

Internal Quarterly Report

Date of Report: 12th Quarterly Report – September 30, 2024

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: September 30, 2024

1: Items Completed During this Quarterly Period:

The Twelfth quarterly update meeting will be held virtually on October 3, 2024.

Activity during Q12 focused on targeted ultrasonic inspections of three pipe samples in the unpressurized and pressurized conditions. These three pipe samples were manufactured such that the various internal layers were not bonded (i.e., commonly referred to as unbonded pipe). Earlier NDE results from this program highlighted difficulties in generating full through-wall UT signals in unbonded pipe due to the intermittent gaps that commonly occur between the various layers in the composite pipe wall.

A final set of additional pipe samples that had been anticipated since early fall of 2023 were delivered to EWI in February 2024. Initial baseline NDE scans were completed on selected samples of these additional pipes in Q11. One of these additional pipes along with two types of previously examined pipes were selected for the more detailed unpressurized and pressurized NDE inspections in Q12.

The three pipe samples selected for inspection trials with internal pipe pressure consisted of an unbonded pipe construction. The NDE methods chosen for these inspections include conventional UT and air coupled UT (ACUT). Originally, a third-party vendor had been under contract to provide ACUT services to the project. As noted in previous quarterly reports, a lack of performance by this vendor necessitated EWI cancelling the vendor's contract and acquiring suitable ACUT equipment and perform these trials in-house. Procurement of that equipment and initial validation inspection trials were undertaken in Q12. At time of preparation of this report, those ACUT initial trials and validation are nearing completion. Consequently, the inspection of the three pressurized pipes in Q12 have centered on traditional UT methods. Initial ACUT scans have been completed and are currently undergoing analysis.

Item #	Task #	Activity/Deliverable	Title
32	10	Submit 12 th Quarterly Report	12 th Quarterly Status Report
29 (previously 21)	11	Summary Report	Inspections of Wrapped composite pipe (includes pressurized scans)

2: Items Not Completed During this Quarterly Period:

EWI completed the initial scans on both unpressurized and pressurized pipes for the mechanical Damage Summary reports. We are finishing off the damaged portions. A preliminary report is provided. EWI has faced challenges with NDE technology designed for metal pipe providing useful results with non-metallic pipes. Due to this, additional scans were completed while the pipe was pressurized to increase the NDE reports and provide a more detailed Mechanical Damage report.

Item #	Task #	Activity/Deliverable	Title
19	12	Mechanical Damage Summary report	Mechanical Damage Added scope

