Internal Quarterly Report

Date of Report: 6th Quarterly Report – March 31, 2023
Contract Number: #693JK3211RA0001
Prepared for: PHMSA DOT
Project Title: Assessment of Nondestructive Examination (NDE) and Condition Monitoring Technologies for Defect Detection in Non-Metallic Pipe
Prepared by: EWI
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For quarterly period ending: March 31, 2023

1: Items Completed During this Quarterly Period:
The sixth quarterly update was completed during Quarter six. The NDE procedures that were developed, we've added the subcontractors' procedures to the report. These are the procedures EWI and our two NDE subcontractors have used for NDE trials and will be updated based on outcomes in Item 12, task 4.

Item #	Task #	Activity/Deliverable	Title	Federal Cost	Cost Share
11	10	Submit 6th Quarterly Report	6th Quarterly Status Report & Quarterly collaboration meeting	$11,602.45	0.00
4	3	Develop NDE procedures for inspection of NMP samples using non-contact and 3 coupled UT methods, microwave inspection method and 2 thermography methods	Completion of written NDE procedures	$49,331	$20,310

2: Items Not Completed During this Quarterly Period:
EWI has completed the first nine erosion tests and will complete the last round of tests in quarter seven. We were slow to start tests due to pipe and sand material delays, and in autumn 2022 adjusted our approach to erosion testing based on our first trial results and greater discussions with the project partners. But the total test length has remained consistent.
EWI is making steady progress on the NDE work, running tests, adjusting the testing protocols, and rerunning NDE tests to evaluate the pipe. This task will continue on into quarter seven to accommodate procedure shifts. The comprehensive report will follow in quarter eight due to proposed scope and schedule changes.

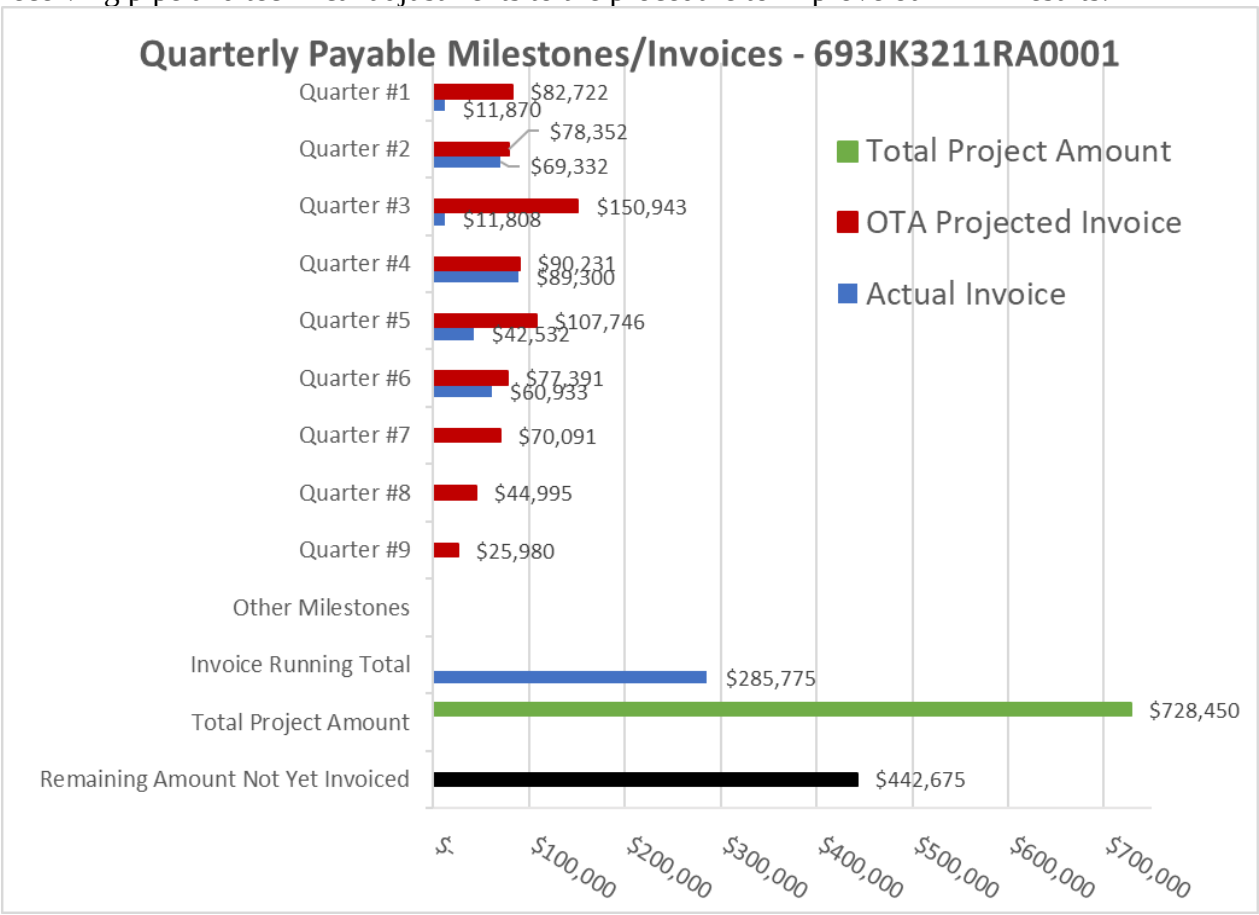
Item #	Task #	Activity/Deliverable	Title	Federal Cost	Cost Share
10	6	Perform inner liner erosion tests & assess NDE detection	Task report summarizing erosion test procedure and results, and NDE inspection results	$95,755.10	1,832.84

