37TH INTERNATIONAL NO-DIG FLORENCE 2019

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# *FRP 101: Taking The Mystery out of Trenchless Repair of Pressure Pipes with Carbon FRP*

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# Introduction



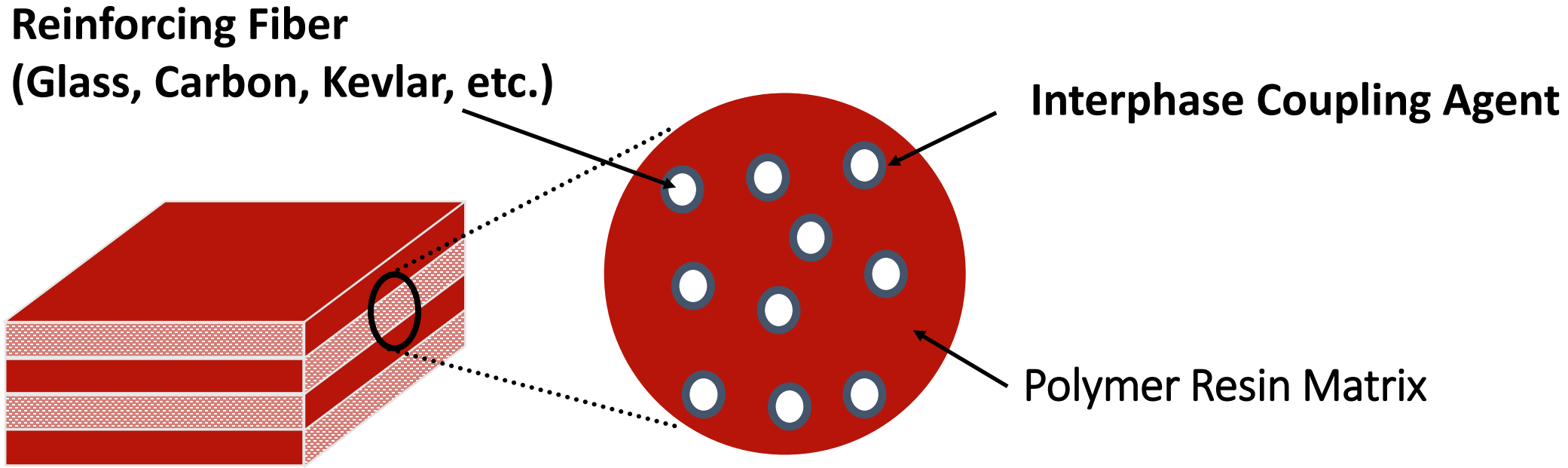
- History of Development
- Application to Pipes

# Fiber Reinforced Polymer (FRP)



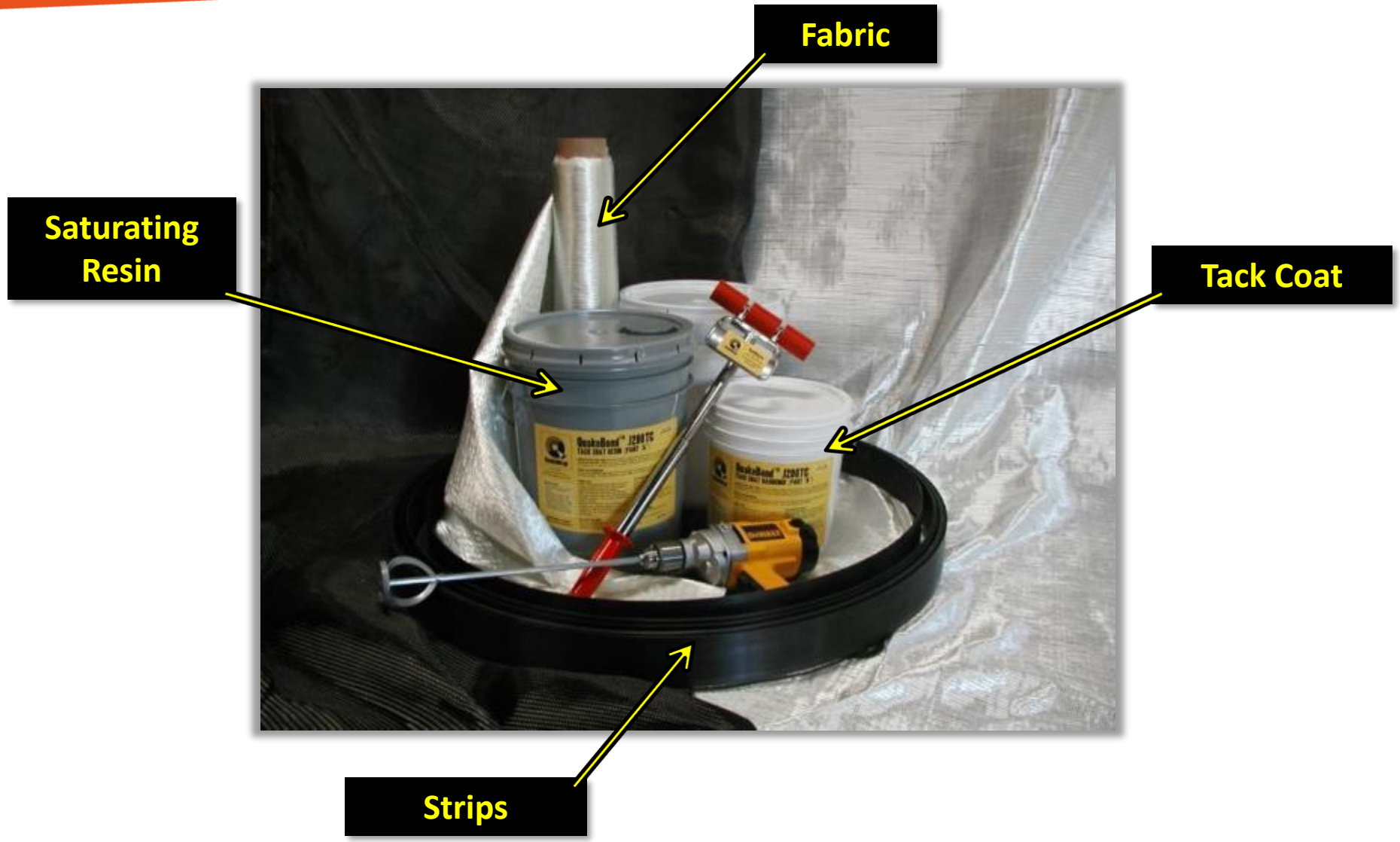
Why is it called FRP?

