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

Steel Thickness

- Thickness vs. Year
- Corrosion allowance
- Replace
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.
Normal FRP Construction

- **Chopped Strand Mat**
  - 2+ layers

- **Veil**
  - 1+ layers

- **Structural Layers**

- **Inner Surface**
  - (Process Side)

- **Corrosion Barrier**
  - 2+ mm thick
  - (Can be thermoplastic)

**Corrosion Barrier serves to protect the structural layers from process conditions**

**Outer Surface**
- (Non-process Side)
FRP Damage & Failure

Damage Mechanisms

- Chemical Changes to Resin
- Thickness Changes
- Change in flexural modulus (Creep)
- Changes to Reinforcement Fibers
- Changes to Fiber/Resin Interface
- Changes from Mechanical Loading – Cracks, Fractures, etc.
- Loss of Protection by Corrosion Barrier
- Mechanical Changes to Resin
- Blisters

Corrosion Barrier

Failure Modes

Structural
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
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
Key Concept

- **Percentage of Design Stiffness (PDS)**
  
  \[
  \text{Percentage} = \frac{\text{Current Flexural Modulus}}{\text{Theoretical Flexural Modulus}} \times 100\%
  \]

- Current Flexural Modulus is available from destructive tests
- Theoretical Flexural Modulus is calculated from Lamination Theory.
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!
Comparison of Steel to 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
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 not allow for recommendations to be given from the information on the screen.

UltraAnalytix Post-Processing of the raw data reveals valuable information about
• Remaining Service Life
• Corrosion Barrier
• Strength
• Thickness
## Calibration

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

$r^2 = 0.88$
FRP Damage & Failure

Damage Mechanisms

- Mechanical Changes to Resin
- Chemical Changes to Resin
- Thickness Changes
- Changes to Reinforcement Fibers
- Changes to Fiber/Resin Interface

Change in flexural modulus (Creep)

Failure Modes

- Blisters
- Loss of Protection by Corrosion Barrier
- Changes from Mechanical Loading – Cracks, Fractures, etc.

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
## Application to Bonding

### Pipe Joint
Pipe inserts into socket

<table>
<thead>
<tr>
<th>Pipe</th>
<th>Elbow</th>
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<tbody>
<tr>
<td>1.000</td>
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</tbody>
</table>

**Legend**
- Bond resin applied
- No bond resin

### UltraAnalytix™

<table>
<thead>
<tr>
<th>Pipe</th>
<th>Elbow</th>
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<tbody>
<tr>
<td>0.8094</td>
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<td>0.6593</td>
<td>0.7178</td>
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</table>

**Legend**
- Minimum Bond
- Maximum Bond
- No bond
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.
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
## Comparison between UltraAnalytix and other types of evaluation

<table>
<thead>
<tr>
<th>Method</th>
<th>Equipment operating</th>
<th>Maintains structural Integrity</th>
<th>Internal Structural Changes</th>
<th>Safety Factor Updated</th>
<th>Repeatable</th>
<th>Reliable</th>
<th>Minimizes confined space entry</th>
<th>Inspect Time</th>
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</thead>
<tbody>
<tr>
<td>UltraAnalytix</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>15-60 min</td>
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<tr>
<td>Visual Inspection</td>
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<td>Destructive Testing</td>
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<td>1-4 hours</td>
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<td>15-60 min</td>
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<tr>
<td>Ultrasonic Thickness Testing</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15-60 min</td>
</tr>
</tbody>
</table>

**Legend**

- **Capable**
- **Possibly Capable**
- **Not Capable**
UltraAnalytiX™ Limitations

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

A number are available at:

www.utcomp.com/case-studies/
Case Study – FRP Scrubbing Column

- **Function**: 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
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?

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519-620-0772
inquiries@utcomp.ca

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

Neil deGrasse Tyson