Quarterly Report No. 4

Slow Crack Growth Evaluation of Vintage Polyethylene Pipes

DOT Project No.: 643
Contract Number: DTPH5615T00007

Reporting Period: 4th Quarterly Report

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1. Objectives

This collaborative program will provide an integrated set of quantitative tools that will provide a structured approach to reducing operational risk in vintage plastic distribution systems susceptible to Slow Crack Growth failures. A novel endoscopic structured light scanning tool will be developed and prototyped for internal inspection of small diameter plastic pipe. The data generated by the tool will be properly reduced to essential parameters to be synthesized with additional available system information including external conditions, inspection and leak records, historic data, and subject matter expertise into a fitness for service evaluation. This assessment will include a probabilistic estimate of the remaining effective lifetime of individual segments of vintage plastic pipe and a yes/no determination of whether a short-term pressure test is capable of validating the maximum defect size in the system. The Bayesian network methods employed are ideally suited to evaluating interacting threats, investigating root causes, and predicting the effect of mitigation strategies based on conditional probabilities calculated from available data.

2. Work Completed During Reporting Period

Work in this quarter included:

- Task 1: Probabilistic Decision Support System Design – The structure of the Bayesian network was revised based on the casual relationship derived from the collected data. The types and states of each node are reasonably assumed to accurately capture the physical phenomenon.
- Task 2: Probabilistic Decision Support System Development:
    - The models developed in quarter 3 report were incorporated in the Bayesian network.
    - Non-linear FEM models were created to compute the stress intensity factor induced by pipeline bending and saddle fitting. A generalized stress intensity factor model was proposed based on the simulation results.
    - The node probability tables for all the critical nodes have been created and they will be continuously refined when new data becomes available.
    - Non-linear FEM models were created to compute the stress intensity factor induced by minor to major scoring of the pipe inner diameter during the extrusion process. The results can be extended to scoring of the inner wall by post installation events.
    - A detailed analysis of historic reference data sets for ductile failure and slow crack growth failure of Aldyl A pipe was undertaken:

- 450 data points covering control pipe, LDIW pipe, LDIW pipe with indentation and squeezed-off pipe were extensively analyzed
- A Stress Intensification Factor (SIF) approach was developed to explain data spread
- Equivalent SIF distributions were developed for all of the known Aldyl A material categories, squeeze-off and impingement
- The SIF were used to calculated expected lifetimes using the Aldyl A control RPM model and a 0.9 correlation to actual test results at all temperatures, stress levels, loading conditions and material categories was calculated
- A damage propagation approach utilizing the control RPM model and the SIF distributions was used to develop models for crack propagation and crack initiation times as a function of SIF and operating pressure
- The Crack initiation and crack propagation based total time to failures calculated have a 0.85 correlation to actual failure times
- Actual data for Aldyl A has a factor of 50 variation in expected lifetime at a given stress level from worst to best in the control data set. The SIF based lifetime expectancy approach reduces this to a factor of 2 variation i.e. an order of magnitude improvement in prediction capability.
- These models provide a closed form solution to assessing the effectiveness of pressure tests and will form the basis of pressure test guidelines

- Task 3: Structured Light Scanning Method Development – is continuing to schedule
- Task 4: Bayesian Methods Development – is continuing to schedule
- Task 6: Project Management Activities – Standard project management activities were performed

3. Payable Milestones and Planned Activity

Figure 1 shows the quarterly payable milestones to the end of the project.

The project manager duties have been taken over by the principal investigator due to the PM leaving GTI for new opportunities elsewhere. The transition of PM activities is close to complete. In addition, The PI at UCD has moved to Michigan State University and we are completing the termination of the UCD sub-contract and opening a new sub-contract with MSU. All planned work for the structured light scanning tool will be completed at MSU.

A detailed review of milestones met will be prepared in October and an invoice will be submitted to cover deliverables up to Quarter 4.

