NYSEARCH PIPELINE SAFETY UPDATE

September 2013
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NYSEARCH Members

- CHG & E
- Con Ed
- Corning
- NGrid/Keyspan
- National Fuel Gas
- NGrid/Niagara Mohawk
- NYSEG
- O & R
- RG & E
- St. Lawrence

- Enbridge Gas
- BG & E
- PSE&G
- PECO Energy
- Questar
- Washington Gas Light
- SoCal Gas
- PG & E
- SouthWest Gas
- XCel Energy
- El Paso/ Kinder Morgan
SAMPLE COMPLETED PIPELINE SAFETY PROJECTS
Inspection Tool for Unpiggable Pipes (M2001-014)

- Develop inspection tool for 20”-26” unpiggable natural gas pipelines
  - Robotic device with state-of-the-art MFL sensing capabilities
  - Tetherless, on-board batteries, wireless communication with operator
  - Able to negotiate all obstacles in pipelines, including plug valves
  - Launching, inspection and retrieval under live conditions

- Project part of a larger effort that has resulted in the commercialization of a range of tools for the inspection of such pipelines
  - Explorer 6/8
  - Explorer 10/14
  - Explorer 20/26

- Under development are:
  - Explorer 16/18
  - Explorer 30/36
Inspection Tool for Unpiggable Pipelines (M2001-014)

- Workscope
  - Phase I: Feasibility studies
  - Phase II: Concept validation
  - Phase III: Preliminary design
  - Phase IV: Design and prototype construction
  - Phase V: Sensor design and sizing algorithms
  - Phase VI: Tech Transfer - platform and sensor redesign
  - Phase VII: Commercial system design and field testing - Commercialization
Inspection Tool for Unpiggable Pipes (M2001-014) (cont.)

• Results
  • Three platform generations built and tested
  • Two sensor generations built and tested
Inspection Tool for Unpiggable Pipes (M2001-014) (cont.)

• Results (cont.)

  • Successful tech transfer from Automatika to Invodane

  • Lengthy process to ensure proper transfer of IP, hardware and software

  • Review of design and operational issues resulted in redesign of system to improve robustness, reliability and operational efficiencies
Inspection Tool for Unpiggable Pipes (M2001-014) (cont.)

Results (cont.)
- Successful system testing
  - Two tests at Test Bed
  - Four live field tests
    - SoCalGas in May 2011
    - Questar in September 2012
    - Enbridge in December 2012
    - Questar in May 2013

Successful commercialization
- Services being offered in N. America to members and non-members through Pipetel Inc.
Robotics Supporting Technologies (M2011-006)
Mechanical Damage Sensor
Robotics Supporting Technologies (M2011-006)
Mechanical Damage Sensor (cont.)

• Deliverable: Working optical system integrated into Explorer 20”-26”

• Status:
  • System built and tested in the lab
  • Underwent live field deployment in May 2013 in Lehi, UT (Questar)
Robotics Supporting Technologies (M2011-006)  
Mechanical Damage Sensor (cont.)

- Laser system on camera module illuminates the pipe
- Three high resolution cameras on modified camera module provide the imaging
- Three-spot system from cameras provides reference point for position of system
- Full 3-D resolution of dents at 25 frames per second
- Data from sensor to be integral part of data analysis software
Robotics Supporting Technologies (M2011-006)
Mechanical Damage Sensor (cont.)

• System resolution:
  • 0.03125” (1/32”) dent height
  • 0.4 inches in axial resolution at 30 frames/sec and 4 in/sec tool speed

• Data processing software nearing completion

• X 30/36 MDS is currently completing development
Robotics Supporting Technologies (M2011-006)  
Mechanical Damage Sensor (cont.)

- Example of Mechanical Damage Usage
  - Questar run statistics
    - 2 Runs (May 14, May 17)
    - Questar Gas, FL-026 East and West
    - Total 1,674 ft inspected
    - No dents observed
    - Data processing ongoing
Robotics Supporting Technologies (M2011-006)  
Mechanical Damage Sensor (cont.)

Questar MDS Typical Data – 10ft
Robotics Supporting Technologies (M2011-006)  
In-Line Charging

• Develop a system to recharge the batteries of the Explorer family of platforms while the robots are in the pipeline

• Deliverable: Working commercial grade system
  • For smaller platforms, the recharging is done via batteries; for larger platforms via a novel in-line generator system

• Status: Completed; first commercial field deployment of tool in May 2013
Robotics Supporting Technologies
In-Line Charging (cont.)

