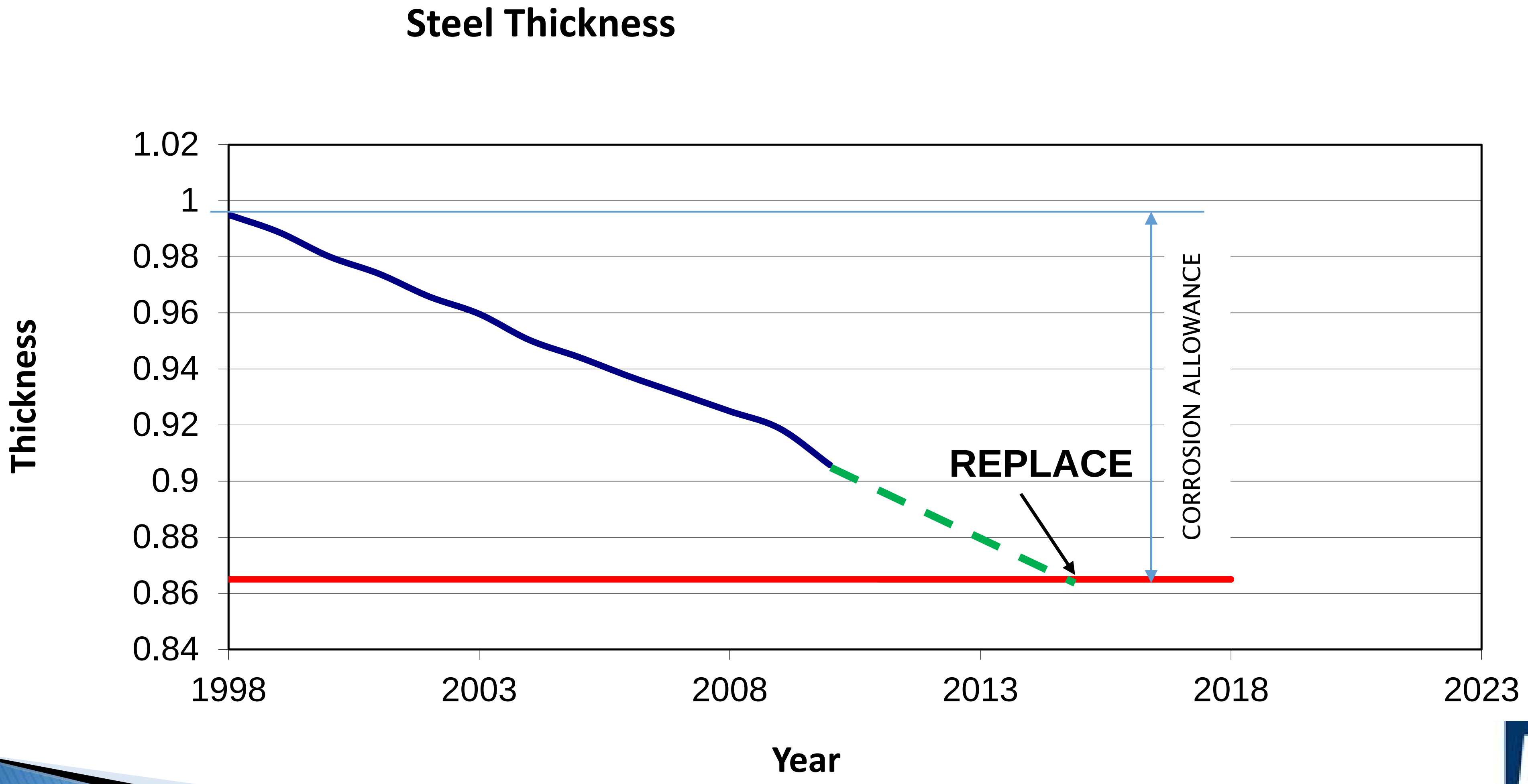
UltraAnalytix™ NDT Technique for FRP

The Challenge: Generate a curve to allow us to plan repair & replacement of FRP as for metals.



Mechanical Integrity and FFS of FRP

- Requires
  - **Non-Destructive Methods** that are repeatable and reliable to evaluate the current structural capacity and condition of a component.
  - **Non-Intrusive** so that plant operations do not have to be shut down to complete and have the safety of plant and personnel in mind.
  - Codes and standards based on data for evaluation.