- A Polymer (i.e. epoxy, vinyl ester, etc.) reinforced with a Fiber (e.g. carbon, glass, etc.)
- FRP does not have the same strength in all directions (*anisotropic)*



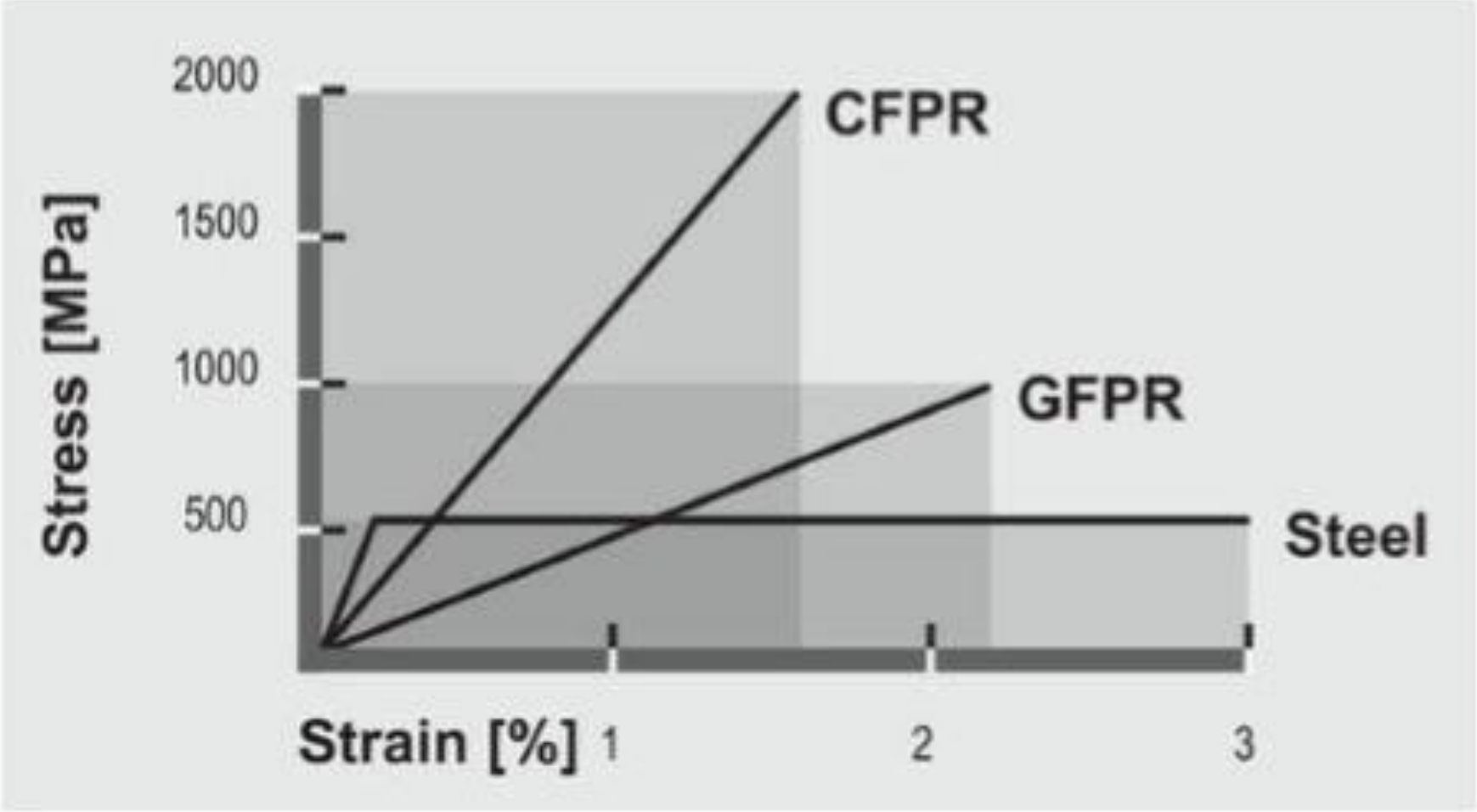
# QuakeWrap® FRP Products





# Comparison of FRP and Steel





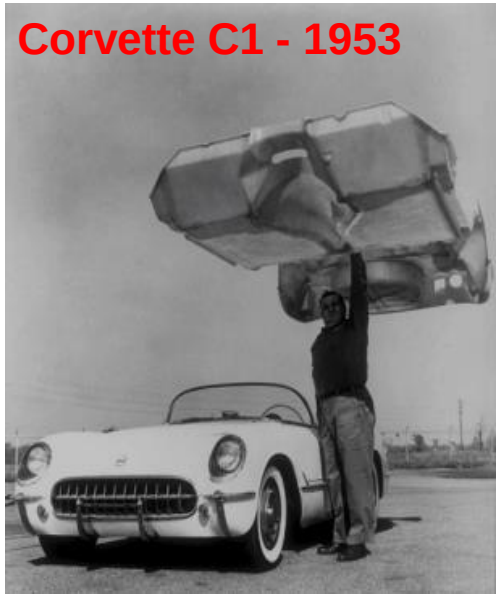
# Advantages of FRP

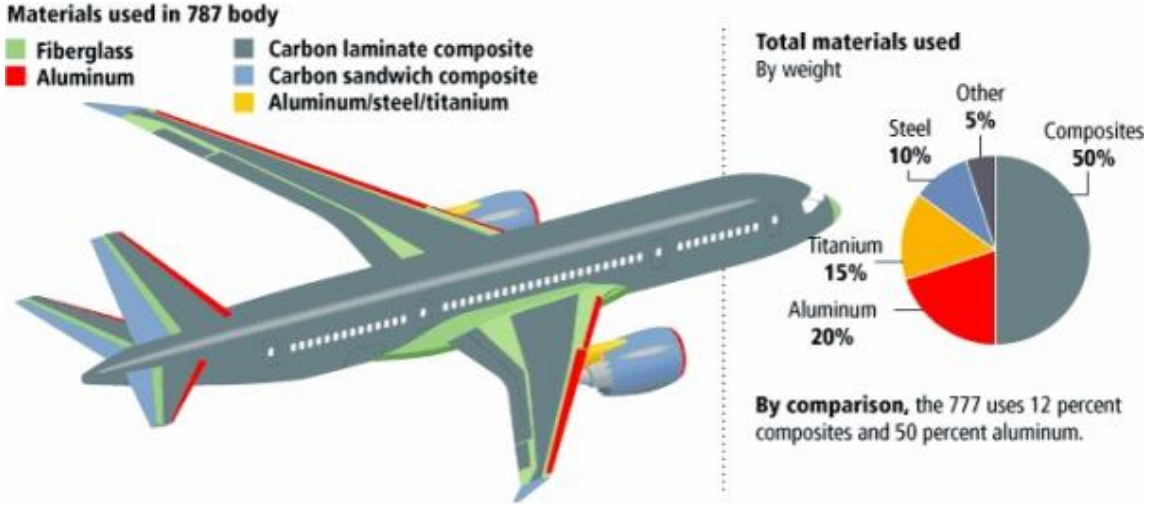


- High Tensile Strength *(3-5 times stronger than Steel)*
- Low Weight *(no foundation adjustments required)*
- Corrosion Resistance & Protection
- Chemical Protection
- Waterproof
- Speed of Construction
- Versatility
- Odorless & Non-Toxic (QuakeWrap Products)
- NSF-61 Certified for pipes ≥ 8 inches
- Minimal Investment

