

Fitness for Service of FRP & Composite Assets



Agenda

- Introduce UTComp, Inc.
- Composite Materials
- Damage Mechanisms
- Composite FFS & Assessment
- Experience



Composite Asset Intelligence™

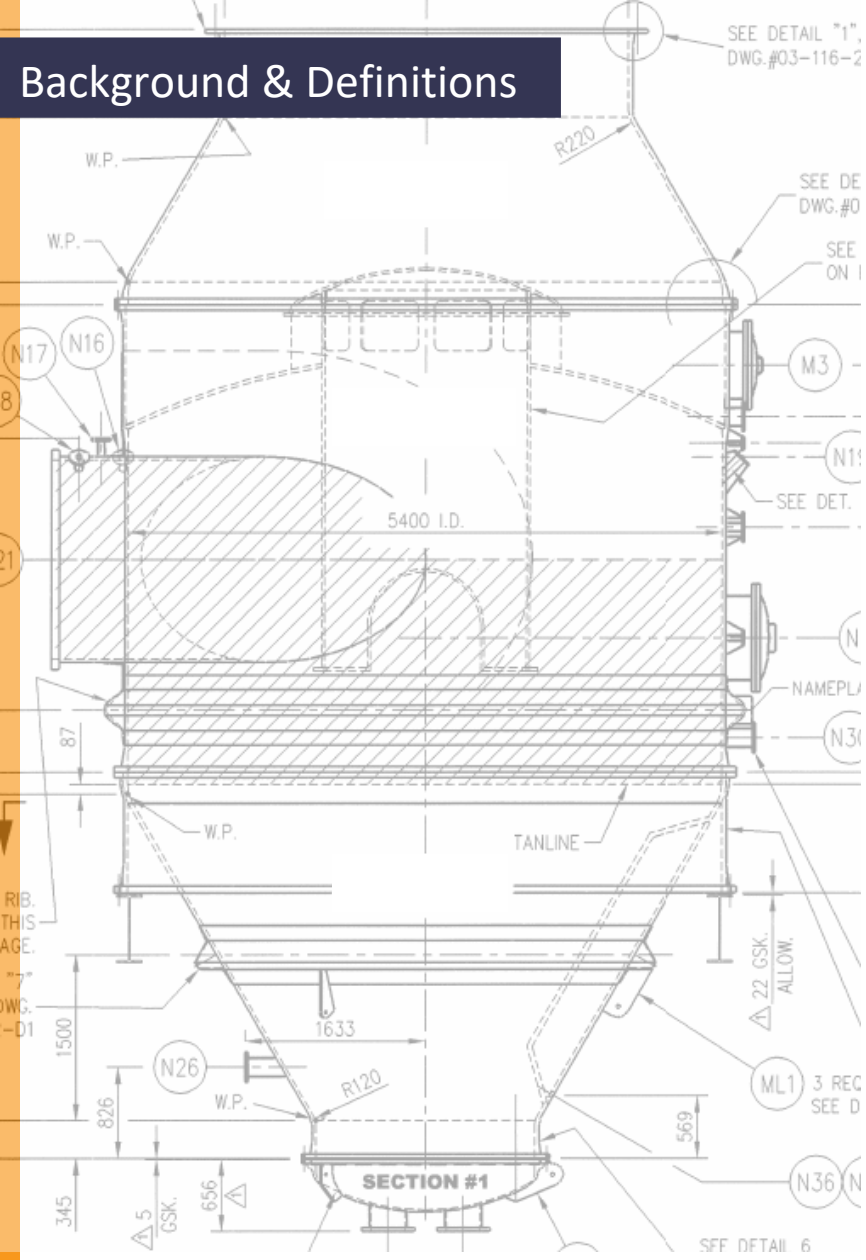
UTComp Inc.

- Polymer composite engineering & assessment
 - Infrastructure
 - Energy
 - Industrial
- Globally positioned
 - HQ in Cambridge. ON
 - Licensees: Africa, North America, Europe, Australia, SEA
 - Has empowered at least 75 people around the world for global delivery with local teams.



Composite Asset Intelligence™

Composite Materials



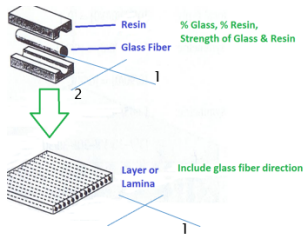
Standards and Codes

- 70+ years of FRP experience
- Recent search:
 - 211 → Design & Construction
 - 1 → Visual Inspection
 - 0 → FFS



Construction Codes

- Allowable stress design or hydrostatic design basis.
- Qualification test required for each configuration.
- Use calculations similar to isotropic materials.
- Often no longer apply after commissioning.

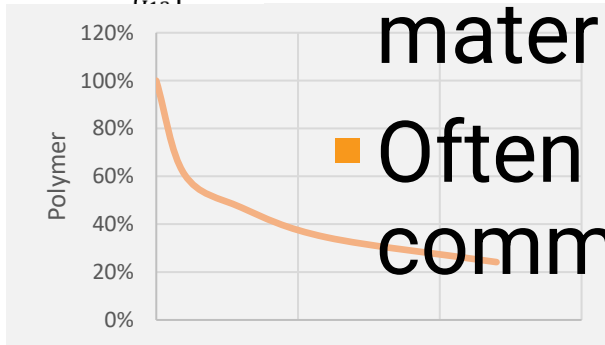


▶ $E_1 = V_m E_m + V_f E_f$

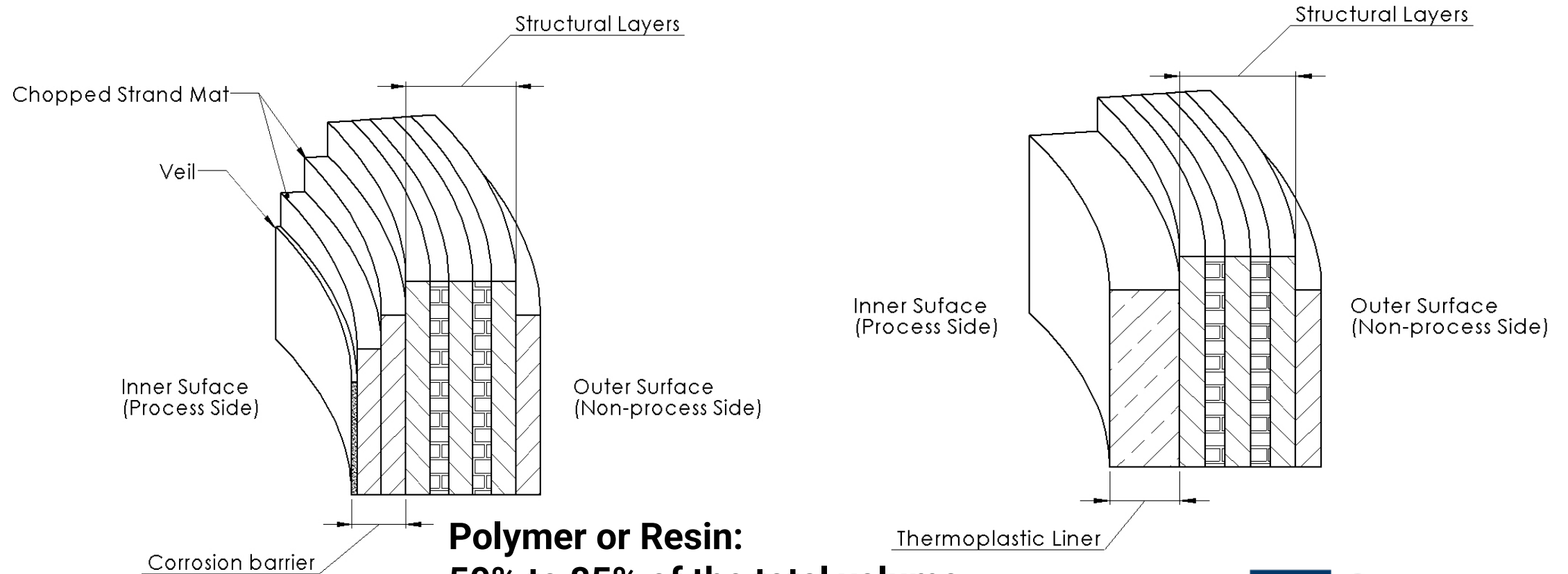
▶ $E_2 = V_m E_m$

▶ Stress-strain for each layer:

$$\begin{bmatrix} \epsilon_{11} \\ \epsilon_{22} \\ 2\epsilon_{12} \end{bmatrix} = \begin{bmatrix} \frac{1}{E_1} & -\nu_{12} & 0 \\ -\nu_{12} & \frac{1}{E_2} & 0 \\ 0 & 0 & \frac{1}{G_{12}} \end{bmatrix} \begin{bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{12} \end{bmatrix}$$