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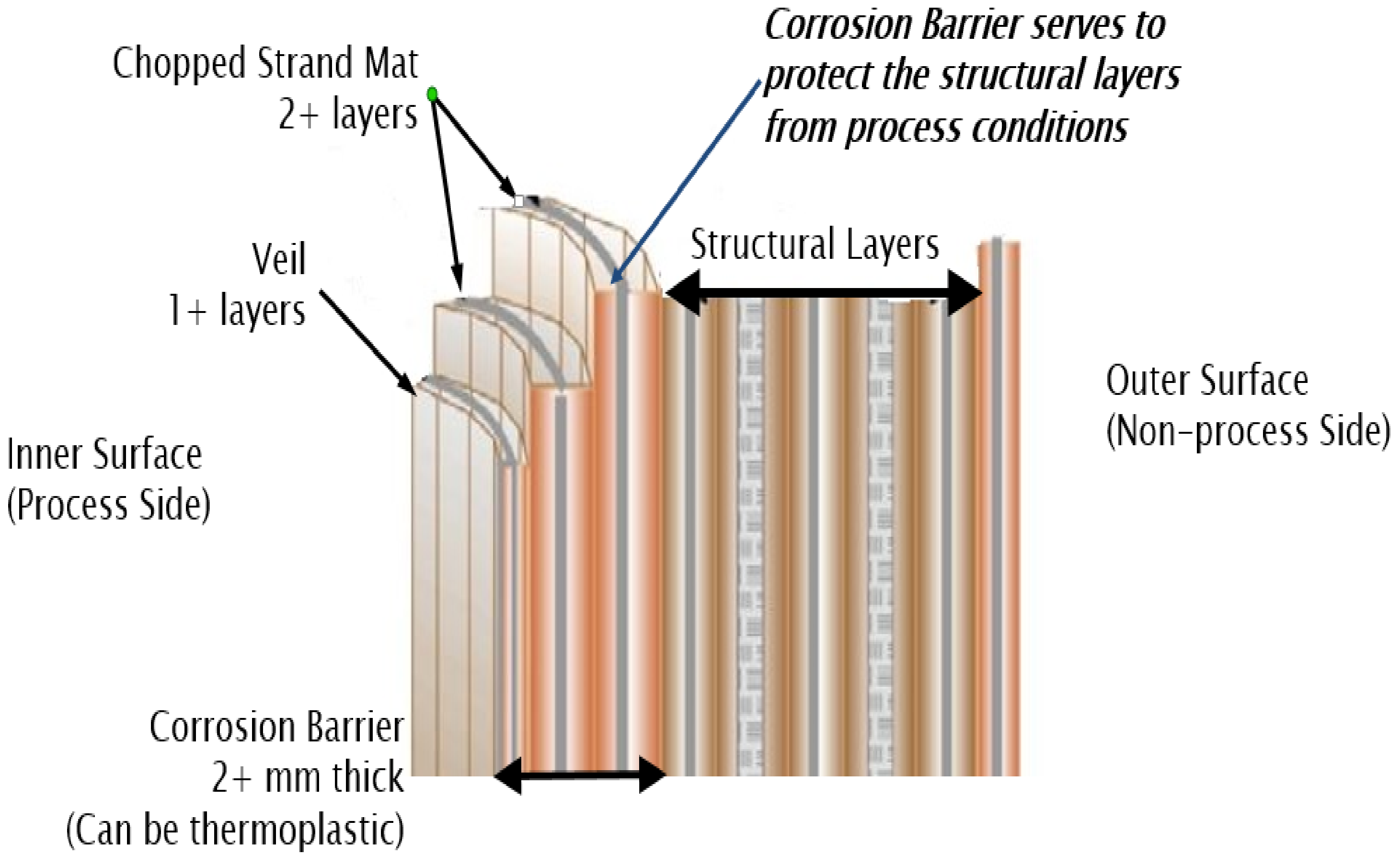
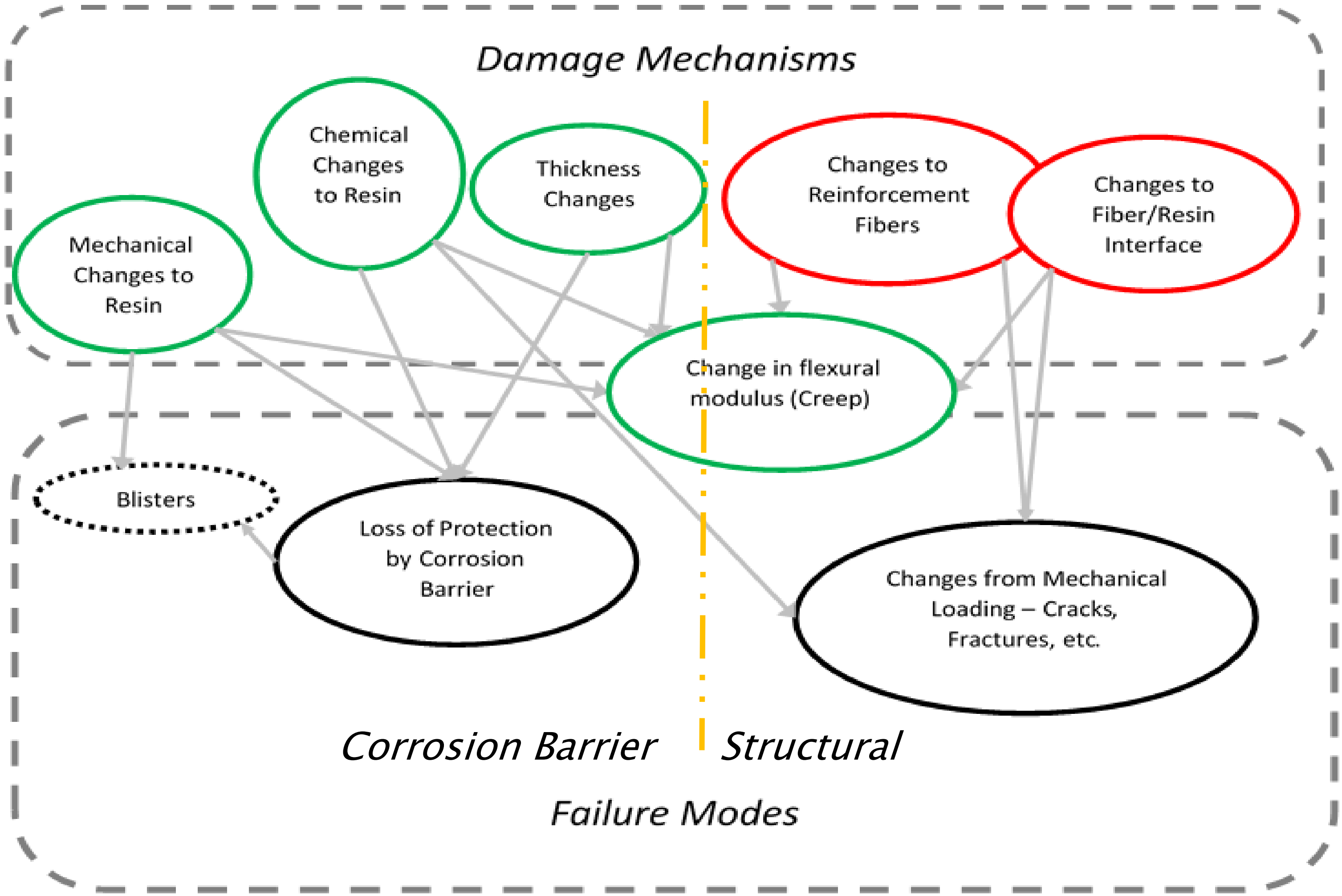
Normal FRP Construction



FRP Damage & Failure



Conventional FRP Inspection

- Life expectancy and fitness for service is determined by the life of the corrosion barrier
  - Life of the corrosion barrier is determined by visual internal inspection to look for:
    - Cracks, Gouges, Blisters, Surface condition, Abrasion
- Mechanical integrity is determined from:
  - Acoustic emission
    - Premature end-of-life determination
  - Destructive testing of cutouts
- *100% INTRUSIVE*

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Conventional FRP Inspection

- No scientific or engineering criteria
- Very limited standards or codes apply
- Limited relationship to the ability of FRP to continue operating.
- Significant differences among inspectors

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Key Concept

- $Percentage\ of\ Design\ Stiffness\ (PDS) = \frac{Current\ Flexural\ Modulus}{Theoretical\ Flexural\ Modulus} x100\%$
- Current Flexural Modulus is available from destructive tests
- Theoretical Flexural Modulus is calculated from Lamination Theory.