# History of FRP in other Industries







# Original Concept Demonstration (1987)

*Carbon FRP instead of reinforcing steel*



# Loma Prieta Earthquake Oct 1989
# Failure of R/C Columns



# Indiana Bridge

## *Indiana Project R-27862-A – SR 49*



# Sample Projects



Testing + R&D

**Condo, FL**

**Statue of Liberty**

**Bridge, NM**

**Settling Tank, MX**

**UN Lebanon**

**High Rise, AK**

**Pipe, Costa Rica**

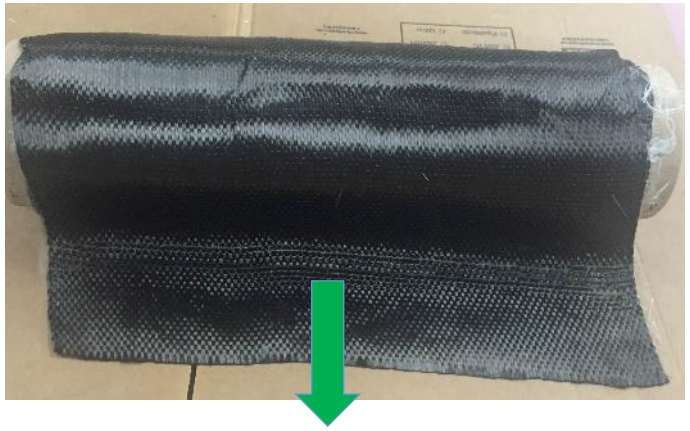
**Kazakhstan**

# Cell Phone Tower Strengthening

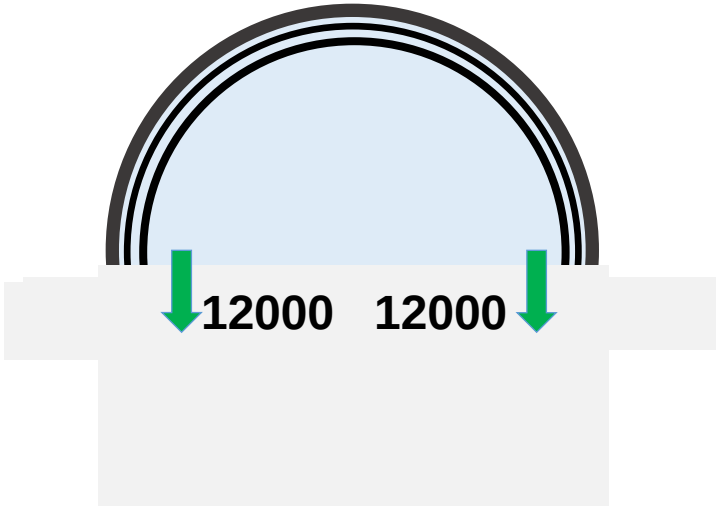


# Design for Internal Pressure





**Carbon Fabric**




**Thickness: 0.05 in. (1.3 mm)**
**Weight: 0.38 lb/ft² (1.83 kg/m²)**
**T = 6000 lb/in. (1050 N/mm)**

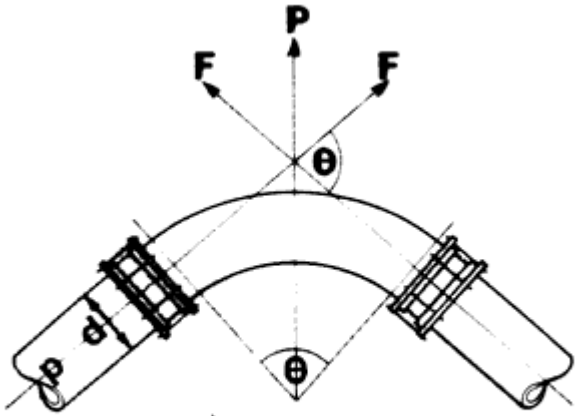
***P = (6,000+6,000)/24 in. = 500 psi (34.5 bar)***

***P = (12,000+12,000)/24 in. = 1,000 psi (69 bar)***

**Note: Little change in weight or thickness**
**Smooth surface reduces friction & improves flow**

# Design for Thrust

- Align the fibers along the length of pipe
- Increase/decrease number of layers based on the thrust magnitude



# Wet Layup Method

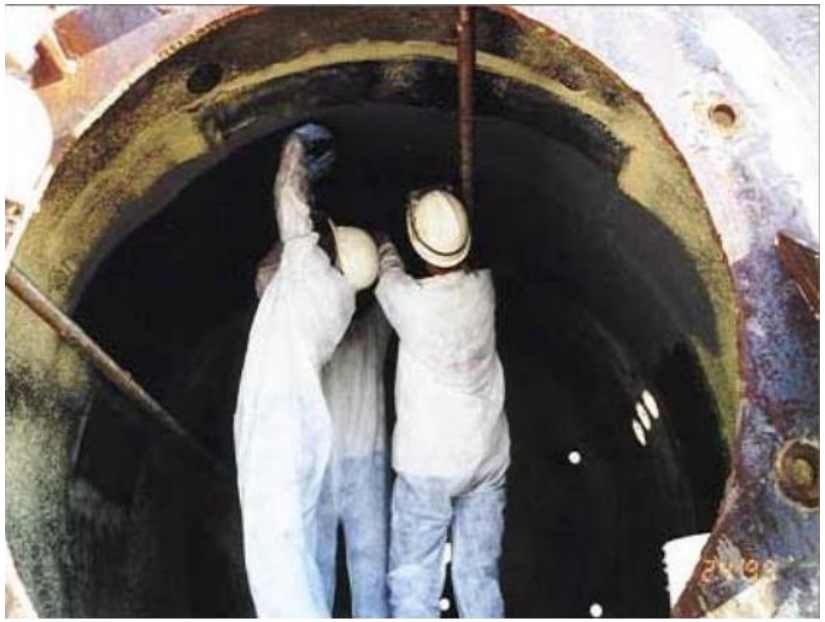


- Carbon fabric saturated with epoxy resin in the field and applied directly to surface of pipe (Externally or Internally)
- Fabric roll width: 24-48 inch (600-1200mm)
- Fabric thickness: 0.05 inch (1.3 mm)
- For diameters 2 inch (50 mm) and larger
- Applied by packer (small dia.) or by hand
- Used for joint/spot repair or full length
- Creates a pressure vessel inside pipe
- Cures in 24 hours in ambient temperature
- Faster cure is possible by heating
- NSF-61 Approved

# Early Applications in 1998



- Paloverde Nuclear Power Plant, AZ
- Prestressed Concrete Cylinder Pipe (PCCP)
- Corrosion of pre-stressing cables
- High design pressures
- Replacement recommended
- CFRP liner installed
- 108 inch (2700mm) Diameter