Proven Construction for Reliability



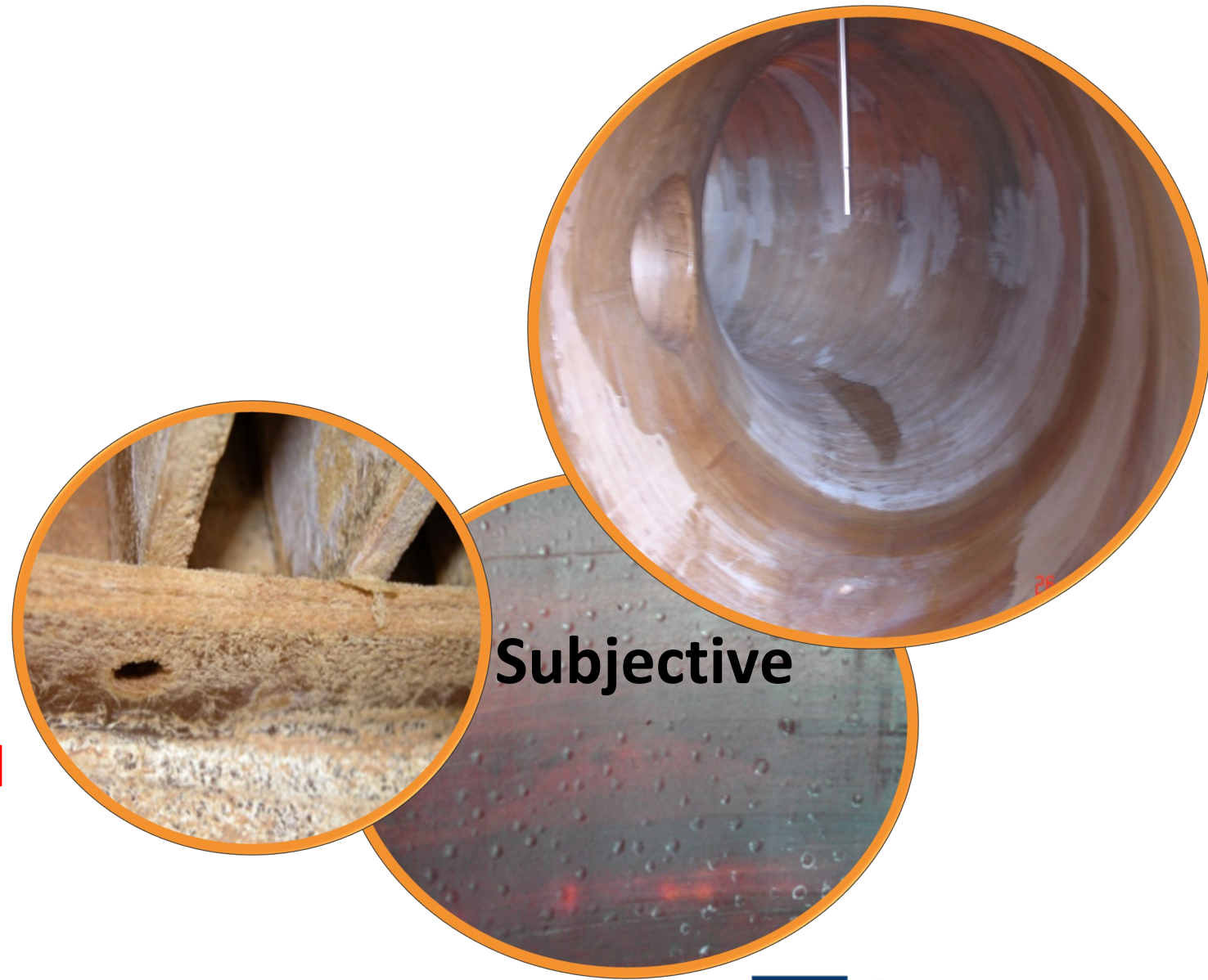
Polymer or Resin:
50% to 85% of the total volume
Provides 100% of corrosion resistance



Conventional FRP Inspection

Intrusive Visual Internal Inspection

- Confined Space Entry Required
- Shutdown Required
- NBIC Supplement.



Fitness for Service (FFS)

- Able to operate as intended by its design:
 - Loads
 - Pressure
 - Temperature
 - Contents
 - Environment
- Only valid when derived from objective engineering criteria.

What About API?

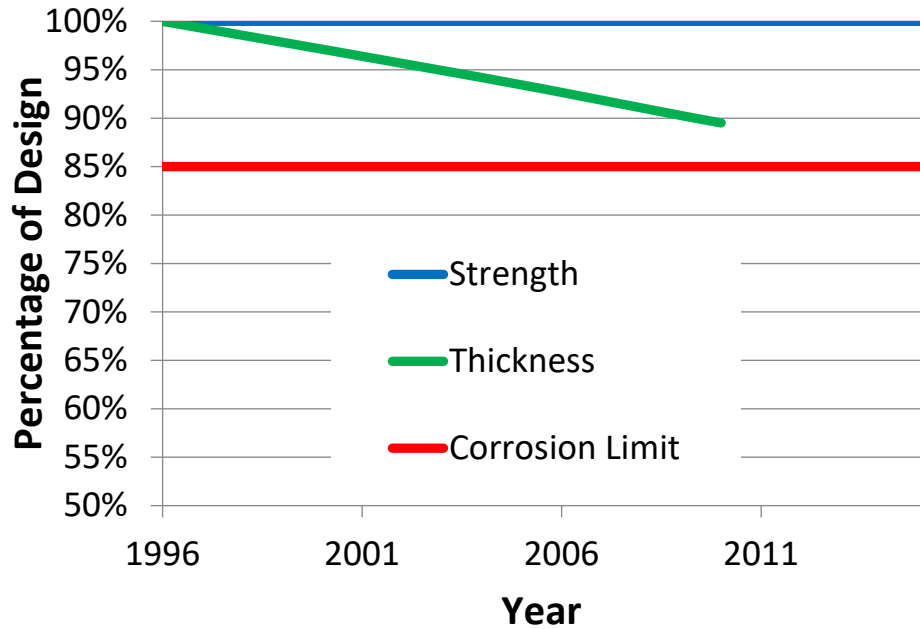
- Good principles and some can be used in assessment.
- API 570 – Piping – Refers reader to API 574
- API 574 – Covers Pre-commissioning inspection and nothing after. “Install and forget”

Nothing for tankage or vessels. Nothing in API 579.



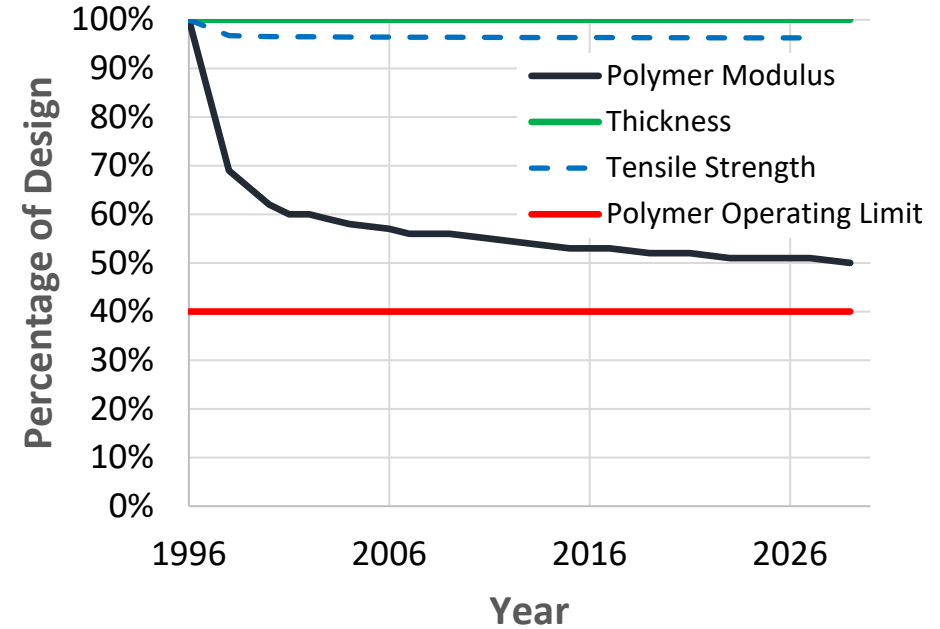
Damage Mechanisms

Steel



Thickness is part of the design and on the drawings.
Nameplate includes thickness and corrosion allowance.