12	4	Comprehensive NDE trials on NMP samples and provide report summarizing procedures and initial outcomes	Task report summarizing NDE methods, procedures and initial outcomes.	$47,738.10	$16,707.00
13	4	Task 4 NDE Project Review	Review Progress to review NDE inspection data, outcome, and trends	8,050.00	$0.00

3: Project Financial Tracking During this Quarterly Period:

The actual spend is behind planned.

- Task 6 – EWI has the completed first nine erosion tests and will complete the last round of tests in quarter seven.
- Task 4 (item 12) the comprehensive NDE trials have taken longer to accomplish due to delays receiving pipe and technical adjustments to the procedure to improve our NDE results.



4: Project Technical Status –

Item	Task	Activity/Deliverable	Title
1	10	Submit 1st quarterly report	1st Quarterly Status Report & Quarterly collaboration meeting
2	**1**	Task report summarizing findings of literature review	Literature review of recent research on NDE of polymers & composites - issue task report
3	2	NMP sample matrix detailing type of pipe and defects, anomalies, or damage per sample	Prepare detailed matrix of NMP samples
4	3	Develop NDE procedures for inspection of NMP samples using non-contact and 3 coupled UT methods, microwave inspection method and 2 thermography methods	Completion of written NDE procedures
5	10	Submit 2nd Quarterly Report	2nd Quarterly Status Report & Quarterly collaboration meeting
6	6	Task 6 Test Procedures and Chamber Assembly	Prepare & Provide a Written Test Procedure for Erosion Tests
7	4	NDE Review Progress to date (samples. procedures, early inspection data)	Task 4 NDE Project Review
8	10	Submit 3rd quarterly report	3rd Quarterly Status Report & Quarterly collaboration meeting
9	10	4th Quarterly Status Report	4th Quarterly Status Report & Quarterly collaboration meeting
10	6	Perform inner linear erosion tests & assess NDE detection	Task report summarizing erosion test procedure and results, and NDE inspection results
11	10	5th Quarterly Status Report	5th Quarterly Status Report & Quarterly collaboration meeting
12	4	Comprehensive NDE trials on NMP samples and provide report summarizing procedures and initial outcomes	Task report summarizing NDE methods, procedures and initial outcomes.
13	4	Task 4 NDE Project Review	Review Progress to review NDE inspection data , outcome, and trends
14	10	6th Quarterly Status Report	6th Quarterly Status Report & Quarterly Collaboration meeting
15	5	Complete NDE validation and assessment. Provide task report document NDE results - POD and sizing performance.	Task report summarizing NDE outcomes and discussing viability of various NDE methods.
16	7	Develop in-plant NDE guidance	Develop best practice guide for implementing in-plant NDE methods as a QC/QA tool
17	8	Draft requirements document for developing in-field NMP inspection protocols	Submit field NDE requirements report
18	10	8th Quarterly Status Report	8th Quarterly Status Report & Quarterly collaboration meeting