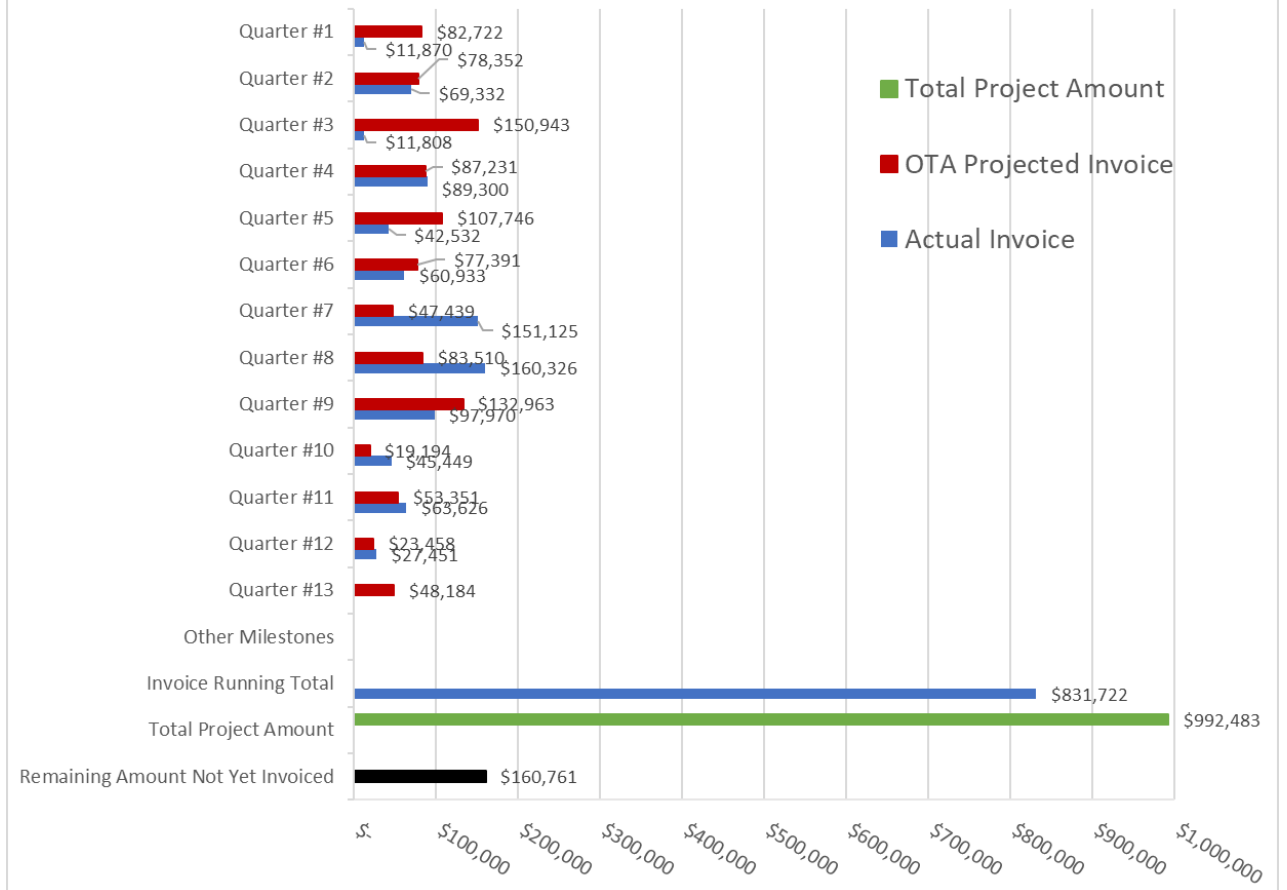
Results from the conventional UT scans of the three pressurized pipe samples are undergoing detailed analysis and interpretation. Initial scan results from the OD suggested through-wall inspection was still not possible even with internal pressure at 500 psi. This suggests gaps between the reinforcement layer and outer jacket may remain even though the pipe has internal pressure. It is believed based on feedback from pipe manufacturers that gaps between the inner liner and the reinforcement layer are eliminated with 500 psi pressure. Gaps remaining between the reinforcement and the outer jacket would not be surprising since the reinforcement is designed to withstand pressure in excess of 500 psi in these pipes and the stiffness of the reinforcement is not likely to be compromised at 500 psi. Regardless, some of the NDE scans may hold some evidence better through wall propagation of the sound waves although more detailed assessment is necessary to confirm. Further inspection trials will be made using ACUT, which may have fewer limitations with any gaps between the outer jacket and reinforcement layers. These trials will be undertaken in Q13 to be followed by inspection trials on the same three pipes after inducing targeted localized damage (kinks, gouges, slits, etc.). As noted in previous quarterly reports, completion of the intentional pipe damage matrix was planned for Q9 but was put on hold to allow the expected new pipe samples to be part of this sample set and to allow incorporation of ACUT as an inspection method to be used for assessing pipe damage. As the pressurized pipe inspections come to a completion, the pipe damage matrix can be finalized and implemented early in Q13. It is important to confirm what portions of the pipe wall can be adequately inspected using conventional UT, ACUT prior to inducing targeted damage. For example, if full through-wall inspections are not possible, designing the type and location of targeted damage to location that are inspectable is important.

Completion of the pipe damage trials, and associated inspections will complete the laboratory effort in this program. The pipe damage trials will also provide valuable inspection samples for quantifying defect detection, characterization and sizing accuracy. Beginning in Q13, statistical assessment of the results of all inspections performed over the course of the program will be undertaken. The results will give insight to which NDE methods are viable for in-plant QA/QC operations and which method(s) hold promise for possible in-service field inspection.