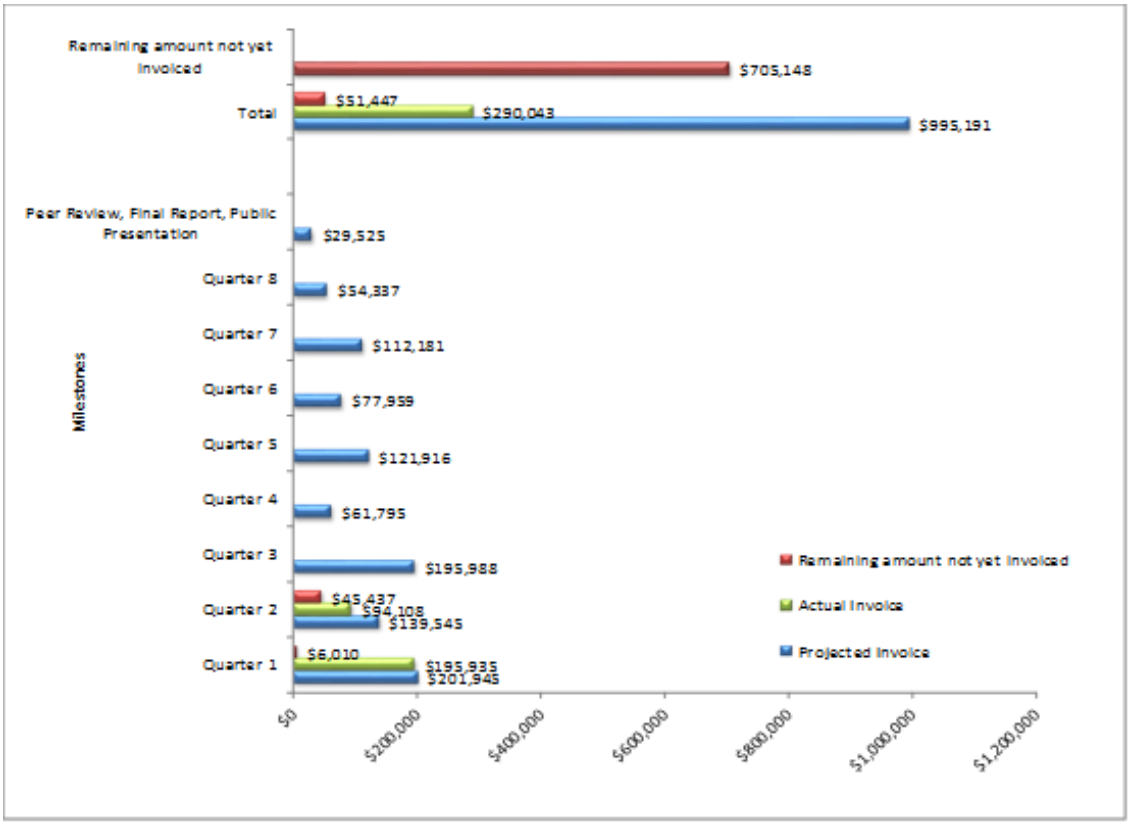

*Figure **Error! No text of specified style in document.**.1. Quarterly payable milestones*

4. Plans for Future Activity (Project Quarter #5)

1. Task 1: Probabilistic Decision Support System Design – Continue refining system per the milestone schedule. No problems anticipated based on current progress.
2. Task 2: Probabilistic Decision Support System Development – Work will continue refining the node probability table and quantitative mapping between nodes. No problems anticipated based on current progress.
3. Task 3: Structured Light Scanning Method Development – No problems anticipated based on current progress.
4. Task 4: Bayesian Methods Development – No problems anticipated based on current progress.
5. Task 6: Project Management Activities – Standard project management activities will be performed.
6. A joint project meeting will be held at GTI on October 17th
7. The transfer of the UCD contract to Michigan State University will be completed