# Wet Layup Process

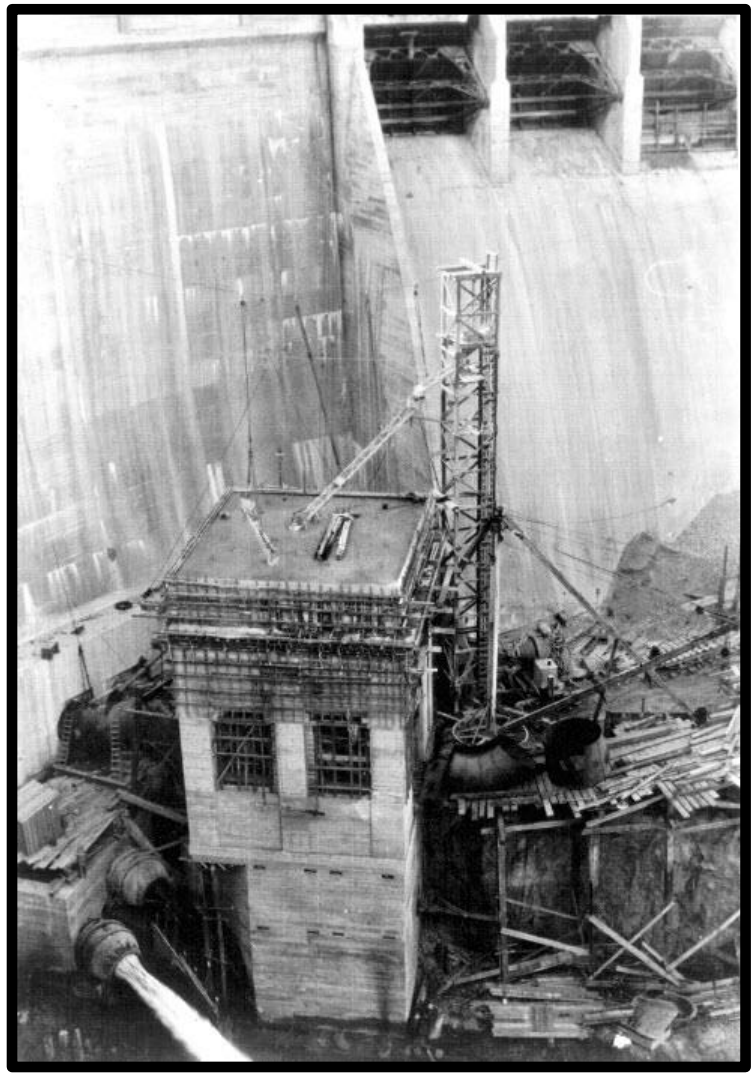


# DC Water – 96-inch (2400 mm) Sewer Repair



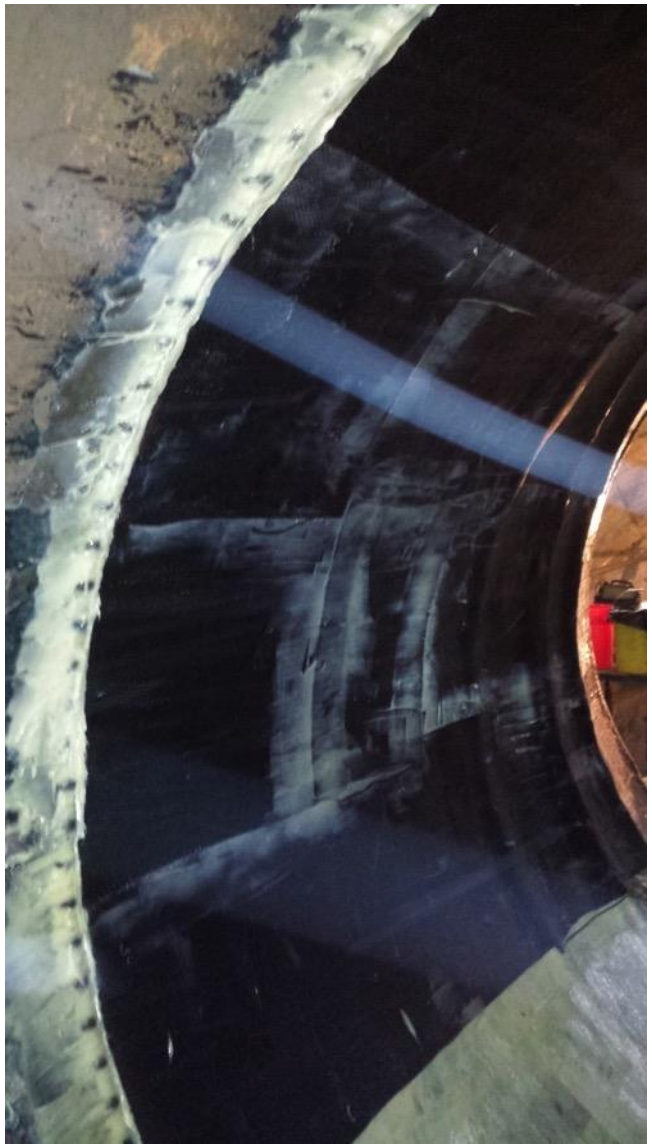
# Salt River Project - Penstock Construction





# Salt River Project – contd.





# El Encanto Hydropower, Costa Rica

*1750m x 2.1m diameter (July 2009)*

**Sloped Terrain**

**Water seeping into pipe**

**Leaks continued after cracks were filled**

# El Encanto Hydropower, Costa Rica

*1.1 miles x 84-inch diameter (July 2009)*



- Four 600x600mm Access Ports
- Poor surface conditions req'd much prep

# El Encanto Hydropower, Costa Rica



- Challenge: Not only strengthen but to leak proof
- Total Time: 3 Weeks
- Successful pressurization tests on July 15, 2009


# Steel Pipes for Hot Air, Carlsbad, CA



- 42-inch (1070 mm) curved steel pipe
- Galvanic corrosion
- Use glass fabric as dielectric barrier


