

# Carbon Fiber Reinforced Polymer Composites (CFRP) Piping Repair

## NDE Update

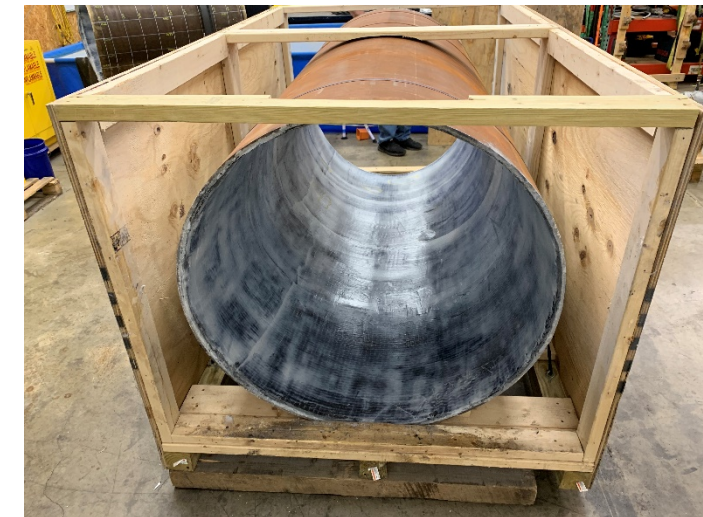
Dylan Cimock, Senior Technical Leader  
Steve Kenefick, Principal Technical Leader

2020 Industry-NRC Composite Repair Technology  
Information Exchange Public Meeting  
January 16, 2020



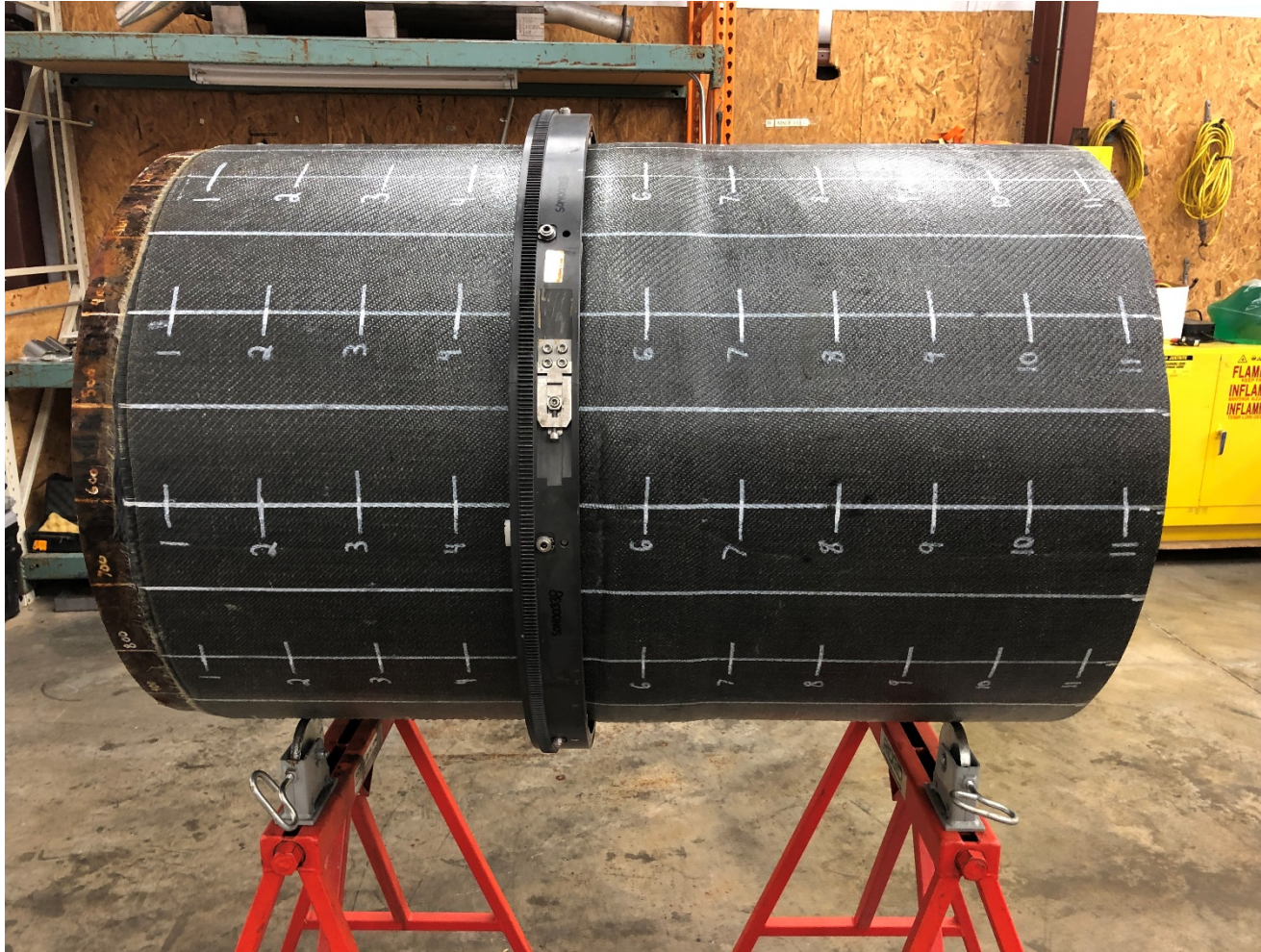
# Summary of EPRI Research: NDE of Composites