Task 1 – Literature Review was completed by EWI and NDE4zero's Mark Lozev. The report was supplied to the project team on 3/31/2022.
Task 2 – NMP Sample Matrix. EWI received additional pipes in late June and is updated the Matrix 10/31/2022.
Task 3 – The internal NDE procedures have been developed internally and collected from our subcontractors. A collection of procedures has been provided 3/31/2023.
Task 4 – CT scanning was completed in mid-June on pipe samples that had been received by the project at that time. New pipe samples were received late summer 2022 and CT scanning was completed in December 2022. EWI NDE has begun testing selected pipe samples from this batch of material. The NDE testing, and analysis is underway, data and images were shared at the Q4 meeting on 9/21/22 and Q5 meeting on 12/16/2022. Testing will continue for several months with EWI completing multiple forms of NDE and then sending pipe to subcontracts for additional methods (air coupled UT and Microwave).

Current NDE Testing and CT scanning Summary:

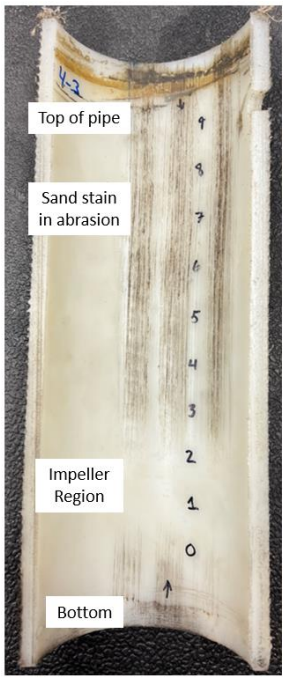
- Immersion UT Conclusions:
    - ID and OD layers can be inspected individually, but core layer has not been detected due to gaps between each material.
- Immersion UT Next Steps:
    - Immersion UT of next set up pipes delivered.
- Thermography Conclusions:
    - Surface markings impact heat transfer observations - Glue from tape and razor marks along pipe obstruct any identification of ID holes or end drilled holes.
    - Clean areas are more easily inspected, however only the outer layer has been observed due to gaps between layers preventing sufficient heat transfer.
    - Interior heating with a halogen lamp has been tested and showed some success in detecting calibration holes. Light source was small compared to the viewing window which did cause only a small portion of the pipe to be evenly heated.
- Thermography Next Steps:
    - Modified heat sources – a longer halogen lamp has been acquired and will be tested to better expose, more evenly distribute heat to the interior of the pipe.

Task 6 – The cost share portion of this task has been completed (Item #6 Task 6): test cells have been built and a test method developed (5/31/2022). The task began in December 2021 and was completed in June 2022. Erosion testing on 5 pipes is completed as of 3/30/2023. The tests were performed over seven weeks. Moving forward the set up needs to be addressed concerning elevated temperature of tests. Periodic inspections showed that a difference was apparent and time on test was adequate for analysis on this first set of tests.

Completed Testing Summary				
Pipe ID	Description	Test Station	Conditions	Time On Test
4-3	Manu 1, white, HDPE liner, steel reinforced	2	1300RPM, RT	54 days
16-1-2	Manu 1, white, HDPE liner, steel reinforced	3	865 RPM, RT	50 days
16-3	Manu 1, white, HDPE liner, steel reinforced	4	865 RPM, 140°F	50 days
5-2-16	Manu 2, HDPE liner, fiber reinforced	5	865 RPM, 140°F	50 days
5-2-2	Manu 2, HDPE liner, fiber reinforced	1	865 RPM, RT	50 days