# Tests of Steel Pipes (5-inch Dia.)
# Pertamina Oil Company, Indonesia










# Corroded Steel Pipe in Mine



# Wastewater Facility Pipe Repair
## *City of Atlanta*






# Wastewater facility Pipe Repair
*City of Atlanta* – cont'd



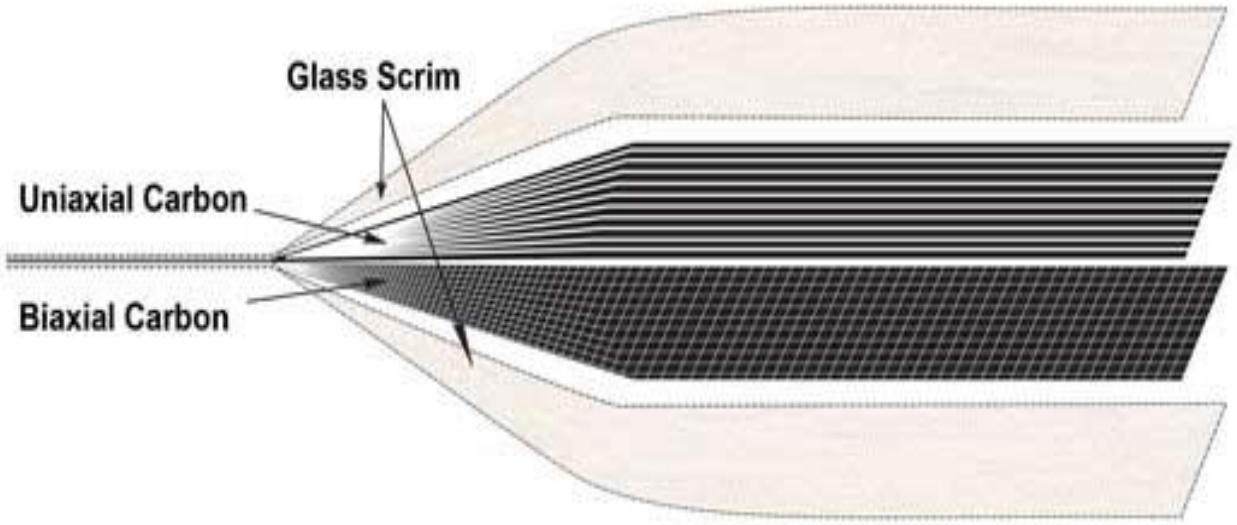
# Quality Control



- Record Lot #
- Adhesion Test (ASTM D7234) (200 psi min.)
- Witness Panel (ASTM D3039); 5 glass and 5 carbon FRP coupons

# Multi-Layered SuperLaminate™ *(Patent Pending)*

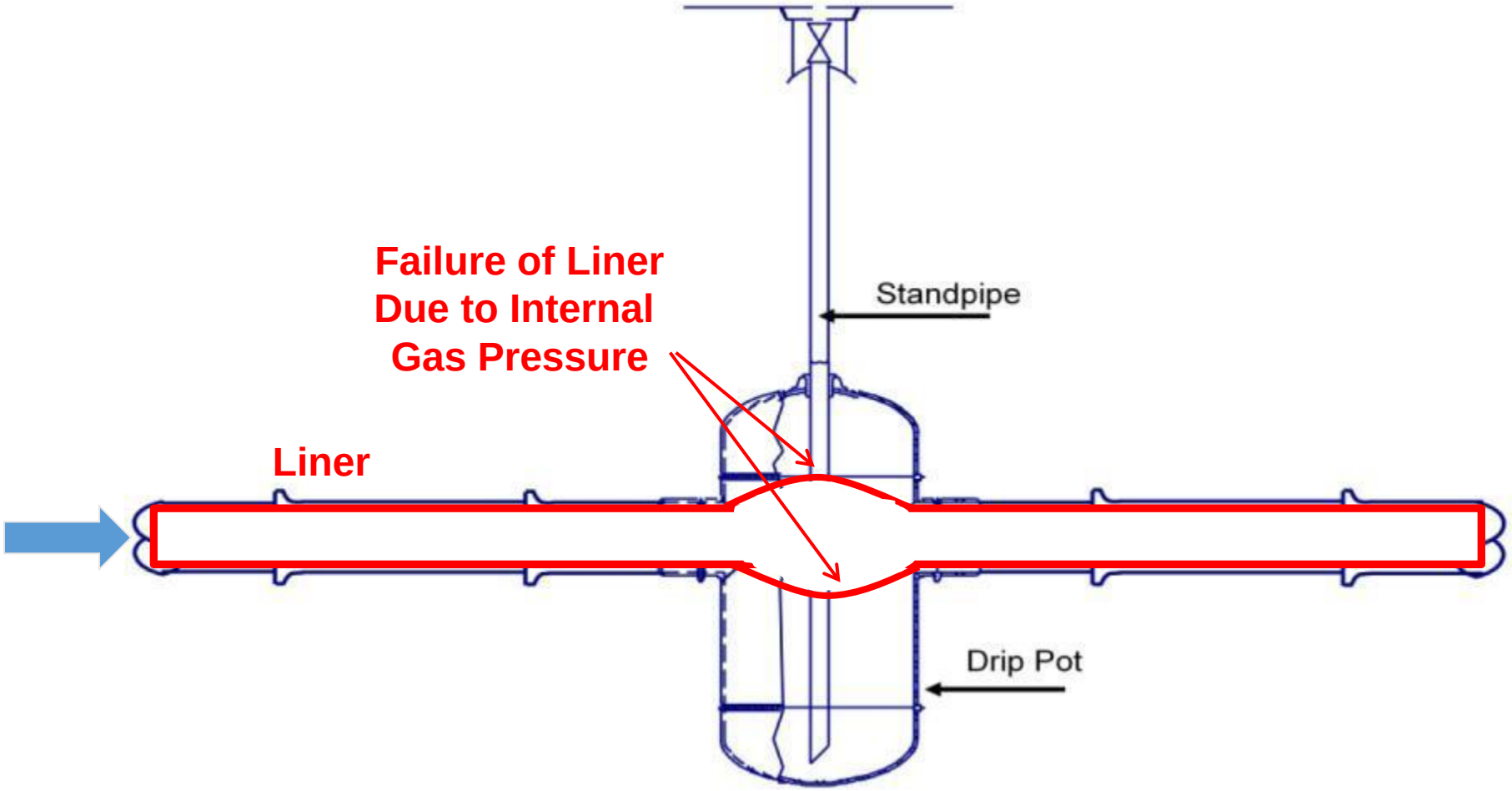





- **Multi-Axial Reinforcement**
- **Thickness ≈ 0.01 -0.025 inch (0.25-0.67mm)**
- **Tensile Strength ≈ up to 155,000 psi (1030 MPa)**
- **Infinite combinations of strength & stiffness can be produced**
- **ISO 9000 Certified**