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Quantifying Overall FRP Condition

- Flexural Modulus
  - Relates to the condition of the entire laminate: resin, glass, interface bonds.
  - Includes corrosion barrier and structural layers.
  - One of the factors included in determining resin response to corrosion (ASTM C581).
  - Includes effects of delaminations and micro-cracking of resin.
  - Includes effects of resin damage – loss of cross-linking, Tg loss, softening, porosity
  - Includes effects of flaws and defects.
- This can be measured!

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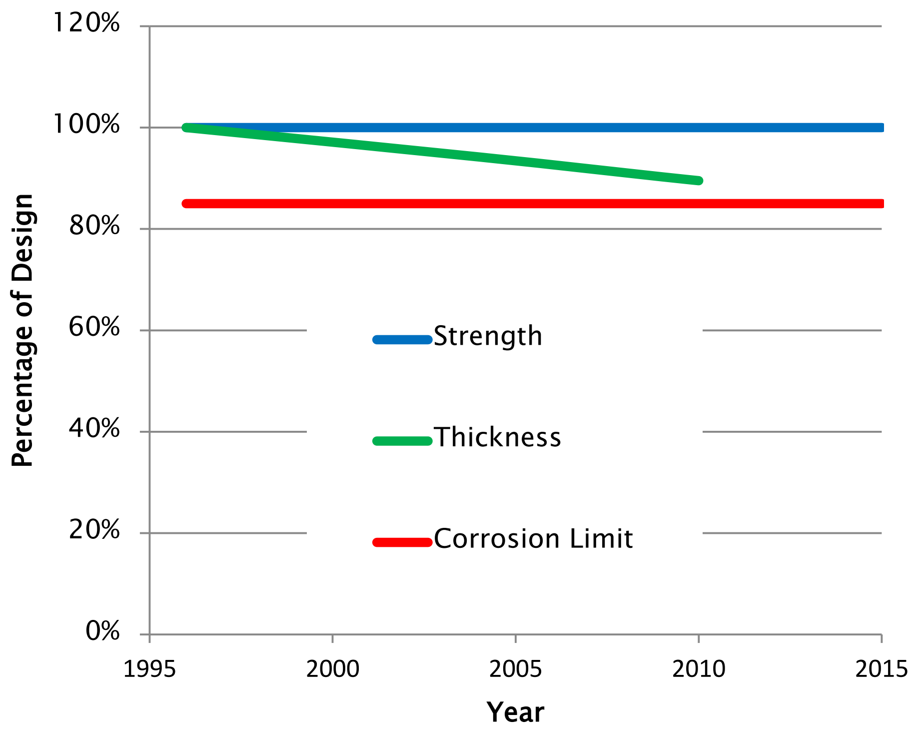
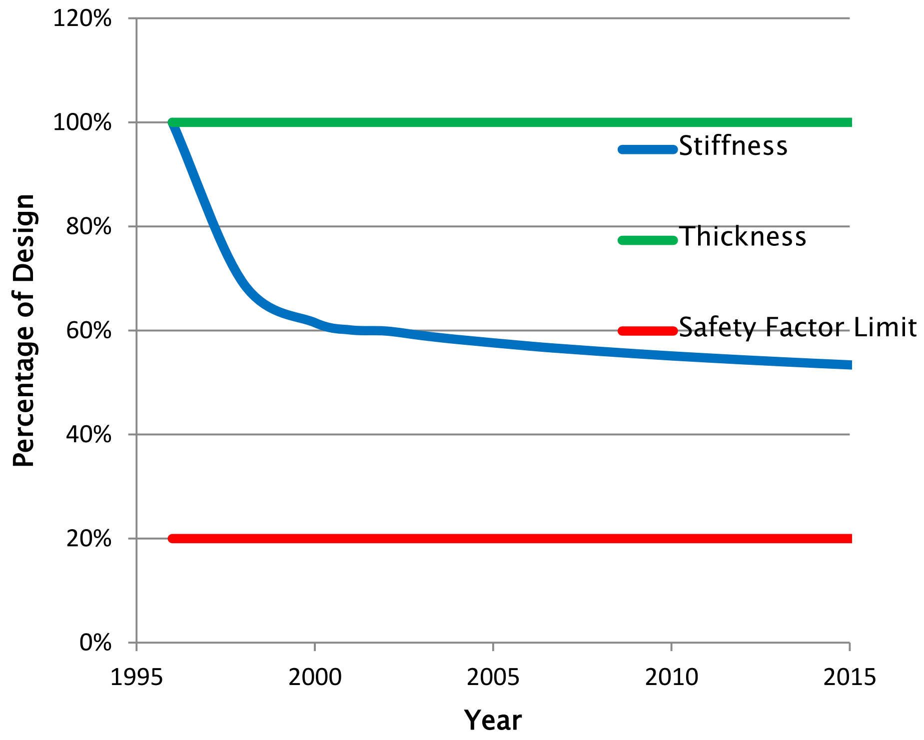
Comparison of Steel to FRP





Steel

FRP

UltraAnalytix™

- Non-destructive, non-intrusive, ultrasonic method.
- Quantifies current condition of FRP.
- Repeatable, Reproducible
  - Validated by Swerea KIMAB, University of Alabama, York University – Toronto, Customers, and UTComp
- Used on New and In-Service Equipment
- No plant shut-down required
- Ongoing updating of Remaining Service Life and database
- Cost Effective
- Mobile
- Available since 2008