FRP & Polymers



Resin and polymer condition limits the life.
Damage indicators are not used in the design nor on the drawings or nameplate.
Occurs with OR without corrosion

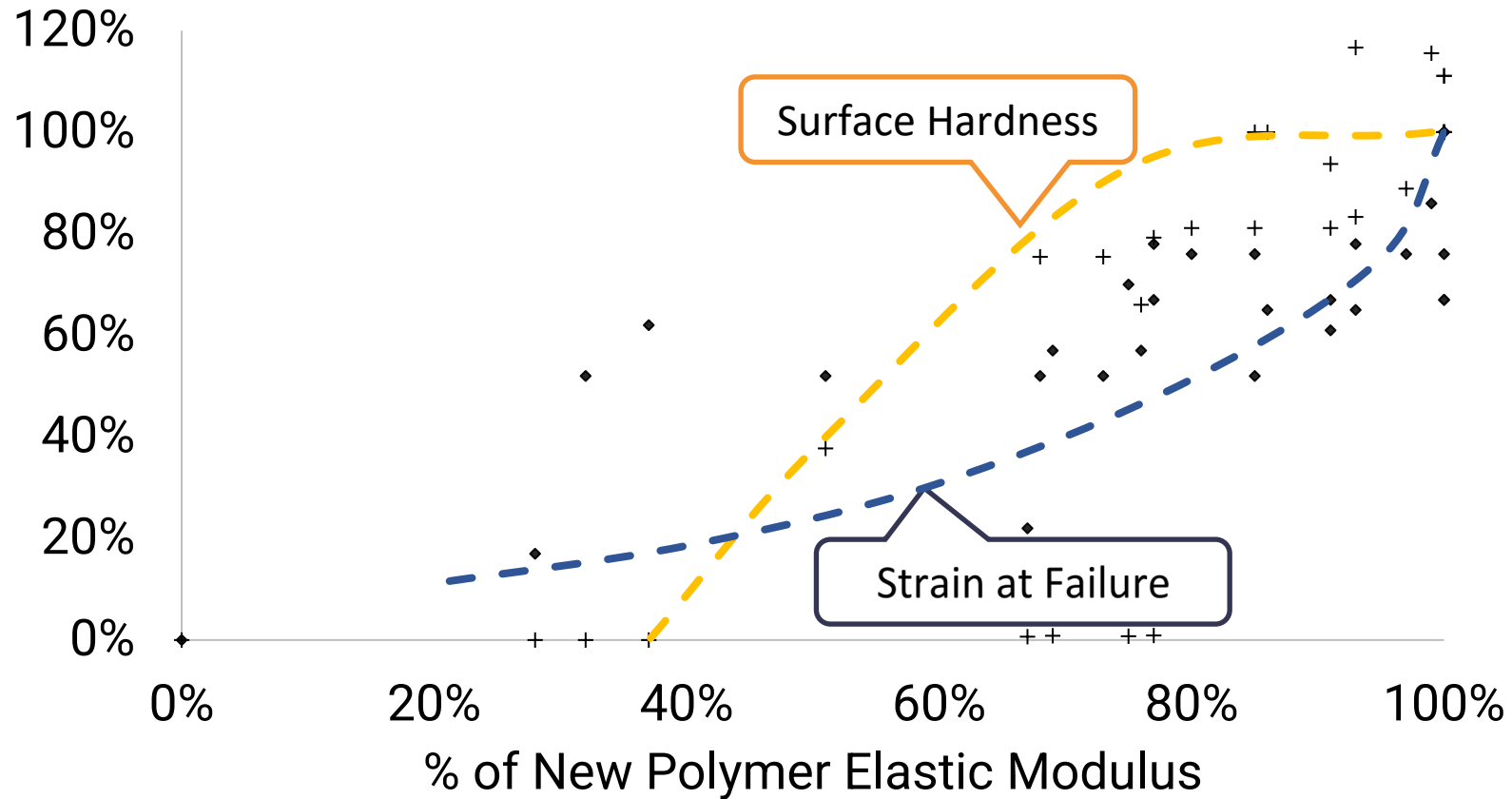
Role of Polymer & Resin

“the polymer matrix is the major constituent contributing to degradation or changes in durability of ...composites”

T. Gates, NASA

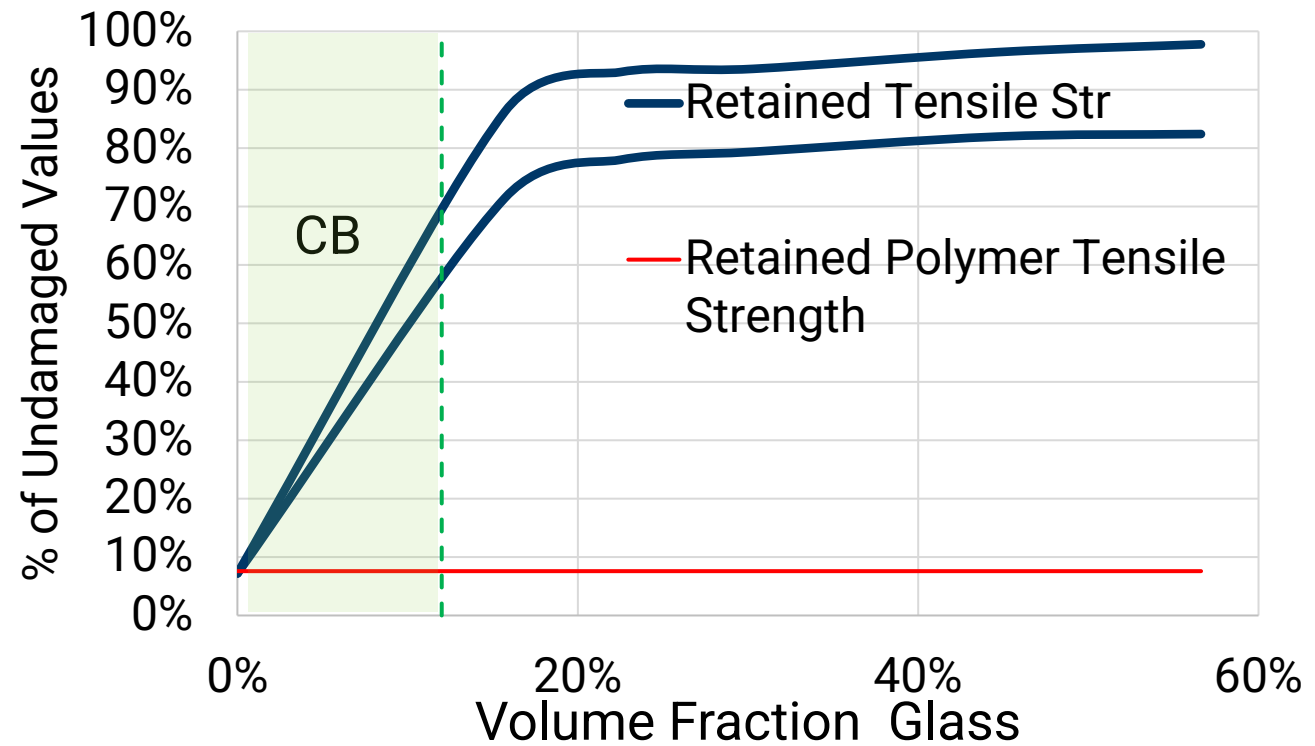
Polymer is 50% to 95% of the volume of composites.