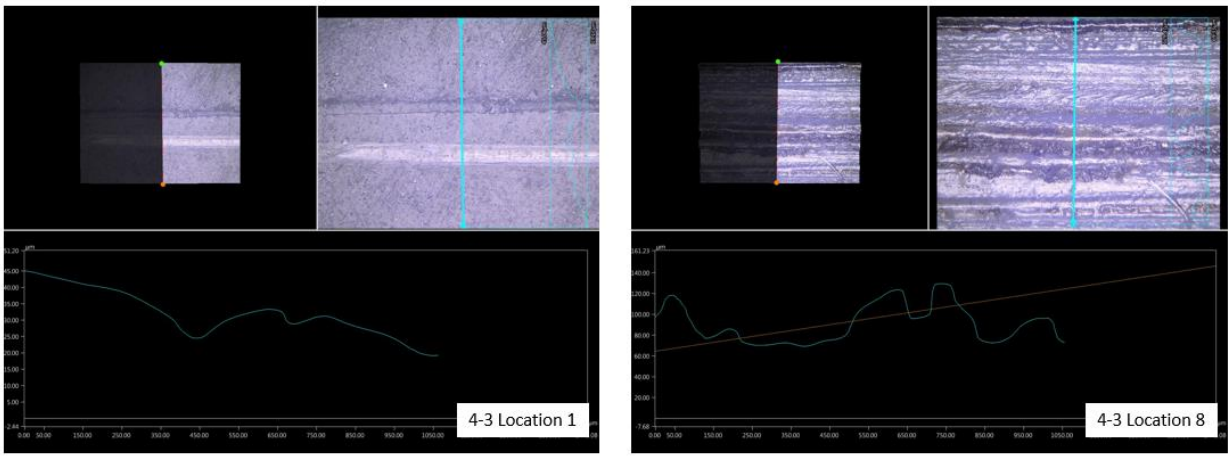
After testing final borescope images were taken for visual comparison. The samples were then submitted for posttest NDE which was completed. The samples were then bisected lengthwise for surface profile analysis.

A Keyence, non-contact profilometer, was used to take images for more detailed visual comparison in approximately 1-inch increments from the bottom of the pipe to the top, in the abraded area. The images show a visual difference in the surface finish, most notably in the location where the impeller was located. The top of the pipe, as expected, had very little physical change as it is an area that was not subject to as much direct sand abrasion during the test. The top of the pipe will be used as the reference baseline to which the impeller region will be compared.



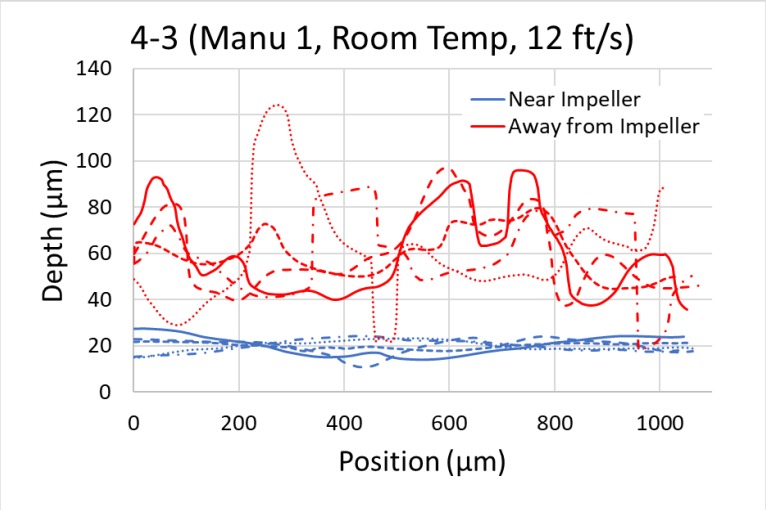
Sample 4-3 post test

To determine erosion rate, Keyence images were taken at 200x magnification, followed by surface profile measurements. This enabled measurements depth of the abrasion and profile of a selected area. 5 profile measurements in slightly different areas of the impeller region (location 1 in above image) were obtained and compared to 5 measurements from the top of the pipe (location 8 in the above image). The difference in the average profiles was determined to be the amount of erosion that has occurred during the test.