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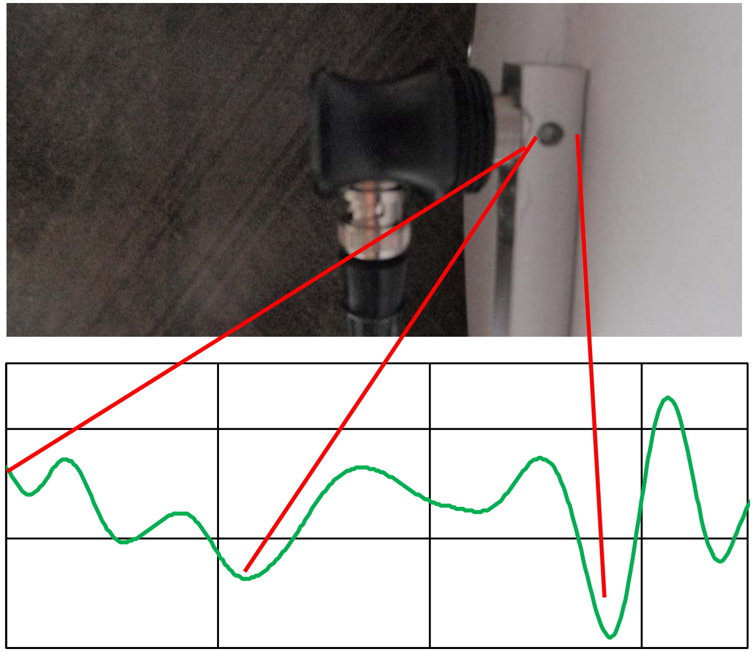
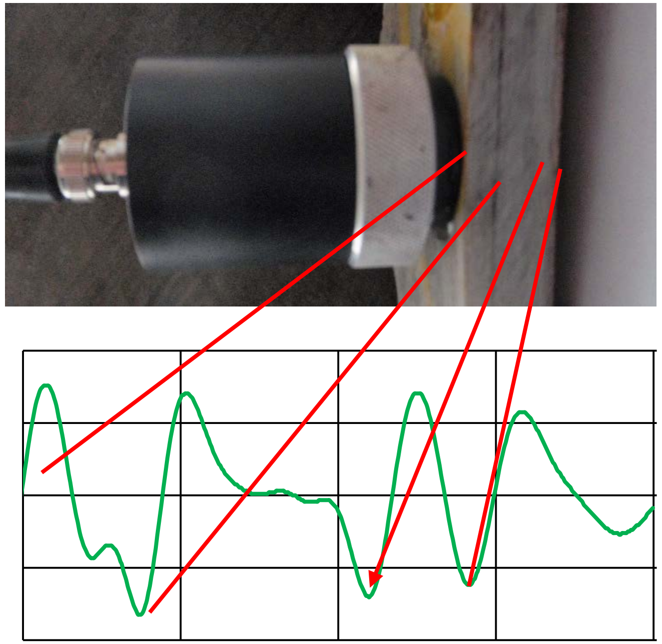
Very Basic Ultrasound

- Metal



Identifies defects.
Material properties are constant, therefore constant UT responses

- FRP



Many features are not defects.
Material properties affect UT responses. Changes in material properties determined from UT.

The complexity of FRP (e.g. glass, matrix, etc.) does <u>not</u> allow for recommendations to be given from the information on the screen.

<u>UltraAnalytix Post-Processing</u> of the *raw* data reveals valuable information about