Polymer Damage

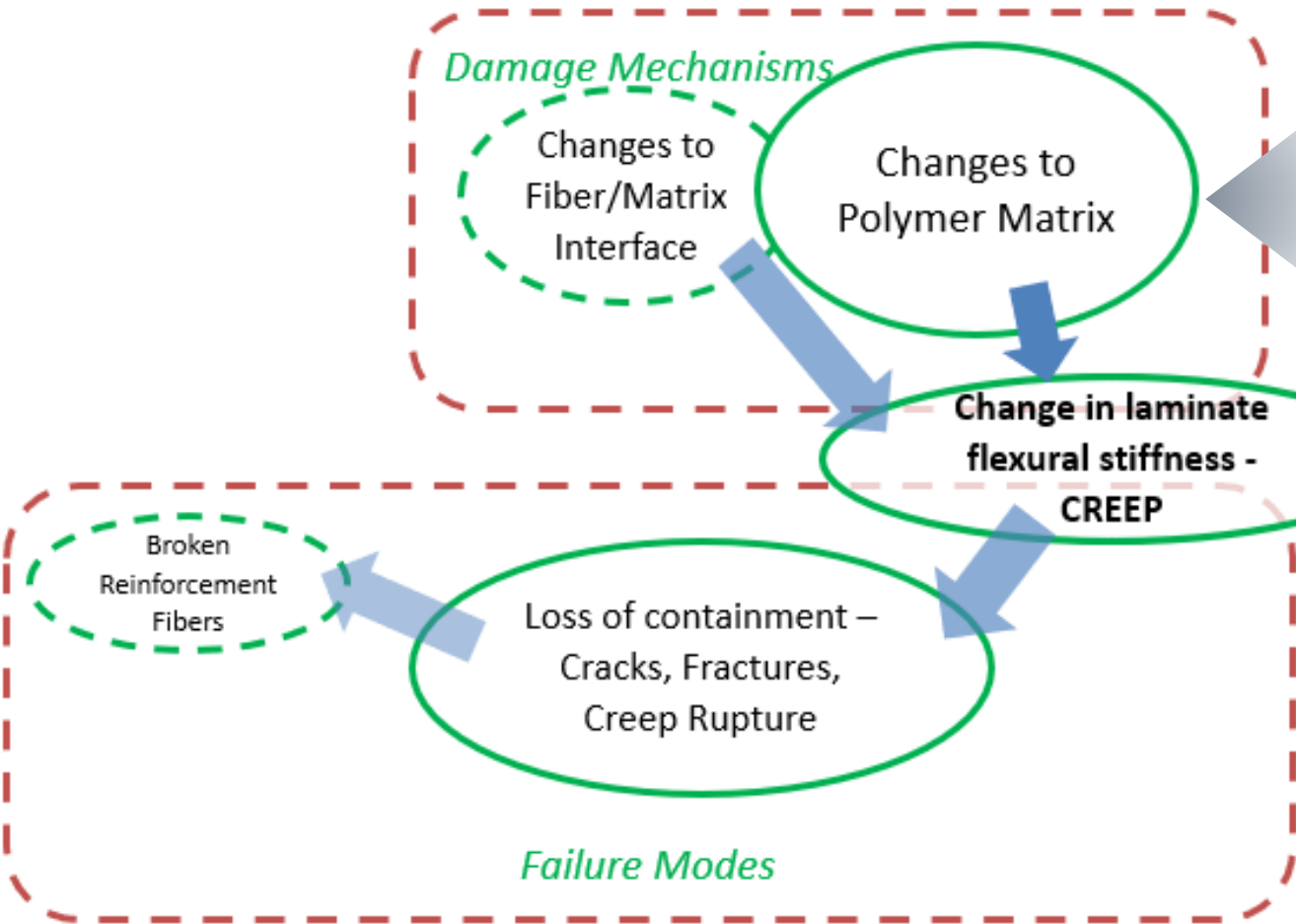


Retention of Code Properties

- Tensile is dominated by reinforcement.
- Bending is most sensitive to polymer or resin
- Damage to reinforcement follows damage to polymer



Damage & Failure



Contributions from: Curing, chemical attack, voids & porosity, stress, foreign substances

Used for Manufacturer Corrosion Resin Recommendations: ASTM C581

CREEP is the Dominant Failure Path



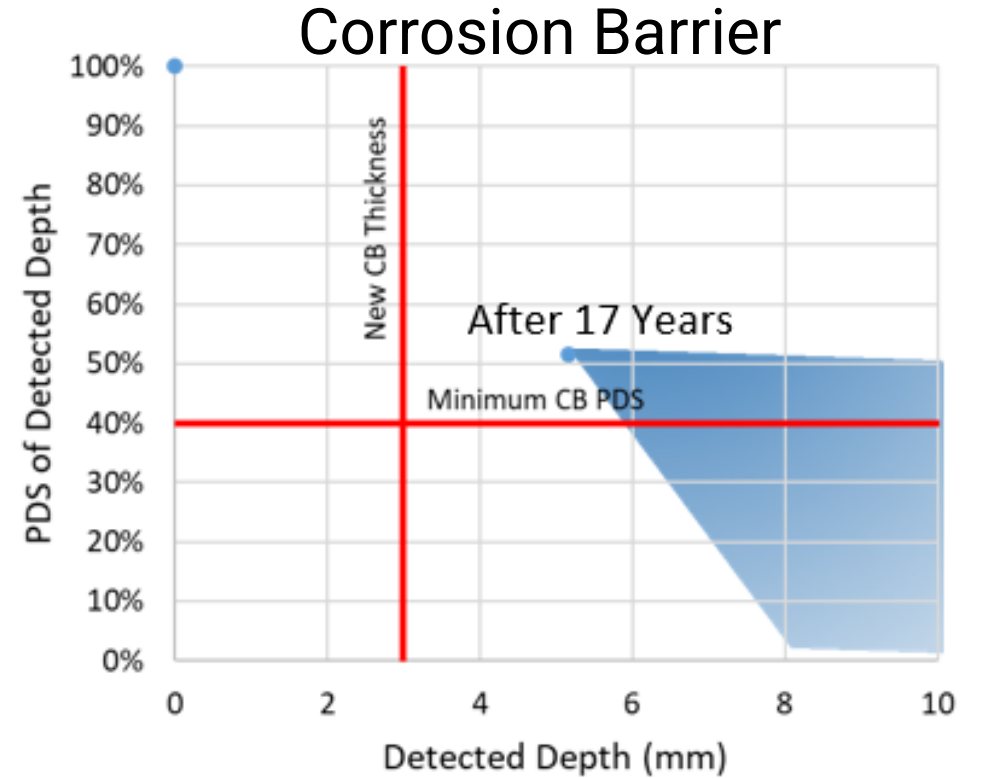
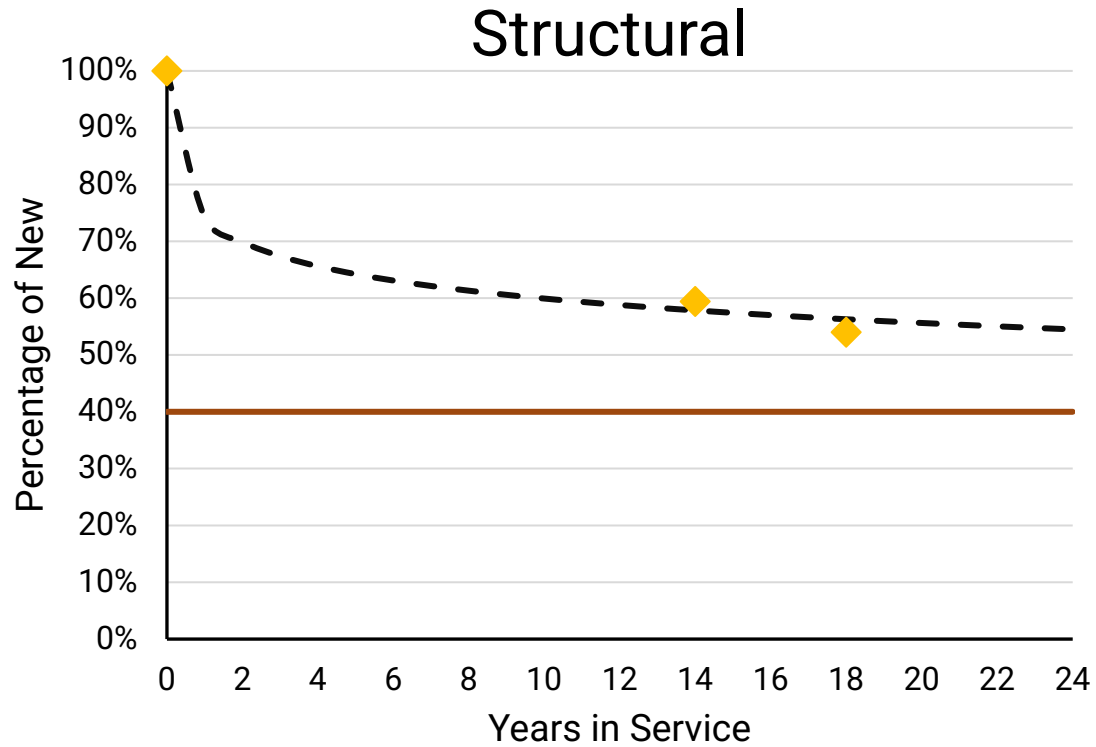
Criteria?