- Objective
  - Identify and/or develop technologies and techniques capable of measuring the metallic substrate thickness beneath composites
- 2018: *Non-contact Nondestructive Evaluation Technology: Dynamic Response Spectroscopy and Pulsed Eddy Current* (EPRI Report 3002013174)
  - Included feasibility study of DRS on 30" diameter piping mock-up
- 2019:
  - Expand DRS Assessment to:
    - Include 3 new CFRP wrap manufacturers
    - Assess multiple CFRP thicknesses that manufacturers plan to install to remediate in-service pipes
    - Assess multiple substrate thicknesses
  - Plan to assess other NDE methods





# CFRP Supplier 1 – Sample 1

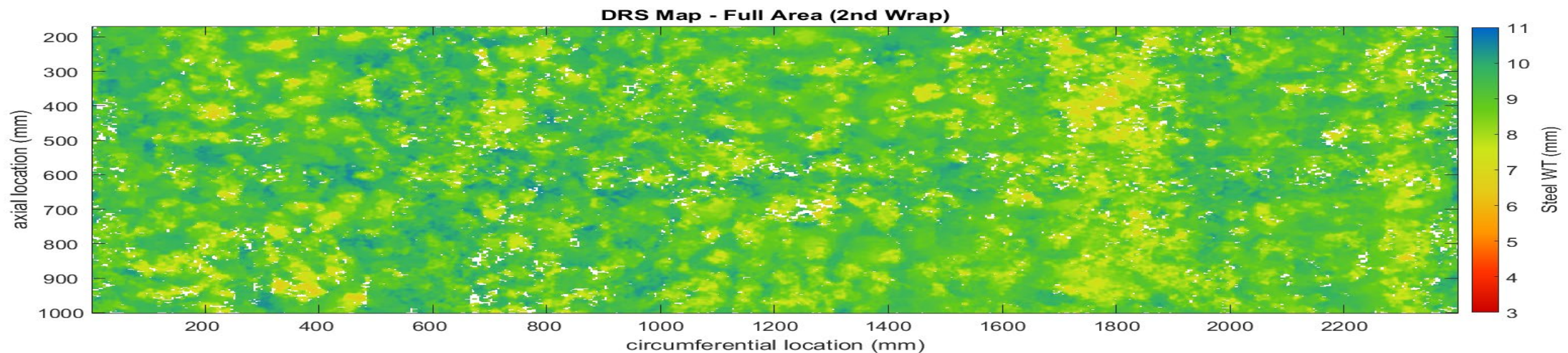
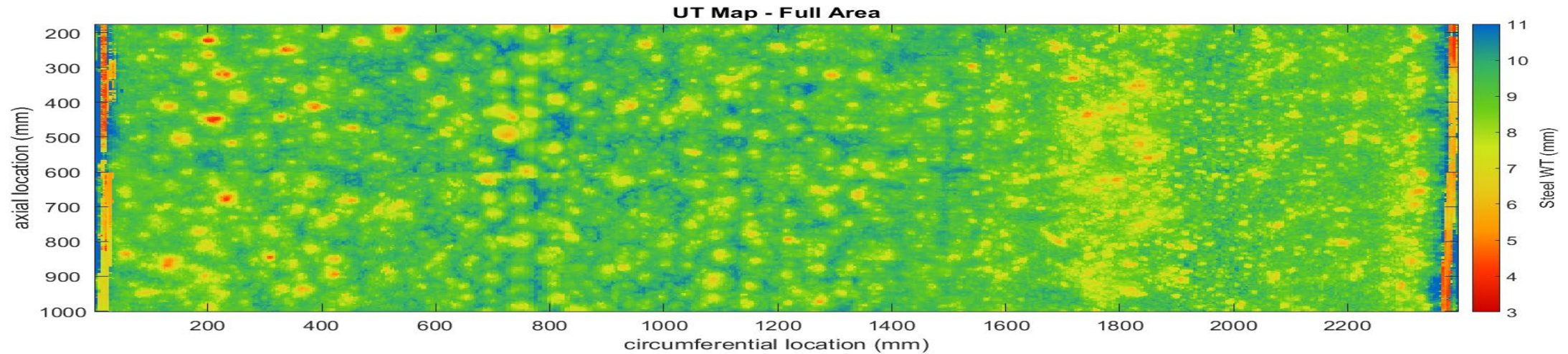