- Remaining Service Life
- Corrosion Barrier
- Strength
- Thickness

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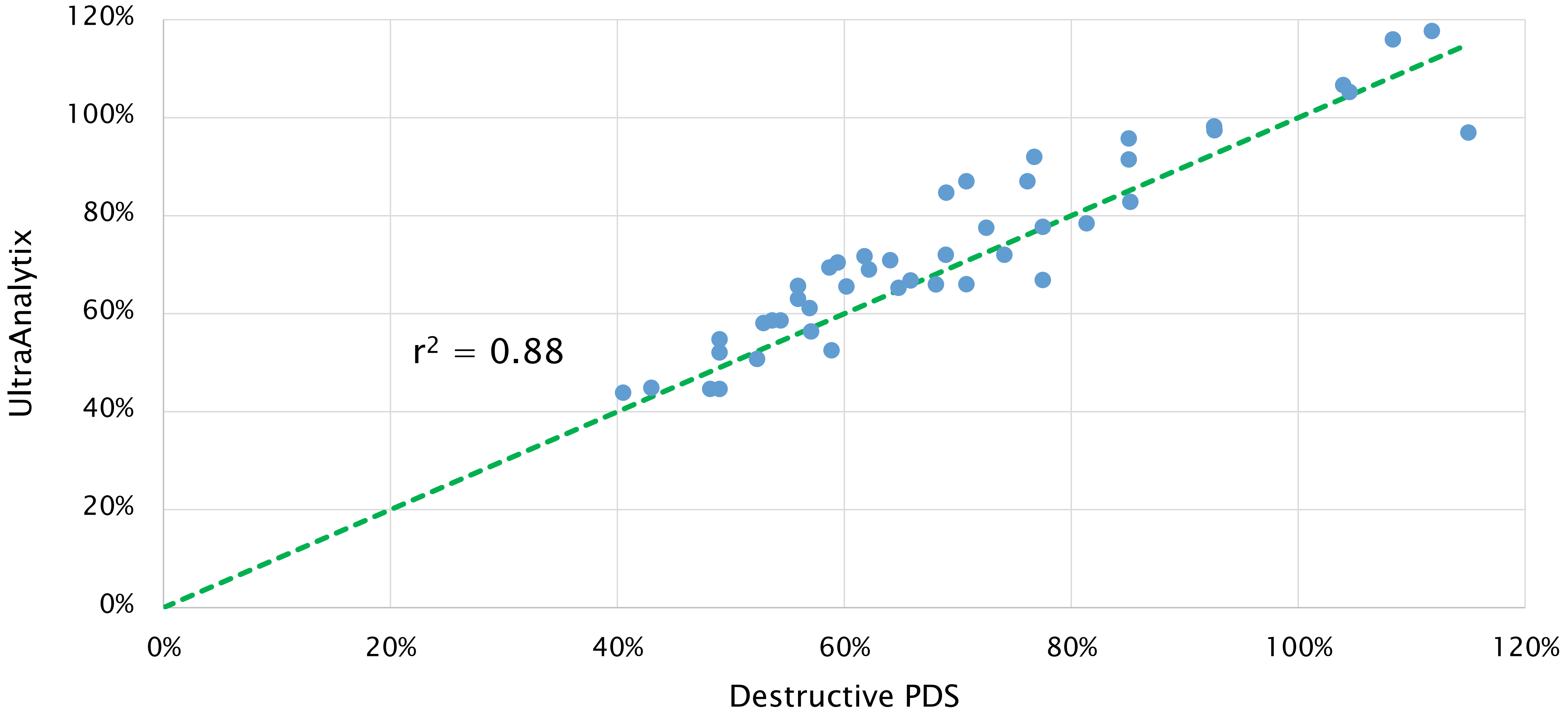
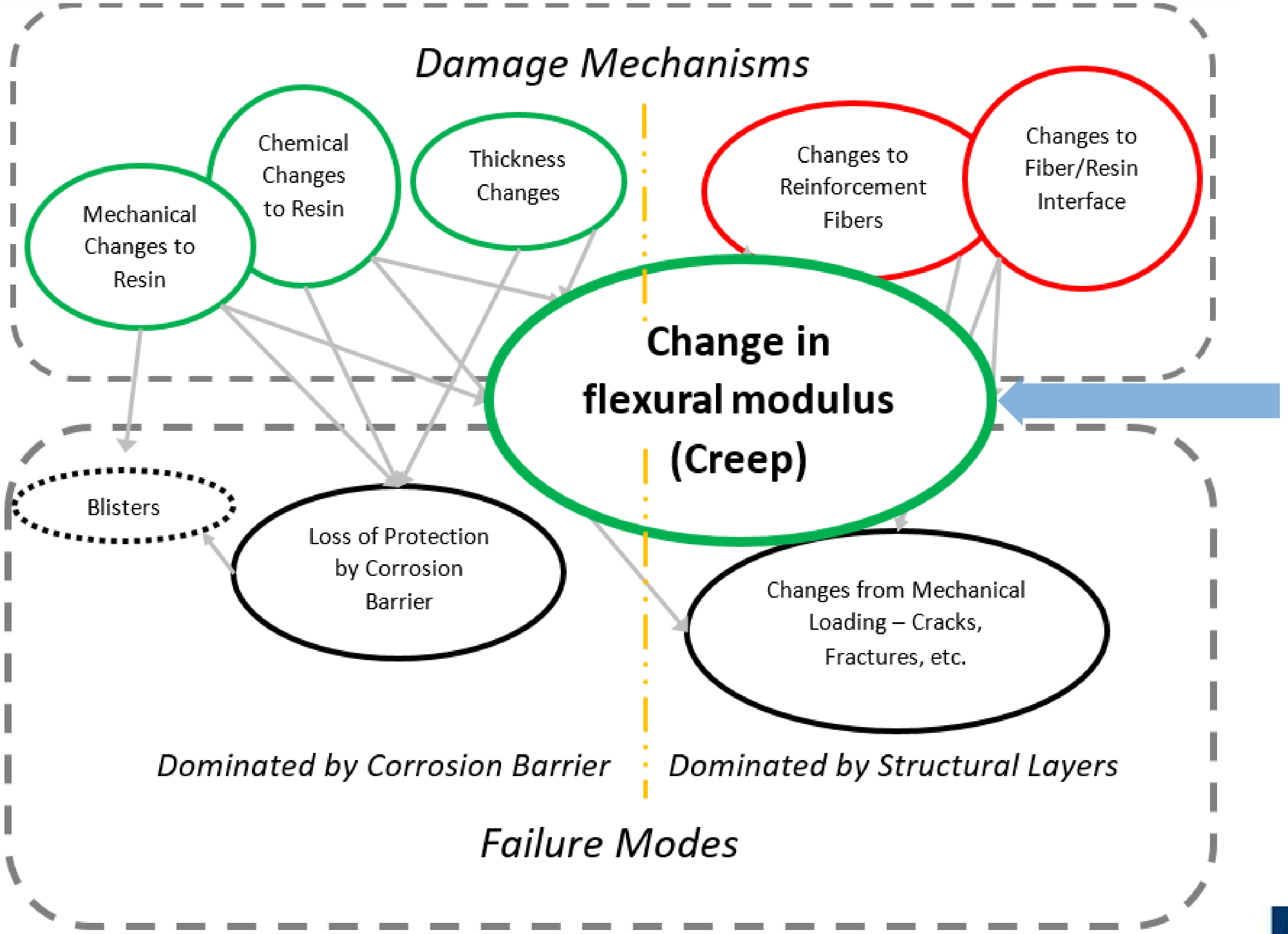
Calibration

Conventional	UltraAnalytix™
▸ Constant sonic velocity ▸ Focussed on flaw and discontinuity detection and classification ▸ Primary results determined from classifying flaws and defects.	▸ Sonic velocity not constant ◦ 15% variation can occur within inches ▸ Focussed on attenuation along signal path. ▸ Primary results are determined only from backwall reflection. ▸ Conventional calibration samples do not provide relevant data.