- No relevance to Construction Codes.
- No relevance to API Standards & Codes

- Empirical Data shows:

End of Service Life when the polymer elastic modulus is 40% to 50% of new value.

Full Thickness & Corrosion Barrier



Composite FFS and Assessment

Fitness for Service.....

...requires non-destructive methods that can verify structural properties from polymer damage.

For composites this requires determining:

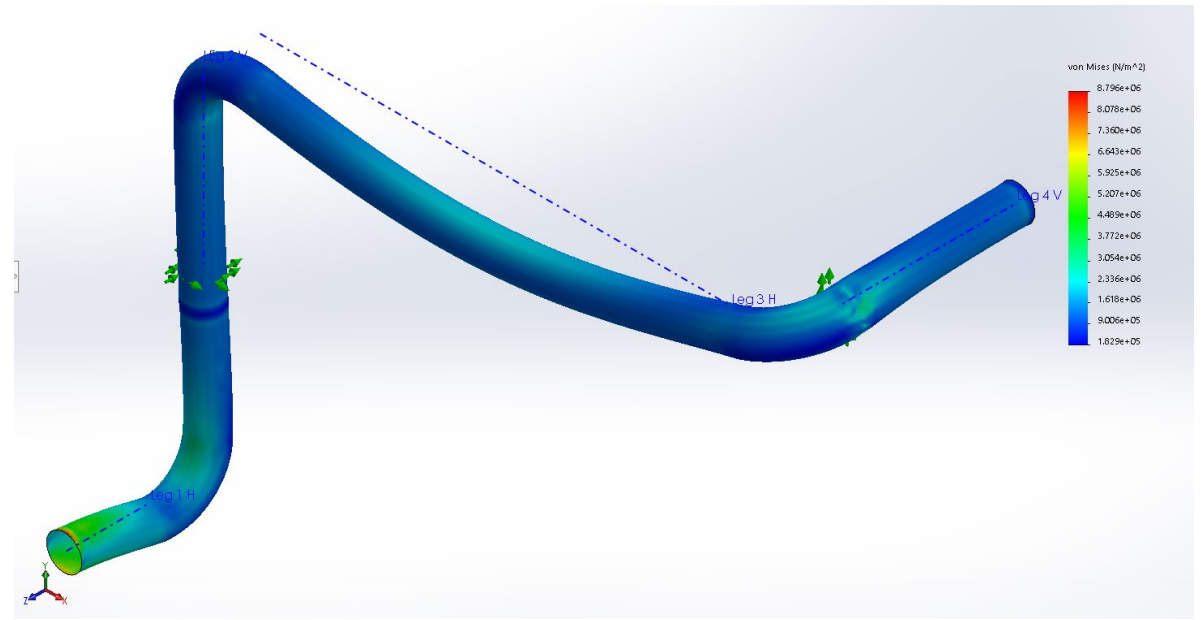
- Polymer damage
 - Elasticity reduction
 - Loss of volume or thickness
 - Extent of chemical damage

History of Ultrasound with Composites

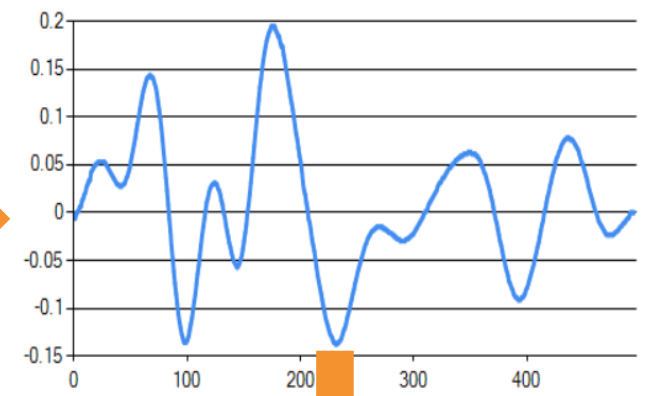
- 1960's – Investigations into use of ultrasound to find defects – just like for steel
- Work by NASA: Ultrasonic results correlate with polymer elastic modulus
- Thickness measurement is common
- Defect or anomaly detection is common in aerospace

Application

- All FRP structures:
 - Piping
 - Vessels and Tanks
 - Wind Turbine Blades
 - Others...



UltraAnalytix® – In Field

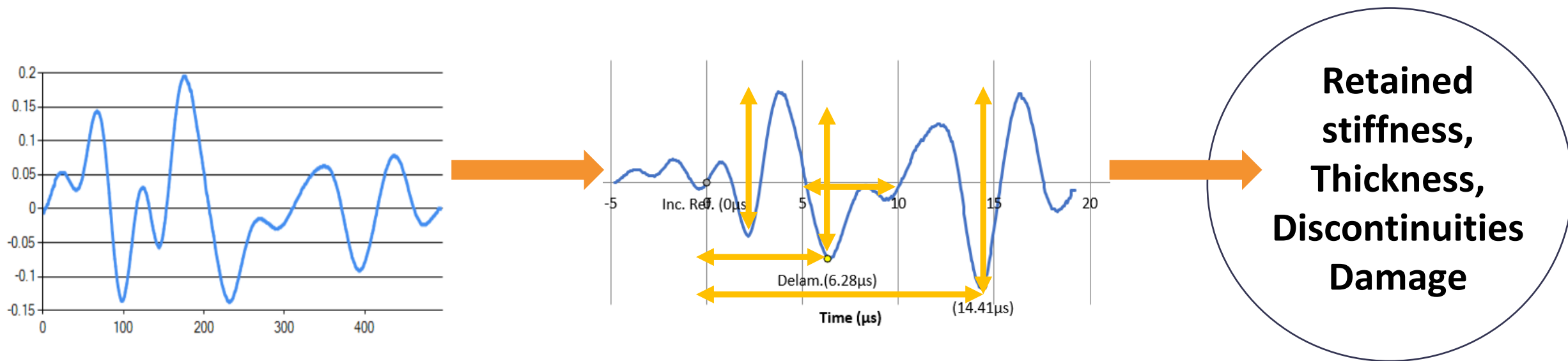


Data Analysis is post-processed and completed remotely

- Standard Procedure
- Non Destructive Ultrasonic
- Non Intrusive
- Complies with ASNT SNT-TC-1A



