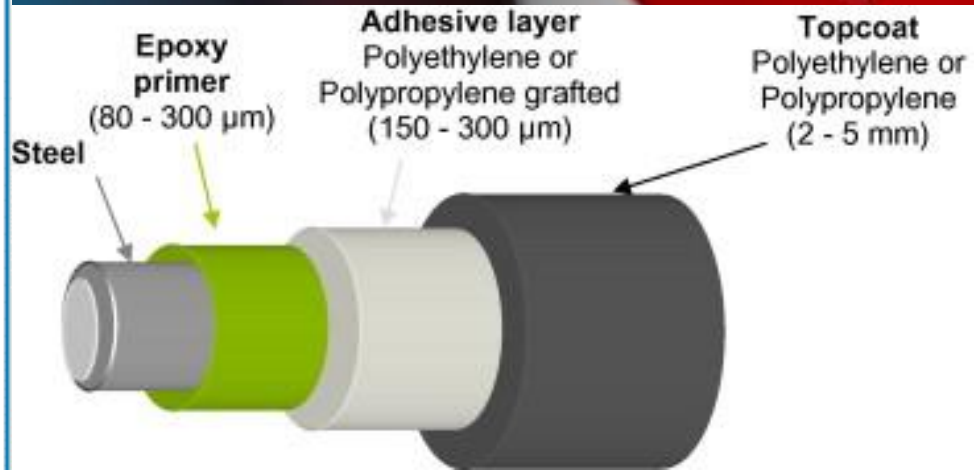
Advantages

- Good track record
- Good handling features
- Good combination features

Disadvantages

- Expensive
- Complex production process
- Difficult on field joints





Fusion Bond Epoxy (FBE)

- Single coat system
  - Consist of one coat of epoxy powder coating
- Dual Layer FBE system
  - One layer of FBE primer followed by
  - Layer of abrasion resistant FBE

Fusion Bond Epoxy

Single Coat application

Advantages

- Good Cost for small diameter pipe
- Corrosion Resistant
- Non-shielding corrosion protection
- Good adhesion

Disadvantages

- Low impact resistance result in easy to damage.
- High permeation
- Easily damaged during transport
- More difficult on field joint
- Hard to coat large diameter pipe

Fusion Bond Epoxy

Dual layer application

Advantages

- Improved impact and abrasion resistance
- Corrosion resistant
- Non-shielding corrosion protection
- Good adhesion

Disadvantages

- Increased cost
- High permeation
- More difficult on field joints
- Hard to coat large diameter pipe

Liquid Coatings

- Epoxy coating
  - Epoxy resin reacting with a polyamine or polyamide
- Polyurethane
  - Isocyanate reacting with polyol with hydroxyl

Epoxy Coatings

Advantages

- Good adhesion to steel
- Good abrasion resistance
- Chemical resistant
- One coat application
- Surface tolerant
- Good for field application

Disadvantages

- Lower flexibility
- Typically takes heated plural airless equipment to apply

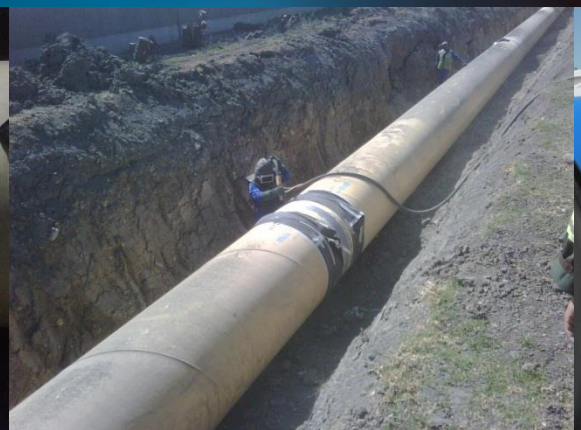
Polyurethane

Advantages

- Excellent adhesion to steel
- High build and rapid setting
- Abrasion resistance
- Low water permeability
- One coat application

Disadvantages

- Will react with moisture
- Requires heated plural airless equipment to apply
- Short recoat window



TRENDS IN THE MARKET

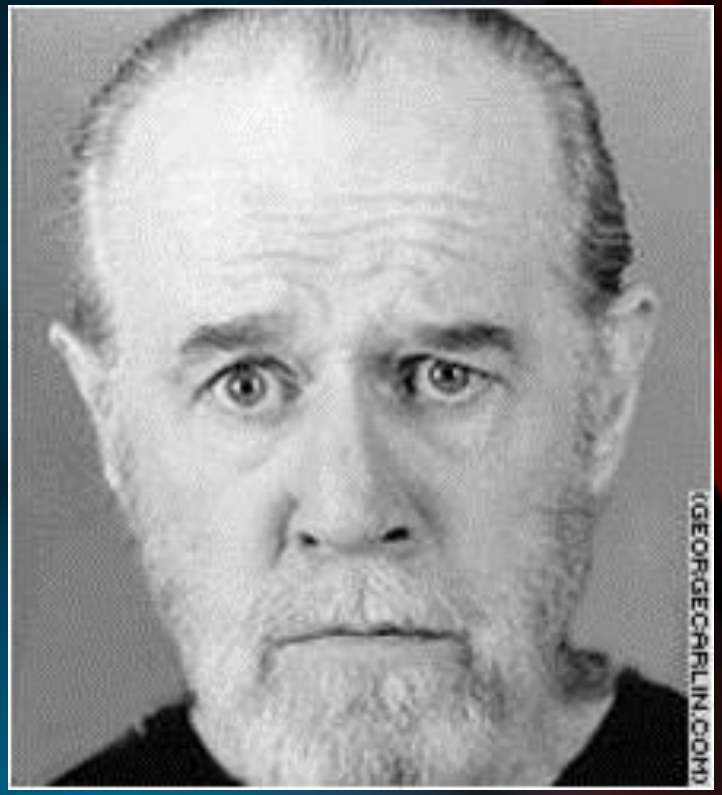
Market Trends

- Higher temperatures
- Higher pressures
- Changes to handle different soil stress
- Corrosion causing bacteria (MIC)


PROTECTIVE COATINGS WILL CONTINUE TO EVOLVE AS CONDITION CHANGE

Resistance to change in technologies

- There is a natural resistance to change
- End user have resistance to buy in to new technologies
- Takes time for new technologies to catch on
- The high cost of building a pipeline tends to prohibit the change to new technologies
- Usually there is a series of events that happen that help push for changes



QUESTIONS?