3: Project Financial Tracking During this Quarterly Period:

The actual spend is behind planned. This is due to a combination of pipe delays, contract modifications, and challenges faced with the most recent NDE at pressure scope of work. EWI has used three methods to hold pressure without success. EWI used another approach in July and was able to successfully pressurize the pipes. With this success the inspection of wrapped composite pipe was completed and new preliminary scans for the mechanical damage were finished. EWI is focused on completing the remaining NDE scans and final reporting during Fall 2024.

Quarterly Payable Milestones/Invoices - 693JK3211RA0001



4: Project Technical Status –

Item	Task	Activity/Deliverable	Title
1	1	Task report summarizing findings of literature review	Literature review of recent research on NDE of polymers & composites - issue task report
2	2	NMP sample matrix detailing type of pipe and defects, anomalies, or damage per sample	Prepare detailed matrix of NMP samples
3	10	Submit 1st quarterly report	1st Quarterly Status Report & Quarterly collaboration meeting
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 2 nd Quarterly Report	2 nd 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 3 rd quarterly report	3 rd Quarterly Status Report & Quarterly collaboration meeting
9	10	4 th Quarterly Status Report	4 th Quarterly Status Report & Quarterly collaboration meeting
11	6	Perform inner linear erosion tests & assess NDE detection	Task report summarizing erosion test procedure and results, and NDE inspection results
12	10	5 th Quarterly Status Report	5 th Quarterly Status Report & Quarterly collaboration meeting
13	4	Comprehensive NDE trials on NMP samples and provide report summarizing procedures and initial outcomes	Task report summarizing NDE methods, procedures and initial outcomes.
14	4	Task 4 NDE Project Review	Review Progress to review NDE inspection data, outcome, and Trends – completed June 2023, reuploaded 2024
15	10	6 th Quarterly Status Report	6 th Quarterly Status Report & Quarterly collaboration meeting
16	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.
17	10	Submit 7 th Quarterly Report	7 th Quarterly Status Report & Quarterly collaboration meeting
18	12	NDE Report Update	Additional NDE effort predamage
19	12	Mechanical Damage Summary	Mechanical Damage Added scope
21	10	Submit 8 th Quarterly Report	8 th Quarterly Status Report & Quarterly collaboration meeting
22	13	Corrosion Damage summary Table	Corrosion Damage Added Scope

24	10	Submit 9 th Quarterly Report	9 th Quarterly Status Report & Quarterly collaboration meeting
27	10	Submit 10 th Quarterly Report	10 th Quarterly Status Report & Quarterly collaboration meeting
27	10	Submit 11 th Quarterly Report	10 th Quarterly Status Report & Quarterly collaboration meeting
29	11	Summary Report	Inspections of Wrapped composite pipe (includes pressurized scans)
30	11	Air Coupled UT Microwave NDE report	Microwave NDE subcontractor added & EWI Air Coupled UT effort
32	10	Submit 12 th Quarterly Report	12 th Quarterly Status Report

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 from two new project team members in December and in mid-February. The Pipe Matrix spreadsheet was updated 3/6/2024.

Task 3 – A revised internal NDE procedures report was prepared in February 2024 to update the original procedures with advancements that have been identified during this program. A revised compendium of NDE procedures was issued February 2024.

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.

Initial air coupled UT (ACUT) scans were completed by Airstar in March-April 2023. Methods for ACUT sensor calibration, determination of sensor offset distances and scanning direction have been identified. Early observations suggest good sensitivity for detecting minor manufacturing anomalies and for dealing with typical pipe eccentricity and dimensional variances (wall thickness variability, air gaps in unbonded pipes, etc.). Unfortunately, data analysis and reporting by Airstar has not been completed and attempts to maintain communication with them have failed. EWI has subsequently decided to remove Airstar as a project subcontractor and has procured the necessary equipment to complete the ACUT scans internally. EWI procured an additional air coupled probe from Microacoustics to work in a pitch catch mode with the existing air coupled probe at EWI. Initial inspection in pitch catch mode from the outer surface indicates sound is only interacting with the first layer and not penetrating through all layers of unbonded pipe. However, in through transmission mode all three unbonded layers pass sound from transmitter to receiver. Improved pitch catch setup and procedure is being developed to determine angle of incidence and position of receiver to catch refracted waves. Attenuation in through transmission mode was substantial, therefore higher attenuation is expected after passing through the pipe wall in reflection.