UltraAnalytix®- Analysis

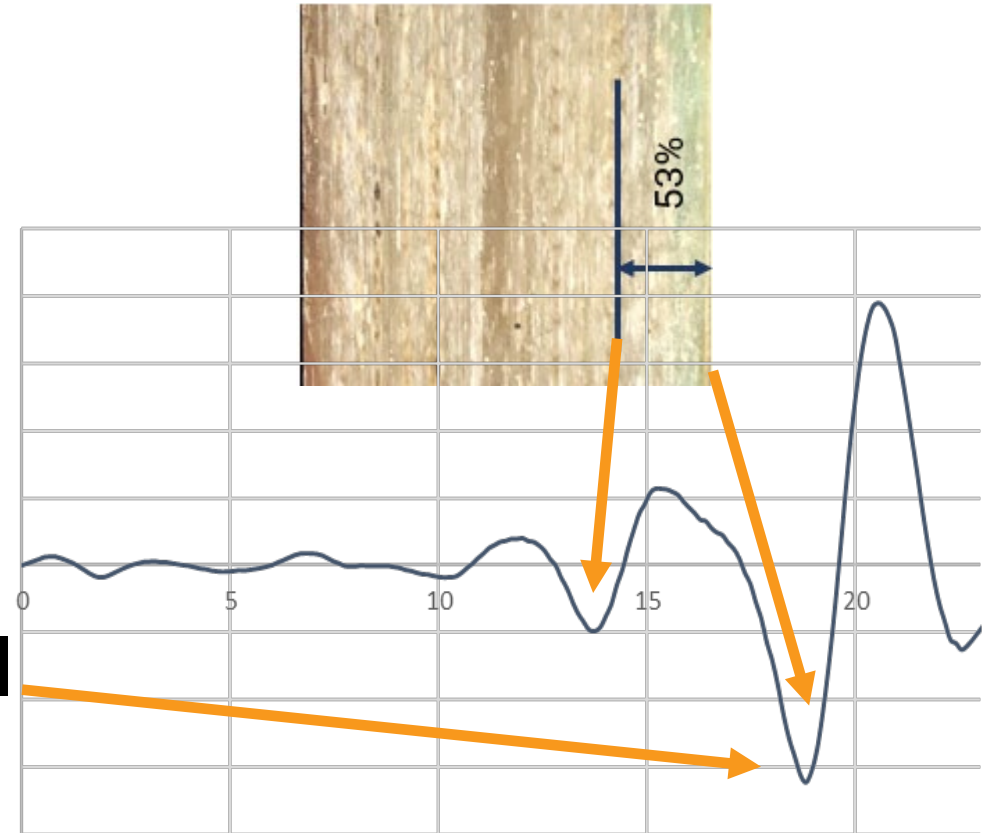


- Damage to the corrosion barrier is isolated at this stage.

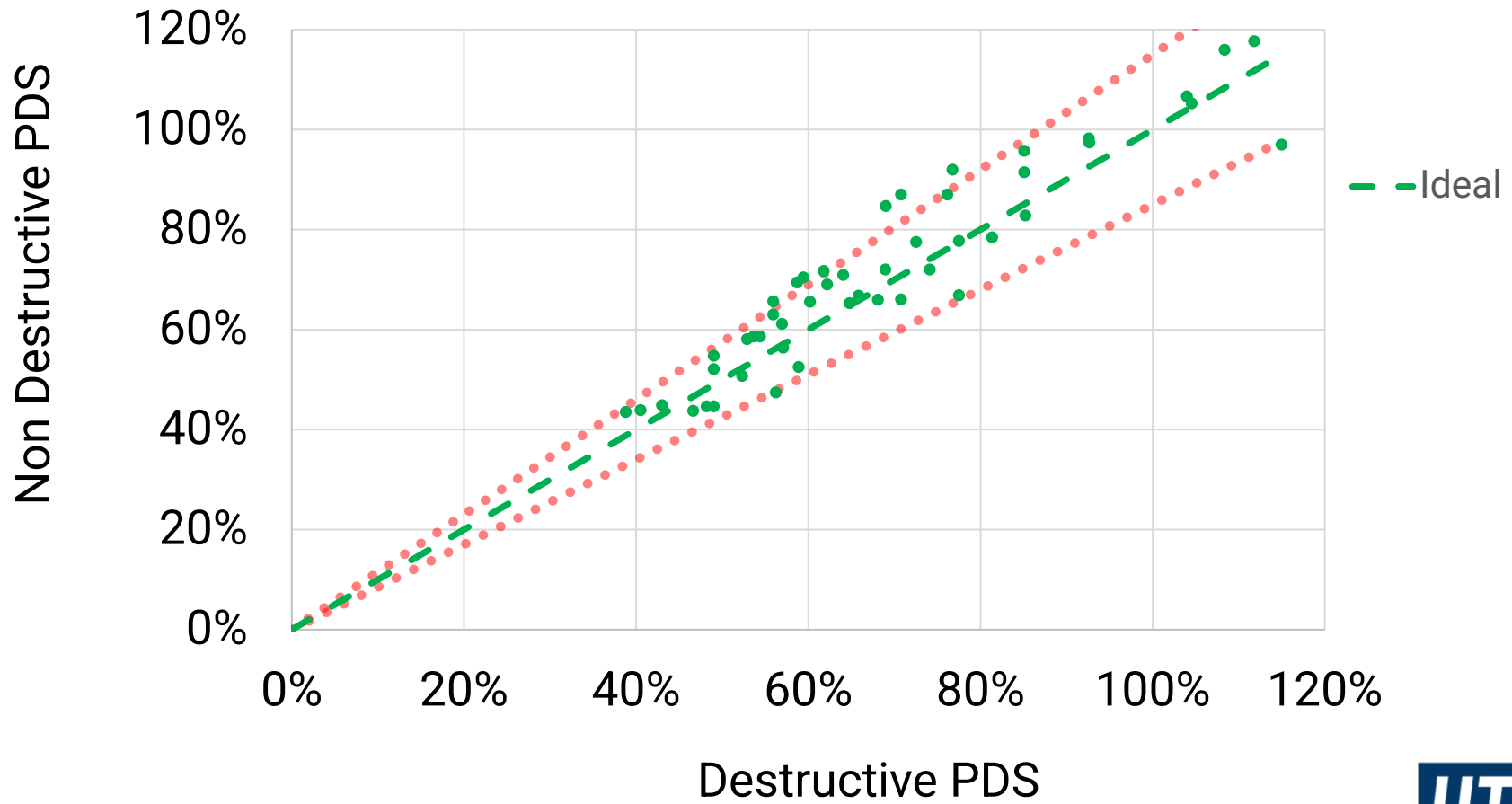


UltraAnalytix®- Analysis

- From the same reading:
 - Corrosion Barrier condition assessment
 - Polymer condition for the full thickness
- Patent pending



Comparison to destructive testing



Other Items

- End of Service Life and Remaining Service Life are independent of any Construction Code.
- Assessment can be done on FRP or polymers of any age in any service.
- Risks created by features of the installation and use can force End Of Life criteria change.

Limitations

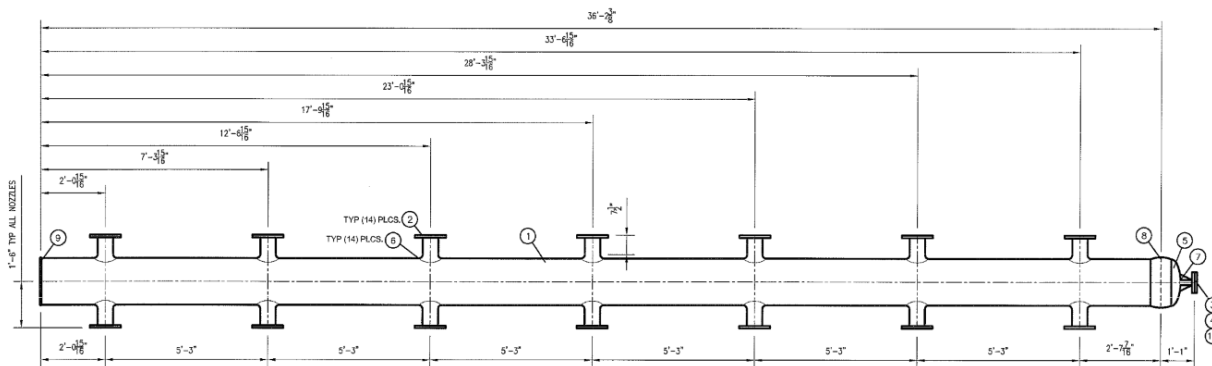
- ▶ Operates best at temperatures $>50^{\circ}\text{F}$ or 10°C
- ▶ Excess porosity in the resin can suppress PDS
- ▶ Does not “see” through foam or thick balsa
- ▶ Equipment does not work in high magnetic fields
- ▶ Must have contact with surface