## Details:

- Pipe
  - Carbon Steel
  - 30" Diameter
  - ~36" Long
  - 0.375" Tnom
  - Natural raw water service corrosion defects (ID)
- CFRP System:
  - Fabric:
    - Carbon: 20 ounce/yd<sup>2</sup>
    - Glass: 10 ounce/yd<sup>2</sup>
  - Number of Layers
    - Ends: 2 Glass / 5-6 Carbon
    - Middle: 2 Glass / 9-10 Carbon



# Visual Correlation Between Ultrasonic and DRS Images





# Supplier 2 – 3 Sample Sets

## Details:

- 17 Carbon steel plates
  - 12" x 18"
  - 5 CFRP thicknesses x 3 plates thicknesses
  - 2 plates with thickened epoxy initial layer



## Details:

- Carbon steel pipe
  - 7' x 42" x 0.375
  - ID natural corrosion flaws
  - ID Wrap

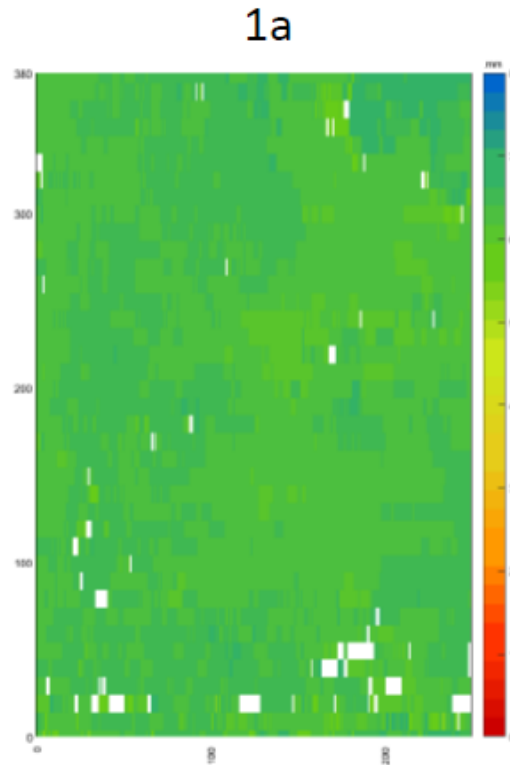


## Details:

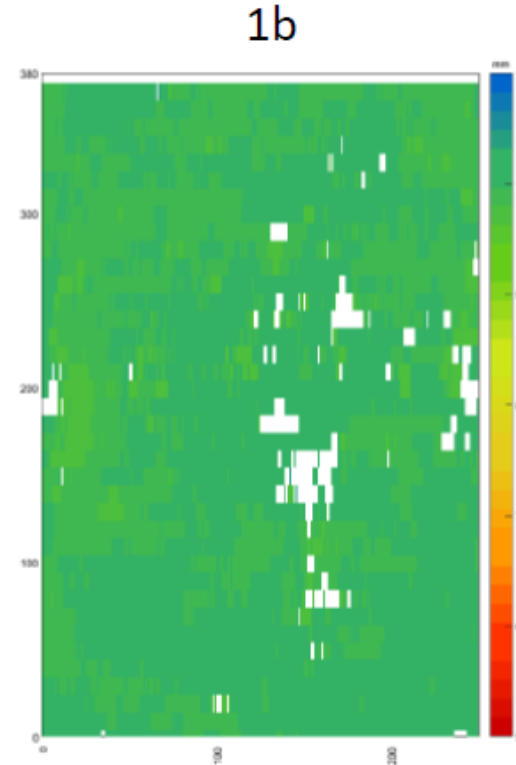
- Aluminum Bronze Pipe
  - 3' x 30" x 0.250"
  - ID Wrap, minimal ID flaws



