



PHMSA RESEARCH & TECHNICAL PERSPECTIVES



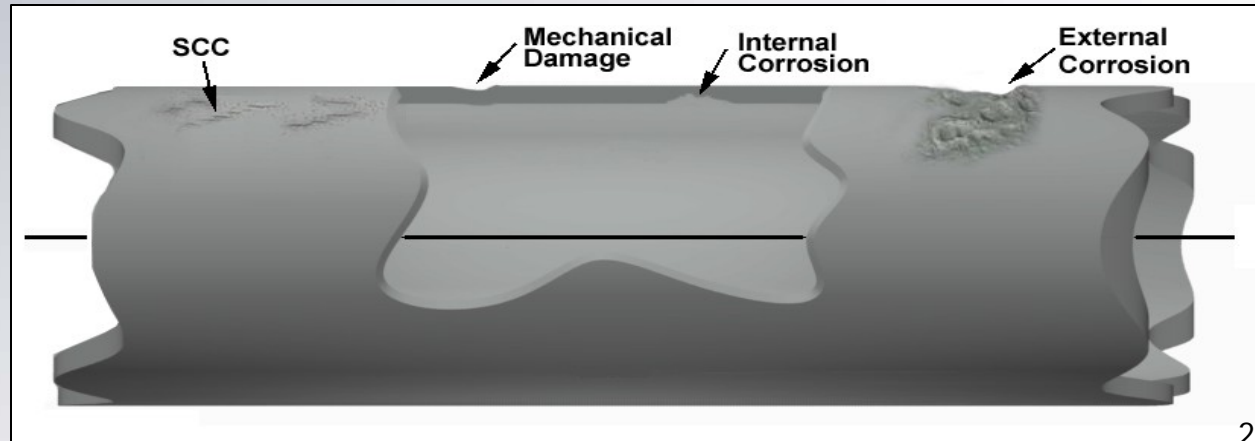
Working Group 3 – Anomaly Detection/Characterization
Gov/Industry Pipeline R&D Forum

November 16-17, 2016



Anomaly Detection/ Characterization Research

- Stakeholder input sought/generated for detection/characterization research at 6 past Pipeline R&D Forums and other public events
- Solicited for related topics in 10 research solicitations since 2002
- Related Investment: 195 tech development, product development & Direct Assessment improvement projects using \$108.6M (PHMSA)





Current Research

BSEE		
DTPH5615X00016	Stress Engineering Services, Inc.	Composite Repair Guideline Document for Nonmetallic Repairs for Offshore Applications
CAAP-2-14		
DTPH5614HCAP06L	Colorado School of Mines	Robust Anomaly Matching for ICIPs: Reducing Pipeline Assessment Uncertainty Through 4-Dimension Anomaly Detection and Characterization
CAAP3-15		
DTPH5615HCAP01	University of Alaska Anchorage	Corrosion Under Insulation (CUI): Innovative Solutions to Cold Climate Corrosion Challenges
DTPH5615HCAP03	Arizona State University	Bayesian Network Inference and Information Fusion for Accurate Pipe Strength and Toughness Estimation
DTPH5615HCAP05L	University of North Dakota Energy & Environmental Research Center	Application of Amorphous Metals for Plastic Pipeline Detection
DTPH5615HCAP10L	University of Missouri (The Curators - Rolla)	Chemically Bonded Porcelain Enamel Coated Pipe for Corrosion Protection and Flow Efficiency
CAAP-4-16		
DTPH5616HCAP01	Iowa State University	Fundamental Mechanochemistry-based Detection of Early Stage Corrosion Degradation of Pipeline Steels
DTPH5616HCAP03	North Dakota State University	Development of New Multifunctional Composite Coatings for Preventing and Mitigating Internal Pipeline Corrosion