# Bridging a Gap in a Pipeline
*(Gas Technology Institute)*






**How do we create a pressurized pipe?**

# Bridging a Gap in a Pipeline

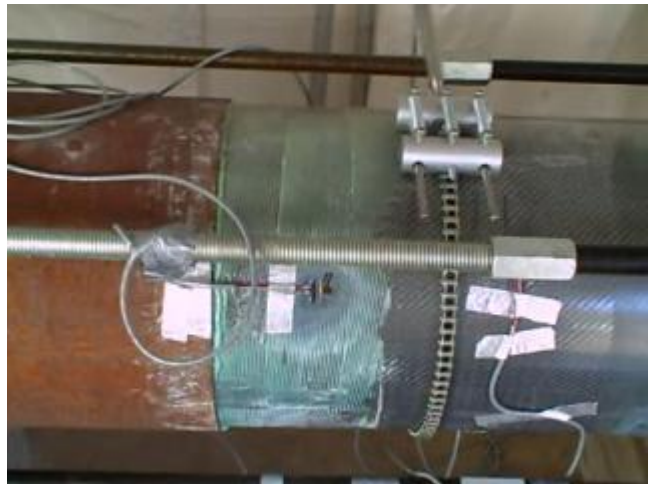
*(600mm Long Gap in 400mm Diam. Pipe)*

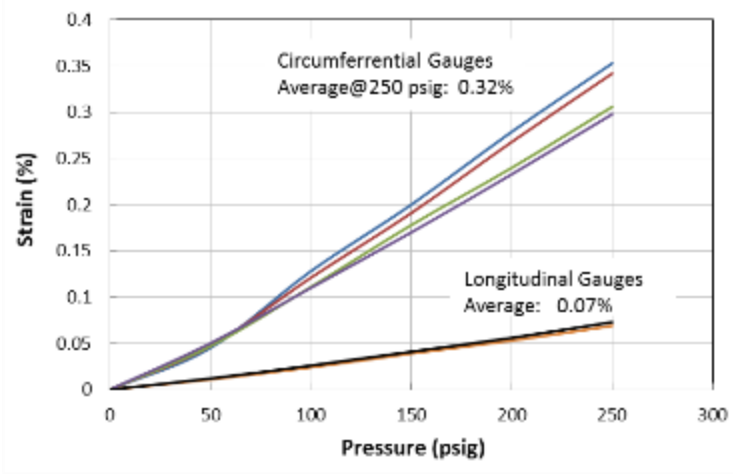


# Pressure Testing

*on October 16, 2010*

- Gas Technology Institute
- Max Operating Pressure = 60 psi (4.1bar)
- Tested to 250 psi (17.2 bar)
- Ultimate Capacity = 900 psi (62 bar)





# Field Application



- First Project was completed in Feb 2011
- Client: PSE&G (NJ Gas Utility)
- Contractor: Progressive Pipeline Management
- 2-ft gap in 16” cast-iron pipe
- Winner of 2011 Trenchless Technology *Project of the Year Award*

- Over 60 similar applications

# EPA SBIR Grant

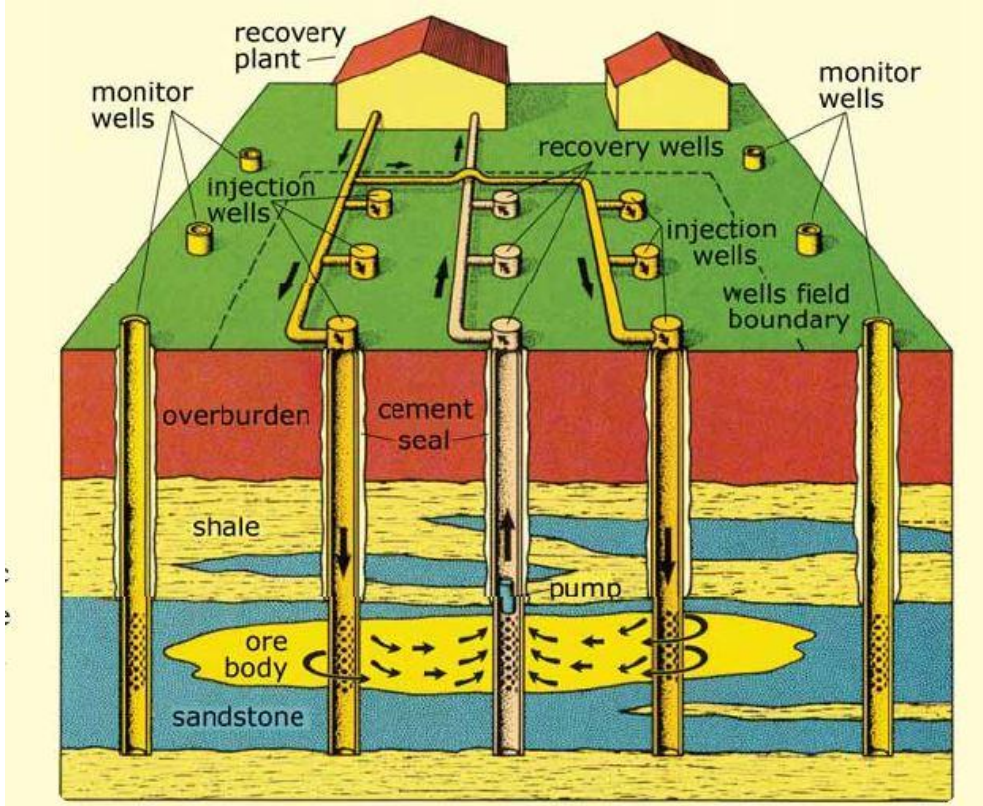


- Trenchless Water Main Point Repairs with SuperLaminate
- Phase I Grant -- $100,000
- May – Oct 2019