Correlation



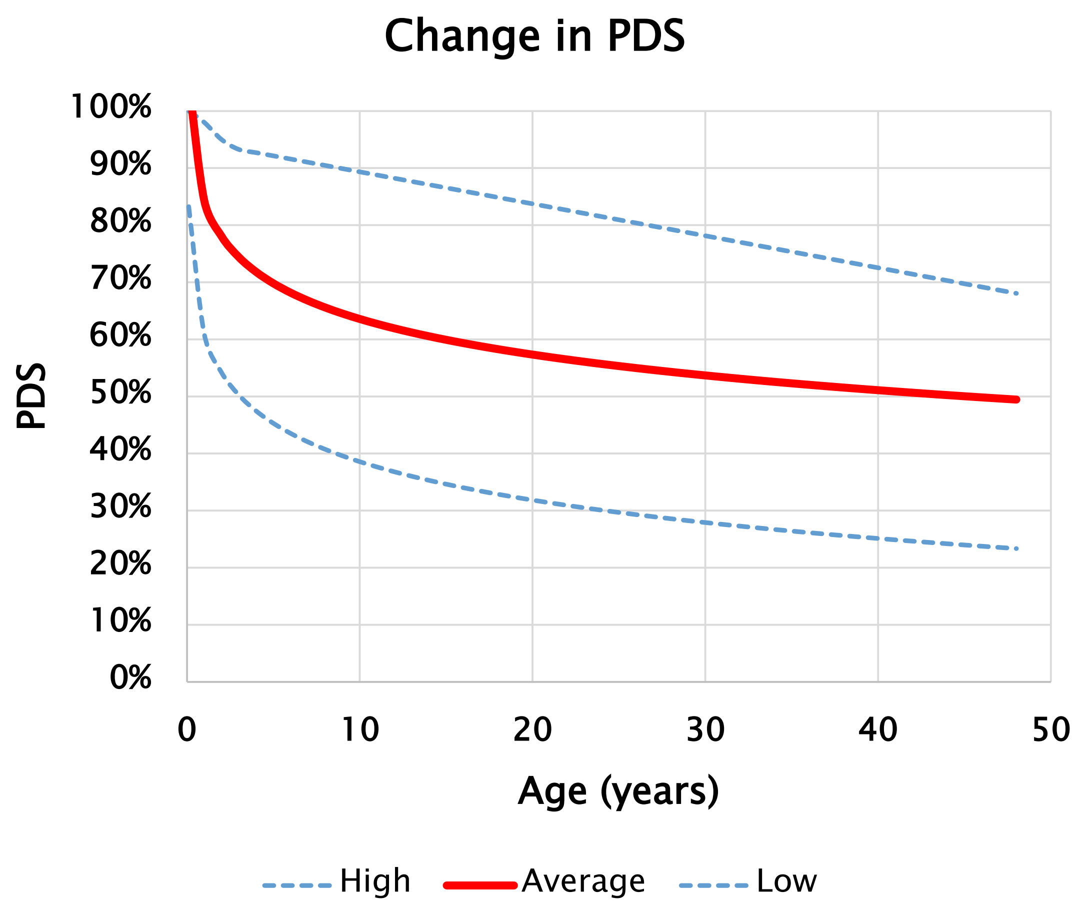
FRP Damage & Failure



ULTRAAnalytix measures changes in laminate flexural modulus

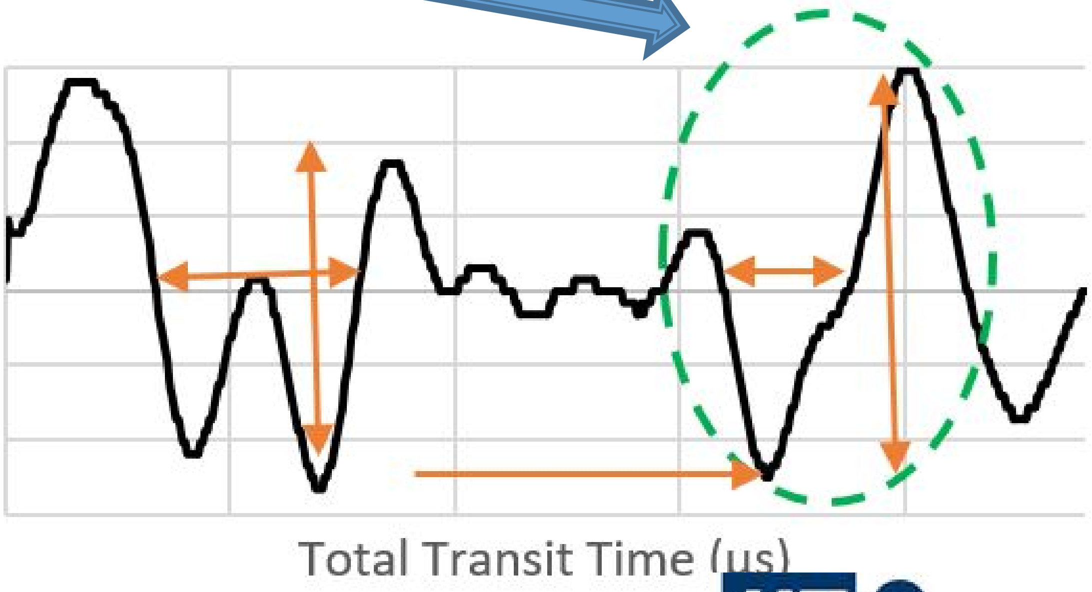
Data from 800 Inspections

- 800 inspections with multi-year data
- FRP Age from 0 to 48 years



Corrosion Barrier Damage

- Non-intrusive assessment of:
  - Depth of damage
  - Possible loss of resin Tg
  - Permeation