Current Research

ERW-RA		
DTPH56-11-T-000003L	Battelle Memorial Institute	Comprehensive Study to Understand Longitudinal ERW Seam Failures
RA-2		
DTPH56-13-T-000008L	RTD Quality Services USA, L.P.	In-Ditch Validation Methodology for Determination of Defect Sizing
DTPH56-14-H-00002L	Electricore, Inc.	Consolidated Project Full Scale Testing of Interactive Features for Improved Models
DTPH56-14-H-00004	Kiefner Applus RTD	Improving Models to Consider Complex Loadings, Operational Considerations, and Interactive Threats
DTPH56-14-H-00007	Kiefner Applus RTD	Improving Leak Detection System Design Redundancy & Accuracy
RA-3		
DTPH5615T00006	Gas Technology Institute	Characterization and Fitness for Service of Corroded Cast Iron Pipe
DTPH5615T00007	Gas Technology Institute	Slow Crack Growth Evaluation of Vintage Polyethylene Pipes
DTPH5615T00009	Kiefner Applus RTD	Development of Comprehensive Pressure Test Design Guidelines
DTPH5615T00012L	Northeast Gas Association	Emissions Quantification Validation Process
DTPH5615T00013	Northeast Gas Association	Development of an AMR Eddy Current-Based Crack Detection Sensor for the Live Inspection of Unpiggable Natural Gas Transmission Pipelines
DTPH5615T00018	Operations Technology Development NFP	EMAT Sensor for Small Diameter and Unpiggable Pipes; Prototype and Testing



Current Research

SBIR		
DTRT5715C10022	JENTEK Sensors Inc.	Pipeline Integrity Assessment using In-Line Inspection - Phase A
UnpigGas		
DTPH5616T00002	QUEST Integrated, LLC	Development of EMAT Sensors for Corrosion Mapping of Unpiggable Natural Gas Pipelines Using ILI Tools
DTPH5616T00003	QUEST Integrated, LLC	Development of High Performance Gas-Coupled Ultrasonic Transducers for Inspection of Unpiggable Natural Gas Pipelines
DTPH5616T00004	ULC Robotics	EMAT Guided wave technology for inline inspections of unpiggable natural gas pipeline



Current Research

Stress Engineering Services, Inc.

Composite Repair Guideline Document for Nonmetallic Repairs for Offshore Applications

This project which is co-sponsored by DOI & DOT, aims to develop a Composite Repair Guideline Document for Nonmetallic Repairs for Offshore Applications including a state-of-the-art assessment of current repair technology and full-scale testing to support the effort. This project will address performance issues related to both offshore and onshore pipeline-related facilities



Current Research

Colorado School of Mines

Robust Anomaly Matching for ICIPs: Reducing Pipeline Assessment Uncertainty Through 4-Dimension Anomaly Detection and Characterization

This work will focus on supporting the unique anomaly matching requirements of Integrated Internal Inspection and Cleaning Pigs (ICIPs). The goal is to develop a novel technique for automatic anomaly matching based on Appearance-SLAM and to optimize the accuracy and data processing capabilities of this algorithm.



Current Research

University of Alaska Anchorage

Corrosion Under Insulation (CUI): Innovative Solutions to Cold Climate Corrosion Challenges

To investigate the corrosion properties of carbon manganese steel in bentonite clays and explore opportunities for mitigating Corrosion Under Insulation (CUI) using injectable bentonite inhibitors.



Current Research

Arizona State University

Bayesian Network Inference and Information Fusion for Accurate Pipe Strength and Toughness Estimation

This research project will focus specifically on Development of Inspection Tools to Quantify Pipe Strength and Toughness.



Current Research

University of North Dakota Energy & Environmental Research Center

Application of Amorphous Metals for Plastic Pipeline Detection

The objective of this project is to evaluate the potential for using amorphous metal foil to enable the below ground detection of plastic pipelines.



Current Research

University of Missouri (The Curators - Rolla)

Chemically Bonded Porcelain Enamel Coated Pipe for Corrosion Protection and Flow Efficiency

This study will explore, develop, and demonstrate electrostatically-applied, chemically-bonded, dense and consistent enamel powder coating for improved corrosion resistance and durability, reduced surface roughness and pressure loss, and increased bond strength of underground steel pipes under combined external pressure, thermal effect, and internal pressure. Expected outcomes can not only address corrosion related safety issues, but also reduce operation cost in hazardous liquid and natural gas pipelines.



Current Research

Iowa State University

Fundamental Mechanochemistry-based Detection of Early Stage Corrosion Degradation of Pipeline Steels

Model guided development of advanced detection methods to quantify the physical and mechanical changes associated with early stage stress corrosion cracking in high strength pipeline steel. This will render a systematic framework to monitor changes in parameters germane to corrosion prevention, while mitigating the corrosion impact on the pipeline infrastructure.