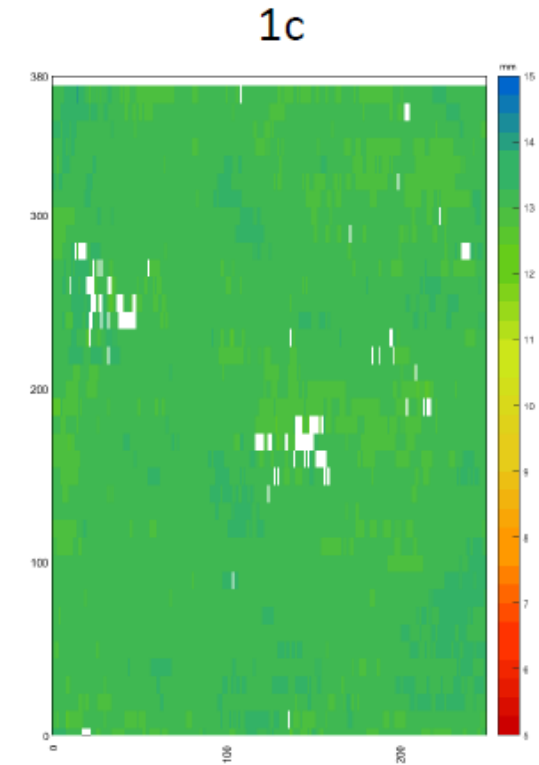
Sample #	# Glass Layers	# CFRP Layers	0.250" steel	0.375" Steel	0.500" steel
1a, 1b, 1c	2	3	1a	1b	1c
2a, 2b, 2c	2	4	2a	2b	2c
3a, 3b, 3c	2	5	3a	3b	3c
4a, 4b, 4c	2	6	4a	4b	4c
5a, 5b, 5c	2	7	5a	5b	5c



Approx. 0.445" (11.3mm) CFRP  
on 0.250" (6.35mm) steel



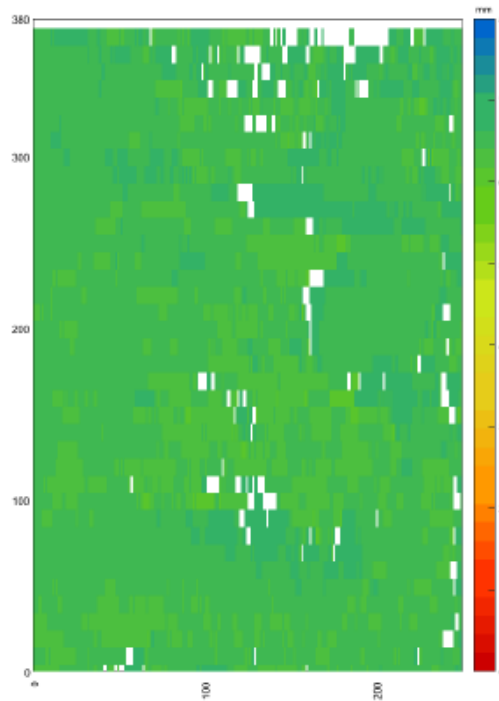
Approx. 0.453" (11.5mm) CFRP  
on 0.375" (9.53mm) steel



Approx. 0.421" (10.7mm) CFRP  
on 0.500" (12.7mm) steel

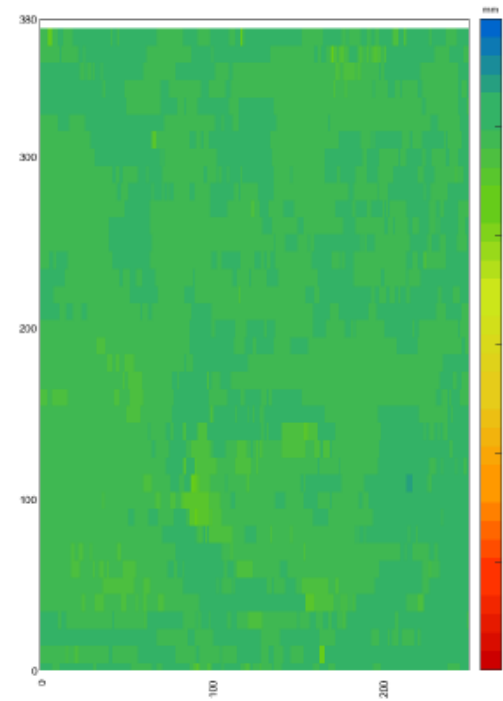
Sample #	# Glass Layers	# CFRP Layers	0.250" steel	0.375" Steel	0.500" steel
1a, 1b, 1c	2	3	1a	1b	1c
2a, 2b, 2c	2	4	2a	2b	2c
3a, 3b, 3c	2	5	3a	3b	3c
4a, 4b, 4c	2	6	4a	4b	4c
5a, 5b, 5c	2	7	5a	5b	5c