Experience

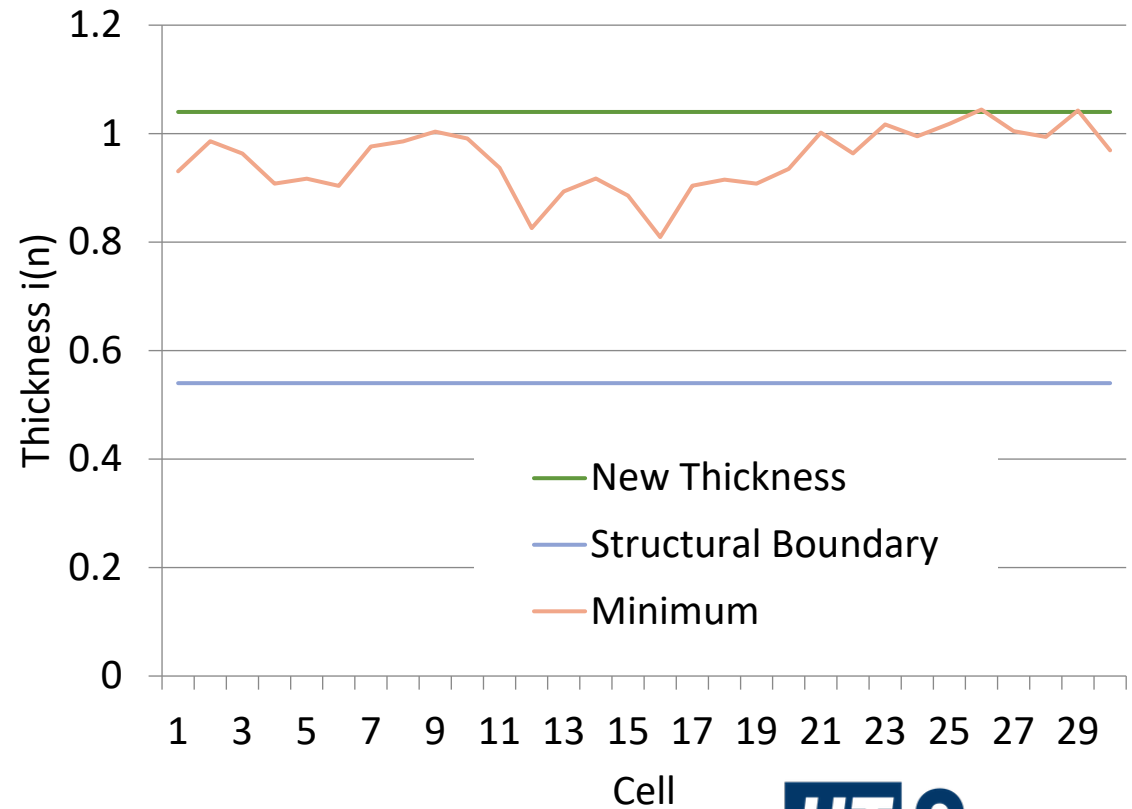
Chlorine Collectors Thickness

- New Headers in 2008.
- Design Thickness: 1.04" Nom.
 - 0.5" Sacrificial Corrosion Barrier
 - 0.54" Structural
- Owner is concerned about current status