Current Research

North Dakota State University

Development of New Multifunctional Composite Coatings for Preventing and Mitigating Internal Pipeline Corrosion

As emerging technology, high performance anti-corrosion coatings have recently demonstrated great potential and attracted significant interest for oil and gas pipeline corrosion control. Towards this endeavor, the combined efforts in new high-performance coating design with superior resistance to corrosion, fouling and wear must be made for enhanced prevention and mitigation of pipeline corrosion.



Current Research

Battelle Memorial Institute

Comprehensive Study to Understand Longitudinal ERW Seam Failures

Three primary objectives

- Integrate industry and PHMSA data to quantify vintage seam failure statistics with focus on LFERW seams
- Understand longitudinal ERW seam failures and on that basis quantify the effectiveness of inspection and hydrotesting to manage integrity and ensure safety to avoid/eliminate catastrophic failures
- Combine outcomes of the first two objectives to help favorably close National Transportation Safety Board Recommendation P-09-1



Current Research

RTD Quality Services USA, L.P.

In-Ditch Validation Methodology for Determination of Defect Sizing

The project will develop, improve and demonstrate a robust technology for accurate and reliable sizing of complex crack like anomalies by adopting an existing, proven technology for the purpose. Applus RTD has developed the technology over the last several years, primarily for girth weld inspection in new pipeline construction. However, the capabilities of the technology and the robustness of the tool make it ideally suited for in-ditch application for pipeline integrity. The tool's ability to discriminate closely spaced defects and accurately size cracks irrespective of their orientation make it an ideal solution for sizing complex cracks such as stress corrosion cracks and seam weld defects.



Current Research

Electricore, Inc.

Consolidated Project Full Scale Testing of Interactive Features for Improved Models

This project addresses pipeline crack growth as influenced by complex operational circumstances by expanding on existing work performed through PHMSA and Pipeline Research Council International, Inc. (PRCI). Through full scale testing, the team will gather data on mechanical damage interacting with secondary features – gouges (with cracks and micro-cracks), corrosion, and welds. The team will create a database which will be used by others to validate and improve burst and fatigue strength models. The team will also gather experimental data to estimate when cracks in stress corrosion cracking (SCC) colonies coalesce.



Current Research

Kiefner Applus RTD

Improving Models to Consider Complex Loadings, Operational Considerations, and Interactive Threats

Interactions of pipe defect conditions with variable loadings, increased loadings, complex loadings, or changing conditions have led to failures under conditions normally considered safe. The industry may need to apply a second level of complexity to the evaluation of degraded conditions where one or all of the following circumstances could exist: (a) loadings are biaxial, (b) loadings vary with time, or (c) environments interact with conditions to adversely alter the condition's stability or rate of degradation.



Current Research

Kiefner Applus RTD

Improving Leak Detection System Design Redundancy & Accuracy

Leak detection systems are an important part of any overall pipeline safety and integrity strategy. The benefits of reliably and rapidly identifying a leak, so that the resulting fluid loss can be controlled and contained as soon as possible, can be very significant, particularly in High Consequence Areas (HCAs). The mission of this project is standardize the approach to designing an appropriate LDS for all pipelines, and that will be accessible to all operators – including the smaller ones – without extended and laborious front-end engineering.



Current Research

Gas Technology Institute

Characterization and Fitness for Service of Corroded Cast Iron Pipe

This project has four primary objectives:

- Provide a Fitness-For-Service (FFS) model and method for operators to characterize and grade graphitic corrosion defects on cast iron natural gas pipes. This will help operators make monitoring, repair, and replacement decisions, as well as prioritize accelerated replacement decisions related to cast iron mains and services.
- Summarize and categorize the required input parameters to the FFS model related to cast iron material, graphitic corrosion geometry and characteristics, and operational environment.
- Validate the FFS model by comparing its output to a statistically analyzed set of historical cast iron failure data.
- Provide a physical testing program to fully validate the FFS model.



Current Research

Gas Technology Institute

Slow Crack Growth Evaluation of Vintage Polyethylene Pipes

Develop 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. The tools will provide 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.



Current Research

Kiefner Applus RTD

Development of Comprehensive Pressure Test Design Guidelines

Develop comprehensive guidelines for the design of pressure tests that could be incorporated into industry standards or regulations. The proposed work will draw heavily on industry experience and scientific knowledge from prior research. The guidelines will assure as much as possible that pressure testing is carried out safely and effectively, that testing is performed to a consistent standard of quality, and that all stakeholders can have confidence in the safety of the tested pipeline.