2a



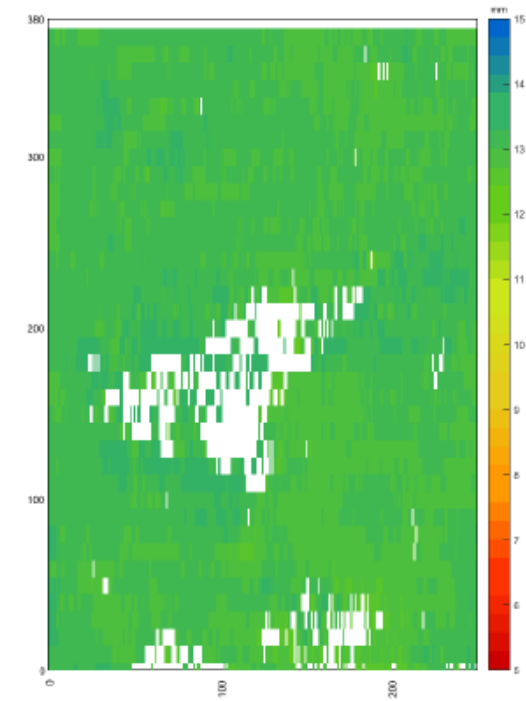
Approx. 0.488" (12.4mm) CFRP  
on 0.250" (6.35mm) steel

2b



Approx. 0.587" (14.9mm) CFRP  
on 0.375" (9.53mm) steel

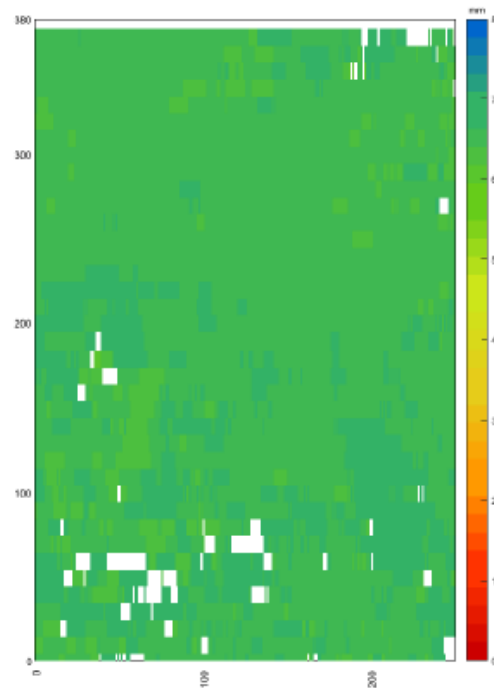
2c



Approx. 0.500" (12.7mm) CFRP  
on 0.500" (12.7mm) steel

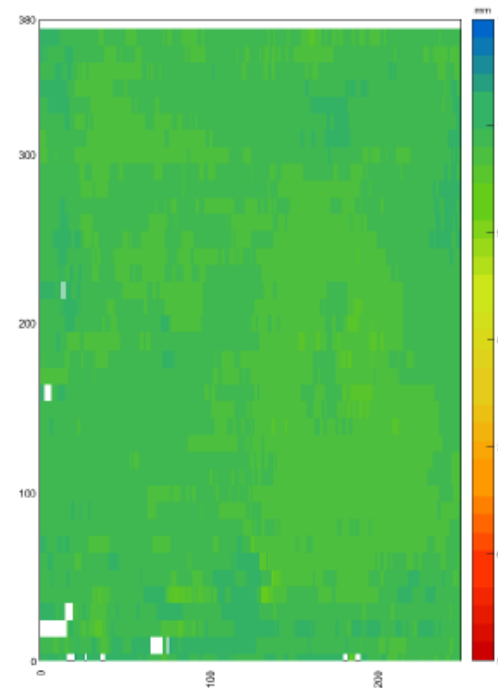
Sample #	# Glass Layers	# CFRP Layers	0.250" steel	0.375" Steel	0.500" steel
1a, 1b, 1c	2	3	1a	1b	1c
2a, 2b, 2c	2	4	2a	2b	2c
3a, 3b, 3c	2	5	3a	3b	3c
4a, 4b, 4c	2	6	4a	4b	4c
5a, 5b, 5c	2	7	5a	5b	5c

3a



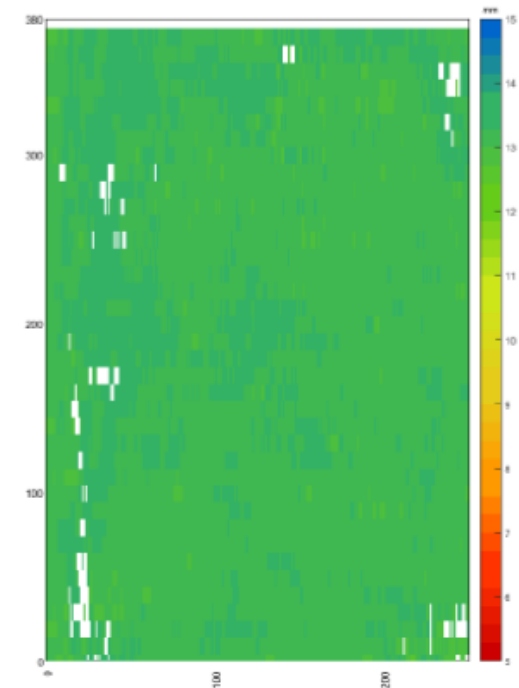
Approx. 0.598" (15.2mm) CFRP  
on 0.250" (6.35mm) steel

