Acoustic Pulse Reflectometry For Identifying Pipeline Properties At Hanford Site

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Background

- Currently, there are approximately 200,000 m^3 of radioactive waste in the 177 underground storage tanks located at the U.S. Department of Energy's Hanford Site
- Storage tanks are corroding, thus hazardous waste must be transported via pipelines
- There are over 8 miles of pipelines in Hanford's C Tank Farm alone
- During transportation of waste, these pipelines become plugged

Introduction

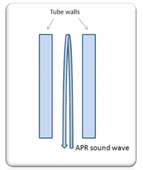
- Acoustic Pulse Reflectometry (APR) is a technique that measures the reflections of a given pulse
- The technology has primarily been applied to tubular systems
- Broadband acoustic pulse is injected into semi-infinite straight-walled tube
- An acoustic/ultrasonic transducer measures the reflected signal
- Conclusions can be drawn from the alterations in the reflected signal

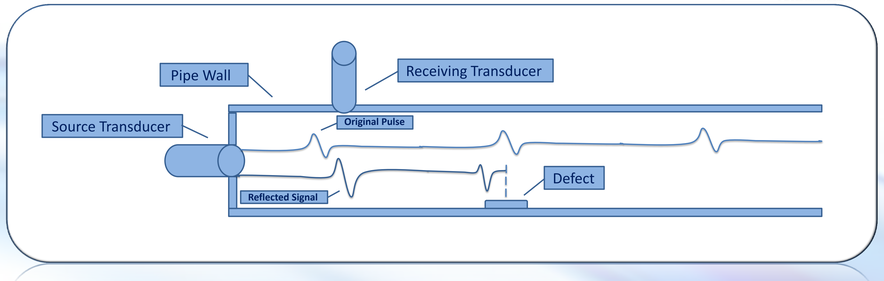
Methodology

- An acoustic pulse is produced by a transducer that is attached at one end of the straight walled tube
- The acoustic pulse propagates down the straight-walled tube
  - No cross sectional discontinuities = No reflections
  - Cross sectional discontinuities / Geometric changes = Reflections
- A small acoustic/ultrasonic transducer with its front surface flush with the internal tube wall measures reflections
- Plot Pulse Return vs. Distance and compare to reference measurement
- Amplitude and form of reflection will vary depending on characteristics of discontinuities, i.e. constriction, expansion or leak
- Time delay will determine location of discontinuity

Design & Implementation

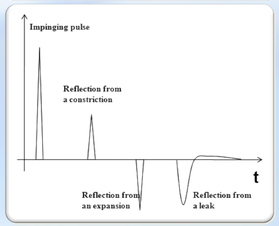
- Design Is Not Complex: Simple design, difficult result interpretation
- Wave Flexibility: Acoustic waves are able to propagate through most mediums in Hanford Site's hazardous waste pipelines
- Implementation Is Feasible: May be attached to any tubular system



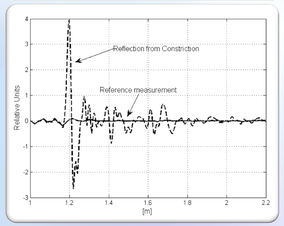


Result Interpretation

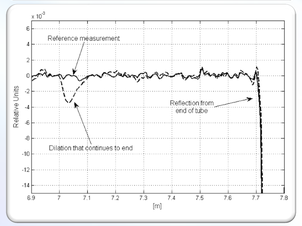
Signal Response in Theory



Constriction Reflection

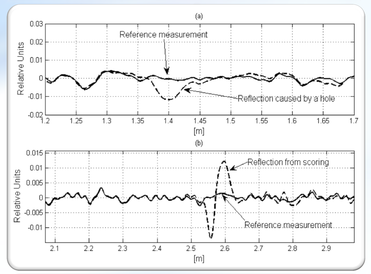


Expansion Reflection



- Result Interpretation is by far the most important part of the implemented system
- Pulse propagates near the speed of sound; this varies by medium & temperature in the straight walled tube
- A conversion from time to distance is made
- Amplitude and shape of reflected signal determines defect
- Detection as low as 0.2 mm in diameter change
- Tests consume minimal time, i.e. A 1km pipe's data acquisition test takes less than 10 seconds

Hole & Scoring Reflection



Complications

1. Pulse Shape: Should be ideally a delta impulse; this implies zero ringing and infinite bandwidth
2. False Reflection Due to Transducer: Any reflection will propagate past the receiving transducer and will also reflect off the source transducer
3. Signal Overlap: Reflections now coming from both directions of the tube may overlap over the receiving transducer
4. Low Noise Requirement: Utilization requires limited-to-no active noise sources above sensitivity of system

Solutions

1. Use high precision transducer to produce clean delta-like signal pulse
2. Although not practical, place transducer in non-defective tube longer than tube being tested such that, in one test cycle, no false reflections occur
3. Utilization of artificial neural networks to improve pipe defect detection for various lengths
4. Develop and use a signal processing algorithm to neglect false reflection due to transducer as well as signal overlaps over receiving transducer
5. Carefully study and interpret results as every system will slightly vary

Conclusion

- Non-invasive technique
- Portable; can be integrated into existing non-invasive pipeline unplugging technologies
- Able to detect partial plugs, full plugs, corrosion, changes in geometry and leaks
- Compatible for use at Hanford Site's pipeline assessment
- May prevent soil contamination if leak or corrosion is detected
- May prevent full plugs if partial plugs are detected and action is taken

References

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- "Acoustic Pulse Reflectometry For The Measurement Of Tubular Structures", Thomas J. MacGillivray, Clive A. Greated, Journal of Acoustical Society of America, February 1999, Vol. 105, No. 2, Pt. 2, pp.1143

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