Current Research

Northeast Gas Association

Emissions Quantification Validation Process

The main objective of this project is to identify, apply and test a methodology or methodologies that validate quantified methane emissions rate measurements in gas distribution systems. This project will build on current and evolving understanding related to the practical application of methane emissions quantification technologies for non-hazardous grade 3 leaks.



Current Research

Northeast Gas Association

Development of an AMR Eddy Current-Based Crack Detection Sensor for the Live Inspection of UnPiggable Natural Gas Transmission Pipelines

The objective of this project is to develop, test and commercialize an Anisotropic Magneto Resistive (AMR) Eddy Current (EC)-based sensor for live, in-line inspection of 6" - 8" diameter, unpiggable natural gas pipelines. This miniaturized sensor system has been proven through a separate feasibility study to have minimal power requirements. Also, the AMR EC crack sensor is suited to the operational characteristics of the Explorer series of robotic platforms where space and power are inherently limited. This project merges the expertise of NYSEARCH and its members, an innovative sensor designer Radiation Monitoring Devices, Inc., and Invodane Engineering/ Pipetel Technologies; the licensee, sensor integrator and commercial service provider for the Explorer range of commercial inspection platforms and sensing technologies.



Current Research

Operations Technology Development NFP

EMAT Sensor for Small Diameter and Unpiggable Pipes; Prototype and Testing

The objective is to build a field-ready EMAT sensor prototype and perform controlled field tests to assess its performance requirements and capabilities in identifying and characterizing pipe defects. The field-ready prototype will be designed for 8 inch diameter pipes and mounted on available platforms commonly used in the natural gas transmission and distribution systems. Sensors for smaller diameter pipes from 8 to 12 inches will be developed based on the success of the prototype.



Current Research

JENTEK Sensors Inc.

Pipeline Integrity Assessment using In-Line Inspection

This Phase II effort will fabricate and test a working prototype ILI tool, including a pull-test on representative samples with representative defects under representative conditions. The focus is on oil pipelines, as well as gas pipelines. This program will address some pressing, high priority needs such as reliable characterization of longitudinal cracks (including cracks at ERW welds), as well as the characterization of other crack types (transverse and SCC) and corrosion. This is particularly important for small diameter pipelines where existing solutions do not exist. This goal is aligned with a substantial commercial opportunity for the delivery of next generation In-line-Inspection (ILI) products and services that can enable more comprehensive inspection of critical pipeline infrastructure, thereby improving safety without adding costs and operational uncertainty.



Current Research

QUEST Integrated, LLC

Development of EMAT Sensors for Corrosion Mapping of Unpiggable Natural Gas Pipelines Using ILI Tools

EMAT wall thickness sensors that are optimized for use in small diameter and traditionally unpiggable pipelines will be investigated and integrated into a bench-scale EMAT system. Accurate wall thickness data can be fed into API 579 Fitness for Service analysis, or failure criteria to allow calculation of remaining wall strength for assessment of pipeline integrity. Of particular importance is optimization of the EMAT sensor performance in the presence of corrosion.



Current Research

QUEST Integrated, LLC

Development of High Performance Gas-Coupled Ultrasonic Transducers for Inspection of Unpiggable Natural Gas Pipelines

New single crystal dry-coupled high efficiency ultrasonic transducers will be investigated to determine feasibility for in-line inspection in unpiggable gas pipelines. An order of magnitude improvement in system sensitivity is targeted. Accurate wall thickness data can be fed into API 579 Fitness for Service analysis, or failure criteria to allow calculation of remaining wall strength for assessment of pipeline integrity, risk assessment and materials evaluation.



Current Research

ULC Robotics

EMAT Guided wave technology for inline inspections of unpiggable natural gas pipelines

ULC's objective for this project is to evaluate an EMAT guided wave sensor for operation in cast iron and steel plates and pipes, optimize the performance, demonstrate the sensor's capabilities in the lab and perform conceptual design and evaluation for the integration of the sensor with the CIRRIIS XITM robot.