• Utilizes standard 2” hot-tap to connect the robot to the recharging system
• Same hot tap is used to insert antenna in the pipe to extend the wireless range of the system
• System results in great improvements in range of robots without having to install additional launcher/retrieval stations
Robotics Supporting Technologies
In-Line Charging (cont.)

For larger sizes an induction coupler with hydraulic drive is used instead of batteries; entire system under pressure for safety
Magal (Senstar) Damage Prevention Monitoring (M2008-001)

Objective of NYSEARCH Program

- Develop the Advanced PipeGuard™ system for distribution pipeline applications and achieve consistent and reliable remote alarm notifications.
- Target goals of < 1% false alarm and third party detection in ≤ 250 feet < 2 minutes.
Advanced PipeGuard™

- Description
  - Series of geophones tuned to detect third party excavators
  - Senses ground vibrations
  - Wireless remote communications

- Features
  - Battery powered - 5 yr life
  - Up to 1000 feet of coverage w/ two sensing units
  - Requires external antenna
  - Detect excavating events only
  - A single control box can handle up to 30 sensing units
Two test sites installed and in full operation - 2012

Typical user interface
Located at company Control/Dispatch Centers

National Grid
Stony Brook, NY

Con Edison
Valhalla, NY
Magal (Senstar) Damage Prevention Monitoring (M2008-001)

Results

• Project goals achieved
• Cost benefit analysis
  • 3 mile coverage – installed cost ≈ $73K/mile
• Recent hardware upgrades
  • High Gain Antenna
  • High performance batteries
PE Repair – Variable Length & Butt Fusion Repair Sleeve (M2000-001)

Objective of NYSEARCH Program

• Develop 4” and 6” variable length repair sleeves (VLRS) and 4” and 6” Butt Fusion Repair Sleeves (BFRS) for PE Piping (124 psig design)

• Conduct lab tests in accordance with ASTM requirements and commercialize all four sleeve designs

FINAL VLRS 180 – 6” DEMONSTRATION

1 ¼” Hole – Repaired by 6” Variable Length Repair Sleeve

Failure – In Pipe Wall Outside 6” Repair Sleeve
6” BFRS/VLRS Specifications

- Material PE 100 – TUB121 resin
- No-blow conditions only
- Fitting length – 8.5” (same as 4”)
- MAOP & fusion times similar to 4” design
- Meet all ASTM/NatGrid requirements
- Meet NYSEARCH testing needs
- Single fitting max. damage length–5.5”
180° VLRS

Total installation and electrofusion time – 30 minutes

Cut section showing repair

Passed all ASTM Tests – approved for PE pipe gouge
PE Repair – Variable Length & Butt Fusion Repair Sleeve (M2000-001)

Project Results

- Commercialization of 4” BFRS in December 2011
- Commercialization of 4” VLRS in December 2012
- Commercialization of 6” VLRS & BFRS June 2013
- Final test data (photos) and fittings distributed to funders
Butt Fusion Integrity (M2006-002)

• Background

  • Industry standards (ASTM, PPI) provide a broad acceptable range of butt fusion (BF) joint parameters

  • It was unknown if there were optimum and specific BF joint parameters to provide the longest life, highest integrity joint

  • Evaluate nondestructive examination (NDE) techniques to interpret overall BF joint integrity
Butt Fusion Integrity (M2006-002)

- **Objective** – Determine the optimal BF parameter to provide high integrity joint performance

- **Cost** – Total Funding $835,206
  - NYSEARCH Funding $417,603
  - PHMSA/DOT Cofunding $417,603

- **Workscope** – Perform BF joining over a wide range of parameters. Test joints to failure, determining their overall projected life span and integrity
Butt Fusion Integrity (M2006-002)

**Results**
- Optimized butt fusion parameters were revealed and statistically confirmed
- The final report provides butt fusion parameters that will provide improved long term performance and joint integrity
- ASTM D2513 has not accepted suggested updates

**Recommendations**
- Revise internal BF procedure standards and procedures to reflect the optimized BF parameters revealed from this study
- Continue NDE evaluation to determine BF integrity
SAMPLE ONGOING PIPELINE SAFETY PROJECTS
Kiefner Interacting Threats Project

Objective & Threats/Risks

• Identify and quantify effects of interacting threats

• Incorporate consensus-based methodology into Kiefner risk assessment model and develop stand-alone spreadsheet for use in other risk modeling software programs

• Nine primary threats/risks from ASME B31.8S
  • External corrosion*
  • Internal corrosion
  • Stress corrosion cracking
  • Manufactured related defects*
  • Welding/fabrication related defect**
  • Equipment
  • Third party/mechanical damage
  • Incorrect operational procedure
  • Weather-related and outside force**
Technical Overview