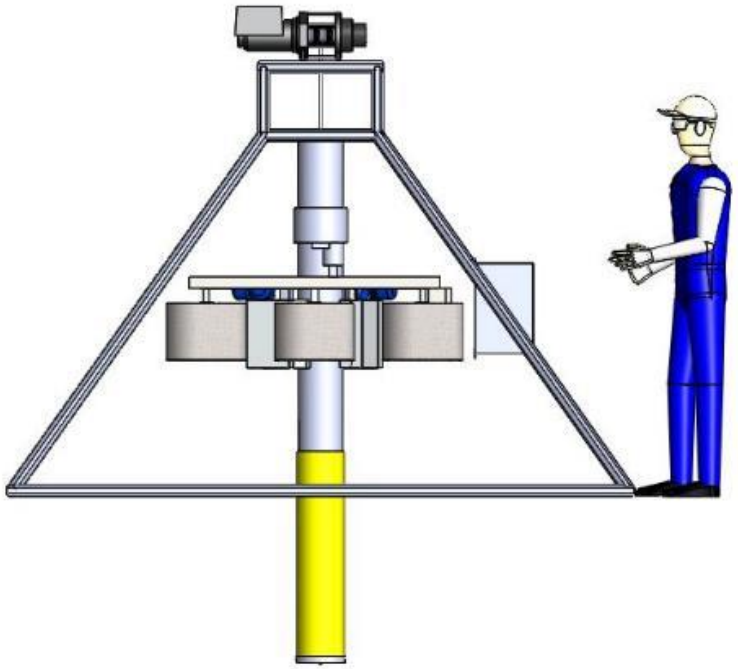
# USDA Grant for InfinitPipe®



- Phase II Grant -- $625,000
- Sept 2019 – Aug 2021



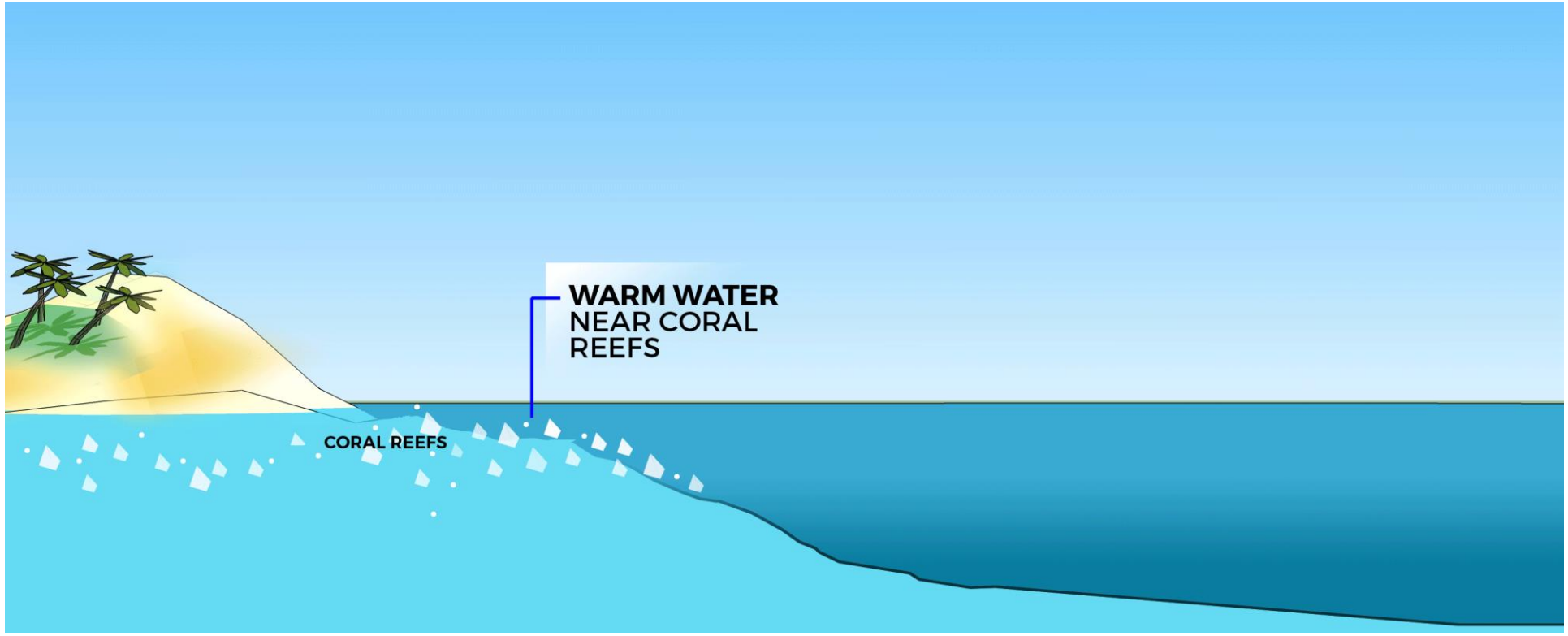

*Schematic of the in-situ mining process.*



# Bleaching of Great Barrier Reef



- **Reef lost 50% of its coral cover from 1985-2012**
  ***(Australian Inst. of Marine Science)***



# Grazie!



## Questions?

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