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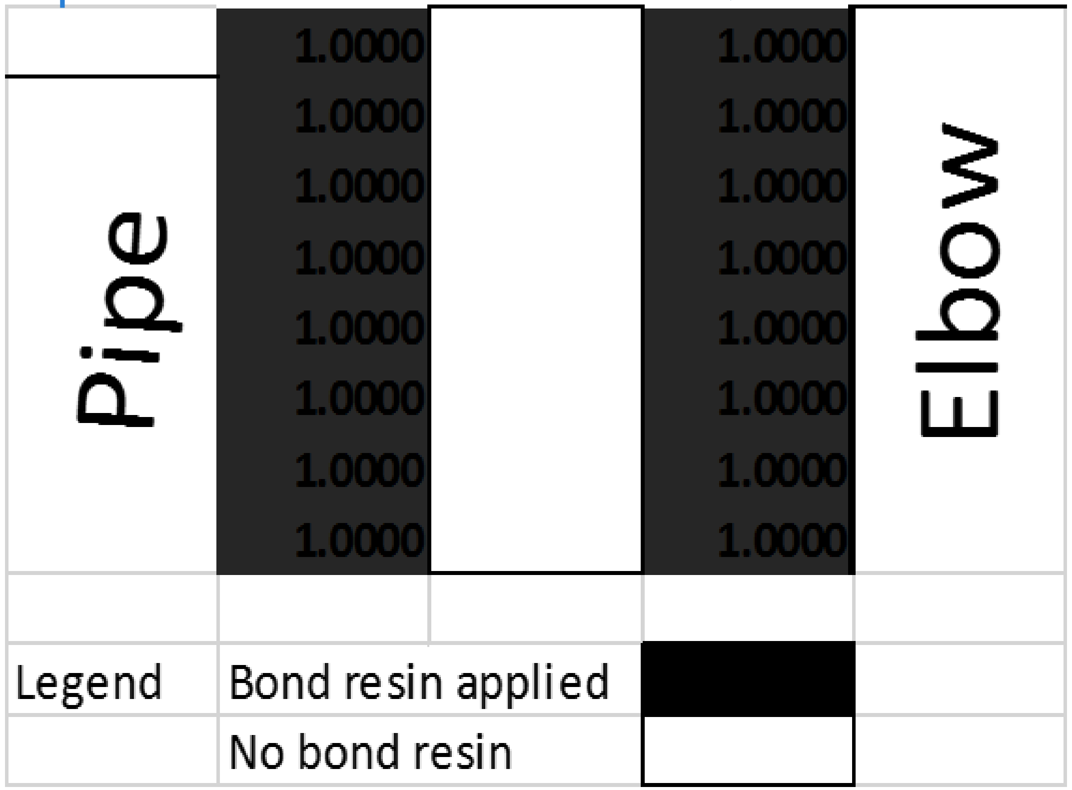
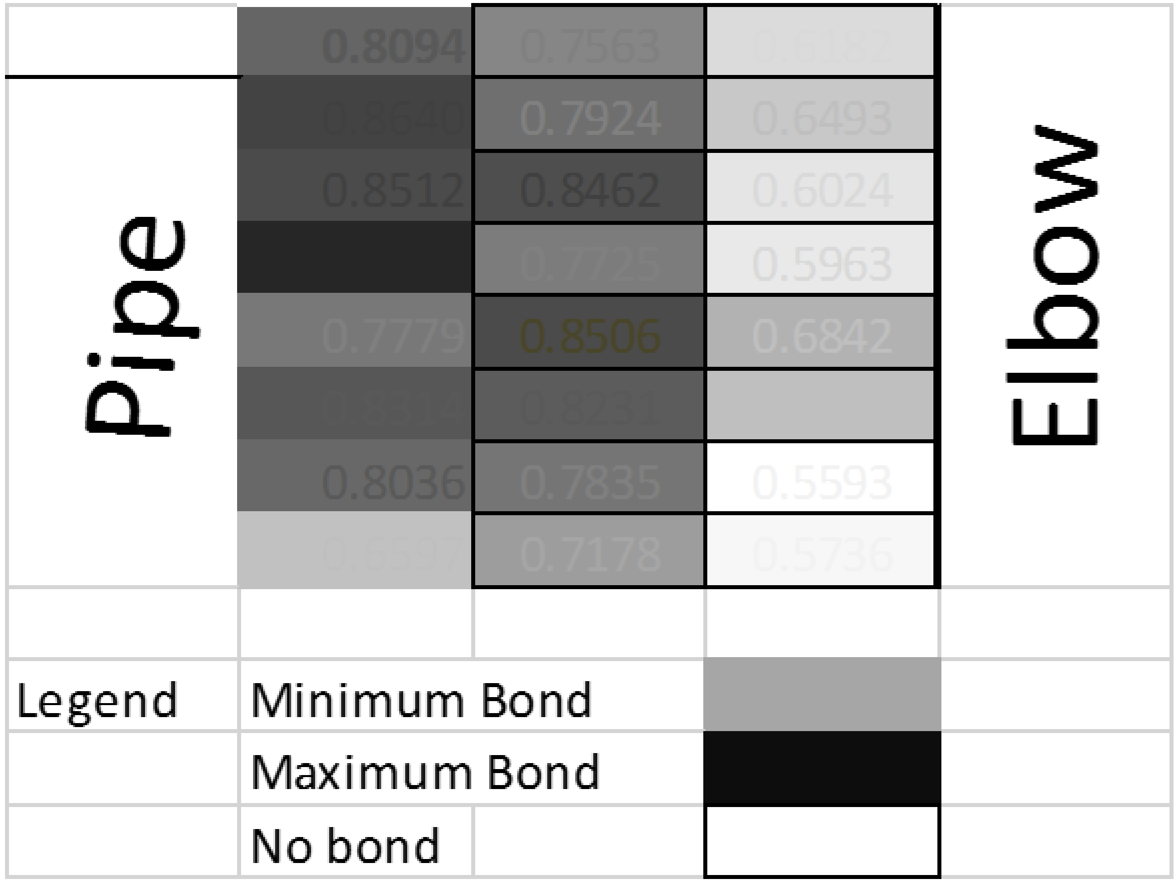
Application to Bonding

- Pipe Joint

Pipe inserts into socket



- UltraAnalytix™



How UltraAnalytix™ works

1. Field data and asset information.
2. Readings and information combined into data file.
3. Transmit data file to UTComp
4. Produce report and send to Customer.

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Return on Investment

- **UltraAnalytix maximizes the lifespan of your FRP assets, saving you money and minimizing production impact**
  - Accurate service-life forecasting
  - Millions spent on premature repair and replacement
  - UTComp has helped Cargill save more than $33 million in tank replacement costs since 2012. **For every $1 spent, saved $10**
  - No downtime for FRP inspections also reduces operating costs

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Comparison between UltraAnalytix and other types of evaluation

Method	Equipment operating	Maintains structural Integrity	Internal Structural Changes	Safety Factor Updated	Repeatable	Reliable	Minimizes confined space entry	Inspect Time
UltraAnalytix	Capable	Capable	Capable	Capable	Capable	Capable	Capable	15-60 min
Visual Inspection	Not Capable	Capable	Not Capable	Not Capable	Not Capable	Not Capable	Not Capable	1-4 hours
Destructive Testing	Not Capable	Not Capable	Possibly Capable	Capable	Capable	Capable	Not Capable	2 days
Acoustic Emission	Not Capable	Capable	Possibly Capable	Not Capable	Possibly Capable	Possibly Capable	Capable	2 days+
Digital Radiography	Capable	Capable	Possibly Capable	Not Capable	Capable	Capable	Capable	1-4 hours
Thermography	Capable	Capable	Possibly Capable	Not Capable	Possibly Capable	Possibly Capable	Capable	15-60 min
Ultrasonic Thickness Testing	Capable	Capable	Possibly Capable	Possibly Capable	Capable	Capable	Capable	15-60 min

Legend	
Capable	(green)
Possibly Capable	(yellow)
Not Capable	(red)

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UltraAnalytix™ Limitations

- Operates best at temperatures >50°F or 10°C
- Structures with foam cores and thick (>3inch or 7.5cm) balsa core
- Pipe <5cm (2inch) outside diameter
- Magnetic fields within 2400mm of conductor carrying 120000+ Amps

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Case Studies

A number are available at:

www.utcomp.com/case-studies/

UTComp

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355 Hespeler Road
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Telephone: 519.620.077

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UTComp® System Used in Preventing Failure

By: Geoff Clarkson, P.Eng., FEC

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Using the UTComp® System to Monitor Vessel Condition and Restoration

By: Geoff Clarkson, P.Eng.