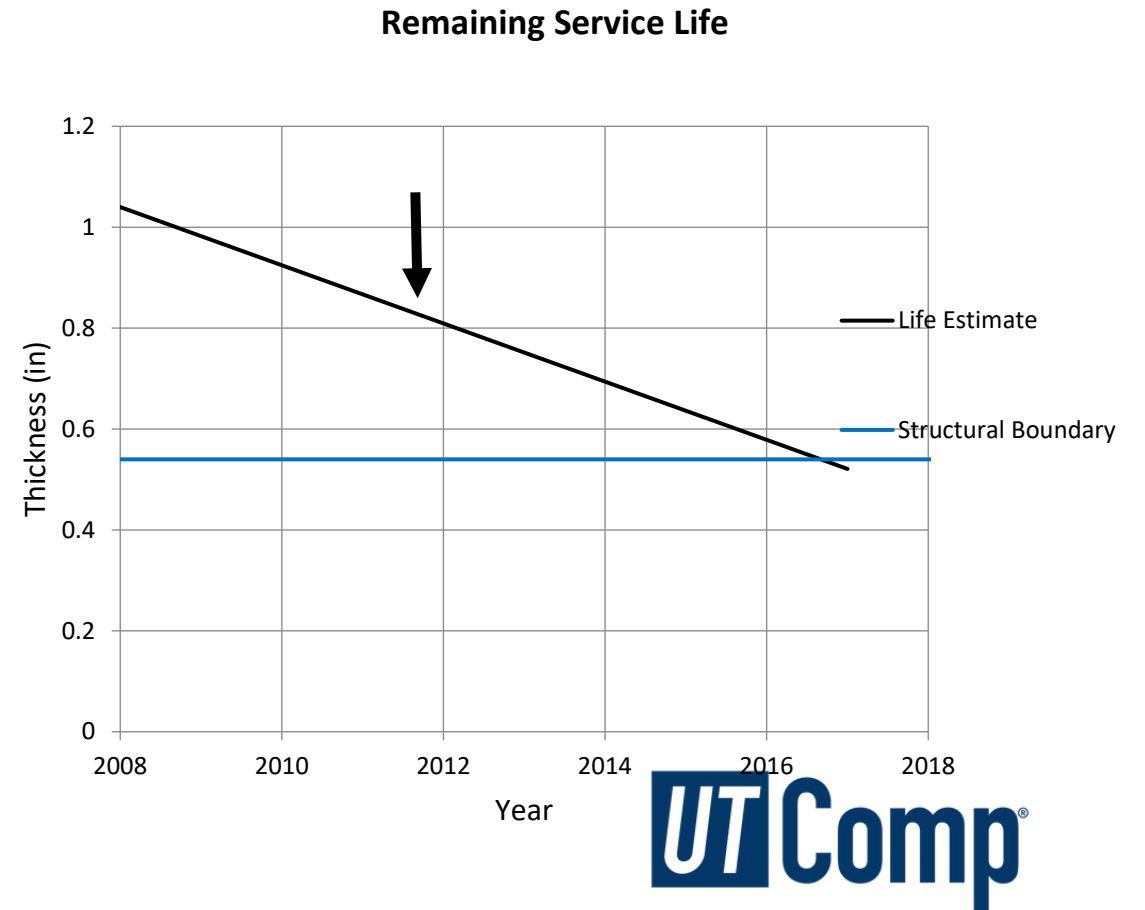
Chlorine Collectors Thickness

- Thickness survey for material loss



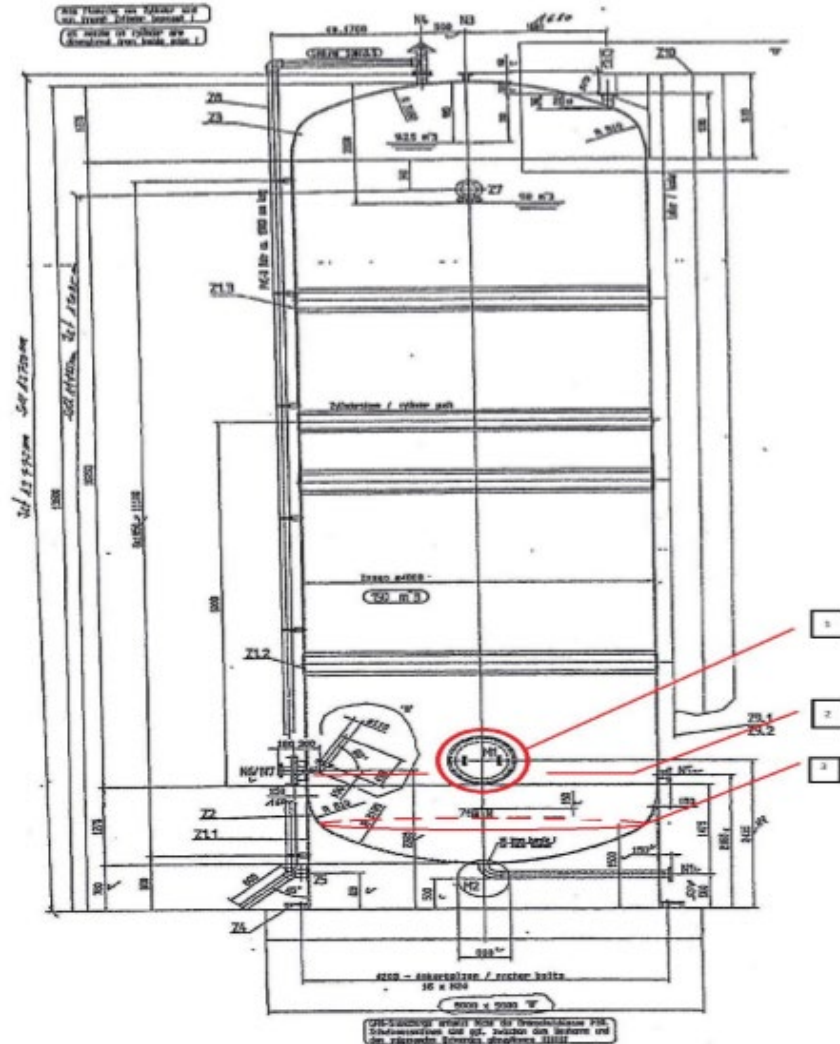
Chlorine Collectors Thickness

- “How soon do we need to replace?”



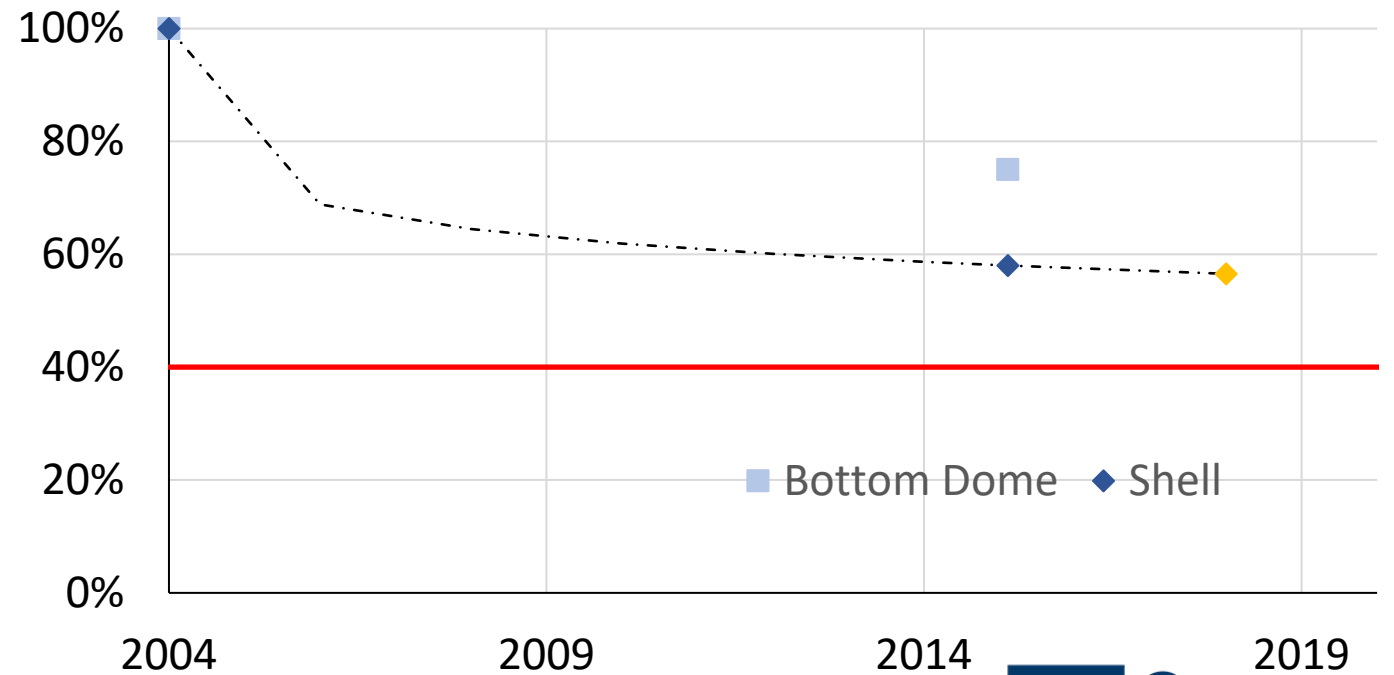
Hypo Tower with PVC Corrosion Barrier

- Inspection



Hypo Tower with PVC Corrosion Barrier

- Results:
 - No defects in PVC-FRP bonds
 - Fit for Service
 - Re-inspect in 2018



Notes on Dual Laminates

- Best place to take readings is at thermoplastic welds.
- Weld map is available from some manufacturers.
- Some thermoplastics provide conservative results due to diffusion, absorption and attack.



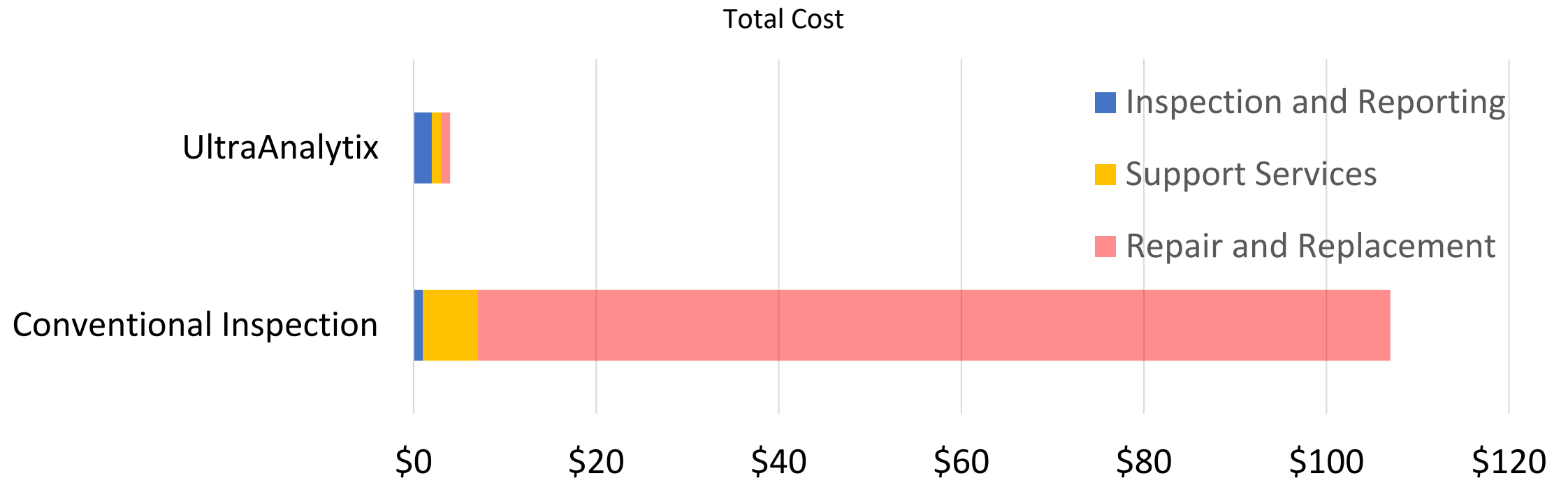
UltraAnalytix Since 2008:

- >7000 Inspections completed on 4000+ assets.
- Customers saved more than \$100million.
- 3 catastrophic failures predicted accurately before failure.
- 0 failures missed.
- >4 x 10⁶ database values



...one final data point

- Per \$1 of conventional inspection fees



Conclusions

1. Fitness For Service Assessment requires structural data.
2. Polymer damage dominates structural changes that lead to failure of FRP.
3. Polymer damage is quantified non-destructively by UltraAnalytix.
4. UltraAnalytix provides proven cost benefits.

Questions?

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