3b



Approx. 0.610" (15.5mm) CFRP  
on 0.375" (9.53mm) steel

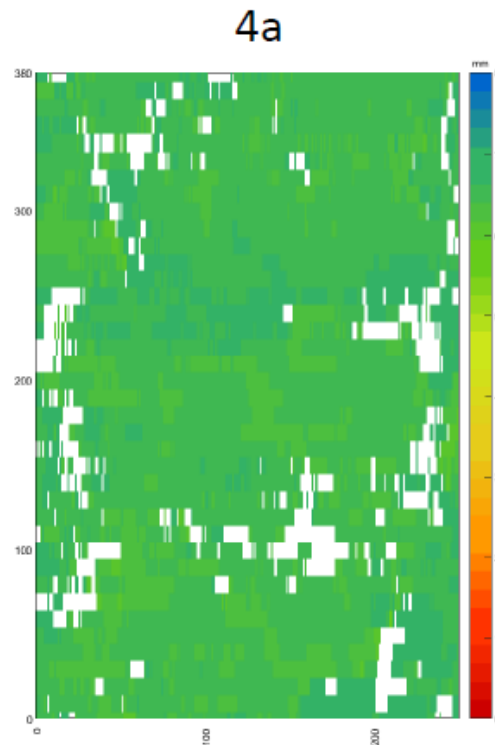
3c



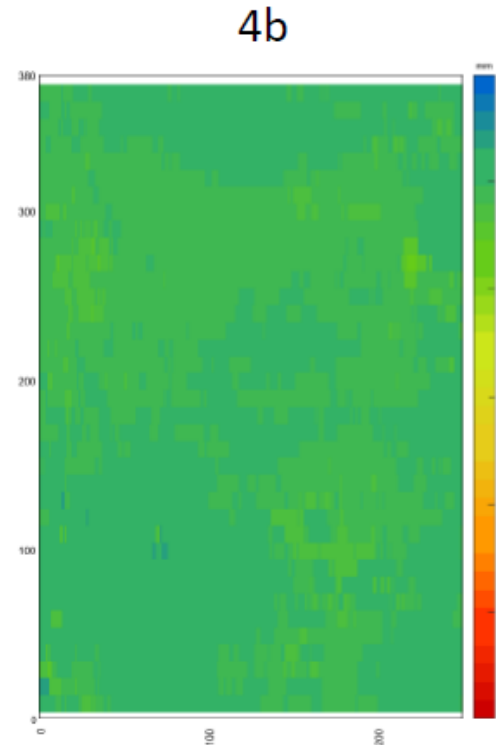
Approx. 0.591" (15.0mm) CFRP  
on 0.500" (12.7mm) steel



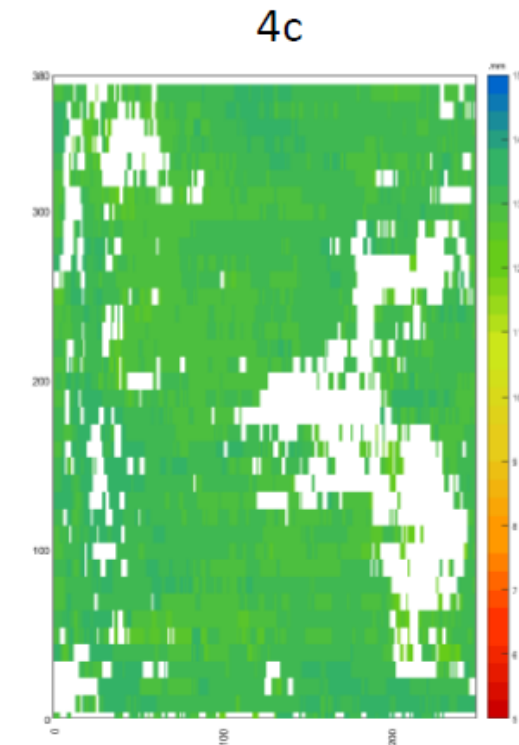
Sample #	# Glass Layers	# CFRP Layers	0.250" steel	0.375" Steel	0.500" steel
1a, 1b, 1c	2	3	1a	1b	1c
2a, 2b, 2c	2	4	2a	2b	2c
3a, 3b, 3c	2	5	3a	3b	3c
4a, 4b, 4c	2	6	4a	4b	4c
5a, 5b, 5c	2	7	5a	5b	5c