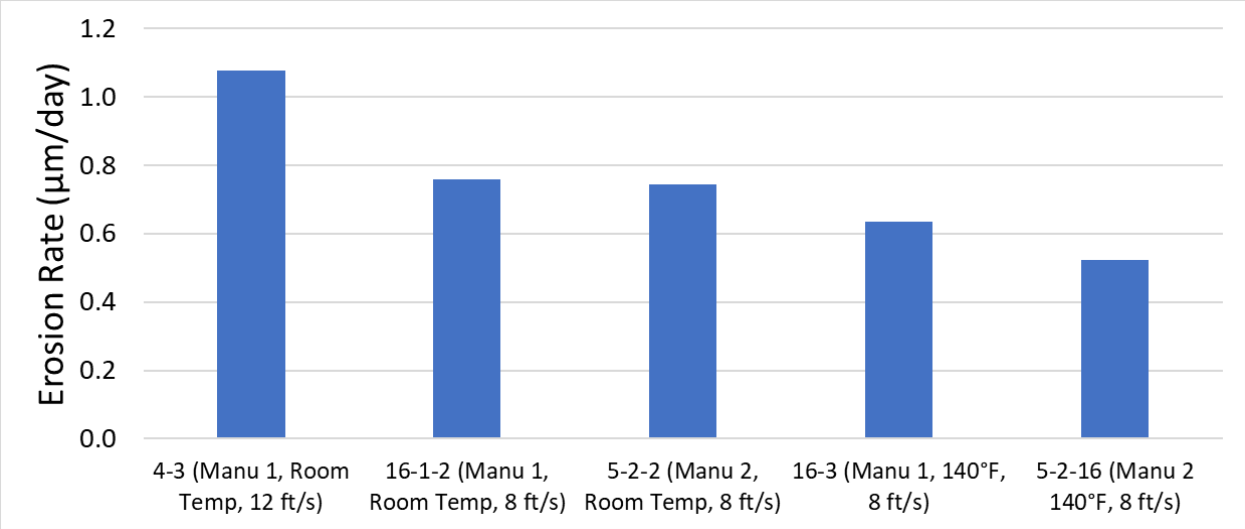
Surface profile analysis in impeller region vs. at top of the pipe

Comparison of the 5 measurements at each location clearly shows the smoothing of the surface in the impeller region. This is interpreted as material loss by erosion, reducing the variance between the peaks and troughs of the scratches induced by our manual abrasion.

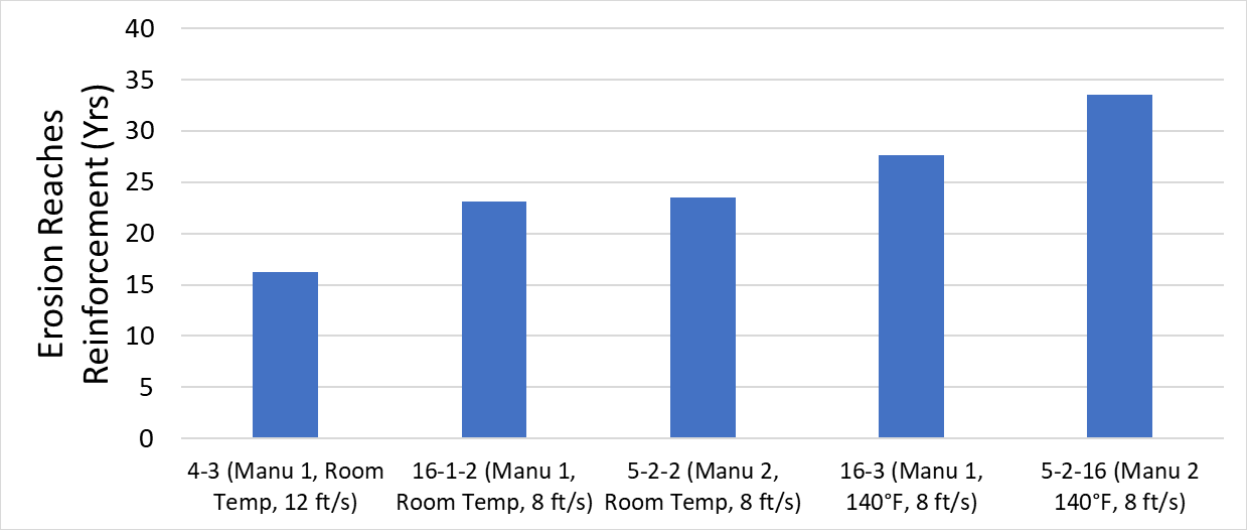


Comparison profile measurements in impeller region and at the top of the pipe.