- Technical Expert
- Sound engineering practice
- Forensic Investigation Database
- Subject matter experts (SMEs)
- Interacting Threat Model
- Normalize Data
- Develop Algorithms

PHMSA – Historical Incident Database
Interacting Threats Project Work Scope

• Identify Interacting Threats
  • Kiefner Failure Database
  • SMEs from NYSEARCH funder Advisory Group
  • Industry papers, past experience
  • PHMSA ‘Reportable Incidents Database’

• Develop Rationale/Technical Support for Selected Interacting Threats

• Develop method for quantifying (scoring/weighting) risks from interacting threats

• Develop/modify software/ create spreadsheet for calculating risk from interacting threats
  • Kiefner Risk model & Stand-alone spreadsheet
Definition of Interacting Threats (IT)

• Definition based on Kiefner conference calls with SMEs and iteration after discussing basis for (20) interacting threats (20 Algorithms)

• Definition
  • Two or more threats acting on a segment or pipeline that increase the probability of failure to a level greater than (the sum of) the effects

• Notes and examples:
  • The distinction that makes threats interacting is that the resulting probability of failure from the Interactive Threat is GREATER THAN the sums of the probabilities of failure of the individual threats
  • Example 1: Consider threats A, B, and C. The probability of failure from these threats are $P_A$, $P_B$ and $P_C$ respectively. Threats are considered interacting if $P_{(A+B+C)} > P_A + P_B + P_C$
First Example of Interacting Threats

- External corrosion (EC) on Previously Damaged Pipe (PDP) will occur more frequently if the external coating is damaged in an area where the cathodic protection was ineffective at preventing external corrosion.
- Thus (EC) and previously damaged pipe (PDP) are interacting where the external coating of the pipe has been damaged BUT they are not interacting when the external coating is intact.
Interacting Threats Approach

• Normalize the number of failures due to interaction of threats to the number of failures due to one threat only

• Compare each interacting threat to one of the individual threats. Identify one threat as the baseline (constant) and let the other threat be a variable.

• Determine whether the threat was associated with the driving factor or the primary cause of the failure and the other interacting threat represented a contributing condition or situation which in some way contributed to:
  1) a more rapid degradation of the pipe,
  2) an increased stress or load on the pipe or,
  3) a reduced tolerance of the pipe to the original flaw or loading condition

• Increased likelihood of failure (%) incorporated into algorithms
  • additional terms with factors based on calculation of probability of both threats occurring (and yielding realistically smaller factors)
Consider a sample **algorithm for external corrosion (20 Threat Model)**

\[
P_{EC-Tot} = P_{EC} + [0.016 \times (P_{EC} + P_{SCC}) + 0.143(P_{EC} + P_{MF}) + 0.016(P_{EC} + P_{CD}) + 0.012(P_{EC} + P_{PDP})]
\]

**Failure frequency**

A pipeline segment **index score** for external corrosion of **115**

A defective **ERW** seam with an index score of **135**

The **new score** due to the threat interactions is now **157.77**
Nine Threat Example

Example Segment

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Interaction

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\[ P_{tot} = 940 \]

\[ \text{Interaction} = 244.84 \]

New \( P_{tot} = 1184.84 \)
Kiefner IA Threats Summary

• Developed reference guide to explain every combination of interacting (or non-Interacting) threats in both 9X9 and 20X20 matrices

• Developed and completed SME evaluation of interactive threat scoring method

• SME input being incorporated into beta versions of both the Kiefner Model software and import spreadsheet
  
  **Note**: Some threat interactions (ie. Selective seam corrosion) can change the failure mode and therefore the consequence of failure

• Target project completion: October 2013

1Study of pipelines that ruptured while operating at hoop stress <30% SMYS by Michael Rosenfeld (Kiefner) and Robert Fassett (Kleinfelder) – PPIM Conference 2/14/2013
Bioball Damage Prevention
Project Objective

• Conduct a test program to determine viability and accuracy of BioBall in locating existing sewer pipes over a broad range of existing residential sewer lateral configurations

• Determine what, if any, improvements to BioBall are needed
Bioball Concept – Avoid Damage by Detection

- Crossbores are an increasing source of damage and incidents
BioBall Concept – Locate by “tracer wire”

- Provide a means of locating by temporarily installing a “tracer wire”
- “Tracer wire” is installed INSIDE the sewer lateral
- Locators use existing knowledge and experience with R/F equipment
Easy “tracer wire” deployment