Approx. 0.689" (17.5mm) CFRP  
on 0.250" (6.35mm) steel



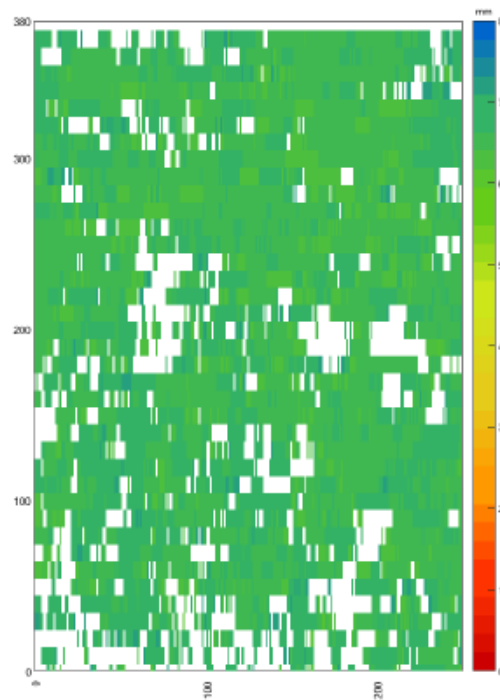
Approx. 0.721" (18.3mm) CFRP  
on 0.375" (9.53mm) steel



Approx. 0.685" (17.4mm) CFRP  
on 0.500" (12.7mm) steel

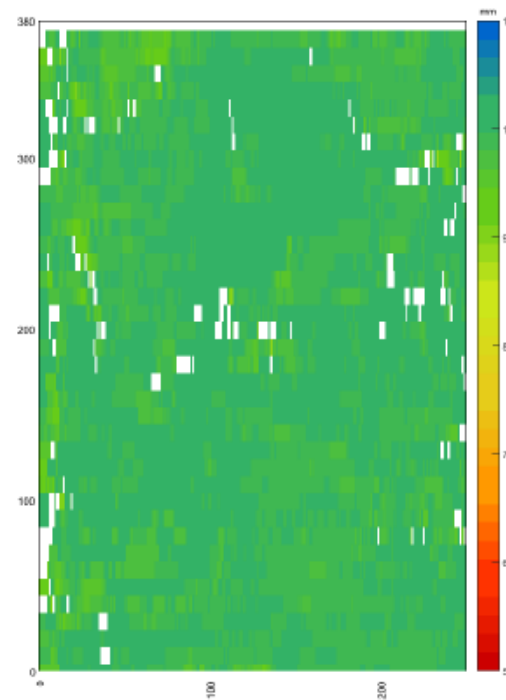
Sample #	# Glass Layers	# CFRP Layers	0.250" steel	0.375" Steel	0.500" steel
1a, 1b, 1c	2	3	1a	1b	1c
2a, 2b, 2c	2	4	2a	2b	2c
3a, 3b, 3c	2	5	3a	3b	3c
4a, 4b, 4c	2	6	4a	4b	4c
5a, 5b, 5c	2	7	5a	5b	5c

5a



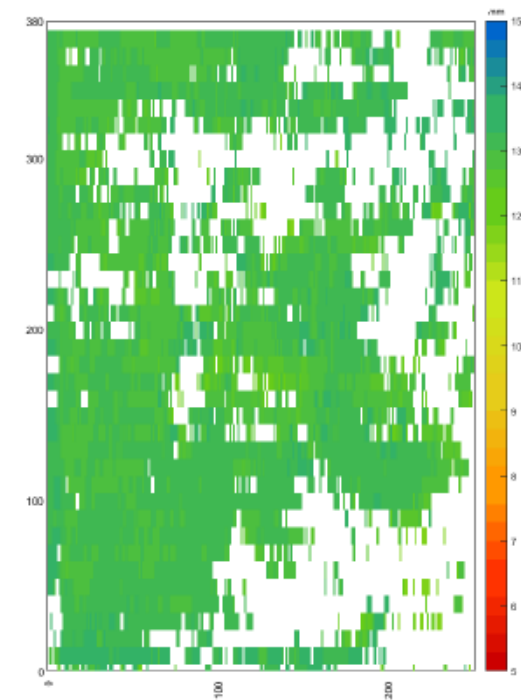
Approx. 0.787" (20.0mm) CFRP  
on 0.250" (6.35mm) steel

5b



Approx. 0.791" (20.1mm) CFRP  
on 0.375" (9.53mm) steel

5c



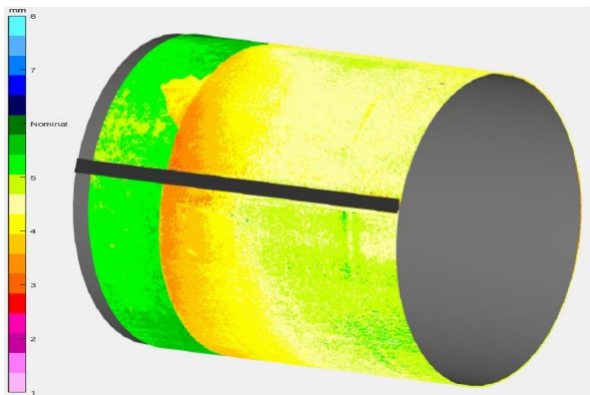
Approx. 0.823" (20.9mm) CFRP  
on 0.500" (12.7mm) steel