The difference between the profile measurements and the time under test was used to calculate the approximate wear. For pipe 4-3, the worst-case erosion rate is calculated to be 1.08µm / day as shown below.



Daily erosion rate for completed tests.



Estimate lifetime for completed tests.

The slide above illustrates estimated erosion lifetime based on a hypothetical assessment that assumes failure would be at the point where the 6.4mm thick HDPE inner liner is compromised. While these tests did not extend erosion test duration to fully quantify lifetime, extrapolation of the measured erosion rates suggests failure would not occur in less than 16.3 years at ambient temperature and even longer at elevated temperature. It is important to note that these erosion tests were carried out in an unpressurized condition with an aggressive aggregate and flow rate scenario that may be more aggressive than typical field flow conditions. Regardless, the results are informative in demonstrating some level of erosion is possible, and furthermore, post-test UT wall thickness measurements correlated well with the erosion test conditions. The highest erosion rate occurred in the condition where the velocity of the abrasive sand is above the projected rate of 8ft/s. The erosion rate was lower in the elevated temperature tests as the higher temperatures cause the HDPE to be more ductile and thus less susceptible to the impact of the flowing sand particles.

It should be noted that this would be considered a worst-case scenario. The erosion rate in a smooth pipe, without an abraded surface, should be much less as there would be less friction generated between the sand and the pipe wall.

Task 10 – The 1st quarterly status report was provided on 1/4/22. The 2nd quarterly status report was provided on 3/31/2022.The 3rd quarterly status report was provided on 6/30/2022. The 4th quarterly status report was provided on 9/30/2022. The fourth quarterly collaborative meeting occurred on 9/21/2022. The Fifth quarterly meeting was hosted on 12/16/22 with its quarterly report submitted on 1/4/2022. TAP attended two meetings 7/13/2022 and 11/29/2022, TAP was invited to the quarterly meeting on 12/16/2022 and these meetings will be combined going forward. The 6th quarterly meeting occurred 3/30/2023.

The next quarterly meeting will occur in June 2023 pending Doodle poll feedback. It will be scheduled for ~2 hours, please see upcoming Doodle calendar poll.

While not tied to a specific milestone during the last quarter, the following activities were undertaken:

(1) Two companies have formally joined the PHMSA partnership.

(2) EWI followed up with two other companies about joining the partnership. They have gone back and forth with NDA redlines and have verbally confirmed their partnership plan but has not provided any documentation.

(3) EWI has submitted a change request to PHMSA to accommodate additional partners, pipe testing, and added scope of work to the testing plan with corrosion and mechanical damage.

5: Project Schedule –

While the project scope is on target the timeline has shifted back due to delays of pipe materials, the matrix, and NDE subcontractor procurement issues – the quotes came back 10X higher than in our initial estimates. The adjustments to our schedule are highlighted in yellow below.

Task	Description	Quarter								
		1	2	3	4	5	6	7	8	9
1	Literature Review & Report	X	X							
2	Selection, Procurement & Preparation of Pipe Samples	X	X	X	X	X				
3	Draft NDE Procedures		X	X	X	X				
4	NDE Trials			X	X	X	X	X	X	
5	NDE Validation & Assessment								X	X
6	Characterization of Erosion Properties and Detectability			X	X	X	X	X		
7	Development of NDE Procedures and Best Practice Guide								X	X
8	Establish Field Inspection Requirements									X
9	Virtual Workshop								X	X
10	Progress Meetings (virtual and in-person)			X			X		X	
	Annual Review				X				X	
	Quarterly Progress Reports	X	X	X	X	X	X	X	X	X
	Final Report								X	X
PM	Program Management	X	X	X	X	X	X	X	X	X

PHMSA and EWI have spoken about expanding the project to include additional samples from our added partners, these tasks and costs have been estimated and a change request to expand the project scope, budget, and timeframe are under review by PHMSA. The final timeline will be impacted by the change request approval as well as pipe availability to EWI to complete additional CT and NDE testing.