• Deployment of BioBall
  1. Secure wire end
  2. Flush ball down toilet
  3. Connect wire to frequency generator
  4. Locate above ground (X,Y,Z)
  5. Remove wire from system
  6. Ball disintegrates in 2hrs.
BioBall Design Parameters

- Developed by InvoDane for Enbridge Gas Distribution
  - 100ft range (length of wire)
  - Neutrally buoyant*
  - Cost-effective
  - Patented
  - Designed for XY lateral location (not depth)
  - Biodegradable ball (pressed wood)

* Buoyancy changes slightly as ball travels through pipe
BioBall Application – Final

- Optimized

**Step 1**
- **Unmapped Lateral**
- Access to cleanout? YES
- **Use Bioball (through C/O)**
- Confidence? YES
- Or alternate C/O based tech NO

**Step 2**
- **Sewer Crawler Applicable?**
- YES
- **Use Sewer Crawler**
- Confidence? YES
- NO

**Step 3**
- **Homeowner consent for BioBall?**
- YES
- **Use BioBall (Toilet)**
- Confidence? YES
- NO

**Step 4**
- **Expose lateral**
- Confidence? YES
BioBall and Other Options in Practice

1. BioBall – detect with easily accessible outside cleanouts
2. Sewer camera – detect with easily accessible outside cleanouts
3. BioBall – detect from inside access toilet
4. Excavation – detect remaining with excavation
SAMPLE NEW PIPELINE SAFETY PROJECTS
Crack Sensor for Robotic Inspection Platforms (M2011-006 Ph IV)

- Develop a crack sensor for integration in the Explorer family of platforms for the inspection of unpiggable pipelines
- Deliverable: Working system integrated into Explorer 20” – 26”
- Integrates TMFL and EMAT sensory systems
- Status: Completed design; initiated manufacturing of sensor module
  - First live field demo expected in late 2013; additional four demos in 2014
Crack Sensor

- Test pipe with cracks (not machined defects)
Crack Sensor (continued)

- **TMFL**
  - Axial Corrosion
  - Deep cracks
  - Open cracks
  - Lack of penetration

- **Crack Sensor**

- **EMAT**
  - Shallow cracks
  - Closed cracks
  - Weld cracks
Crack Sensor - EMAT

- Testing various configurations of EMAT (type, orientation, spacing) on weld and weld-defect detection to establish capabilities
Self-Healing Pipe (M2011-001 PhII)

- Develop plastic pipe that self-heals when damaged by cracking or mechanical impact
- Deliverable: Prototype of PE pipe with self-healing characteristics
  - Nanocomposite material, with PE as the matrix material
- Feasibility study to determine proof-of-concept;
- Status: Manufactured sample of self-healing material
  - Nanocomposite material retained the mechanical properties of the matrix material (PE)
  - Test for self-healing properties initiated
Self Healing of HDPE Pipes

- Combination of microcapsules (including epoxy) and catalyst

- Issues with self healing in M/HDPE are centered in the manufacturing process
  - Most established healing materials/agents cannot withstand the high temperatures of extrusion

- The problem requires the concurrent study of materials properties, structural analysis and manufacturing processes
Self Healing of HDPE Pipes (continued)

- Project to study/establish the following
  - Chemical synthesis of microcapsules agent and catalyst; chemical composition, rheology, thermal properties
  - Solvent for uniform dispersion of capsules
  - Mechanical properties of microcapsules (need to rupture when crack reaches them, but need to survive extrusion process)
  - Manufacturing process
  - Mechanical and self healing properties of pipe
Self-Healing Pipe Project Status

- Project initiated in December 2012 with setting up facility for production of microcapsules
Self-Healing Pipe Project Status (continued)

- Have optimized process for manufacturing microcapsules (size depends on stirring speed of the solution that generates them)
Self-Healing Pipe Project Status (continued)

- Microcapsules were imbedded into epoxy for a first testing; under bending most of them ruptured; need to determine uniformity of distribution in matrix material
Self-Healing Pipe Project Status (continued)

- Next step is to determine mechanical strength of samples after self healing process has been induced by damaging samples.

- If successful, we will proceed with manufacturing pipe samples from self-healing material.
Overall Summary

• Program has produced important products and knowledge to improve safety and decision-making
• Many of the earlier long-term projects are closed or are coming to completion
• NYSEARCH and others are working towards next generation solutions such as self-healing pipe, crack sensing etc.
• Leverage and participation in collaborative R & D funded through NYSEARCH remains high