# Supplier 2 – Samples 2 & 3



- Aluminum Bronze Pipe
  - 30" Diameter
  - ~36" Long
  - 0.250" Tnom
  - CFRP Fabric:
    - Carbon: 38 ounce/yd<sup>2</sup>
    - Glass: 24.6 ounce/yd<sup>2</sup>
    - Layers: 2 Glass / 3 Carbon
  
- Carbon Steel Pipe
  - 30" Diameter
  - ~7' Long
  - 0.375" Tnom
  - CFRP Fabric:
    - Carbon: 38 ounce/yd<sup>2</sup>
    - Glass: 24.6 ounce/yd<sup>2</sup>
    - Layers:
      - 2 Glass / 3 Carbon (~2/3<sup>rd</sup> of pipe)
      - 2 Glass / 5 Carbon (~1/3<sup>rd</sup> of pipe)
  
- Status
  - Baseline UT scans from OD complete
  - DRS scans from ID: January 2020



# Supplier 3 – Sample Set 1

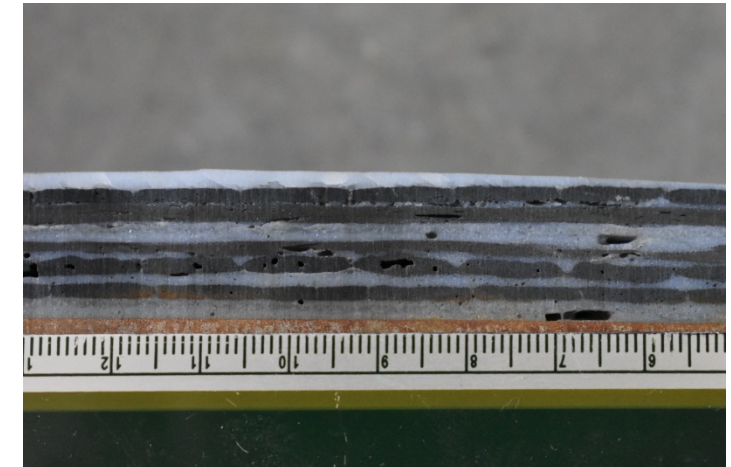
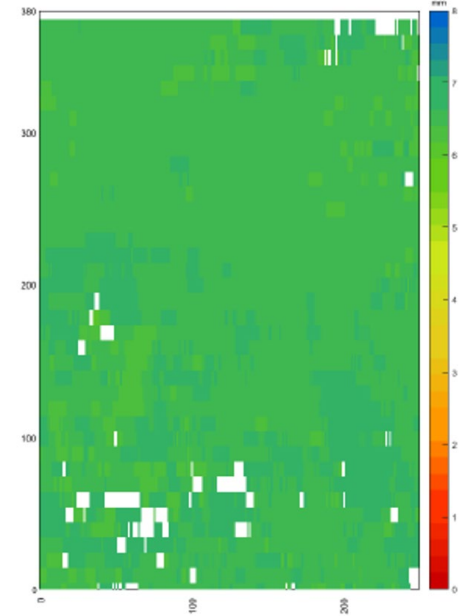


- 15 Carbon Steel Plates
- 12" x 18"
- 0.250", 0.375", 0.500" Thick
- Fabric:
  - Carbon: 42 ounce/yd<sup>2</sup>
  - Glass: 8.6 ounce/yd<sup>2</sup>
- Number of Layers
  - 2 Glass / 3 Carbon
  - 2 Glass / 4 Carbon
  - 2 Glass / 5 Carbon
  - 2 Glass / 6 Carbon
  - 2 Glass / 7 Carbon
- Status
  - DRS Scanning In-Progress (January 2020)
  - Destructive Tests (as-needed) 2Q2020



# 2020 Research Plans

- Plates
  - Destructively section samples in areas of interest indicated by DRS
  - Use as feasibility study for alternative techniques
    - Electromagnetic / eddy current techniques (screening areas)
    - “Conventional” UT technique development
- Pipes
  - Complete DRS scanning
  - Evaluate alternative techniques demonstrated effective on plates
- Deliverable
  - Technical Report: Review of NDE Techniques for Measuring Substrate Thickness Beneath Carbon Fiber Composites
  - 1Q-2Q 2021
  - Interim updates planned through EPRI and ASME meetings



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