All NDE work at EWI has been done without internal pressure prior to Q12. This can reduce sensitivity due to natural air gaps that can occur between the inner liner, reinforcement, and outer jacket in unbonded pipe when unpressurized. Initial pressurized pipe inspections were undertaken in Q12 on three different types of composite pipe – all consisting of an unbonded construction method that commonly results in small gaps intermittently located between the various layers making up the pipe wall. . Custom end flanges have been produced to seal the ends of the test pipe segments and allow

filling with water and subsequent pressurization. A target pressure of 500psi was applied and maintained for ultrasonic inspection in each pipe. Single element ultrasonic transducers were used in pulse echo mode on the outer jacket to inspect the pressurized pipes and determine if sound could be transmitted beyond the first layer, reflected, and received by the same transducer. Reflections beyond the outer jacket were not detected. Air coupled UT will also be tested while the pipes are under pressure with the pair of probes focused on the outside surface for a pitch/catch arrangement.

A final NDE report will be provided following completion of the pipe damage task in Q1. This report will include documentation about the various NDE methods used in this program, present final results and observations, and discuss factors that either aid or inhibit feature or flaw detection, sizing and characterization for the types of NMP included in this program.

In Quarter 8 EWI completed microwave NDE testing with Evisive LLC using 24GHz probes. Non-metallic pipes were fully volumetrically inspectable using Microwave NDE. Four pipes were scanned from the outside while mounted on a rotating lathe-type unit with probes mounted to a linear stage for testing. This inspection will be repeated on pipe segments that undergo damage testing at EWI.

Task 6 – The entire erosion task has been completed. The cost share portion of this task was completed 5/31/ 2022 (Item #6 Task 6): erosion test cells have been built and a test method developed. The task began in December 2021 and was completed in June 2022. The federally funded portion of this work began in August 2022. Erosion testing and analysis on a total of nine pipes from three manufacturers has been completed and NDE inspections were completed in September 2023 which completes the federally funded portion of this task. To provide a realistic configuration where the flow path of the sand is in the same direction as pipe scratches and defects, EWI completed a test where a pipe was abraded internally circumferentially in line with the flow path of the sand. Post test analysis of the change in surface scratches was performed to approximate the amount of erosion that was induced by the impeller and sand throughout the test.

The goal of this testing is to create a laboratory scale representative test to be able to quantify internal pipe erosion and erosion rate. This data will be able to be used to create a lifetime use prediction model for the NMP.

A final task report was issued in October 2023.

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 7th quarterly report was completed on 6/29/2023. The 8th quarterly meeting is scheduled for 10/6/2023. The most recent quarterly report on 9/30/2023 was the 8th quarterly report. The quarterly meeting planned for December 2023 we eliminated based on feedback from PHMAS and the delayed pipe samples to conserve funds for 2024. EWI resumed meetings in 2024 on Wednesday March 24th and completed our 11th quarter meeting on June 25th. The 12th quarter meeting will be virtually held on October 3rd, 2024.

Task 13 – Non-destructive evaluation of corrosion of a steel reinforced non-metallic pipe was performed intermittently over a period of 41 days. Corrosion was targeted in two locations of the pipe:

a small hole on the outer jacket and a small hole on the inner jacket exposing the steel wire. Prior to corrosion, a full 360-degree inspection was performed on the outside of the pipe and a 120-degree inspection was performed on the inside of the pipe. At the end of the corrosion study with ultrasonic inspection an infrared video was recorded for 40 seconds or more to capture the heat transfer through the pipe and the steel wires.

Results were presented at the October 5, 2023, quarterly review meeting. During this meeting, a preliminary plan was proposed by EWI to expand on this effort to more fully quantify NDE detection thresholds for locating embedded corrosion damage, but project team members felt this was not needed at this stage. Future trials may be warranted but team members suggested the project focus remain as is to assess manufacturing anomalies and mechanically induced service damage.

5: Project Schedule – The project schedule has been updated to incorporate the modification requested in March 2023 and awarded in June 2023 as well as the project modification in March 2024.

Below is the Updated Project Schedule:

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