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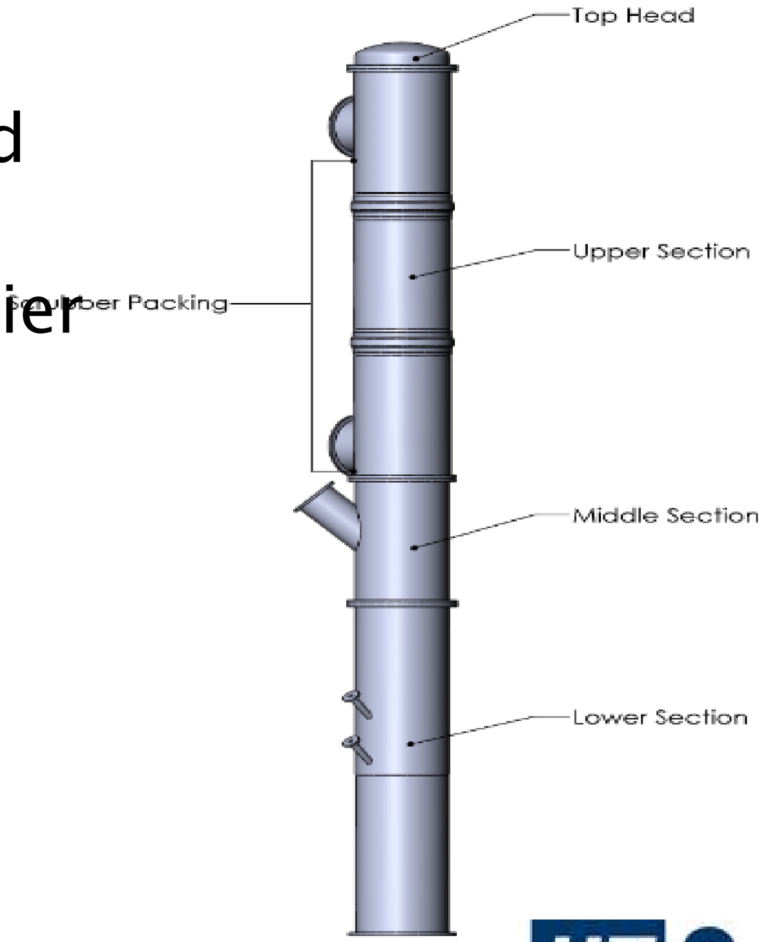
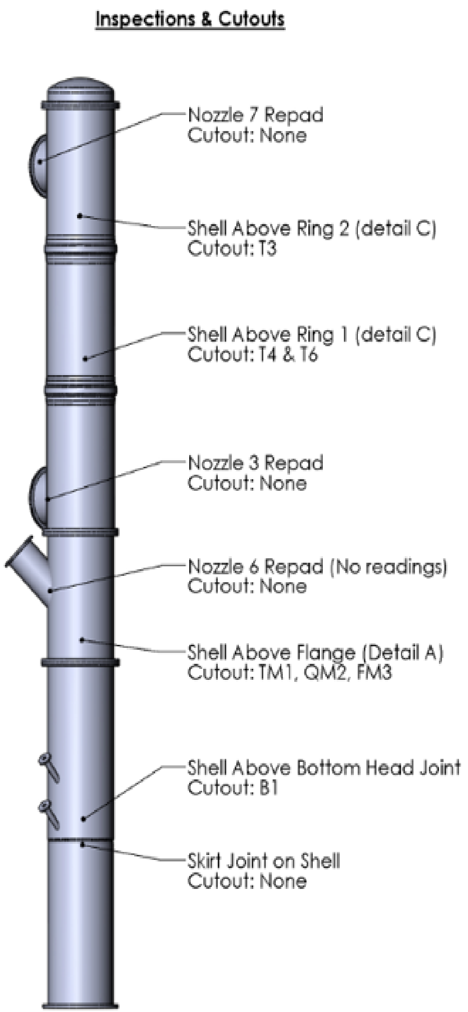
Case Study – FRP Scrubbing Column

- <u>Function</u>: Scrub vapors of aHCl, aHF and organics with sodium hydroxide
- Hand lay-up with 2N 4M corrosion barrier
- Bisphenol-A vinyl ester resin with BPO/DMA cure
- Removed from service by the plant operations in 2015 based on internal visual inspection of corrosion barrier



Case Study – FRP Scrubbing Column

- No access to any of the inner surface.
- Simulated non-intrusive inspection while operating.
- After NDT, cut-outs were removed for verifications.
- Destructive Stiffness values were within 14% of UltraAnalytix values
- Corrosion Barrier damage – same for UltraAnalytix and cutout sections



Number of Ultrasonic Readings
14
31
32
17
33
19
12

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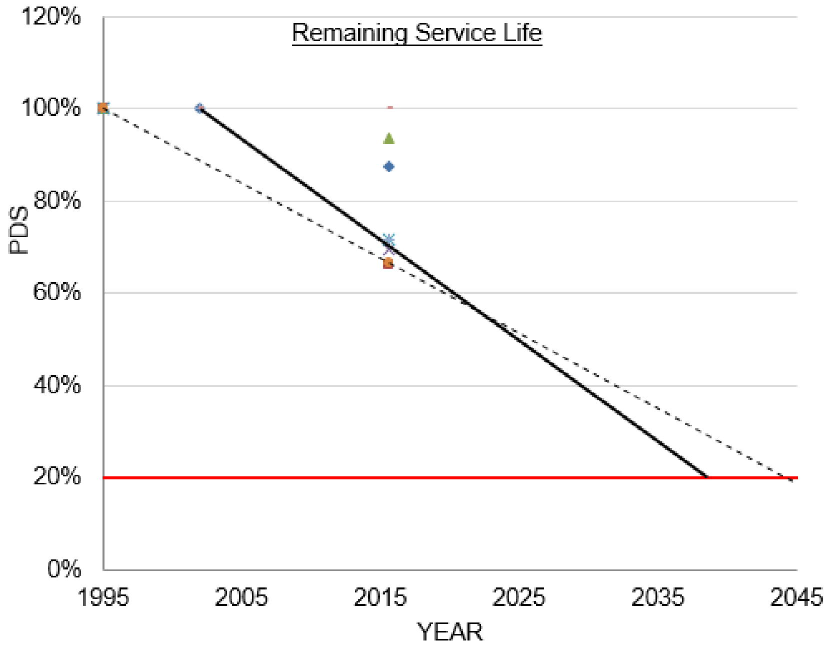
Case Study – FRP Scrubbing Column

- Based on PDS, conservative prediction of remaining Structural life : 25 to 27 years
- Based on Corrosion Barrier damage Remaining Service Life: Approx. 45 years



Questions?

Geoff Clarkson or Jo Anne Watton
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inquiries@utcomp.ca

The good thing about science is that it is true whether you believe it or not.

Neil deGrasse Tyson

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