Completed Research

CAAP-2-14		
DTPH5614HCAP03	Iowa State University	Experimental Characterization and Monitoring of Early Stage Corrosion Degradation of Pipeline Steels
DTPH5614HCAP04L	University of Colorado Denver	Optimized Diagnosis and Prognosis for Impingement Failure of PA and PE Piping Materials
RA-2		
DTPH56-13-T-000006	Northeast Gas Association	Development, Field Testing and Commercialization of a Crack and Mechanical Damage Sensor for Unpiggable Natural Gas Transmission Pipelines
DTPH56-13-T-000007	Operations Technology Development NFP	EMAT Sensor for Small Diameter and Unpiggable Pipe
DTPH56-13-T-000009L	Kiefner Applus RTD	Improve and Develop ILI Tools to Locate, Size, and Quantify Complex/Interacting Metal Loss Features
DTPH56-13-T-000011L	Gas Technology Institute	Above-ground Detection Tools Including Disbondment and Metal Loss for all Metals Including Cast-Iron Graphitization
DTPH56-14-H-00005	Kiefner Applus RTD	Threat/Anomaly Mitigation Decision-Making Process
RA-3		
DTPH5615T00002L	Kiefner Applus RTD	White Paper on Risk Tolerance



Completed Research

Iowa State University

Experimental Characterization and Monitoring of Early Stage Corrosion Degradation of Pipeline Steels

Enhance pipeline safety through understanding the early corrosion mechanisms in high strength pipeline steels that lead to stress corrosion cracking with a focus on measurable degradation parameters that can guide the development of advanced NDE measurement procedures.



Completed Research

University of Colorado Denver

Optimized Diagnosis and Prognosis for Impingement Failure of PA and PE Piping Materials

Optimized diagnosis - find existing impingement damage at the earliest stage before it becomes failure critical in Polyethylene (PE) and Polyamide (PA) materials, conduct comprehensive comparison studies to identify the differences in micro-cracking mechanism between these two materials; Optimized prognosis - accurately predict the remaining strength and RUL of PE and PA components through mechanical modeling and experimental investigations.



Completed Research

Northeast Gas Association

Development, Field Testing and Commercialization of a Crack and Mechanical Damage Sensor for Unpiggable Natural Gas Transmission Pipelines

The project will carry out demonstrations of the combined mechanical sensor and crack sensor technologies in live natural gas pipelines using the Explorer 20/26 robotic system for the inspection of unpiggable natural gas pipelines. This combined sensor is under development through an on-going effort. These additional demonstrations are needed in order to validate the new sensors, establish their ability to detect mechanical damage and crack defects in complex live pipeline environments, and carry out improvements on their design and sizing algorithms based on the results of each prior demonstration.



Completed Research

Operations Technology Development NFP

EMAT Sensor for Small Diameter and Unpiggable Pipe

This project will develop Electromagnetic Acoustic Transducer (EMAT) sensors that can be used to detect cracks and assess welds in unpiggable pipe segments. The work will develop an EMAT sensor independent of any specific platform to allow integration with multiple unpiggable pipe inspection platforms and for use by multiple vendors. OTD has partnered with GTI and Quest Integrated, Inc on this project to bring EMAT technology to the natural gas industry for unpiggable pipes.



Completed Research

Kiefner Applus RTD

Improve and Develop ILI Tools to Locate, Size, and Quantify Complex/Interacting Metal Loss Features

The ability to accurately locate and size individual metal loss pits within an area of large corrosion and characterization of metal loss associated with dents/gouges and the longitudinal seam are three of the remaining problems with in-line inspection (ILI) integrity assessment of metal loss defects.



Completed Research

Gas Technology Institute

Above-ground Detection Tools Including Disbondment and Metal Loss for all Metals Including Cast-Iron Graphitization

The project will develop, test, and then commercialize a mobile platform for detecting coating disbondment and external corrosion by measuring magnetic fields from above ground. Alternating current is injected into the pipe being tested. The current creates magnetic fields around the pipe. These fields are affected by corrosion and disbondment.



Completed Research

Kiefner Applus RTD

Threat/Anomaly Mitigation Decision-Making Process

Better guidance is needed for deciding when the combined effects of two or more threats and the associated anomalies create a higher probability of failure than the individual threats/anomalies themselves. While satisfactory models exist for calculating the effects on pressure-carrying capacity of individual types of anomalies (e.g., corrosion-caused metal loss, cracks, gouges, plain dents), better guidance is needed regarding how to assess the effects of combined threats/anomalies.



Completed Research

Kiefner Applus RTD

White Paper on Risk Tolerance

Our approach to solve the challenges proposed by this program is to conduct an initial literature search to understand what other regulatory bodies and industries have done to define risk criteria. This information will be supplemented with data gathered from a survey of pipeline industry members about their risk management decision-making process. Together, these activities will identify methods for defining risk criteria and highlighting best practices across the pipeline industry.



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